

Measuring the Effects of Management on Dissolved Solutes in the Salt River, AZ, USA

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Canal Distribution

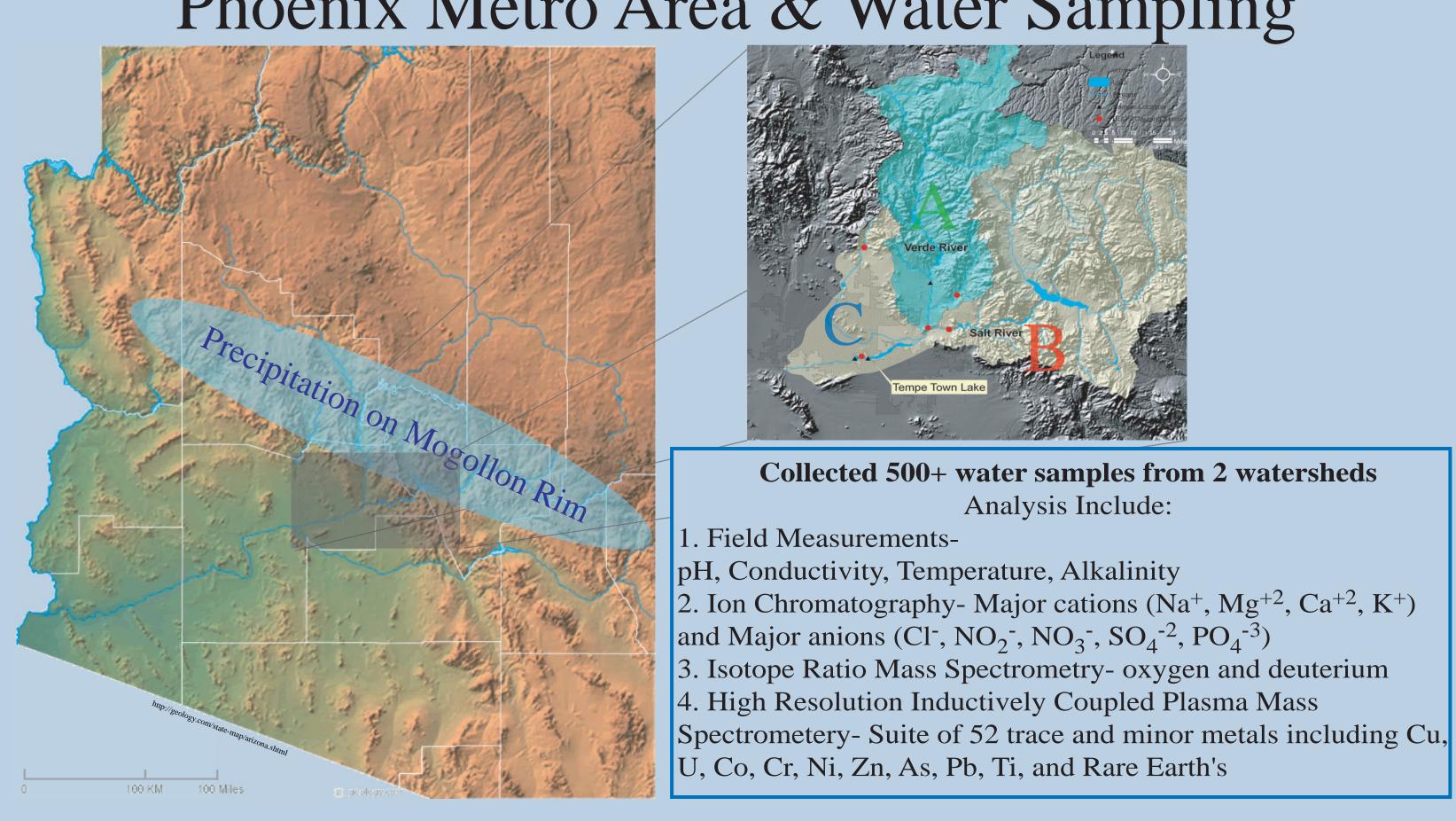
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Project Motivation

During rain events, the in-stream composition of an unmanaged river is a dynamic combination of various source waters that are directly linked to the hydrologic cycle. In a temperate, or sub-tropical climate these include fluctuating groundwater, surface water, and soil water. In an effort to understand complex mixing in natural rivers, researchers envision that a concentrated groundwater solution, or base flow, is diluted by surface flow mostly from rainwater, with secondary inputs from a delayed through-flow component. Many studies have been conducted that extract percentages of these flow components using a mass balance approach with simple 2-end-member mixing models (Pinder and Jones, 1969), 5 end-members (Tardy et al., 2004), or the more robust multi-variant statistical mixing analyses (Hooper and Christophersen, 1990). Many times these models assume constant concentrations, or loads, in source components and use a limited number of conservative constituents or environmental isotopes as tracers.

