SANTA BARBARA CHANNELKEEPER®

Ventura Stream Team 2001 - 2005

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Protecting and restoring the Santa Barbara Channel and its watersheds

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Ventura Stream Team 2001 - 2005

A review of the findings of Santa Barbara Channelkeeper's Ventura Stream Team January 2001 - January 2006

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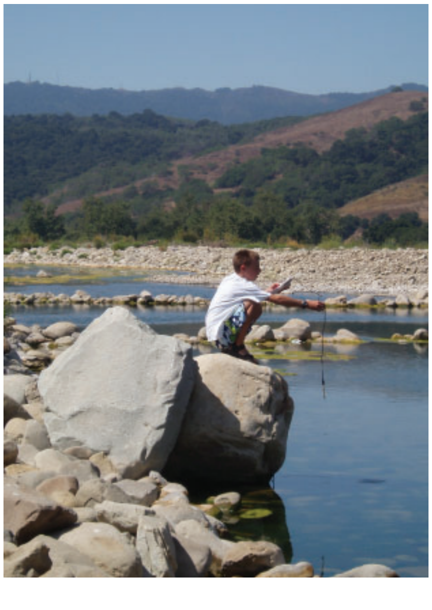
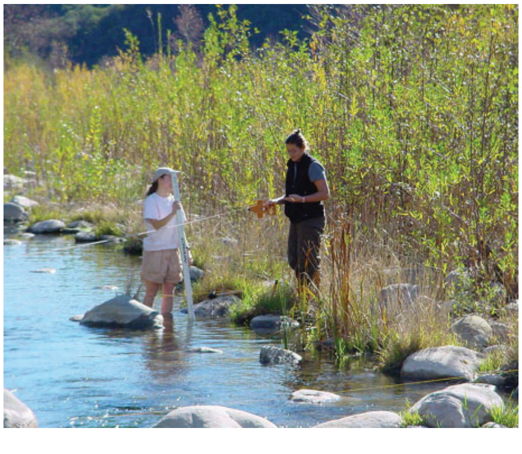
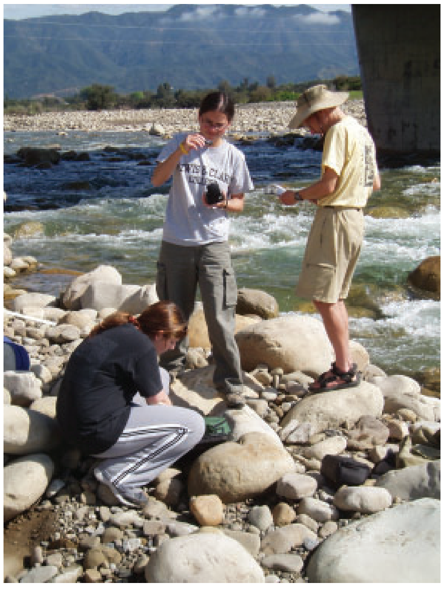

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About Santa Barbara Channelkeeper

Santa Barbara Channelkeeper is a local non-profit organization whose mission is to protect and restore the Santa Barbara Channel and its watersheds through citizen action, education and enforcement. We are a member of the international Waterkeeper Alliance, and like the other 153 Waterkeepers across the globe, we work on the water and in our community to monitor local waterways, restore aquatic ecosystems, advocate for clean water, enforce environmental laws, and educate and engage citizens in identifying and devising solutions to local pollution problems. Our efforts are focused on cleaning up the leading sources of pollution that threaten the health of our local beaches, waterways and wetlands, including storm water and urban runoff, sewage, agricultural operations, offshore oil drilling, and large municipal and industrial dischargers.

Funding for this project has been provided in part by the U.S. Environmental Protection Agency (US EPA) pursuant to Assistance Agreement No. C9-98998901-0 and any amendments thereto which has been awarded to the State Water Resources Control Board (SWRCB) for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the US EPA or the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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EXECUTIVE SUMMARY

Santa Barbara Channelkeeper, along with the Ventura Chapter of the Surfrider Foundation, launched the Ventura Stream Team water quality monitoring program in January 2001. The program has three goals: to collect baseline data on the health of the Ventura River watershed; to educate and train a force of volunteer watershed stewards; and to identify sources of pollution in the watershed. Over the past five years, more than 350 local citizens have participated as volunteers in the program, contributing in total more than 3,600 hours of their time. Each month, these volunteers collected valuable water quality data at 15 sites on the Ventura River and its major tributaries: San Antonio, Stewart, Thacher, Canada Larga, and Matilija creeks. At each site, volunteers took in-stream measurements on temperature, dissolved oxygen, pH , turbidity, conductivity, and flow, and collected samples that were later analyzed in the laboratory for bacteria and nutrients. Visual observations, such as algae coverage and weather conditions, were also recorded at every site.

The data collected by Ventura Stream Team serve as an excellent source of information about normal, or baseline, conditions throughout the Ventura River watershed. In the future, these data can be used as a yardstick to compare how water quality conditions change over time. In addition, the data have enabled Channelkeeper to identify problem areas throughout the watershed, which can also be used to guide future clean-up and restoration efforts by environmental groups, regulatory agencies and other stakeholders.

The most egregious problem that Channelkeeper identified through its Ventura Stream Team monitoring efforts was that of nutrient pollution. Throughout the five years of sampling, mean nitrate and phosphate levels exceeded the limits recommended by the US Environmental Protection Agency (EPA) at most sampling sites. With nitrate, the most serious problems were seen in two distinct zones of the watershed: the lower river and the San Antonio Creek tributary. High nitrate levels on the lower river are probably the result of treated sewage effluent that enters the river upstream of the Ventura River at the Shell Road sampling site. On San Antonio Creek, which drains much of the Ojai area, high nitrate levels likely come from multiple sources, including animal waste from horse and cattle facilities, faulty septic systems, general urban nuisance flows, and fertilization and irrigation of golf courses, parks and landscaping. Phosphate presents a more complicated picture, as elevated phosphate levels are due somewhat to natural geologic conditions in the watershed and cannot necessarily be attributed to contamination. However, as with nitrate, the highest levels were seen on the lower river and along San Antonio Creek; treated sewage effluent (in the lower river) and animal waste from horse and cattle facilities are the most likely causes.

Ventura Stream Team sampling revealed a serious problem with bacteria levels in only one distinct watershed zone: the Canada Larga Creek tributary. While the three "indicator bacteria" that Channelkeeper tests for (total coliform, E.coli and enterococcus) are not usually harmful in and of themselves, they do indicate the possible presence of pathogenic bacteria, viruses, and protozoans. Results for all three tests from both the upper and lower Canada Larga sampling sites regularly exceeded public health limits set forth by local and federal regulatory agencies. While these standards are meant to protect public health from contact through recreational use of waterbodies, and these sampling sites are not commonly used for human recreation, it cannot be disputed that they do exhibit problems with bacterial contamination. On Canada Larga Creek, the most obvious cause of this contamination is animal waste, as the major land use in the area is cattle grazing. Although not as serious as the problem on Canada Larga Creek, the two sampling sites on San Antonio Creek also exhibit high enterococcus levels; possible causes include animal waste and faulty septic systems.

Other parameters measured by Ventura Stream Team provide additional information about these, and other water quality problems. One of the largest problems associated with high nutrient levels is over-growth of algae, which lowers dissolved oxygen levels and can subsequently harm or kill oxygen-dependent aquatic life. Evidence of this process (called eutrophication) has been found in Stream Team data. For example, high pH levels and extreme dissolved oxygen levels at many sites are indicative of excessive algal growth. High conductivity levels on Canada Larga Creek may signify other kinds of problems. Eroded soils from pastures, industrial nuisance flows, and a concrete channel above the Lower Canada Larga Creek sampling site may contribute to elevated conductivity there.

In light of the findings from the first five years of Ventura Stream Team's water quality monitoring efforts, Channelkeeper believes there is cause for concern and grounds for action to address the problems described above. Stretches of the Ventura River are already listed by the State of California as impaired, and the watershed is set to undergo major changes with the upcoming removal of the Matilija Dam. To mitigate existing and future water quality impairments in the watershed, Channelkeeper recommends that the following actions be taken:

- Regular monitoring efforts by Channelkeeper and other entities should be continued and expanded to assist regulatory agencies in their land use planning and water quality protection efforts.
- Specific pollution sources should be pinpointed by conducting creek walks, sampling at specific discharge points, and identifying the land uses associated with any contaminated discharges.
- Once specific sources are identified, Channelkeeper and other entities should reach out to the appropriate landowners to educate them about the problems of, and solutions to, the water quality issues associated with runoff and/or discharges from their properties.
- Regulatory agencies should strictly enforce water quality regulations and ordinances, including issuing fines or cease and desist orders when necessary.
- Regulatory agencies should scrutinize the results of monitoring conducted by the Ojai Valley Sanitary District to ensure compliance with its discharge permit.
- Regulatory agencies should continue to implement additional treatment methods, including active treatment systems such as ultraviolet and ozone systems, and best management practices (BMPs) such as vegetated swales, constructed wetlands, and permeable pavement, to remove pollutants before they contaminate waterbodies.
- Regulatory agencies should provide incentives to encourage developers to implement low-impact development BMPs in new residential and commercial developments or re-developments.

While this list of recommendations is by no means exhaustive, the implementation of these and related measures will help to reduce the pollution identified by Santa Barbara Channelkeeper's Ventura Stream Team water quality monitoring efforts.

INTRODUCTION

Santa Barbara Channelkeeper's Stream Team program is a volunteer-based water quality monitoring program that focuses on two major local watersheds, the Ventura River and the Goleta Slough. The streams and rivers that drain these watersheds transport pollutants such as bacteria and excess nutrients into downstream wetlands and the ocean. The purpose of Stream Team is to provide a comprehensive and long-term effort to monitor conditions on these ecologically important waterways.

Ventura Stream Team was launched in early 2001 as a partnership between Santa Barbara Channelkeeper and the Ventura Chapter of the Surfrider Foundation, and was followed by the Goleta Stream Team program, launched by Channelkeeper in June 2002. Both Stream Team programs share the same three goals: to collect baseline data on the health of the watershed; to educate and train a force of volunteer watershed stewards; and to identify sources of pollution in these ecologically important watersheds.

Ventura Stream Team conducts monthly on-site testing at designated locations on the Ventura River and its major tributaries. Teams of volunteers measure physical and chemical parameters in the field using portable hand-held instruments. Data collected include on-site measurements of dissolved oxygen, turbidity, conductivity, pH, temperature, and flow. Water samples collected at each site are processed in Channelkeeper's laboratory for three Public Health bacterial indicators using approved standard methodology (Colilert-18 and Enterolert-24, manufactured by Idexx Laboratories; US EPA, 2003). Additional samples are analyzed for nutrients (ammonium, nitrite plus nitrate, orthophosphate, total dissolved nitrogen and particulate carbon, nitrogen and phosphorus) through cooperation with the Santa Barbara Channel – Long Term Ecological Research Project (SBC-LTER) at the University of California, Santa Barbara (UCSB). Visual observations such as vegetation and aquatic life are also recorded monthly at each site. To ensure quality control, all meters are checked and calibrated against traceable standards prior to every sampling event (see Appendix for details on methodology).

Citizen volunteers are a critical element in the success of Ventura Stream Team. To date, over 350 volunteers have participated in the program, contributing over 3,600 hours of their time to the monitoring discussed in this report. Volunteers include a wide range of local residents, from high school and college students to environmental scientists. While some volunteers come to earn community service hours for school, most participate to gain experience and knowledge and to make a contribution to their community. Many of our volunteers are users of coastal resources - hikers, surfers and fishermen - who are eager to give back to their community.

From 2001-2005, over 350 volunteers participated in Ventura Stream Team.

BACKGROUND

The South Coast[1]

Climate

The climate of the South Coast, from Point Conception to Ventura, is considered "Mediterranean," typified by relatively mild winters, hot dry summers, and coastal fog during much of the dry season. Rain generally occurs only between the months of November and March, and temperatures at lower elevations are almost always above freezing. High pressure systems which develop over Utah and Nevada are strong enough to keep the weather warm and sunny for much of the summer and fall. These systems also divert rain, and consequently there is little summer precipitation in the region. Higher watershed elevations may have summer daytime temperatures of 85-100^{o} Fahrenheit (F), while the coastal regions are generally about ten to fifteen degrees cooler. Fall daytime temperatures are generally 70-90^{o} F in inland areas, but are considerably colder at night. In the fall, Santa Ana winds can blow hot and dry from desert regions to the east. These warm winds and the prevalent dry conditions often give rise to severe wildfires, which are a natural part of the ecosystem. Winter is characterized by periodic bouts of heavy rainfall, often delivering several inches of precipitation in each storm. The upper mountainous regions receive more rainfall than the lower coastal areas as Pacific storms are uplifted over the coast range. Higher elevations, on average, experience about 22-29 inches of rain a year, while amounts near the ocean are closer to 15 inches. Snow can fall at high elevations during particularly cold winter storms.

Geology

South Coast drainages lie within the western Transverse Ranges of California, mountain ranges notable for easily eroded sedimentary rocks. These ranges have been produced by clockwise crustal rotations between the Pacific and North American plates (the same plate movements that produced the infamous San Andreas fault). California's largest earthquakes have rotated and uplifted the region's coastal mountains (Jaeger and Smith, 1988; Michaelson, 2004), and they are still being uplifted, at rates of 1-3 mm per year (Keller and Capelli, 1992). Regional tectonics have produced numerous faults and folds, and some of the youngest sedimentary rocks have been deformed until they stand nearly vertical. The rocks near the surface are usually recent sedimentary layers of marine origin (Cenozoic – younger than 65 million years) - hard sandstones alternating with weak shales and mudstones. The surrounding geology is responsible for much of the character of local streams. Steep mountains with easily eroded rocks yield "flashy" creeks (quick to rise as rain begins, quick to fall when it ends) with some of the highest sediment loads in the world (Scott and Williams, 1978; Taylor, 1983; Hill and McConaughy, 1988). In addition, fragile marine sediments cause high background conductivities and total dissolved solids (high in sulfate, calcium, magnesium and chloride).

Land Use

Land use in the region is primarily open space, agriculture and urbanized development. Higher elevations are usually covered in native chaparral with areas of oak woodland and tree-lined riparian corridors. In the foothills, many areas have been converted to exotic grass rangeland and avocado and citrus orchards. The coastal lowlands have been put to numerous uses, including urban, agriculture (row crops and greenhouses) and orchards. Light industry and oil production exist in some areas. Nearly half the coastal watershed – mainly at higher elevations – is within the boundaries of the Los Padres National Forest. A number of coastal margin wetlands can be found at the mouth of streams. Most are small and are completely flushed during winter rains, but the Carpinteria Salt Marsh, Goleta Slough, Devereux Slough and the Gaviota Marsh have appreciably larger associated wetlands.

Vegetation

Numerous plant communities are found within South Coast watersheds: non-native annual grasslands, Venturan coastal sage scrub, chaparral, coast live oak woodland, and three types of riparian woodland (south coast live oak, central coast cottonwood-sycamore, and southern willow scrub). Each of these habitats have evolved to the specific conditions of the coastal climate of Southern California, and the plants of all communities show traits adapted to fit their niche. Elevation, aspect (shade or sun), rainfall and water availability are the primary determinants of where each community exists.

Plants play a crucial role in the ecology and hydrology of the watershed. They provide habitat, food and shelter for the dozens of animal species that inhabit the region. Plants help to prevent soil erosion by literally holding the soil together with their root systems. Leaf and branch canopies also reduce the impact of rain, and by absorbing rainfall from the soil, they also minimize runoff.

An ongoing problem in these watersheds is the invasion of non-native species of plants – foreign plants that have been introduced, intentionally or unintentionally, and then thrive in local environments, often because of the absence of natural predators. In the process of replacing native species, they present problems for local animals that are not adapted to living with, and on, these invaders. Invasive, non-native species damage the biodiversity of both plants and animals in the region.

Riparian Zones

The riparian zone is the vegetative corridor at the boundary of a body of water. Often unique and different from the surrounding vegetation due to its proximity to water, it acts as the interface between terrestrial and aquatic zones. During the dry season, the riparian zone bordering a stream is usually the only area with green plant growth. Riparian areas are often the only home for deciduous trees, like sycamores and willows, which need year-round water to survive. This growth helps to preserve threatened aquatic species like steelhead trout by providing shade and lower water temperatures. Large trees also contribute coarse organic material to the stream. This provides food for benthic macroinvertebrates that are food for other organisms including steelhead trout. These trees also provide instream structure or habitat when they fall into the stream. By preventing erosion, riparian plants keep water silt-free for trout eggs to hatch, and by providing shade, stream temperatures stay cool enough for spawn to survive. Riparian areas also provide protected habitat and travel corridors for much of the area's terrestrial wildlife, and frequently serve as habitat for endangered and threatened species. Studies have shown that as much as 85% of a region's wildlife inhabit riparian zones at some point in their life cycle. Riparian areas also serve as a buffer between land use and the stream, filtering out pollutants before they reach the water and acting as a bacteriological and chemical factory to cleanse stream water as it moves between channel and stream bank.

Hydrology[2]

The dominant hydrologic characteristic of the Ventura River, and indeed of all streams in coastal Southern California, is extreme inter-annual variation in rainfall and watershed runoff. Mean annual flows in the Ventura River have varied from 5-3,400 cubic feet per second (cfs) (e.g., a 700-fold variation) over the last 75 years.

Since 1878, the average winter rainfall in Los Angeles has been 15 inches (NWS-LA).[3] However, "average" in this case does not convey the extreme annual variability (Figure 1, upper panel). Very few years actually have average rainfall;

most are drier, and a relatively few very wet years heavily influence the record (these are usually, but not always, associated with strong El Niño events; Null, 2004; Monteverdi and Null, 1997). If a year of significantly high rainfall is defined as having rainfall at least 150% above the average (greater than 22 inches in downtown Los Angeles), there have been seventeen years of significantly high rainfall since 1878, approximately one every seven and a half years. The 1990s were unusual in that three years of significantly high rainfall (1993, 1995 and 1998) occurred within a relatively short span of time.

However, El Niños are just one of the climate cycles influencing local weather. The region is also impacted by the Pacific Decadal Oscillation (PDO), a roughly 50-year pattern of alternately cold and warm waters that abruptly shift location in the Pacific Ocean (Mantua et al., 1997; Minobe, 1997; Mantua, 2000). The "cold" PDO phase moves the jet stream (and a majority of winter rain) northward, while the "warm" phase pushes it, and rainfall, southward, giving Southern California wetter winters.

Figure 1 (lower panel), a plot of cumulative departure from the mean for Los Angeles rainfall (NWS-LA), attempts to show the influence of this pattern by plotting the cumulative rainfall excess or deficiency. In other words, the graph displays a running summary of how much each year's rainfall affected the long-term departure from the annual 15-inch average. The plot shows a pattern of alternately rising and falling trends, where rainfall was either generally above or generally below average, lasting decades. The 1880s and the 1930s had strong increasing trends, trends generally caused by an increased frequency of years of significantly high rainfall. The general pattern between 1944-1968 was below-average rainfall (a decreasing trend), but from 1968-1998 the trend reversed, except during the California drought of 1987-1992.

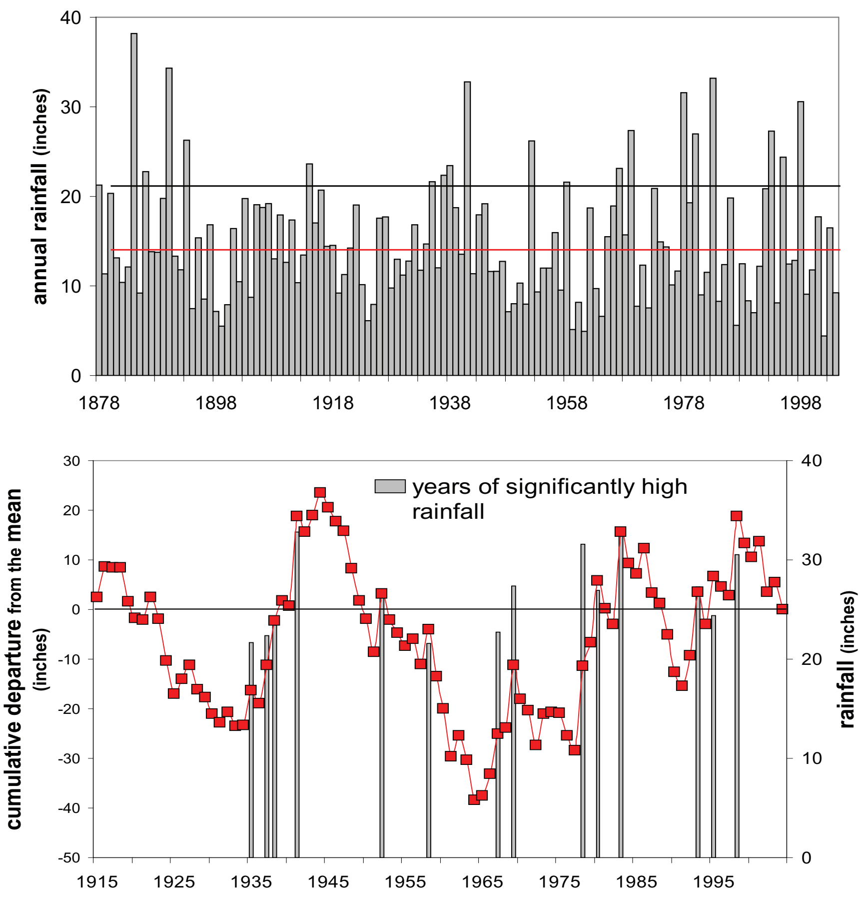


Figure 1. Annual (water-year) rainfall in downtown Los Angeles: 1878-2004 (upper panel). The lower line represents the annual average of 15 inches, the upper, 150% of average. Lower panel: The cumulative rainfall excess or deficiency – in other words, a running account of how much each year's rainfall varied from the 15-inch average. The plot reveals a pattern of alternately rising and falling trends generally lasting decades. The lower panel also shows years of significantly high rainfall, years when rainfall exceeded 150% of average, e.g., rainfall greater than 22 inches. Years of significantly high rainfall, many of which coincide with major El Niño episodes (but not all), heavily influence the rainfall record; a close grouping of unevenly spaced high rainfall years causes an increasing rainfall trend.

Annual flows in the Ventura River mimic this rainfall record (flows measured at Foster Park, USGS-NWIS). Figure 2 (upper panel) shows how much each year's flow differed from the median flow of 21 cfs (half the years had average flows less than the median, half greater). The 1930s, early 1940s and 1990s were years of above average flow, whereas other decades were below average. The lower panel of Figure 2 displays the cumulative flow excess or deficiency – the running total of how much each water-year's flow (measured in inches of runoff at Foster Park) moved the long-term trend away from the 4.8 inch overall average, and in which direction. The plot shows the same pattern of rising and falling trends, heavily influenced by very wet years, as Los Angeles rainfall. Years of significantly high rainfall, in Figure 2, represent Ojai rainfall greater than 31.5 inches. Note that in the late 1960s it took two years of significantly high rainfall to reverse a 10-year declining trend.

As an aside, the average annual Foster Park runoff is 4.8 inches, while the average Ojai rainfall is 21 inches, indicating that roughly only 20% of the rain is ever discharged into creeks and rivers. As for the rest, most is evaporated or transpired by plants and trees, and a smaller part recharges the groundwater table or is stored as soil moisture.

A new cold phase appears to have begun after 2000. With less rainfall, we can expect conditions similar to those of the 1950s, when lower flows were more common. More wildfires, increased summer fog and extended drought conditions may also be anticipated.

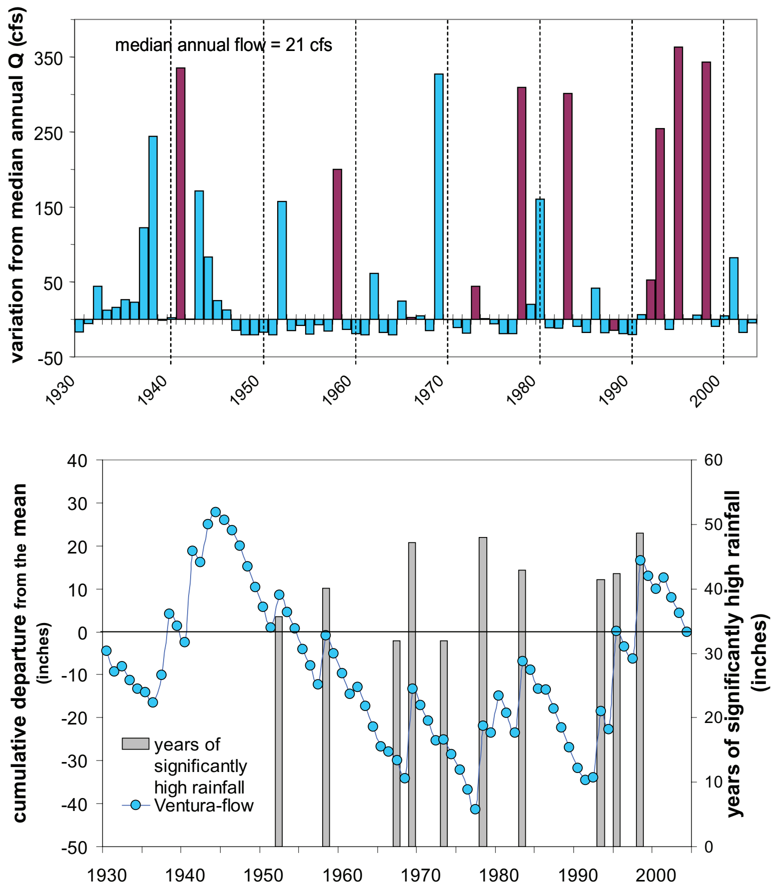


Figure 2. Upper panel: Median annual flow on the Ventura (at Foster Park) is 21 cubic feet per second (cfs), e.g., half the years on the chart had average flows less than this, the other half had greater. The distribution is skewed – "above the median" years tend to be very wet. Years shown as dark bars were major El Niño episodes. The 1940s, 1950s and 1990s were relatively "wet" decades. Lower panel: The cumulative flow excess or deficiency – a running total of how much each water-year's flow (measured in inches of runoff at Foster Park) moved the long-term trend from the 4.8 inch overall average. The plot shows a pattern of rising and falling trends, heavily influenced by wet years. Wet years, in this chart, represent Ojai rainfall above 31.5 inches. Note that in the late 1960s it took two wet years to reverse a 10-year declining trend.

The Ventura River

The Ventura River watershed, with headwaters in the Santa Ynez Mountains north of the City of Buenaventura, has an area of 222 square miles. The river and its catchment can be divided into three zones: (1) the mountainous areas of the basin; (2) the main stem of the river, from the confluence of Matilija and the North Fork of Matilija creeks to the river delta or estuary; and (3) the delta, which is approximately two miles wide at the coast and extends about a mile upstream, almost to the Main Street Bridge.

The mountainous areas produce a majority of the winter runoff and most of the sediment that eventually finds its way to the ocean. The major tributary watersheds that originate in this zone are Matilija Creek (55 sq. miles), the North Fork of Matilija Creek (16 sq. miles) and San Antonio Creek (51 sq. miles). Coyote and Santa Ana creeks (41 sq. miles) were once major tributaries, but almost no runoff or sediment from these drainages has flowed into the Ventura since the creation of Lake Casitas, which lies behind a 285-foot earthen dam storing up to 254,000 acre-feet of water. Matilija Creek also has a dam, built in 1948 and designed to store 7,000 acre-feet. However, sedimentation (principally from the El Niño floods of 1969) has reduced its capacity to 500 acre-feet, and it is now mainly used to enhance diversions to Lake Casitas via the Robles canal. The main stem of the Ventura River is roughly 15 miles long and is characterized by the storage and transport of sediment along a broad flood plain (generally about a half-mile wide). Two major diversion structures on the main stem govern dry-season flow, although their capacity is too low to affect storm flows. Uppermost is the Robles diversion dam, which diverts Ventura River water, two miles below Matilija Dam, into Lake Casitas via the Robles canal. A minimum flow of 20 cfs must be allowed to pass the diversion, but everything above this (up to the canal's maximum capacity of 500 cfs) may be diverted. Given the high infiltration rate of the porous sediments and cobbles that form the Ventura River bottom, this usually ensures that the river goes dry a short distance below the diversion.

Further downstream, a concrete weir extends underground, beneath the river and Coyote Creek, approximately ¼ mile above the Foster Park Bridge. While there is also a surface diversion here, the weir was designed to raise the water table to facilitate pumping from below the river to Ventura's water treatment plant. Since the weir does not fully confine the river, raising the groundwater table usually ensures some river flow past Foster Park. Approximately a mile and a half below Foster Park, effluent from the Ojai wastewater treatment plant (2-3 cfs) helps maintain this year-round flow all the way to the ocean.

The estuary, which covers approximately 30 acres, includes a main lagoon usually separated from the ocean by a sand/cobble bar during the dry season. The sand bar is breached by winter storms and is slowly rebuilt in summer, fed by longshore drift sand. In dry years the bar may not be breached at all, and it may never become established in extremely wet years. With the bar, the lagoon is mainly fresh water, and without it, is mainly salt or brackish water subject to tidal flushing.

The Ventura River watershed is roughly 45% mountains, 40% foothills, and 15% valley; 75% can be considered rangeland (shrub/brush) and 20% forest (half of the catchment is within the Los Padres National Forest). While the basin is mostly undeveloped, urbanization, cattle raising and oil production dominate the coastal plain and adjacent foothills.

The average annual rainfall is 20 inches, and the seasonal and inter-annual variation in river runoff is extreme – as mentioned earlier, mean annual flows vary from 5-3,400 cfs; in other words, a "wet" year can have almost 700 times more flow than a "dry" year. More than 90% of the annual rainfall occurs between November and April, and a majority of the annual runoff usually occurs within a period of three to seven days. The river is hydrologically "flashy" and responds within hours to storms and changes in rainfall.[4]

Sampling Locations

When Ventura Stream Team was established conceptually in the spring of 2000 as a joint project of Santa Barbara Channelkeeper and the Ventura Chapter of the Surfrider Foundation, 14 sampling sites were selected to exemplify the range of conditions found on the river and its tributaries. These sites extend from just above the estuary at Main Street in Ventura to Matilija Creek and its North Fork. Shortly after sampling began in January 2001, a fifteenth site was added upstream of Matilija Dam. A list of site names and abbreviations is shown in Table 1 and a map of the watershed and sampling locations is shown in Figure 3. Aerial photos of selected watershed zones are also included on the following pages.

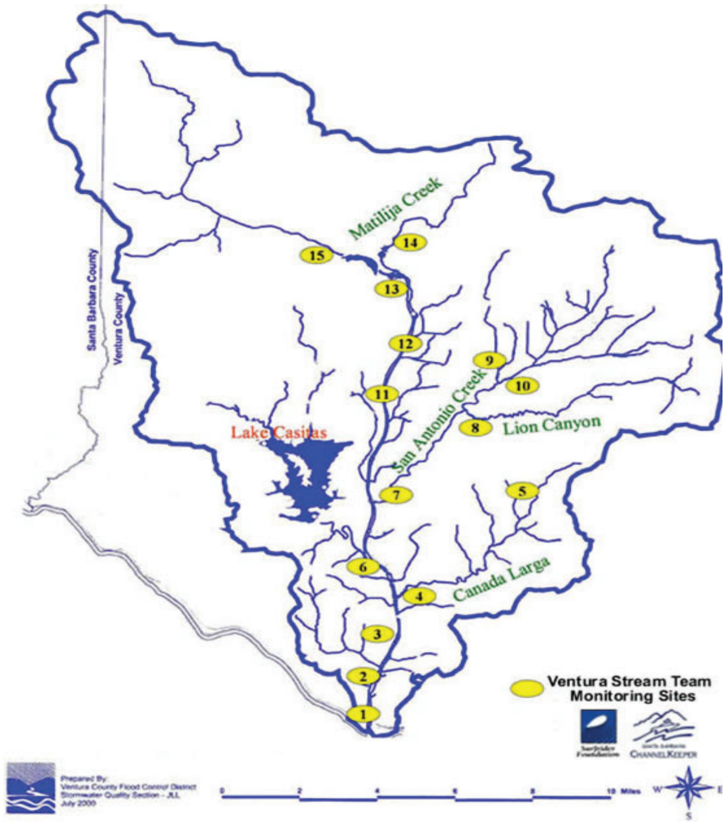


Figure 3: Map of the Ventura watershed with Ventura Stream Team sampling sites.

Table 1. Ventura Stream Team site names and abbreviations.

Site Name	Abbreviation
Ventura River at Main Street Bridge	VR01
Ventura River near Stanley Drain	VR02
Ventura River at Shell Road	VR03
Lower Canada Larga Creek	VR04
Upper Canada Larga Creek	VR05
Ventura River at Foster Park	VR06
San Antonio Creek at Old Creek Road	VR07
Lion Canyon	VR08
Stewart/Fox Creek	VR09
Thacher Creek	VR10
Ventura River at Santa Ana Road	VR11
Ventura River at Highway 150	VR12
Matilija Creek	VR13
North Fork Matilija Creek	VR14
Upper Matilija Creek	VR15

Ventura River at the Main Street Bridge (VR01) is sampled immediately upstream of the bridge. This site is just above marine influence from the nearby estuary and marks the freshwater boundary. The floodplain here is wide and delta-like, a mix of sandy soils with willows and large patches of non-native Arundo donax. During heavy storms, when access becomes difficult and dangerous, sampling is conducted by lowering a bucket from the bridge. The location of the specific sampling site has changed over the course of the program; originally downstream of the bridge, it was moved upstream in late summer of 2002, when prolonged blockage of the estuary by a sand berm inundated the site with brackish backwater.

Ventura River near Stanley Drain (VR02) is located just above the confluence with the large Stanley storm drain, which serves semi-industrial and brownfield areas in northern Ventura. Flow is typically confined within a narrow channel on the far side of a wide floodplain.

Ventura River at Shell Road (VR03) is slightly downstream of the Shell Road bridge. The bridge serves a major oil field development and is gated on the west side. The main channel (and the sampling location) has moved during the years of sampling, from the oil company side to the center of the floodplain, and then back. The flood plain here is approximately forty yards across and confined within steep rip-rapped slopes. The Ojai wastewater treatment plant is approximately a mile upstream of this location. VR03 allows us to monitor conditions below the sewage treatment plant and, with two sampling locations further downstream (VR02 and VR01), track the sequential changes that occur as this mixture of normal river water and treated effluent flows to the estuary.

Lower Canada Larga Creek (VR04) is located off of Ventura Avenue, just downstream of the Canada Larga bridge. Canada Larga flows through extensive ranch lands before passing through industrial development on its way to the river. Upstream concrete channelization of Canada Larga ends at this sampling location. A Ventura County flood gauge is located at the bridge, but the automated gauge does not begin recording until water levels reach one and a half feet. The stream is approximately forty feet in width at this location. During the dry season, there is usually little or no flow here.

Upper Canada Larga Creek (VR05) is located 3.5 miles up Canada Larga Road, at a small bridge over the creek. The hills and valley bottom around this location provide extensive grazing lands for local ranches. The stream is typically small and slow-flowing, and is often dry during the dry season. Upstream are pastures and old walnut orchards, and the area is marked with signs of frequent grading and tilling. City sewage sludge was once tilled into the soil here. Evidence of appreciable bank and hillside erosion from overgrazing within the drainage is common. The two Canada Larga sites monitor a major Ventura River tributary as land use changes from ranching to industrial.

Ventura River at Foster Park (VR06) is located below the County's Foster Park, slightly downstream of the Casitas Vista Drive bridge. Both a Ventura County flood gauge and a USGS gauging station are located alongside an old fenced and gated bridge abutment. A ladder on the abutment, installed to maintain the gauges, is used to access the sampling site. Thickets of Arundo line the bank and center of the riverbed, and the channel width is approximately 100 yards. A bedrock reef located a quarter mile upstream, in conjunction with the aforementioned underground weir used to enhance withdrawal of domestic water supplies, force groundwater to the surface and ensure year-round flow at this location. Heavily influenced by relatively clean groundwater, VR06 exemplifies relatively natural conditions on the lower river and provides a contrast from which to assess the impacts from the introduction of treated effluent below this point.

San Antonio Creek at Old Creek Road (VR07) monitors a major tributary of the Ventura River and represents the combined drainage from various Ojai Valley land uses. This location, and three additional upstream sampling siteson major sub-drainages, track conditions and changes in what is arguably the center of development in the Ventura River watershed and its most important tributary. Sampling takes place at the Old Creek Road low water crossing, just off of Highway 33. Ventura County has a flood gauge approximately 400 meters downstream of this location at the Highway 33 bridge. Surrounding land uses include residential housing and livestock grazing. Horse stables, ranching and grazing, golf courses and the urban area of Ojai lie upstream.

Lion Canyon (VR08) is sampled just before it enters San Antonio Creek. A sub-watershed of approximately eight square miles, the entire catchment is mostly under single ownership and is used for cattle grazing and dude ranch activities associated with the Ojai Valley County Club. The lower creek flows over mudstone and shale, and its riparian vegetation is relatively natural. Highway 150 skirts the creek near the top of the drainage.

Stewart/Fox Creek (VR09), adjacent to VR10, samples the combined flow out of Stewart and Fox canyons, both of which flow through western Ojai and are partially channelized through the town (this stream is shown on some maps as Pirie Creek). Dense non-native vegetation includes thick Arundo, Eucalyptus, periwinkle (Vinca), and watercress. Crayfish are seen in the deeper pools, and three species of native fish have been observed at this site: Arroyo chub, Steelhead trout, and Stickleback.

Thacher Creek (VR10), adjacent to VR09, combines flow from the upper San Antonio and Thacher drainages in eastern Ojai. Thick non-native vegetation, such as Arundo and Eucalyptus, are prevalent along its banks.

Ventura River at Santa Ana Road (VR11) is sampled below the Santa Ana Road bridge, down a steep rip-rap bank. The channel is approximately 100 yards in width, but flow usually occupies only a small fraction. A large storm drain enters at this location. River flow typically disappears below ground just downstream from the bridge. This site is typically dry during much of the year.

Ventura River at Highway 150 (VR12) is upstream of the bridge. As at VR11, a climb down steep rip-rap and a short downstream hike are required to reach the sampling site, which is usually dry. VR11 and VR12 monitor conditions on the upper Ventura River. The Robles Diversion Dam diverts water to Lake Casitas above these sites. These diversions, and the porous sediments that form the river bottom in this reach, typically leave little flow in the channel after the rainy season.

Matilija Creek (VR13) is approximately one kilometer downstream of Matilija Dam, at an out-of-use USGS stream gauging station. A small concrete dam at this site creates a large, deep pool that is a popular swimming area, particularly in the summer.

North Fork Matilija Creek (VR14) is located below a bridge on Highway 33 used as a Ventura County flood gauging station. Sampling during high flow can be conducted from the bridge. The creek bed is relatively natural with native vegetation and is often visited by sunbathers and kids. VR14 represents the most pristine sampling location in the program, the site least affected by anthropomorphic impacts.

Upper Matilija Creek (VR15) is the uppermost sampling location in the watershed. It is in Matilija Canyon, approximately 1.5 miles above Matilija Dam. The three Matilija sites, in relatively pristine environments, serve as a yardstick by which we can measure the effects of human impacts on the lower Ventura and other tributaries. By sampling above and below Matilija Dam, a candidate for removal and restoration, they allow us to monitor the impact of its sediment-filled reservoir.

The 15 sampling sites represent four distinct reaches or sub-watersheds: four on the lower Ventura River, two on Canada Larga, four on San Antonio Creek and its tributaries, and five upper Ventura/Matilija locations. Sampling is accomplished by three teams, with Group I sampling on the lower Ventura and Canada Larga, Group II on San Antonio Creek, and Group III on the upper Ventura/Matilija. Since these groupings divide the watershed into reasonable geographic and ecological units, whenever possible we display and discuss the data that follows using a similar format. When the variation of a measured parameter with time is shown or discussed, four sites, VR04, VR05, VR11 and VR12, will be omitted, as flow in these locations has become increasingly rare with the passage of time.[5] However, we do include these sites in our presentation of the overall results for each parameter.

Cycles of Change

The extreme rainfall variability experienced in the Ventura watershed engenders cycles of sediment deposition and removal, algal growth, and the advance and retreat of riparian and aquatic vegetation along the river. In turn, these changes dramatically alter the appearance and biological functioning of the river and riparian zone, and regulate the uptake of nutrients.

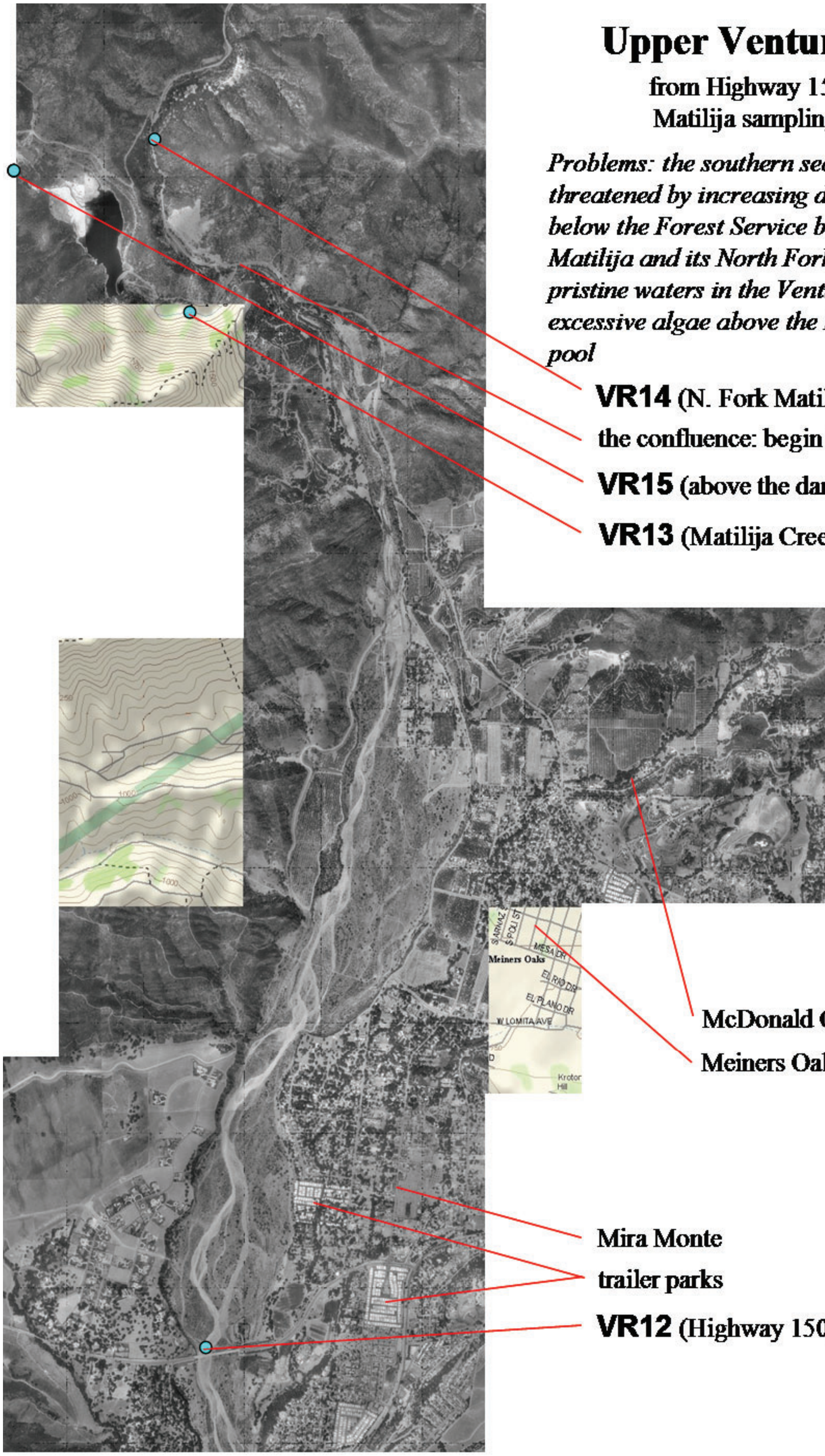
Following large storms that scour streambeds, filamentous algae often take over. This photo was taken at VR12 in May 2005, following the large January storms.

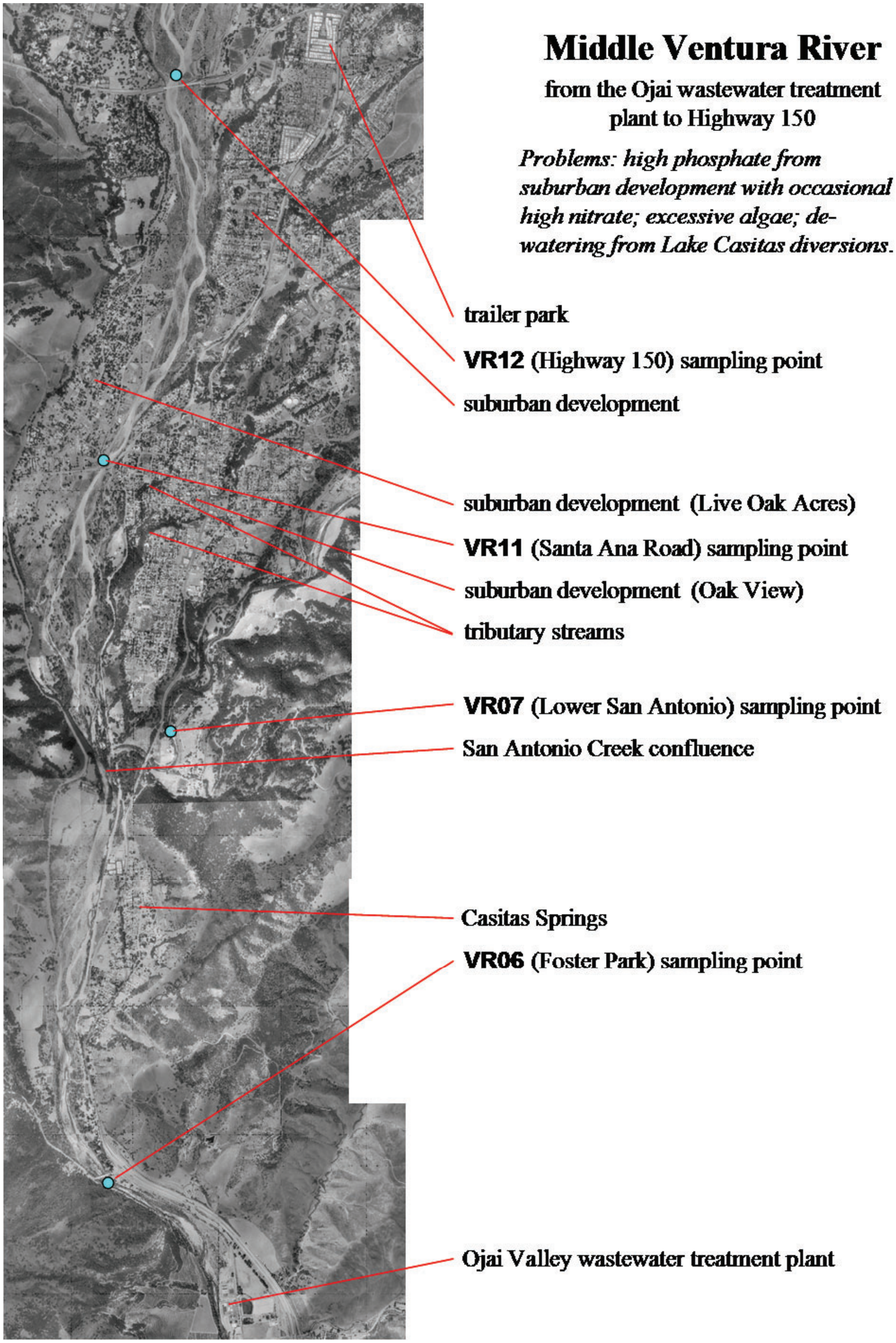
Major winter storms, such as occur during severe El Niño years, begin a transformational cycle by completely scouring the channel of vegetation and fine sediment (Figure 4); this occurs, on average, once every 7-10 years (Leydecker et al., 2003). Heavy flows scour streambeds of vegetation and fine sediment, clearing the way for a complete takeover by filamentous algae (principally Cladophora, Rhizoclonium, Enteromorpha and Spirogyra spp.). This is true even in the more pristine, undeveloped upper sections of the Ventura River. However, sooner or later a low runoff year occurs, as two out of three years have less than half the average runoff (Figure 2). In the absence of severe winter floods, sediment accumulates in the channel and exuberant plant growth begins the competitive replacement of algae by aquatic vegetation (Leydecker and Alstatt, 2002). Where the growth of taller riparian vegetation appreciably blocks sunlight, algae may disappear entirely. Over the years these processes increasingly stabilize the channel and elevate the threshold flow of a future scouring storm.

