3.3 Hydrology

Ventura River Downstream of Santa Ana Bridge

Photo courtesy of Scott Lewis

3.3 Hydrology

Hydrology is the study of water and its properties, distribution, and circulation—in the air, on the ground, and beneath the surface. This chapter addresses primarily the distribution and circulation of surface water and groundwater in the watershed. Water quality is addressed in "3.5 Water Quality." Other important factors that affect hydrology are described in other sections, including rainfall ("3.2.1 Climate"), vegetation ("3.6.1 Habitats and Species"), and land use ("3.7.3 Land Use").

3.3.1 Surface Water Hydrology

3.3.1.1 Drainage Network

The Ventura River drainage network includes five significant tributaries that feed into the Ventura River: Matilija Creek, North Fork Matilija Creek, San Antonio Creek, Coyote Creek, and Cañada Larga. A notable feature of the Ventura River watershed is that its primary stream network remains largely unchannelized, with relatively natural stream shape and hydrologic patterns in many reaches (Beller et al 2011). Two dams, three levees, and high rates of runoff from urban areas have modified stream shape and hydrologic patterns in other reaches.

Table 3.3.1.1.1 Summary of Primary Drainages in the Ventura River Watershed

	Drainage Area (Square Miles)	Drainage Area (Acres)	Length (Miles)
Ventura River Mainstem	44.0	28,143	16.23
Matilija Creek[1]	54.6	34,927	17.31
North Fork Matilija Creek	16.1	10,291	8.14
San Antonio Creek	51.2	32,746	9.66
Coyote Creek[1]	41.3	26,414	14.62
Cañada Larga Creek	19.2	12,312	7.85
Total	**226.4**	**144,833**	**73.81**

1. Includes the area under the reservoirs built on these creeks.

Ventura River

The Ventura River mainstem covers a distance of 16.2 miles on its journey from the mountains to the ocean. In that short distance the river can look and behave quite differently. The river's five distinct reaches are described in the following sections.

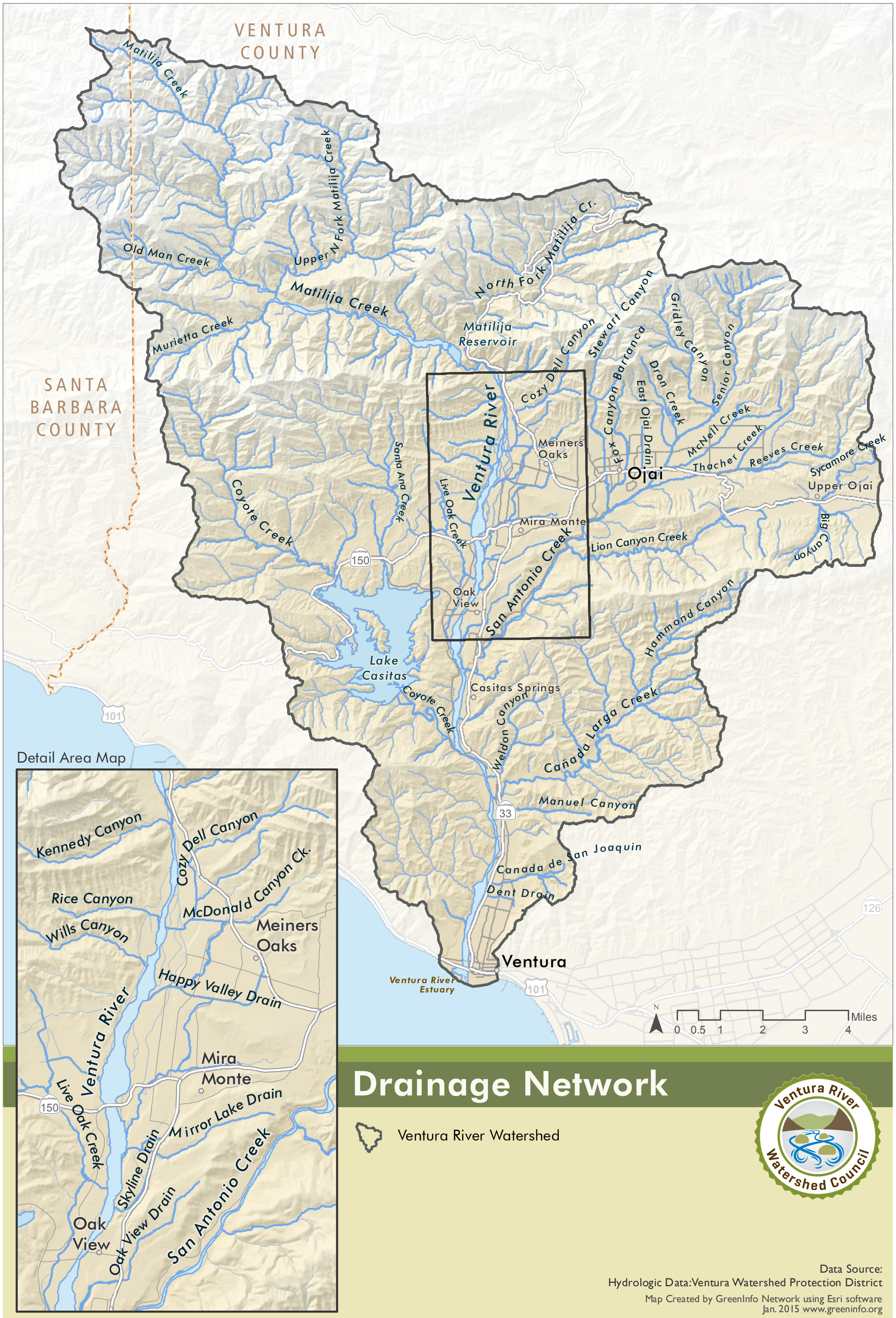


Figure 3.3.1.1.1 Drainage Network Map

Above the Robles Diversion

The Ventura River begins at the confluence of Matilija Creek and North Fork Matilija Creek, just south of Matilija Hot Springs Road. The river's beginning marks the transition from the steep canyons associated with these two creeks to flatter land and the exit of these creeks from the Los Padres National Forest. Still constrained by mountains, the river remains narrow for about a mile as it flows past orchards and the community of Ojala off of Camino Cielo Road.

Aerial View of Ventura River's Beginnings, Looking Downstream
Photo courtesy of Google Earth.

Ventura River's Beginnings. Upstream of Camino Cielo Bridge, June 2008
Photo courtesy of Santa Barbara Channelkeeper

Ventura River at Camino Cielo Bridge

Ventura River Exits the Mountains

Below the Robles Diversion – The Dry Reach

About 1.5 miles downstream from the river's formation, the landscape opens up and becomes much flatter. The river responds by becoming "depositional," dropping its largest sediments (very large boulders and cobbles) as the force of the flow from the steep canyons dissipates onto the gentler gradients.

Robles Diversion Facility

The Robles Diversion Facility—the structure that diverts Ventura River flow to Lake Casitas—is located on the west bank of the Ventura River channel, opposite and just below where Cozy Dell Canyon Creek enters.

Past the Robles Diversion, the riverbed widens considerably and splits into multiple braided channels. The river flows past the community of Meiners Oaks and through the Ventura River Preserve, picking up Kennedy, Rice, and Wills Canyon creeks from the west and McDonald Canyon Creek and Happy Valley Drain from the east before flowing under the Highway 150 Bridge.

Ventura River below Robles Diversion at Ventura River Preserve

Photo courtesy of Rick Wilborn

Happy Valley Drain, Meiners Oaks

The stretch of the Ventura River from below the Robles Diversion to just above the river's confluence with San Antonio Creek (just below Oak View) is the river's "dry reach." (The exact boundaries of the dry reach depend on the time of year, magnitude of the previous rainy season, and the level of groundwater storage.) This stretch of the river to just above the Santa Ana Boulevard Bridge is also referred to as the "Robles Reach" (CMWD 2010). Except during very wet rainfall years, surface water in this part of the river quickly disappears underground once storm flows have passed—even when the river is still flowing above and below this reach. About 80% of the time there is no significant surface flow in the Ventura River in this reach (Cardno-Entrix 2012).

The stretch of the Ventura River from below the Robles Diversion to just above the river's confluence with San Antonio Creek is the river's "dry reach." Except during very wet rainfall years, surface water in this part of the river quickly disappears underground once storm flows have passed—even when the river is still flowing above and below the reach.

> Flow duration curves were developed by the BOR [Bureau of Reclamation] for various stream gauges along the river. Over 60 percent of the time, the flow is less than ten cfs in the Ventura River at Foster Park, and approximately 80 percent of the time the flow is less than ten cfs in the Ventura River at Meiners Oaks. The river has no flow at least 30 percent of the time at Meiners Oaks.
>
> —*Draft Environmental Impact Statement/Environmental Impact Report for the Matilija Dam Ecosystem Restoration Project* (USACE 2004)

The San Francisco Estuary Institute documented numerous historical records going back to the 19th and early 20th century indicating that this reach of river has regularly gone dry, or exhibited intermittent flow (Beller et al. 2011).

Ventura River above Highway 150 Bridge

Past the community of Mira Monte, the Ventura River picks up two channelized drainages from the east: Mirror Lake Drain and Skyline Drain. It then flows past the Live Oak Acres development on the west, where the Live Oak Levee constricts the river down to a small fraction of its width and guides it under the Santa Ana Bridge on Santa Ana Road.

Definitions: Perennial, Intermittent, and Ephemeral

Ephemeral Stream: A stream that flows in direct response to and only during and shortly after precipitation events. Ephemeral streams may or may not have a well-defined channel. Their beds are always above the elevation of the water table, and stormwater runoff is their primary source of water. Ephemeral streams include normally dry arid or semi-arid region desert washes.

Intermittent Stream: A stream that flows only at certain times of the year when it receives water from springs, groundwater, rainfall, or surface sources such as melting snow. Includes intermittently dry desert washes in arid or semi-arid regions.

Perennial Stream: A stream that flows continuously during a year of normal rainfall (Vyverberg 2010).

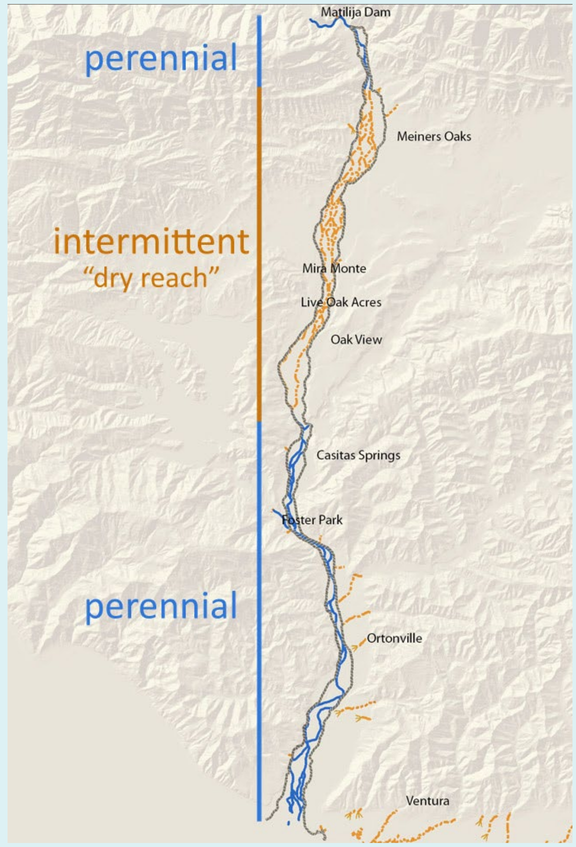
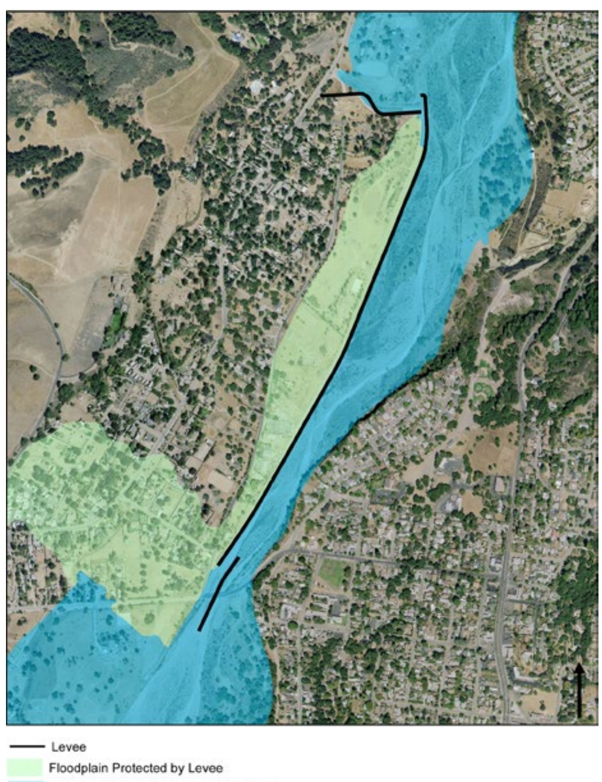


Figure 3.3.1.1.2 Ventura River Dry Reach. Since the 19th and early 20th century, the dry reach of the Ventura River has had intermittent flows, in contrast to the reaches above and below it. In many years, the dry reach could even be called "ephemeral," because flows disappear so quickly after storms. The transitions between intermittent and perennial reaches are approximate boundaries, which shift from year to year. Image courtesy of San Francisco Estuary Institute (Beller et al. 2011)

Live Oak Levee Protects Live Oak Acres Community. Live Oak Acres, to the left, is protected by the Live Oak Levee. Oak View is to the right.



Past the Santa Ana Bridge, the river widens again and flows by the community of Oak View, receiving the Oak View Drain before reaching the confluence with San Antonio Creek.

San Antonio Creek Confluence to Foster Park – The Live Reach

Just above the San Antonio Creek confluence, the Ventura River's wide depositional channel begins to narrow. The river then picks up water and momentum from San Antonio Creek for the last half of its journey to the ocean. During wetter years or winter rainy periods, rising groundwater springs in the river cause the Ventura River's flow to begin increasing above the San Antonio Creek confluence.

Ventura River Looking Upstream From San Antonio Creek Confluence
Photo courtesy of Santa Barbara Channelkeeper

A large pool forms at the confluence of the Ventura River and San Antonio Creek, providing important habitat for fish and other animals.

Confluence Pool, Ventura River at San Antonio Creek. San Antonio Creek can be seen flowing into the Ventura River at the confluence pool.
Photo courtesy of Santa Barbara Channelkeeper

Casitas Springs Levee and Pool

In-river groundwater springs are also found in the river as it passes through the aptly named "Casitas Springs" area below the San Antonio Creek confluence (EDAW 1978). The community of Casitas Springs is protected here by the Casitas Springs Levee.

Farther downstream at Foster Park, underground geologic structures also force subsurface flow to the surface (USACE 2004). At Foster Park, Coyote Creek enters from the west; however, this drainage contributes very little water to the river since the construction of Casitas Dam in 1959. Highway 33, which closely parallels the river, turns into a freeway at this point.

Ventura River at Foster Park Bridge

Because of the significant contributions of water from San Antonio Creek and naturally rising groundwater, the stretch of the Ventura River between the San Antonio Creek confluence and Foster Park is referred to as "the live reach." This reach typically flows year round except in multi-year dry periods.

Because of the significant contributions of water from San Antonio Creek and naturally rising groundwater, the stretch of the Ventura River between the San Antonio Creek confluence and Foster Park is referred to as "the live reach." This reach typically flows year round except in multi-year dry periods.

The City of Ventura draws subsurface water from the river and groundwater in the Foster Park area. The City also has a surface water diversion in the river at Foster Park, but this location has been dry since the mid 1990s because the main channel of the river has meandered.

Below Foster Park to the Estuary

In the mile between Foster Park and the Ojai Valley Sanitary District's wastewater treatment plant, there are several good-sized pools surrounded by the denser vegetation typical of this area.

Pool Below Foster Park

Downstream from this location, the river receives treated effluent from the wastewater treatment plant. The effluent constitutes a significant input and, in many years, accounts for the perennial flow in the remaining stretch of the Ventura River.

Aerial View of Wastewater Treatment Plant. The Ojai Valley Sanitary District's wastewater treatment plant contributes treated wastewater to the flow of the river. Located to the east of the wastewater plant is the City of Ventura's plant for treating water pulled from the river upstream at Foster Park.

Just past the wastewater treatment plant, Cañada Larga Creek enters the Ventura River from the east; the river then flows through an area of active oil production wells. Several minor drainages (Manuel Canyon Creek, Cañada de San Joaquin, and Dent Drain) flow into the river from the east in this reach. The last 2.6 miles of the river are constrained by the Ventura River Levee on the east, which protects the City of Ventura from flooding.

Ventura River Flowing Through Active Oil Fields

Photo courtesy of Brian Hall, Santa Barbara Channelkeeper and LightHawk

Ventura River Levee

Photo courtesy of Rick Wilborn

Ventura River Estuary

In its final stretch, the Ventura River flows through the Ventura River estuary, which extends from around the 101 Freeway bridge to the ocean. The estuary is a shallow body of water that receives both freshwater from the river and salt water from the ocean. A sandbar typically separates the estuary from the ocean during the dry season; when storms breach the sandbar, however, the flow of the river can proceed directly to the ocean. A smaller estuary at the "second mouth" of the Ventura River also exists to the west of the main estuary, but is only open to the ocean during very large floods (RWQCB-LA 2002).

Ventura River Estuary

Photo courtesy of Rick Wilborn

Ventura River Estuary, Sandbar Breached, March 2014

Matilija Creek

Matilija Creek, considered the primary headwaters of the Ventura River, originates in the rugged mountains in the northwest corner of the watershed.

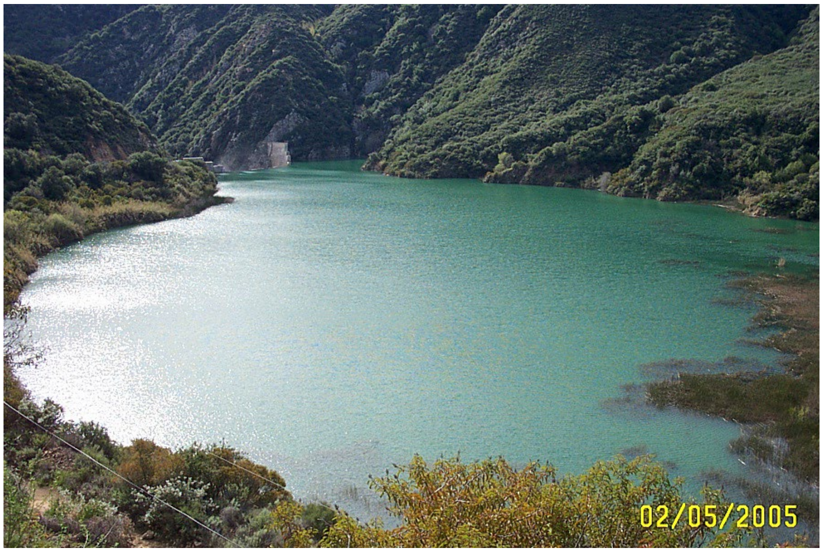
Matilija Falls, Near the Headwaters of the Watershed
Photo courtesy of Michael McFadden

Matilija Creek flows southeast, and is fed along the way by a number of smaller tributaries including Upper North Fork Matilija Creek from the north (not to be confused with North Fork Matilija Creek, described later in this section), and Old Man and Murrieta creeks draining the Santa Ynez Mountains from the south. Matilija Creek and its tributaries originate at elevations between 4,000 and 6,000 feet in the watershed's tallest and steepest mountains.

Matilija Creek

Matilija Reservoir

Photo courtesy of Paul Jenkin



Matilija Dam Spilling, March 2014

Photo courtesy of Mike Sullivan

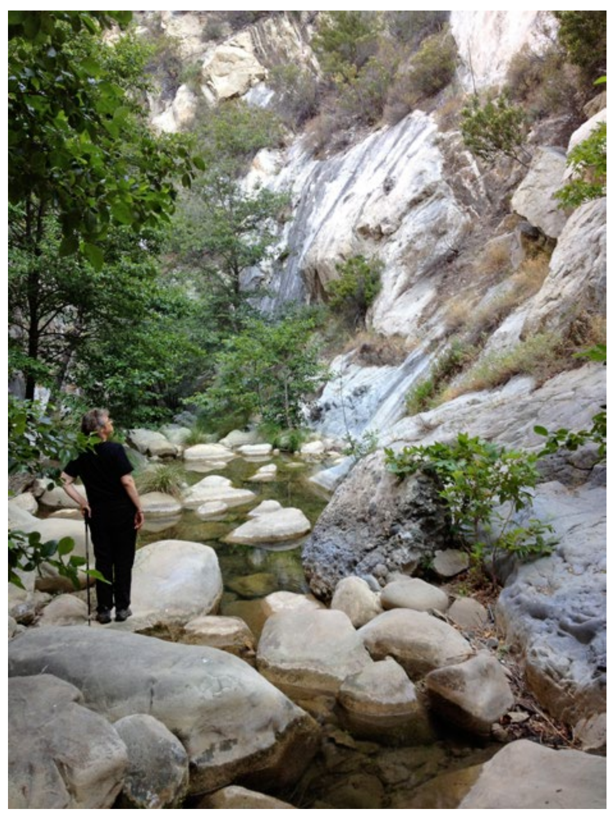
Matilija Creek flows for about 15 miles until it meets Matilija Reservoir behind Matilija Dam, and for an additional half mile after the reservoir until it joins with North Fork Matilija Creek. In the past, water was released from the reservoir a few times during the winter to enhance diversions to Lake Casitas via the Robles Canal; however this practice was discontinued in 2011 because of regulatory concerns related to instream water quality (Evans 2013). Even during low flow periods, water flowing into Matilija Reservoir commonly flows over the top of Matilija Dam.

Almost all, 93% (32,391 acres), of Matilija Creek's drainage area is in the Los Padres National Forest, and 67% (23,477 acres) is in a federal wilderness area.

Almost all, 93% (32,391 acres), of Matilija Creek's drainage area is in the Los Padres National Forest, and 67% (23,477 acres) is in a federal wilderness area. Several hot springs and a few cold springs are located along the creek's course. With the exception of Matilija Dam, Matilija Creek is unchannelized.

North Fork Matilija Creek

From its origins at the top of the watershed near the Rose Valley turnoff, North Fork Matilija Creek parallels Highway 33 down about 8 miles to where it joins Matilija Creek below Matilija Dam. The course of North Fork Matilija Creek winds southwest out of the mountains through a steep and rugged canyon, which in places becomes a narrow, confined gorge bordered by vertical walls of bare, folded, and tilted rock. North Fork Matilija Creek is relatively unmodified.



Wheeler Gorge, North Fork Matilija Creek

Swimming Hole, North Fork Matilija Creek

Many seeps and springs flow out of the rocks along this canyon. Until 2006, Bellyache Springs, a perennial spring located next to Highway 33, had an easy access spigot that allowed people to fill water bottles with spring water. Wheeler Hot Springs, located along the creek, was a popular tourist destination in the area from 1891 to 1997.

Except for a few properties along the highway, all of North Fork Matilija Creek's drainage area (94% or 9,673 acres) is in the Los Padres National Forest.

San Antonio Creek

In terms of water volume, San Antonio Creek is the Ventura River's most significant tributary after Matilija Creek.

In terms of water volume, San Antonio Creek is the Ventura River's most significant tributary after Matilija Creek. San Antonio Creek originates in the northeast part of the watershed on the eastern end of the Ojai Valley floor, and serves as the main drainage for the greater Ojai Valley. Lion Canyon Creek, a major tributary to San Antonio Creek, contributes a significant amount of flow from the Upper Ojai Valley at the extreme eastern end of the Ventura River watershed.

A number of East End creeks, all draining the steep Topatopa Mountains, feed into upper San Antonio Creek. The creek's beginning is marked by the convergence of Gridley and Senior Canyon creeks; it then flows southwest through orchards on the valley floor and picks up Dron Creek and Crooked Creek from the north, then McNell Creek (near Highway 150) from the east. In Soule Park Golf Course, Thacher Creek adds its considerable flow. Reeves Creek, a tributary to Thacher, also adds substantial flow.

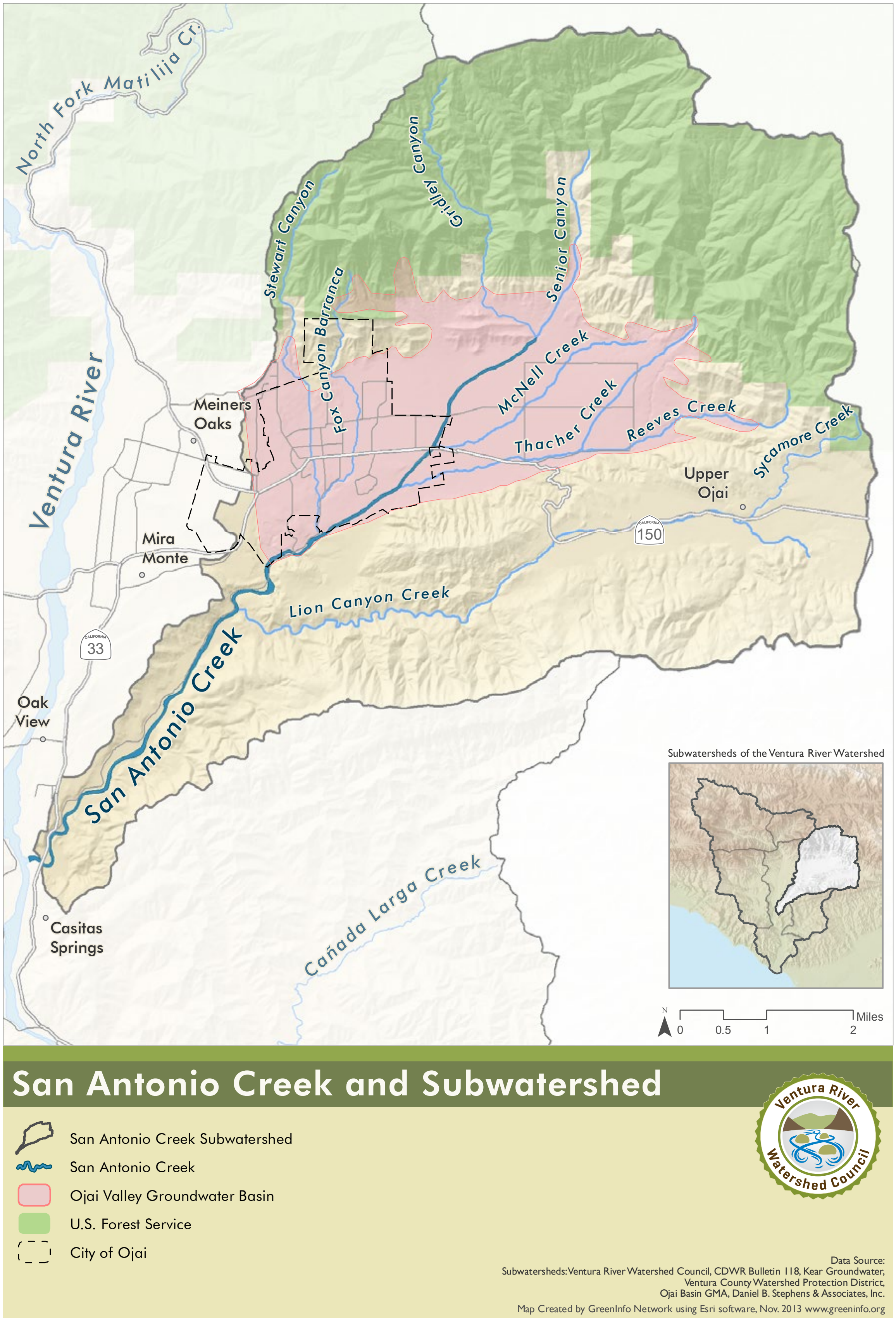


Figure 3.3.1.1.3 San Antonio Creek Subwatershed Map

Upper San Antonio Creek at Grand Avenue

Thacher Creek at Highway 150

Reeves Creek at McNell Road, March 2014

The headwater drainages of San Antonio Creek are also responsible for forming the alluvial fans of the East End and the underlying alluvial Ojai Valley groundwater basin.

Continuing southwest along the edge of the City of Ojai, San Antonio Creek receives flow from Stewart Canyon Creek at the beginning of Creek Road. Stewart Canyon Creek is an important drainage that flows south from the Topatopa Mountains through the City of Ojai. Much of it is underground or channelized through the City, but the lower reach, which receives flow from Fox Canyon Barranca, is primarily unchannelized and often has perennial flow (Magney 2005).

Fox Canyon Barranca, Downtown Ojai

Stewart Canyon Creek Going Underground Above Ojai

Stewart Canyon Creek Flowing into San Antonio Creek Below Ojai. Stewart Canyon Creek converges with San Antonio Creek just below Creek Road

"Typical" in the Ventura River Watershed

Given the extreme variability of rainfall and other factors in the Ventura River watershed, describing what streamflow conditions are like in a "typical" year is highly suspect. The reader must keep in mind that, by necessity, fairly gross generalizations have been made in the descriptions of "typical" conditions.

Below its junction with Stewart Canyon Creek, San Antonio Creek winds along Creek Road, picking up Lion Creek—which drains the Upper Ojai Valley—just past Camp Comfort, and finally converges with the Ventura River after passing under Highway 33 above Casitas Springs.

Upstream of the Thacher Creek confluence in Soule Park Golf Course, San Antonio Creek is ephemeral—typically drying quickly after storm flows have passed. After the confluence with Thacher Creek, San Antonio Creek typically exhibits perennial flow downstream to about a half mile past the Lion Canyon Creek confluence. From that point to the Ventura River confluence, San Antonio Creek's flow characteristics typically alternate between perennial (~65% of this length of creeek), intermittent (~10%), and ephemeral (~25%) (Lewis 2014).

Lion Canyon Creek. Lion Canyon Creek drains Upper Ojai and is a significant tributary to San Antonio Creek.

Lower San Antonio Creek, Camp Comfort. San Antonio Creek during storm flows, March 2014.

San Antonio Creek is 9.66 miles long and is, except for revetments at bridges, primarily unchannelized.

Coyote Creek

Coyote Creek originates in the Santa Ynez Mountains on the western rim of the watershed. From its origins at an elevation of 4,200 feet, the creek flows southeast. Before Lake Casitas was built, Coyote Creek picked up Santa Ana Creek as a tributary from the north before converging with the Ventura River at Foster Park. The Lake Casitas Dam was built across Coyote Creek and has transformed much of the creek into a reservoir. Now Santa Ana Creek and most of Coyote Creek flow directly into the lake.

Coyote Creek Flowing into Lake Casitas

Coyote Creek is 14.62 miles long (including the stretch now under the reservoir). Because of Casitas Dam, the lower 2.5 miles of the creek below Lake Casitas is now disconnected from its original hydrology and only receives water from surrounding small drainages. With the exception of Casitas Dam, Coyote Creek is unchannelized. Forty-seven percent (12,384 acres) of its drainage area lies within the Los Padres National Forest.

Cañada Larga Creek

Cañada Larga Creek originates on the lower eastern edge of the watershed at 1,400 feet. It is the last major tributary to add water to the Ventura River, and the least steep. It flows southwest through a wide, largely undeveloped valley of low foothills used primarily for cattle grazing.

There is at least one major spring as well as numerous smaller springs and seeps throughout the Cañada Larga Creek drainage area. These are more common during wetter years. Oil is found in some of the springs (Williams 2014). Cañada Larga Creek is joined by Hammond Canyon Creek from the north in its upper reaches and a handful of smaller tributaries farther downstream as it winds along Cañada Larga Road.

