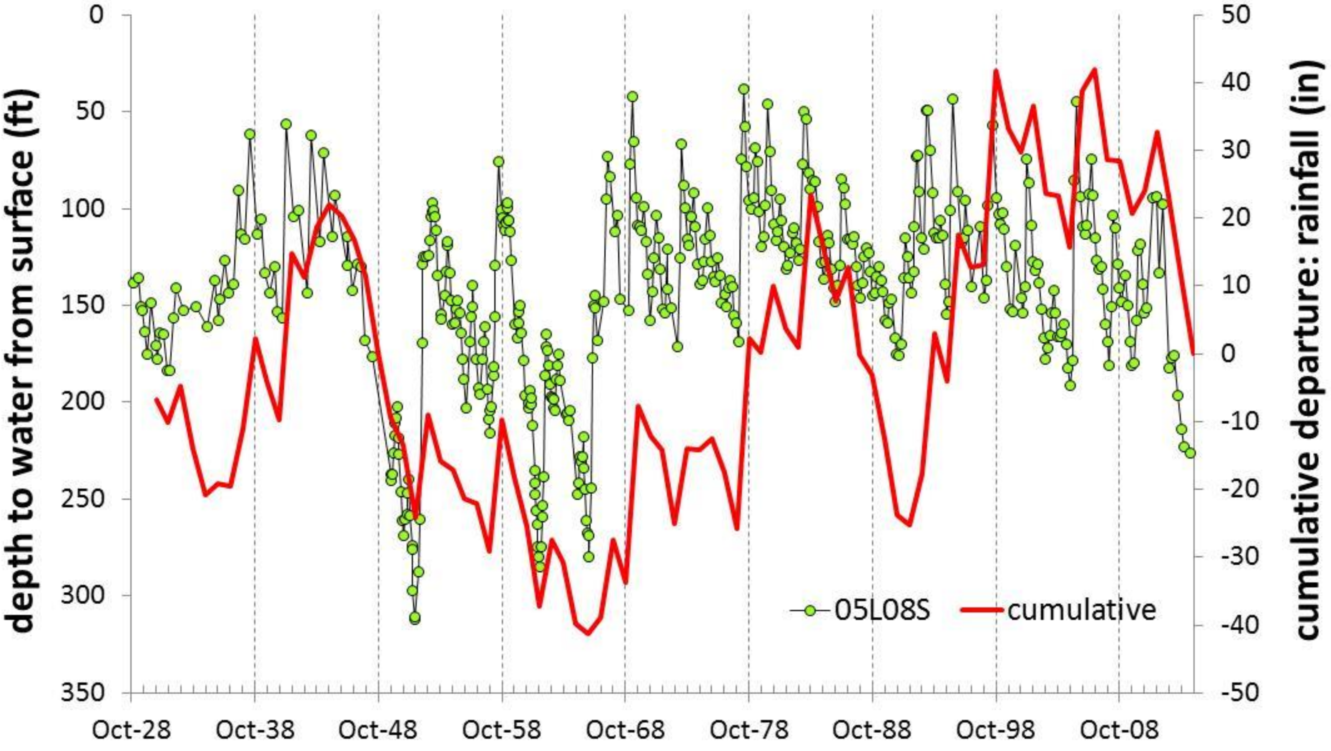


Ojai Valley Groundwater Basin

The graph above shows depth to groundwater for well 05L08 from 1928 to June 2014. 05L08 is in the Ojai Valley near the intersection of Grand and Carne, and is regarded as the “key well” for analysis and management of the Ojai groundwater basin; its record begins in 1949 but the older well that it replaced (05L01S), located a hundred or so feet away, can be used to extend the record back to 1927. The graph also shows the cumulative departure, since 1930, of Ojai rainfall from its mean.

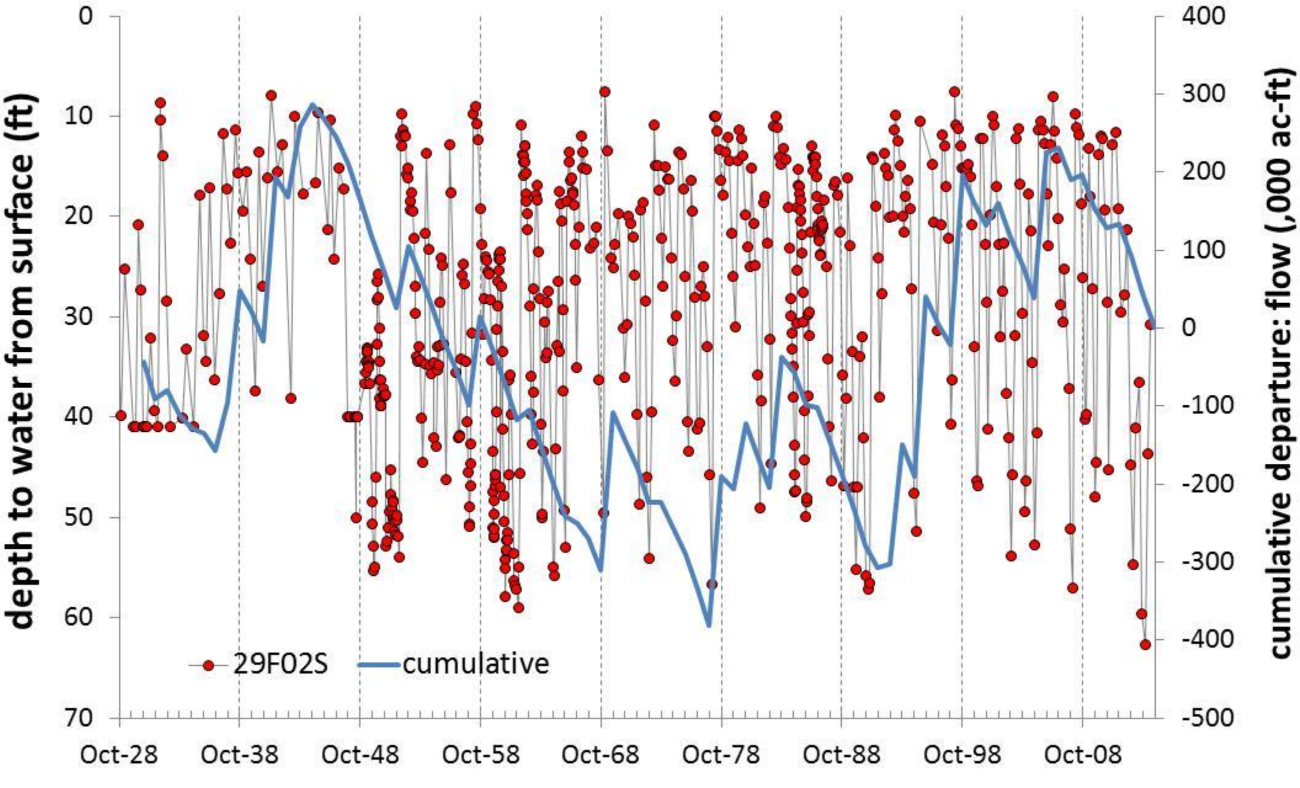
Don’t panic, it’s simpler than it looks. The mean or average is calculated using rainfall data from 1930-2014, and the individual annual values are re-stated as their variation from the mean, i.e., an annual rainfall of 30 inches is expressed as 9.3 in. above the mean (+9.3, the Ojai mean being 20.7 inches). An annual rainfall of 10 inches as 10.7 in. below the mean (-10.7). The cumulative departure for any year is simply the sum of all the departures (variations from the mean) that have gone before.

