Expanded Stream Gauging Includes Groundwater Data and Trends

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Population growth has increased water scarcity to the point that documenting current amounts of worldwide water resources is now as critical as any data collection in the Earth sciences. As a key element of this data collection, stream gauges yield continuous hydrologic information and document long-term trends, recording high-frequency hydrologic information over decadal to centennial time frames.

The U.S. Geological Survey (USGS) has been providing this type of hydrologic information since the 1880s and over the years has expanded its infrastructure to the current total of more than 7000 gauges. Meanwhile, over the past quarter century, there has been a gathering recognition that streams and groundwater are a single linked resource and need to be considered together when assessing water availability in terms of management issues such as irrigation, recreation, wildlife, and overall ecology of watersheds. Fortunately, the robust nature of the USGS stream gauging network provides a reliable infrastructure to link monitored wells to existing stream gauges to observe and study the coupling of stream and groundwater resources.

To evaluate this type of compound data collection, USGS and the U.S. Army Corps of Engineers (ACE) funded a groundwater stream gauge pilot study that coupled groundwater data and active stream gauges to record both groundwater elevations and temperatures as well as stream elevations and temperatures and to provide both real-time availability and archival trends of these key environmental parameters. Additionally, advanced analysis using thermal tracing [see *Constantz*, 2008] of the four-parameter suite can provide estimates of stream exchanges with groundwater. The newly released pilot study [*Eddy-Miller et al.*, 2012] describes the successful implementation of this upgrade of USGS stream gauges as well as site-specific findings applicable to water management, hazard reduction, fishery habitat, and general watershed ecology over a diverse geographic range.

Prototypes for Linking Stream Gauge Data to Well Observations

Prototype sites for concurrent groundwater and stream monitoring were established in July 2005, when continuous groundwater temperature monitoring was added to ongoing surface water monitoring at existing USGS stream gauges on Fish Creek in Wyoming and the Bogue Phalia in Mississippi.

Just a month after temperature monitoring began at the Bogue Phalia stream gauge, Hurricane Katrina caused an onshore surge in streamflows that resulted in dramatic hydraulic and thermal responses (Figure 1) due to rapid water exchanges between surface water in streams and groundwater [*Barlow and Coupe*, 2009]. Thermal tracer analysis of the results yielded invaluable hydraulic parameters for characterizing stream exchanges along the Bogue Phalia, with the potential for spatial upscaling data to extrapolate a model of regional groundwater spatial distribution. Although hurricane destruction was immense and its tragic aftermath is still ongoing, the fortuitous capture of storm-induced exchanges between surface water and groundwater provided the impetus for a broader examination of the value of continuous groundwater monitoring at existing USGS stream gauges.

Meanwhile, at Fish Creek in Wyoming, an upgrade allowed both temperature and water elevation data from an observation well to be transmitted to an existing USGS stream gauge, thus establishing the first linked USGS groundwater stream gauge system that transmitted the four-parameter suite of stream and groundwater elevations and temperatures. This upgraded stream gauge provided conclusive data demonstrating the potential of a network of groundwater stream gauges.

Pilot Study

Building on these initial successes, USGS and ACE funded a 2-year pilot study at seven sites to collocate observation wells for water level and temperature with USGS stream gauges in Mississippi, Montana, and Wyoming to evaluate the cost, reliability, and benefit of groundwater stream gauges over a range of hydrologic conditions.

For the pilot study, groundwater stream gauges (Figure 2a) were designed to provide provisional stream stage, stream temperature, groundwater elevation, and groundwater temperature at a 15-minute frequency to be uploaded to satellite several times a day. Existing USGS stream gauges in alluvial settings were selected for installation of adjacent groundwater observation wells. Beyond well installation costs, additional field costs compared with existing stream gauges are minimal since routine site visits occur anyway per USGS protocol. Increased costs are mostly related to additional parameter quality assurance and control analysis, which occur back in USGS Water Science Centers.