In a managed system, the flow components are derivatives of human decision-making rather than products of precipitation, and as a result river flow is disconnected from the hydrologic cycle. Likewise, river composition depends on management practices such as storage and release from reservoirs, basin-to-basin transfers of water, efficient flow over impervious surfaces resulting in storm water drainage, and permitted effluent discharges, resulting in only minor dependence on natural contributions. Depending on the flow component, constant composition is no longer a valid assumption, and the addition of new, unnatural components can transport nutrients and toxins downstream or into shallow aquifers. It is this recharge of aquifers during storm events on managed rivers that is of particular interest for water quality, especially when trace metal transport is enhanced in an urbanizing environment. Using the data set we have collected, we can fully characterize the composition of recharge water, and distinguish trace-element and nutrient fluxes that are unique products of the urban area.

Phoenix Metro Area & Water Sampling



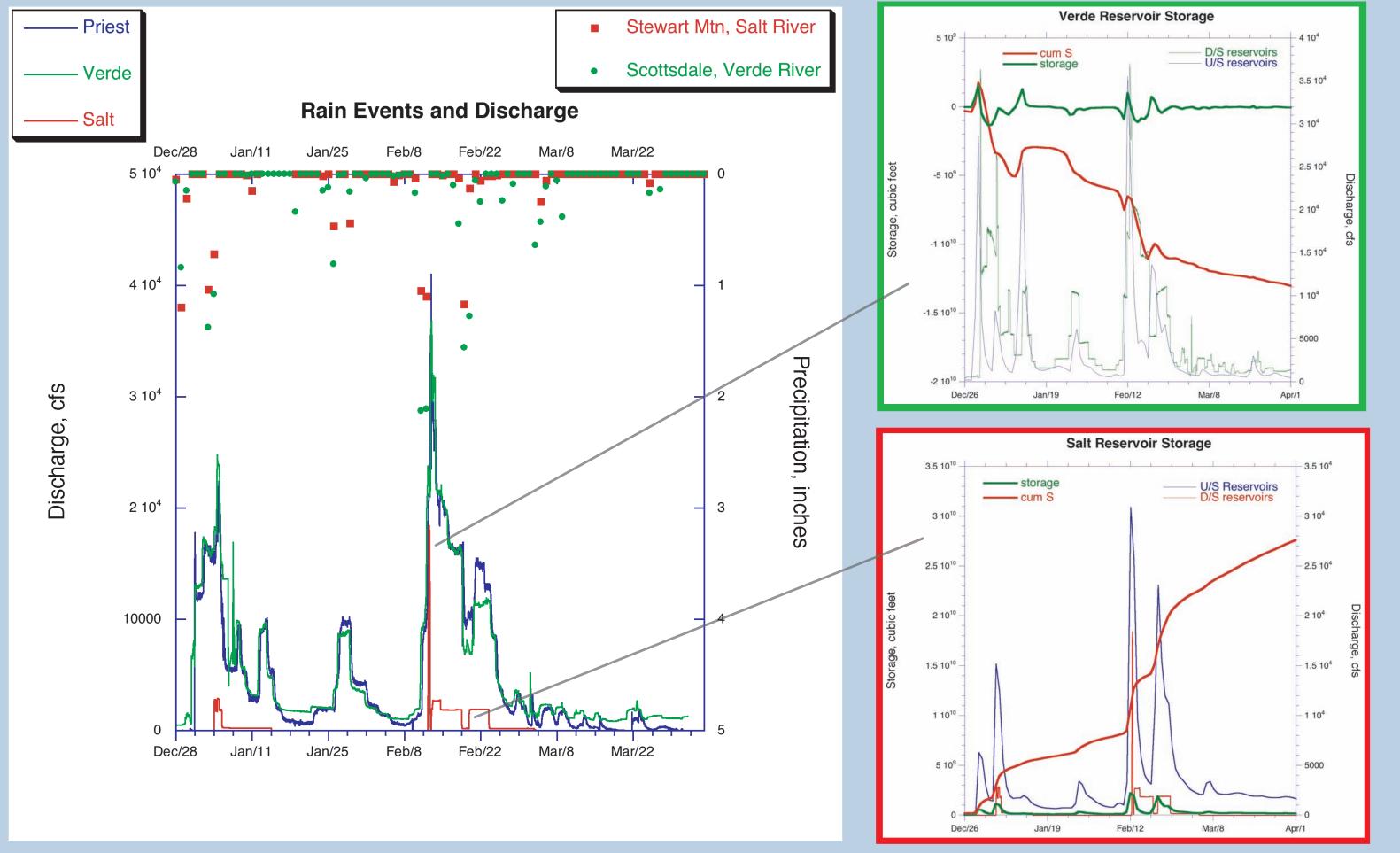
Project Approach and Design: A+B=C?



