Integrated Field Research Challenge
Rifle, Colorado

Floodplain-scale hydrological, isotopic and geochemical states and fluxes at DOE's Rifle Integrated Field Research Challenge site

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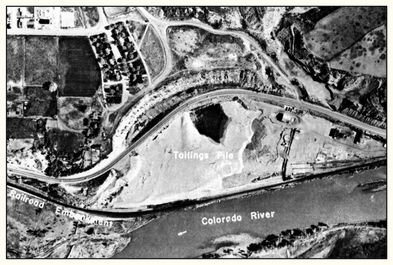
OVERVIEW, BACKGROUND & APPROACH

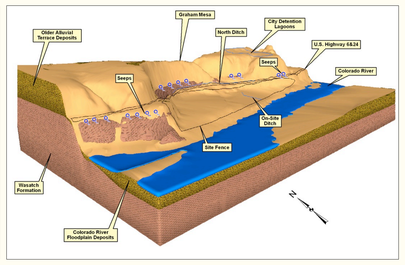
The overarching objective of this work is to assemble an inventory of geochemical and geophysical data that provides insight into transport processes at the Rifle IFRC site and their relation to surface water-groundwater interactions, aquifer heterogeneity, and uranium plume dynamics.

Initiated in December 2010, this work involves assembly of a spatially & temporally dense geochemical dataset through bi-weekly to monthly sampling of IFRC site groundwater and surface water (e.g. springs, seeps, and Colorado River). Geochemical constituents include:

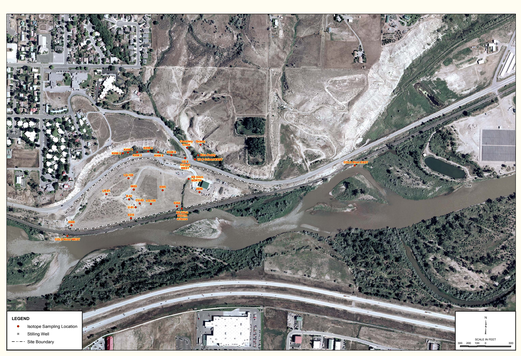
d^2H, $d^{18}O$, $d^{87}Sr$, $d^{34}S$-SO_4^{2-}, $^{234}U/^{238}U$, anions, cations & TIC/TOC

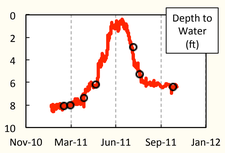
Geochemical data are being interpreted within the context of floodplain scale surface & borehole geophysical measurements, including electromagnetic (EM) induction, resistivity, and magnetic data. Through data synthesis, the intent is to develop a refined floodplain model that accounts for (a) influx of U bearing groundwater from off-site and (b) the role that subsurface heterogeneity and magnetic mineral fraction may play in impeding natural flushing of U.





Left: Historical image of Rifle IFRC site (ca. 1940) showing location of tailings pile, mill, and pond along northern site boundary. Right: Conceptual model of Rifle aquifer location relative to terrace gravels, detention lagoons, springs, seeps, and Colorado River (right; courtesy Dick Dayvault, S.M. Stoller).

