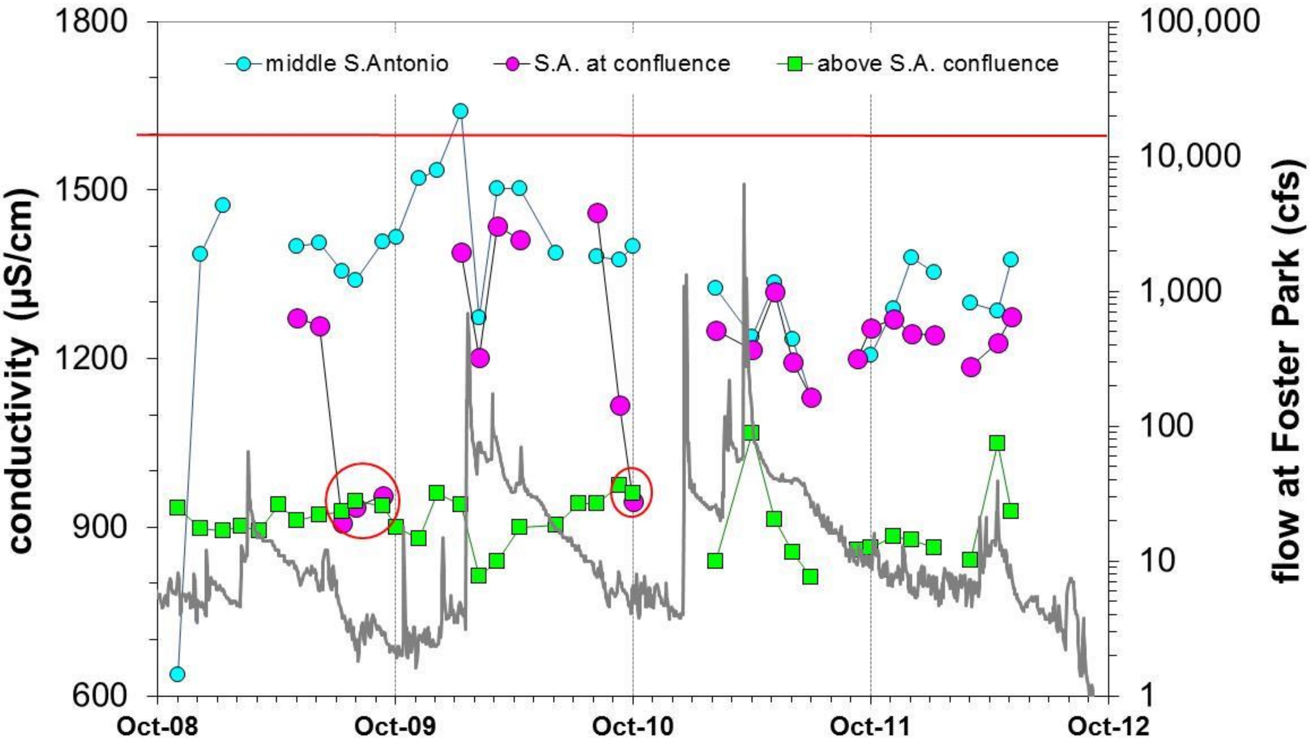


San Antonio Creek at the Ventura Confluence:

Over the past few months we've been seeing a reasonable amount of water flowing in lower San Antonio Creek (the sampling location is just before its confluence with the Ventura). This during a second consecutive dry year and when flow at the closest upstream sampling point (VR17, middle San Antonio Creek, 4.2 miles upstream) is down to barely a trickle. It seems rather inconceivable that flow could be continuous between these two locations or that subsurface flow from upstream could be resurfacing this far downstream. There are two other possibilities: (1) the water originates from what we might call a "nuisance flow" – a probable source being the horse stabling facility on north bank bluff just upstream; or (2) it's simply surfacing groundwater from the same aquifer supplying flow in nearby Ventura River upstream of the conjunction. That measured conductivities at these two sampling locations seem suspiciously similar, and a look at the old lower S. Antonio sampling point (about a ½ mile upstream) showed it to be bone dry, leads me to conclude that the latter is the true culprit.

