Crown of the Continent Hydrologic Observatory (CCHO)

Controls on Snow-melt Driven River Systems: Consequences of Drought and Climate Change on Spatial and Temporal Hypothetic Exchange Rates.

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Introduction

The effects of climate variation on headwater river basins cause a complex hydrologic response. It is anticipated that watersheds in which streams are dominated by snow melt are especially vulnerable to human and climatic perturbations. Such headwater rivers in the drier western United States (and throughout the North American and South American Cordillera) are likely to be extremely sensitive to subtle basin alterations as basin flow modification and storage capacities are dominated by winter snow accumulation, the magnitude of hyporheic exchange and groundwater storage. The annual discharge of western U.S. rivers currently attributed to snow ranges from 40-75%. This water underpins a number of river and basin components including ecosystems, municipal and agricultural water supplies, aquifer recharge, flushing flows, and stream quality including temperature control. Thus, such systems provide researchers an opportunity to examine how alterations, both anthropogenic and natural, to snow and precipitation volume and timing translate to basin water yields and the duration and magnitude of stream discharge. However, our ability to measure, interpolate and extrapolate basin data sets across large time and space scales is severely hampered, in part, by our poor understanding of how hyporheic exchange moderates stream flows, changes during short and longer term climatic variations, and underpins ecological systems. A portion of our work examines this issue by applying first principle analyses to floodplain systems by deciphering sedimentary architecture that underpins hyporheic exchange rates and sites at local and floodplain scales. We propose to use geophysical techniques combined with small scale sedimentological and hydrological characterization methods to identify key controlling hyporheic exchange in snow dominated headwater river systems

The exchange between a river channel and the subsurface water of its associated bars and floodplain underpins riparian and subsurface ecological systems, and modifies stream channel environments (Stanford and Ward, 1993; Wondsell and Swanson, 1996; Jones and Holmes, 1996; Brunke and Gonser, 1997; Boulton *et al.*, 1998; Woessner, 2000; Malard *et al.*, 2002). The maintenance of healthy river systems and restoration of channels and floodplains requires a clear understanding of the locations, extents and rates of water transport, and associated chemical constituents and biological assemblages (Anderson and Caissie, 2003; Gooseff et al., 2005; Harvey and Bencala, 1993). Hyporheic zones have been recognized as components of river systems that moderate water temperatures, cycle nutrients and house complex biological communities (Ellis *et al*., 2000; Constanz, 1998; Huggenberger *et al*., 1998; Hendricks, 1993; Harvey and Bencala, 1993).

In gravel-dominated braided river deposits, the character of the hyporheic zone is poorly understood because traditional sediment sampling and characterization methods are hampered by the coarse-grained nature of the deposits and shallow water table (Bridge *et al*., 2000). It is extremely difficult to characterize alluvial sediments because of their loose, friable nature and because of the difficulties presented in obtaining spatially representative samples, particularly below the water table (Anderson *et al*, 1999). This lack of site specific data is compounded by the known complex architecture of braided bar sediments (Ritzi et al., 2004; Lunt et al., 2004). Assessment using surface geophysical techniques to image sediment package characteristics looks promising (Daily et al., 1992; Gawthorpe *et al*., 1993; Bridge *et al.*, 1995; Davis and Annan, 1989; Beres and Haeni, 1991; Westaway *et al*., 2001; Huggenberger, 1993; Hyndman and Gorelick, 1996; Becht *et al*., 2003). In some braided river settings, macroinvertibrates have been found in portions of the hyporheic zone located from 10's to 100's of meters from the point in the stream channel where they were laid as eggs (Stanford et al, 1974, 1994, 1999). Such observations suggest that preferential flow networks, most likely composed of patches of interconnected open frame-work gravels, extend over large portions of the floodplain, and are important avenues for hyporheic exchange. In addition of the need to establish hyporheic flow paths, subsurface ecological system processes including how hyporheic food chains function are unknown. The focus of this work is to characterize how gravel dominated braided river deposits influence and control the spatial and temporal locations and rates of hyporheic exchange at multiple scales.

Geophysical survey design

Current ongoing research at the sites is aimed at characterizing the subsurface using numerous techniques, including borehole testing, water chemistry, and natural tracers. The goal of this characterization is an improved understanding of groundwater – surface water interactions within these alluvial valleys at a range of scales. The majority of these techniques are based on point source measurements, which is a limiting factor in this typically very heterogeneous environment. The aim of the geophysical surveying is to fill in these gaps, producing an essentially continuous detailed characterization of the subsurface. For the summer our efforts will be concentrated at two areas, Movie Bar and Wally Spring, within the Nyack Floodplain research site.

Through integration of the geophysical data collected with detailed measurements of hydrological parameters we envisage improving the spatial understanding of variations in permeability of the alluvial sediments making up the floodplain. This would enable improved constraints on hydrogeological models of this floodplain and aid the understanding of groundwater – river interactions.

