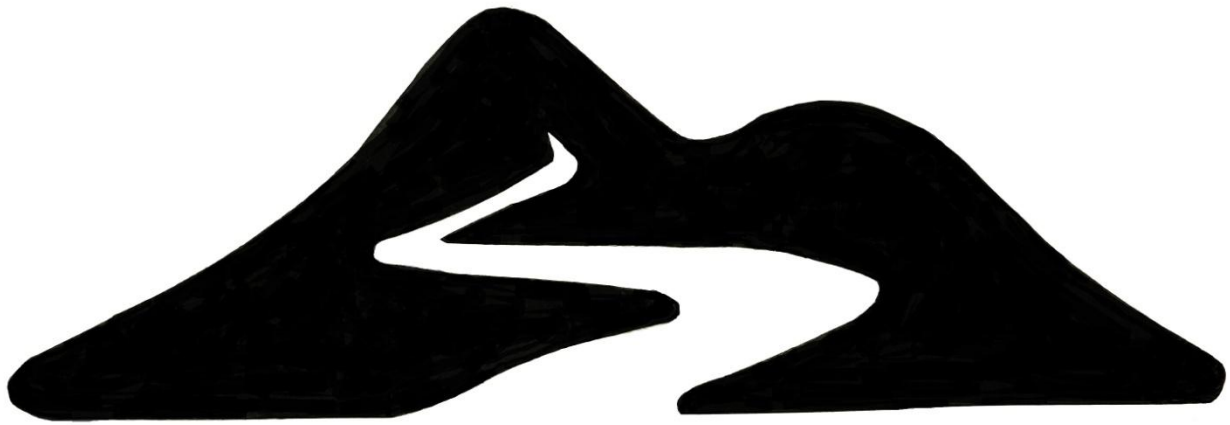


**A METHOD FOR FORECASTING
UNUSUALLY LOW SUMMER FLOWS AND
ELEVATED SPRING PEAK FLOWS
IN THE LOWER PRICE RIVER, UTAH**



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for The Nature Conservancy**

March 18, 2026

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Executive Summary

The Nature Conservancy (TNC), in coordination with other basin interests, anticipates securing water in future years that may be used to augment flows in the lower Price River, Utah, for purposes of benefiting freshwater resources including native fishes. Researchers have identified base flows and peak flows in the lower Price River that appear to benefit the river environment, including key life stages of native fish species.

An evaluation of 25 years of data available annually on April 1 from the National Integrated Drought Information System (NIDIS) and from the Colorado Basin River Forecast Center (CBRFC) reveals that these data sources historically have been robust indicators of subsequent atypically low base flow and atypically high peak flow conditions in the lower Price River. This report describes these data sources and provides a tool, in the form of an evaluation matrix, that TNC and other water managers may find useful for making informed decisions regarding the likely use of available supplemental water.

1. Introduction and Purpose of this Report

The Price River is tributary to the Green River and eventually to the Colorado River. It drains an area of approximately 4,900 km² in east-central Utah. Its headwaters arise in the Wasatch Plateau at an elevation of about 2,800 m, with the river entering the Green River in Gray Canyon at around 1,300 m elevation. The Price flows into the Green River about 19 kilometers north of the town of Green River, Utah.

The Price River drainage basin sits in a generally arid landscape. Maximum average annual precipitation within the basin exceeds 800 mm (31 inches) at the higher altitudes of the Wasatch Plateau. However lower basin elevations receive less than 250 mm (10 inches) annually (Waddell et al. 1986; Worqlul et al. 2021) and mean annual precipitation at the town of Price is about 234 mm (9.2 inches). Within the Price River basin, mean annual precipitation displays a very strong linear relationship to elevation (Worqlul et al. 2021; see their Figure 2).

The lower Price River is important for conservation of native fish in the Colorado River system. It provides habitat on at least a seasonal basis for the federally-listed Colorado Pikeminnow (*Ptychocheilus lucius*), Razorback Sucker (*Xyrauchen texanus*), and Bonytail (*Gila elegans*) (McAda et al. 1977, Masslich and Holden 1995, Cavalli 1999, Hudson 2002). It also provides year-round habitat for several other native fish, including Bluehead Sucker (*Catostomus discobolus*), Flannelmouth Sucker (*Catostomus latipinnis*), and Speckled Dace (*Rhinichthys osculus*).

The Nature Conservancy (TNC), in coordination with other basin interests, anticipates securing water in future years that may be used to augment lower Price River flows and provide native fish benefits. To help inform TNC's planning, Chart and Anderson (2025) characterized flows in the lower Price River that appear to support a sound environment, including key life stages of native fish species. That report offered suggestions pertaining to desirable peak flows and base flows in the lower Price River (Sections 5.1 and 5.2), along with a conceptual decision tree for determining the most effective use of water available to augment lower Price River flows any given year (Section 5.3).

In their 2025 report, Chart and Anderson also recommended some ‘priority follow-up study needs’ (Section 5.4) to fill data gaps relevant to each of the following themes:

- Understanding River Channel Conditions
- Fisheries Data Collection, Evaluation, and Application, and
- Hydrologic Tools

With respect to the latter, one Chart and Anderson recommendation was:

“If supplemental water becomes available to augment environmental flows in the Price River, it may be worthwhile to develop a ‘stream forecasting tool’ focused on annually projecting April-September flow conditions in the lower river ... A systematic analysis of historic spring-through-fall streamflow at Woodside as a function of hydrologic variables such as snow accumulation, soil moisture conditions, seasonal climate outlooks, and irrigation demands could provide managers with a valuable tool for better anticipating priority instream flow needs and opportunities over coming months.”

In response to that recommendation, the purpose of this report is to provide TNC with an initial evaluation tool that uses information readily available around April 1 of each year to assess (a) the likelihood that problematically low flows will develop in the lower Price River during the June-through-September period, and (b) the likelihood that peak flows during the April-June snowmelt high-flow period may approach bankfull-flow conditions.¹

2. Hydrologic Context

The primary source of stream flow data for the lower Price River is the U.S. Geological Survey’s (USGS’s) gage #09314500, located at the U.S. Highway 6 crossing near the town of Woodside, Utah (latitude 39.264 north, longitude -110.343). This gage operated from December 1945 through October 1992, ceased operation from fall 1992 to summer 2000, then resumed data collection in July 2000. It has been continuously recording flows ever since.

The Price River’s flow regime is characterized by a spring peak of extended duration, which is dominated by basin snowmelt and typically crests sometime in April, May, or June. This is normally followed by a decline to considerably lower base flows for the remainder of the year that are frequently interrupted by sharp spikes of flashy runoff generated by high-intensity convective storms (Figure 1). These short-duration high-flow events in the summer and fall can sometimes keep river flows relatively elevated throughout the July-through-November period.

¹ Disclaimer: While the author of this document has made every effort to assemble the best information possible, he makes no guarantee that information in this report is 100% accurate and up-to-date.

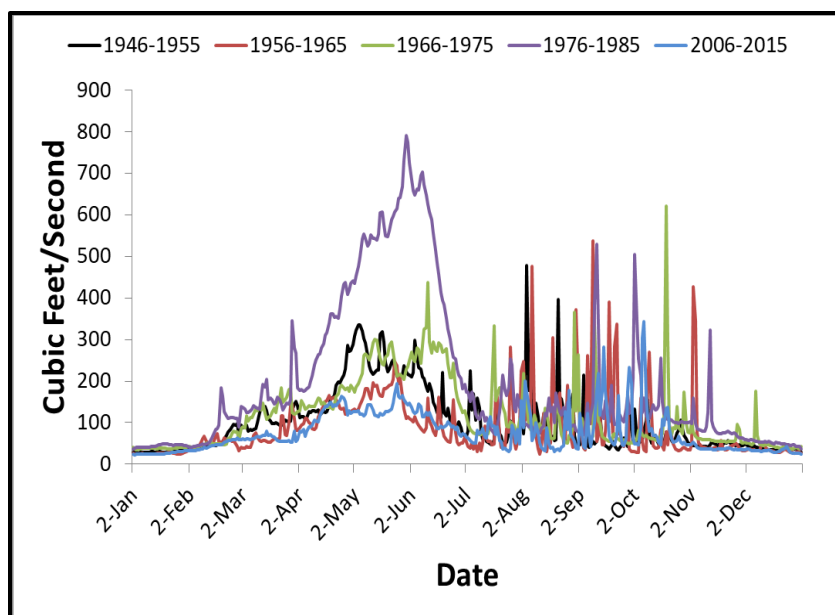


Figure 1. Mean daily streamflow in the Price River over various decadal periods, 1946 through 2015. Reproduced Figure 4 from Laub et al. 2020.