This is not the first time we've seen this situation. The graph shows conductivity measured by SBCK since October 2008 at three sampling sites: lower San Antonio at the confluence, middle San Antonio and the Ventura River just above the confluence. Notice that conductivity (the water's ability to conduct electricity) is much higher on San Antonio than it is on the Ventura River. Notice also that conductivity on lower San Antonio is relatively close to that of the middle San Antonio (we'll come back to possible reasons why it's slightly lower), but there have been two exceptions. I've circled them in red. They show times during late summer or early fall when conductivity at San Antonio abruptly dropped from its usual higher value (circa 1300 µS/cm) to that of the Ventura River above the confluence.

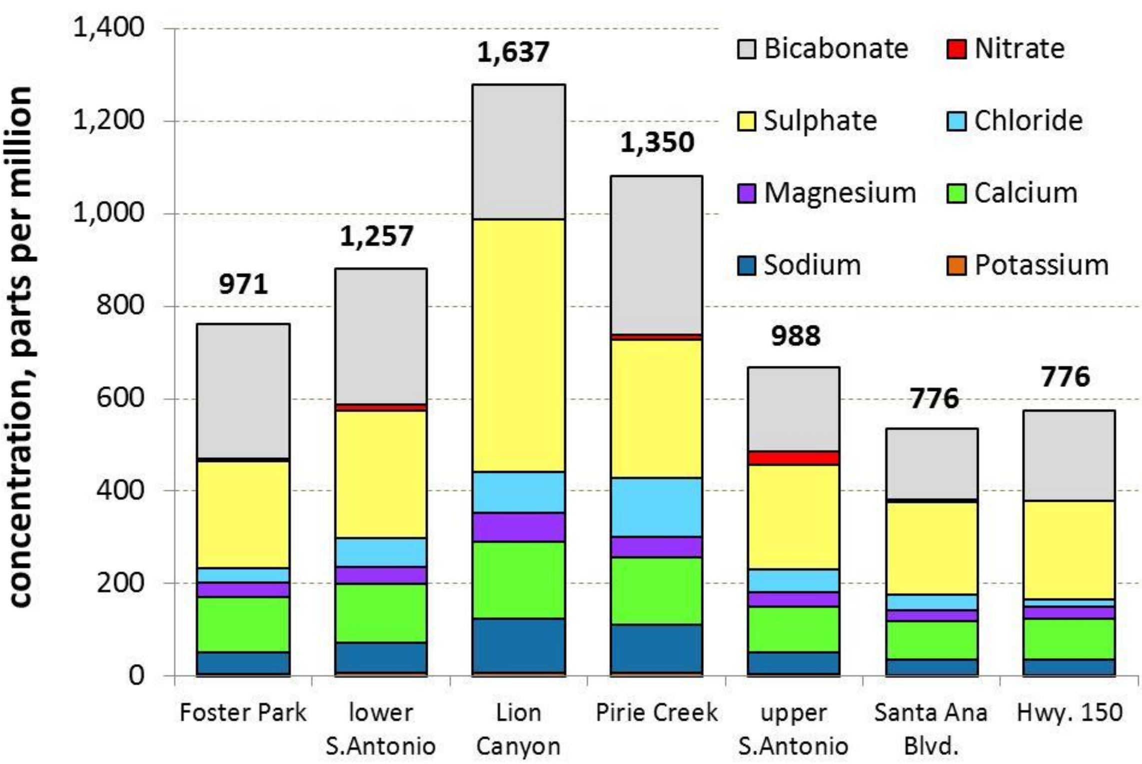
Notice that conductivity on lower San Antonio is *lower* than on the middle San Antonio. Usually we would expect conductivity to *increase* as water flows downstream (if, as is true in this case, no significant amounts of new water are entering the creek). Flowing water sometimes increases in conductivity by picking up additional minerals, but it's more likely that evaporation during the long dry-season is increasing mineral content, especially when flows are both low and slow towards the end of summer. Lower instead of higher S. Antonio conductivity at the confluence probably indicates that groundwater flow from the middle Ventura aquifer always influences flow and conductivity at this location. Points on the graph when middle and lower S. Antonio conductivity are almost identical mostly occur during higher flows, i.e. when small amounts of inflowing groundwater will exert only minor influence.