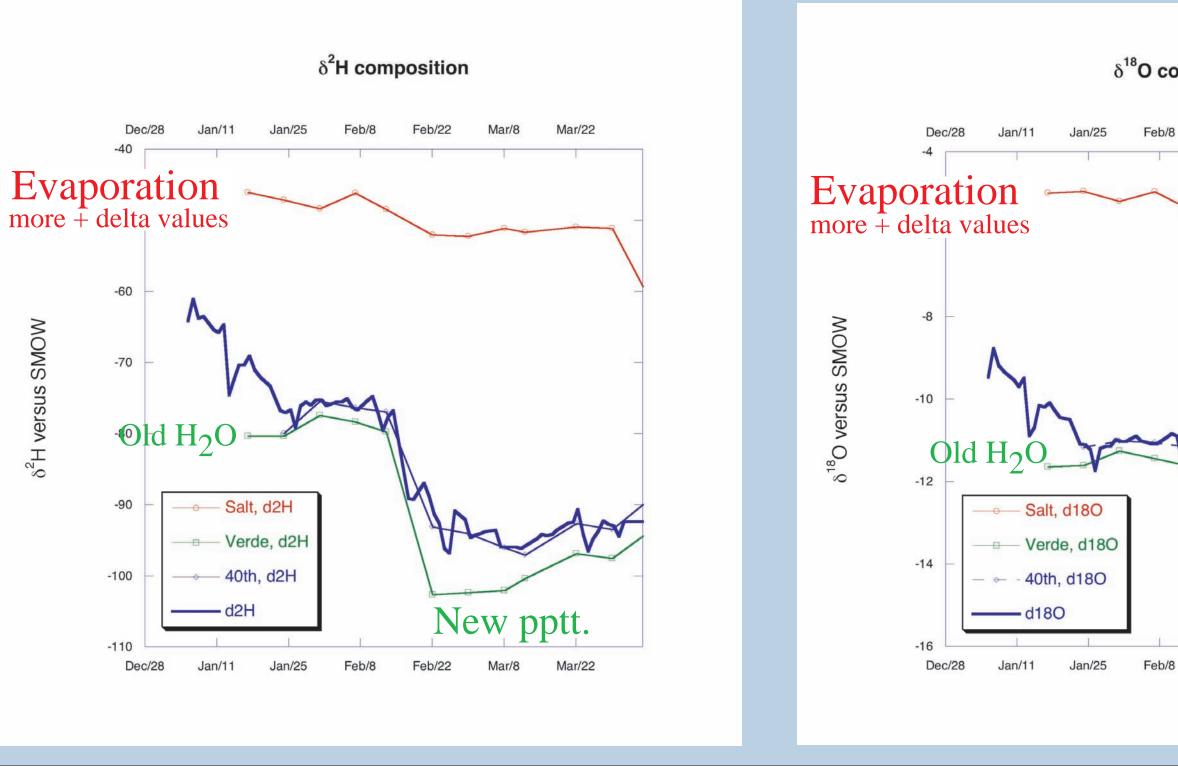
Use data gathered to answer 3 fundamental questions about management effects and solute transport:

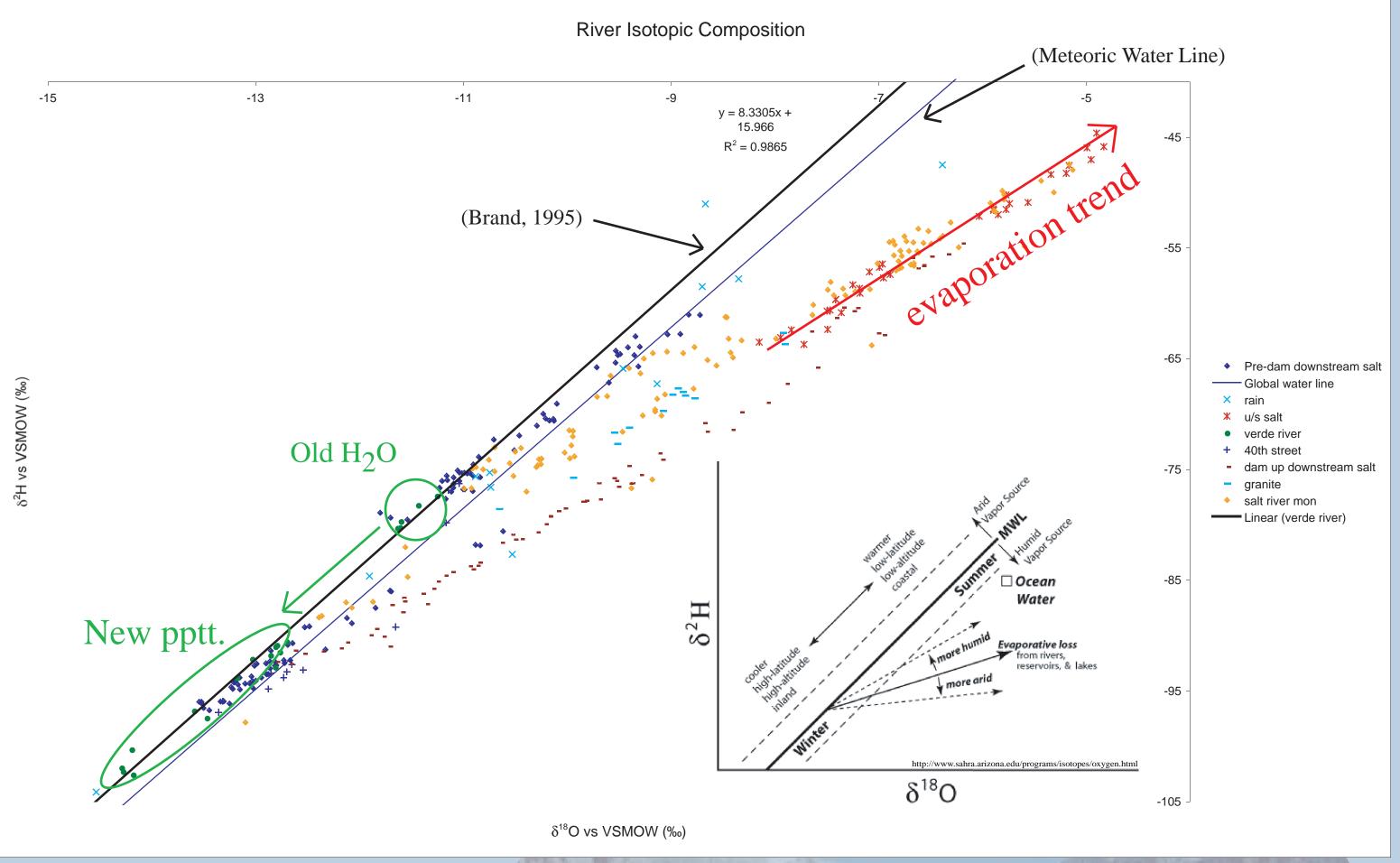
- 1. How do rain events affect solute transport within rivers in semi-arid regions, including river channels that are
- 2. How are natural mechanisms of solute transport during storms affected by management practices (human ecosystem interaction like dam release), which can be reflected in the changing chemical composition of these
- 3. Can unique anthropogenic signals generated in an urbanizing environment (e.g., trace element ratios) be detected as water moves into and through the study area?