Cañada Larga Creek Drainage Area

Channelized Cañada Larga Creek
Photo courtesy of Santa Barbara Channelkeeper

To expedite freeway construction, Cañada Larga Creek was diverted so that the streambed now makes a sharp bend where it meets Highway 33 and flows south along the east side of the highway for a stretch. A concrete channel conducts Cañada Larga Creek under Highway 33 and North Ventura Avenue and subsequently through an undeveloped field before converging with the Ventura River just above the abandoned Petrochem gasoline refinery site. Cañada Larga Creek is 7.85 miles long.

3.3.1.2 Streamflow

Sources of water for streamflow in the watershed include rainwater, groundwater (baseflow and springs), treated wastewater, and urban runoff.

In the often dry and ever-variable Ventura River watershed, flowing water is a precious resource. Streamflow is vital for habitat and wildlife, both aquatic and terrestrial, on all levels in the food chain. Streamflow determines how much Lake Casitas refills each year, and plays a big role in groundwater recharge. Flow affects pollutant concentrations and water quality. It affects whether or not there will be water in the swimming holes, and whether fish can swim to spawning grounds. Flow can also flood property, damage infrastructure, and scour the riverbed clean of vegetation. Streamflow is also the major contributor to sediment transport, scour, and erosion within the watershed.

Inputs and Outputs

Sources of water for streamflow in the watershed include rainwater, groundwater (baseflow and springs), treated wastewater, and urban runoff. Snowmelt is typically an insignificant contributor to streamflow in the watershed.

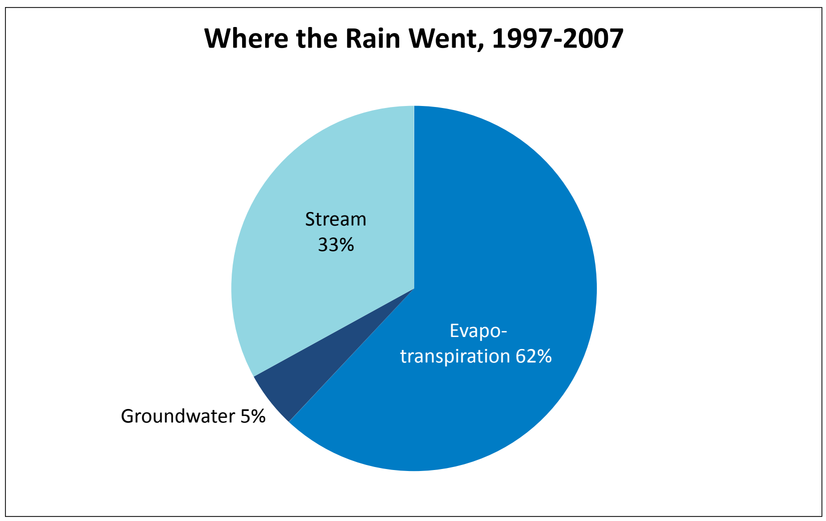
Rainwater

A watershed hydrology model, called the HSPF model (Hydrological Simulation Program – Fortran), was developed for the watershed in 2009 based on data from water years 1997 to 2007. The average Ventura River streamflow during these 11 years was 87.69 cubic feet per second (cfs) (at Foster Park), 30% greater than the long-term average of 65.38 cfs. However, the average rainfall during these years (22.41 inches in downtown Ojai), was very similar to the long-term average of 21.31 inches. Based on the data from these 11 years, the model estimated that about 322,008 acre-feet (AF) of rain falls on the watershed in a typical year and that 33% of that rainfall (113,275 AF) makes its way directly into streams and rivers (Tetra Tech 2009a, Table 6-6).

(See "4.4 Appendices" for a table of monthly average and annual average streamflow at Foster Park between 1930 and 2013.)

Figure 3.3.1.2.1 Where the Rain Went, 1997–2007

Source: Baseline Model Calibration and Validation Report (Tetra Tech 2009a, Table 6-6)



Exchanges between surface water and groundwater have an important effect on the total amount of streamflow in the watershed. Changes in either the surface water or groundwater system can affect the other in both positive and negative ways.

Surface Water/Groundwater Interaction

Exchanges between surface water and groundwater have an important effect on the total amount of streamflow in the watershed. The Ventura River and San Antonio Creek are known to have "gaining reaches" and "losing reaches"—stretches of the river where the stream "gains" water from groundwater and stretches where it "loses" water to groundwater (Entrix 2001a). This surface water/groundwater relationship is dynamic and influenced by many variables. Changes in either the surface water or groundwater system can affect the other in both positive and negative ways.

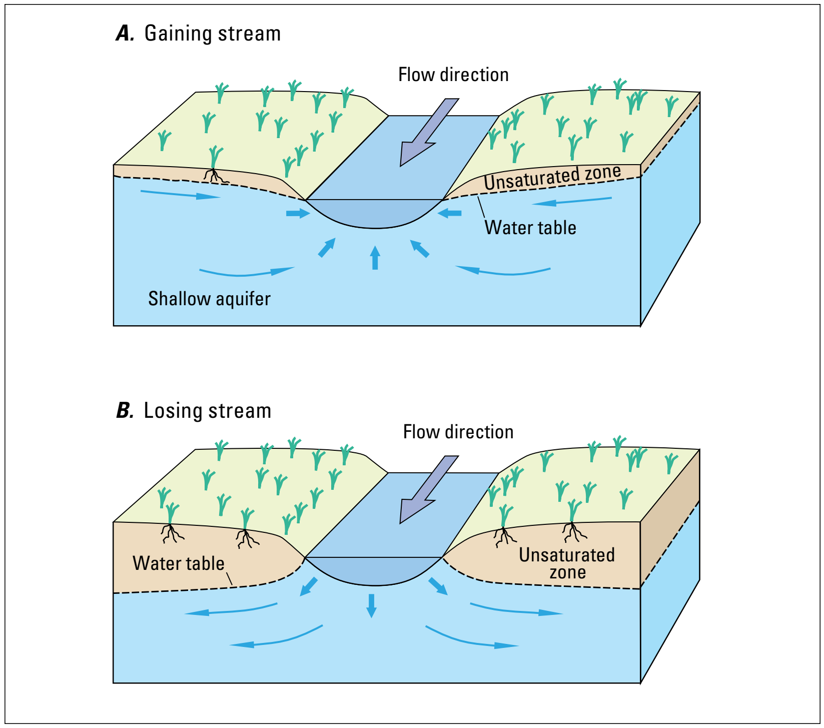


Figure 3.3.1.2.2 Gaining and Losing Streams. These images illustrate the concept of gaining and losing streams. In some places the stream recharges the groundwater below, and in other areas it receives groundwater from the aquifer—depending on the relationship between the water level in the stream and the elevation of the water table in the nearby aquifer.

Source: Streamflow Depletion by Wells (Barlow & Leake 2012). Reprinted with permission.

Because many animals and riparian habitats depend on the availability of surface flow, the condition of the groundwater basins can have important consequences for both terrestrial and aquatic species. The availability of surface water for recreation, aesthetic value, or water supply diversions can also be impacted.

> One of the primary concerns related to the development of groundwater resources is the effect of groundwater pumping on streamflow. Groundwater and surface-water systems are connected, and groundwater discharge is often a substantial component of the total flow of a stream. Groundwater pumping reduces the amount of groundwater that flows to streams and, in some cases, can draw streamflow into the underlying groundwater system. Streamflow reductions (or depletions) caused by pumping have become an important water-resource management issue because of the negative impacts that reduced flows can have on aquatic ecosystems, the availability of surface water, and the quality and aesthetic value of streams and rivers.
>
> —*Streamflow Depletion by Wells—Understanding and Managing the Effects of Groundwater Pumping on Streamflow* (Barlow & Leake 2012)

The surface water/groundwater interconnection is an important water management issue in the Ventura River watershed for a number of reasons, including the need to provide habitat for the endangered southern California steelhead.

The surface water/groundwater interconnection is an important water management issue in the Ventura River watershed for a number of reasons, including the need to provide habitat for the endangered southern California steelhead. Ventura River Reaches 3 and 4 (from Camino Cielo

FINAL DRAFT

The link between groundwater pumping and streamflow in the Ventura River watershed is poorly understood at this time because neither the collection of sufficient field measurements nor the development of a groundwater model have been undertaken.

Road below Matilija Dam to the confluence with Weldon Canyon, just north of Cañada Larga Creek) are on the Section 303(d) list of impaired waterbodies for diversion and pumping. In adding these reaches to the 303(d) list, the Regional Water Quality Control Board associated groundwater pumping and surface water diversion with impacts to the cold freshwater habitat needed by the steelhead (USEPA 2012).

Changes in surface flows can also affect groundwater recharge. For example, the requirement that the Robles Diversion must allow a minimum of 20 cfs of Ventura River water to flow downstream is in place to prevent unreasonable interference with prior rights to the use of underground water.

The link between groundwater pumping and streamflow in the Ventura River watershed is poorly understood at this time because neither the collection of sufficient field measurements nor the development of a groundwater model have been undertaken. The HSPF model developed in 2009 to understand surface water hydrology in the watershed lacked critical information about these surface water/groundwater relationships, and thus does not constitute a comprehensive model of the watershed's overall hydrology.

An improved understanding of this surface water/groundwater relationship—how the magnitude, timing, and location of groundwater pumping affects the flow in the river and creeks— is critical for better management of water supplies among multiple competing needs.

Ventura River Dry Reach Going Dry
This photo was taken in December 2011 on the Ventura River Preserve (Meiners Oaks area), just a few hundred feet downstream of "the swimming hole" where children were jumping off rocks into a large pool. This marks the point where the river disappeared underground.

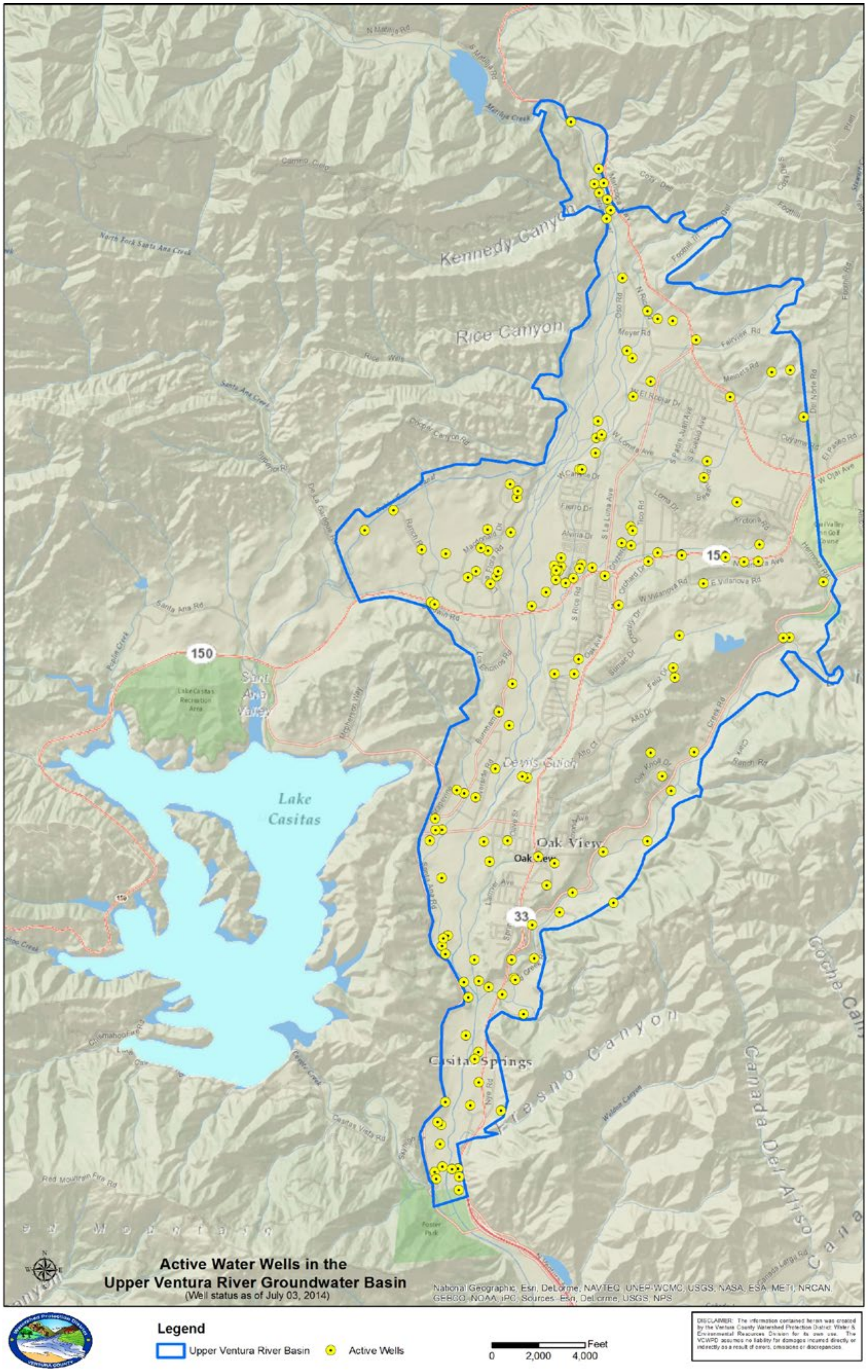


Figure 3.3.1.2.3 Map of Wells in Upper Ventura River Basin. The link between groundwater pumping and streamflow in the Ventura River watershed is not well understood at this time.

Various studies have estimated the amount of water flowing between surface water and groundwater, but without more sophisticated measurements and analyses, the findings of these studies are understood to be preliminary and based on insufficient data. The key studies focused on this interaction and some of their findings are described below:

Drying Ventura River above Highway 150 Bridge

Photo courtesy of Paul Jenkin

The *Draft Environmental Impact Report for the Ventura River Conjunctive Use Agreement,* prepared by EDAW [consultants] in 1978, described a very close correspondence between the groundwater level in a well located on the floodplain adjacent to the Ventura River just above Highway 150 bridge and the surface flow 250 feet below the mouth of the San Antonio Creek (in the live reach). When the water level in the well falls below approximately 495 feet msl (mean sea level), surface flow in much of the live reach stops (though some pools remain). A flow of 1 cfs or more in the live reach corresponds with a water level in this well of greater than 507 feet msl. When the groundwater in the Upper Ventura River Basin is depleted or nearly depleted, flows due to rising groundwater springs in the area of San Antonio Creek will cease (EDAW 1978).

The *Surface Water-Groundwater Interaction Report,* a comprehensive study prepared by Entrix in 2001 to inform a Habitat Conservation Plan for the Ventura River, estimated that annual groundwater contributions from the Upper Ventura River basin to surface water flow at Foster Park range from approximately 3,000 to 10,000 AF per year (Entrix 2001). To put this into perspective, the annual median flow at Foster Park between 1930 and 2013 was approximately 6,226 AF (USGS 2014b).

When the groundwater in the Upper Ventura River Basin is depleted or nearly depleted, flows due to rising groundwater springs in the area of San Antonio Creek will cease.

The HSPF model of the Ventura River watershed estimated that 7,375 AF of water from streams in the watershed infiltrates into groundwater basins annually, and that 4,252 AF of groundwater is contributed back to surface waterbodies annually (Tetra Tech 2009a, Table 6-6).

A groundwater budget study for the Upper and Lower Ventura River Basins, prepared by Daniel B. Stephens & Associates in 2010, estimated a *net* of 2,290 AF of surface water from the river infiltrates into the Upper Ventura River Basin; and that in the Lower Ventura River Basin a *net* of 1,254 AF of groundwater discharges to surface water (DBS&A 2010, Tables 13 & 14).

A surface water/groundwater interaction study focused on the City of Ventura's groundwater extractions in the Foster Park area concluded that, for this area, "As long as there is surface flow in the river, the alluvial aquifer is completely refilled in less than a week (2 to 4 days) after cessation of city pumping." (Hopkins 2010)

The Ojai Basin Groundwater Model estimated that an average of 2,282 AF per year is discharged to San Antonio Creek from the Ojai Valley Basin (DBS&A 2011).

A Ventura River Water District analysis of groundwater pumping in the dry reach of the Upper Ventura River Groundwater Basin during the 2010 steelhead migration season found that pumping by the two water districts using that part of the basin was equivalent to a continuous flow of 3.5 cfs and private pumping in the reach was estimated to be equivalent to a flow of 1.1 cfs (VRWD 2014).

Natural springs found throughout the watershed also contribute to streamflow (Entrix & URS 2004).

Ventura River at Casitas Springs, Very Wet and Very Dry. Both of the photos above were taken on August 14, 2013, in the Ventura River at Casitas Springs. The lake-like pool was next to the levee immediately adjacent to the Casitas Springs Mobile Home Park (top); about 400 feet downstream, the main channel of the river disappeared underground (bottom).

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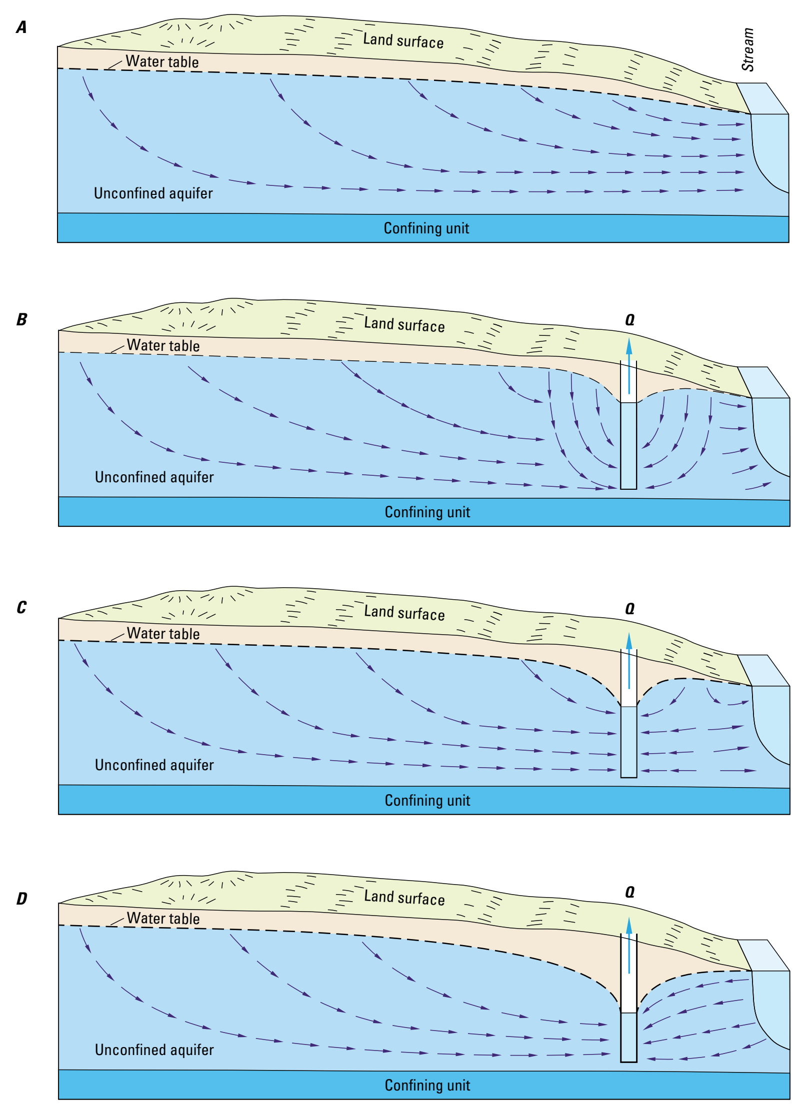


Figure 3.3.1.2.4 Effects of Pumping on an Unconfined Aquifer that Discharges to a Stream. Effects of pumping from a hypothetical water table aquifer that discharges to a stream. A, Under natural conditions, recharge at the water table is equal to discharge at the stream. B, Soon after pumping begins, all of the water pumped by the well is derived from water released from groundwater storage. C, As the cone of depression [a depression of the water level that occurs when groundwater is pumped from a well] expands outward from the well, the well begins to capture groundwater that would otherwise have discharged to the stream. D, In some circumstances, the pumping rate of the well may be large enough to cause water to flow from the stream to the aquifer, a process called induced infiltration of streamflow. [Q, represents the pumping rate at the well]

Note: this example is a generalization and may not apply to all situations.
Source: Streamflow Depletion by Wells (Barlow & Leake 2012). Reprinted with permission.

The contribution to the Ventura River of treated effluent from the wastewater treatment plant averages 2.1 million gallons per day, which is equivalent to an average year-round streamflow of approximately 3.3 cubic feet per second.

Wastewater

The watershed's primary wastewater treatment plant is located next to the Ventura River just below Foster Park, about five miles from the ocean. Managed by the Ojai Valley Sanitary District (OVSD), it produces highly treated water, called effluent, which is discharged to the Ventura River. The contribution from the treatment plant averages 2.1 million gallons, or 6.44 AF, per day, which is equivalent to an average year-round streamflow of approximately 3.3 cfs. During the rainy season, this contribution of effluent to streamflow is a relatively small portion of the total volume of water. During the dry season, however, the effluent can constitute more than 50% of the streamflow below the treatment plant (Entrix & Woodward Clyde1997).

Urban and Agricultural Runoff

Some storm drains in urban areas of the watershed continue to have a minor trickle of flow even in the driest times of summer. This water can come from a variety of urban sources, including irrigation runoff, car washing, other types of cleaning, leaking pipes, etc. This water can make its way to streams.

Urban Runoff in Fox Canyon Barranca, Summer 2013 After Two Dry Winters

Urban development—specifically impervious surfaces such as roads, parking lots, and rooftops—prevents natural infiltration of rain water, thus decreasing recharge to groundwater and increasing the amount of water entering the drainage network.

Urban development—specifically impervious surfaces such as roads, parking lots, and rooftops—prevents natural infiltration of rain water, thus decreasing recharge to groundwater and increasing the amount of water entering the drainage network. Because water runs off pavement and rooftops so quickly, these impervious surfaces also increase peak flows during storms. Increased urban development can thus put a strain on existing channels lacking sufficient width and depth to carry additional storm flows, as well as levees built to protect developed areas.

Excess agricultural irrigation water may also contribute to streamflows.

Outputs

Once in the drainage network, streamflow is discharged to the ocean, diverted for use, used by riparian plants, evaporated, or infiltrated into soil and groundwater basins. The HSPF model estimated, based on data from water years 1997 to 2007, that approximately 71% of the water entering the stream network travels fairly quickly to the ocean by way of the Ventura River, 16% is diverted for consumption, 6% recharges groundwater basins, and 7% is lost to stream and reservoir evaporation (Tetra Tech 2009a).

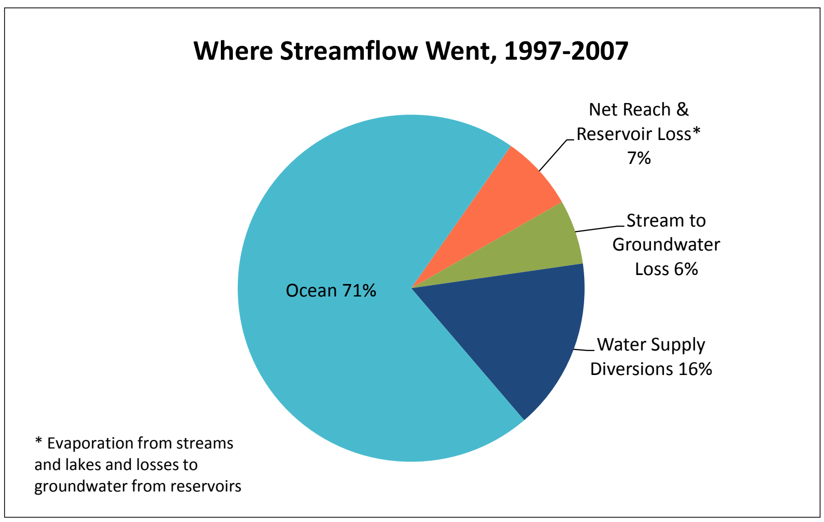


Figure 3.3.1.2.5 Where Streamflow Went, 1997–2007
Data source: Baseline Model Calibration and Validation Report (Tetra Tech 2009a, Table 6-6)

Table 3.3.1.2.1 Factors Affecting Streamflow

Climate	Rainfall is the primary factor affecting streamflow in the watershed. Because groundwater basins are readily recharged by big rain events, and groundwater discharges water to the stream network, rainfall ultimately determines the amount of water contributed to the stream network from groundwater. (See "3.2.1 Climate" for more information.) Temperature, which affects plant water demand as well as evaporation, also affects streamflow.
Groundwater and Springs	The greatest total volume of water comes from rainwater. However, once the rains and associated runoff have passed, the primary source of water in local streams for the rest of the year is groundwater. Natural springs are also found throughout the watershed, and can contribute to streamflow.
Geology and Soils	The watershed's steep mountains cause runoff water to flow very quickly, resulting in "flashy" streamflow after rain events. Steep mountains also increase the amount of rain received because of "orographic lift"—air coming in from the ocean hits the mountains, rises up quickly, cools, condenses, and forms rain. The cobbly, alluvial nature of the watershed's streambeds and groundwater basins plays a key role in the dynamic relationship between surface water and groundwater. (See "3.2.2 Geology and Soils" for more information.)
Water Withdrawals	The amount of water withdrawn from streams for consumption affects streamflow. Because groundwater is an important source of streamflow, groundwater withdrawals may also affect streamflow.
Water Additions	The addition of treated wastewater to the lower Ventura River is a significant contribution to streamflow, especially in the dry season.
Dams, Channel Modifications, and In-Channel Structures	Streamflow is reduced by the watershed's two dams, is increased during rain events by cement-lined drainage channels, and is modified by other in-channel structures such as debris basins, levees, and groundwater recharge basins.
Urban Development	Impervious surfaces reduce infiltration and increase storm flow volumes and rate of flow. Irrigation water can also contribute to streamflow.
Fires and Vegetative Cover	Recently burned hill slopes in steep, semi-arid lands can respond to winter rains with increased runoff. The removal of natural vegetation, such as floodplain riparian plants, can increase the flashy response of rivers during flood events (Stillwater Sciences 2011).
Native & Invasive Riparian Plants	The growth of all riparian vegetation follows cycles of flood scour and regrowth. Denser vegetation consumes more water. The nonnative, invasive plant *Arundo donax*, which occupies many parts of the watershed, is significantly thirstier than native streamside plants.

Besides the obvious contribution from rainfall, there are many other factors that influence the amount and duration of flow in the watershed's streams.

Arundo **in Ventura River**

Photo courtesy of Santa Barbara Channelkeeper

FINAL DRAFT

aStreamflow Characteristics

Definition: Base Flow

Base flow is the flow of water in streams that remains well after storms have passed.

Storms contribute the greatest volume of water to streamflow, so seasonal flows mimic rainfall seasonality. However, the watershed typically experiences only a few major storms a year. Outside of the direct runoff of these infrequent wet periods, it is groundwater that provides base flow, if it exists, to the Ventura River and its tributaries (RWQCB-LA 2012).

Streamflows fall into the "major flood" category on the Ventura River when flows hit 40,000 cfs or more as measured at Foster Park. This has occurred about once every 14 years since 1933. Between 1933 and 2011, the highest peak flow measurement obtained for the Ventura River at Foster Park was 63,600 cfs, measured on February 11, 1978 (VCWPD 2013).

Of the watershed's major tributaries, Matilija Creek and San Antonio Creek are the biggest contributors of water. Table 3.3.1.2.3 shows the relative amount of peak flow in the watershed's various drainages.

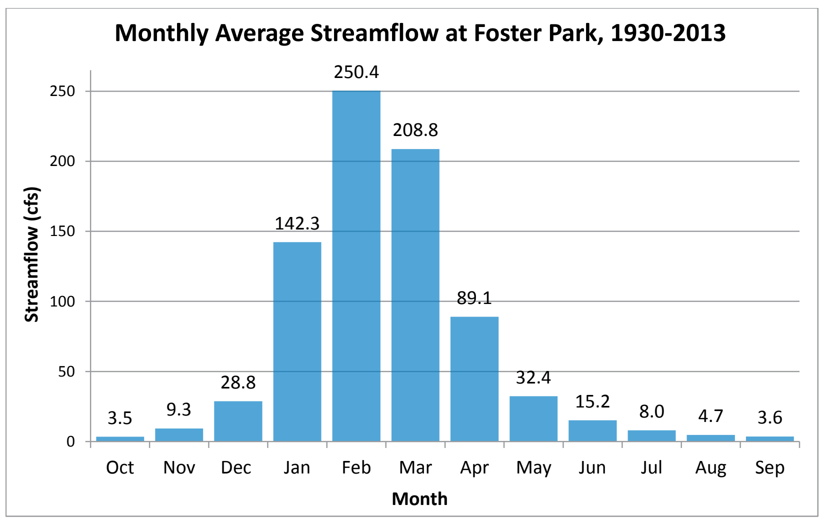


Figure 3.3.1.2.6 Monthly Average Streamflow at Foster Park, Water Years 1930–2013

Data Source: USGS National Water Information System Website (USGS 2014b)

Table 3.3.1.2.2 Monthly Average Streamflow (cfs) at Foster Park, Water Years 1930–2013

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average	3.5	9.4	29.2	142.3	250.4	208.8	89.1	32.4	15.2	8.0	4.7	3.6
Median	0.6	1.4	5.0	12.6	34.1	30.7	18.3	9.2	5.1	2.9	1.5	0.5
Highest	41	278	234	1,880	2,919	1,954	1,351	408	158	64	36	29
Water Year	1984	1966	1966	1969	1998	1938	1958	1998	1998	1998	1941	1998
Lowest	0	0	0	0	0	0	0	0	0	0	0	0
Water Year	Multiple Years											

Monthly average streamflow is the average of all daily streamflows for the month.
Data Source: USGS National Water Information System Website (USGS 2014b)

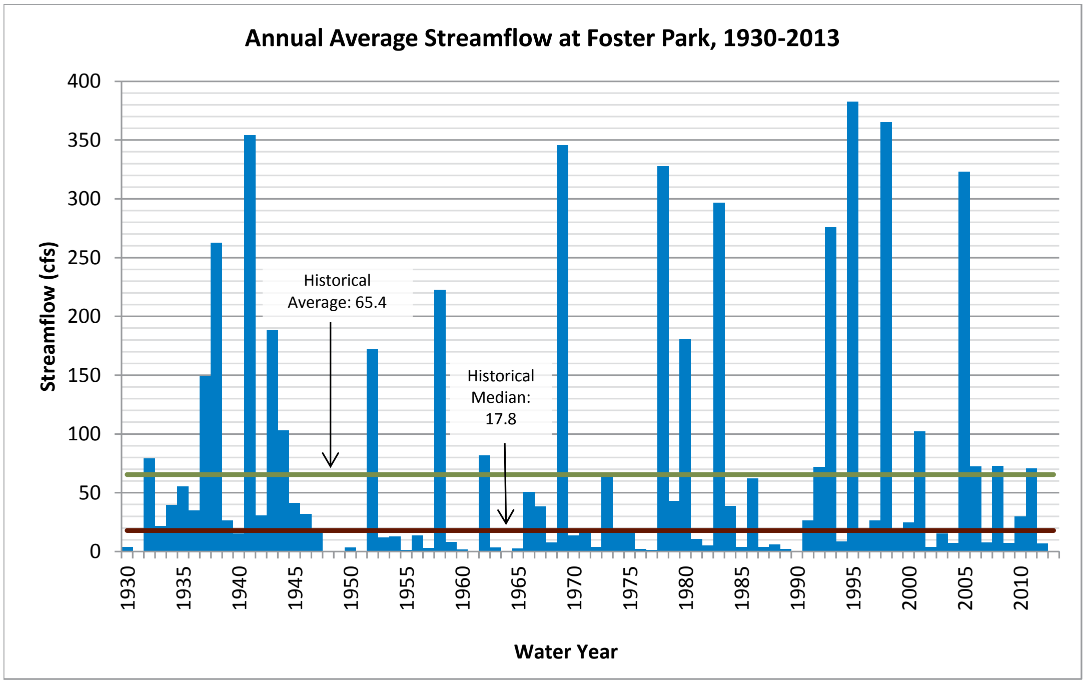


Figure 3.3.1.2.7 Annual Average Streamflow at Foster Park, Water Years 1930–2013. As this chart indicates, the historical annual average streamflow in the watershed rarely occurs in actuality. This is because occasional extreme flows skew the average. Historical annual median streamflow is much more common. The "median" represents the midpoint of the set of data, such that half of the years had an average rate of flow less than the median and half had an average rate of flow greater than the median.