Since the starting point is arbitrary and since the last value (given the math) has to end at zero, the actual departure values are not that important. What is important is whether sequential values are increasing, decreasing, or remaining more-or-less the same. If every year’s rainfall was equal to the mean the cumulative departure line would be perfectly horizontal—beginning and ending at zero. An upward slope means that rainfall is generally increasing with time; a downward slope indicates decreasing annual rainfall. In other words, dry periods are indicated by long stretches of decreasing values or a downward slope, wet periods by increasing values and an upward slope.

The graph begins in the middle of a dry period, this is the *Great Dust Bowl Drought*, generally given as 1928 to 1935 (although it may have started earlier in California); this depression-era drought didn’t just happen in Oklahoma and Kansas, but was felt throughout most of the west. The next dry period was the big one: 1945-65. But this long, dry, 20-year period was broken up by a handful of very wet winters: 1952 (with 35.7 in. of rain), 1962 (30.4 in.), and 1958 (40.1 in.). It was finally brought to an end in 1966-67 (1966 with 23.2 in. and 1967 with 32.1 in.).

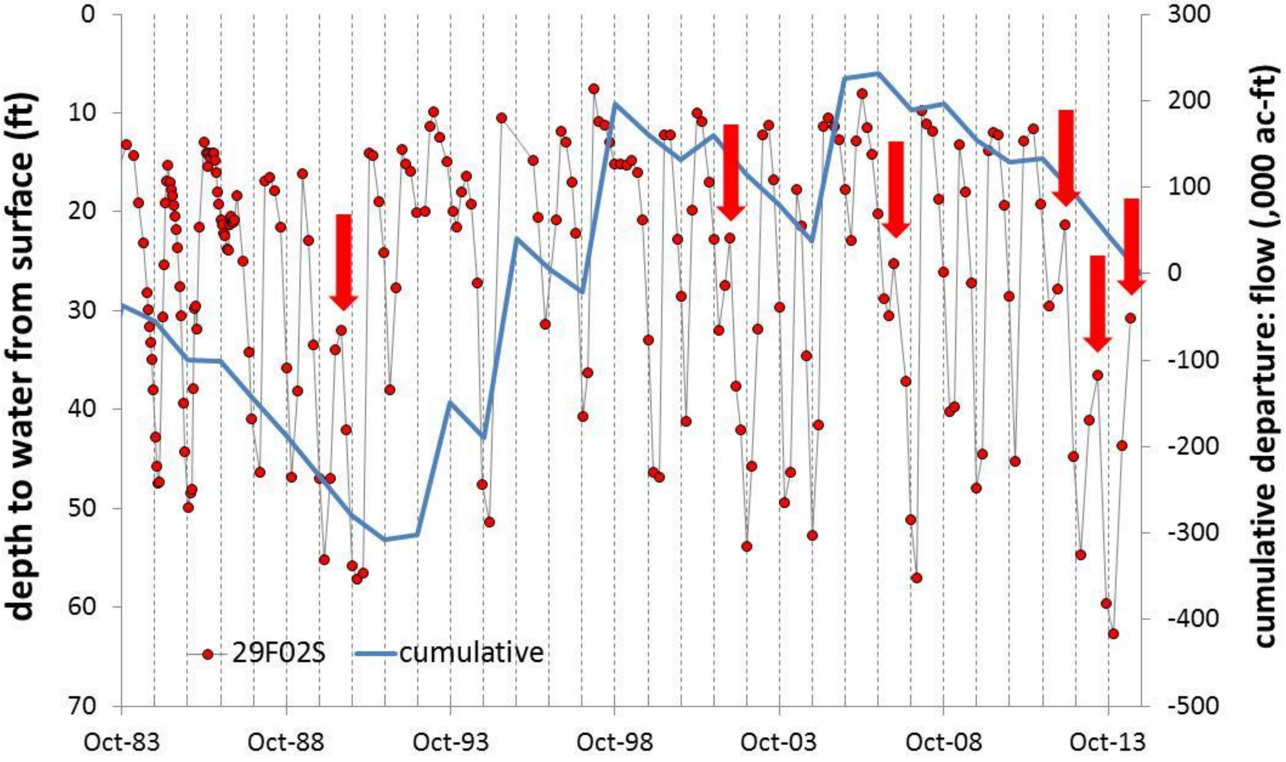
During this dry period Ojai's water table dropped to the 3 lowest points ever recorded: the lowest in 1952, the next in 1958 and the last in 1962 (all these minimums were measured in October). Aside from these three years, the water table is now (in 2014) at the lowest elevation ever seen (the actual situation is somewhat worse than the graph indicates since the last recorded depth was measured in mid-June of this year and can be expected to be appreciably lower by October).

