Geochemical dynamics of a spring-fed stream in an arid climate

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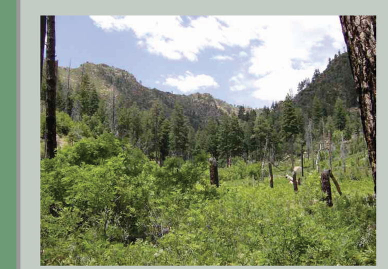


Photo of Bonita creek valley looking north toward the Mogollon Rim.


Photos of minor (above) and major source springs. Major spring is perennial; minor spring runs only during late spring.


Photos of the sample site on three different days (left to right): February 2, July 3, and July 12, 2008. The picture from July 12 was taken just after the rainfall event discussed below. Flow volume changes are clearly visible between photos when compared with the rock in each picture (as indicated by the red dot). Also note the difference in turbidity between photos 2 and 3.

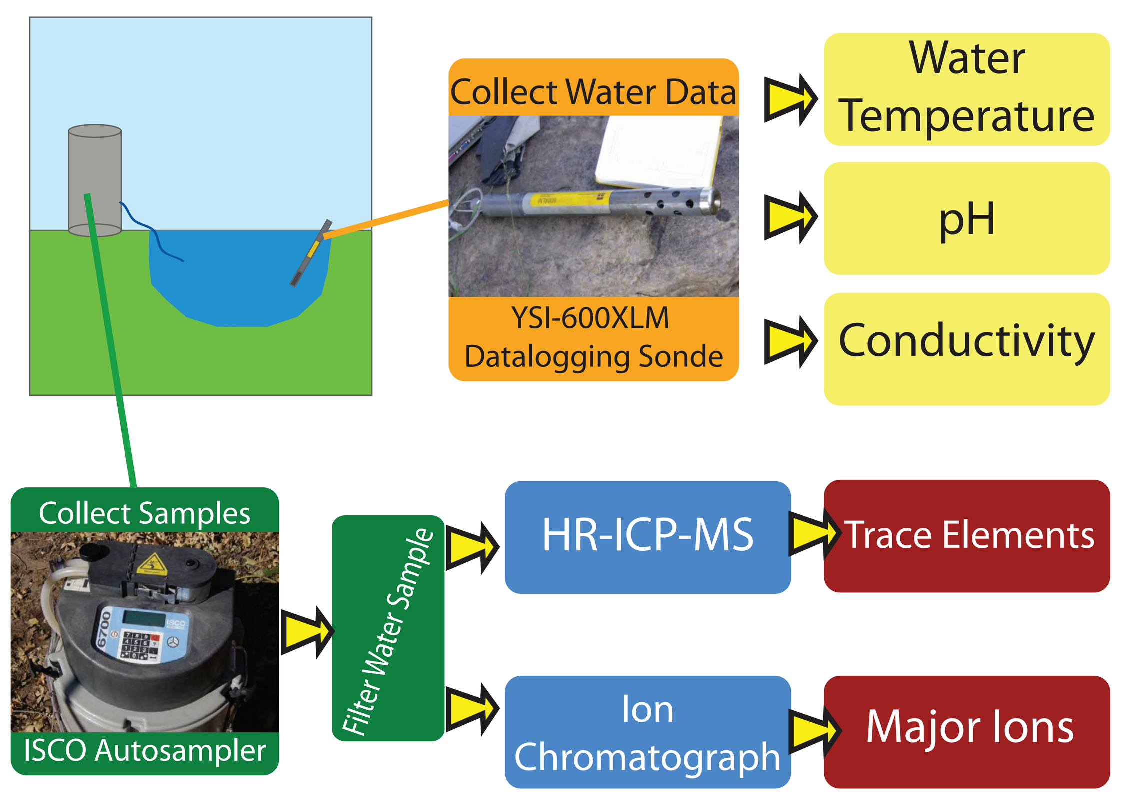
Studying this site is important because:

* Bonita creek represents one of many tributaries that provide water that ultimately flows via the Verde river into the greater Phoenix metro area and is used as drinking water.
* While studies have analyzed major ion composition in streams at different time scales (Parker et al, 2007; Miller & Drever, 1977) and nutrient loads in rural and urban arid streams (Marti et al., 1997; Jones et al., 1996) over different time scales and in response to weather events, little is known about long-term, seasonal trends of trace elements in perennial, minimally-managed, semi-arid streams.

