Technical Note 23-001

Comparative Flow Analysis between the Pedernales River and Barton and Onion Creeks

Barton Creek and Colorado River Confluence at Zilker Park in Austin, Texas © Ryan Conine, stock.adobe.com

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THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT

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- We analyzed streamflow data from September 24, 1998, through August 31, 2022, since this was the period for which data existed at the four stations we investigated.
- Flood flows in the Pedernales are larger than those in Barton and Onion creeks due to a larger catchment area (about 6 times larger than Onion Creek, about 12 times larger than Barton Creek, and 4 times larger than Barton and Onion creeks combined).
- The Pedernales River contributed no water to the Colorado River 5.3 percent of the time while Barton Creek consistently contributed flow to the river, including during severe droughts, thanks to Barton Springs.
- The Pedernales River contributed about two-thirds more water than Barton and Onion creeks combined; however, flow contributions have been similar since 2008.
- An average acre of land in the watersheds of Barton and Onion creeks produced 2.25 times more water to the Colorado River than an average acre of land in the watershed of the Pedernales River.

Introduction

The Colorado River system relies on tributary flows to sustain aquatic habitat and fill its reservoirs, which provide critical water supplies for Austin, businesses, industry, electrical power generation, and Texas Hill Country residents. During severe droughts in the Texas High Plains, when flow in the Colorado River upstream of Lake Buchanan ceases, local tributary flows may be the only contributors to the river. The Pedernales River, Onion Creek, Barton Creek, and Barton Springs all provide critical sustaining flows to the Colorado River in Central Texas (Figure 1).

Part of the City of Austin's program to protect the reliability of its water supply includes purchasing conservation lands within the watersheds that contribute to Barton Springs and the Colorado River. The purpose of this report is to quantify the relative flow contributions from the Pedernales River, Onion Creek, and Barton Creek watersheds to the Colorado River to support efficient and effective resource allocation decisions to preserve contributing watersheds.

To our knowledge, an analysis of the relative contributions to the Colorado River of the Pedernales River and Barton and Onion creeks has either not been conducted or is not publicly available. Therefore, we analyzed and compared flows at four U.S. Geologic Survey stream gages: one on the Pedernales River near Johnson City (Figure 2), one for Barton Creek just above Barton Springs, one for Barton Springs (Figure 3), and one for Onion Creek near Highway 183 (Figure 4).

Background

The Pedernales River flows for about 106 miles, starting in Kimble County, and discharges into Lake Travis downstream from the Highway 71 Bridge. The watershed spans about 1,280 square miles and includes all or parts of Kimble, Kerr, Gillespie, Blanco, Hays, and Travis counties (Wierman and others 2017).

Barton Creek begins in northern Hays County and flows 40 miles east into Travis County and through Austin before discharging into Lady Bird Lake in Zilker Park. The Barton Creek watershed covers an area of about 109 square miles (City of Austin 2009). Barton Creek crosses the recharge zone of the Edwards Aquifer, and all or part of its flow infiltrates into the Edwards rocks exposed in the creek bed.

The Edwards Aquifer is charaterized by karst features such as sinkholes, cave openings, and underground passages that enhance groundwater flow (Small and others 1996). West of the Balcones Fault Zone and northwest of the Mount Bonnell Fault in Travis County, the Barton Creek watershed is underlain by the Glen Rose Formation (Johns and Pope 1998). Most of the flow from Barton Creek entering the Edwards Aquifer reemerges from Cold Springs along the shores of Lady Bird Lake (Texas Stream Team 2019).

Onion Creek begins 12 miles southeast of Johnson City in Blanco County and flows approximately 79 miles eastward before discharging into the Colorado River 2 miles northwest of Garfield in Travis County (TSHA 1995). The entire watershed spans about 211 square miles (City of Austin 2011). Like Barton Creek, Onion Creek crosses the recharge zone of the Edwards Aquifer, and all or part of its flow infiltrates into the Edwards rocks exposed in its creek bed. The water eventually discharges at Barton and San Marcos springs (Hunt and others 2016).