One thing that struck me when drawing the graph was the extraordinary water table recovery following the 1952 low point, a recovery occasioned by 36 inches of rain. Note that nothing comparable happened in the 90s (even though we had 3 big wet El Nino winters, 41 inches in 1993, 42 inches in 1995, 49 inches in 1998) or in 2005 (44 inches). Part of this, no doubt, is due to the bowl-shaped nature of the Ojai groundwater basin, but note also how during the 90s water levels yo-yoed between wet and not-so-wet years compared with much slower and steadier decreases during the 1945-65 dry period. This leads me to believe that we are seeing the impact from appreciably increased groundwater withdrawals of more recent decades. In other words, because of increased withdrawals our recovery from this drought will not be as rapid as in the past.



Upper Ventura Groundwater Basin

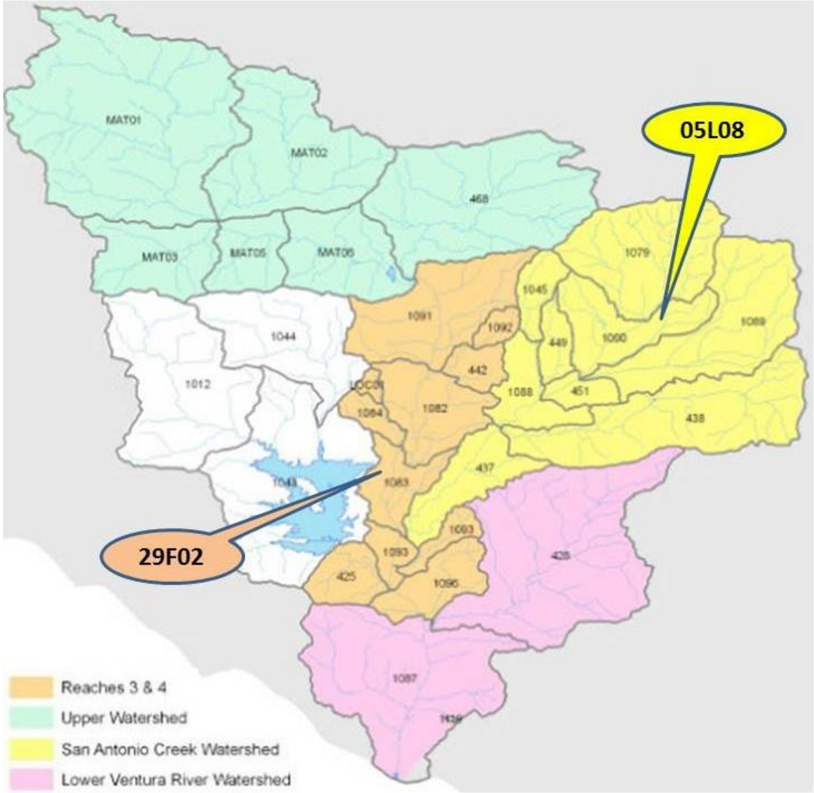
Again, don't panic. This is the same kind of data but for a different well. 29F02S is in the upper Ventura watershed, relatively close to and west of the river near the Santa Ana bridge; its record extends back to 1928. Being near the river means its water table is much closer to the surface than was the case with the Ojai well, and that it fluctuates very rapidly. The graph also shows a different *cumulative departure from the mean* parameter: flow as measured at the downstream Foster Park gauging station. Average annual (water-year) flow at Foster Park is 47,000 acre-feet (equivalent to an average daily flow of 65 cfs). This is a pretty big number, highly influenced by runoff during our relatively few extremely wet winters; the median annual flow is much lower: 12,000 ac-ft (or about 17 cfs—half the years have had less runoff than the median, half have greater).



In order to make the jumble of the previous graph a little more understandable, I've redrawn it with less data. This graph now begins with October 1983, one of our wettest years on record, and ends in June 2014. The gridlines mark October of each year; measurements taken during this month pretty much mark the lowest point in annual water-table fluctuation; the high point follows soon after the peak of the rainy season (when most of the water-year's rainfall has already fallen) and generally occurs between February and the end of April.

Notice that the groundwater fluctuation does not follow the overall cumulative cycle of alternating wet and dry periods (as was the case with the Ojai well). In many years the end of the rainy season sees a complete restoration of the groundwater level (to approximately 10 ft. below the surface at this location). The greatest exception occurs during very severe dry-years when there is no post-rainy-season recovery to the 10-15 foot level. I've marked these years with red arrows: 1990, at the peak of our previous multi-year drought; 2002 and 2007, the driest years of the past decade; and 2012, 2013 and 2014, our current drought. Only the relatively heavy rainfall we had back in March 2014 prevented the setting of a new lowest-ever, *end-of-rainy-season*, water-level record for this well. As it is, that honor is currently held by 2013. 2013 also marked the lowest *end-of-water-year* (October) level since 1928.

This begs the question as to why this groundwater basin (the upper Ventura groundwater basin) can typically restore itself so quickly and yet show such drastic dry-season fluctuations. And why the noticeable differences between it and the Ojai basin? From this point on I'm going to be mostly theorizing, but here goes: First, the watershed of the upper Ventura basin is much larger. It's also "funnel shaped," compared with the Ojai basin's "bowl." (The broad part of the funnel being the watershed of the Matilija and its numerous branches, the narrow part extending south



From the mouth of Matilija Canyon through Ventura reaches 3 &4, see map.) The high elevation areas of the Matilija also get much more rain. Water for this groundwater basin comes from three sources: local recharge from rainfall (falling on the sub-basins shown in orange on the map), downward seepage of flow from the "losing" reaches of the Ventura River (when the river bottom is higher than the local water-table), and the slow southward movement of Matilija groundwater (coming from map areas shown in blue). That's the input.

