Indicators of Hydrologic Alteration Analysis for the Patuca River

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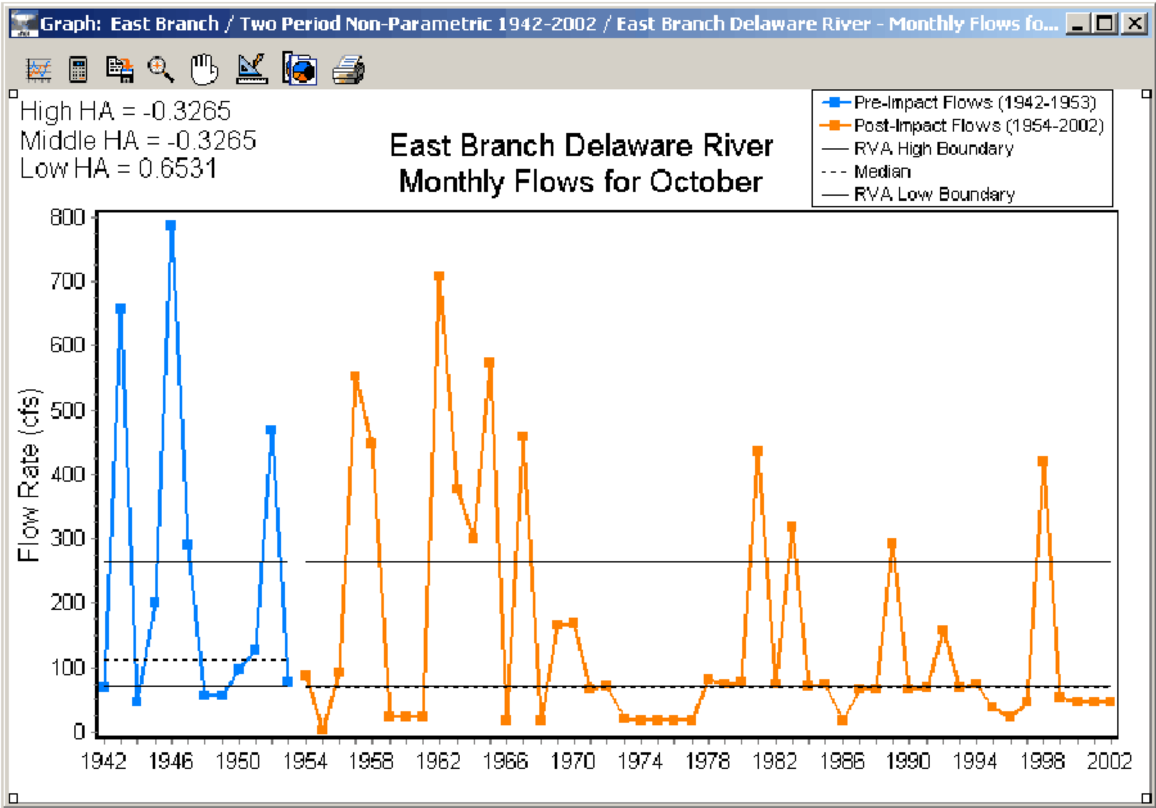
Introduction to IHA software
This report provides a preliminary analysis of the hydrology of the Patuca River with and without an operational Patuca Dam. I used The Nature Conservancy's software Indicators of Hydrologic Alteration (IHA) for two sites along the river: Cayetano and Kurpha. Hydrological data were provided by ENEE.

The Indicators of Hydrologic Alteration summarizes long periods of hydrological data into sets of ecologically important parameters. The scientific basis of this program is summarized in several papers (Richter et al. 1996, Richter et al. 1997). These papers and the IHA software itself can be downloaded from the web site: nature.org/freshwater (specifically: http://www.nature.org/initiatives/freshwater/conservationtools/index.html).

Thirty-three parameters can be lumped into five groups: (1) magnitude of monthly flow conditions; (2) magnitude and duration of extreme flow events (e.g. high and low flows); (3) the timing of extreme flow events; (4) frequency and duration of high low flow pulses; and (5) the rate and frequency of changes in flows. For these parameters, the IHA can perform a Range of Variability Analysis. For each of the parameters, IHA calculates a Hydrologic Alteration factor, which is calculated as follows:

1. For each parameter, IHA divides the full range of 'pre-impact data' into three different categories, generally percentiles (e.g., lowest third, middle third, highest third).
2. The program then analyzes the 'post-impact' data and compares the observed distribution of data with the distribution expected from the pre-impact data.
3. HA factor = (observed frequency-expected frequency)/expected frequency
4. A positive HA factor means that the frequency of values in the category (percentile grouping) has increased in the post-impact period, while a negative HA factor means that the frequency of values in the category (percentile grouping) has decreased in the post-impact period

For example, if a dam was able to store and attenuate all high flow events, then, for floods, the HA factor for the 'high category' (highest third of all flows from pre-impact data) would be negative, while the 'low category' (lowest third of all flows from pre-impact data) would be positive. For a second example, see the figure below. In this example, there are fewer than expected October flows in the 'high' category (highest third of pre-impact flows): during the 48 years post impact, one would expect 16 years to fall into the 'high' category, but only 11 do. Thus, the High HA factor is negative.



