

# Hydrologic Instrumentation and Data Collection in Wyoming

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## Abstract

Wyoming is currently expanding and improving its hydrologic instrumentation and data collection network by installing new instrumentation in high alpine watersheds, expanding collection sites for soil moisture and precipitation data, and augmenting stream and meteorological collections across the state. The alpine watersheds are being instrumented in a nested network of meteorological stations, precipitation and snow gauges, soil moisture measurement sites, and runoff gauges to quantify the origins, fate, and transport of water. Additional instrumentation includes dendrometers and sediment samplers. In a complementary project, 18 soil moisture monitoring sites are distributed across the state in grasslands and shrublands. Installations are arranged in a shallow profile of 3 soil moisture probes and a tipping bucket rain gauge. In addition, runoff and meteorological sites are being installed in key basins around the state. These efforts are intended to (1) provide more detailed hydrologic data to better estimate parameters of watershed models; (2) improve drought forecasting and flood prediction; (3) increase the accuracy of water availability predictions in key basins; and (4) improve dissemination of hydrologic information across the state. Collaborators are the U.S. Forest Service, National Weather Service, U.S. Geological Survey, Wyoming Water Development Commission, and Wyoming Department of Agriculture.

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## Introduction

Water and natural resource managers in semiarid states of the Intermountain West are challenged to quantify and allocate scarce water resources. Many western states are faced with increased demands on their water resources coupled with changing climate and diminished water supply. Wyoming is a semiarid state (average annual precipitation is 16.4 in), ranking the 5<sup>th</sup> most arid state in the United States. Though a headwater state, over 70 percent of the state receives less than 12 in of precipitation annually. Most of Wyoming's water resources are derived from high elevation (>10,000 ft) snow pack and associated spring runoff; its mountains receive more than 36 in of precipitation—predominately as snow.

Wyoming, as much of the Intermountain West, is often subjected to periods of drought. Additionally challenging for hydrologists is determining how hydrologic and ecological systems will respond to ongoing climate change. During the past 100 years of instrumented record, Wyoming has experienced at least four significant drought periods, most recently from 2000 to 2008. Other significant periods of drought have been revealed using proxy data such as tree ring reconstruction (Woodhouse et al. 2002, Gray et al. 2004). The distribution, timing, and severity of the droughts have varied greatly in Wyoming. The extent, severity, and duration of droughts are critical data in a state where 70 percent of the land area is grazed by domestic livestock and wildlife. However, droughts are difficult to identify and predict, and management to accommodate periods of prolonged drought is further complicated by the uncertainty of climate change.

Researchers are currently expanding and improving hydrologic instrumentation and data collection across Wyoming to enhance our ability to record and respond to fluctuating water availability and demands. The objectives in expanding these

monitoring networks are to provide: (1) detailed hydrologic data for parameterizing watershed models; (2) improved drought and flood forecasting; (3) increased accuracy of predicted water availability in key basins; and (4) more precise hydrologic information for dissemination to Wyoming residents. Efforts are targeting rangeland soil moisture, high alpine watersheds, and additional stream and meteorological stations.

## Soil Moisture Instrumentation

Rangeland productivity is affected by variations in the amount and timing of precipitation and the ability of the soil to hold water. A network of soil moisture sites (18 across the state) was established in 2003–05 to determine local relationships between spring soil moisture content and forage production.

Each site was initially instrumented with Campbell Scientific CS625 soil moisture probes installed vertically at depths of 0–30, 30–60, and 60–90 cm. At the time of installation, no site specific soil characteristics were measured. Starting in 2007, these soil moisture sites have been updated by performing site-specific calibrations to increase the accuracy of the data. Vertical installation of the probes results in an average soil moisture reading for the depth of the probe. Horizontal positioning of probes is preferred for accurate estimation of soil moisture content at a given depth. During the updating process, any replaced sensors were installed horizontally in the soil at depths of 15, 45, and 75 cm. All soil water monitoring sites have recently been fitted with tipping bucket rain gauges (Texas Electronics TE525WS-L), weather-proof enclosures, and solar panel power sources (Figure 1). By measuring both the soil water dynamics and precipitation at the same location, we can directly link the site's moisture conditions to local rangeland productivity. Rangeland production is currently measured on most of the sites using annual clippings of fenced enclosures.

