I want to comment on the recent *Source Assessment Report* prepared by Larry Walker Associates. I felt it to be a useful summary of basic information, and I really liked the maps and some of the charts. I found some sections, like the one on horse urine, particularly enthralling. But . . . there is always a but isn't there? But they'd probably take away my PhD if I didn't quibble about a few things.

One problem was a rather persistent effort to compare apples with oranges, to compare nitrogen or phosphorus deposited on land surfaces of the watershed (e.g., septic tanks and leach fields, and the above mentioned horse deposition) from whence it may find its way to the water table and thus, eventually, to the river . . . to compare deposition with high nutrient runoff (e.g., from urban and agricultural sources) directly flowing into streams. You *can* probably estimate the number of septic tanks and leach fields in the catchment with reasonable accuracy; you *may*, based on data from other jurisdictions, justifiably infer how many could be going bad for whatever reasons; you *might* even estimate from that how much nitrogen and phosphorus could *potentially* reach the water table; but you really don't have any idea how much is actually reaching the stream. And that "estimated" quantity cannot be compared with visible runoff from agricultural or urban development, nor with monitored amounts of wastewater treatment plant effluent.

The basic assumption has to be that almost no septage or leach field effluent is directly reaching the stream – a possibility greatly reduced by the County's mandatory setback requirements, not to mention that leaking septage from failing leach fields is usually reported by offended neighbors. Runoff should be compared with runoff, and deposition on land surfaces (with the possibility of leakage into the water table) with deposition. The comparison of horse manure and urine, or failing septic systems, should not be with agricultural or suburban runoff (as an example), but with basin wide fertilizer use: deposition vs. deposition.

But this is a minor point. My major objection is the report's emphasis on mean or average nutrient loading: mean monthly loading and mean annual loading. Now I freely admit that the concept of a mean or average quantity is a perfectly valid statistical concept. Whether or not it's a useful concept when applied to how and when nutrients reach the Ventura River and its tributaries or the fluxes that result, however, is a debatable issue. My view, the view I've tried to sell throughout this process, is that it isn't. Variability is the basic characteristic of the Ventura system, and we only fool ourselves by thinking that the "average" has actual meaning. Talking about average flow or average loading on the Ventura is about as useful as saying that the average human being has one ball and one tit, or that a person with their legs in a freezer and head in a fire is enjoying an average temperature of 70 ° F.

Let's discuss flux for a minute. Flux means amount; in a river or stream it's the amount of whatever constituent – let's, for argument sake, say total nitrogen – is flowing downstream. It's determined by multiplying the concentration of total nitrogen by flow. Now both flow and concentration vary, they vary from hour to hour, day to day, month to month, and year to year. So the amount or flux also varies. But, and here's the important point, *concentration and flow do not vary in the same way, and the term – either concentration or flow – with the greatest variation determines how the flux will vary*. It so happens that flow varies a hell of a lot more than concentration so the variation in flux ends up looking a lot like variation in flow.

In Figure 1 I show average total nitrogen concentrations of baseflow (dry-season flow) and stormflow for 4 catchments in Santa Barbara County in 2001. These are *flow-weighted* averages so

