HYDROLOGY

The transitory origins of rivers

Streams that only flow occasionally are major contributors to river flow

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A river's journey typically starts in temporary streams that flow sporadically when wet conditions prevail. During dry periods, streamflow slows and then stops as the waters recede below ground. When streamflow resumes over recently dry streambeds, it mobilizes and transports energy-rich materials and nutrients that stimulate aquatic ecosystem productivity downstream (*1*). Temporary streams are present in all climate zones (*1*–*3*), and most of the world's streams and rivers do not flow continuously (*4*). However, the quantity of flow that temporary streams deliver to larger rivers remains unknown. On page 1476 of this issue, Brinkerhoff *et al.* (*5*) report that ephemeral streams—the class of temporary streams that flow least often—collectively convey on average 55% of the flow to perennially flowing rivers in the conterminous United States. The analysis has implications for downstream water quality and water resources management in the United States and elsewhere.

Ephemeral streams are on the dry end of the spectrum of temporary flows, distinguished by the lack of a sustained connection to groundwater. By contrast, intermittent streams remain connected to groundwater and tend to flow for longer periods of time. Ephemeral streams typically flow only when rainfall or snowmelt triggers overland and/or shallow subsurface flow that quickly moves toward the channel, entraining solutes and particulates along the way. As a result, flash flooding and higher-than-usual sediment and pollutant loads can be gener-

The Amargosa River is an ephemeral desert river that flows briefly after rainfall in southern Nevada and southeastern California.

ated from ephemeral streams (*6*, *7*). Yet, because these streams are usually dry, they are often excluded from regulatory safeguards and best management practices to protect downstream water quality (*8*, *9*).

Despite the low frequency and short duration of ephemeral flows, Brinkerhoff *et al.* suggest that they convey substantial quantities of water to the rivers downstream. The amount of ephemeral flow has been difficult to estimate because direct measurements from long-term stream-gaging networks substantially underrepresent temporary streams (*10*, *11*). Brinkerhoff *et al.* merged information from several published datasets to estimate which streams in the United States are ephemeral and when and how much they flow. The authors combined high-resolution channel location datasets, estimates of depth to groundwater and stream bank-full height (the level at which the water reaches the top of the banks before overflowing), and water budget estimates of mean monthly streamflow averaged over several decades. They estimated that ephemeral streams in the southwest and western United States flow less often (4 and 46 days per year on average) compared with those in the eastern United States, where ephemeral streams flow on average 173 days per year. Nonetheless, despite their infrequent flow, ephemeral streams in the west contributed a larger proportion of the flow in downstream rivers (often exceeding 75% in midsize basins) compared with eastern ephemeral streams, which contributed slightly less than 50% of the flow on average to downstream rivers in midsize drainage basins.

The resulting high-resolution ephemeral stream dataset of Brinkerhoff *et al.* provides opportunities for exploring when and where ephemeral streams connect to mainstem rivers. Although the dataset that they developed from a variety of data and model sources may not produce accurate results everywhere, it provides scientists with a starting point to explore ephemeral flow patterns across the continent. The authors acknowledge uncertainties by assessing limitations of their input datasets as well as investigating potential error propagation from high-resolution mapping and measurement errors in tens of millions of streams.

The dataset from Brinkerhoff *et al.* could be useful for exploring major drivers of temporary streams, such as how hydroclimate interacts with landscape factors, for example, watershed slope, drainage area, and soil properties; bedrock geology; and vegetation. Also important are stream channel features, such as valley bottom width and channel sediment texture and permeability (*2*, *12*, *13*). In addition to conveying water downstream, ephemeral streams also recharge groundwater systems (*2*). In arid regions, these streams may be the dominant source of groundwater recharge (*3*), an aspect deserving greater attention. Although commonly located in the uppermost headwaters, ephemeral streams are also present downstream, where stream valleys abruptly widen, and near areas where streamflow is depleted by anthropogenic modifications. Consistent information about river flow modifications by diversions, dams, groundwater pumping, and other human influences is critical for understanding temporary streams (*4*, *5*, *10*, *12*).

Changes in both climate and human influences can affect how often ephemeral streams flow and how much water they convey to downstream rivers. Anticipating how these changes may affect the magnitude, duration, and timing of ephemeral flows can inform land and water management decisions. For example, ephemeral streams may flow more frequently after land development, causing stream channels to incise or widen and expanding areas at risk of flooding. By contrast, flow diversions may reduce or eliminate ephemeral streamflow, disrupting pathways of groundwater recharge. Ephemeral streams are critical components of freshwater systems, and their connectivity to downstream waters affects the water quality and biology of downstream rivers, lakes, and estuaries.

The prominent role of temporary streams in river systems emphasizes that streams are not simply pipes draining the landscape. Rather, streams are surface expressions of dynamically coupled landscape and river systems, with surface and subsurface interactions that support healthy and biologically rich river corridors (*14*). Temporary streams perform valuable functions, such as providing habitats and migration corridors for diverse biological communities, storing water during dry periods, and performing natural purification functions. Large river systems receive water from vast connected networks of ephemeral and intermittent streams. Even though the ephemeral channels are often overlooked because of their infrequent flow, they are critical to downstream water availability. Climate- and land use–driven changes will alter flows and related functions of ephemeral streams in ways that influence future outcomes for water supply, drinking water quality, and the health of aquatic ecosystems in streams and rivers of all sizes. ■

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