Annual average streamflow is the average of all daily streamflows for the year.
Data Source: USGS National Water Information System Website (USGS 2014b)

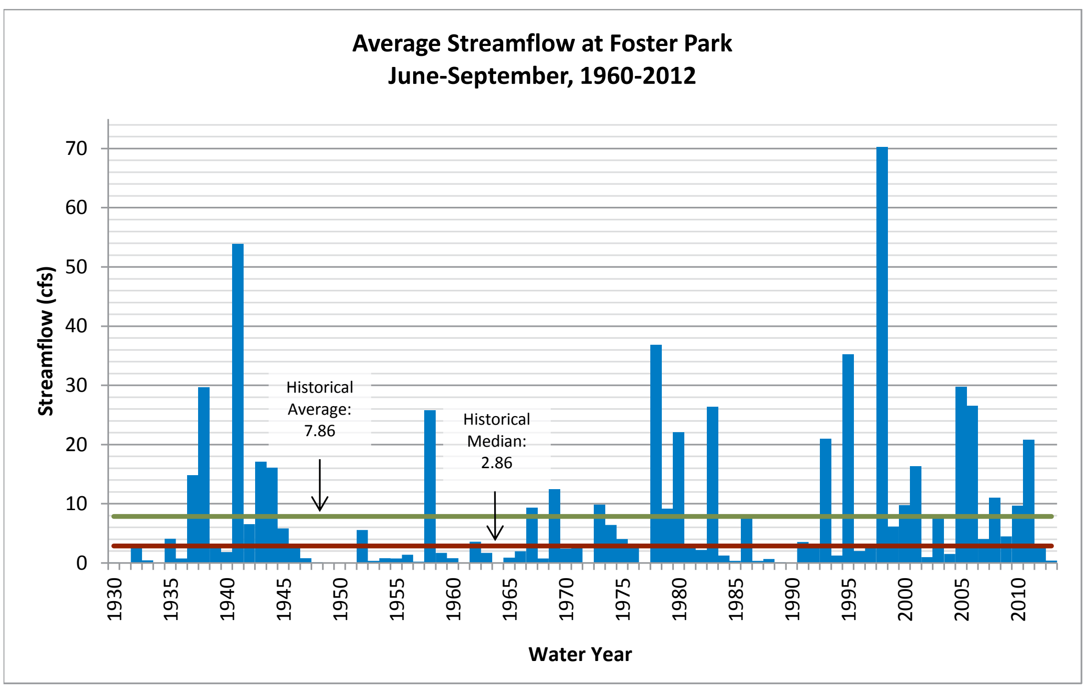


Figure 3.3.1.2.8 Average Streamflow at Foster Park, June–September, Water Years 1960–2012
Data Source: USGS National Water Information System Website (USGS 2014b)

Table 3.3.1.2.3 Storm Peak Flow Estimates Based on Modeling

	Peak Flow (cfs)	
Stream Name	**10-Yr**	**50-Yr**
Ventura River and Smaller Tributaries		
Below Matilija Creek/N. Fork Matilija Creek Confluence	15,000	24,000
Ventura River Baldwin Rd	16,000	24,800
Ventura River Casitas Springs	35,200	56,600
Ventura River Gauge at Foster Park	36,400	59,700
Ventura River at Shell	41,300	67,900
Matilija Creek		
Matilija Creek below dam and above N. Fork Matilija Creek	12,500	18,800
North Fork Matilija Creek		
N. Fork Matilija (upper part)	3,830	10,380
N. Fork Matilija (lower part)	3,960	10,740
San Antonio Creek and Tributaries		
Senior and Gridley	4,590	12,440
San Antonio Creek below McNell Creek	5,760	15,630
Reeves Creek above Thacher Creek	1,530	4,150
Thacher Creek above San Antonio Creek	2,860	7,750
San Antonio Creek below Thacher Confluence	7,490	20,330
San Antonio Creek above Stewart Creek	7,620	20,690
Stewart Canyon above San Antonio Creek with Fox	1,070	2,920
San Antonio after Stewart Confluence	8,590	23,320
San Antonio Creek above Lion Confluence	7,760	21,050
Big Canyon (Upper Ojai)	690	1,880
Lower Lion Canyon Creek	3,430	9,310
San Antonio after Lion Canyon Confluence	10,430	28,300
San Antonio Creek above Ventura River Confluence	9,960	27,020
Coyote Creek		
Coyote Creek above Ventura River	680	1,980
Cañada Larga Creek		
Cañada Larga Creek above Ventura River	5,370	14,580

This table shows model-generated estimates of peak flows of various streams and stream reaches in the watershed. These 10-year and 50-year peak flows are expected to occur once every 10 or 50 years, respectively. The largest peak flows ever measured in the watershed (63,600 cfs) were at the Foster Park gauge and were the equivalent of a 65-year peak flow.

Source: Ventura River Watershed Design Storm Modeling Final Report (VCWPD 2010)

Streamflow patterns in the Ventura River watershed reflect the same extreme variation found in rainfall patterns.

Extremely Variable

As in other watersheds in the region, streamflow patterns in the Ventura River watershed reflect the same extreme variation found in rainfall patterns. As shown in Table 3.3.1.2.4, between 1930 and 2013, the average annual rate of flow of the Ventura River at Foster Park was 65.4 cfs, but this period saw an annual low of 0 cfs and a high of 382.8 cfs. Table 3.3.1.2.4 also indicates the equivalent volume of water from these flow rate amounts. The annual runoff volume of the wettest water year was 227,096 AF—almost five times greater than the annual average and over 18 times greater than the annual median. These numbers help illustrate the extremely variable nature of streamflow in the watershed.

Table 3.3.1.2.4 Annual Average Streamflow at Foster Park, Water Years 1930–2013

	Avg.	Median	Low (1951)	High (1995)
Cubic feet/second (cfs)	65.4	17.8	0.0	382.8
Acre feet/year (AF/yr)	47,329	12,349	0.0	227,096

For comparison purposes, the rate of flow (cfs) was converted into the equivalent acre-feet for the year (AF/yr).

Annual average streamflow is the average of all daily streamflows for the year. 2012–2013 data is provisional.

Data Source: USGS National Water Information System Website (USGS 2014b)

Table 3.3.1.2.5 Annual Peak Flows at Foster Park, Water Years 1933–2013

	Avg.	Median	Low (1951)	High (1978)
Cubic feet/second	10,410	3,330	0.0	63,600
Acre-feet/minute	14.34	4.59	0.0	87.60

For comparison purposes, the peak rate of flow (cfs) was converted into acre-feet per minute.

Data Source: Ventura County Watershed Protection District Hydrologic Data Server (VCWPD 2013)

An average flow that is almost four times the median flow indicates high streamflow variability.

The median rate of flow is also provided in Table 3.3.1.2.4. The median represents the midpoint of the set of data, such that half of the years had an average rate of flow less than the median and half had an average rate of flow greater than the median. When data sets have an extreme range of variability, a few extreme numbers, such as a few extreme flood years, can skew the average. In such instances the median represents a much truer picture of "typical"—in this case, what flow is like in a typical year. Median flows, those closer to 17.8 cfs, are experienced much more often than average flows of 65.4 cfs. An average flow that is almost four times the median flow indicates high streamflow variability. Table 3.3.1.2.5 shows similar data for *peak* flows at Foster Park between the years 1933 and 2013.

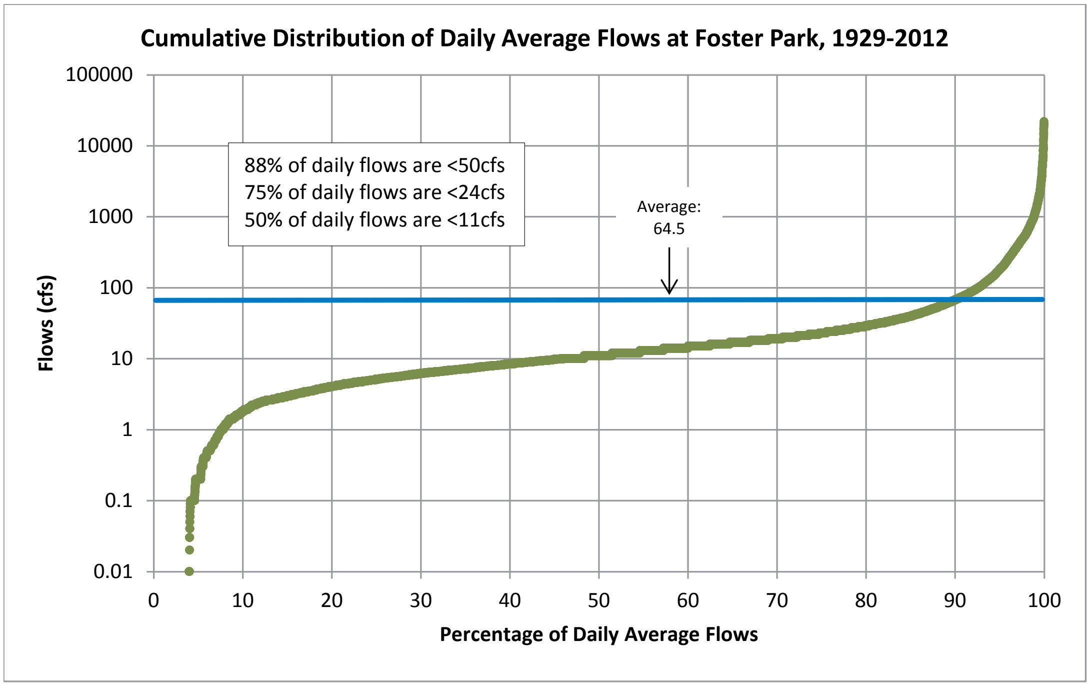


Figure 3.3.1.2.9 Cumulative Distribution of Daily Average Flows at Foster Park, Sept. 1926–Oct. 2012.
This chart illustrates that typical flows in the river are relatively low: 88% of the time average daily flows at the Foster Park gauge are less than 50 cfs, 75% of the time flows are less than 24 cfs, and 50% of the time flows are less than 11 cfs.
Data Source: USGS National Water Information System Website (USGS 2014b)

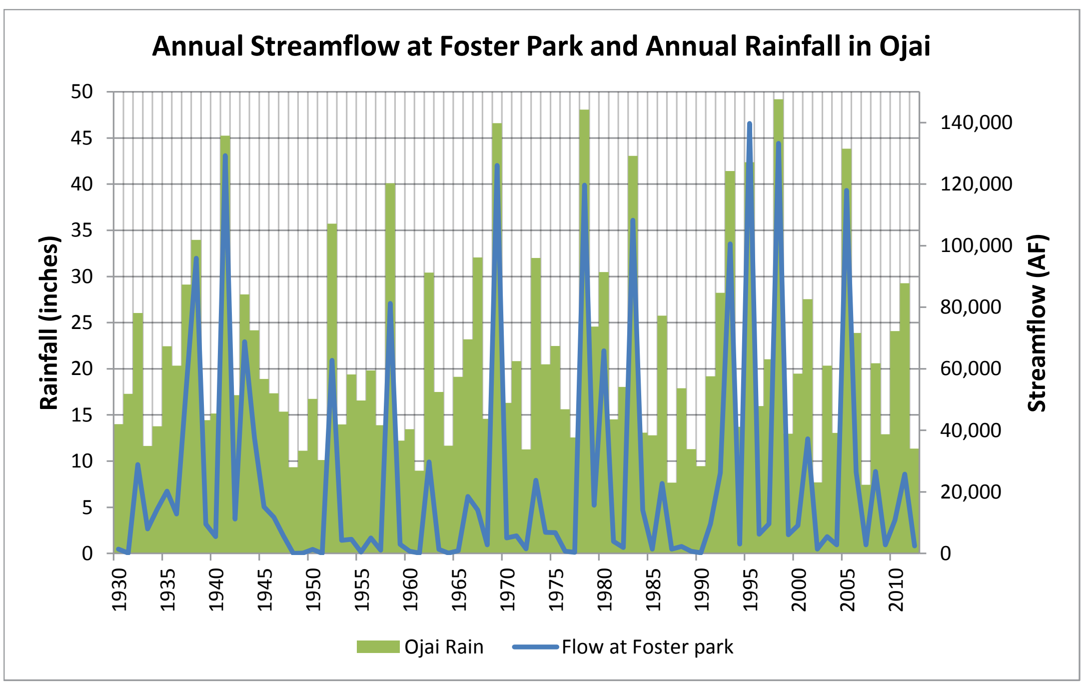


Figure 3.3.1.2.10 Total Annual Streamflow Volume and Ojai Rainfall, Water Years 1930–2012
Data Sources: Streamflow: USGS National Water Information System Website (USGS 2013); Rainfall: VCWPD Hydrologic Data Server (VCWPD 2013)

Cubic Feet Per Second and Acre-Feet

Water in motion—streamflow—is usually measured in "cubic feet per second" or "cfs," which is equal to the volume of water one-foot wide and one-foot high, flowing a distance of one foot in one second. A cubic foot equals 7.48 gallons flowing each second, or 449 gallons flowing each minute. One cfs will produce 646,272 gallons per day, or 724 AF of water per year.

Water that is in storage or impounded is typically measured in "acre-feet" or "AF," which is equal to the volume of water that would cover an acre of land (43,560 square feet) to a depth of one foot. An AF equals 325,851 gallons of water. One AF is equal to 0.504 cfs/day, meaning that that if water was flowing at 0.504 cfs for the duration of one day, the volume discharged during that day would be one AF (USGS 2014).

Below are photos that illustrate what different streamflows look like on the Ventura River.

35 and 200+ CFS of Streamflow, Ventura River, Below Robles Diversion.

These photos are intended to show what different rates of flow (cubic feet per second, or cfs) look like. The top photo shows a flow of about 35 cfs and the bottom photo, a flow 200+ cfs.

Photo courtesy of Casitas Municipal Water District

Streamflow of 30,000 cfs, Ventura River at Casitas Springs, 1998

Photo courtesy of Ventura County Watershed Protection District

Flashy and Intermittent

Streamflow in the Ventura River watershed responds very quickly to rainfall. During the rainy season, streamflows in the watershed are typically "flashy"—they increase, peak, and subside rapidly in response to storms. The rainy season is between October 15 and April 1, and rainfall tends to occur in just a few significant storms during this time. Streamflows generally peak in January through March and are lowest from August through October. See also "3.3.2 Flooding" for a look at streamflow and flood events.

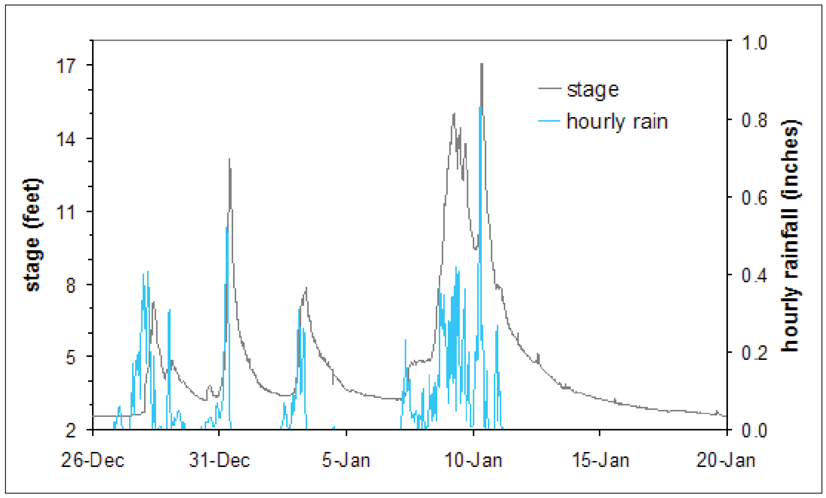


Figure 3.3.1.2.11 Flood Hydrograph at Foster Park, December 2004 to January 2005. Hydrographs illustrate how long it takes for streamflows (or "discharge") to build up in response to rain. This example compares the intensity of rainfall (in blue) with the flood stage (in grey) in the Ventura River at Foster Park during the December 2004 to January 2005 flood events. The term "stage" refers to how high water levels rose at the streamflow gauge; when the gauge reads 2.5 feet, the river is flowing at a trickle. The hydrograph shows that streamflow had a delayed response to rainfall at the beginning of the storm, because the watershed's dry and porous soils absorbed the initial rain. Twenty-three inches of rain fell during the period shown on the graph, but only about 6 inches of this rain flowed down the river, most of it during the second storm pulse.

Data source: Ventura Stream Team 2001–2005 (Leydecker & Grabowsky 2006)

The amount of streamflow that persists outside the rainy season, called "base flow," depends upon how much rain fell the previous winter and consequently how much recharge the groundwater basins received and how saturated the soil became. Typically, after the rains have passed, the amount of water flowing in streams in the watershed diminishes fairly rapidly. For the "ephemeral" streams, this marks the end of flow altogether; for the "intermittent" streams or stream reaches, flow will continue on for some time; and for the "perennial" stream reaches, flow will continue all year except in extended drought periods.

Direct Runoff vs. Base Flow

Direct runoff is the surface flow that contributes to a stream during and immediately after a storm. Base flow is the flow of water in streams that remains well after storms have passed. The source of base flow is groundwater that has made its way into the stream channel (Williamson & Klamut 2001). Base flow is a critical factor in the life cycle of some species, such as the endangered southern California steelhead, and is highly impacted by sustained drought or water withdrawals for human use. Because streamflow in the Ventura River watershed comes primarily from rain and not snowmelt, and because a few big storms often bring the bulk of the rain, the majority of total annual flow occurs as storm flow, or direct surface runoff, rather than as base flow.

Of the six major streams in the watershed, only Matilija Creek and North Fork Matilija Creek are typically perennial for their entire lengths, although sections of Matilija Creek occasionally dry up. Some of the tributaries of San Antonio Creek that are spring fed, such as Gridley Canyon and Senior Canyon Creeks, are also known to be perennial in their upper reaches. All other major streams are typically intermittent for either their entire length or parts of it. In rare, very wet years, the Ventura River may have continuous flow to the ocean; however, in most years, flow is intermittent, with the river drying up in the dry reach between the Robles Diversion Facility and the confluence with San Antonio Creek. Many of the watershed's smaller streams are ephemeral, existing only briefly after storms.

The intermittent nature of the Ventura River mainstem has been a condition of the river for over one hundred years.

Although the increased consumption of water by people in recent times has certainly influenced streamflow in the watershed, an extensive study of historical records by the San Francisco Estuary Institute demonstrated that the intermittent nature of the Ventura River mainstem has been a condition of the river for over one hundred years. As observed today, surface flows commonly became intermittent when the river dropped out of the mountains and entered flatter terrain. At the confluence with San Antonio Creek, and from Foster Park to the mouth of the river, flows were perennial (Beller et al. 2011).

> "…we found ourselves at the mouth of…the Matilija Cañon…A rapid brook runs down the anon, shrinking into the deserted bed of what must once have been a broad river, and here and there the gravel spreads far over the desolate bottom. But soon after entering the ravine, the eye is relieved by patches of wood and verdure which at short intervals break in upon the sand" (Hassard 1887).
>
> Documentation of flow conditions on the Ventura River consistently depicts three reaches with distinct summer flow regimes within the study area. These reaches are depicted on the historical topographic quad for the river (USGS 1903c; fig. 4.9). The first perennial reach extends from beyond the northern edge of the study area (Matilija Hot Springs) downstream to around the Cozy Dell Canyon (Matilija reach). Below this, the Ventura River valley begins to open up into the head of the Ojai Valley, and the river is intermittent until below Oak View and the river's confluence with San Antonio Creek (Oak View reach). Last, perennial flow is shown from just above the San Antonio Creek confluence downstream to the ocean (Avenue/Casitas reach).
>
> —*Historical Ecology of the Lower Santa Clara River, Ventura River, and Oxnard Plain* (Beller et al. 2011)

3.3.1.3 Surface Water Diversions, Dams and Reservoirs

The natural flow of water through the stream network has been altered by diversions of water for human use. These include dams and surface water diversions, which are discussed below, but also the extraction of groundwater. See "3.3.3 Groundwater Hydrology" and "3.4 Water Supplies and Demands" for information on groundwater withdrawals.

There are two major dams within the Ventura River watershed: Casitas Dam, which forms Lake Casitas, and Matilija Dam, which forms the Matilija Reservoir. There are two minor dams: Senior Canyon Dam, which forms Senior Canyon Reservoir, and the Stewart Canyon Debris Basin Dam, which exists to slow storm flows and capture storm debris. There is also one subsurface dam in the Ventura River at Foster Park and two significant surface water diversions, the Robles Diversion and the Foster Park Diversion (although the Foster Park surface diversion has not been used since the mid 1990's because the river has been dry in that location). Many others in the watershed, including individuals, farms and ranches, and small water companies, hold and use rights to divert smaller amounts of surface water (SWRCB 2013). As of March 2014, 21 different entities were registered in the state's eWRIMS (Electronic Water Rights Information Management System) database as having rights to withdraw surface water or water from subterranean streams in the watershed (SWRCB 2014b).

Lake Casitas and Robles Diversion

When winter rains result in sufficient surface flows at the Robles Diversion, the amount of water diverted to the lake versus that required to be released downstream is dictated by a regulatory document called the Robles Fish Passage Facility Biological Opinion.

Lake Casitas is the watershed's principal water supply reservoir, providing water to users throughout the watershed and to the small adjoining coastal watersheds (including the Rincon area and the City of Ventura). Lake Casitas gets its water from Coyote and Santa Ana Creeks (~55%), which flow directly into the lake; and from Ventura River diversions (~45%), transported to the lake via the 5.4-mile Robles Canal from the Robles Diversion and Fish Passage Facility (Robles Diversion) located on the river. The relative amounts from these sources depend upon a variety of factors that change from year to year (Wickstrum 2014). The lake has a maximum storage capacity of 254,000 AF.

The Robles Diversion is located on the western bank of the Ventura River about 1.5 miles downstream of the junction of Matilija and North Fork Matilija Creeks, and it includes a fish ladder to facilitate passage of migrating fish. In low rainfall years, there is typically little or no surface flow in the river at the diversion. When winter rains result in sufficient surface flows at the diversion, the amount of water diverted to the lake versus that required to be released downstream is dictated by a regulatory

Lake Casitas Dam and Reservoir

Photo courtesy of Rick Wilborn

Santa Ana Creek Entering Lake Casitas Recreation Area

document called the *Robles Fish Passage Facility Biological Opinion* (NMFS 2003). The Biological Opinion was prepared by the National Marine Fisheries Service as a required part of construction of a fish passage facility (which became operational in 2006) at the Robles Diversion. It outlines complex operational and flow guidelines to provide for the migration and passage of the endangered southern California steelhead up and down the main stem of the Ventura River and through the diversion during the steelhead migration season, which is between January 1 and June 30. Outside of the migration season, the flow guideline is simpler: a minimum flow of 20 cfs must be released downstream to protect rights of downstream groundwater users.

Robles Diversion Aerial
Photo courtesy of Google Earth

Robles Diversion. The Robles Diversion structure is located 1.5 miles downstream of the confluence of Matilija and North Fork Matilija Creeks, the beginning of the Ventura River. The concrete structure is located on the western bank of the river, and has diversion gates, bypass gates, and a fish ladder. A 350-foot-long by 9.5-foot-high earthen dam is located across the river to divert flows to the diversion structure (Entrix & Woodward Clyde 1997). Both photos were taken during the dry season when no water diversions were occurring.

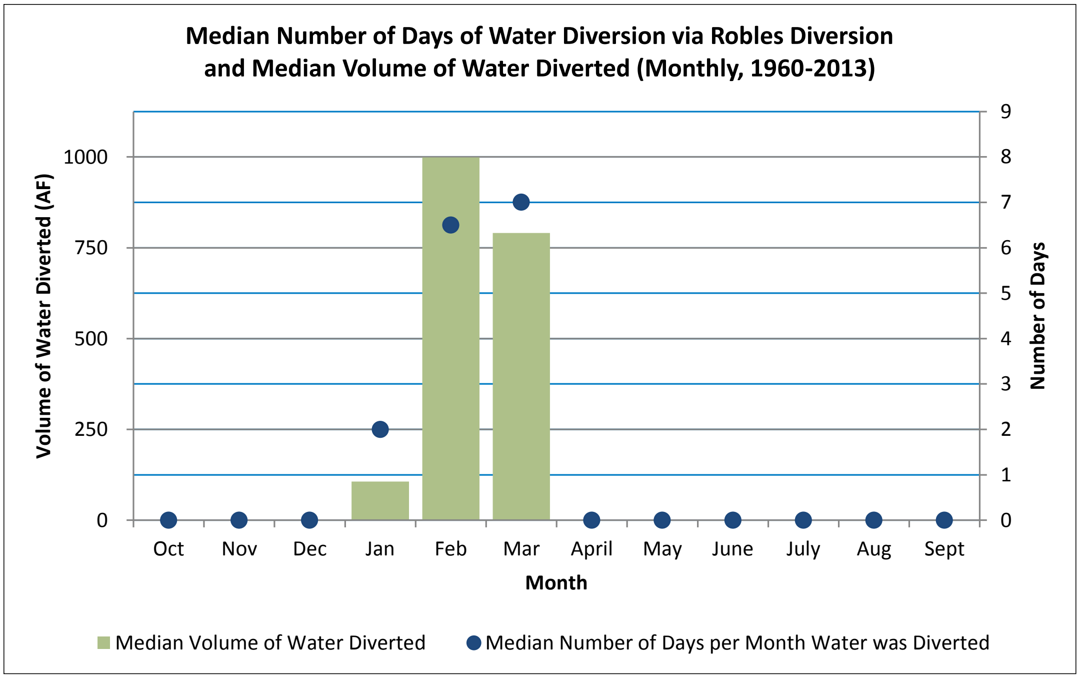


Figure 3.3.1.3.1 Median Number of Days of Water Diversion via Robles Diversion & Median Volume of Water Diverted, Monthly: Water Years 1960–2013

Source: Casitas Municipal Water District (CMWD 2014)

Table 3.3.1.3.2 Diversion via Robles Diversion, Water Years: 1960–2013

Number of Days of Diversion				Volume Diverted (acre-feet per year)			
Annual Average				Annual Average			
Avg.	Median	High (1967)	Low (1990, 1999, 2002, 2007, 2013)	Avg.	Median	High (1969)	Low (1990, 1999, 2002, 2007, 2013)
52	38	198	0	11,376	6,007	50,080	0

Source: Casitas Municipal Water District (CMWD 2014)

Matilija Reservoir and Dam

Matilija Reservoir is an older, smaller reservoir built on Matilija Creek. It was originally built to hold 7,000 AF of water, but is now nearly full of sediment and holds less than 500 AF (USACE 2004b). During the 1950s and 1960s, irrigation water from Matilija Reservoir was delivered by gravity flow to the western Ojai Valley via a pipeline system, called the Matilija Conduit, originating at the face of the dam. In the past, reservoir water was also sometimes released in the winter through a gate valve in the dam to enhance diversions to Lake Casitas via the Robles Diversion; however, this practice was discontinued in 2011 because of regulatory concerns over instream water quality (Evans 2013).

Matilija Dam and Reservoir

A concerted, multi-stakeholder effort to remove Matilija Dam has been underway since 1998 because the reservoir no longer provides a water supply function, blocks the migration of the endangered southern California steelhead and restricts the natural transport of sediment to the Ventura River and coastal beaches. See "3.6.3 Matilija Dam" for a more detailed discussion about the dam.

Foster Park Subsurface Dam and Diversion

In 1906, a subsurface diversion dam was built across the river to enhance the amount of water available for diversion to the City of Ventura.

A small dam also exists in the Ventura River at Foster Park. This is an area of the river that naturally has regular flow, in part because underground geologic structures force subsurface flow to the surface. In 1906, this natural geologic feature was enhanced by construction of a subsurface diversion dam across the river to enhance the amount of water available for diversion to the City of Ventura. The dam crosses the Ventura River as well as the mouth of Coyote Creek (Entrix & Woodward Clyde 1997), and works in combination with subsurface collector pipes.

Foster Park Subsurface Dam and Diversion, August 2013. This photo was taken in August after two dry winters.

The City of Ventura also has a surface diversion in the Ventura River in this area; however, the intake for the surface diversion is located in a part of the river that has been dry since 2000. In addition, the City has four wells, referred to as the Nye well field, located between 1,000 and 2,890 feet north of the subsurface dam (Entrix & Woodward Clyde 1997).

3.3.1.4 Streamflow Monitoring

Streamflow data are regularly monitored in the watershed by the Ventura County Watershed Protection District (VCWPD), the United States Geological Survey (USGS), Casitas Municipal Water District (CMWD), and Santa Barbara Channelkeeper (SBCK). The City of Ventura has also conducted intermittent streamflow monitoring.

The VCWPD and USGS have websites that make these data available to the public.

Streamflow Data Limitations

Streamflow monitoring is subject to a number of data quality challenges and limitations, as described in this excerpt:

Data quality is an important issue for stream gauge records. Many of the streams in the watershed flow through unstable channels that shift dimensions over time and become choked with debris, causing the relationship between measured stage and discharge to change over time. In addition, flood peaks that exceed the range for which velocities have been measured (or those that disable the stage recorder) are often estimated with considerable uncertainty.

—*Data Summary Report, Ventura River Watershed Hydrology Model* (Tetra Tech 2008)

Table 3.3.1.4.1 Streamflow Gauges in the Ventura River Watershed, 2013

VCWPD #	USGS #[1]	Location	Agency[2]	Monitored
603	11114495	Matilija Creek above Matilija Reservoir	USGS (with $ from VCWPD)	Continuous flow
		Matilija Creek at Matilija Hot Springs	CMWD	Continuous flow
602	(11115500)	Matilija Creek at Matilija Hot Springs	VCWPD	Continuous flow
604	(11116000)	North Fork Matilija Creek	VCWPD	Continuous flow
	(11116550)	Ventura River below Robles Diversion (Meiners Oaks)	CMWD	Continuous flow
605	(11117500)	San Antonio Creek at Hwy 33	VCWPD	Continuous flow
		Santa Ana Creek above lake	CMWD	Continuous flow
	(11117600)	Coyote Creek above lake	CMWD	Continuous flow
608	11118500	Ventura River at Foster Park	USGS (with $ from VCWPD & CMWD)	Continuous flow
630		Cañada Larga Creek at Ventura Ave	VCWPD	Storm peak and event data only
631		Fox Canyon Drain below Hwy 150	VCWPD	Continuous flow
633		Happy Valley Drain at Rice Rd	VCWPD	Storm peak and event data only
669		Thacher Creek at Boardman	VCWPD	Event peak and flood warning only
		Robles Diversion Canal, 1 near Diversion; 1 inside park before lake	CMWD	Continuous flow

1: Gauge numbers in parentheses indicate gauges that were historically, but are no longer, monitored by USGS.