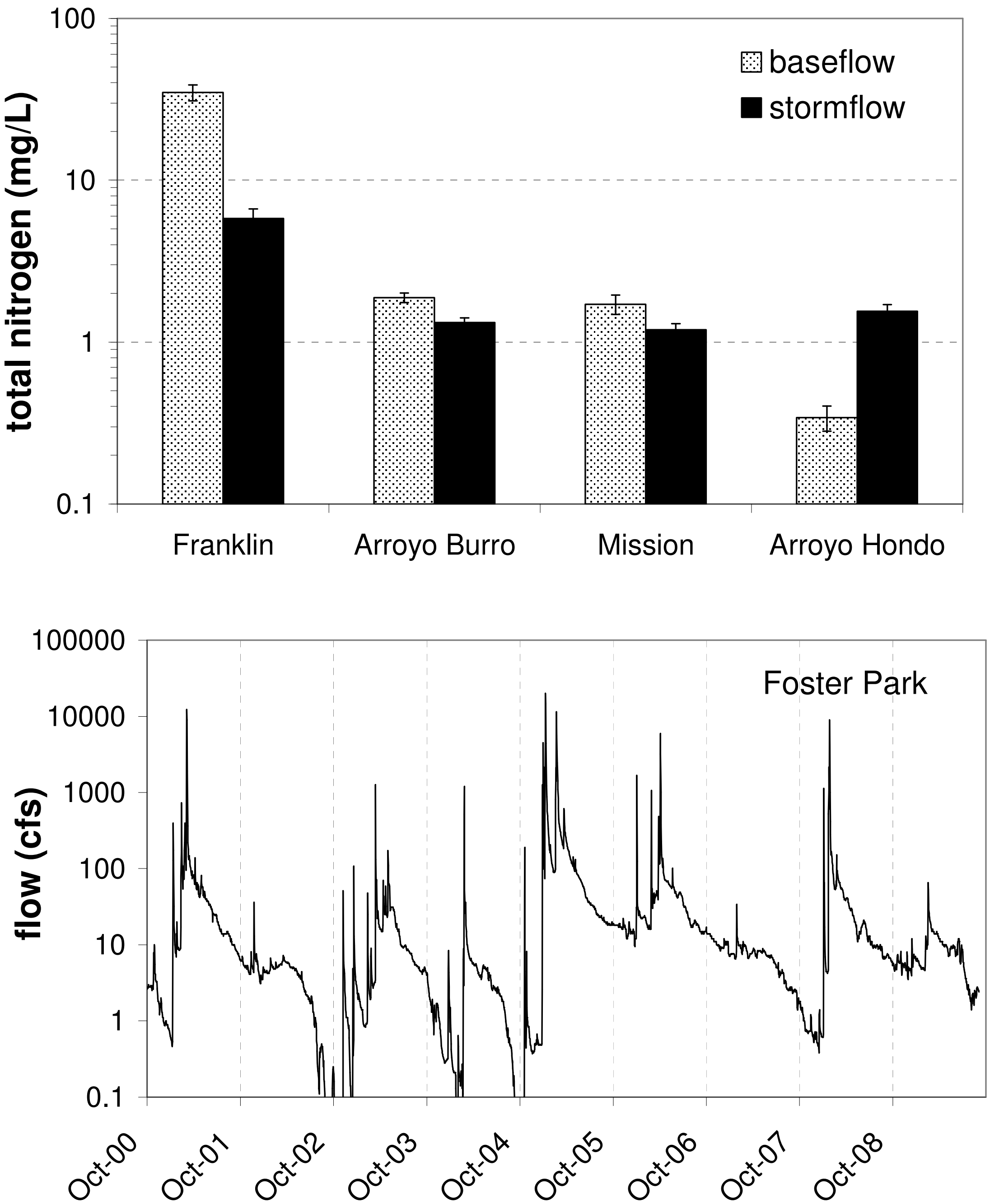


Figure 1. (upper panel) Mean baseflow and stormflow (flow-weighted-mean) concentrations of total nitrogen for four creeks in the Santa Barbara Area: industrial agriculture is the major land use in the Franklin watershed, Mission and Arroyo Burro are predominantly urban, and Arroyo Hondo is an almost pristine catchment. Note that baseflow and stormflow concentrations vary by less than an order-of-magnitude, much less in the urban creeks. (lower panel) Mean daily flow on the Ventura River at the Foster Park USGS gauge from the beginning of water-year 2000 to the present. Note that at Foster Park daily flow varies by more than 5 orders-of-magnitude. The mean daily Foster Park flux (concentration multiplied by flow) will therefore have almost the same variation. Error bars indicate the standard error of the mean.

