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Long-term stream discharge and suspended-sediment database, Reynolds Creek Experimental Watershed, Idaho, United States

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Abstract. The U.S. Department of Agriculture, Agricultural Research Service, Northwest Watershed Research Center initiated a stream discharge and suspended-sediment research program at Reynolds Creek Experimental Watershed in the early 1960s. Continuous discharge measurements began at two sites in 1963, at three additional sites in 1964, and at eight additional sites in subsequent years. Contributing areas to these gauging stations range from 1.03 to >23,822 ha, selected to represent the broad range of environmental settings found across northwestern rangelands. Quality-controlled, validated breakpoint and hourly stream discharge data sets are available for these 13 sites for the period 1963 through 1996 (or for a subset of that time for some sites). Suspended-sediment data are available for three gauging stations (high elevation, middle elevation, and low elevation). All data are available on the Northwest Watershed Research Center anonymous ftp site (ftp.nwrc.ars.usda.gov).

1. Introduction

The Reynolds Creek Experimental Watershed (RCEW) stream discharge and sedimentation program provides fundamental information for research into hydrologic processes, precipitation-runoff relationships, hydrograph characteristics, water yield, and the interactive effects of climate, vegetation, soils, and land use on rangeland hydrologic response [*Slaughter and Pierson*, 2000]. The RCEW database provides a basis for evaluating temporal variability in hydrologic regime and water yield and for evaluating spatial variability within a typical upland rangeland landscape. Rangeland watersheds with high-elevation seasonal snowpacks are vital sources of streamflow during spring and early summer to support in-stream and near-stream habitat and downstream uses including irrigation, recreation, and hydropower generation. See *Slaughter et al*. [this issue] for more details on additional RCEW data available on the ftp site.

2. Data Collection

Locations of all stream gauging stations within RCEW are shown in Plate 3b [*Slaughter et al*., this issue]. Watershed drainage areas range from 1.03 to >23,822 ha with flow characteristics including ephemeral, intermittent, and perennial regimes (Table 1). Discharge records are available for 13 stations with varying lengths of record ranging from 8 to 34 years. Duration of discharge record, type of stream gauge, and mean annual discharge for each watershed within RCEW can be found in Table 2. A detailed description of the spatial data on soils, geology, topography, and vegetation for each watershed is provided by *Seyfried et al*. [this issue]. Brief physical descriptions of each gauged watershed can also be found on the ftp site.

Innovations in discharge measurement and sediment sampling have been tested and applied in RCEW. Cooperative studies with the Albrook Hydraulics Laboratory at Washington State University were successful in developing the drop-box weir design that can pass high sediment loads and does not require regular channel cleaning [*Brakensiek et al*., 1979]. Drop-box weirs have performed well in RCEW over a wide range of discharges and sediment loads. Four additional types of stream-gauging devices are used in RCEW: (1) self-cleaning overflow V-notch (SCOV) weir, (2) 30° V-notch weir, (3) 90° V-notch weir, and (4) Parshall flume [*Brakensiek et al*., 1979]. All stations are equipped with stilling wells and floats for obtaining instantaneous measures of stage height. Instrument shelters are heated to permit collection of discharge and sediment data during cold winter periods. Gauging stations are visited on a weekly or biweekly basis to obtain independent stage height readings for error checking and to service all instrumentation.

Stage height measurements were originally recorded using Leopold-Stevens A-35 and FW-1 strip chart recorders [*Brakensiek et al*., 1979], later supplanted by electronic data loggers. Pressure sensors are now used for redundant backup measurements of stage height to guard against the occasional plugging of stilling well inlet pipes. Accuracy of the continuous stage height measurements is periodically checked against independent staff gauge measurements. If necessary, corrections are made to the recorded data in a linear stepwise fashion between independent staff gauge readings. Stage height measurements are then used to create a digital record of discharge using appropriate calibration equations derived from standard design equations and refined using in situ current measurements. An hourly discharge record is also available on the ftp site and was created from breakpoint runoff data using linear interpolation between breakpoint estimates.

Samples of suspended-sediment concentration were col-

[1] Retired July 2000.