Data Source: VCWPD (VCWPD 2014)

2: USGS-United States Geological Survey; CMWD-Casitas Municipal Water District; VCWPD-Ventura County Watershed Protection District

VCWPD Historic Streamflow Data. Data from eight active streamflow monitoring stations (#s 602, 603, 604, 605, 608, 630, 633, and 669) are collected by VCWPD and can be found at www.vcwatershed.net/hydrodata/php/getstations.php?dataset=stream_day. Some VCWPD stream gauges are operated or co-operated by the USGS.

VCWPD Current Streamflow Data. VCWPD also provides current (almost real-time) observed and forecasted streamflow data at a website that is updated every 10 minutes. Website: www.vcwatershed.net/fws/VCAHPS/#.

USGS Historic and Current Streamflow Data: The USGS currently operates two streamflow gauges (#s 11114495 and 11118500) in the watershed. They have also operated gauges at other locations in the watershed in the past. Streamflow data are available in real-time (updated every 15 minutes) or as a daily average of streamflow dating back to the beginning of the period of record. The USGS data can be found at: http://waterdata.usgs.gov/ca/nwis/sw.

CMWD Streamflow Data: CMWD operates five streamflow gauges and helps fund a sixth gauge, as indicated in Table 3.3.1.4.1. Data from the gauges are compiled in the district's annual hydrology report.

Santa Barbara Channelkeeper Streamflow Data: Santa Barbara Channelkeeper's Stream Team has collected estimated streamflow measurements since 2001. From 2001 to November 2006, estimated measurements were made utilizing a "float" method. In December 2006, Stream Team began collecting measurements using electronic current velocity meters. In accordance with an adapted USGS streamflow measurement protocol, flow is estimated based on measurements of the cross-sectional width, velocity, and depth of the stream at several equally spaced intervals along the cross section. Streamflow measurements have been irregularly collected at various Stream Team sites throughout the duration of the program. Channelkeeper maintains its streamflow dataset and makes it available by request to educators, agencies, and the public.

City of Ventura Data: Since 2009 the City of Ventura has conducted intermittent monitoring of groundwater levels and streamflow in the vicinity of the City's wellfield at Foster Park. This monitoring is a part of a Surface/Groundwater Interaction Study that looks at the effect of the City's pumping on flows in the Foster Park Area. In addition, the City has monitored the pools and riffles (shallow areas of a stream where water moves fast enough that it ripples) within the Foster Park reach of the river on several occasions in an attempt to compare changes in flow rates with changes in fish habitat using a Habitat Suitability Index based on 18 variables (indicators) including water temperature, flow velocity, substrate, and shading. These studies are intermittent for the purpose of developing data for CEQA documentation for the installation of additional wells.

3.3.1.5 Key Data and Information Sources/ Further Reading

Below are some of key documents that address surface water hydrology in the watershed. See "4.3 References" for complete reference citations.

HSPF Model

In 2008, under contract from the VCWPD, Tetra Tech completed a hydrologic model for the Ventura River Watershed using the USEPA's Hydrological Simulation Program-Fortran (HSPF). Data integrated into this model include precipitation, evapotranspiration, land use and land cover, soils, slopes and elevations, watershed segmentation, planning and zoning, fire regime, hydrography, channel characteristics, flood elevation modeling (HEC-RAS), reservoir management for Casitas and Matilija, diversion structures, debris and detention basins, groundwater recharge, discharge, and surface water interactions, irrigation, point sources, and stream gauging. While the HSPF model has the ability to account for some aspects of groundwater, groundwater-surface water interactions are a potential source of uncertainty because limited groundwater information was included in the majority of the model runs, and the model has limited capability for groundwater simulation and dynamic exchanges with surface water features. The HSPF model was validated against data from water years 1997–2007. Following the validation, the model was used to perform a natural conditions simulation to determine what the state of water resources in the Ventura River Watershed would be without human influence. The input data and the results of the model runs are listed in several reports:

> Data Summary Report, Ventura River Watershed Hydrology Model (Tetra Tech 2008),
>
> Natural Condition Report, Ventura River Watershed Hydrology Model (Tetra Tech 2009),
>
> Baseline Model Calibration and Validation Report, Ventura River Watershed Hydrology Model (Tetra Tech 2009a).

A Review of the Findings of Santa Barbara Channelkeeper's Ventura Stream Team January 2001–January 2005 (Leydecker & Grabowsky 2006)

Casitas Municipal Water District Hydrology Report, Water Year 2008–2009 (CMWD 2009)

Channel Geomorphology and Stream Processes (Entrix 2001a)

Acronyms

AF—acre-feet

AF/yr—acre-feet per year

BOR—Bureau of Reclamation

cfs—cubic feet per second

CMWD—Casitas Municipal Water District

eWRIMS—Electronic Water Rights Information Management System

HSPF—Hydrological Simulation Program – Fortran

msl—mean sea level

OVSD—Ojai Valley Sanitary District

SBCK—Santa Barbara Channelkeeper

USGS—United States Geological Survey

VCWPD—Ventura County Watershed Protection District

City of Ojai Urban Watershed Assessment and Restoration Plan (Magney 2005)

Design Hydrology Manual (VCWPD 2010a)

Draft Ventura River Habitat Conservation Plan (Entrix & URS 2004)

Historical Ecology of the lower Santa Clara River, Ventura River, and Oxnard Plain: an analysis of terrestrial, riverine, and coastal habitats. (Beller et al. 2011)

Groundwater Budget and Approach to a Groundwater Management Plan Upper and Lower Ventura River Basin (DBS&A 2010)

Hydrologic Assessment San Antonio Creek Sub-Watershed, Ventura County, California (DBS&A 2006)

Hydrology, Hydraulics and Sediment Studies of Alternatives for the Matilija Dam Ecosystem Restoration Project (USBR 2007)

Preliminary Hydrogeological Study, Surface Water/Groundwater Interaction Study, Foster Park (Hopkins 2010)

Report on the Environmental Impacts of the Proposed Agreement Between Casitas Municipal Water District and the City of San Buenaventura for Conjunctive Use of the Ventura River–Casitas Reservoir System (EDAW 1978)

Surface Water-Groundwater Interaction Report for the Ventura River Habitat Conservation Plan (Entrix 2001)

Ventura River Steelhead Restoration and Recovery Plan (Entrix & Woodward Clyde 1997)

Ventura River Watershed Design Storm Modeling Final Report (VCWPD 2010)

3.3.2 Flooding

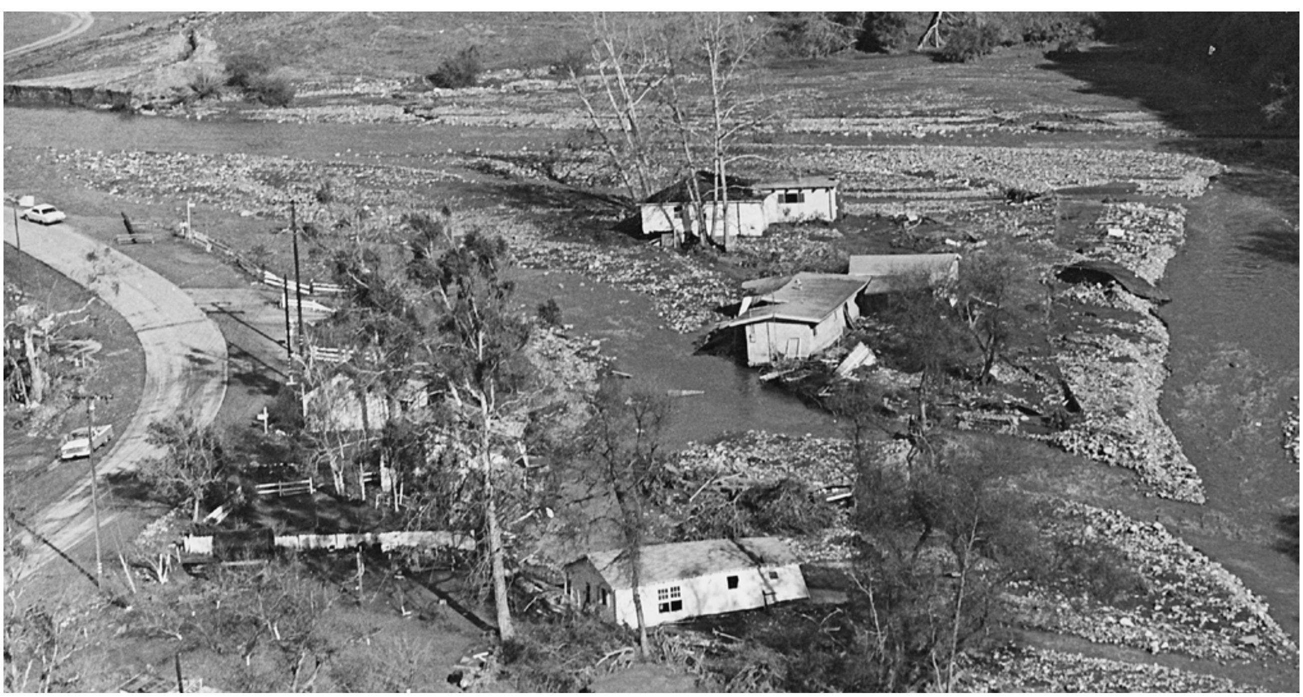
This section describes the recurring pattern of floods in the Ventura River watershed. The major flood types—riverine, alluvial, coastal, and urban—are defined, and the nature of these floods is described, including the role that the watershed's steep mountains play in the flashy nature of local floods. Coastal floods and erosion, which stem not from fresh water but from saltwater, are also examined. Finally, existing infrastructure and systems that are in place to protect lives and the built environment are reviewed.

Floodplain Management

Floods are, of course, natural events; it is only human-created infrastructure—either put in the pathway of flood flows or altering flooding conditions—that presents the need to "manage" them. Fortunately, those charged with managing floods are moving beyond simple "flood control" approaches focused strictly on moving water quickly in order to protect human life and property, to a "floodplain management" approach that acknowledges the functions and values of floodplains, such as water infiltration and groundwater recharge, providing critical riverine and aquatic habitats, and naturally attenuating flood flows.

Some flood-related topics are covered in other sections of this report: precipitation in "3.2.1 Climate," topography and well as the flood-related hazards of landslides, debris flows, and liquefaction in "3.2.2 Geology and Soils," and surface water flows in"3.3.1 Surface Water Hydrology."

San Antonio Creek Ranch, 1969 Flood
Photo courtesy of Ventura County Star



FINAL DRAFT

3.3.2.1 Flood Frequency and Intensity

Ventura River watershed residents are no strangers to floods. Damaging floods, like droughts, are an unpredictable yet relatively frequent occurrence. What local officials consider "major" floods—peak flows of 40,000 cubic feet per second (cfs) or more (as measured at Foster Park)—have occurred once every 14 years on average since 1933. Some of the watershed's bigger floods are in the "moderate" category, those with peak flows of 20,000 cfs to 39,999 cfs (at Foster Park). Major or moderate flood flows on the Ventura River have occurred once every 5 years on average since 1933. Sometimes multiple peak flow events are seen in the course of one rainy season. Two of the watershed's six major peak flows on record occurred during one wet season: the flood of 1969; of the 18 major and moderate flows on record, three occurred during the winter of 2005.

Major or moderate flood flows on the Ventura River have occurred once every 5 years on average since 1933.

Since 1962, there have been eight Presidentially declared major flood disasters in Ventura County (see Table 3.3.2.1.2). "A Presidential major disaster declaration puts into motion long-term federal recovery programs, some of which are matched by state programs and designed to help disaster victims, businesses and public entities." (FEMA 2014)

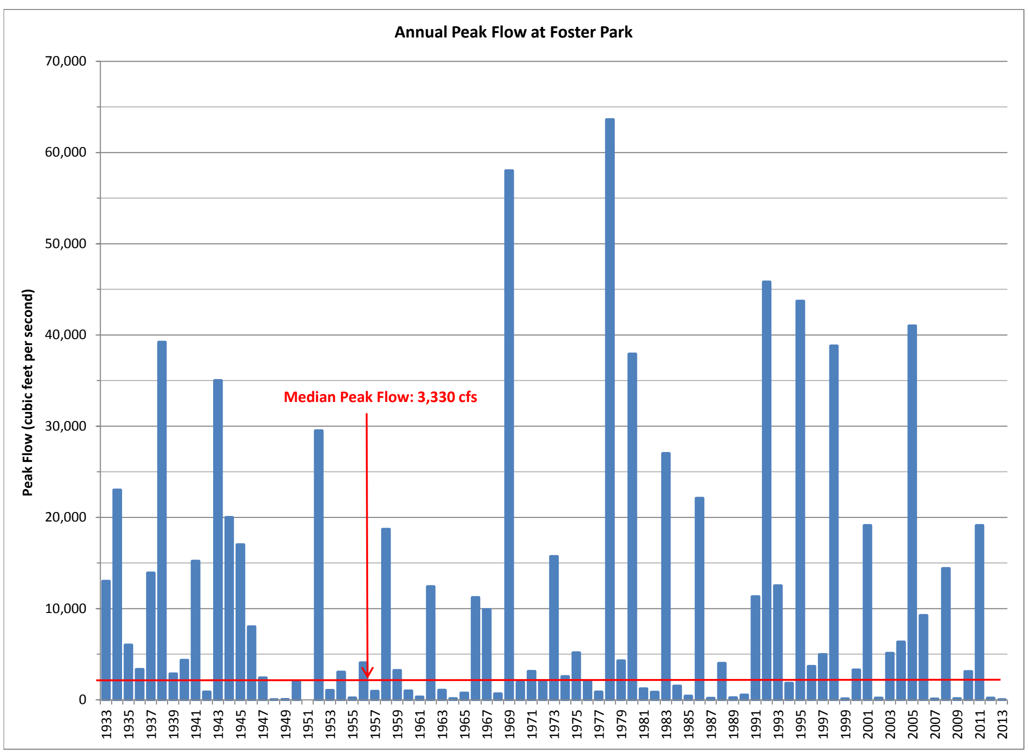


Figure 3.3.2.1.1 Annual Peak Flow at Foster Park, 1933–2013. This graph shows the largest peak flow event for each of the years from 1933 to 2013.

Table 3.3.2.1.1 summarizes significant flood flows since streamflow monitoring began in 1933.

Table 3.3.2.1.1 Ventura River Flood Flows Greater than 15,000 cfs, 1933–2011

Date	Water Year	Peak Flow (cfs)[1]	% Annual Exceedance Probability[2]	Flood Category[3]
1978, February	1978	63,600	1.5%	Major
1969, January	1969	58,000	2.2%	Major
1992, February	1992	45,800	5.2%	Major
1995, January	1995	43,700	6.0%	Major
2005, January	2005	41,000	7.3%	Major
1969, February	1969	40,000	7.8%	Major
1938, March	1938	39,200	8.2%	Moderate
1998, February	1998	38,800	8.5%	Moderate
1980, February	1980	37,900	9.0%	Moderate
1943, January	1943	35,000	11.0%	Moderate
1952, January	1952	29,500	16.1%	Moderate
2005, January	2005	29,400	16.2%	Moderate
1983, March	1983	27,000	19.1%	Moderate
1952, March	1952	24,600	22.5%	Moderate
1934, January	1934	23,000	25.2%	Moderate
1986, February	1986	22,100	26.8%	Moderate
2004, December	2005	20,600	29.7%	Moderate
1944, February	1944	20,000	30.9%	Moderate
2011, March	2011	19,100	32.9%	Flood
2001, March	2001	19,100	32.9%	Flood
2005, February	2005	18,800	33.6%	Flood
1958, April	1958	18,700	33.8%	Flood
1945, February	1945	17,000	38.1%	Action
1969, January	1969	16,600	39.1%	Action
1973, February	1973	15,700	41.6%	Action
1941, March	1941	15,200	43.1%	Action

1: Peak flows are as measured, in cubic feet per second (cfs), at the Foster Park gauging station.

2: The Annual Exceedance Probability (AEP) values indicate the chance that specific flood flows will occur in any one year. A 1% AEP means there is a 1 in 100 chance that a flood will occur in any one year. AEP values are most accurate for the highest flows, but estimates are provided for the lower flows to indicate the general trend. See sidebar definition of 100-year flood and AEP.

3: Flood Category thresholds are different in different parts of the watershed, as determined by Ventura County Watershed Protection District.

Data Sources: Hydrologic Data Server (VCWPD 2013); (VCWPD 2014)

Definitions

100-Year Flood (also called Base Flood)—A misleading term that does NOT mean a flood that will occur once every 100 years. It is a flood whose flow has a 1% chance of being *exceeded* in any given year. A 50-year flood (which has smaller peak flows) has a greater chance, 2%, of being exceeded in any given year; and a 500-year flood (which has greater peak flows) has a lesser chance, 0.2%, of being exceeded in any given year.

1% Annual Exceedance Probability Flood—"Annual Exceedance Probability (AEP) Flood" is the current preferred term, because it describes the probability of specific flood flows occurring, rather suggesting the length of time (years) between floods of specific flows. A 100-year flood could occur more than once in a short period of time.

According to the Federal Emergency Management Agency's (FEMA) statistics, a 100-year flood has a 26% chance of occurring during a 30-year period, which happens to be the length of many mortgages. People living inside of the 100-year, or 1% AEP, flood hazard zone are subject to flood insurance requirements if their mortgage is backed by the federal government through the National Flood Insurance Program (VCWPD 2014; CRS 2013).

The Ventura River's greatest recorded peak flood flow, 63,600 cfs (in February 1978), was the equivalent of a 65-year flood or 1.5% AEP flood (VCWPD 2014). Since streamflow measuring began in 1929, the Ventura River has never experienced a 100-year (1% AEP) flood.

As described in more detail in "3.3.1 Surface Water Hydrology," streamflows in the watershed are closely correlated with rainfall, and thus flood events are almost exclusively associated with rainfall events. As indicated in Table 3.3.2.1.1, most of the watershed's major and moderate floods have occurred in January or February, well into the rainy season when soils may have already been saturated and "primed" for runoff.

Most of the watershed's major and moderate floods have occurred in January or February, well into the rainy season when soils may have already been saturated and "primed" for runoff.

The total amount of rainfall, however, is not the only factor involved; the timing and intensity of the rainfall, the timing and quantity of previous rainfall, soil saturation levels, and the condition of the stream channels, among other factors, also matter. Snowmelt is not a significant contributor to flooding in the Ventura River watershed. The snow that sometimes does fall on the mountains of the watershed generally melts gradually and fairly quickly—not lasting long enough for a warmer storm to cause the fast melting that boosts flood flows.

Table 3.3.2.1.2 Presidentially Declared Major Flood Disasters in Ventura County[1]

1962, February (Kennedy)
1965, November–December (Johnson)
1967, November–December (Johnson)
1969, January (Nixon)
1983, February–March (Reagan)
1992, February (Bush)
1995, January–March (Clinton)
2005, January (Bush)

1: The Presidents declaring the disaster are shown in parenthesis.

Data Source: Flood Histories of the Counties in the Alluvial Fan Task Force Study Area (Earp 2007)

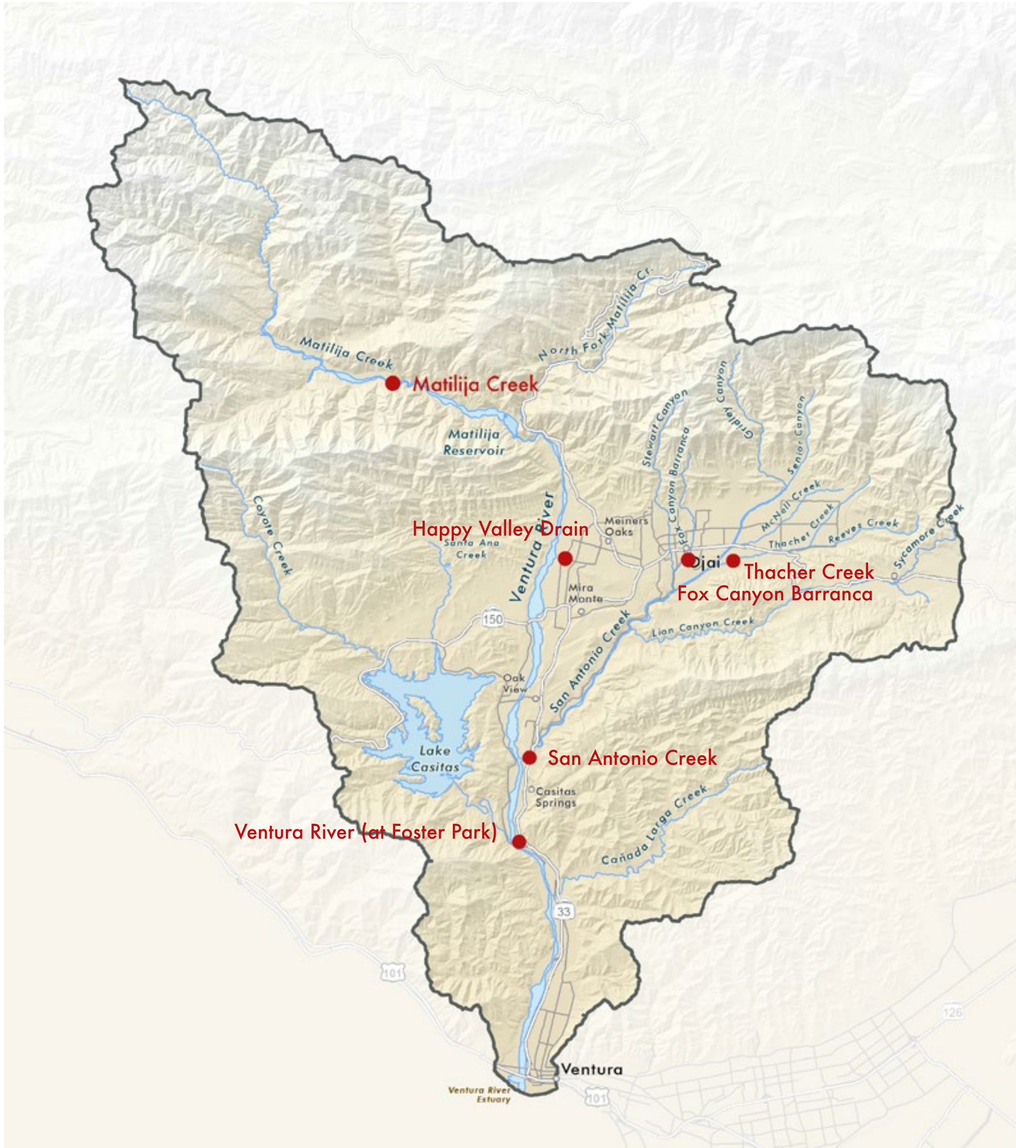


Figure 3.3.2.1.2 Select Flow Monitoring Locations Map. This map of select streamflow monitoring locations accompanies Table 3.3.2.1.3.

Table 3.3.2.1.3 Flood Flows (cfs) by Flood Category on Various Drainages

Drainage Location[1]	Major	Moderate	Flood	Action
Matilija Creek (above Matilija Dam)	9,000	8,000	7,000	6,000
Ventura River (at Foster Park)	40,000	20,000	18,000	15,000
Thacher Creek (at Boardman)	5,500	5,000	4,000	3,000
Fox Canyon Barranca (at Athletic Club)	2,050	1,950	1,900	1,700
Happy Valley Drain (at Rice Rd.)	2,000	1,900	1,700	1,500
San Antonio Creek (near confluence with Ventura River)	10,000	9,000	8,000	6,000

1: See Figure 3.3.2.1.2 for a map of these locations.

The flow, in cubic feet per second (cfs), that is considered "major," "moderate," or "minor" is different for different streams and different sections of the river. On San Antonio Creek, for example, a flow of 10,000 cfs or higher at the creek's confluence with the Ventura River indicates a major flood, whereas on the Ventura River, a flow of 40,000 cfs or higher (at Foster Park) is considered a major flood.

Data Source: VCWPD Google Maps Interface for rainfall, stream, and evaporation stations (www.vcwatershed.net/fws/VCAHPS/#)

San Antonio Creek Flood Flows

Major floods along San Antonio Creek are described as having a peak discharge greater than 10,000 cfs. The most severe flood on record on San Antonio Creek occurred in 2005, with a peak flow of 24,000 cfs recorded at the gauging station on San Antonio Creek at Casitas Springs (VCWPD 2013c).

As discussed later in this section, coastal flooding, caused by ocean water tide and wave inundation, often occurs when riverine flooding occurs, but can also occur independently of inland flooding. Table 3.3.2.1.4 summarizes past coastal floods in the watershed.

Table 3.3.2.1.4 Significant Coastal Floods in the Watershed

1907, December
1939, September
1969, December
1977–78, Winter
1982–83, Winter
1988, January
1997–98, Winter
2010, January

Data Source: Ventura County Open Pacific Coast Study (FEMA 2011)

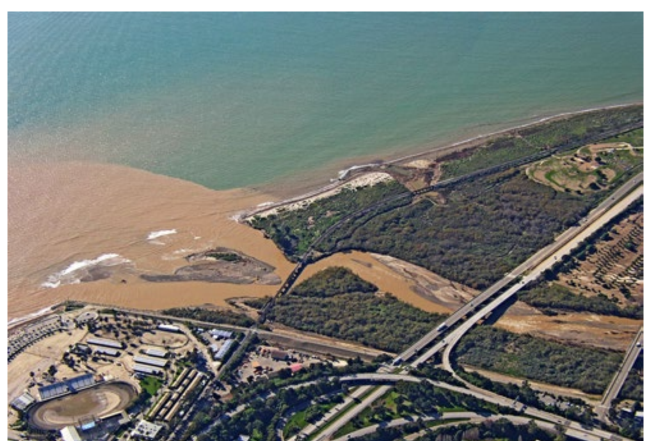
Of Water and Sediment

Flooding in the Ventura River watershed is as much about sediment and boulders as it is about water. The erosive rocks of the Transverse Ranges supply a steady stream of boulders and sediment, easily eroded in the intense downpours that occur in the watershed's upper elevations. When a flood is rolling down the river valley, the chocolate brown flow is thick with rocks, sediment, and other debris, and residents report the sound of thunder as boulders crash downstream.

Debris from the river's flood flows is carried out to sea or gets deposited along the way, typically in wider and flatter areas of the river channel. Piled-up debris can also create islands in the river or change the path of the river altogether. This topic is discussed further in "3.2.3 Geomorphology and Sediment Transport."

Thacher Creek in Siete Robles Neighborhood, 2005 Flood

Photo courtesy of Ventura County Watershed Protection District



Sediment Flowing Out to Sea, 2005 Flood

Photo copyright David L. Magney

3.3.2.2 Flood Hazard Zones

The Federal Emergency Management Agency (FEMA) manages the National Flood Insurance Program. As part of that program FEMA creates and updates flood hazard maps, called Flood Insurance Rate Maps (or FIRM), for communities across the country. These maps indicate areas where there is a 1% or greater probability of inundation by flood flows in any year, now called a "1% annual exceedance probability (AEP) flood" (formerly referred to as the 100-year flood).

Homes and buildings in areas mapped as having a 1% AEP are considered at high risk for floods and are required to have flood insurance if they have mortgages from federally regulated or insured lenders. These areas have a 1% or greater chance of flooding in any given year, which is equivalent to a 26% chance of flooding during a 30-year mortgage period (FEMA 2013).

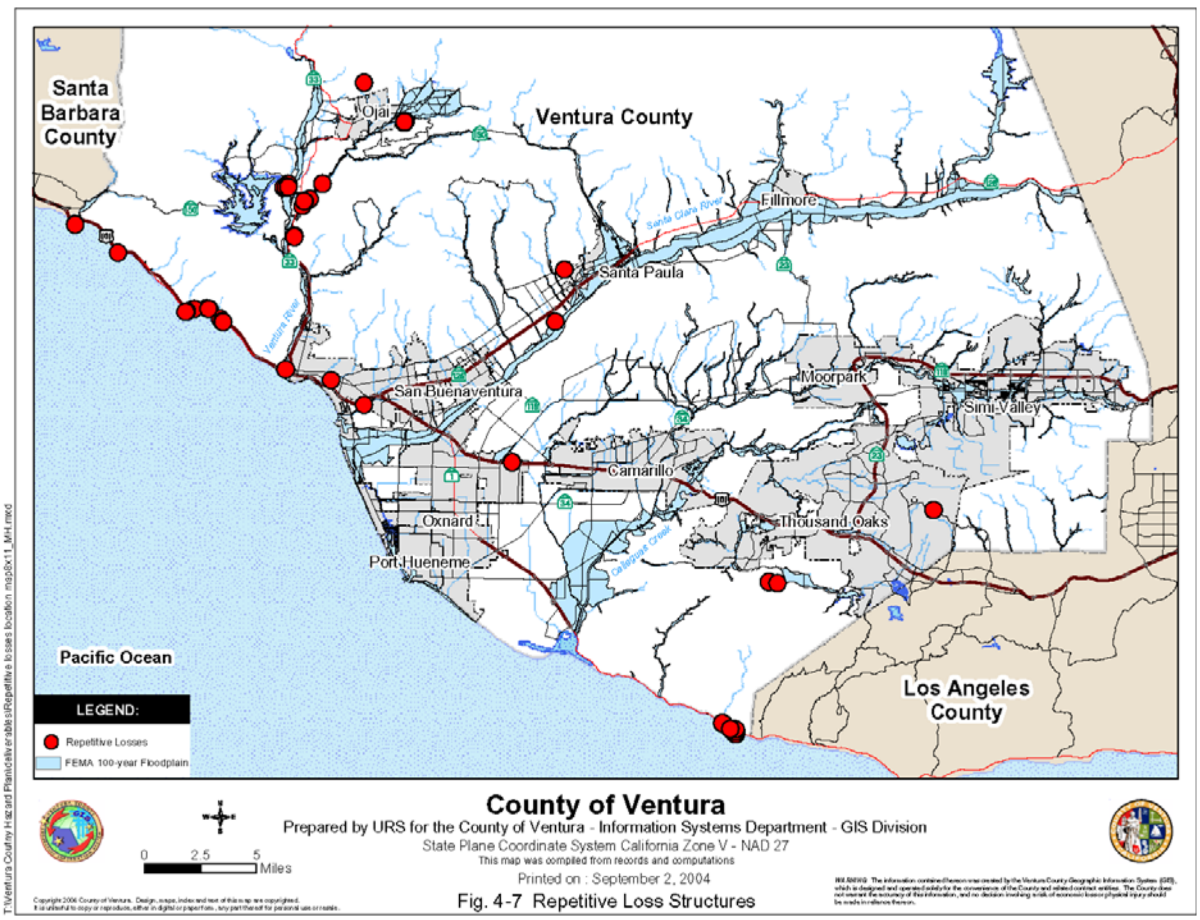


Figure 3.3.2.2.1 Repetitive Loss Structures Map. Repetitive loss structures are buildings identified by FEMA that, since 1978 and regardless of any change(s) of ownership during that period, have experienced one of the following: 1) four or more paid flood losses of more than $1,000 each; 2) two paid flood losses within a 10-year period that, in the aggregate, equal or exceed the current value of the insured property; and 3) three or more paid losses that, in the aggregate, equal or exceed the current value of the insured property (URS 2005). Of the 49 repetitive loss structures in Ventura County (as of 2004), 19 (39%) are located in the Ventura River watershed. Because of the high incidence of repetitive loss claims, FEMA has been working to reduce the losses experienced by repetitively flooded properties.