Upper Ventura River

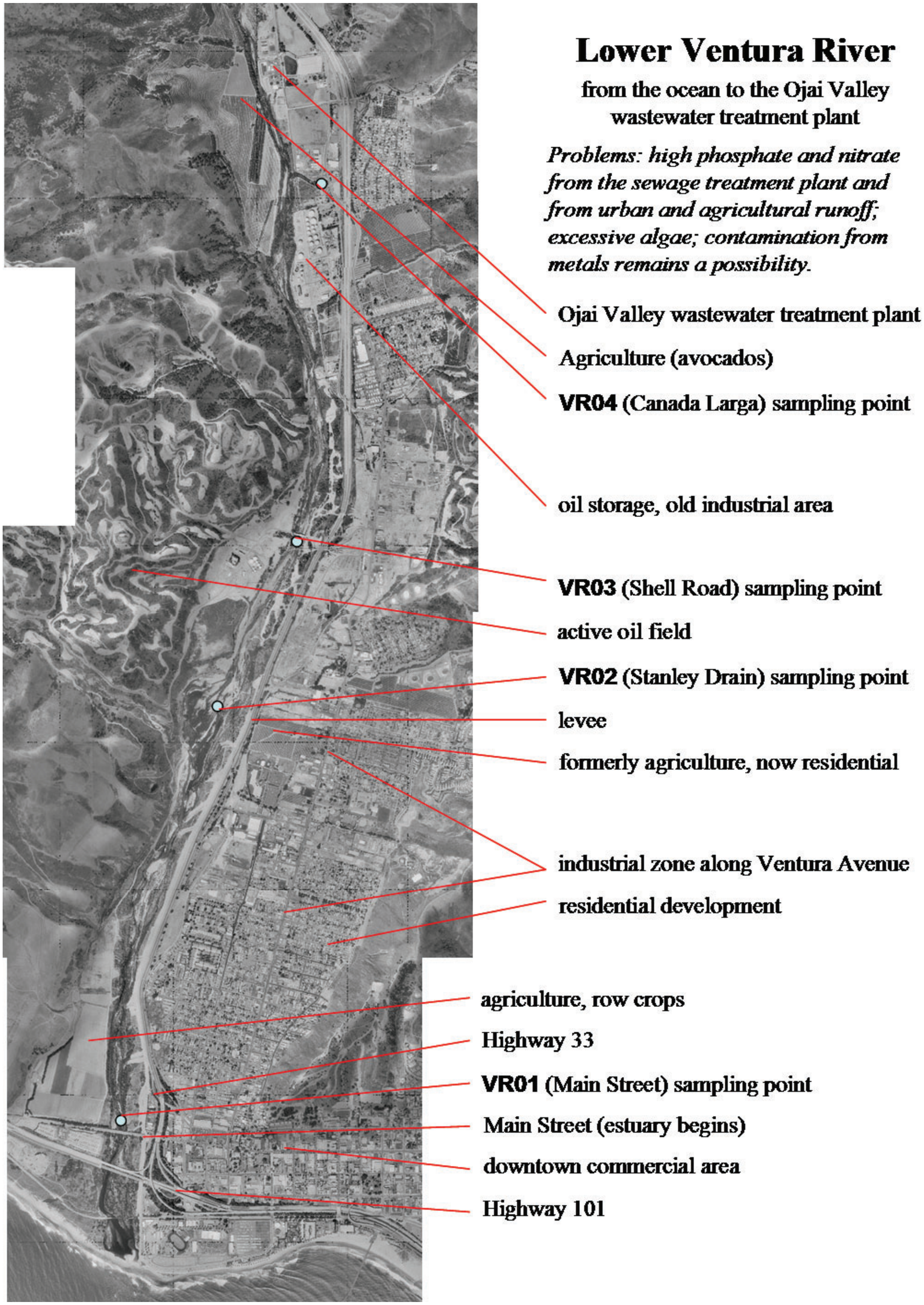
from Highway 150 to the Matilija sampling points

Problems: the southern section is threatened by increasing development below the Forest Service boundary; the Matilija and its North Fork are the most pristine waters in the Ventura system; excessive algae above the Matilija Dam pool





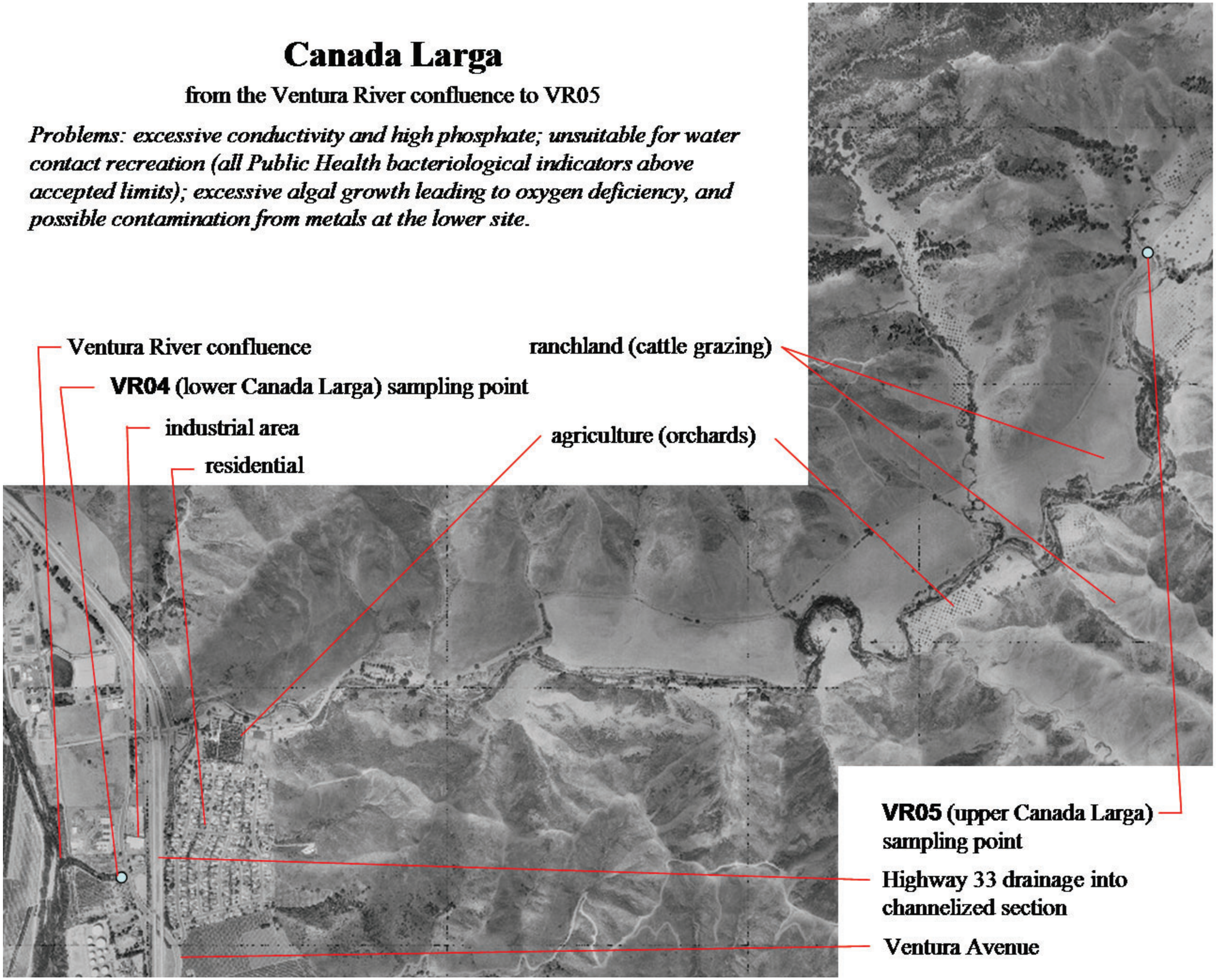
Middle Ventura River
from the Ojai wastewater treatment plant to Highway 150
Problems: high phosphate from suburban development with occasional high nitrate; excessive algae; de-watering from Lake Casitas diversions.
trailer park
VR12 (Highway 150) sampling point
suburban development
suburban development (Live Oak Acres)
VR11 (Santa Ana Road) sampling point
suburban development (Oak View)
tributary streams
VR07 (Lower San Antonio) sampling point
San Antonio Creek confluence
Casitas Springs
VR06 (Foster Park) sampling point
Ojai Valley wastewater treatment plant


Lower Ventura River
from the ocean to the Ojai Valley wastewater treatment plant
Problems: high phosphate and nitrate from the sewage treatment plant and from urban and agricultural runoff; excessive algae; contamination from metals remains a possibility.
Ojai Valley wastewater treatment plant
Agriculture (avocados)
VR04 (Canada Larga) sampling point
oil storage, old industrial area
VR03 (Shell Road) sampling point
active oil field
VR02 (Stanley Drain) sampling point
levee
formerly agriculture, now residential
industrial zone along Ventura Avenue
residential development
agriculture, row crops
Highway 33
VR01 (Main Street) sampling point
Main Street (estuary begins)
downtown commercial area
Highway 101

Canada Larga

from the Ventura River confluence to VR05

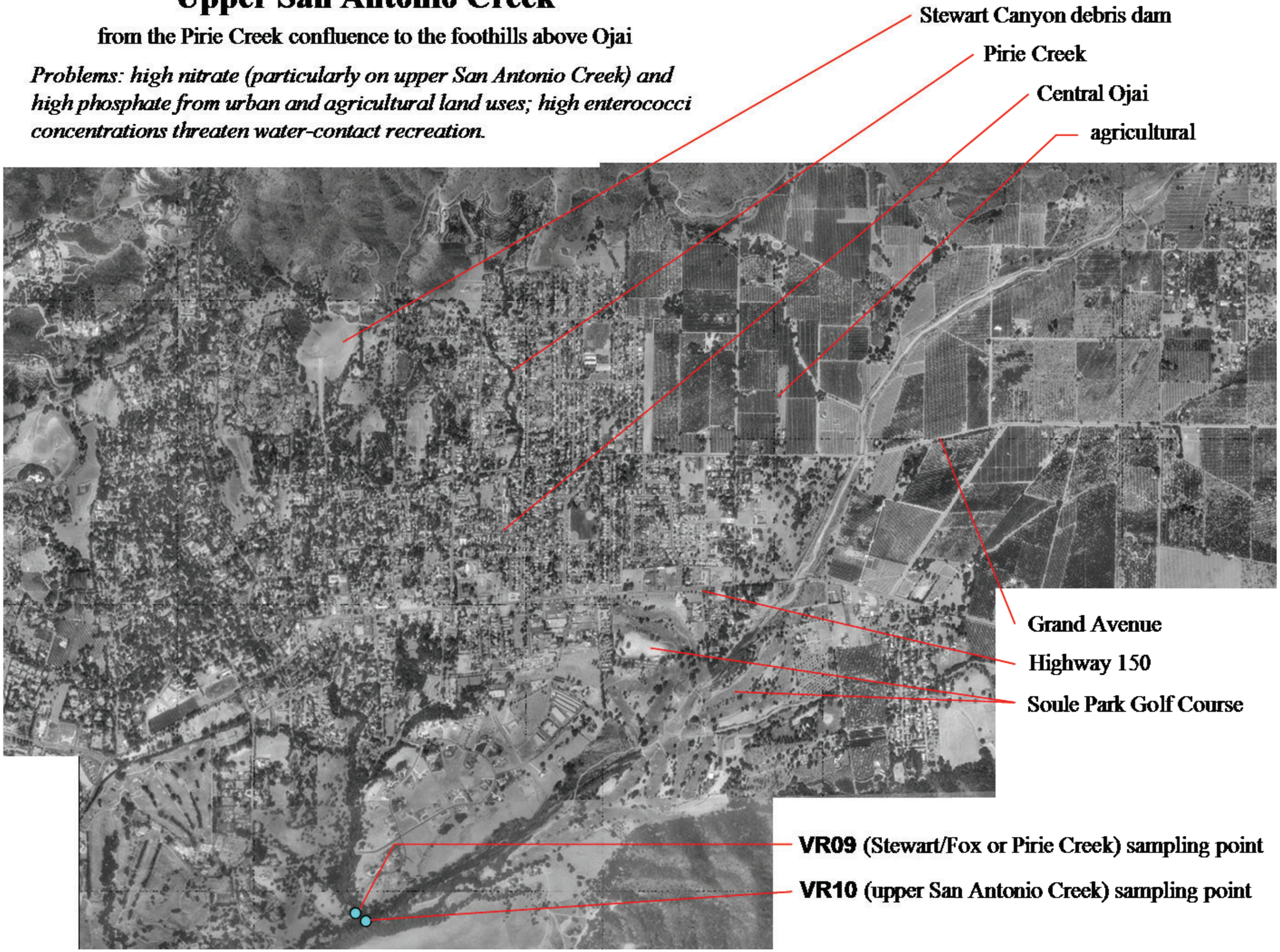
Problems: excessive conductivity and high phosphate; unsuitable for water contact recreation (all Public Health bacteriological indicators above accepted limits); excessive algal growth leading to oxygen deficiency, and possible contamination from metals at the lower site.



Upper San Antonio Creek

from the Pirie Creek confluence to the foothills above Ojai

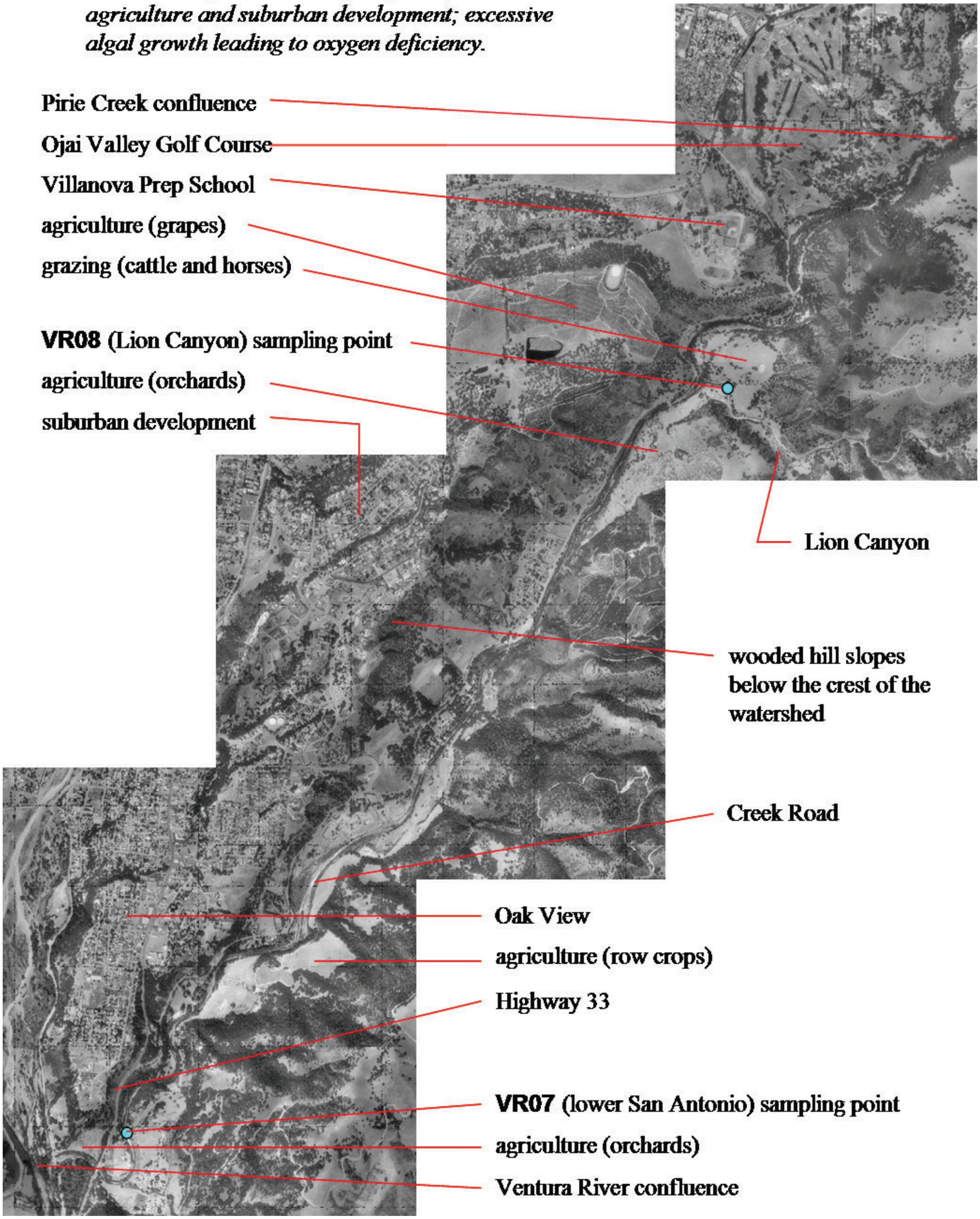
Problems: high nitrate (particularly on upper San Antonio Creek) and high phosphate from urban and agricultural land uses; high enterococci concentrations threaten water-contact recreation.



Lower San Antonio Creek

from the Ventura confluence to Pirie Creek

Problems: high nitrate and phosphate from agriculture and suburban development; excessive algal growth leading to oxygen deficiency.



From 2001-2005, Channelkeeper's Ventura Stream Team has sampled a wide variety of conditions dictated by the annual variation in rainfall. The previous significant rainfall event, the last big flood that reset the transformational cycle seen over the sampling period and described above, occurred during the severe El Niño winter of 1998. Throughout the 2001-2005 sampling period, Ventura Stream Team has observed and documented these changes (SBCK(b)).

Figure 4. The view of the Ventura River looking downstream from Shell Bridge (VR03) on October 2, 2004 (upper) and February 2, 2005 (lower).

Figure 5 shows the variations in both monthly and annual rainfall that have occurred during the study period. Two of the years were slightly above normal (2001 and 2003) and two were below normal (2002 and 2004), one of which could be characterized as a severe drought year (2002). However, 2005 was a special year.

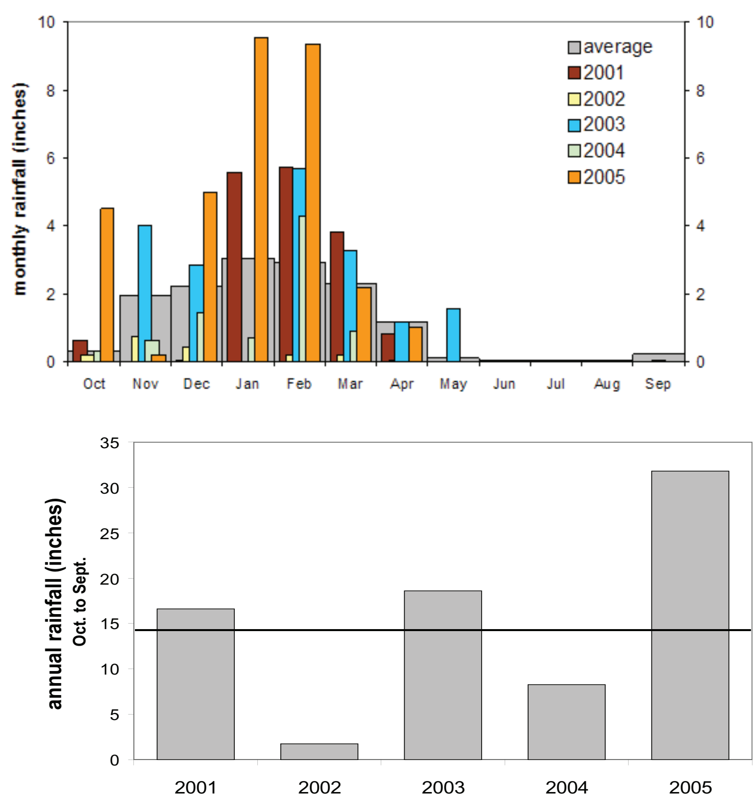


Figure 5. Monthly (upper panel) and yearly (lower panel, for October to September water-years) rainfall for the years of Channelkeeper's Ventura Stream Team surveys. The data is for Oxnard, and 2005 only includes rainfall through April. 2005 was an extraordinarily wet year, with rainfall throughout the region, as of the end of April 2005, varying from 200-250% of the average annual totals (222% in Oxnard, 268% in Los Angeles, 204% in Santa Barbara and 239% at Lake Cachuma). The heavy line in the lower panel represents the average annual rainfall at Oxnard: 14.3 inches.

The 2005 water-year, characterized by weak El Niño conditions in the Pacific, began with expectations of another below-normal rainfall winter. However, in the three weeks following Christmas of 2004, the South Coast was hit with a series of major winter storms delivering impressive amounts of rainfall in two distinct pulses: the first from December 26, 2004, through January 4, 2005, and, after a few days of sunshine, the second from January 7-11, 2005. In Ojai, 10.4 inches were recorded during the first phase and 12.6 inches in the second (Figure 6, upper panel). By the end of January, a total of 28.8 inches had fallen since the beginning of the rainy season, compared with the annual average of 20.9 inches. As storms coming out of the Pacific were uplifted over the coastal mountains, even larger amounts of rain were released - San Marcos Pass received 18.2 and 24.6 inches during the first and second storm pulse, and amounts even greater than this were recorded at Old Man Mountain.

However, as shown in the upper panel of Figure 2, not all years with significantly high rainfall are severe El Niño years. At times, some really wet winters are caused by a much shorter weather cycle of 30-60 days called the "Madden-Julian Oscillation." Simplifying the process greatly, atmospheric high pressure off the Pacific Northwest moves west, allowing a low pressure system to develop offshore, which in turn sweeps heavy moisture from Indonesia into Southern California. This type of weather system is often called a "pineapple express," as the moisture plume passes over the Hawaiian Islands en route. This system delivered extraordinary amounts of rainfall in the winter of 2005, rainfall that continued through March and April (Figure 6, lower panel).

The hydrographs in Figure 6 portray how stream flow changed with time. The upper panel represents the variation in height of Ventura River water at Foster Park (VR06) during the storms. Stage is simply the term for how high water levels rose at the USGS gauge downstream of the bridge; when the gauge reads 2.5 feet, the river is flowing at a trickle. The chart also shows hourly Ojai rainfall.

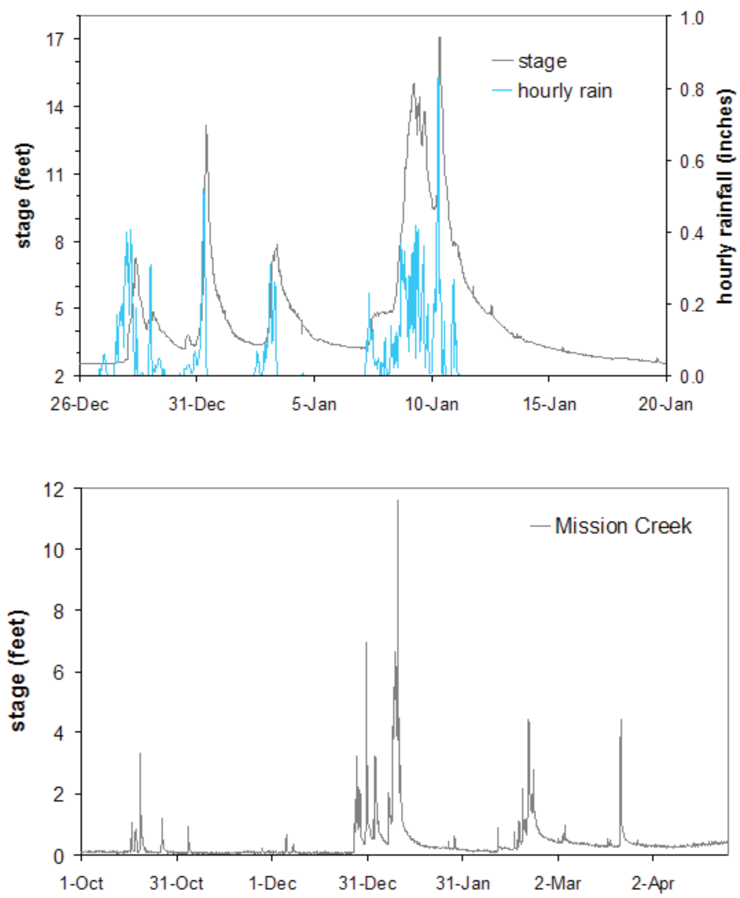


Figure 6. Upper panel: Stage (river height) on the Ventura River (at Foster Park, VR06) and hourly rainfall (Ojai) during the Christmas 2004 series of winter storms. Lower panel: Stage during the winter of 2005 at Mission Creek (Santa Barbara).

The river reacted rapidly to changes in rainfall. This is what is meant by the term "flashy" – water levels are quick to rise and quick to fall. The Ventura River is relatively short and steep, and thus flashy. The USGS has not as yet formally issued flow data for this gauge, because discharge during the storm rose above previous measurements and re-arranged the channel bottom, but the current estimate for peak flow on January 11, 2005, is 152,000 cfs, equivalent to a wall of water 15 feet high and 400 feet wide, moving at 18 miles per hour.

Figure 6 (upper panel) also shows a greater delay between rainfall and the river's response at the beginning of the storm period than at the end. It also shows a proportional increase in the amount of runoff per inch of rainfall during the latter half of the storm period (noticeably increased runoff from similar amounts of rainfall). The coastal mountains tributary to the Ventura River contain a thin but highly porous layer of soil. This layer acts like a sponge during the first storms of the season, absorbing rainfall and limiting the amount of flow that comes from higher elevations. But when these soils become saturated, they deliver copious amounts of runoff to the valley below, and mountain rainfall becomes the primary cause of flooding on the coastal plain. Twenty-three inches of rain fell during the period shown on the graph, but only about six inches of this rain flowed down the river, most of it during the second storm pulse.

The lower panel of Figure 6 shows the stage hydrograph for Mission Creek (in downtown Santa Barbara, UCSB-LTER) during the entire 2005 rainy season.[6] It demonstrates that large storms continued throughout February and March (with occasional rainfall as late as May), making 2005 one of the wettest rainfall years on record. Rainfall throughout the region varied between 200-250% of the annual average.[7] The 2005 water-year is now officially the second wettest year in the century and a half record of Los Angeles weather. Thus, 2005 became the new transformational year; the year that begins the cycle anew.

Foster Park (VR06) during the January 2005 storm.

RESULTS

Conductivity[8]

Water is one of the most efficient solvents in the natural world, with the ability to dissolve a great many solids. Many of these solids carry an electrical charge when put into solution. For example, chloride, nitrate and sulfate carry negative charges, while sodium, magnesium and calcium have positive charges. These dissolved substances increase water's conductivity – its ability to conduct electricity. Therefore, measuring the conductivity of water indirectly indicates the amount of total dissolved solids (TDS) in solution. It is not a perfect measure because some dissolved substances, particularly organic compounds such as alcohol or sugar, are very poor conductors. Each stream tends to have a relatively consistent range of conductivity that, once established, can be used as a baseline for future comparisons. Conductivity tends to decrease in winter when heavy rainfall and runoff increase the amount of fresh, lower-conductivity water entering the river. With increased flow, mineral concentrations typically become more dilute. Conversely, in late summer and fall, especially during periods of drought, high evaporation rates cause dissolved solids to become more concentrated, raising conductivity.

Conductivity is affected by temperature: as temperature rises, conductivity increases. For this reason, conductivity is usually reported at a standard temperature: conductivity at 25 degrees Celsius (25°C). The basic unit of measurement is the siemen. Conductivity is measured in micro-siemens per centimeter (μS/cm) or milli-siemens per centimeter (mS/cm). Distilled water has a conductivity in the range of 0.5-3 μS/cm. The conductivity of rivers in the United States generally ranges from 50-1,500 μS/cm. Drinking water typically must meet a standard of 1,000 mg/L total dissolved solids, and a maximum conductivity not to exceed 1,600 μS/cm.

A volunteer tests conductivity at VR01.

Conductivity in the Ventura River is often above 1,000 μS/cm because of the high and readily dissolved mineral content in the loosely consolidated marine sediments that form the coastal mountains of the upper watershed. In spite of the 1,600 μS/cm drinking water limit, high conductivity waters are not necessarily unhealthy ecologically. As long as there are acceptable reasons for higher values, as there are in this case, high conductivity is not necessarily associated with increased pollution.

Conductivity, everything else being equal, generally increases with the age of water – the longer water is in contact with soil or geologic strata, the higher its conductivity. Groundwater has higher conductivity than water in the soil, and older groundwater has higher conductivity than younger.

In the Ventura River, Ventura Stream Team observed a long-term trend towards increasing conductivity until the winter of 2005 (Figure 7, summarized in Figure 8). The increasing trend (SBCK, 2004) was caused by increasingly depleted and generally older groundwater inflows, enhanced uptake by growing riparian vegetation, and a relative increase in evaporation as dry-season river flows continually diminished since the last year with significantly high rainfall (the high El Niño rainfall of 1997-98).

Evidence of lower groundwater inflows to the river is shown in Figure 9. The lower panel displays the "relative" amount of dry-season flow for the big El Niño year of 1998 and every year since, or, in other words, the average amount of water flowing in the river from April to September for every inch of rainfall that fell the previous winter (USGS-NWIS). Since almost no rain falls during this period, river flow is a direct indicator of groundwater input, and an indirect indicator of the height of the groundwater table.

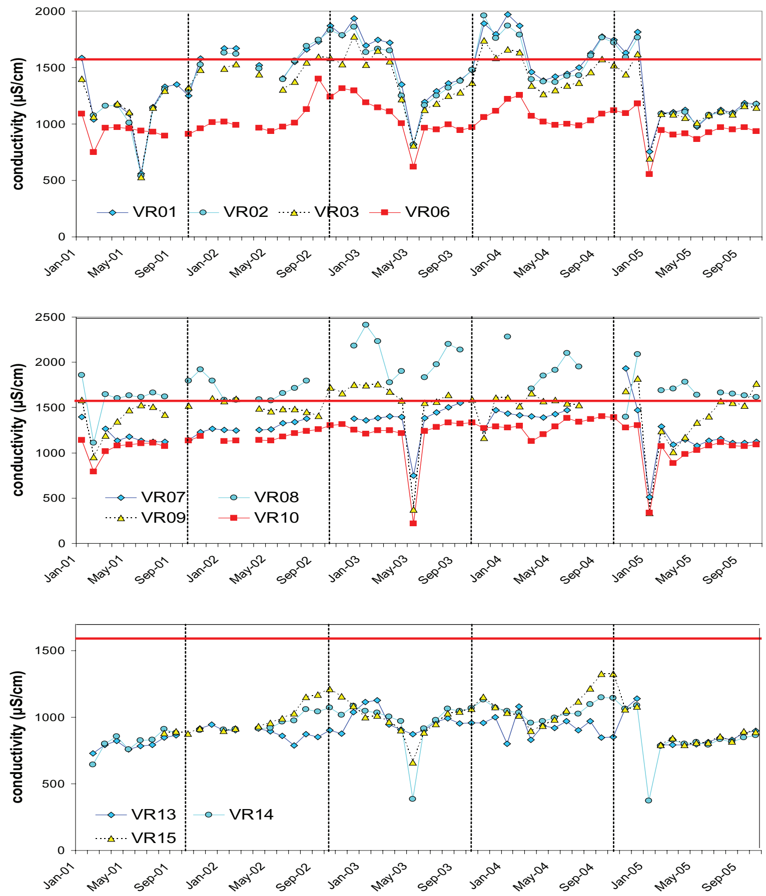


Figure 7. Conductivity, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The overall trend indicates a gradual increase until the significant rainfall of the winter of 2005; very low values usually mark storm events (or, in some cases, meter error). The bold horizontal line indicates the typical 1,600 µS/cm drinking water limit.

In 1999, flow remained high despite low rainfall (9 inches vs. an average annual rainfall of 14.3 inches in Ventura). This high flow was a carryover from heavy El Niño rainfall in 1998 (37 inches) and an almost total loss of riparian vegetation due to flood scouring of the river bottom. Although total summer flows increased in 2000 (upper panel), there was much less discharge than might have been expected from above average rainfall (19 inches), and the ratio of flow to rainfall continued to decrease. Only in 2001, another above-average year with 17 inches of rain, did the relative flow increase. Flows in 2004 were as low as they were in 2002, a year with almost no rain (less than 2 inches).

In 2005, the situation abruptly changed. The advent of a year of significantly high rainfall (rainfall of 36.2 inches in Ojai) caused a dramatic increase in dry-season flows. The increased flows are the result of a higher water table and increased groundwater inflows into the river and its tributaries. The flows shown in Figure 8 were measured at the USGS gauging station at Foster Park (USGS-NWIS). This is a good location for evaluating groundwater conductivity; just upstream of the sampling site a seam of bedrock and a concrete weir below the riverbed force deep groundwater to the surface, ensuring year-round flow. Since the river is usually dry above this section, summer flows at Foster Park are a good measure of groundwater input.

In Figures 7 and 8, the conductivity trend for Foster Park (VR06) is upward, but it is weaker than the trend at other, higher elevation locations, such as the North Fork of Matilija Creek (VR14). The occasional sharp dip in the trend indicates a sample taken during, or shortly after, a storm. Recent rain dramatically lowers river conductivity, since rainfall is about as young as water gets, with a conductivity in the Ventura area around 20 µS/cm. Even though conductivity increases as runoff moves by various pathways to the river, it still remains much lower during storms. All sites show the drop in values measured during the storm of May 3, 2003.

The four-year pattern of rising conductivity showed a sudden change with the arrival of the January 2005 storms. The January 2005 measurements were made during the early stages of a major storm and exhibit the low values expected during rainfall. However, low values, in many cases lower than seen during 2001, continued into April and May and beyond. High river levels, caused by increased flows from higher elevations (which generally have lower conductivities) and increased inputs from a water table replenished with recent, lower conductivity, runoff generally have lower conductivities.[9]

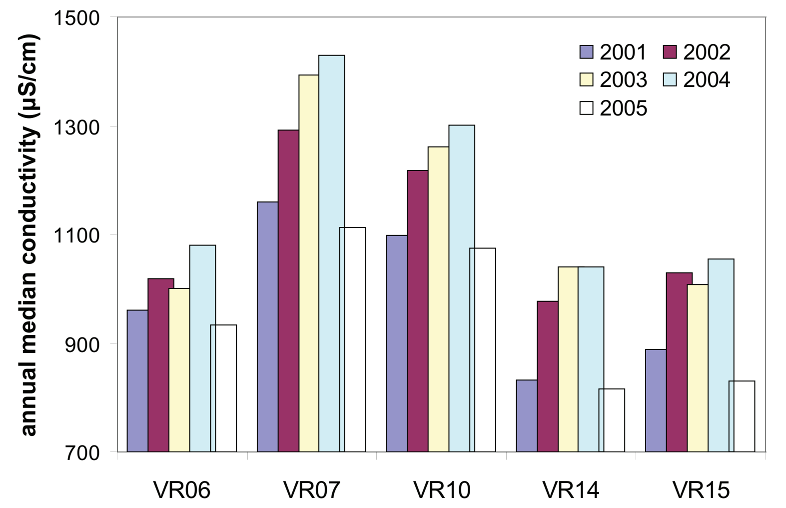


Figure 8. Changes in annual median conductivity for Ventura Stream Team sampling sites with relatively natural, year-round flows, 2001 to 2005. There has been a consistent increase in conductivity over the initial four years of sampling, with the occasional exception of the 2002 drought year (possibly due to a relative increase in evaporation of the extremely low flows of that year). The percent increase from 2001 to 2004 has been 12, 23, 19, 25 and 19 for VR06, VR07, VR 10, VR14 and VR15, respectively. However, in 2005, conductivity abruptly decreased by 20% throughout the Ventura River system.

The conductivity results are summarized in Figure 10. Only three sites show median conductivity levels that exceed the 1,600µS/cm drinking water limit: VR04, 05 and 08. These sites are heavily impacted by cattle grazing and have very low flows prone to evaporative concentration.

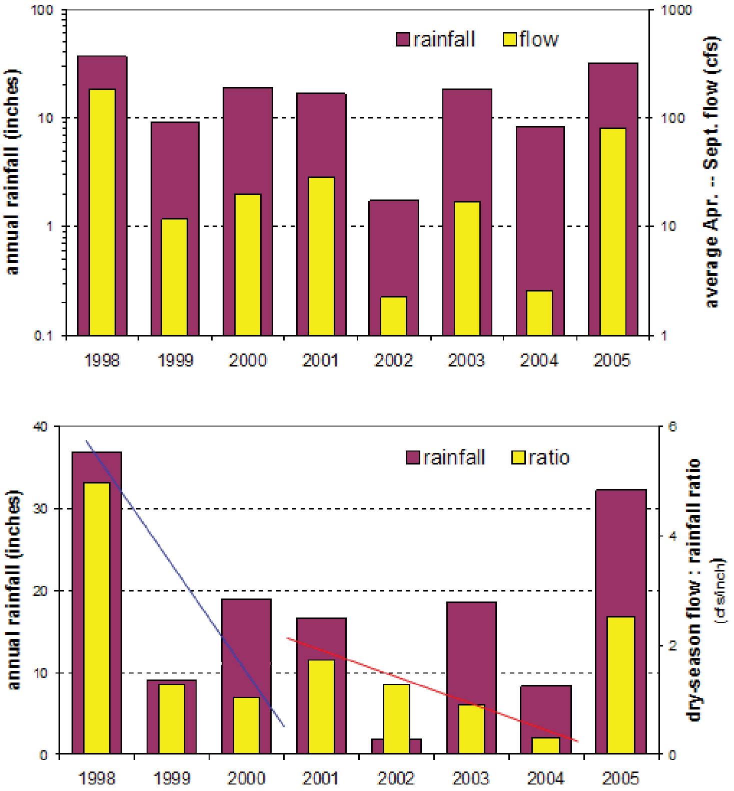


Figure 9. In the upper panel, annual rainfall (Oxnard) is plotted for the severe El Niño year of 1998 and every year since, and average April to September flow is shown on the right-hand axis. Rainfall is again plotted in the lower panel, but the right-hand scale now shows the ratio between average April to September flow and rainfall, e.g., the average dry-season flow divided by the previous winter's rainfall. The bold lines show the trend towards less flow per inch of rain as we get further from a large El Niño; it required two years of above average rainfall (2000 and 2001) to partially recover from low rainfall in 1999. In 2004, river flow was as low as in 2000, in spite of approximately five times the rainfall.

Temperature

Temperature is the simplest parameter measured, yet one of the most important. The expected annual pattern is straightforward: temperature rising from winter lows to summer highs, and then decreasing in early fall, paralleling seasonal changes in air temperature. On the Ventura River, that pattern is observed at all sites (Figure 11).

The temperature graphs include three horizontal lines, which mark important threshold temperatures for steelhead trout: above 24°C leads to death; below 16°C indicates good dry-season conditions, and below 11°C in winter provides ideal conditions for spawning and incubation (Brungs and Jones, 1977; Armor, 1991; McEwan and Jackson, 1996; Sauter et al., 2001). As temperatures rise, fish have increasing difficulty extracting oxygen from water, while at the same time the maximum amount of oxygen able to be held in solution decreases.

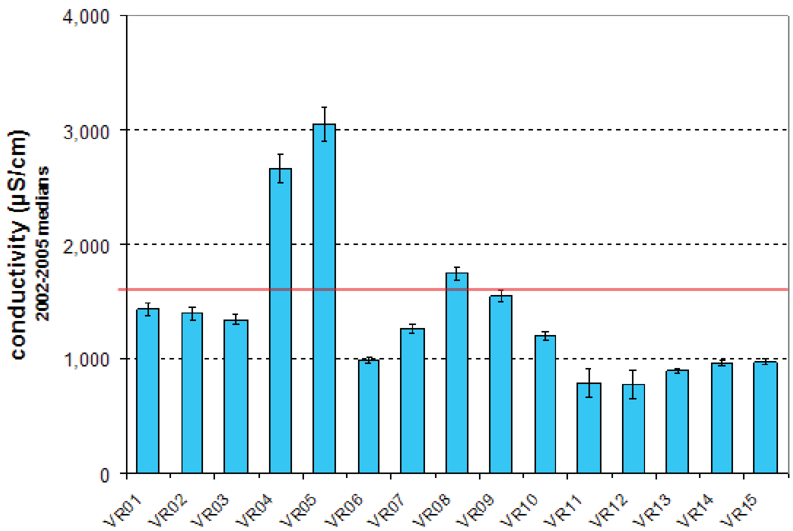


Figure 10. Median conductivity values, January 2001 to October 2005. The "error bars" indicate the standard error of the median. The solid line represents a generally accepted upper conductivity limit of 1,600 µS/cm for drinking water. VR04, 05 and 08 are heavily impacted by cattle grazing and have very low flows prone to evaporative concentration.

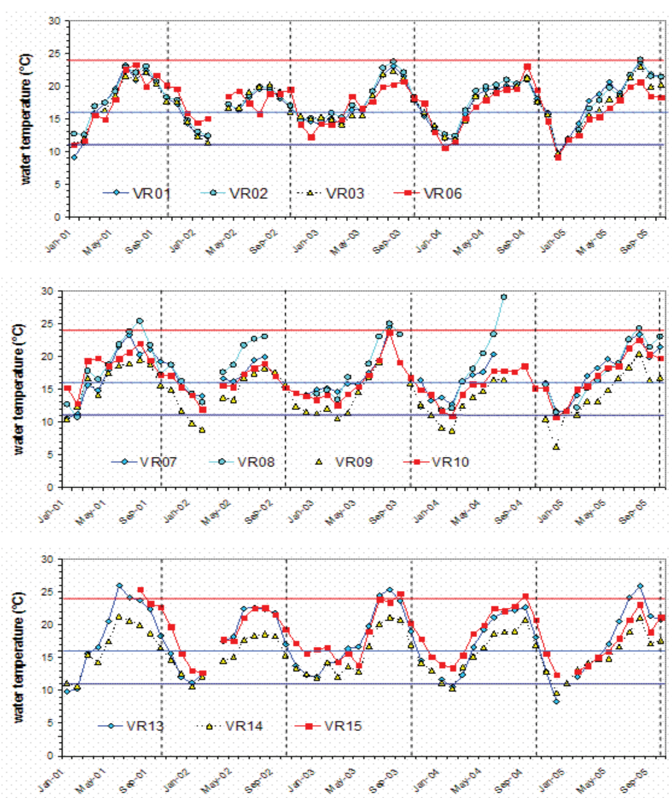


Figure 11. Stream temperature, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The three horizontal lines mark important steelhead temperature milestones: above 24°C leads to death; below 16°C indicates good dry season conditions; and below 11°C is excellent for spawning and incubation.

Consideration of the conditions necessary for good steelhead habitat are often used as water quality criteria in this report, since water good enough for steelhead is very good water indeed, and since a widespread return of these symbolic fish to the South Coast is a popular enthusiasm (NMFS, 1996). This does not mean that steelhead are present at all sampling locations (although a small resident population still survives in the Ventura River), nor that they would return or increase in numbers if water quality were good enough. Other questions such as water availability and fish passage are equally, if not more important. However, water meeting criteria for steelhead can be considered high quality water.

While the temperature requirements for steelhead are rather stringent, warm-water fish have greater tolerance for higher temperatures. Channelkeeper's Ventura Stream Team data show that temperatures occasionally increase above 24°C in late summer and rarely drop below 11°C in winter. Many of the sites that exceed the 24°C limit, such as

VR08, VR13 and VR15, are subject to shallow flow conditions and high exposure to sunlight in the summer. Reasonable departures from these criteria are likely not a vital concern; southern steelhead evolved in what are essentially warm-water rivers and streams, and undoubtedly have greater tolerance for higher temperatures than their more northern cousins. Furthermore, fish are not passive participants, but are free to seek out more favorable conditions (Matthews and Berg, 1997; Stoecker, 2002).

It is interesting that the lower river sites (VR01, VR02 and VR03, upper panel) have lower summer temperatures than elsewhere, lower even than those seen on the Matilija (VR13-15, lower panel). This is due to inflows from the Ojai sewage treatment plant. Deeper water is usually cooler water, and higher flows on the lower river keep temperatures lower, even though the river is at a lower elevation and more exposed to sunlight.

Dissolved Oxygen

Aquatic organisms rely on the presence of oxygen in streams; not enough oxygen and they will relocate, weaken or die. On land, oxygen makes up 20% of the surrounding atmosphere, whereas in water, oxygen is a dissolved gas with a maximum concentration of about 16 parts per million (a maximum of 0.0016 %) - not at all plentiful. Water temperature, altitude, time of day, and season all affect the amount of oxygen in the water. Water holds less oxygen at warmer temperatures and higher altitudes. Dissolved oxygen (DO) is measured either in milligrams per liter (mg/L) or "percent saturation."[10]

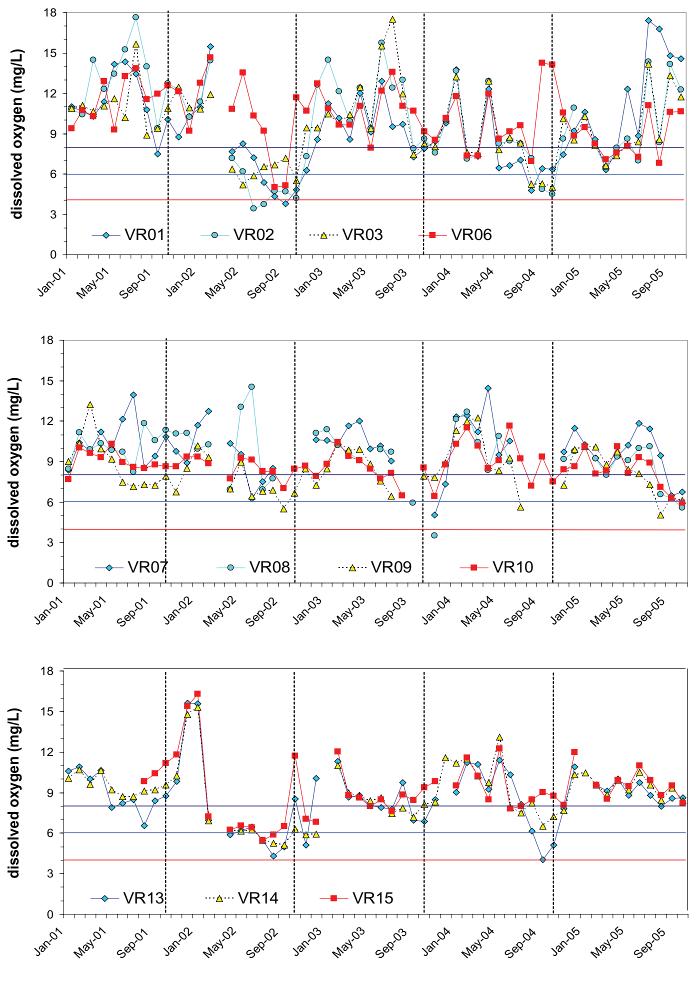


Figure 12. Dissolved oxygen, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The three horizontal lines mark important DO milestones for steelhead: above 8 mg/L represents near ideal conditions; at 6 mg/L hypoxia begins and fish start to feel stress; and below 4 mg/L lies severe damage and death.

When dissolved oxygen levels in water drop below 5 mg/L, aquatic life is put under stress. Cold-water fish (trout and steelhead) need levels above 6 mg/L, and DO above 8 mg/L may be required for spawning (Davis, 1975; EPA, 1986; Bjornn and Reiser, 1991; Deas and Orlob, 1999). Warm-water fish can tolerate levels as low as 4 mg/L. The lower the oxygen concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills.

The DO trends on the Ventura River are shown in Figure 12. As for temperature, three important benchmarks are shown as horizontal lines: above 8 mg/L represents near ideal conditions; at 6 mg/L hypoxia begins and fish begin to feel stress (but no lasting harm is done in the short term); and below 4 mg/L lies severe damage and death.[11] At first glance, river conditions look fine: very few samplings indicate DO concentrations below 3 or 4 mg/L, and even readings below 6 mg/L are relatively rare. Although no clear annual pattern emerges, there are noticeable differences between years, with lower summer concentrations in 2002 and 2004 for both the lower river and Matilija locations. Lower flows in these two years,

A volunteer tests dissolved oxygen at VR13.

and the absence of algae, account for this decrease. As flows drop, streams become more sluggish and there is both less opportunity for water to entrain oxygen through re-aeration (e.g., riffles and cascading white water) and more time for aquatic species and biochemical processes to extract oxygen.

However, there are potential problems that are not immediately apparent. Ironically, very high DO concentrations can indicate problems. Ventura Stream Team sampling takes place during daylight. While the sun is out, algae and underwater aquatic vegetation photosynthesize, removing carbon dioxide from the water column and replacing it with oxygen. This process is reversed at night, when oxygen is removed and carbon dioxide added (Carlsen, 1994; NM-SWQB, 2000). Thus very high daytime oxygen concentrations can indicate an overabundance of algae. Under these conditions, oxygen falls to a minimum just before sunrise, and it is concentrations during this critical period that determine the actual threat to fish and other aquatic species, a threat that is usually not evaluated but should be (Windel et al., 1987; Deas and Orlob, 1999; PIRSA, 1999). Notice that in Figure 12 the relatively pristine Matilija sites (lower panel) show the least overabundance of oxygen.

The absence of an annual DO pattern mentioned earlier is another cause for concern. Oxygen has a greater solubility in colder water, and as temperature increases, DO should decrease, and vice versa. If DO and temperature are plotted on the same graph, they should appear roughly 180° out of phase, one rising as the other falls. To demonstrate, both DO and temperature are plotted for three sites in Figure 13. Note the absence of this expected variation at VR06 (upper panel, Foster Park), where both parameters have similar patterns. This is evidence of algal dominance, where warmer, more sluggish summer waters produce high daylight DO concentrations. There is an opposing DO and temperature pattern at VR13 (lower panel, Matilija Creek, one of the most pristine sites sampled), indicating minimal influence from algae. The middle panel (VR10, upper San Antonio Creek) shows a combination of both patterns, indicating a possible algal problem in late summer or early fall, but low algal growth during the rest of the year.

