Field Characterization of Streamflow Dynamics of Prairie Streams in Eastern Montana

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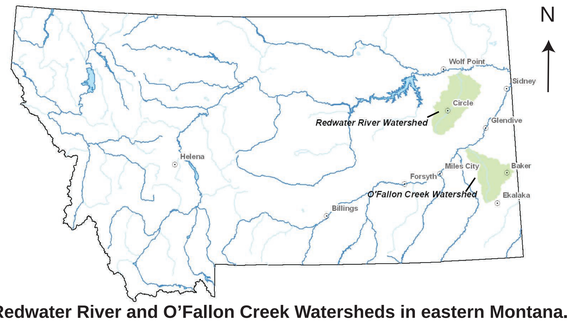
Project Background

U.S. Geological Survey researchers are studying potential stream ecosystem responses to varying climate scenarios in eastern Montana. In order to provide a better understanding of the dynamics of these prairie streams, field characterizations of streamflow in two prairie-stream watersheds, Redwater River and O'Fallon Creek, were conducted in eastern Montana.



Redwater River and O'Fallon Creek Watersheds in eastern Montana.

Redwater River watershed:
- Area: 2,113 square miles
- Elevation: 1,950 to 3,600 feet
- Main-stem length: 209 miles
- Tributary to the Missouri.

O'Fallon Creek watershed:
- Area: 1,580 square miles
- Elevation: 2,140 to 3,600 feet
- Main-stem- length: 157 miles
- Tributary to the Yellowstone.

Similar to other prairie streams in the Great Plains, Redwater River and O'Fallon Creek consist of a series of interconnected pools and channels. Some pools extend thousands of feet and can exceed 10 feet in depth, while connecting channels are oftentimes less than 0.5 feet across and less than 0.1 feet deep. Seasonally, these pools can become isolated or dry completely, restricting or eliminating fish passage and habitat.

Pool-riffle setting, Tussler Creek in the Redwater River watershed, Montana - April 2012

Isolated pool in the O'Fallon Creek watershed, Montana - September 2011

These watersheds are characterized by rolling hills, dissected river breaks, buttes, and prairies which are mostly underlain by the Tertiary Fort Union Formation. Vegetation consists primarily of mixed grassland. Livestock grazing is the main land use with some dryland farming.

Both watersheds are semi-arid with annual precipitation ranging from about 11 to 17 inches, with the highest mean monthly precipitation occuring in May or June. Mean monthly temperatures range from about 6 degrees Fahrenheit in the winter to the mid-80s in the summer (National Oceanic and Atmospheric Administration, 2014)

Annual streamflow patterns for these streams vary dramatically. For example, recorded streamflows for USGS streamgaging station 06177500 (Redwater River at Circle, Montana) are less than 1 cubic feet per second (cfs) for about 60 percent of the time, but five floods above 5,000 cfs were recorded between 1929 and 2012 (U.S. Geological Survey, 2014). Annual peak flows for the Redwater at Circle gage ranged from 2 cfs in 1981 to 6,960 cfs in 1986. There are currenlty no gaging stations on O'Fallon Creek.

Study Design and Approach

Field Considerations

- Continuous data collection with limited field visits
- Extreme streamflow variation - dry to high flows
- Soft sediment and frequent channel migration
- Livestock and wildlife - area streams are natural focal points and riffles are the preferred crossings. Therefore, instrumentation has to be durable, but safe for the cattle and wildlife

Field Methods

1. Synoptic Streamflow

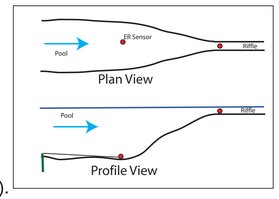
Synoptic streamflow measurements (seepage runs) were conducted at two times during low-flow conditions. Streamflow was measured at about 20 sites in each watershed during 1 to 2 day seepage runs.

2. Time-Lapse Photography

Cameras were installed at pool-riffle settings and were set to take photographs twice daily.

3. Electrical Resistance and Temperature

Continuous water-temperature monitoring has been effectively used for years to study hydrologic systems, however interpretation of stream intermittency is sometimes difficult. Electrical resistance (ER) sensors have been successfully implemented as an alternative to examine stream intermittency with more definitive interpretation (Chapin and others, 2014).



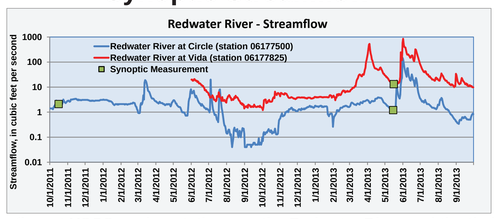
Sensors were deployed in the main stem and tributaries at 40 sites. Each site was instrumented in tandem with sensors placed in the deepest part of a pool and another in the adjacent riffle.