Soil physical characterizations such as bulk density and particle size analysis have been determined for all sites. Soils material was collected from each site and soil-specific sensor calibrations completed by wetting dry soil to a range of soil water contents and measuring the response from the CS625 probe.

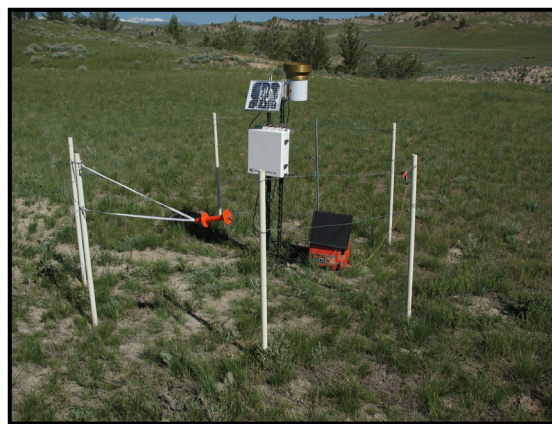


Figure 1. Newly instrumented soil moisture and rainfall recording site near Meeteetse, WY.

After each wetting, the soil was carefully packed in a bucket, for a soil moisture probe reading. Soil moisture readings were taken with the CS625, with a Campbell Scientific TDR100 probe, and with a Stevens Water Hydra probe for comparison. The sensor-observed soil permittivity (i.e., the energy storage due to polarization) was then plotted against soil water content readings from the three sensors to obtain calibrations (results for a site near Meeteetse, WY, are shown in Figure 2). The soil water content versus permittivity relationship developed by Topp et al. (1980) is shown for comparison. The soil moisture relationships for the CS625 probes for each site were programmed into individual site datalogger programs. The newly developed calibrations will also be used to “back calculate” existing soil moisture measurement datasets that used a generic calibration.

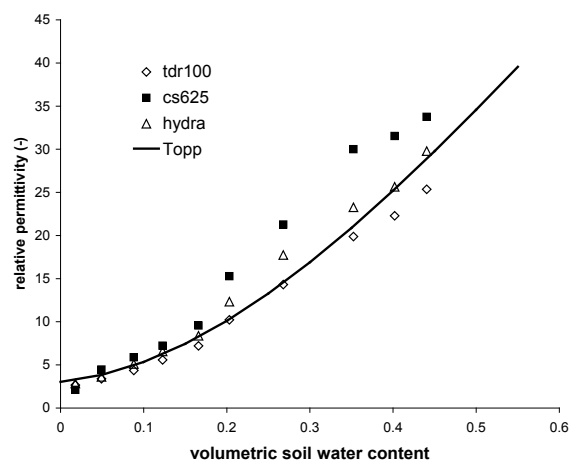


Figure 2. Laboratory calibration of repacked soil from the top 30 cm of soil at the Meeteetsee soil moisture monitoring site.

There is a recognized need for spatially distributed soil moisture content data, nationwide (Robinson et al. 2008). Since 1991, the National Water and Climate Center (U.S. Department of Agriculture–National Resources Conservation Service) has maintained a national network of 129 SCAN (Soil Climate Analysis Network) sites (Schaefer et al. 2007). The network of geographically dispersed soil moisture monitoring sites, coupled with precipitation gauges across the state, is of great value for (1) increasing our knowledge of the relationships between rainfall, soil moisture dynamics, and forage production, and (2) developing a drought risk prediction tool.

### Nested Alpine Watershed

The majority of Wyoming's annual water supply comes from high-elevation alpine snow pack. Insights into the amount and timing of snowmelt are critical for managing the State's water resources and downstream allocations to neighboring states. To increase our understanding of high alpine watershed processes, we are installing a hydrologic instrumentation network in Lower Libby Creek Watershed in the Snowy Range of the Medicine Bow Mountains in southeast Wyoming. The Libby Creek Watershed was instrumented and ecological and hydrologic data were collected in the watershed from the 1960s to the 1990s. Re-instrumentation of sections of this large watershed will allow us to draw comparisons with "historic" datasets. In addition, more than 1.5 million acres of forest in northern Colorado and southern Wyoming are affected by the Mountain Pine Bark Beetle epidemic, which was triggered by the extended drought in the late 1990s and early 2000s. A large portion of the Snowy Range has experienced die-off due to the infestation, and the extent of the die-off is expected to increase over the next several years (<http://www.fs.fed.us/r2/mbr/resources/BarkBeetles/index.shtml>). It anticipated that hydrologic patterns and the water balance will be altered as a result of the Pine Bark Beetle infestation. Positioning our instrumentation in an area experiencing die-off from the infestation will allow us to track changes to the hydrologic cycle over time.