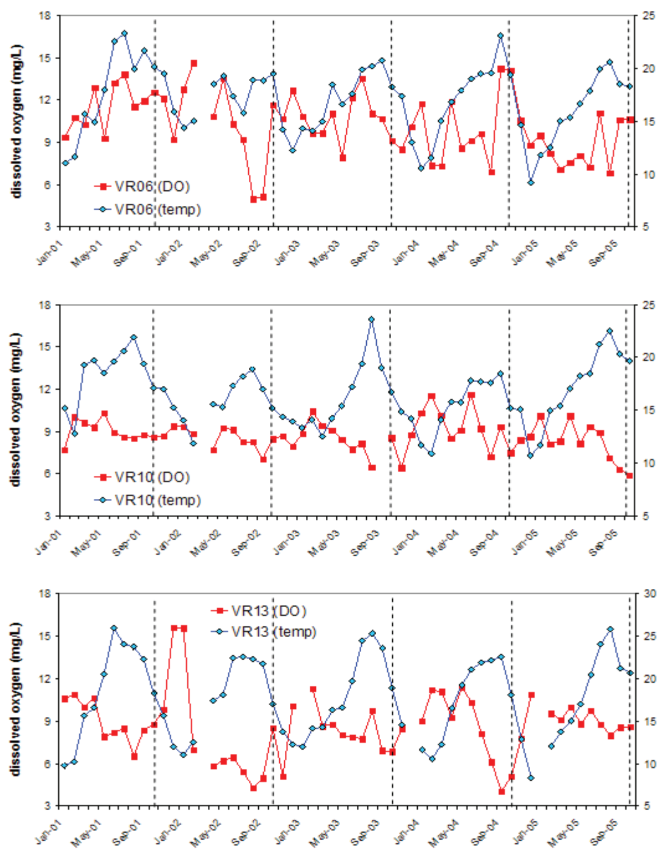


Figure 13. Dissolved oxygen and temperature for three sampling locations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. Under ideal conditions, as temperature rises DO should fall, and vice versa. The absence of this pattern in the upper panel indicates problems with algae.

A DO meter also measures percent saturation, the amount of DO compared with what water at the measured temperature and altitude can hold at equilibrium.[12] These data (Figure 14, summarized in Figure 15) confirm the summer problem with algae in the lower river and at some Group II sites. Typically, a DO concentration in excess of 120% of saturation is a good indicator of algal problems.[13] Finally, we can summarize both the DO and temperature results by showing the mean, minimum, and maximum measured values at each location (Figure 16).

The winter storms of 2005 created ideal conditions for extravagant algal growth on the Ventura River during the summer dry season. The river is open to sunlight, vegetation has been removed (lessening competition), sediment has been flushed leaving a rocky bottom (the ideal substrate for most problem-causing algal species in the area), insect predators have been swept out to sea by winter floods, and nutrients are relatively plentiful. During the April 2005 sampling, and for months afterwards, exces-

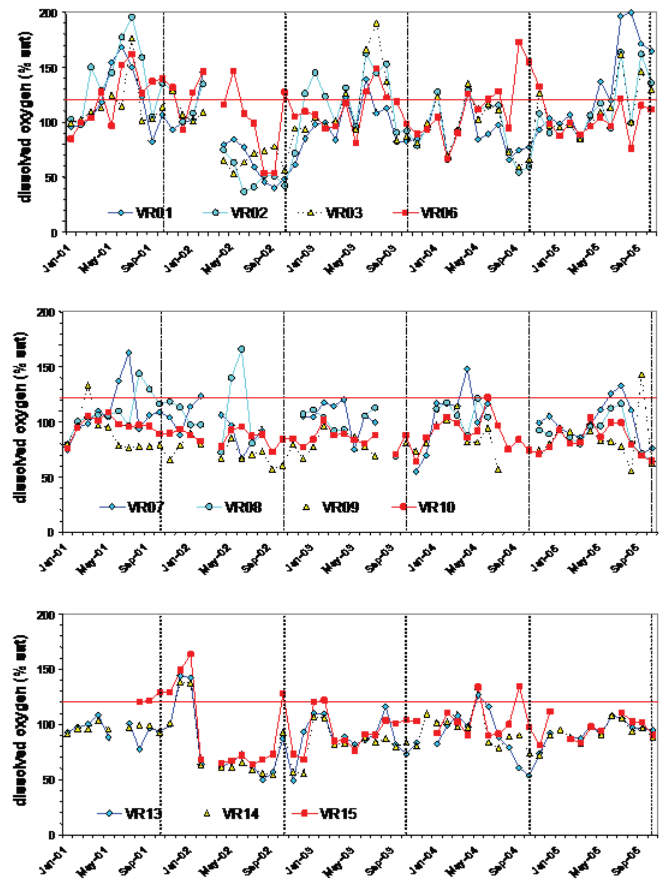


Figure 14. Dissolved oxygen measured in percent saturation, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. Concentrations above 120% saturation (horizontal line) usually indicate problems with algal growth; over-saturation during daylight followed by depleted concentrations at night.

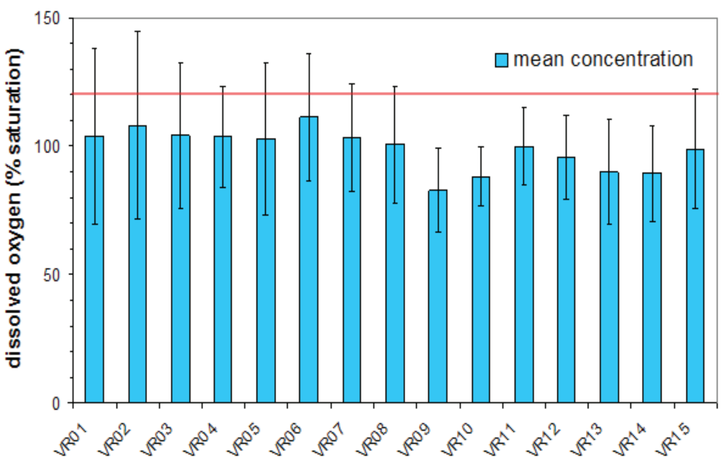


Figure 15. Mean dissolved oxygen (in percent saturation) values, January 2001 to October 2005. Concentrations above 120% saturation (horizontal line) usually indicate problems with algal growth; over-saturation during daylight is followed by depleted concentrations at night. The error bars indicate ± the standard deviation of sampled concentrations at each site (e.g., 67% of the monthly samples will have values between the error bars). Locations from VR01 to VR08, and VR15, have periodic problems with algae.

sive amounts of algae were recorded at every location. However, excessive concentrations of day-time dissolved oxygen were relatively rare, with major exceptions at the lower Ventura River and San Antonio Creek (Figure 14).

Relatively deep flows containing large amounts of high-quality upper catchment waters lessened the adverse impact of the algal bloom. But algal growth on the Ventura River often undergoes two or three cycles over the course of the dry season. Our expectation was that the peak of the last cycle, when water levels would be much lower and temperatures higher, would create the most critical oxygen situation. Fortunately this did not happen. The dominant alga in the Ventura system, Cladophora, made only a single appearance, and oxygen problems were not as severe as expected, the exception being a heavy growth of diatoms keeping lower river concentrations abnormally high into the fall (particularly at VR01, Figure 14).

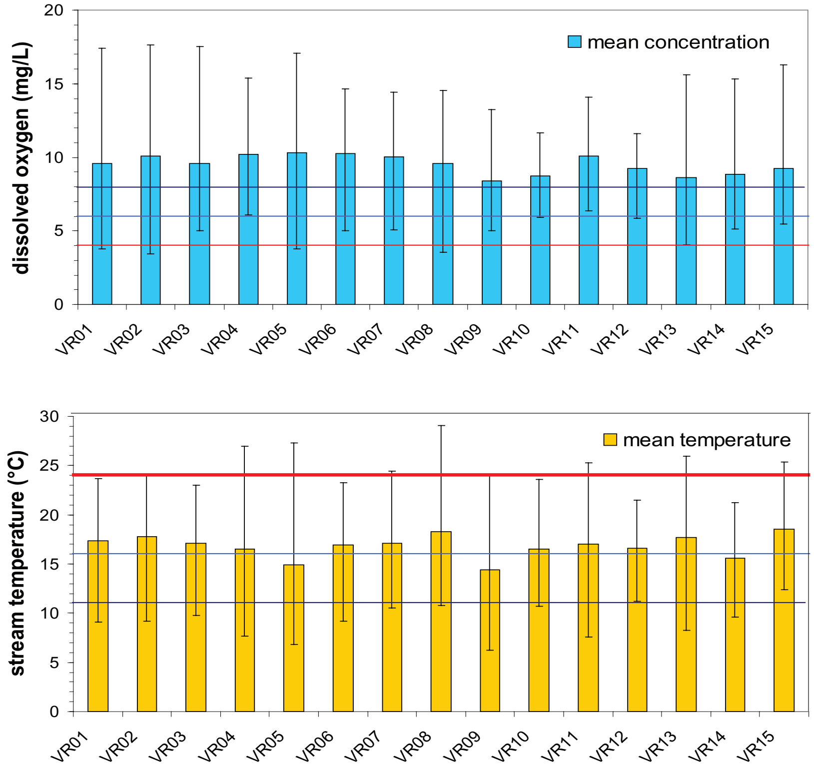
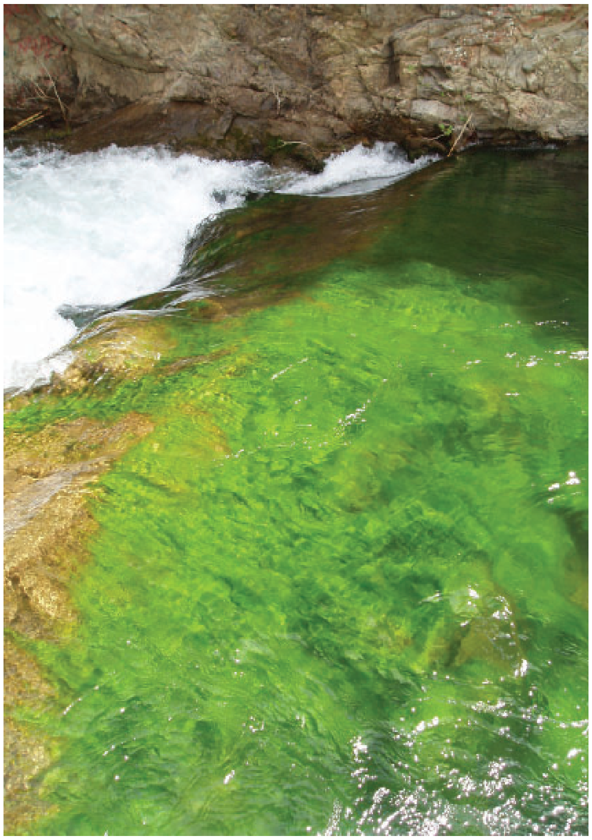


Figure 16. Upper panel: Average dissolved oxygen, January 2001 to October 2005. The three horizontal lines mark the important DO milestones for trout and steelhead explained in Figure 12. Lower panel: Average stream temperature, January 2001 to October 2005. Above 24°C leads to death; below 16°C indicates good dry season conditions; and below 11°C is excellent for spawning and incubation. The "error bars" represent the maximum and minimum measured values. Extreme values become critical at locations with measurements below (for DO) or above (for temperature) the bold line. As stressed, night-time oxygen depletion at sites with significant algal growth remains largely unknown, a complete evaluation of DO conditions on the river depends on collecting this data.



Following the large winter storms of 2005, even relatively pristine sites such as VR13 contained excessive amounts of algae.

Turbidity

Turbidity is a measure of the amount of sediment in the water column, and sediment has both long- and short-term effects on steelhead and other fish (Sigler et al., 1984; Newcombe and MacDonald, 1991; ODEQ, 2001a, 2001b). Over the long term, sediment settles on the bottom and fills the interstices between streambed gravel and rocks, decreasing the amount of desirable habitat for spawning and for the insects that fish feed upon. Over the short term, turbidity reduces the ability of fish to see and feed. Water quality begins to be degraded by suspended sediment somewhere between turbidities of 3-5 Nephelometric Turbidity Units (NTU), and above 25 NTU, impacts on steelhead and other trout begin to be noticeable. These limits should be considered applicable only during the dry season and periods between storms. During storms in the Ventura area, these limits become meaningless as local suspended sediment concentrations reach tens of thousands of milligrams per liter - turbidity readings in the hundreds of thousands if turbidity meters were capable of reading that high. Fortunately, on the Ventura River, turbidities rapidly drop soon after the end of rainfall and return to near-background levels within three to seven days of a storm.

Turbidity results are shown in Figure 17. Normally, readings are below 5 NTU, but if sampling is done during or soon after a storm, they reach into the hundreds and often far higher - above the ability of Channelkeeper's meters to record a value. The horizontal lines on the figures represent typical Public Health drinking water limits: less than 5 NTU and no more that 5% of samples greater than 0.5 NTU. As long as it is not raining, Ventura River water usually meets these standards.

Results are summarized in Figure 18. This figure also shows a line for a third typical standard - no higher than 1 NTU for 8 hours. Figure 18 shows median concentrations (the median is a better indicator of "average" conditions than the mean when a dataset is complicated by a few extraordinarily high readings such as we see during storms). The EPA has suggested a turbidity limit of 1.9 NTU for streams in this region, and aside from storms, all of our sampling sites met this criterion. However, VR01 (Main Street Bridge), the site with the highest median turbidity, 1.91 NTU, is right at the limit.

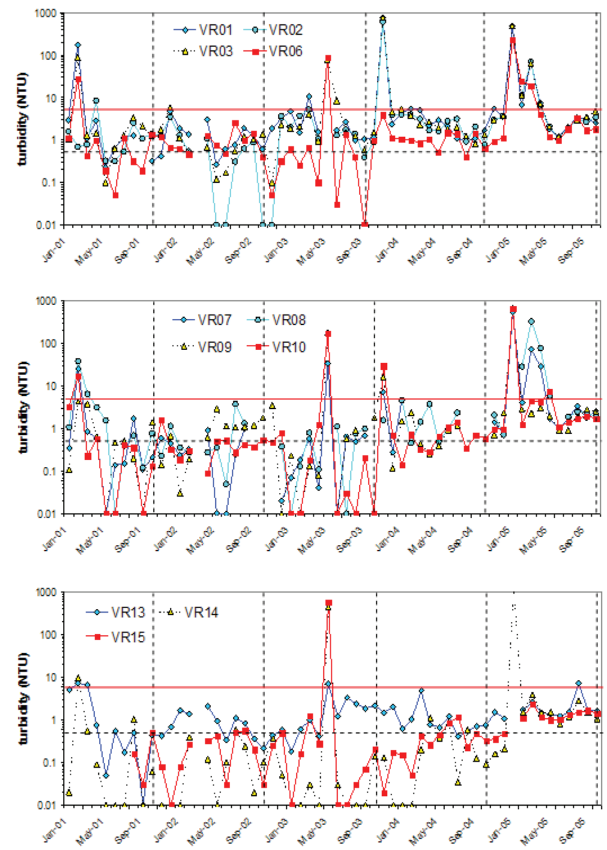


Figure 17. Turbidity, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The two horizontal lines mark Public Health drinking water quality benchmarks: a maximum turbidity of 5 NTU, and no more than 5% of monthly samples with greater than 0.5 NTU.

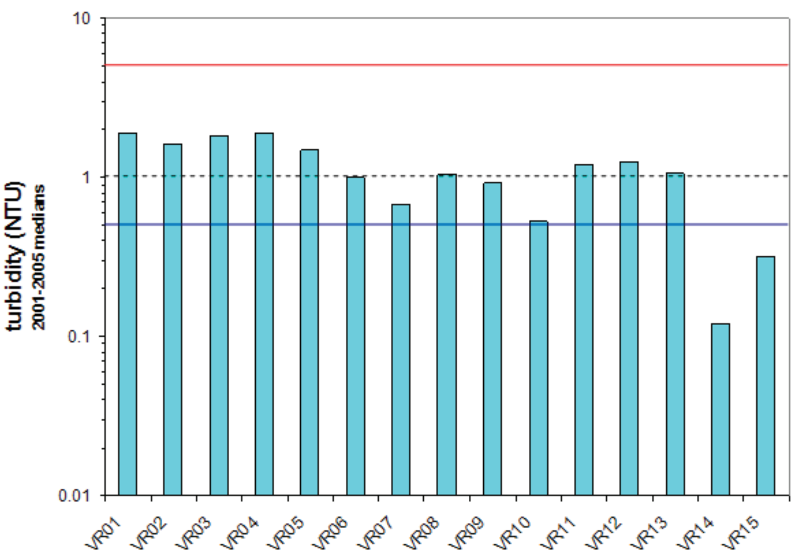


Figure 18. Median turbidity values, January 2001 to October 2005. The three horizontal lines mark typical Public Health drinking water quality benchmarks: a maximum turbidity of 5 NTU; no higher than 1 NTU for 8 hours; and no more than 5% of monthly samples with greater than 0.5 NTU.

pH

pH is a relative measure of acidity and basicity, an expression of the number of free hydrogen atoms present. It is measured on a scale of 1 to 14, with 7 indicating neutral - neither acid nor base. Lower numbers show increasing acidity, whereas higher numbers indicate more basic waters. Blood (pH of 7.5), seawater (9.3) and household ammonia (11.4) are all alkaline or basic; urine (6.0), orange juice (4.5), Coca Cola Classic (2.5) and human stomach contents (2.0) are acidic. pH numbers represent a logarithmic scale, so small differences in numbers can be significant; a pH of 4 is one hundred times more acidic than a pH of 6. All plants and aquatic species live within specific ranges of pH, and altering pH beyond these ranges causes injury or death. Pollutants can push pH toward the extremes, and low pH is particularly dangerous because it allows toxic elements and compounds to mobilize (go into solution) and be taken in by aquatic plants and animals. A change of more than two points on the pH scale can kill many species of fish. The US EPA and

Los Angeles Regional Water Quality Control Board regard a pH change of more than 0.5 as harmful (RWQCB-LA, 1994).

Deciding what is an unsuitable pH is difficult, as there are numerous standards. Fish can tolerate a range of 5-9, but the best conditions lie between 6.5-8.2. The Central Coast Regional Water Quality Board uses a standard of 7.0-8.5 for surface water, 6.5-8.3 for potable water and swimming (RWQCB-CC, 1994). The Los Angeles Regional Water Board uses 6.5-8.5 (RWQCB-LA, 1994), and US EPA recommends 6.5-8.0 as best for aquatic animals. This report uses 8.5 as an upper reference limit since the Los Angeles Regional Water Board establishes the legal standard for the Ventura River.

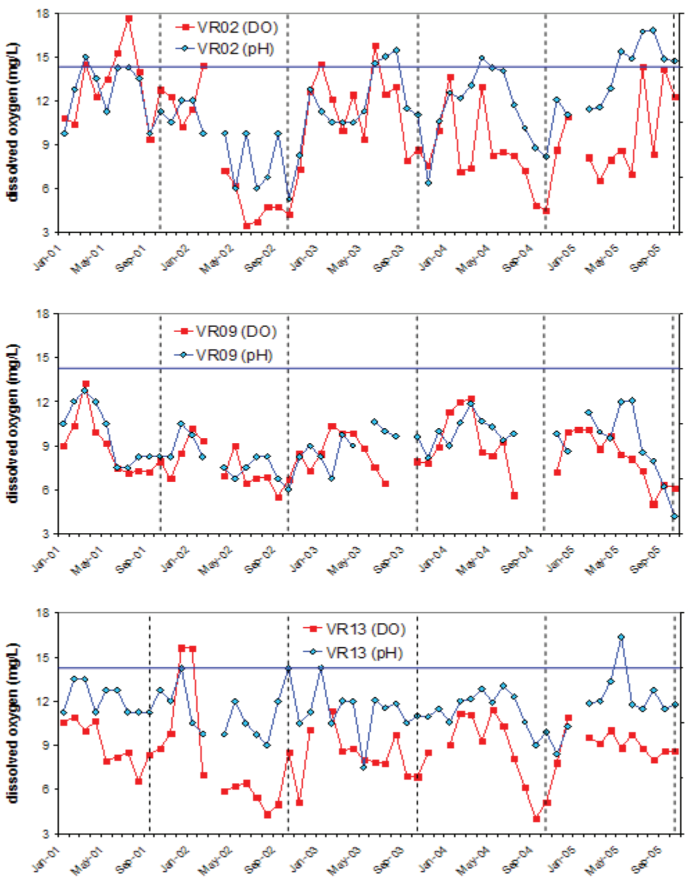


Figure 20. Dissolved oxygen and pH for three sampling locations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year and the horizontal line represents the 8.5 upper pH limit. Ordinarily, pH should bear little resemblance to DO concentrations. However, significant algal growth causes similar patterns in both parameters as carbon dioxide removed from water by photosynthesis (decreasing acidity) is replaced by oxygen.

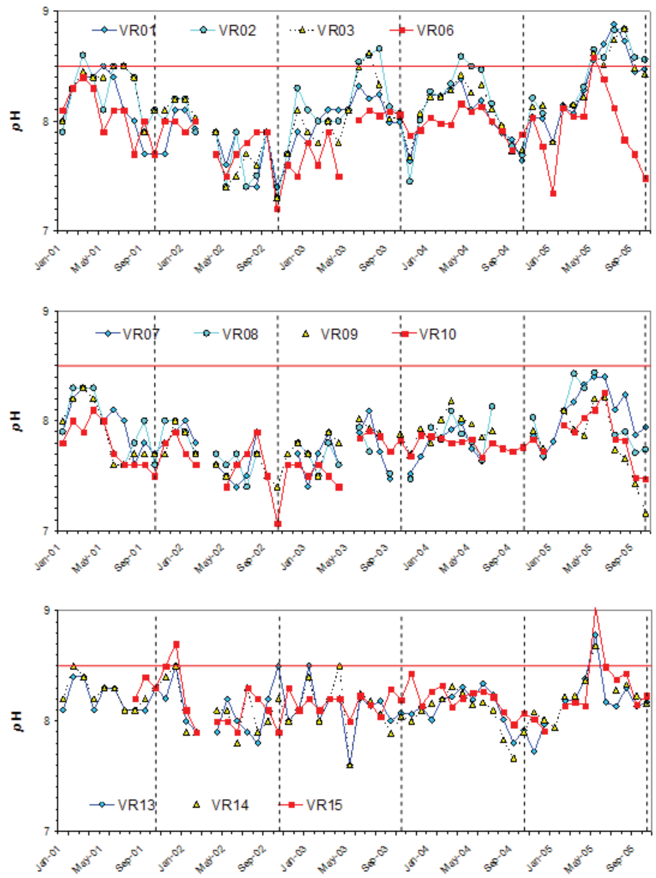


Figure 19. pH concentrations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the Regional Water Quality Control Board's upper pH limit of 8.5.

Figure 19 shows the variation in pH at the Ventura Stream Team sampling locations.[14] There is a pattern in the pH data, best observed on the lower river (upper panel), of lower values occurring around the beginning of the new water-year (and with the start of winter rains), while the highest occur in spring or early summer (June-August 2003 and April-June 2004). This pattern was repeated in 2005, when measurements peaked in July and August. Rain has a lower pH than baseflow in the Ventura and its tributaries,[15] and the first few storms usually lower river values. The spring/summer increase is caused by the same algal and plant growth responsible for increasing daylight concentrations of dissolved oxygen.

Photosynthesis withdraws carbon dioxide from the water at the same time as it releases oxygen. Removing carbon dioxide is the same as removing acidity, thus it increases pH (PIRSA, 1999; NM-SWQB, 2000). Normally, absent this process, we should see little change in pH. The same dissolved minerals that give Ventura waters high conductivity usually "buffer" the river against large variations,[16] but changes in dissolved carbon dioxide are a major exception.

Figure 20 shows the variation in DO and pH at three sampling locations. Similarity in the temporal patterns of these two parameters is an indicator of algal growth, the simultaneous addition of DO and removal of acidity (increasing pH). The removal of acidity by photosynthesis is responsible for most of the very high values seen in the data (Figure 19). The similarity between pH and DO is stronger in some years than in others, such as at VR02 in 2001 and 2002, when larger storms opened the river to greater algal growth. In 2002 there were no high pH values because no storm was strong enough to disturb plant growth at this location.

Were Channelkeeper to sample the Ventura Stream Team locations around the clock, variations in both pH and DO similar to those in the monthly data would occur over a 24-hour period (Figure 21) (cf. Carlsen, 1994; Windell et al., 1987). The variation would be appreciable at sites with algal problems, and relatively muted in locations with normal conditions. Indeed, this kind of testing would be one of the better ways of estimating the extent of eutrophication and algal growth on the river. Although we did not sample around the clock in 2005, pre-dawn dissolved oxygen and pH concentrations were measured on June 2 and July 20, 2005, to track the impact of excessive algal growth at select sites.

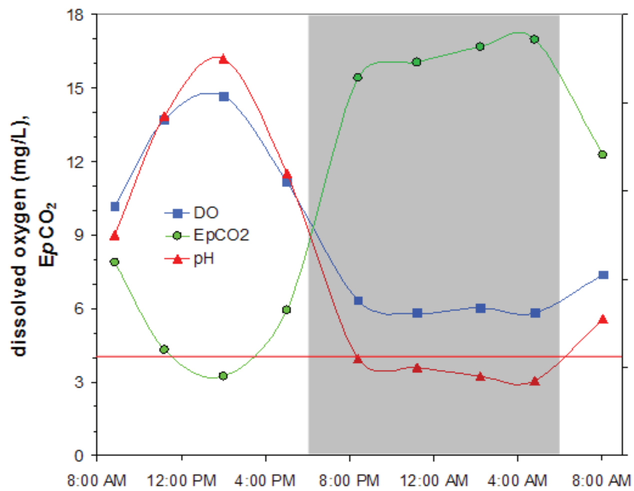


Figure 21. The chart shows results from a 24-hour sampling at Foster Park on September 10-11, 2003. These measurements provide a look at daily (diel or diurnal) changes during an episode of abundant algal growth. The grey area on the chart indicates night-time measurements. Dissolved oxygen changed from a high of 15 mg/L in the early afternoon to a low near 5 mg/L at night. The change in acidity (pH) follows the change in DO, from a high of 8.4 to a low of 7.6. EpCO2 is the ratio of measured CO2 to what would normally be dissolved in water of the same temperature at equilibrium. CO2 varied in opposition to DO and pH, from three times the equilibrium concentration during the day to 17 times greater at night. These changes are caused by algal photosynthesis - the removal of carbon dioxide from water during sunlight in the creation of biomass. During photosynthesis algae generate oxygen, increasing dissolved oxygen concentrations as they decrease CO2. At night, algae respire, reversing the process by removing oxygen and increasing CO2.

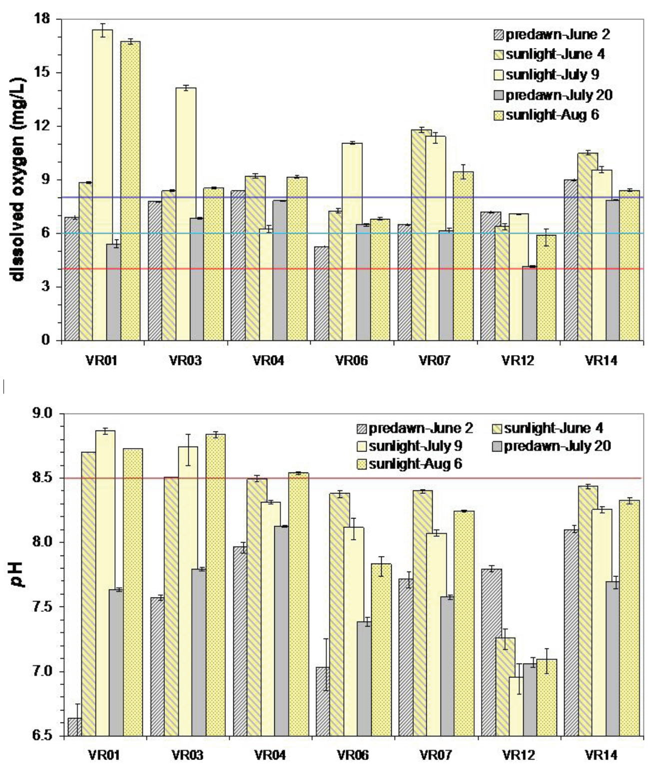


Figure 22. Predawn dissolved oxygen concentrations and pH at selected Ventura Stream Team sampling sites compared with values measured on regular sampling days. The horizontal lines mark important DO (for steelhead) and pH milestones (see Figures 12 and 14). The "error bars" represent the maximum and minimum values measured at the time of sampling.

Figure 22 shows the results of the early morning Ventura sampling compared with dissolved oxygen concentrations and pH measured on adjacent regular sampling days. Only VR12 showed a decrease in oxygen close to the 4 mg/L danger zone (4.2 mg/L). However, the Basic Plan for the Ventura River calls for dissolved oxygen concentrations greater than 7 mg/L (RWQCB-LA, 1994), and only VR04 and VR14 consistently met this standard.[17]

Pre-dawn oxygen measurements on July 20, 2005, were in almost all cases lower than on June 2 (VR06 being the only exception). As flow decreased throughout the summer, algae exerted a greater influence. It is a matter of proportion; equal amounts of algal growth will hve a greater effect on smaller quantities of water. Off-setting this, the peak of the algal bloom occurred earlier, when water levels and flows were much higher and oxygen concentrations were less depressed than initially expected.

In Figure 23 (upper panel), data from Figure 22 are shown as line graphs instead of bars, so the progression of change in DO over time can be more easily visualized (the shaded portions represent pre-dawn measurements). On the lower river (VR01, VR03 and VR06), the combination of algal density and river flow produced the highest daylight DO concentrations in early July, but on the North Fork of the Matilija (VR14), maximum DO occurred in June. This suggests that either the peak of the algal bloom occurred earlier on the Matilija (and probably on San Antonio), or algal densities decreased more rapidly at this site, or both.

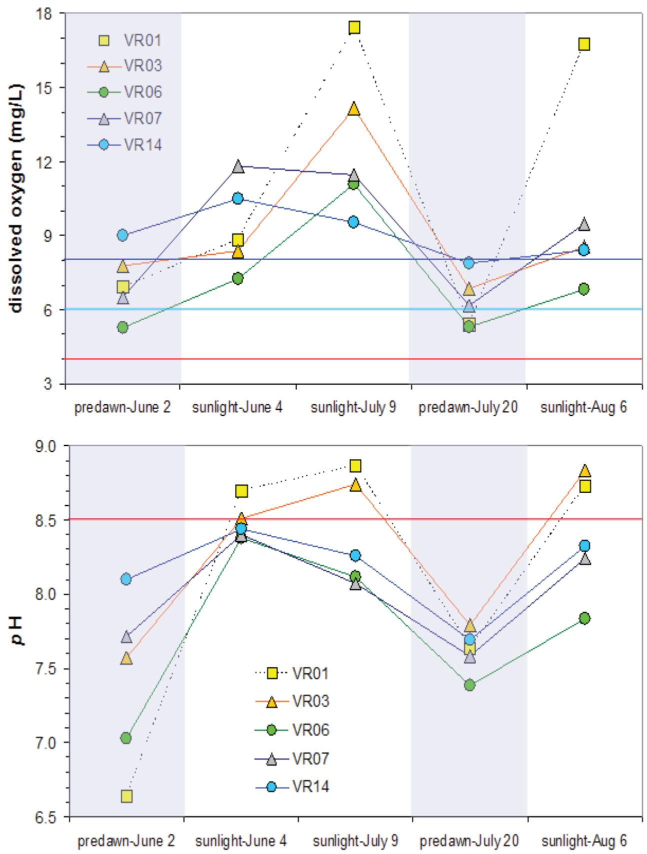


Figure 23. Dissolved oxygen (upper panel) and pH (lower panel) at selected Ventura Stream Team sites: June 2 to August 6, 2005. Pre-dawn measurements are shown against a shaded background and the horizontal lines mark important DO (for steelhead) and pH milestones (see Figures 12 and 19).

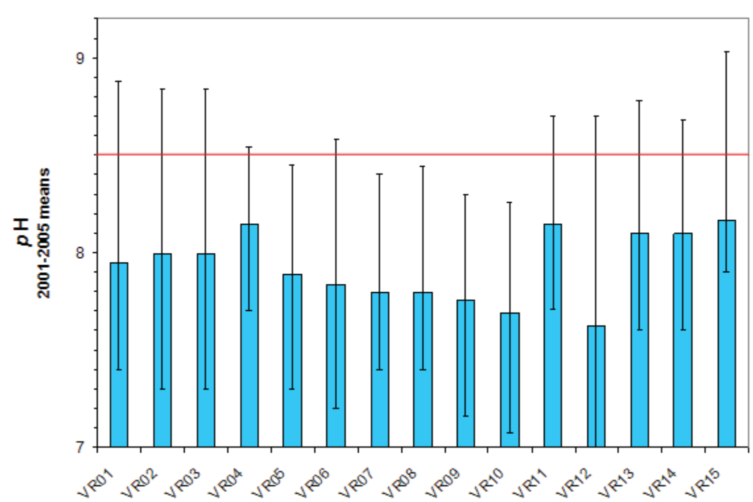


Figure 24. Average pH values, January 2001 to October 2005. The "error bars" indicate the highest and lowest values measured at each sampling location. The horizontal line represents the Los Angeles Regional Water Quality Control Board's upper pH limit of 8.5 (from the Basin Plan). Average pH is equivalent to the mean hydrogen ion concentration.

Lower daylight DO concentrations in August 2005 made it obvious that the algal bloom had passed its peak at all locations by that time (except perhaps at VR01). The progressions in pH change are shown in the lower panel of Figure 23. The day to night fluctuations are appreciable, exceeding the maximum limit of 0.5 units in almost all cases (VR14 is the only possible exception). All sites showed the expected night-time decrease.

Finally, average results for all sampling sites, with the maximum and minimum recorded values, are shown in Figure 24. While most sites have occasional measurements above the 8.5 limit, only the lower river locations (VR01-03) persistently exceeded this value during the summer.

Nutrients

Phosphorus and nitrogen are essential nutrients for aquatic plants and animals. Nitrogen is used for protein synthesis, and phosphorus for energy transformation in cells. However, in excess amounts they cause severe water quality problems (Sterner, 2002; Smith et al, 1999; Carpenter et al., 1989).

A major source of nutrient contamination is manure from horse and cattle facilities. At the horse facility shown in the photo, large piles of horse manure line the banks of San Antonio Creek.

Phosphorus is the nutrient in short supply in most fresh waters, and even modest increases in phosphorus can, under certain conditions, set off a chain of undesirable events including accelerated plant growth, algal blooms, low dissolved oxygen, and the death of oxygen-dependent aquatic life. This nutrient over-fertilization is called eutrophication.

Phosphorus in the Ventura River can come naturally from soil and rocks, decaying plants and animal waste, or unnaturally from runoff from pastures, fertilized lawns and cropland. Failing septic systems ad wastewater treatment plants are other sources, as are disturbed land areas and drained wetlands. Phosphorus, both as phosphate and in organic molucles, can be found in solution or attached to suspended particles within the water column.

Nitrogen moves with water as dissolved inorganic nitrogen (nitrate, nitrite and ammonium) and is dissolved or suspended organic nitrogen (complex molecules associated with living, or once living tissue). Nitrates are the most comon form of nitrogen found in the Ventura River. Together with phosphorus, nitrogen in excessive amounts can also cause eutrophication. Nitrate can also be toxic to war-blooded animals, particularly babies (methemoglobinemia or blue baby disease), at concentrations greater than 10 mg/L, and there may also be a link between high nitrate levels and cancer (non-Hodgkin's lymphoma, Ward et al., 1996). Sources of nitrate include effluent from wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, animal manure and industrial discharges. Nitrates move quickly into streams and rivers since they readily dissolve and are not absorbed on soil particles.

Nitrate

Nitrate is the most important form of dissolved nitrogen in the Ventura River, comprising approximately 70% of the total dissolved nitrogen in river and stream samples (ammonium contributes about 1% and organic forms make up the rest). Since nitrogen is vital for life and growth, an obvious question is how much is too much? A nearly universal Public Health limit is 10 mg-N/L (10 milligrams of nitrogen per liter).[18]

However, 10 mg/L is far too much nitrate in terms of eutrophication and river health. US EPA has suggested standards for various eco-regions in the United States, and the goal for Ecoregion III, the xeric (dry) west, in which the Ventura River is located, is less than 0.38 mg/L of total nitrogen (US EPA, 2000). Note that this is less than 4% of the Public Health nitrate limit (RWQCB-LA, 2001). Ecoregion III has been further divided by the EPA into sub-regions, and the sub-region in which the Ventura River lies (Sub-region 6) may end up with a slightly higher limit of 0.52 mg/L. Sub-region 6 also has a suggested nitrate limit of 0.16 mg/L. To simplify, only the 0.16 mg/L suggested total nitrate limit is shown on our figures.

As it turns out, a fine line is not necessary to determine which sampling locations in the Ventura River watershed have unhealthy amounts of nitrogen; sites are either very good or very bad. The Matilija sites (Figure 25, lower panel) are very good, with nitrate levels almost always below the 0.16 mg/L nitrate benchmark.[19] At the opposite extreme, the lower river sites generally, but not always, have very high nitrate values that are hundreds of times greater than the recommended EPA limit. The Group II locations have mixed results: VR08 (Lion Canyon) has very low nitrate, while VR10 (Upper San Antonio Creek) has the most severe excess nitrate problem on the river.

However, the rise in nitrate concentrations at VR10 following the late December 2004 storms, and a simultaneous rise at almost all other locations during the same period, clearly identify the increase with recharge of the upper groundwater table with high nitrate runoff from the winter storms. The increase in nitrate continued until July 2005 at most locations. Only with decreased summer flows and substantial algal growth did concentrations begin their normal dry season decline.

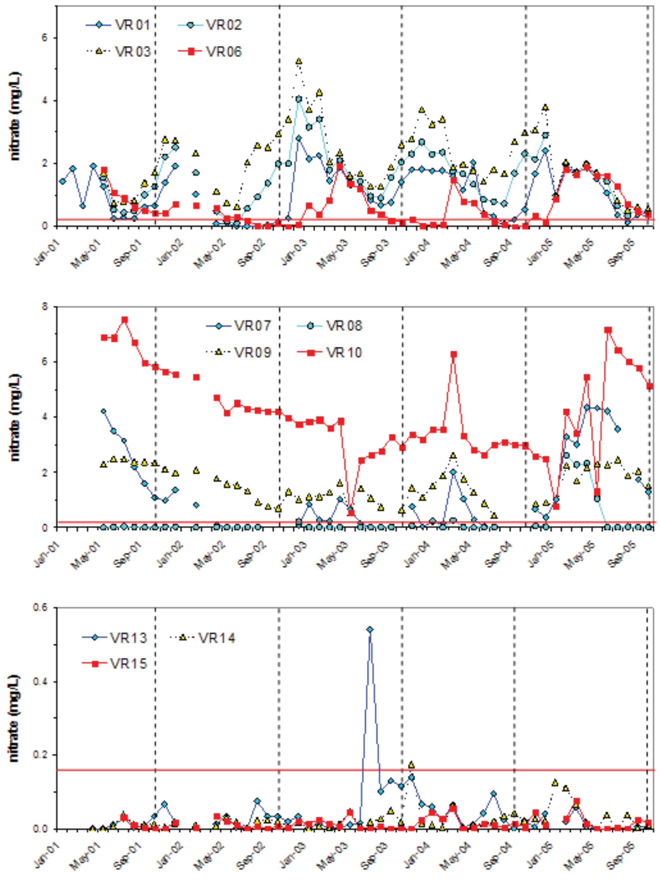


Figure 25. Nitrate concentrations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the EPA's proposed limit for maximum nitrate in this region (Ecoregion III, sub-region 6): 0.16 mg/L. Note that the graphs use different vertical scales.

The most noticeable change during the summer of 2005 was decreased nitrate at the lower river sites (VR01-03, shown in the upper panel of Figure 25). The influx of high-nitrate groundwater and unusually high flows nearly erased the typical pattern of summer and fall Ojai sewage treatment plant dominance of river water below VR06. The pattern of nitrate variation at VR01-03 described in Figure 26 was completely absent in 2005; higher flows minimized the impact of treated sewage effluent throughout the year. Measured lower river flow was 25 cfs as late as September 2005, minimizing the effect of the 2-3 cfs of treated effluent. In contrast, flow at VR01 in September 2005 was only 2 cfs.

Results summarizing the mean concentrations at each site are shown in Figure 25. While no sites exceeded the Public Health nitrate maximum of 10 mg/L, only the Matilija locations met the EPA nitrogen and nitrate criteria. VR10 had the highest nitrate concentrations in the study.

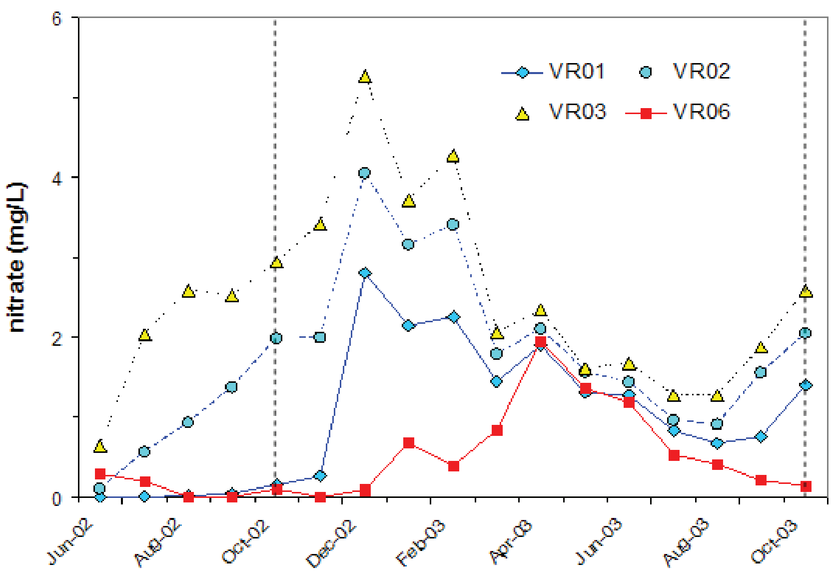


Figure 26. Nitrate concentrations on the lower Ventura River from June 2002 to October 2003. The vertical lines mark the beginning of the water-year. The lower river provides an interesting view of what happens with nitrate over the course of a year. VR06 (Foster Park) represents the normally expected variation in nitrate: a slow rise during the winter to peak values at the end of the rainy season (caused by increasing amounts of high nitrate soil- and ground-waters entering the river as the rainy season progresses), followed by a slow decrease (as plants and algae remove nutrients) throughout the growing season.

The other sampling locations (VR03 to VR01) progressively follow the river downstream from below the Ojai wastewater treatment plant (VR03) to the tidal limit at Main Street (VR01). In this section, the variation in nitrate is different; the rise in concentration begins in summer and continues until December or January. This pattern, of a much earlier rise, is caused by high nitrate outflows from the Ojai sewage treatment plant. By late spring or early summer, natural flows in the river have decreased to a point where treated sewage effluent becomes the major source of water. From then on, until the beginning of appreciably greater discharge due to winter rains, nitrate concentrations increase as effluent increasingly dominates river flow.

The first storms of winter do not noticeably change river flow; most of the rain goes to replenish moisture deficits in dry soil. The early runoff that does enter the lower river comes from more developed parts of the watershed and is usually high in nitrate, thus the increase in nitrate continues until later in the winter. Put simply, winter rains increase concentrations in sections with low nitrate (VR06) and decrease concentrations where nitrate is high. Note that concentrations always decrease from VR03 to VR02 to VR01; biological processes (plants, algae, bacteria) remove nitrate as the river flows towards the ocean.

Phosphate

As with nitrate, the question arises, how much phosphorus is too much? US EPA has recommended maximum levels of phosphorus concentration for streams in this region (Ecoregion III), with an overall recommendation of 0.022 mg/L, and 0.03 mg/L for Sub-region 6 (US EPA, 2000). In this report, the 0.03 mg/L benchmark is used. All the streams in the region have high phosphate concentrations because phosphorus content is high in the marine deposits that make up a large part of the underlying geologic strata (Dillon, 1975; Grobler and Silberbauer, 1985; Schlesinger, 1997), and this is reflected in the increased Sub-region 6 EPA limit.

Figure 29 summarizes our results, showing average phosphate concentrations at each location. All sites had mean phosphate concentrations above the 0.03 mg/L phosphorus limit.[20]

A discussion on patterns of phosphate variation on the lower river, paralleling the nitrate discussion, is provided in Figure 28. At the remaining locations, there is a noticeable association of increased phosphate with the beginning of the rainy season (Figure 27). The first storms mobilize much of the phosphate accumulated on impervious surfaces and in riparian areas during the dry season and transport it to streams (Hager, 2001; MBCWMN, 2002). These storms also move a great deal of sediment and accumulated debris in what were initially dry or near stagnant streams, which also increases phosphate concentrations. The effects of these storms usually remain evident for days afterwards, which is why these increases are evident in the data.[21]

Typically, during the remainder of the winter, high phosphate concentrations are only seen during actual storms (May 3, 2003 was one of those rare days when it rained while sampling was occurring, and increased phosphate concentrations were obvious in many of that day's results; see Figure 27, middle and lower panels). High phosphate is associ-

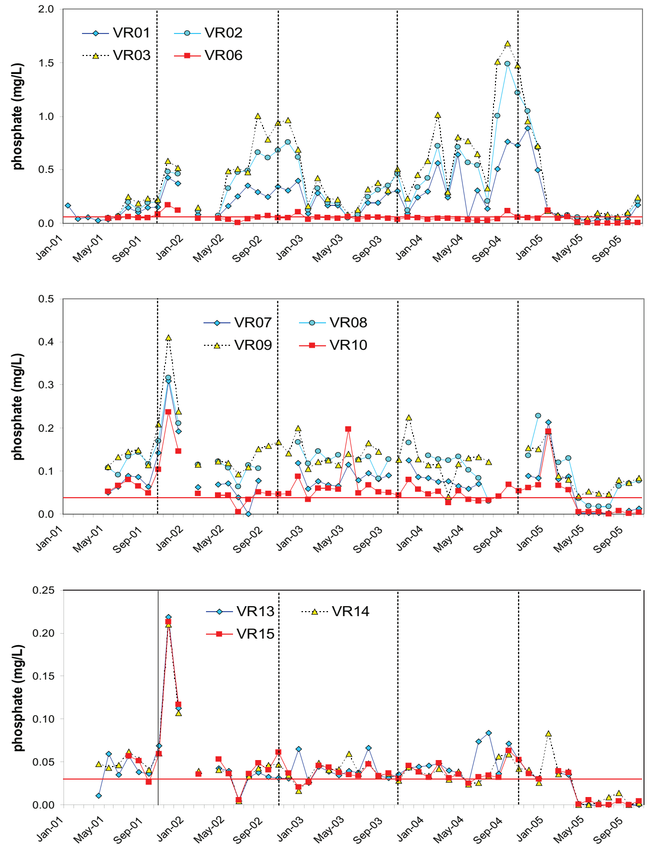


Figure 27 (above). Phosphate concentrations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the EPA proposed target for maximum phosphorus in this region: 0.030 mg/L (Ecoregion III, sub-region 6). The graphs show phosphate, which typically makes up around 90% of the total phosphorus in the stream. Note that the graphs use different vertical scales.

ated with high sediment loads during storms, as phosphate is usually attached to soil particles. The width and condition of streamside buffer areas, the extent of stream-bank armoring and the proximity of unvegetated, easily erodable soil to the channel or storm drain inlet, as well as the intensity of the rainfall, determine how much sediment ends up in the creek, and how much phosphate concentrations increase.

Phosphate levels in 2005 were noticeably lower when compared with those of previous years (Figure 27) due to the extraordinary algal blooms. The probability is that even greater amounts of phosphorus were exported from the watershed to the river in 2005, but the extremely favorable conditions for algal growth (e.g., removal of vegetation and ediment, greater availability of sunlight, reduction in predator numbers and higher levels of nitrate) led to extremely high biological uptake and reduced concentrations throughout the system. Likewise, the ordinary pattern of phosphate variation below the Ojai sewage treatment plant (as described in Figure 28) was not present. Again, similar to what transpired with nitrate, higher than normal flows, combined with high phosphorus uptake, minimized the impact of sewage effluent on the river.

Overall, the three sites below the Ojai sewage treatment plant (VR01-03) have the highest phosphate concentrations found on the river (Figure 29). However, concentrations at VR09 and VR10, below Ojai, are also high, probably due to golf course fertilization and irrigation.

