Section 6

Section 6
HYDROLOGY, FLOODING, AND FLUVIAL GEOMORPHOLOGY

TABLES

FIGURES

Section 6
HYDROLOGY, FLOODING, AND FLUVIAL GEOMORPHOLOGY

Basic information on the surface water, groundwater, and geomorphology of the Tehama West Watershed is presented in this section. The surface water portion includes a discussion of reference conditions, surface water runoff, water rights, and water use. The groundwater portion includes a discussion of key groundwater basins and water use. Supporting information on geology and soils is summarized in Section 4, "Geology and Soils," and supporting information on climate is summarized in Section 5, "Climate."

Often, the relationship between hydrology, geomorphology, and geology is overlooked in a baseline watershed assessment. This relationship is critical to understanding conditions in the Tehama West Watershed because geology divides the watershed into two very distinct regions. The eastern portion of the watershed is underlain by rocks of the Great Valley Geomorphic Province. In general, this portion of the watershed is characterized by low elevations, low precipitation, relatively gentle topography, low erosion potential, and a significant groundwater reservoir. The western portion of the watershed is underlain by rocks of the Coast Range Geomorphic Province. This portion of the watershed is characterized by high elevations, high rainfall, steep slopes, high erosion potential, and a relatively poor fractured groundwater reservoir. As a result, streams originating in the eastern or Great Valley portion of the watershed have very different characteristics from streams originating in the western or Coast Range portion of the watershed. The transition between the two geomorphic provinces generally trends north-south, passing through Paskenta. This transition serves as the western boundary of the Sacramento Groundwater Basin. Significant groundwater recharge occurs in the alluvial deposits associated with this transition zone.

SOURCES OF DATA

Key sources of data used in the preparation of this section are listed below. Additional information is provided in the references section.

- Daily Stream Flow Statistics for Elder Creek near Paskenta, Elder Creek at Gerber, Thomes Creek at Paskenta, and Red Bank Creek near Red Bluff (USGS 2005)
- Thomes Creek Watershed Study (DWR 1982)
- Thomes Creek Sediment Budget (CSUC 2005)
- Sacramento Valley Westside Tributary Watershed Erosion Study (DWR 1992)
- Coordinated AB3030 Groundwater Management Plan, Tehama County Flood Control and Water Conservation District (Law 1996)
- Water Inventory and Analysis Report, Tehama County Flood Control and Water Conservation District (CDM 2003)
- California Groundwater Bulletin 118-03 (DWR 2003)

- Sacramento River Groundwater Basin Water Levels (DWR 2005)
- Tehama County: A Small Water Systems Drought Vulnerability Study (CDM 2005)
- Thomes Creek Watershed Analysis Report (USDA 1997)
- Resource Capabilities Affecting Sedimentation, Red Bank Creek Pilot Study Area, Tehama County, California (SCS 1978)

SURFACE WATER HYDROLOGY

As defined for this watershed assessment, the Tehama West Watershed includes approximately 670,000 acres, or approximately 1,050 square miles. It includes portions of the Sacramento Lower Cow Creek, Lower Clear Creek Hydrologic Unit (HUC 18020101), Sacramento Lower Thomes Creek Hydrologic Unit (HUC 18020103), and the Upper Elder Creek, Upper Thomes Creek Hydrologic Unit (HUC 18020114) as defined by the United States Geological Survey (USGS). The general location of the watershed is shown on Figure 6-1.

The Tehama West Watershed drains to the Sacramento River. Major tributaries are shown on Figure 6-2 and include:

- Thomes Creek
- Elder Creek
- Red Bank Creek
- Reeds Creek

Thomes and Elder Creeks are the largest drainages in the watershed. They originate in the rugged coniferous forest zone along the crest of the Coast Range, including the Yolla Bolla Wilderness Area. The upper-most elevations for these drainages exceed 5,000 feet and may have significant, but highly variable, snowpacks. Shorter drainages within the watershed originate in the foothill areas dominated by chaparral, oak woodlands, or rangelands. Snowfall is infrequent in this lower zone and does not significantly contribute to stream flow patterns. The watershed is comprised of 11 sub-units. These subunits are summarized in Table 6-1 and are shown on Figure 6-3.

In order to discuss the hydrology of a watershed, it is necessary to quantify the volume of precipitation received within the watershed boundaries. Average annual precipitation in Red Bluff (NCDC Station 047292) between 1905 and 2004 is 22.8 inches, ranging from 7.2 inches in 1976 to 49 inches in 1983. Throughout the watershed, average annual precipitation varies from less than 18 inches along the eastern side of the watershed, south of Red Bluff, to more than 50 inches along the crest of the Coast Range. Precipitation isohyetals are shown on Figure 6-4.

Average annual precipitation across the watershed is 24.8 inches, or approximately 1,380,000 acre-feet. In 1977, a drought year, average annual precipitation was approximately 54 percent of normal (CDM 2003). Additional climate data are summarized in Section 5, "Climate."

Table 6-1 WATERSHED SUB-UNITS			
Sub-unit	**Tributary Length (miles)**	**Acreage**	**Percent of Watershed**
Blue Tent Creek	10.0	15,142	2.3%
Burch Creek	24.1	94,199	14.1%
Dibble Creek	33.9	21,327	3.2%
Elder Creek	72.1	96,350	14.4%
Jewett Creek	21.4	35,902	5.4%
McClure Creek	22.4	29,761	4.5%
Oat Creek	22.4	44,612	6.7%
Red Bank Creek	56.2	74,450	11.1%
Reeds Creek	20.9	48,814	7.3%
Spring Creek	4.5	14,494	2.2%
Thomes Creek	70.0	193,117	28.9%
Total	357.9	668,168	100%

Reference Conditions

The twentieth century was one of relatively high rainfall compared to the past 500 years. However, current conditions are "normal" in the context of the last 100 years. Droughts exceeding 3 years are relatively rare in Northern California. Historical multi-year droughts include: 1912–13, 1918–20, 1923–24, 1929–34, 1947–50, 1959–61, 1976–77, and 1987–92 (DWR 2000a).

A 420-year reconstruction of Sacramento River runoff from tree ring data was made for the California Department of Water Resources (DWR) in 1986 by the Laboratory for Tree Ring Research at the University of Arizona. The tree ring data suggested that the 1929–34 drought was the most severe in the reconstructed record from 1560 to 1980. The data also suggested that a few droughts prior to 1900 exceeded 3 years, and none lasted over 6 years, except for one period of less than average runoff from 1839–46. John Bidwell, an early pioneer who arrived in California in 1841, confirmed that 1841, 1843, and 1844 were extremely dry years in the Sacramento area (Meko et al 2001).

A 1994 study of relict tree stumps rooted in present-day lakes, rivers, and marshes suggest that California sustained two epic drought periods. The first epic drought lasted more than 2 centuries before the year 1112, the second drought lasted more than 140 years before 1350. The conclusion that can be drawn from these investigations is that California is subject to droughts more severe and more prolonged than witnessed in the historical record (DWR 2000a).

Surface Water Runoff

Headwaters of the streams in the watershed have relatively little, if any, drainage area with significant snowpack. Therefore, in contrast to streams flowing from the high Sierra Nevada with relatively predictable and significant snow packs, snow melt and run-off play a minor role in the flow characteristics of the streams in the watershed. Watershed streams show rapid responses to storms, and flow levels fluctuate greatly between storm-periods and intervening dry spells.

Stream gaging stations within the Tehama West Watershed are summarized in Table 6-2. Mean annual flows for Thomes Creek at Paskenta between 1921 and 1996 are shown on Figure 6-5a. Mean annual flows vary between a minimum of 72.4 cubic feet per second (cfs) in 1976 and a maximum of 884 cfs in 1983, averaging 289 cfs. Mean annual flows for Elder and Red Bank Creeks are shown on Figures 6-5b and 6-5c.

Table 6-2
ANNUAL MEAN STREAM FLOW
UNITED STATES GEOLOGICAL SURVEY

USGS Site Name	USGS Site Number	Drainage Area (sqm)	Period of Record [1]	Min. (cfs)	Max. (cfs)	Mean (cfs)	Mean (aft/yr)
Red Bank Creek near Red Bluff	11378800	93.5	1960-1982	1.38 (1976)	114 (1978)	48.7	35,260
Red Bank Creek at Rawson Road Bridge near Red Bluff	11378860	109	1965-1967	---	---	48.8	35,330
Elder Creek near Paskenta	11379500	92.4	1949-2004	11.8 (1976)	343 (1983)	99.4	71,970
Elder Creek near Henleyville	11380000	130	1931-1941	10.3 (1939)	198 (1940)	73.6	53,290
Elder Creek at Gerber	11380500	136	1950-1979	44.1 (1959)	287 (1958)	100	72,400
Thomes Creek Tributary at Paskenta	11381990	0.65	1968-1970	---	---	0.5	360
Thomes Creek at Paskenta	11382000	203	1921-1996	72.4 (1976)	884 (1983)	289	209,240
Thomes Creek at Rawson Road Bridge near Richfield	11382090	284	1978-1980	---	---	338	244,700

[1] Based on a water year of October through September. For example, the 2004 water year extends from October 1, 2003 through September 30, 2004.

Monthly flows for Thomes Creek, Elder Creek, and Red Bank Creeks are summarized in Table 6-3 and are shown on Figures 6-6a through 6-6c. Peak monthly flows in Thomes Creek and Elder Creek occur in February. As peak monthly precipitation occurs in January, the February peak indicates that snowmelt affects runoff in these watersheds. For comparison, peak monthly flows in Red Bank Creek occur in conjunction with peak precipitation.

Assuming the runoff coefficient of 530 acre-feet per square mile for Elder Creek (72,400 acre-feet / 136 square miles) applies to the entire watershed, surface water runoff during an average year would be 550,000 acre-feet (530 acre-feet per square mile * 1,050 square miles). This represents approximately 40 percent of the average annual precipitation.

Table 6-3 MONTHLY STREAM FLOW									
Month	Thomes Creek (1921-1996)			Elder Creek (1949-2004)			Red Bank Creek (1960-1982)		
	Mean	Min.	Max	Mean	Min.	Max	Mean	Min.	Max
Jan	583	12.4	2,900	253	5.38	1,208	184	0	696
Feb	706	23.2	3,483	295	7	1,636	146	0	522
Mar	620	48.9	2,080	238	22.6	1,176	111	3.39	482
Apr	551	45.3	1,879	150	13.8	497	50.6	0.41	230
May	354	18.2	1,406	83.7	13.4	463	7.77	0	27.3
Jun	116	1.41	591	31.1	2.52	262	1.76	0	17.1
Jul	23.5	0	133	8.87	0.32	49.6	0.15	0	1.57
Aug	6.28	0	38.1	3.44	0.002	17.5	0	0	0
Sep	5.08	0	25.5	3.05	0.14	11.3	0.021	0	0.48
Oct	24.7	0	310	8.8	0.66	102	0.47	0	9.79
Nov	159	2.85	1,500	45.9	2.89	310	26.7	0	140
Dec	395	6.93	2,879	142	4.06	649	60.1	0	233
Average	295	---	---	99.4	---	---	48.7	---	---

Mean monthly flows for the Sacramento River above Bend Bridge near Red Bluff are shown in Figure 6-7. As shown, peak flows occur between January and March. Flows throughout the rest of the year are relatively constant. Being in an area characterized by heavy winter precipitation and long dry summers, these variations would be more pronounced under natural conditions. Shasta Dam, diversions into the Sacramento River from the Trinity River, and agricultural diversions from the Sacramento River mute or mask natural flow conditions. Present day Sacramento River flow patterns more closely reflect downstream water needs than natural hydrologic and weather factors.

Flood History

There is scarce information about floods in the Sacramento River basin prior to the 1850s. The primary sources of information during this period are histories of early settlement that include eyewitness accounts from Indians and pioneer settlers. Notable floods are reported to have occurred around 1800 and in 1826, 1840, and 1847.

Between 1850 and 1900 major flooding occurred in 1850, 1862, 1867, 1881, and 1890. Flooding during the 1860s constitutes one of the greatest flood periods in the history of California. Major floods after 1900 occurred in 1904, 1907, 1909, 1911, 1928, 1955, 1964, 1967, 1969, 1970, 1974, 1983, 1986, 1995, and 1997 (USAC 1999). The 1904 flooding resulted in the highest peak flows to date in the Upper Sacramento River between Kennet and Red Bluff.

Although 1983 was one of the wettest water years in California this century, due to the "El Nino" weather phenomenon, the magnitude of the peak flows were not the highest of the century. By early May, snow water content in the Sierra exceeded 230 percent of normal, and the ensuing runoff resulted in approximately four times the average volume for Central Valley streams.

The largest and most extensive flooding on record in the Upper Sacramento River occurred in December 1996 and January 1997. The flooding followed a series of three storms delivered over a period of 5 days between Christmas and New Year.

Annual peak flows occurring with a return period of 5 years or more in Thomes Creek at Paskenta and Elder Creek near Paskenta are summarized in Table 6-4. Thomes Creek peak flows in excess of 14,400 cfs have a return period of 5 years, and flows in excess of 20,000 cfs have a return period of 10 years. Recurrence intervals for peak annual flows in Thomes Creek are shown on Figure 6-8.

Table 6-4
ANNUAL PEAK FLOWS
RETURN PERIOD > 5 YEARS

Thomes Creek (1921-1996)			Elder Creek (1949-2004)		
Date	**Gage Height (feet)**	**Flow (cfs)**	**Date**	**Gage Height (feet)**	**Flow (cfs)**
Dec. 22, 1964	12.7	37,800	Feb. 28, 1983	12.1	17,700
Feb. 17, 1986	12.11	32,900	Feb. 14, 1986	11.62	15,300
Jan. 16, 1974	12.3	29,400	Mar. 04, 2001	11.58	15,100
Dec. 21, 1955	12.14	23,500	Dec. 11, 1983	11.17	13,200
Mar. 09, 1995	10.54	20,100	Dec. 16, 2002	12.11	13,100
Mar. 26, 1928	10.5	19,600	Feb. 24, 1958	13.9	11,700
Jan. 26, 1983	10.19	19,500	Dec. 31, 1996	10.75	11,500
Jan. 31, 1963	12.63	19,200	Dec. 22, 1964	13.23	10,300
Jan. 13, 1980	10.1	18,800	Mar. 09, 1995	10.3	9,740
Feb. 08, 1960	12.32	18,700	Mar. 07, 1975	11.22	9,000
Jan. 21, 1943	10.92	18,600	Jan. 16, 1974	11.14	8,850
Jan. 23, 1970	12	18,000	Dec. 21, 1955	12.52	8,840
Feb. 28, 1940	14.3	17,000	Jan. 23, 1970	11.05	8,690
Dec. 10, 1937	16.8	16,500	Feb. 17, 2004	10.41	8,340
Feb. 15, 1982	9.57	16,400	---	---	---
Feb. 24, 1958	9.78	14,300	---	---	---

Prior to the completion of Shasta Dam in 1945, the Sacramento Valley's low gradient, wide expanse, maze of sloughs, ox-bows, and low-lying swales allowed the river to quickly extend beyond its banks and cover immense areas. Early day flooding had serious impacts on transportation and the development of infrastructure within the Sacramento River Valley. Since flows over the dam have been regulated, the Sacramento River does not flood in the same pattern or with the same magnitude that it had previously. Currently, floods tend to be relatively infrequent and highly localized with damage occurring in well-known and expected locations. As the number and extent of the flooding has been reduced, development has extended into the areas where it was previously infeasible or impossible. One result from these changing land use patterns is that flood flow features, such as the natural levees and ox-bow lakes, are now often difficult to identify or have been modified.

The Federal Emergency Management Agency has determined areas within the watershed that are subject to flood inundation (see Figure 6-9). While most of these potential flood areas are located near the Sacramento River, significant acreage with flood potential exists along lower sections of Thomes, Elder, and Red Bank Creeks, as well as along low-gradient, Sacramento Valley reaches of all assessment area streams.

Jurisdictional Dams

Jurisdictional dams are defined as "artificial barriers, together with appurtenant works, which are 25 feet or more in height or have an impounding capacity of 50 acre-feet or more." Any artificial barrier under 6 feet, regardless of storage capacity, or that has a storage capacity less than 15 acre-feet, regardless of height, are not considered jurisdictional (CARA 2005). No jurisdictional dams are located within the Tehama West Watershed (CDM 2003).

It should be noted that DWR has studied the feasibility of constructing two water projects that would involve constructing dams within the Tehama West Watershed. The Red Bank Project would involve constructing a dam and reservoir on Red Bank Creek, and the Thomes-Newville Project would include constructing a dam and diverting water from Thomes Creek into the Newville Reservoir on Stony Creek. Much of the hydrologic data available for the Tehama West Watershed were collected in conjunction with these proposed projects.

Water Rights

Water rights in the Tehama West Watershed are either appropriated or riparian. An appropriated right is an exclusive right to take a specific amount of water from a particular source, for a specific use on a specific site, for a specific amount of time. Riparian rights, on the other hand, belong to the land bordering a water source. The following discussion is provided as a general introduction to the concept of water rights and should not be considered a legal opinion (California Water Law and Policy 2003).

Appropriated Rights
An appropriative right is an entitlement to water based on a specific use. This type of right may be sold or transferred with the property or separately. In general, the party that first diverts the water has priority rights over subsequent appropriators or users. Actual levels of priority are generally specified in the appropriation. In situations where priorities conflict, or in situations where rights were established prior to the appropriation system, the rights may be adjudicated. Adjudications are judgments decreed by the court and carry the full force of law. The court or an assigned water master generally administers adjudicated rights. Appropriated water rights in the Tehama West Watershed have not been adjudicated.

A senior may not change an established use of the water to the detriment of a junior. This restriction includes junior's reliance on a senior's return flow. A senior may not enforce a water right against a junior if such a right would not be put to beneficial use.

The elements of appropriation include:

- Intent to use the water
- Diversion or control of the water
- Reasonable and beneficial use of the water
- Priority of appropriation

Appropriative right is an acquisition of a water right subject to the issuance of a permit by the State Water Resources Control Board. The priority is based on the date a permit is issued. A priority-based permit system was implemented under the Water Commission Act of 1913. Presently, the system is codified in CWC § 1200, et seq.

Table 6-5 lists post-1914 major appropriative water rights for the Tehama West Watershed. Major water rights are defined as those greater than 1,000 acre-feet per year or approximately 600 gallons per minute (gpm).