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Table 1. Characteristics for Each Gauged Watershed in the Reynolds Creek Experimental Watershed, Idaho, United States

Watershed	Watershed Identification	Original Survey Drainage Area, ha	DEM[a] Drainage Area, ha	DEM Elevation Range, m	Weir UTM, (E/N)	Discharge Regime
Reynolds Creek Outlet	036x68	23,372	23,822	1099–2244	520111E 4789673N	perennial
Reynolds Creek Tollgate	116x83	5,444	5,468	1398–2244	519393E 4776495N	perennial
Reynolds Mountain East	166x76	40.5	38.97	2024–2139	519954E 4768494N	perennial
Reynolds Mountain West	166x74	51.0	49.59	2028–2127	519746E 4768519N	spring fed perennial
Salmon Creek	046x17	3,638	3,614	1123–1919	520015E 4788996N	perennial
Macks Creek	046x84	3,175	3,237	1132–1891	519506E 4787853N	intermittent
Dobson Creek	135x17	1,409	1,400	1474–2244	518432E 4774338N	perennial
Murphy Creek	043x04	123.8	128.79	1388–1823	514728E 4789016N	spring fed intermittent
Upper Sheep Creek	138x12	26.1	26.01	1839–2015	522462E 4774262N	intermittent
Summit Wash	048x77	83.0	87.84	1266–1455	523520E 4788031N	ephemeral
Flats	057x96	0.9	1.03[b]	1186–1192	521407E 4786030N	ephemeral
Nancy Gulch	098x97	1.3	1.23[b]	1406–1416	523420E 4779426N	ephemeral
Lower Sheep Creek	117x66	13.4	12.96	1576–1650	521616E 4776893N	ephemeral

[a]DEM is digital elevation map.
[b]Values are estimated using GPS readings.

lected at Outlet, Tollgate, and Reynolds Mountain East gauging stations starting in the 1960s and continuing to the present. In early years, samples were collected manually during storm events using integrated samplers at the large weirs or simple grab samples at the smaller weirs. Later, a variety of early sediment samplers such as the U.S. PS-67 and U.S. PS-69 pumping samplers [*Brakensiek et al.*, 1979] were tested and used in RCEW through cooperative efforts with other Agricultural Research Service locations, federal and state agencies, and universities. In recent years, automated Sigma pump samplers have been used at all gauging stations to collect a continuous record of instantaneous point measures of suspended-sediment concentration during high and low flows. Available on the ftp site are two records of suspended sediment: one containing only measured sediment concentration values and one containing breakpoint sediment concentrations based on measured sediment concentration values and streamflow records. Details on the sediment sampler used and the length

Table 2. Duration of Discharge Record, Type of Stream Gauge, and Mean Annual Discharge for Each Gauged Watershed in the Reynolds Creek Experimental Watershed, Idaho, United States

Watershed	Watershed Identification	Duration of Record	Type of Weir/Flume	Mean Annual Discharge	
				Cubic Meters Per Second	Millimeters
Reynolds Creek Outlet	036x68	1963–1996	self-cleaning overflow V-notch (SCOV)	0.560	75.7
Reynolds Creek Tollgate	116x83	1966–1996	drop-box V-notch	0.424	245.9
Reynolds Mountain East	166x76	1963–1996	90° V-notch	0.00671	523.1
Reynolds Mountain West	166x74	1964–1984	drop-box V-notch	0.00686	424.9
Salmon Creek	046x17	1964–1996	drop-box V-notch	0.0823	71.4
Macks Creek	046x84	1964–1990	drop-box V-notch	0.0724	72.0
Dobson Creek	135x17	1973–1980	Parshall flume	0.132	295.9
Murphy Creek	043x04	1967–1977	drop-box V-notch	0.00752	191.7
Upper Sheep Creek	138x12	1970–1975 1983–1996	90° V-notch	0.000756	91.6
Summit Wash	048x77	1967–1975	drop-box V-notch	0.0000181	0.7
Flats	057x96	1972–1996	30° V-notch	0.000000566	2.0
Nancy Gulch	098x97	1971–1996	30° V-notch	0.00000280	7.0
Lower Sheep Creek	117x66	1967–1984 1989–1996	drop-box V-notch	0.0000362	8.6

Table 3. Duration of Record for Measured and Estimated Suspended-Sediment Concentrations Using Different Types of Sediment Samplers for Each Gauged Watershed in Reynolds Creek Experimental Watershed, Idaho, United States