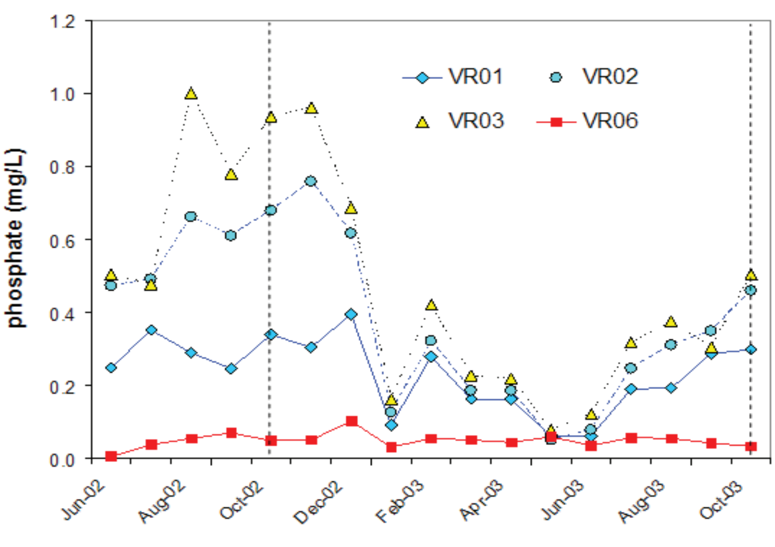
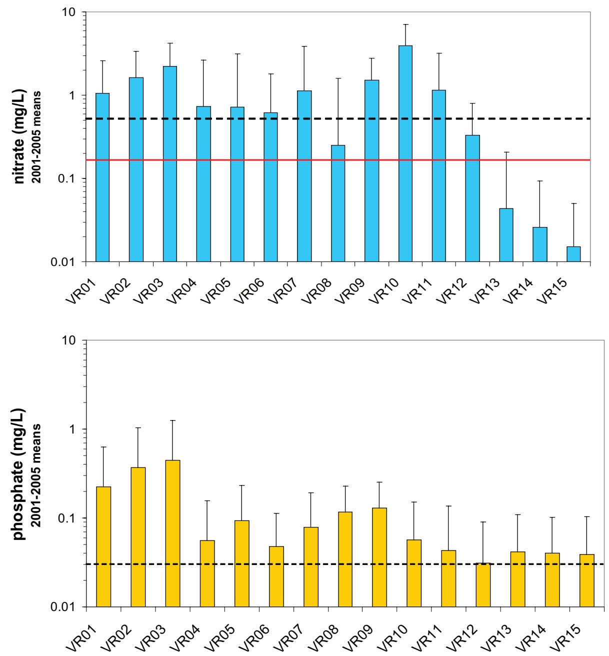


Figure 28 (left). Phosphate concentrations on the lower Ventura River from June 2002 to October 2003. The vertical lines mark the beginning of the water-year. Unlike nitrate (Figure 26), there is very little variation in phosphate concentrations at VR06 (Foster Park). Sometimes there is an increase in phosphate around the time of storms, particularly for the first storm of the year (Figure 27, middle and lower panels), but generally, concentrations are relatively stable. However, the situation is quite different for sampling locations below the Ojai wastewater treatment plant (VR03 to VR01). Here, concentrations have a dramatic pattern: a continuous rise from the beginning of summer until late fall. This pattern is the same one exhibited by nitrate at these sites and it has the same cause - outflows from the treatment plant. Treated effluent is not only high in nitrate but also high in phosphorus, and as effluent increasingly dominates flow in the lower river during the dry season, phosphate concentrations correspondingly rise. When winter runoff finally begins to influence flow, concentrations decrease. Because of sewage effluent, these three sites have the highest phosphate concentrations on the river (Figure 27, upper panel). Again, as with nitrate, concentrations decrease downstream from VR03 to VR02 to VR01, as plants, algae and bacteria, and chemical transformations remove phosphate.



Combining Nitrate and Phosphate[22]

Living organisms need both nitrogen (N) and phosphorus (P), therefore it is necessary to consider both nutrients in combination. Absent either nitrogen or phosphorus, a plant or alga needing both cannot grow and begins to die. Oceanic plankton need N and P in a ratio of 16 atoms of nitrogen to one atom of phosphorus.[23] For freshwater organisms, the average ratio is closer to 30:1 (Nordin, 1985; Sterner and Elser, 2002). A stream with this ratio contains almost the perfect amount of both. A ratio of less than 30:1 means some of the phosphorus goes unused; this case is called "N-Limited." At ratios greater than 30:1, nitrogen is underutilized; this case is called "P-Limited." This is an important concept in stream ecology, since unused nutrients cannot contribute to eutrophication and its associated problems (Borchardt, 1996).

Figure 29. Upper panel: Average nitrate concentrations, January 2001 to October 2005. The solid horizontal line marks the EPA's proposed limit for maximum nitrate in this region: 0.16 mg/L; the dashed line is the recommended limit for nitrogen (0.52 mg/L). Nitrate typically makes up only 50-60% of the total nitrogen in the stream. Lower panel: Average phosphate concentrations, January 2001 to October 2005. The horizontal line marks the EPA's proposed limit for maximum phosphorus in this region: 0.030 mg/L. Phosphate typically makes up more than 90% of the total phosphorus in the stream. The error bar represents twice the standard deviation of samples taken at each site; 95% of the measured values can be expected to be below this limit.

Table 2. Median concentrations (±S.E. of the median) for nutrient species at Channelkeeper's Ventura Stream Team sampling sites, 2001-2005. All concentrations are expressed in micromoles per liter (µM). Sites VR04, VR05, VR11 and VR12 have high standard errors since they are typically dry and are represented by relatively few samples.

	uM	uM	uM	uM	uM	uM	uM
site	**NH4**	**NO3**	**PO4**	**DON**	**DOP**	**TDN**	**TDP**
VR01	0.6±0.2	83.2±8.3	4.8±1.1	24.0±2.3	1.4±0.5	114.3±8.9	5.8±1.2
VR02	1.0±1.2	119.0±10.2	10.5±2.0	29.2±3.3	1.1±0.5	156.3±11.6	10.6±2.1
VR03	1.5±0.4	134.8±12.3	10.5±2.2	27.8±3.4	1.0±1.1	172.9±14.3	11.2±2.3
VR05	0.5±1.2	24.4±14.9	1.7±0.4	29.5±4.9	0.5±0.4	68.1±18.1	2.5±0.4
VR06	0.3±0.1	30.2±7.1	1.5±0.3	9.0±1.6	0.5±0.2	37.6±8.1	1.6±0.3
VR07	0.3±0.1	56.3±18.5	2.4±0.3	14.8±3.3	0.5±0.3	75.9±21.2	2.6±0.4
VR08	0.3±0.1	0.6±9.0	3.9±0.4	26.6±2.4	0.5±0.3	28.4±10.6	4.2±0.4
VR09	0.2±0.1	111.0±8.3	4.0±0.4	15.8±2.7	1.1±0.3	132.6±8.5	4.6±0.4
VR10	0.1±0.1	277.6±19.9	1.6±0.2	24.1±13.0	0.7±0.3	300.7±21.8	2.0±0.3
VR11	0.3±0.1	57.7±20.8	1.1±0.5	9.6±3.4	1.0±0.5	66.2±22.6	1.12±0.6
VR12	0.3±0.1	16.1±5.2	1.1±0.3	7.6±2.6	0.2±0.5	22.0±6.1	0.6±0.5
VR13	0.4±1.3	1.3±1.0	1.2±0.2	9.1±1.3	0.7±0.3	11.7±3.1	1.5±0.3
VR14	0.1±0.1	1.1±0.4	1.3±0.2	4.4±0.8	0.6±0.2	5.3±1.0	1.5±0.2
VR15	0.4±0.1	0.6±0.2	1.2±0.2	5.8±1.9	0.8±0.2	7.5±1.9	1.6±0.2
mean	1.0±0.1	81.2±3.9	4.7±0.3	22.0±0.9	1.3±0.1	102.6±4.3	4.9±0.3

However, there are exceptions. Some aquatic plants and algae do not get nitrogen from the water, but have the ability "fix" nitrogen from the air, or in other words, convert nitrogen gas into ammonia and then use ammonia for cell metabolism. Ammonia is an important source of N, normally found only in low concentrations in the Ventura River (typically around 1-2% of the nitrate concentration, Table 2). These organisms literally carry their own nitrogen supply, since attached symbiotic bacteria do the conversion. This is a relatively rare ability, and these plants and algae are normally not very competitive in aquatic environments where dissolved nitrogen is abundant. However, when nitrogen becomes limiting, these nitrogen-fixing organisms flourish. Because plants, algae and micro-organisms are the foundation of the aquatic food chain, it is important to know which assemblage of species provides this function, and the type of nutrient limitation and its severity help determine this.

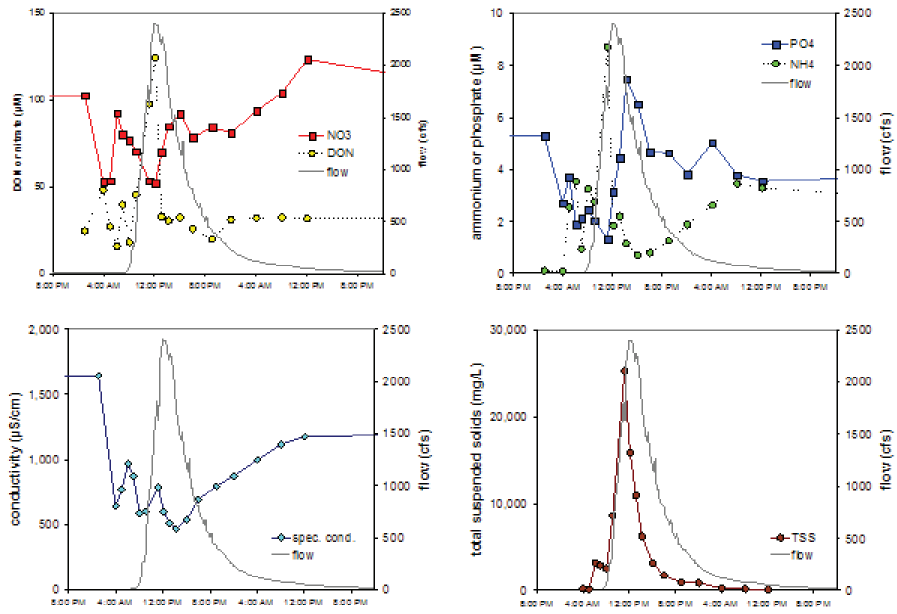


Figure 30. Variation in dissolved nutrients, conductivity and suspended sediment at Main Street (VR01) on March 15, 2003 (the largest storm of that year). The hydrograph measured at Foster Park (VR06) is shown; it only approximates conditions at VR01. The most intense rainfall occurred prior to 4 AM, and the first third of the variations exemplify the response of the lower, more urbanized, Ventura River watershed: initial pulses of urban runoff are characterized by a peak in ammonium, a rise in DON and depressed concentrations of nitrate, phosphate and conductivity. Maximum flow occurred hours after the rain had stopped; considerable time is needed for runoff from Ojai and more distant parts of the watershed to reach Foster Park.

The peak in ammonium, DON and sediment that occurred at VR01 just before peak flow at Foster Park probably marks the arrival of runoff from Ojai via San Antonio Creek. Notice that nitrate and phosphate concentrations were depressed at this same time. This is typical, as storm runoff usually dilutes constituents with high background concentrations and increases those with low (flushes out pollutants). Concentrations that occurred after peak discharge indicate contributions from the relatively pristine, higher-elevation parts of the watershed within the National Forest; runoff from this area was relatively high in both phosphate and nitrate. Large storms flush out nitrate and mobilize phosphate from upstream areas, particularly from areas of chaparral. However, most of the sediment was flushed much earlier, in rising flood waters from the area between Ojai and Casitas Springs.

The Ventura Stream Team sampling locations provide examples of both N-limitation and P-limitation, and at some sites the situation flips back and forth. Figure 31 shows three examples. The vertical nitrate and phosphate scales in Figure 31 were set in a proportion of 20:1 - a concentration of 20 µM nitrate is directly across from 1 µM phosphate, 40 opposite 2, etc. A 20:1 nitrate to phosphate ratio is roughly equivalent to a 30:1 N to P ratio at the Ventura Stream Team sampling locations. The unit is micro-moles per liter (µM – "M" is the symbol for moles/liter).[24] When the nitrate and phosphate concentrations shown in Figure 31 are close together, the nutrients are roughly in balance; when they are apart, one nutrient is in limited supply, and the nutrient in the lower position is limiting.

The Matilija and North Fork Matilija creek sampling sites and Lion Canyon are always N-limited, as phosphate is naturally abundant and nitrogen in short supply (VR14 – Figure 31, upper panel). VR10 (upper San Antonio Creek, middle panel) is the only example of a consistently P-limited location, as nitrate is always far too plentiful here. Fortunately, overhanging vegetation and trees along the bank usually restrict the amount of sunlight reaching the stream, retarding the growth of algae in this reach. VR09 typically has a rough balance of nutrients. The remaining sites shift from one form of limitation to the other (VR03 – lower panel). The general tendency is for N-limitation in the summer and fall, P-limitation in late winter and spring. However, there is a great deal of variation from site to site. The N/P ratio results are summarized in Figure 32.

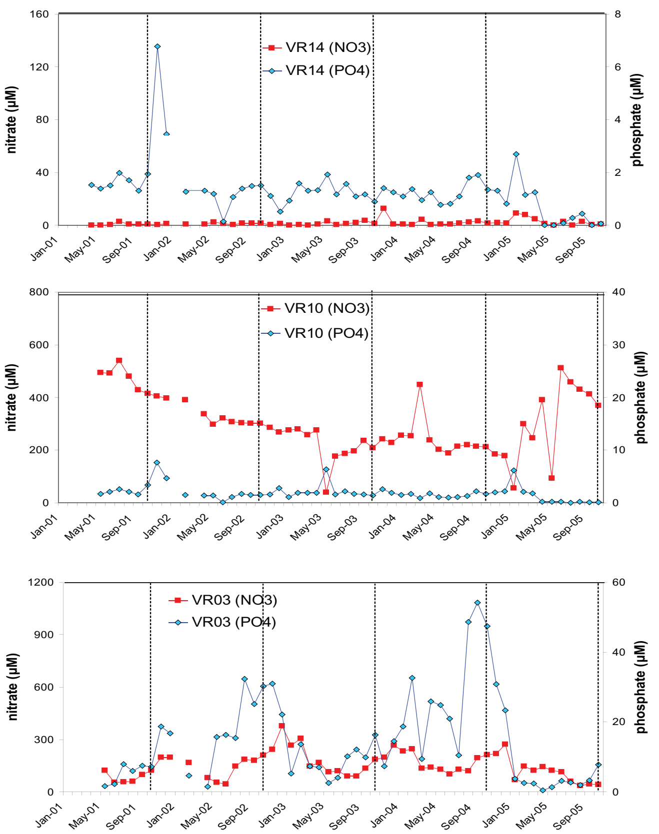


Figure 31. Nitrate and phosphate for three sampling locations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. Concentrations are given in micro-moles/L (µM) and the nitrate scale is 20 times the magnitude of the phosphate scale: 20:1 roughly represents the nutrient uptake ratio (N to P) of terrestrial aquatic organisms.

Dry season nutrient concentrations are both qualitatively and quantitatively different following winters with high rainfall than after seasons of low rainfall. The appreciable groundwater recharge that follows a wet winter disproportionately increases both the amount and concentration of nitrate in stream flow (caused by increased higher nitrate groundwater inflows) over phosphorus. At the same time, the large floods of a wet winter open up stream and river channels to greatly increased dry season algal growth, growth that is to some extent fueled by the increase in nitrate availability.

Thus, after a wet winter, we expect to see an increase in N:P ratios due to both the disproportion-

It is important to consider flow in the discussion of nutrients. During the 2002 drought, and during the decreased flows observed in 2004, N-limitation began earlier and was more severe. Nutrient concentrations indicate relative abundance, they do not provide a measure of the total amount of available nitrate or phosphate. Often the amount is far more important. The amount, or the flux or export, is the product of both concentration and flow: high concentrations provide only small amounts of nitrate when flows are very low. Under these conditions, the supply of nitrogen becomes severely limited as water moves downstream (to reiterate, 30 times more nitrogen than phosphorus is typically needed), and nitrate concentrations often decrease to zero in summer and early fall (Figure 25). At these times, N-fixing plants and algae become dominant and can dramatically change what is observed on the river. Possible impacts of these changes on the food chain remain unexplored.

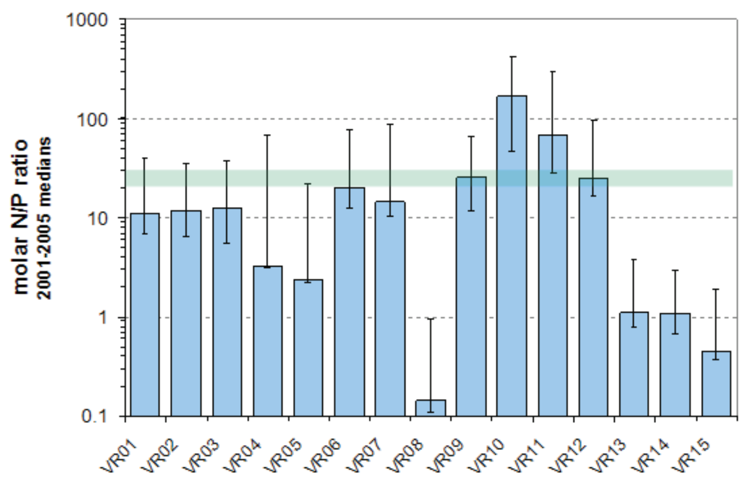


Figure 32. Median nitrate to phosphate ratios for the Ventura Stream Team sampling sites, January 2001 to October 2005. Life requires both nitrogen and phosphorus, but in different amounts. Plankton, on which the oceanic food chain is based, use nitrogen and phosphorus in a ratio of 16 molecules of N to 1 of phosphorus; this is known as the "Redfield Ratio." In creeks and rivers, the ratio is closer to 30:1 and is indicated by the shaded horizontal bar in the figure (the nitrate to phosphate ratio is being used as an approximation of the nitrogen to phosphorus ratio; on average, nitrate is approximately 85% of the total nitrogen and phosphate 90% of the total phosphate). The Matilija tributaries and Lion Canyon are severely "nitrogen limited," meaning that while phosphorus is plentiful, nitrogen is often exhausted. VR10, below Ojai, is "phosphorus limited"; more than sufficient nitrogen is present but phosphorus is typically in short supply. All other locations move across the boundary depending on time of year, typically being phosphorus limited during winter and spring and nitrogen limited in summer and fall. The error bars indicate the quartile points, e.g., 50% of the monthly N/P ratios for that location lie within the band represented by the error bar.

al increase in nitrate and the accelerated utilization of phosphorus by increased algal uptake. Contrasting average N:P ratios for the 2004 dry season with those from 2005 (May through September) demonstrates that this is precisely what happened (Figure 33). At half of the sampling sites, phosphate was undetectable during most of this period.[25]

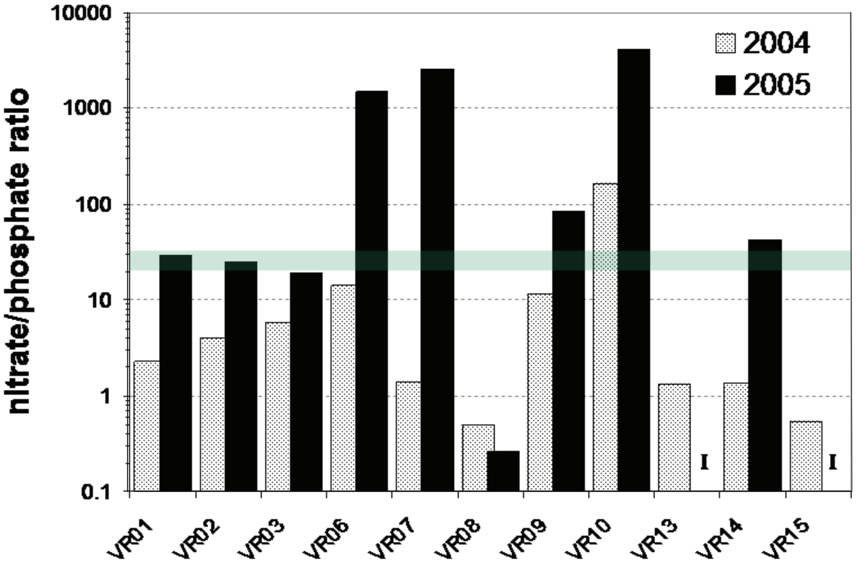


Figure 33. Average dry season (June through September) nitrate to phosphate ratios for 2004 and 2005. The shaded horizontal bar marks the approximate 20:1 to 30:1 zone where both nutrients are in balance. The letter "I" indicates sites where phosphate concentrations fell below detection limits (< 0.3 µM) and the N:P ratio was indeterminate. The increased nitrate concentrations and heavy algal growth following a wet winter produced a substantial increase in N:P ratio at all locations except VR08 (Lion Canyon).

The export of nutrients from the Ventura River into the Santa Barbara Channel is probably of little ecological importance. The mixing of relatively small volumes of river water with vast quantities of saltwater circulating in the Channel precludes a meaningful impact from terrestrial nutrients.[26] However, variations in nutrient export undoubtedly have noticeable and severe effects on the Ventura lagoon and estuary.

The lagoon and its fringing salt marsh are subject to drastic changes over the course of a year. Tidal inflows, normally the major influence on coastal lagoon or marsh systems, may be reduced or eliminated by the formation of sand berms at the river mouth. Depending on river flow and blockage at the mouth, lagoon water may be alternately brackish (low salinity; 5-30 parts per thousand, approximately 4-46 mS/cm) or hyper-saline (greater than 40 parts per thousand salinity or 60 mS/cm), and finally, the lagoon is periodically flushed with freshwater during winter storms. On top of this extreme seasonal variation, since river flow exercises a large degree of control on lagoon conditions, the year-to-year variation is also considerable.

Wet years are characterized by large inputs of water and nutrients from the Ventura River (Figure 34), and since the

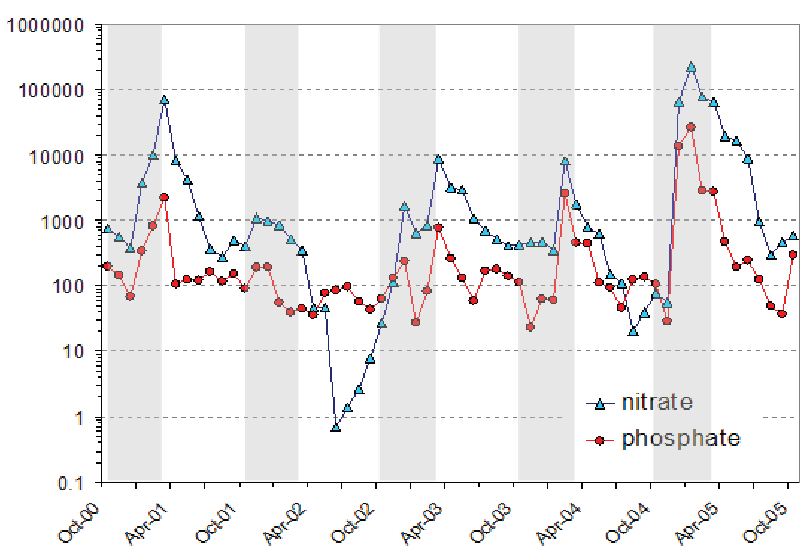


Figure 34. Monthly export of nitrate and phosphate to the Ventura Lagoon, 2001-2005. The shaded areas represent winter rainy seasons. Units are kilograms of nitrogen or phosphorus per month. Export was calculated as the product of monthly concentrations (bi-monthly in 2003 and 2004) and estimated flow at VR01 (USGS gauging data at Foster Park plus average Ojai wastewater treatment plant discharge). Nitrate varies substantially: the kilogram scale is a log scale, each major division representing a factor of 10; the difference between the highest and lowest monthly fluxes is little less than six major divisions, e.g., six decimal places – a difference of almost a million. There is also a big difference from year to year. During drought or relatively dry years (2002 and 2004), nitrate almost disappears from the river at this location. Note that phosphate export is quite different: the flux, particularly during the dry season, is relatively consistent at roughly 100 kg/month. The Ventura lagoon generally gets sufficient phosphate, but depending on the year, nitrate usually becomes either mildly or strongly limiting as the growing season develops, and in drought years a lack of nitrogen is probably extremely limiting.

In the Ventura River, Ventura Stream Team observed a long-term trend towards increasing conductivity until the winter of 2005 (Figure 7, summarized in Figure 8). The increasing trend (SBCK, 2004) was caused by increasingly depleted and generally older groundwater inflows, enhanced uptake by growing riparian vegetation, and a relative increase in evaporation as dry-season river flows continually diminished since the last year with significantly high rainfall (the high El Niño rainfall of 1997-98).

Evidence of lower groundwater inflows to the river is shown in Figure 9. The lower panel displays the "relative" amount of dry-season flow for the big El Niño year of 1998 and every year since, or, in other words, the average amount of water flowing in the river from April to September for every inch of rainfall that fell the previous winter (USGS-NWIS). Since almost no rain falls during this period, river flow is a direct indicator of groundwater input, and an indirect indicator of the height of the groundwater table.

In 1999, flow remained high despite low rainfall (9 inches vs. an average annual rainfall of 14.3 inches in Ventura). This high flow was a carryover from heavy El Niño rainfall in 1998 (37 inches) and an almost total loss of riparian vegetation due to flood scouring of the river bottom. Although total summer flows increased in 2000 (upper panel), there was much less discharge than might have been expected from above average rainfall (19 inches), and the ratio of flow to rainfall continued to decrease. Only in 2001, another above-average year with 17 inches of rain, did the relative flow increase. Flows in 2004 were as low as they were in 2002, a year with almost no rain (less than 2 inches).

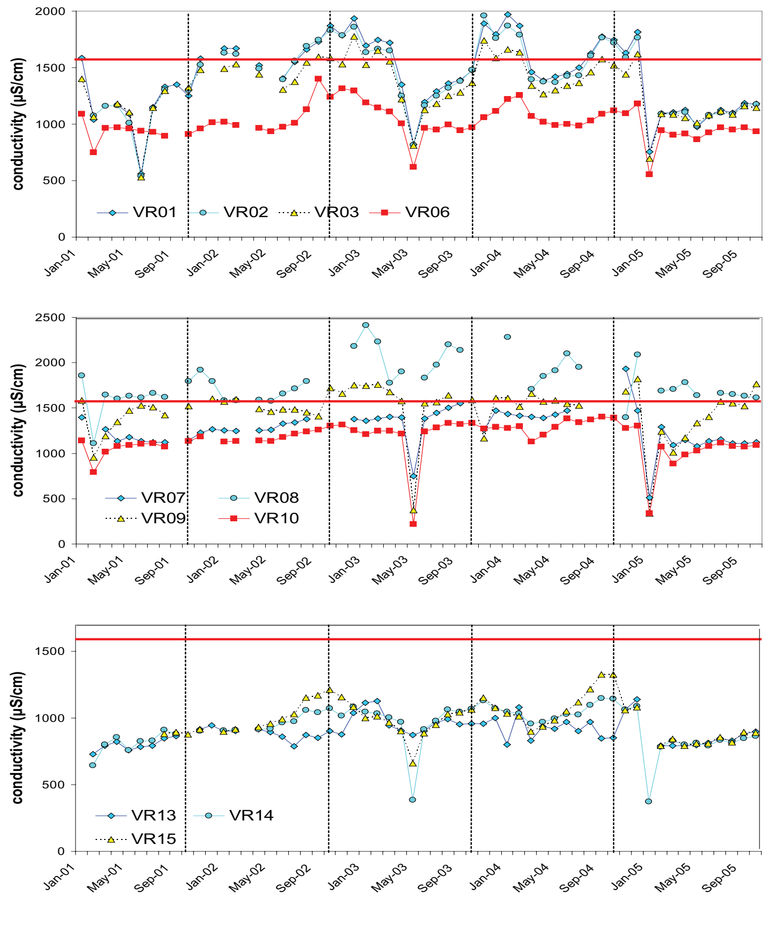


Figure 7. Conductivity, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The overall trend indicates a gradual increase until the significant rainfall of the winter of 2005; very low values usually mark storm events (or, in some cases, meter error). The bold horizontal line indicates the typical 1,600 µS/cm drinking water limit.

In 2005, the situation abruptly changed. The advent of a year of significantly high rainfall (rainfall of 36.2 inches in Ojai) caused a dramatic increase in dry-season flows. The increased flows are the result of a higher water table and increased groundwater inflows into the river and its tributaries. The flows shown in Figure 8 were measured at the USGS gauging station at Foster Park (USGS-NWIS). This is a good location for evaluating groundwater conductivity; just upstream of the sampling site a seam of bedrock and a concrete weir below the riverbed force deep groundwater to the surface, ensuring year-round flow. Since the river is usually dry above this section, summer flows at Foster Park are a good measure of groundwater input.

In Figures 7 and 8, the conductivity trend for Foster Park (VR06) is upward, but it is weaker than the trend at other, higher elevation locations, such as the North Fork of Matilija Creek (VR14). The occasional sharp dip in the trend indicates a sample taken during, or shortly after, a storm. Recent rain dramatically lowers river conductivity, since rainfall is about as young as water gets, with a conductivity in the Ventura area around 20 µS/cm. Even though conductivity increases as runoff moves by various pathways to the river, it still remains much lower during storms. All sites show the drop in values measured during the storm of May 3, 2003.

The four-year pattern of rising conductivity showed a sudden change with the arrival of the January 2005 storms. The January 2005 measurements were made during the early stages of a major storm and exhibit the low values expected during rainfall. However, low values, in many cases lower than seen during 2001, continued into April and May and beyond. High river levels, caused by increased flows from higher elevations (which generally have lower conductivities) and increased inputs from a water table replenished with recent, lower conductivity, runoff generally have lower conductivities.[9]

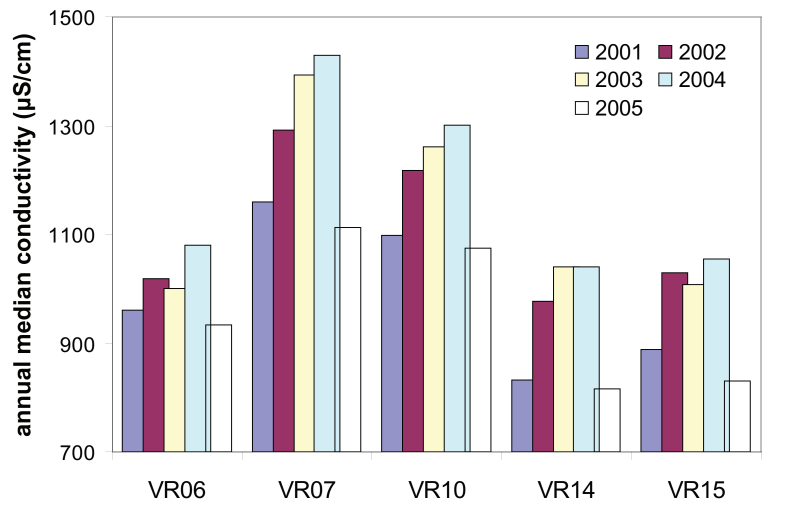


Figure 8. Changes in annual median conductivity for Ventura Stream Team sampling sites with relatively natural, year-round flows, 2001 to 2005. There has been a consistent increase in conductivity over the initial four years of sampling, with the occasional exception of the 2002 drought year (possibly due to a relative increase in evaporation of the extremely low flows of that year). The percent increase from 2001 to 2004 has been 12, 23, 19, 25 and 19 for VR06, VR07, VR 10, VR14 and VR15, respectively. However, in 2005, conductivity abruptly decreased by 20% throughout the Ventura River system.

The conductivity results are summarized in Figure 10. Only three sites show median conductivity levels that exceed the 1,600µS/cm drinking water limit: VR04, 05 and 08. These sites are heavily impacted by cattle grazing and have very low flows prone to evaporative concentration.

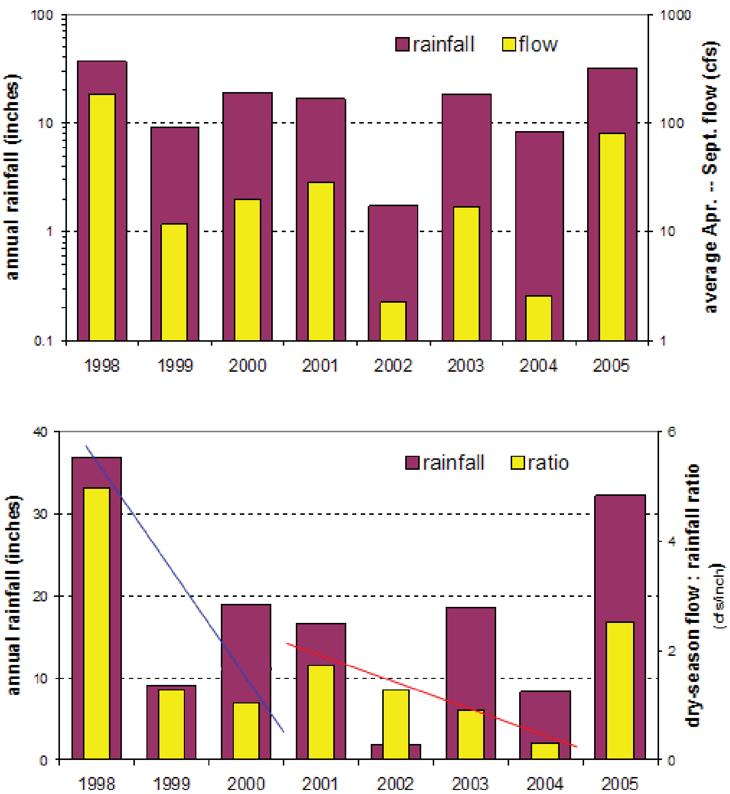


Figure 9. In the upper panel, annual rainfall (Oxnard) is plotted for the severe El Niño year of 1998 and every year since, and average April to September flow is shown on the right-hand axis. Rainfall is again plotted in the lower panel, but the right-hand scale now shows the ratio between average April to September flow and rainfall, e.g., the average dry-season flow divided by the previous winter's rainfall. The bold lines show the trend towards less flow per inch of rain as we get further from a large El Niño; it required two years of above average rainfall (2000 and 2001) to partially recover from low rainfall in 1999. In 2004, river flow was as low as in 2000, in spite of approximately five times the rainfall.

Temperature

Temperature is the simplest parameter measured, yet one of the most important. The expected annual pattern is straightforward: temperature rising from winter lows to summer highs, and then decreasing in early fall, paralleling seasonal changes in air temperature. On the Ventura River, that pattern is observed at all sites (Figure 11).

The temperature graphs include three horizontal lines, which mark important threshold temperatures for steelhead trout: above 24°C leads to death; below 16°C indicates good dry-season conditions, and below 11°C in winter provides ideal conditions for spawning and incubation (Brungs and Jones, 1977; Armor, 1991; McEwan and Jackson, 1996; Sauter et al., 2001). As temperatures rise, fish have increasing difficulty extracting oxygen from water, while at the same time the maximum amount of oxygen able to be held in solution decreases.

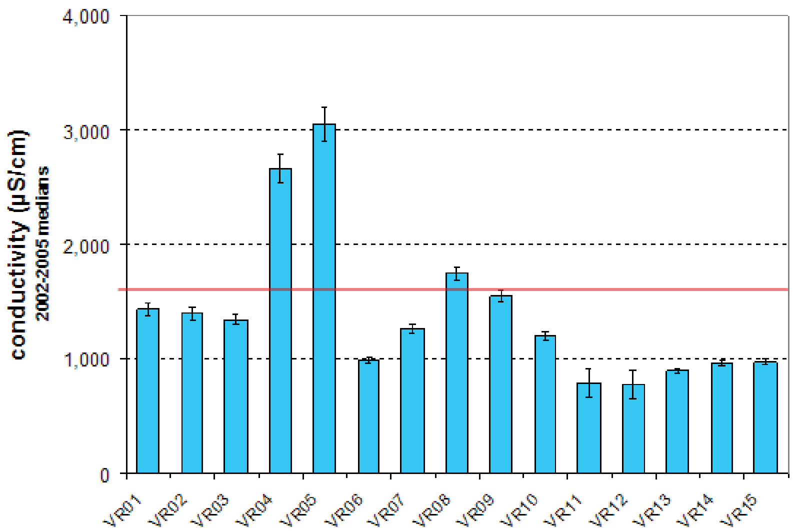


Figure 10. Median conductivity values, January 2001 to October 2005. The "error bars" indicate the standard error of the median. The solid line represents a generally accepted upper conductivity limit of 1,600 µS/cm for drinking water. VR04, 05 and 08 are heavily impacted by cattle grazing and have very low flows prone to evaporative concentration.

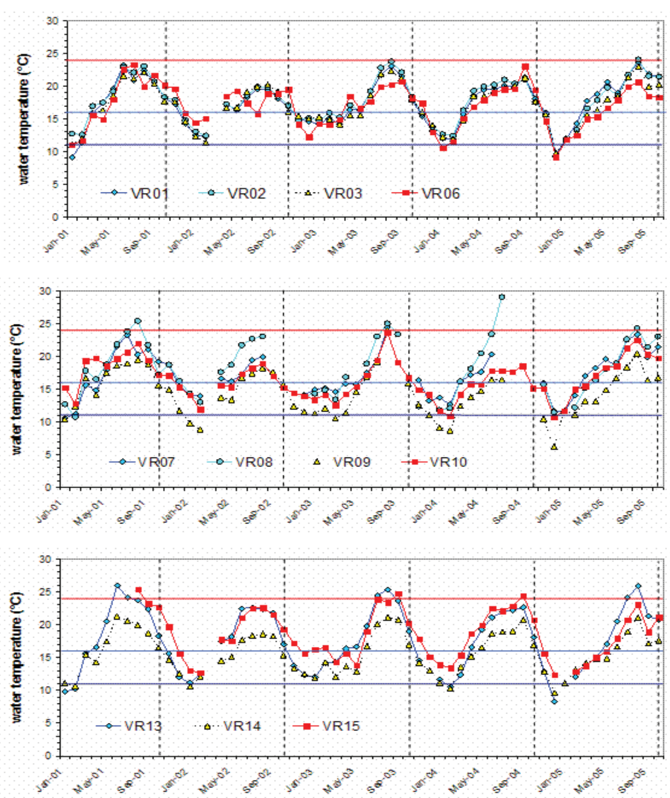


Figure 11. Stream temperature, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The three horizontal lines mark important steelhead temperature milestones: above 24°C leads to death; below 16°C indicates good dry season conditions; and below 11°C is excellent for spawning and incubation.

Consideration of the conditions necessary for good steelhead habitat are often used as water quality criteria in this report, since water good enough for steelhead is very good water indeed, and since a widespread return of these symbolic fish to the South Coast is a popular enthusiasm (NMFS, 1996). This does not mean that steelhead are present at all sampling locations (although a small resident population still survives in the Ventura River), nor that they would return or increase in numbers if water quality were good enough. Other questions such as water availability and fish passage are equally, if not more important. However, water meeting criteria for steelhead can be considered high quality water.

While the temperature requirements for steelhead are rather stringent, warm-water fish have greater tolerance for higher temperatures. Channelkeeper's Ventura Stream Team data show that temperatures occasionally increase above 24°C in late summer and rarely drop below 11°C in winter. Many of the sites that exceed the 24°C limit, such as

VR08, VR13 and VR15, are subject to shallow flow conditions and high exposure to sunlight in the summer. Reasonable departures from these criteria are likely not a vital concern; southern steelhead evolved in what are essentially warm-water rivers and streams, and undoubtedly have greater tolerance for higher temperatures than their more northern cousins. Furthermore, fish are not passive participants, but are free to seek out more favorable conditions (Matthews and Berg, 1997; Stoecker, 2002).

It is interesting that the lower river sites (VR01, VR02 and VR03, upper panel) have lower summer temperatures than elsewhere, lower even than those seen on the Matilija (VR13-15, lower panel). This is due to inflows from the Ojai sewage treatment plant. Deeper water is usually cooler water, and higher flows on the lower river keep temperatures lower, even though the river is at a lower elevation and more exposed to sunlight.

Dissolved Oxygen

Aquatic organisms rely on the presence of oxygen in streams; not enough oxygen and they will relocate, weaken or die. On land, oxygen makes up 20% of the surrounding atmosphere, whereas in water, oxygen is a dissolved gas with a maximum concentration of about 16 parts per million (a maximum of 0.0016 %) - not at all plentiful. Water temperature, altitude, time of day, and season all affect the amount of oxygen in the water. Water holds less oxygen at warmer temperatures and higher altitudes. Dissolved oxygen (DO) is measured either in milligrams per liter (mg/L) or "percent saturation."[10]

When dissolved oxygen levels in water drop below 5 mg/L, aquatic life is put under stress. Cold-water fish (trout and steelhead) need levels above 6 mg/L, and DO above 8 mg/L may be required for spawning (Davis, 1975; EPA, 1986; Bjornn and Reiser, 1991; Deas and Orlob, 1999). Warm-water fish can tolerate levels as low as 4 mg/L. The lower the oxygen concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills.

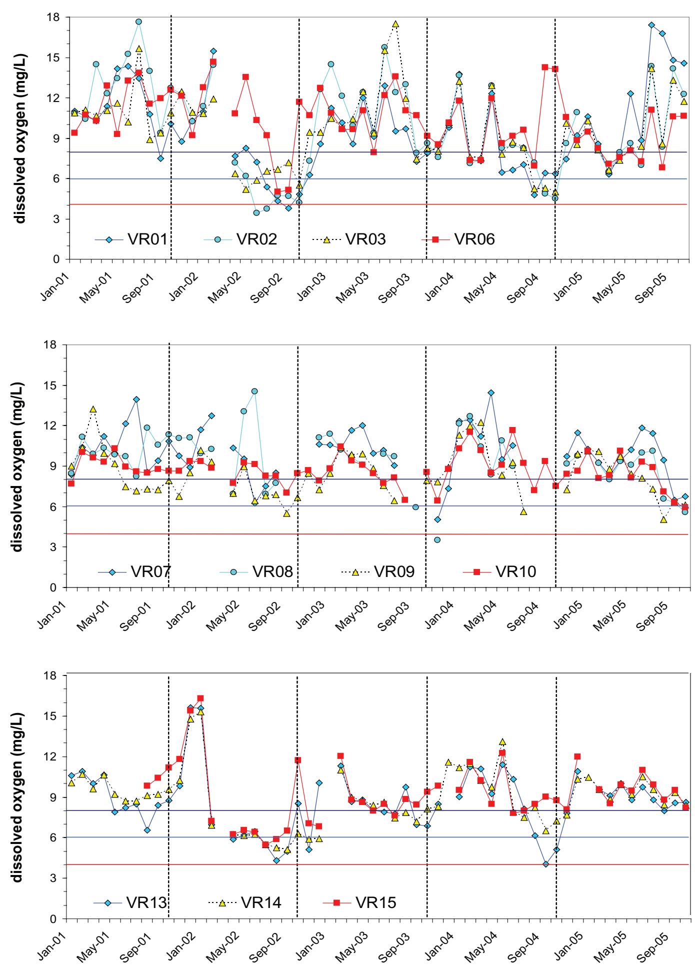


Figure 12. Dissolved oxygen, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The three horizontal lines mark important DO milestones for steelhead: above 8 mg/L represents near ideal conditions; at 6 mg/L hypoxia begins and fish start to feel stress; and below 4 mg/L lies severe damage and death.

The DO trends on the Ventura River are shown in Figure 12. As for temperature, three important benchmarks are shown as horizontal lines: above 8 mg/L represents near ideal conditions; at 6 mg/L hypoxia begins and fish begin to feel stress (but no lasting harm is done in the short term); and below 4 mg/L lies severe damage and death.[11] At first glance, river conditions look fine: very few samplings indicate DO concentrations below 3 or 4 mg/L, and even readings below 6 mg/L are relatively rare. Although no clear annual pattern emerges, there are noticeable differences between years, with lower summer concentrations in 2002 and 2004 for both the lower river and Matilija locations. Lower flows in these two years,

A volunteer tests dissolved oxygen at VR13.

and the absence of algae, account for this decrease. As flows drop, streams become more sluggish and there is both less opportunity for water to entrain oxygen through re-aeration (e.g., riffles and cascading white water) and more time for aquatic species and biochemical processes to extract oxygen.

However, there are potential problems that are not immediately apparent. Ironically, very high DO concentrations can indicate problems. Ventura Stream Team sampling takes place during daylight. While the sun is out, algae and underwater aquatic vegetation photosynthesize, removing carbon dioxide from the water column and replacing it with oxygen. This process is reversed at night, when oxygen is removed and carbon dioxide added (Carlsen, 1994; NM-SWQB, 2000). Thus very high daytime oxygen concentrations can indicate an overabundance of algae. Under these conditions, oxygen falls to a minimum just before sunrise, and it is concentrations during this critical period that determine the actual threat to fish and other aquatic species, a threat that is usually not evaluated but should be (Windel et al., 1987; Deas and Orlob, 1999; PIRSA, 1999). Notice that in Figure 12 the relatively pristine Matilija sites (lower panel) show the least overabundance of oxygen.

The absence of an annual DO pattern mentioned earlier is another cause for concern. Oxygen has a greater solubility in colder water, and as temperature increases, DO should decrease, and vice versa. If DO and temperature are plotted on the same graph, they should appear roughly 180° out of phase, one rising as the other falls. To demonstrate, both DO and temperature are plotted for three sites in Figure 13. Note the absence of this expected variation at VR06 (upper panel, Foster Park), where both parameters have similar patterns. This is evidence of algal dominance, where warmer, more sluggish summer waters produce high daylight DO concentrations. There is an opposing DO and temperature pattern at VR13 (lower panel, Matilija Creek, one of the most pristine sites sampled), indicating minimal influence from algae. The middle panel (VR10, upper San Antonio Creek) shows a combination of both patterns, indicating a possible algal problem in late summer or early fall, but low algal growth during the rest of the year.

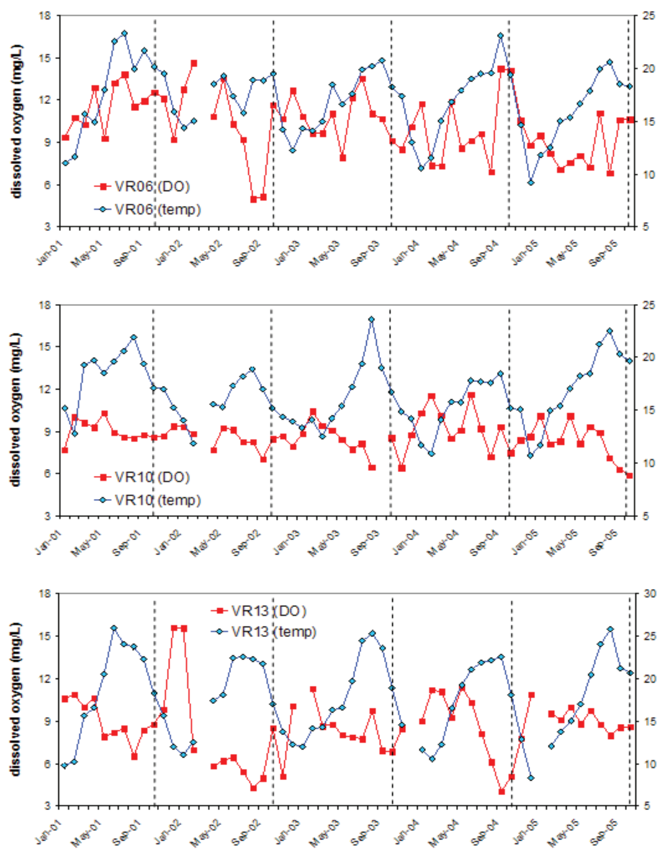


Figure 13. Dissolved oxygen and temperature for three sampling locations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. Under ideal conditions, as temperature rises DO should fall, and vice versa. The absence of this pattern in the upper panel indicates problems with algae.

A DO meter also measures percent saturation, the amount of DO compared with what water at the measured temperature and altitude can hold at equilibrium.[12] These data (Figure 14, summarized in Figure 15) confirm the summer problem with algae in the lower river and at some Group II sites. Typically, a DO concentration in excess of 120% of saturation is a good indicator of algal problems.[13] Finally, we can summarize both the DO and temperature results by showing the mean, minimum, and maximum measured values at each location (Figure 16).

The winter storms of 2005 created ideal conditions for extravagant algal growth on the Ventura River during the summer dry season. The river is open to sunlight, vegetation has been removed (lessening competition), sediment has been flushed leaving a rocky bottom (the ideal substrate for most problem-causing algal species in the area), insect predators have been swept out to sea by winter floods, and nutrients are relatively plentiful. During the April 2005 sampling, and for months afterwards, excessive amounts of algae were recorded at every location. However, excessive concentrations of day-time dissolved oxygen were relatively rare, with major exceptions at the lower Ventura River and San Antonio Creek (Figure 14).