Questions and Hypotheses

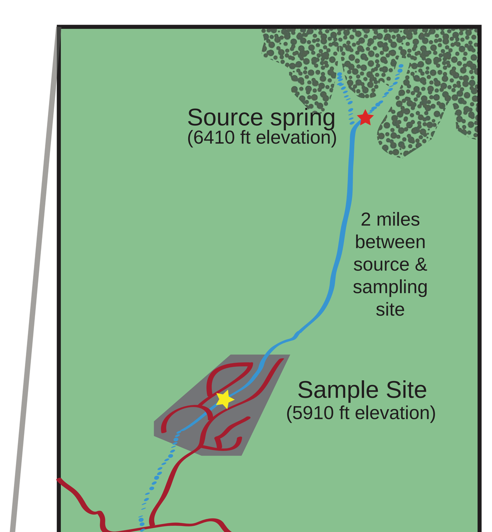
* How do seasonal changes affect chemical parameters (pH, conductivity) and elemental concentrations of a perennial, spring-fed watershed in an arid climate?
Hypothesis: As dry periods persist, spring water chemical contributions should obscure surface chemical signals as surficial flow slows and ceases.
* How do precipitation events alter elemental concentrations and pH and conductivity?
Hypothesis: Spring water-derived elemental signals should be overwhelmed during and immediately after rainfall events as surficial flows are at peak volume.

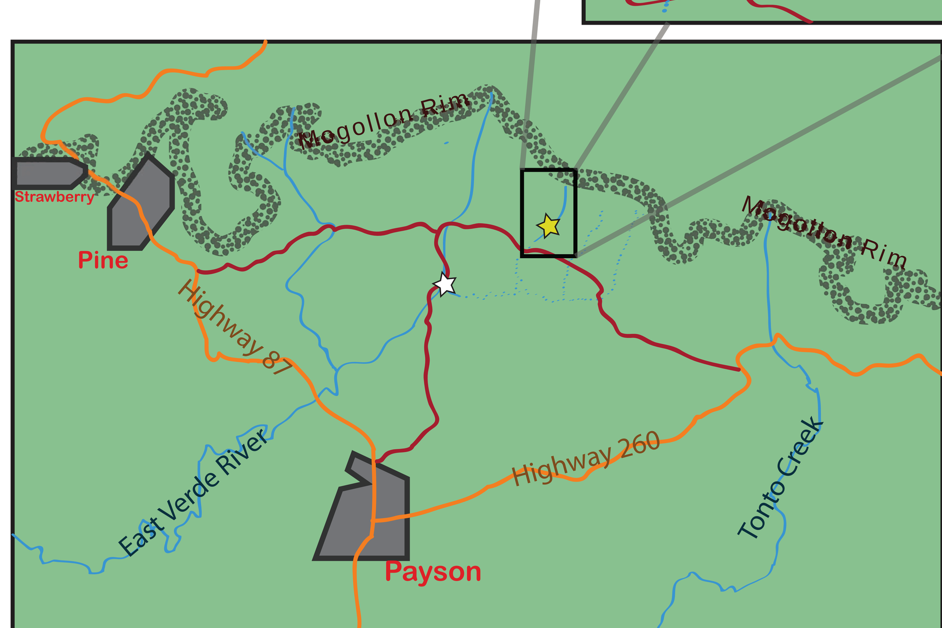
Creek Sampling Scheme



Bonita Creek

* Source spring emerges from base of Mogollon Rim at approximately 6410 ft (1954 m) elevation.
* Creek flows for 2 miles through the Tonto National Forest before flowing into the community of Bonita Creek.
* Flow provides drinking water for Bonita Creek residents.
* Stream flows for ~ 2.5 miles before re-infiltrating as groundwater.





* Cold Springs, near Whispering Pines (represented by the white star in the Payson area inset), a major spring system southwest of Bonita Creek, is the most likely point of re-emergence.
* Water from Cold Springs flows out of the area via the East Verde River.

Figure 1. Location of study site in relation to the state of Arizona, inset of the Payson, AZ, region and an inset of Bonita creek.