Total annual flow in the lower Price River as measured at the USGS Woodside gage since 1947 has ranged from a high of 346,640 acre-feet (in 1983) to a low of 18,751 acre-feet (in 1990). From 2001 through 2024, annual flow averaged 50,800 acre-feet (AF)/year. Prior to 1992, average annual flow was about 87,800 AF/year, with a seven-year running average varying between 50,000 and 200,000 AF/year (Figure 2). In short, annual flow in the Price River over the post-2000 period has generally been substantially lower than in the earlier gaged period.

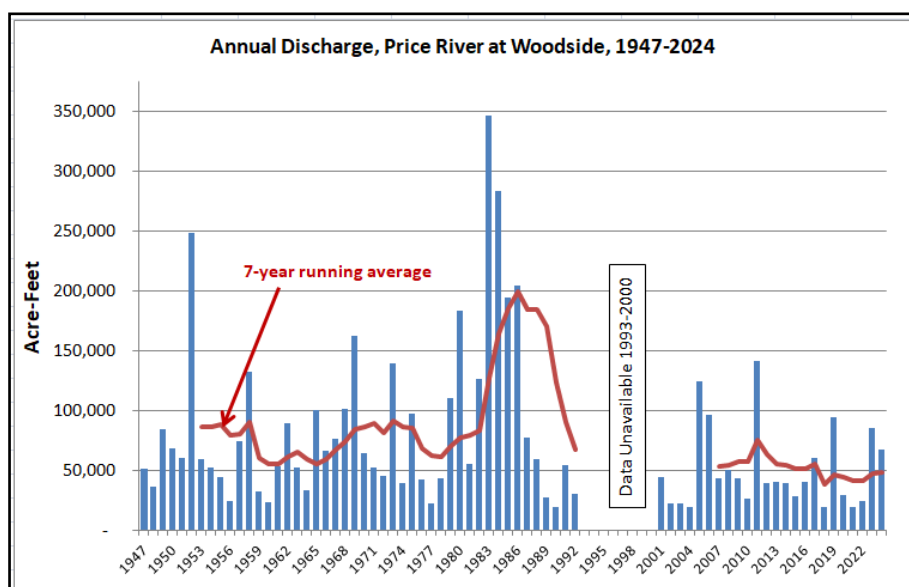


Figure 2. Annual runoff measured at the USGS Woodside gage beginning in 1947, with the seven-year running average overlaid as a red line.

Peak flows are a critical component of the hydrographs of western rivers. They typically transport a disproportionate amount of river sediments, which in turn govern channel form and complexity, including habitat conditions for native fish (e.g., the location and quality of spawning bars). Elevated flows also can affect the availability of warm productive areas on inundated floodplains, and provide important spawning and migratory cues for fish.

Over the available 71-year record, annual peak flows in the lower Price River, on an *instantaneous basis*, have occurred 89% of the time in July through October, and 56% of the time in either August or September. However, on a *monthly basis*, annual maximum flows over the same period at Woodside show a marked bi-modal pattern. With only one exception, the highest-flow months corresponded to either March-June (58% of years), or August-October (41% of years). (Chart and Anderson, 2025)

Late-summer peak flows, normally associated with convective storm events, are typically short-lived, but are capable of delivering substantial volumes of eroded sediments from the landscape into the river channel. In contrast, the March-June peak flows, normally associated with peak snowmelt in the basin, are typically longer-duration events capable of generating greater overall runoff volumes and mobilizing larger volumes of sediment within the river channel.

While the Price River still displays this annual runoff pattern and bimodal timing of annual peaks, the gage record shows a substantial reduction in the magnitude of spring floods over the decades, presumably a result of changes in water use and climate over the available period of record (Figure 1). Interestingly, examination of the hydrologic data also suggests that late summer and fall runoff volumes have similarly declined, and in nearly comparable proportions to spring flows (Chart and Anderson, 2025).

Adequate **base flows** during the irrigation season are important in most Colorado River tributaries because they support and allow native fish to access to an adequate mix of habitats, including resting, foraging, and spawning habitats. As higher river runoff declines, sufficient base flows allow fish to seek out favorable habitats, evade predators, and return to their home ranges after spawning. Base flows also help sustain a productive forage base for native fish.

In some years, base flows in the Price River can become severely dewatered for extended periods in the summer and fall. The USGS reported flows of less than 0.5 cubic feet per second (cfs) for multiple days at Woodside in 1960, 1961, 1977, 1992, 2002, 2003, 2004, 2013, 2016, 2018, 2021, 2022, and 2025. Since 2001, very low flows at Woodside have not been uncommon in the July-through-September period when more elevated flows likely would be beneficial for Colorado Pikeminnow and other native species.

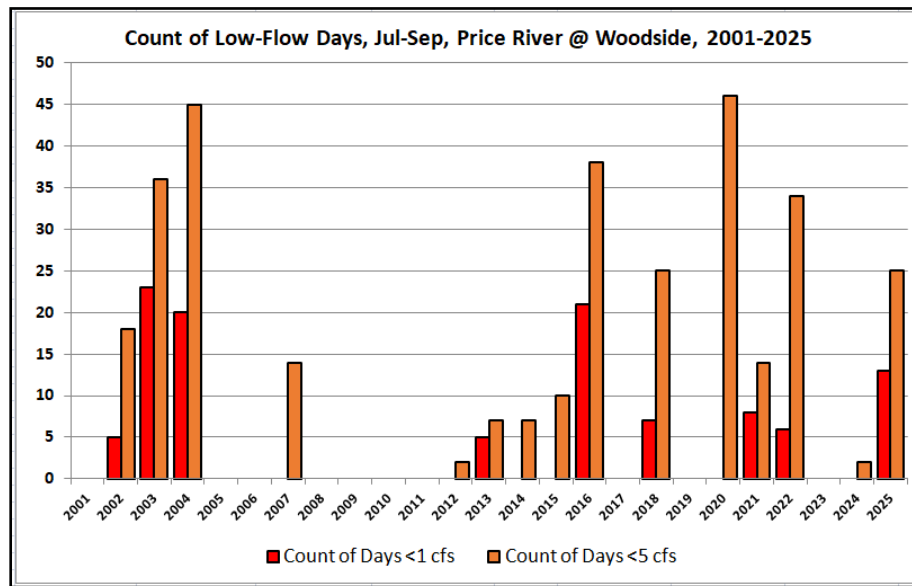


Figure 3. Count of days in each year, 2001 through 2025, in which mean daily discharge at the Woodside gage fell below 1 cfs (red bars) and 5 cfs (orange bars).

3. Desirable Flow Targets

Chart and Anderson (2025) offered preliminary recommendations for desirable flows in the lower Price River for supporting freshwater resources, particularly native fishes. Those recommendations addressed both base flow conditions and peak flow occurrences. The authors summarized desirable flows as follows:

“We believe that any opportunity to manage environmental flows in the Price River should focus first on trying to safeguard base flow conditions during the irrigation season (July – September), particularly in dry and average year hydrologies. As a first tier of management, we support the recommendations of Chart and Mohrman (2012) for reducing and preferably eliminating fish kills by maintaining a minimum 5 cfs at the Woodside gage. Secondly, if sufficient water is available to further augment environmental flows, we encourage managing toward the Chart and Mohrman recommended base flow exceedances shown in Table 9 (or, at least, targeting the 90% exceedance flow of 15 cfs) ... If the opportunity arises to maintain even higher summer base flow levels than this, we believe that would further increase benefits to the native species.

“... if the opportunity arises to manage for higher flows, we suggest that flow managers weigh the immediate benefits of providing additional ‘base flows for fish’ against the potential long-term benefits of reserving water to augment high flows and achieve more targeted channel maintenance and habitat improvement objectives.” (Chart and Anderson 2025, p. 29)

To recap, Chart and Anderson highlighted **5 cfs** and **15 cfs** as suggested low-flow targets in the lower Price River, along with opportunities to **augment unusually high spring flows** when doing so is likely to mobilize coarser river bed and bank sediments, rework the channel geometry, and potentially improve the mix and quality of habitat available for native fish.² Based on their review of readily available hydrologic data, Chart and Anderson inferred that flows in the range of 729 - 913 cfs may roughly correspond to ‘bankfull flow’ in the lower Price River. If so, that range may be a useful target for periodic pulse flows³ for purposes of maintaining a desirable mix of channel habitats.