The Ventura River just above the confluence (left) and lower San Antonio at the confluence on June 1 of this year. San Antonio had as much (and perhaps even more) flow; the same aquifer supplies water to both (and to the confluence pond that both flow into).

Looking behind conductivity:

Conductivity is a measure of water's ability to conduct electricity; but what enables water to do so? The short answer is impurities that carry electrical charge. Salts placed into solution split into negative and positively charged halves called *ions* (an ion being an atom or molecule with either missing or extra electrons). For example, common table salt is a mineral called sodium chloride; in water it splits into a sodium ion (carrying a positive charge) and a chloride ion (with negative charge). [Saltwater, having lots of sodium chloride, is a terrific conductor of electricity, with a conductivity greater than 50,000 µS/cm.] The greater the number of ions in solution, the greater the conductivity. Simply put, S. Antonio water at the confluence contains more impurities and thus has greater conductivity than the Ventura River.

But this tells us nothing about what those impurities might be. For that we need a chemical analysis. And I just happen to have one handy.



The chart shows the major constituents found in water at each of the sampling locations shown. When I mentioned impurities I bet you were thinking about all sorts of nasty things: PCBs, organics, lead, copper, arsenic, DDT, whatever. Many of those things might well be there, but they represent only a very tiny fractions of the total impurities in most waters; more to the point, most of them carry little or no electrical charge and have no noticable affect on conductivity.

Mostly what is found in water are the major ions: calcium, magnesium, sodium and potassium (cations carrying a positive charge); and chloride, sulfate, nitrate and bicarbonate which carry a negative charge (anions). [Water itself is neutral, otherwise washing up or jumping in for a swim would be an even more eye-opening experience; the positive and negative ions cancel each other out, their presence simply allows water to conduct electricity.] Impurities don't necessarily have to be bad. We probably don't need to be putting any more sodium or chloride in our bodies, not to mention sulfate, but calcium and magnesium are needed minerals, potassium a necessary nutrient, and bicarbonate is what we take for an upset stomach (it plays an important role in buffering pH changes in natural systems).

All in all, these impurities, and others, add up to but a small fraction. Lion Canyon Creek, which shows the highest concentration, has a combined total of 1,280 parts-per-million (ppm or mg/L); i.e. for every million "parts-of-water" there are 1,280 parts-of-ions (or, to use more modern terminology, 1,280 milligrams (mg) of impurities in every liter (L) of water – a liter of water weighing 1 kilogram, 1,000 grams or 1,000,000 mg). Thus these ions make up only 0.13% of the Lion Creek water sample, i.e. the water is still 99.9% pure water. [Other dissolved impurities, usually found in concentrations of fractions of a ppm or in parts-per-billion (ppb) or parts-per-trillion (ppt), do not substantially add to the total. For comparison, seawater with a salinity of about 35 parts per thousand has a concentration of salts about 30-times higher than the 1.28 ppt of Lion Creek.]

The numbers at the top of each column in the chart represent the median conductivity at each location (measured over 8 years at Lion Canyon, 11 years at the others): the greater the ion concentration, the higher the conductivity. [The major ion data comes only from 2001, thus the slight miss-match at the last two sites.]

The chart indicates that two of the major ions are but bit players: potassium is found only in low concentrations, as is nitrate, except on upper San Antonio and Pirie creeks where human land use generates higher amounts (credit agriculture, domestic animals, suburban development, etc.) [However, with nitrate, a vital nutrient, a little can go a long way.] The dominant ions are calcium (followed by sodium) and either sulfate or bicarbonate, and the major sources are probably geologic (the easily eroded former seabed sediments piled up as our mountains contain lots of limestone and dolomite – calcium and magnesium carbonate – and probably gypsum – calcium sulfate). An exception may be Lion and Pirie creeks, where some of the high chloride could be coming from animal excrement. Rainfall and atmospheric deposition also contribute measurable amounts of sodium and chloride – we do live near an ocean – and for sulfur think air pollution.