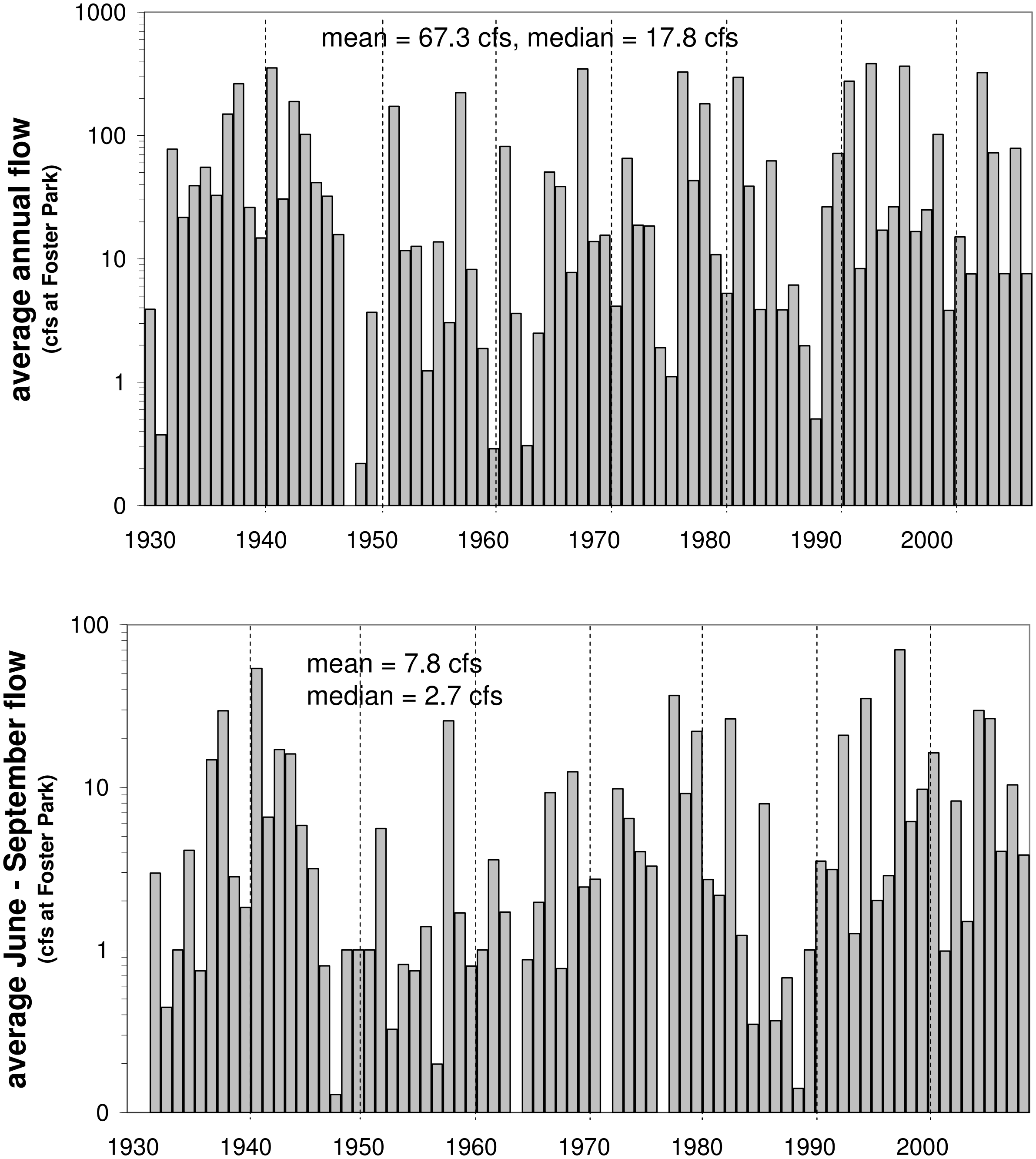


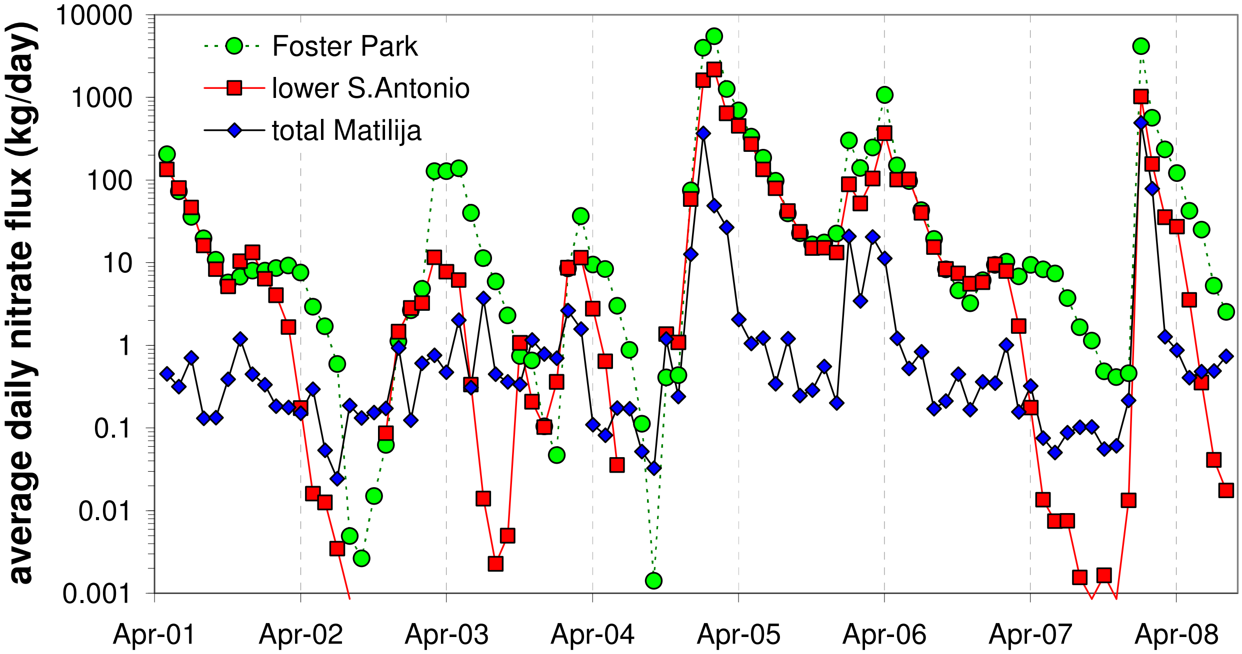
Figure 2. (upper panel) Average annual flow (mean daily flow for the water-year) from the Foster Park USGS gauging station. (lower panel) Average annual flow from June through September at Foster Park. As the time period is extended data differences between periods decrease: daily flows show less variation than instantaneous flows; monthly flows less than daily flows; and annual flows show less variation than monthly flows. However, even with this reduction in differences, annual flows (water-year) still vary by about 3 orders-of-magnitude, a thousand-fold difference. And dry-season flows alone vary by about two and a half orders of magnitude – a 500-fold difference. Fluxes on the Ventura and its tributaries will have approximately the same variation (slightly greater for dry-season flows at undeveloped locations where higher concentrations are usually associated with higher summer flows).

they accurately show the average concentrations of these two components. Franklin Creek is an industrial agricultural stream in Carpenteria – more akin to Calleguas Creek than the Ventura River – and needn't concern us too much here, but Mission and Arroyo Burro are urban streams with concentrations similar to what we see at Main Street on the Ventura, and Arroyo Hondo is a relatively pristine watershed similar to the upper Ventura basin. Note that streams with a relatively high concentration of nitrogen in baseflow exhibit lower concentrations in storm runoff, and that the stream (Arroyo Hondo) with very low baseflow concentrations shows an increase in stormflow. This usually holds true for most pollutants in