Table 6-5
APPROPRIATIVE WATER RIGHTS HOLDERS

Owner	Filings (acre-feet)	Date Filed	Use	Source
State Water Resources Control Board	7,237,950	9/30/	Domestic, Fish & Wildlife Protection, Industrial, Irrigation, Municipal, Other, Recreational	Thomes Creek; North Fork Stony Creek; Stony Creek; Sacramento River
Bureau of Reclamation	4,806,792	7/30/1927	Domestic, Irrigation, Recreational, Stockwatering	Sacramento River
State Water Resources Control Board	3,039,939	9/30/1977	Domestic, Fish & Wildlife Protection, Incidental Power, Industrial, Irrigation, Municipal, Other, Recreational	Funks Creek; Willow Creek; Stone Corral Creek; Sacramento River
B. Fishman Corning Orchard	1,829	12/27/1954	Irrigation	Thomes Creek
Foley, Bill & Mke	1,344	5/21/1991	Fish & Wildlife Protection	Thomes Creek
Williams, D.	1,273	12/16/1953	Irrigation, Stockwatering	Thomes Creek
Leviathian, Inc.	1,126	3/31/1950	Irrigation, Stockwatering	Sacramento River

Riparian Rights

A riparian right is the right to use water based on the ownership of property that abuts a natural watercourse. Water claimed by virtue of a riparian right must be used on the riparian parcel. Such a right is generally attached to the riparian parcel of land except where a riparian right has been preserved on non-contiguous parcels after the land has been subdivided (*Hudson v. Dailey* 1909 156 Cal. 617). Riparian rights were adopted in California as a part of the English Common Law when California entered statehood in 1850. At that time, however, gold miners were already operating under their own system of prior appropriation to claim water rights. Conflicts between appropriations and riparian rights have continued since.

In general, riparian users are entitled to enough water to make beneficial use of the water on the land as long as no other riparian users are harmed by such use. Riparian rights in California are now limited to "reasonable and beneficial use." In contrast to appropriative rights, there is no priority of riparian right; senior and junior riparian users do not exist. Water conflicts between riparian users are resolved on the basis of reasonable use. The court has held that in times of water shortage, all riparians must adjust water use to allow for an equal sharing of the available water supply.

California Doctrine

The California Doctrine is a system of water rights that recognizes both appropriative and riparian rights. Early California law recognized both appropriation and riparian rights by applying priority to disputes between appropriators and by applying riparian principles to disputes between riparian users. In 1872, California officially recognized the rights of appropriators by allowing the filing of water claims with county recorders. Within 14 years, the California Supreme Court had to determine who had superior water rights when a downstream riparian rancher and an upstream appropriator each claimed a superior right to use water. The Supreme Court held that riparian rights are superior to the rights of an appropriator except in cases where the water had been appropriated before the riparian acquired the patent to his land, and after the passage of the 1866 Mining Act, which recognized appropriation. Generally, a reasonable use by a riparian will trump an appropriative right so long as the patent to the riparian parcel was acquired from the United States prior to the date of appropriation.

In 1926 the Supreme Court held that a riparian could assert priority over an appropriator to make beneficial use of the water even if the riparian use was unreasonable. In response, in 1928 the California Constitution was amended to require all water use in California to be "beneficial and reasonable." Generally today, a riparian user cannot defeat an appropriative right unless the riparian user proves the appropriation is causing undue interference with the riparian user's reasonable use of the water.

Surface Water Use

Water use history in the watershed has a direct correspondence to population and economic growth, development of regional water storage and supply projects, and water supply pricing and reliability. Agriculture is an economic driving force in the watershed and much of the water use history is directly tied to the development and use of water sources to satisfy agricultural needs (CDM 2003).

The history of agricultural development in Tehama County has documented gradual changes in the source of irrigation water. In the early days of European settlement, surface water was primarily used to irrigate fields in Tehama County. A gristmill operated on the Rancho Bosque, a Mexican Land Grant, served as the first water extraction device used for irrigation, sometime between 1847 and 1852. Even into the early years of the twentieth century agricultural users primarily depended upon surface water as no large storage areas existed that would allow wide-spread irrigation. However, during this time, most domestic water came from shallow wells.

Chronic flooding along the Sacramento River inhibited development in Tehama County, which along with the promise of irrigation water, led to the 1935 authorization of the Central Valley Project (CVP). Important elements of the CVP included the completion of Shasta Dam in 1945 and subsequent construction of the Tehama-Colusa and Corning Canals. Following these projects and the lessening of flood risk, agricultural development greatly expanded in the county and water usage increased significantly. In the 1970s two-thirds of irrigation water used in the county came from surface sources.

Gradually, the cost of CVP-delivered water increased at the same time as demand was increasing. This led to an increased usage of groundwater over the last quarter-century. By the 1990s, the proportion of surface-sourced irrigation water used declined to represent only one-third of that being used, with two-thirds coming from groundwater sources.

During this period of change there has been an excess of federal, state, and local programs to affect the management of the area's waters and resources. For instance, in 1992 the Central Valley Project Improvement Act required protection, restoration, and enhancement of fish and wildlife in CVP projects. Legislative actions have also been instrumental, including AB3030 (1992), Proposition 204 (1996), Proposition 13 (2000), and Proposition 50 (2002). All of these addressed various water quality and quantity issues and other environmental factors associated with the county's waters.

A Water Inventory and Analysis of water use in Tehama County was conducted by the Tehama County Flood Control and Water Conservation District in 2003 (CDM 2003). In this analysis, the county was divided into numerous inventory units. The inventory units encompassing the Tehama West Watershed include all of the Red Bluff East and Red Bluff West inventory units, and portions of the Corning East, Corning West, Bowman, and Mountain Region West inventory units. These units are shown on Figure 6-10.

A summary of the estimated 2000 water demand for each of these units along with the source is summarized in Table 6-6.

Table 6-6
2000 SURFACE WATER AND GROUNDWATER USE

	Red Bluff East	Red Bluff West	Corning East	Corning West
Water Demand (acre-feet per year applied)				
Agriculture	75,000	2,100	113,900	3,200
Municipal and Industrial	8,100	1,800	4,600	100
Conveyance Losses	2,300	0	1,300	400
Total	85,400	4,000	119,800	3,600
Water Supply (acre-feet per year supplied)				
Local Stream Diversions	0	200	2,200	2,400
CVP and Sacramento River	9,500	0	12,400	0
Groundwater Extraction	73,800	3,700	102,200	1,000
Surface Water Reuse	2,100	100	3,000	200
Total	85,400	4,000	119,800	3,600

Does not include West Mountain Unit because total demand is less than 500 acre-feet per year. Also, does not include Bowman Unit because the majority of the water demand in this unit is outside the watershed in Lake California, Anderson, and Cottonwood.

Nearly 90 percent of the water demand associated with the Red Bluff East and Corning East inventory units (188,900 out of 213,100 acre-feet) is for agricultural purposes, and the majority of this water is supplied from the groundwater reservoir (177,400 out of 182,400 acre-feet). Surface water is supplied primarily by the CVP via the Corning and Tehama-Colusa Canals which divert water from the Sacramento River at the Red Bluff Diversions Dam. Less than 5,000 acre-feet of surface water is derived from local stream diversions.

GROUNDWATER

Currently, groundwater is the primary water supply in the Tehama West Watershed, and because surface water supplies are unpredictable and limited, future growth in the region and water demand during drought conditions will depend on the continued availability of groundwater. Recognizing the importance of groundwater in the county, the Tehama County Flood Control and Water Conservation District has been authorized as a groundwater management agency to develop a comprehensive groundwater management plan. The overall purpose of the plan is to: 1) prevent long-term overdraft of groundwater, 2) provide a reliable long-term water supply, and 3) protect groundwater quality. Unfortunately, the majority of the groundwater used in the county is extracted by independent users, not organized districts, for agricultural purposes.

Groundwater can be defined as the portion of water occurring beneath the earth's surface, which completely fills (saturates) the void space of racks or sediment. Given that all rock has some degree of void space, it is fairly safe to say that groundwater can be found underlying nearly any location in the State. Several key properties help determine whether the subsurface environment will provide a significant, usable groundwater resource. Most of California's groundwater occurs in material deposited by streams, called alluvium. Alluvium consists of coarse deposits, such as sand and gravel, and finer-grained deposits such as clay and silt. The coarse and fine materials are usually coalesced in thin lenses and beds in an alluvial environment. In an alluvial environment, the coarse materials such as sand and gravel deposits, usually provide the best source of water and are termed aquifers, whereas the finer-grained clay and silt deposits are relatively poor sources of water and are referred to as aquitards.

Groundwater Basins

A groundwater basin is defined as alluvial aquifer or a series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom. Lateral boundaries are features that significantly impede groundwater flow such as rock or sediments with very low permeability or a geologic structure such as a fault. Bottom boundaries would include rock or sediments of very low permeability if no aquifers occur below those sediments within the basin.

Individual groundwater basins identified within the Tehama West Watershed are listed in Table 6-7 and are shown on Figure 6-11. In general, the basins encompass the portion of the watershed located between the Sacramento River to the east, and the geologic faults separating rocks of the Great Valley Sequence from the Franciscan Complex. The western area contains very little groundwater. Groundwater that does occur is generally found in fractures at relatively shallow depth. This area is not considered a groundwater basin and is designated as either the Western Highlands or Mountain Region West.

The following descriptions for the Red Bluff and Coring subbasins were taken from the California Department of Water Resources Bulletin 118-03 (DWR 2003).

Table 6-7 TEHAMA WEST GROUNDWATER BASINS			
Groundwater Basin	**Subbasin**	**Subbasin Number**	**Total Area/Area in Watershed (acres)**
Redding	Bowman	5-6.01	85,330/6,330
Sacramento	Red Bluff	5-21.50	266,750/266,750
Sacramento	Corning	5-21.51	205,640/143,920

Hydrogeology

Red Bluff Subbasin
The Red Bluff Subbasin is bounded on the west by the Coast Ranges, on the north by the Red Bluff Arch, on the south by Thomes Creek and on the east by the Sacramento River. The Red Bluff Arch is a hydrologic divide between the Redding Basin to the north and the Sacramento Valley. The Red Bluff Subbasin is likely contiguous with the Corning Subbasin at depth.

The Red Bluff Subbasin aquifer system is composed of continental deposits of late Tertiary to Quaternary age. The Quaternary deposits include Holocene stream channel deposits and Pleistocene Modesto and Riverbank formations. The Tertiary deposits consist of Pliocene Tehama and Tuscan formations.

Holocene Stream Channel Deposits. These deposits consist of unconsolidated gravel, sand, silt and clay derived from the erosion, reworking, and deposition of adjacent Tehama Formation and Quaternary stream terrace deposits found at or near the surface along stream and river channels. The thickness varies from 1 to 80 feet (Helley and Harwood 1985). This unit represents the upper part of the unconfined zone of the aquifer. Although it is moderately to highly permeable it is not a significant contributor to groundwater because of its limited areal extent.

Pleistocene Modesto Formation. The Modesto Formation (deposited between 14,000 to 42,000 years ago) consists of poorly indurated gravel and cobbles with sand, silt, and clay derived from reworking and deposition of the Tehama and Riverbank formations. The deposit ranges from less than 10 feet to nearly 200 feet across the valley floor (Helley and Harwood 1985). The terrace deposits are observed along Thomes, Elder, and Red Bank Creeks.

Pleistocene Riverbank Formation. The Riverbank Formation (deposited between 130,000 to 450,000 years ago) consists of poorly-to-highly permeable pebble and small cobble gravels interlensed with reddish clay sands and silt. The formation ranges from less than 1 foot to over 200 feet thick depending on location (Helley and Harwood 1985). Riverbank terrace deposits are observed along Thomes, Pine, Dibble, Reeds, Red Bank, Oat and Elder Creeks.

Pliocene Tehama Formation. The Tehama Formation consists of sediments originating from the Coast Range and Klamath Mountains, and is the primary source of groundwater for the subbasin. The majority of the Tehama Formation consists of fine-grained sediments indicative of deposition under floodplain conditions (McManus 1993). The thickness of coarse-grained beds of sand and gravel, as indicated by drill log data, are typically no more than 5 to 10 feet. The majority of both coarse and fine-grained sediments appear unconsolidated or moderately consolidated. The thickness of the formation is estimated to be up to 1,200 feet north of the City of Corning (DWR 2000b).

Pliocene Tuscan Formation. The Tuscan Formation consists of volcanic gravel and tuff-breccia, fine- to coarse-grained volcanic sandstone, conglomerate and tuff, and tuffaceous silt and clay; derived predominantly from andesitic and basaltic sources of the Cascade Range. In the subsurface the Tuscan Formation is found juxtaposed with the Tehama Formation in the axis of the valley near the Sacramento River. Permeability is moderate to high with yields ranging from 100 to 1,000 gpm, excluding areas where beds of the impermeable tuff-breccia exist.

Corning Subbasin

The Corning Subbasin comprises the portion of the Sacramento Valley Groundwater Basin bounded on the west by the Coast Ranges, on the north by Thomes Creek, on the east by the Sacramento River, and on the south by Stony Creek. Stony Creek is believed to be a hydrologic boundary throughout the year. The Corning Subbasin is likely contiguous with the Red Bluff Subbasin at depth.

The Corning Subbasin aquifer system west is comprised of deposits of late Tertiary to Quaternary age. The Quaternary deposits include Holocene alluvium and the Pleistocene terrace deposits of the Modesto and Riverbank Formations. The Tertiary deposits consist of the Pliocene Tehama and Tuscan Formations.

Holocene Stream Channel Deposits. These deposits consist of unconsolidated gravel, sand, silt and clay derived from the erosion, reworking, and deposition of adjacent Tehama Formation and Quaternary stream terrace deposits. The thickness varies from 1 to 80 feet (Helley and Harwood 1985). The unit represents the upper part of the unconfined zone of the aquifer and is moderately to highly permeable; however, the thickness and areal extent of the deposits limit the water-bearing capability.

Pleistocene Modesto Formation. The Modesto Formation (deposited between 14,000 to 42,000 years ago) consists of poorly indurated gravel and cobbles with sand, silt, and clay derived from reworking and deposition of the Tehama and the Riverbank formations. The deposit ranges from less than 10 feet to nearly 200 feet across the valley floor (Helley and Harwood 1985). These terrace deposits are observed along Thomes Creek, Burch Creek, and Stony Creek.

Pleistocene Riverbank Formation. The Riverbank Formation (deposited between 130,000 to 450,000 years ago) consists of poorly to highly permeable pebble and small cobble gravels interlensed with reddish clay sands and silt. The formation ranges from less than 1 foot to over 200 feet thick depending on location (Helley and Harwood 1985). Surficial deposits are observed over the eastern third of the subbasin and along Burch Creek and its tributaries.

Pliocene Tehama Formation. The Tehama Formation consists of sediments originating from the coastal mountains and is the primary source of groundwater for the subbasin. The formation ranges in thickness up to 2,000 feet, increasing in thickness from west to east, dipping 4 degrees to the east (DWR 1982). The majority of the formation consists of fine-grained sediments indicative of deposition under floodplain conditions (McManus 1993). The majority of both coarse and fine-grained sediments are unconsolidated or moderately consolidated.

Pliocene Tuscan Formation. The Tuscan Formation is located within the eastern third of the subbasin. The formation occurs at a depth of approximately 200 feet from the surface and is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone, and volcanic ash layers. The formation is described as four separate but lithologically similar units, A through D (with Unit A being the oldest), which in some areas are separated by layers of thin tuff or ash units (Helly and Harwood 1985). Units A, B, and C are believed to extend as far west as the Corning Canal. Unit A is the oldest water-bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone. Unit B is composed of fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Unit C consists of massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. In the subsurface, these low permeability lahars form thick, confining layers for groundwater contained in the more permeable sediments of Unit B.

Subareas of the Corning Subbasin

Subareas of the Corning Subbasin located within the Tehama West Watershed include the Sacarmaneto Floodplain, Dissected Uplands, and Thomes Creek Floodplain.

Sacramento Valley Floodplain. Pleistocene and Holocene silt, sand, and gravel deposits in the vicinity of the City of Corning extend to depths of 50 to 185 feet. The proportion of sand and gravel in the unconsolidated alluvium overlying the Tehama Formation averages 20, 18, and 25 percent for depth intervals of 20 to 50 feet, 50 to 100 feet, and 100- to 200-feet respectively (Olmsted and Davis 1961). The Tehama Formation near the City of Corning consists of yellow clay, poorly consolidated sandstone, and conglomerate.

Dissected Uplands. The surface of the upland area within the central third of the subbasin between Thomes Creek and Stony Creek includes a coarsegrained gravelly conglomerate locally capping the Tehama Formation. Wells drilled in this area encounter up to 60 feet of coarse deposits before reaching fine-grained Tehama deposits. The deposits are believed to be formed as a response to a fixed base level by impeded or enclosed drainages and have been referred to as the Red Bluff Formation. (Helley and Harwood 1985). The shallow gravel is not a significant contributor to groundwater storage due to its position above the saturated zone.

Thomes Creek Floodplain. Bounding the northern extents of the subbasin, the Thomes Creek floodplain includes Holocene alluvium underlain by deposits of both the Modesto and Riverbank Formations. The floodplain averages about 1 mile in width and extends from the Coast Ranges to the Sacramento River floodplain.

Groundwater Recharge and Discharge

Natural recharge of aquifers occurs where mountain ranges intersect with a groundwater basin, where streams pass over permeable geologic formation, and where precipitation infiltrates through permeable soil and the underlying formations. In some cases, recharge occurs from infiltration from drainage ditches. Percolation of surface waterbodies where there are cross-permeable formations are considered to represent a significant portion of the natural recharge to aquifers in Tehama County (CDM 2003). However, there are no studies that quantify the amount of recharge that occurs in this or other manners.

Groundwater Use

Estimates of groundwater extraction for the Red Bluff Subbasin are based on a survey conducted by the DWR in 1994. The survey included land use and sources of water. The estimate of groundwater extraction for agricultural use is estimated to be 81,000 acre-feet. Groundwater extraction for municipal and industrial uses is 8,900 acre-feet. Therefore, total groundwater extraction in 1994 was 89,900 acre-feet. The total groundwater extraction estimate of 89,900 acre-feet in 1994 is slightly higher than the 2004 estimate of 77,500 acre-feet (see Table 6-6). Deep percolation from applied water in 1994 was estimated to be 20,000 acre-feet.

Estimates of groundwater extraction for the Corning Subbasin are based on surveys conducted during the years of 1993, 1994, and 1997. Surveys included land use and sources of water. Groundwater extraction for agricultural use is estimated to be 152,000 acre-feet. Groundwater extraction for municipal and industrial uses is estimated to be 6,600 acre-feet. The total groundwater extraction estimate of 158,600 acre-feet is significantly higher than the 2004 estimate of 103,200 (see Table 6-6). Deep percolation of applied water during 1993, 1994, and 1997 was estimated to be 54,000 acre-feet.

Groundwater Levels

Goundwater movement in the Tehama West Watershed generally flows from west to east. The Red Bluff Arch structure located between Cottonwood Creek and Red Bluff deflects water flow to the north, as north of this structure groundwater tends to flow to the northeast. Groundwater in the Tehama West Watershed seeps into and augments Sacramento River flow through much of the assessment area, as the river serves as a drain being recharged by valley aquifers.

Typically, water levels decline during the summer irrigation season and rebound during the winter. Also, groundwater levels typically are reduced during periods of drought, but generally rebound during moist cycles. However, an indication of depletion of groundwater is exhibited by lowering groundwater levels during periods of normal or above precipitation.