Therefore, the analysis here considers annual opportunities to assess (a) the likelihood that Woodside gage flows will dip below 5 cfs and 15 cfs during the June-through-September period, and (b) the likelihood that peak flows will approach bankfull magnitudes during the April-through-June high flow period.

4. Potential Data Sources for Flow Outlooks

For purposes of developing this outlook tool, I compiled historic data for the Price River basin area including:

- Daily and monthly streamflow volumes as measured at the USGS Price River at Woodside gage #09314500;
- April 1 water supply forecasts provided by the CBRFC for two Price River locations: (1) Price River near Scofield Reservoir (SFSU1), and (2) White River below Tabbyune Creek near Soldier Summit (WRSU1);
- Climate Data Center (CDC) mid-April 2.5-month lead outlook for July-Aug-Sep temperature and precipitation probabilities; and
- National Integrated Drought Information System (NIDIS) April 1 Carbon County, Utah drought characterizations.

Below are descriptions of these data sets, and how they were used to develop a hydrologic outlook tool.

4.1. Price River at Woodside Flows

I compiled USGS data on Price River flows at the Woodside gage to serve as the dependent variable to be predicted by this forecast model. As mentioned earlier, USGS gage #09314500 is located at the U.S. Highway 6 crossing near the town of Woodside, Utah, approximately 32 km upstream of the mouth of the Price River. For purposes of this analysis, I compiled both daily and monthly estimated

² Potential risks to human life and property associated with flood flows also should be considered. If flood flows in the lower Price River are likely to create such threats, then augmenting them with additional controllable water is not advisable.

³ Studies by Laub et al. (2013) in the neighboring San Rafael River basin suggest that achieving bankfull flow with a frequency of at once every three years (ideally), or once every five years (at a minimum) is desirable.

flow volumes for this gage location for the 2001 through 2025 period.⁴

4.2. CBRFC Water Supply Forecasts

The Colorado Basin River Forecast Center (CBRFC), operated by the National Weather Service under the National Oceanic and Atmospheric Administration (NOAA), provides various spatial datasets that characterize and forecast hydrologic conditions within the Colorado River basin. These include CBRFC forecasts for ‘total water supply’ anticipated to become available at various points in the river network over the April-July snowmelt period; these forecasts begin in January and are regularly updated by CBRFC through June.

To this author’s knowledge, no such water supply forecasts are provided for specific locations in the *lower* Price River, such as at Woodside.⁵ However, beginning in January of each year the CBRFC regularly publishes water supply forecasts for two key locations in the upper Price River basin: the [Price River near Scofield Reservoir](#) (SFSU1), and the [White River tributary below Tabbyune Creek](#) (WRSU1) – see Figure 4. Together, these two sites receive runoff from nearly the entire drainage area upstream of Colton, Utah. While this is a relatively small portion of the entire Price River watershed, it does capture a substantial portion of the winter snowpack that generates the spring-through-summer runoff available for irrigation, domestic and industrial uses downstream, as well as instream flows.

NOAA [describes](#) these datasets as follows:

- The forecast for April-through-July water supply volume is based on RFC’s modeling of basin conditions, including snow measurements.
- CBRFC provides its official forecast values on the 1st of each month. In contrast to the daily updated forecasts for intervening dates, these first-of-the-month values reflect “a more rigorous analysis of model guidance, hydrologic conditions, and verification statistics by the forecaster”.
- Precipitation is the primary driver of the snow states in the model throughout the winter and spring season.
- Manual adjustments occasionally are made to the model states, for example when the assumed snow conditions appear too high or too low. “How accurately the model may represent snowpack is often limited by the observation network and quality of data inputs,” according to CBRFC.
- CBRFC’s default water supply forecast does not incorporate precipitation forecasts. Instead, it assumes historic climatological conditions going into the future (using climatology based on the most recent three decades).
- The model does incorporate 10 days of forecast temperatures. Beyond those 10 days, the model uses climatology.

⁴ At the time I undertook this analysis, Woodside gage daily discharge data after February 2, 2025 were characterized as ‘provisional’ by the USGS, subject to change following their quality-review of the data. For the sake of this analysis, I included all 2025 streamflow data, including provisional.

⁵ The CBRFC [does](#) provide 10-day flow forecasts for the Price River at Woodside gage location (WOPU1) but does not, to my knowledge, provide longer-term runoff forecasts.

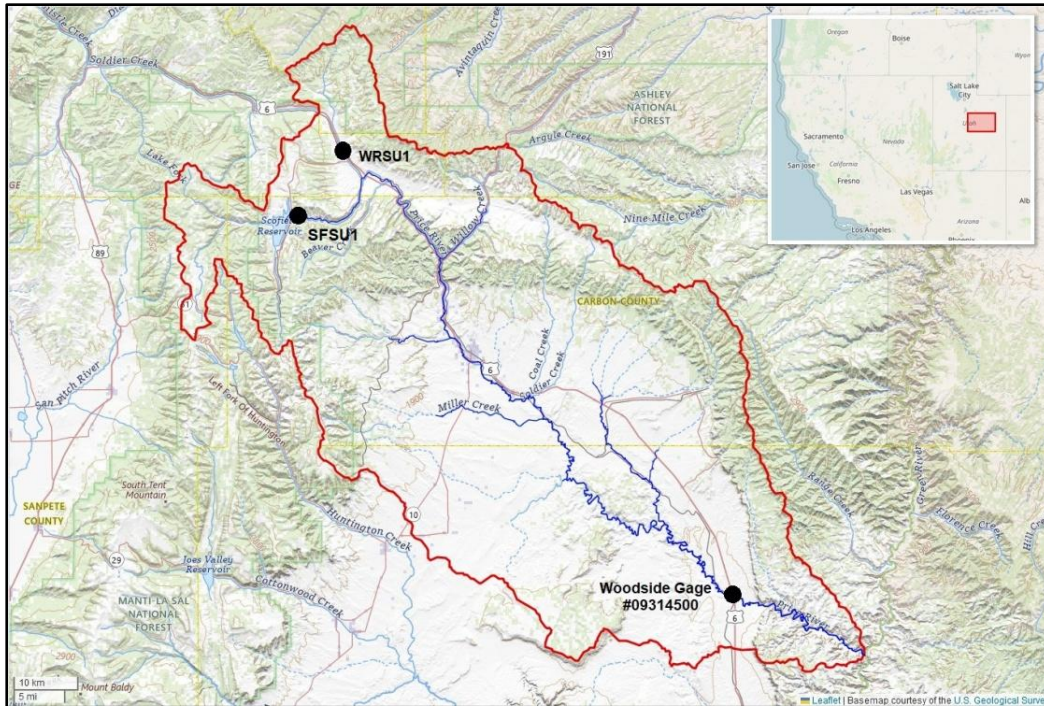


Figure 4. Price River drainage basin showing locations of the CBRFC seasonal runoff forecasting sites Price River near Scofield Reservoir (SFSU1) and White River below Tabbayne Creek (WRSU1), along with the USGS Price River at Woodside gage #09314500.

Downstream of these two CBRFC water supply forecast locations, and prior to reaching the Woodside gage, substantial quantities of natural Price River flow and water released from or bypassed through Scofield Reservoir, or entering the Price River via the White River, may be diverted for irrigated agriculture and other purposes. Therefore, while the water supply forecasts are valuable indicators of volumes available to support downstream flows from April through October, the actual fate of that water downstream depends on multiple additional factors, including (a) Scofield Reservoir operations, (b) demand for agricultural water use over the course of the irrigation season, (c) weather conditions during these months (including basin temperatures and precipitation), and (d) the effects of downstream water diversions and storage on the routing, timing, and volume of flow remaining in and returning to the Price River channel itself.

4.3. U.S. Drought Monitor Drought Classifications

Historic drought information is provided via the [National Integrated Drought Information System](#) (NIDIS). This includes current and historical information about the location and intensity of drought across each county in the United States, in terms of five U.S. Drought Monitor⁶ classifications: Abnormally Dry (D0), which shows areas that “may be going into or are coming out of drought”, and four levels of drought: Moderate (D1), Severe (D2), Extreme (D3) and Exceptional (D4). Historic

⁶ The U.S. Drought Monitor is a joint effort of the National Drought Mitigation Center, the U.S. Department of Agriculture, and NOAA.

datasets quantify the percentages of each county's area in each drought category at the beginning of each month.

