Understanding storm induced release and solute pulse response along the Salt River, Arizona

McLean, Brandon and Shock, Everett
Arizona State University, School of Earth and Space Exploration, Tempe, AZ 85287

Concept of the Critical Transition State

Storm pulses are widely used in unmanaged, temperate and subtropical river systems to resolve the in-stream surface and subsurface flow components. An example is shown in the figure at bottom left from Tardy et al, 2004. Resulting catchment-scale hydrochemical mixing models yield insight into mechanisms of solute transport. Managed systems, shown at bottom right, are far more complicated due to the human need for high quality water resources, which drive processes, such as dam release, canal diversion and suface alterations that are superimposed on most, if not all, of the unmanaged components. During large storm events, this managed system is perturbed towards natural behavior as it receives input from natural hydrologic pathways in addition to impervious surfaces and storm water drainage channels. Our goals in studying managed rivers during this critical transition state are to determine how the well-characterized behavior of natural systems break down as the watershed responds then returns back to the managed state. Using storm events as perturbations we can contrast an arid managed watershed with the unmanaged watershed it approaches during the storm event. In the process, we can extract geochemical consequences specifically related to the unknown urban components that may be transporting pollutants, in the form of heavy metal loading, or nutrients through the river.

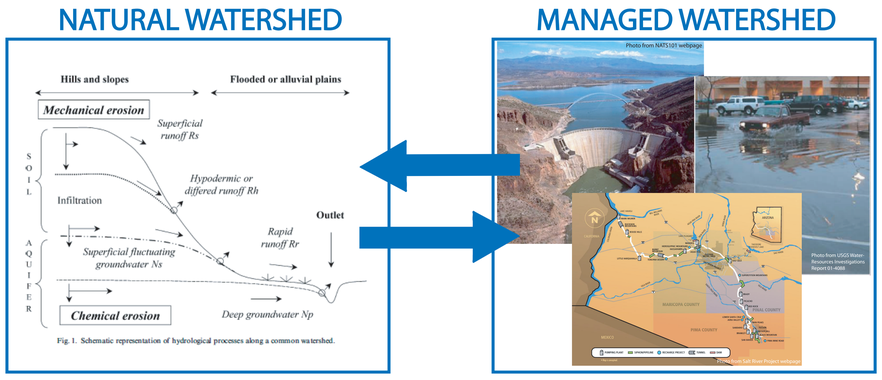
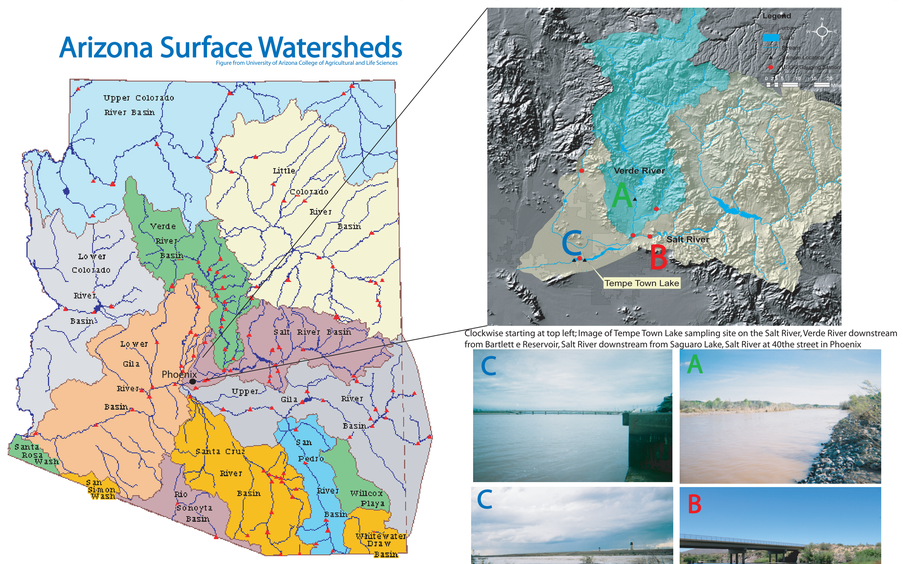
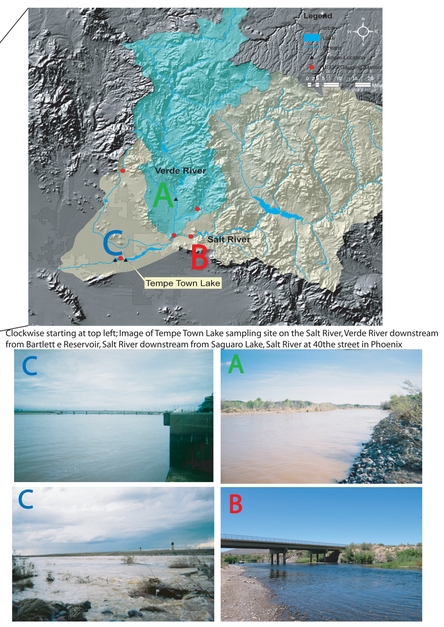