Review of hydrographs for long-term comparison of spring-spring groundwater levels indicates a decline of 3 to 12 feet associated with the 1976–77 and 1987–94 droughts, followed by a recovery to pre-drought conditions of the early 1970s and 1980s. Generally, groundwater level data show a seasonal fluctuation ranging from 3 to 15 feet for unconfined wells, up to 30 feet for semi-confined wells away from the Sacramento River, and up to 50 feet in confined wells. Data indicates a decline in groundwater levels during the period from 1998 to 2002, throughout the water basin, even though precipitation was at or above normal. This may indicate that groundwater usage exceeds recharge rates. Overall however, there does not appear to be any increasing or decreasing trends in the groundwater levels.

Example hydrographs for irrigation wells near Corning and Red Bluff are shown on Figures 6-12 and 6-13. As expected, the hydrographs show minimum groundwater levels occur in the late fall in response to irrigation pumping. Maximum groundwater levels occur in Spring. Variations are between 20 and 30 feet. Levels decreased during the 1970s drought and increased during the 1980s. During the period of record, there are no increasing or decreasing trends indicating that current extraction does not exceed recharge.

Fall 2004 and spring 2005 groundwater elevations for the groundwater basin are shown on Figures 6-14 and 6-15. The elevations show a decline of approximately 25 feet in the Corning area in response to seasonal irrigation use.

GEOMORPHOLOGY

Geomorphology is the study of landforms and the processes that create landforms, and fluvial geomorphology is the study of channel-forming processes. Understanding fluvial processes and the current condition of stream channels within the Tehama West Watershed is an important component of this watershed assessment. For example, Thomes Creek is one of the fastest eroding watersheds draining into the Sacramento Valley (DWR 1982).

Channel-forming processes include erosion, transport, and deposition. Erosion includes removal of sediment from hill slopes above the channel network as well as from channel banks and beds. Erosion within the channel may be lateral, causing channels to get wider, or vertical, causing channels to get deeper or to form gullies. Transport refers to the entrainment and movement of the material that is delivered to the channel, whether the material originates from within the channel or upslope. Channels transport water, sediment, and other materials such as wood and debris. Deposition of sediment, wood, and debris occurs when streams lose the physical capacity to transport the material. Deposition may occur within or above the channel.

The condition of the channel network in a watershed affects a wide variety of resources including the amount of water, sediment, and debris that the channel is capable of carrying; timing and duration of high-flow or flood events; health and vigor of riparian vegetation communities; water quality conditions including water temperature and turbidity; and habitat and passage conditions for fish and other aquatic organisms.

Channel Characteristics

Basin shape influences the discharge characteristics of a watershed. A circular watershed with a uniform slope and permeability will result in runoff from various parts of the watershed reaching the outlet at the same time. An elongated watershed with the same area, but having the outlet at one end of the major axis, will cause the runoff to be spread out over time, producing lower peak flows at the outlet.

As previously mentioned, Thomes Creek originates in the western portion of the watershed. This portion of the watershed is characterized by high elevations, high rainfall, steep slopes, and high erosion potential. The creek flows in a southerly direction for approximately 16 miles from its headwaters, and then flows eastward to the Sacramento Valley. The stream is approximately 36 miles long from its headwaters to Paskenta. It occupies an "L"-shaped basin 6 to 10 miles wide, having a dendritic drainage pattern. As shown in Figure 6-16, Thomes Creek has a rough, concave-upward stream profile. From its headwaters for 10 miles to the confluence of Fish Creek, Thomes Creek has an average gradient of 0.05 feet per foot. From there the gradient decreases to 0.025 for 17 miles to the confluence of Slate Creek. Below Slate Creek, the gradient is 0.0053 feet per foot.

The gradient change at Slate Creek corresponds with the mountain front of the Coast Ranges. Upstream, Thomes Creek and its tributaries are confined by steep-walled canyons having up to 3,000 feet of relief. Canyon slopes are steep, averaging 20 to 25 degrees. An "inner gorge" with slopes up to 40 degrees has formed at the bottom of the larger stream canyons. Below Slate Creek, Thomes Creek enters the valley, loses its confinement, and forms highly sinuous meander loops. The lateral meander movement of Thomes Creek has periodically cut terraces adjacent to the stream. Several remnant terraces are present at various levels above the present stream, giving the adjacent landscape a broad, stepped appearance.

Red Bank Creek also originates in the Coast Range Geomorphic Province at a maximum elevation of approximately 5,500 feet. The Red Bank Creek drainage is about 30 miles long and 7 miles at its widest. The lower 7 miles are only 2 miles wide at the widest point. The creek enters the Sacramento River just upstream from the Red Bluff Diversion Dam and the intake gates for the Tehama-Colusa Canal. The basin drains about 112 square miles.

In the upper reaches Red Bank Creek is incised deeply, forming narrow canyons and steep gorges. Just after entering the valley, the creek is joined by a number of side streams with alluvial sand and gravel channels. These include the North Fork Red Bank, Clover Creek, Pigpen Creek and Vale Gulch. In the lower 12 miles, Red Bank Creek flows as a single channel with steep banks downcut through the Tehama Formation. Peak flows occur between October and April in response to rainfall. During the summer months, Red Bank Creek is normally dry except for isolated places that tap the free water table and have standing water. Channel slope of Red Bank Creek is shown in Figure 6-17.

Reeds Creek is a geologically young stream system that developed after the Red Bluff pediment formed about a half million years ago. The pediment surface sloped gently toward the Sacramento River. The drainage that has developed on this uniform slope is approximately 18 miles long and has a maximum width of 6.7 miles. It is elongated in the east-west direction. Hydraulically, the Reeds Creek drainage more closely resembles a circular basin because the three major tributaries, Liza, Reeds, and Pine Creeks are approximately equal in length and they join Reeds Creek about 5 miles upstream from the mouth. Because of equivalent stream lengths, flood peaks meet at the same time, and have caused serious flooding in the lower 5 miles of stream.

The maximum elevation in Reeds Creek is about 1,150 feet. The stream flows eastward and enters Lake Red Bluff on the Sacramento River at the maximum pool elevation of 253 feet. Most of the basin topography consists of low, rounded hills and flat ridges between broad, flat-bottomed tributary stream valleys. The creek is an intermittent stream and is typically dry from June to October.

Most of Reeds Creek's tributaries are in narrow, incised channels that cut through flat bottomed valleys for most of their lengths. This configuration is effective in moving bedload through the system. The terraces that contain most of the gravel in the Reeds Creek basin are isolated from the active channel by steep banks. In some reaches, such as North Fork Reeds in Burr Valley, Liza Creek, and along parts of Pine Creek, the stream flows in multiple channels. In lower reaches near the mouth, the channel is alluvial. Channel slope of Reeds Creek is shown in Figure 6-18.

Channel Slope

A Level 1 assessment calls for the division of the channel network into slope ranges of greater than 20 percent, between 3 and 20 percent, and less than 3 percent. These slope ranges divide the channel network into areas that are likely to respond similarly to changes in input variables.

Channels and unchanneled areas with slopes greater than 20 percent are classified as source reaches. These very steep slope areas are likely to be dominated by mass-wasting processes (e.g., debris flows, landslides, etc.) and contribute sediment and debris to stream channels downstream or downslope. Channels with slopes between 3 and 20 percent are classified as transport reaches. Both mass-wasting and fluvial processes may significantly influence these moderate-to-steep reaches, but the channel slopes are steep enough to transport the sediment and debris. Channels with slopes less than 3 percent are classified as response reaches because they are "likely to exhibit pronounced and persistent morphologic adjustments to changes in sediment supply" (DNR 1997). These classifications are summarized in Table 6-8.

Table 6-8
CHANNEL SLOPE RANGES, RESPONSE POTENTIALS, AND TYPICAL BED MORPHOLOGIES

Slope Range (percent)	Response Potential	Typical Channel Bed Morphology
>20	Source	Colluvial
3–20	Transport	Cascade, step pool, plane-bed, forced pool-riffle
<3	Response	Plane-bed, forced pool-riffle, pool riffle, regime

Source reaches (i.e., channels that are greater than 20 percent slope) are dominated by colluvial processes. Sediment and other debris tend to accumulate in these channels, not as a result of running water (fluvial processes), but as a result of debris flows, landslides, soil creep, and other mechanisms related more to weathering and gravity.

Transport reaches (i.e., channels between 3 and 20 percent slope) exhibit a high variability of channel forms. Generally, cascades dominate channels between 8 and 20 percent. The cascades may be vertical at some locations (e.g., at knickpoints where falling water has undercut a resistant rock outcrop), but may also fall along the hill slope gradient. These channels may be deeply entrenched within walls that range from bedrock to various types of unconsolidated colluvial material, or they may be within shallow crenulations in a steep hill slope. Whatever the bank configuration, the steepness of the channel does not allow anything but very coarse substrate to remain, so bedrock or boulders usually dominate channel beds. In the 4 to 8 percent slope range, channels are likely to have step-pool morphologies in which relatively short (typically vertical) cascades alternate with plunge pools. The spacing of the pools is inversely related to channel steepness: the steeper the gradient the shorter the distance between pools. Specifically, pool spacing is related to the ratio of step steepness (height/length of the step) to the average channel slope, which is commonly between 1 and 2 in free-forming step-pool channels (Abrahams et al 1995). Pool lengths are typically on the order of only 3 to 4 channel-widths (Church 1994). In the 3 to 4 percent slope range, the likely channel types are plane-bed and forced pool-riffle.

Plane-bed channels may vary in roughness (i.e., coarseness of dominant substrate and amount of coarse material protruding from the bed), but they lack alternate pool-riffle or step-pool morphology. Instead, the beds are more uniform and relatively flat in both cross-section and longitudinal profile. Forced pool-riffle morphology is commonly found in bedrock-controlled channels. Bedrock outcropping along one side of a channel commonly results in scour of mobile material that creates and anchors a pool adjacent to the outcrop. Material scoured out of the pool tends to deposit immediately downstream of the pool creating a shallow riffle. The length and spacing of pools and riffles are controlled by the location of the resistant outcroppings rather than sediment transport and energy dissipation processes of free-forming pool-riffle channels (Church 1994). As a result, pools and riffles in this channel type may have very irregular lengths and spacing.

As with transport reaches, response reaches (i.e., channels with slopes less than 3 percent), which are the dominant channel morphology in the watershed, exhibit a variety of likely bed forms. Likely channel types associated with the 2 to 3 percent slope range are the same as that of the 3 to 4 percent range: plane-bed and forced pool-riffle (see description above). In the one to 2 percent slope range, the likely bed morphologies include plane-bed (see description above) and pool-riffle. Pool-riffle beds are free-forming channels whose beds are constructed primarily of alluvium. The dominant features of these beds are the regularly spaced pools and riffles. The spacing of riffles and pools is found to be in close balance to channel dimensions; riffles and pools are typically spaced every 5 to 7 bankfull channel-widths (Leopold 1994). Pool-riffle beds are also common at slopes less than 1 percent.

Regime bed channels have sand beds and lack regular pool-riffle morphology. Regime beds typically do have bedforms such as ripples, dunes, and bars. Because of their low slopes and relatively lower sediment transport capacities, regime channels are among the most susceptible channel forms to perturbation and adjustment (Montgomery and Buffington 1993).

Channel slope categories for major creeks in the Tehama West Watershed are shown on Figure 6-19.

Disturbances and Perturbations

Disturbances and perturbations can occur as man-caused or natural processes in a watershed. Severe storms for example, may result in disturbances such as debris flows, landslides, and large-scale tree blow-downs that are substantial enough to cause geomorphic channel adjustments. An example of a natural perturbation would be a lightening-caused wildfire resulting in a change in storm runoff rates or an increase in sediment influx to a channel that begins to push the channel network out of its old balance and toward a new one.

Events that create watershed perturbations or disturbances include, but are not limited to, severe storms, tectonic activity, fire, flooding, grazing, logging, agriculture, roads, dam construction, water diversion, stream channelization, mining, and urbanization.

Mass Wasting

As previously mentioned, Thomes Creek is one of the highest sediment-producing streams in the western Sacramento Valley of Northern California (CSUC 2005). Two primary sources of sediment include mass wasting in the upper watershed, especially the steeply sloped area between the Gorge and Slab (see Figure 6-19), and remobilization of sediment previously stored in the stream channel. Slope failures as debris slides, block slides, rotational/translational slides, debris avalanches and rock slides are common and widespread. It has been estimated that the annual sediment yield of the Thomes Creek watershed is greater than 450,000 cubic yards. As a result, there are 11 sand and gravel operations in the Thomes Creek channel between Paskenta and the Sacramento River confluence (CSUC 2005).

Landslide Types

The following landslide discussion was taken from the Thomes Creek Watershed Study (DWR 1982).

Common types of landslides are debris slides, debris flows, rock slides, translational-rotational slides, and mantle creep zones. Other mass movement features mapped in the Thomes Creek watershed include block slides, "gutted" streams, and undifferentiated slides. Debris slides and flows probably were the greatest sources of sediment during the December 1964 flood.

Debris slides involve slow-to-rapid downslope movement of predominantly unconsolidated and incoherent soil, rock, and organic matter. The mass becomes jumbled as it moves downhill from its source, leaving a barren main scarp and an irregular, hummocky deposit. These slides generally occur along oversteepened slopes of the inner gorge, especially along the outsides of meander bends where high floodwaters undercut riverbanks.

Debris flows involve similar materials as debris slides, but in a water-saturated state. The flow's movement resembles that of a viscous fluid, leaving a chaotically mixed, lobate deposit. Flows also occur in the inner gorge, commonly along the metastable toe of a large, deep-seated slide mass. Debris flows are generally activated during large storm events, but observations indicate snowmelt and small, late-spring storms may also initiate them.

Rockslides are common in the watershed, especially in the Thomes Creek channel between Dark Canyon and the Gorge. Rockslides involve a sudden, rapid downward movement of bedrock fragments. These may break up further and accumulate as talus deposits.

Block slides are a relatively uncommon form of large, deep-seated mass movement. These coherent masses are displaced along a plane of weakness, commonly an inclined bedding or fracture surface.

Translational-rotational slides are generally large-scale, deep-seated features that have a composite failure surface. They typically originate from amphitheater-shaped scarp areas. The slide mass generally fails along a concave upward-shear surface and rotates outward. Some material is transported downhill over a shear plane roughly parallel to the original ground surface. Slide material accumulates as lobate, hummocky deposits at the toe, often blocking or displacing stream drainage. Translational-rotational landslides are generally found along the canyon slopes adjacent to Thomes Creek and major drainages. Most are found at mid-elevations of the watershed, where slopes are longer and steeper and thereby more prone to saturation and failure. These do not occur in the Great Valley Sequence; "gutted" stream channels are scoured and corraded by debris torrents or by torrential debris-laden floodwaters cresting well above the elevation of normal channel flow. Gutted channels are easily recognized because near-stream vegetation has been stripped. Gutted streams occur on steep slopes of the Lazyman Buttes unit, and in long, straight tributary streams on the

South Fork Mountain Schist. Although they occur more frequently in logged areas, they also occur in virgin forests. Gutted streams are indicators of very sensitive soil and rock types.

Soil mantle creep zones have indistinct boundaries and relatively shallow, irregularly moving slide material. Failure rates overall are generally imperceptible, but small-scale slumping does occur. Mantle creep zones support mostly grassy vegetation. The zone is highly susceptible to gullying.

Mantle creep zones typically occur on south-facing slopes in the upper watershed. These slopes undergo more extreme seasonal changes in soil water content. Clayey soils typical of these zones are subject to desiccation cracking. During the rainy season water percolates into cracks quickly and saturates these masses. The lack of deep or extensive rooted vegetation adds to the instability of these slopes.

Causes of Landslides

Landsliding and erosion are natural watershed processes related to such long-term events such as climatic changes and regional geologic uplift. In the last few decades, however, a dramatic increase in active landslides appears to be related to land-use activities.

The multi-staged uplift of the Coast Ranges from the late Pliocene to mid-Quaternary was accompanied by rapid erosion and landsliding of the unstable Franciscan terrain. Now deep V-shaped canyons with compound slopes and bedrock channels characterize the upper watershed. Large-scale inactive translational-rotational landslides are common on the steeper slopes of the watershed. These landslides were apparently initiated by a combination of factors: 1) the weak rock types present in the Franciscan Complex and ophiolite can be very unstable when wet, 2) rapid stream downcutting apparently oversteepened the adjacent valley slopes, and 3) the glacially dominated climate in the northern hemisphere during the Quaternary was much wetter than at present. It is possible that most of the large-scale, deep-seated landslides were products of a wetter climate and higher streamflow.

Many active debris slides and flows are present along Thomas Creek and its major tributaries, Willow, Fish and Auger Creeks. However, the number of active slides has increased dramatically since significant timber harvesting began in the watershed. Active landslides were mapped from 1952, 1962, 1969, and 1979 air photos. The landslide area and area increases are shown in Table 6-9. Active landslide area increased 400 percent between 1952 and 1979; nearly all the increase has been due to debris slides and flows activated, along stream channels of the middle and upper watershed.

TABLE 6-9
ACTIVE LANDSLIDE AREA
THOMES CREEK WATERSHED

Year Evaluated	Active Landslide Area (acres)	Percent Increase
1952	200	---
1962	300	50
1969	740	145
1979	1,000	35

Roads

Roads can also create significant watershed perturbations by channel impingement and increased sediment supply, leading to bank instability and sedimentation (i.e., sediment deposition and reduction of dominant substrate sizes within the channel). Failure of road crossings, particularly culverts, can cause disturbances including, bed and bank erosion and change in channel course. Ungated roads may also promote erosion by allowing vehicles into areas that should be closed seasonally because of sensitive conditions.

In January 2001, the Forest Service adopted a new road management policy for all national forests which directs the agency to maintain a safe, environmentally sound road network that is responsive to public needs and affordable to manage. As part of this process, the Mendocino National Forest completed a Road Analysis Process Report in 2002 (USDA 2002). The results included an evaluation of road impacts including sediment production. Although this study included the entire Mendocino National Forest, which covers significantly more area than the Tehama West Watershed, the results are applicable in the upland areas.

Overall, the study concluded that roads contribute about 3 to 7 percent of the average sediment production from natural and human causes. This includes both surface erosion and mass wasting sources. Furthermore, sediment from roads and other human causes does not appear to be in excess of the sediment transport capabilities of the stream systems.

A detailed evaluation of forest roads located in Thomes Creek, Elder Creek, and Red Bank Creek is included in the Analysis Process Report. Overall, roads within these three drainages are ranked as having a high sediment potential. Additional information on soil erosion hazards is included in Section 4, "Geology and Soils."

Fire

Fire deserves some specific discussion in its role as a disturbance/perturbation. Natural wildfires are among the agents that can cause disturbance within a watershed. Fire may also, however, be an intentional, human-caused disturbance or perturbation. In addition, fire has a greater potential to cause disturbance or perturbation since the advent of fire suppression as a forest management practice early in the twentieth century. Fire suppression has resulted in widespread over-accumulation of fuels throughout the forests in the west. Now when wildfires ignite, whether natural or human caused, they burn with much greater intensity and are much more detrimental ecologically than they would have been before fire suppression. From a channel morphology perspective, high-intensity burns are much more likely to result in disturbance or perturbation than presuppression wildfires that burned in more open forest stands with much lighter fuel loads.