For this Price River analysis, I downloaded April 1 Drought Monitor data for each year 2001 through 2025 for Carbon County, Utah. Although the boundaries of Carbon County do not precisely correspond to the Price River drainage basin, there is substantial overlap, and I decided to use these historic Carbon County data as a reasonable surrogate for drought conditions across the Price River basin.

4.4. CPC Temperature and Precipitation Outlooks

The [Climate Prediction Center \(CPC\) website](#) provides current and historic climate condition outlooks (including outlooks for temperature and precipitation) over various outlook periods, ranging from 6-to-10 days to three months into the future.

The products of these modeled outlooks include maps displaying CPC-assigned probabilities that temperature or precipitation will be above or below normal over the outlook period (*e.g.*, Figure 5 shows a recent example). For this Price River analysis, I visually inspected CPC's historic mid-April 2.5-month outlook maps (*i.e.*, outlooks for July-Aug-Sept) from 2001 through 2025 for both temperature and precipitation probabilities. Based on my inspection, I classified each year into an appropriate temperature outlook category (*e.g.*, 40-50 percent above-average temperature probability) and appropriate precipitation outlook category (*e.g.*, 33-40 percent below-average precipitation probability), corresponding to the Price, Utah location on CPC's maps for the continental United States.⁷

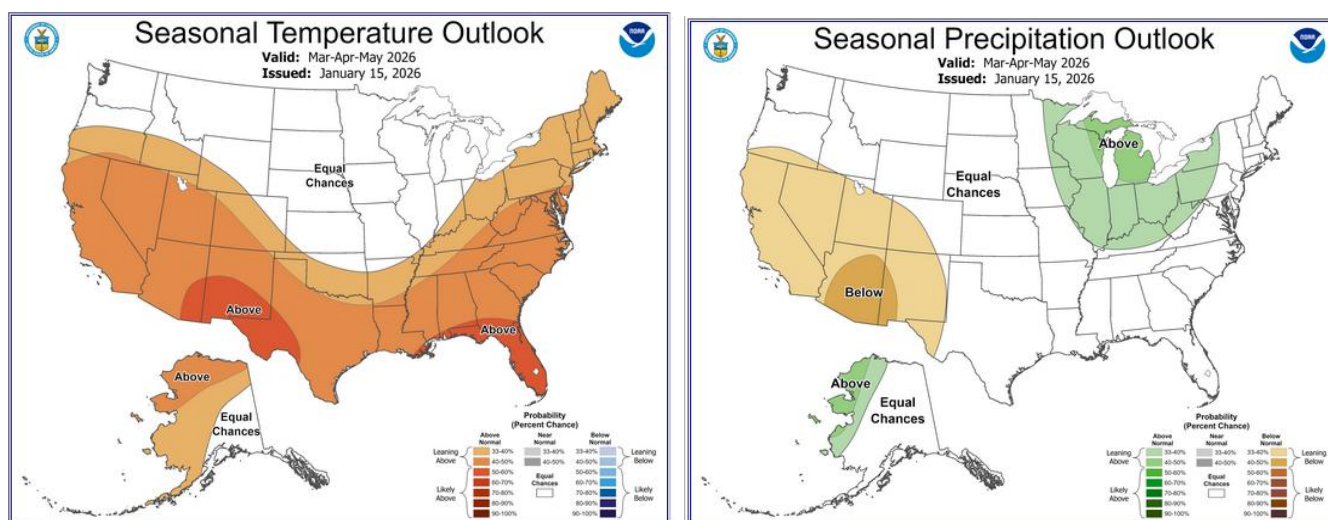


Figure 5. Example CPC maps illustrating forecast probabilities of above-normal and below-normal temperatures (left) and precipitation (right) 2.5 months into the future. (This example illustrates outlooks issued in mid-January 2026 for March-April-May 2026 conditions).

⁷ For example, I would identify the outlooks illustrated in Figure 5 as a 40-50% above-normal temperature probability, and a 33-40% below-normal precipitation probability for the Price River basin for the indicated March-May 2026 period. In cases where the Price, Utah location appeared to fall on or very close to the boundary of a probability band, I recorded the boundary value itself (*e.g.*, 40% “above average” probability).

5. Analysis of the 2001-2025 Period

For this analysis, I used data from calendar years 2001 through 2025, resulting in a 25-year period of record. I selected these years because:

- USGS streamflow data for the Woodside gage for earlier years (November 1992 through summer of 2000) are unavailable, thus providing no useful ‘target data’ to forecast for this earlier period;
- Historic drought data for Carbon County are not available from the NIDIS website prior to 2000, versus the complete record available for 2001-2025;
- In any case, it may not be advisable to evaluate data greater than 25 or 30 years old for purposes of developing a forecast methodology intended for current and future application in this area, given strong evidence that the Colorado River basin is permanently shifting toward warmer and probably drier hydrologic conditions (*e.g.*, Udall and Overpeck 2017). Indeed, since 2000, the average annual Colorado River basin water supply has been 18% lower than the long-term historic average (Lukas and Payton 2020). Additionally, as is evident from Figure 2 of this paper, hydrologic conditions in the lower Price River basin have been notably drier in the post-2000 period compared to earlier periods of the hydrologic record.

5.1. Criteria Applied

For this analysis, I undertook a correlation analysis of each of the historic April datasets representing potentially useful independent (predictive) variables versus the subsequent June-September low-flow conditions in the lower Price River, and versus subsequent peak flows in the lower Price from April through June. The potentially useful predictive variables I used were: CBRFC April 1 water supply forecasts; NIDIS April 1 Carbon County drought status maps; and CPC April 2.5-month temperature and precipitation outlooks for July through September.

It is important to acknowledge some significant limitations associated with the approach I describe in this paper:

- Due to ongoing climate change, the historic relationships between hydrologic and climatologic watershed variables in April and subsequent streamflow in the lower Price River may shift in future years. Changes to factors such as the amount of precipitation occurring as snow versus rain, the efficiency of snowmelt conversion to streamflow, local rates of evaporation and evapotranspiration, and the controlling weather patterns, could over time alter the relationships suggested by my analysis.
- Uses of water in the Price River basin could shift substantially over time in unforeseeable ways. This could include changes in water rights ownership, in reservoir operations, in the spatial and temporal distributions of basin water uses, in the amount of river flow lost to basin consumptive uses, and possibly new programs to shepherd protected water downstream.

- The correlation analyses used here did not assess or simulate individual factors affecting basin runoff quantities, routing, or timing, such as the hydrologic response of runoff source areas, or the location and timing of runoff diversions, storage, releases and deliveries. The method described here is more of a ‘black box’ approach for assessing lower Price River flow as a function of hydrologic variables broadly representative of the watershed (*i.e.*, snowpack, soil moisture, precipitation, temperature). I did not consider specific basin runoff pathways or water management practices affecting flows within the basin.
- Due to the limited period of record available (25 years), I made no attempt to divide the evaluated data into ‘calibration’ and ‘validation’ years to test model validity. So, possibly, the relationships suggested here between the specified predictive variables and subsequent river flows may be simple historical correlations that do not reflect meaningful cause-and-effect hydrologic relationships within this watershed.

5.2. Analysis of the Predictive Value of April Variables

5.2.1. June-September Low Flows

To develop an annual dependent variable to be predicted by this flow outlook tool, I totaled the volume of daily mean flow shortfalls to 15 cfs at the Woodside gage over the months of June through September in each year. (I used 15 cfs rather than 5 cfs for this metric in order to take advantage of the greater sensitivity to intermediate hydrologic conditions in years neither unusually wet nor unusually dry). In only 5 of the 25 years over this period of record were there *no* shortfalls to 15 cfs; in 8 years, shortfalls exceeded 1,000 acre-feet, with a maximum of 1,782 acre-foot shortfall occurring in 2004 (see Appendix Table A.1).

Two of the predictive variables proved useful. Historically, CBRFC’s April 1 forecast total water supply for both the ‘Price River near Scofield Reservoir’ and ‘White River below Tabbyune Creek’ locations were useful indicators of subsequent low flow conditions in the lower Price River. Additionally, NIDIS-designated drought conditions on April 1 were also useful indicators. In contrast, CPC’s temperature and precipitation outlooks appeared to provide little or no forecast skill. These relationships are further described below.