Rainfall through time

Rainfall totals throughout the study time are shown to the right. Winter precipitation is largely over by March 1. Summer monsoons are clearly shown as starting around June 25, as indicated by the green arrow. The rainfall event discussed in Part 3 of this poster is indicated by the red box. This data set was provided by a local Bonita Creek resident. Precipitation events and totals correspond with events recorded by surrounding USGS monitoring stations and the Payson AZMet Station.

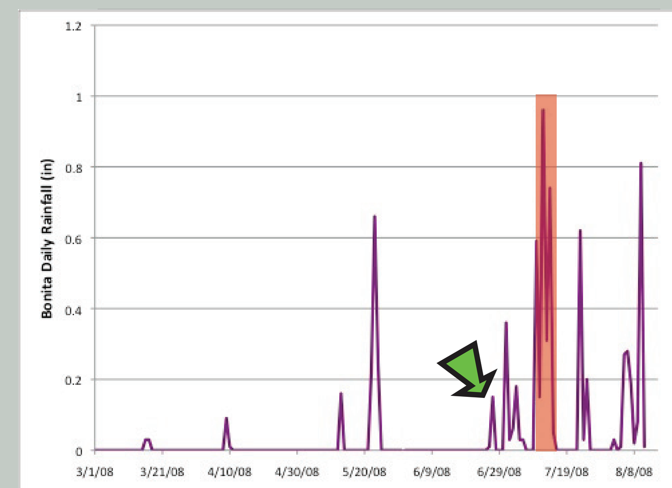


Figure 2. Daily rainfall amounts at Bonita Creek from March 1 through August 10, 2008.

In-situ Conditions

Measurements from the YSI sonde are pictured in Figures 3, 4 and 5 (right and below). Specific conductivity, a measurement relating to the concentration of all ions in solution, is shown in Figure 3. The conductivity increases by 2.5 times between April 20 and August 1. pH, a measurement of hydrogen ions in solution, increases slightly from March 1 to July 1 (Figure 4). The seeming downward trend in pH values during the summer is due to a buildup of sediment on the pH electrode and does not reflect actual site conditions. Figure 5 shows water temperature during the study. Daily temperature variations reflect the time of day and ambient air temperature. Greater data density reflects increased sampling frequency (up to hourly during and after rainfall events).

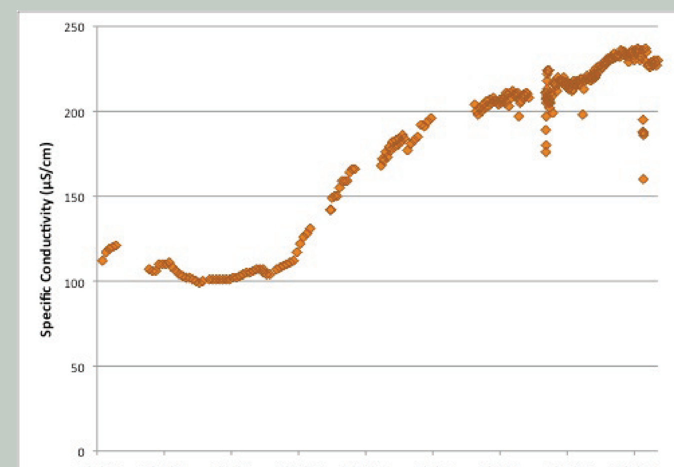


Figure 3. Specific conductivity values through time.

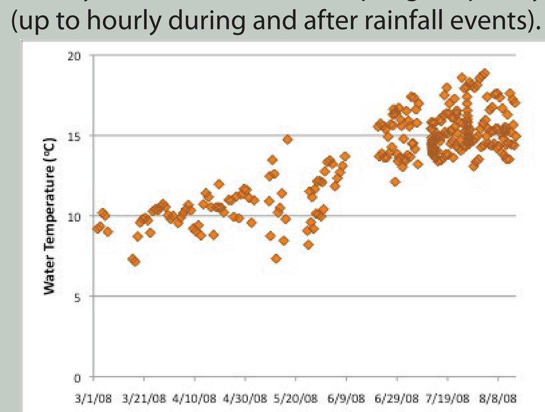


Figure 5. Water temperature (in Celsius) through time.

