Monitoring Series No. 9

California Rangelands Research and Information Center

Streamflow

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Streamflow is a major factor controlling channel morphology, water quality, and aquatic habitat. Streamflow patterns through time result from the complex interactions of weather and watershed characteristics. It is important to understand how watersheds generate streamflow, particularly during storm events. How watersheds generate stormflow has implications for how management will influence flood frequency and magnitude, nonpoint source pollution generation and transport, and aquatic habitat.

Terms

Streamflow is the process by which water is transported out of a watershed via a stream channel. Streamflow is composed of ***baseflow*** and ***stormflow***. During, and shortly after, a storm event streamflow is dominated by stormflow. Between storm events and in the summer streamflow is dominated by baseflow resulting from ground water discharge to the channel.

A ***perennial*** stream is one which flows year around. ***Intermittent*** and ***ephemeral*** streams flow seasonally or during storm events.

Discharge (q) is the flow rate of water passing a point on a stream at an instant in time. Discharge is expressed as a unit volume of water per unit of time, usually as cubic feet per second (cfs). One cfs equals 7.5 gallons per second.

Current velocity (v) is the speed at which water in the channel is moving, expressed as feet per second (ft/s).

Flow volume (Q) is estimated as discharge (q) multiplied by the time duration of interest:

$$[Q\ (ft) = q\ (ft^3/sec) * time\ (sec)]$$

The Hydrograph

A ***hydrograph*** is a continuous record of discharge plotted over time. Figure 1 illustrates the hydrograph for a intermittent stream draining a 342 acre oak savanah rangeland watershed on the San Joaquin Experimental Range in Madera County, California. The peaks represent stormflows, and the low flow periods represent baseflow (17 Feb).

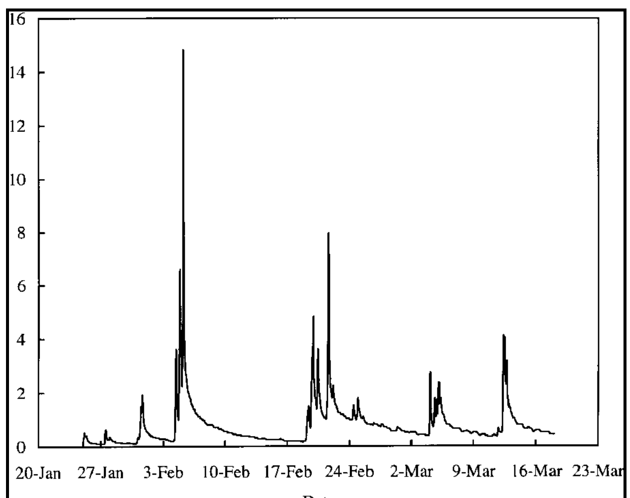

Figure 1. Hydrograph for seasonal flow on a 342 acre hardwood range watershed.

An individual storm hydrograph is composed of the rising limb, the peak, and the falling limb (Figure 2). The area under the hydrograph represents the flow volume [Q = q * time].

Note that the storm hydrograph in Figure 2 rises and falls quickly, or is flashy. This is characteristic of small headwater streams. Generally, as stream size increase the hydrograph becomes wider and more rounded, with the runoff spread over a longer time period.

The shape and peak of the hydrograph will be different for each storm on each watershed. The shape and peak of the hydrograph depends upon how watershed characteristics such as soil type, basin shape, land use, etc., interact with storm characteristics such as rainfall intensity and amount to determine interception, infiltration, overland flow, and subsurface flow. Because watershed and storm characteristics are ever changing, no two storm hydrographs are the same.

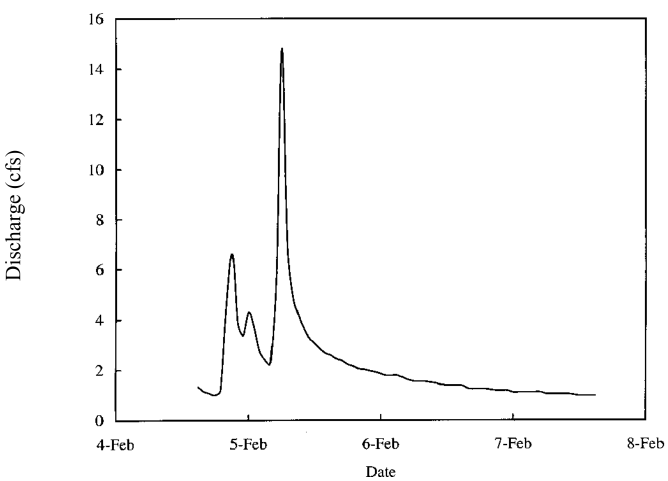

Figure 2. Hydrograph for a single storm on a 342 acre hardwood range watershed.

How do Watersheds produce stormflow?

Hortonian Overland Flow

There are two basic concepts of how watersheds produce stormflow during rainfall events. In 1933, a hydrologist named Horton proposed the concept that "the surface of a permeable soil acts like a diverting dam and head-gate in a stream" where rainfall is partitioned into rainfall which infiltrates the soil and rainfall which does not infiltrate the soil, becoming stormflow transported to streams as overland flow. ***Overland flow*** is the process by which precipitation is transported downslope as sheet flow over the soil surface. Overland flow occurs when rainfall intensity exceeds the soil's infiltration capacity. Rangeland Watershed Fact Sheet #37 discribes in detail the process of infiltration and overland flow and the potential for livestock production to impact them.