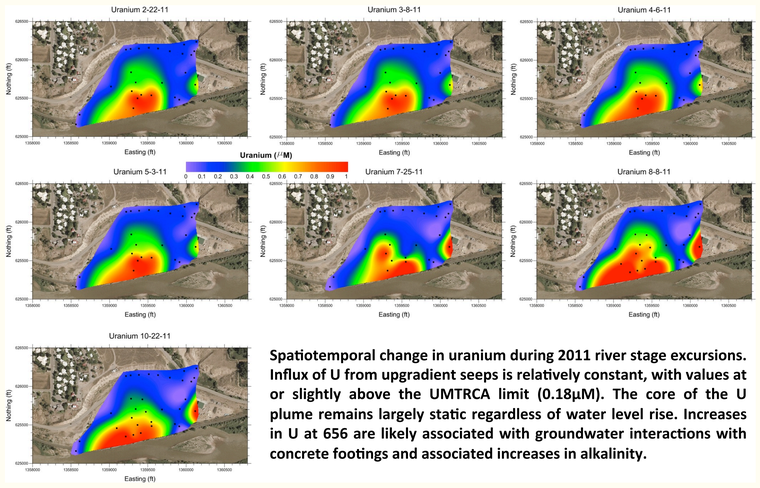




2011 Colorado River hydrograph upstream from Rifle site; contour plot dates shown as open symbols.

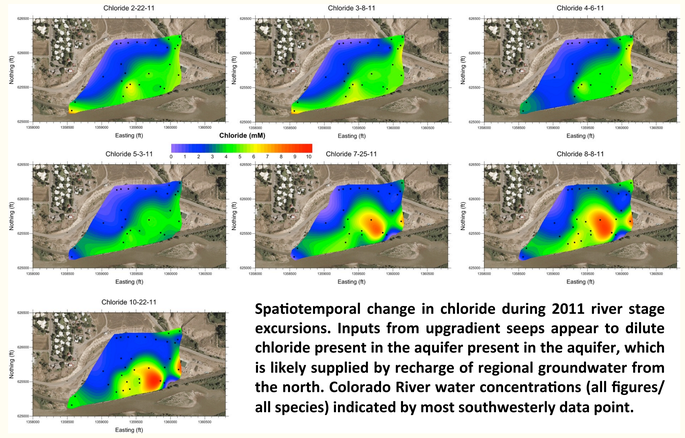
Aerial photograph of the Rifle IFRC site indicating groundwater and surface water sampling locations; river gauging station (0294) is located upriver and to the east. City of Rifle detention lagoons are atop the bluff to the northeast of the site and receive treated drinking water derived from the Colorado River.

GEOCHEMICAL RESULTS: Uranium

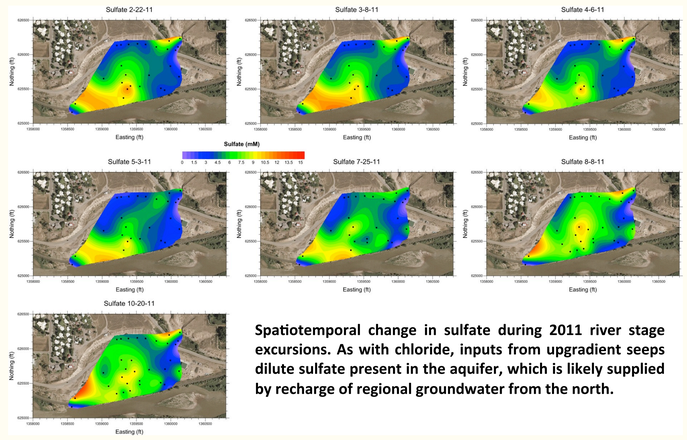


Spatiotemporal change in uranium during 2011 river stage excursions. Influx of U from upgradient seeps is relatively constant, with values at or slightly above the UMTRCA limit (0.18μM). The core of the U plume remains largely static regardless of water level rise. Increases in U at 656 are likely associated with groundwater interactions with concrete footings and associated increases in alkalinity.

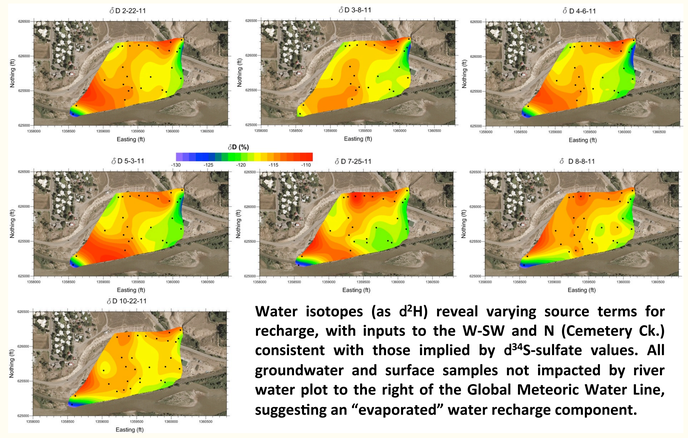
GEOCHEMICAL RESULTS: Anions and Isotopes



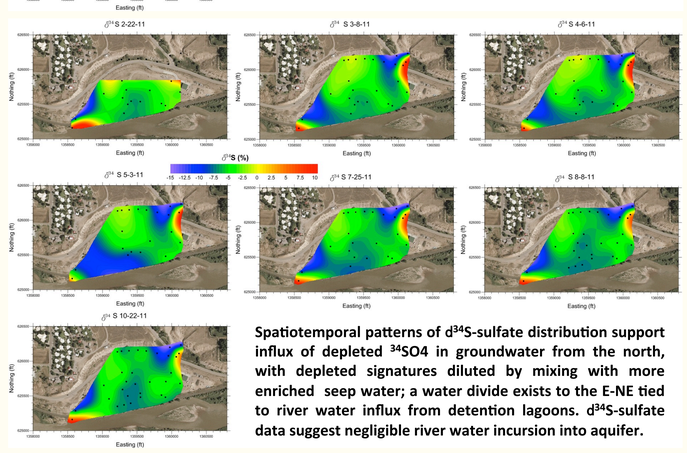
Spatiotemporal change in chloride during 2011 river stage excursions. Inputs from upgradient seeps appear to dilute chloride present in the aquifer present in the aquifer, which is likely supplied by recharge of regional groundwater from the north. Colorado River water concentrations (all figures/ all species) indicated by most southwesterly data point.