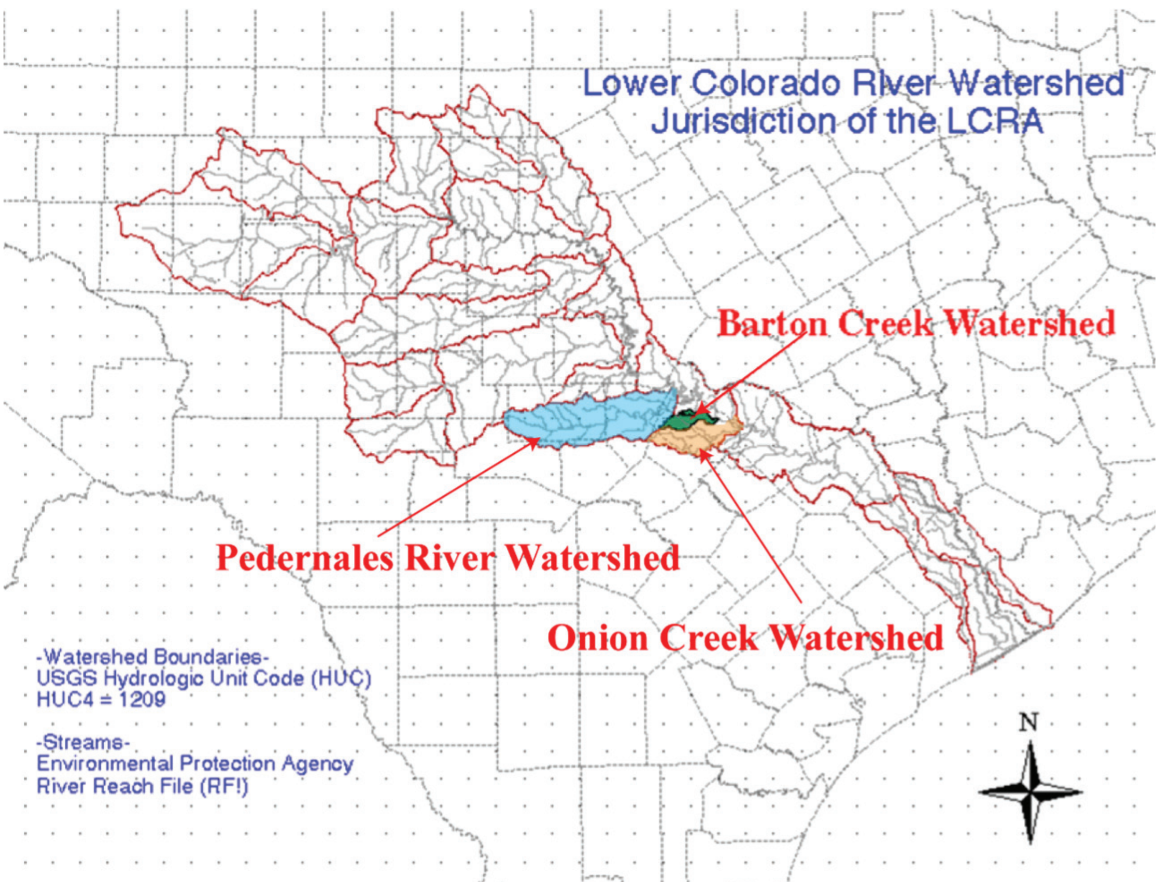

Figure 1. Location and extend of the watersheds for the Lower Colorado River, including those for the Pedernales Rive, Barton Creek, and Onion Creek. (LCRA = Lower Colorado River Authority; modified from Kaough [undated])