streamflow: low baseflow levels typically increase during storms, high levels are diluted. Notice also that the difference between concentrations in stormflow and those in baseflow are considerably less than a order-of-magnitude (an order-of-magnitude is a ten-fold difference, two orders-of-magnitude would be a hundred-fold difference, three a thousand fold). In the case of Mission and Arroyo Burro, the urban streams, it's much less: stormflow concentrations being only 30-50 % lower than those in baseflow. For a number of storms monitored at Main Street in Ventura I can be more precise; the big storm of 2003 occurred on March 15 with 2.20 mg/L as the highest measured total nitrogen concentration and 1.17 mg/L as the lowest – a difference of not quite half – quite similar to what we usually see in Santa Barbara.

On the other hand flow can vary by more than 5 orders-of-magnitude (Figure 1). At Foster Park, prior to the big storms of 2005, baseflow was less than 1 cfs; peak flow reached 41,000 cfs (a more than 50,000-fold increase, or four and a half orders-of-magnitude). Continuing this example: by combining flow and total nitrogen concentrations, we can easily see that the nitrogen flux during 2005 had to vary by at least four orders of magnitude (a variation slightly less than that of flow at locations where concentrations decreased during stormflow, but for locations in the upper basin, where concentrations increase during storms, the flux variation would have been greater than the flow variation). Again, not a 4-fold variation but 4 orders-of-magnitude – the flux during peak stormflow was *10,000 times* greater (pardon all the emphasis, but I believe this to be a crucial point).