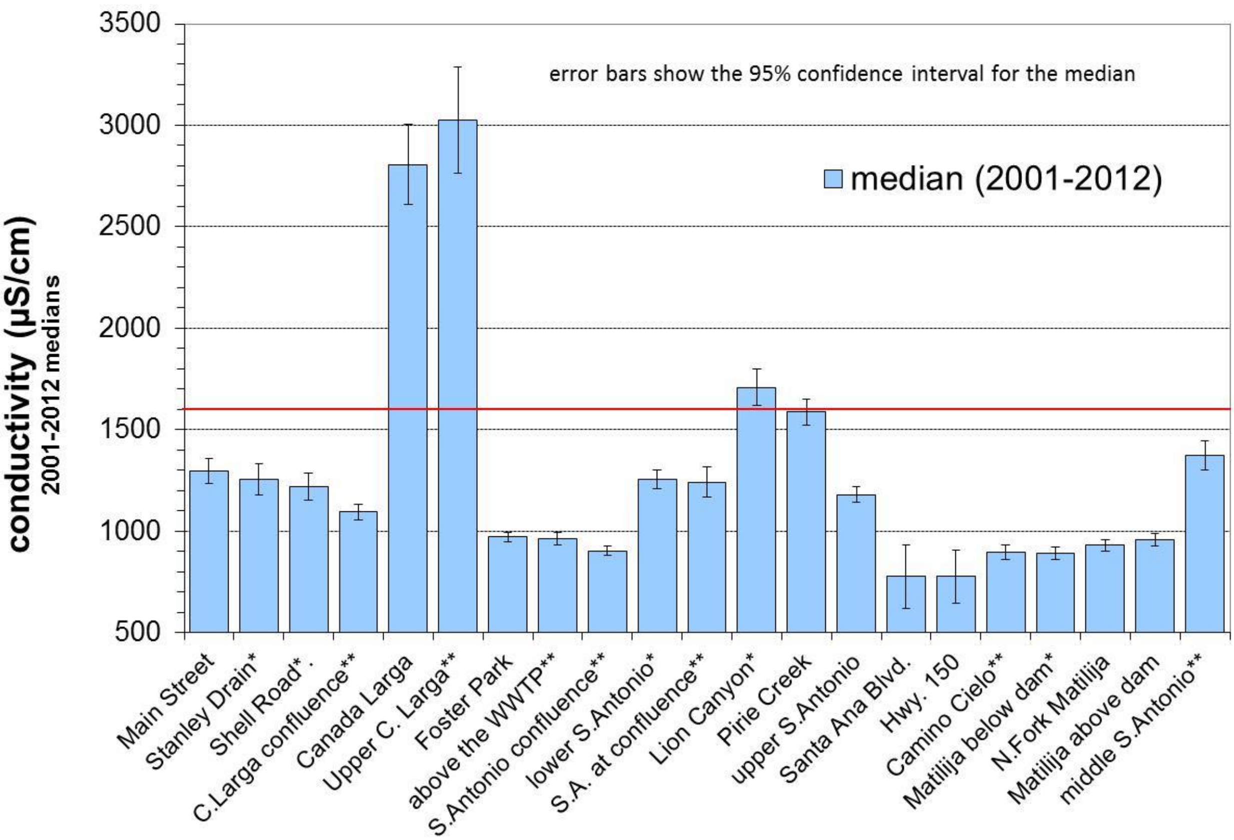
There are no available data for the river just above the confluence, but samples collected upstream at the Santa Ana and Hwy. 150 bridges provide a reasonable estimate of what we might have seen further down. [It's interesting that Santa Ana has noticeably higher concentrations of nitrate and chloride, two pollution related contaminants that are probably entering the river via groundwater.] Foster Park, a few miles below the confluence, shows a chemical content somewhere between that of Santa Ana and lower S. Antonio -- just what we might expect after these two waters were combined. In a similar fashion, lower S. Antonio represents a combination of its three major tributaries. [2001 was a wet year, with a big storm in early March, and all these streams flowed throughout the summer.]