DATA GAPS

Stream flow data are not available for most creeks in the watershed.

CONCLUSIONS AND RECOMMENDATIONS

- Evaluate the possibility of augmenting stream flows by storage and retention of winter flood flows to improve habitat for fish and wildlife
- Evaluate possibility of vegetation management, including riparian restoration, to augment stream flows to improve habitat for fish and wildlife
- Obtain more flow data on tributaries to determine potential impacts
- Determine how to improve water conditions for fish and other riparian obligate species
- Conduct a comprehensive, watershed-wide road inventory to evaluate the contribution to erosion and develop a plan for prioritizing road improvement activities
- Install water gauging stations on at least the major streams in the watershed, particularly those that can provide information for other streams that may not have gauging stations
- Assess the effects of storm water runoff and non-point source pollution especially along roads in development areas
- Establish baseline information on geomorphology of the streams including slope, basic channel types, extent and type of riparian vegetation, and gravel counts. Future planning and assessment strategies could include:
    - Stream prioritization of major streams based on a variety of criteria including water quality, biological value, and need and opportunities for restoration
    - Stream classification according to Rosgen Stream Classification System to develop basic quantitative and qualitative knowledge of natural channel conditions
    - Site specific geomorphic assessments including site reconnaissance, cross-section surveys, sediment sampling, and determination of important geomorphic parameters including bankfull-discharge channel geometry and flows, and sediment transport characteristics

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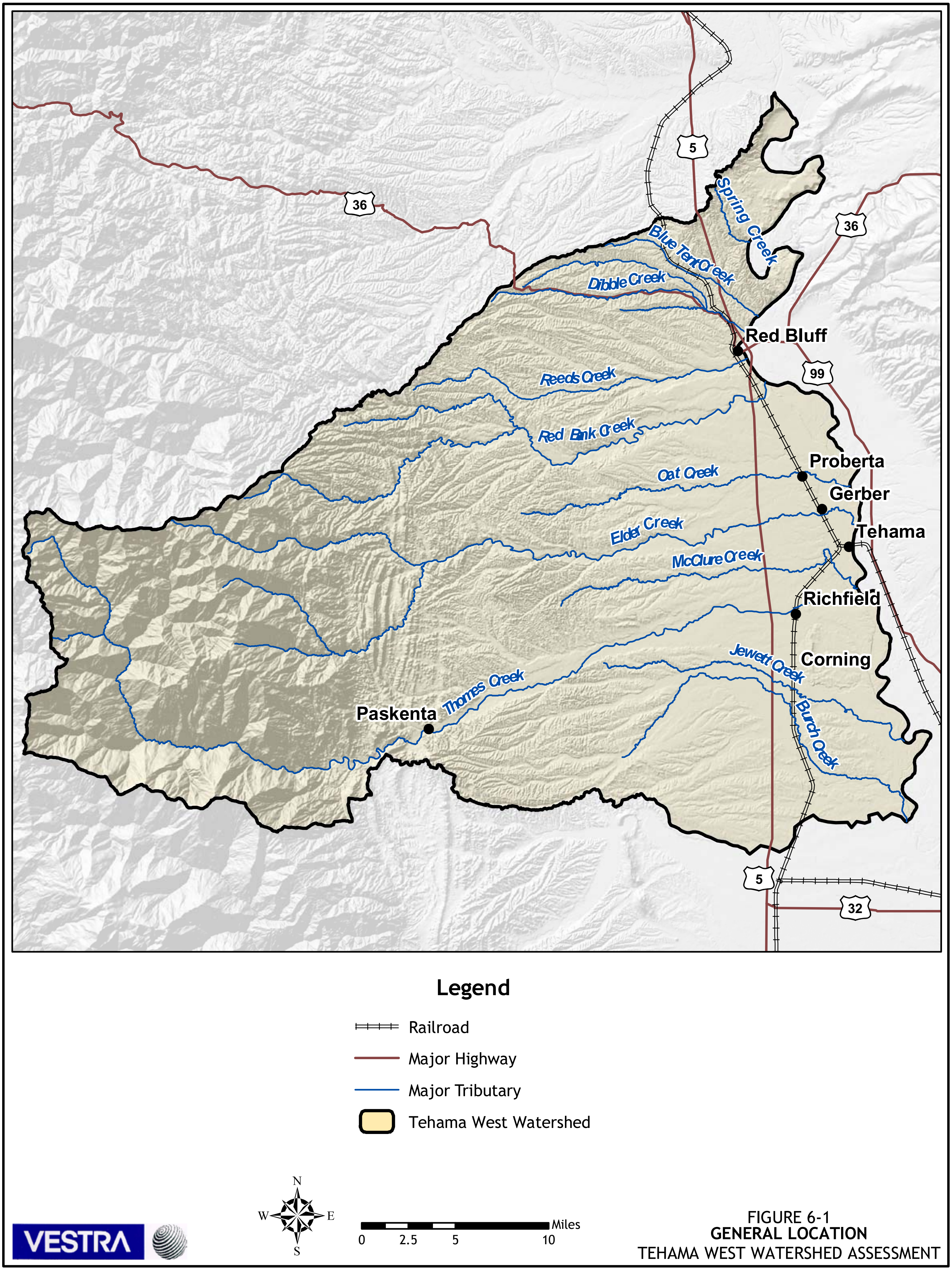
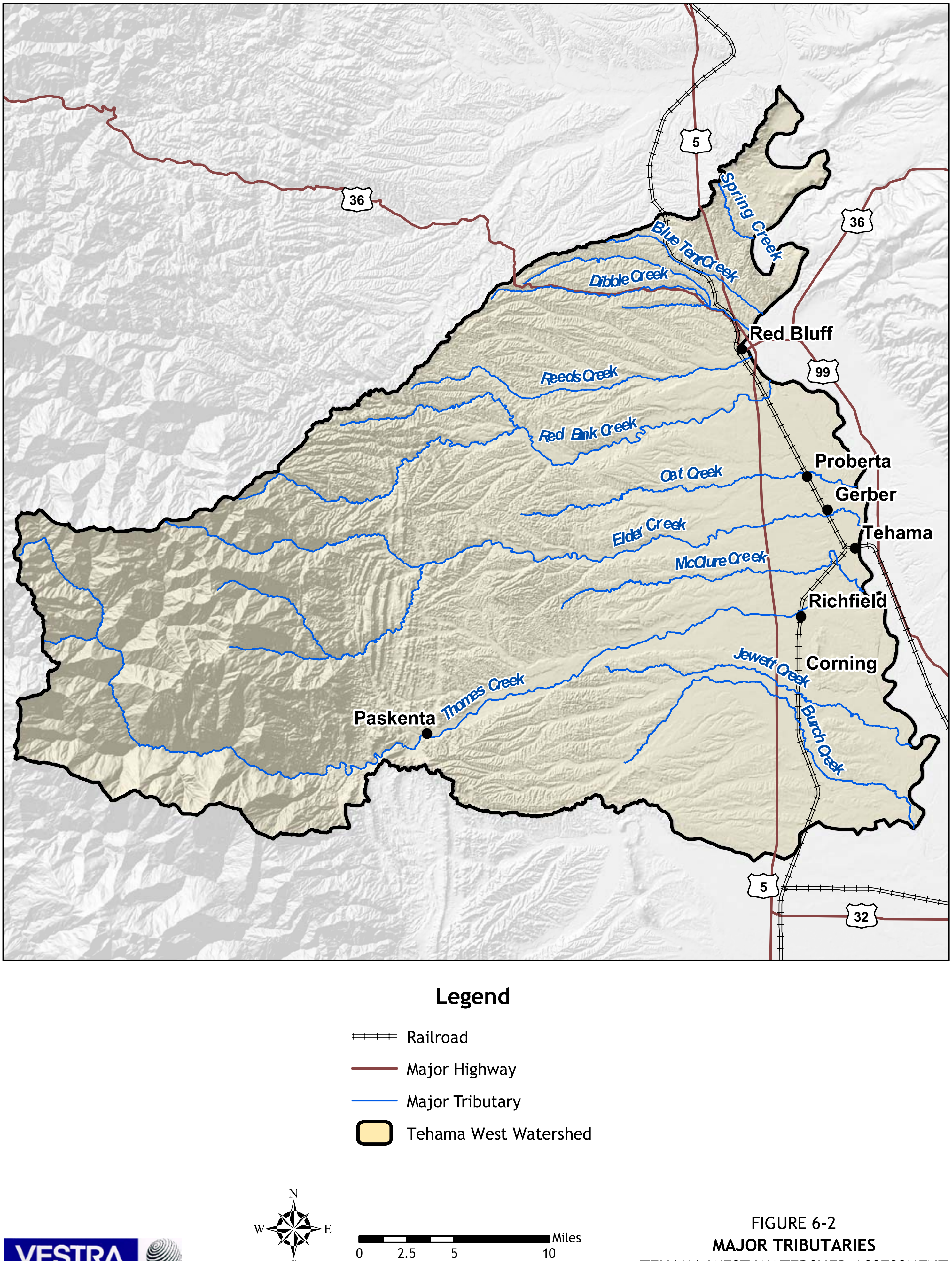