The **CBRFC’s Price River near Scofield Reservoir (SFSU1) and White River below Tabbyune Creek (WRSU1) April 1 50-percentile (median) water supply forecasts** provided nearly identical R^2 values when these data were individually regressed against subsequent shortfalls to 15 cfs of flow in the lower Price River (specifically, an R^2 of about 0.39 using a logarithmic line fit). In light of the similar correlations, and for purposes of developing this tool, I summed the annual CBRFC forecasted water supply volumes for these two locations for each year and evaluated this summed value as an independent variable for forecasting irrigation season low-flows.⁸

⁸ Note: summing these volumetric estimates by CBRFC results in weighting the ‘Price River near Scofield Reservoir’ forecast more heavily than the ‘White River below Tabbyune Creek’ forecast, due to the larger snowmelt runoff contributions normally associated with the former. On average over these 25 years, CBRFC’s forecast seasonal water supply for ‘Price

Figure 6 illustrates the relationship between these variables. Logically, the likelihood of low-flow conditions is *inversely* related to the total summed water supply volume at the two forecast locations – *i.e.*, the greater the forecast runoff volumes, the lower the probabilities of diminished instream flow in subsequent months. However, the most notable feature of the inverse relationship illustrated in Figure 6 is the apparent threshold crossed once the forecast water supply drops below approximately 60,000 AF. Note in Figure 6 that for 14 of the 17 years below this forecast threshold, shortfalls to the 15 cfs flow threshold exceeded 500 acre-feet, while *none* of the eight years above this threshold saw shortfalls greater than 134 acre-feet.

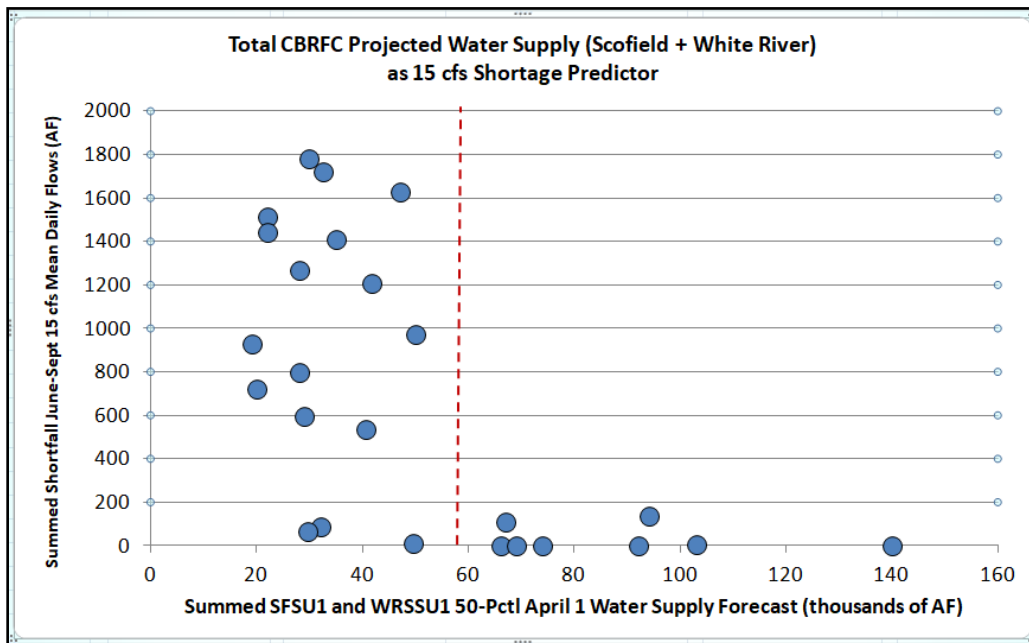


Figure 6. Cumulative shortfalls to 15 cfs mean daily flow at Woodside, Utah gage from July-September annually (2001-2025) as a function of the sum of CBRFC's April 1 median water supply forecasts for the 'Price River near Scofield Reservoir' plus the 'White River below Tabbayne Creek' locations. Red dashed vertical line denotes a suggested threshold water supply value.

In order to assess the predictive value of **NIDIS drought data**, I isolated the April 1 percentage of Carbon County identified as being in D1 ("Moderate") or greater drought status. I used D1 percentages rather than the more intense D2, D3, or D4 drought categorizations because this provided greater sensitivity to intermediate conditions in years that were neither unusually wet nor unusually dry. Using this metric, 11 of 25 years were "drought-free" on April 1, with zero county area mapped as in 'Moderate' or more extreme drought. In contrast, in eight of the 25 years, the entirety of Carbon County was mapped as being in 'Moderate' or more extreme drought conditions on April 1, and therefore scored '100%' under this metric. Table A.2 in the Appendix tabulates the scoring for each year.

River near Scofield Reservoir' was about 37.1 KAF/year, versus 13.1 KAF/year for 'White River below Tabbayne Creek' – *i.e.*, on average greater by a factor of about 2.8.

For purposes of developing a forecast tool, I examined the relationship between the April 1 D1 metric and subsequent irrigation season low flows. Figure 7 illustrates these results. Because of the tendency for Carbon County to be at one extreme or the other – *i.e.*, either 100% or 0% in drought condition – the points plotted in Figure 7 tend to be clustered to the far left and right sides of the graph. Nevertheless, I offer the following observations for these plotted points:

- In *all eight years* when Carbon County D1 drought status was 100%, the 15 cfs shortfall metric exceeded 700 acre-feet.
- In 13 of the 14 years that the county D1 status was greater than zero percent on April 1 (*i.e.*, ranging from 8% to 100%), the 15 cfs shortfall totaled 572 AF or more.
- In 10 of the 11 years with 0% of the county in D1 status, the subsequent 15 cfs shortfall was a relatively modest 150 acre-feet or less.

Clearly, the county’s drought status on April 1 historically has been a strong indicator of subsequent low-flow conditions in the lower Price River.

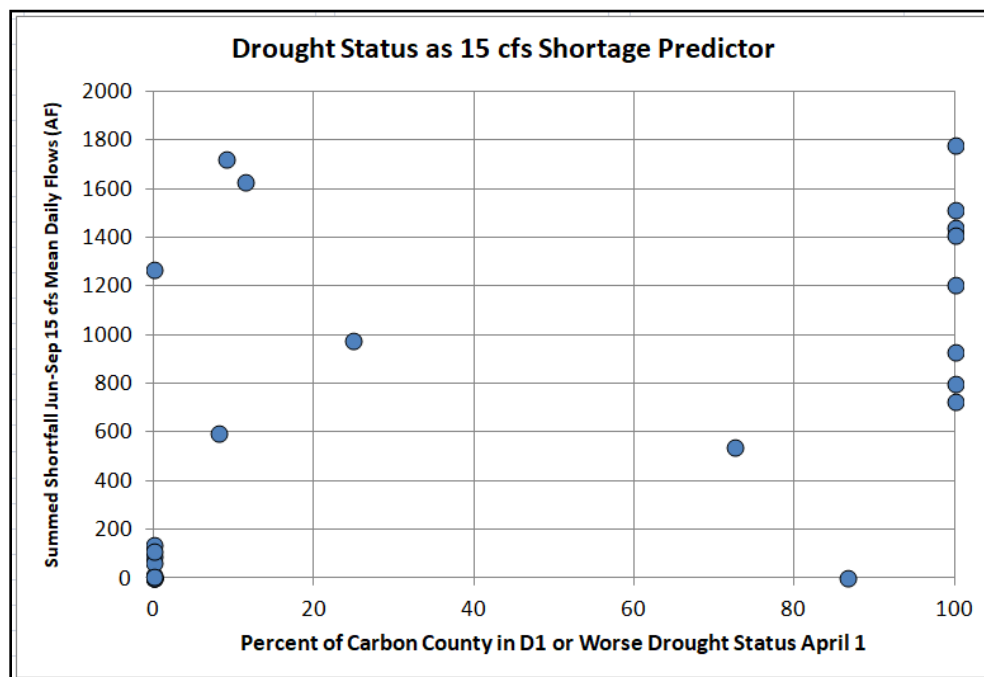


Figure 7. Cumulative shortfalls to 15 cfs mean daily flow at Woodside, Utah gage from July-September annually (2001-2025) as a function of the percent of Carbon County classified as being in D1 or more severe drought conditions on April 1.

In contrast to the above two independent variables discussed, the CPC’s April 2.5-month ‘**outlook**’ **probability forecasts for temperature and precipitation** provided little or no predictive value for subsequent low-flow conditions. Remarkably, in *every year* 2001 through 2025, with the sole exception of 2001, the CPC’s outlook probability was for temperatures to be “above normal” in July-September, with probability values ranging from 10% to 50-60%. This suggests a concerning bias in the CPC

temperature outlook model for this area, as it seems improbable that temperatures will be “above normal” for 24 consecutive years – even under current conditions of a gradually warming climate. In any case, with or without a bias in the CPC models, their consistent projection of above-normal temperatures rendered this metric largely useless for lower Price River streamflow forecasting purposes.