Compared with the river, S. Antonio water is higher in calcium and bicarbonate implying greater amounts of limestone in its drainage. It's also considerably higher in sulfate, particularly in water flowing from Lion Canyon. The source is probably geologic strata rich in magnesium or calcium sulfate (Lion Creek is enriched in both magnesium and calcium). [That Lion Creek flows north from a ridge called Sulphur Mountain, and that Canada Larga, also very high in sulfate, flows down the other side, might be considered a clue.] None of these amounts present a drinking-water quality hazard, with the possible exception of high sulfate in Lion Creek. The EPA has secondary standards governing contaminants that, while not considered a health problem, can affect odor and taste. The standard for sulfate (and for chloride) is less than 250 mg/L. Pirie, lower S. Antonio and, especially Lion Creek exceed this standard (and the others come close: almost every stream in the Ventura watershed has a sulfate concentration higher than 200 mg/L); at 548 mg/L Lion Creek also exceeds the recommended maximum of 400 mg/L for infants (those raising families on nearby well water should probably have it tested). The chloride limit has not been reached in any location or stream analyzed by SBCK.

Water from the sites shown on the chart, indeed, from any location in the entire watershed, is considered *hard*; make that very hard. Hard meaning "hard to work up a lather" with a bar of soap; high concentrations of calcium and magnesium make a water hard. It's not a health problem (hard waters tend to be better for you), but it is an economic concern – hard water forms scale (deposits of calcium and magnesium carbonate) in pipes and boilers and makes any kind of washing-up operation extremely difficult (which is why almost all of our homes have water "softeners"). One way hardness is measured is in ppm or mg/L of calcium carbonate equivalent: anything over 60 is considered hard, very hard if it's over 180. Waters in the Ventura watershed are usually over 300, and streams like Lion Creek over 1,000.

How conductivity varies:

The chart below shows median conductivity at every SBCK sampling location (a single asterisk identifies sites where measurements began at the end of 2008; a double asterisk where they were discontinued in 2009). I've used the median (the number that falls exactly in the middle of a series of measurements) since, unlike the average, it minimizes the influence of very low or very high measurements such as those that occur in trickling end-of-summer flows (high) or during rainfall (low) or by error.