FIGURE 6-1
GENERAL LOCATION
TEHAMA WEST WATERSHED ASSESSMENT

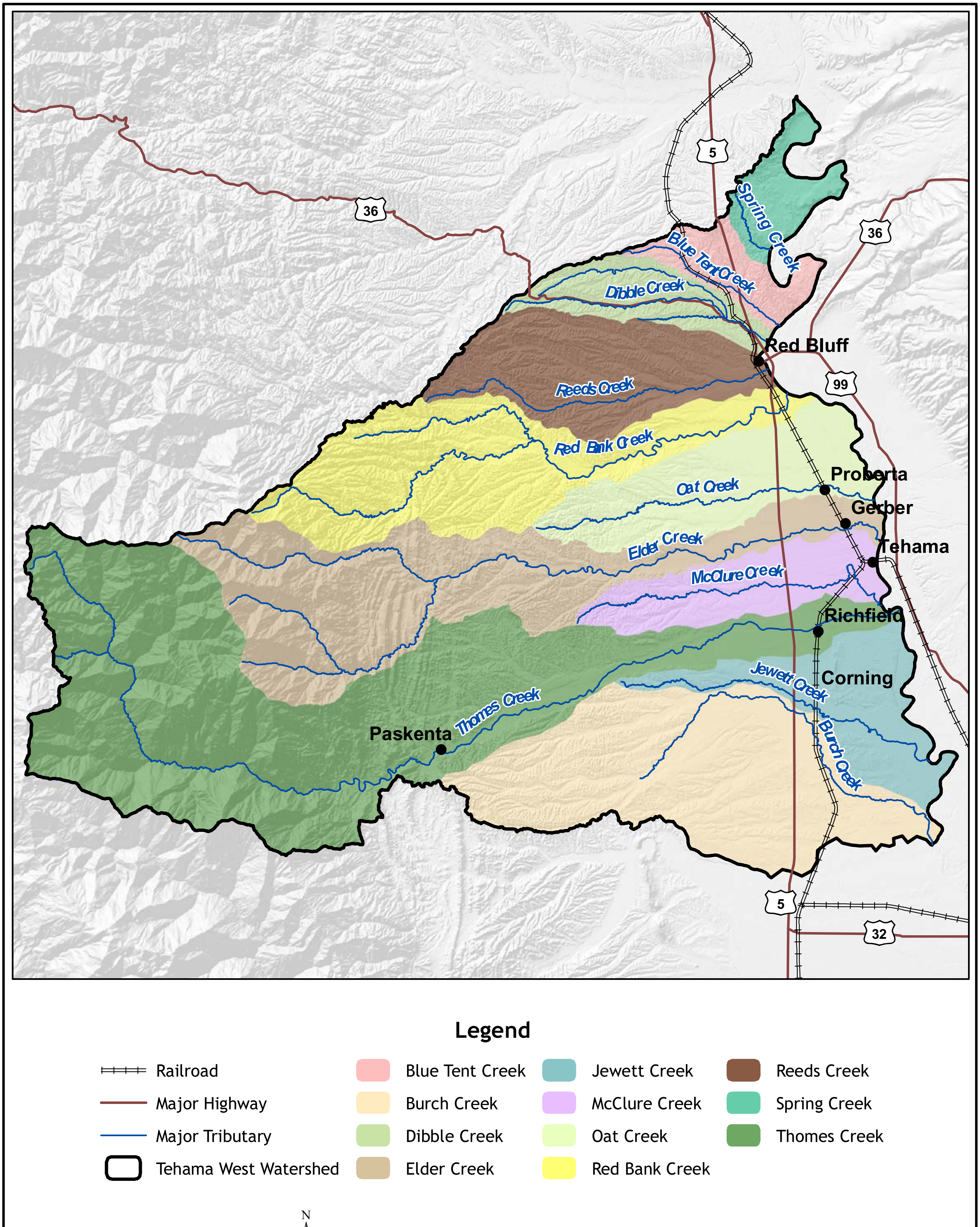
SOURCE: CALIFORNIA SPATIAL INFORMATION LIBRARY



VESTRA

FIGURE 6-2
MAJOR TRIBUTARIES
TEHAMA WEST WATERSHED ASSESSMENT

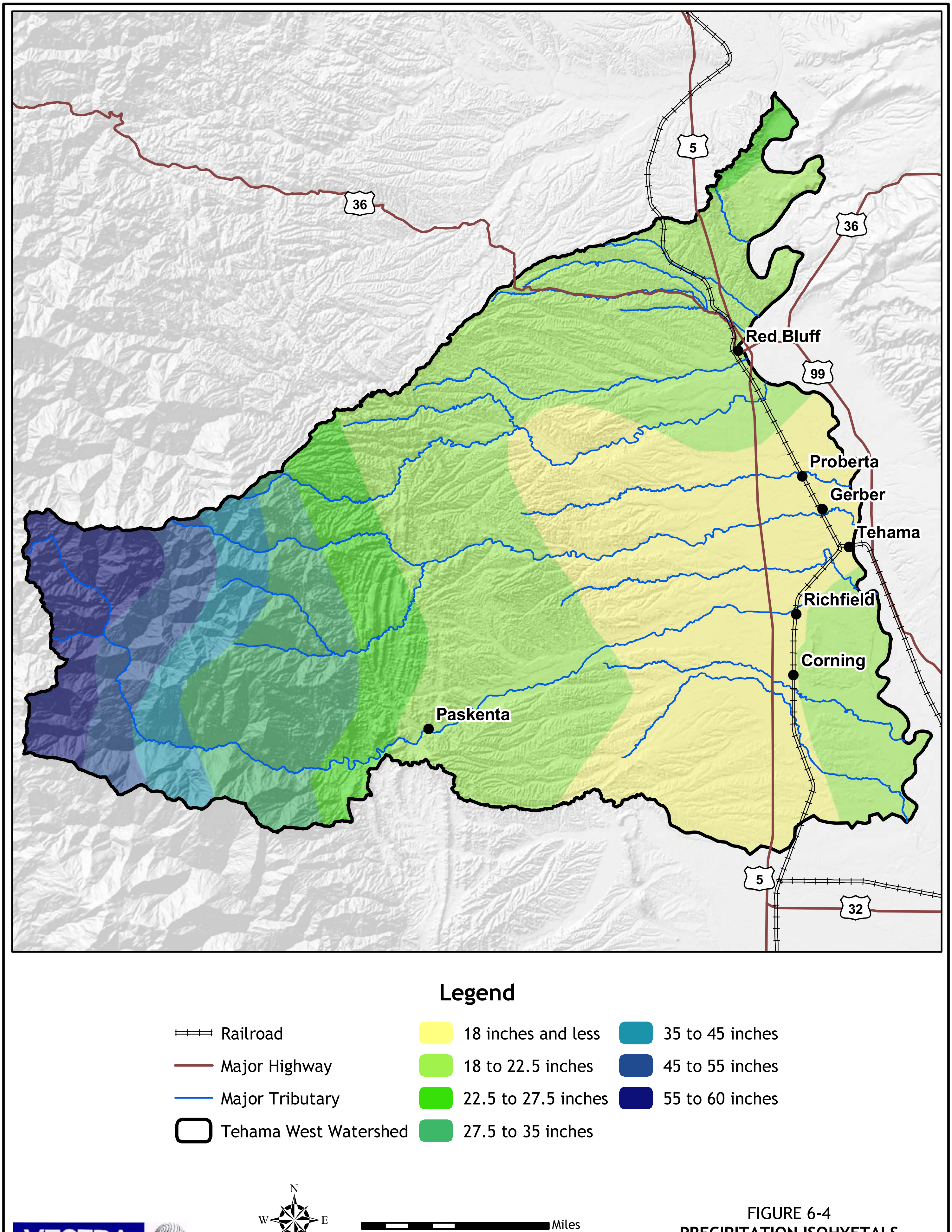
SOURCE: CALIFORNIA SPATIAL INFORMATION LIBRARY



VESTRA

FIGURE 6-3
SUB-UNITS
TEHAMA WEST WATERSHED ASSESSMENT

SOURCE: CALIFORNIA SPATIAL INFORMATION LIBRARY



VESTRA

FIGURE 6-4
PRECIPITATION ISOHYETALS
TEHAMA WEST WATERSHED ASSESSMENT

SOURCE: CALIFORNIA SPATIAL INFORMATION LIBRARY

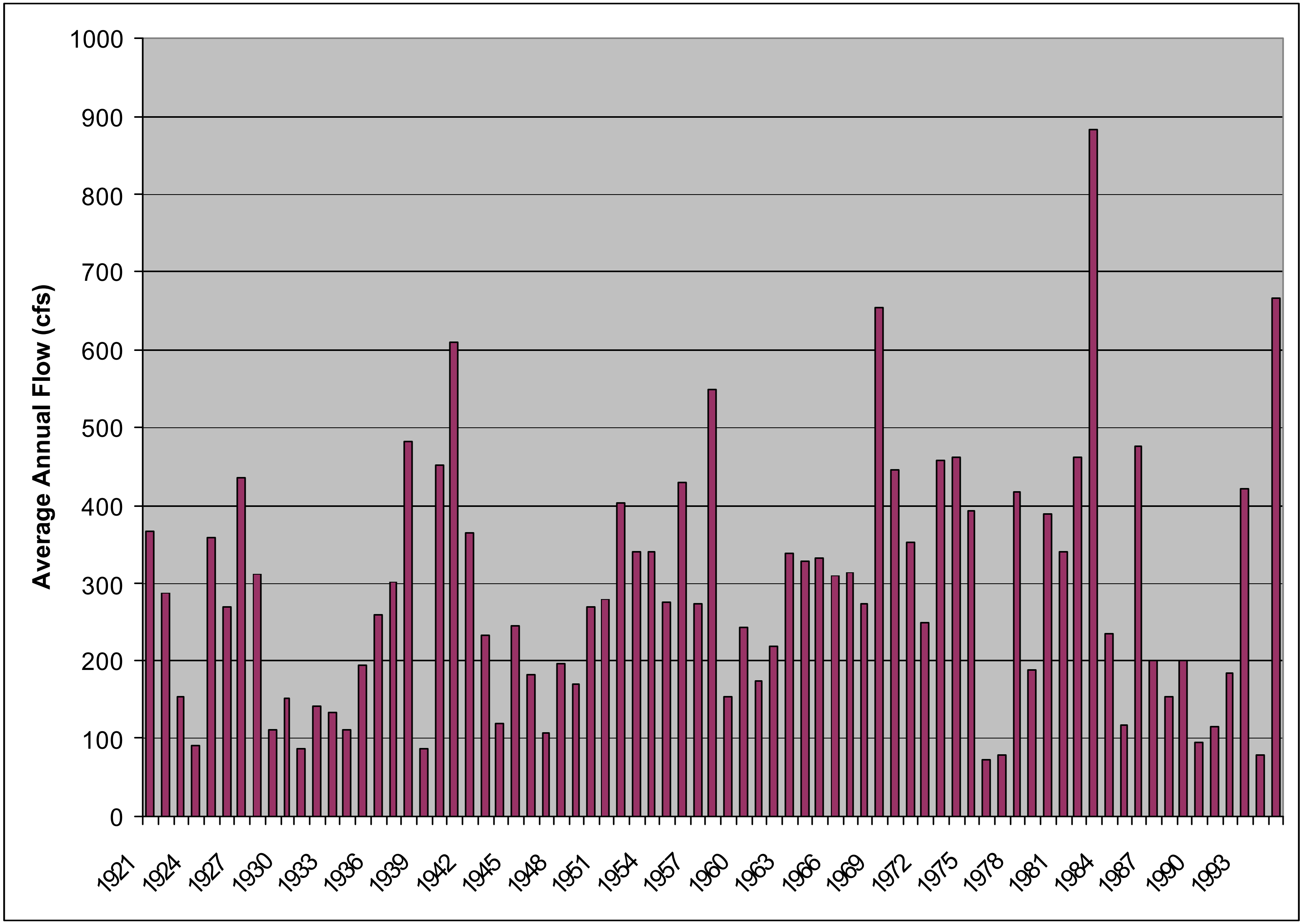


FIGURE 6-5A
MEAN ANNUAL FLOWS
THOMES CREEK AT PASKENTA
1921 - 1995
TEHAMA WEST WATERSHED ASSESSMENT

VESTRA

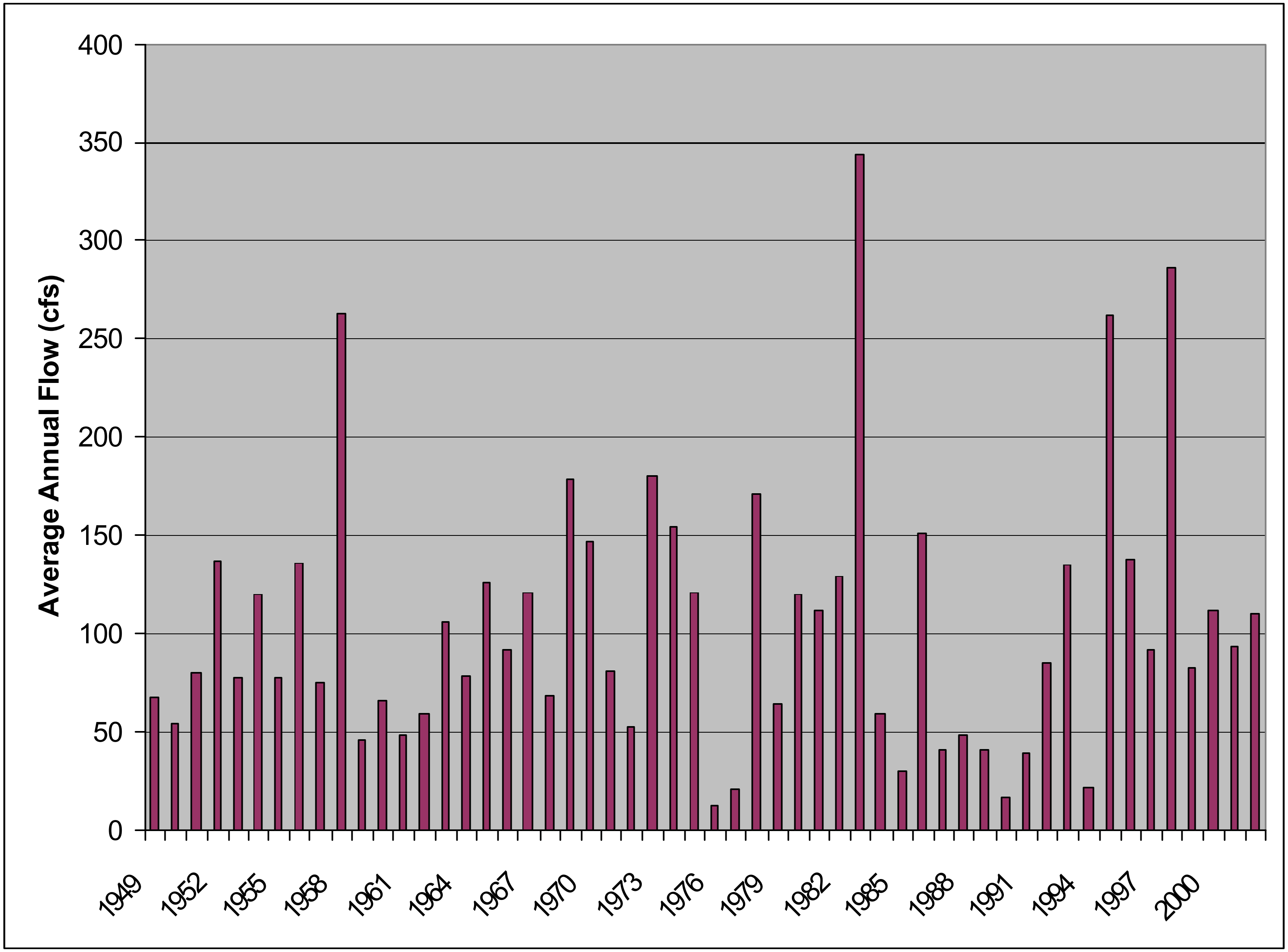


FIGURE 6-5B
MEAN ANNUAL FLOWS
ELDER CREEK NEAR PASKENTA
1949 - 2002
TEHAMA WEST WATERSHED ASSESSMENT

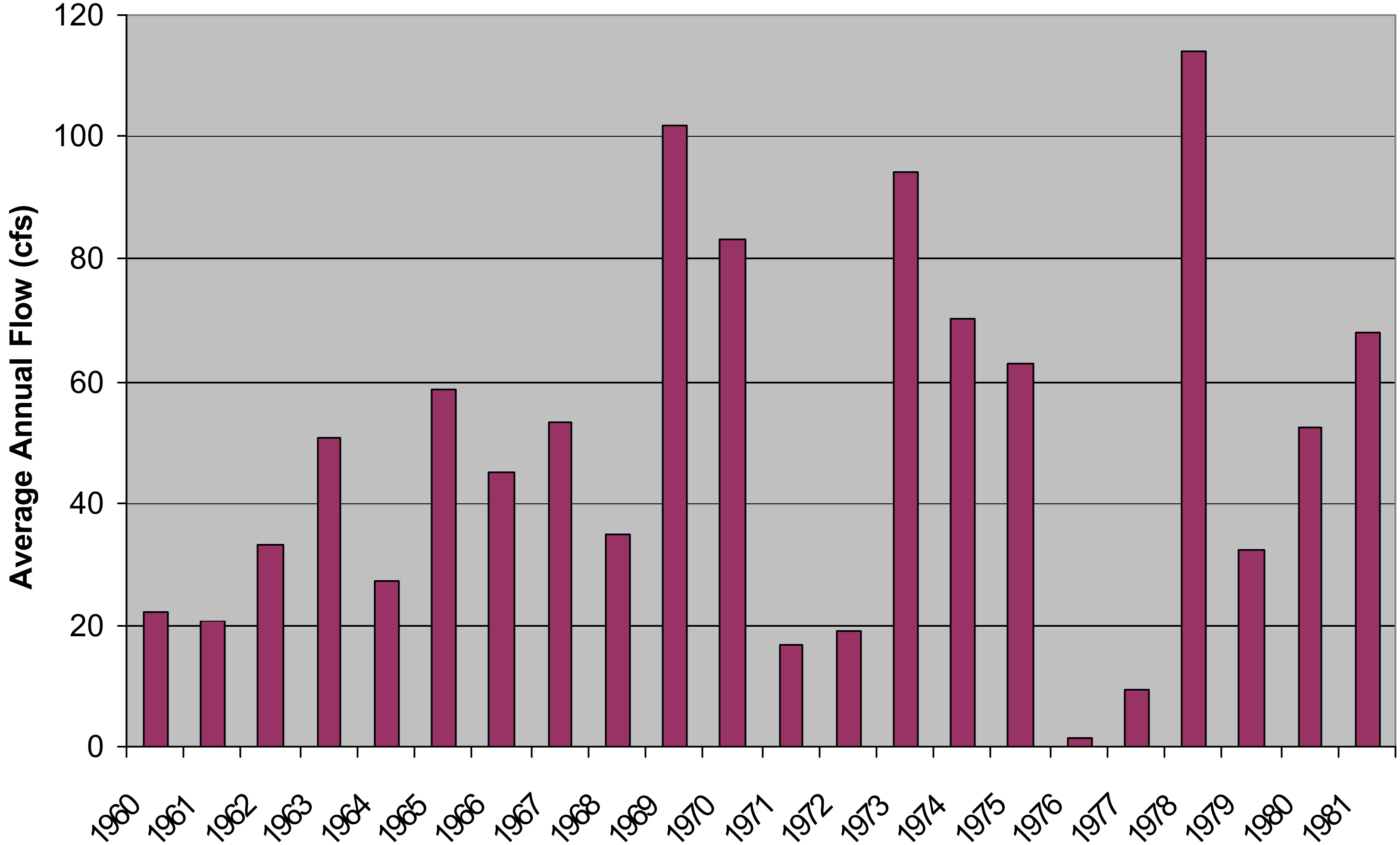


FIGURE 6-5C
MEAN ANNUAL FLOWS
RED BANK CREEK NEAR RED BLUFF STATION
1960 - 1981
TEHAMA WEST WATERSHED ASSESSMENT