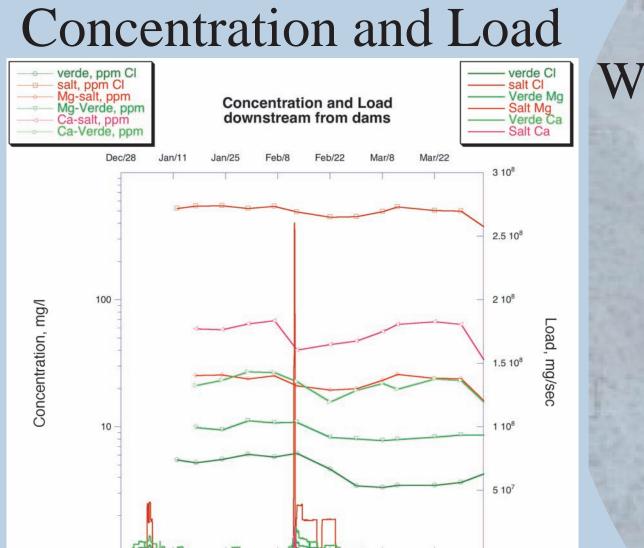
Water Management: Solution to population growth and arid climate



Consequences of Water Management: Isotope Hydrology







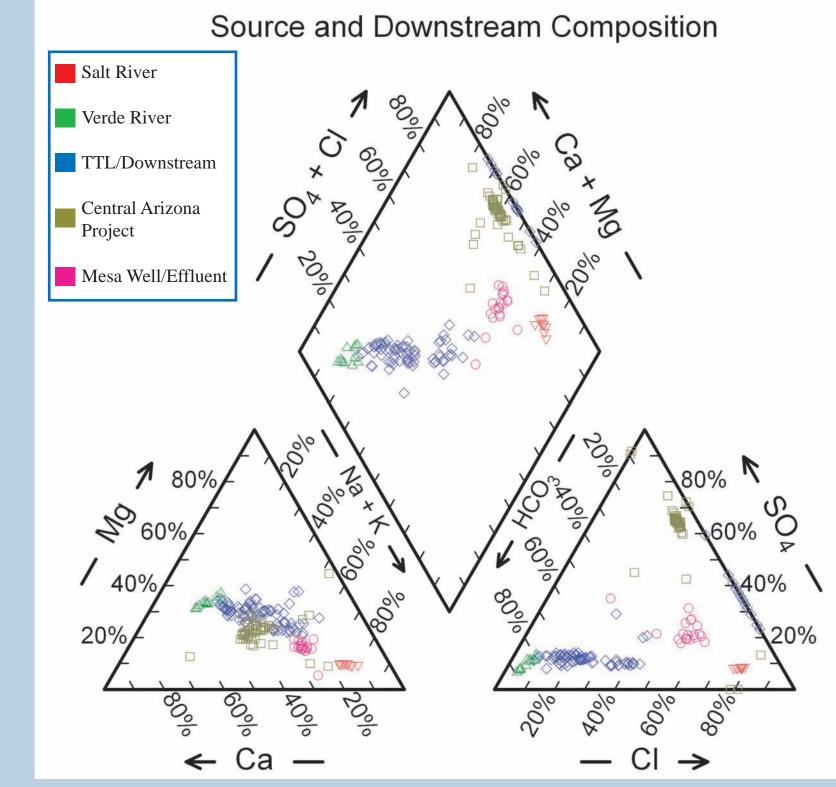
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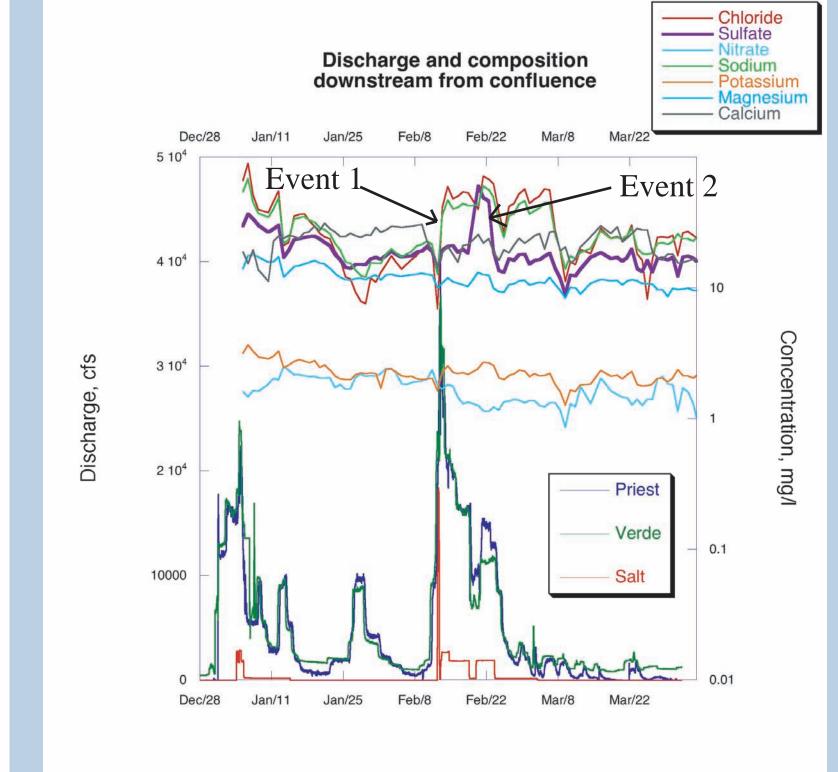
Water management acts to:

- o Disturb natural hydrologic input to rivers (see flat peaked hydrographs and hyetograph)
- o Stratify water in reservoirs isotopic evidence in shift from old to new precipitation along Verde (Brand, 1995), high turnover along Verde River, enhanced evaporation in Salt reservoirs from stagnation
- o Reduces loads (amount per time) to simple function of discharge, chemical concentrations fluctuate little downstream

Chemical Mixing: solute dynamics

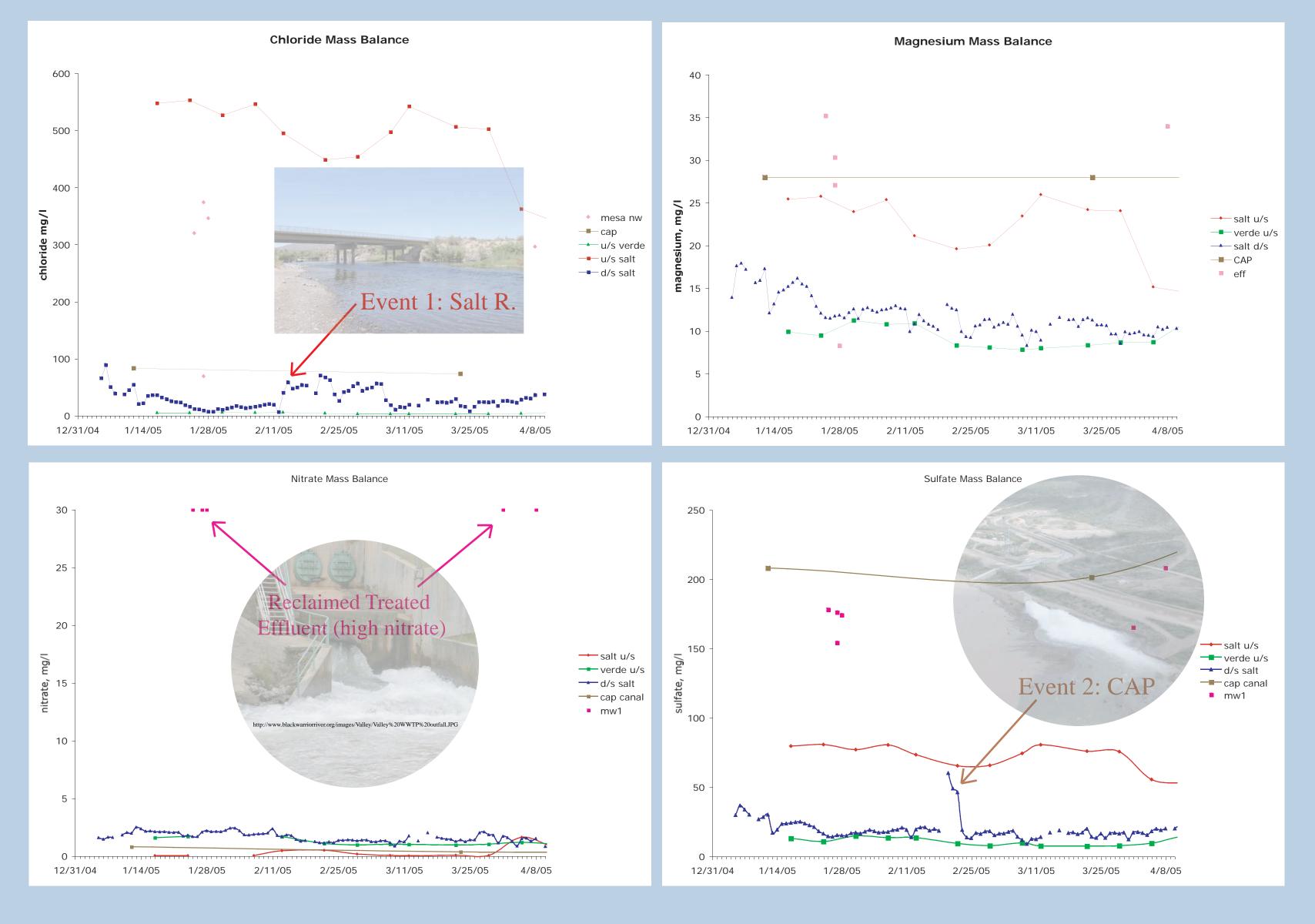
Mixing of water from two distinct sources drives dynamic changes in chemical composition downstream. Pulses in the loads of major ions from upstream dictate changes in ion concentrations downstream of the confluence with the Verde River (green) As an example, during event 1 chloride and sodium first respond to an increase in input of the Verde River water by decreasing in concentration, followed by a prolonged increase in concentration owing to Salt River input. However, during event 2 sulfate responds by increasing sharply while discharge is decreasing from both the Verde and Salt Rivers. This requires at least a third source of water.