Source: VCWPD 2014e

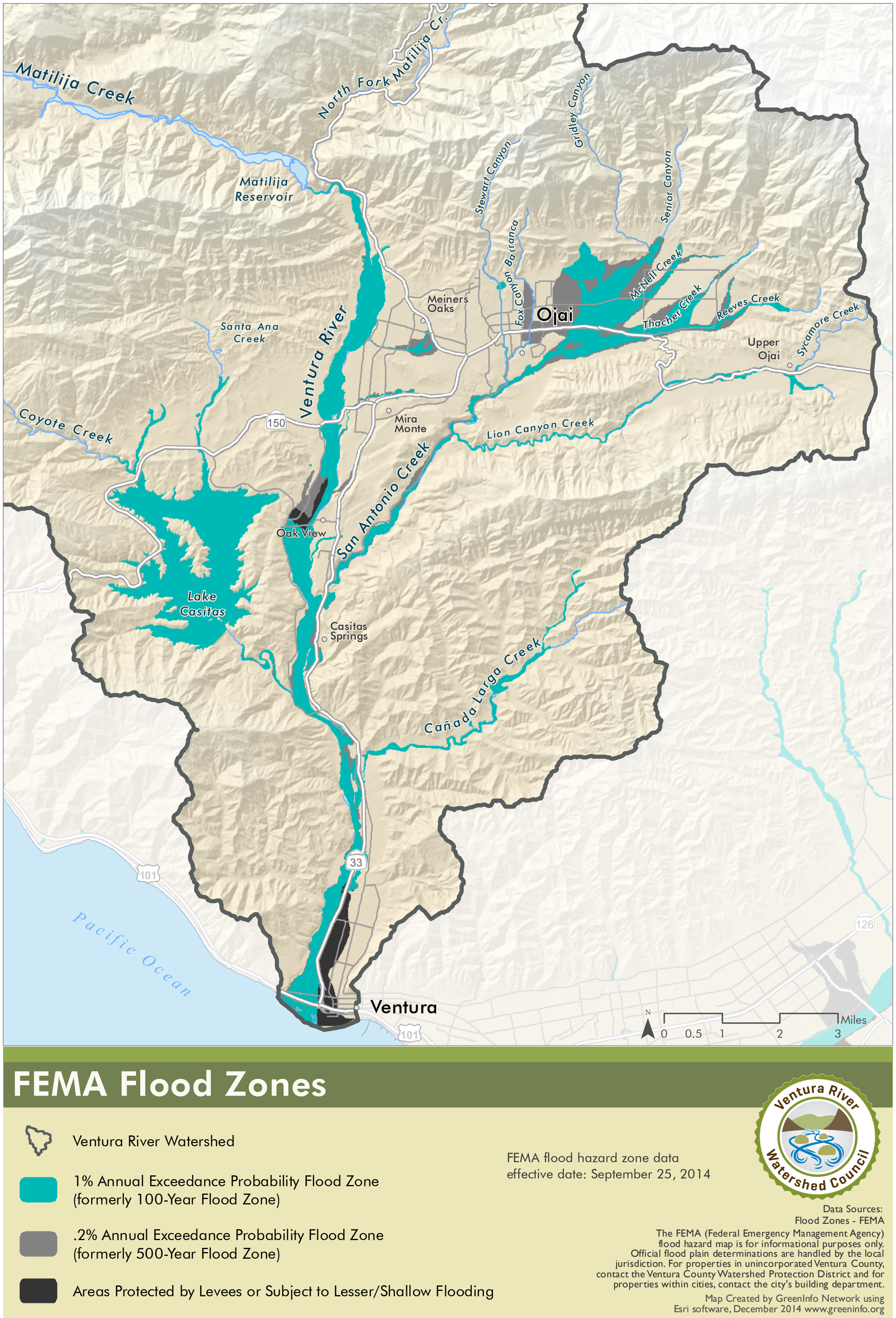


Figure 3.3.2.2.2 Flood Hazard Zone Map

3.3.2.3 Types of Floods and Where They Occur

The Ventura River watershed experiences several distinct types of flooding, including riverine flooding, alluvial fan flooding, coastal flooding, and urban drainage flooding; it also has the potential for dam failure flooding.

Riverine Floods

Definition: Floodplain

A floodplain is the area adjacent to a watercourse or other body of water that is naturally subject to recurring floods.

Riverine flooding occurs when a stream or river channel receives so much water that the excess water flows over its banks and onto the adjacent floodplain. The periodic inundation of floodplains is a natural and important ecosystem function that renews nutrients and triggers cycles of successive vegetation. As described in "3.3.1 Surface Water Hydrology," a long list of factors influence streamflows. Two important factors that strongly influence the nature of riverine flooding in the watershed are the steepness of the terrain and the intensity of rain events.

In the flood of 1992, the rate of flow of the Ventura River rose from less than 100 to 46,700 cubic feet per second—an increase of 46,600%—within about three hours.

The steep terrain of the Ventura River watershed is carved by a network of streams that discharge water in a very short distance. The distance from the headwaters to the ocean is only 33.5 miles. Stormflows move fast in such a steep environment which, when coupled with the intense downpours that can occur in the upper watershed, results in streamflows that sometimes cannot be contained by their banks.

Floods in these conditions are called "flashy" because floodwaters tend to rise and fall in a matter of minutes. In the flood of 1992, as an extreme example, the rate of flow of the Ventura River rose from less than 100 to 46,700 cfs—an increase of 46,600%—within about three hours. The Ventura can be a fiercely flashy river.

Ventura River Rescue, 1992 Flood
Photo courtesy of Ventura County Star

Ventura River Preserve Swimming Hole, Dry and During 2005 Flood

Flood photo courtesy of David Magney

City of Ventura's Nye Well 1A, 2005 Flood. The City's Nye Well 1A replaced Nye Well 1, lost in a previous flood. The February 2005 flood took out the rest of its replacement.

Photo courtesy of Ventura Water, City of Ventura

San Antonio Creek, 2005 Flood

Photo courtesy of Paul Jenkin

Casitas Springs, 2005 Flood

Photo courtesy of Ventura County Watershed Protection District

Overflowing Manhole in San Antonio Creek, 2005 Flood. Stormwater caught in the sewer system flows out the manhole.

Photo courtesy of Ojai Valley Sanitary District

Live Oak Acres, 1969 Flood
Photo courtesy of Ventura County Star

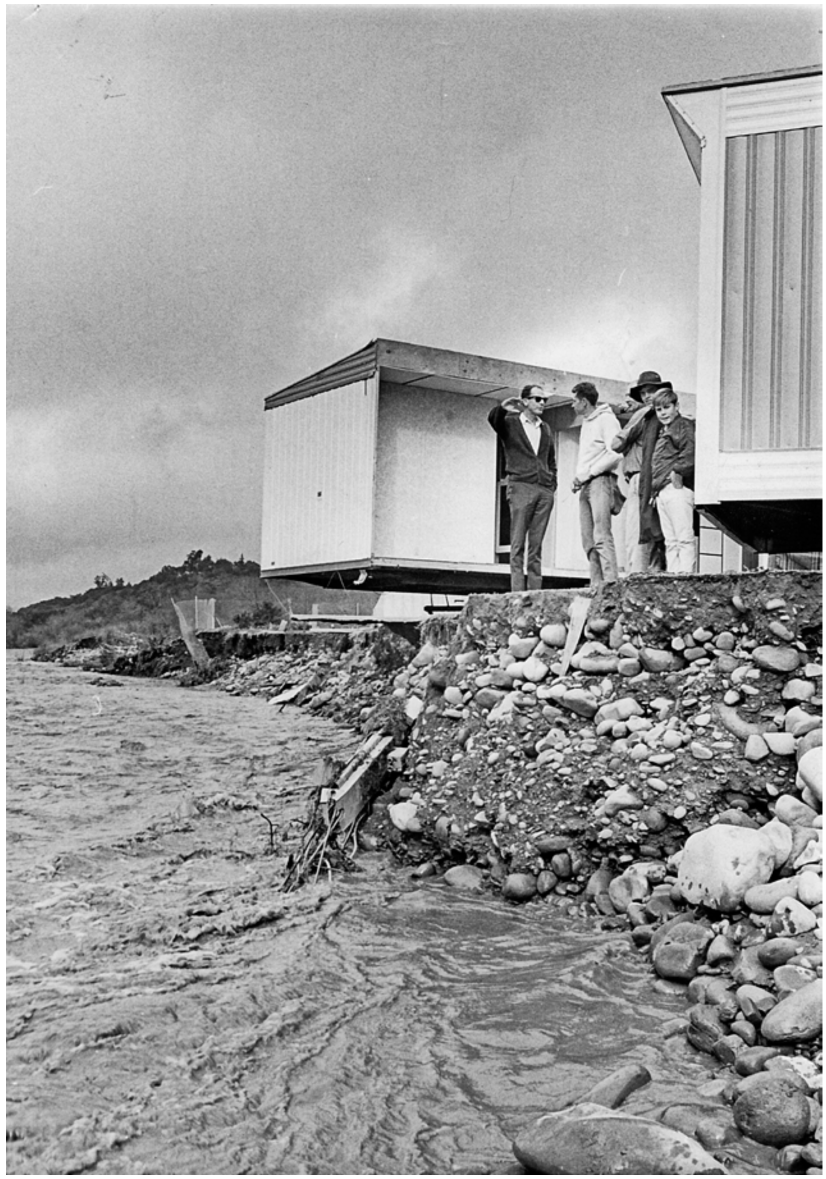
In addition to the risks associated with water overflowing its banks, riverine floods also pose risks related to erosion. Properties adjacent to streams and rivers can be scoured and undercut during floods, threatening homes, roads, and infrastructure. The floods of 1969 and 2005 both washed out a number of sewer mainlines along the edges of San Antonio Creek and the Ventura River. In the 2005 flood, this caused raw sewage mixed with stormwater to spill into the river for several days.

Cañada Larga Creek, Looking Upstream, 2005 Flood
Photo courtesy of Ventura County Watershed Protection District

Coyote Creek, 2005 Flood
Photo courtesy of Ventura County Watershed Protection District

Rancho Trailer Park, Casitas Springs, 1969 Flood

Photo courtesy of Ventura County Star



The high sediment load carried and deposited by local streams is a very significant factor in local riverine flood risks.

The high sediment load carried and deposited by local streams is a very significant factor in local riverine flood risks. Deposited rocks and sediment readily fill established channels which, if not cleaned out, can cause channel overflow and exacerbate flooding.

The wildland fires that occur in the forest and chaparral habitats that frame the watershed are also important contributors to flooding. After an intense fire, a waxy substance from the burning of brush and trees can be left on the soil, which makes the soil repel water. These “hydrophobic” soils decrease infiltration and increase runoff. A pattern of floods following fires within watersheds has been closely observed for more than 90 years in southern California (Earp 2007).

The Flood of 1969: The Watershed's Most Damaging Flood

The most damaging riverine flood recorded in the Ventura River watershed occurred in 1969. The watershed above Ojai received a staggering 43 inches of rain in nine days between January 18 and January 27. The floodwaters and associated debris rolled down out of the mountains, flooding homes in Casitas Springs and Live Oak Acres. Much agricultural land, primarily citrus groves, was seriously damaged or destroyed. All over Ventura County, transportation facilities, including roads, bridges, and railroad tracks, were damaged. The wastewater treatment plant below Foster Park was severely damaged and dumped raw sewage into the Ventura River. In addition, sewer trunk lines were broken along the Ventura River and San Antonio Creek. Untreated sewage polluted the river and beach (VCPD 2011a). The capacity of the Matilija reservoir was significantly reduced by siltation from the flood (USACE 2004). See "4.4 Appendices" for a more detailed description of the 1969 flood.

Highway 33 Destroyed at North Fork Matilija Creek, 1969

Photo courtesy of Ventura County Star

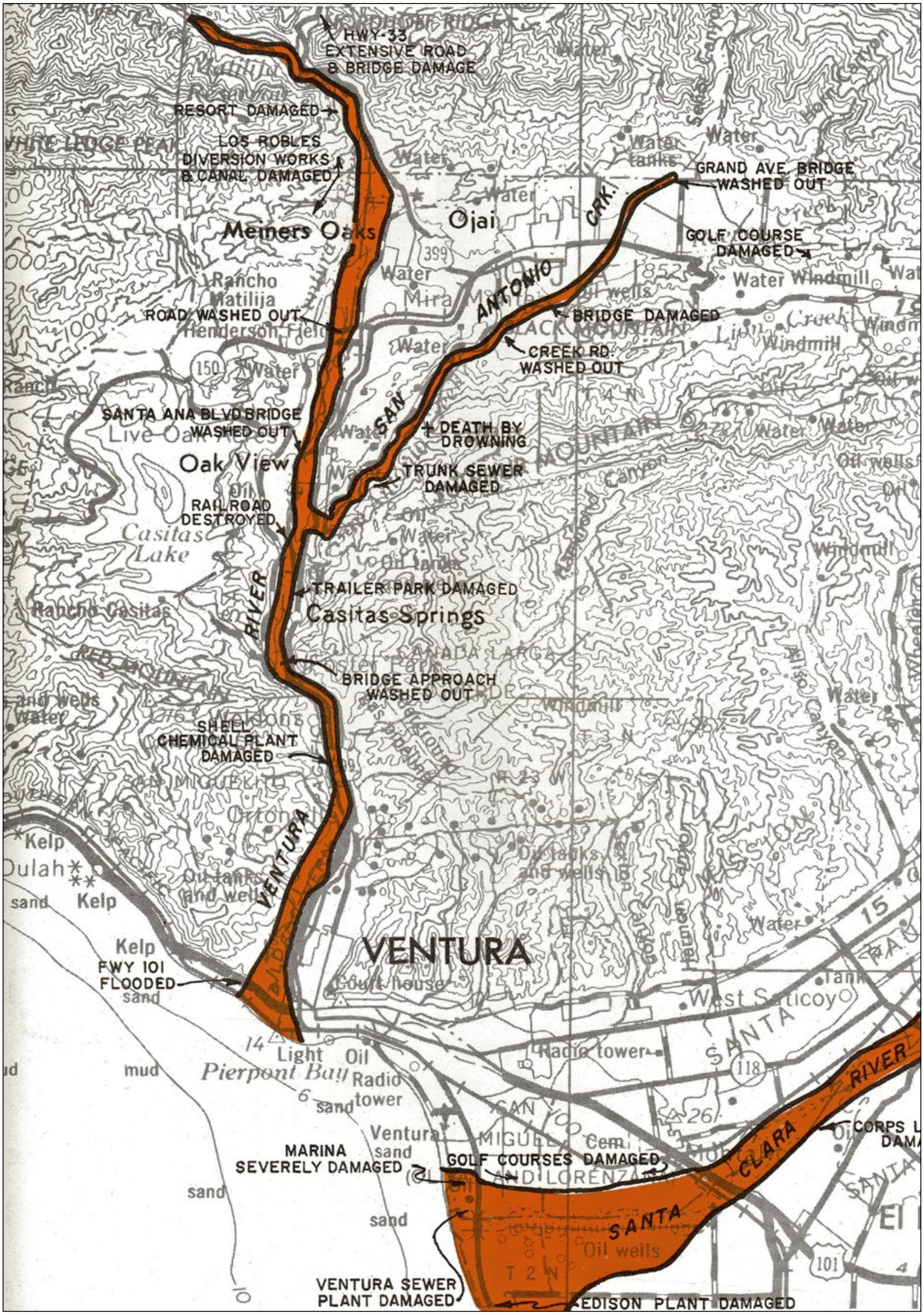


Figure 3.3.2.3.1 1969 Flood Damages Map

Source: Ventura County Flood Control District

Alluvial Fan Floods

Alluvial fans are the fan-shaped deposits of rock and sediment that accumulate on valley floors at the mouths of canyons in steep erosive mountains, typically in dry climates. The stream channels associated with alluvial fans are shallow and poorly defined, and their path is unpredictable. During heavy rains, water runs off the steep mountains above alluvial fans very quickly and with tremendous erosive force. The water picks up sediment, rocks, and boulders that can easily fill the shallow stream channels and cause floodwaters to spill out, spread out, and cut new channels. Alluvial fan floods can cause significant damage due to the high velocity of water flow, the amount of debris carried, and the broad area affected.

East Ojai Avenue, 1969 Flood
The stream channels associated with alluvial fans are shallow and poorly defined, and their path is unpredictable.
Photo courtesy of *Ventura County Star*

Soule Park Golf Course, 2005 Flood
Photo courtesy of Ventura County Watershed Protection District

Siete Robles Neighborhood after 2005 Flood. The Siete Robles neighborhood is located on the active depositional area of the alluvial fans in Ojai's East End.

Photo courtesy of Ventura County Watershed Protection District

A significant area of the Ojai Valley's East End appears on FEMA floodplain maps because of alluvial fan flood risk. Three alluvial fans occur in this area: Thacher Creek Alluvial Fan, San Antonio Creek Alluvial Fan, and Dron-Crooked Canyon Alluvial Fan (VCWPD 2009).

San Antonio, Thacher, McNell, Reeves, and Dron Creek-Crooked Creeks are associated with the alluvial fan flooding on the East End of Ojai. These creeks have some of the highest erosion rates in Ventura County (Hawks & Associates 2005). This area of the watershed is dominated by citrus orchards, and flooding of the creeks can cause erosion and damage to the orchards, as well as to homes and roads. Residential neighborhoods built in these areas have a history of repeated flood damage. The Siete Robles neighborhood on Ojai's East End, located directly on the "active" or depositional area of the alluvial fans, has seen severe flooding over the years.

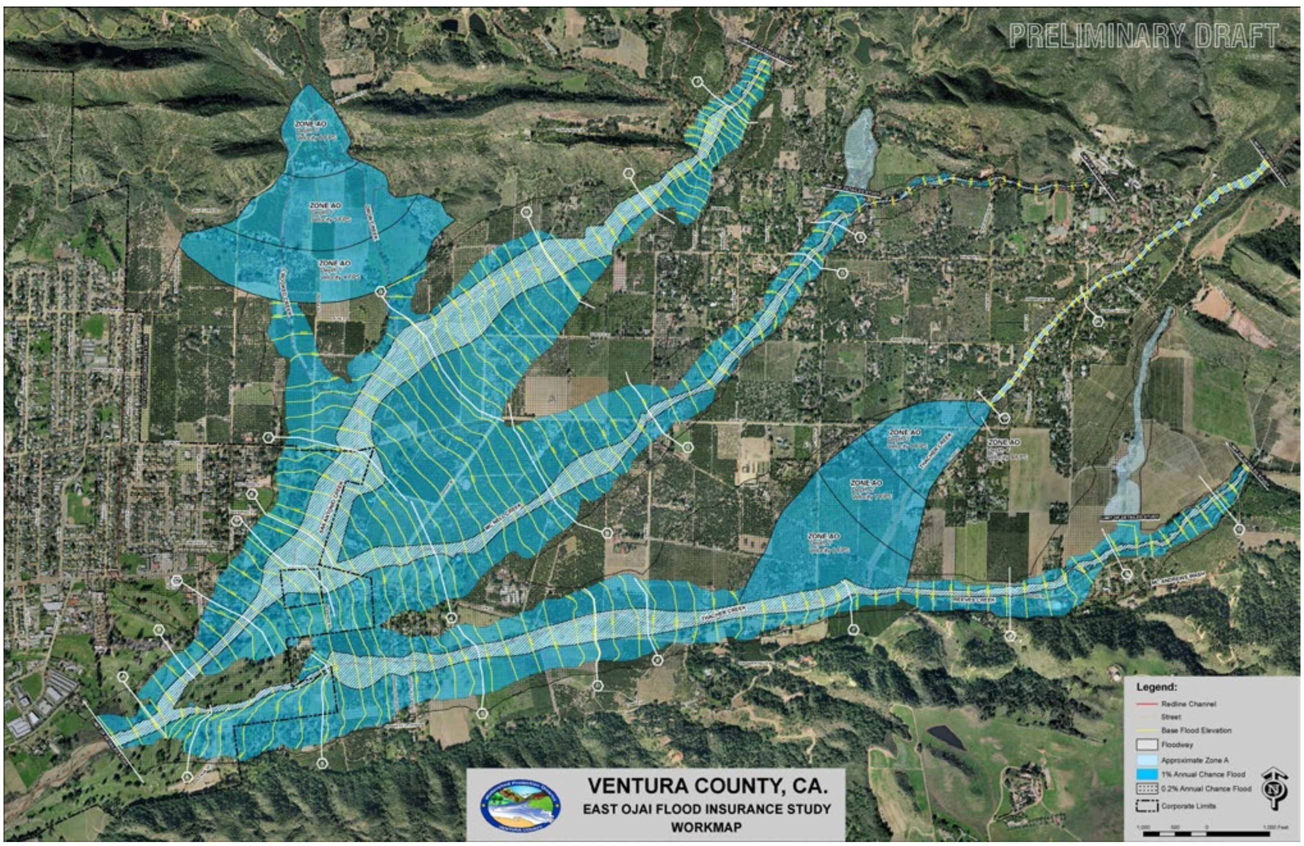


Figure 3.3.2.3.3 East Ojai 100-Year (1% AEP) Floodplain Map. In a Cooperative Technical Partnership with FEMA, Ventura County Watershed Protection District performed a comprehensive floodplain study of the east Ojai area, which culminated in 2011 with a proposal to FEMA to revise the floodplain map of this area. The revised map, which is very different than the old map, became effective in September of 2014.

Source: Addendum to East Ojai Alluvial Fan Flood Insurance Study, Technical Support Data Notebook (VCWPD 2012a).

Coastal Floods

Coastal flooding occurs when water from the ocean is driven onto land by storm surges, storm-generated wind, tides and waves, or tsunamis.

Coastal flooding may cause damaging erosion of the coast, beaches, and structures along the coast, and this hazard is exacerbated by the reduction in the natural transport of sand and gravel to replenish local beaches. Rising sea level from climate change also presents a potential coastal flooding hazard. Backwater flooding at the river mouth, where the flow of the river to the ocean is "backed up" by exceptionally high ocean water or sand berms, is a type of flooding that is possible under conditions of higher sea level. Backwater flooding regularly occurs at the drainage to the coast on San Jon Road in Ventura, just outside of the watershed.

Backwater Flooding at San Jon Road, Ventura

Photo courtesy of Paul Jenkin

A tsunami is a series of sea waves generated by an earthquake, landslide, volcanic eruption, or other large disruption to the ocean. These sea waves can move more than 500 miles per hour and their destructive power can be enormous when they hit land. Damaging tsunamis have occurred infrequently in California, but they are a possibility that must be considered in coastal regions (CGS 2013).

The tsunami from an earthquake in Alaska in 1964 caused approximately $35,000 of damage to the marinas in Ventura County. A major earthquake off the coast of Chile in 2010 generated a tsunami that caused over $200,000 in damages to structures and vessels in Ventura Harbor. The worst recorded tsunami to hit California was in 1812, when an earthquake occurred in the Santa Barbara Channel; the resulting waves were probably 15 feet or higher above sea level at Ventura (VCPD 2011a).

Definition: Flood

FEMA's official definition of "flood" includes: "Collapse or subsidence of land along the shore of a lake or similar body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels that result in a flood." (FEMA 2013a)

FINAL DRAFT

Ventura Pier 1998

Photo courtesy of Paul Jenkin

Coastal flooding often occurs at the same time that riverine flooding occurs because both are associated with major storms, but this is not always the case. Sometimes powerful storms can flood or significantly erode the coast but not drop enough water to cause significant riverine flooding.

Coastal flooding often occurs at the same time that riverine flooding occurs because both are associated with major storms, but this is not always the case.

The boundaries of the watershed at the coast extend from the upper end of the City of Ventura's Seaside Wilderness Park adjacent to Emma Wood State Beach to just west of the tall Crowne Plaza Hotel at California Street. Coastal development in this area consists primarily of the 62-acre Ventura County Fairgrounds, several apartment complexes, and the Ventura Promenade.

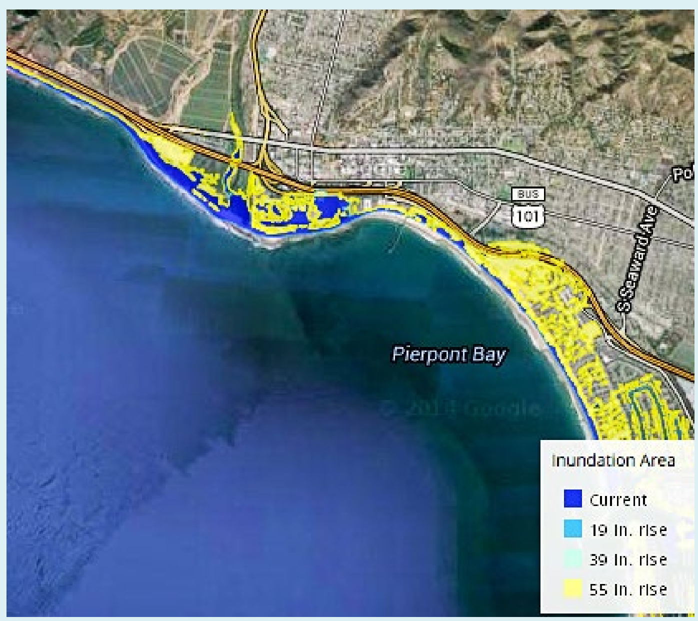
Relative to other parts of the coastline, this area is sheltered from ocean storm swells by both Point Conception and the Channel Islands (BEACON 2009). Nonetheless, Emma Wood State Beach and the Ventura Promenade in front of the Ventura County Fairgrounds—both located on the river's delta—have experienced repeated coastal flooding and erosion damage over the years. Emma Wood State Beach is eroding at a rate of about 0.6 feet annually, and past storms have caused extensive damage and led to its temporary closure (VCPD 2011a).

A reduction in the natural flow of sediment and sand to the beach is one of the reasons the ocean has been able to cause so much erosion here. The natural supply of sediment to the beaches in this region of the coast is principally from the steep gradient mountain creeks of the Santa Ynez and Topatopa Mountains. Over half of this natural sand and gravel supply is now blocked from reaching the beach, largely by Matilija Dam, but also by other dams, diversions, and debris basins (Beller et al. 2011).

Erosion of the coastal bluffs northwest of the Ventura River delta has historically contributed sediment to local beaches, but this natural process has also been modified. The Rincon Parkway, the 17-mile stretch of coastline above the mouth of the Ventura River, is almost entirely protected with either seawalls or revetments installed to protect the railroad, freeway, and development from erosion and the impact of waves (BEACON 2009).

Sea Level Rise

California's Cal-Adapt website states that "Global models indicate that California may see up to a 55 inch (140 cm) rise in sea level within this century given expected rise in temperatures around the world." The map below from the website shows the latest projections for sea level rise at the watershed's coastline. These data were developed by scientists from the USGS and Pacific Institute (Cal-Adapt 2014).



Projected Sea Level Rise Map
Source: Cal-Adapt 2014

The City of Ventura is a beach town; its inviting and accessible beaches are a central part of its cultural identity, and the health and maintenance of these beaches and coastal habitats are strongly supported by watershed stakeholders. A well-used promenade and bike path runs along the coast, east of the river mouth in front of the fairgrounds, and connects to paths up and down the coast, as well as up the river. This area of the coast is a highly regarded surfing spot, a point break known as "Surfers' Point." Erosion of the beach in this area is a significant issue of concern in the watershed. The bike path and parking area eroded more than 60 feet back in some places since originally installed. See "3.2.3 Geomorphology and Sediment Transport" for a discussion on the innovative "managed retreat" project being implemented in this location to address the loss of beach sand.

Surfers' Point in Front of Ventura County Fairgrounds, 1995

Photo courtesy of Paul Jenkin

Surfers' Point Wave Run-Up, 1995

Photo courtesy of Paul Jenkin

FINAL DRAFT

Urban Drainage Floods

Storm drain infrastructure can be overwhelmed by storm flows and cause urban flooding.

Storm drain infrastructure (systems of ditches, culverts, pipes, and lined channels designed to quickly move storm flows out of urban areas) can be overwhelmed by storm flows and cause urban flooding. These systems may be undersized or poorly designed, become damaged, or get clogged by debris, resulting in flooding in areas outside the expected flood zone. Urban drainage problems can also result in areas protected by levees because the natural flow towards the river is blocked by the levee itself. Urban drainage flooding is primarily nuisance flooding since significant flows are not usually involved. This type of flooding does not generally pose a serious threat to life and property.

Development in natural wetlands is another reason for urban drainage flooding in the watershed. Springs, vernal ponds, and other types of wetlands are commonly associated with geological faults. The highly folded and faulted Ventura River watershed, one of the most tectonically active uplifting regions of the world, comprises several fault-associated wetlands scattered throughout the area (Ferren 2004). Some areas in the watershed have a very high water table, which can also present urban drainage flooding problems.

Ojai Meadows Preserve Flood Management Wetland. The restoration of the Ojai Meadows Preserve in Meiners Oaks by the Ojai Valley Land Conservancy is addressing a historic urban drainage problem by re-establishing the natural wetland drainage in that area.

Photo courtesy of Rick Wilborn

Stormwater Infiltration Infrastructure

Impervious surfaces—rooftops, roadways, and parking lots—in urban areas exacerbate flood flows because water flowing over these surfaces cannot infiltrate or evapotranspire; it simply flows off—fast. The result is that both peak streamflow rates and runoff volumes can be increased by impervious surfaces. Groundwater recharge is also diminished. Impervious surfaces also accumulate pollution and sediment, which increases nutrients, bacteria, and other pollutant concentrations in local channels, rivers, and the ocean.

As a result of these impacts to water quality, state and local regulators have developed stormwater "best management practice" (BMP) programs and requirements to increase the retention and infiltration of stormwater onsite, so that the amount and quality of water leaving the site during storms more closely matches that of predevelopment conditions. These BMPs include bioswales, rain gardens, vegetated filter strips, small neighborhood retention basins, and other types of infiltration systems (and curb cuts that direct runoff into these infiltration systems), as well as pervious pavements, green roofs and other systems. The photos below illustrate some of these systems installed in the watershed.

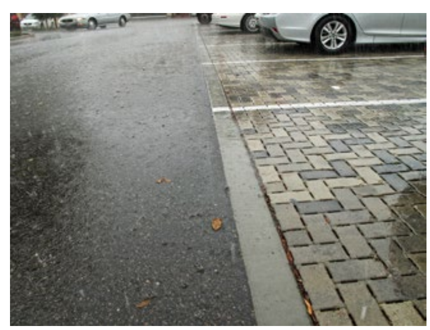
Bioswale, Oak Street Parking Lot, Ventura

Bioswale, Surfers' Point, Ventura

Bioswale, Hwy 33, Mira Monte

Bioswale, Downtown Ventura Parking Lot

Pervious Parking Lot, Ojai
Photo courtesy of Lisa Brenneis



Pervious Pavers, Oak Street Parking Lot, Ventura

Dam Failure Floods

Flooding as a result of dam failure is another type of flooding that could potentially occur in the watershed. Dam failure can result in severe flooding because the flows that would result would be much larger than the capacity of the downstream channels. Four dams are of sufficient size to be regulated for safety in the watershed: Casitas Dam, Matilija Dam, Senior Canyon Dam, and the dam associated with Stewart Canyon Debris Basin. Because of the size of Lake Casitas, the Casitas Dam poses the greatest flooding potential. Depending on whether a dam is federally or locally owned, dams are under the regulatory jurisdiction of either an agency of the Federal government, as is the case for Casitas Dam, or under the California Division of the Safety of Dams (DSOD), as is the case for Matilija Dam, Senior Canyon Dam, and Stewart Canyon Debris Basin (USACE 2004b). Table 3.3.2.3.1 summarizes the four dams in the watershed.

