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Sediment database, Walnut Gulch Experimental Watershed, Arizona, United States

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[1] Improving the scientific understanding of erosion and sedimentation processes within semiarid rangeland watersheds has been a primary objective of data collection on the Walnut Gulch Experimental Watershed since its establishment in 1953. Sampling instruments and techniques are described, including the traversing slot sediment sampler, pump samplers on both V notch weirs and H flumes, and stock tank sedimentation surveys. Sediment collected at the outlets of seven small watersheds and long-term data collected through stock tank sedimentation surveys at eight sites dating from the 1950s are described. Data are available at http://www.tucson.ars.ag.gov/dap/.

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1. Introduction

[2] The Walnut Gulch Experimental Watershed (WGEW) sediment collection program provides event-based data for semiarid rangeland erosion, sediment transport, and yield research. At the time WGEW was instrumented there were very few semiarid data sets describing basic relations between runoff and sediment. Sediment samples were collected to improve samplers for dryland channels [*Renard et al.*, 1986; *Simanton et al.*, 1993] and to understand the influence of vegetative cover on sediment yield [*Osborn et al.*, 1978]. The long-term objective of sediment data collection is to support an evolving set of research objectives to understand the interactions among climate, vegetation, and land use that affect erosion, sediment transport, and yield in semiarid regions. The data are also fundamental to developing simulation models and conducting short-term hypothesis driven research.

[3] Sediment loads carried through the channel network on the WGEW are high, but are typical of semiarid rangelands, and are influenced by soils, geologic parent material, and geomorphology. Sediment data collection in dryland ephemeral channels is notoriously difficult, and early efforts to measure sediment were hindered by inadequate measurement technologies. Most of the measurement methods and instruments available in 1953 when the WGEW was initiated were based on designs for sampling perennial flow [*Renard et al.*, 2008]. Typical monsoon thunderstorm generated flows in dryland regions are characterized by high velocities, short durations, and heavy and coarse sediment loads. Early attempts to use V notch weirs for runoff and sediment accumulation measurements failed when hydraulic control required for accurate flow measurement was lost as sediment was deposited behind the structure. Significant effort went into designing and evaluating instruments for collecting sediment [*Renard et al.*, 1986; *Simanton et al.*, 1993]. Attempts to measure sediment moving through the large flumes along the main channels on the watershed were limited to the suspended load, and collecting those samples took place under less than ideal weather conditions. The sediment sampling program at sites along the main channels was stopped in the early 1980s. This paper summarizes data and instrumentation associated with a subset of the WGEW sediment data that are currently available through the Southwest Watershed Research Center (SWRC) Web site.

2. Instrumentation

[4] The most comprehensive sediment data set available through the SWRC Web site is made up of samples collected during runoff events at the outlets of seven small watersheds ranging in size from 0.19 ha to 4.53 ha (Table 1). In addition, high-quality data are available from annual topographic surveys to measure sediment accumulation in eight stock tanks at the outlet of watersheds ranging from 35.2 to 159.2 ha. A map showing the locations of currently active measurement sites can be found at http://tucson.ars.ag.gov/DAP. Measurement detail for the small watershed and stock tank data sets are described in sections 2.1 and 2.2.

2.1. Small Watersheds

[5] Sediment is measured in conjunction with discharge measurements [*Stone et al.*, 2008] that are integral to converting sample values to runoff event–based values. Sampling initiated in the 1960s was done with point intake pump samplers. The single point sampler intake tubes were later replaced with tubes that rise in response to flow and are perforated to collect depth integrated samples (Figure 1). Sampling with each of these systems is limited to suspended sediment smaller than the 0.635 cm diameter of the intake slots. Pump samplers are in use at the outlet of small watersheds where overland flow is the dominant hydrologic driver of sediment transport, and particles are small.