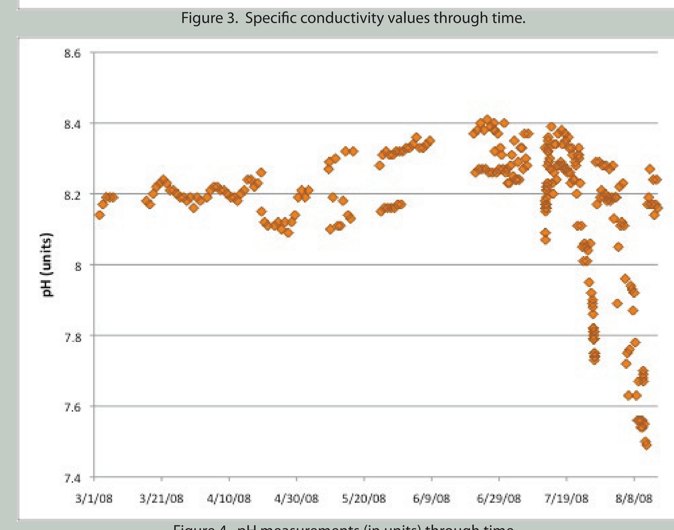


Figure 4. pH measurements (in units) through time.

Major ion concentrations through time

Monovalent Ions

Monovalent cations sodium and potassium (Figures 6 & 7) exhibit similar seasonal trends overall, with a decline until mid April, followed by an increase until the end of May. Concentrations plateau from June 1 through the monsoon season. Chloride, the only measureable major monovalent anion found, shows similar concentration trends (Figure 8).

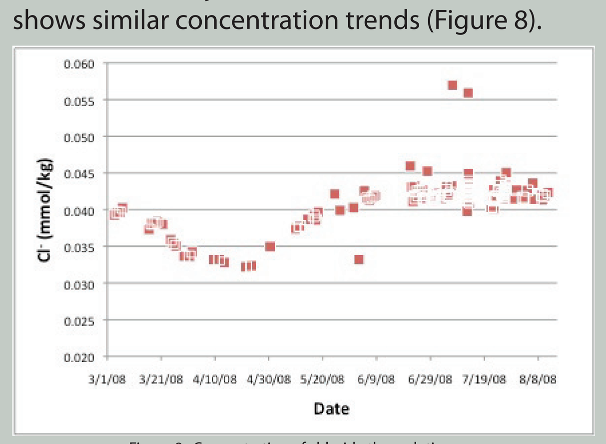
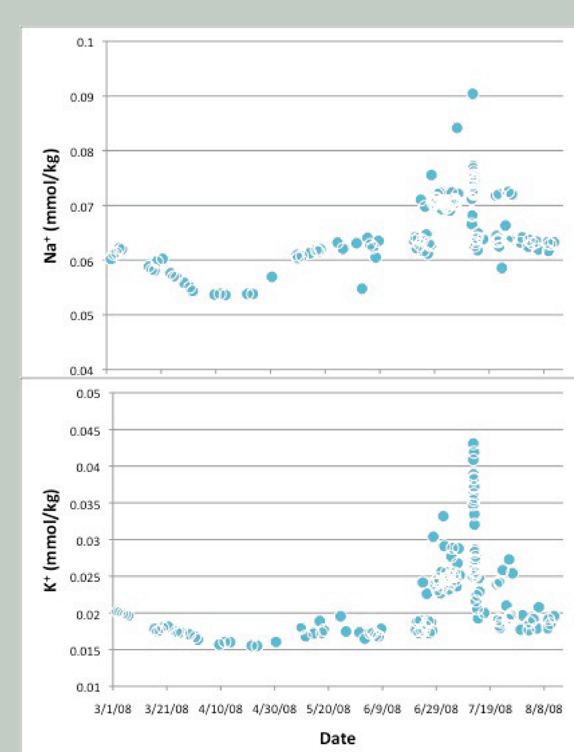


Figure 8. Concentration of chloride through time.


Figures 6 & 7. Concentrations of sodium (top) and potassium through time.

Divalent Ions

Calcium and magnesium concentrations show a two-fold increase from April 10 to July 1(Figures 9 & 10). Concentrations remain steady throughout the monsoon season. Sulfate concentrations steadily decrease by 3x from March 1 to August 10 (Figure 11). Concentrations decrease slightly during the course of the monsoons.