VESTRA

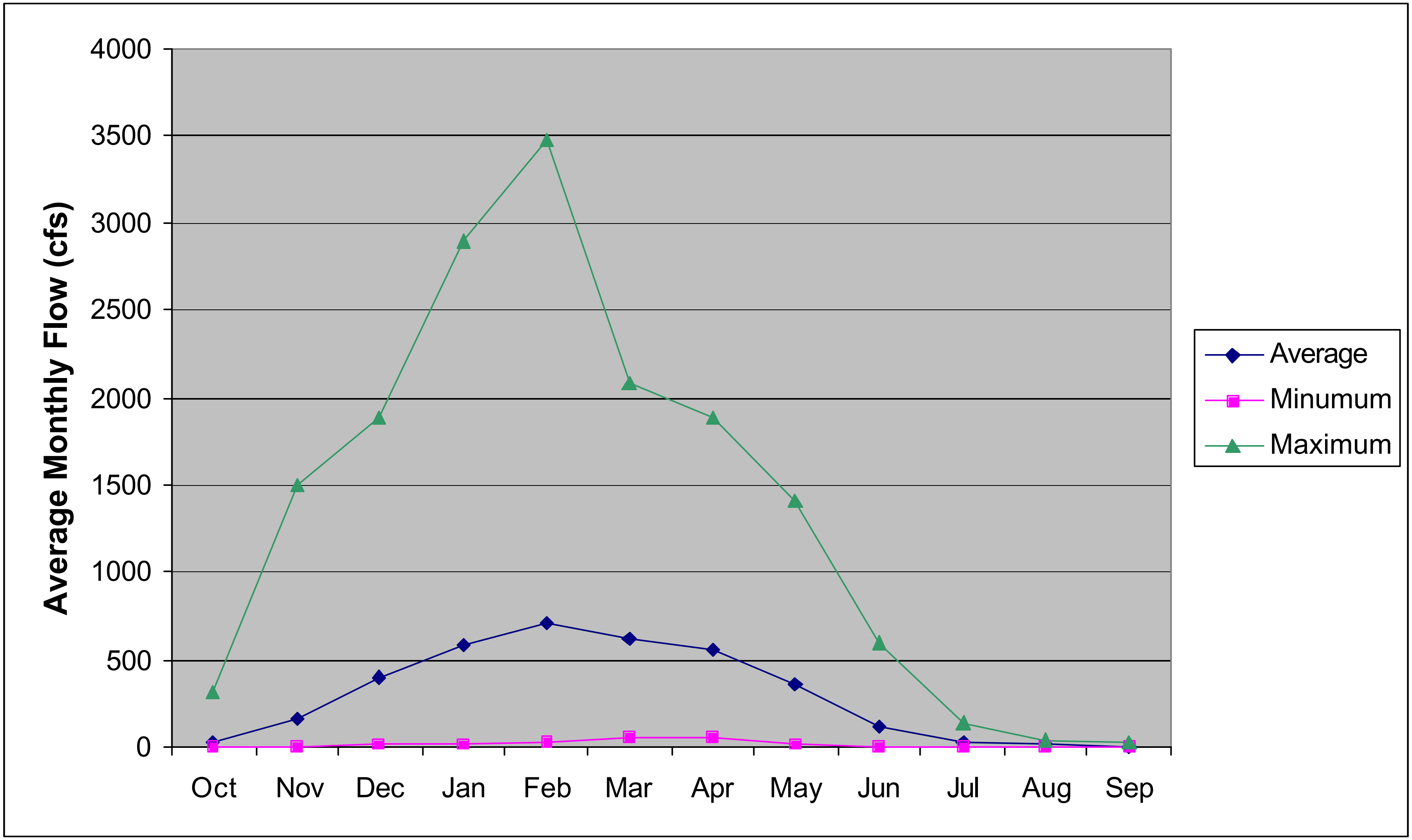


FIGURE 6-6A
MEAN MONTHLY FLOWS
THOMES CREEK AT PASKENTA
1920 - 1996
TEHAMA WEST WATERSHED ASSESSMENT

VESTRA

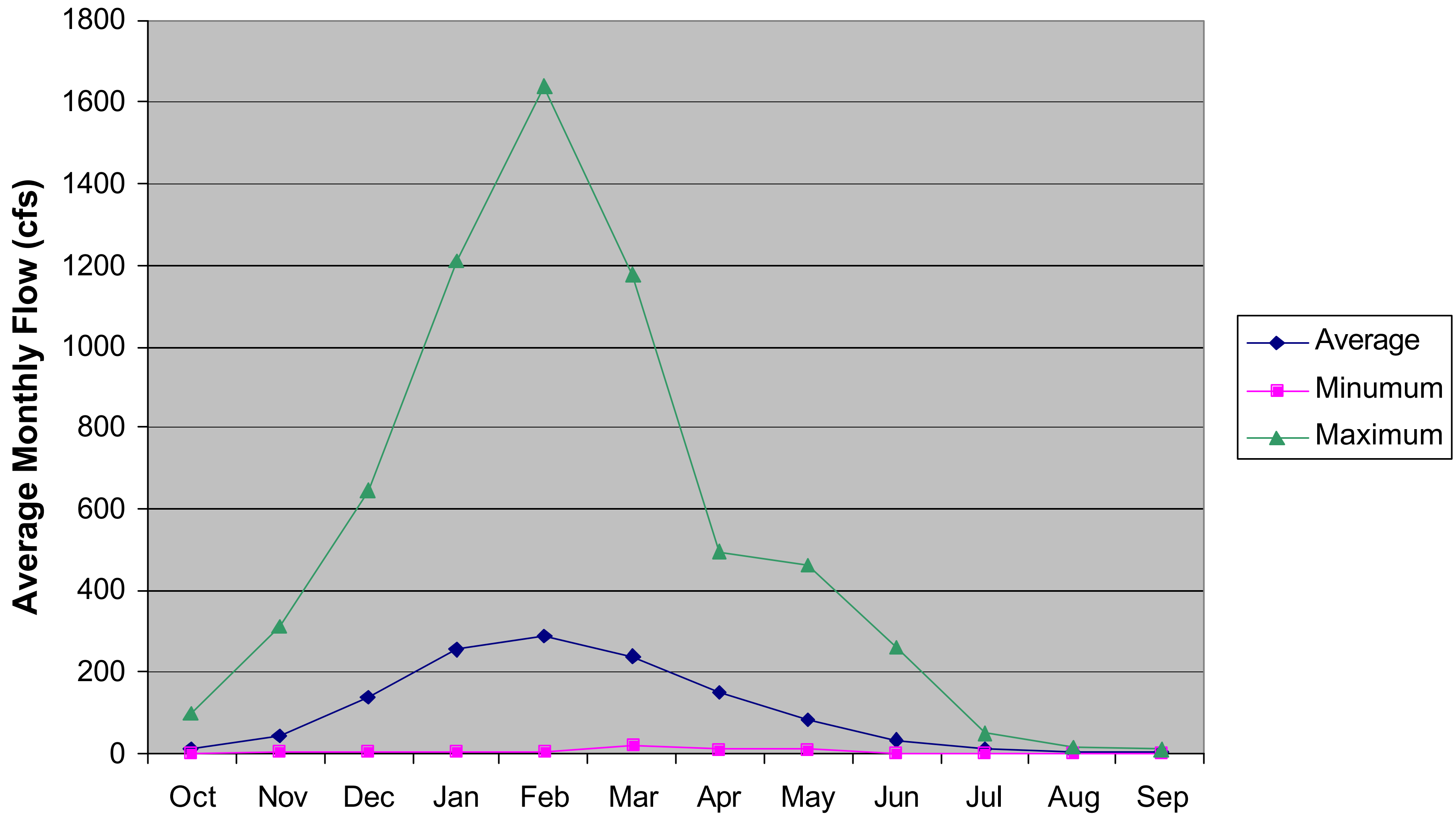


FIGURE 6-6B
MEAN MONTHLY FLOWS
ELDER CREEK NEAR PASKENTA
1948 - 2003
TEHAMA WEST WATERSHED ASSESSMENT

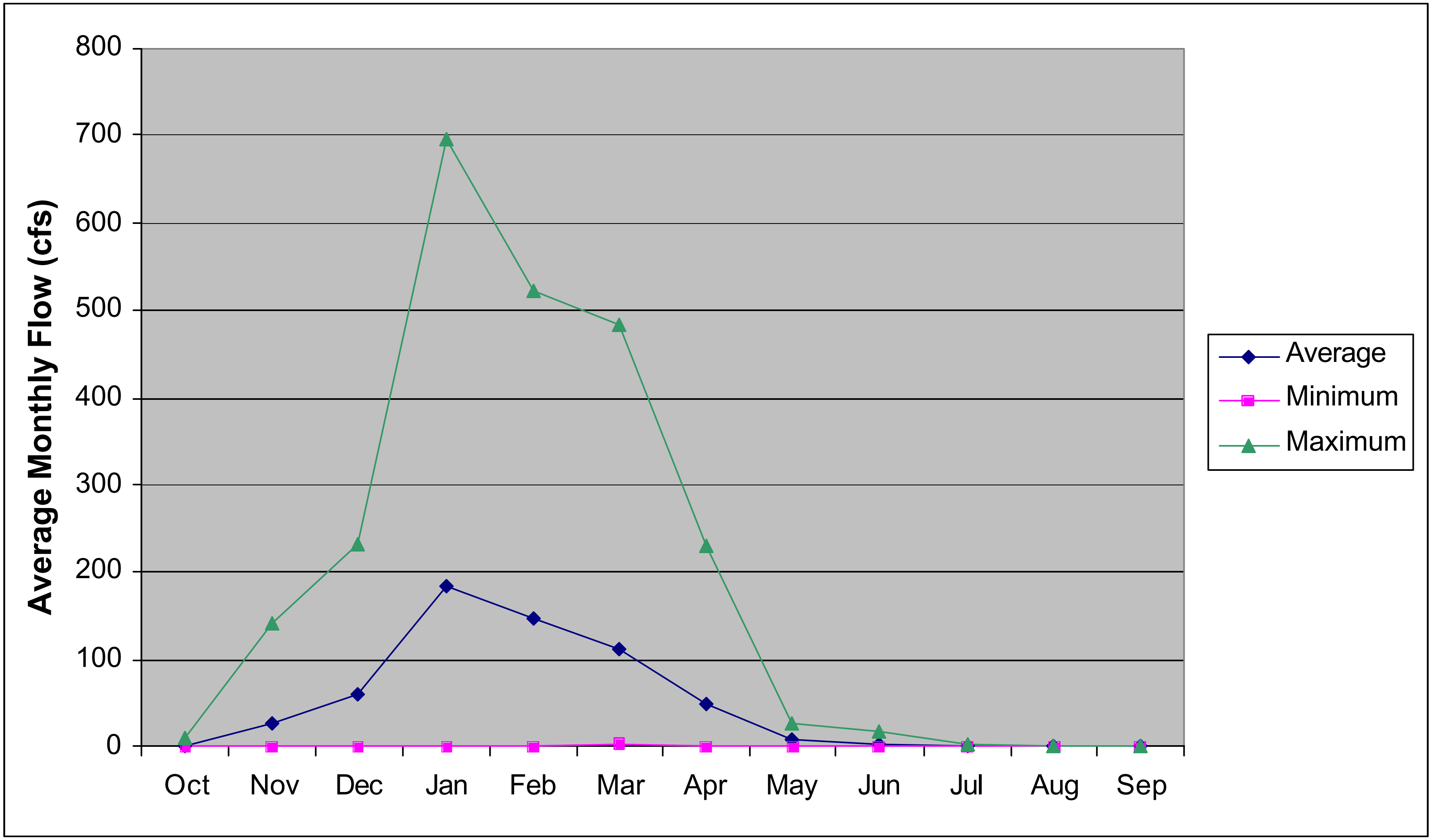


FIGURE 6-6C
MEAN MONTHLY FLOWS
RED BANK CREEK NEAR RED BLUFF
1959 - 1982
TEHAMA WEST WATERSHED ASSESSMENT

VESTRA

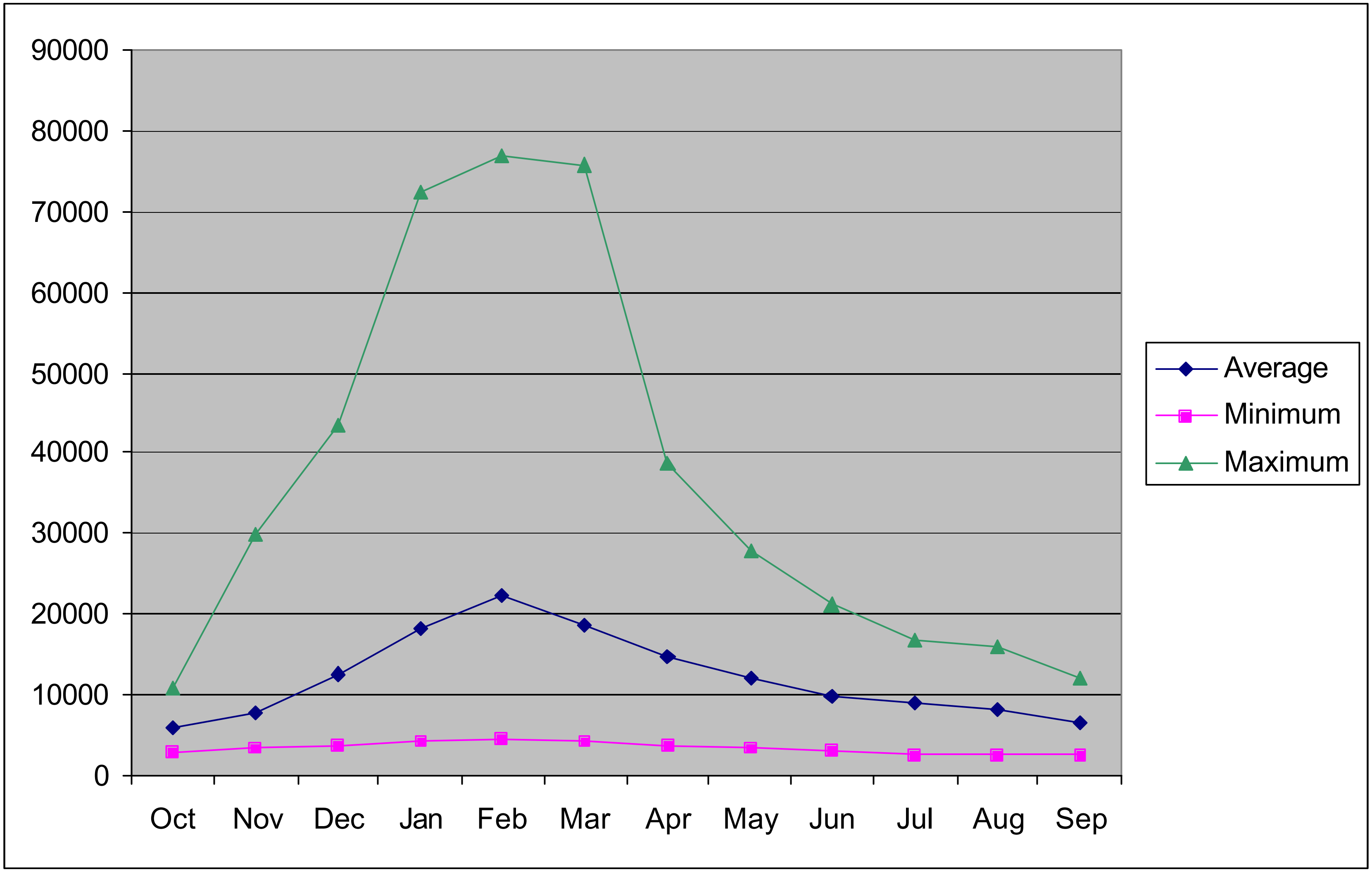


FIGURE 6-7
MEAN MONTHLY FLOWS
SACRAMENTO RIVER AT THE BEND ABOVE RED BLUFF
1891 - 2004
TEHAMA WEST WATERSHED ASSESSMENT

VESTRA

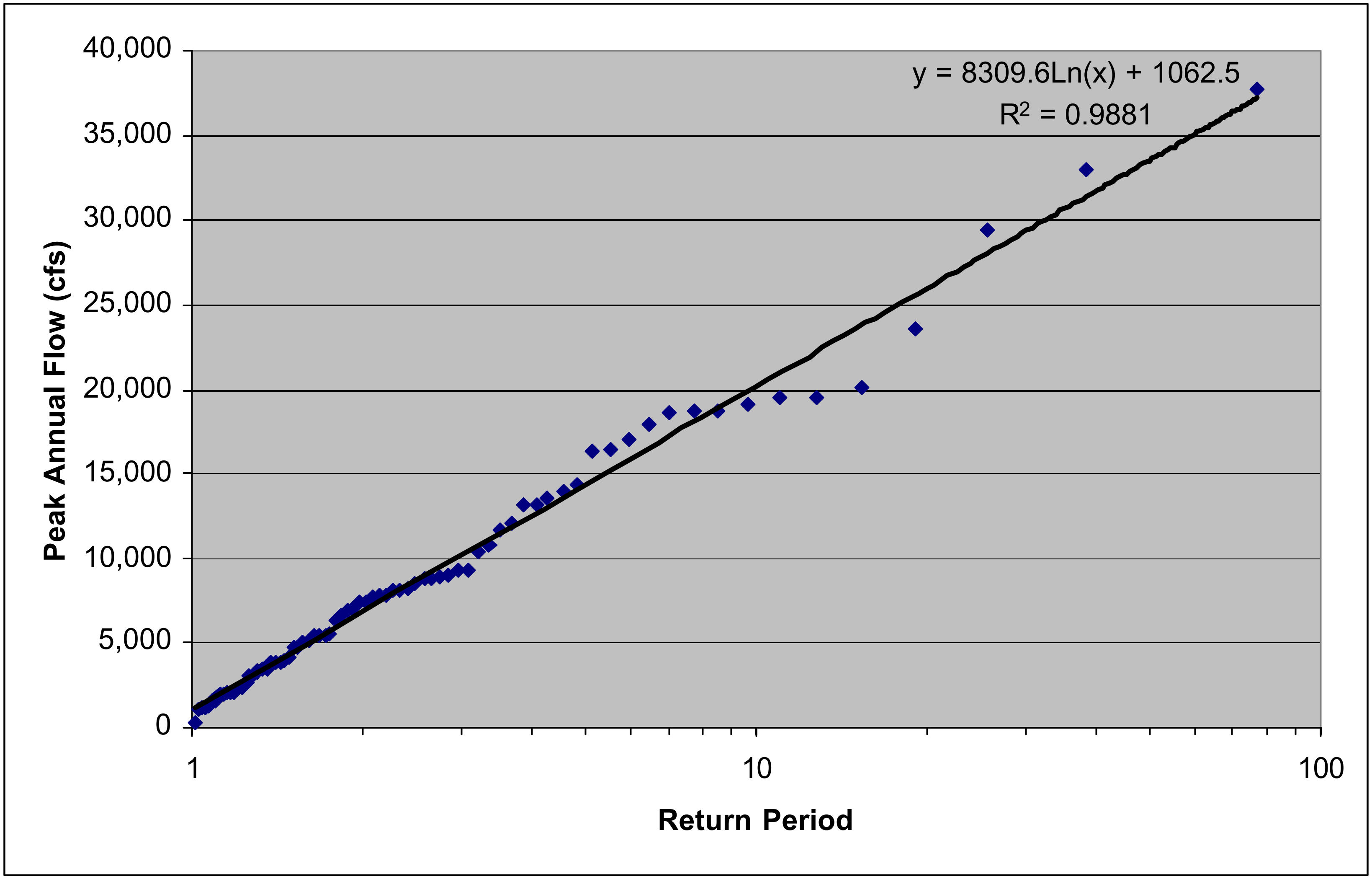
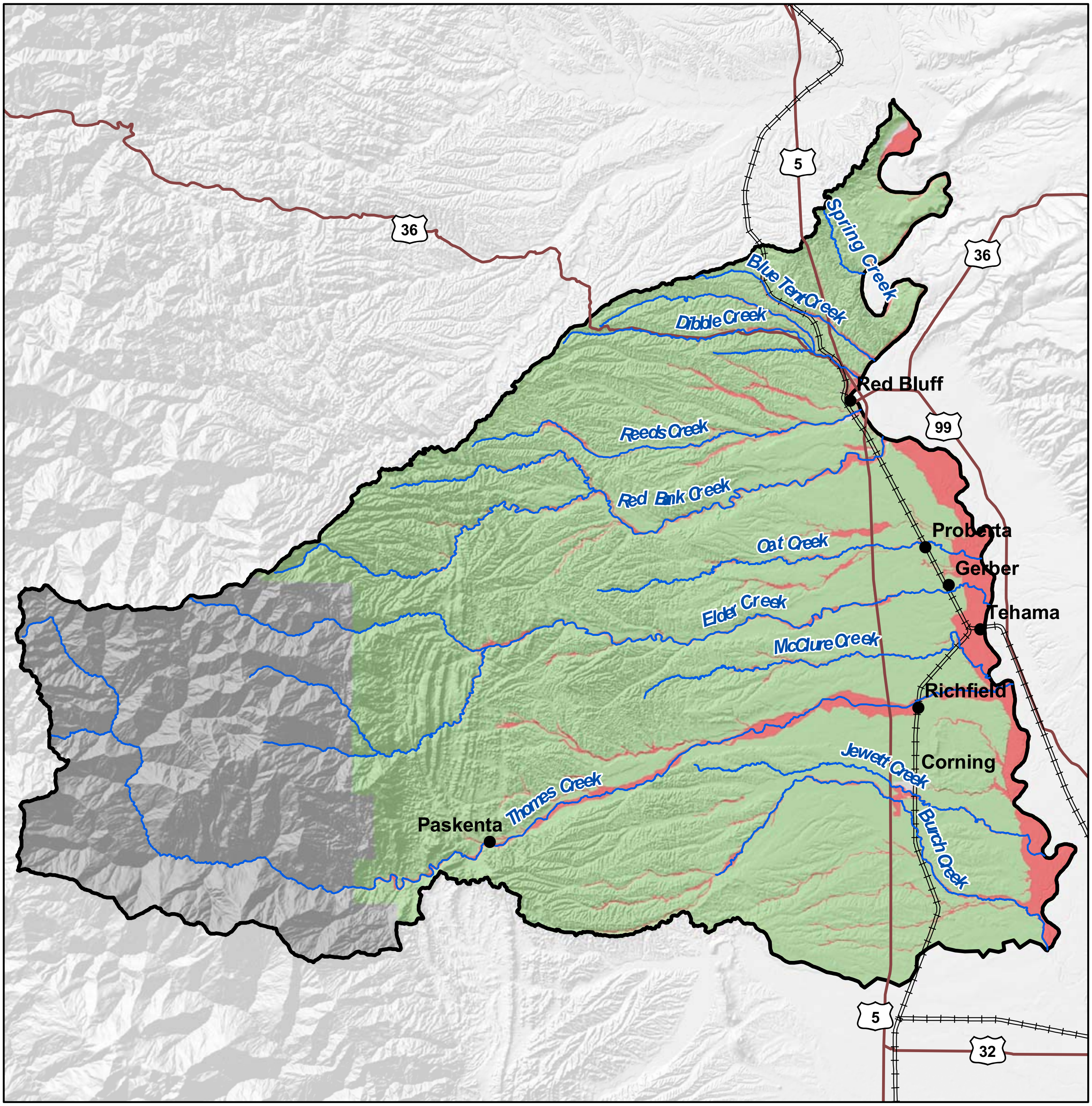


FIGURE 6-8
PEAK ANNUAL FLOW RETURN PERIOD
THOMES CREEK
TEHAMA WEST WATERSHED ASSESSMENT

VESTRA



Legend

- Railroad
- Major Highway
- Major Tributary
- Tehama West Watershed
- Zone A - Area subject to inundation
- Zone X - Area outside of 500-year flood
- Zone D - Unstudied area