Fig. 1. Schematic representation of hydrological processes along a common watershed.

Phoenix Metro area

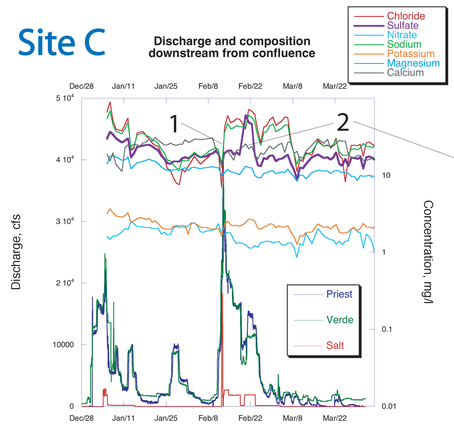
An increasingly large portion of the water supply for the Phoenix metropolitan area is derived from multiple surface water sources (Salt River, Verde River, Central Arizona Project - Colorado River water) that are impounded, diverted and otherwise managed upstream from the urban core (shown as the cross-hatched area in the figure at top right) that consumes the water and produces anthropogenic impacts.

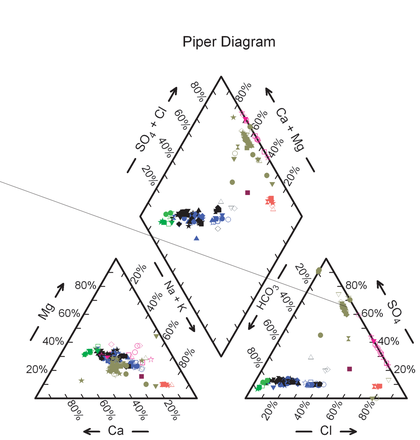




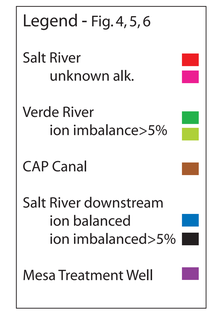
Clockwise starting at top left: Image of Tempe Town Lake sampling site on the Salt River, Verde River downstream from Bartlett e Reservoir, Salt River downstream from Saguaro Lake, Salt River at 40the street in Phoenix

Site C

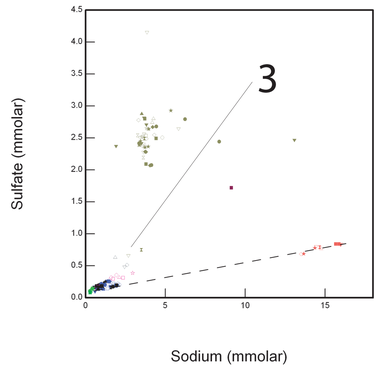




Chemical Mixing



Figures 3, 4 (above). Mixing of water from two distinct sources drives dynamic changes in chemical composition. Pulses in the loads of major ions from upstream dictate changes in ion concentrations downstream of the confluence with the Verde River. For example, during event 1 chloride and sodium first respond to an increase in input of Verde water by decreasing in concentration, followed by prolonged increase in concentration due to Salt river input. However, during event 2 sulfate responds during a decrease in both Verde and Salt river water by increasing sharply. This requires at least a third source of water. The third source could be input from the Central Arizona Canal (CAP) Canal, and the elevated sulfate content of CAP water is demonstrated with the Piper diagram in Figure 4.