Watershed	Watershed Identification	Sediment Sampler Used	Duration of Measured Concentrations	Duration of Estimated Breakpoint Concentrations
Reynolds Creek Outlet	036x68	hand	1965–1975	1967–1975
		PS-67	1975–1979	1975–1979
		PS-69	1980–1988	1980–1986
		Sigma	1989–1996	
Reynolds Creek Tollgate	116x83	hand	1967–1969	1967–1969
		PS-67	1969–1979	1969–1979
		PS-69	1980–1986	1980–1986
		ISCO	1987–1994	
		Sigma	1994–1996	
Reynolds Mountain East	166x76	Chickasha	1969–1984	1969–1984
		Manning	1984–1986	1984–1986
		ISCO	1987–1996	

of sediment record for each gauging station are given in Table 3. Further details on data collection and processing procedures can be found on the ftp site.

3. Stream Discharge

Stream discharge throughout RCEW is dominated by runoff from spring snowmelt, particularly at higher elevations (Figure 1). Average monthly discharge is greatest during May at all elevations. However, lower elevations also show the impact of rain-on-snow events during the winter months, resulting in a more even distribution of discharge from December through June. Mean annual discharge is quite variable between locations, varying with basin size, basin elevation, and specific setting within RCEW (Figure 2).

Discharge is quite variable between years at all locations (Figure 2). During high-flow years, discharge follows the expected pattern of increasing with drainage area: Outlet has the greatest discharge, followed by Tollgate then by Reynolds Mountain East. During low-flow years, discharge rates are generally an order of magnitude lower, with highest flows being measured at Tollgate rather than Outlet because of water being diverted from Reynolds Creek below Tollgate for local irrigation of ~690 ha of pasture and hay lands. The amount of streamflow diverted for irrigation averages 24% and varies from 14% during high-flow years to 74% during low-flow years [*Johnson and Smith*, 1979]. When discharge rates are normalized for watershed size (Figure 2), unit-area discharge rates are higher for watersheds with greater proportions of their area at high elevations.

The highest flows at Outlet have been driven primarily by rain-on-snow winter events, while Reynolds Mountain high flows have been dominated by rapid spring snowmelt. The winter flood in December 1964 was the highest peak flow recorded for all stations (109 $m^3 s^{-1}$) at Reynolds Creek Outlet). Middle elevations represented by the Tollgate weir experience both winter rain-on-snow and spring snowmelt events. Occasional intense thunderstorms can impact all elevations but are particularly important for lower elevations and the eastern side of RCEW. The fifth-largest peak flow recorded at Outlet (31.7 $m^3 s^{-1}$) was the result of a short-duration high-intensity convective storm centered over Summit Wash in the dry northeastern sector of RCEW.

4. Suspended Sediment

A record of suspended-sediment concentrations is available for Outlet, Tollgate, and Reynolds Mountain East watersheds.

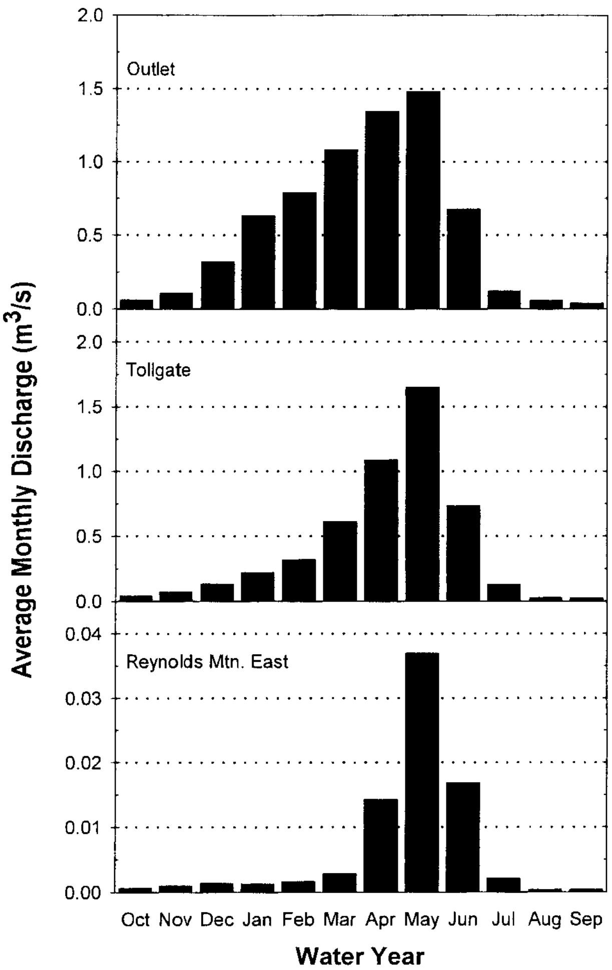

Figure 1. Average monthly discharge rate over the period of record for Outlet, Tollgate, and Reynolds Mountain East watersheds in Reynolds Creek Experimental Watershed, Idaho, United States.

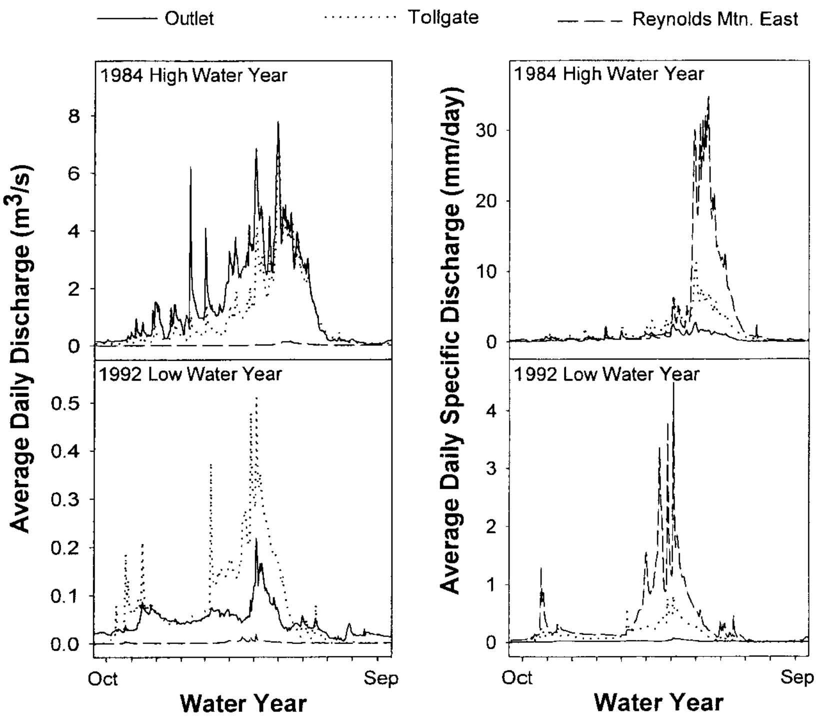

Figure 2. Average daily and specific discharge rates for Outlet, Tollgate, and Reynolds Mountain East watersheds during high (1984) and low (1992) water years in Reynolds Creek Experimental Watershed, Idaho, United States.

The record began at Outlet weir in 1965 when major streamflow events were sampled using periodic grab samples throughout the duration of events. The first pump samplers were used in 1969 increasing the number of events sampled and the number of samples taken during each event (Table 3). In current practice, sediment concentrations are intensely sampled during all events and are periodically sampled during low flows. Figure 3 illustrates the frequency at which suspended-sediment concentration is currently sampled at Outlet, Tollgate, and Reynolds Mountain East weirs during runoff events.

Large runoff events account for most of the sediment yielded from RCEW [*Johnson et al.*, 1978]. Sediment concentrations are highest during the rising stages of an event and then sharply decrease until discharge rate again rapidly increases during the next runoff event (Figure 3). Sediment concentrations are generally 2 orders of magnitude lower during low flows than during high-runoff events and contribute little to the overall RCEW sediment budget. *Johnson and Hanson* [1976] reported that average sediment yields from RCEW and individual subwatersheds (3200–23,000 ha) ranged from 1.14 to 1.9 t ha^{-1} yr^{-1}. Sediment concentrations and annual sediment yield increase with drainage area, as illustrated in Figure 3. During spring runoff, sediment concentrations for the entire RCEW can be an order of magnitude higher than for high elevations above Tollgate weir (Figure 3).