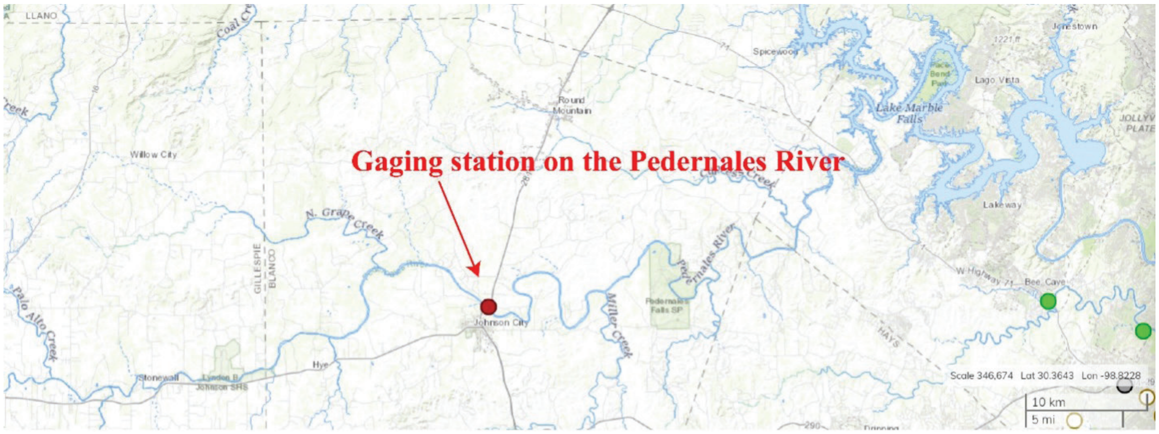

Figure 2. Location of gaging station near Johnson City on the Pedernales River (map from USGS 2022).

Figure 3. Locations of the gaging stations for Barton Creek upstream of Barton Springs and Barton Springs (map modified from USGS [2022]).

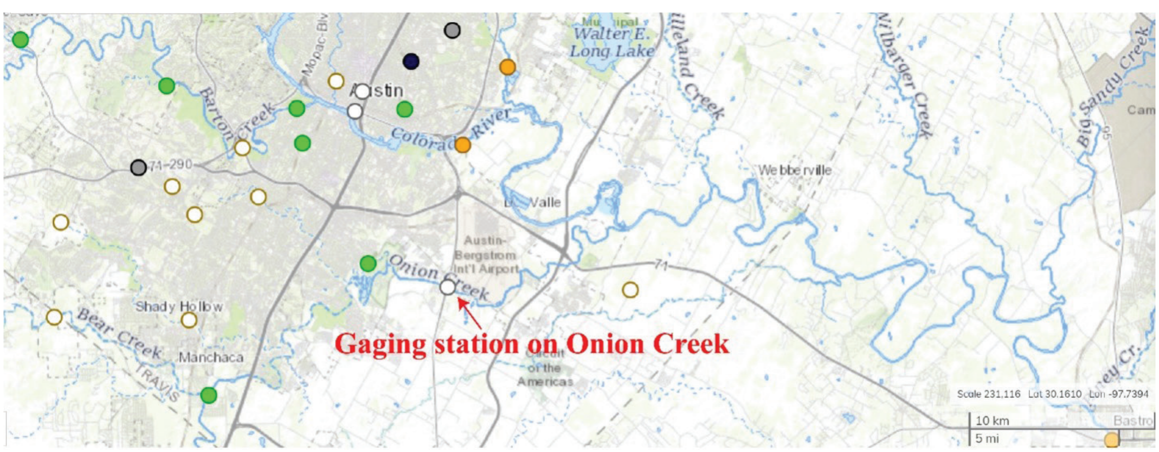

Figure 4. Location of gaging station near Highway 183 on Onion Creek (map modified from USGS [2022]).

Methods

Our methods were simple: we (1) downloaded data for the stream and spring gages from the National Water Dashboard (USGS 2022), (2) adjusted the flow for the Pedernales River, and (3) summarized the data statistically and graphically.

We downloaded streamflow data from September 24, 1998, through August 31, 2022, to analyze daily discharge rates at all four stations. We used this time range since this was the period for which data existed at all four stations.

We adjusted the flow in the Pedernales River to account for the lack of a streamflow gaging station closer to the confluence of the river with Lake Travis (that is, where the river emptied into Lake Travis). To do this, we used the Drainage Area Ratio Method (Asquith and others 2006) based on the discharge rate measured at the gaging station near Johnson City.

The Drainage Area Ratio Method equates the ratio of streamflow at two stream locations to the ratio of the respective drainage areas. It is a technique that statistically transfers same-day streamflow information from one location to another based on the drainage areas above the two locations.