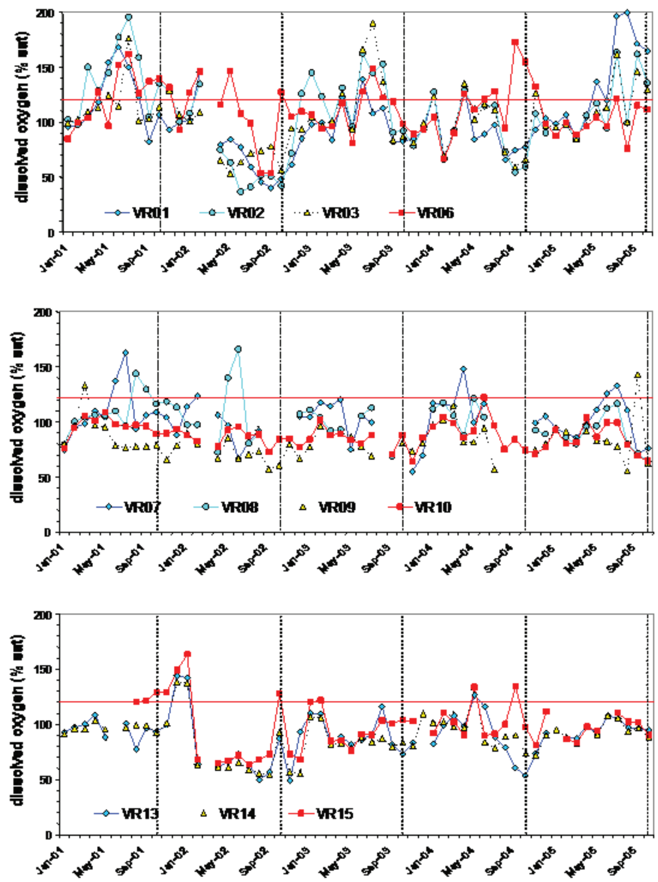


Figure 14. Dissolved oxygen measured in percent saturation, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. Concentrations above 120% saturation (horizontal line) usually indicate problems with algal growth; over-saturation during daylight followed by depleted concentrations at night.

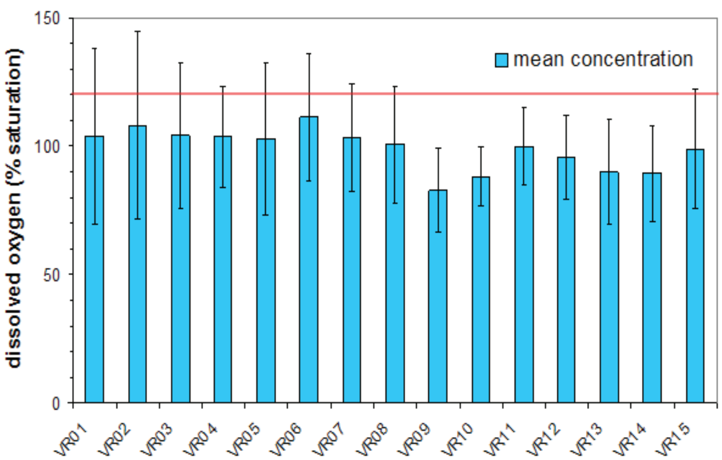


Figure 15. Mean dissolved oxygen (in percent saturation) values, January 2001 to October 2005. Concentrations above 120% saturation (horizontal line) usually indicate problems with algal growth; over-saturation during daylight is followed by depleted concentrations at night. The error bars indicate ± the standard deviation of sampled concentrations at each site (e.g., 67% of the monthly samples will have values between the error bars). Locations from VR01 to VR08, and VR15, have periodic problems with algae.

Relatively deep flows containing large amounts of high-quality upper catchment waters lessened the adverse impact of the algal bloom. But algal growth on the Ventura River often undergoes two or three cycles over the course of the dry season. Our expectation was that the peak of the last cycle, when water levels would be much lower and temperatures higher, would create the most critical oxygen situation. Fortunately this did not happen. The dominant alga in the Ventura system, Cladophora, made only a single appearance, and oxygen problems were not as severe as expected, the exception being a heavy growth of diatoms keeping lower river concentrations abnormally high into the fall (particularly at VR01, Figure 14).

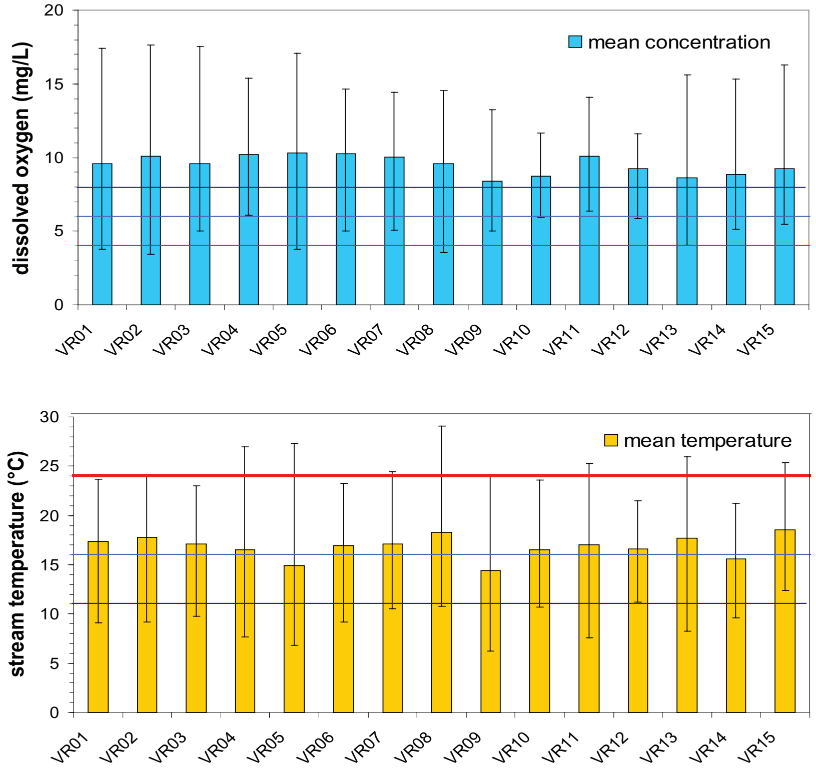
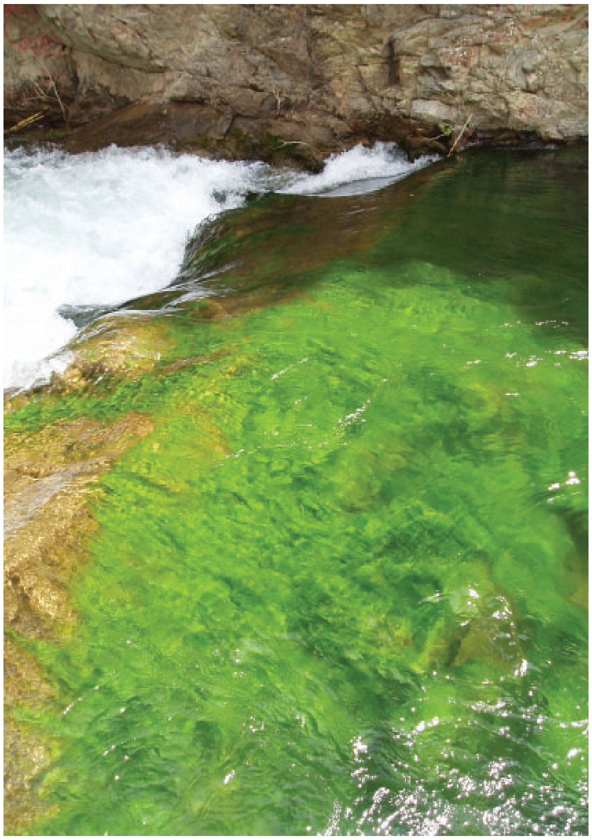


Figure 16. Upper panel: Average dissolved oxygen, January 2001 to October 2005. The three horizontal lines mark the important DO milestones for trout and steelhead explained in Figure 12. Lower panel: Average stream temperature, January 2001 to October 2005. Above 24°C leads to death; below 16°C indicates good dry season conditions; and below 11°C is excellent for spawning and incubation. The "error bars" represent the maximum and minimum measured values. Extreme values become critical at locations with measurements below (for DO) or above (for temperature) the bold line. As stressed, night-time oxygen depletion at sites with significant algal growth remains largely unknown, a complete evaluation of DO conditions on the river depends on collecting this data.



Following the large winter storms of 2005, even relatively pristine sites such as VR13 contained excessive amounts of algae.

Turbidity

Turbidity is a measure of the amount of sediment in the water column, and sediment has both long- and short-term effects on steelhead and other fish (Sigler et al., 1984; Newcombe and MacDonald, 1991; ODEQ, 2001a, 2001b). Over the long term, sediment settles on the bottom and fills the interstices between streambed gravel and rocks, decreasing the amount of desirable habitat for spawning and for the insects that fish feed upon. Over the short term, turbidity reduces the ability of fish to see and feed. Water quality begins to be degraded by suspended sediment somewhere between turbidities of 3-5 Nephelometric Turbidity Units (NTU), and above 25 NTU, impacts on steelhead and other trout begin to be noticeable. These limits should be considered applicable only during the dry season and periods between storms. During storms in the Ventura area, these limits become meaningless as local suspended sediment concentrations reach tens of thousands of milligrams per liter - turbidity readings in the hundreds of thousands if turbidity meters were capable of reading that high. Fortunately, on the Ventura River, turbidities rapidly drop soon after the end of rainfall and return to near-background levels within three to seven days of a storm.

Turbidity results are shown in Figure 17. Normally, readings are below 5 NTU, but if sampling is done during or soon after a storm, they reach into the hundreds and often far higher - above the ability of Channelkeeper's meters to record a value. The horizontal lines on the figures represent typical Public Health drinking water limits: less than 5 NTU and no more that 5% of samples greater than 0.5 NTU. As long as it is not raining, Ventura River water usually meets these standards.

Results are summarized in Figure 18. This figure also shows a line for a third typical standard - no higher than 1 NTU for 8 hours. Figure 18 shows median concentrations (the median is a better indicator of "average" conditions than the mean when a dataset is complicated by a few extraordinarily high readings such as we see during storms). The EPA has suggested a turbidity limit of 1.9 NTU for streams in this region, and aside from storms, all of our sampling sites met this criterion. However, VR01 (Main Street Bridge), the site with the highest median turbidity, 1.91 NTU, is right at the limit.

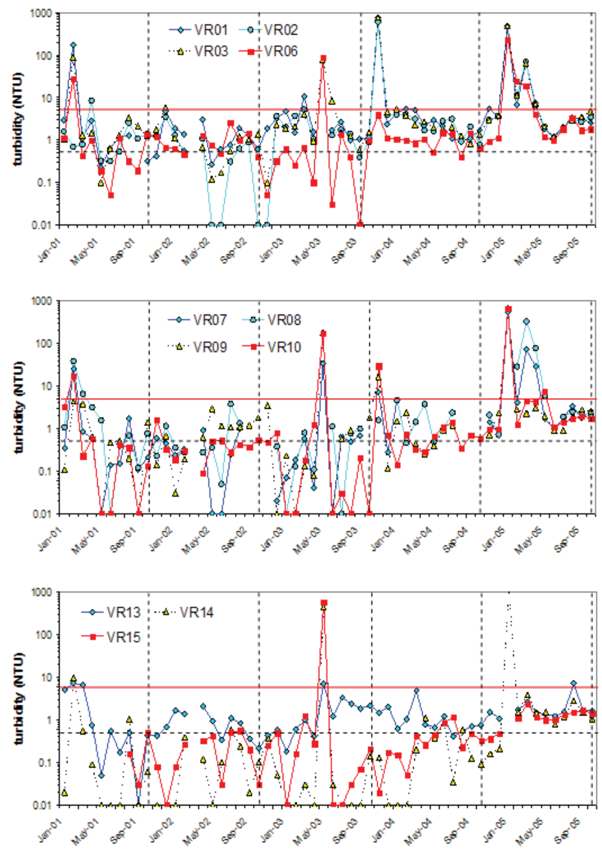


Figure 17. Turbidity, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The two horizontal lines mark Public Health drinking water quality benchmarks: a maximum turbidity of 5 NTU, and no more than 5% of monthly samples with greater than 0.5 NTU.

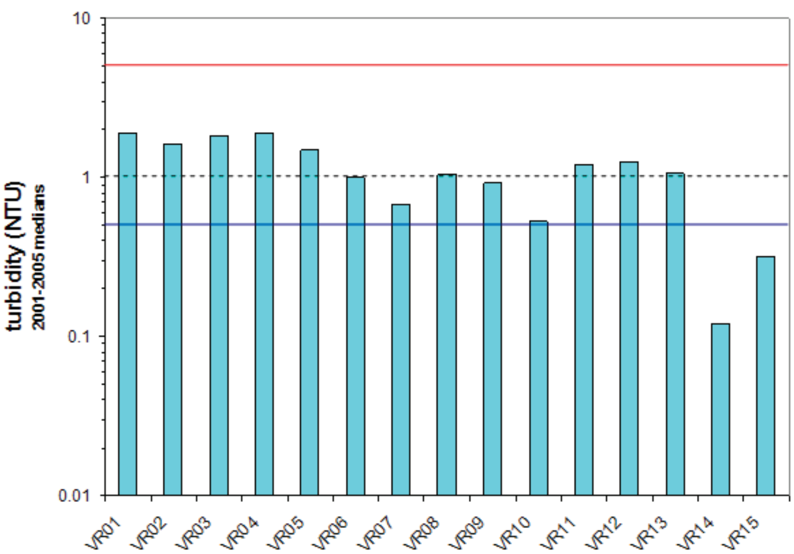


Figure 18. Median turbidity values, January 2001 to October 2005. The three horizontal lines mark typical Public Health drinking water quality benchmarks: a maximum turbidity of 5 NTU; no higher than 1 NTU for 8 hours; and no more than 5% of monthly samples with greater than 0.5 NTU.

pH

pH is a relative measure of acidity and basicity, an expression of the number of free hydrogen atoms present. It is measured on a scale of 1 to 14, with 7 indicating neutral - neither acid nor base. Lower numbers show increasing acidity, whereas higher numbers indicate more basic waters. Blood (pH of 7.5), seawater (9.3) and household ammonia (11.4) are all alkaline or basic; urine (6.0), orange juice (4.5), Coca Cola Classic (2.5) and human stomach contents (2.0) are acidic. pH numbers represent a logarithmic scale, so small differences in numbers can be significant; a pH of 4 is one hundred times more acidic than a pH of 6. All plants and aquatic species live within specific ranges of pH, and altering pH beyond these ranges causes injury or death. Pollutants can push pH toward the extremes, and low pH is particularly dangerous because it allows toxic elements and compounds to mobilize (go into solution) and be taken in by aquatic plants and animals. A change of more than two points on the pH scale can kill many species of fish. The US EPA and

Los Angeles Regional Water Quality Control Board regard a pH change of more than 0.5 as harmful (RWQCB-LA, 1994).

Deciding what is an unsuitable pH is difficult, as there are numerous standards. Fish can tolerate a range of 5-9, but the best conditions lie between 6.5-8.2. The Central Coast Regional Water Quality Board uses a standard of 7.0-8.5 for surface water, 6.5-8.3 for potable water and swimming (RWQCB-CC, 1994). The Los Angeles Regional Water Board uses 6.5-8.5 (RWQCB-LA, 1994), and US EPA recommends 6.5-8.0 as best for aquatic animals. This report uses 8.5 as an upper reference limit since the Los Angeles Regional Water Board establishes the legal standard for the Ventura River.

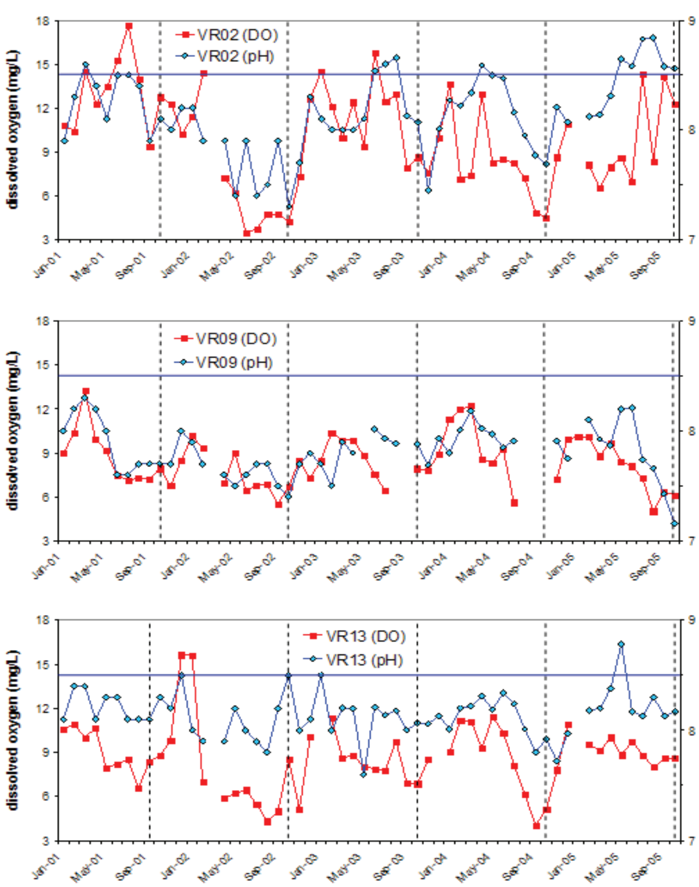


Figure 20. Dissolved oxygen and pH for three sampling locations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year and the horizontal line represents the 8.5 upper pH limit. Ordinarily, pH should bear little resemblance to DO concentrations. However, significant algal growth causes similar patterns in both parameters as carbon dioxide removed from water by photosynthesis (decreasing acidity) is replaced by oxygen.

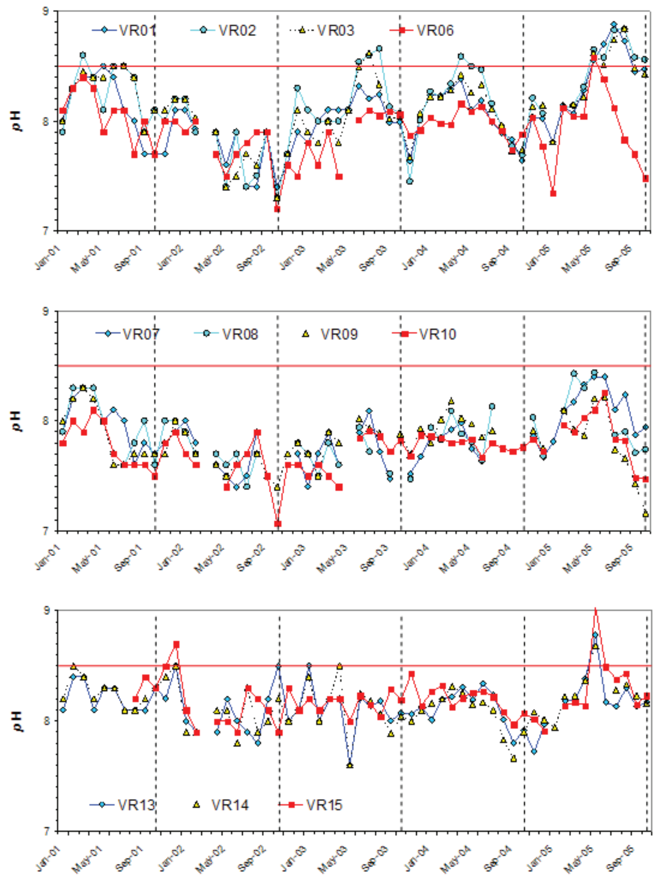


Figure 19. pH concentrations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the Regional Water Quality Control Board's upper pH limit of 8.5.

Figure 19 shows the variation in pH at the Ventura Stream Team sampling locations.[14] There is a pattern in the pH data, best observed on the lower river (upper panel), of lower values occurring around the beginning of the new water-year (and with the start of winter rains), while the highest occur in spring or early summer (June-August 2003 and April-June 2004). This pattern was repeated in 2005, when measurements peaked in July and August. Rain has a lower pH than baseflow in the Ventura and its tributaries,[15] and the first few storms usually lower river values. The spring/summer increase is caused by the same algal and plant growth responsible for increasing daylight concentrations of dissolved oxygen.

Photosynthesis withdraws carbon dioxide from the water at the same time as it releases oxygen. Removing carbon dioxide is the same as removing acidity, thus it increases pH (PIRSA, 1999; NM-SWQB, 2000). Normally, absent this process, we should see little change in pH. The same dissolved minerals that give Ventura waters high conductivity usually "buffer" the river against large variations,[16] but changes in dissolved carbon dioxide are a major exception.

Figure 20 shows the variation in DO and pH at three sampling locations. Similarity in the temporal patterns of these two parameters is an indicator of algal growth, the simultaneous addition of DO and removal of acidity (increasing pH). The removal of acidity by photosynthesis is responsible for most of the very high values seen in the data (Figure 19). The similarity between pH and DO is stronger in some years than in others, such as at VR02 in 2001 and 2002, when larger storms opened the river to greater algal growth. In 2002 there were no high pH values because no storm was strong enough to disturb plant growth at this location.

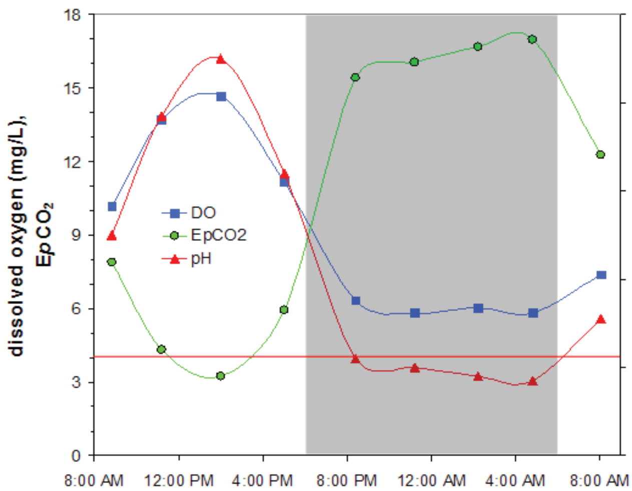


Figure 21. The chart shows results from a 24-hour sampling at Foster Park on September 10-11, 2003. These measurements provide a look at daily (diel or diurnal) changes during an episode of abundant algal growth. The grey area on the chart indicates night-time measurements. Dissolved oxygen changed from a high of 15 mg/L in the early afternoon to a low near 5 mg/L at night. The change in acidity (pH) follows the change in DO, from a high of 8.4 to a low of 7.6. EpCO2 is the ratio of measured CO2 to what would normally be dissolved in water of the same temperature at equilibrium. CO2 varied in opposition to DO and pH, from three times the equilibrium concentration during the day to 17 times greater at night. These changes are caused by algal photosynthesis - the removal of carbon dioxide from water during sunlight in the creation of biomass. During photosynthesis algae generate oxygen, increasing dissolved oxygen concentrations as they decrease CO2. At night, algae respire, reversing the process by removing oxygen and increasing CO2.

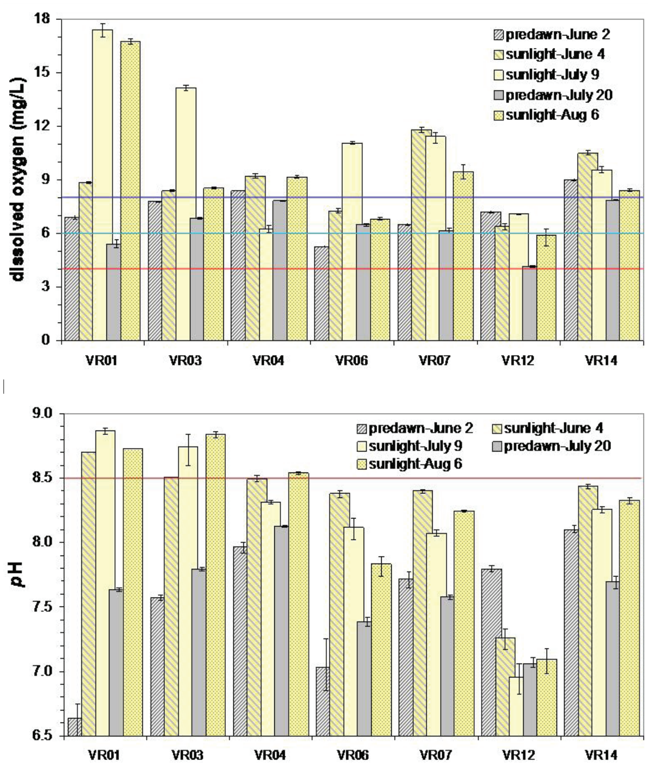


Figure 22. Predawn dissolved oxygen concentrations and pH at selected Ventura Stream Team sampling sites compared with values measured on regular sampling days. The horizontal lines mark important DO (for steelhead) and pH milestones (see Figures 12 and 14). The "error bars" represent the maximum and minimum values measured at the time of sampling.

Were Channelkeeper to sample the Ventura Stream Team locations around the clock, variations in both pH and DO similar to those in the monthly data would occur over a 24-hour period (Figure 21) (cf. Carlsen, 1994; Windell et al., 1987). The variation would be appreciable at sites with algal problems, and relatively muted in locations with normal conditions. Indeed, this kind of testing would be one of the better ways of estimating the extent of eutrophication and algal growth on the river. Although we did not sample around the clock in 2005, pre-dawn dissolved oxygen and pH concentrations were measured on June 2 and July 20, 2005, to track the impact of excessive algal growth at select sites.

Figure 22 shows the results of the early morning Ventura sampling compared with dissolved oxygen concentrations and pH measured on adjacent regular sampling days. Only VR12 showed a decrease in oxygen close to the 4 mg/L danger zone (4.2 mg/L). However, the Basic Plan for the Ventura River calls for dissolved oxygen concentrations greater than 7 mg/L (RWQCB-LA, 1994), and only VR04 and VR14 consistently met this standard.[17]

Pre-dawn oxygen measurements on July 20, 2005, were in almost all cases lower than on June 2 (VR06 being the only exception). As flow decreased throughout the summer, algae exerted a greater influence. It is a matter of proportion; equal amounts of algal growth will hve a greater effect on smaller quantities of water. Off-setting this, the peak of the algal bloom occurred earlier, when water levels and flows were much higher and oxygen concentrations were less depressed than initially expected.

In Figure 23 (upper panel), data from Figure 22 are shown as line graphs instead of bars, so the progression of change in DO over time can be more easily visualized (the shaded portions represent pre-dawn measurements). On the lower river (VR01, VR03 and VR06), the combination of algal density and river flow produced the highest daylight DO concentrations in early July, but on the North Fork of the Matilija (VR14), maximum DO occurred in June. This suggests that either the peak of the algal bloom occurred earlier on the Matilija (and probably on San Antonio), or algal densities decreased more rapidly at this site, or both.

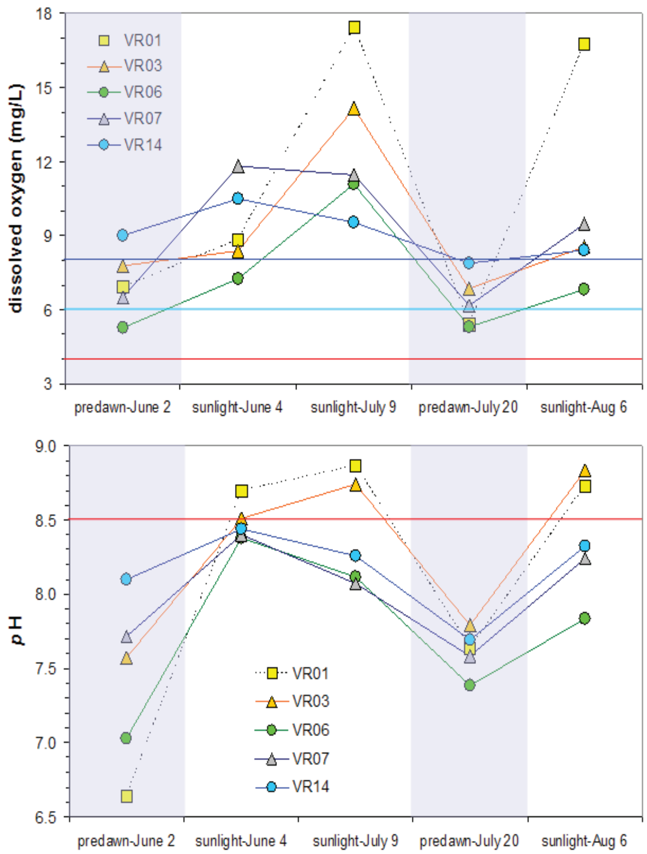


Figure 23. Dissolved oxygen (upper panel) and pH (lower panel) at selected Ventura Stream Team sites: June 2 to August 6, 2005. Pre-dawn measurements are shown against a shaded background and the horizontal lines mark important DO (for steelhead) and pH milestones (see Figures 12 and 19).

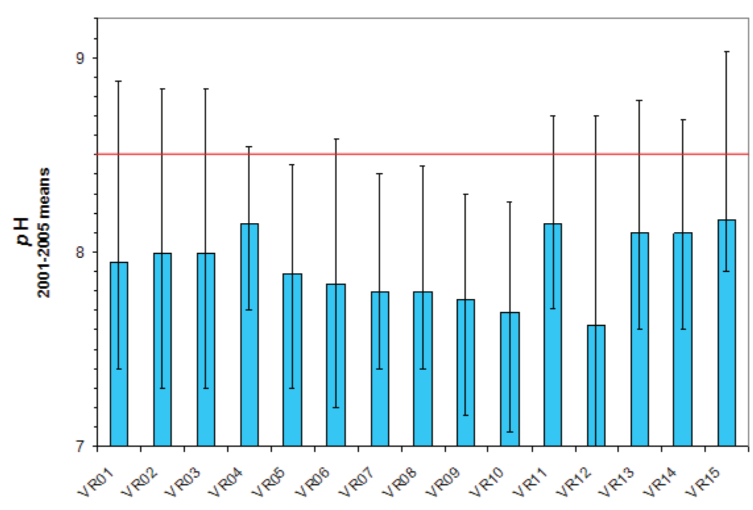


Figure 24. Average pH values, January 2001 to October 2005. The "error bars" indicate the highest and lowest values measured at each sampling location. The horizontal line represents the Los Angeles Regional Water Quality Control Board's upper pH limit of 8.5 (from the Basin Plan). Average pH is equivalent to the mean hydrogen ion concentration.

Lower daylight DO concentrations in August 2005 made it obvious that the algal bloom had passed its peak at all locations by that time (except perhaps at VR01). The progressions in pH change are shown in the lower panel of Figure 23. The day to night fluctuations are appreciable, exceeding the maximum limit of 0.5 units in almost all cases (VR14 is the only possible exception). All sites showed the expected night-time decrease.

Finally, average results for all sampling sites, with the maximum and minimum recorded values, are shown in Figure 24. While most sites have occasional measurements above the 8.5 limit, only the lower river locations (VR01-03) persistently exceeded this value during the summer.

Nutrients

Phosphorus and nitrogen are essential nutrients for aquatic plants and animals. Nitrogen is used for protein synthesis, and phosphorus for energy transformation in cells. However, in excess amounts they cause severe water quality problems (Sterner, 2002; Smith et al, 1999; Carpenter et al., 1989).

A major source of nutrient contamination is manure from horse and cattle facilities. At the horse facility shown in the photo, large piles of horse manure line the banks of San Antonio Creek.

Phosphorus is the nutrient in short supply in most fresh waters, and even modest increases in phosphorus can, under certain conditions, set off a chain of undesirable events including accelerated plant growth, algal blooms, low dissolved oxygen, and the death of oxygen-dependent aquatic life. This nutrient over-fertilization is called eutrophication.

Phosphorus in the Ventura River can come naturally from soil and rocks, decaying plants and animal waste, or unnaturally from runoff from pastures, fertilized lawns and cropland. Failing septic systems ad wastewater treatment plants are other sources, as are disturbed land areas and drained wetlands. Phosphorus, both as phosphate and in organic molucles, can be found in solution or attached to suspended particles within the water column.

Nitrogen moves with water as dissolved inorganic nitrogen (nitrate, nitrite and ammonium) and is dissolved or suspended organic nitrogen (complex molecules associated with living, or once living tissue). Nitrates are the most comon form of nitrogen found in the Ventura River. Together with phosphorus, nitrogen in excessive amounts can also cause eutrophication. Nitrate can also be toxic to war-blooded animals, particularly babies (methemoglobinemia or blue baby disease), at concentrations greater than 10 mg/L, and there may also be a link between high nitrate levels and cancer (non-Hodgkin's lymphoma, Ward et al., 1996). Sources of nitrate include effluent from wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, animal manure and industrial discharges. Nitrates move quickly into streams and rivers since they readily dissolve and are not absorbed on soil particles.

Nitrate

Nitrate is the most important form of dissolved nitrogen in the Ventura River, comprising approximately 70% of the total dissolved nitrogen in river and stream samples (ammonium contributes about 1% and organic forms make up the rest). Since nitrogen is vital for life and growth, an obvious question is how much is too much? A nearly universal Public Health limit is 10 mg-N/L (10 milligrams of nitrogen per liter).[18]

However, 10 mg/L is far too much nitrate in terms of eutrophication and river health. US EPA has suggested standards for various eco-regions in the United States, and the goal for Ecoregion III, the xeric (dry) west, in which the Ventura River is located, is less than 0.38 mg/L of total nitrogen (US EPA, 2000). Note that this is less than 4% of the Public Health nitrate limit (RWQCB-LA, 2001). Ecoregion III has been further divided by the EPA into sub-regions, and the sub-region in which the Ventura River lies (Sub-region 6) may end up with a slightly higher limit of 0.52 mg/L. Sub-region 6 also has a suggested nitrate limit of 0.16 mg/L. To simplify, only the 0.16 mg/L suggested total nitrate limit is shown on our figures.

As it turns out, a fine line is not necessary to determine which sampling locations in the Ventura River watershed have unhealthy amounts of nitrogen; sites are either very good or very bad. The Matilija sites (Figure 25, lower panel) are very good, with nitrate levels almost always below the 0.16 mg/L nitrate benchmark.[19] At the opposite extreme, the lower river sites generally, but not always, have very high nitrate values that are hundreds of times greater than the recommended EPA limit. The Group II locations have mixed results: VR08 (Lion Canyon) has very low nitrate, while VR10 (Upper San Antonio Creek) has the most severe excess nitrate problem on the river.

However, the rise in nitrate concentrations at VR10 following the late December 2004 storms, and a simultaneous rise at almost all other locations during the same period, clearly identify the increase with recharge of the upper groundwater table with high nitrate runoff from the winter storms. The increase in nitrate continued until July 2005 at most locations. Only with decreased summer flows and substantial algal growth did concentrations begin their normal dry season decline.

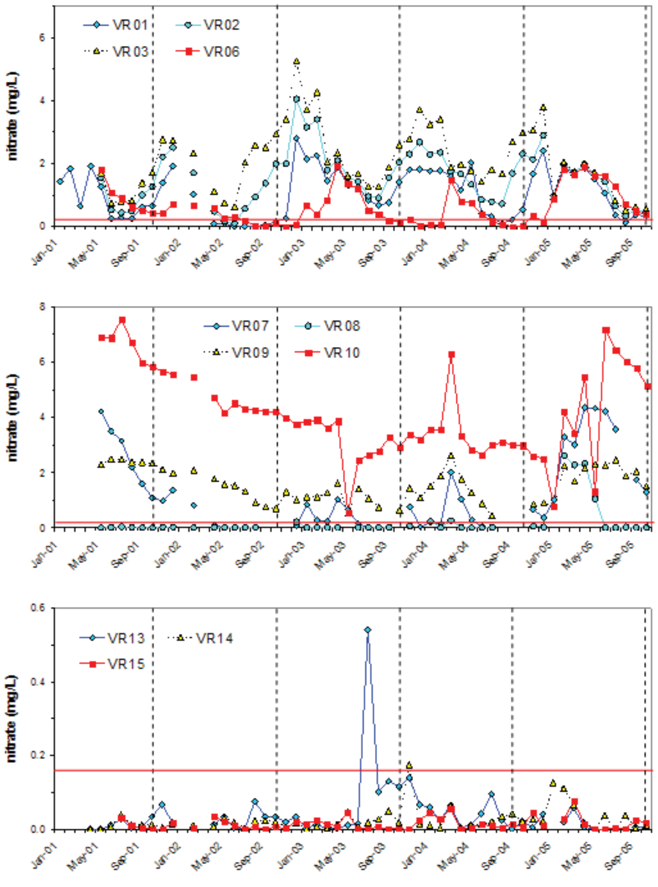


Figure 25. Nitrate concentrations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the EPA's proposed limit for maximum nitrate in this region (Ecoregion III, sub-region 6): 0.16 mg/L. Note that the graphs use different vertical scales.

The most noticeable change during the summer of 2005 was decreased nitrate at the lower river sites (VR01-03, shown in the upper panel of Figure 25). The influx of high-nitrate groundwater and unusually high flows nearly erased the typical pattern of summer and fall Ojai sewage treatment plant dominance of river water below VR06. The pattern of nitrate variation at VR01-03 described in Figure 26 was completely absent in 2005; higher flows minimized the impact of treated sewage effluent throughout the year. Measured lower river flow was 25 cfs as late as September 2005, minimizing the effect of the 2-3 cfs of treated effluent. In contrast, flow at VR01 in September 2005 was only 2 cfs.

Results summarizing the mean concentrations at each site are shown in Figure 25. While no sites exceeded the Public Health nitrate maximum of 10 mg/L, only the Matilija locations met the EPA nitrogen and nitrate criteria. VR10 had the highest nitrate concentrations in the study.

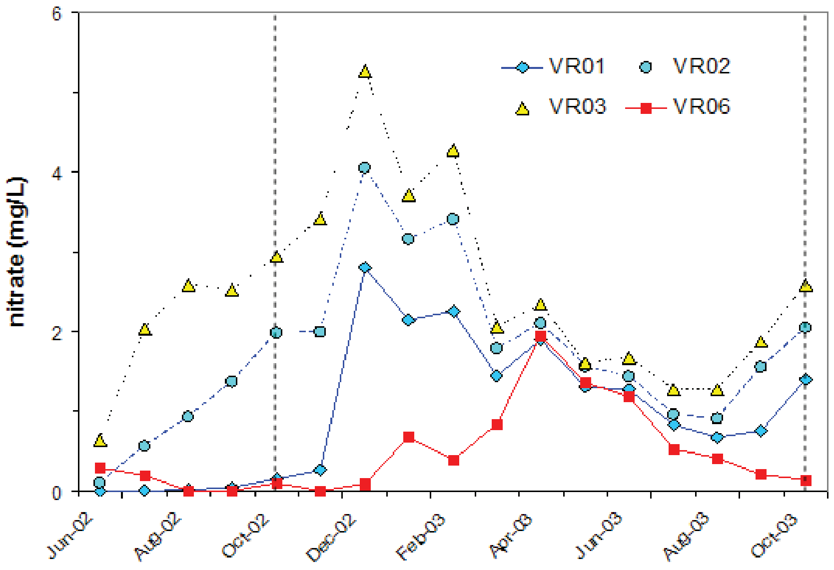


Figure 26. Nitrate concentrations on the lower Ventura River from June 2002 to October 2003. The vertical lines mark the beginning of the water-year. The lower river provides an interesting view of what happens with nitrate over the course of a year. VR06 (Foster Park) represents the normally expected variation in nitrate: a slow rise during the winter to peak values at the end of the rainy season (caused by increasing amounts of high nitrate soil- and ground-waters entering the river as the rainy season progresses), followed by a slow decrease (as plants and algae remove nutrients) throughout the growing season.

The other sampling locations (VR03 to VR01) progressively follow the river downstream from below the Ojai wastewater treatment plant (VR03) to the tidal limit at Main Street (VR01). In this section, the variation in nitrate is different; the rise in concentration begins in summer and continues until December or January. This pattern, of a much earlier rise, is caused by high nitrate outflows from the Ojai sewage treatment plant. By late spring or early summer, natural flows in the river have decreased to a point where treated sewage effluent becomes the major source of water. From then on, until the beginning of appreciably greater discharge due to winter rains, nitrate concentrations increase as effluent increasingly dominates river flow.

The first storms of winter do not noticeably change river flow; most of the rain goes to replenish moisture deficits in dry soil. The early runoff that does enter the lower river comes from more developed parts of the watershed and is usually high in nitrate, thus the increase in nitrate continues until later in the winter. Put simply, winter rains increase concentrations in sections with low nitrate (VR06) and decrease concentrations where nitrate is high. Note that concentrations always decrease from VR03 to VR02 to VR01; biological processes (plants, algae, bacteria) remove nitrate as the river flows towards the ocean.

Phosphate

As with nitrate, the question arises, how much phosphorus is too much? US EPA has recommended maximum levels of phosphorus concentration for streams in this region (Ecoregion III), with an overall recommendation of 0.022 mg/L, and 0.03 mg/L for Sub-region 6 (US EPA, 2000). In this report, the 0.03 mg/L benchmark is used. All the streams in the region have high phosphate concentrations because phosphorus content is high in the marine deposits that make up a large part of the underlying geologic strata (Dillon, 1975; Grobler and Silberbauer, 1985; Schlesinger, 1997), and this is reflected in the increased Sub-region 6 EPA limit.

Figure 29 summarizes our results, showing average phosphate concentrations at each location. All sites had mean phosphate concentrations above the 0.03 mg/L phosphorus limit.[20]

A discussion on patterns of phosphate variation on the lower river, paralleling the nitrate discussion, is provided in Figure 28. At the remaining locations, there is a noticeable association of increased phosphate with the beginning of the rainy season (Figure 27). The first storms mobilize much of the phosphate accumulated on impervious surfaces and in riparian areas during the dry season and transport it to streams (Hager, 2001; MBCWMN, 2002). These storms also move a great deal of sediment and accumulated debris in what were initially dry or near stagnant streams, which also increases phosphate concentrations. The effects of these storms usually remain evident for days afterwards, which is why these increases are evident in the data.[21]

Typically, during the remainder of the winter, high phosphate concentrations are only seen during actual storms (May 3, 2003 was one of those rare days when it rained while sampling was occurring, and increased phosphate concentrations were obvious in many of that day's results; see Figure 27, middle and lower panels). High phosphate is associ-

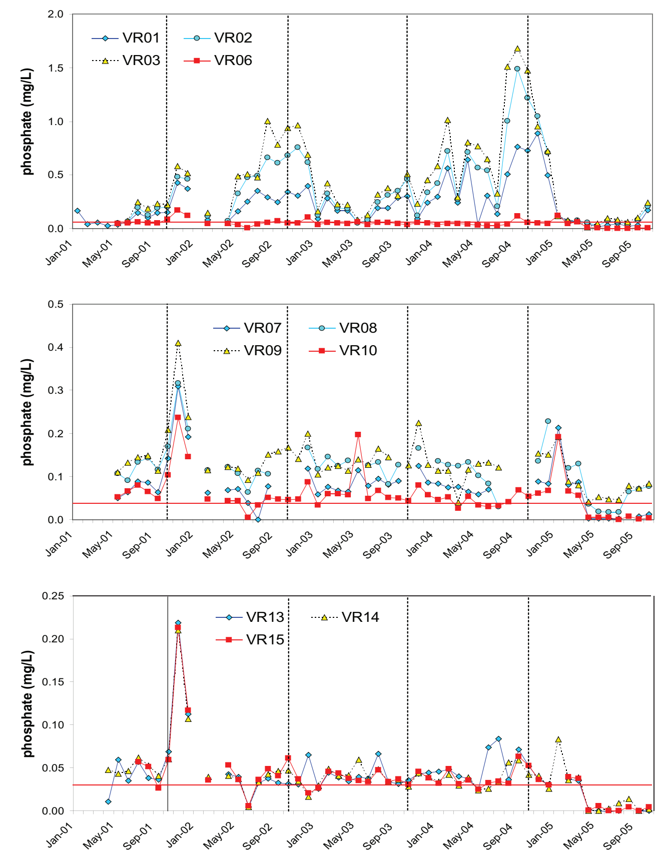


Figure 27 (above). Phosphate concentrations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the EPA proposed target for maximum phosphorus in this region: 0.030 mg/L (Ecoregion III, sub-region 6). The graphs show phosphate, which typically makes up around 90% of the total phosphorus in the stream. Note that the graphs use different vertical scales.

ated with high sediment loads during storms, as phosphate is usually attached to soil particles. The width and condition of streamside buffer areas, the extent of stream-bank armoring and the proximity of unvegetated, easily erodable soil to the channel or storm drain inlet, as well as the intensity of the rainfall, determine how much sediment ends up in the creek, and how much phosphate concentrations increase.

Phosphate levels in 2005 were noticeably lower when compared with those of previous years (Figure 27) due to the extraordinary algal blooms. The probability is that even greater amounts of phosphorus were exported from the watershed to the river in 2005, but the extremely favorable conditions for algal growth (e.g., removal of vegetation and ediment, greater availability of sunlight, reduction in predator numbers and higher levels of nitrate) led to extremely high biological uptake and reduced concentrations throughout the system. Likewise, the ordinary pattern of phosphate variation below the Ojai sewage treatment plant (as described in Figure 28) was not present. Again, similar to what transpired with nitrate, higher than normal flows, combined with high phosphorus uptake, minimized the impact of sewage effluent on the river.

Overall, the three sites below the Ojai sewage treatment plant (VR01-03) have the highest phosphate concentrations found on the river (Figure 29). However, concentrations at VR09 and VR10, below Ojai, are also high, probably due to golf course fertilization and irrigation.

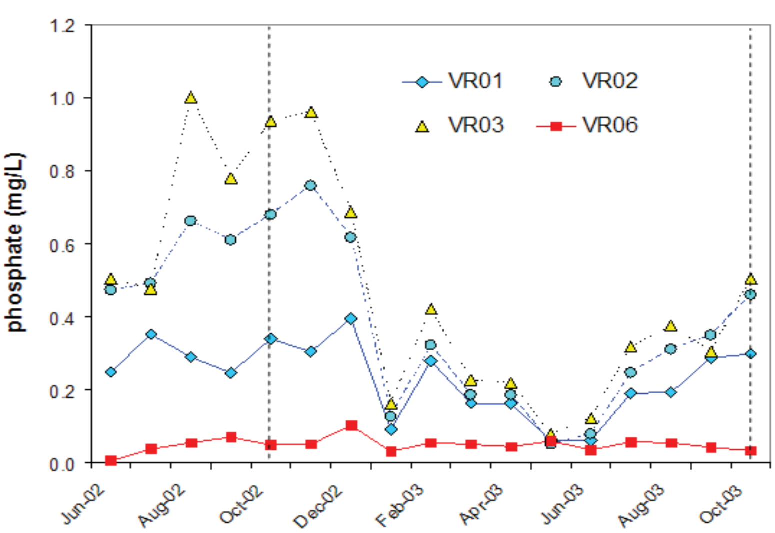
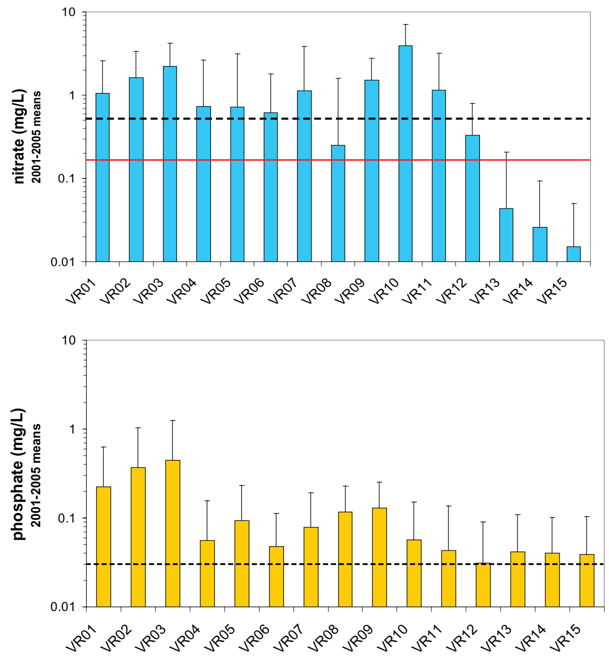


Figure 28 (left). Phosphate concentrations on the lower Ventura River from June 2002 to October 2003. The vertical lines mark the beginning of the water-year. Unlike nitrate (Figure 26), there is very little variation in phosphate concentrations at VR06 (Foster Park). Sometimes there is an increase in phosphate around the time of storms, particularly for the first storm of the year (Figure 27, middle and lower panels), but generally, concentrations are relatively stable. However, the situation is quite different for sampling locations below the Ojai wastewater treatment plant (VR03 to VR01). Here, concentrations have a dramatic pattern: a continuous rise from the beginning of summer until late fall. This pattern is the same one exhibited by nitrate at these sites and it has the same cause - outflows from the treatment plant. Treated effluent is not only high in nitrate but also high in phosphorus, and as effluent increasingly dominates flow in the lower river during the dry season, phosphate concentrations correspondingly rise. When winter runoff finally begins to influence flow, concentrations decrease. Because of sewage effluent, these three sites have the highest phosphate concentrations on the river (Figure 27, upper panel). Again, as with nitrate, concentrations decrease downstream from VR03 to VR02 to VR01, as plants, algae and bacteria, and chemical transformations remove phosphate.



Combining Nitrate and Phosphate[22]

Living organisms need both nitrogen (N) and phosphorus (P), therefore it is necessary to consider both nutrients in combination. Absent either nitrogen or phosphorus, a plant or alga needing both cannot grow and begins to die. Oceanic plankton need N and P in a ratio of 16 atoms of nitrogen to one atom of phosphorus.[23] For freshwater organisms, the average ratio is closer to 30:1 (Nordin, 1985; Sterner and Elser, 2002). A stream with this ratio contains almost the perfect amount of both. A ratio of less than 30:1 means some of the phosphorus goes unused; this case is called "N-Limited." At ratios greater than 30:1, nitrogen is underutilized; this case is called "P-Limited." This is an important concept in stream ecology, since unused nutrients cannot contribute to eutrophication and its associated problems (Borchardt, 1996).