Table 3.3.2.3.1 Regulated Dams in the Ventura River Watershed

Dam	Owner	Regulatory Jurisdiction	Capacity (acre-feet)	Flood Route
Casitas Dam	U.S. Bureau of Reclamation	U.S. Bureau of Reclamation	254,000	Coyote Creek, Ventura River
Matilija Dam	Ventura County Watershed Protection District	California DSOD[1]	500	Matilija Creek, Ventura River
Senior Canyon Dam	Senior Canyon Mutual Water Company	California DSOD	78	Senior Canyon, San Antonio Creek
Stewart Canyon Debris Basin	Ventura County Watershed Protection District	California DSOD[1]	64.6	Stewart Canyon Creek Channel, Stewart Canyon Creek, San Antonio Creek

1: California Division of the Safety of Dams

Data Sources: URS 2005; Cardno-Entrix 2012; USACE 2004 and 2004b, Magney 2005

The Casitas Dam is located in an area of high seismicity, which presents a potential hazard to the dam's integrity, as described in the following excerpt:

> Casitas Dam is located in an area where the earth's crust is being compressed rapidly (on a geologic time scale). As a result, the area surrounding the dam contains numerous active faults, including the Red Mountain thrust fault less than 2 miles from the dam. A peer-reviewed study shows this fault to be capable of producing an earthquake of approximate magnitude $M_w 7$. The resulting accelerations could exceed 0.7 times the earth's gravity (0.7 g). A seismic hazard assessment was performed considering the Red Mountain Fault as well as other nearby faults. This evaluation

concluded that there is from 1 chance in 100 to 1 chance in 300 in any given year of accelerations exceeding 0.6 g. This probability is unusually high, even for California.

—*Design Summary, Casitas Dam Modification* (USBR 2001)

Much of the embankment of the dam bears upon stream-channel alluvial substrate (USBR 2001), a material that is susceptible to liquefaction during earthquakes (URS 2005a). Liquefaction occurs when ground shaking causes loose, saturated soil to lose cohesive strength and act as a viscous liquid for several moments (VCPD 2011a).

Modifications to Casitas Dam were designed to alleviate concerns about the potential liquefaction of the alluvium substrate under the dam in a severe earthquake. These upgrades to the facility, including stabilization of the downstream slope and modification of the crest to accommodate instability of the upstream slope, were implemented in 2001 (USBR 2007). At the crest, the earth filled Casitas Dam originally measured 40 feet from lakeside to the face of the dam. The foot of the dam was 1,750 feet thick. This seismic retrofit increased the thickness of the dam by 110 feet (CMWD 2013).

Casitas Dam

Photo courtesy of US Bureau of Reclamation

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Dam Failure Response

In Ventura County, disaster coordination and planning is the responsibility of the Sheriff's Office of Emergency Services (OES). The OES serves as the depository for Ventura County's Dam Inundation Maps and is charged with ongoing maintenance of the County's Dam Failure Response Plan (VCPD 2011a).

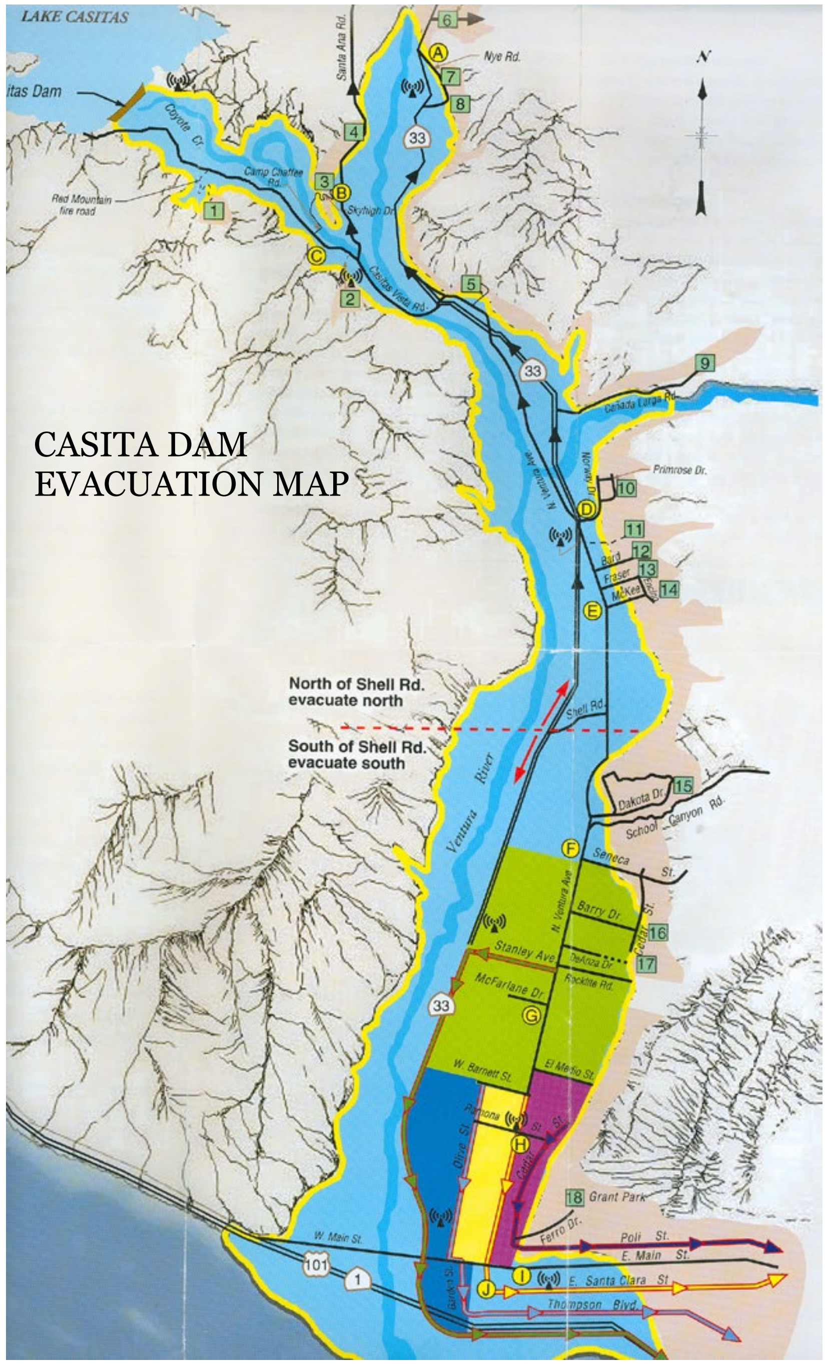


Figure 3.3.2.3.4 Casitas Dam Evacuation Map. For the complete map, with legend and instructions, go to http://readyventuracounty.org/pdf/CasitasDamEvacuationMap.pdf

Source: Casitas Dam Evacuation Route (VCOES 2013)

3.3.2.4 Flood Protection Infrastructure

The primary flood control infrastructure in the watershed consists of levees; debris basins; stormwater channels, pipes and culverts; and bank revetments such as riprap. Dams and reservoirs can also provide some potential flood control functions. Most of the flood management infrastructure in the watershed is designed, managed, and maintained by the Ventura County Watershed Protection District.

Most of the flood management infrastructure in the watershed is designed, managed, and maintained by the Ventura County Watershed Protection District.

Levees

There are three major levees along the Ventura River, all owned and operated by the Ventura County Watershed Protection District. Of the 16.23 miles of the mainstem of the Ventura River, 4.93 miles (30%) of the length of the river have a levee on one side.

Channel Meandering vs. Channel Hardening

Levees are embankments built to prevent the overflow of a body of water, such as a river. Levees are a conventional "bricks and mortar" approach to flood control. While such structures have become essential in some areas to protect urban developments, they are inconsistent with and counteract the natural tendency of rivers to erode and deposit sediments. Channel meandering is a natural process by which a river dissipates its energy during floods. Channel straightening and hardening of banks tend to increase the energy of the river during floods and potentially create accelerated erosion at other locations. Flood control agencies have come to understand this, and are now attempting to integrate more nonstructural approaches to flood management that combine natural and man-made alternatives.

Federal regulations administered by FEMA, the federal agency that offers flood insurance, require levee owners and operators to certify that their levees will continue to provide a barrier to the base flood (generally the 1% AEP flood) in order for FEMA to accredit such flood protection levels on Digital Flood Insurance Rate Maps (DFIRMs). In November of 2009, the Ventura County Watershed Protection District completed the mandated engineering evaluations for the levees in the watershed. The three levees in the watershed were found to have deficiencies such that they could not be certified as fully meeting federal standards by the November 2009 compliance deadline.

Consequentially, property owners behind the non-certified levees would be in a flood hazard zone, when new FEMA flood hazard maps are created. At that time, property owners with federally backed mortgages would be subject to mandatory federal flood insurance requirements. FEMA's DFIRMs do not get updated often, and a number of studies and

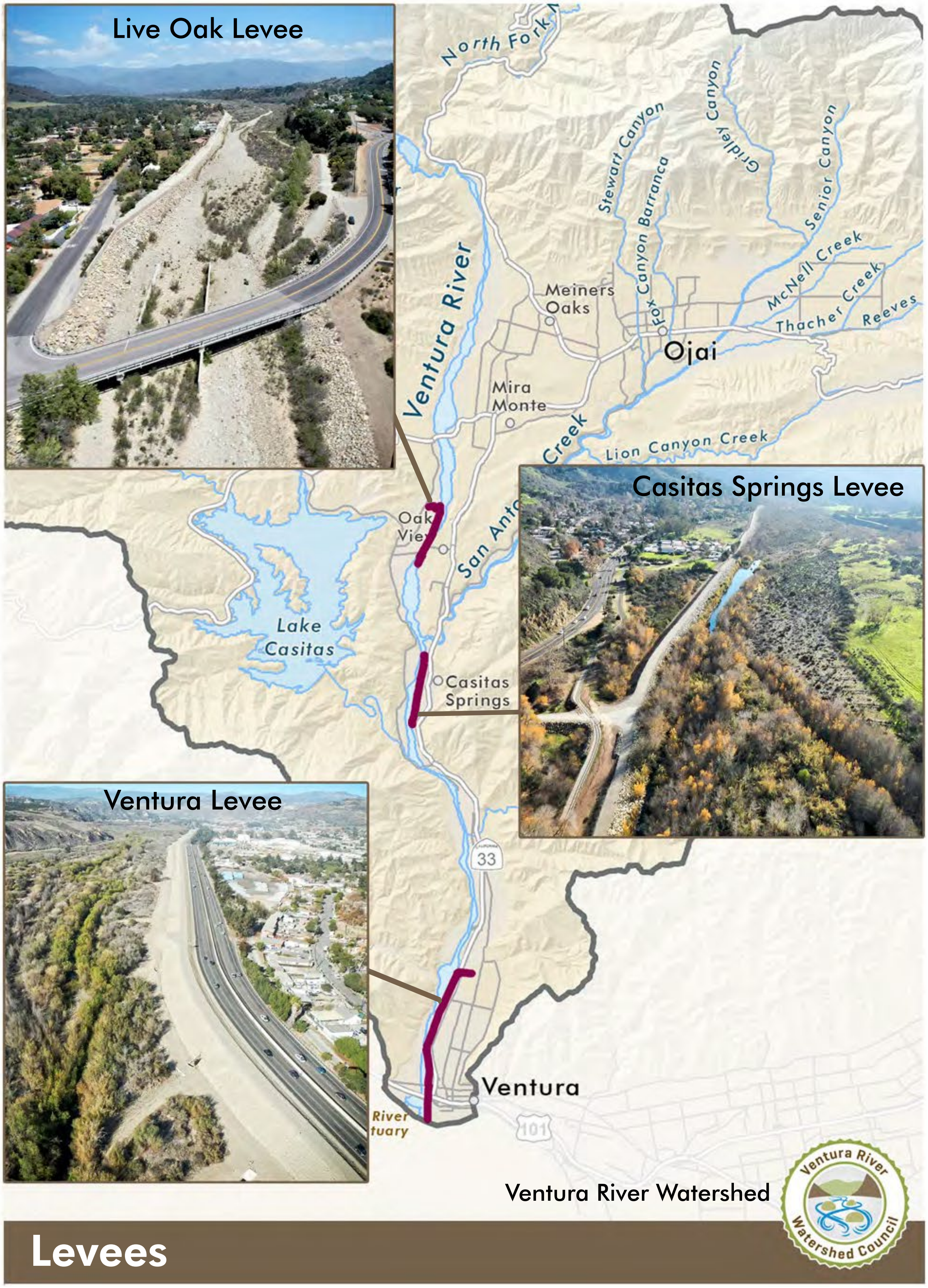


Figure 3.3.2.4.1 Levees in the Ventura River Watershed Map

Table 3.3.2.4.1 Levees in the Ventura River Watershed

Levee	Year Built	Location[1]	Length (miles)	Built to Protect
Ventura River Levee	1948	From Pacific Ocean to Canada de San Joaquin, City of Ventura	2.65	City of Ventura
Live Oak Levee	1978	From Santa Ana Blvd. Bridge to the Live Oak Diversion (near the junction of Riverside and Burnham Roads), Oak View	1.28	Live Oak Acres
Casitas Springs Levee	1979	From Santa Ana Blvd north to Riverside Rd., Casitas Springs	1	Casitas Springs

1: See Levees Map, Figure 3.3.2.4.1

Data Source: Cardno Entrix 2012; USACE 2004b

steps are required before they are updated for the Ventura River watershed. FEMA has not yet released an official date to issue new DFIRMs for the watershed. The projected earliest release date for new DFIRMs for the areas protected behind the three levees would be sometime during 2016 (VCWPD 2013d).

The Matilija Dam removal project, called the Matilija Dam Ecosystem Restoration Project, involves installing and upgrading a number of flood control structures in the river, including enhancing the Casitas Springs and Live Oak levees, as well as constructing a new levee at Meiners Oaks. Design work is already in process, and if sufficient construction funding can be secured for these levee rehabilitation projects, federal levee certification requirements should be met for these two levees.

For the Ventura River levee, the Ventura County Watershed Protection District is engaged in preliminary reconnaissance and feasibility work in support of levee retrofit and/or enhancement projects required to certify the levee, and is researching possible sources of funding.

Limited Flood Management Funding

It is the mission of the Ventura County Watershed Protection District to protect life, property, watercourses, watersheds, and public infrastructure from the dangers and damages associated with floods and stormwaters in Ventura County. The District has four service areas that roughly correspond to the major river systems in the County; the district's Zone 1 comprises the Ventura River watershed and adjacent coastal drainages.

Ongoing funding for the District's activities comes from property taxes, benefit assessments, and land development fees. In addition, supplemental funding from grants, cost-share programs, and other funding sources has become increasingly important to the District's ability to complete large, capital-intensive flood protection projects.

The relative amount of funding available for flood management in each of the District's zones differs because of how the District is funded. Benefit assessment monies collected from each zone are dedicated to support operations and maintenance and NPDES (National Pollutant Discharge Elimination System) permit activities within that zone. Property tax monies raised within a zone are spent on construction projects and to support District planning studies within that zone (VCWPD 2005).

Due to the limited development in the Ventura River watershed, revenues from property taxes, land development fees, and benefit assessment fees in Zone 1 are significantly lacking, and are much less than in zones comprising the County's other two major watersheds. Annual revenues available for flood management projects in Zone 1 have averaged less than $2 million a year.

Debris and Detention Basins

Typically placed at canyon mouths, debris basins capture the sediment, gravel, boulders, and vegetation that are washed out of canyons during storms.

Debris basins are a very important component of flood control systems in areas where streams carry high sediment loads. Typically placed at canyon mouths, debris basins capture the sediment, gravel, boulders, and vegetation that are washed out of canyons during storms. The basins capture the material and allow the water to flow into downstream drainage channels. Removing sediment and debris helps prevent blockage of channels and associated flooding. One of the drawbacks of debris basins is that by removing the sediment from the water, the flowing water becomes "hungry" for sediment and as a result increased erosion and scour downstream of debris basins has been observed (VCWPD 2013a).

There are four functioning debris basins that collect sediment from drainages before they enter the mainstem of the Ventura River: Dent, Live Oak, McDonald Canyon, and Stewart Canyon. All of these basins are owned and operated by the Ventura County Watershed Protection District.

An earth and rock debris basin was built on San Antonio Creek in 1986 as an emergency structure in response to the Wheeler Fire that had burned the watershed in 1985. It served its purpose, accumulating 26,600 cubic yards of debris during the first year of operation. The basin has been damaged and filled over the years and is no longer functioning as a debris basin (Hawks & Associates 2005).

Some basins have been designed specifically as "detention basins," which detain large volumes of water during the early phases or peak of a storm event, then slowly release the water over time. Detention basins reduce the peak downstream flows, which reduces flooding, but they also act to retain debris. Similarly, basins designed primarily as debris basins also help to attenuate peak flow, depending on their storage capacity.

Table 3.3.2.4.2 Debris Basins in the Ventura River Watershed

Basin	Year Built	Location[1]	Watershed Area (acres)	Maximum Debris Storage Capacity (cubic yards)	Expected Debris Production for 1% AEP[2] Flood (cubic yards)
Dent Debris Basin	1981	Ventura, behind De Anza Middle School	19	4,100	1,624
Live Oak Diversion Dam	2002	Oak View, west of Burnham Rd. between Santa Ana Rd. and Hwy 150	794	28,700	20,952
McDonald Canyon Detention Basin	1998	Meiners Oaks, east of Hwy 33/ Fairview Rd junction	573	23,400	20,179
Stewart Canyon Debris Basin	1963	Ojai, at north end of Canada St.	1,266	328,300	209,000

1: See Dams and Debris Basins Map, Figure 3.3.2.4.2

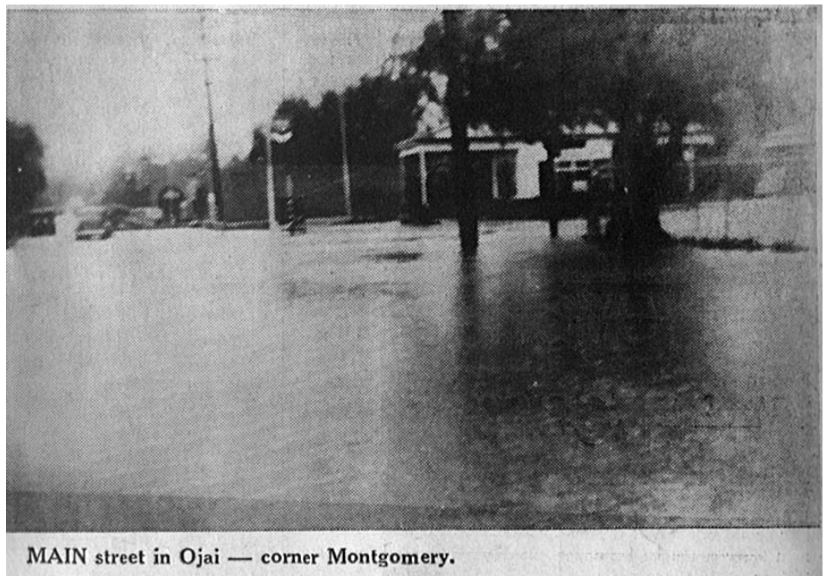
2: Annual Exceedance Probability

Data Sources: VCWPD 2005a; Cardno-Entrix 2012

Figure 3.3.2.4.2 Dams and Debris Basins Map

Stewart Canyon Debris Basin

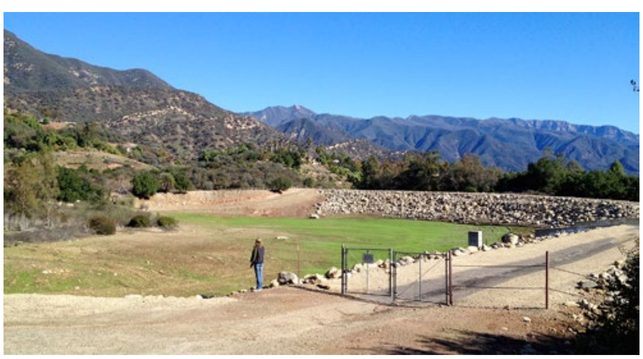
The Stewart Canyon Debris Basin is worth special mention. It is so massive that it stands out in aerial photos of the City of Ojai. The basin sits at the base of Stewart Canyon, one of the primary drainages off of Nordhoff Peak. Stewart Canyon naturally drains through the center of the City of Ojai, and in the flood of 1938 this became a big problem. A 1938 newspaper stated, "The Arcade was awash from a cascade down Montgomery Street and Signal Street. Lion and Aliso were also completely flooded as water raced down Stewart Canyon." (OVN 1969)



Downtown Ojai Before Stewart Canyon Debris Basin was Built, 1938 Flood

Photo courtesy of Ojai Valley News

This flood provided motivation for the construction of the Stewart Canyon Debris Basin, which is credited with saving the City of Ojai from major property damages and loss of lives. It is estimated that over 200,000 cubic yards of material were deposited in the basin during the storms in January and February of 1969 (City of Ojai 1991).



Stewart Canyon Debris Basin, Dry

Stewart Canyon Debris Basin Map. Stewart Canyon debris basin is the large brown area in the upper center of the image.

Map photo courtesy of Google Earth, 2013

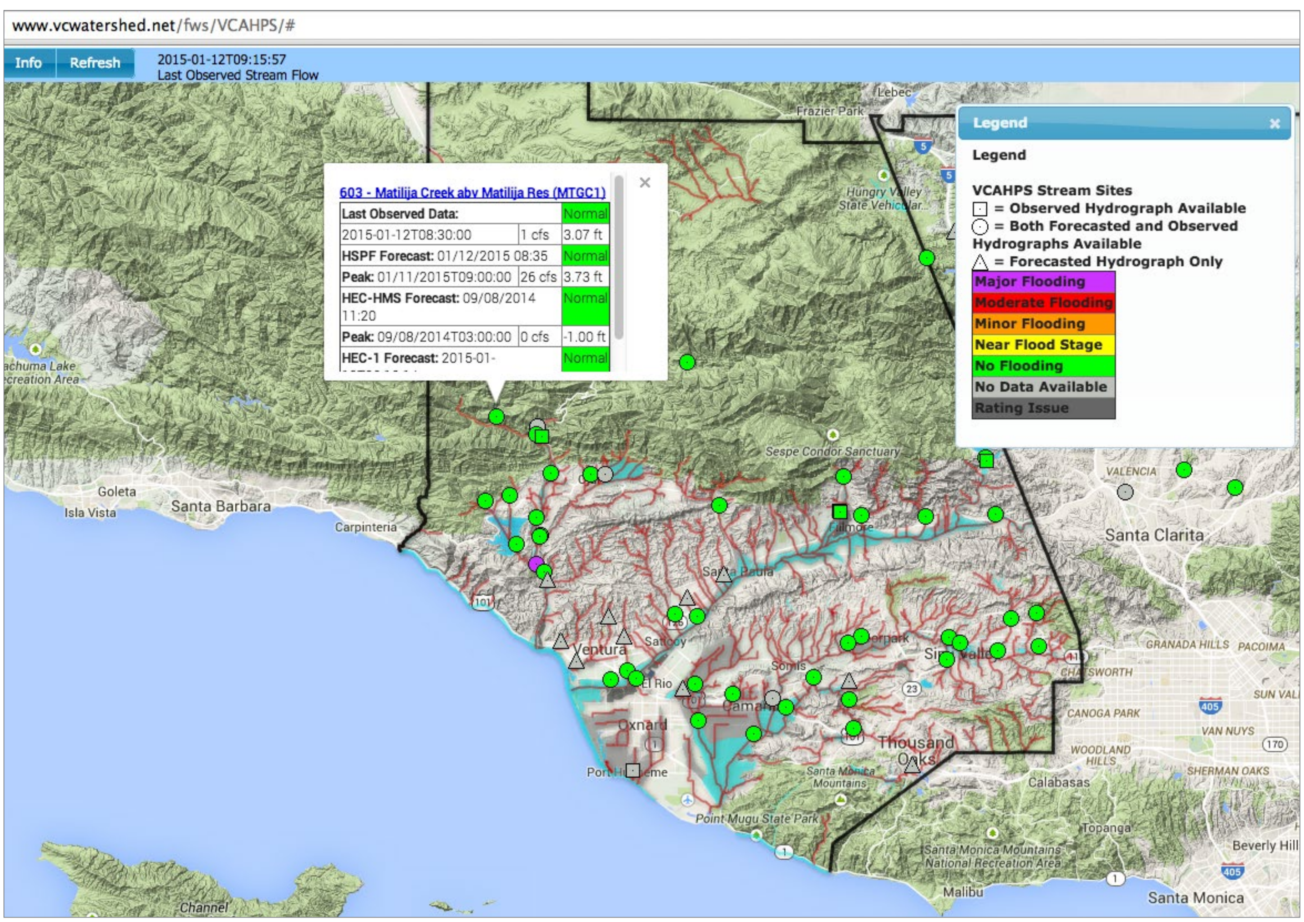
Dams and Reservoirs

The Matilija Reservoir no longer serves a significant flood control function because it is largely full of sediment. The capacity at Lake Casitas (if available) provides attenuation of flood flows downstream of the dam, as the stormwater from upper Coyote Creek and Santa Ana Creek flows into the lake. The exception to this is if the lake is full. Additionally, up to 500 cfs can be diverted from Ventura River to Lake Casitas; however, this diversion has little effect on large Ventura River peak flows (Entrix & URS 2004). See “3.3.1 Surface Water Hydrology” for more information on the watershed’s dams and reservoirs.

3.3.2.5 Flood Monitoring

The Ventura County Watershed Protection District maintains a Google Maps interface that provides current (almost real-time) streamflow observations. The monitoring location icons are color-coded to indicate the current flooding status. Clicking on a specific monitoring location icon opens a window with last observed flow data and forecast information. The monitoring location link within this window provides access to more detailed information on flood flow categories and potential flood impacts for that location. Website: www.vcwatershed.net/fws/VCAHPS/#.

Figure 3.3.2.5.1 VCWPD’s Advanced Hydrologic Prediction System Website. See “3.3.1 Surface Water Hydrology” for a summary of the other streamflow monitoring programs in the watershed.



3.3.2.6 Key Data and Information Sources/ Further Reading

"4.4 Appendices" contains additional information on flooding in the watershed, including the following documents:

Ventura River Mainstem Flood Risk Areas

1969 – Our Most Damaging Flood

Past Floods in Brief

Table of Storm Event Peak Flows, Foster Park (Station 608), 1933–2013

Below are some of key documents that address flooding in the watershed. See "4.3 References" for complete reference citations:

The Ventura County Watershed Protection District's websites (http://portal.countyofventura.org/portal/page/portal/PUBLIC_WORKS/Watershed_Protection_District and www.vcfloodinfo.com) have considerably more information on the topic of flooding.

Alluvial Fan Floodplain Mapping: East Ojai FLO-2D Floodplain Study (VCWPD 2009)

Coastal Regional Sediment Management Plan (BEACON 2009)

Design Summary, Casitas Dam Modification (USBR 2001)

Draft Environmental Impact Statement/Environmental Impact Report for the Matilija Dam Ecosystem Restoration Project (USACE 2004)

Final Environmental Impact Statement/Environmental Impact Report for the Matilija Dam Ecosystem Restoration Project (USACE 2004a)

Flood Histories of the Counties in the Alluvial Fan Task Force Study Area (Earp 2007)

Flood Mitigation Plan for Ventura County, California (URS 2005)

Hydrologic Data Server, Foster Park Gauge. Includes info on flood flow categories, potential flood impacts by flow, and flooding hot spots. (VCWPD 2013b) www.vcwatershed.net/fws/VCAHPS/php/ahps.php?gage=608

Hydrologic Data Server, San Antonio Creek Gauge. Includes info on flood flow categories and potential flood impacts by flow (VCWPD 2013c) www.vcwatershed.net/fws/VCAHPS/php/ahps.php?gage=608

Hydrology, Hydraulics and Sediment Studies of Alternatives for the Matilija Dam Ecosystem Restoration Project (USBR 2007)

Levee Certification Public Safety Project website. www.vcwatershed.com/levee/ (VCWPD 2013d)

Acronyms

AEP—Annual Exceedance Probability (flood)

BMP—best management practice

cfs—cubic feet per second

DFIRM—Digital Flood Insurance Rate Map

DSOD—California Division of the Safety of Dams

FEMA—Federal Emergency Management Agency

OES—Office of Emergency Services

NPDES—National Pollutant Discharge Elimination System

Matilija Dam Ecosystem Restoration Feasibility Study Final Report (USACE 2004b)

San Antonio Creek Debris Basin Feasibility and Upper San Antonio Creek Deficiency Study (Hawks & Associates 2005)

Tsunamis website of the California Geological Survey: www.consrv.ca.gov/cgs/geologic_hazards/tsunami/pages/about_tsunamis.aspx (CGS 2013)

Ventura County General Plan, Hazards Appendix (VCPD 2011a)

Ventura County Open Pacific Coast Study (FEMA 2011)

Ventura River Watershed Protection Plan Report (Cardno-Entrix 2012)

Ventura River Watershed Design Storm Modeling Final Report (VCWPD 2010)

3.3.3 Groundwater Hydrology

This section summarizes the physical location, capacity, and dynamics of the Ventura River watershed's major groundwater systems. These groundwater systems form essential water storage and transport functions in the watershed. For the water quality aspects of groundwater in the watershed, see "3.5.2 Groundwater Quality," and for the water supply aspects of groundwater in the watershed, see "3.4 Water Supplies and Demands."

Water that falls on the earth is disposed of in three ways. It evaporates into the air, it sinks into the ground, or it runs off the surface of the earth…Water on the land surface is visible in lakes, ponds, rivers, and creeks or surface water. What is not seen is the important water that is out of sight—called groundwater. It is convenient to refer to surface and groundwater separately in describing the location of the water, even though they are not different kinds of water. Both come from precipitation.

—*Luna B. Leopold,* Water, Rivers and Creeks

The watershed's groundwater basins generally lie within geologic depressions that have filled with alluvium, layered sediments primarily deposited by streams over long periods of time. The deposited material includes coarse deposits, such as sand and gravel that form the aquifers where water is stored and can flow, and finer-grained deposits, such as clay and silt that form the aquacludes, barriers to groundwater movement.

The boundaries of the groundwater basins are essentially defined by the alluvium that fills the basins and overlies low-permeability rock or, in a few cases, large geologic fault blocks (VCFCD 1971). When groundwater basins are full, the water table often occurs at relatively shallow depths—sometimes at, or just a few feet below ground surface—with depths varying depending on location.

There are four groundwater basins of significance in the Ventura River watershed: Ojai Valley Basin, Upper Ventura River Basin, Lower Ventura River Basin, and Upper Ojai Basin.

There are four groundwater basins of significance in the Ventura River watershed: Ojai Valley Basin, Upper Ventura River Basin, Lower Ventura River Basin, and Upper Ojai Basin. Some sources consider the Upper and Lower Ventura River Basins to be sub-basins of one large Ventura River Basin. A fifth small basin, the San Antonio Creek Basin, was identified as a separate basin in the extensive 1971 study prepared by the Ventura County Flood Control District (now Watershed Protection District) (Entrix 2001), but this small, shallow basin is now considered part of the Upper Ventura River Basin by the State of California (CDWR 2003) and the Ventura County Watershed Protection District.