As the time period under consideration increases, differences between measures will decrease: daily flows show less variation than instantaneous flows; monthly flows less than daily flows; and annual flows show less variation than monthly flows. However, even with this reduction in differences, as Figure 2 (upper panel) shows, annual flows (water-year) still vary by about 3 orders-of-magnitude, a *thousand-fold* difference. Since, in the TMDL, we are concerned mainly with algae it's dry-season flows (and dry-season fluxes) that are the most critical – since these are the fluxes that directly fuel algal blooms. But as Figure 2 (lower panel) shows, summer flows also vary by similar amounts; the flux variation being even greater since, whereas nitrogen concentrations decrease at high stormflows during winter, during the dry-season higher concentrations are usually combined with higher flows.

We don't have to confine this discussion to theoretical possibilities. Channelkeeper measurements of nutrient concentrations can be combined with gauging station flows (USGS and Ventura County gauging stations) to determine the daily flux (actually, calling it an hourly flux might be more accurate, but since almost all Channelkeeper sampling takes place during non-storm periods, both concentration and flow remain relatively stable on any given day). The upper panel of Figure 3 shows the variation in the daily nitrate flux from April 2001 to August 2008 for three Ventura locations: Foster Park, lower San Antonio Creek and Matilija Creek (at Ventura County gauging station locations). Each point on the graph represents the nitrate flux on a sampling day – approximately one sampling day each month – and the month to month variation gives a rough



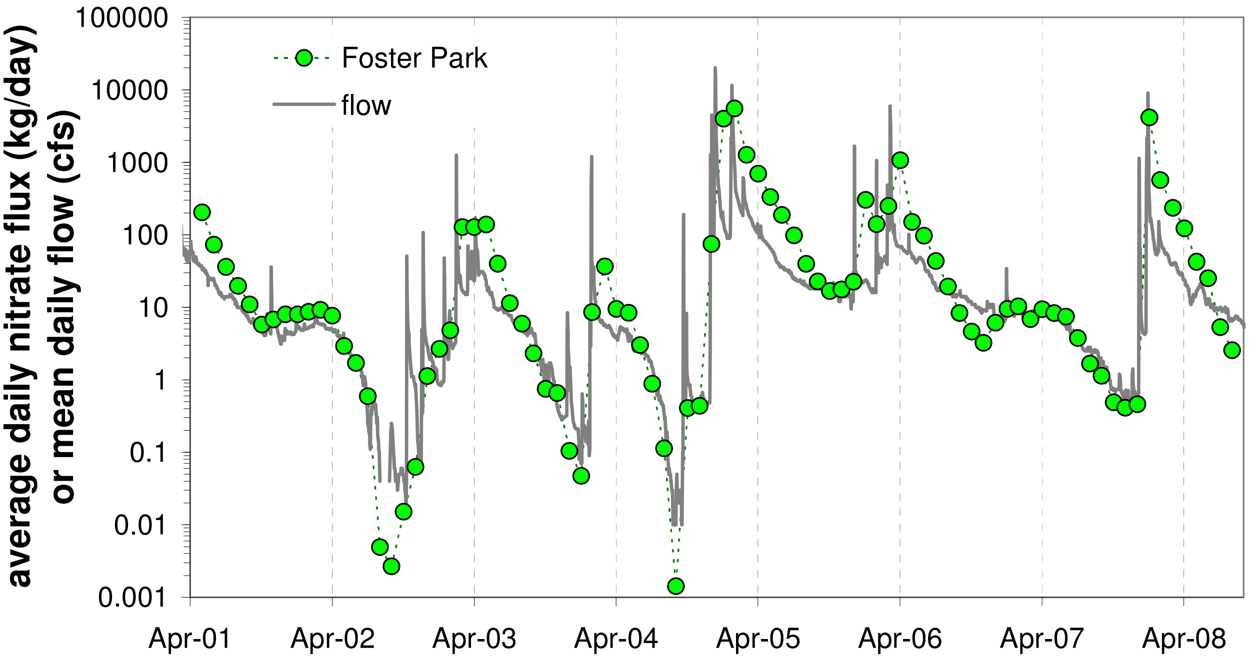
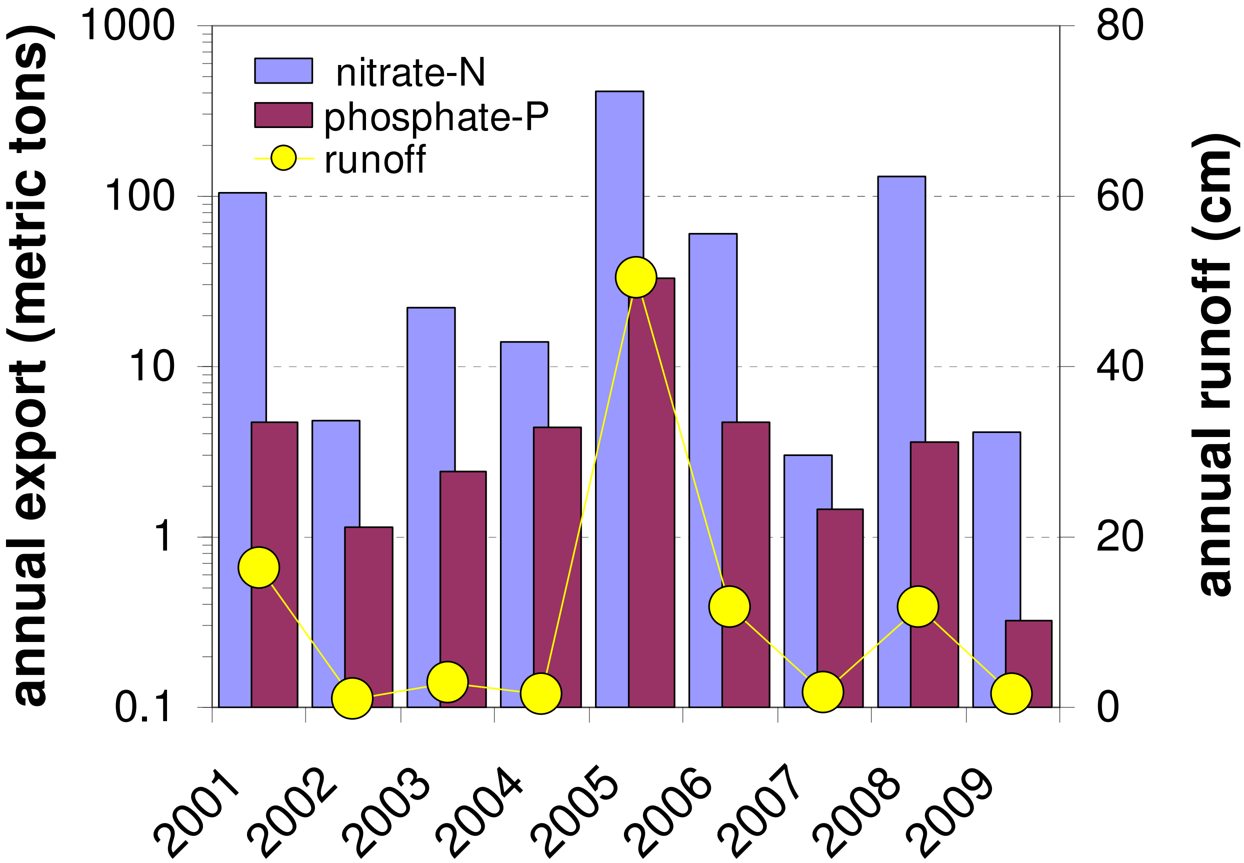