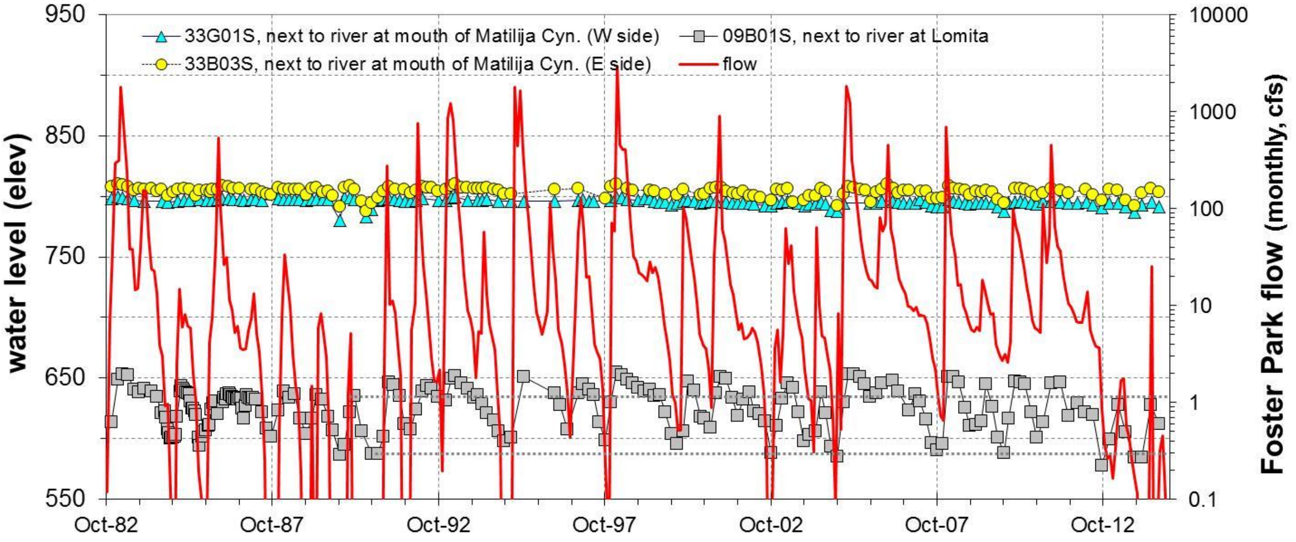
As for output, groundwater is lost by further southward movement towards the ocean, by seepage *into* the river in "gaining" reaches (any section where we see dry-season flow, Foster Park being a good example), but mostly via well pumping. For well 29F02 recharge occurs during the latter part of the rainy season and as long as river flow continues—aided by the constant flow of groundwater from further north. Given the reduced groundwater pumping at this time (during winter and early spring, outside most of the growing season), this is enough to usually recharge the water-table in all but the driest years. In those years, dry years such as we are experiencing now, increased dry-season pumping combined with very low (or nearly absent) local recharge and the complete absence of flow in much of the Ventura River means not enough inflow to bring the water-table up to its typically high level. Should one really dry year be followed by another . . . well, what we would see is the 2012-13 progression shown in the graph. And should 2015 see a continuing of the drought, we will see new minimum groundwater level records set.

The "bowl-like" Ojai groundwater basin (along with its representative well, 05L08) almost never sees enough tributary rainfall to fully recharge except during exceptionally wet years like 2005 (as the basin becomes full, wells in lower elevation areas begin to "artesian," i.e. their effective water-level becomes higher than the ground surface—think of it as a bowl having a slight tip, with groundwater leaking out of the lower side). Ojai, with less tributary watershed area (the two lowest sub-watersheds shown on the map in yellow—437 & 438—fall outside the basin) and lower rainfall, has more than double the groundwater storage of the upper Ventura basin. Thus the typical groundwater level in the Ojai basin is less than full, usually much less. This allows the variation in water levels to exhibit the same long-term pattern as cumulative rainfall (the 05L08 graph) or cumulative river flow (as shown in the 29F02 graph).

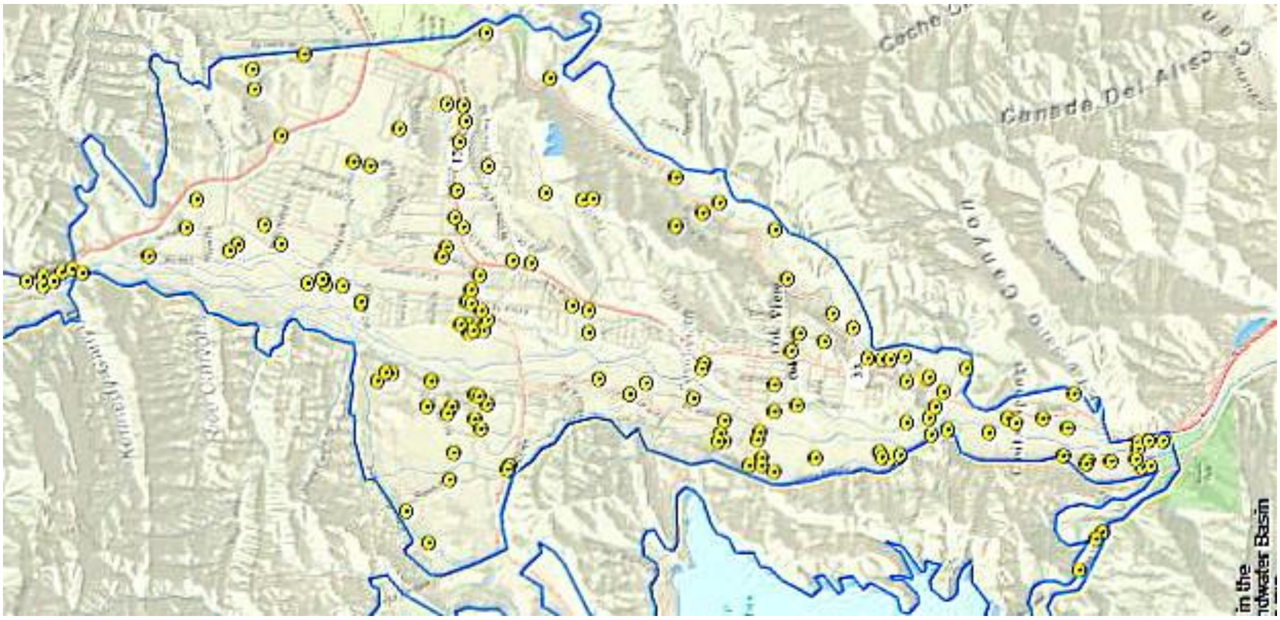
A Downriver Journey

Now for something a little different: I want to follow the progression of changes in water levels (as measured in wells) as groundwater in the upper Ventura Basin makes it's way from the mouth of Matilija Canyon to Foster Park. The wells I've selected are shown in the Google Earth image. I've tilted the image so that it follows the path of north-to -south Ventura River flow from left-to-right; well 33G01 (and 33B03) are right next to the river at the mouth of the canyon and 08B07 is an inactive Foster Park well used for monitoring. The red lines drawn on the image represent the approximate surface traces of the Santa Ana (the longer line to the left) and Villanova (passing close to 16P01 and 20A01) faults.