The equation for the correction is

$$Q_y = Q_x \left(\frac{A_y}{A_x}\right)$$

where Qy is the streamflow for the ungaged location, Qx is the streamflow for the gaged location, Ay is the drainage area upstream of the ungaged location, and Ax is the drainage area upstream of the gaged location.

The Drainage Area Ratio Method assumes that the gaged and ungaged parts of the basin produce the same amount of streamflow on a per area basis. In the case of the Pedernales River, this adjustment may underestimate flows from the river to Lake Travis. One might expect more groundwater discharge into the lower reaches of the basin than the upper reaches. Furthermore, there is a general decrease in rainfall in Texas as one moves west (TWDB 2012). Regardless of its limitations, this is the method used by the Lower Colorado River Authority to calculate inflow into Lake Travis from the Pedernales River (Riley 2022). For our analysis, we used a drainage area ratio (Ay / Ax) of 2.03 as defined by Wierman and others (2017) and Riley (2022).

For Barton Creek, we simply added the flows at the station just above Barton Springs and the flows reported for Barton Springs together. Flows reported for Barton Springs only account for flows from the springs and not flows in the creek. Flows upstream of Barton Springs are routed around the Barton Springs Pool, so our analysis does not double count flows in the creek. A small part of the drainage system is missed from just below Barton Springs to Lady Bird Lake resulting in a slight underestimate of flow.

For Onion Creek, we simply used the flow at the lower station as a proxy for flow into the Colorado River. Part of the drainage system is missed from that station down to the confluence with the Colorado River resulting in an underestimate of flows. Onion Creek loses flow to the Edwards Aquifer where it crosses the recharge zone. The component of recharge that flows toward the northeast either discharges from Barton Springs (and is thus included in flow measurements there) or is intercepted by pumping (which doesn't contribute inflows to Lady Bird Lake) or heads southwest towards San Marcos Springs (which doesn't contribute inflows to the Colorado River).

To represent Barton and Onion creeks together, we simply added their two flow numbers together.

Results

For our results, we first discuss the unadjusted data and then the adjusted data. After that, we summarize the statistics for daily flows and present cumulative flows for the drainages and cumulative flows divided by catchment areas.

Unadjusted Data

Daily discharge for Onion Creek and for Barton Creek upstream of Barton Springs approximately resembles the behavior of discharge for the Pedernales River near Johnson City (Figure 5), especially in terms of flashiness related to flooding events. Discharge rates of Onion Creek and Barton Creek upstream of Barton Springs show that the two behave almost concurrently with each other—not surprising since the two watersheds are next to each other and therefore experience similar weather (Figure 5). The magnitudes of Onion Creek's peak discharges are larger than that of Barton Creek due to Onion Creek's larger catchment area, nearly twice the size of Barton Creek's catchment. Flow from Barton Springs is less variable reflecting a semi-regional groundwater system with storage (Figure 5). The 2009 to 2015 drought is easier to identify in the discharge data for the Pedernales River than that for the creeks and springs (Figure 5).