4. Groundwater/Surface-Water Monitoring

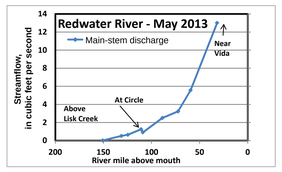
Staff gages and shallow monitoring wells were installed in selected streams. Both the staff gages and monitoring wells were instrumented with pressure transducers and temperature loggers to examine the general groundwater and surface-water flow direction. However, this method proved unsuccessful in this environment. The observation wells filled with sediment and plugged the pressure transducers.

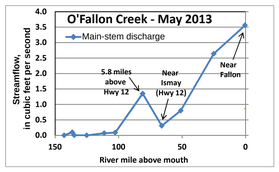
Results

Synoptic Streamflow



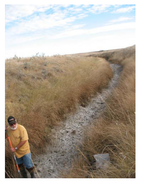
Streamflow at USGS gaging stations on the Redwater River and the timing of seepage runs, water year 2012 and 2013.





Instantaneous streamflow of Redwater River and O'Fallon Creeks during a May 2013 seepage run.

As shown in the graphs (above), synoptic streamflow data indicated that some stream reaches gained streamflow while others were losing reaches. Some tributaries repeatedly varied between flowing and dry conditions along their course.



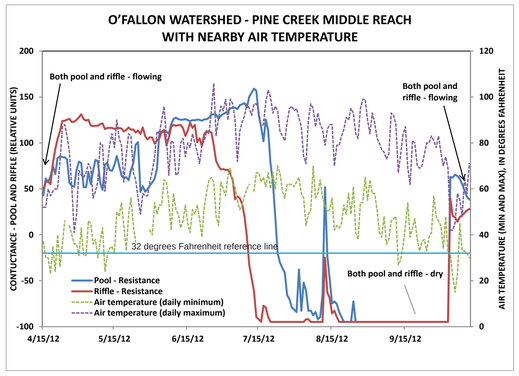
Time-Lapse Photography

Time-lapse photography proved to be a low-cost option (<$100 per site) to evaluate the dynamics of the setting. The time-lapse photography corroborated the ER sensor data collected and appears to be a promising tool.

Results

Electrical Resistance and Temperature

Data from the ER sensors reliably indicated periods of wet and dry conditions.The benefit of using a combination of these methods (namely air temperature and electrical resistance monitoring) is highlighted at a Pine Creek site (see graph below) which became dry in the late summer of 2012.

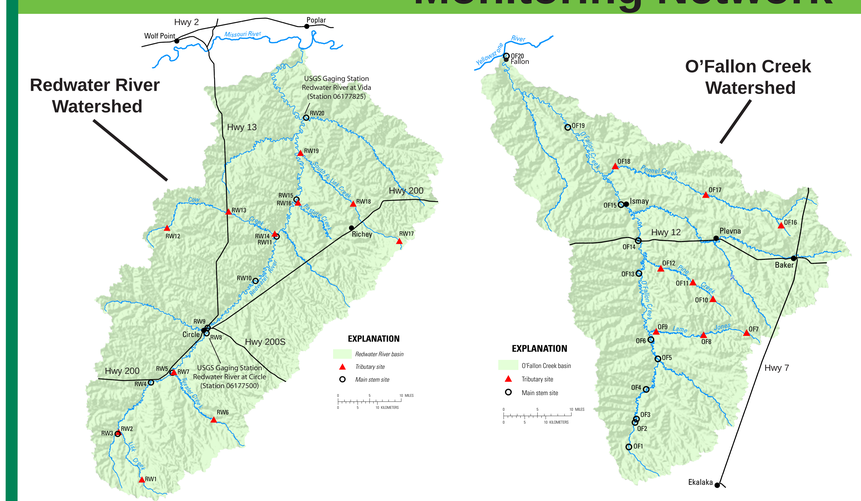


The ER sensor indicated a return of flow to the stream in the early fall of 2012. Nearby weather station data and collected air temperature data indicated that this response occurred coincident with the first widespread, below-freezing air temperatures for several hours; probably the season's first killing frost. The killing frost likely resulted in reduced evapotranspiration and potentially, a slight rise in the local water table. The rise in the near-stream water table would explain the onset of streamflow as water flowed to the stream from the local groundwater system. Several monitored sites in the area showed similar responses.

Conclusion

Synoptic streamflow measurements, time-lapse photography, and continuous monitoring within these prairie streams described the timing and duration of streamflow, isolation of pools, and periods and locations where sites were essentially dry.

Monitoring Network



The ER sensors were modified Onset Tidbit thermisters as described in Blasch and others (2002). Sensors were placed in open-ended, polyvinyl-chloride lined, metal pipes and set to record at 15-minute intervals.

Location of data loggers and synoptic streamflow measurement sites in the Redwater River and O'Fallon Creek Watersheds, 2011 to 2013

References

Blasch, K.W., T.P.A. Feere, A.H. Christensen, and J.P. Hoffman, 2002, New field method to determine streamflow timing using electrical resistance sensors, Vadose Zone, J.,1, 289-299, doi: 10.2113/1.2.289.

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