Groundwater: Water in the Saturated Zone

The pores, fractures, and other voids that are present in the sediments and rocks that lie close to the earth's surface are partially to completely filled with water. In most locations, an unsaturated zone in which both water and air fill the voids exists immediately beneath the land surface. At greater depths, the voids become fully saturated with water. The top of the saturated zone is referred to as the water table, and the water within the saturated zone is groundwater.

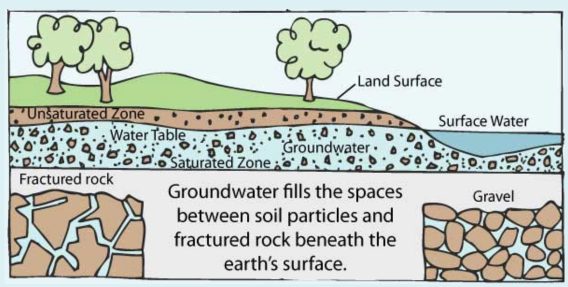
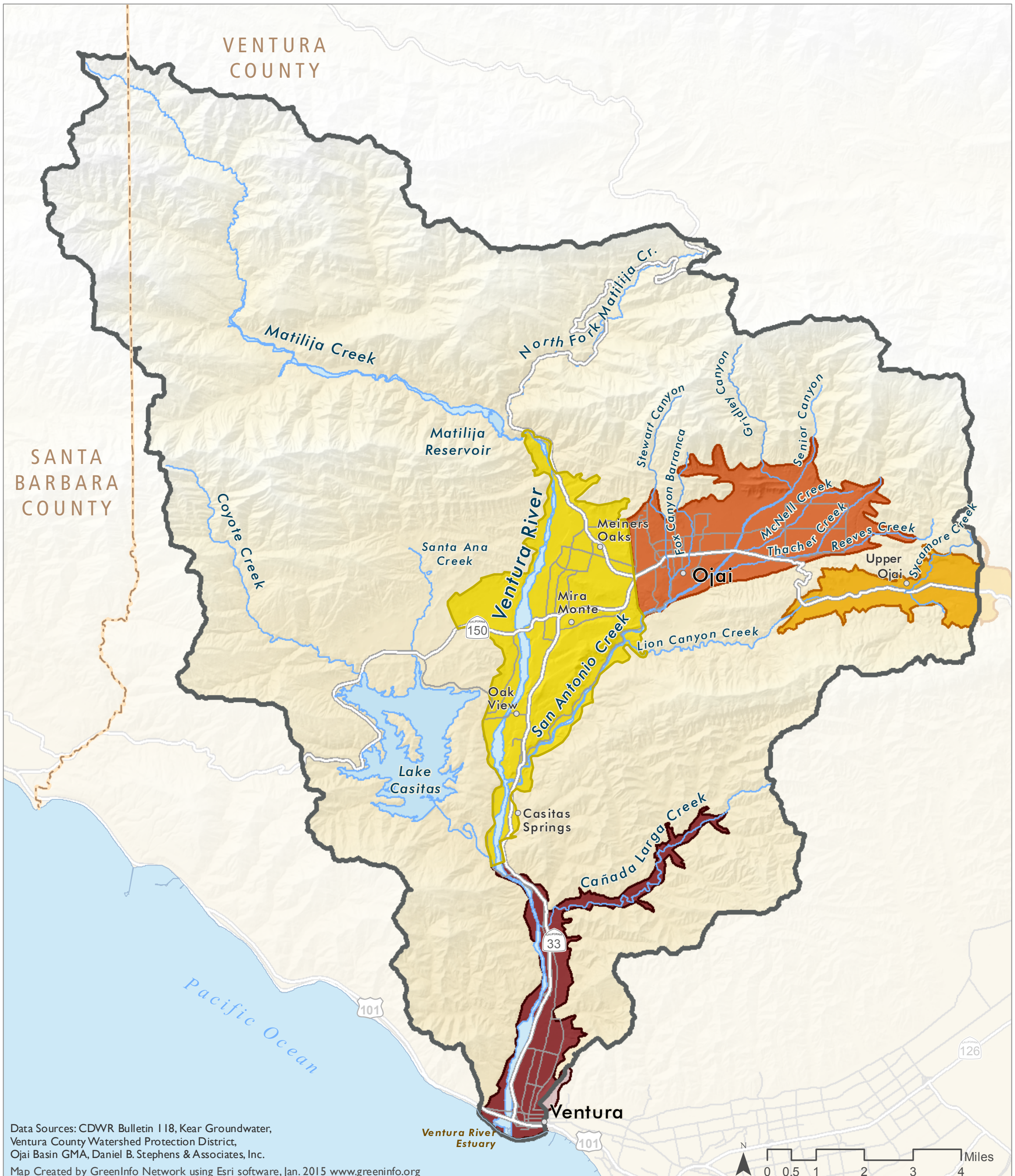


Figure 3.3.3.1 Groundwater Illustrated
Image courtesy of The Groundwater Foundation

Although voids beneath the water table are filled with water, the ability of subsurface materials to store and transmit water varies substantially. The term aquifer refers to subsurface deposits and geologic formations that are capable of yielding usable quantities of water to a well or spring, whereas a confining layer (or confining bed) refers to a low-permeability deposit or geologic formation that restricts the movement of groundwater. An aquifer can refer to a single geologic layer (or unit), a complete geologic formation, or groups of geologic formations.

—*Streamflow Depletion by Wells: Understanding and Managing the Effects of Groundwater Pumping on Streamflow* (Barlow & Leake 2012)



Groundwater Basins

Ventura River Watershed

Groundwater Basin	Acres	Sq. Mi.	Shallow Depth to Water (ft.)	Max. Capacity	Avg. Well Yield	Active Wells	Approx. Safe Yield
Upper Ojai	2,840	4.4	0-40	5,681 AF	50 gpm	95	Unavail.
Ojai Valley	6,471	10.1	0-80	85,000 AF	383 gpm	149	5,026 AF
Upper Ventura River	9,360	14.6	0-5	35,118 AF	600 gpm	160	9,482 AF
Lower Ventura River	6,090	9.5	3-13	8,743 AF [a]	20 gpm	16	2,130 AF [b]

a - Represents unconsolidated alluvium
b - Preliminary estimate, based on groundwater balance for water years 1997-2007

Source: Daniel B. Stephens & Associates, Inc. 2010 & 2013

Figure 3.3.3.2 Groundwater Basins Map

Data sources: See Table 3.4.2.1.3 Groundwater Basins Map Data Sources in "3.4.2 Water Supplies" for an explanation of the various data in the table.

The Ojai Valley Basin, which lies under the City of Ojai and the Ojai Valley's East End, has the largest capacity of the four groundwater basins. It is a relatively deep, bowl-shaped basin and is heavily relied upon for serving municipal and agricultural water users. It is the only basin in the watershed that has a formal management oversight entity—the Ojai Basin Groundwater Management Agency (OBGMA)—with specific authority to manage the supply and demand of the groundwater resource (Senate 1991).

The Upper Ventura River Basin supplies the greatest volume of groundwater in the watershed, even though its water holding capacity at any one time is not the largest.

The Upper Ventura River Basin, which lies under and adjacent to the Ventura River from the upper end at the Matilija Creek–North Fork Matilija Creek junction down to Foster Park, supplies the greatest volume of groundwater in the watershed, even though its water holding capacity at any one time is not the largest. This basin is tilted at a slight southward gradient, unconfined (see "Unconfined and Confined Aquifers" later in this section), and much shallower than the Ojai Valley Basin (SWRCB 1956; Entrix 2001).

The Lower Ventura River Basin is similar to the Upper Ventura Basin in that it primarily underlies the river. The basin begins at Foster Park and extends to the coast (deep layers of this basin extend offshore as submerged alluvial delta deposits). This basin has water quality limitations (VCFCD 1971) and is used minimally for industrial or agricultural needs.

The Upper Ojai Valley Basin is a fairly deep, bowl-shaped basin. It is an important source of water for residential users in Upper Ojai, as well as some agricultural users. Less hydrologic information is known about this basin than the others.

Each of these basins is described in more detail in "Groundwater Basins" later in this section.

3.3.3.1 Unconfined and Confined Aquifers

Aquifers can be confined, unconfined, or semi-confined. A confined aquifer lies between two confining layers, such as impermeable or low-permeable clay or rock. An unconfined aquifer has no upper confining layer—its upper boundary is the water table (i.e., the boundary between water-saturated ground and unsaturated ground) (Barlow & Leake 2012). Unconfined aquifers are sometimes called "leaky aquifers," aquifers that lose or gain water through adjacent less permeable layers (USGS 2014a). A semi-confined aquifer has some characteristics of both a confined and an unconfined aquifer.

Unconfined aquifers are typically located closer to the ground surface and are permeable, so they can be directly recharged by rain, irrigation water, septic tank effluent, or infiltration from lakes and streams. Confined aquifers tend to be located deeper beneath the ground surface; they can be recharged by rain or surface water infiltrating the ground at considerable distance away from the aquifer (Barlow & Leake 2012). Often aquifers are unconfined along their highest elevation reaches where they "crop out" (intersect with the ground), and may become confined at lower elevations (Schnaar 2013).

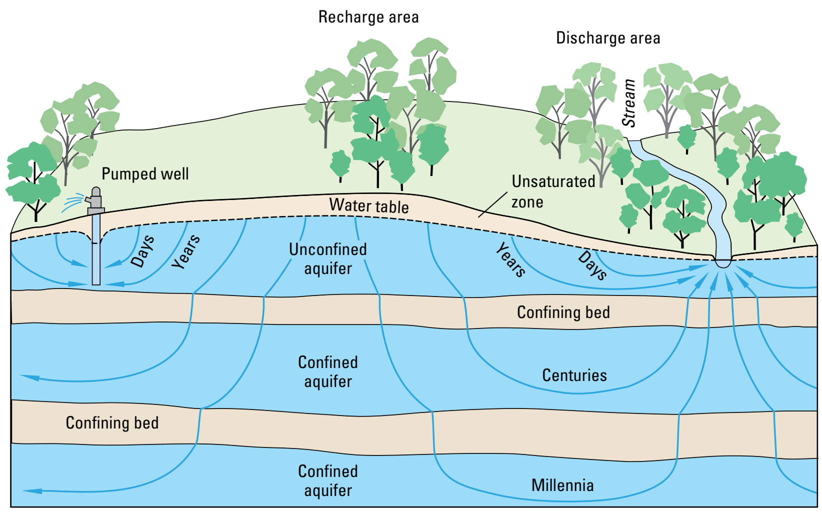


Figure 3.3.3.1.1 Unconfined and Confined Groundwater Aquifers. The image shows how groundwater systems can be composed of a vertical sequence of aquifers, with an upper, unconfined aquifer underlain by one or more confined aquifers. Groundwater systems can also be composed of a single, unconfined aquifer underlain by largely impermeable bedrock.

Image Source: Streamflow Depletion by Wells (Barlow & Leake 2012)

Unconfined aquifers are usually recharged by rain or irrigation water infiltrating directly through the overlying soil, and by infiltration from lakes and streams. The water table of unconfined aquifers is free to fluctuate up and down in response to recharge and discharge rates. Groundwater in these aquifers tends to be young (Barlow & Leake 2012), so surface conditions can directly affect water quality.

Except for the Ojai Valley Basin, current understanding is that the watershed's usable aquifers are unconfined. The Ojai Valley Basin has areas of confined, semi-confined, and unconfined groundwater (Kear 2005).

3.3.3.2 Recharge and Discharge

The concepts of groundwater recharge and discharge are introduced in this section. See also the surface water/groundwater interaction discussion in "3.3.1 Surface Water Hydrology."

Recharge

Groundwater recharge occurs when surface water percolates to groundwater and adds to the total volume in storage.

Surface water makes its way into groundwater basins by percolation of:

1) Streamflow in established drainages (such as the Ventura River, San Antonio Creek, and other streams). Stream reaches that lose water to the underlying aquifer are called "losing reaches."
2) Rain falling directly on wetlands and valley floors.
3) Reservoir leakage.
4) Irrigation water (in excess of plant use).
5) Septic system effluent seepage.
6) Enhanced recharge systems designed to increase the amount of water stored in aquifers.

In addition, water finds its way into groundwater basins by inflow from bedrock and neighboring groundwater basins (DBS&A 2010; CDWR 2003). Table 3.3.3.2.1 shows the relative amount of recharge from different sources in the Ojai Valley Basin.

Table 3.3.3.2.1 Ojai Valley Basin Groundwater Model - Annual Inflows and Outflows by Source

	Entire Calibration Period (1970–2013)		End of Calibration Period (2009–2013)	
Source	**AF[1]/Year**	**%**	**AF/Year**	**%**
Groundwater Inflows				
Precipitation Recharge (Basin Floor)	4,743	65%	2,639	64%
Precipitation Recharge (Upgradient Alluvial Channels)	2,032	28%	1,114	27%
Irrigation Recharge	364	5%	341	8%
Recharge from Septic Systems, Wastewater, & Former San Antonio Creek Spreading Grounds	173	2%	13	0%
Total Inflows:	7,312	—	4,107	—
Groundwater Outflows				
Pumping from Private Wells	2,606	35%	3,457	52%
Pumping for Ojai City Use (Golden State Water Co.)	1,673	23%	1,710	26%
Discharge to San Antonio Creek	2,744	37%	1,157	17%
Riparian Evapotranspiration	265	4%	190	3%
Groundwater Flow Exiting Basin	135	2%	124	2%
Total Outflows:	7,423	—	6,638	—
Net Change in Storage	**–111**	**—**	**–2532**	**—**

1: AF – acre-feet

Data Source: Update to the 2010 Ojai Basin Groundwater Model (DBS&A 2014)

Enhanced Recharge

Enhanced, or artificial, recharge refers to systems specifically designed to introduce and store water in aquifers. Enhanced recharge is used to stabilize or raise groundwater levels, smooth out supply/demand fluctuations, reduce losses from evaporation and runoff, and store water in aquifers for future use. Common methods include surface infiltration, percolation of recharge water at some depth below the ground surface, and direct injection of recharge water into the aquifer (Reddy 2008). The San Antonio Creek Spreading Grounds (see "3.4.2 Water Supplies") on Ojai's East End is an example of enhanced recharge using passive percolation recharge wells.

Recharge from Irrigation

Irrigation—primarily for crops, but also for watering large residential landscapes, golf courses, schools, and parks—comprises a significant use of water in the watershed. Agriculture alone comprises about 40% of water demand (see "3.4.3 Water Demands"). Irrigation water applied in excess of plant needs is recharged to groundwater. A 2010 study estimated that crop and landscape irrigation water contributes an average of 2,891 acre-feet (AF) per year to the Upper Ventura River Basin and 655 AF per year to the Lower Ventura River Basin (DBS&A 2010). A 2014 study estimated that crop and landscape irrigation water contributes 364 AF per year (5% of total recharge) to the Ojai Valley Basin (see Table 3.3.3.2.1) (DBS&A 2014).

The source of irrigation water is both groundwater and Lake Casitas water. During extended dry periods when groundwater is less available, much more Casitas water is used for irrigation. The water from Lake Casitas then becomes an input into the system, indirectly recharging groundwater basins.

Recharge from Septic Systems

Large areas of the watershed rely on septic systems for wastewater treatment; one of the largest populated areas is Ojai's East End (see Figure 3.5.3.1.1 Sewer Lines and Septic Systems Map in "3.5.3 Wastewater Quality"). This area sits over the Ojai Valley Basin. Some of the consumed water from households using septic systems is eventually recharged to groundwater. Like irrigation water, water used by households with septic systems can come from groundwater or Lake Casitas water.

Since the watershed's unconfined aquifers are permeable and open to infiltration from the surface, they can recharge quite rapidly during wet periods.

Since unconfined aquifers are permeable and open to infiltration from the surface, they can recharge quite rapidly during wet periods. This is especially the case in the Ventura River watershed, where groundwater basins are for the most part surrounded by mountains of impermeable bedrock that essentially funnel water into the alluvial basins. The sediments in the watershed's stream channels tend to be loose and unconsolidated deposits of gravel and sand—very permeable materials that water readily infiltrates. Underlying faults and folds are also found in these streambeds and may facilitate downward flow into aquifers. By inhibiting subsurface underground flows, these faults and folds can also delay or retain available water, enhance percolation time, and cause springs (Entrix 2001).

The following study excerpt describes the importance of the inflow of San Antonio Creek to the recharge of the Upper Ventura River Basin where the City of Ventura has their well field, and how quickly the basin can recharge:

> We conclude that the inflow from San Antonio Creek is a direct and significant influence on flow in this reach of the River system during the low-flow conditions observed by the study. We also conclude that high streambed infiltration rates and high

> aquifer hydraulic conductivity values result in a very rapid rate of groundwater recharge. These conditions result in a quick groundwater level response to changes in City production. Based on data provided from the controlled shutdown period when the wells were turned off, we conclude that when the surface flow entering the Foster Park reach from the live reach of the River is 5 cfs or greater, the alluvial aquifer affected by City wellfield diversions is completely refilled within a week (or sooner) after cessation of City pumping.
>
> —*Preliminary Hydrogeological Study, Surface Water/Groundwater Interaction Study, Foster Park* (Hopkins 2013)

An example of rapid groundwater recharge occurred in 1952, when the heavy winter rainfall was sufficient to return the groundwater in the Ojai Valley Basin to near maximum levels, even though the basin was at historic low levels following five years of deficient rainfall (Kear 2005). More recently, the groundwater level in one of Ventura River Water District's (non-pumping) wells in the Ventura River floodplain (located just above the Highway 150 Bridge) was raised 15 feet within 20 days and 22 feet within 40 days following a four-day, 7.3-inch storm in the spring of 2014 (Rapp 2014).

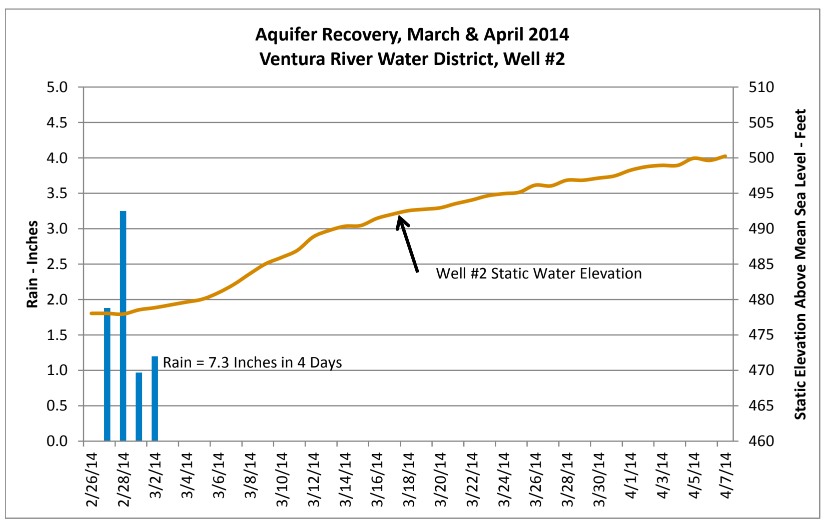


Figure 3.3.3.2.1 Aquifer Recovery, March–April 2014, Ventura River Water District Well #2. Following a four-day, 7.3-inch storm in the spring of 2014, the groundwater levels in one of Ventura River Water District's (static/non-pumping) wells in the Ventura River floodplain (located just above the Highway 150 Bridge) was raised 15 feet within 20 days and 22 feet within 40 days.

Source: Ventura River Water District

Discharge

Discharge of water from groundwater basins in the watershed occurs via groundwater pumping for municipal, industrial, domestic, and agricultural purposes; consumption by riparian and other natural vegetation; outflow to the ocean or neighboring groundwater basins; and discharge into open channels or drainages (DBS&A 2010). During wet periods, artesian conditions or springs can occur when the elevation to which groundwater will naturally rise exceeds the ground surface elevation.

For much of the year—and almost all of the dry-season—nearly all of the water in the Ventura River and its tributaries is from groundwater and springs (excluding the lower stretch of the river that is partially fed by treated wastewater).

This is not uncommon in the southwestern part of Ojai Valley Basin (Kear 2005; DBS&A 2011).

Groundwater rising above the level of a stream bottom results in what is called a "gaining stream," where groundwater seeps out of the surface and flows downstream. For much of the year—and almost all of the dry-season—nearly *all* of the water in the Ventura River and its tributaries is from groundwater and springs (excluding the lower stretch of the river that is partially fed by treated wastewater).

> It is not unusual for streams in Southern California that are rain fed and lack groundwater support to dry up in summer months, in both average and below average precipitation years. In the Ventura River watershed, however, several of the small tributaries and even the mainstem have short perennial reaches that are fed by springs and/or the perched groundwater over shallow bedrock.
>
> —*Surface Water–Groundwater Interaction Report for the Ventura River Habitat Conservation Plan* (Entrix 2001)

Only during storms, and for a relatively short period of time afterwards, do surface runoff and flows from soil water (water diffused in the soil) add to the base flow.

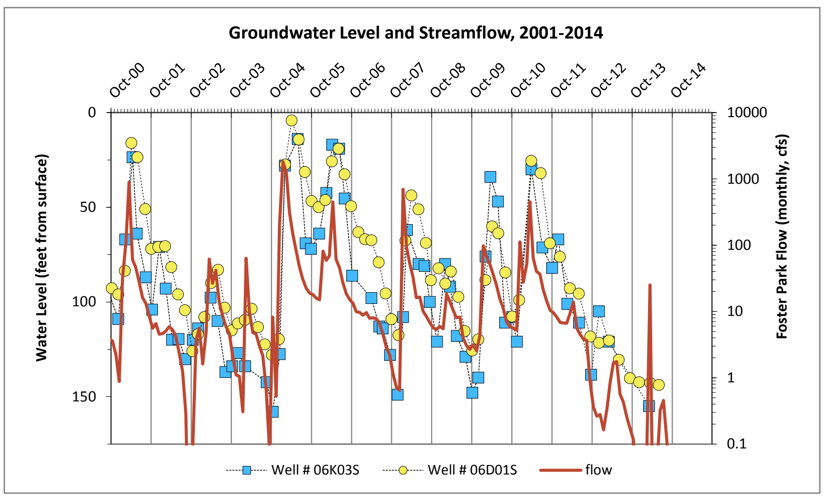


Figure 3.3.3.2.2 Groundwater Level and Streamflow, Water Years 2001–2014. The graph shows the depth-to-water measurements for two wells (indicated by green circles and blue squares) in the upper San Antonio Creek subwatershed—one to the east and the other to the west of San Antonio Creek about two miles above the San Antonio/Stewart Canyon Creek confluence. Also shown are average monthly Ventura River flows measured at Foster Park (monthly flows were used to remove the multiple spikes in the hydrograph caused by individual storms). The graph indicates that the elevation of the water table in the Ojai Valley Basin and flow of the Ventura River at Foster Park are extremely well correlated.

Data Source: Nitrate in the Ventura River Watershed (Leydecker 2013a)

The Upper Ventura River Basin, has been referred to by locals as a series of "tea cups" rather than a "basin," because of its relatively small capacity and the tendency for groundwater to collect more in some areas than others.

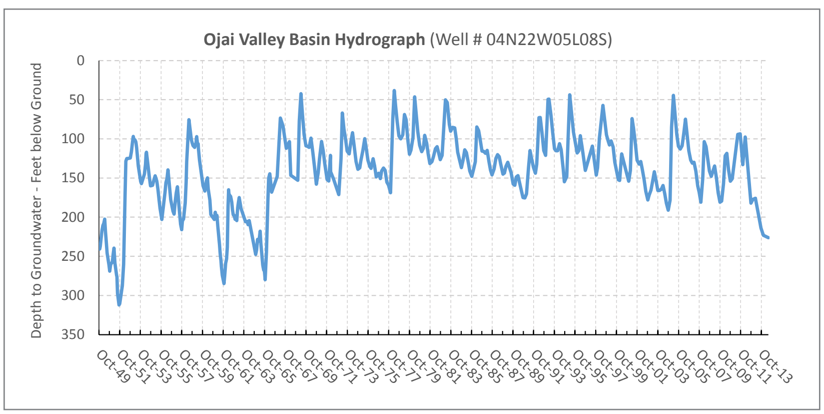
Because the watershed and its basins follow the topography and slope toward the coast (SWRCB 1956; Entrix 2001), some groundwater also drains downward into other basins or is lost to the ocean. The Upper Ventura River Basin drains into the Lower Ventura River Basin, and the Lower Ventura River Basin loses water to the ocean; the Ojai Valley Basin drains indirectly into the Upper Ventura River Basin by way of its discharge to San Antonio Creek. Coastal basins in the region are prone to seawater intrusion (CDWR 2003) because of the hydraulic connection between groundwater and seawater.

The basins along the Ventura River can be drawn down relatively quickly during dry periods by well extractions, evapotranspiration, and other discharge mechanisms. This may be especially true for the Upper Ventura River Basin, which has been referred to by locals as a series of "tea cups" rather than a "basin," because of its relatively small capacity and the tendency for groundwater to collect more in some areas than others.

Because of the relatively rapid discharge and recharge that occurs in the watershed's groundwater basins, groundwater levels and storage volumes can fluctuate dramatically from one year to the next. For example, in just seven months, between March 2012 and October 2012, water levels in the Ojai Valley Basin dropped 84 feet (VCWPD 2014). However, historical analysis (on the Ojai Valley Basin) and the experience of pumpers indicate that the long-term average amount of groundwater in storage has been fairly stable (DBS&A 2011; CDWR 2003).

Figure 3.3.3.2.3 Ojai Valley Basin Monitoring Well Hydrograph, 1949 to 2013

Source: Ventura County Watershed Protection District



Seasonal Groundwater Levels

The following excerpt describes typical variations in seasonal groundwater levels in the two most developed basins in the watershed:

> Groundwater levels in the Upper Ventura River Basin, the Ojai Basin, and the Lower San Antonio Creek Basin [now considered part of the Upper Ventura River Basin] fluctuate seasonally with the highest water levels occurring in the winter and early spring and the lowest levels occurring in the late summer and early fall.

> In general, groundwater levels in these basins recover rapidly following periods of precipitation and decline slowly under natural conditions, which is characteristic of unconfined groundwater basins. In the Upper Ventura River basin, groundwater levels in the vicinity of Meiners Oaks appear to fluctuate less than groundwater levels in the vicinity of Casitas Springs, which may be related to differences in groundwater extraction and/or potentially related to a threshold-response relationship for groundwater flow across the Santa Ana/Arroyo Parida fault.
>
> —*Surface Water-Groundwater Interaction Report for the Ventura River Habitat Conservation Plan* (Entrix 2001)

3.3.3.3 Groundwater Basins

Ojai Valley Basin

The Ojai Valley Basin is one of the most important basins in the watershed in terms of serving a large number of people and agricultural acres. It also contributes regular annual flow volumes to San Antonio Creek (DBS&A 2011), providing critical base flow and supporting its riparian habitat, which serves many important ecological functions, including supporting endangered steelhead.

The Ojai Valley Basin is one of the most important basins in the watershed in terms of serving a large number of people and agricultural acres.

Below is an excerpt from a 2011 report on the development of a groundwater model for this basin.

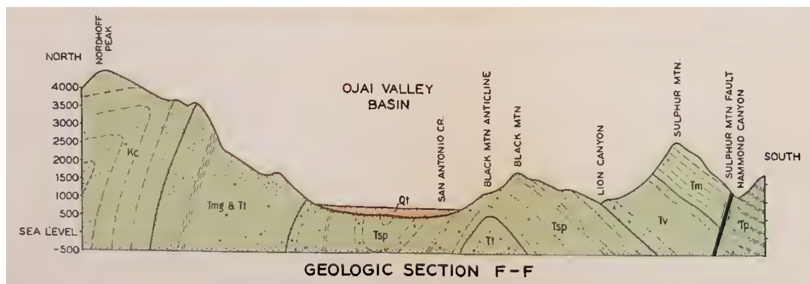
> In the lower elevations of the Basin, below the confluence of Thacher Creek and San Antonio Creek, it has generally been understood that gaining reaches are present in San Antonio Creek, with nearly perennial flow as the creek exits the Basin. This observation is supported by data collected from the nearest streamflow gage on San Antonio Creek, which is located 4 miles downstream of the Basin at the confluence of San Antonio Creek and the Ventura River. Flow was present in that location of San Antonio Creek 88 percent of the time during the model calibration period.
>
> The model-simulated results are consistent with these observations. Groundwater discharge rates to the streamflow channels (represented by Drain boundary conditions) vary based on model-wide recharge rates; however, discharge is maintained at minor levels during dry periods (Figure 19). Additionally, groundwater discharge zones simulated by the model are limited to the lower-elevation areas of the domain, consistent with the general understanding of the Basin hydrogeology.
>
> —*Groundwater Model Development – Ojai Basin* (DBS&A 2011)

The Ojai Valley Basin is bounded on the west and east by non-water-bearing Tertiary age rocks, on the south by the Santa Ana Fault and Black Mountain, and on the north by the Topatopa Mountains (CDWR 2003).

Major surface drainages that contribute influx or recharge to this basin include San Antonio Creek and the various tributary streams that drain the East End of the Ojai Valley and flow into San Antonio Creek. Steep slopes in these creeks—especially those flowing out of Senior Canyon, Horn Canyon/Thacher Creek, and Horn Canyon (VCWPD 2009)—are responsible for forming extensive alluvial fan deposits as the fast-moving, debris-laden water coming out of the mountains slows, spreads out, and deposits suspended sediment. These deposits of sand and gravel, thickest closest to the mountains in the northeastern portion of the basin, are largely responsible for filling the Ojai Valley Basin over time and forming the water-bearing aquifers of the basin (VCFCD 1971; Kear 2005).

1933 Ojai Valley Basin Geologic Cross Section

Source: Bulletin 46, Ventura County Investigation (CDWR 1933)



Unconfined conditions exist in the northern and eastern portions of the basin, in the areas of the alluvial fan heads. Groundwater in the rest of the aquifer system is, depending on the amount of water in storage and groundwater level position, mostly confined to semi-confined in the central, southern, and western portions of the basin (Kear 2005).

> With respect to aquifer confinement conditions, it appears that water levels are imperative to the status of confined versus unconfined conditions observed in the basin…
>
> —*Hydrogeology of the Ojai Groundwater Basin: Storativity and Confinement, Ventura County, CA* (Kear 2005)

Groundwater generally flows in a southwesterly direction; however, it also flows towards the municipal wells in the central portion of the basin (DBS&A 2011).

Bowl-like in shape, the basin is deepest in the center and southern areas where sediments have built up against the boundary defined by the Santa Ana Fault. The thickness of the water-bearing alluvium is as much as 715 feet (DBS&A 2011). The primary storage areas are approximately four sand and gravel units that are each on the order of up to 100 feet thick (Kear 2005).

Ojai Basin Groundwater Model

The Ojai Basin Groundwater Management Agency commissioned the development of an advanced, linked distributed-parameter groundwater model. Completed in 2011 and updated in 2014, the model provides a quantitative method for understanding the impacts of rainfall cycles and droughts on groundwater levels in the Ojai Valley Basin, including the basin's safe yield and associated impacts to flow in San Antonio Creek (DBS&A 2011).