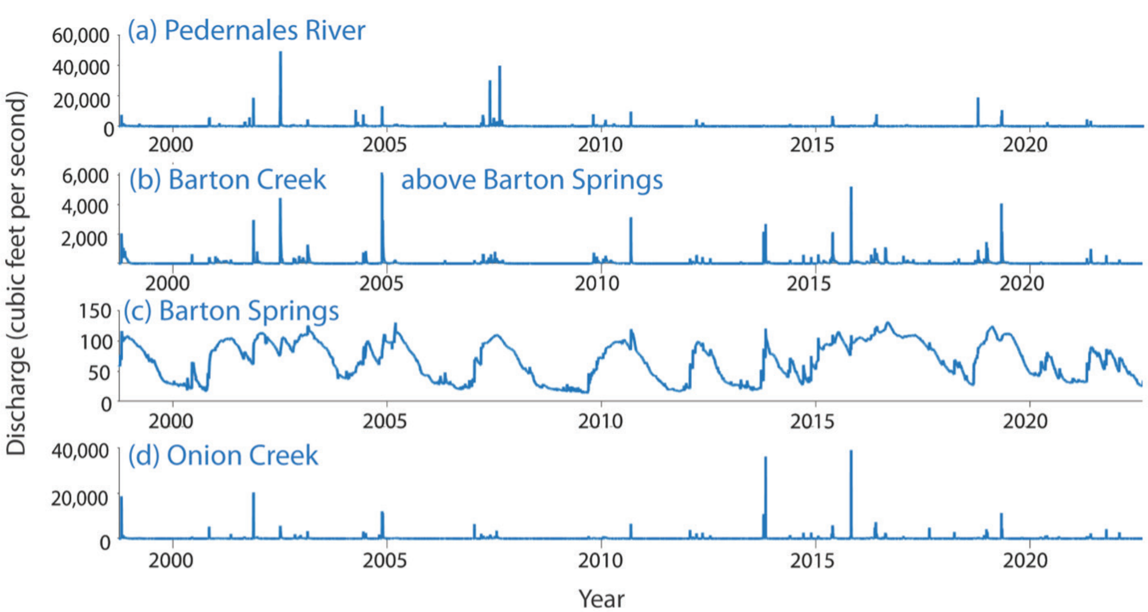

Figure 5. Unadjusted data for daily discharge rates at the gaging stations for (a) the Pedernales River, (b) Barton Creek upstream of Barton Springs, (c) Barton Springs, and (d) Onion Creek. Note that the vertical scales are different for each gage.

Adjusted Data

Similar patterns can be seen in the adjusted data where flow in the Pedernales River is adjusted with the Drainage Area Ratio Method (hereafter referred to as the Pedernales River), the gage for Barton Creek just above Barton Springs and Barton Springs are added together (hereafter referred to as Barton Creek), and the data is then plotted on the same plot along with Onion Creek (which has no adjustment) (Figure 6). Flows into Lake Travis and Lady Bird Lake are hereafter referred to as flows into the Colorado River.

Flood flows in the Pedernales are much larger than those in Barton and Onion creeks due to a much larger catchment area (about six times larger than Onion Creek and about 12 times larger than Barton Creek; Figure 6).

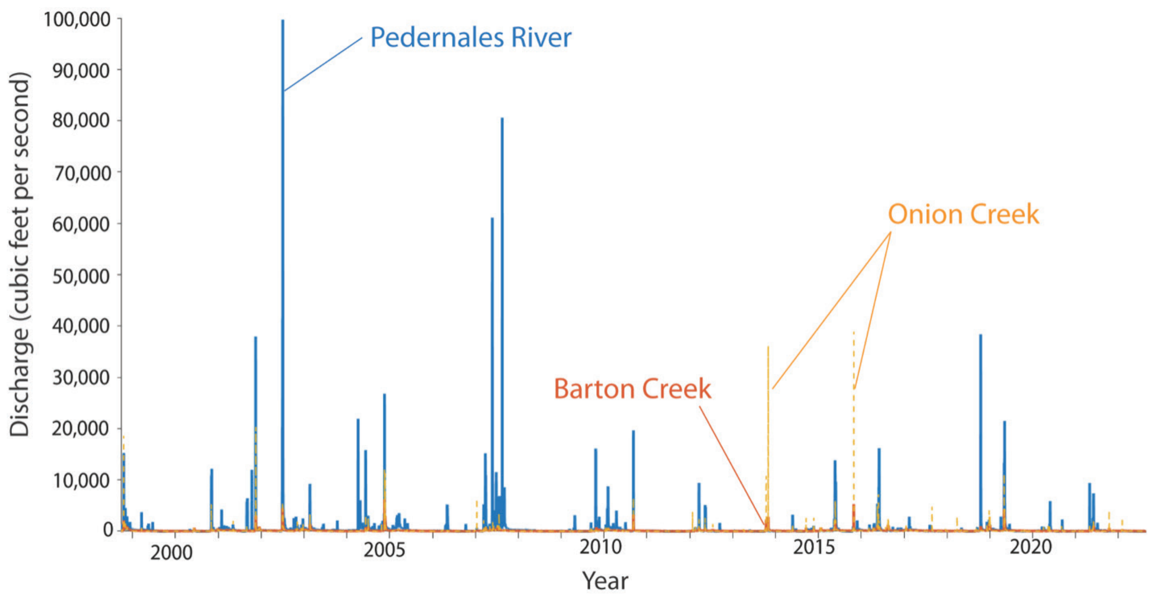

Figure 6. Adjusted daily stream discharge rate into the Colorado River for the Pedernales River, Barton Creek, and Onion Creek.