The CPC’s precipitation outlook probabilities were more normally distributed over the 25-year period than their temperature outlooks, with four years forecasting below-normal July-September precipitation probabilities, six years forecasting above-normal probabilities, and the remaining 15 years forecasting neutral probabilities. However, a review of the historic outcomes relative to these CPC outlooks suggested to me very little to no useful value for purposes of making Price River flow forecasts. Therefore I eliminated both the temperature and precipitation CPC outlooks from any further consideration here.

5.2.2. April-June Peak Flows

For purposes of developing an annual spring Price River peak flow variable to be predicted by this flow outlook tool, I calculated the total stream discharge volume occurring over the *highest five consecutive days of runoff* in each year between the dates of April 1 and June 30.⁹ Later dates were not considered, as peak flows after June 30 likely were generated by short-duration storm events largely unrelated to basin snow and spring soil moisture conditions. The corresponding dates and total acre-feet of spring high flows over five days are summarized in Table A.3 of the Appendix. The central date of these five-day peak flows occurred most frequently in April (13 years), followed by May (6 years) and June (also 6 years).¹⁰

Similar to the results for June-September low flows, CBRFC’s April 1 historic forecast total water supply for both the Price River near Scofield Reservoir and for the White River below Tabbyune Creek locations provided useful data for forecasting subsequent April-June high flow conditions in the lower Price River, and NIDIS drought conditions on April 1 also were a useful indicator. And, again, the CPC’s temperature and precipitation outlooks provided little or no apparent forecast skill. These relationships are further described below.

Summing CBRFC’s Price River near Scofield Reservoir and White River below Tabbyune Creek April 1 water supply forecasts, and regressing these values linearly against subsequent five-day spring high flows in the lower Price River, resulted in an R^2 value of 0.69. See Figure 8.

⁹ In two cases over the 25 years evaluated, the five consecutive days of spring peak flow began in the waning days of March, prior to April 1. For purposes of this evaluation, I arbitrarily limited my five-day total volume calculation in those years (2022 and 2025) to those five days surrounding April 1 as their central date – applying the logic that if this forecast methodology is to be applied, it will only be useful for anticipating conditions beginning April 1.

¹⁰ Note that *annual instantaneous peak flows* in the lower Price River are more commonly associated with short-lived late summer/fall storm events. Over the period investigated, 92% of the instantaneous annual peaks occurred from July through October (particularly in August and September). However the total flow volumes associated with these later runoff events only rarely exceed flow volumes associated with the generally longer-lived, snowmelt-dominated spring peak flows in the Price River. See Chart and Anderson (2025), Section 2.2.2 *Peak Flows*, for additional discussion.

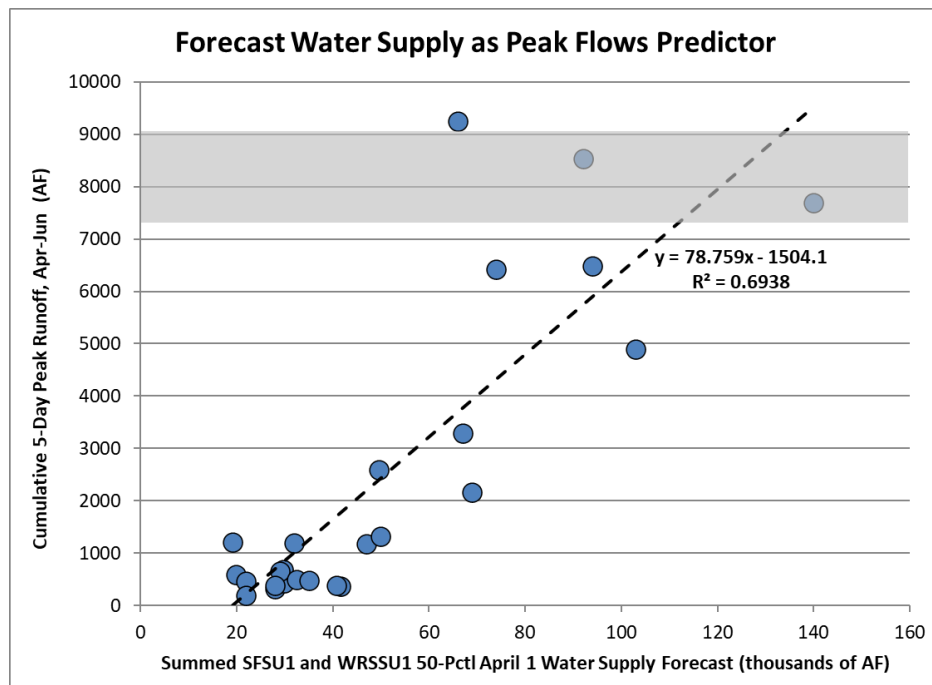


Figure 8. 5-Day Peak Flows in the lower Price River, April-June, as a function of CBRFC’s April 1 median water supply forecasts for the SFSU1 and WRSU1 locations summed. Shaded band denotes five days of flow corresponding to the possible bankfull flow thresholds inferred by Chart and Anderson (2025).

This suggests that, over this period of record, the April 1 projected seasonal water supply at these two locations explained nearly 70% of the subsequent variability in five-day spring high flows in the lower Price River. In at least the case of the SFSU1 location, this is consistent with historic operational water management practices at Scofield Reservoir, for example as described in Chart and Anderson (2025):

“Peak flows below the [Scofield] dam occur in wet years when the reservoir is full and water flows over the spillway or when releases are made in excess of downstream demands. These total releases and spills averaged 51,815 acre-feet for 1960–2002 but historically have varied from 13,762 to 154,475 acre-feet/year (Reclamation 2000). While normal dam releases in June are about 150 cfs, the total releases with these spills have ranged up to more than 1,100 cfs. Because spills are in excess of downstream consumptive use requirements, they usually increase river flows throughout the lower Price River to the confluence with the Green River. From 1960–2002, the reservoir filled and spilled 17 times (Reclamation 2000).”

Scofield Reservoir is the principal feature of the Bureau of Reclamation’s Scofield Project. It is the only sizable impoundment on the Price River, controlling water supplies in the upper 155 square miles (401 km²) of the Price River basin (Reclamation and SCS 1993). It has a capacity to store 73,600 AF of water for irrigation, flood control, recreation, fish and wildlife benefits, and M&I water supply. Primary beneficiaries of irrigation water deliveries from the Scofield Project are the Carbon Water Conservancy District and the Price River Water Conservancy District. Total depletions associated with the Scofield

Project and the Price-San Rafael River Salinity Control Project have been estimated at approximately 82,412 AF annually, or about 52% of estimated natural inflow to the Price River (Reclamation and SCS 1993; Reclamation 1998; Chart and Anderson 2025).

With respect to the predictive value of the **NIDIS drought data**, I again examined the relationship between the percentage of Carbon County’s area classified as being in D1 or greater drought condition on April 1 and subsequent spring peak flow volumes. Figure 9 illustrates these results. In general, one would expect an inverse correlation between these data – *i.e.*, the greater the percentage of Carbon County in drought status, the lower the likelihood of elevated spring flood runoff. And again, because of the tendency for Carbon County to be at one extreme or the other in any given year – either 100% or 0% in drought status – the points plotted in Figure 9 tend to be clustered on the left and right ends of the graph. This makes the use of this factor as a predictive variable more of a binary Yes/No consideration than a scalable predictive variable. Nevertheless, I offer the following observations for these plotted points:

- In *all eight years* when Carbon County D1 drought status was 100%, the spring 5-day cumulative peak flow was less than 1,210 acre-feet (equivalent to about 122 cfs for five days).
- Of the five years experiencing the *highest* 5-day spring cumulative peak flows (4,900 acre-feet or more, equivalent to a range of 494 to 953 average cfs over five days¹¹), four were years in which 0% of the county was in D1 status on April 1.