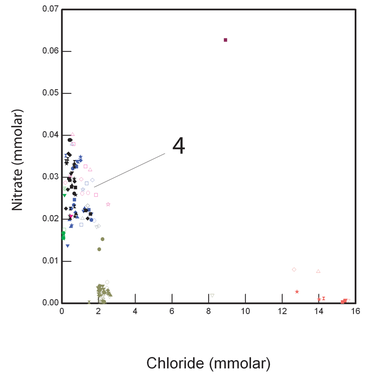
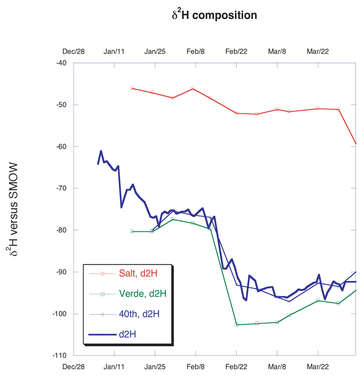


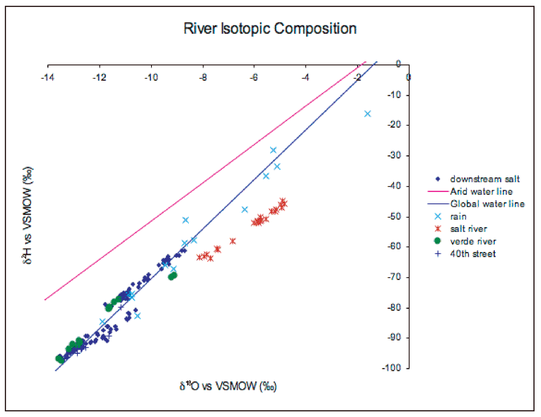
Figure 5 (far left). The sulfate anamoly is also depicted in the plot of sulfate versus sodium. Mixing between inputs from the Salt and Verde rivers should fall along the dashed line near the bottom of the plot. Downstream samples show higher sulfate concentrations consistant with input from the CAP canal (line 3).

Figure 6 (near left). Nutrients are also affected by the mixing process. Concentrations of nitrate plotted versus chloride reveal a more complex story. Mixing of Salt river, Verde river, and CAP canal water can not explain the downstream nitrate concentrations (line 4). Input from shallow aquifer recharge (purple square) may explain some, but not most downstream data. This suggests that another high nitrate/ low chloride component is needed.

Isotope Hydrology

Figures 7a,7b,8 (below). Our interpretation of the effects of water management practices is confirmed by stable isotope measurements. Values of $\delta^{18}O$ and $\delta^{2}H$ shown in Figure 7a and 7b confirm that a majority of the downstream water is supplied by the Verde River (both daily samples at Tempe Town Lake and weekly at 40th street - farther downstream). We believe that the step in the Verde River isotopic data (mid-February) reflects the sudden transition from old reservoir water to new input from rainfall, which is consistant with our turnover estimates. The heavy signature of the Salt River may also reflect long term storage (with continuous evaporation), which is also consistant with the departure of the Salt River data from a meteoric water line in Figure 8.





Trace Metal Response

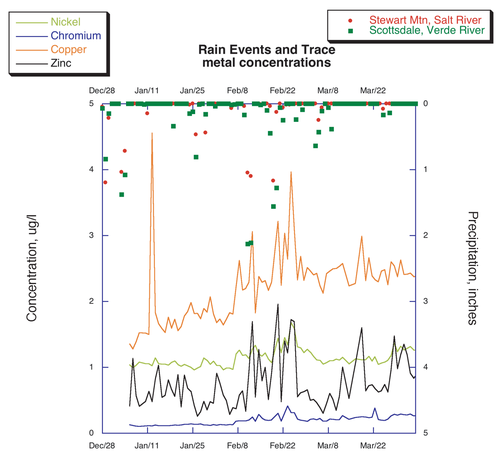


Figure 9. Precipitation and trace metal concentrations downstream from the mixing zone show pulses of Cu, Cr, Zn and Ni that may correspond with rain events and indicate smaller, chemically distinct inputs during storm response. Also, the steady increase in Cu may be a press due to repeated storm events.