Daily Discharge Rates

For the Pedernales River, the maximum daily discharge of 99,700 cubic feet per second occurred on July 4, 2002. The average daily discharge rate in the river was 327 cubic feet per second, while the median was 2 cubic feet per second and the mode was 0 (see Table 1 for a summary of statistics). A mean much larger than the median indicates that the distribution of discharge rates is positively skewed toward lower values. A mode of zero means that the most common flow is zero. About 5.3 percent of the daily flow measurements in the Pedernales River were zero.

For Barton Creek, the maximum daily discharge of 6,240 cubic feet per second occurred on November 17, 2004. The average daily discharge rate in the creek was 109 cubic feet per second, while the median was 74 cubic feet per second and the mode was 28 cubic feet per second (see Table 1 for a summary of statistics). A mean somewhat larger than the median indicates that the distribution of discharge rates is somewhat positively skewed toward lower values. Thanks to the consistency of flows at Barton Springs, none of the daily flow measurements in Barton Creek were zero at the confluence with the Colorado River.

For Onion Creek, the maximum daily discharge of 38,900 cubic feet per second occurred on October 30, 2015. The average daily discharge rate in the creek was 87 cubic feet per second, while the median was 7 cubic feet per second and the mode was 0 (see Table 1 for a summary of statistics). About 15.9 percent of the daily flow measurements were zero.

The percentage of time when the daily discharge in Barton and Onion creeks was higher than that in the Pedernales River is 49.7 percent, nearly half. In other words, daily flow into the Colorado River from Barton and Onion creeks is greater than that from the Pedernales about half of the time.

Table 1. Descriptive statistics of daily discharge rates in cubic feet per second into the Colorado River.

	MAX	MEAN	MEDIAN	MODE	PERCENTILES			
					5TH	10TH	25TH	90TH
Pedernales River	99,700	327	74	0	0	2	32	514
Barton Creek	6,240	109	74	28	20	23	37	200
Onion Creek	38,900	87	7	0	0	0	1	118

Cumulative Flow

Cumulative flow is a running total of flow starting with a specified date. Given the large variability of flows in these surface-water drainages, particularly for the Pedernales River and Onion Creek, cumulative flows are easier to interpret and to compare and contrast with each other (Figure 7). Cumulative flows also relate directly to the question at hand—which drainage is contributing the most flow to the Colorado River.

Over the investigated time period, the Pedernales River produced more water—about two-thirds more—than Barton and Onion creeks (Figure 7). The upward jumps in cumulative discharge—particularly evident in the Pedernales River—are due to large flooding events, long flow events, or both (Figure 7b).

Since the beginning of 2008, about the time the new drought of record started for the Colorado River in Central Texas and the Highland Lakes, the rate of increase in cumulative flows have been about the same between the Pedernales River and Barton and Onion creeks (compare the slopes of the lines in Figure 7b after 2008). Although the new drought-of-record ended in 2015 for the Colorado River and the Highland Lakes, it appears—based on cumulative flows—that drought or drought-like conditions have continued for runoff in the Pedernales River Basin.

The catchment for the Pedernales River is about four times larger than the combined catchment for Barton and Onion creeks. Therefore, we normalized flows between the two catchments to assess the amount of cumulative streamflow per unit area by dividing the cumulative flows by the watershed area. In other words, we calculated the amount of streamflow contributed to the Colorado River on a per square mile basis.