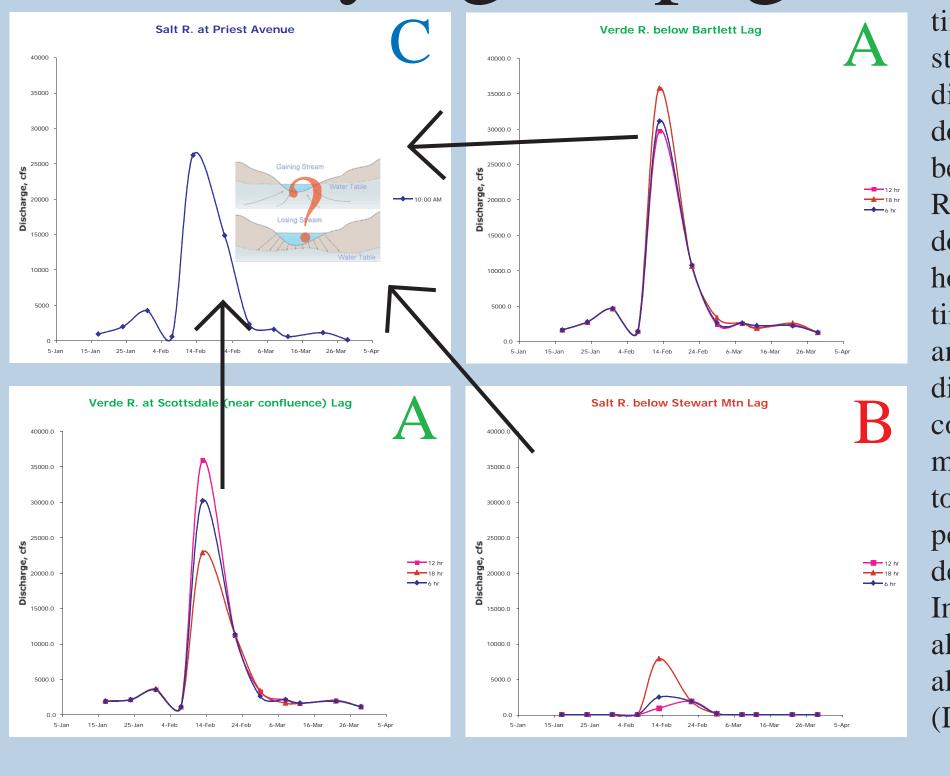




Source water composition and downstream mixing

Mass balance plots show concentrations in potential source waters over time. Cl- and Mg+2 can be fully explained by addition of Salt and Verde River water only. NO3- and SO4-2 will not balance with same ratio of water derived above and require additional inputs with different composition. SO4-2 concentrations in Colorado River water from canals (CAP, shown in brown) evacuated in mid-February shown as event 2 will explain high SO4-2 concentrations. Effluent from Mesa Northwest, a recharge facility, account for elevated NO3- downstream from confluence.





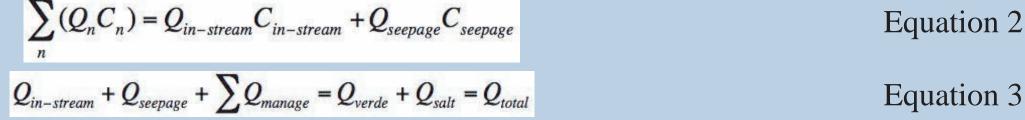
Instantaneous measurements of discharge at sampling locations could never balance because there is a travel stations. Using high resolution (15-minute) USGS lischarge data we tested three lag times to see if downstream discharge recorded at Priest Avenue could be explained by flood wave lag along the Verde and Salt Rivers. We calculated mean discharge (4-hours of data) downstream and mean discharge upstream 6, 12, & 18 hours before downstream record. Plots of discharge with time show that none of the upstream discharges, using any variation of lag time discharges, fully explains discharge downstream at Priest Ave. Discharge must be conserved between these sites. Changes in channel orphology can be disregarded as a possible explanation to the discharge imbalance because the volume of water per time will be preserved through acceleration and deceleration during dimension changes (Q=m*d*V). Infiltration through the channel bottom provides a likely alternative for balancing the discharge. The Salt River alluvium is capable of infiltration rates as high as 6m/day (Dahlen, 2000) from infiltration studies on recharge