Figure 29. Upper panel: Average nitrate concentrations, January 2001 to October 2005. The solid horizontal line marks the EPA's proposed limit for maximum nitrate in this region: 0.16 mg/L; the dashed line is the recommended limit for nitrogen (0.52 mg/L). Nitrate typically makes up only 50-60% of the total nitrogen in the stream. Lower panel: Average phosphate concentrations, January 2001 to October 2005. The horizontal line marks the EPA's proposed limit for maximum phosphorus in this region: 0.030 mg/L. Phosphate typically makes up more than 90% of the total phosphorus in the stream. The error bar represents twice the standard deviation of samples taken at each site; 95% of the measured values can be expected to be below this limit.

Table 2. Median concentrations (±S.E. of the median) for nutrient species at Channelkeeper's Ventura Stream Team sampling sites, 2001-2005. All concentrations are expressed in micromoles per liter (µM). Sites VR04, VR05, VR11 and VR12 have high standard errors since they are typically dry and are represented by relatively few samples.

	uM	uM	uM	uM	uM	uM	uM
site	**NH4**	**NO3**	**PO4**	**DON**	**DOP**	**TDN**	**TDP**
VR01	0.6±0.2	83.2±8.3	4.8±1.1	24.0±2.3	1.4±0.5	114.3±8.9	5.8±1.2
VR02	1.0±1.2	119.0±10.2	10.5±2.0	29.2±3.3	1.1±0.5	156.3±11.6	10.6±2.1
VR03	1.5±0.4	134.8±12.3	10.5±2.2	27.8±3.4	1.0±1.1	172.9±14.3	11.2±2.3
VR05	0.5±1.2	24.4±14.9	1.7±0.4	29.5±4.9	0.5±0.4	68.1±18.1	2.5±0.4
VR06	0.3±0.1	30.2±7.1	1.5±0.3	9.0±1.6	0.5±0.2	37.6±8.1	1.6±0.3
VR07	0.3±0.1	56.3±18.5	2.4±0.3	14.8±3.3	0.5±0.3	75.9±21.2	2.6±0.4
VR08	0.3±0.1	0.6±9.0	3.9±0.4	26.6±2.4	0.5±0.3	28.4±10.6	4.2±0.4
VR09	0.2±0.1	111.0±8.3	4.0±0.4	15.8±2.7	1.1±0.3	132.6±8.5	4.6±0.4
VR10	0.1±0.1	277.6±19.9	1.6±0.2	24.1±13.0	0.7±0.3	300.7±21.8	2.0±0.3
VR11	0.3±0.1	57.7±20.8	1.1±0.5	9.6±3.4	1.0±0.5	66.2±22.6	1.12±0.6
VR12	0.3±0.1	16.1±5.2	1.1±0.3	7.6±2.6	0.2±0.5	22.0±6.1	0.6±0.5
VR13	0.4±1.3	1.3±1.0	1.2±0.2	9.1±1.3	0.7±0.3	11.7±3.1	1.5±0.3
VR14	0.1±0.1	1.1±0.4	1.3±0.2	4.4±0.8	0.6±0.2	5.3±1.0	1.5±0.2
VR15	0.4±0.1	0.6±0.2	1.2±0.2	5.8±1.9	0.8±0.2	7.5±1.9	1.6±0.2
mean	1.0±0.1	81.2±3.9	4.7±0.3	22.0±0.9	1.3±0.1	102.6±4.3	4.9±0.3

However, there are exceptions. Some aquatic plants and algae do not get nitrogen from the water, but have the ability "fix" nitrogen from the air, or in other words, convert nitrogen gas into ammonia and then use ammonia for cell metabolism. Ammonia is an important source of N, normally found only in low concentrations in the Ventura River (typically around 1-2% of the nitrate concentration, Table 2). These organisms literally carry their own nitrogen supply, since attached symbiotic bacteria do the conversion. This is a relatively rare ability, and these plants and algae are normally not very competitive in aquatic environments where dissolved nitrogen is abundant. However, when nitrogen becomes limiting, these nitrogen-fixing organisms flourish. Because plants, algae and micro-organisms are the foundation of the aquatic food chain, it is important to know which assemblage of species provides this function, and the type of nutrient limitation and its severity help determine this.

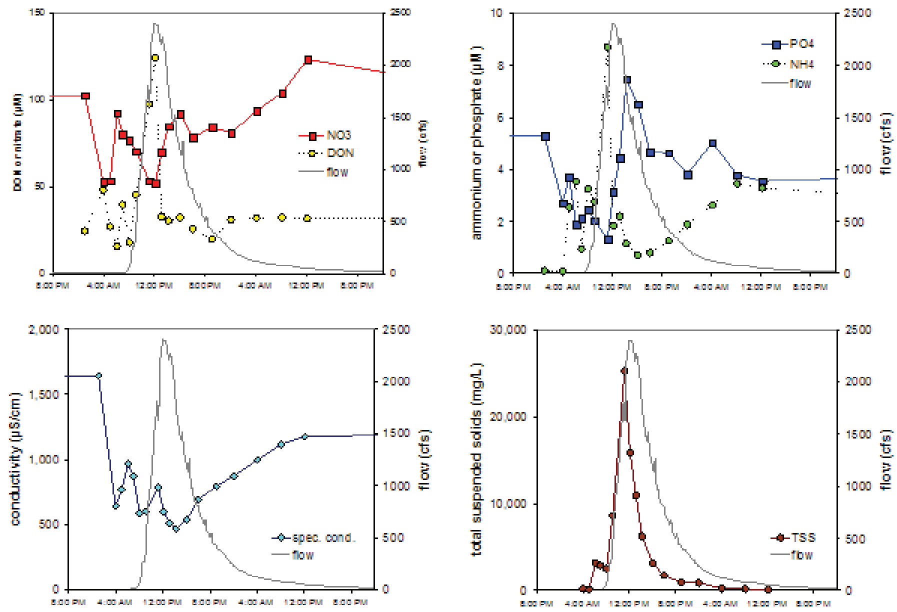


Figure 30. Variation in dissolved nutrients, conductivity and suspended sediment at Main Street (VR01) on March 15, 2003 (the largest storm of that year). The hydrograph measured at Foster Park (VR06) is shown; it only approximates conditions at VR01. The most intense rainfall occurred prior to 4 AM, and the first third of the variations exemplify the response of the lower, more urbanized, Ventura River watershed: initial pulses of urban runoff are characterized by a peak in ammonium, a rise in DON and depressed concentrations of nitrate, phosphate and conductivity. Maximum flow occurred hours after the rain had stopped; considerable time is needed for runoff from Ojai and more distant parts of the watershed to reach Foster Park.

The peak in ammonium, DON and sediment that occurred at VR01 just before peak flow at Foster Park probably marks the arrival of runoff from Ojai via San Antonio Creek. Notice that nitrate and phosphate concentrations were depressed at this same time. This is typical, as storm runoff usually dilutes constituents with high background concentrations and increases those with low (flushes out pollutants). Concentrations that occurred after peak discharge indicate contributions from the relatively pristine, higher-elevation parts of the watershed within the National Forest; runoff from this area was relatively high in both phosphate and nitrate. Large storms flush out nitrate and mobilize phosphate from upstream areas, particularly from areas of chaparral. However, most of the sediment was flushed much earlier, in rising flood waters from the area between Ojai and Casitas Springs.

The Ventura Stream Team sampling locations provide examples of both N-limitation and P-limitation, and at some sites the situation flips back and forth. Figure 31 shows three examples. The vertical nitrate and phosphate scales in Figure 31 were set in a proportion of 20:1 - a concentration of 20 µM nitrate is directly across from 1 µM phosphate, 40 opposite 2, etc. A 20:1 nitrate to phosphate ratio is roughly equivalent to a 30:1 N to P ratio at the Ventura Stream Team sampling locations. The unit is micro-moles per liter (µM – "M" is the symbol for moles/liter).[24] When the nitrate and phosphate concentrations shown in Figure 31 are close together, the nutrients are roughly in balance; when they are apart, one nutrient is in limited supply, and the nutrient in the lower position is limiting.

The Matilija and North Fork Matilija creek sampling sites and Lion Canyon are always N-limited, as phosphate is naturally abundant and nitrogen in short supply (VR14 – Figure 31, upper panel). VR10 (upper San Antonio Creek, middle panel) is the only example of a consistently P-limited location, as nitrate is always far too plentiful here. Fortunately, overhanging vegetation and trees along the bank usually restrict the amount of sunlight reaching the stream, retarding the growth of algae in this reach. VR09 typically has a rough balance of nutrients. The remaining sites shift from one form of limitation to the other (VR03 – lower panel). The general tendency is for N-limitation in the summer and fall, P-limitation in late winter and spring. However, there is a great deal of variation from site to site. The N/P ratio results are summarized in Figure 32.

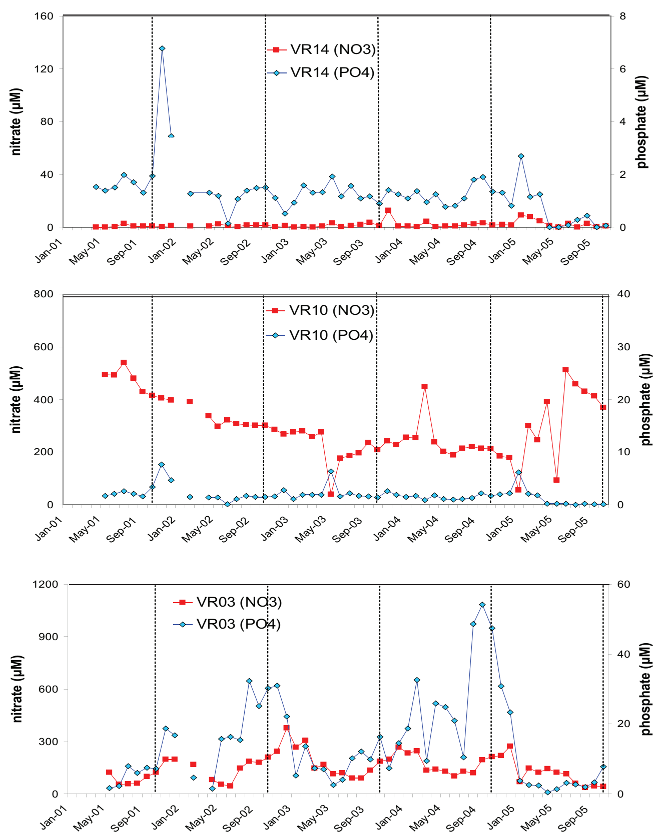


Figure 31. Nitrate and phosphate for three sampling locations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. Concentrations are given in micro-moles/L (µM) and the nitrate scale is 20 times the magnitude of the phosphate scale: 20:1 roughly represents the nutrient uptake ratio (N to P) of terrestrial aquatic organisms.

Dry season nutrient concentrations are both qualitatively and quantitatively different following winters with high rainfall than after seasons of low rainfall. The appreciable groundwater recharge that follows a wet winter disproportionately increases both the amount and concentration of nitrate in stream flow (caused by increased higher nitrate groundwater inflows) over phosphorus. At the same time, the large floods of a wet winter open up stream and river channels to greatly increased dry season algal growth, growth that is to some extent fueled by the increase in nitrate availability.

Thus, after a wet winter, we expect to see an increase in N:P ratios due to both the disproportion-

It is important to consider flow in the discussion of nutrients. During the 2002 drought, and during the decreased flows observed in 2004, N-limitation began earlier and was more severe. Nutrient concentrations indicate relative abundance, they do not provide a measure of the total amount of available nitrate or phosphate. Often the amount is far more important. The amount, or the flux or export, is the product of both concentration and flow: high concentrations provide only small amounts of nitrate when flows are very low. Under these conditions, the supply of nitrogen becomes severely limited as water moves downstream (to reiterate, 30 times more nitrogen than phosphorus is typically needed), and nitrate concentrations often decrease to zero in summer and early fall (Figure 25). At these times, N-fixing plants and algae become dominant and can dramatically change what is observed on the river. Possible impacts of these changes on the food chain remain unexplored.

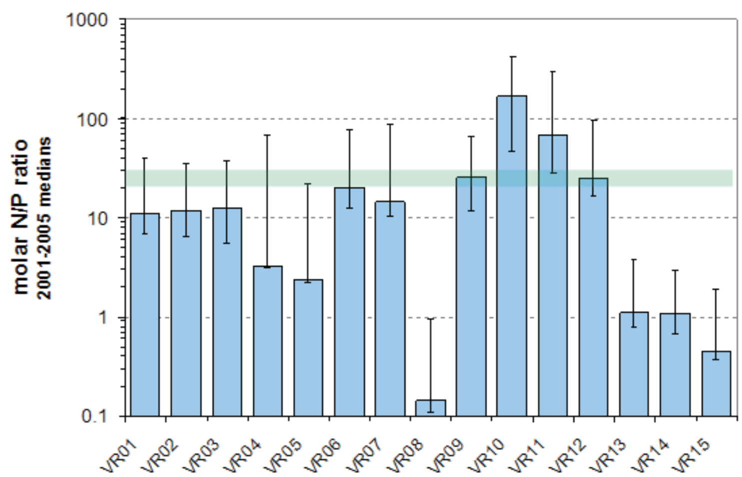


Figure 32. Median nitrate to phosphate ratios for the Ventura Stream Team sampling sites, January 2001 to October 2005. Life requires both nitrogen and phosphorus, but in different amounts. Plankton, on which the oceanic food chain is based, use nitrogen and phosphorus in a ratio of 16 molecules of N to 1 of phosphorus; this is known as the "Redfield Ratio." In creeks and rivers, the ratio is closer to 30:1 and is indicated by the shaded horizontal bar in the figure (the nitrate to phosphate ratio is being used as an approximation of the nitrogen to phosphorus ratio; on average, nitrate is approximately 85% of the total nitrogen and phosphate 90% of the total phosphate). The Matilija tributaries and Lion Canyon are severely "nitrogen limited," meaning that while phosphorus is plentiful, nitrogen is often exhausted. VR10, below Ojai, is "phosphorus limited"; more than sufficient nitrogen is present but phosphorus is typically in short supply. All other locations move across the boundary depending on time of year, typically being phosphorus limited during winter and spring and nitrogen limited in summer and fall. The error bars indicate the quartile points, e.g., 50% of the monthly N/P ratios for that location lie within the band represented by the error bar.

al increase in nitrate and the accelerated utilization of phosphorus by increased algal uptake. Contrasting average N:P ratios for the 2004 dry season with those from 2005 (May through September) demonstrates that this is precisely what happened (Figure 33). At half of the sampling sites, phosphate was undetectable during most of this period.[25]

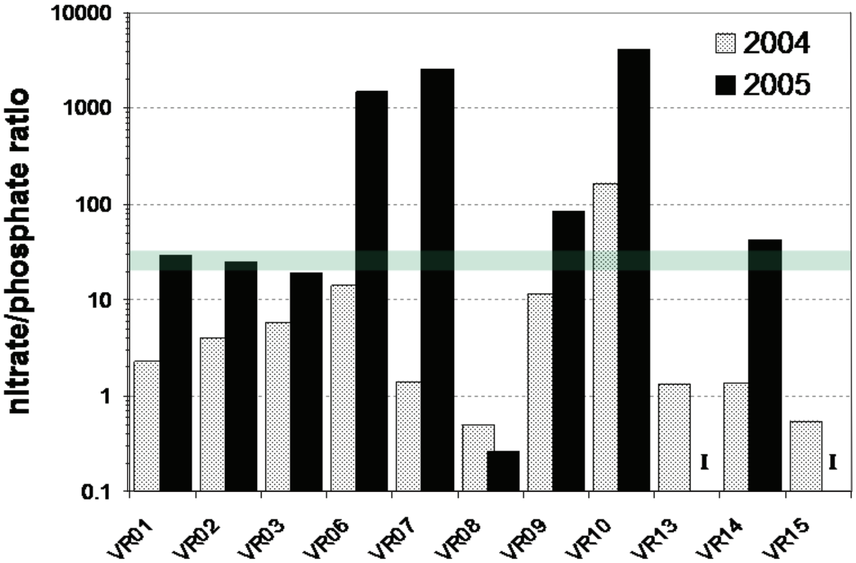


Figure 33. Average dry season (June through September) nitrate to phosphate ratios for 2004 and 2005. The shaded horizontal bar marks the approximate 20:1 to 30:1 zone where both nutrients are in balance. The letter "I" indicates sites where phosphate concentrations fell below detection limits (< 0.3 µM) and the N:P ratio was indeterminate. The increased nitrate concentrations and heavy algal growth following a wet winter produced a substantial increase in N:P ratio at all locations except VR08 (Lion Canyon).

The export of nutrients from the Ventura River into the Santa Barbara Channel is probably of little ecological importance. The mixing of relatively small volumes of river water with vast quantities of saltwater circulating in the Channel precludes a meaningful impact from terrestrial nutrients.[26] However, variations in nutrient export undoubtedly have noticeable and severe effects on the Ventura lagoon and estuary.

The lagoon and its fringing salt marsh are subject to drastic changes over the course of a year. Tidal inflows, normally the major influence on coastal lagoon or marsh systems, may be reduced or eliminated by the formation of sand berms at the river mouth. Depending on river flow and blockage at the mouth, lagoon water may be alternately brackish (low salinity; 5-30 parts per thousand, approximately 4-46 mS/cm) or hyper-saline (greater than 40 parts per thousand salinity or 60 mS/cm), and finally, the lagoon is periodically flushed with freshwater during winter storms. On top of this extreme seasonal variation, since river flow exercises a large degree of control on lagoon conditions, the year-to-year variation is also considerable.

Wet years are characterized by large inputs of water and nutrients from the Ventura River (Figure 34), and since the

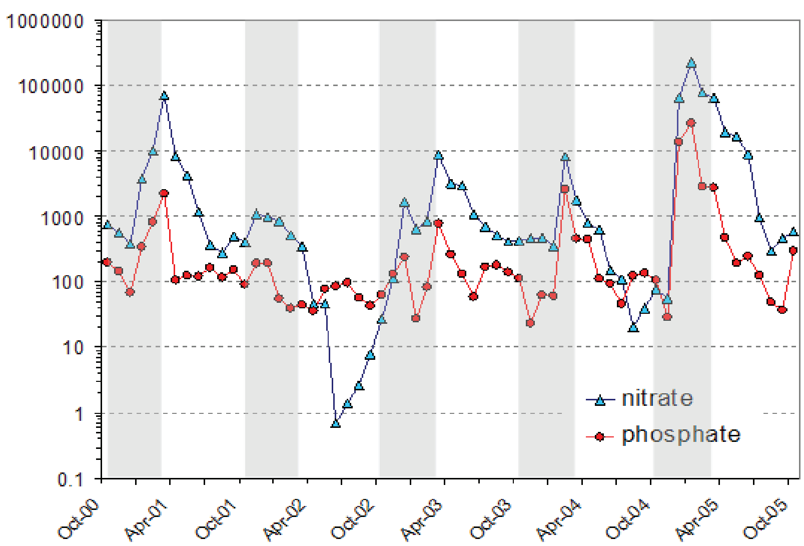


Figure 34. Monthly export of nitrate and phosphate to the Ventura Lagoon, 2001-2005. The shaded areas represent winter rainy seasons. Units are kilograms of nitrogen or phosphorus per month. Export was calculated as the product of monthly concentrations (bi-monthly in 2003 and 2004) and estimated flow at VR01 (USGS gauging data at Foster Park plus average Ojai wastewater treatment plant discharge). Nitrate varies substantially: the kilogram scale is a log scale, each major division representing a factor of 10; the difference between the highest and lowest monthly fluxes is little less than six major divisions, e.g., six decimal places – a difference of almost a million. There is also a big difference from year to year. During drought or relatively dry years (2002 and 2004), nitrate almost disappears from the river at this location. Note that phosphate export is quite different: the flux, particularly during the dry season, is relatively consistent at roughly 100 kg/month. The Ventura lagoon generally gets sufficient phosphate, but depending on the year, nitrate usually becomes either mildly or strongly limiting as the growing season develops, and in drought years a lack of nitrogen is probably extremely limiting.

lagoon mouth remains open to the ocean for longer periods, tidal inflows play a more important role during the dry season. In dry years, the mouth of the lagoon remains closed for longer periods of time, while inflows of freshwater and nitrogen decrease appreciably; the difference in summer N export between wet and dry years approaches three orders of magnitude, a 1,000-fold difference. The phosphate flux, particularly during the dry season, is relatively consistent – roughly around 100 kg/month. The Ventura lagoon generally receives sufficient phosphate input, but depending on the year, nitrate usually becomes either mildly or strongly limiting as the growing season develops, and in drought years, lack of nitrogen is probably extremely limiting (Figure 35).

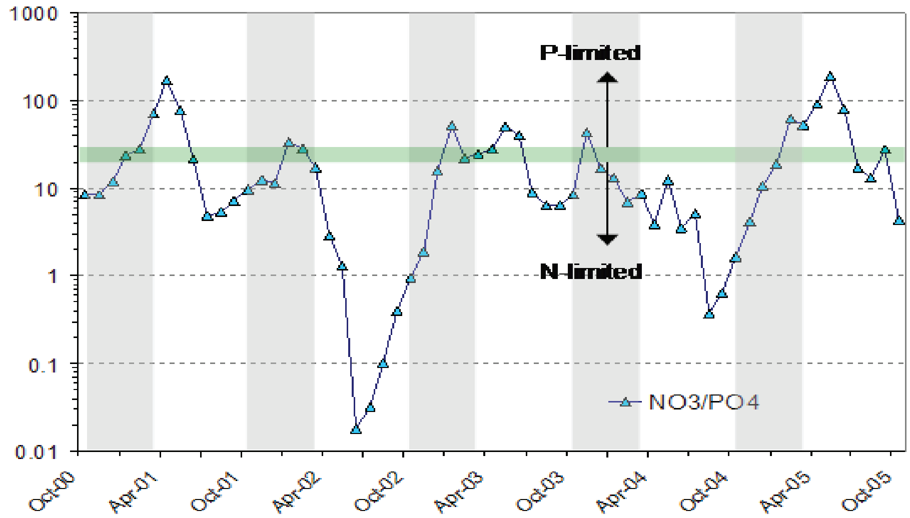


Figure 35. The relative proportions of nitrate and phosphate export to the Ventura Lagoon, 2001-2005. The graph simply shows the nitrate concentration divided by the phosphate concentration for each month's sampling data at VR01. The shaded vertical bars indicate rainy seasons. The thick horizontal shaded bar represents a molecular ratio of 20:1 to 30:1; the approximate zone where both nutrients are in balance. If the ratio is above the line, water going into the lagoon is phosphorus limited, and if below the line, nitrogen limited. Winters and early spring are mostly in balance or phosphorus limited, while the remainder of the dry season is nitrate limited. In some drier, low-rainfall years (2002 and 2004), freshwater supplies to the lagoon become severely nitrogen deficient.

Unfortunately, the changes that these variations produced in the lagoon and marsh remain unknown. Expansion of the Ventura Stream Team sampling program into these areas would therefore be a meaningful addition.

Indicator Bacteria[27]

Members of two bacteria groups, the coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses and protozoans that also live in human and animal digestive systems. Their presence in streams suggests that pathogenic micro-organisms might also be present, or that swimming and eating shellfish might pose a health risk. Since it is difficult, time-consuming and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. Typically, a single sample is collected from each location (along with duplicates collected for quality control), brought back to the Channelkeeper lab, and analyzed within six hours for three indicators: total coliform, E. coli and enterococcus.

Total Coliform

Total coliforms are a large and widespread group of bacteria. Coliforms can occur in human feces but are also found in animal manure, soil, vegetation, submerged wood, and in other places outside the human body. Therefore, the usefulness of total coliforms as an indicator of fecal contamination depends on the extent to which the bacteria found are fecal and human in origin. For recreational waters, total coliforms are no longer recommended by the

US EPA as an indicator, but they are still the standard test for drinking water because their presence indicates contamination of a water supply by some outside source. The State of California still requires a total coliform test for recreational waters because the ratio of fecal to total coliforms remains a good indicator of swimming-related illness.

E. coli

E. coli is a species of fecal coliform bacteria specific to fecal material from humans and other warm-blooded animals. The EPA recommends E. coli as the best indicator of health risk from water contact in freshwater; California state regulations still require the broader fecal coliform test.

Canada Larga Creek did not meet any bacteria standards.

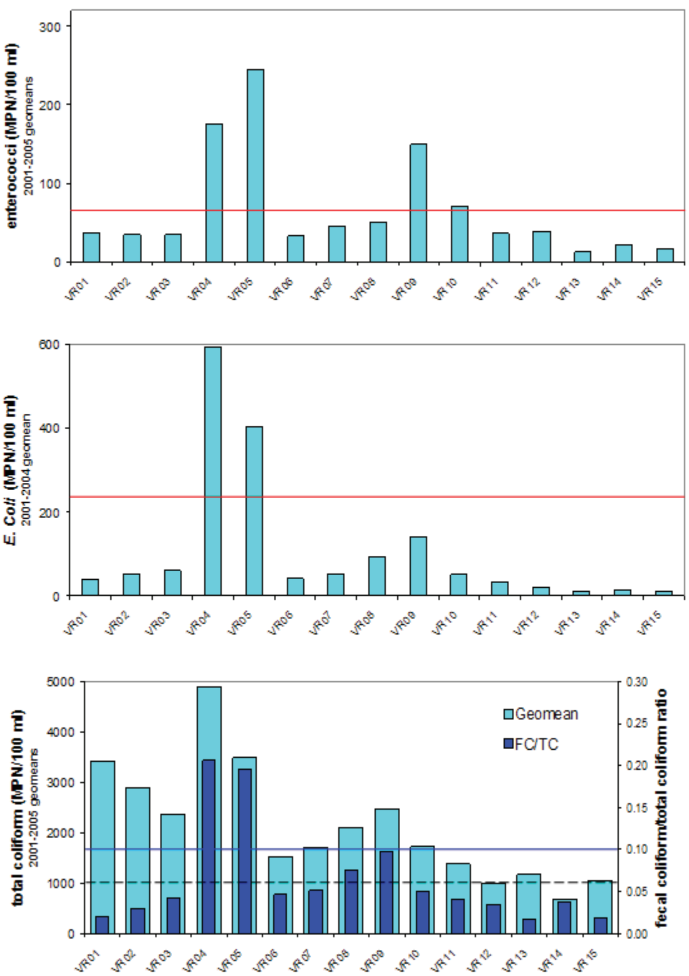


Figure 36. Average enterococci, E. Coli and total coliform concentrations, January 2001 to October 2005. Solid horizontal lines mark the EPA's recommended freshwater beach Public Health limits for maximum enterococcus (61 MPN/100 ml) and E. Coli (235 MPN/100 ml). The California limit for total coliform (10,000 MPN/100 ml) decreases to 1,000 (dashed line) if the fecal coliform/total coliform ratio exceeds 0.1 (solid horizontal line).

Enterococcus

Enterococci are a more human-specific subgroup of fecal streptococci bacteria. Enterococci are distinguished by their ability to survive in salt water, and in this respect they mimic many pathogens more closely than the other indicator bacteria. The EPA recommends enterococci as the best indicator of health risk in saltwater used for recreation, and as a useful indicator in freshwater as well.

Bacteria levels are reported as the *most probable number* (MPN) of bacteria in 100 milliliters of water (100 ml is about 4 ounces). Channelkeeper uses a statistical test instead of directly counting bacteria, so the actual reported number remains a statistical estimate.[28] There are two California Public Health limits for each test: a single sample limit and a limit for an average of five or more samples collected over a period of either five weeks or a month (called the "geomean").[29] For freshwater recreational use, the total coliform limits are "no more than 10,000 per 100 ml in a single sample and an average of less than 1,000." For E. coli, the average limit is 126 bacteria/100 ml of water, and the single sample limit varies from 235 to 500 depending on intensity of use.[30] For enterococcus, the "average of five or more samples" limit is 33 and the single sample limit can vary from 61 to 151, again depending on frequency of use.

The total coliform limits are an average of 1,000 and a single sample of 10,000, *as long as the fecal/total coliform ratio is less than 0.1.*[31] If the ratio rises above 0.1, the single sample limit decreases to 1,000 MPN/100 ml.

Since Channelkeeper's Ventura Stream Team samples only once a month, using average geomean standards would be inappropriate. However, the geomean concept, of reducing the importance of occasional very high or very low samples, is a useful tool. Accordingly, geomean values of all samples taken from January 2001 to October 2005 for each of the three types of bacteria were calculated, and the results are shown in Figure 36.

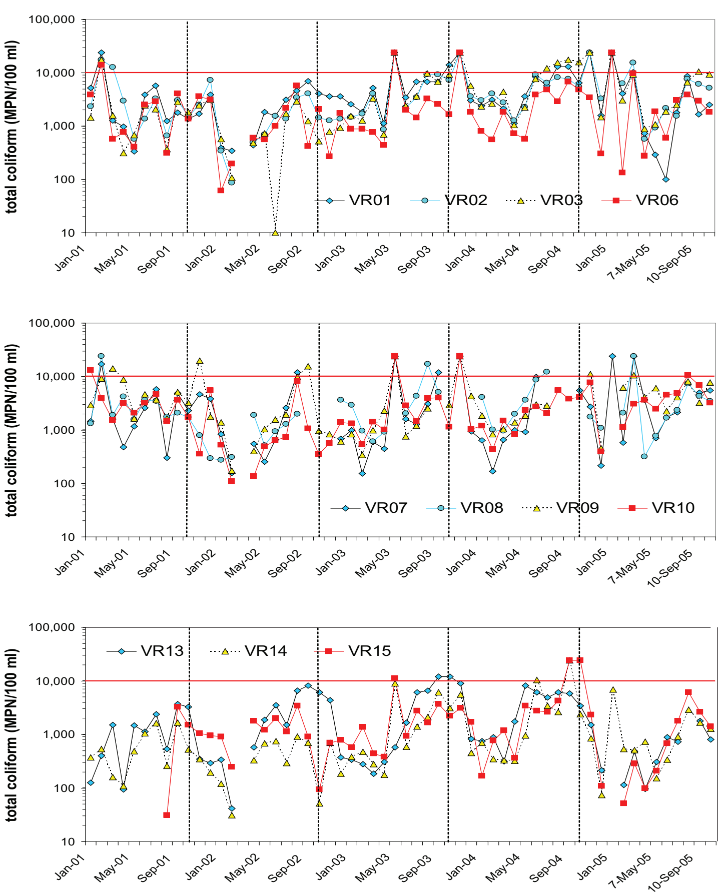


Figure 38. Total coliform concentrations, January 2001 to October 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the Public Health single sample freshwater-beach limit of 10,000 MPN/100 ml. The dilution typically used during the test procedure cannot determine concentrations above 24,192 MPN/100 ml, so concentrations greater than 24,192 have been assigned this number.

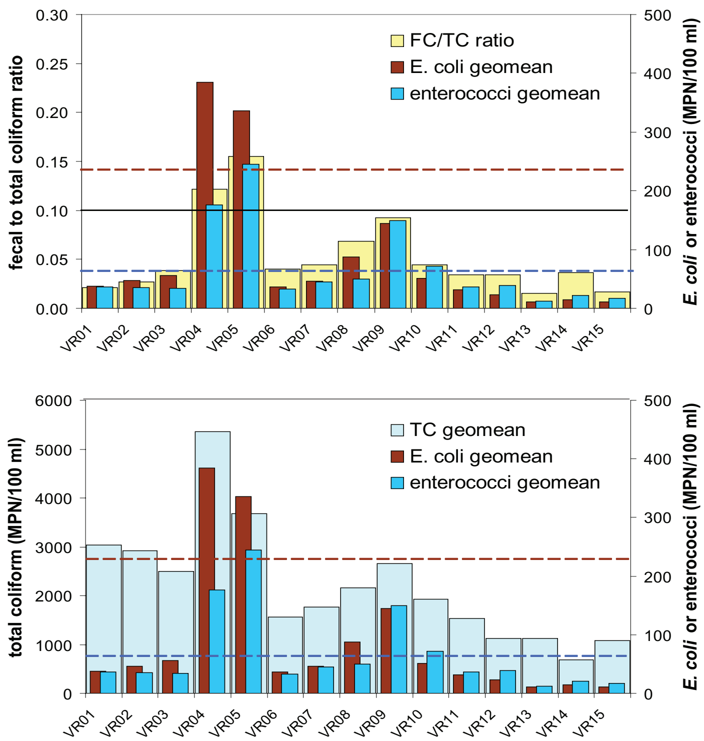


Figure 37. Upper panel: The average fecal to total coliform ratio, and E. coli and enterococci concentrations, January 2001 to October 2005 (as geomeans). Dashed horizontal lines mark the EPA's recommended freshwater beach Public Health limits for maximum enterococcus (61 MPN/100 ml) and E. Coli (235 MPN/100 ml). The California limit for total coliform (10,000 MPN/100 ml) decreases to 1,000 (indicating a pollution problem) if the fecal coliform/total coliform ratio exceeds 0.1 (solid line). Lower panel: Total coliform, E. coli and enterococci geomean concentrations, January 2001 to October 2005.

With regard to which sampling locations generally have the highest numbers of bacteria, there is relatively good agreement between all three bacteria tests (Figure 37), or four tests in total if the fecal to total coliform ratio is included. However, in terms of which sites meet the standards for freshwater recreation (using single sample standards of 61 enterococci, 235 E. coli and 10,000/1,000 total coliforms as criteria), the results present a mixed picture. All three tests agree that VR04 and VR05 (Canada Larga) are highly polluted and do not meet any of the standards. However, VR09 and VR10 (Stewart and Thacher/Upper San Antonio creeks) fail the enterococci standard, but they are well below the E. coli standard. VR09 approaches but does not fail the total coliform standard.

These findings are quite typical. Studies generally show that while there tends to be agreement between the three tests at either highly polluted or pristine sites, they can diverge appreciably on sites that lie in the middle (Kinzelman, 2003; Nobel et al., 2003).[32]

Figures 38, 39 and 40 show the monthly variation in total coliform, E. coli and enterococci, respectively. Concentrations dramatically increase during storms and remain elevated for three to four days afterwards. This is most readily seen in the data for May and November 2003 and January 2005, when sampling occurred during storm events. Aside from these storm peaks, there is a hint of a pattern in the total coliform data, and possibly with the other two indicator bacteria at some locations. Concentrations increase from a minimum near the end of the rainy season (February to April), reaching a maximum just before the start of winter rains, usually around September. Concentrations then begin a gradual decrease until they reach a spring minimum. Presumably a winter decrease could be expected, caused by higher and colder wet-weather flows after the first flushing storms of the season wash bacteria from impervious surfaces. Periodic flushing, colder water temperatures and faster flows may reduce concentrations throughout the wet season and keep them low until spring.

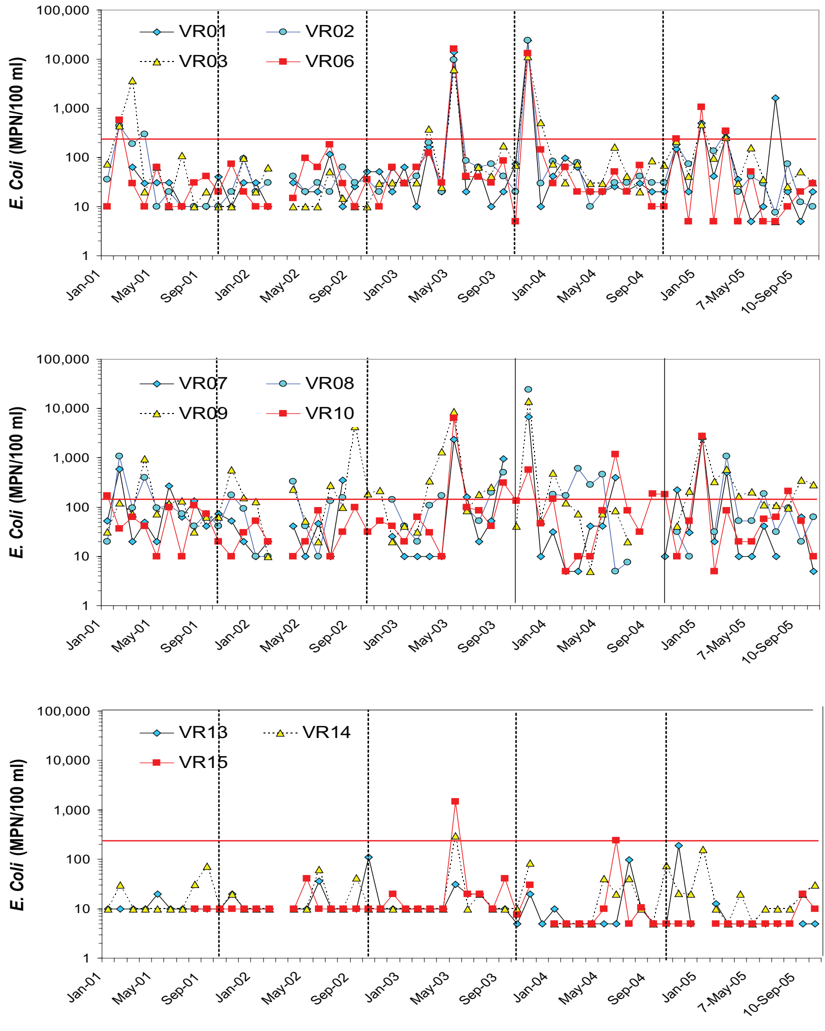


Figure 39. E. Coli concentrations, June 2002 to October 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the Public Health single sample freshwater beach limit of 235 MPN/100 ml. The dilution typically used during the test procedure cannot determine concentrations above 24,192 MPN/100 ml, so concentrations greater than 24,192 have been assigned this number (during stormflow in November 2003).

It is more difficult to envision why numbers of bacteria should increase as the dry season progresses, and why they would peak around September. While warmer water temperatures are probably more conducive to the survival of bacteria, the primary mechanism that removes indicator organisms from open water appears to be predation by zooplankton, rather than adverse environmental conditions (Rassoulzadegan and Sheldon, 1986). However, research has shown that coliforms and enterococci can survive and grow in natural waters (Francy et al., 2000; Nasser and Oman, 1999) and reproduce in plants and soil (Solomon et al., 2002; Hardina and Fujioka, 1991; Marino and Gannon, 1991).[33] Therefore, it is possible that these bacteria could not only be surviving but reproducing in the streamside environment during the warm temperatures of a South Coast summer. Another explanation may be that bacteria become more concentrated as flows decrease throughout the dry season.

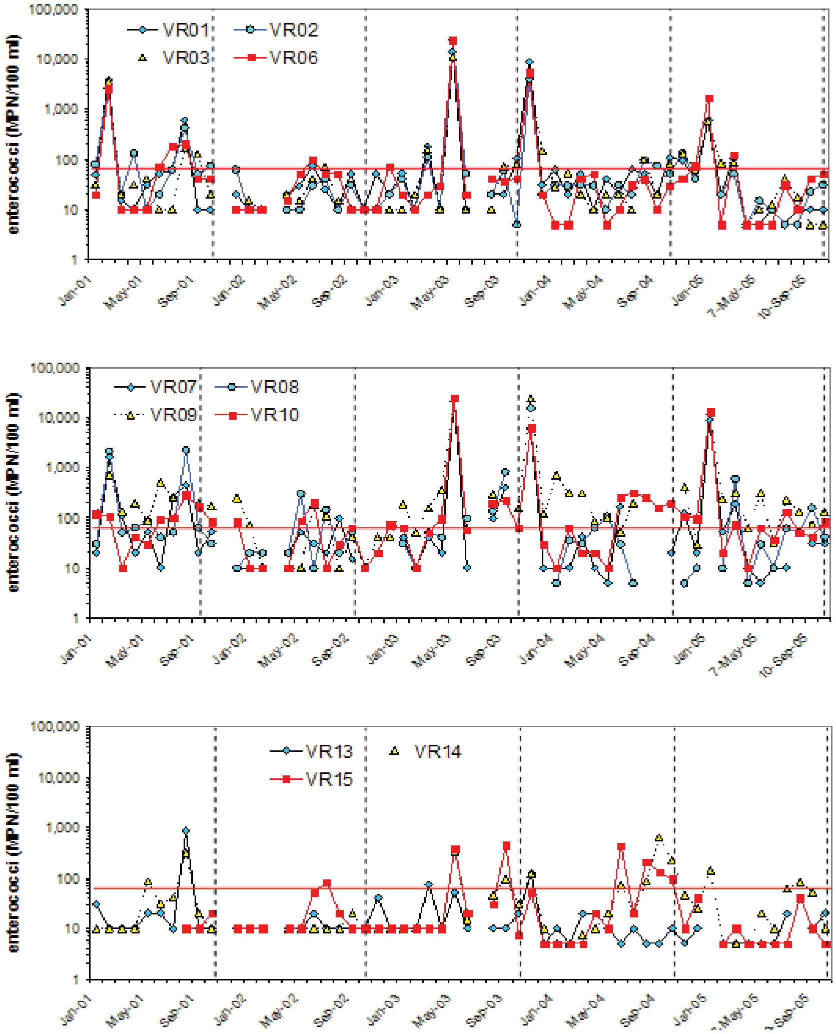


Figure 40. Enterococci concentrations, January 2002 to April 2005. Dashed vertical lines mark the start of each water-year. The horizontal line marks the Public Health single sample freshwater beach limit of 61 MPN/100 ml. The dilution typically used during the test procedure cannot determine concentrations above 24,192 MPN/100 ml, so concentrations greater than 24,192 have been assigned this number (during stormflow in May 2003).

Summary of Results: Problem Areas

In this section, the sampling results discussed previously are reviewed to identify overall problem areas and potential causes. Three categories of data are examined: physical parameters, biological parameters, and Public Health parameters.

Physical Parameters

Conductivity, water temperature, pH, and turbidity are grouped into the physical parameters category. Table 3 summarizes problem locations identified by abnormal values found in Ventura Stream Team sampling results.

Table 3. Physical parameters. Numbers in the table are calculated criteria values that identify specific problems at Channelkeeper's Ventura Stream Team sampling sites. Column headings show the parameters, measurement units and criteria used flag problem areas. The specific criteria were: (1) median conductivity > 2,000 µS/cm; (2) 10% of monthly water temperatures ≥ 26.4°C; (3) 10% of monthly pH values > 8.5; and (4) median non-storm turbidity > 1.9 NTU.

site	conductivity	temperature	pH	turbidity
	µS/cm	percent	percent	NTU
	median	10% ≥ 26.4 °C	10% ≥ 8.5	median
VR01			12.3%	
VR02			25.0%	
VR03			15.8%	
VR04	2,663			
VR05	3,048			
VR06				
VR07				
VR08				
VR09				
VR10				
VR11				
VR12				
VR13				
VR14				
VR15				

Conductivity

Excessively high conductivities can signify any combination of waste flows and dry-season runoff containing high concentrations of dissolved salts, high evaporation rates occurring under stagnant conditions, and possibly, dissolution of cement by trickling flows in concrete channels. Canada Larga is the only Ventura tributary with excessive conductivity. The probable causes are grazed pasture runoff at the upper site and industrial nuisance flows at the lower site. Both locations are prone to low flows with high evaporation, and the concrete canal above VR04 may also contribute to the problem. The criterion used to identify excessive conductivity was a median value greater than 2,000 µS/cm (25% above the maximum limit for domestic water supplies). Although conductivity at VR08 did not exceed the 2,000 µS/cm standard, its high median conductivity (1,748 µS/cm), likely due to pasture runoff and high evaporation, is cause for some concern.

Temperature

The criterion for water temperature was a statistical test - if 10% of the monthly values were equal to or exceeded 26.4°C, it was judged excessive (26.4°C is 10% higher than the maximum temperature benchmark of 24°C used earlier). No Ventura Stream Team sites had excessive temperatures, and only VR04, VR05 and VR08 had any recorded temperatures greater than 26.4°C. These sites typically have shallow trickling flows, little riparian cover, and high exposure to sunlight.

*p*H

A similar statistical criterion was used for pH - excessive pH was identified if more than 10% of the monthly values exceeded 8.5.[34] Excess pH in the Ventura River and its tributaries is almost always caused by algal blooms. Excessive pH on the lower river (VR01-03) was mainly due to algal growth during the summers of 2001, 2003 and 2005.

Turbidity

Excessive turbidity was identified as non-storm median values exceeding the suggested EPA limit of 1.9 NTU. The sites exceeding this limit are typically characterized by relatively stagnant waters and excessive biological productivity (the presence of microscopic algae and bacterial films at the site or immediately upstream). No Ventura Stream Team sampling sites exceeded the 1.9 NTU criterion, but VR01, with a median of 1.88 (3.73 mean value), approached it.

Biological parameters

Biological problem areas were identified by examining nitrate, phosphate, minimum dissolved oxygen and excessive dissolved oxygen saturation. Excessive biological productivity or eutrophication is the major biological problem identified by Ventura Stream Team sampling. Excessive nutrient concentrations are the major causal factors, and both minimum DO values and excessive DO saturation pinpoint the deleterious effects. Problem locations are summarized in Table 4.

Table 4. Biological parameters. Numbers in the table are calculated criteria values that identify specific problems at Channelkeeper's Ventura Stream Team sampling sites. Column headings show the parameters, measurement units and the criteria used flag problem areas. The specific criteria were: (1) median nitrate > 0.52 mg-N/L; (2) median phosphate > 0.03 mg-P/L; (3) greater than 5% of monthly DO < 5 mg/L and a minimum DO ≥ 4.0 mg/L; and (4) 10% of the monthly values exceeding 120% saturation. Particularly egregious results are shown in bold.

site	nitrate	phosphate	minimum DO	% DO sat.
	mg-N/L	mg-P/L	% (mg/L)	percent
	median	median	5% < 5 (min)	10% < 120%
VR01	1.04	**0.164**		**26.0%**
VR02	1.67	**0.270**	8.1% (4.0)	**37.5%**
VR03	2.00	**0.312**		**22.8%**
VR04		0.044	10.8% (3.5)	12.9%
VR05		0.080		
VR06		0.044		**31.6%**
VR07	0.66	0.076	11.1% (3.9)	14.9%
VR08		0.121	11.1% (3.9)	11.1%
VR09	1.44	0.124		
VR10	3.75	0.051		
VR11		0.033		11.8%
VR12		0.034		11.8%
VR13		0.037		
VR14		0.039		
VR15		0.036		**23.4%**

Nutrients

The criteria used to identify excessive nutrients were median nitrate concentrations above 0.52 mg/L and median phosphate concentrations above 0.030 mg/L. These limits are, respectively, the suggested EPA values for nitrogen and phosphorus in the Ventura region. As applied here, they are slightly less conservative, since they evaluate only the nitrate and phosphate fractions of these elements.

Almost all sampling locations showed excessive nutrients. To distinguish particularly problematic situations, concentrations far above the norm are shown in bold ("far above the norm" being defined as five times the EPA limit). Urban and agricultural runoff are the major sources of high nitrate at VR09 and VR10 (below Ojai) if the definition of agriculture is extended to include "urban agriculture," e.g., runoff from the fertilization and over-watering of lawns, landscaping, parks and golf courses. However, on the lower river (VR01-03), treated sewage effluent is the primary source of high nitrate. Other sources contributing to the overall nitrate problem in the Ventura watershed include deposition of airborne pollutants, auto emissions, and high groundwater concentrations from prior land uses. However, the effects of these inputs are mainly observed during storms and the rainy season, whereas the majority of Ventura Stream Team sampling takes place during dry weather, when urban nuisance flows and the discharge of treated sewage effluent dominate.

Every Ventura Stream Team sampling location has problems with high phosphate, with all sites exhibiting median phosphate concentrations that exceed the EPA recommended limit for total phosphorus. This is largely a consequence of natural geological conditions in the watershed. However, the release of treated sewage effluent above VR03 adds appreciably to the problem on the lower river (VR01-03). Elsewhere, VR08 and VR09 in the San Antonio drainage also have markedly high phosphate. The probable main cause at VR08 is animal waste from cattle and horses. The precise cause of high phosphate concentrations at VR09 remains unknown, but urban agriculture (fertilizer, pesticides, etc.) and domestic pets and horses undoubtedly contribute.

Cattle grazing is a major source of nutrient contamination in San Antonio Creek. This photo was taken just downstream of VR08.

Dissolved oxygen

Actual rather than potential algal problems can be identified by dangerously low levels of dissolved oxygen (DO) and excessive oxygen saturation. Two criteria were used to identify low DO: minimum concentrations equal to or below 4 mg/L, and greater than 5% of the monthly values lower than 5 mg/L. The criterion for percent saturation was greater than 10% of the monthly values exceeding 120% saturation. Locations where more than 20% of monthly DO saturation exceeded 120% are highlighted in bold.

The DO criteria are somewhat contradictory, as excessive percent saturation values are likely to be found only during daylight, while minimum DO concentrations generally occur at night. Since almost all Ventura Stream Team sampling takes place during daylight, excessive percent saturation is the better metric. With continued pre-dawn sampling and the further accumulation of this type of data, a better minimum DO criterion can be established. At present, only problem locations with relatively deep stagnant waters, and with high concentrations of bacteria, can be identified by minimum DO levels. It is for this reason that different problem areas have been identified by each of the two parameters. This is particularly true for locations with the most egregious percent saturation values, where low DO concentrations are unlikely to be found during daylight hours.