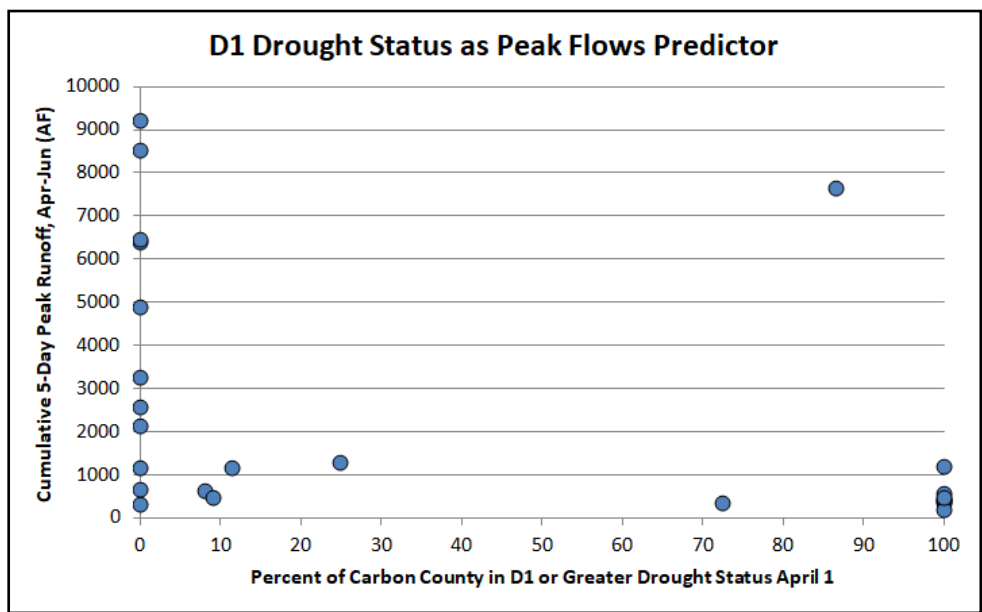


Figure 9. 5-Day peak flows in the lower Price River, April-June, as a function of the percentage of Carbon County, Utah mapped as being in D1 or greater drought status on April 1 by the U.S. Drought Monitor.

¹¹ These are peak flows approaching or exceeding the 729-913 cfs magnitudes that may correspond to bankfull flows in the lower Price River. Thus, they may represent promising opportunities to achieve or bolster channel-forming flows. See Chart and Anderson 2025, Section 2.2.2 for further discussion.

As with my low-flow analysis, the CPC's April 2.5-month 'outlook' forecasts for temperature and precipitation appeared to provide little or no predictive value for subsequent peak flow conditions in the lower Price River. Therefore I dropped those historic outlooks for temperature and precipitation from any further consideration for peak flow forecasting purposes.

6. An Outlook Tool for Unusually Low Base Flows and Unusually High Peak Flows

The analysis discussed above suggests that instead of developing a formulaic approach for quantitatively predicting low flow and peak flow magnitudes in the lower Price River from April through September annually, a more binary, Yes/No evaluation matrix to identify prognostic hydrologic conditions is more appropriate. I offer such a matrix in Table 1.

To use this matrix, the user would consult two key data sources around April 1 of each year: (1) the U.S. Drought Monitor's mapping of drought conditions in Carbon County, Utah, and (2) the CBRFC's median forecast of total Apr-July runoff (in acre-feet) for the combined SFSU1 and WRSU1 locations in the Price River basin. Using these two data sources, the user would then classify the year as being in a 'Dry' or 'Not Dry' drought status, and in a 'Lower' or 'Higher' projected runoff status, in both cases using threshold criteria described in the table. (Those key thresholds are: summed water supply forecasts from SFSU1 + WRSU1 being above or below 60,000 acre-feet, and Carbon County drought status being above or below 4%).

Table 1. Annual Outlook Evaluation Matrix: Likelihood of seeing unusually low June-September flows or unusually high April-June peak flows in the lower Price River based on April 1 drought classifications and water supply forecasts.

		CBRFC WATER SUPPLY FORECASTS	
		LOWER	HIGHER
		The sum of CBRFC's April 1 median forecast of total Apr-Jul water supplies for the SFSU1 plus the WRSU1 locations is <u>less than 60,000 acre-feet</u>	The sum of CBRFC's April 1 median forecast of total Apr-Jul water supplies for the SFSU1 plus the WRSU1 locations is <u>greater than 60,000 acre-feet</u>
NIDIS DROUGHT STATUS	DRY (The April 1 U.S. Drought Monitor mapping for Carbon County, Utah, identifies <u>four percent or more of the county</u> in D1 or greater drought status)	"CASE A" High likelihood that June to September mean daily flows at the Woodside gage location will fall below 15 cfs on multiple days with a cumulative volumetric <u>shortfall of 500 to 1,800 acre-feet.*</u>	NEUTRAL Neither exceptionally low flows in Jun-Sep nor unusually high spring peak flows anticipated. (i.e., cumulative shortages to 15 cfs mean daily flows are likely to be less than 150 acre-feet, and 5-consecutive day peak flows are likely to deliver less than 3,000 cumulative acre-feet)
	NOT DRY (The April 1 U.S. Drought Monitor mapping for Carbon County, Utah, identifies <u>zero percent</u> of the county in D1 or greater drought status)	NEUTRAL Neither exceptionally low flows in Jun-Sep nor unusually high spring peak flows anticipated. (i.e., cumulated shortages to 15 cfs mean daily flows are likely to be less than 150 acre-feet, and 5-consecutive day peaks likely to deliver less than 3,000 cumulative acre-feet)	"CASE B" High likelihood that the five-consecutive-day peak flow at Woodside gage in Apr-May-Jun will range from <u>3,000 to 10,000 acre-feet</u> (equal to approximately 300 to 1,000 mean cfs)

* Relative to the 5 cfs threshold, cumulative shortfalls fell between 30 and 350 acre-feet in 11 of 13 'Case A' years (near zero in other 2 years)

For 'Case A', in which drought conditions are 'Dry' and runoff forecasts are 'Lower', there is a high likelihood that mean daily flows at the Woodside gage location will drop below the significant threshold of 15 cfs for multiple days in the June-September period in an amount totaling 500 to 1,800 acre-feet.¹² For 'Case B', in which drought conditions are 'Not Dry' and forecasts are for 'Higher' runoff, there is a high likelihood that the 5-day peak flow in the April-May-June period will range from 3,000 to 10,000 acre-feet of total streamflow, or roughly 300 to 1,000 cfs mean flow over five days. In the former case, water managers interested in maintaining adequate Price River base flows may want to prioritize their management of available water to address the likely development of problematically low flows. In the latter case, water managers may want to be alert for opportunities to boost the likely higher-than-normal spring peak flows with additional water in order to maximize the mobilization of bed sediments, re-work channel geometry, and rejuvenate aquatic habitats in the lower Price River channel – depending upon

¹² While this analysis focused on the 15 cfs low-flow threshold, these same matrix criteria also to apply to 5 cfs low-flow threshold conditions. In the latter case, and for comparison purposes, the historic aggregate shortfalls to 5 cfs of flow from June-September corresponding to 'Case A' conditions typically ranged from 30 to 350 acre-feet.

the recent history of peak flows in the Price River and the nature of recently completed stream restoration work (see Chart and Anderson 2025, Section 5.3 and Figure 15).

In all other years, *i.e.* when drought conditions are ‘Not Dry’ and runoff forecasts are ‘Lower’, or conversely when drought conditions are ‘Dry’ but runoff forecasts are ‘Higher’, history suggests that neither of the above lower Price River runoff scenarios is likely. Historically, five of the 25 years evaluated (20%) did not meet the criteria for either a ‘Case A’ or ‘Case B’ hydrologic classification, and four of the 25 years (16%) did not have a ‘Case A’ or ‘Case B’ outcome.¹³

Of note, there were no years over the 25 years of record in which the 15 cfs summer shortfalls totaled more than 400 acre-feet and the lower Price also experienced a five-day spring peak in excess 3,000 acre-feet. That is, over the past quarter-century, we’ve never seen both of these scenarios materialize in the same year. This is significant, as it suggests that river managers would be wise to prepare for one or the other flow-augmentation opportunity in any given year, but realistically they should not expect both. Over these 25 years, 84% had one outcome or the other, 16% had neither outcome, while no years had both.

Table 2 summarizes the historical accuracy of this evaluation approach. The ‘Outlook’ column classifies each year, 2001-2025, based on the Table 1 evaluation criteria. The ‘Outcome’ column identifies the actual hydrologic outcome in each year. Thirteen of the 13 years forecast to have low summer flows did experience low flows as defined here. Six of the 7 years forecast to have elevated spring flows did experience elevated flows as defined here. Three of the 5 years forecast to be ‘neutral’ (with neither low summer flows nor elevated spring flows) did experience neutral outcomes.