N W E S

0 2.5 5 10 Miles

VESTRA

FIGURE 6-9
FLOOD INUNDATION ZONES
TEHAMA WEST WATERSHED ASSESSMENT

SOURCE: FEDERAL EMERGENCY MANAGEMENT AGENCY

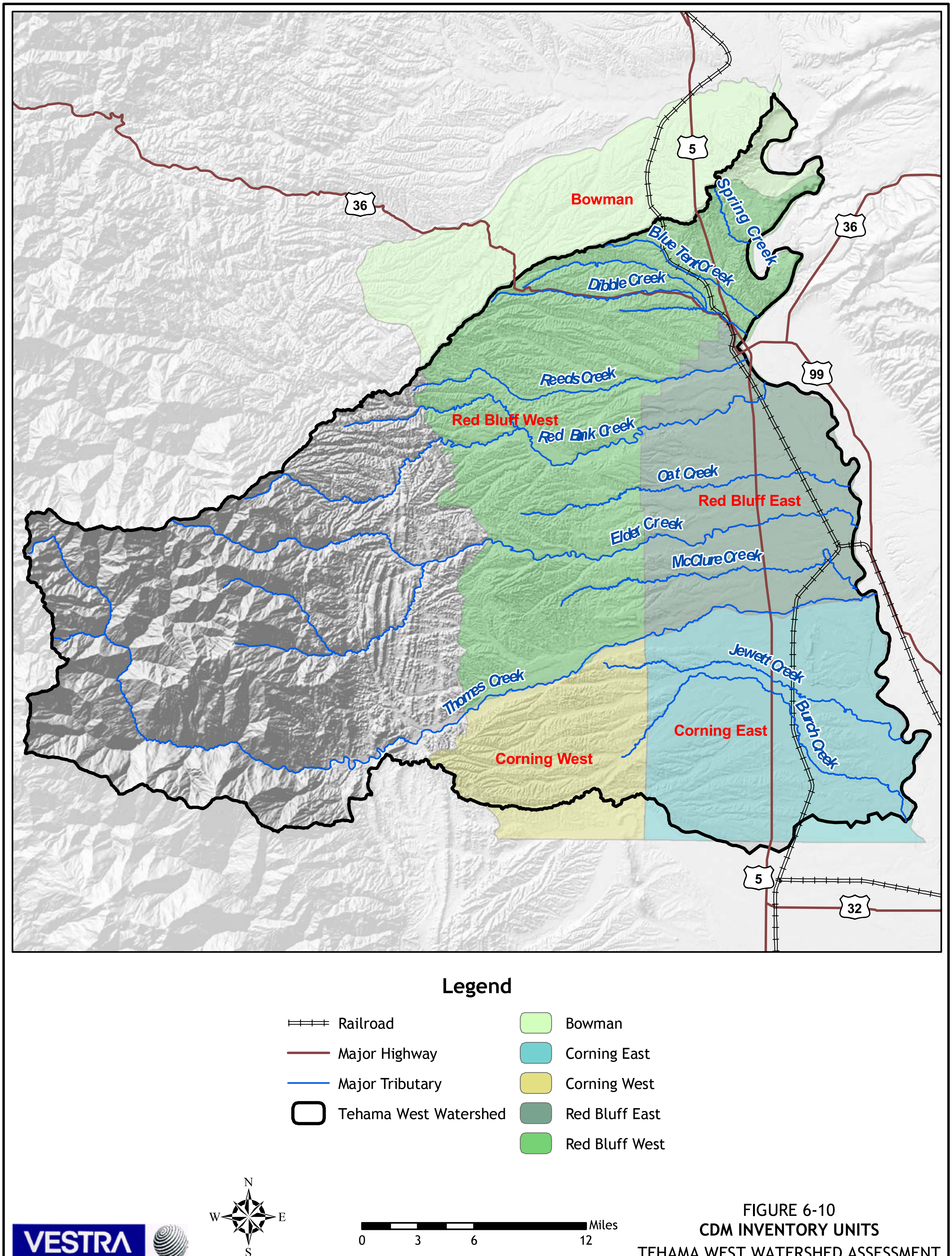
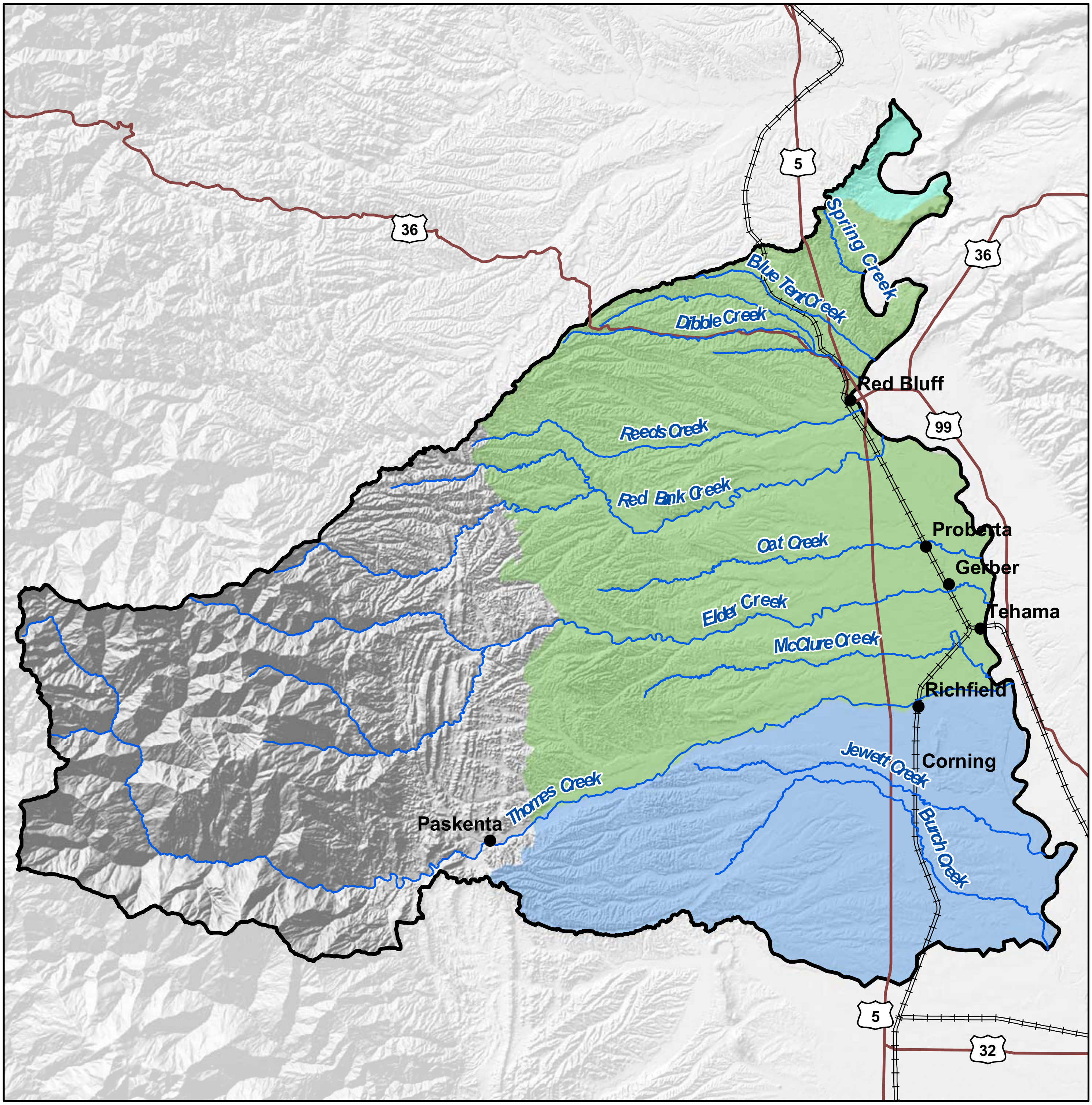


FIGURE 6-10
CDM INVENTORY UNITS
TEHAMA WEST WATERSHED ASSESSMENT

SOURCE: CDM



Legend

- Railroad
- Major Highway
- Major Tributary
- Tehama West Watershed
- Sacramento Valley - Bowman
- Sacramento Valley - Corning
- Redding Area - Red Bluff

N W E S

Miles 0 3 6 12

VESTRA

FIGURE 6-11
GROUNDWATER BASINS
TEHAMA WEST WATERSHED ASSESSMENT

SOURCE: CDM

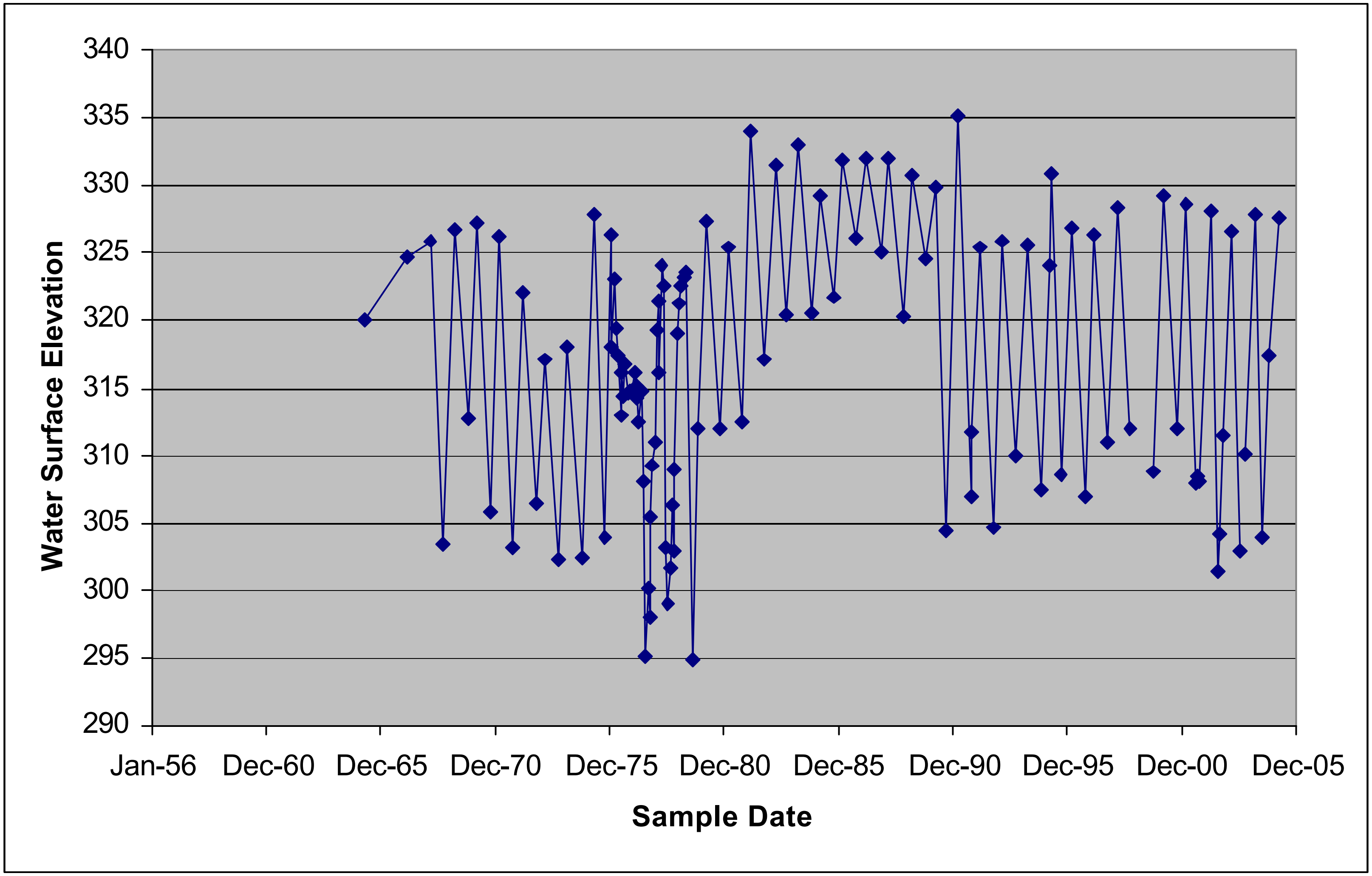
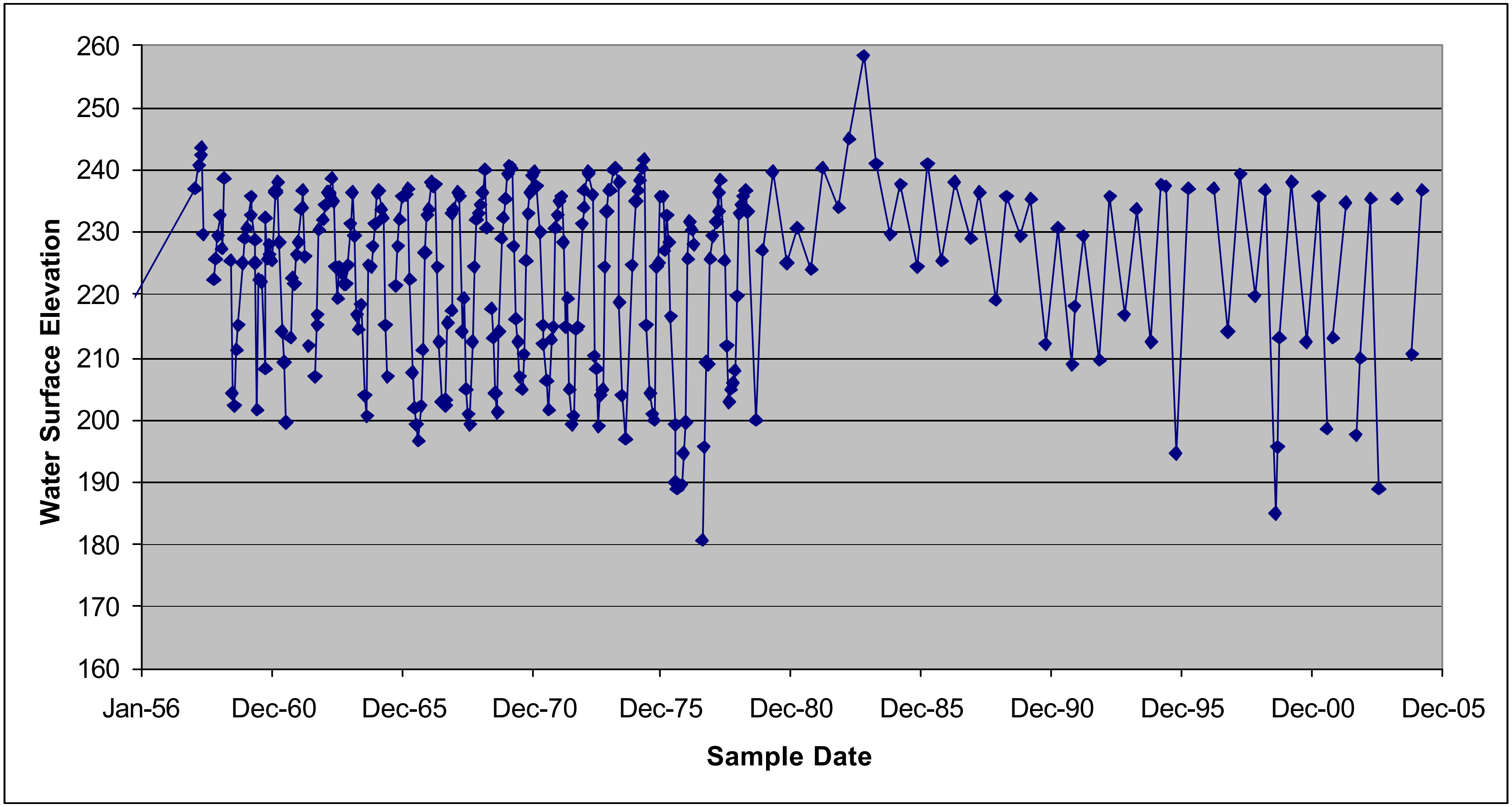


FIGURE 6-12
GROUNDWATER HYDROGRAPH
WELL 27N04W35E001M
TEHAMA WEST WATERSHED ASSESSMENT

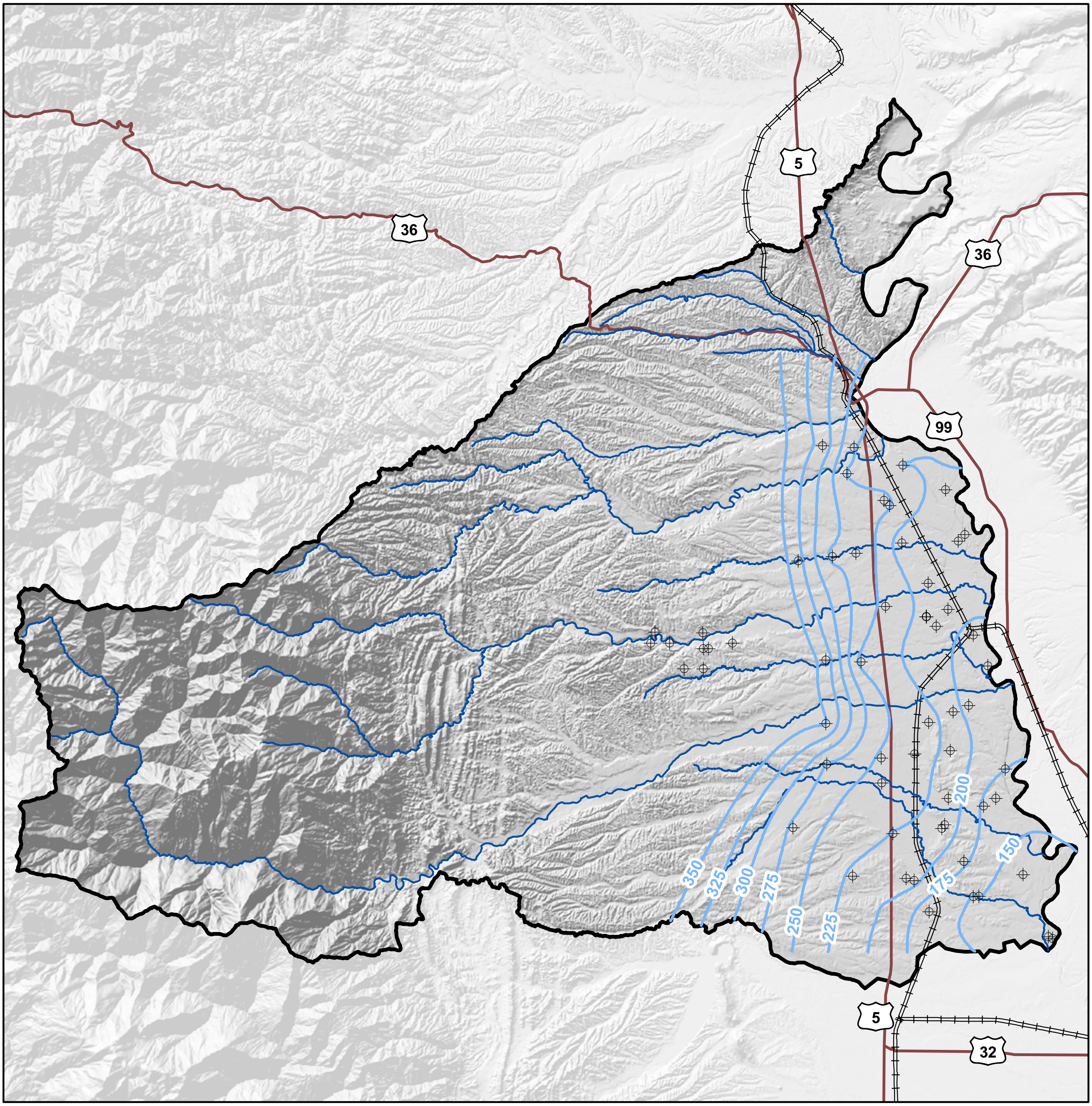
SOURCE: CALIFORNIA DEPARTMENT OF WATER RESOURCES, 2005



VESTRA

FIGURE 6-13
GROUNDWATER HYDROGRAPH
WELL 26N03W21P001M
TEHAMA WEST WATERSHED ASSESSMENT

SOURCE: CALIFORNIA DEPARTMENT OF WATER RESOURCES, 2005



Legend

- Railroad
- Major Highway
- Major Tributary
- Fall 2004 Monitoring Well
- Fall 2004 Groundwater Contour