[6] As watershed size increases on the WGEW, in general, the channel network can dominate sediment delivery processes as it evolves to carry an increasingly coarse, and

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Table 1. Summary of Sediment Measurement Infrastructure at Seven Small Watershed Sites on the WGEW

Watershed	Area, ha	Date	Sampler
63.101	1.29	June 1962	2:1 V notch weir with pondage, FW-1 recorder 6 h
		1973	pump sampler installed, floating intake
		1986	end of measurement
		2005	weir removed
63.102	1.46	July 1963	2:1 V notch weir with pondage, FW-1 recorder 6 h
		March 1973	concrete Smith flume, FW-1 recorder 6 h
		1977	pump sampler installed
		1998	Smith flume, traversing slot sediment sampler
63.103	3.68	June 1963	2:1 V notch weir with pondage, FW-1 recorder 6 h
		1973	pump sampler installed
		March 1977	Smith flume, traversing slot sediment sampler
63.104	4.53	June 1963	2:1 V notch weir with pondage, FW-1 recorder 6 h
		1971	pump sampler, floating intake, weir pondage
		March 1978	Smith flume, traversing slot sediment sampler
63.105	0.19	July 1965	3′ H-flume, FW-1 recorder 6 h
		1975	pump sampler installed
63.106	0.34	June 1965	3′ H-flume, FW-1 recorder 6 h
		1975	pump sampler installed, floating intake
63.112	1.83	July 1962	3:1 V notch weir with pondage, FW-1 recorder 6 h
		1973	pump sampler, floating intake, weir pondage

vertically sorted, sediment load. A traversing slot sediment sampler (Figure 2) was designed in response to limitations of alternative sampling methods such as the pump sampler [*Smith et al.*, 1981; *Renard et al.*, 1986]. The traversing slot normally is positioned out of the flow. When flow depth is greater than 0.06 m, the chain driven traversing slot travels at a uniform speed across the outlet of the flume and diverts a depth-integrated sample to evenly spaced, stationary slots below the flume exit. Samples are collected at 3 min intervals through the first 15 min and then samples are collected on a 5 min interval for an additional 15 min. If flow continues beyond 30 min, the sampler switches to a 10 min for the duration of the flow. Water and particles smaller than the 13 mm slot are directed into two liter sample bottles (Figure 3). In practice, particles larger than eight mm are rarely collected. Each sample is stored in one

Figure 1. View of H flume at LH105 showing (1) flume exit, (2) float that raises perforated sediment sampling tube in response to water level, (3) stilling well, (4) water level instrument house, (5) sediment intake tube, (6) pump sampler tube, and (7) housing for pump sampler.

Figure 2. Smith-type supercritical flow flume and sediment sampler at LH104 showing traversing slot during a runoff event.

of twenty plastic two liter bottles stationed in a vertical wheel housing. If a single transverse is inadequate to capture a two liter sample, a weight gauge under the sample bottle will trigger an additional transverse. After each sampler transverse, the wheel advances to an intermediate position with no bottle present in the sampling position to prevent contamination. The next empty sample bottle is rotated into the sampling position immediately preceding the initiation of a sampling sequence. The sampler is powered by a solar generator connected to two 12-V DC motors, one attached to the sampling arm and the other to the wheel of bottles. Initial calibration tests of the transverse slot sampler showed measurements well correlated to depth integrated samples taken with a US D-48 or dip sampler at flows under 0.3 $m^3 s^{-1}$. At larger discharges with high fine material concentrations, the slot sampler measured total concentrations 10% higher than the alternate methods [*Renard et al.*, 1986].

[7] Collected samples are taken to the lab where they are dried at 97°C for 24 h, and then are weighed to compute sediment concentration [*Brakensiek et al.*, 1979]. Sediment yields are calculated for each event during which 3 or more samples were collected. Details of sediment collection, data reduction, and sediment yield computations from the seven small watersheds are summarized by *Nearing et al.* [2007].

[8] In 1999, as part of a larger effort to convert analog data collection instruments on the WGEW to a digital electronic recording network, the timing components of the sediment samplers were upgraded. The mechanical components remain in place, but sampler operation is currently controlled with electronic clocks, and water level measurement methods have been upgraded [*Stone et al.*, 2008].