Ecosystem Flow Components
The IHA also calculates 34 parameters that relate to Ecosystem Flow Components (EFCs): low flows, extreme low flows, high flow pulses, small floods and large floods. These various flow components have specific ecological relevance.

Methods
ENEE provided the hydrological data for this analysis (QDenvio1TNC.xls). I performed an IHA analysis for Cayetano and Kurpha. For 'pre-impact' data for Cayetano I used the column 'Patuca 3 Cayetano Q Completado' and for the 'post-impact' data I used the column 'Patuca 3 Con Embalse Caudal.' For the 'pre-impact' data for Kurpha I used the column 'Kurpha Q Completado Caudal' and for the 'post-impact' data I used the column 'Kurpha Q (efecto embalse Patuca 3).'

The IHA is designed to analyze a hydrological data series which has some 'impact' occurring within the time interval, such as the construction of a dam. In this analysis, I was using two data sets that covered the same set of years – one modeling current flows and one modeling flows with dam operations. To use these concurrent data sets in IHA, I gave a new range of dates to the dam-affected data. Thus, the pre-impact data sets cover 1973 to 2002 and the post-impact data sets cover 2002 to 2030. However, keep in mind that the data sets actually reflect hydrology over the *exact same range of years* with one reflecting hydrology without the dam (1973-2002) and one reflecting hydrology with the dam (2002-2030).

Results

Cayetano

The greatest Hydrologic Alteration (HA) factors were the increase in magnitude of baseflows, low-flow events and monthly flows from February to May (Figures 1 – 4). Extreme low-flow events are projected to almost never occur (Figures 5 and 6). The magnitude of the thirty-day minimum flow is expected to increase approximately by a factor of three (Figure 7). Monthly flows in July and August are projected to be lower with dam operation (Figures 1, 2, and 8; note that in Figure 8 the 'post-impact' median falls below the lower RVA line; recall that the RVA lines visible in this figure are the expected category boundaries based on pre-impact flows), while monthly flows from September to January are projected to be essentially unchanged (Figures 2 and 9).

The IHA analysis indicates that there will be approximately half as many high flow pulses with the dam (5) than without the dam (10) (Figure 10). The magnitude (Figure 11) and duration (Figure 12) will be similar, although they will tend to occur later in the year (Figure 13). High flow events will essentially be unchanged in magnitude (Figure 14) and floods will essentially be unchanged in magnitude, timing, frequency, duration, and rate of fall.

The change with dam operation can be visualized by comparing pre-dam and 'post-dam' hydrographs for three years (1989 – 1991; Figures 15 and 16; these same data are shown superimposed on one another in Figures 17 and 18). Figure 15 shows the gradual decline of pre-dam flows into the low-flow season, punctuated by frequent small pulses; in contrast, Figure 16 shows that post-dam flows will have a relatively quick decline followed by long periods of very steady flow. Post-dam low flows will be considerably higher than pre-dam (Figure 18). In the early summer, precipitation events result in numerous high flow pulses with pre-dam flows. In the post-dam scenario, the steady flow continues for a few more months before high flow pulses begin to appear (Figures 16 and 18). However, in a very wet year, such as 1990, the high-flow pulses begin sooner. Flood events are unchanged (Figure 17).

Kurpha

Approximately 1/3 of the flow at Kurpha is derived from the portion of the watershed above Cayetano (i.e., the portion of the drainage area above the proposed dam; Table 1). Hydrologic alteration factors for Kurpha are shown in Figure 19. Because over two-thirds of the flow at Kurpha is derived from areas not influenced by the proposed Patuca dam, the post-dam monthly flows shows for Kurpha show less change than for Cayetano (compare Figures 2 and 20). The basic pattern of monthly flows is similar to Cayetano: elevated base flows from January through May and lower flows during August.

Base flows and low flow events are elevated (Figure 19); for example, the 30-day minimum flow is about 50% larger post-dam than it is pre-dam (Figure 21). Post-dam monthly flows are projected to be elevated for much of the spring and summer compared to pre-dam flows (Figures 20 and 22).

From June through January, flows with dam operation have very similar variability as current flows and, accordingly, HA values are very small (Figure 19). For example, while median monthly flows in August are predicted to be about 1/3 lower with dam operations, the flows with dam operations retain much of the variability observed with pre-dam flows (Figure 23). The characteristics of maximum flows are very similar between the two data sets (Figure 19).