Over the duration of the pilot study, October 2009 through October 2011, stream and adjacent groundwater elevation and temperature data were acquired and continuously transmitted to a satellite from the seven sites spread over nearly 2000 miles (3200 kilometers) and were made available to the public in graph form within hours via the online USGS water information portal (http://waterdata.usgs.gov/nwis). This near–real time availability allowed comparisons with other time-sensitive near-stream activities

For example, real-time stream and groundwater information from the Big Hole River in southwestern Montana (Figure 2b), augmented by rancher flood irrigation schedules, reveals a clear correlation between the irrigation schedule and the rise in water table at the near-stream well as water from irrigation seeped into the ground and flowed past to discharge into the Big Hole River. This rise was seen with each irrigation cycle.

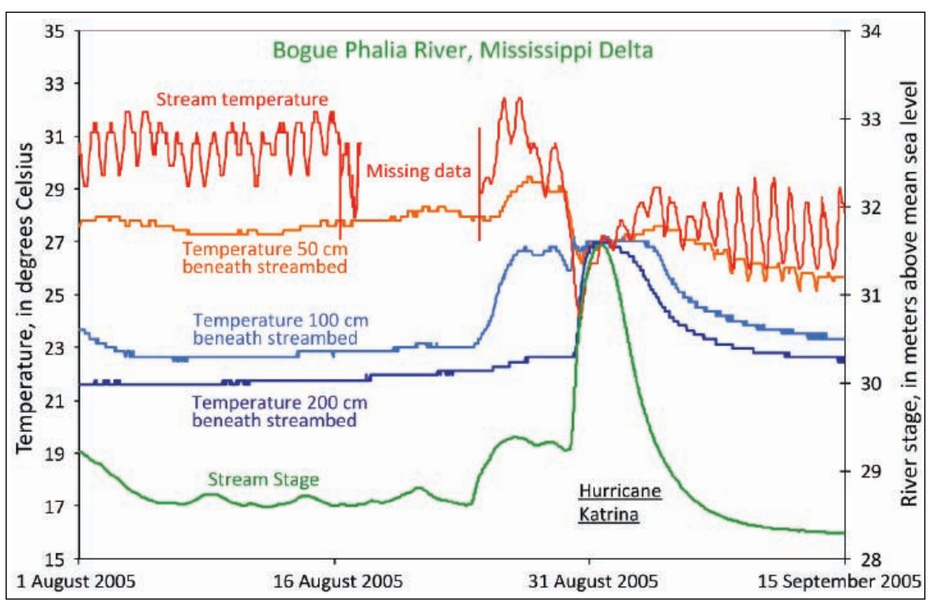

Fig. 1. Combination data for stream stage (i.e., stream surface elevation), stream temperature, and groundwater temperature at the temperature-enhanced U.S. Geological Survey stream gauge on the Bogue Phalia in Mississippi.

Using Coupled Data

In the example of irrigation trends in Montana, continuous logging provided both four-parameter real-time data display and seasonal trends, while the "irrigation spikes" provided opportunities to refine best practices in water management beneficial to local ranchers who could use knowledge of increased water influx to conserve both water and fertilizer use as well as reduce the potential excess of either from reaching the Big Hole River. Such information could also potentially help improve water quality and fishery habitat in the future, with better management of timing of fertilizer application in conjunction with irrigations scheduling.

Beyond successful real-time and long-term data collection at all seven pilot sites, correlations between stream water elevation and groundwater elevation permitted reconstruction of surface water elevation data when surface water measurements were occasionally disrupted by adverse surface conditions. Other site-specific results for other pilot Wyoming and Mississippi sites include timely information on ice hazards by analyzing thermal patterns and the suitability of fish streambed habitats by analyzing groundwater discharge patterns implied by the difference in stream and near-stream groundwater levels.

Collecting the four-parameter suite at all seven groundwater stream gauges can also potentially provide enhanced hydraulic parameter estimates, thereby reducing uncertainty in regional groundwater models. USGS Fact Sheet 2012-3054 [*Eddy-Miller et al.*, 2012] summarizes project results and lists an array of potential applications for future continuous groundwater stream gauging stations elsewhere.