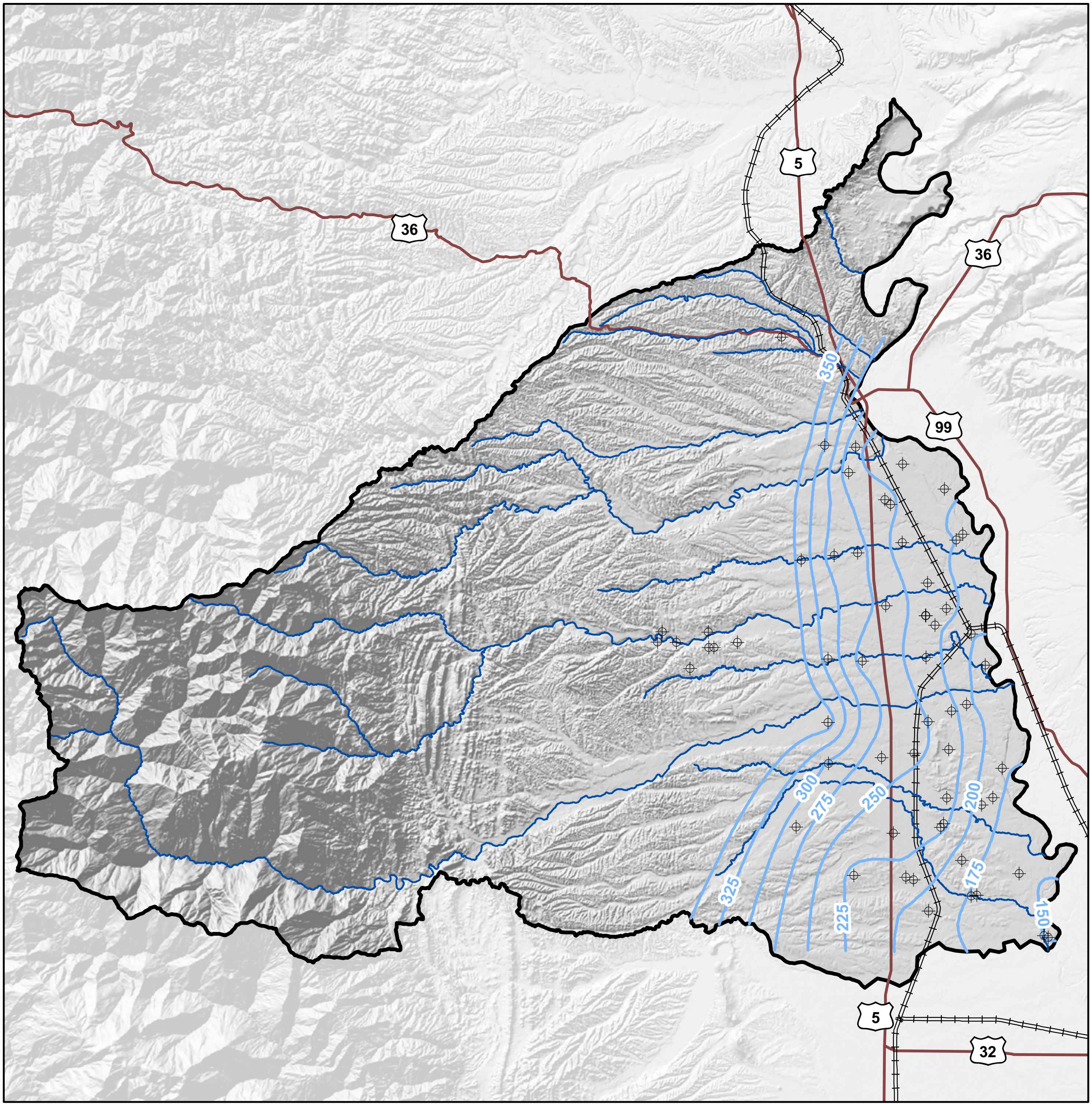
N W E S

0 2.5 5 10 Miles

VESTRA

FIGURE 6-14
FALL 2004 GROUNDWATER ELEVATIONS
TEHAMA WEST WATERSHED ASSESSMENT

SOURCE: CALIFORNIA DEPARTMENT OF WATER RESOURCES, 2005



Legend

- Railroad
- Major Highway
- Major Tributary
- Spring 2005 Monitoring Well
- Spring 2005 Groundwater Contour

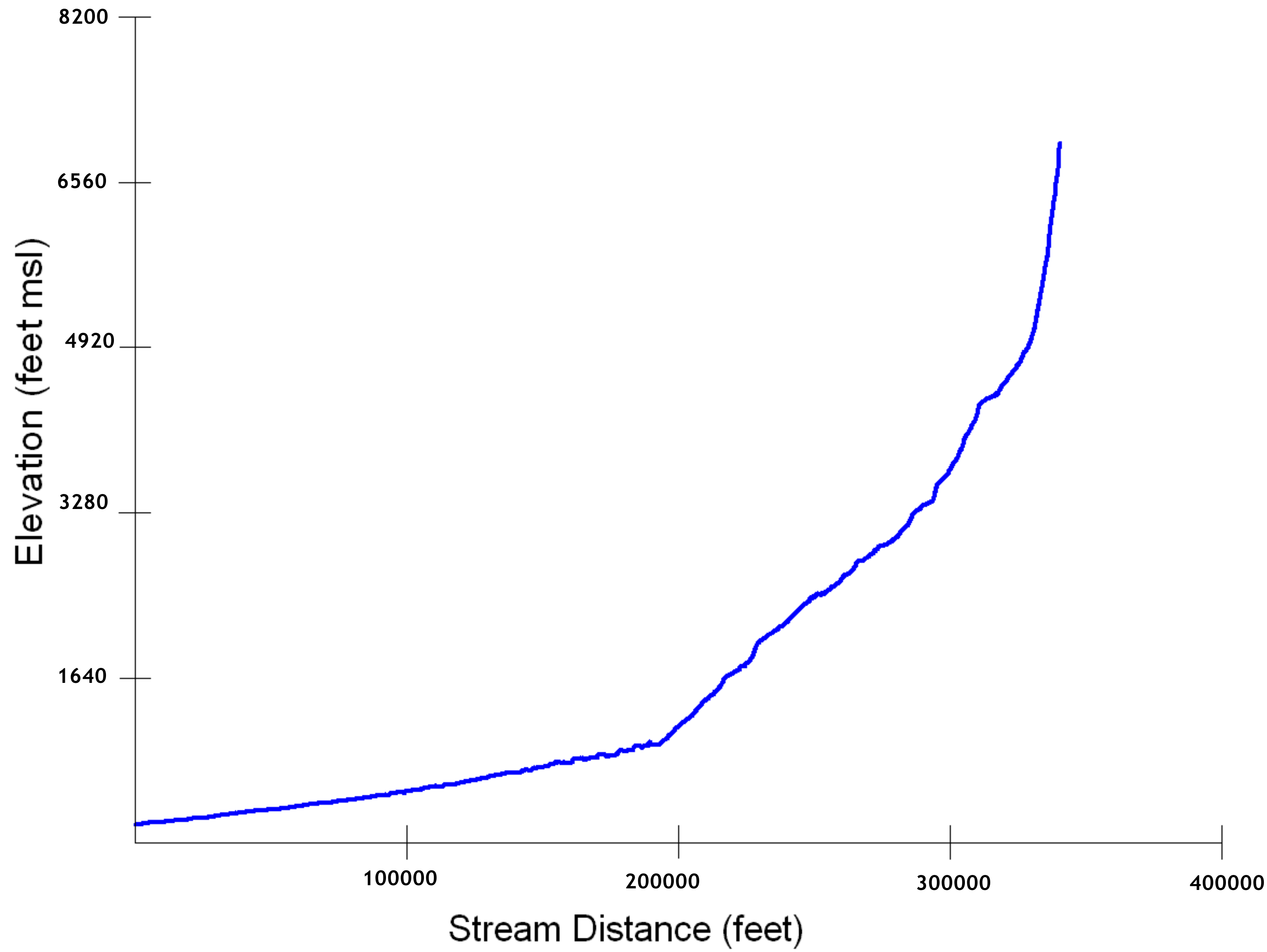
N
W E
S

0 2.5 5 10 Miles

VESTRA

FIGURE 6-15
SPRING 2005 GROUNDWATER ELEVATIONS
TEHAMA WEST WATERSHED ASSESSMENT

SOURCE: CALIFORNIA DEPARTMENT OF WATER RESOURCES, 2005



VESTRA

FIGURE 6-16
LONGITUDINAL PROFILE - THOMES CREEK
TEHAMA WEST WATERSHED ASSESSMENT

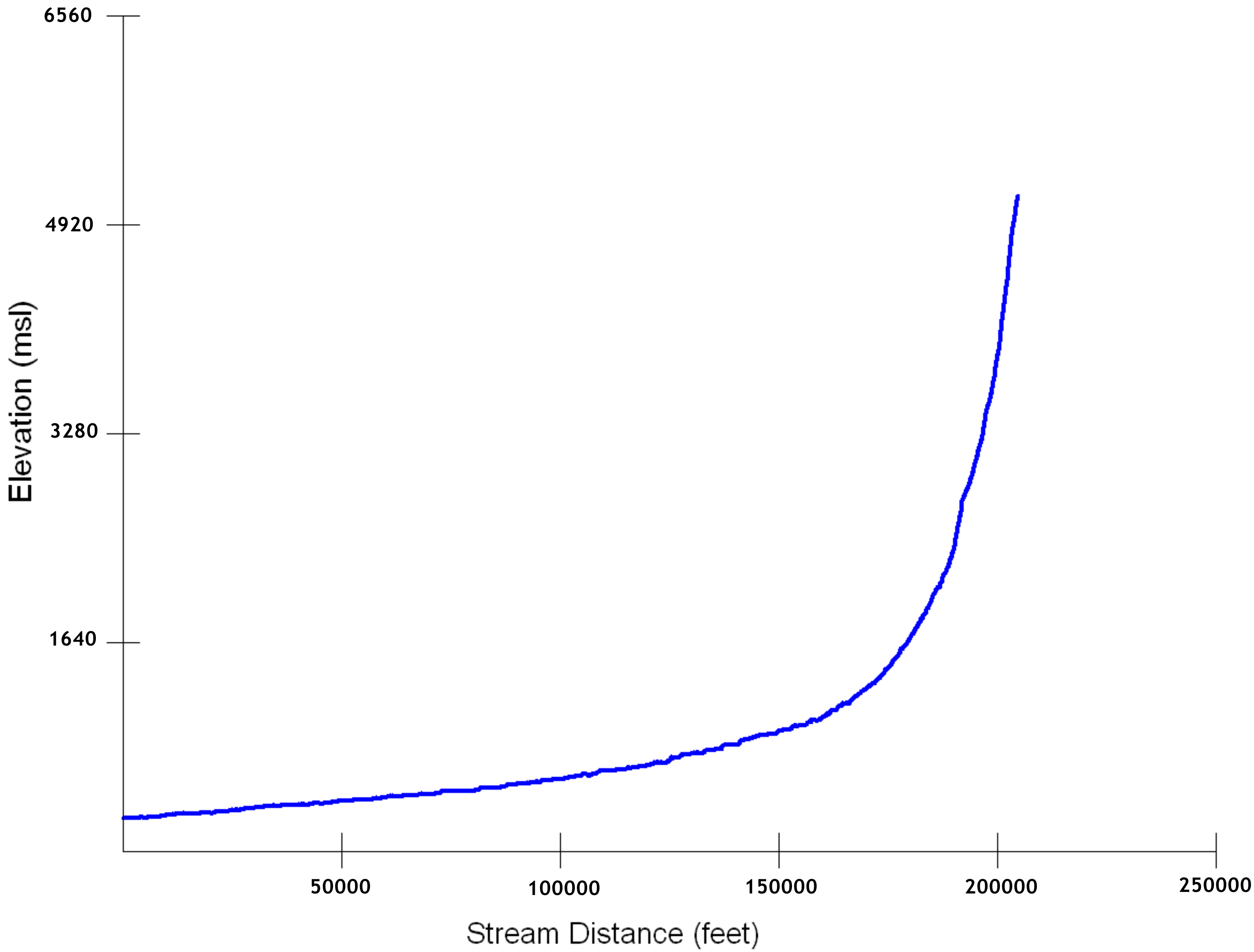
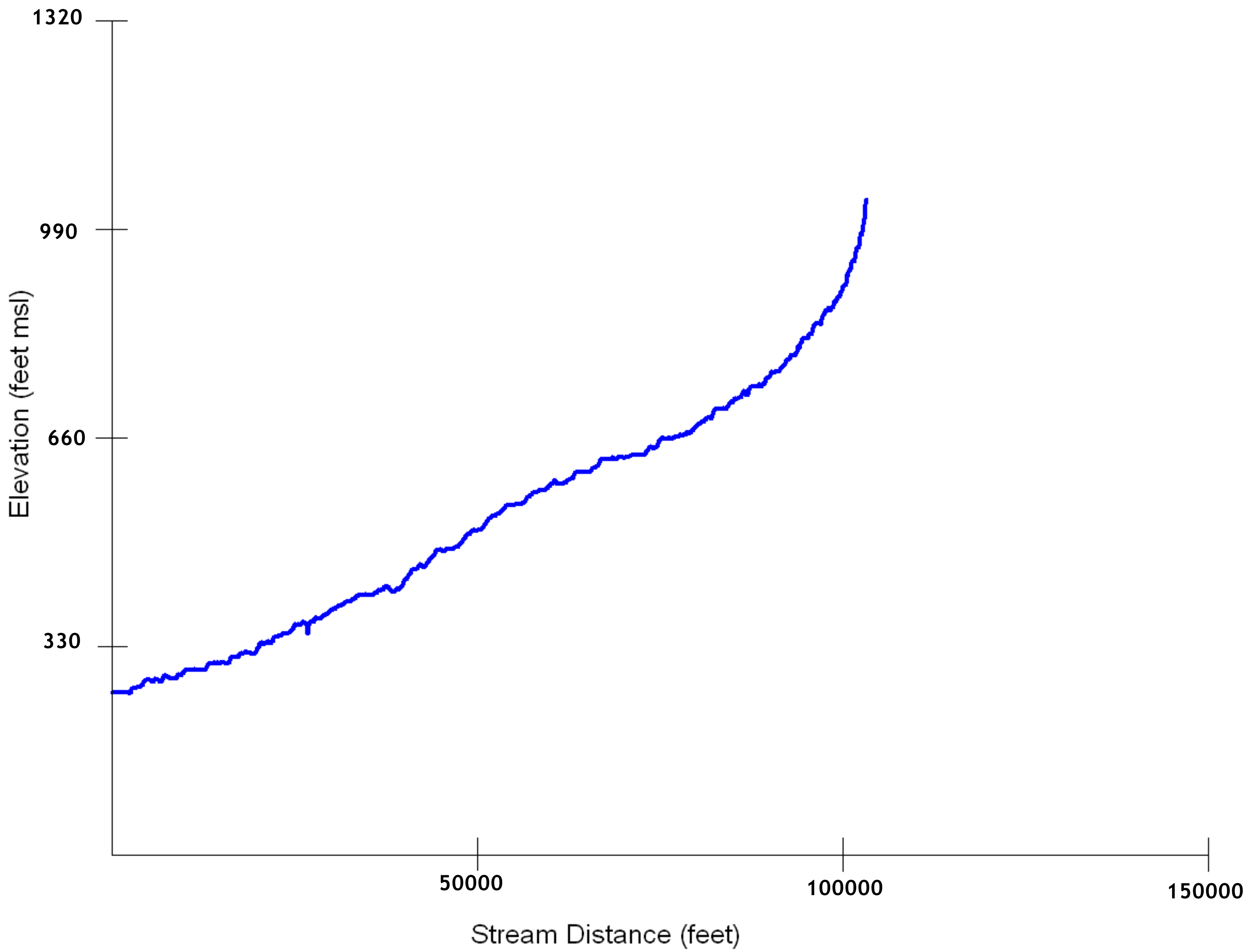


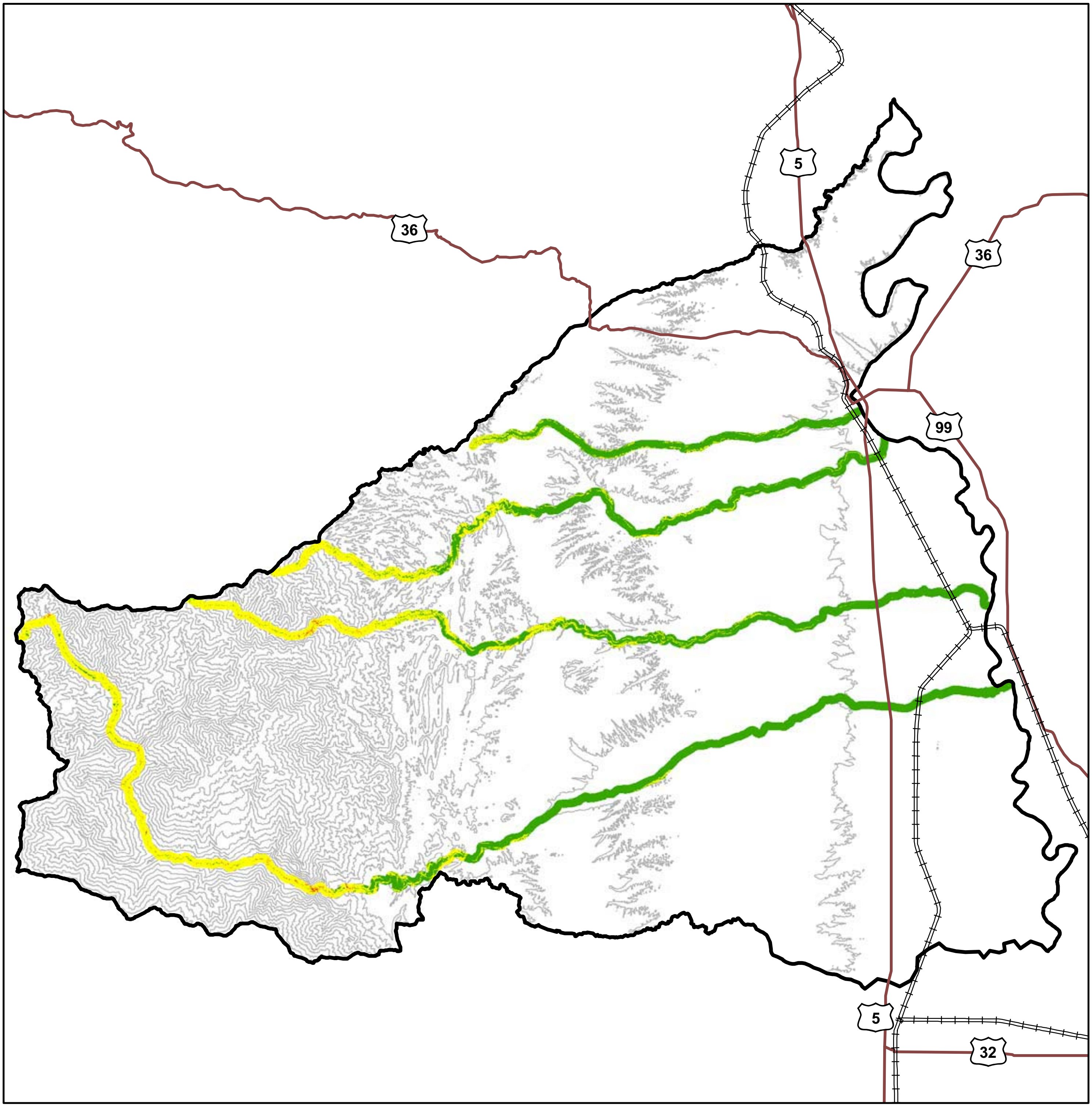
FIGURE 6-17
LONGITUDINAL PROFILE - RED BANK CREEK
TEHAMA WEST WATERSHED ASSESSMENT

VESTRA

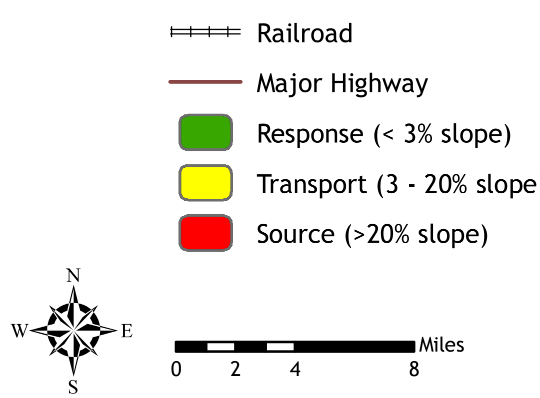


VESTRA

FIGURE 6-18
LONGITUDINAL PROFILE – REEDS CREEK
TEHAMA WEST WATERSHED ASSESSMENT



Legend



VESTRA

FIGURE 6-19
CHANNEL SLOPES
TEHAMA WEST WATERSHED ASSESSMENT