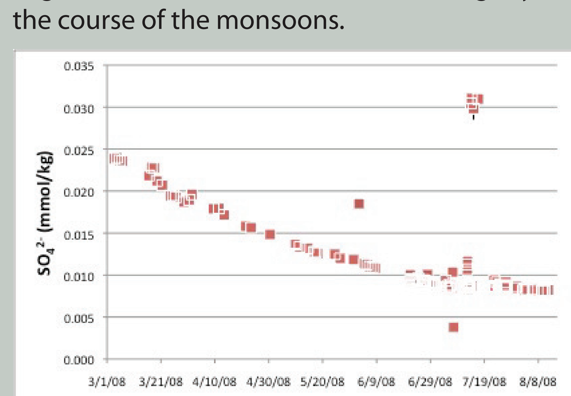
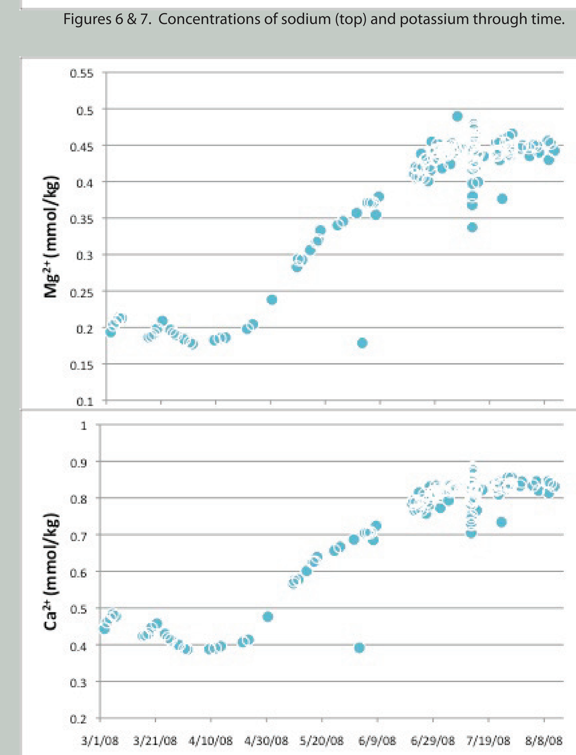


Figure 11. Concentration of sulfate through time.


Figures 9 & 10. Concentrations of magnesium (top) and calcium through time.

Trace element concentrations

Trace element concentrations show at least 2 distinct trends through time. Figure 12 shows yttrium, zirconium, copper and neodymium (Figures 12A, B, C & D, respectively) decreasing by various amounts from March until August. These four elements show a spike during the July 12 rain event, indicating that these are likely enriched during times of high overland flow. Figure 13 shows uranium, chromium, arsenic and rubidium concentrations (Figures 13A, B, C & D, respectively) increasing from March until August. Uranium, arsenic and rubidium show a sharp downward spike during the July 12 rain event, which would indicate that these elements are groundwater components contributed by the source spring. Figure 14 shows vanadium, iron and aluminum (Figures 14A, B & C, respectively) concentrations through time. Vanadium concentrations do not indicate any clear increase or decrease, but a slight increase may be present during the study time pictured. Iron concentrations hint at a decrease, with an upward spike during the July 12 rain event, but the trend is more subtle than elements shown in Figure 12. Aluminum, acknowledged by geochemists as a chemical weathering proxy, is more concentrated in late winter and early spring, indicating that surficial flow is, indeed greater during those periods than in summer.