The lower Ventura River (VR01-03 and VR06) and upper Matilija Creek have the greatest problems with excessive algal growth (as identified by percent DO saturation). These problem locations all feature open reaches with high levels of sunlight. High nutrient levels at VR01-03 undoubtedly contribute, and the algal problem at these three locations is the primary cause of excessive pH. Although critically low values of dissolved oxygen were not found at these sites (except at VR02), we suspect they may occur periodically.

Public Health Parameters

In this section, concentrations of indicator bacteria and the fecal to total coliform ratio (FC/TC) were used to identify threats to public health. While many problem locations are not common sites for human recreation, it is clear that bacterial contamination is still a problem at several sites. Results are summarized in Table 5.

Table 5. Public Health parameters. Numbers in the table are calculated criteria values that identify specific problems at Channelkeeper's Ventura Stream Team sampling sites. Column headings show the parameters, measurement units and the criteria used to flag problem areas. The specific criteria were: (1) geomean > 235 MPN/100 ml for E. coli; (2) geomean > 61 MPN/100 ml for enterococci; (3) FC/TC geomean ratio > 0.1; and (4) total coliform geomean > 10,000 MPN/100 ml, unless FC/TC exceeds 0.1, then reduced to 1,000. Geomeans exceeding the EPA standards for "infrequent full body contact recreation" are shown in bold.

site	E. Coli	enterococci	FC/TC	total coliform
	MPN/100 ml	MPN/100 ml	ratio	MPN/100 ml
	geomean	geomean	geomean	geomean
VR01				
VR02				
VR03				
VR04	**595**	**176**	0.21	4950
VR05	403	**245**	0.20	3490
VR06				
VR07				
VR08				
VR09		**150**		
VR10		71		
VR11				
VR12				
VR13				
VR14				
VR15				

Geomean concentrations above acceptable EPA, Santa Barbara County or State of California limits were used as selection criteria to identify locations unsuitable for water contact recreation. This may be too high a standard since these concentrations (E. coli < 235 MPN/100 ml; enterococci < 61; total coliform < 10,000 or 1,000 if FC/TC > 0.1) are applicable to freshwater public beaches. Accordingly, egregious sites (in bold) are identified as those which exceed a lower standard, identified by the EPA as "infrequent full body contact recreation": E. coli < 576 and enterococci < 151 MPN/100 ml.

Very few sites failed to meet the Public Health standards for swimming, and only VR04 and VR05 (Canada Larga) may present a true hazard for occasional recreational users, the most likely public form of public contact with these waters. E. coli is judged by the EPA as the best freshwater indicator of problems, and only VR04 had concentrations consistently exceeding the "infrequent use" standard. Some of the possible reasons for high enterococci counts at VR09 and VR10 were discussed in earlier sections of the report. The very high FC/TC ratios at Canada Larga are most likely due to cattle grazing.

Based on the criteria identified above, all of the Ventura Stream Team sampling sites show at least some water quality problems. However, at sites VR13 and VR14, the only problem identified was with phosphate, which, as explained earlier, is probably due to natural geologic conditions. The sites demonstrating the fewest impairments were VR06, VR12, VR13, VR14, and VR15, each exceeding two or less of the twelve criteria. However, it must be noted that VR12 is frequently dry and therefore had a smaller dataset than many of the other sites. The site which exceeded the most criteria was VR04 (Lower Canada Larga) with eight, followed by its upstream neighbor, VR05, with six. Based on this information, it is fairly safe to conclude that Canada Larga Creek has the most water quality impairments of all of the areas tested by Channelkeeper's Ventura Stream Team sampling program.

The criterion that was most frequently exceeded was that for phosphate - all 15 sites had median phosphate levels above the .030 mg/L standard. However, as mentioned several times, this is in many cases due to natural geologic conditions. The next criterion to be exceeded most often was that for dissolved oxygen percent saturation, with 10 sites exceeding the standard. This signals major problems with algal growth throughout most reaches of the watershed. The third criterion to be exceeded most frequently was for nitrate, with seven. Two criteria, for temperature and turbidity, were never exceeded. Based on this information, it is clear that nutrient pollution and the resulting algal problems are the most significant water quality problems identified by Ventura Stream Team sampling.

Full-Suite Testing[35]

"Full-suite testing," chemical analysis for trace amounts of organic chemicals and metals, was conducted at a selected sub-set of Ventura Stream Team sampling locations three times during the 2005 water-year (December 2004, February and September 2005), thus we present the results separately here. Trace contaminants (volatile organics, pesticides, herbicides, PCBs and metals) are most often found in streams tributary to heavily developed agricultural and urban areas. The sites selected were on the main stem of the lower Ventura River (VR01 at the estuary boundary at Main Street and VR03 below the Ojai wastewater treatment plant), on lower San Antonio Creek below Ojai (VR07), and on Canada Larga just above its confluence with the Ventura River (VR04). During the December 2004 sampling, Stewart Creek (VR09, which flows through western Ojai) was substituted for VR04 since Canada Larga was dry.

Results are shown in Tables 7, 8 and 9. Two separate laboratories were used for chemical analysis, Zymax at 71 Zaca Lane, San Luis Obispo, CA 93401 (California Dept. of Health Services Certification #1717) in December 2004 and February 2005; and FGL Environmental at 853 Corporation Street, Santa Paula, CA 93061 (Certification #1563) in September 2005. Analysis methods, the suite of organic compounds evaluated and the minimum detection concentrations varied to some extent between laboratories. Zymax, for example, analyzed for a greater number of organophosphorus pesticides, while FGL included a broader range of volatile organics. Below we briefly discuss the tests preformed, the results and their possible implications.

Volatile Organic Compounds

"Volatile Organic Compounds" (VOCs) is a term applied to an assemblage of carbon-containing chemicals that evaporate at relatively low temperatures. Drinking water containing VOCs can increase the risk for a variety of health problems. Some VOCs are considered possible carcinogens while others have been proven to cause cancer after prolonged exposure. VOCs may also be implicated in other illnesses. These chemicals do not occur naturally in drinking water, but improper storage or disposal can contaminate groundwater and drinking water supplies and pollute tributary streams and rivers. Hundreds of VOCs have been designed and produced for use in a variety of products, including gasoline, dry cleaning solvents and degreasing agents. In addition to threats to human health, these compounds present problems for aquatic life. Although most VOCs found in the environment are due to contamination, others may be formed when drinking water is treated with chlorine. Chlorine reacts with organic materials found in water and forms certain VOCs known as chlorination by-products. This possibility was one of the principal reasons for testing at VR01 and 03.

Detectable amounts of VOCs were not found at any of the sampled locations during the three rounds of testing. The level of VOC detection during analysis was typically either 0.5 or 1.0 μg/L (for Zymax and FGL, respectively), and a result of "non-detection" (ND) does not indicate the absolute absence of VOCs, but indicates that concentrations of any contaminants present were below the detection limit.

Concentrations below 0.5-1.0 μg/L usually present no problems to human or aquatic health. Typically, concentrations need to be in the range of 10-100 μg/L (recall that 1 μg/L is one part per billion) before being considered dangerous to human health, and 100-10,000 μg/L as endangering aquatic life. To illustrate, benzene, which can leak from gas storage tanks and landfills or be found in industrial discharges (such as plastics, resins, printing, dry cleaning), has a maximum contaminant level (MCL) of 5 μg/L; in other words, 5 μg/L is the highest level allowable in drinking water (US EPA). The threat to aquatic life from chemical compounds can be evaluated by their "LC 50" concentrations, the concentration producing 50% mortality in laboratory studies. The LC 50 concentration for benzene varies from 4,600 μg/L for salmon to 42,000 μg/L for channel catfish to less than 1,000 μg/L for some aquatic invertebrates (USGS, 1997).

The absence of detectable concentrations in the 2005 round of testing, as well as their absence during earlier testing in 2001 (samples in April at VR04, 07, 08 and 12; and in October at VR01, 07, 08, 14), indicates no present VOC problem on the river or in its tributaries.

Chlorinated Pesticides

Chlorinated pesticides are either no longer used or their use is strictly controlled in the United States. Banned in the 1970s and 1980s for ecological reasons, chlorinated pesticides are now classified as possible human carcinogens by the EPA. Their range of negative health effects extends to the human nervous, digestive, immune and reproductive systems. These compounds do not break down easily in nature and bind strongly with soil, often persisting in the environment for many years. Examples of prohibited pesticides within this group include DDT, chlordane, dieldrin, endrin, mirex and heptachlor. Others, such as lindane, dicofol, and methoxychlor continue to have registered uses in this country. Methoxychlor pesticide products are still available in a variety of formulations for the control of various indoor and outdoor insects. The historic application of chlorinated pesticides to soils and crops and the continuing introduction of sediment from these areas into streams (including urban lawns and gardens), is the primary current source of these compounds in fresh water.

Detectable amounts of chlorinated pesticides were not found at any of the sampled locations (nor were they found in 2001). Analysis levels of detection were usually either 0.03 or 0.05 μg/L (Zymax and FGL Environmental, respectively). Where the EPA lists drinking water contaminant levels (MCLs) for specific pesticides, they are usually greater than an order-of-magnitude higher (40, 3, 2, 0.4 μg/L for Methoxychlor, Endrin, Toxaphene and Heptachlor, respectively; US EPA), and it is unlikely that these chemicals present any human health problems on the Ventura River. However, the possibility of a threat to aquatic life cannot be altogether dismissed by this level of testing. For example, Washington State defines chronic freshwater toxicity from Endrin, Toxaphene and Heptachlor at concentrations greater than 0.0023, 0.0002 and 0.0038 μg/L, respectively (WS-DE, 2005; 1997), e.g., at concentrations well below the detection limit.

Polychlorinated Biphenyls

Polychlorinated biphenyls, more commonly known as PCBs, are a mixture of individual chemicals no longer produced in the United States, but, like chlorinated pesticides, are still found in the environment. Health effects associated with exposure to PCBs include acne-like skin conditions in adults and neurobehavioral and immunological changes in children. PCBs are known to cause cancer in animals. PCBs are either oily liquids or colorless to light yellow solids with no known smell or taste. There are no natural sources of PCBs. PCBs have been used as coolants and lubricants in transformers, capacitors, and other electrical equipment because they are good insulators and do not burn easily. Their manufacture was halted in 1977 in response to evidence of environment accumulation and adverse health effects.

No detectable PCB concentrations were found at the sampled locations (Zymax and FGL detection limits were 0.3 and 0.5 μg/L, respectively). The EPA drinking water MCL for PCB is 0.5 μg/L. The EPA also has a maximum contaminant level goal (MCLG) for PCBs of zero. MCLGs are usually set lower than MCLs but are considered goals for future attainment rather than legally enforcable present limits. No tests were conducted for PCBs in 2001.

Organophosphorus Pesticides

The organphosphates are a large group of over 50 pesticides which vary from moderate to extreme toxicity to mammals. Organophosphates were the first group of insecticides used to begin large-scale replacement of the chlorinated hydrocarbons. Unlike chlorinated hydrocarbons, organophosphates do not accumulate in the tissues of humans or animals. This property, combined with a much shorter residual life, reduces the possibility of long-term environmental contamination. However, many insect species worldwide, including flies, mosquitoes and cockroaches, have developed resistance to organophosphate insecticides because of their frequent use and similar modes of action.

Organophosphates work by interfering with an enzyme, cholinesterase, necessary for proper nerve function. Absent the action of this enzyme, impulses continue to pass down the nerve fiber disrupting the nervous system and ultimately causing death by respiratory failure. Some of the more toxic organophosphate insecticides present a high risk of irreversible organophosphate poisoning in humans. This risk is highest for pesticide applicators and non-target animals. Many of the organophosphates are now being replaced by pyrethrins, synthetic pyrethroids and fluorinated baits. However, others are still being used in low-impact pesticide applications.

Nation-wide, the most commonly used organophosphates are chlorpyrifos, diazinon and malathion (USGS, 2000). The EPA, utilizing USGS and other available data, conducted a preliminary risk assessment for an area labeled the "Southwest Fruitful Rim" (which includes Ventura County), and found the most prevalent organophosphates (in order of frequency of occurrence in surface and ground water samples) to be diazinon, chlorpyrifos, malathion and azinphos methyl (US EPA, 2001). To give some idea of the water-borne concentrations of these pesticides in California waters, results of an EPA study for the San Joaquin-Tulare Basin are given in Table 6. The table also shows the maximum allowable drinking water concentrations (for Canada, PAN), the EPA's one-day and lifetime health advisory concentrations (the concentration in drinking water that is not expected to cause any adverse effect if ingested over that period of time), and the acute and chronic aquatic life limits (US EPA).

The EPA does not consider organophosphates in drinking water to be an important contributor to the overall risk from these chemicals. To quote from the executive summary of their premiminary risk assessment (US EPA, 2001): "The contribution from drinking water is one to two orders of magnitude lower than the contribution from organophosphates in food at percentiles above the 95th percentile for all population subgroups evaluated." In other words, the chances of food contamination far outweigh possible drinking water contamination.

In Channelkeeper's Ventura Stream Team full-suite sampling, no organophosphate pesticides were detected. However, the detection levels (0.5 and 2 μg/L) were such that, while human health is not threatened, the threat to aquatic life by pesticides whose aquatic life criterion fall below the detection level remains unknown (e.g., all four pesticides shown in Table 6). No tests for organophosphates were conducted by Channelkeeper in 2001.

Table 6. Results from the EPA's Preliminary Risk Assessment of Orthophosphate Pesticides for the San Joaquin-Tulare Basin (US EPA, 2001). The table shows the percent occurrence (percentage of groundwater and surface water samples in which the pesticide was found), the average, 95 percentile (the concentration exceeded by 5% of the samples), and maximum concentrations found in the study. The maximum acceptable Canadian drinking water concentration (PAN), the EPA lifetime health advisory (HAL) concentrations, and the aquatic life acute and chronic concentrations for the four most frequently found orthophosphate pesticides are shown. All concentrations are given in μg/L. Dashes indicate that there is no established value.

	Chlorpyrifos	Diazinon	Malathion	Azinphos Methyl
percent occurrence	61.3	83.9	13.8	10.5
average conc.	0.005	0.016	<0.005	<0.001
95 percentile conc.	0.053	0.340	0.027	0.056
maximum conc.	0.340	9.050	0.390	0.100
max. allowable (Canada)	90	20	190	20
one-day HAL	30	20	200	---
lifetime HAL	20	0.6	100	---
aquatic life acute	0.040	0.080	0.100	0.010
aquatic life chronic	0.080	---	---	---

Chlorinated Herbicides

Chlorinated herbicides are used to control woody plants and broadleaf herbaceous weeds in a wide range of agricultural crops and in rangeland improvement programs. They are also used in urban and industrial areas for the control of weeds on lawns and empty lots, and for the same purpose in aquatic areas in ditches, on floodways, and along the banks of canals, reservoirs, streams and rivers. Possible adverse effects health effects of the herbicides sampled for in the full-suite tests are listed below, with EPA maximum contaminant levels (MCLs), health advisory levels (HALs), and chronic aquatic life criteria, if available. EPA health advisory levels are given for two categories, the single-day limit (below which adverse, non-carcinogenic health effects are not expected for up to one day of exposure, based on a 22-pound child consuming one liter of water per day), and the lifetime limit (below which adverse, non-carcinogenic health effects are not expected for up a lifetime of exposure, based on a 154-pound adult consuming two liters of water per day).

2,4-D: Possible health impacts include cancer, cardiovascular or blood toxicity, developmental toxicity, endocrine toxicity, gastrointestinal or liver toxicity, neurotoxicity, reproductive toxicity, respiratory toxicity, and skin sensitivity. It has an MCL of 70 μg/L, lifetime and single-day HALs of 70 and 1,000 μg/L, respectively, and a Canadian aquatic life guideline of 4 μg/L (CCME, 1999).

2,4-DB: An unregulated herbicide. Potential health impacts include developmental toxicity, gastrointestinal or liver toxicity, and reproductive toxicity. The Canadian aquatic life guideline is 4 μg/L (CCME, 1999).

2,4,5-T: Banned in 1985. Potential health impacts include cancer, endocrine toxicity, neurotoxicity, and reproductive toxicity. It has lifetime and single-day HALs of 70 and 800 μg/L, respectively, and a Canadian aquatic life guideline of 4 μg/L (CCME, 1999).

2,4,5-TP (Silvex): Banned in 1985. It has an MCL of 50 μg/L, lifetime and single-day HALs of 50 and 200 μg/L, respectively, and a Canadian aquatic life guideline of 4 μg/L (CCME, 1999).

Dalapon: Dalapon has produced kidney damage in rats, kidney damage, throat irritation and weight loss in cows, and is also slightly toxic to mallard eggs. It has an MCL of 200 and lifetime and single-day HALs of 200 and 3,000 μg/L, respectively.

Dicamba: Potential health impacts include developmental toxicity and reproductive toxicity. It has lifetime and single-day HALs of 200 and 300 μg/L, respectively, and a Canadian aquatic life guideline of 10 μg/L (CCME, 1999).

Dichlorprop: An unregulated herbicide. Potential health impacts include developmental toxicity and neurotoxicity.

Dinoseb: In animal studies, dinoseb was found to cross the placental barrier. It can cause birth defects and miscarriages, as well as damage to the heart, lung, brain, liver, and spleen. It has an MCL of 7 μg/L, lifetime and single-day HALs of 7 and 300 μg/L, respectively, and a Canadian aquatic life guideline of 0.05 μg/L (CCME, 1999).

No chlorinated herbicides were found in Ventura Stream Team full-suite samples (detection limits were between 0.13 and 0.25μg/L, and 2 and 5 μg/L, for Zymax and FGL, respectively). As was the case for organophosphates, herbicide detection limits were low enough to eliminate the possibility of potential human health effects from drinking Ventura water, but not low enough to preclude the possibility of adverse impacts on aquatic life from concentrations below the detection limit. No tests for chlorinated herbicides were done in 2001.

Metals

The California Toxics Rule (US EPA, 2000) establishes long-term (chronic) and short-term (acute) aquatic life criteria for metals in salt and freshwater. The chronic criterion is the limiting concentration to which aquatic life can be exposed to without detriment for an extended time (four days), while the acute limit pertains to shorter intervals of exposure. For certain metals, these criteria are not straightforward but are expressed as a function of hardness (a measure of the amount of calcium and magnesium in water). Hardness is a good surrogate for a number of water chemistry parameters which affect the toxicity of metals; simply put, increasing hardness decreases toxicity. Ventura River water can be considered "very hard" (values greater than 180 mg of CaCO3 per liter). Although samples for major cation (e.g., calcium, magnesium, sodium and potassium) and anion (nitrate, sulfate, chloride) analysis are not usually taken for Channelkeeper's Ventura Stream Team program, they were routinely collected in 2001. A total of 78 samples were analyzed for calcium and magnesium that year, yielding an average hardness value of 301 mg/L (range 137-611). The average hardness at the five full-suite sampling locations was 315 mg/L, and we have used that value, where appropriate, to calculate the chronic aquatic life limits used below.

Antimony: Used as a flame retardant and in batteries, pigments, ceramics and glass, antimony is also found in natural ore deposits. The drinking water MCL is 6 μg/L. High concentrations can cause nausea, vomiting and diarrhea over the short term, and it is a potential human carcinogen over the long term. Antimony was not detected in Ventura Stream Team samples. However, detection limits of 50 and 10 μg/L preclude knowing whether the drinking water standard was exceeded. Since antimony is not included in Ventura County's mandatory water testing for water drawn from Foster Park, the possibility of an antimony problem on the river appears remote (Ventura, 2005; continual monitoring is only required when concentrations above the MCL are found).

Arsenic: Arsenic enters drinking water supplies from natural mineral deposits or as a byproduct of agricultural and industrial practices. Arsenic has been linked to cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate. Its non-cancer effects can include thickening and discoloration of the skin, stomach pain, nausea, vomiting, diarrhea, numbness in hands and feet, partial paralysis, and blindness. The EPA drinking water standard (MCL) is 10 μg/L; the aquatic life standard is 150 μg/L. No arsenic was detected in Ventura Stream Team full-suite samples. Respective detection limits (for Zymax and FGL, 5 and 10 μg/L, respectively) indicate little cause for concern.

Barium: Barium is naturally found only in ores containing mixtures of elements. Used in making a wide variety of electronic components, in metal alloys, bleaches, dyes, fireworks, ceramics and glass, it is directly deposited on land during well-drilling operations. Barium can cause gastrointestinal disturbances and muscular weakness and, over the long term, high blood pressure. The drinking water MCL for barium is 2 mg/L. There are no current aquatic life standards for barium, but a study done for EPA on the Ottawa River in Ohio documents a literature value of 1.45 mg/L (Parametrix, 2001).

Measurable concentrations of barium were found in every collected full-suite sample (Tables 7-9). Interestingly, concentrations did not greatly vary between sites but changed considerably with flow conditions. During low flow in December and September, average concentrations were 52 (range 39-62) and 48 (range 36-65) μg/L, respectively, increasing to 183 (range 110-330) μg/L during the much higher flows of February (two orders-of-magnitude higher, see the section on lead below). This points to sediment mobilization as the probable source, with drilling muds from past and present oil exploration and production as a possible contributor. However interesting, the measured concentrations were too low to pose any public health or environmental problem (the barium detection limit was 5 μg/L (0.005 mg/L)).

Baryllium: Found naturally in combination with other mineral ores and used in aerospace alloys, ingestion of baryllium can result, over time, in bone and lung damage as well as cancer. The MCL is 4 μg/L. No beryllium was detected in Ventura Stream Team samples. The detection limit (5 μg/L) probably precludes concentrations exceeding the MCL. There is no generally acceptable standard for aquatic life; only Kansas seems to have a chronic limit, and its value of 5.3 mg/L would eliminate any possibility of baryllium as a problematic metal in the Ventura River watershed.

Cadmium: Cadmium is primarily used in metal plating and coating operations (transportation equipment, machinery and baking enamels, photography and television phosphors), in nickel-cadmium and solar batteries, and in pigments. The MCL has been set at 5 μg/L. Short-term exposure to high concentrations can cause nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure. Over the long term it causes kidney, liver, bone and blood damage. The aquatic life criterion is 5 μg/L (hardness dependent). No detectable amounts of cadmium were found in Ventura Stream Team's full-suite testing (the detection limits were 10 and 5 μg/L).

Chromium: Chromium is used in stainless steel, metal coatings, magnetic tapes and in pigments for paints, cement, paper, rubber, composition floor covering and other materials. Soluble forms are used in wood preservatives. Lifetime exposure can cause damage to liver, kidney circulatory and nerve tissues, as well as skin irritations. Chromium is considered a carcinogen. The MCL for total chromium is 0.1 mg/L. The environmental chemistry of chromium is complicated by oxidation and reduction reactions that convert between the toxic and soluble hexavalent (Cr(VI), mainly as CrO42) and the non-toxic trivalent (Cr(III), which is relatively insoluble except in organic complexes) forms. The chronic aquatic life criteria for Cr (III) and Cr (VI) are 11 and 456 µg/L, respectively (the Cr (VI) criterion is hardness dependent).

Chromium was detected during the February sampling, in concentrations of 20 µg/L at VR01, VR03 and VR07, and at 50 µg/L at VR04 (the detection limit is 10 µg/L). Since it remained undetected at all other times, the probable origin is sediment mobilization, with perhaps subsequent oxidation to the more soluble chromate form, during the late February storm. All these concentrations were below the acceptable drinking water limit of 100 µg/L, but since the analysis did not discriminate between the more (VI) and less (III) toxic forms, no determination of any potential environmental hazard can be made.

Cobalt: Cobalt is released into the environment from the combustion of coal and oil, and through exhaust emissions. It is used in a variety of industrial processes - for metal alloys, as a paint drier, in enameling and to produce colored pigments. Cobalt is relatively non-toxic compared with other metals, but high levels may induce vomiting and nausea and can impact the heart and lungs (MOE, 2001). There is no EPA drinking water MCL for cobalt. Likewise, there is no current aquatic life standard, but a study done for EPA on the Ottawa River in Ohio documents a literature value of 74 µg/L (chronic limit; Table B-3; Parametrix, 2001). Cobalt was undetected during Ventura Stream Team's full-suite testing (the detection limit is 10 µg/L), and is not considered a problem at the sites sampled.

Copper: Found in natural deposits as sulfides, arsenates, chlorides and carbonates, copper is widely used in household plumbing. It is an essential nutrient required by the body in very small amounts, but can cause stomach and intestinal distress, liver and kidney damage, and anemia at higher levels. Copper contamination generally occurs from corrosion of copper plumbing, and the metal is rarely found naturally in surface waters above the MCLG drinking water limit of 1.3 mg/L. Copper in drinking water is governed by an "action level" rule set at this same concentration of 1.3 mg/L (10% of samples having concentrations above this limit trigger remedial action). The chronic aquatic life limit for copper recommended by the EPA is 24 µg/L (hardness dependent). Copper was not detected in Ventura Stream Team's full-suite samples (the detection limit is 10 µg/L).

Lead: Commonly used in household plumbing materials and water service lines, lead also occurs naturally. In drinking water it can cause a variety of adverse health effects, including retarded physical and mental development in children, and kidney problems and high blood pressure in adults. The EPA has established a drinking water "action level," requiring remedial action if more than 10% of a utility's samples exceed 155 µg/L. The aquatic life standard for Ventura River water is calculated at 9 µg/L. During the February testing, concentrations of 26 and 13 µg/L were found at VR03 and VR04, respectively. Both exceed the aquatic life limit, and the VR06 sample exceeds the drinking water standard. Lead was detected in no other Ventura Stream Team samples. (Detection limits of 5 and 10 µg/L indicate the aquatic life standard was below detection in September 2005.)

Although there is no direct evidence, it is interesting to speculate as to possible sources. Because VR03 is the closest sampling point below the Ojai sewage treatment plant and VR04 is downstream of a small but rather seedy industrial zone, the possibility of direct contamination remains open. However, on the sampling date, flows on the Ventura were extraordinarily high; the average daily flow was well over 1,000 cfs at Foster Park (the big February storm occurred on February 21st). During high flows, any point source contamination is usually greatly diluted, disappearing into the background chemistry. The absence of detectable lead at either site during the much lower flows of December and September (when the respective Foster Park flows were 3 and 18 cfs) indicates sediment mobilization as a more probable cause for the February concentrations.

Mercury: Mercury is a liquid metal found naturally in the ores of other metals. Electrical products such as dry-cell batteries, fluorescent light bulbs, switches, and other control equipment account for 50% of the mercury used in the United States. Exposure to high levels of mercury can cause kidney damage in a relatively short time. The drinking water MCL has been set at 2 μg/L. Environmentally, mercury is an insidious and potent contaminant because of its persistent and bioaccumulative effects. Perhaps best known for its weakening of bird eggs and subsequent hatching failures, the determination of allowable aquatic life limits for mercury is too complicated a subject for this report. Possible guidelines are suggested by an additional EPA criterion of 0.05 μg/L for waters from which organisms are taken for human consumption and chronic and acute criteria established by the San Francisco Water Quality Control Board for San Francisco Bay of 2.1 and 25 μg/L, respectively (SWQCB-SF, 2004). Only one Ventura Stream Team sample had detectable mercury: 0.01 μg/L at VR04 in September 2005. Detection limits were 0.5 and 0.01 μg/L, respectively, so the possibility of similar mercury concentrations during the earlier VR04 samples exists. A point source in the industrial area surrounding Canada Larga is the likely cause of contamination.

Molybdenum: Molybdenum is used in alloys and electrodes and as a catalyst in the refining of petroleum. It is an essential trace element in plant nutrition (plants and animals generally have molybdenum concentrations of a few ppm), but based on animal experiments, molybdenum and its compounds can be highly toxic. Some evidence of liver dysfunction was reported in workmen chronically exposed in a Soviet molybdenum copper plant, and above normal occurrences of gout have been found in factory workers and among inhabitants of molybdenum-rich areas of Armenia. However, compared with many heavy metals, molybdenum is of relatively low toxicity and no negative environmental effects have been reported. There are no general drinking water or aquatic life standards for molybdenum.

Detectable concentrations (>10 μg/L) were found during Ventura Stream Team full-suite sampling: 20-30 μg/L on all occasions at VR04 and VR07, with similar concentrations during December 2004 at VR01 and 03. The single low-flow occurrence on the lower Ventura River indicates a possible wastewater treatment plant contribution, while some sort of industrial discharge can be suspected as the source at Canada Larga. The source on lower San Antonio Creek remains a complete mystery.

Nickel: Nickel is used in making stainless steel and other alloys. Excessive exposure can cause decreased body weight, heart and liver damage, and skin irritation. The Department of Health and Human Services (DHHS) has determined that nickel metal may be reasonably anticipated to be a carcinogen and that nickel compounds are known human carcinogens. The MCL for drinking water had been set at 0.1 mg/L, but this requirement was reversed on February 9, 1995. There is currently no legal EPA limit on an acceptable of nickel in drinking water, but a standard of 0.61 mg/L does exist as the maximum allowable concentration for water from which both drinking water and organisms (e.g., fish) will be taken for human consumption (4.6 mg/L for organisms only). A chronic aquatic life criterion has also been set for nickel; hardness dependent, it is estimated to be circa 0.137 mg/L on the Ventura (1.24 mg/L for acute conditions).

Nickel was found during the February 2005 Ventura Stream Team full-suite sampling in concentrations of 20-30 μg/L (0.02-0.03 mg/L) at VR01, VR03 and VR07, and at 80 μg/L at VR04. It was not detected during the other two sampling events, which occurred during low-flow periods, and its presumed origin is from mobilized sediments, as in the case of lead and chromium. These concentrations are well below the limits recommended for aquatic life and the prior drinking water MCL concentration, and nickel is not considered a problem metal.

Selenium: Selenium is used extensively in the manufacture and production of glass, pigments, rubber, metal alloys, textiles and petroleum. It is usually found in the sulfide ores of the heavy metals. Soils near volcanoes tend to have enriched amounts of selenium. Coal is also enriched in selenium, and selenium compounds are released into the air during the combustion of coal and petroleum and the smelting and refining of other metals. It is an essential micronutrient, but can accumulate to harmful levels in fish and birds at the top of the food chain. The effects of extreme selenium poisoning were perhaps most famously demonstrated in the 1980s, when hundreds of fish and birds were killed at California's Kesterson National Wildlife Refuge. Chronic exposure to relatively low doses (only a few times higher than normal in some studies) leads to developmental effects in bird and fish embryos. In humans, acute exposure can cause hair and fingernail changes, damage to the peripheral nervous system, and fatigue and irritability. Over the long term, kidney and liver tissue and nervous and circulatory systems are damaged.

Selenium concentrations in fresh water generally range from 0 to 0.02 mg/L and are greatly influenced by pH - higher concentrations can be found in both acidic (pH < 3.0) and alkaline waters (pH > 7.5). Selenium accumulates in living tissues. For example, the selenium content of human blood is about 0.2 ppm, about 1,000 times greater than the selenium found in surface waters. The problem becomes more exaggerated in birds and fish. Selenium has been found in marine fish meal at levels of about 2 mg/L, approximately 50,000 times greater than seawater concentrations.
The EPA's drinking water MCL for selenium is 0.05 mg/L, and the chronic aquatic life standard is 5 µg/L (0.005 mg/L). Both standards have been questioned. Canada and most European countries have a 0.01 mg/L drinking water standard, and biologists from the US Fish and Wildlife Service (FWS) and the US Geological Survey (USGS) have argued that aquatic life standard should be cut in half to better protect fish and birds.

Selenium was detected in only a single sample during the full-suite testing: 0.02 mg/L at VR03 in September 2005 (detection levels were 0.05 and 0.015 mg/L). While these results indicate probable concentrations below the MCL, the single positive result and the relatively high detection limit (50 µg/L) during the first two rounds of testing indicate a possible chronic aquatic life problem. In April 2001, analyses done with a detection limit of 2 µg/L found concentrations from 7 to 12 µg/L at VR04, VR07 and VR08, but not at VR12 (only four locations were tested), indicating a possible selenium problem throughout the lower Ventura, San Antonio and Canada Larga drainages. The City of Ventura reports an average concentration of 9.3 µg/L (range 0-25) in groundwater used for domestic water supplies, but reports no detectable concentrations in Foster Park water used for the same purpose (Ventura, 2005).

Silver: Silver, a rare but naturally occurring metal often found deposited as a mineral ore in association with other elements, enters the environment from smelting operations, the manufacture and disposal of photographic and electrical supplies, coal combustion, and cloud seeding. Levels in rivers, lakes, and estuaries generally hover around 0.01 µg/L in pristine, unpolluted areas, and 0.01–0.10 µg/L in areas with urban and industrialized land uses (IPCS-ICHEM). There is no drinking water MCL for silver, but the EPA does have a recommended "secondary standard" guideline for a maximum concentration of 0.1 mg/L. Secondary standards are used to minimize problems with taste, color and odor. Silver ingestion can produce a skin discoloration known as argyria. It causes no medical problems, nor has it ever been found to result from drinking water in the United States, but the potential exists since silver is used as an antibacterial agent in many home water treatment devices.

The ability to bioaccumulate dissolved silver varies widely between species, and at concentrations normally encountered in the environment, food-chain biomagnification of silver in aquatic systems is unlikely. There is a hardness-dependent acute aquatic life standard for silver estimated at 25 µg/L for the Ventura River. The detection level during analysis was 10 µg/L, and silver was not found in any samples. There is no chronic standard, but since ionic silver concentrations of 1-5 µg/L can be lethal to sensitive species of aquatic plants, invertebrates, and teleosts, and since adverse effects on trout development (0.17 μg/L) and on phytoplankton species composition and succession (0.3–0.6 μg/L) can occur at very low concentrations, the possibility of a silver problem cannot be ruled out completely.

Thallium: A trace metal associated with potassium in copper, gold, zinc and cadmium ores, thallium pollution originates from ore processing operations, the gaseous emissions of cement factories and coal burning power plants, and from metal sewers. Acute thallium concentrations can cause gastrointestinal irritation and peripheral neuropathy, while long-term exposure can lead to changes in blood chemistry, damage to liver, kidney, intestinal and testicular tissues, and hair loss. The drinking water MCL is 2 μg/L, but the long-term EPA goal is a reduction to 0.5 μg/L (MCLG). There are no current aquatic life criteria for thallium, but earlier EPA documentation listed 700 and < 40 μg/L for acute and chronic limits, respectively (Table B-3; Parametrix, 2001).

Thallium was undetected in any of the Ventura Stream Team full-suite samples, but the detection limits (50 and 10 μg/L), while indicating that it is probably not an aquatic life concern, were not low enough for comparison with the MCL. A concentration of 10 μg/L found at VR07 in October 2001 indicates that trace amounts of thallium may exist in the Ventura River system. However, thallium is not reported in the annual water consumer report, indicating that no concentrations above 2 μg/L have been found either in groundwater or at Foster Park (Ventura, 2005).

Vanadium: Vanadium is found in both fresh and sea water within a natural background range of approximately 1–3 μg/L. Locally high concentrations of this metal, up to about 70 μg/L, have been reported in fresh waters, often associated with leaching from volcanic lava flows and uranium deposits. Data on concentrations in surface waters influenced by industrial waste are few, but mainly fall within the natural range (up to about 65 μg/L) (IPCS-ICHEM). There are no current EPA standards for vanadium, but it is on their Candidate Contaminant List for future consideration. Toxicity values for freshwater and marine organisms range between 0.2 and 120 mg/L (generally concentrated between 2-10 mg/L). However, reports of sub-lethal effects at around 10 μg/L for algal photosynthesis, 50 μg/L for oyster larval development, and 1,130 μg/L for Daphnia reproduction have been reported (IPCS-ICHEM). This is in general agreement with values of acute and chronic toxicity limiting values of 310 and 62 μg/L, respectively, given in Parametrix (2001, Table B-3).

Vanadium was found in Ventura Stream Team full-suite samples during the February 2004 sampling, at concentrations of 20 μg/L at VR01, VR03 and VR07, and at 80 μg/L at VR04 (the detection limit was 10 μg/L). As previously proposed, the absence of this metal at any other time probably indicates an origin in sediment mobilization during storm runoff. Concentrations in this range are probably too low to constitute an environmental problem, but the situation should be monitored. 80 μg/L was also reported at VR07 in October 2001.

Zinc: Used in the manufacture of plastics, rubber, paper, paints and lubricants, zinc is found ubiquitously in the environment. Its wastes generally originate from mining, ore processing and metal plating operations. Concentrations in fresh water are strongly determined by local geological and anthropogenic influences and vary substantially; natural background concentrations usually vary from < 0.1 to 50 μg/L (0.002 to 0.1 μg/L in seawater), up to 3.9 mg/L in highly contaminated environments (IPCS-ICHEM). Although the ingestion of large amounts of zinc (150–2000 mg/day) can lead to vomiting and diarrhea, and over the long term, anemia and leucopenia, the amounts found in water are usually too low to cause these adverse effects. Only a secondary EPA standard of 5 mg/L, designed to control an adverse metallic taste, exists for zinc.

Environmentally, concentrations from 50-100 μg/L can have chronic impacts on freshwater insects, and at 100-200 μg/L on fish and mollusks. At concentrations above 1 mg/L, these impacts become acute for almost all freshwater species. The hardness-based EPA acute and chronic aquatic life standard for Ventura waters is around 310 µg/L (extreme hardness raises the nominal value of 120 µg/L to these higher limits). Zinc was detected in all samples collected at VR01 and VR03 - 10 and 20 µg/L, respectively, in December; 40 and 40 µg/L, respectively, in February; and 30 and 40 µg/L, respectively, in September. During the February sampling it was also found at Canada Larga (100 µg/L at VR04) and at San Antonio (30 µg/L at VR07) (detection limits were 10 and 20 µg/L). Earlier testing found concentrations of 4 and 8 µg/L at VR04 and VR08, respectively, in April 2001 (the detection limit was 4 µg/L), and 30 µg/L at VR01 and VR14 in October 2001 (the detection limit was 20 µg/L). Thus zinc seems to be present in the Ventura River system in more or less detectable concentrations throughout the year. Fortunately, all of the detected results are appreciably below the aquatic life limits.

Table 7. Full suite analysis of selected Ventura Stream Team sampling locations on December 9, 2004.

sampling site		VR01	VR03	VR07	VR09
	PQL	12/9/04	12/9/04	12/9/94	12/9/04
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILE ORGANIC COMPOUNDS: method EPA 8260					
Benzene	0.5	ND	ND	ND	ND
Bromobenzene	0.5	ND	ND	ND	ND
Bromodichloromethane	0.5	ND	ND	ND	ND
Bromoform	0.5	ND	ND	ND	ND
Bromomethane	0.5	ND	ND	ND	ND
n-Butylbenzene	0.5	ND	ND	ND	ND
n-Butylbenzene	0.5	ND	ND	ND	ND
tert-Butylbenzene	0.5	ND	ND	ND	ND
Carbon Tetrachloride	0.5	ND	ND	ND	ND
Chlorobenzene	0.5	ND	ND	ND	ND
2-Chloroethylvinyl ether	1.0	ND	ND	ND	ND
Chloroform	0.5	ND	ND	ND	ND
Chloromethane	0.5	ND	ND	ND	ND
2-Chlorotoluene	0.5	ND	ND	ND	ND
4-Chlorotoluene	0.5	ND	ND	ND	ND
1,2-Dibromo-3-Chloropropane	1.0	ND	ND	ND	ND
Dibromochloromethane	0.5	ND	ND	ND	ND
1,2-Dichlorobenzene	0.5	ND	ND	ND	ND
1,3-Dichlorobenzene	0.5	ND	ND	ND	ND
1,4-Dichlorobenzene	0.5	ND	ND	ND	ND
Dichlorodifluoromethane1	0.5	ND	ND	ND	ND
1,1-Dichloroethane	0.5	ND	ND	ND	ND
1,2-Dichloroethane (EDC)	0.5	ND	ND	ND	ND
1,2-Dichloroethene	0.5	ND	ND	ND	ND

Table 7 (continued). Full suite analysis of selected Ventura Stream Team sampling locations on December 9, 2004.

sampling site		VR01	VR03	VR07	VR09
	PQL	12/9/04	12/9/04	12/9/04	12/9/04
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILE ORGANIC COMPOUNDS: method EPA 8260					
trans-1,2-Dichloroethene	0.5	ND	ND	ND	ND
2,2-Dichloropropane	0.5	ND	ND	ND	ND
1,3-Dichloropropane	0.5	ND	ND	ND	ND
2,2-Dichloropropane	0.5	ND	ND	ND	ND
1,1-Dichloropropene	0.5	ND	ND	ND	ND
cis-1,3-Dichloropropene	0.5	ND	ND	ND	ND
trans-1,3-Dichloropropene	0.5	ND	ND	ND	ND
Dichlorotrifluoroethane	0.5	ND	ND	ND	ND
Ethylbenzene	0.5	ND	ND	ND	ND
Ethylene Dibromide (EDB)	0.5	ND	ND	ND	ND
Hexachlorobutadiene	0.5	ND	ND	ND	ND
Isoprotylbenzene	0.5	ND	ND	ND	ND
Methylene Chloride	0.5	ND	ND	ND	ND
Naphthalene	0.5	ND	ND	ND	ND
n-Propylbenzene	0.5	ND	ND	ND	ND
Styrene	0.5	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	0.5	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	0.5	ND	ND	ND	ND
Tetrachloroethene (PCE)	0.5	ND	ND	ND	ND
Toluene	0.5	ND	ND	ND	ND
1,2,3-Trichlorobenzene	1.0	ND	ND	ND	ND
1,2,4-Trichlorobenzene	1.0	ND	ND	ND	ND
1,1,1-Trichloroethane (TCA)	0.5	ND	ND	ND	ND
1,1,2-Trichlorotrifluoroethane	0.5	ND	ND	ND	ND
Trichloroethene (TCE)	0.5	ND	ND	ND	ND
Trichlorofluoromethane (freon 11)	0.5	ND	ND	ND	ND
1,2,3-Trichloropropane	0.5	ND	ND	ND	ND
1,1,2-Trichlorotrifluoroethane	0.5	ND	ND	ND	ND
1,2,4-Trimethylbenzene	0.5	ND	ND	ND	ND
1,3,5-Trimethylbenzene	0.5	ND	ND	ND	ND
Vinyl Chloride	0.5	ND	ND	ND	ND
t-Butyl Alcohol (TBA)	0.5	ND	ND	ND	ND
Dispropylether (DIPE)	0.5	ND	ND	ND	ND
Ethanol	50	ND	ND	ND	ND
Ethyl-t-Butyl Ether (ETBE)	0.5	ND	ND	ND	ND

Table 7 (continued). Full suite analysis of selected Ventura Stream Team sampling locations on December 9, 2004.

sampling site		VR01	VR03	VR07	VR09
	PQL	12/9/04	12/9/04	12/9/04	12/9/04
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
CHLORINATED PESTICIDES: method EPA 8081					
t-Amyl Methyl Ether (TAME)	0.5	ND	ND	ND	ND
Methyl t-Butyl Ether (MTBE)	0.5	ND	ND	ND	ND
Aldrin	0.03	ND	ND	ND	ND
Alpha-BHC	0.03	ND	ND	ND	ND
Beta-BHC	0.03	ND	ND	ND	ND
Delta-BHC	0.03	ND	ND	ND	ND
Gamma-BHC (Lindane)	0.03	ND	ND	ND	ND
Chlordane	0.3	ND	ND	ND	ND
4,4'-DDD	0.03	ND	ND	ND	ND
4,4'-DDE	0.03	ND	ND	ND	ND
4,4'-DDT	0.03	ND	ND	ND	ND
Dieldrin	0.03	ND	ND	ND	ND
Endosulfan I	0.03	ND	ND	ND	ND
Endosulfan II	0.03	ND	ND	ND	ND
Endosulfan sulfate	0.03	ND	ND	ND	ND
Endrin	0.03	ND	ND	ND	ND
Endrin aldehyde	0.03	ND	ND	ND	ND
Heptachlor	0.03	ND	ND	ND	ND
Heptachlor epoxide	0.03	ND	ND	ND	ND
Methoxychlor	0.03	ND	ND	ND	ND
Toxaphene	1.0	ND	ND	ND	ND
POLYCHLORINATED BIPHENYLS (PCBs): method EPA 8082					
PCB 1016	0.3	ND	ND	ND	ND
PCB 1221	0.3	ND	ND	ND	ND
PCB 1232	0.3	ND	ND	ND	ND
PCB 1242	0.3	ND	ND	ND	ND
PCB 1248	0.3	ND	ND	ND	ND
PCB 1254	0.3	ND	ND	ND	ND
PCB 1260	0.3	ND	ND	ND	ND
ORGANOPHOSPHORUS PESTICIDES: method EPA 8141A					
Acetamaprid	2.0	ND	ND	ND	ND
Ametryn	1.0	ND	ND	ND	ND
Atrazine	0.5	ND	ND	ND	ND
Azinphos-methyl	0.5	ND	ND	ND	ND

Table 7 (continued). Full suite analysis of selected Ventura Stream Team sampling locations on December 9, 2004.

sampling site		VR01	VR03	VR07	VR09
	PQL	12//9/04	12/9/04	12/9/04	12/9/04
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
ORGANOPHOSPHORUS PESTICIDES: method EPA 8141A					
Azoxystrobin	0.5	ND	ND	ND	ND
Benthiocarb	2.0	ND	ND	ND	ND
Bolstar	0.5	ND	ND	ND	ND
Benstar	0.5	ND	ND	ND	ND
Carbofenthion	2.0	ND	ND	ND	ND
Chlorfenvinphos	0.5	ND	ND	ND	ND
Chlorpyrifos	0.3	ND	ND	ND	ND
Chlorpyrifos-methyl	0.3	ND	ND	ND	ND
Clofrin	0.5	ND	ND	ND	ND
Cumaphoa	1.5	ND	ND	ND	ND
Cyanazine	0.5	ND	ND	ND	ND
DEF	0.5	ND	ND	ND	ND
Demeton O/S Analogues	0.5	ND	ND	ND	ND
Diazinon	0.5	ND	ND	ND	ND
Dibrom	0.5	ND	ND	ND	ND
Dicrotophos	0.5	ND	ND	ND	ND
Dimethate	0.5	ND	ND	ND	ND
Diphenyl Amine	2.0	ND	ND	ND	ND
Disulfoton	0.3	ND	ND	ND	ND
EPN	1.0	ND	ND	ND	ND
Ethion	0.5	ND	ND	ND	ND
Ethoprop	0.5	ND	ND	ND	ND
Fenamiphos	0.5	ND	ND	ND	ND
Fenitrothion	0.5	ND	ND	ND	ND
Fenthion	0.5	ND	ND	ND	ND
Fonotos	0.5	ND	ND	ND	ND
Hexazinone	1.0	ND	ND	ND	ND
Imazalil	2.0	ND	ND	ND	ND
Imidan	0.5	ND	ND	ND	ND
Isofenphos	0.5	ND	ND	ND	ND
Malathion	0.5	ND	ND	ND	ND
Metalaxyl	2.0	ND	ND	ND	ND
Methidathion	0.5	ND	ND	ND	ND
Methyl Parathion	0.5	ND	ND	ND	ND
Metolachlor	1.0	ND	ND	ND	ND

Table 7 (continued). Full suite analysis of selected Ventura Stream Team sampling locations on December 9, 2004.

sampling site		VR01	VR03	VR07	VR9
	PQL	12/9/04	12/9/04	12/9/04	12/9/04
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
ORGANOPHOSPHORUS PESTICIDES: method EPA 8141A					
Metribuzin	1.0	ND	ND	ND	ND
Mevinphos	0.5	ND	ND	ND	ND
Molinate	1.0	ND	ND	ND	ND
Myclobutanil	0.5	ND	ND	ND	ND
Parathion	0.5	ND	ND	ND	ND
Phorate	0.5	ND	ND	ND	ND
Phosalone	1.5	ND	ND	ND	ND
Phosphamidon	1.0	ND	ND	ND	ND
Primiphos-methly	0.5	ND	ND	ND	ND
Profenofos	1.0	ND	ND	ND	ND
Prometon	0.5	ND	ND	ND	ND
Prometryne	0.5	ND	ND	ND	ND
Propetamiphos	0.5	ND	ND	ND	ND
Pymetrazine	0.5	ND	ND	ND	ND
Ronnel	0.5	ND	ND	ND	ND
Simazine	0.5	ND	ND	ND	ND
Terbacil	5.0	ND	ND	ND	ND
Tetrachlorvinphos	0.5	ND	ND	ND	ND
Thiabendazole	1.0	ND	ND	ND	ND
Thionazin	0.5	ND	ND	ND	ND
CHLORINATED HERBICIDES: method EPA 8151A					
2,4-D	0.25	ND	ND	ND	ND
2,4-DB	0.25	ND	ND	ND	ND
Dicamba	0.13	ND	ND	ND	ND
Dichloroprop	0.13	ND	ND	ND	ND
Dinoseb	0.13	ND	ND	ND	ND
2,4.5.-T	0.13	ND	ND	ND	ND
2,4.5.-TP (Silvex)	0.13	ND	ND	ND	ND
TOTAL METALS: method EPA 6020/7470					
	mg/L	mg/L	mg/L	mg/L	mg/L
Antimony	0.05	ND	ND	ND	ND
Arsenic	0.05	ND	ND	ND	ND
Barium	0.005	0.053	0.039	0.062	0.055
Baryllium	0.005	ND	ND	ND	ND
Cadmium	0.01	ND	ND	ND	ND

Table 7 (continued). Full suite analysis of selected Ventura Stream Team sampling locations on December 9, 2004.

sampling site		VR01	VR03	VR07	VR09
	PQL	12/9/04	12/9/04	12/9/04	12/9/4
constituent	mg/L	mg/L	mg/L	mg/L	mg/L
TOTAL METALS: method EPA 6020/7470					
Chromium	0.01	ND	ND	ND	ND
Cobalt	0.01	ND	ND	ND	ND
Copper	0.01	ND	ND	ND	ND
Lead	0.005	ND	ND	ND	ND
Mercury	0.0005	ND	ND	ND	ND
Molybdenum	0.01	0.03	0.02	0.02	ND
Nickel	0.01	ND	ND	ND	ND
Selenium	0.05	ND	ND	ND	ND
Silver	0.01	ND	ND	ND	ND
Thallium	0.05	ND	ND	ND	ND
Vanadium	0.01	ND	ND	ND	ND
Zinc	0.01	0.01	0.02	ND	ND
MBAS: method SM5540C					
MBAS	0.03	0.05	0.04	ND	0.08

*PQL is the practical quantitation limit.
ND indicates no determination, e.g., results were below the practical quantitation limit.