At the end of the study period, Barton and Onion creeks produced more than twice as much water to the Colorado River on a per area basis (per acre, per square mile) than the Pedernales River (Figure 8). By August 31, 2022, Barton and Onion creeks had produced more than 450 million cubic feet per square mile of catchment compared to just under 200 million cubic feet per square mile for the Pedernales River (Figure 8). In other words, an acre of land conserved in the watersheds of Barton and Onion creeks would have produced 2.25 times more water than an acre of land conserved in the watershed of the Pedernales River during the study period.

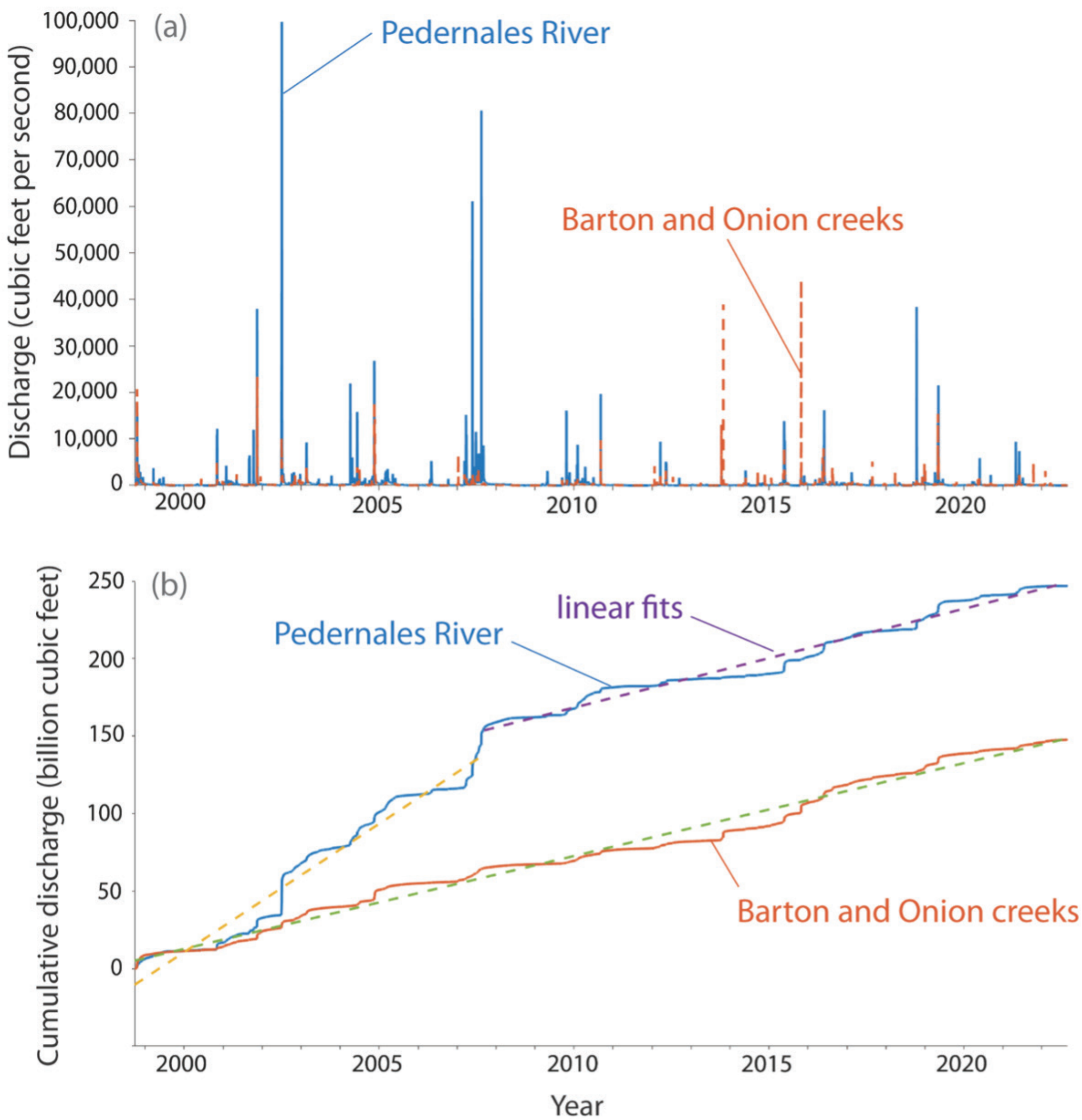

Figure 7. (a) Daily discharge rate and (b) cumulative flow for the Pedernales River and Barton and Onion creeks.