With respect to evaluation tool errors: three out of 25 years over the period evaluated had hydrologic Outcomes that did not match the April 1 Outlooks. Two of these years had ‘errors of omission’, in which opportunities to augment what turned out to be problematically low summer flows (2002), or what turned out to be promisingly elevated high spring flows (2023) would not have been anticipated by relying the Outlook. Conversely, one of the 25 years (2008) had an ‘error of commission’ in which relying on the Outlook would have erroneously suggested that a spring peak runoff above target threshold was likely to occur, but it didn’t.

Generally speaking, this Outlook methodology would have provided helpful forecasts over the period evaluated, with 22 of 25 Outlooks resulting in the predicted Outcomes. That said, there is no guarantee this approach will be equally helpful in the future, for reasons already discussed in Section 5.1. For those reasons, I suggest applying the evaluation matrix with an appropriate pinch of skepticism.

¹³ These ‘neutral forecast’ years were 2001, 2002, 2009, 2010, and 2023. The ‘neutral outcome’ years were 2001, 2008, 2009, and 2010.

Table 2. Comparison of the Annual Outlook Evaluation Matrix classifications, 2001-2025, to actual hydrologic outcomes in those years.

	Outlook	Outcome	NOTE
2001	Neutral	Neutral	
2002	Neutral	Low Summer Flows	Omission error
2003	Case A	Low Summer Flows	
2004	Case A	Low Summer Flows	
2005	Case B	High Spring Peaks	
2006	Case B	High Spring Peaks	
2007	Case A	Low Summer Flows	
2008	Case B	Neutral	Commision error
2009	Neutral	Neutral	
2010	Neutral	Neutral	
2011	Case B	High Spring Peaks	
2012	Case A	Low Summer Flows	
2013	Case A	Low Summer Flows	
2014	Case A	Low Summer Flows	
2015	Case A	Low Summer Flows	
2016	Case A	Low Summer Flows	
2017	Case B	High Spring Peaks	
2018	Case A	Low Summer Flows	
2019	Case B	High Spring Peaks	
2020	Case A	Low Summer Flows	
2021	Case A	Low Summer Flows	
2022	Case A	Low Summer Flows	
2023	Neutral	High Spring Peaks	Omission error
2024	Case B	High Spring Peaks	
2025	Case A	Low Summer Flows	

7. Summary and Conclusions

A review of 25 years of data available annually on April 1 from NIDIS and from the CBRFC reveals that these data sources historically have been robust indicators of subsequently atypical low base flow and atypical high peak flow conditions in the lower Price River.

Specifically, two metrics available around April 1 annually have been useful indicators of subsequent April-October flow conditions in the lower Price River relevant to habitat conditions for native fish, and they may continue to be useful for such forecasting purposes into the future: (1) the U.S. Drought

Monitor's mapping of D1 or greater drought conditions for Carbon County, Utah, and (2) the CBRFC's median forecast of total April-July runoff for the combined SFSU1 and WRSU1 locations in the Price River basin.

Annual comparison of these data to the thresholds specified in this report's evaluation matrix (Table 1) may assist TNC and other water managers in making more informed decisions regarding use of available water to supplement lower Price River instream flows over coming months, based on probabilities suggested by this analysis for abnormal summer low-flow or spring peak-flow conditions that year.

Acknowledgment

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APPENDIX – DATA TABLES

TABLE A.1 Annual Shortfalls to Target Base Flows

Total volume of daily mean flow shortfalls to 15 cfs at the Woodside gage for the months of June through September of each year.

	Total June-Sep Shortfalls to 5 cfs	Total June-Sep Shortfalls to 15 cfs
	AF	AF
2001	0.0	89
2002	146.6	1270
2003	280.2	1206
2004	332.3	1782
2005	0.0	0
2006	0.0	0
2007	57.7	723
2008	0.0	0
2009	0.0	11
2010	0.0	64
2011	0.0	0
2012	0.1	594
2013	141.6	798
2014	32.8	537
2015	6.8	928
2016	338.9	1724
2017	0.0	8
2018	226.1	1515
2019	0.0	134
2020	161.7	1630
2021	310.9	1441
2022	223.5	1407
2023	0.0	0
2024	8.2	111
2025	165.9	974

TABLE A.2 Portion of Carbon County in Drought Status Annually April 1

Percentage of Carbon County identified as being in various drought categories on April 1st, 2001 through 2025, according to NIDIS.

		Percentage of Carbon County in Various Drought Categories						Date Range	
		None	D0	D1	D2	D3	D4	Begin	End
2000	Carbon Cc UT	100	0	0	0	0	0	3/28/2000	4/3/2000
2001	Carbon Cc UT	100	0	0	0	0	0	3/27/2001	4/2/2001
2002	Carbon Cc UT	0	100	0	0	0	0	3/26/2002	4/1/2002
2003	Carbon Cc UT	0	100	100	100	100	0	4/1/2003	4/7/2003
2004	Carbon Cc UT	0	100	100	100	77.13	0	3/30/2004	4/5/2004
2005	Carbon Cc UT	57.73	42.27	0	0	0	0	3/29/2005	4/4/2005
2006	Carbon Cc UT	100	0	0	0	0	0	3/28/2006	4/3/2006
2007	Carbon Cc UT	0	100	100	0	0	0	3/27/2007	4/2/2007
2008	Carbon Cc UT	100	0	0	0	0	0	4/1/2008	4/7/2008
2009	Carbon Cc UT	99.87	0.13	0	0	0	0	3/31/2009	4/6/2009
2010	Carbon Cc UT	0	100	0	0	0	0	3/30/2010	4/5/2010
2011	Carbon Cc UT	100	0	0	0	0	0	3/29/2011	4/4/2011
2012	Carbon Cc UT	0	100	7.99	0	0	0	3/27/2012	4/2/2012
2013	Carbon Cc UT	0	100	100	68.9	0	0	3/26/2013	4/1/2013
2014	Carbon Cc UT	0	100	72.4	0	0	0	4/1/2014	4/7/2014
2015	Carbon Cc UT	0	100	100	61.96	0	0	3/31/2015	4/6/2015
2016	Carbon Cc UT	57.28	42.72	8.94	0	0	0	3/29/2016	4/4/2016
2017	Carbon Cc UT	100	0	0	0	0	0	3/28/2017	4/3/2017
2018	Carbon Cc UT	0	100	100	100	12.84	0	3/27/2018	4/2/2018
2019	Carbon Cc UT	100	0	0	0	0	0	3/26/2019	4/1/2019
2020	Carbon Cc UT	0	100	11.37	0	0	0	3/31/2020	4/6/2020
2021	Carbon Cc UT	0	100	100	100	100	60.1	3/30/2021	4/5/2021
2022	Carbon Cc UT	0	100	100	100	0	0	3/29/2022	4/4/2022
2023	Carbon Cc UT	0	100	86.54	0	0	0	3/28/2023	4/3/2023
2024	Carbon Cc UT	67.2	32.8	0	0	0	0	3/26/2024	4/1/2024
2025	Carbon Cc UT	0	100	24.73	0	0	0	4/1/2025	4/7/2025

TABLE A.3 Total Streamflow over 5-day Peak Spring Flow Annually

Total stream discharge volume occurring over the highest five consecutive days of runoff in each year 2-2002-2025 between the dates of April 1 and June 30.

YEAR	Apr-Jun Peak 5 days (CFS-days)	Equivalent AF	Central Date
2001	601	1192	21-Apr
2002	161	319	26-May
2003	185	367	23-Jun
2004	219	434	30-Jun
2005	4665	9253	23-May
2006	3235	6417	25-Apr
2007	299	593	24-Apr
2008	1092	2166	23-Apr
2009	1305	2588	23-Jun
2010	345	684	14-Jun
2011	4306	8541	31-May
2012	327	649	30-Apr
2013	196	389	11-May
2014	191	379	28-Apr
2015	610	1210	8-Jun
2016	252	500	30-Apr
2017	2471	4901	13-Jun
2018	237	470	10-Apr
2019	3272	6490	29-Apr
2020	592	1174	4-May
2021	100	198	20-Apr
2022	268 *	532	1-Apr
2023	3874	7684	20-May
2024	1658	3289	18-Apr
2025	664 **	1317	1-Apr

* Largest spring 5-day peak mean 275 cfs was centered on March 30; adjusted for Apr 1 central date

** Largest spring 5-day peak of mean 682 cfs was centered on March 30; adjusted for Apr 1 central date