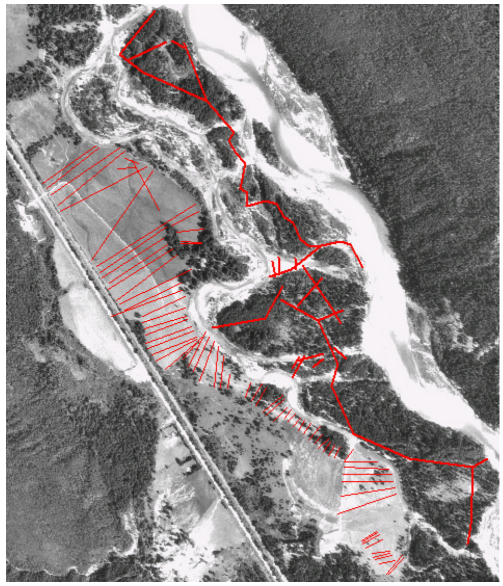

Figure 1. Aerial photograph of the Nyack Floodplain illustrating the numerous GPR transects collected (red lines).

Proposed dates for this survey are at present between 29th July 2007 and 25th August 2007. This will ensure that we miss the peak flows in the river and the associated potential for flooding.

There have been a number of previous geophysical surveys conducted at various locations on the Nyack Floodplain research site. A variety of different techniques, including gravity, ground-penetrating radar (GPR) and electrical resistivity imaging (ERI), were applied to different research issues, including modeling depth to bedrock and various subsurface characterization studies. Of particular relevance to our aims are the GPR surveys interested in the detection of preferential groundwater flow paths. These flow paths were thought to be related to palaeochannels within the floodplain sediments acting as high permeability subsurface hydraulic corridors. A large number of transects of GPR data were collected over these various studies (figure 1).

Although the results from these surveys were inconclusive in identifying the presence of these palaeochannels (figure 2), it allows us a much improved understanding of the viability of the various geophysical techniques at these sites.

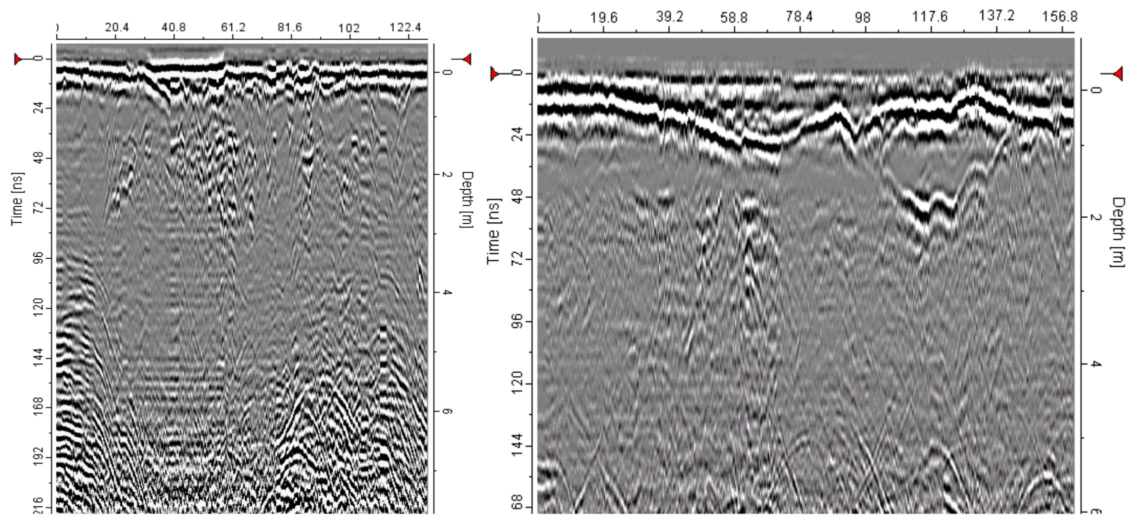

Figure 2. Example radargrams from previous studies on the Nyack Floodplain.

We propose to use several different methods in conjunction to characterize the subsurface. A preliminary survey consisting of the electromagnetic induction technique will be conducted at both sites. Data collected using this technique is quick to acquire making it a very useful reconnaissance tool. This makes it ideal for identifying any potential interesting areas to later survey in more detail with additional techniques, or locations to avoid with certain techniques.

Surface and borehole electrical resistivity imaging and tomography will be used to conduct high resolution subsurface characterization. In the first instance a series of test surveys will be conducted, using 2D configurations of surface imaging and cross-borehole tomography, in the vicinity of a sample of the wells. The wells will provide high resolution well testing and logging information, including hydraulic conductivity, borehole video that has been previously collected. This will enable a detailed characterization of the geophysical response collected and allow an optimization of the acquisition configurations.

Once this detailed testing is complete the aim will be to expand the characterization to further wells, through a series of 2D and 3D surveys. These surveys will consist of a combination of cross-borehole tomography and surface imaging configurations. Access is available to most of the wells at each site, and since they are slotted along there entire length no additional modifications are needed. We will construct a number of electrode strings for this purpose which can simply be lowered down into the well. The University of Montana posses the ability to drill and install additional wells as required using a geoprobe system.