5. Data Availability

Discharge data from 13 weirs, including nine currently in operation and four that were discontinued prior to October 1, 1996, are available from the anonymous ftp site ftp.nwrc.ars.usda.gov maintained by the U.S. Department of Agriculture, Agricultural Research Service, Northwest Watershed Research Center in Boise, Idaho, United States. See "README" files located on the ftp site for further information.

6. Examples of Data Use

Discharge and sediment data from RCEW have been particularly valuable for understanding complex upland runoff and sediment generation processes of rain and snowmelt on snow and frozen soils, which can produce flooding and property damage throughout the northwestern United States. Of the 10 highest peak flow rates at the Outlet and Tollgate weirs all but two were caused by winter or spring rain-on-snow events [*Hanson and Pierson*, 2001]. RCEW data have been used to focus on relationships between runoff source areas and water and sediment yield. Studies of selected source areas of varying size, elevation, aspect, climate, geology, soils and vegetation characteristics have found that watersheds dominated by snowmelt runoff produce higher flows [*Slaughter and Pierson*, 2000], but watersheds dominated by thunderstorm runoff produce higher sediment yields [*Johnson and Smith*, 1978]. *Seyfried and Wilcox* [1995] used hydrologic data from RCEW to examine the partial area contributions, effects of scale, and the nature of variability on a variety of hydrologic processes including streamflow. RCEW has provided an infrastructure for studying small-scale runoff and erosion processes and the framework to link such work to larger scales. *Pierson et al.* [2001] successfully used small-scale variations in surface runoff and erosion [*Pierson et al.*, 1994] to parameterize the Simulation of Production and Utilization on Rangeland (SPUR 2000) model, then validated models results with larger-scale runoff and erosion yields from the Nancy Gulch watershed. Stream discharge and precipitation data from Macks Creek were used to test and validate a raster-based hydrologic model of spatially varied surface

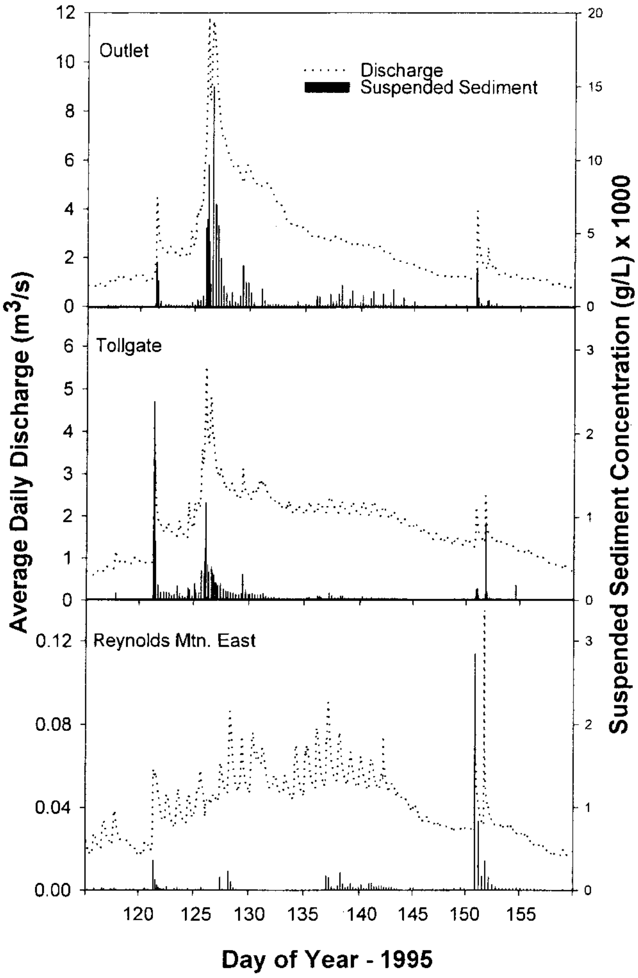

Figure 3. Average daily discharge rate and associated suspended sediment concentrations for Outlet, Tollgate, and Reynolds Mountain East watersheds during spring flow 1995 in Reynolds Creek Experimental Watershed, Idaho, United States.

runoff for a thunderstorm as it moved across the Macks Creek watershed [*Julien et al.*, 1995].

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