Spatiotemporal change in sulfate during 2011 river stage excursions. As with chloride, inputs from upgradient seeps dilute sulfate present in the aquifer, which is likely supplied by recharge of regional groundwater from the north.

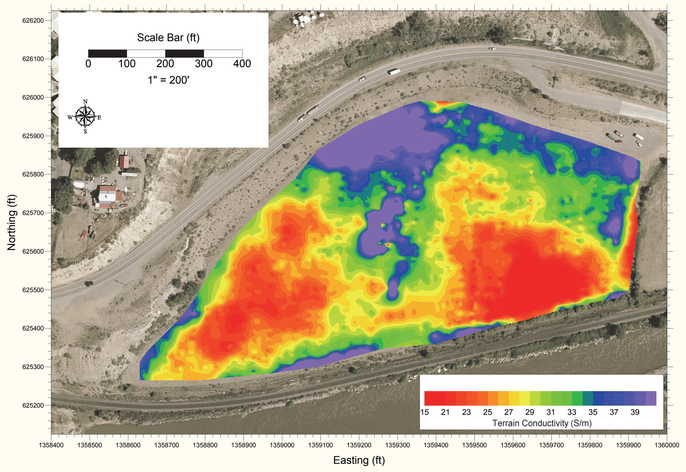


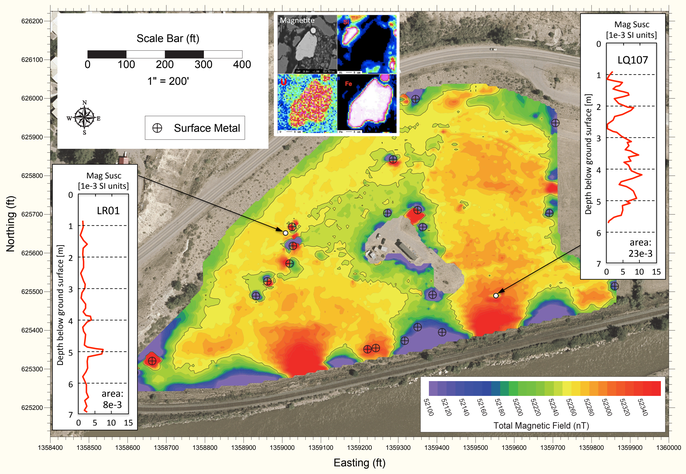
Water isotopes (as d^2H) reveal varying source terms for recharge, with inputs to the W-SW and N (Cemetery Ck.) consistent with those implied by $d^{34}S$-sulfate values. All groundwater and surface samples not impacted by river water plot to the right of the Global Meteoric Water Line, suggesting an "evaporated" water recharge component.



Spatiotemporal patterns of $d^{34}S$-sulfate distribution support influx of depleted $^{34}SO4$ in groundwater from the north, with depleted signatures diluted by mixing with more enriched seep water; a water divide exists to the E-NE tied to river water influx from detention lagoons. $d^{34}S$-sulfate data suggest negligible river water incursion into aquifer.

GEOPHYSICAL RESULTS: EM and Magnetics





Geophysical data collected across the Rifle floodplain. Upper: EM results consist of short coil spacing data with higher electrical conductivity (EC; S/m) values inferred to result from spring/seep inputs along the northern boundary and resultant increases in vadose zone moisture content; similar elevated EC values are observed along the SW corner, perhaps related to seep input associated with depleted $d^{34}S$ and enriched d^2H & $d^{18}O$ values in the same area. Lower: Magnetic data reveal areas of elevated magnetic mineral fraction, as evidenced by two distinct anomalies along the S boundary of the site; where indicated, surface metal (e.g. pin flags, metal casing, buried utilities) impacted the magnetometer readings. Borehole magnetic susceptibility data collected at LR01 and LQ107 are shown as constraints, with LQ107 co-located with a surface magnetic anomaly. Regions with elevated magnetic mineral fraction may constitute areas of preferential U retention due to adsorption onto magnetite; inset: 170ppm U associated with detrital magnetite grain (Qafoku and Kukkadapu, unpublished data).

FUTURE DIRECTIONS

- **Finalize analysis of additional parameters: TIC/TOC, cations, $d^{87}Sr$, and $^{234}U/^{238}U$**
- **Continue bi-weekly/monthly sampling [*near term*]**
- **Acquire additional time-lapse surface EM data and additional borehole EM and magnetic susceptibility data in floodplain boreholes [*near term*]**
- **Incorporate geochemical and geophysical data into floodplain-scale hydrological model for the Rifle IFRC site; use approach as template for coupled characterization-modeling effort for future site(s) of interest to the SFA [*long term*]**
- **Test impact of variable natural processes on contaminant plume dynamics (e.g. aquifer oxidation, elevated seep input, biogeochemical cycling) [*long term*]**
- **Develop generalized, coupled biogeochemical-hydrological subsurface models that honor floodplain-scale states and fluxes [*long term*]**

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