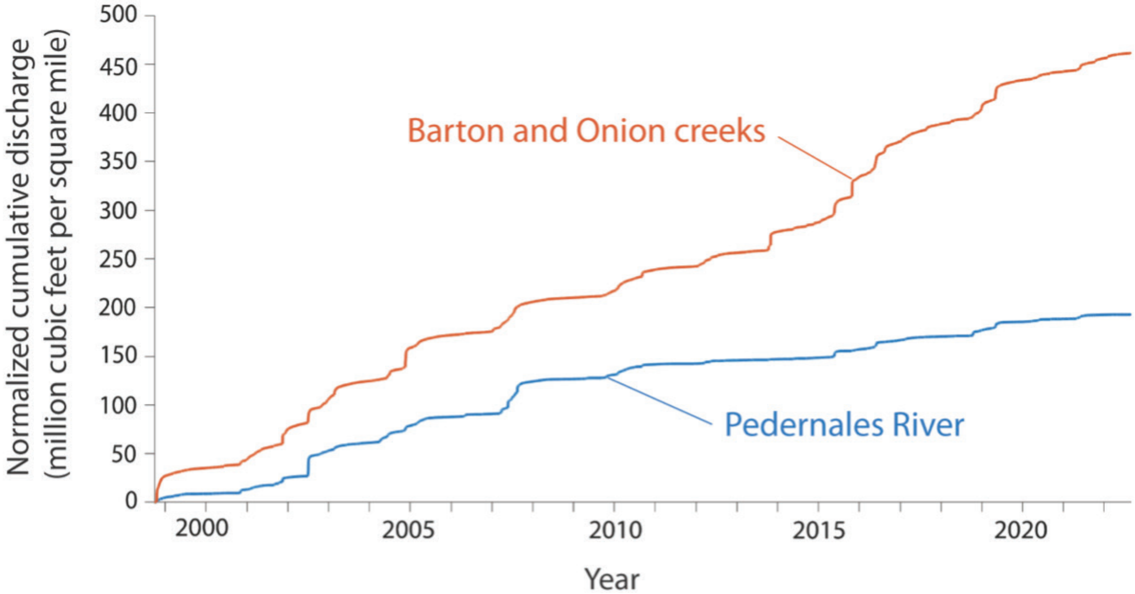

Figure 8. Cumulative discharge per square mile of catchment for the Pedernales River and Barton and Onion creeks.

Conclusions

We quantified the relative streamflow contributions of the Pedernales River and Barton and Onion creeks to the Colorado River. We did this by analyzing daily streamflow data available for all three drainages, which was from September 24, 1998, through August 31, 2022. We adjusted streamflow in the Pedernales River to account for the gage being located substantially upstream from the confluence with Lake Travis. We made this adjustment using the Drainage Area Ratio Method, an approach used by the Lower Colorado River Authority and others.

Flood flows in the Pedernales River are larger than those in Barton and Onion creeks due to a larger catchment area (about 12 times larger than Barton Creek, about six times larger than Onion Creek, and 4 times larger than Barton and Onion creeks combined). Accordingly, for the period investigated, the Pedernales River had a larger maximum daily discharge of 99,700 cubic feet per second than that of Barton Creek (6,240) and Onion Creek (38,900). However, the Pedernales River contributed no water to the Colorado River 5.3 percent of the time while Barton Creek consistently contributed flow to the river, including during the drought of record, thanks to Barton Springs. Daily flow into the Colorado River from Barton and Onion creeks is greater than that from the Pedernales River about half of the time.

From September 24, 1998, through August 31, 2022, the Pedernales River contributed about two-thirds more water than Barton and Onion creeks combined; however, flow contributions have been similar since 2008. When compared on an acre-by-acre basis, an average acre of land conserved in the watersheds of Barton and Onion creeks produced 2.25 times more water to the Colorado River than an average acre of land in the watershed of the Pedernales River.

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