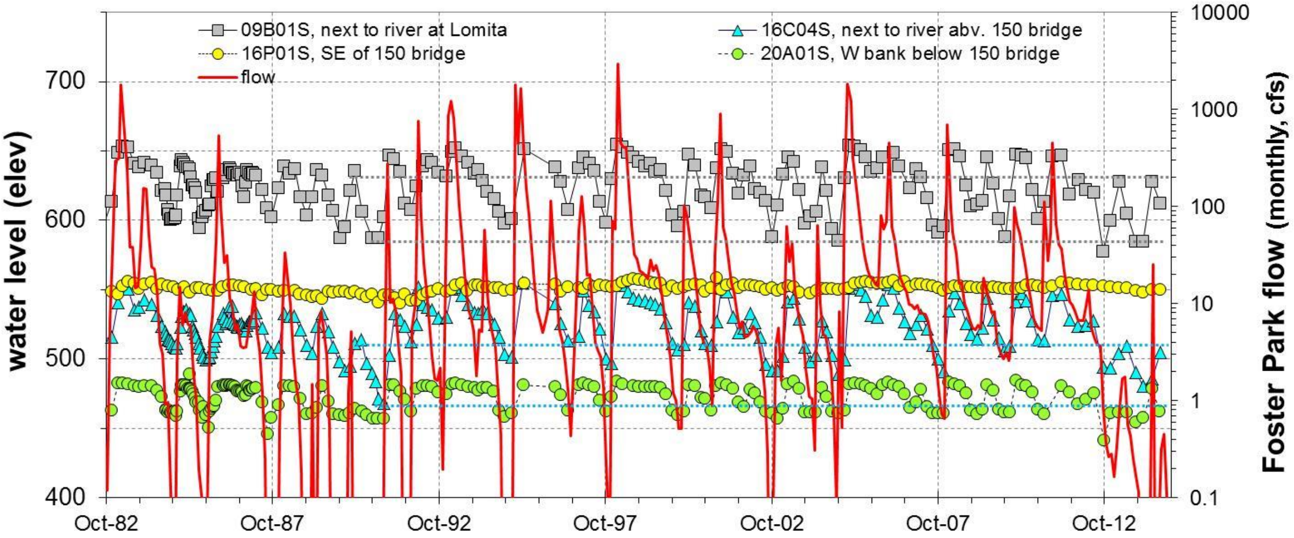
The water level data shown will follow the style used in the graph below. Elevation of the water surface above sea level will be used instead of depth-below-ground to separate the measurements from each well and to make clear that we are following the movement of groundwater from higher to lower elevation. Instead of cumulative departure from the mean, used in the earlier graphs, the red line now represents monthly average flow in the Ventura River—measured at Foster Park. Monthly flow (which removes much of the "spikiness" caused by individual storms) gives a good indication of conditions during each water-year (the higher the annual peak, the greater the amount of seasonal rainfall). Finally, each graph begins with October 1982, the start of the 1983 water-year, one of the wettest years on record; so we start, if you will, on a high note. This also allows inclusion of what groundwater conditions looked like during an earlier severe drought (1987-92). To allow a direct comparison from then to now, I've drawn dotted horizontal lines from conditions during the late spring and fall of 1990 to the present for some of the data. As you can see, current conditions at 09B01 are now slightly worse.



The major point of the graph however, is the comparison between a relatively stable groundwater level at the mouth of Matilija Canyon (20 ft below the surface at 33G01, and rarely varying by more than a couple of feet, except during severe drought years when the level can drop as much as 7-8 ft) compared with a 50-70 ft annual variation further downstream at Lomita (from 10 ft below the surface to about 80). The reason for the difference is simple: groundwater pumping.



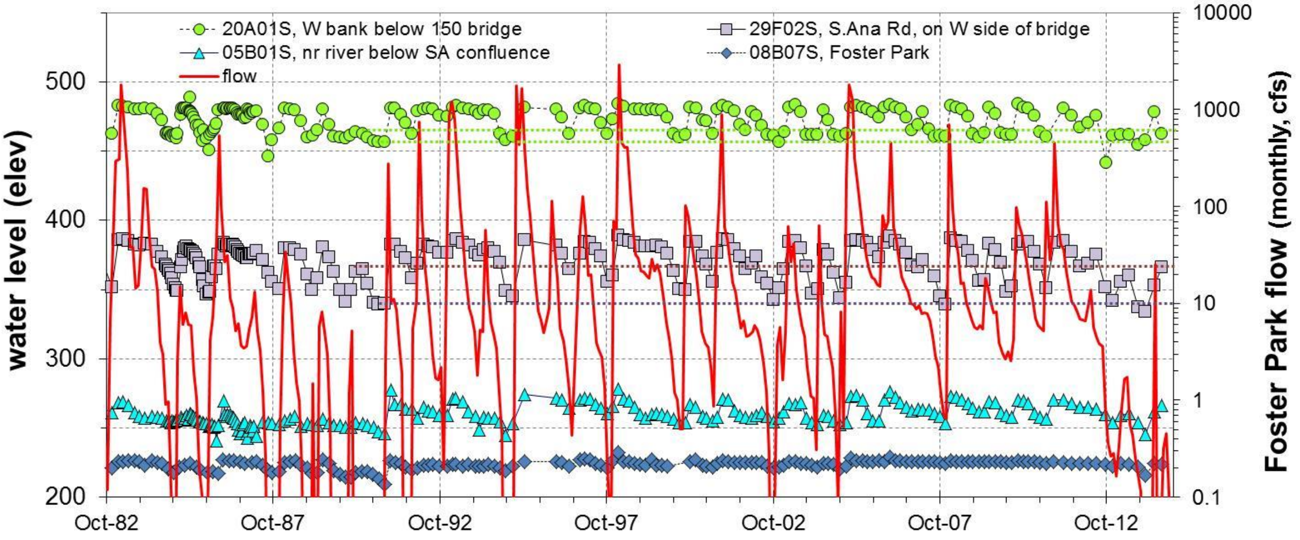
The above map, oriented similarly to the previous Google image, shows well locations (as yellow dots) in the upper Ventura groundwater basin (outlined in blue). Note the dense concentrations of wells at the mouth of the canyon—placed to take advantage of its high and stable groundwater level—followed by further concentrations, heavily focused on the river, as you move downstream. It's pumping, which becomes particularly heavy during the dry-season for obvious reasons, that causes the dramatic fluctuations seen at 09B01 and elsewhere.