Table 8. Full suite analysis for selected Ventura Stream Team sampling locations on February 28, 2005.

sampling site		VR01	VR03	VR04	VR07
	PQL	2/28/05	2/28/05	2/28/05	2/28/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILE ORGANIC COMPOUNDS: method EPA 8260					
Benzene	0.5	ND	ND	ND	ND
Bromobenzene	0.5	ND	ND	ND	ND
Bromodichloromethane	0.5	ND	ND	ND	ND
Bromoform	0.5	ND	ND	ND	ND
Bromomethane	0.5	ND	ND	ND	ND
n-Butylbenzene	0.5	ND	ND	ND	ND
n-Butylbenzene	0.5	ND	ND	ND	ND
tert-Butylbenzene	0.5	ND	ND	ND	ND
Carbon Tetrachloride	0.5	ND	ND	ND	ND
Chlorobenzene	0.5	ND	ND	ND	ND
2-Chloroethylvinyl ether	1.0	ND	ND	ND	ND

Table 8 (continued). Full suite analysis for selected Ventura Stream Team sampling locations on February 28, 2005.

sampling site		VR01	VR03	VR07	VR09
	PQL	2/28/05	2/28/05	2/28/05	2/28/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILE ORGANIC COMPOUNDS: method EPA 8260					
Chloroform	0.5	ND	ND	ND	ND
Chloromethane	0.5	ND	ND	ND	ND
2-Chlorotoluene	0.5	ND	ND	ND	ND
4-Chlorotoluene	0.5	ND	ND	ND	ND
1,2-Dibromo-3-Chloropropane	1.0	ND	ND	ND	ND
Dibromochloromethane	0.5	ND	ND	ND	ND
1,2-Dichlorobenzene	0.5	ND	ND	ND	ND
1,3-Dichlorobenzene	0.5	ND	ND	ND	ND
1,4-Dichlorobenzene	0.5	ND	ND	ND	ND
Dichlorodifluoromethane1	0.5	ND	ND	ND	ND
1,1-Dichloroethane	0.5	ND	ND	ND	ND
1,2-Dichloroethane (EDC)	0.5	ND	ND	ND	ND
1,2-Dichloroethene	0.5	ND	ND	ND	ND
cis-1,2-Dichloroethene	0.5	ND	ND	ND	ND
trans-1,2-Dichloroethene	0.5	ND	ND	ND	ND
2,2-Dichloropropane	0.5	ND	ND	ND	ND
1,3-Dichloropropane	0.5	ND	ND	ND	ND
2,2-Dichloropropane	0.5	ND	ND	ND	ND
1,1-Dichloropropene	0.5	ND	ND	ND	ND
cis-1,3-Dichloropropene	0.5	ND	ND	ND	ND
trans-1,3-Dichloropropene	0.5	ND	ND	ND	ND
Dichlorotrifluoroethane	0.5	ND	ND	ND	ND
Ethylbenzene	0.5	ND	ND	ND	ND
Ethylene Dibromide (EDB)	0.5	ND	ND	ND	ND
Hexachlorobutadiene	0.5	ND	ND	ND	ND
Isoprotylbenzene	0.5	ND	ND	ND	ND
Methylene Chloride	0.5	ND	ND	ND	ND
Naphthalene	0.5	ND	ND	ND	ND
n-Propylbenzene	0.5	ND	ND	ND	ND
Styrene	0.5	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	0.5	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	0.5	ND	ND	ND	ND
Tetrachloroethene (PCE)	0.5	ND	ND	ND	ND
Toluene	0.5	ND	ND	ND	ND
1,2,3-Trichlorobenzene	1.0	ND	ND	ND	ND

Table 8 (continued). Full suite analysis for selected Ventura Stream Team sampling locations on February 28, 2005.

sampling site		VR01	VR03	VR04	VR07
	PQL	2/28/05	2/28/05	2/28/05	2/28/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILE ORGANIC COMPOUNDS: method EPA 8260					
1,2,4-Trichlorobenzene	1.0	ND	ND	ND	ND
1,1,1-Trichloroethane (TCA)	0.5	ND	ND	ND	ND
1,1,2-Trichlorotrifluoroethane	0.5	ND	ND	ND	ND
Trichloroethene (TCE)	0.5	ND	ND	ND	ND
Trichlorofluoromethane (freon 11)	0.5	ND	ND	ND	ND
1,2,3-Trichloropropane	0.5	ND	ND	ND	ND
1,1,2-Trichlorotrifluoroethane	0.5	ND	ND	ND	ND
1,2,4-Trimethylbenzene	0.5	ND	ND	ND	ND
1,3,5-Trimethylbenzene	0.5	ND	ND	ND	ND
Vinyl Chloride	0.5	ND	ND	ND	ND
t-Butyl Alcohol (TBA)	5.0	ND	ND	ND	ND
Dispropylether (DIPE)	0.5	ND	ND	ND	ND
Ethanol	50	ND	ND	ND	ND
Ethyl-t-Butyl Ether (ETBE)	0.5	ND	ND	ND	ND
t-Amyl Methyl Ether (TAME)	0.5	ND	ND	ND	ND
Methyl t-Butyl Ether (MTBE)	0.5	ND	ND	ND	ND
CHLORINATED PESTICIDES: method EPA 8081					
Aldrin	0.03	ND	ND	ND	ND
Alpha-BHC	0.03	ND	ND	ND	ND
Beta-BHC	0.03	ND	ND	ND	ND
Delta-BHC	0.03	ND	ND	ND	ND
Gamma-BHC (Lindane)	0.03	ND	ND	ND	ND
Chlordane	0.3	ND	ND	ND	ND
4,4'-DDD	0.03	ND	ND	ND	ND
4,4'-DDE	0.03	ND	ND	ND	ND
4,4'-DDT	0.03	ND	ND	ND	ND
Dieldrin	0.03	ND	ND	ND	ND
Endosulfan I	0.03	ND	ND	ND	ND
Endosulfan II	0.03	ND	ND	ND	ND
Endosulfan sulfate	0.03	ND	ND	ND	ND
Endrin	0.03	ND	ND	ND	ND
Endrin aldehyde	0.03	ND	ND	ND	ND
Heptachlor	0.03	ND	ND	ND	ND
Heptachlor epoxide	0.03	ND	ND	ND	ND
Methoxychlor	0.03	ND	ND	ND	ND

Table 8 (continued). Full suite analysis for selected Ventura Stream Team sampling locations on February 28, 2005.

sampling site		VR01	VR03	VR07	VR9
	PQL	2/28/05	2/28/05	2/28/05	2/28/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
CHLORINATED PESTICIDES: method EPA 8081					
Toxaphene	1.0	ND	ND	ND	ND
POLYCHLORINATED BIPHENYLS (PCBs): method EPA 8082					
PCB 1016	0.3	ND	ND	ND	ND
PCB 1221	0.3	ND	ND	ND	ND
PCB 1232	0.3	ND	ND	ND	ND
PCB 1242	0.3	ND	ND	ND	ND
PCB 1248	0.3	ND	ND	ND	ND
PCB 1254	0.3	ND	ND	ND	ND
PCB 1260	0.3	ND	ND	ND	ND
ORGANOPHOSPHORUS PESTICIDES: method EPA 8141A					
Acetamaprid	2.0	ND	ND	ND	ND
Ametryn	1.0	ND	ND	ND	ND
Atrazine	0.5	ND	ND	ND	ND
Azinphos-methyl	0.5	ND	ND	ND	ND
Azoxystrobin	0.5	ND	ND	ND	ND
Benthiocarb	2.0	ND	ND	ND	ND
Bolstar	0.5	ND	ND	ND	ND
Benstar	0.5	ND	ND	ND	ND
Carbofenthion	2.0	ND	ND	ND	ND
Chlorfenvinphos	0.5	ND	ND	ND	ND
Chlorpyrifos	0.3	ND	ND	ND	ND
Chlorpyrifos-methyl	0.3	ND	ND	ND	ND
Clofrin	0.5	ND	ND	ND	ND
Cumaphoa	1.5	ND	ND	ND	ND
Cyanazine	0.5	ND	ND	ND	ND
DEF	0.5	ND	ND	ND	ND
Demeton O/S Analogues	0.5	ND	ND	ND	ND
Diazion	0.5	ND	ND	ND	ND
Dibrom	0.5	ND	ND	ND	ND
Dicrotophos	0.5	ND	ND	ND	ND
Dimethate	0.5	ND	ND	ND	ND
Diphenyl Amine	2.0	ND	ND	ND	ND
Disulfoton	0.3	ND	ND	ND	ND
EPN	1.0	ND	ND	ND	ND
Ethion	0.5	ND	ND	ND	ND

Table 8 (continued). Full suite analysis for selected Ventura Stream Team sampling locations on February 28, 2005.

sampling site		VR01	VR03	VR07	VR9
	PQL	2/28/05	2/28/05	2/28/05	2/28/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
ORGANOPHOSPHORUS PESTICIDES: method EPA 8141A					
Ethoprop	0.5	ND	ND	ND	ND
Fenamiphos	0.5	ND	ND	ND	ND
Fenitrothion	0.5	ND	ND	ND	ND
Fenthion	0.5	ND	ND	ND	ND
Fonotos	0.5	ND	ND	ND	ND
Hexazinone	1.0	ND	ND	ND	ND
Imazalil	2.0	ND	ND	ND	ND
Imidan	0.5	ND	ND	ND	ND
Isofenphos	0.5	ND	ND	ND	ND
Malathion	0.5	ND	ND	ND	ND
Metalaxyl	2.0	ND	ND	ND	ND
Methidathion	0.5	ND	ND	ND	ND
Methyl Parathion	0.5	ND	ND	ND	ND
Metolachlor	1.0	ND	ND	ND	ND
Metribuzin	1.0	ND	ND	ND	ND
Mevinphos	0.5	ND	ND	ND	ND
Molinate	1.0	ND	ND	ND	ND
Myclobutanil	0.5	ND	ND	ND	ND
Parathion	0.5	ND	ND	ND	ND
Phorate	0.5	ND	ND	ND	ND
Phosalone	1.5	ND	ND	ND	ND
Phosphamidon	1.0	ND	ND	ND	ND
Primiphos-methly	0.5	ND	ND	ND	ND
Profenofos	1.0	ND	ND	ND	ND
Prometon	0.5	ND	ND	ND	ND
Prometryne	0.5	ND	ND	ND	ND
Propetamiphos	0.5	ND	ND	ND	ND
Pymetrazine	0.5	ND	ND	ND	ND
Ronnel	0.5	ND	ND	ND	ND
Simazine	0.5	ND	ND	ND	ND
Terbacil	5.0	ND	ND	ND	ND
Tetrachlorvinphos	0.5	ND	ND	ND	ND
Thiabendazole	1.0	ND	ND	ND	ND
Thionazin	0.5	ND	ND	ND	ND

Table 8 (continued). Full suite analysis for selected Vntura Stream Team sampling locations on February 28, 2005.

sampling site		VR01	VR03	VR07	VR9
	PQL	2/28/05	2/28/05	2/28/05	2/28/05
	mg/L	mg/L	mg/L	mg/L	mg/L
CHLORINATED HERBICIDES: method EPA 8151A					
2,4-D	0.25	ND	ND	ND	ND
2,4-DB	0.25	ND	ND	ND	ND
Dicamba	0.13	ND	ND	ND	ND
Dichloroprop	0.13	ND	ND	ND	ND
Dinoseb	0.13	ND	ND	ND	ND
2,4.5.-T	0.13	ND	ND	ND	ND
2,4.5.-TP (Silvex)	0.13	ND	ND	ND	ND
TOTAL METALS: method EPA 6020/7470					
Antimony	0.05	ND	ND	ND	ND
Arsenic	0.05	ND	ND	ND	ND
Barium	0.005	ND	ND	ND	ND
Baryllium	0.005	ND	ND	ND	ND
Cadmium	0.01	ND	ND	ND	ND
Chromium	0.01	ND	ND	ND	ND
Cobalt	0.01	ND	ND	ND	ND
Copper	0.01	ND	ND	ND	ND
Lead	0.005	ND	ND	ND	ND
Mercury	0.0005	ND	ND	ND	ND
Molybdenum	0.01	ND	ND	0.03	0.02
Nickel	0.01	0.02	0.02	0.08	0.03
Selenium	0.05	ND	ND	ND	ND
Silver	0.01	ND	ND	ND	ND
Thallium	0.05	ND	ND	ND	ND
Vanadium	0.01	0.02	0.02	0.08	0.02
Zinc	0.01	0.04	0.04	0.10	0.03
MBAS: method SM5540C					
MBAS	0.02	ND	0.04	ND	ND
OIL AND GREASE: method EPA 413.2					
Oil and Grease	1.0	ND	ND	1.5	ND

*PQL is the practical quantitation limit.

ND indicates no determination, e.g., results were below the practical quantitation limit.

Table 9. Full suite analysis for selected Ventura Stream Team sampling locations on September 21, 2005.

sampling site		VR01	VR03	VR07	VR09
	PQL	9/21/05	9/21/05	9/21/05	9/21/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILE ORGANIC COMPOUNDS: method EPA 8260A/8260B					
Acetone	10	ND	ND	ND	ND
Acrolein	100	ND	ND	ND	ND
Acrylonitrile	50	ND	ND	ND	ND
Benzene	1	ND	ND	ND	ND
Bromobenzene	1	ND	ND	ND	ND
Bromochloromethane	1	ND	ND	ND	ND
Bromodichloromethane	1	ND	ND	ND	ND
Bromoform	1	ND	ND	ND	ND
Bromomethane	1	ND	ND	ND	ND
2-Butanone (MEK)	10	ND	ND	ND	ND
Carbon Disulfide	1	ND	ND	ND	ND
Carbon Tetrachloride	1	ND	ND	ND	ND
Chlorobenzene	1	ND	ND	ND	ND
Chloroethane	1	ND	ND	ND	ND
Chloroform	1	ND	ND	ND	ND
Chloromethane	1	ND	ND	ND	ND
2-Chlorotoluene	1	ND	ND	ND	ND
4-Chlorotoluene	1	ND	ND	ND	ND
cis-1,3-Dichloropropene	1	ND	ND	ND	ND
Dibromochloromethane	1	ND	ND	ND	ND
Dibromomethane	1	ND	ND	ND	ND
1,2-Dibromo-3-Chloropropane	1	ND	ND	ND	ND
1,2-Dichloromethane (EDB)	1	ND	ND	ND	ND
1,3-Dichlorobenzene	1	ND	ND	ND	ND
1,4-Dichlorobenzene	1	ND	ND	ND	ND
1,1-Dichloroethane	1	ND	ND	ND	ND
1,2-Dichloroethane (EDC)	1	ND	ND	ND	ND
1,1-Dichloroethylene	1	ND	ND	ND	ND
Dichlorodifluromethane	1	ND	ND	ND	ND
1,4-Dioxane	200	ND	ND	ND	ND
Dispropylether (DIPE)	2	ND	ND	ND	ND
Ethylbenzene	1	ND	ND	ND	ND
Ethyl-t-Butyl Ether (ETBE)	2	ND	ND	ND	ND
Hexachlorobutadiene	1	ND	ND	ND	ND

Table 9 (continued). Full suite analysis for selected Ventura Stream Team sampling locations on September 21, 2005.

sampling sites		VR01	VR03	VR07	VR09
	PQL	9/21/05	9/21/05	9/21/05	9/21/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILE ORGANIC COMPOUNDS: method EPA 8260					
2-Hexanone	10	ND	ND	ND	ND
Isoprotylbenzene	1	ND	ND	ND	ND
Methyl t-Butyl Ether (MTBE)	2	ND	ND	ND	ND
Methylene Chloride	1	ND	ND	ND	ND
4-Methyl-3-pentanone (MIBK)	10	ND	ND	ND	ND
Naphthalene	1	ND	ND	ND	ND
n-Butylbenzene	1	ND	ND	ND	ND
n-Propylbenzene	1	ND	ND	ND	ND
p-Isopropyltoluene	1	ND	ND	ND	ND
sec-Butylbenzene	1	ND	ND	ND	ND
Styrene	1	ND	ND	ND	ND
t-Amyl Methyl Ether (TAME)	20	ND	ND	ND	ND
tert-Butanol	1	ND	ND	ND	ND
tert-Butylbenzene	1	ND	ND	ND	ND
Tetrachloroethylene	1	ND	ND	ND	ND
Toluene	1	ND	ND	ND	ND
trans-1,3-Dichloropropene	1	ND	ND	ND	ND
1,2,3-Trichlorobenzene	1	ND	ND	ND	ND
1,2,3-Trichloropropane	1	ND	ND	ND	ND
1,2,4-Trichlorobenzene	1	ND	ND	ND	ND
1,1,1-Trichloroethane (TCA)	1	ND	ND	ND	ND
1,1,2-Trichloroethane	1	ND	ND	ND	ND
1,2,4-Trimethylbenzene	1	ND	ND	ND	ND
Trichloroethylene	1	ND	ND	ND	ND
Trichlorofluoromethane (freon 11)	1	ND	ND	ND	ND
1,3,5-Trimethylbenzene	1	ND	ND	ND	ND
1,1,1,2-Tetrachloroethane	1	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	1	ND	ND	ND	ND
Vinyl Acetate	1	ND	ND	ND	ND
Vinyl Chloride	1	ND	ND	ND	ND
Xylenes	1	ND	ND	ND	ND
CHLORINATED PESTICIDES: method EPA 8081					
Aldrin	0.05	ND	ND	ND	ND
Alpha-BHC	0.05	ND	ND	ND	ND
Beta-BHC	0.05	ND	ND	ND	ND

Table 9 (continued). Full suite analysis for selected Ventura Stream Team sampling locations on September 21, 2005.

sampling site		VR01	VR03	VR07	VR09
	PQL	9/21/05	9/21/05	9/21/05	9/21/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
CHLORINATED PESTICIDES: method EPA 8081					
Delta-BHC	0.05	ND	ND	ND	ND
Gamma-BHC (Lindane)	0.05	ND	ND	ND	ND
Chlordane	0.05	ND	ND	ND	ND
4,4'-DDD	0.05	ND	ND	ND	ND
4,4'-DDE	0.05	ND	ND	ND	ND
4,4'-DDT	0.05	ND	ND	ND	ND
Dieldrin	0.05	ND	ND	ND	ND
Endosulfan I	0.05	ND	ND	ND	ND
Endosulfan II	0.05	ND	ND	ND	ND
Endosulfan sulfate	0.05	ND	ND	ND	ND
Endrin	0.05	ND	ND	ND	ND
Endrin aldehyde	0.05	ND	ND	ND	ND
Heptachlor	0.05	ND	ND	ND	ND
Heptachlor epoxide	0.05	ND	ND	ND	ND
Methoxychlor	0.5	ND	ND	ND	ND
Toxaphene	2.0	ND	ND	ND	ND
POLYCHLORINATED BIPHENYLS (PCBs): method EPA 8082					
PCB 1016	0.5	ND	ND	ND	ND
PCB 1221	0.5	ND	ND	ND	ND
PCB 1232	0.5	ND	ND	ND	ND
PCB 1242	0.5	ND	ND	ND	ND
PCB 1248	0.5	ND	ND	ND	ND
PCB 1254	0.5	ND	ND	ND	ND
PCB 1260	0.5	ND	ND	ND	ND
ORGANOPHOSPHORUS PESTICIDES: method EPA 8141A					
Azinphos-methyl	2.0	ND	ND	ND	ND
Bolstar	2.0	ND	ND	ND	ND
Benstar	2.0	ND	ND	ND	ND
Chlorpyrifos	2.0	ND	ND	ND	ND
Coumaphos	2.0	ND	ND	ND	ND
Demeton O/S Analogues	2.0	ND	ND	ND	ND
Diazinon	2.0	ND	ND	ND	ND
Dichlorvos	2.0	ND	ND	ND	ND
Dimethoate	2.0	ND	ND	ND	ND
Disulfoton	2.0	ND	ND	ND	ND

Table 9 (continued). Full suite analysis for selected Ventura Stream Team sampling locations on September 21, 2005.

sampling site		VR01	VR03	VR07	VR9
	PQL	9/21/05	9/21/05	9/21/05	9/21/05
constituent	µg/L	µg/L	µg/L	µg/L	µg/L
ORGANOPHOSPHORUS PESTICIDES: method EPA 8141A					
EPN	2.0	ND	ND	ND	ND
Ethoprop	2.0	ND	ND	ND	ND
Fenitrothion	2.0	ND	ND	ND	ND
Fenthion	2.0	ND	ND	ND	ND
Malathion	2.0	ND	ND	ND	ND
Merphos	2.0	ND	ND	ND	ND
Mevinphos	2.0	ND	ND	ND	ND
Monocrotophos	2.0	ND	ND	ND	ND
Naled	2.0	ND	ND	ND	ND
Parathion	2.0	ND	ND	ND	ND
Parathion Methyl	2.0	ND	ND	ND	ND
Phorate	2.0	ND	ND	ND	ND
Ronnel	2.0	ND	ND	ND	ND
Stirophos	2.0	ND	ND	ND	ND
Sulfotepp	2.0	ND	ND	ND	ND
Thionazin	2.0	ND	ND	ND	ND
Tokuthion	2.0	ND	ND	ND	ND
Trichloronate	2.0	ND	ND	ND	ND
CHLORINATED HERBICIDES: method EPA 8151A					
2,4-D	2.0	ND	ND	ND	ND
2,4-DB	5.0	ND	ND	ND	ND
Delapon	5.0	ND	ND	ND	ND
Dicamba	2.0	ND	ND	ND	ND
Dichloroprop	2.0	ND	ND	ND	ND
Dinoseb	2.0	ND	ND	ND	ND
2,4.5.-T	2.0	ND	ND	ND	ND
2,4.5.-TP (Silvex)	2.0	ND	ND	ND	ND
TOTAL METALS: method EPA 6020/7470					
	mg/L	mg/L	mg/L	mg/L	mg/L
Aluminum	0.1	ND	ND	ND	ND
Antimony	0.01	ND	ND	ND	ND
Arsenic	0.01	ND	ND	ND	ND
Barium	0.005	0.043	0.048	0.036	0.065
Baryllium	0.005	ND	ND	ND	ND
Cadmium	0.005	ND	ND	ND	ND

Table 9 (continued). Full suite analysis for selected Ventura Stream Team sampling locations on September 21, 2005.

sampling site		VR01	VR03	VR07	VR09
	PQL	9/21/05	9/21/05	9/21/05	9/21/05
constituent	mg/L	mg/L	mg/L	mg/L	mg/L
TOTAL METALS: method EPA 6020/7470					
Chromium	0.01	ND	ND	ND	ND
Cobalt	0.01	ND	ND	ND	ND
Copper	0.01	ND	ND	ND	ND
Lead	0.01	ND	ND	ND	ND
Mercury	0.00001	ND	ND	0.00001	ND
Molybdenum	0.01	ND	ND	ND	ND
Nickel	0.015	ND	ND	ND	ND
Selenium	0.01	ND	0.02	ND	ND
Silver	0.01	ND	ND	ND	ND
Thallium	0.01	ND	ND	ND	ND
Vanadium	0.01	ND	ND	ND	ND
Zinc	0.02	0.03	0.04	ND	ND
MBAS: method SM5540C					
MBAS	0.01	ND	ND	ND	ND

*PQL is the practical quantitation limit.

ND indicates no determination, e.g., results were below the practical quantitation limit.

RECOMMENDED ACTIONS

The first five years of Channelkeeper's Ventura Stream Team water quality monitoring efforts identified a number of water quality impairments, which demonstrate the need for action to address water pollution in the area. Although five years of data are not necessarily conclusive, there are several reasons to implement proactive measures now to reduce pollution in this important watershed.

Stretches of the Ventura River, Canada Larga and San Antonio Creeks are listed as impaired waterbodies on the State's 303(d) List of Water Quality Limited Segments due to contamination from non-point source pollution. Moreover, the river is poised to undergo major restoration in the near future with the removal of the Matilija Dam, which may further impact water quality in the watershed.

The Los Angeles Regional Water Quality Control Board is required to develop Total Maximum Daily Loads (TMDLs) for pollutants of concern in impaired waterbodies, and development of TMDLs for the Ventura River watershed are scheduled for 2008-09. Further, Ventura County is implementing a Storm Water Management Program (required pursuant to the State General Permit for Municipal Separate Storm Sewer Systems), and must demonstrate that the strategies therein are effectively reducing pollution in stormwater and runoff. Channelkeeper's data have been and continue to be used by the County for this purpose, as well as for its efforts to assess the overall health of the watershed and to facilitate watershed planning and restoration.

Continue and expand monitoring: Channelkeeper's data can continue to serve as an important resource for municipalities, regulatory agencies and other stakeholders in evaluating the need for and effectiveness of local water quality protection and restoration efforts. Our data will also provide a useful baseline of water quality conditions prior to the removal of the Matilija Dam. Therefore, Channelkeeper's Ventura Stream Team program should be continued, and should further be expanded to include sampling sites in the estuary and in the surf zone at the mouth of the river.

Conduct creek walks: The Ventura Stream Team data would be even more useful if they were supplemented by additional efforts to pinpoint particular sources of the nutrient and bacterial pollution identified through Channelkeeper's sampling efforts. This could be achieved by conducting creek walks to identify discharge points and discrete sources of runoff that may be contributing polluted water to the creeks, testing the discharged water for pollutants, then consulting the County's land use and storm sewer maps to pinpoint potential sources contributing to the pollution.

Educate property owners and enforce ordinances: Once specific sources are identified, Channelkeeper and/or other environmental groups as well as local regulatory agencies should reach out to owners of properties from which polluted discharges may be originating. The focus of the outreach efforts should be to educate business or property owners on the potential problems posed by their particular discharges, and present solutions and best management practices (BMPs) which different types of business or property owners can implement to prevent pollution in the future. The Ventura County Watershed Protection District already possesses brochures targeting pet and horse owners, gardeners, residents and business owners, as well as specific categories of activities for businesses (such as building and grounds maintenance; building repair, remodeling and construction; vehicle and equipment fueling, repair and cleaning; and waste management and disposal); these should be distributed to business owners or residents that own property from which discharges may be originating. This outreach and education should be followed by targeted inspections and monitoring by relevant RWQCB, County or City agency staff responsible for enforcement of existing water quality protection regulations and ordinances. If such monitoring efforts or inspections identify ongoing pollution problems from particular sources, the appropriate agencies should follow up with enforcement action, such as issuing fines or cease and desist orders, to ensure that discharges cease. In the Ventura River watershed, these education and enforcement efforts should target owners/managers of horse facilities and cattle grazing operations, which Channelkeeper believes contribute significant amounts of nutrients into many of the creeks monitored by Ventura Stream Team.

Monitor compliance with Ojai Valley Sanitary District permit: Regulatory agencies should scrutinize the results of monitoring conducted by the Ojai Valley Sanitary District. The District is required by their National Pollutant Discharge Elimination System (NPDES) permit to conduct regular monitoring of waters receiving the discharge from the Ojai wastewater treatment plant (in this case, the Ventura River). Since the treatment plant is a known source of excessive nutrients on the Ventura River, the monitoring results for these parameters in particular should be tracked closely to ensure that discharge limitations for nutrients, biochemical oxygen demand and suspended solids spelled out in the facility's permit are met. If they are exceeded, the Regional Water Quality Control Board (RWQCB) should take enforcement action to bring the facility back into compliance. If these limitations are exceeded on a regular basis, the RWQCB should tighten the effluent limits for these parameters next time the facility's five-year permit is renewed.

Implement stormwater treatment controls: There are a variety of treatment technologies and methods available for reducing bacteria and other pollutants in creeks and storm drain systems, including active treatment systems, such as ultraviolet (UV) light and ozone treatment systems, and stormwater treatment BMPs, such as vegetated swales, infiltration basins, constructed wetlands, and porous pavement, to name just a few. Priority sites that would benefit from treatment controls should be identified, and local municipalities should allocate funding to implement more of these types of stormwater treatment controls in priority areas throughout the Ventura River watershed.

Encourage installation of low-impact development BMPs: In an effort to reduce the mobilization of pollutants in runoff, urban planners are increasingly looking to the use of structural BMPs such as infiltration practices. One example is the use of porous pavement as opposed to impervious asphalt or concrete. Regulatory agencies should seek to encourage the installation of such BMPs by developing and providing incentives, such as facilitated permitting or cash stipends or rebates, to property owners.

In conclusion, while there are a number of water quality problems throughout the Ventura River watershed, there are also many opportunities to address them. Santa Barbara Channelkeeper is committed to improving water quality throughout the watersheds draining to the Santa Barbara Channel, and looks forward to continued cooperation with government agencies, environmental groups, and the public to achieve this goal.

ENDNOTES

1. The sections on the South Coast and the Ventura River were adapted from Veirs et al. (1998), SWRCB-LA (2002), USACE (2002), USBR (2002) and USDA-FS (2004). A reference list is included at the end of the report. When available, references with web addresses were chosen so documents can be easily accessed for additional information. In addition to these general references, specific citations are used when warranted.
2. Climate data for the Ventura region are available from a number of internet sources: DRI-WRCC, CDEC, CCDA and JISAO. The discussions on hydrology reference the "water-year" instead of using a calendar year. The water-year begins on October 1st and ends the following September 30th, e.g., water-year 1998 began on October 1, 1997, and ended on September 30, 1998. Hydrologists and agencies concerned with water in California use the water-year concept because it better fits the seasonal progression of annual precipitation - rainy to dry, snowfall to snowmelt.
3. Los Angeles is used as the example because its rainfall record goes back much further than any other nearby location.
4. For example, average daily and peak 15-minute flows during a storm on February 12, 1992, were 12,400 and 43,800 cfs, respectively, compared with the 5-10 cfs usually seen at Foster Park.
5. For example, the last three years saw only eleven months of flow at VR04 and VR05, four at VR11 and five at VR12.
6. Mission Creek is used as the example because the Foster Park gauge, the only USGS gauge on the Ventura River, became indefinitely inoperable as of February 2005.
7. By the end of April 2005, the amount of rainfall was 222% of the annual average at Oxnard, 268% at Los Angeles, 204% at Santa Barbara and 239% at Lake Cachuma.
8. US EPA (1997), Deas and Orlob (1999) and Heal the Bay (2003) were used in the preparation of the water quality parameters sections.
9. Other abrupt decreases shown in the figure are probably due to error. In June 2001, very low conductivities were measured at VR01, VR02 and VR03 (Figure 7, upper panel), all Group I sites. However, normal readings were recorded elsewhere by Groups II and III, which clearly indicates a meter malfunction.
10. Milligrams per liter is the weight of oxygen in a liter of water. It is often simpler to think of mg/L as "parts per million." Since a liter of water weighs a million milligrams, 1 mg/L is the same as one part of dissolved oxygen in a million parts of water. Percent saturation is the amount of oxygen dissolved in water relative to the total amount of oxygen that can be held under equilibrium conditions at that temperature.
11. As before, these markers are for steelhead and trout; for warm-water fish, each limit could lowered by 1 mg/L, decreasing them to 7, 5 and 3 mg/L, respectively.
12. In other words, the oxygen excess or deficiency (the meter makes this calculation based on measured temperature and an entered value of the sampling elevation).
13. A percent saturation above 100% simply indicates that water is not at equilibrium but is in the process of releasing oxygen into the atmosphere, just like a glass of recently poured soda sheds an over-saturation of carbon dioxide as streams of bubbles.
14. Three sets of data were combined to make the pH charts: field measurements through June 2003, laboratory measurements made from collected samples from June 2003-March 2005, and finally, field measure-

ments again from April 2005 onward. pH is a difficult measurement to make, even in the laboratory, and the initial portable meters used by Channelkeeper proved unreliable. Newer, higher quality meters are now available and were used beginning with the April 2005 sampling. During the intervening period, laboratory measurements were made with a meter borrowed from the UCSB-LTER program. When looking at Figure 19, more faith should be placed on the 2003-2005 data than on earlier measurements.

15. In this area, water is usually slightly acidic with a pH of 4-5.

16. Ventura waters are high in carbonates with acid neutralizing capacities (ANC), e.g., ANC typically around 4,000 μeq/L.

17. Since it is not regarded as a cold water stream, Canada Larga (VR04) only needs to meet a standard of > 6 mg/L. Sites not shown on Figure 23 (VR09, VR10 and VR11) also underwent pre-dawn sampling on June 2,

2005, and all met the 7 mg/L criterion.

18. There are other ways of expressing chemical concentration, but this is the most common. Again, it is easier to think of mg/L as "parts per million," e.g., 10 mg/L as 10 parts of nitrogen in a million parts of water.

19. The single poor result likely represents a sampling error.

20. Note that we are underestimating the actual situation – phosphate is only part of the total phosphorus concentration in Ventura River samples, with organic phosphorus making up the remainder. Typically phosphate represents approximately 80% of the total phosphorus in our nutrient samples.

21. Sampling rarely takes place on a rainy day because rainy days only occur about 4% of the time; with sampling occurring once a month during the winter, there is only a one in ten chance of encountering rain, or about once every two years.

22. Given that the suggested EPA eutrophication limits are typically measured as total nitrogen and total phosphorus, some explanation of why phosphate was used instead of phosphorus, and nitrate in place of total nitrogen, during the previous discussions is warranted. The University of California, Santa Barbara's Long-Term Ecological Research project (UCSB-LTER) analyzes the Stream Team nutrient samples for Channelkeeper. Nitrate and phosphate (and ammonium) are analyzed as soon as possible (typically within a few days), but total nitrogen and total phosphorus are analyzed months or even a year later (samples undergo initial processing as soon as possible, but are then stored in a preserved condition). Therefore, delay is part of the reason; nitrate and phosphate are used because results are available sooner. Typically, nitrate and phosphate results are available two months after other sampling data, while total nitrogen and phosphorus are 5-10 months further behind.

    Error and imprecision are part of all laboratory analysis; a result is never simply a number, but a number plus or minus some error. Total nitrogen and total phosphorus are analyzed to determine the concentrations of organic nitrogen and organic phosphorus in a sample. The inorganic concentration is simply subtracted from the total – phosphate from total phosphorus, inorganic nitrogen (nitrate + ammonium) from total nitrogen, and what remains is the organic fraction.

    Sometimes analysis error or the precision of the result is such that the inorganic concentration is higher than the total concentration, e.g., a larger number has to be subtracted from a smaller. For example, the total phosphorus concentration may end up being lower than the phosphate in a sample. Obviously, this cannot be true; something either went wrong or the precision of the analysis was not high enough to produce a satisfactory result by subtraction. This happens about 4% of the time with nitrogen (which is acceptable, particularly when concentrations are high), but 50% of the time with phosphorus. The phosphorus results present a real problem, one that the UCSB laboratory has not been able to solve. Something in our local stream water removes phosphorus from solution during the test procedure, and since the total phosphorus results are undependable, phosphate is used instead.

This is not an important distinction. Phosphate makes up a large majority of total phosphorus in the Ventura Stream Team samples, and nitrate is the dominant nitrogen fraction at most sites. Analysis of filtered vs. unfiltered samples to determine nutrient composition is another difference without a distinction. Tests on filtered and unfiltered samples at most of the Ventura Stream Team sampling sites show no statistical difference between these two types of samples. Except for the rare rainy days, Ventura River water is relatively sediment free (see the turbidity results shown in Figures 17 and 18). Summarized results of the overall nutrient analysis (through September 2005) are given in Table 2. The variation of nutrient concentrations and other constituents during storms is not part of the Channel keeper sampling program, nor is it discussed in this report. However, it remains an important topic, since the great majority of the annual load of pollutants flushed into the neighboring ocean occurs during these events. Figure 30, showing variations in concentration during the major storm of 2003 (data from UCSB-LTER), is included to demonstrate what does occur.

23. This ratio, 16 atoms of nitrogen to one atom of phosphorus, is named the "Redfield ratio" after its discoverer (Sterner and Elser, 2002).

24. Redfield ratios are proportions between atoms. Previously, nutrient concentrations were shown in mg/L, a unit based on the weight of nitrogen or phosphorus in water. The µmole, a measure of the number of atoms, is more useful when comparing the proportions of nutrients; 1 mg/L of nitrate as nitrogen is equal to 72 µM, 1 mg/L of phosphate as phosphorus equals 32 µM.

25. A nitrate to phosphate ratio in the thousands indicates the virtual disappearance of phosphate.

26. A possible exception may be greatly increased export during El Niño years when the upwelling and circulatory processes that normally provide a large supply of nitrogen to the Channel are greatly diminished in warmer ocean waters.

27. The following documents were used as references in the preparation of the bacteria section: US EPA, 2002 and 2004; SWRCB, 2003 and 2004; RWQCB-LA, 2001. There are significant differences between EPA indicator bacteria guidelines and current California State regulations, as well as among those of the different Regional Water Quality Control Boards and counties within the state. The regulatory situation is in flux as some of these differences are being ironed out, and thus the narrative on bacteria should be considered a reasonable overview and not taken as definitive.

28. California Public Health requirements for bacteria counts are complicated and vary somewhat by jurisdiction; what follows is simply a broad outline.

29. This average is the "geometric average" or "geomean" - bacteria counts are converted into logarithms, averaged, and the average log value converted back into a regular number. The geomean reduces the influence of very high or low numbers, which might unfairly represent aberrant samples.

30. 235 for beach areas, 500 for occasional recreational use.

31. In other words, as long as less than 10% of the coliforms are of fecal origin.

32. Channelkeeper does not actually test for fecal coliform. Instead, the E. coli values have been multiplied by

1.7 to estimate fecal coliform concentrations (this assumes that a fecal coliform sample would consist of approximately 60% E. coli; this equivalency is the value assumed by most regulatory standards and is a conservative estimate; see also Cude, 2005).

33. It was found that riverbank soil was the principal source of dry weather E. coli in a Florida stream, and that E. coli exhibited a competitive advantage over predators as soils dried (Solo-Gabriele et al., 2000).

34. 8.5 is the LA Regional Water Board's upper limit for pH for surface waters.

35. The following websites were used as references in the preparation of the full-suite sampling section: US EPA, Ground and Drinking Water (http://www.epa.gov/safewater/mcl.html#mcls); US EPA, Pesticides: Health and Safety (http://www.epa.gov/pesticides/cumulative/); Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/); Ontario, Ministry of the Environment (http://www.ene.gov.on.ca/cons/); and the International Programme on Chemical Safety – ICHEM (http://www.inchem.org/). The subject of trace contaminants is complicated and the regulatory situation constantly changing. The narrative in this section should be considered simply as an introduction to the subject, and is intended to be neither a complete overview nor definitive in a regulatory sense.

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APPENDIX

METHODOLOGY

All Stream Team sampling and laboratory analysis is conducted in compliance with a Quality Assurance Project Plan approved by the State Water Resources Control Board. This Quality Assurance Project Plan can be viewed on-line at www.stream-team.org. The following narrative summarizes all Stream Team testing procedures.

Water sampling and chemical analyses

Stream water samples were collected manually at mid-depth near the center of flow. Sample bottles (and caps) of high-density polyethylene (HDPE) were rinsed three times with deionized water before being used, and three times again with sample water immediately prior to being filled. Samples were placed in coolers as soon as possible and transported on ice, and were stored at 4°C once in the laboratory.

Samples for dissolved constituents were generally filtered in the field through Gelman A/E glass fiber filters, pre-flushed with deionized water and then sample water. A syringe was used to force the sample through the filter unit. Stormflow samples with high sediment concentrations could not be field-filtered and were either centrifuged or allowed to settle before filtration in the laboratory. Samples were analyzed for nitrogen (dissolved organic nitrogen, nitrate (NO3 + NO2) and ammonium) and phosphorus (soluble reactive phosphate, SRP). Nitrate, ammonium and phosphate were determined colorimetrically on a Lachat® auto-analyzer. Ammonium was measured by adding base to the sample stream, converting ammonium to ammonia, which diffuses across a Teflon® membrane (Willason and Johnson, 1986) and into phenol red pH indicator. Nitrate was measured using a standard Griess-Ilosvay reaction after Cd reduction (EPA, 1983). Phosphate was measured after reaction with ammonium molybdate and antimony potassium tartrate and reduction by ascorbic acid with heating at 45°C.

Detection limits were 0.3 μmol L-1 for NH4+ and PO43- and 0.5 μmol L-1 for NO3-; accuracy is ±5%. Total dissolved nitrogen (TDN) was determined after persulfate digestion (Valderrama, 1980) followed by measurement of nitrate. The basic persulfate reagent was added to a separate aliquot at the time of initial processing or laboratory filtration, and the digestion completed within one week. The detection limit was 0.5 μmol L-1 and accuracy was + 10%. Dissolved organic nitrogen (DON) was computed as the difference between TDN and dissolved inorganic nitrogen (DIN: nitrate and ammonium).

The goal was to analyze inorganic nutrient samples and begin the digestion of total dissolved nitrogen samples within 48 hours of collection, and we were able to meet this goal for most of the samples collected. However, during winter storm periods, when high sediment concentrations prevented filtration in the field and the laboratory was inundated with hundreds of samples, the 48-hour limit was often exceeded by one to five days. To evaluate the effect of delay, three types of samples were collected from six streams with widely varying nutrient chemistry: (1) samples filtered in the field and analyzed in duplicate within 12 hours; (2) samples filtered in the laboratory on the day of collection, stored at 4°C, and repeatedly re-analyzed after delays of 1-14 days; and (3) an unfiltered sample, stored at 4°C, subsamples of which were repeatedly filtered and analyzed after similar delays. Numerous duplicate and deionized water samples provided quality assessment and control. The average error (the combined error of processing, delay, instrument calibration and analysis) for nitrate was 5-10% (the higher percentage error in the second week of delay), 10% for phosphate, and 20% for ammonium. Samples filtered within two days showed almost no variation in nitrate and phosphate from initial values, while ammonium was usually within 10%. Delays greater than two days did sometimes cause significant increases in ammonium concentrations.

Bacteriological analysis

Water samples for bacteria analysis were collected manually, at mid-depth near the center of flow, in sterile plastic bottles pre-charged with small amounts of sodium thiosulfate to remove residual chlorine (a possible problem below sewage treatment plants and in urban nuisance waters). Samples were placed in coolers, transported on ice, and analyzed within six hours of collection.

Each sample was analyzed for three indicator bacteria: total coliform, E. coli, and enterococci, using IDEXX Colilert® and Enterolert® methodologies (ASTM #D6503-99). Both methods are approved by the US Environmental Protection Agency (EPA, 2003a). The sample, diluted with distilled, bacteria-free water (typically using a dilution of 10:1), was used to fill multiple wells in an analysis tray. Colilert uses two indicators, one that changes color when metabolized by total coliform, and another that fluoresces when metabolized by E. coli; the Enterolert indicator fluoresces when metabolized by enterococci. The number of positive wells after incubation for 18 hours at 35°C (Colilert) or 24 hours at 41°C (Enterolert) provides a statistical determination of concentration. The unit of measure is the "most probable number" of "colony forming units," abbreviated as either "MPN" or "cfu," in 100 ml of sample.

Quality control was evaluated by analyzing laboratory "blanks" (zero bacteria samples), duplicate field samples, and by performing multiple tests on single samples. The reproducibility of the bacteria results can be evaluated by examining the differences between duplicate field samples. Two duplicates (consecutive samples taken at the same location) were collected on each sampling day. A measure of reproducibility is the difference proportion, the absolute value of the difference between two samples divided by the average value, or

$$\text{difference proportion} = (2 \mid N1 - N2 \mid)/ (N1 + N2)$$

where N1 and N2 are the concentrations of the first and second samples (Kayhanian et al., 2005). The mean and median difference proportions for the bacteria analyses are shown in Table A1.

Table A1. Average and median difference proportions (expressed as a percentage ± the standard deviation) of duplicated samples collected in Channelkeeper sampling programs, 2001 - 2005.

		MPN/100 ml	**%**	**%**
	no. of duplicates	**average concentration**	**average difference proportion**	**median difference proportion**
E.coli	124	460	43.3 ± 38.9	34.9 ± 48.6
enterococci	126	485	55.7 ± 50.9	42.3 ± 63.6
total coliform	116	4670	37.2 ± 34.7	27.0 ± 43.4

In-field measurements

Portable, hand-held meters were used to take field measurements for dissolved oxygen, pH, conductivity, water temperature and turbidity. Measurements were typically taken near the center of flow, below the surface in the upper half of the water column. The objective was to obtain measurements characteristic of the bulk of stream flow and not a spectrum of variation at the testing location. All instruments were calibrated according to manual instructions using certified laboratory standards on the day prior to sampling. Table A2 shows the type and accuracy of each meter used.

Table A2. Meters and accuracy.

Meter	Accuracy
YSI Model 55 Dissolved Oxygen/Temperature Meter	± 0.3 mg/L or 2%, ± 0.2°C
Oakton CON 410 Conductivity/TDS/Temperature Meter	± 1%, ± 0.5°C
LaMotte 2020 Turbidimeter	± 2% or 0.05 NTU
Oakton Waterproof pH Tester 2 (prior to April 2005)	± 0.1 pH
Oakton pH/mV/Temperature Meter (April 2005 and later)	± 0.01 pH

At each site, three readings were taken in three different areas of the creek with each meter (six for stream temperature using temperature scales on both the conductivity and dissolved oxygen meters). For the turbidimeter, two separate sample vials are tested three times each. All readings are later averaged to produce the final result that is entered into the database.

After sampling, all results are checked for quality control purposes. Any suspicious results are re-tested within six hours at the lab using a 500 ml sample collected at each location and transported on ice. Suspicious results are those that (1) are unusual in light of past measurements at the location, (2) have widely varying multiple measurements, or (3) are expressed in doubtful units (e.g., milli vs. micro, or ppt vs. ppm). The "back-up" samples were also used in cases of on-site equipment failure or suspected meter malfunctions.

The difference proportion used to evaluate duplicate bacteria samples can also be used to examine the repeatability of multiple measurements. In this case, the difference between maximum and minimum measurements is expressed as a percentage of the average of all measurements (typically either three, in the case of dissolved oxygen, conductivity and pH, or six for turbidity and water temperature). The median difference proportions for each parameter for all measurements made by both the Ventura and Goleta Stream Teams from June 2004 through July 2005 are shown in Table A3.

The repeatability of measurements is usually very good. With the exception of turbidity, a majority of the multiple measurements are within a few percentage points of each other. Turbidity measurements are afflicted by problems similar to those that effect bacteria concentrations: a spatially and temporally varying dispersion in stream flow. In addition, turbidity can vary with stream velocity, and its measurement is particularly susceptible to errors in collection and measurement, e.g., disturbing bottom sediment while collecting samples and/or failure to properly clean sample vials. This occasionally accounts for proportional errors greater than 100%.

Table A3. Median difference proportions (expressed as a percentage) and standard deviations of multiple parameter measurements collected in Channelkeeper sampling programs, June 2004-July 2005.

parameter	n	unit	median value	maximum value	minimum value	median standard deviation	median difference proportion
VENTURA STREAM TEAM							
dissolved oxygen	142	mg/L	8.86	17.43	4.05	0.09	2.1%
% saturation	142	%	94.1	196.5	53.8	1.09	2.1%
pH	142	units	8.15	9.03	6.95	0.04	1.0%
conductivity	142	µS/cm	1091	2747	335	3.8	0.8%
temperature	126	° C	16.9	24.6	6.2	0.15	2.1%
GOLETA STREAM TEAM							
dissolved oxygen	129	mg/L	9.33	19.76	3.41	0.15	3.4%
% saturation	125	%	94.4	32.8	98.2	1.65	3.3%
pH	130	units	8.17	8.90	7.10	0.03	0.7%
conductivity	142	µS/cm	1923	47600	164	23.1	1.8%
temperature	117	° C	16.9	27.1	7.2	0.23	3.1%
turbidity	118	NTU	3.96	309.5	0.13	0.30	16.4%

Santa Barbara Channelkeeper

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Mitch Levin
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Timothy Robinson
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Kit Stolz
Bill Stratton
Leah Svete
Stephen Svete
Robin Tams
Lindsay Thompson
Hanh Trick
John Vogel
Steve Wages
Emily Wages
George Williams
Judi Wiltjer
John Wingate

The volunteers listed above are those who participated in three or more Ventura Stream Team sampling events. However, Channelkeeper also sincerely thanks the hundreds more who donated their time to Ventura Stream Team over the past five years.