Blair Wallis -- The Only Mountain Hydrology Research Well Field in the US

The University of Wyoming Blair Wallis Fractured Rock Research Site in Buford, Wyoming, which lies within the Laramie Range, is unique in the country, as it will yield new knowledge into mountain hydrology via the integration of wellbore aquifer characterization techniques with a variety of non-invasive geophysical measurements. To our knowledge, Blair Wallis well field is the only research well field in the US devoted to investigating mountain groundwater hydrology.

Securing sustainable water supply has always been a bottleneck in the development of arid and semiarid lands in the western US. According to the City of Cheyenne’s 2013 Water and Wastewater Master Plans, water demand for the Cheyenne area is projected to increase by 87 percent by 2063. The well field development project in Belvoir Ranch, which lies downstream from the Laramie Range, will exploit groundwater from the Casper Aquifer as a source of municipal water supply. Groundwater in this aquifer is primarily sourced from snowmelts and runoffs from the Laramie Range. However, the location, timing, pathway, and magnitude of this recharge to the aquifer remain poorly understood. In addition to recharge from surficial sources, mountain block recharge (MBR) via subsurface pathways has been proposed as an important mechanism of water supply into basin fill aquifers (Williams, et. al, 2004; also see figure). Research into aquifer characteristics and hydraulic properties at Blair Wallis will contribute to our understanding of MBR for the Casper aquifer and insights gained will be applicable to developing successful management strategies for similar aquifer systems in Wyoming and the western US.

During Fall, 2015, a series of single- and cross-hole hydraulic tests was carried out aiming to estimate aquifer bulk parameters at the wellbore locations (BW1 to BW5). Results are reported in this link: http://geofaculty.uwyo.edu/yzhang/files/Summary_HydraulicTests.pdf Overall, the fractured granite at Blair is capable of yielding significant quantities of freshwater, suggesting an important resource. The aquifer appears strongly heterogeneous, with the slug- and pumping-test derived horizontal hydraulic conductivity ($K_H$) ranging over 3 orders of magnitude ($10^{-4}$ to $10^{-6}$ cm/s).

During Fall, 2016, new drilling and testing have identified cross-hole hydraulic communications during step testing of BW6 (10/24/2016—10/25/2016; see below hydrographs of BW1 and BW7). And, also during the drilling and airlift development of BW9 and BW8 (11/20/2016—12/5/2016; see below hydrographs of BW7). With cross-hole data, we can estimate additional aquifer properties such as hydraulic diffusivity and storativity.
Airlift development for 1 hour consisted of blowing out the hole at 20 main intervals three times. For both BW9 and BW8, borehole water came up clean each time.
Moreover, downhole hydraulic profiling by FLUTe yields additional information of high resolution $K_H$, which suggests that bedrock fractures are responsible for most of the water yield from the wells tested. $K_H$ of discrete fractures is often 1 to 2 orders of magnitude higher than those derived from slug and pumping tests, suggesting “scale effect” due to the different sampling volumes tested (see below FLUTe profiling results). Importantly, traditional well tests cannot reveal detailed heterogeneity in the subsurface, in particular, the location of high-$K$ preferential flow paths. New aquifer characterization technology is needed, combining high resolution $K_H$ imaged at borehole locations with geophysical logging and advanced numerical aquifer inversion techniques.

New Research

New research is being proposed to carry out hydraulic tomography (HT), a new technology to characterize aquifer heterogeneity at high resolution and to quantify the estimation uncertainty. To our knowledge, there have only been 2 reported applications of HT to characterize fractured aquifers:

- Mizunami Underground Research Site in central Japan: sedimentary rock overlying granite; Depth of the wells ranges from 100 m to 1300 m (Illman et al., 2009, WRR);
- Plattsburgh in New York: a single horizontal bedding plane fracture in a sandstone formation. Depth of the wells ~12 m (Castagna et al., 2011, WRR).

Neither sites lie in mountain environments where hydrology is dominated by snow and groundwater contribution to the water budget is virtually unknown. Though extensive hydrogeophysical research was carried out at the USGS Mirror Lake fractured rock research site in New Hampshire, there is no longer activity there on aquifer characterization in the last decade or so.

After HT is carried out, our next objective is to integrate aquifer characterization with geophysical measurements to look at the mountain hydrology at larger (i.e., away from the well field) scales to derive water balance estimates useful for water management purposes. See below diagram of the proposed research.
Improved subsurface characterization for integrated water balance modeling at the watershed scale

(1) Interpret steady-state and transient well hydraulic data to characterize multiscale $K$ of the fractured aquifer at the Blair Wallis (BW) fractured rock research site; One idea is to do HT (right) in addition to traditional well tests.

(2) Investigations by the geophysics team: subsurface and/or downhole geophysical properties (seismic, resistivity, NMR, GPR, magnetic, gravity) obtained at the same site at multiple scales;

(3) Explore correlations & develop petrophysical relations at multiple scales for (1) loose surficial deposit, (2) granitic matrix, (3) fractures;

(4) Apply the petrophysical relations to obtain watershed-scale K field (away from the wells) at BW where geophysical data provide spatial coverage.

(5) Integrated modeling at the watershed scale in Blair Wallis to quantify sw/gw interaction, including water balance, fluxes, and rate.

(6) Petrophysical relations: site-specific to BW or generally applicable to other granitic aquifers? Test this idea at the NoName watershed in the Snowy Range (with no boreholes) by converting appropriate geophysical properties to K and evaluate if performance of the integrated model will be improved.

References:

