Hydrologic Instrumentation at the USDA-ARS Grassland, Soil and Water Research Laboratory, Riesel, TX

R. Daren Harmel, Clarence W. Richardson, Kevin W. King, Jeff G. Arnold

Abstract

The USDA-ARS Grassland, Soil and Water Research Laboratory watershed facility near Riesel, TX, is one of the most intensively monitored hydrological research sites in the country. The 340 ha research site is currently divided into sub-watersheds ranging from 0.1 to 125 ha under pasture and cropland management. Currently in operation are 18 runoff stations, 15 rain gauges, a weather station, a lateral flow station, and 7 shallow groundwater wells. Data from these stations are stored on dataloggers, downloaded with radio telemetry, and placed on the internet. Nutrient and sediment data are also collected for each runoff event with automated sampling equipment.

Keywords: hydrologic instrumentation, radio telemetry

Introduction

The objective of this paper is to describe the equipment and techniques used to collect and manage data at the USDA-ARS Grassland, Soil and Water Research Laboratory watershed facility near Riesel, TX. Rainfall, runoff, and erosion data for the site date from the late 1930s when the laboratory was established to evaluate the hydrologic response from watersheds influenced by various agricultural practices in the Texas Blackland Prairie.

In the mid 1930s, the Soil Conservation Service (SCS), now the Natural Resources Conservation Service (NRCS), realized a need to understand and analyze hydrologic data from agricultural fields and watersheds. Based on this need, the Hydrologic Division of the SCS was established and a number of experimental watersheds were formed across the US. The primary functions of the facilities were to collect hydrologic data (precipitation, percolation, evaporation, runoff, etc.) and evaluate the hydrologic response from watersheds influenced by various agricultural land management practices (USDA-SCS 1942). One of those watersheds, originally called the Blackland Experimental Watershed, was established in 1937 in the heart of the Blackland Prairie near Riesel, TX, on the 2372 ha Brushy Creek watershed (Figure 1).

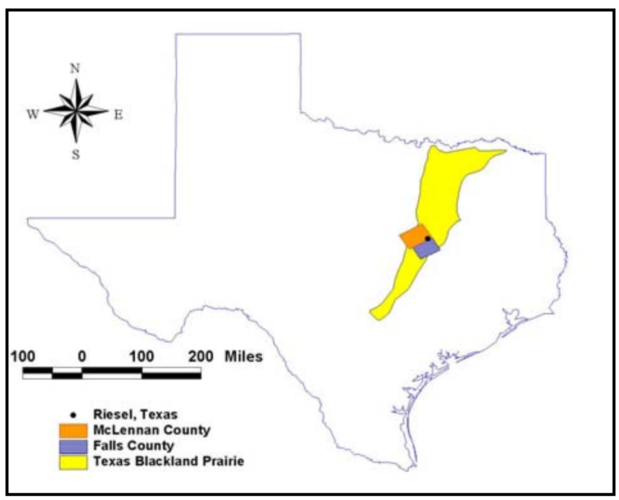

Figure 1. The USDA-ARS Grassland, Soil and Water Research Laboratory watersheds near Riesel, TX.

The experimental watershed facility later became part of the USDA-ARS Grassland, Soil and Water Research Laboratory with headquarters in Temple,

Harmel, Richardson, and Arnold are Agricultural Engineers, USDA-ARS Grassland, Soil and Water Research Laboratory, Temple, TX 76502. E-mail: dharmel@spa.ars.usda.gov. King is an Agricultural Engineer, USDA-ARS Soil Drainage Research Unit, Columbus, OH 43210.

TX. Since 1937 hydrologic data have been collected throughout the Riesel watersheds, and during the height of activity, 35 runoff sites and 35 recording rain gauges were in operation. These data sets have been used for numerous purposes such as water quality studies, farming practice evaluations, and model development and evaluation. The long hydrologic records (in excess of 60 years on some watersheds) make the data particularly valuable for studies designed to identify trends or changes caused by climate change or other factors.

Site Description

The 4.45 million ha Blackland Prairie in Texas is a region of fertile agricultural land extending from San Antonio north to the Red River. Houston Black clay (fine, smectitic, thermic, udic Haplustert), which exhibits a strong shrink/swell potential, dominates the region. The slopes generally range from 1-3 % and are classified as gently rolling. Present day agricultural land use in the region consists of cattle production on pasture and rangeland, and corn, wheat, grain sorghum, and oat production under a wide range of tillage and management operations.

Hydrologic Instrumentation

Currently in operation at Riesel are 18 runoff stations, 15 rain gauges, a weather station, a lateral flow station, and 7 shallow groundwater wells. Data from these stations are stored on dataloggers, downloaded daily with radio telemetry, and placed on the internet with annual updates. Nutrient and sediment data are also collected for each runoff event with automated sampling equipment.

The USDA-ARS Grassland, Soil and Water Research Laboratory, Temple, TX website (http://arsserv0.tamu.edu/hydata.htm.) contains the data referred to in this paper.

Runoff stations

Collection of runoff data began at the Riesel site in 1938. Ten of the 18 runoff stations currently in operation are located at the outlet of small, single landuse watersheds (1.2 to 8.4 ha) to measure “edge of field” processes (Figure 2). Four of the stations are located at the outlet of 0.1 ha plots. Four of the stations are located at the outlet of larger downstream watersheds (17.1 to 125.1 ha) with mixed land uses to evaluate integrated processes.

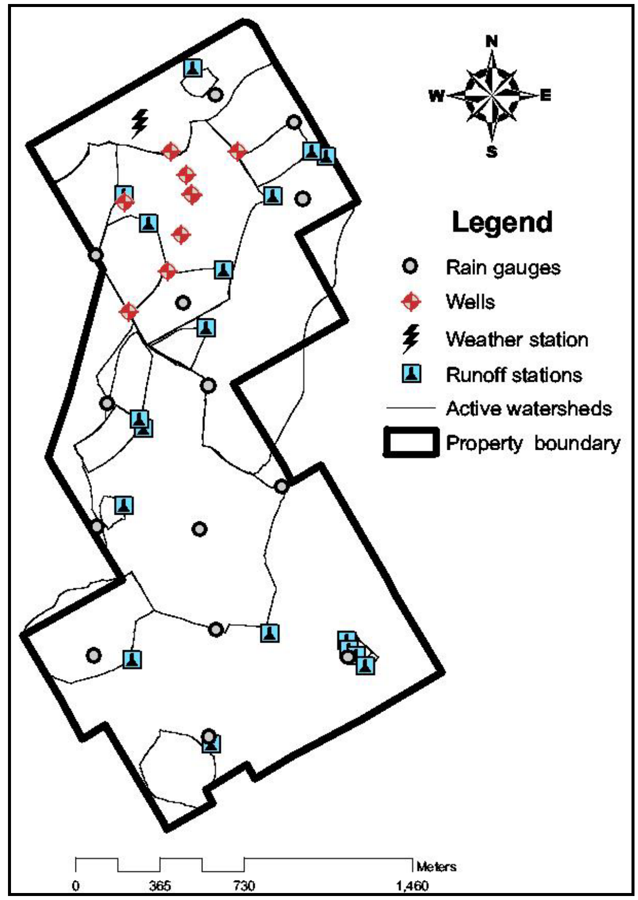

Figure 2. Hydrologic instrumentation network.

Currently, each of these runoff structures is instrumented with three flow level recording devices: 1) a KPSI pressure transducer (Keller Pressure Systems, Inc., Hampton, VA) connected to Campbell Scientific datalogger (Campbell Scientific, Inc., Logan, UT); 2) a float gauge with chart recorder; and 3) an ISCO automated sampler with bubbler level recorder (ISCO, Inc., Lincoln, NE). ISCO bubblers are used as the primary depth measurement devices, and the transducers and float gauges serve as back up devices. Discharge measurements are made by continuously recording flow levels in a stilling well located in each calibrated flume or weir structure (Figure 3). Flow depth data are converted to flow rate with established stage discharge relationships.

Historically, float gauges served as the primary flow measurement devices. The float gauges with chart recorders recorded flow depths, and each chart was digitized to create a record of flow depth (specifically, points of change in slope representing change in runoff rate were digitized). From the continuous stage records, flow rates were calculated with a known stage-discharge relationship.

Figure 3. Flow control structure located on a 53.4 ha watershed.

Historical data from 1938 to 2002 for 40 runoff stations (approximately 1250 runoff station years) are accessible via the web. The internet site lists the stations, their watershed size, and the years for which runoff data are available for viewing and download. Specifically, flow rate (cfs and in/hr) with corresponding date and time (min) and daily runoff depth (in) data are available.

Water quality sampling

Water quality data, as well as flow data, are collected at the 18 active runoff structures. Currently, ISCO samplers are used to collect runoff samples, which are analyzed for dissolved and sediment-bound nitrogen and phosphorus concentrations and sediment amount. These automated samplers, installed in 2001, begin sampling when activated by a bubbler flow level recorder. Discrete samples are taken on variable time intervals with more frequent samples taken on the rising leg of the hydrograph.

From the 1970s to 2001, runoff water samples were taken with Chickasha samplers (Chichester and Richardson 1992). These automated, mechanical samplers were turned on with a float-activated water level switch. Discrete samples were taken on variable time intervals with more frequent samples taken on the rising leg of the hydrograph. Prior to the 1970s, runoff water samples were collected by hand during runoff events (Knisel and Baird 1970). On-call personnel collected discrete samples on variable time intervals similar to the collection frequency of the automated samplers.

Historically, sediment loss was the water quality issue of concern at Riesel, but limited nutrient and chemical data were also collected for specific studies. To quantify soil loss and sediment concentrations in runoff, collected sediment was dried, weighed, and recorded with the corresponding flow rate. Sediment data mostly from the late 1960s to 2002 for 22 runoff stations are accessible via the web. The internet site lists the stations and contains sub-daily concentration (ppm) and sediment amount (t/ac) data, and daily and monthly sediment amount data (t/ac).

Rain gauges

Collection of rainfall data at the Riesel watersheds began in 1938. Currently, 15 rain gauges are in operation (Figure 2). The Riesel rain gauge network is one of the denser rain gauge networks in the world with 15 gauges located within 340 ha. The current rain gauge network is comprised of Hydrologic Services tipping bucket rain gauges (Hydrologic Services PTY, Ltd., Sydney, Australia) connected to Campbell Scientific dataloggers (Figure 4). Sub-daily rain data are recorded in 10 min intervals (sensitivity 0.254 mm). A standard rain gauge is also

used at each site as backup and calibration device.

Figure 4. Recording tipping bucket rain gauge and datalogger setup with adjacent standard rain gauge.

Historically, rainfall data were collected by various types of weighing rain gauges and recorded on chart recorders on 5 to 10 min intervals during precipitation events (sensitivity 0.254 mm). A standard rain gauge at each weighing gauge was used as a backup and calibration device. The electronic tipping buckets were installed in the 1990s.

Historical data from 57 rain gauges within the Brushy Creek watershed are available on the internet site, which list the stations and the years for which rainfall data are available (approximately 1350 rain gauge years). Specifically, accumulated sub-daily rainfall (in) with corresponding date and time (min) and daily rainfall (in) data are available for viewing and download. Rainfall estimates for individual watersheds can be calculated from Thiessen polygon weights, which are also available.

Weather station

Selected weather data have been collected at the Riesel weather yard since 1938 (Figure 2). Currently, weather data are measured and recorded with a Campbell Scientific weather station and datalogger, which were installed in 1996. Meteorological data collected includes: air temperature (average, maximum, minimum -°C), solar radiation (kJ/m^2), wind speed (m/s) and direction (°), precipitation (mm), maximum and minimum soil temperature (°C), and heating and cooling degree days. Daily data from the weather station are accessible on the web for 1996 to 2002.

From 1990 to 1995, daily maximum and minimum air temperature (°C), solar radiation (kJ/m^2), average wind speed (m/s), and rainfall (mm) data were measured with Campbell meteorological equipment connected directly to a computer at the Riesel headquarters building.

Daily temperature range data (°C) from 1940 to 1989 measured with a maximum temperature and a minimum temperature mercury thermometer are available. Daily evaporation data (in) measured from an evaporation pan from 1962 to 1972 are also available.

Lateral flow station

A lateral flow station was installed in 1970 to measure lateral subsurface flow from a portion of one watershed. Flow from a French drain is released into a boxed, sharp-crested v-notch weir. In 2000, a KPSI pressure transducer was installed with a Campbell Scientific datalogger to measure and record flow depth over the weir. Lateral flow is calculated with the weir's stage discharge relationship. Flow data (cfs) from late 2000 through 2002 are available on the website.