Hortonian Overland Flow is widely accepted as the principle stormflow generation mechanism on thinly vegetated or disturbed watersheds located in arid to subhumid climates. This description encompasses most agricultural and many rangeland watersheds.

Variable Source Area

Attempts to apply overland flow based stormflow generation concepts to well vegetated forest and wildland watersheds met with limited success. Forest hydrologists began to doubt the occurrence of Hortonian Overland Flow on forest watersheds, in particular on undisturbed forest watersheds.

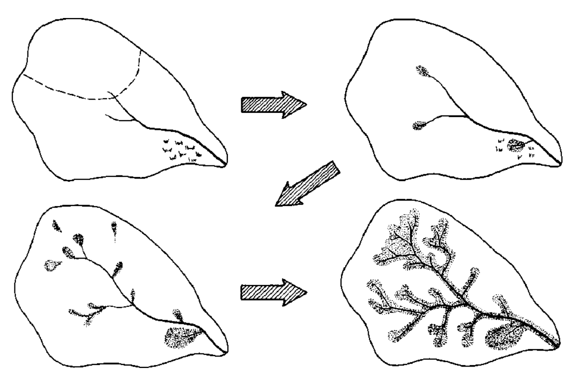

Figure 3. Expansion of variable source area during a storm.

In 1943, Horton himself stated that "owing to somewhat unusual conditions, surface runoff rarely occurs from soil well protected by forest cover."

A new theory of stormflow generation was needed, Hewlett and Hibbert (1967) proposed one in the form of the variable source area concept.

The variable source area concept assumes that water infiltrates in the uplands and travels downslope as lateral subsurface flow and preferrential flow. ***Lateral subsurface flow*** is the process by which precipitation infiltrates and is transported downslope through the soil profile. Transport can be quite rapid in shallow, well structured soils overlaying clay or bedrock. ***Preferrential flow*** is the transportation of precipitation downslope as flow through macropores, rodent tunnels, root channels, etc. This flow receives "preferrential treatment" in that it essentially by-passes the soil matrix.

During a storm event, lateral subsurface flow and preferrential flow provide a rapid influx of water to the stream channel areas and riparian zones maintaining near saturated soil conditions throughout a storm event. These stream channel areas readily contribute overland flow and subsurface flow to the stream channel, becoming the ***source areas*** for stormflow generation. The source area is not constant, but is ***variable*** during and between storms.

Figure 3 illustrates the variable source area concept of storm flow generation. During a storm the source area expands laterally (upslope from the streambank) and longitudinally (up the channel into the ephemiral streams channels). The size and dynamic of the variable source area for each storm depends upon initial soil moisture as well as precipitation amount and duration. The volume of stormflow generated, and the shape of the storm hydrograph, vary between watersheds and storms.

What Happens on California Rangelands?

There is limited scientific information concerning how stormflow is generated on California rangelands. Califorina rangelands are quite diverse, ranging from the annual grassland-hardwood rangeland type, to the arid intermountain sagebrush type. Intuition indicates that Hortonian overland flow dominates stormflow generation in the more arid and thinly vegetated of California's rangelands, such as the sagebrush or juniper types. However, there is limited scientific evidence and observation which indicate that the variable source area concept may apply to some of California's hardwood rangelands.

While developing a watershed water balance for an oak woodland range watershed at the Sierra Foothill Research and Extension Center in Yuba County, Dahlgren and Singer (1994) concluded that lateral subsurface flow above bedrock was the primary flow path during storm events.

The author of this fact sheet has witnessed preferrential flow through rodent tunnels on oak woodland range at the Hopland Research and Extension Center inMendocino County, as well as lateral subsurface flow on oak savanahs at the San Joaquin Experimental Range in Madera County.

For those rangelands driven by snow melt, neither concept of stormflow generation may have application.

So who cares?

Perhaps the most important reason to understand how California's rangeland watersheds generate streamflow is so that we can accurately predict (simulate with a model) how they behave and how our management will modify this behavior.

Almost every agricultural hydrologic, erosion, and water quality simulation model is founded upon Horton's concept of stormflow generation.

What if the Hortonian Overland Flow concept does not apply to all watersheds? Will these models accurately predict the impact of management on California's rangeland watersheds?

We have a lot to learn about basic streamflow processes on rangeland watersheds and how our management might impact them.

Literature Cited

Dahlgren, R.A., and M.J. Singer. 1994. Nutrient cycling in managed and non-managed oak woodland-grass ecosystems. Final Report to Integrated Hardwood Management Program.

Hewlett, J.D., and A.R. Hibbert. 1967. Factors affecting the response of small watersheds to precipitation in humid areas. pp. 275-290. In: W.E. Sopper and H.W. Lull (eds) Forest Hydrology. Pergamon Press, N.Y., NY.

Horton, R.E. 1933. The role of infiltration in the hydrologic cycle. Trans. Amer. Geophys. Union 14:446-460.