Figure 3. (upper panel) Average daily nitrate flux (nitrate concentrations from the Channelkeeper dataset multiplied by mean daily flow for the sampling day) for three Ventura sampling locations with gauging stations: Foster Park, lower San Antonio Creek and Matilija Creek. (lower panel) The flow record for Foster Park (mean daily flow at the USGS gauge) is superimposed on the flux measurements to show the general correspondence between variations in flow and variations in flux. Note that the Foster Park flux varies over 7 orders-of-magnitude, lower San Antonio over roughly the same range, and Matilija Creek over 5 orders-of-magnitude. Since Channelkeeper sampling days rarely coincide with stormflows, the actual flux variation is even greater than shown.

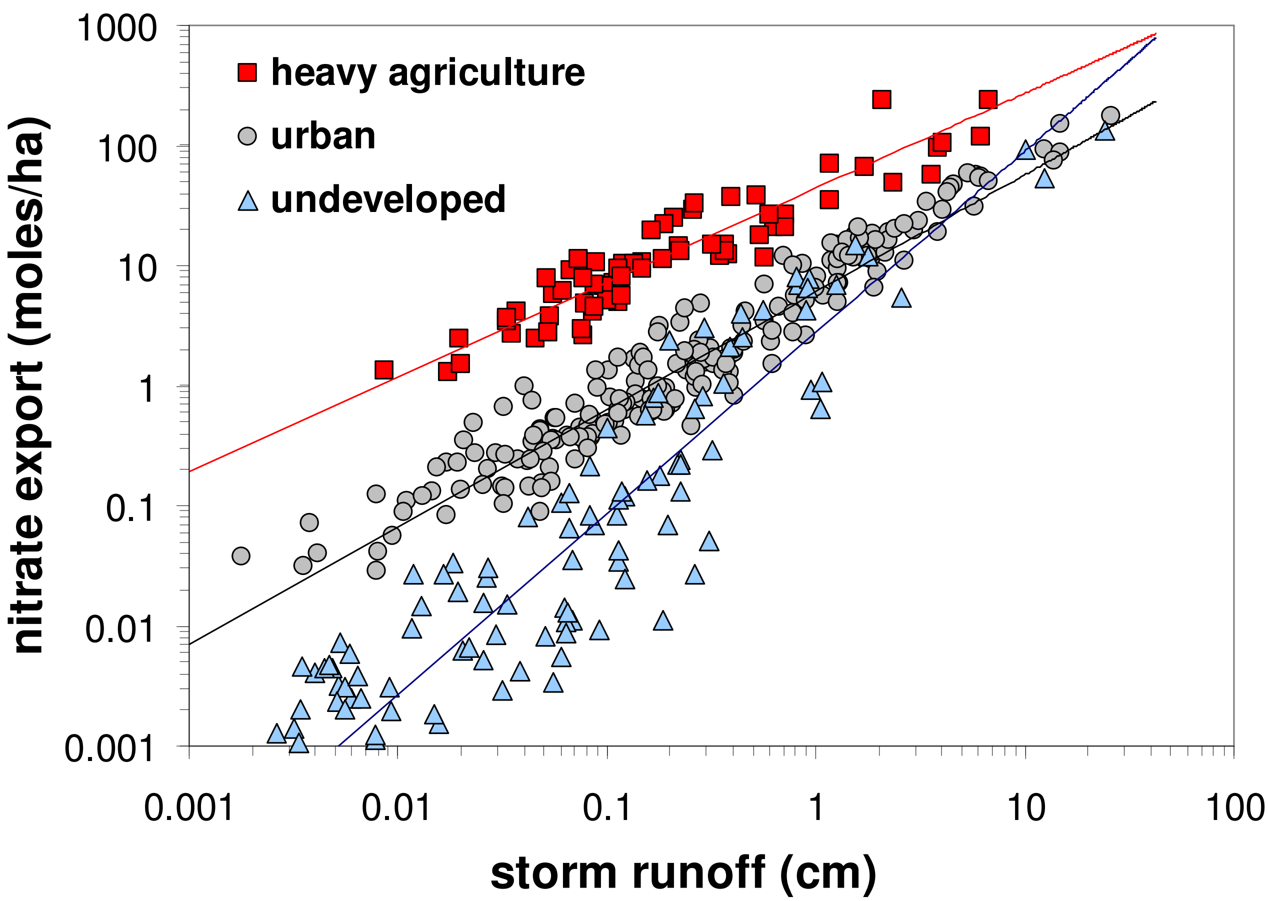
approximation of how the flux varies over time. In the lower panel I've super-imposed Foster Park flow (mean daily flow) for the same time interval over the flux measurements to show that the flux and flow variations *are* quite similar. Since Channelkeeper sampling days rarely coincide with stormflow the actual day-to-day flux variation is even greater than shown (peak fluxes occur at times of peak flow and are almost never sampled). Even so the daily flux varies over 7 orders-of-magnitude at Foster Park, over roughly the same range on lower San Antonio, and over 5 orders-of-magnitude on Matilija Creek.



I've also calculated the total annual nitrate and phosphate fluxes exported from the Ventura system (Main Street concentrations and flow) for every water-year from 2001 through 2009. The above graph shows these results along with annual runoff in cm (runoff per unit area). These estimates, unfortunately, are less than perfect since they are based on Channelkeeper monthly sampling, supplemented on occasion by storm samples I've collected at Main Street. Since there is no gauging station at Main Street I've estimated flow at this location by simply adding treatment plant outflows to Foster Park flow. This seriously underestimates flow during storms when appreciable runoff enters the river below Foster Park. However nutrient concentrations during those same storms are overestimated due to lack of storm sampling. I'd like to believe that overestimates of nitrate and phosphate roughly balance underestimates of stormflow, and that the fluxes on the graph are reasonably correct. Based on that assumption, note that the estimated nutrient fluxes in a year like 2005 are 3 orders-of-magnitude above those of 2009. Pardon me if I again stress that this represents a *thousand-fold* difference.