Following the river downstream, the fluctuation becomes further exaggerated just upstream of the Hwy 150 (Baldwin Rd.) Bridge (at 16C04, note the concentration of wells around this location on the map). This is particularly noticeable when comparing wet years with those of drought: the March 1983 water level in 16C04 was less than 4 ft below the surface (it artesianed in February 1995, a big El Nino year) but dropped to 101 ft below the ground in December 1990.

However, the next well down (16P01, downstream but uphill and further north of 16C04 giving it a similar water table elevation) presents a totally different picture: a groundwater elevation that stays relatively constant (it does fluctuate, but generally by less than 10 ft, it's maximum elevation of 62 ft below ground reached in August 1998, the minimum of around 79 ft during the drought water-year of 1991). A good guess as to the source of this steady flow of groundwater would be the Villanova fault (with possible contributions from the Santa Ana fault just upstream). Given the steady level in 16P01, compared with the greater variation in 20A01 (located downstream on the opposite side of the river, but still adjacent to the fault—probably on the upstream side), the supposition would be that the groundwater flow is coming from the east, from the direction of the Ojai Valley. The well chemistry of 16P01 supports this, being high in nitrate but relatively low in chloride and conductivity—this is the chemical signature of agricultural activity noted in the groundwater of the eastern half of Ojai Valley.

Notice that the water level variation in 20A01 is less than that seen in 16C04 (a 45 ft variation from Spring '83 to early Winter '90 vs. over 100 ft at 16C04). I would attribute this to the appreciable groundwater influx coming from the direction of 16P01. We will see this same phenomena again in the next graph, but in this case from San Antonio groundwater flowing into the Ventura River confluence with that creek.



The last graph in this series shows the final progression: from 20A01, on the west-side of the river below the Hwy 150 Bridge; to 29F02, also on the west-side but adjacent to the Santa Ana Bridge; to 05B01, next to the river about a half mile below the San Antonio confluence; to 08B07 at Foster Park.

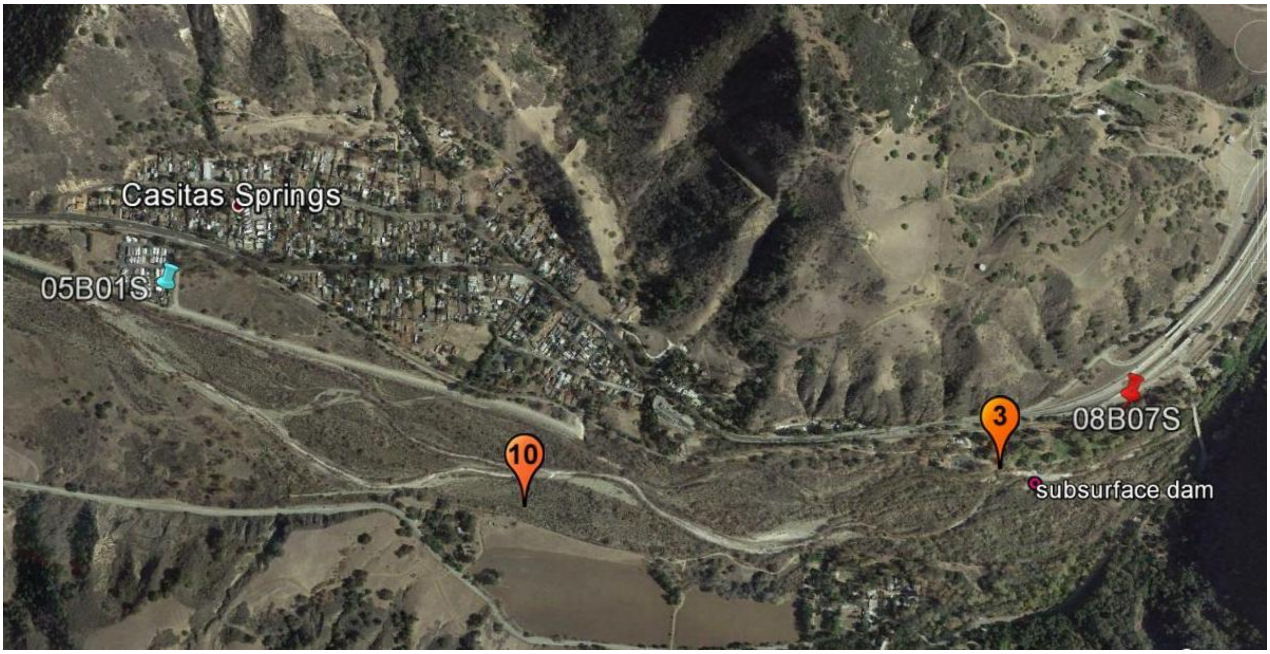
Moving south of 20A01, the amount of seasonal variation increases until a relatively steady flow of S. Antonio groundwater intersects the river near the confluence (this point was expanded upon in a previous report: *Confluence Pool Water Levels, October 2014*). This increased input, as with well 20A01, appreciably reduces the fluctuation in wells below the confluence; groundwater inflow at the confluence reduces the 05B01 fluctuation by about half when compared with 29F02.