The hydrologic and meteorologic instrumentation are being installed in a nested watershed framework in the lower Libby Creek Watershed (Figure 3). There is a single order watershed, draining

approximately 122 ha, that intersects Libby Creek, which drains an area over 2,200 ha. The instrumentation network comprises a meteorological station, precipitation and snow gauges, soil moisture measurement sites, submersible pressure transducers (to measure runoff), dendrometers (to measure tree stem growth), and stable isotope and sediment samplers. The network is expected to expand over time as resources become available.

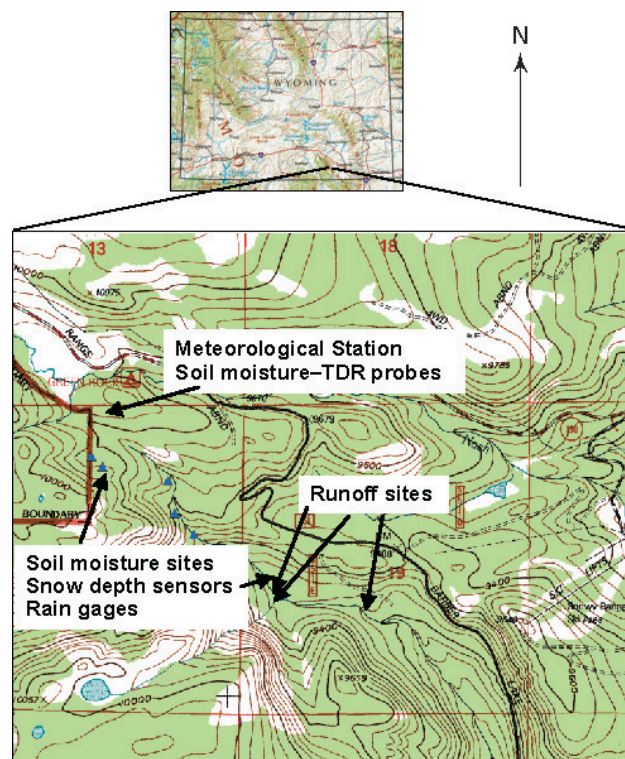


Figure 3. Instrumentation sites in the Lower Libby Creek Watershed in the Snowy Range, southeast Wyoming.

The long-term effort will increase our understanding of surface hydrologic processes in high alpine watersheds and provide a valuable dataset for improved watershed model parameterization for snow-dominated systems. The nested watersheds also serve as an outdoor classroom for students at the University of Wyoming. As part of an upper-level and graduate student course in watershed hydrology, students are introduced to critical field equipment through installation, maintenance, and data collection in a research watershed. An additional objective of this project is to quantify impacts of the Mountain Pine Bark Beetle infestation on the surface water hydrologic processes of a high alpine system.



The lower Libby Creek Watershed is a collaborative study site that engages researchers from several departments at University of Wyoming, the Wyoming State Climatologist Office, and the U.S. Forest Service. The watershed is located adjacent to and downstream from the U.S. Forest Service Glacial Lakes Ecosystem Experiments Site (GLEES; <http://www.fs.fed.us/rm/landscapes/Locations/Glees/GLEES.shtml>). GLEES is a high elevation research site intended to determine the effects of atmospheric deposition and climate change on alpine and subalpine aquatic and terrestrial ecosystems and the upper treeline ecotone. Concomitantly with the intensive instrumentation of the Libby Creek watershed, additional runoff and meteorologic instrumentation is being installed in selected locations around the state.

## Summary

Wyoming, along with the rest of the semiarid Intermountain West, is challenged to adapt to periodic drought conditions while planning for future uncertainties in water budgets and water supplies associated with climate change. One potentially significant long-term effect of a warmer climate in Wyoming is decreased water availability, necessitating changes in livestock production and other agricultural practices. In the face of growing uncertainty about the rainfall and runoff cycle, water resource professionals in Wyoming are expanding our hydrologic data network in a unified effort to (1) improve our knowledge of our current water supply, and (2) improve our ability to identify droughts and water supply deficiencies across the state. Neither of these tasks is simple, but each may be more manageable with timely and detailed data.

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