Depth to water can be on the order of 300 feet in the eastern and northern alluvial fan-head portions of the basin (with seasonal variations between 50 and 90 feet). In the southern and western portions of the basin, depth to water is typically less than 50 feet (with seasonal variations on the order of 15 feet). The southwestern wells sometimes exhibit flowing artesian conditions when the basin reaches its storage limit during periods of high water levels (Kear 2005).

The maximum water-holding capacity of the basin is about 85,000 AF (CDWR 2003), the largest capacity of the watershed's four basins.

Upper Ventura River Basin

The Upper Ventura River Basin plays a major role in providing municipal and agricultural water. Of the four watershed basins, it has the largest surface area extent—9,360 acres. With less depth than the Ojai Valley Basin, the Upper Ventura River Basin has the second largest water storage capacity at 35,118 AF (CDWR 2003). This storage capacity is small relative to annual surface water runoff (Entrix 2001).

The basin is bounded on the south by the Lower Ventura River Basin, on the east by the Ojai Valley Basin, and on the north and west by impermeable rocks of the Santa Ynez Mountains. The boundary between the Ojai Valley Basin and the Upper Ventura River Basin is roughly Camp Comfort to the south and the Arbolada to the north (Entrix 2001). Shallow bedrock and near surface faults in some places cause water levels to remain or rise near the surface (Entrix & Woodward Clyde 1997). The east-west trending Santa Ana Fault crosses the basin just below the Highway 150 Bridge.

Major surface drainages that contribute water to this basin include San Antonio and Matilija creeks and the Ventura River (CDWR 2003). Another indirect contributor of surface water is Lake Casitas. Drainage around and under Lake Casitas flows towards the bottom of Upper Ventura River Basin. It is estimated that about 2,003 AF of water a year are contributed from the lake to recharge of this basin (DBS&A 2010).

The basin is unconfined, with generally thin water-bearing alluvial deposits. In some areas (e.g., near San Antonio and Coyote creeks), alluvium thickness is only 5 to 30 feet (CDWR 2003); below the point where the Santa Ana Fault crosses the Ventura River, alluvium attains a thickness of about 65 feet, whereas alluvium thickness is greater than 200 feet just north of the fault the (VCFCD 1971). This location is a good example of how faults can create enhanced groundwater deposits on the upstream side of a natural barrier to underflow.

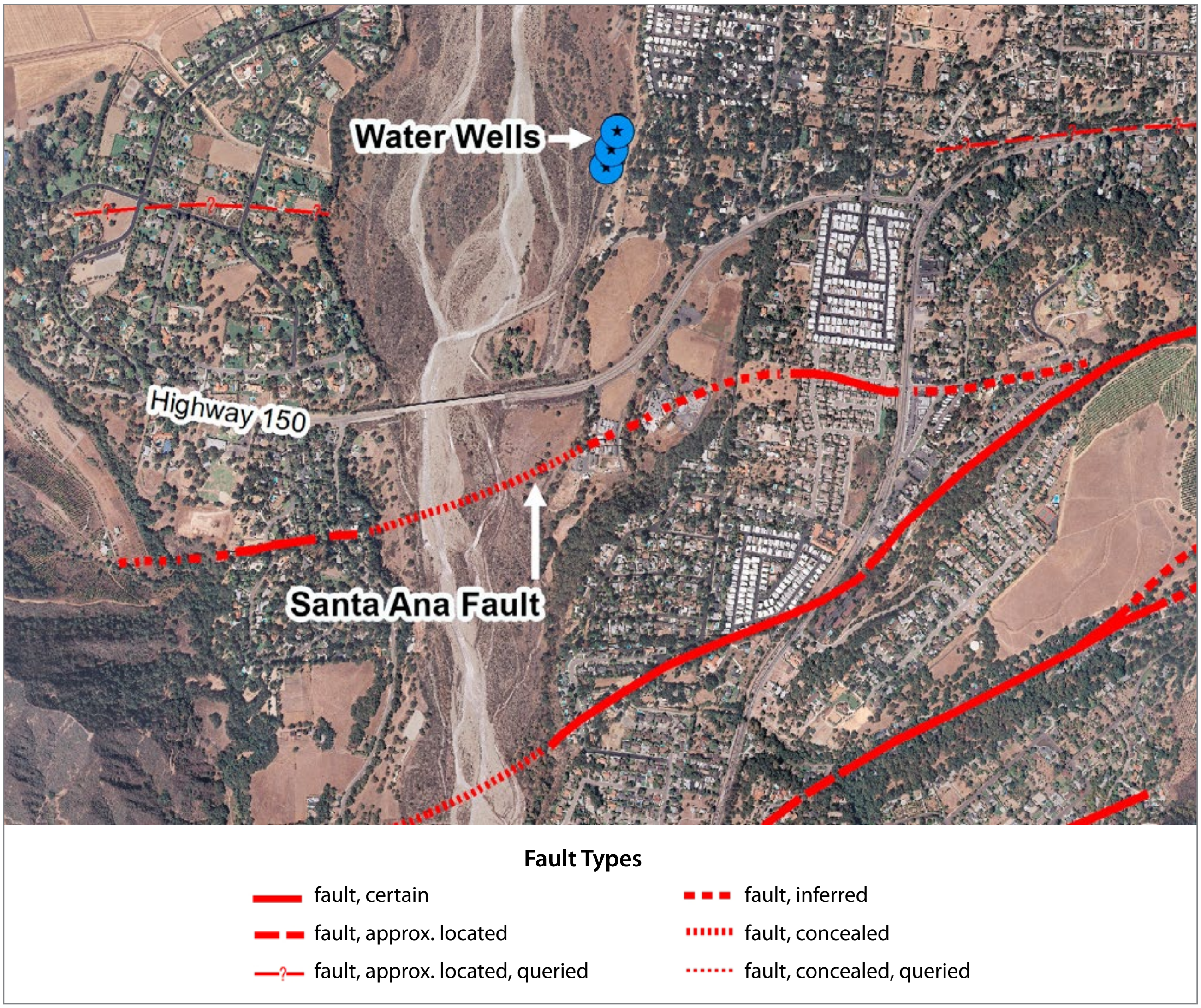


Figure 3.3.3.3.1 Map of Santa Ana Fault Crossing Ventura River

Fault Data Source: Gutierrez, C.I., Tan, S.S., and Clahan, K.B, 2008, Geologic map of the east half Santa Barbara 30' x 60' quadrangle, California: California Geological Survey, Preliminary Geologic Map, scale 1:100,000

The unconfined Upper Ventura River Basin has an open and direct relationship with the surface water of the Ventura River.

This unconfined groundwater basin has an open and direct relationship with the surface water of the Ventura River (EDAW 1978; VCFCD 1971; Entrix 2001; DBS&A 2006; Tetra Tech 2009a; Hopkins 2010; DBS&A 2010). Much of the river bottom overlying the Upper Ventura River Basin is known locally as "the dry reach," where, in low to moderate rainfall years, the surface water quickly disappears underground once storm flows have passed—even when the river is still flowing above and below this reach.

The boundaries of the dry reach depend on the magnitude of the previous rainy season and the state of groundwater storage, but they generally extend from somewhere below the Robles Diversion to just above the river's confluence with San Antonio Creek (just below Oak View). See "3.3.1 Surface Water Hydrology" for a more in-depth discussion on the dry reach.

Ventura River Dry Reach above Highway 150 Bridge
Photo courtesy of Rick Wilborn

Geographically, this dry reach is where boulders, cobbles, and sediments that have been eroded from the tallest mountains in the watershed are deposited as the gradient flattens and storm flows spread out. Water rapidly filters down through this coarse material to the groundwater basin below.

Groundwater flows through the alluvium from north to south, following the surface drainage and the slight but relatively consistent gradient of the basin (SWRCB 1956). Well logs and historic accounts of rising water above the Highway 150 bridge and above where the Santa Ana Fault crosses the river suggest that the fault slows the flow of underground water (VCFCD 1971); however, this phenomena remains to be studied. The Ventura River Water District's wells are located in this area to take advantage of this potential effect.

Groundwater is known to upwell via in-river springs in the area just above Foster Park. The community in this area is aptly named "Casitas Springs."

Upstream of the San Antonio Creek confluence, a groundwater constriction forces water in the Upper Ventura River Basin to the surface (USBR 2007).

Groundwater is known to upwell via in-river springs in the area just above Foster Park (EDAW 1978). The community in this area is aptly named "Casitas Springs." Farther downstream at Foster Park, groundwater becomes indistinguishable from surface water where the shallow, 33-foot-deep (DBS&A 2010), water-holding alluvium runs into a natural bedrock barrier that forces subsurface flow to the surface (USACE 2004). Faults often block groundwater flow and cause springs to emerge upstream. The bedrock in this area could be associated with the Red Mountain fault, which is inclined (dips) to the north, so at depth is closer to Foster Park (Keller 2014). This natural bedrock barrier was enhanced by the Ventura County Power Company in 1906 through the construction of a subsurface diversion structure to increase water retention in that area for extraction purposes (CDWR 2003).

City of Ventura's Subsurface Diversion Structure at Foster Park. The diversion dam slows the flow of subsurface water downstream. The City of Ventura extracts water at the structure and also has a number of wells just upstream.

The subsurface diversion structure at Foster Park marks the border between the Upper and Lower Ventura River Basins. A 1956 assessment of groundwater resources in Ventura County considered the Upper and Lower Ventura River Basins one groundwater basin until the subsurface diversion was installed:

> Under natural conditions, this basin was undifferentiated from the Upper Ventura River Basin, but it has been treated separately herein because of the impedance to ground water movement effected by the artificial subsurface barrier at Foster Park.
>
> —*Bulletin 12, Ventura County Investigation* (SWRCB 1956)

A 2010 groundwater budget study estimated that the groundwater flux into the Lower Ventura River Basin from the Upper Ventura River Basin is 535 AF per year (DBS&A 2010).

> The largely unconfined [Upper Ventura River] aquifer is aligned along a moderately sloping valley profile and has a persistent downvalley flow direction. However, the rate of downvalley flow is not uniform through the various river reaches and groundwater nodes. Differential depths to bedrock and bedrock controls on valley width along the river reaches create varied aquifer storage

and transmission rates that affect groundwater and surface water interactions. The Santa Ana fault configuration has a fundamental influence on downvalley movement of groundwater. North of the fault, on the down-dropped side, the thicker aquifer has a relatively large storage capacity while the south side of the fault has a much thinner alluvial veneer over bedrock. When groundwater levels on the upvalley (north) side of the fault fall below certain elevations, downvalley movement of groundwater can be reduced or eliminated. This situation is likely to have a fundamental effect on groundwater support to surface water flows downstream of the fault.

—*Surface Water-Groundwater Interaction Report* (Entrix 2001)

The Ventura River Water District, one of two water districts that have water wells in the river in the upper part of the Upper Ventura River Basin, has found that the section of the basin where it pumps tends to hold about an 18 month supply of water (estimated from pumping during an extended dry spell following a good rainfall winter). Conversely, the basin can go from empty to full with just three months of average winder (Rapp 2013).

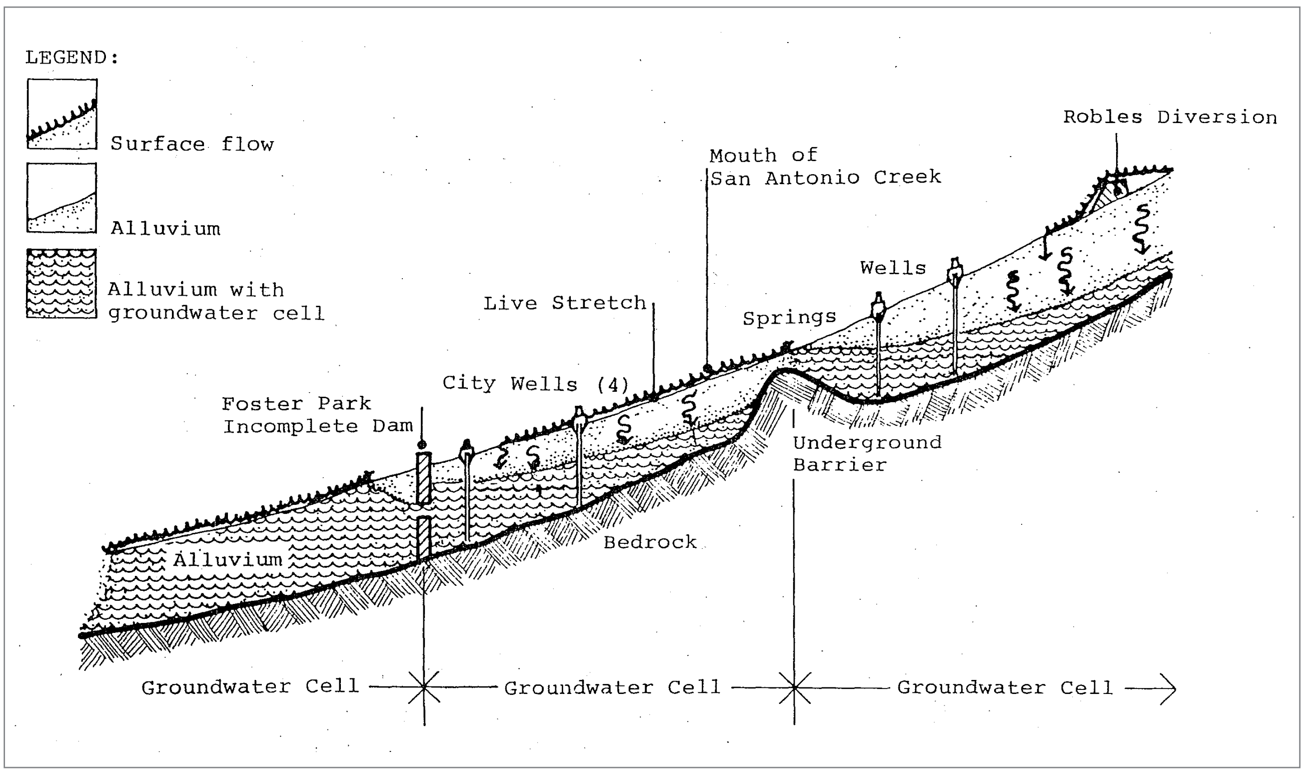
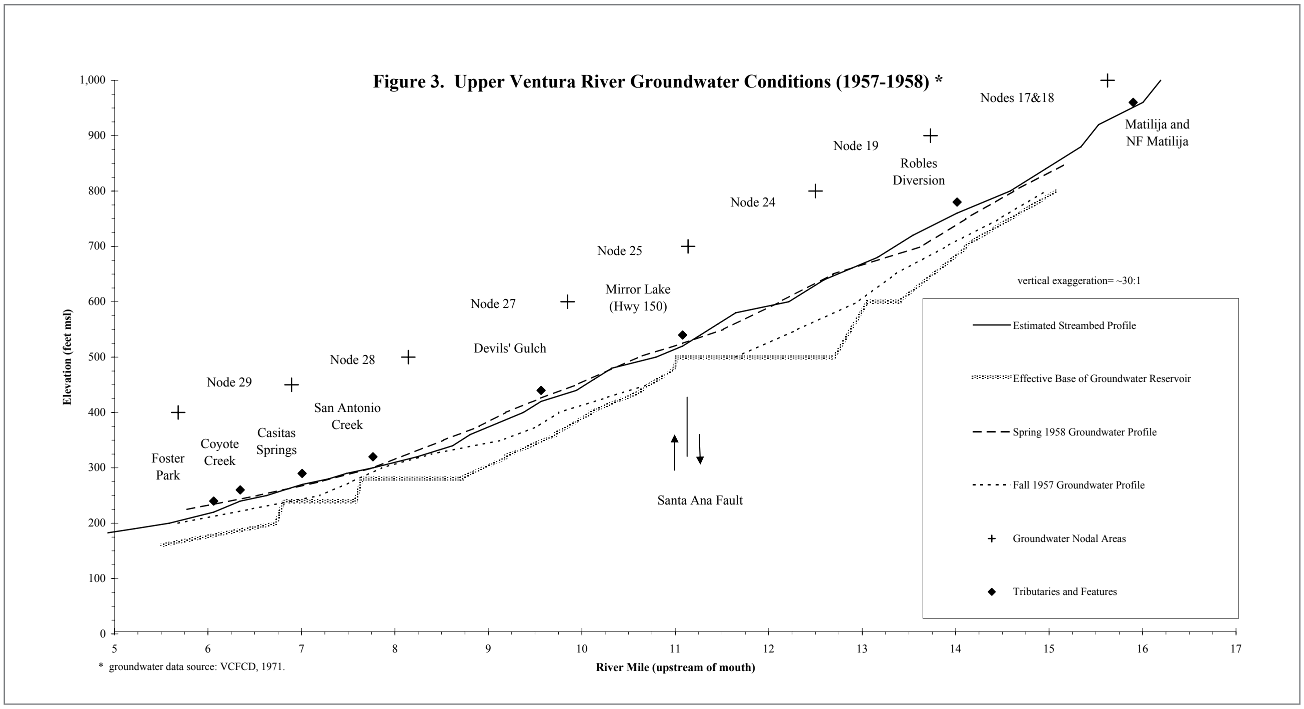


Figure 3.3.3.3.2 Ventura River, Robles Diversion to Foster Park, Summer Conditions. "There is usually no continuous surface flow in the Ventura River during the summer. However, two important local areas of surface flow do occur as a result of rising groundwater springs in the river. These are shown above as the 'live stretch' that occurs at and below the mouth of San Antonio Creek and the stretch below the Foster Park area. Flow in these stretches is stimulated by the presence of groundwater in the river alluvium, which depends on recharge from releases and spills at Robles Dam and flow from San Antonio Creek."

Note: Illustration not to scale. Source: EDAW 1978



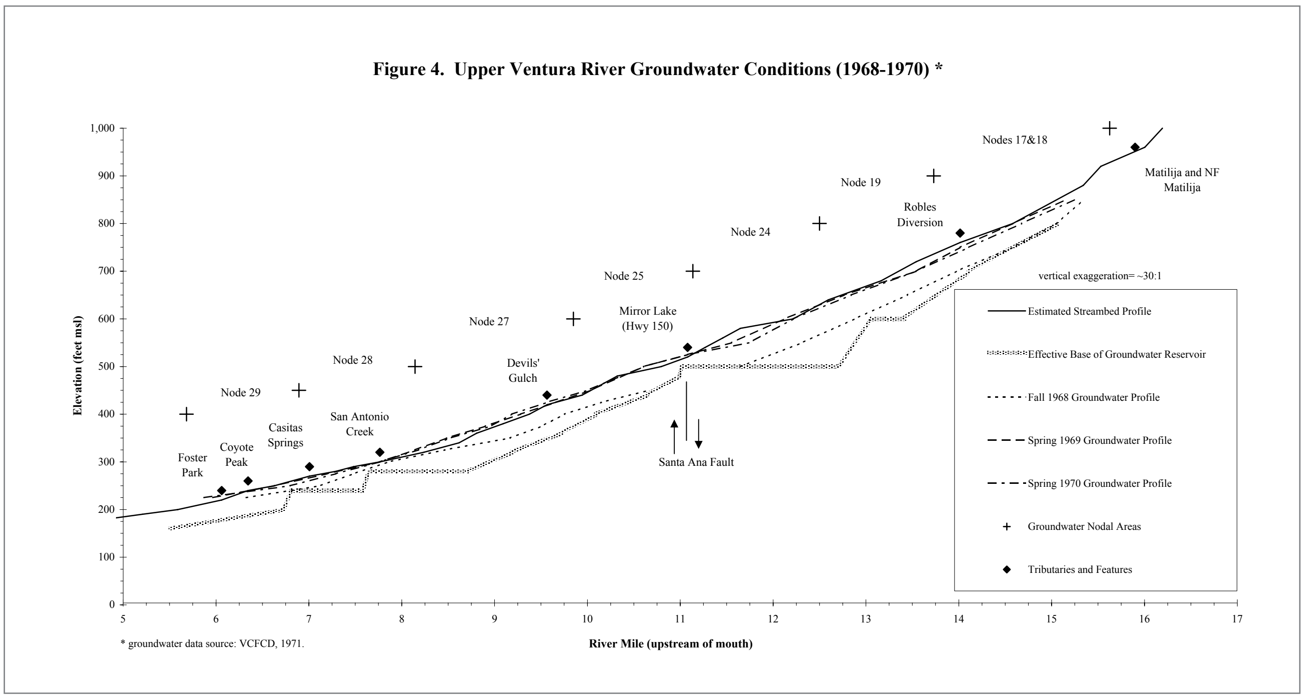


Figure 3.3.3.3.3 Comparison of Upper Ventura River Groundwater Conditions 1957–1958 (upper) and 1968–1970 (lower). "The consistency of the two fall groundwater profiles (1957 and 1968), despite different antecedent water year conditions, suggests that when high groundwater levels occur, they do not have long duration."

"The seasonal profiles presented in Figures 3 and 4 [1957–1958 and 1968–1970 figures respectfully] demonstrate the impacts of the Santa Ana/Arroyo Parida fault zone on the groundwater profile for the Upper Ventura River groundwater basin. Groundwater levels downstream of the Highway 150 crossing may be impacted when the groundwater elevations north of the fault fall below the base of the downstream aquifer (approximately 495 feet msl [above mean sea level]) which results in a disconnection in groundwater flow across the fault."

Source: Surface Water–Groundwater Interaction Report (Entrix 2001)

Lower Ventura River Basin

The Lower Ventura River Valley Basin has the lowest water supply withdrawals in the watershed.

The Lower Ventura River Valley Basin has the lowest water supply withdrawals in the watershed. Its storage capacity is estimated at 8,743 AF—assuming a basin area of 3,192 acres and an estimated average saturated thickness of 33 feet (DBS&A 2010). The California Department of Water Resources' Bulletin 118 lists its capacity as 243,000 AF (CDWR 2003); this very large figure may be due to inclusion of storage in very deep geologic formations underlying the basin as well as offshore components of those formations. The 8,743 AF estimate is based on the onshore, unconsolidated alluvium layer of the basin and not any deep or offshore layers.

The basin is bounded on the north by the Upper Ventura River Basin, on the south by the Pacific Ocean, to the southeast by the Mound Basin, and to the west and northwest by near-surface impermeable rocks of the Santa Ynez Mountains (CDWR 2003).

Major surface drainages that contribute water to this basin include the Ventura River, Coyote Creek, and Canada Larga. The flow of the Ventura River in this area is consistently enhanced by the addition of treated wastewater from the Ojai Valley Sanitary District. Unlike some other parts of the river, the stretch from the wastewater treatment plant to the coast rarely goes dry.

The basin is unconfined; the depth to groundwater is about 3 to 13 feet below ground surface in the floodplain and deeper as elevation increases towards the edge of the basin (VCWPD 2012). The alluvium continues offshore and may be in hydraulic continuity with the ocean (CDWR 1975).

As in the Upper Ventura River Basin, water flows through the alluvium from north to south, following the surface drainage and the slight gradient of the basin. A significant amount of groundwater, up to an estimated 2,412 AF a year, is discharged to the Pacific Ocean from the basin (DBS&A 2010).

Upper Ojai Basin

The Upper Ojai Basin, the third most important basin from a water supply perspective, serves residential and agricultural users in the Upper Ojai Valley. It is the smallest of the watershed's groundwater basins in aerial extent (2,840 acres) and storage capacity (5,681 AF) (CDWR 2003).

The Upper Ojai Valley Basin is narrowly elongated in an east-west direction, and is bounded by non-water-bearing Tertiary age rocks (Tan & Irvine 2005), including the Topatopa Mountains to the north, Black Mountain to the west, Sulphur Mountain to the south, and the convergence of the Topatopa Mountains and Sulphur Mountain to the east.

A surface and groundwater structural arch or divide is found in the eastern part of the basin (near Sisar Road); the divide separates groundwater flow westward toward Lion Canyon Creek and eastward toward Santa Paula Creek and into the Santa Clara River watershed (CDWR 2003).

Upper Ojai Basin: Historical Changes to Overlying Drainages

The strata in the underground Saugus formation (between San Cayetano and Lion Canyon faults) tilts toward Santa Paula in the ancient Sisar Creek from the surface through at least 400 feet, which I have dowsed and seen dowsed. Most of the water follows ancient well-sorted stream channels, which gently curve toward the east in those levels. In the late 1800's, I was told by old residents (Hofmeister, Romp, Thompson) that during El Nino-type rainfall Sisar Creek occasionally flooded to the west until the mid-1890's. At those times, it ran down Sycamore Creek into Arnaz Creek, bypassing the Ojai Valley geologic structure.

I was told by the above-listed people that Tom McGuire's father was an early settler in the late 1800's and owned the property east of the current Black Mountain Ranch. He dryland farmed as my ancestors did. When the occasional flood happened, it littered his fields with rocks and flotsam that took a great amount of effort to remove for growing hay. Tom told my uncle that in the mid 1890's his father had hired local laborers to wall up and divert Sisar Creek water to the east. My uncle said that a few years later, a large slide slid down from the San Cayetano escarpment at the mouth of the creek, which built it up so the flow now always continues to the east (although it almost came over in 1969 and again in 2004/05.)

—Rod Thompson, Historian, 4th generation Upper Ojai resident, and Sisar Mutual Water Company board president

Lion Canyon Creek drains the Upper Ojai Valley to the west. Major tributaries to this creek include Sycamore Creek, draining the Topatopa Mountains, and Big Canyon Creek, draining Sulphur Mountain.

The Upper Ojai Valley Basin is a fairly deep, bowl-shaped unconfined basin filled primarily with alluvial fan deposits derived from erosion of the surrounding mountains. The average thickness of water-bearing deposits is approximately 60 feet, reaching a maximum of about 300 feet near Sisar Creek. Depth to groundwater is about 45 to 60 feet below ground surface (VCWPD 2012; CDWR 2003).

3.3.3.4 Key Data and Information Sources/ Further Reading

The most comprehensive evaluation of groundwater in the watershed was done by the California State Water Resources Control Board in the *Ventura County Investigation included in Bulletin 12, 1956*. The California Department of Water Resources' *Bulletin 118* is the state's current, comprehensive evaluation of groundwater basins in California; the bulletin is actually a series of bulletins that have been updated over the years.

In 1971, John Turner of the Ventura County Flood Control District (now the Ventura County Watershed Protection District) produced a detailed analysis of groundwater basins in the watershed, estimating their storage capacity and actual storage. This report, *Geohydrology of the Ventura River System: Groundwater Hydrology* (VCFCD 1971), is one of the most often cited analyses of the basins in the watershed (excluding the Lower Ventura River Basin).

Subsequent to the Turner report, a number of detailed studies have been prepared for the Ojai Valley Basin, which is now the watershed's most well studied groundwater basin. A graduate thesis published in 2005 documented the geology, degree of confinement, and hydraulic characteristics of the Ojai Valley Basin (Kear 2005). A comprehensive groundwater model prepared in 2010 estimated the basin's safe yield and provided additional information about the basin's subsurface structure (DBS&A 2011). An update to this model prepared in 2014 calibrated the original model using data through the end of 2013 and improved estimates of recharge from turf and crop irrigation (DBS&A 2014). The updated model is being used to evaluate how basin groundwater levels are expected to respond to various drought scenarios.

An important study conducted in 2010, *Groundwater Budget and Approach to a Groundwater Management Plan Upper and Lower Ventura River Basin*, provides estimates of water inputs and outputs for these basins, as well as a final groundwater budget (DBS&A 2010).

The Ventura County Watershed Protection District also produces an annual report summarizing well-monitoring data, well levels, and water quality (VCWPD 2012).

The OBGMA collects continuous groundwater level and temperature data in the Ojai Valley Basin via data loggers in five production wells and the San Antonio Creek Spreading Grounds depth discrete monitoring well.

Acronyms

AF—acre-feet

eWRIMS—electronic Water Rights Information Management System

msl—above mean sea level

OBGMA—Ojai Basin Groundwater Management Agency

Below is a list of some of the key documents that address groundwater hydrology in the watershed. See "4.3 References" for complete reference citations.

Bulletin 46: Ventura County Investigation (CDWR 1933)

Bulletin 12: Ventura County Investigation (SWRCB 1956)

Bulletin 118: California's Groundwater (CDWR 2003)

Groundwater Budget and Approach to a Groundwater Management Plan Upper and Lower Ventura River Basin (DBS&A 2010)

Groundwater Model Development – Ojai Basin (DBS&A 2011)

Update to Ojai Basin Groundwater Model Memo (DBS&A 2014)

Groundwater Section Annual Report, 2013 (VCWPD 2013g)

Hydrogeologic Investigation, Ojai Groundwater Basin, Section 602 and 603 Study Tasks (SGD 1992)

Hydrogeology of the Ojai Groundwater Basin: Storativity and Confinement (Kear 2005)

Hydrologic Assessment San Antonio Creek Sub-Watershed (DBS&A 2006)

Hydrology, Hydraulics and Sediment Studies of Alternatives for the Matilija Dam Ecosystem Restoration Project (USBR 2007)

Surface Water–Groundwater Interaction Report for the Ventura River Habitat Conservation Plan (Entrix 2001)

Status and Understanding of Groundwater Quality in the Santa Clara River Valley, 2007 – California GAMA Priority Basin Project: US Geological Survey Scientific Investigations Report (Burton et. al. 2011)

Ventura County Water Resources Management Study, Geohydrology of the Ventura River System: Ground Water Hydrology (VCFCD1971)

Gaps in Data/Information

A better understanding of groundwater, specifically its relationship with surface water, is considered one of the critical information gaps in the watershed. The extent to which groundwater pumping affects surface flows of water needs further investigation. With a better understanding of this relationship—including when pumping has the greatest effects and the location and extent of these effects—surface and groundwater supplies could be better managed to provide for both the instream water needs of the endangered steelhead at critical times of the year and the ongoing water supply needs of homes and businesses.

California's Sustainable Groundwater Management Act

The Sustainable Groundwater Management Act, signed into law in September, 2014, created a framework for sustainable, local groundwater management for the first time in California history.

The Act established a definition of sustainable groundwater management and requires local agencies to adopt management plans for the state's most important groundwater basins. The legislation prioritizes groundwater basins and sets a timeline for implementation:

- By 2017, local groundwater management agencies must be identified;
- By 2020, overdrafted groundwater basins must have sustainability plans;
- By 2022, other high and medium priority basins not currently in overdraft must have sustainability plans; and
- By 2040, all high and medium priority groundwater basins must achieve sustainability.

For the purposes of this act, the Upper Ventura River and Ojai Valley Groundwater Basins are considered medium priority basins, and the Lower Ventura River Basin and the Upper Ojai Basin are low priority basins.

Implementation of the requirements in the Act will result in more groundwater management plans with additional data collection that should help address groundwater data gaps in the watershed.

Further investigation is warranted for many groundwater hydrology parameters throughout the Ventura River system including:

groundwater extraction[1]

groundwater elevation

accurate storage and safe-yield capacity

groundwater flow within and between the basins

definition of aquifer depth, barriers, and boundaries

enhanced groundwater recharge alternatives

groundwater–surface water interactions

detailed location and nature of faults, and how they affect groundwater hydrology

cross sections of subterranean geology

quantity of agricultural irrigation infiltration

recharge and discharge areas

1. At this time, groundwater extractions are only comprehensively reported and monitored in the Ojai Valley Basin; however, anyone with wells having aggregate extractions of more than 25 AF (or extractions of 10 AF or more from a single source) must file a report with the State Water Resources Control Board if there is no delegated local agency such as the OBGMA (Water Code §4999-5009). This has been a requirement in Ventura County since the 1950s. However, this requirement is not enforced, and the record of extractions in the State's electronic Water Rights Information Management System (eWRIMS) database is incomplete.