As a further example, the drawdown in 2010 varied thusly: (moving downstream) from 24 ft at 20A01 (below the Hwy 150 Bridge); to 31.5 ft at 29F02 (at the Santa Ana Bridge); to 14.1 ft at 05B01 (at Casitas Springs below the S. Antonio confluence); and finally, to 2 ft at 08B07 (at the Foster Park Bridge) where something totally different is happening.

Foster Park

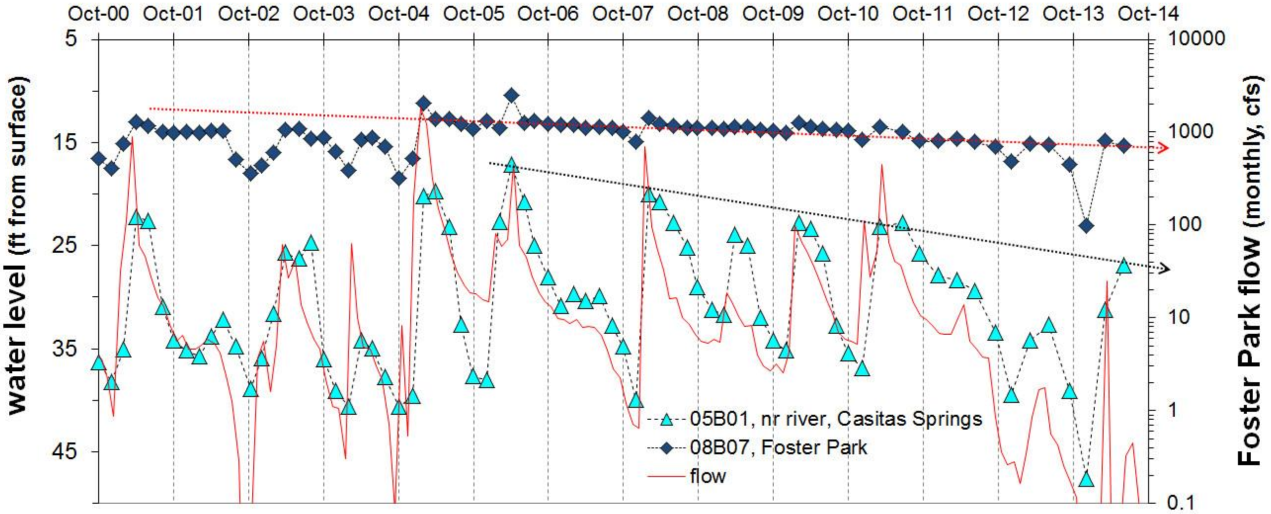
At Foster Park surface-trending bedrock, aided by a concrete subsurface dam, forces a relatively steady supply of groundwater to, or just below, the surface where it's utilized by the City of Ventura as part of their drinking water supply (extracted via an under-river gallery and a number of wells above the subsurface dam). It's this "improved" upon natural feature that maintains the stable groundwater elevation seen in the graph at well 08B07, and it also kept the river reach at Foster Park watered year-round (at least in my experience). Monitoring the Ventura since 2000, I had never seen the river above the bridge run dry. Until October 2012. My shock at first seeing it bone dry has since wore off, as this reach stayed dry until March of 2013, was again dry from May 2013 through February 2014, and yet again from April/May 2014 until the present.

Although I've already written something about the situation at Foster Park (*Some Comments on the Hopkins Report, November 2014*), I want to end this piece by again looking at what I think is happening here. But first we need a better view of the river and a closer look at the data for wells 05B01 and 08B07.

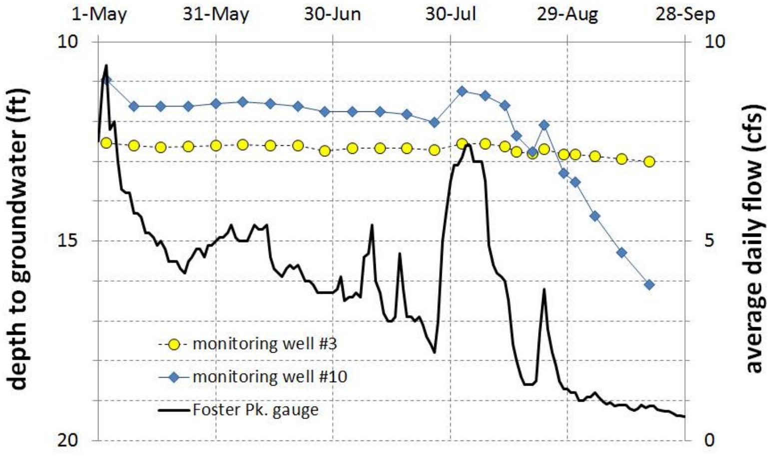


First a view of the river: The Google image shows the dry riverbed on December 9, 2013. Marked on the image are the locations of wells 05B01 & 08B07 and two additional groundwater monitoring wells, #3 & #10, used in the 2012 Hopkins study. Also shown is the location of the subsurface dam. The Foster Park (Casitas Road) Bridge can be seen at the far right.

The next graph shows depth to groundwater (this time measured from the surface of the ground and not as elevation) for the 05 and 08 wells, as well as average monthly Foster Park flow. 05B01 is a water supply well (probably for the mobile home park on which it's located) and 08B07 is currently a no longer operational monitoring well although I suspect, given the much greater variation in drawdown prior to October 2004 shown in this and the previous figure, it had earlier been used as a production well. The time line now begins in October 2000 and differences between the two wells can be more clearly seen.