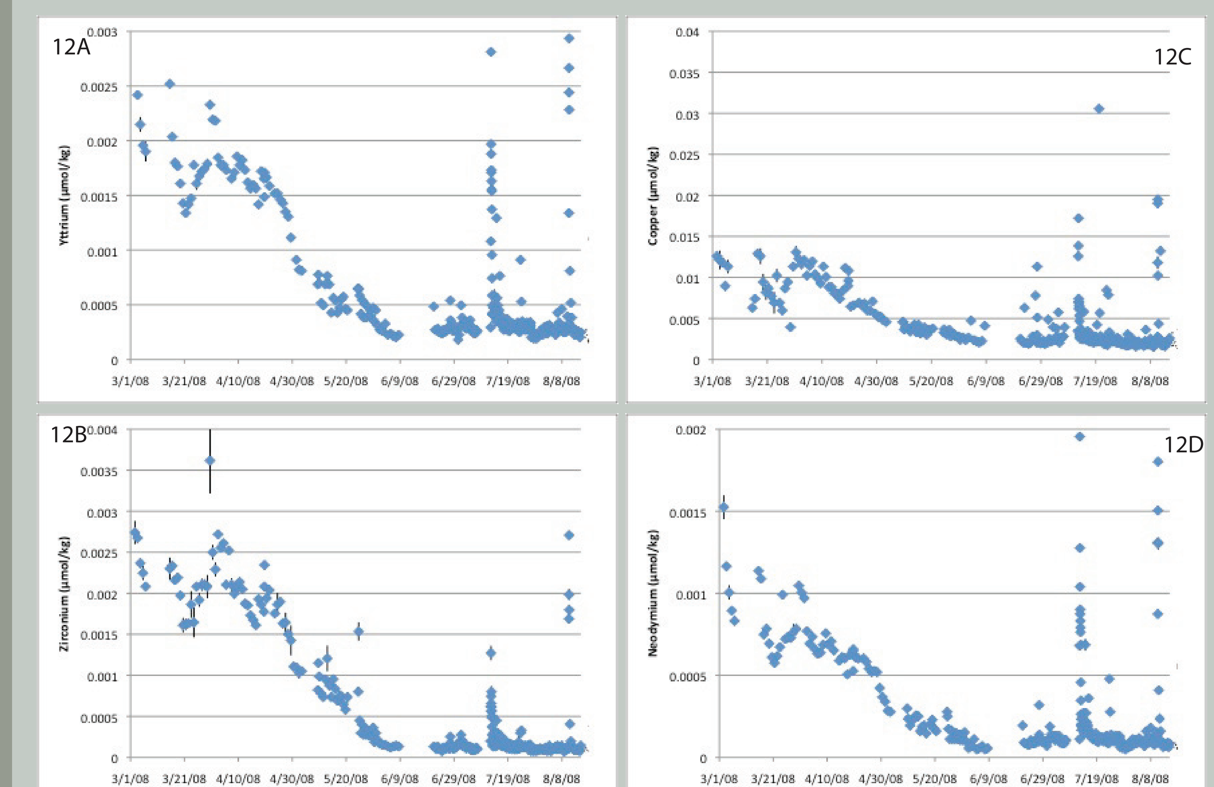


Figure 12. Concentrations of yttrium, zirconium, copper and neodymium (12A, B, C and D, respectively) through time. All four elements show similar seasonal trends. The large deviation in July and represents the precipitation event noted in Figure 2.

Figure 13. Concentrations of uranium, chromium, arsenic and rubidium (13A, B, C and D, respectively) through time. All four elements show similar seasonal concentration trends, with an increase to a summer plateau.

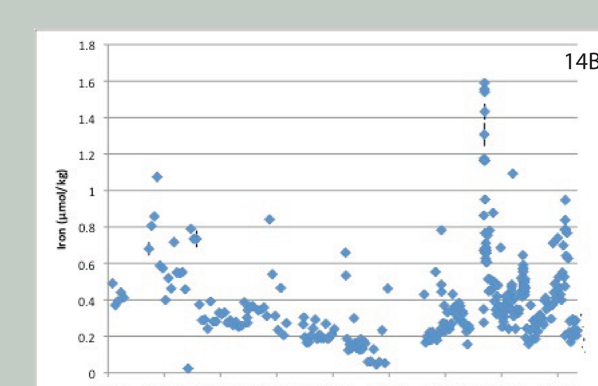
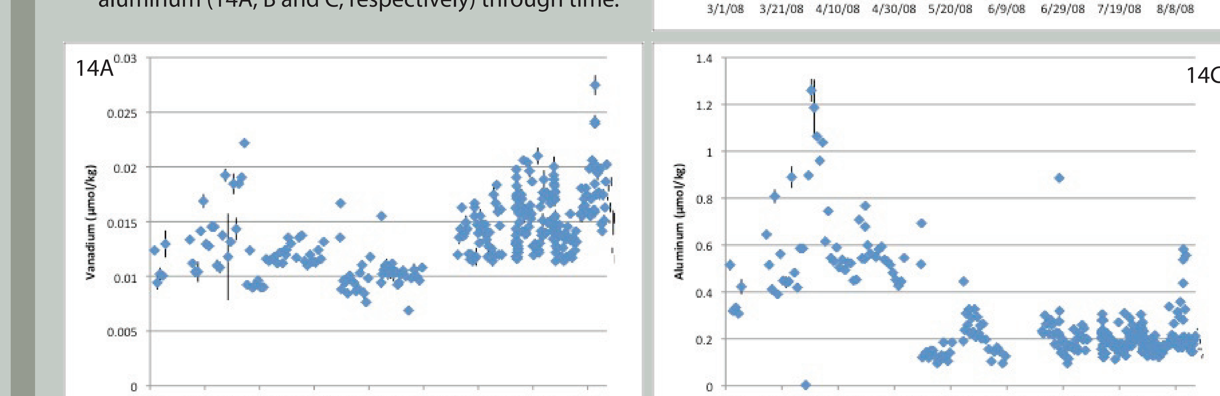