Well stations

In 1998, seven new wells were installed at Riesel to monitor shallow aquifer water levels and recharge properties. Five of the new wells are instrumented with KPSI pressure transducers connected to Campbell Scientific dataloggers to provide a continuous record of piezometric head. All of these seven active wells are monitored twice-weekly with a hand-held "e-line" water depth gauge to provide back-up and calibration data. Groundwater level data (relative elevation - ft) from these seven wells from late 2000 through 2002 are currently available on the website.

Telemetry network

Installation of a Campbell Scientific radiotelemetry network was completed in 2001. A total of 39 field telemetry stations were established at the 18 runoff stations, 15 rain gauges (including the weather station), lateral flow station, and the 5 shallow wells. A base station was established at the Riesel headquarters building to communicate with the field stations with a VHF radio signal. An automated data collection schedule runs continuously and collects data daily from each field station. From the base station, we can maintain and calibrate equipment and monitor realtime weather conditions, water levels, and rainfall amount. The base station is linked via phone modem to a dedicated computer at the laboratory headquarters in Temple, TX to automated data transfer. This phone link also allows manual operation and adjustment of the Riesel radio telemetry network from Temple. This radio telemetry network is unique in its location, the Texas Blackland Prairie, and is valuable in its ability to provide up-to-date hydrological data.

Current Research

The rare combination of a long, continuous hydrologic record and land dedicated for research make the Riesel facility a valuable research site, particularly for studies of hydrologic processes, water quality mechanisms, and climate change impacts. Previous research at Riesel includes water quality studies (Williams et al. 1971, Kissel et al. 1976, Richardson and King 1995), farming practice evaluations (Baird et al. 1970, Baird and Knisel 1971), and natural resource modeling (Arnold and Williams 1987, King et al. 1996, Harmel et al. 2000).

Several research projects are in progress at Riesel. These projects require data collection from land available for long time periods, reliable research funds, and dedicated staff. Without such a research commitment, studies such as these would be much more difficult and possibly infeasible.

A study of the water quality, crop production, and economic impacts of land-applied poultry litter was initiated in 2000. It is hoped that this cooperative study will continue for many years and address long-term impacts, which are often not addressed in short-term studies. The results of this study, funded by the Texas State Soil and Water Conservation Board and USDA-ARS, should impact agricultural and environmental policy and practice in terms of crop and pasture production, poultry litter utilization, and water quality.

Another current study at Riesel is attempting to quantify the hydrologic influence of the Blackland Prairie soils, which commonly exhibit strong shrink/swell potential. This behavior and the resulting slow permeability when soils are wet and rapid infiltration into cracks when soils are dry impacts rainfall/runoff, recharge, and lateral flow relationships. In addition to affecting hydrologic relationships, the shifting associated with shrink/swell processes can cause significant damage to building and road foundations. The soil physical properties also create challenges for tillage implement performance. Results from this study should provide valuable information on water resource management, construction design, and crop production.

Other research underway at Riesel includes studies of drought effects on native prairie pasture, nutrient cycling as influenced by soil microbial activity, performance of automated storm water sampling equipment, and nutrient transformations in land-applied poultry litter.

Conclusions

The hydrologic instrumentation network at the USDA-ARS Grassland, Soil and Water Research Laboratory watershed facility near Riesel, TX has been a valuable research tool since the late 1930s. The continuous data collection effort makes Riesel one of the most intensively monitored hydrological research sites in the country. Many years of data on runoff, water quality, precipitation, weather, and groundwater levels resulting from this coordinated monitoring effort are available on the USDA-ARS Grassland, Soil and Water Research Laboratory, Temple, TX website. The recent instrumentation updates should allow Riesel to remain a premiere research site for many years and continue to provide timely, pertinent information that benefits agriculture, the environment, and natural resource management.

Acknowledgments

We would like to recognize the efforts of many technicians that have contributed to the collection of data at Riesel. Operation of a hydrologic instrumentation network of this magnitude requires a talented and dedicated staff; and we have been blessed with a wonderful staff. We especially want to recognize current staff members Lynn Grote, Steve Grote, James Haug, and Gary Hoeft for their outstanding efforts in equipment maintenance, data collection, and record keeping. Without their service the intensive hydrologic monitoring program at Riesel would not be possible.

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