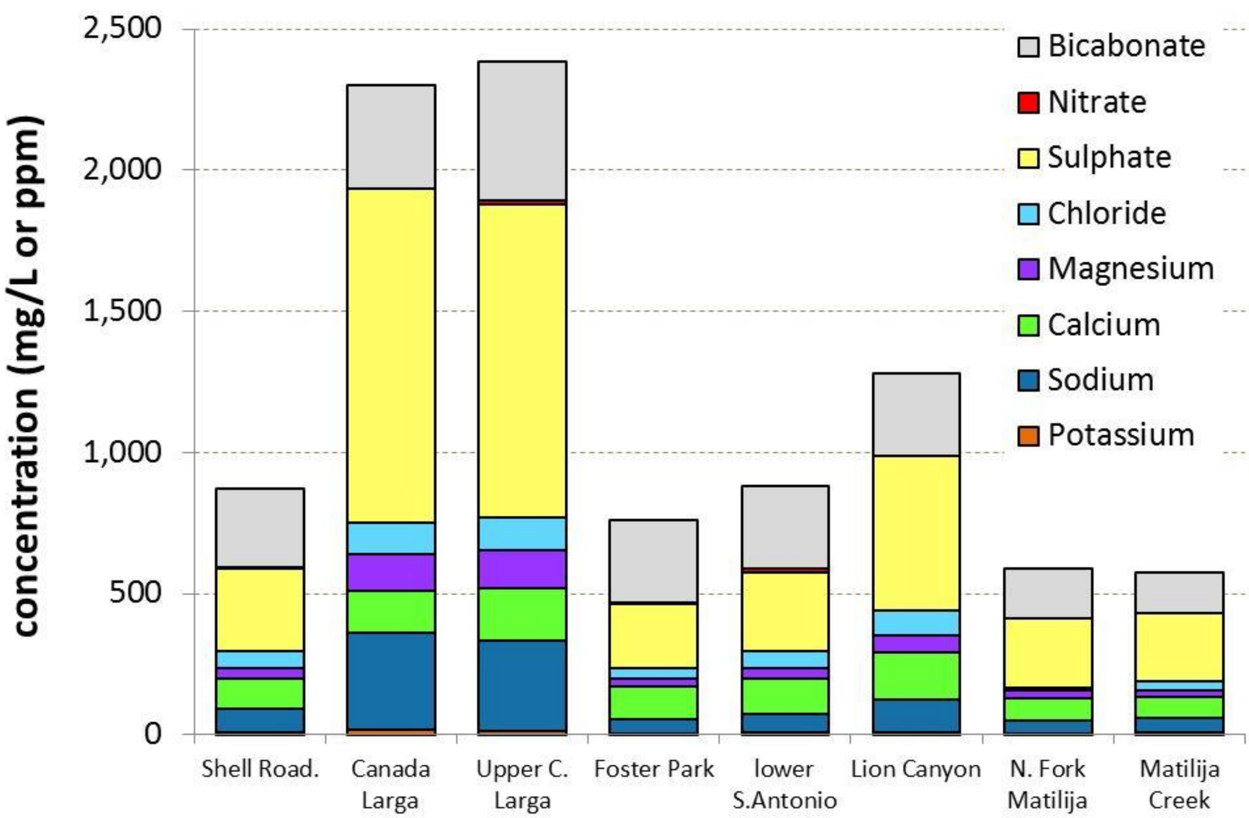


The red line indicates the EPA drinking-water conductivity limit (1,600 µS/cm). The error bars show the 95% confidence interval for the median, i.e. were we to repeat these measurements the odds of a new median falling somewhere outside the error bars would be 20 to 1 (only a 5% chance). Locations where the error bars don't overlap can be considered as significantly different from each other. For example, locations below the Canada Larga confluence do not have significant differences (although they show the gradual increase with downstream flow mentioned earlier), but all are significantly higher than flow above the confluence; the difference being caused by very high conductivity C. Larga water entering the river. Similarly, none of the sites above the S. Antonio confluence are significantly different, but the addition of S. Antonio water causes a significant change. As might be expected, there is no real difference between the old and new lower S. Antonio sampling locations, but there is considerable variation as we move upstream because of the high conductivity of the Pirie and Lion tributaries; both exceed the EPA 1600 limit. Pirie (some call it Steward Creek) lacks the high sulfate concentrations of Lion, but makes up for it with particularly high concentrations of sodium and chloride (and the high concentrations of calcium, magnesium and bicarbonate characteristic of limestone). It would be interesting to pin down the source(s) of its sodium chloride.

The high conductivities of Pirie and Lion, however, pale besides those of Canada Larga. What in the world is happening there?

Revisiting chemical composition:

This is the last chart . . . I promise.



It's the same as the earlier chart except I've kept a few sites for comparison and added some others to provide better coverage of the entire watershed. As with conductivity, C. Larga stands out: much higher levels of almost everything but especially sulfate (probably that backside of Sulphur Mountain business again). Sodium also stands out – concentrations are almost 3-times higher than in Lion Ck.

Chloride is up too, but it's only a 50% increase compared with Lion. So is the chloride coming from a geologic source, or are we seeing – at least partially – an artifact of all the cattle grazing going on in the drainage? It's pretty obvious cattle are the source of nitrate (and also of a dramatic increase in phosphorus but one too small to be seen in this kind of chart), but chloride? It remains an open question.

Calcium is up, magnesium even more so, but since both are somewhat balanced by an increase in bicarbonate it probably indicates lots of limestone in the C. Larga watershed (or dolomite – richer in magnesium – or even magnesium sulfate). A look at a geologic map might clear most of this up, but would be a lot less fun. In the meantime I wouldn't recommend drinking any Canada Larga water, although I have to say that it would sure cut down on cost for anyone regularly taking laxatives. [Sulfate concentrations are over 1,000 mg/L, high but not extraordinarily so; but it would take a bit of time for your digestive system to adapt.]

Luckily, flow from Canada Larga into the Ventura is both low and intermittent, and while it noticeably changes the downstream chemistry from that upstream (contrast Shell Road with Foster Park) the change is not as drastic as it could be. In fact most of the change is not due to C. Larga but from the wastewater treatment plant whose effluent reflects the "Ojai" character of incoming sewage. This is especially true in drought years when summer flow in the lower Ventura River becomes mostly treatment plant effluent.

Interestingly, more chloride is showing up in Matilija Creek (above the dam) than in the North Fork of the Matilija. There could be a number of reasons for this, but a local source of pollution is a possibility (other evidence, e.g. a positive correlation between nitrate and conductivity, also suggests this).