Model Approach

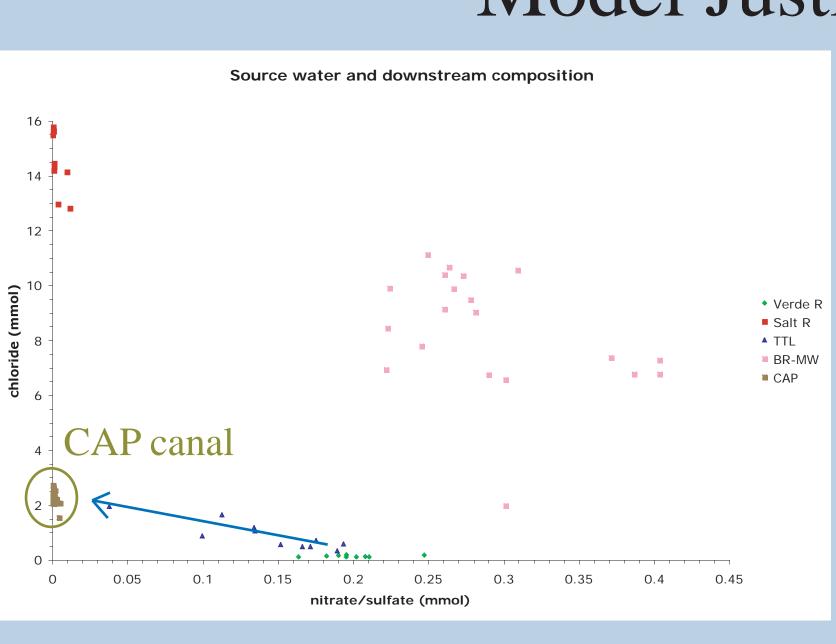
We start by attempting to balance major ion concentrations from the Salt and Verde Rivers measured weekly with downstream samples measured daily using minimal components and equations derived for binary or ternary mixing in natural rivers. This method is described by Eqn. (1) where n represents 1) groundwater or baseflow, 2) rainwater or direct flow, or 3) soil water as interflow included with three component mixing models. An underlying assumption is that total discharge is the sum of individual components. This approach often uses a limited number of constituents to solve the mass balance equation such as chloride concentrations or conductivity measurements.

$$(Q_n C_n) = Q_{in-stream} C_{in-stream}$$
 Equation 1

Next, include modifications from research to model managed river system response to storm events; here n represents Verde and Salt River flow, as well as various management components, which include known contributions from evacuated CAP water, Mesa Northwest effluent, possible stormwater drainage, etc. The equations below describe the managed model of stream water chemistry. The continuity, or mass balance equation (2), relates loads of dissolved solutes from individual components and now includes an infiltration component. The equations are iteratively solved using tracer source concentrations (nitrate and sulfate) to converge on potential discharges from various components. Equation 3 assumes water mass loss is equivalent to seepage during storm-related flows derived from reservoir release.