2.2. Stock Tank Sedimentation

[9] There are 21 stock tanks on the WGEW and ten of them are instrumented to measure runoff [*Stone et al.*, 2008] and sediment accumulation. High-quality coupled runoff and sediment measurements for eight of the ten stock tanks recently have been updated, processed, and converted to electronic form [*Nichols*, 2006]. Four of the tanks are instrumented with sharp crested weirs in the outlet spillways, and runoff exceeding capacity at the remaining tanks drains through earth spillways. Sediment accumulation is measured through periodic topographic surveys of the surface of each stock tank when the tanks are dry, generally in the months prior to the start of the monsoon season.

Figure 3. View of the inside of the instrument house at LH103 showing the sediment sample bottle carousel.

Standard reservoir survey methods are employed [*Brakensiek et al.*, 1979]. Tank volumes are computed from the topographic surveys, and differences in volume between successive surveys are attributed to sediment infill. Volumes are converted to mass on the basis of sampled bulk densities from each tank. Although overflow spills are relatively rare, these volumes are computed using standard weir formulae. The sediment transported during spills is estimated on the basis of measured sediment concentrations within the WGEW. Two of the stock tanks, 63.212 and 63.214 were part of the national reservoir sedimentation survey data set that contains measurements dating from the 1930s [*U.S. Department of Agriculture*, 1973].

3. Data Quality

[10] High-quality WGEW sediment data sets are developed by considering measurement error and sampling equipment, and through quality assurance and control procedures implemented prior to data processing. Collecting sediment during runoff using either a pump sampler or the traversing slot sampler is subject to a range of mechanical problems, such as clogged intake tubes and failure of moving parts. In addition, sample handling and laboratory procedures can introduce errors. Historically, the pen traces for runoff and sediment measurements operated independently, thus potentially introducing timing errors. The recent instrumentation upgrade improved data collection by incorporating electronic clocks for time stamping measurements. The improvements to data collection are paralleled by improved data reduction and processing procedures. After the summer "monsoon season" sediment sample concentration values are evaluated, and outliers are removed from the data set. Total sediment yields are computed for events during which three or more samples, distributed through the hydrograph, were collected. The quality of stock tank sediment accumulation measurements is maintained by conducting surveys on the basis of three horizontal and vertical control benchmarks established at each tank. In general at least two additional points, such as a weir or the depth recorder platform, are available for additional control.

4. Data Availability

[11] Event sediment discharge from seven small watersheds for data collected from 1995 to 2007 are available on the Internet at http://tucson.ars.ag.gov/dap. Efforts are currently underway to expand this database to include sediment data collected prior to 1995.

[12] Prior to the mid 1980s, suspended sediment was collected during runoff events through the large Walnut Gulch supercritical flumes. Sampling was accomplished by lowering a P-61 sampler from a cableway suspended approximately 30 m above the flumes. Depth integrated samples were collected during extreme weather conditions. These data have been published [*Renard and Laursen*, 1975]; however, their addition to the current SWRC database is pending processing using current procedures.

5. Examples of Data Use

[13] Sediment data sets are notoriously sparse for semiarid regions, and are often limited to short temporal records. The WGEW sediment database provides baseline information for characterizing erosion and sediment delivery on semiarid rangelands. These data have been used to computed sediment yields from small rangeland watersheds [*Osborn et al.*, 1978; *Osborn and Simanton*, 1989; *Renard and Stone*, 1982; *Nichols*, 2006, *Nearing et al.*, 2007].

[14] Sediment data collected on the WGEW have been critical for developing erosion prediction technologies. Examples of simulation models that have used data from WGEW watersheds for development, calibration, and validation include the revised universal soil loss equation (RUSLE) [*Renard et al.*, 1991, 1997], the Water Erosion Prediction Project (WEPP) [*Lane and Nearing*, 1989; *Tiscareno-Lopez et al.*, 1993, 1995], the Kinematic Runoff and Erosion Model (KINEROS) [*Canfield and Goodrich*, 2006; *Canfield and Lopes*, 2004; *Lopes and Canfield*, 2004; *Smith et al.*, 1994], and the basin-scale version of the Simulation of Production and Utilization on Rangelands (SPUR) [*Lane*, 1983].

[15] Recent research is focused on process-based interpretations of sediment transport. The data collection network was expanded in 2002 and pit traps were added below the overfall at flumes 63.103 and 63.104. Analysis of these data, and efforts to process and make available the historic data, are ongoing.

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