In addition we aim to conduct parallel acquisition of cross-borehole ground penetrating radar. Initial surveys will test the viability of this technique in these sediments. Whilst the previous surface surveys were inconclusive, geological logs from several wells indicate clay rich layer is present in the near surface across the sites. This would explain the severe signal attenuation seen in figure 2. By using the cross-borehole configuration we hope to bypass this near surface layer and the associated attenuation.

Another research focus of the group is on the contribution of glacial ice to runoff and groundwater recharge. This work is conduced by Joel Harper and his group on the glaciers of Glacier National Park. If weather conditions allows during the visit, we also aim to conduct a preliminary survey on the Sperry glacier. The goals of this survey would be twofold; to map the thickness of ice using ground penetrating radar and also provide informal hands-on training for Joel Harpers grad students. This would be a short exploratory survey conducted if conditions and logistics dictate during the planned work on the Nyack Floodplain.

Infrastructure

There a large number of wells presently installed at the sites of interest, these can provide ground truthing for the geophysical surveys, including geological logs and recording of depth to the water table. In addition high resolution borehole testing has been conducted in many of these wells, providing records of the hydraulic conductivity, flow velocity and down hole temperature variations.

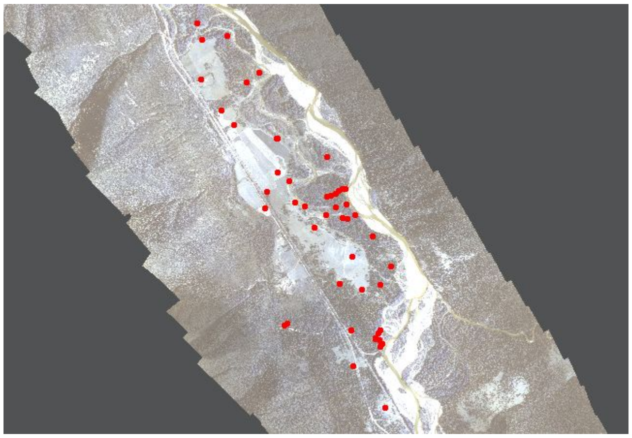

Figure 3. Aerial photograph of the Nyack Floodplain, a selection of the available observation wells (red dots) are overlain.

Borehole video logs are available from a number of wells, through the use of transparent well casings. University of Montana posses a geoprobe system capable of installing further wells if necessary.

Budgets

We would be out in the field for a total of 28 days, this includes 2 days travel, 1 day to set up and 1 day to pack away, and 24 days on site to carry out the surveys (includes 3 days spare for downtime, etc.).

The plan is to use a rental vehicle to drive up to the research site in Montana, taking all the needed equipment with us. Accommodation has been offered for the weekday portion of the field work in a research cabin at the Nyack floodplain research site. All remaining accommodation would be found in the nearby town of West Glacier, approximately 15 miles north of the research site. In addition to the usual consumables costs, we are requesting funds to cover the cost of constructing the electrode cables to be used in the borehole surveys.

On-site support provided by University of Montana

We are receiving on-site support in several ways, including;

- Personnel to assist with the acquisition of the geophysical data are being provided for the duration of the proposed field work.
- Accommodation in the form of space in a cabin (during weekdays) has been provided free of charge for the duration of the proposed fieldwork. This is located in close proximity to the field site.
- University of Montana are equipped to drill shallow wells in the floodplain and are willing to install additional monitoring wells if required by the geophysical surveys.

Additional costs

		Unit price	**Taxes & extras**	**Total price**
TRANSPORTATION				
Rental Car	30 days rental Intermediate sized SUV Includes LDW and supplementary liability insurance	$2600.00	$150.00	$2750.00
Fuel Charge	Includes a round trip to research site (2700 miles) and assuming 30 miles per day, vehicle running at 18 mpg, and a fuel price of $3.00 per gallon.	$600.00	included	$600.00
ACCOMMODATION				
Hotel	11 nights stay (@ $100 per night) Motel – West Glacier	$1100.00	$110.00	$1210.00
	4 nights stay (@ $80 per night) Motel – on route to and from research site	$320.00	$32.00	$352.00
Subsidence	30 days @ $38 per day	$1140.00	included	$1140.00
CONSUMABLES				
	Includes: replacing batteries in each system, cover any minor breakages (cables and connectors for example), on site purchase of tools, etc.	$300.00	included	$300.00
Borehole resistivity cable construction	Stainless steel mesh electrode material 18 AWG hook-up wire (1000 ft reel x 2) Connectors (x 100) Adaptor box construction (x 2)	$375.00 $240.00 $100.00 $200.00	$40.00 $34.00 $15.00 $30.00	$415.00 $234.00 $115.00 $230.00
GRAND TOTAL				**$7346.00**

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