Figure 14. Concentrations of vanadium, iron and aluminum (14A, B and C, respectively) through time.



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Marti E., Grimm N.B. and Fisher S.G. (1997) Pre- and post-flood retention efficiency of nitrogen in a Sonoran Desert stream. *Journal of the North American Benthological Society* 16, 805-819.
Jones J.B., Fisher S.G. and Grimm N.B. (1996) A long-term perspective of dissolved organic carbon transport in Sycamore Creek, Arizona, USA. *Hydrobiologia* 317, 183-188.

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July 12-13, 2008 rainfall event


Figure 15. Specific conductivity, major ion concentrations and trace element concentrations as a function of time during and after the July 12 rain event indicated in Figure 2.

Figure 15 shows half-hourly rainfall totals, specific conductivity and major and trace element concentrations from midnight of July 12, 2008 to midnight of July 14, 2008. The rain event started just before 3:00 pm and was essentially over by 5:30 pm. Specific conductivity dips from 211 µS/cm at 3:00pm to 176 µS/cm at 5:00pm. From 5:00pm to 8:00pm, conductivity increases to 205 µS/cm before slowly increasing to 225 µS/cm by 6:00am the next day. The sudden decrease after 12:00pm on July 13 is due to cleaning and recalibrating the probe.

Major ion concentrations are also perturbed by the rainfall event. Calcium and magnesium are diluted by the increased surficial flow input and show trends identical to specific conductivity. Both major ions return to pre-event concentrations by 12:00pm on July 13. Potassium and sulfate show concentration spikes that also return to normal by 12:00pm. Sodium and chloride concentrations do not show any notable trends.

Trace element concentrations show similar changes. Copper, neodymium and strontium all exhibit an initial concentration spike within four hours of the onset of rainfall and resume pre-event concentrations within 18 hours. Iron and aluminum also show an increase in concentration, with a gradual resumption of pre-event concentrations within 18 hours, however the rates of change are far more gradual, with the maximum values being reached 9 hours after the onset of rainfall. Other trace elements--arsenic, rubidium and uranium--are diluted by the influx of surficial flow. Arsenic and rubidium both exhibit a quick dilution and recover to pre-event concentrations within 5 to 8 hours after the rainfall event. Uranium is not diluted until 3 hours after the onset of rain and does not resume pre-event concentrations until 12 hours after the start of rainfall.

Conclusions

* Seasonally, major and trace elements fall into three categories:
- Elements that increase in concentration
- Elements that decrease in concentration
- Elements that do not appear to have a single, clear trend through the study period

* Major and trace elements, such as calcium, magnesium, uranium, arsenic, and rubidium, show similar initial dilution during rainfall events, indicating a possible groundwater source as surficial flows are at their greatest intensity.
* Other major and trace elements such as potassium, sulfate, copper, neodymium, and strontium show a concentration spike during rainfall events that returns to pre-rainfall levels within 24 hours, indicating that these elements stem from a surficial source.

Continuing Work

* Sampling will continue until March 1, 2009, to establish a year-long dataset.
* Water from surrounding streams (i.e. Tonto creek, East Verde River, some springs on the Mogollon Rim) will be collected and analyzed for a regional perspective.
* Rock strata at the source spring will be analyzed to put water elemental content into perspective.