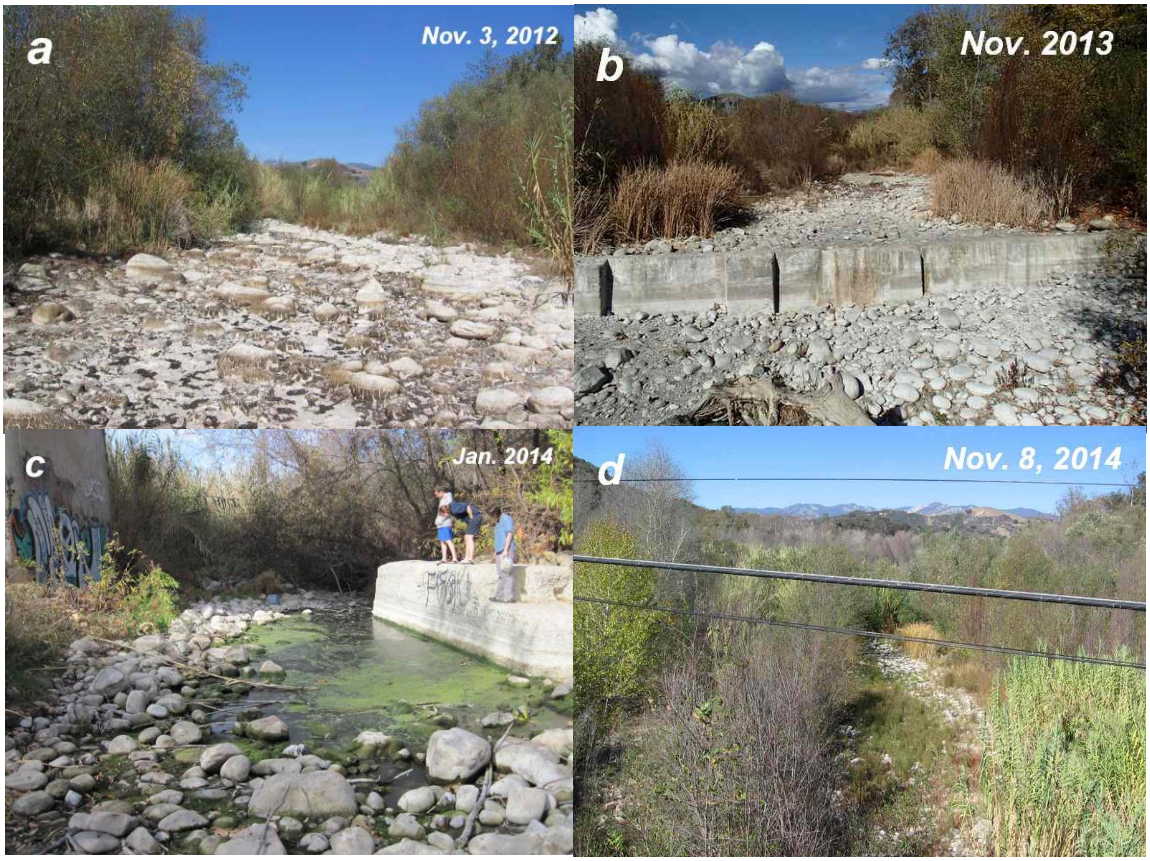
It's now easier to pick out water-years (Oct-00 to Oct-01 marks the 2001 water year, etc.) of no substantial recharge of the upper Ventura groundwater basin (2002, 2004, 2007, 2011 and 2012), and water-years of below normal recharge (2003, 2009 and 2014). Given that these total 8 out of the 14 years shown on the graph, we might want to re-think the paradigm that this small groundwater basin refills almost every year. In fact the black dotted line illustrates an increasing trend, ever since the spring of 2006, of the basin *not* filling; the decrease in maximum groundwater elevation over this time period being about 10 ft. Although 08B07 shows no dramatic seasonal groundwater fluctuation at the Foster Park Bridge, it also exhibits a long-term increase in depth to groundwater: 2.5 ft over the past 9 years. That might easily be the difference during a time of low flow between surfacing groundwater above the bridge or a dry riverbed.



It's my considered opinion that the primary reason for the drying out of the Foster Park reach has not been the drought (although this has surely added to the problem), but the continued pumping and extraction of water above the bridge by the City of Ventura. The graph on the left shows, along with Foster Park flow during the 2012 dry-season, monitoring well data from the Hopkins study.

During the study the City was pumping roughly 4 cfs and extracting another 2 cfs via the under-river gallery. In an experiment near the end of July the well pumps were stopped for a number of days resulting in the upward 5 cfs bulge in Foster Park flow seen in the graph; a short, later stoppage led to the sharp spike in flow that follows it. In fact, every upward departure from the long-term decrease in Foster Park flow seen in the graph (after June) was caused by either short stoppages or decreases in pumping rate at one of the three pumps working during this period. Prior to the "stop pumping" experiment there had been flow throughout the reach, and groundwater levels in the monitoring wells remained relatively steady. However, near mid-August, when pumping restarted, conditions had changed (much of the reach having gone dry although surface water still remained in the vicinity of 05B01 and the bridge) and groundwater levels above the subsurface dam rapidly decreased (as exemplified by monitoring well #10). In contrast, groundwater levels at the dam remained steady (#1). Over the course of the next month groundwater levels at #10 decreased 4 ft.

It is no surprise that fluctuations in depth-to-groundwater measured in wells often mimic Ventura flow at Foster Park (as shown in many of the previous graphs) since they share the same root causes: winter rains producing both recharge and high streamflows; dry-season extractions lowering groundwater elevations while decreasing infiltration into streams and river. But there may be an even more direct connection between the close resemblance of water levels in 05B01 and Foster Park flow (pg. 9 graph). No great leap of imagination is required to see that as the City's extractions decrease groundwater elevations upstream at #10, especially during low or no flow conditions, those decreases may extend even further to well 05B01 (double the distance upstream) and beyond. Or that robbing the river of 6 or more cfs during critical periods is enough to turn it into a meadow.



Foster Park: (a) totally dry within a month of the end of the Hopkins Study, note the dried out remains of algae lying on the cobbles; (b) almost no flow during the following year, even at the subsurface dam; (c) pooled groundwater under the bridge, it's easy to visualize how a foot or two of additional groundwater elevation might have resulted in flow; (d) the Foster Park "meadow," other that some flow during March & April the river has remained dry during 2014—thank you City of Buenaventura.