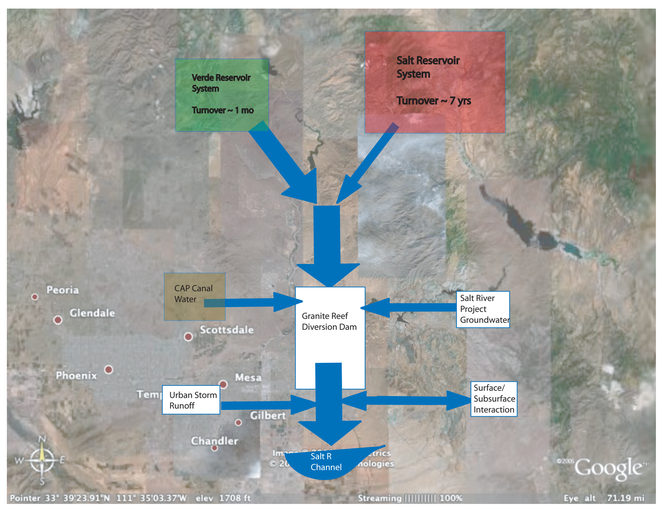


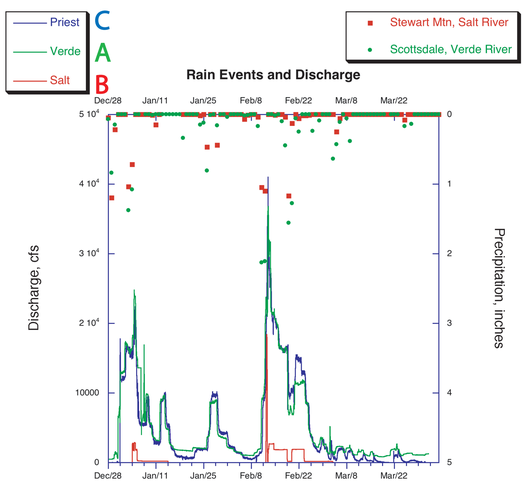
Figure 10. The box model illustrates our present understanding of the system. Can we extract and quantify the urban runoff signal from the three dominating source contributions? Calculations of impervious area indicate a 0.5 in storm could produce roughly 2-5,000 cfs for 1 day

Managed Reponse

Reservoir Turnover Calculation 12/30/2004 to 4/4/2005

	Total capacity, acre-feet	Total discharge, acre-feet	Average discharge, acre-feet/day	Average turnover, days	Total turnovers
Verde River	317728	956079	9959	32	3.0
Salt River	1754335	64796	675	2599	0.04

Table 1. Calculations of average turnover rates in the two reservoir systems from USGS discharge data and Salt River Project reservoir capcities are shown in the table above. Average discharge for approximately a 3 month period was divided by total reservoir capacity which gives the number of days it would take at that rate of discharge to flush the entire reservoir system. The number of times that the reservoir could be flushed during the period of study is called the total turnovers.



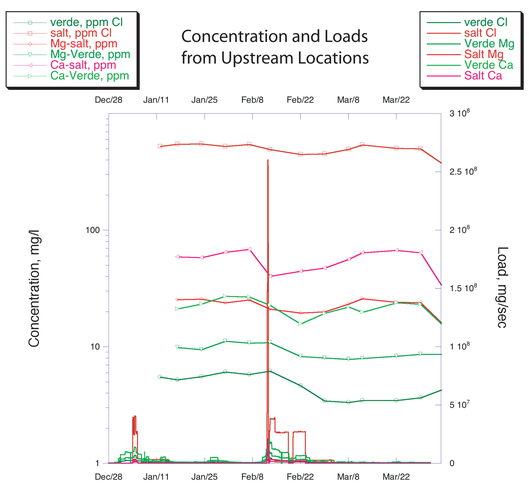


Figure 1. The managed response to storm events can be seen in the discharge hydrograph and rainfall hyetograph above. Peaks in discharge correlate with rain events, however, not all storm events result in reservoir release water (see the Salt River hydrograph after late January rain). Broad flat peaks are indicative of reservoir release, and are more common in the Salt River hydrograph than in the Verde River hydrograph (mid February on Salt river). Note also the time lag between pulses at the Verde and Priest Avenue gauging station.

Figure 2. The figure above shows concentrations of majors ions (Cl, Mg, Ca) downstream of dams along the Salt and Verde rivers, and calculated chemical loads. Note that loads in the Salt river are larger despite smaller discharges. Also, note that the rivers differ more in their Cl concentration than in concentration of Ca or Mg.

Special thanks to all those who contributed:
This includes Brad Brown with sampling, Panjai Prapaipong, Natasha Zolotova, and Anthony Michaud for assistance with instruments, and Hilairy Hartnett for discussions of data