In the companion piece on the relationship between Chl-a and total nitrogen that accompanies these comments, I've tried to stress the very large differences that occur from year to year. Each year may not be in a class by itself, but big water years bear little resemblance to dry years; and years that fall in-between resemble neither. I would note again that concentrations are a poor measure of available nitrogen, and of the differences that occur between years. Let me give a final example: during the first week in June, 2005, the nitrate concentration at Foster Park was 1.62 mg/L; on approximately the same date in 2007 it was 0.45 mg/L; while the 2005 concentration was roughly 3-times greater, the 2005 nitrate flux was 26-times greater than in 2007, and over 70-times greater than in 2002.

Before closing, I want to say something about atmospheric deposition, and about how the nitrogen flux from undeveloped catchments varies as storm size increases.



This is a version of my all-time favorite graph – if graphing were an Olympic event this would be my submittal. I look for any excuse to show it off. It shows nitrate flux (export) on the x-axis plotted against storm runoff on the y-axis for every urban, undeveloped and heavily agricultural watershed monitored by the UCSB-LTER (Long Term Ecological Research) Project from 2001 through 2005. It includes every storm sampled during that time. The data has been *normalized*, i.e., converted to a common base so that catchments of different sizes can be directly compared: export (total nitrate flux during the storm) is measured in moles/hectare (1 mol/ha is about an ounce of nitrate per acre) and storm runoff in centimeters (runoff per unit area). As storm runoff increases (i.e., increasing rainfall) the flux increases – no surprise there. In general, runoff from agricultural lands is higher than from urban areas, which is higher than from undeveloped areas. Again, no surprise. For small storms the flux differences are great – more than an order of magnitude separates each of the three land uses. For very large storms the difference between agriculture and urban narrows a bit, but the big change is a huge increase in the nitrate flux coming off of relatively pristine, undeveloped areas. Indeed, as the regression lines drawn through the various sets of point show, for a big enough storm nitrogen export from undeveloped lands can exceed that from urban areas. And LTER research has shown that this is, in fact, true. In big storms the majority of nitrogen being exported to the ocean was coming from undeveloped areas of the various Santa Barbara catchments that have been studied. This finding holds true for the Ventura River also.

And where all this nitrogen is coming from? The answer is *atmospheric deposition*. Atmospheric deposition (pollutants from the sky) is continually raining down on us, in the form of rainfall (which typically has nitrogen concentrations of about 0.5 mg/L) and, more importantly, particulate matter (otherwise known as dry deposition). Whereas rainfall is usually confined to a few events during winter months, dry deposition occurs year-round, and since we are in southern California, the total amount can be considerable. And it accumulates, in and on the soil and on plants. It accumulates until there is a storm big enough to transport it laterally to streams and the river, and horizontally down into the water table. The key to this whole process being that that big enough storm doesn't occur every year (a big enough storm being one that causes appreciable runoff from backcountry areas and the upper watershed). It didn't occur in 2009 which means that nitrogen deposition has be continually piling up since the last big storm of 2008 (in February), and it continues to accumulate.

This has lots of consequences. First, it means that when that big storm does arrive it will carry lots of nitrogen with it, and the bigger the storm the more nitrogen it will flush out (up to a point) – thus providing the explanation for the steep upward trajectory of the undeveloped catchment line on my nitrate graph. Second, the big storm will carry a significant portion of that accumulating nitrogen deposit on down into the water table where it will be fed – via groundwater inflows – into the streams and river the following dry-season. And from where it will fuel the inevitable algal bloom. And third, if the big storm doesn't arrive there will be no injection of fresh nitrogen into the river during the coming dry-season.

2008 was a great algal year not just because it had a big storm. But because that big storm came after the very dry year of 2007.

So big storms do more than simply prepare the riverbed for algae by removing sediment and aquatic plants. Or because they increase flows dramatically widening the river and expanding available habitat. They also make sure nitrogen is in plentiful supply, not only by transporting it to groundwater in the more developed areas of the watershed, but in the relatively pristine backcountry as well. Call it a triple whammy.