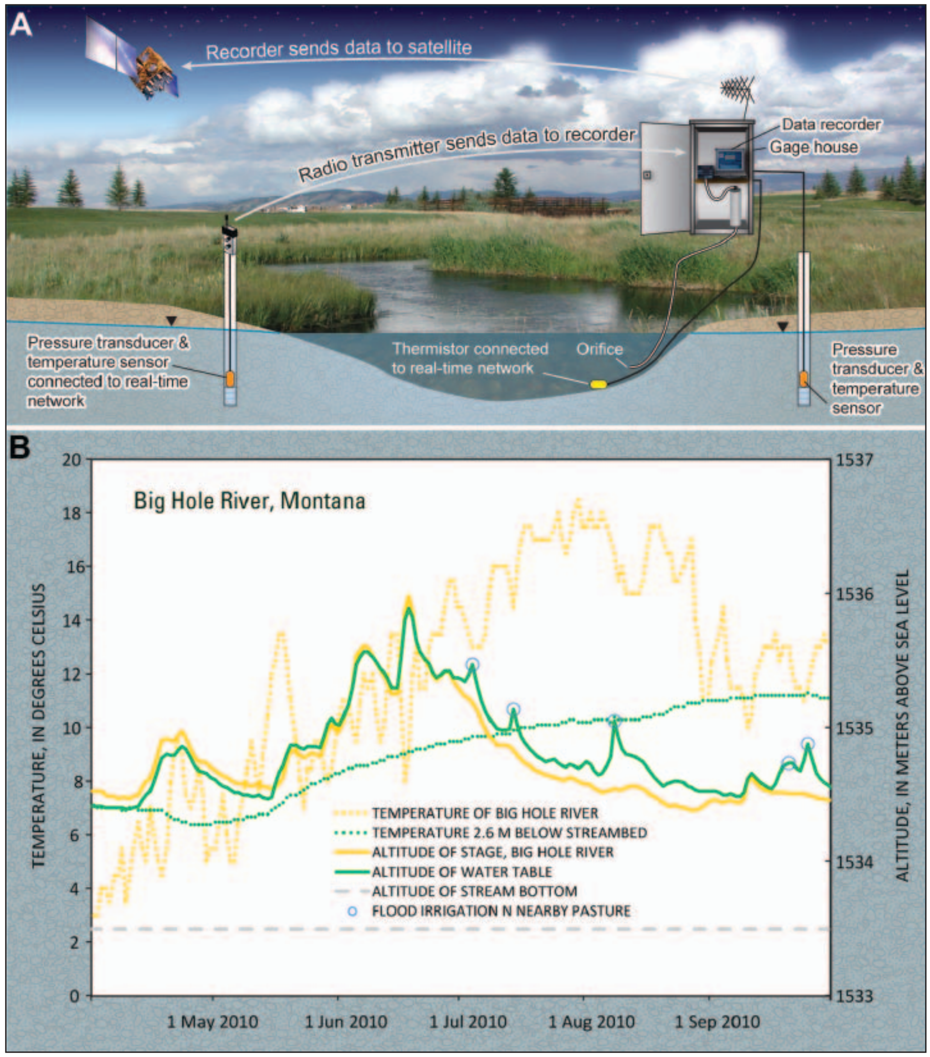

Fig. 2. (a) Generalized schematic of a groundwater stream gauge, in which groundwater elevation and temperature monitoring is coupled to an established automated stream gauge. (b) Data from the groundwater stream gauge on the Big Hole River, Montana, retrieved via satellite and merged into a single graph from separate hydrographs and thermographs. Solid yellow and green lines indicate the elevation of the stream surface (stage) and groundwater surface (water table), respectively, while the dashed yellow and green lines indicate the temperature of the stream and groundwater, respectively. Blue circles mark the timing of irrigation as determined independently.

References

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