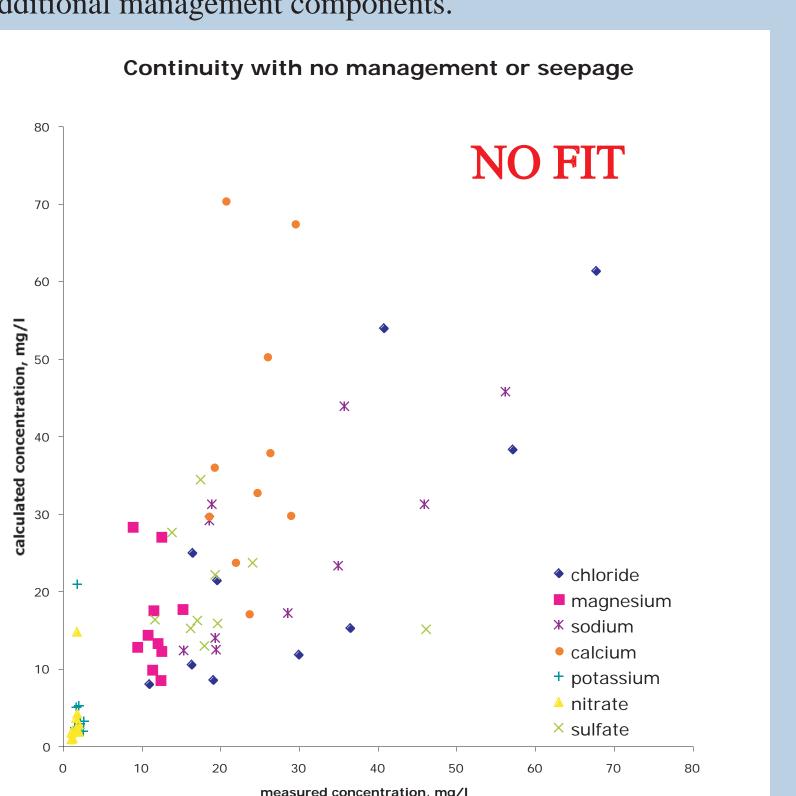


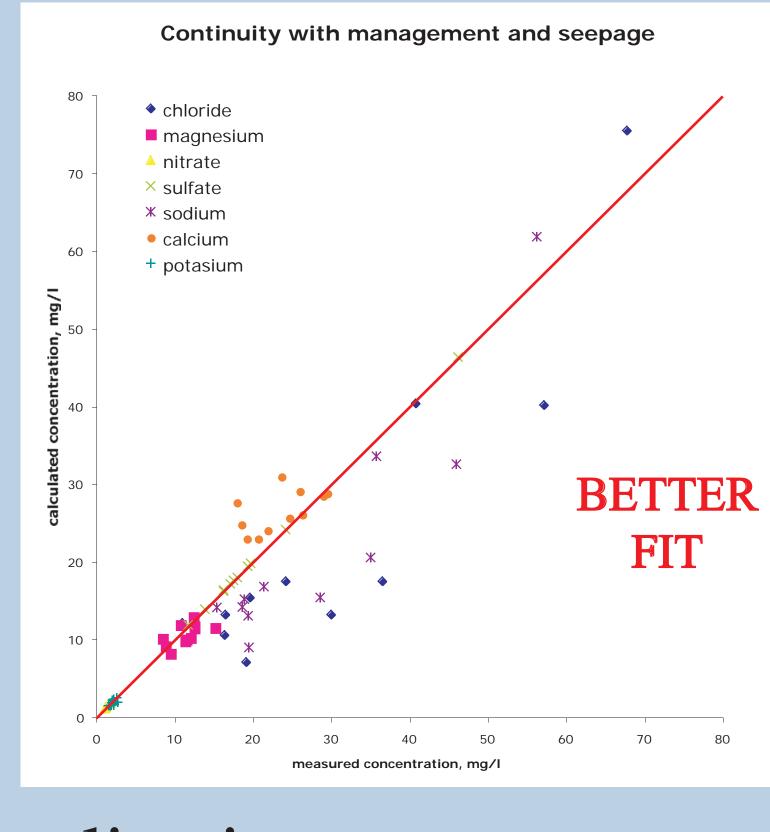


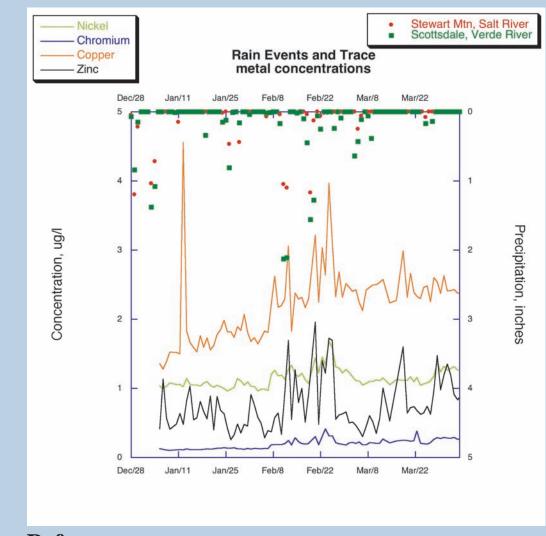
Component concentrations (shown at left) of chloride on the y-axis and the ratio of nitrate to sulfate on the x-axis show how the flood water composition changed as contributions from various sources mere managed. In addition to the evacuation event of CAP water during event 2, minor inclusions of CAP water are required to balance the continuity equations during non-discharge • Salt R periods as well. We hypothesize that recharge basins located just downstream from Granite Reef Diversion Dam that are normally filled with a mixture of CAP, Verde and Salt River waters were flushed during early storm events. This approach allows the resolution of two additional management components (CAP and BR-MW as shown here). The continuity equations in conjunction with the proper lag times then allow us to quantify the composition of seepage required to balance the solutes.

Model Results

The figure shown at bottom left shows measured concentrations of various major ions on the x-axis and calculated concentrations without seepage or managed inflows on the y-axis. Contrast this with the figure at bottom right which shows calculated concentrations from the seepage mass balance model with nitrate and sulfate concentrations constraining the additional management components.







Model Applications

Shown at left are the responses of Ni, Cr, Cu, and Zn to rain events in the Phoenix metro area. Spikes could indicate input from urban sources. We believe the anagement mixing model we have derived is capable of including trace metal loading from impervious surface runoff through storm drains during first flush conditions. These conditions will result in an urban fingerprint that can be used to study trace metal transport during storm events in a managed environment. The inclusion of a seepage component could have implications for trace metal loading into the shallow quifer and quantification of concentrations within that component. uture goals involve including these trace metals in the interative quantification of oncentrations from various components.

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Hooper R. and Christophersen, N., 1990. Modelling streamwater chemistry as a mixture of soilwater end-members - An application to the Panola Mountain Catchment,

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