Table 1. Monthly flows and mean annual flow (MAF) for Cayetano and Kurpha.

	Cayetano	Kurpha	Proportion
January	60	285	0.21
February	47	232.5	0.20
March	34	168	0.20
April	23	124.5	0.18
May	23	95	0.24
June	70	104	0.67
July	145	203	0.71
August	180	465	0.39
September	207	603	0.34
October	232	683	0.34
November	120	545	0.22
December	82	421	0.19
MAF	135	429	0.31

References

Richter, B. D., J. V. Baumgartner, J. Powell, and D. P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conservation Biology **10**:1163-1174.

Richter, B. D., J. V. Baumgartner, R. Wigington, and D. P. Braun. 1997. How much water does a river need? Freshwater Biology **37**:231-249.

Figure 1. Hydrologic alteration values for the Patuca at Cayetano.

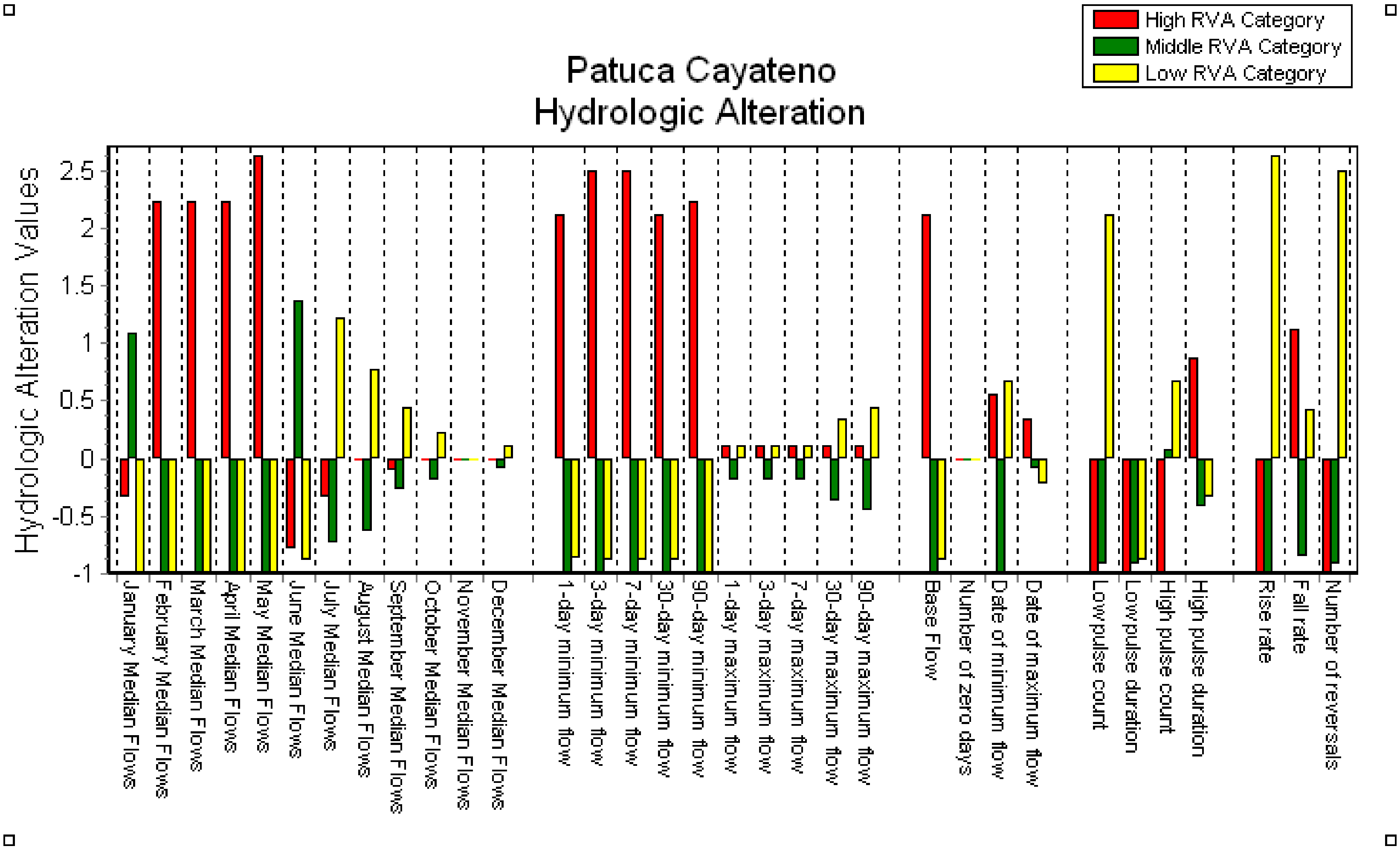


Figure 2. Monthly flows with (green) and without (red) the Patuca dam.

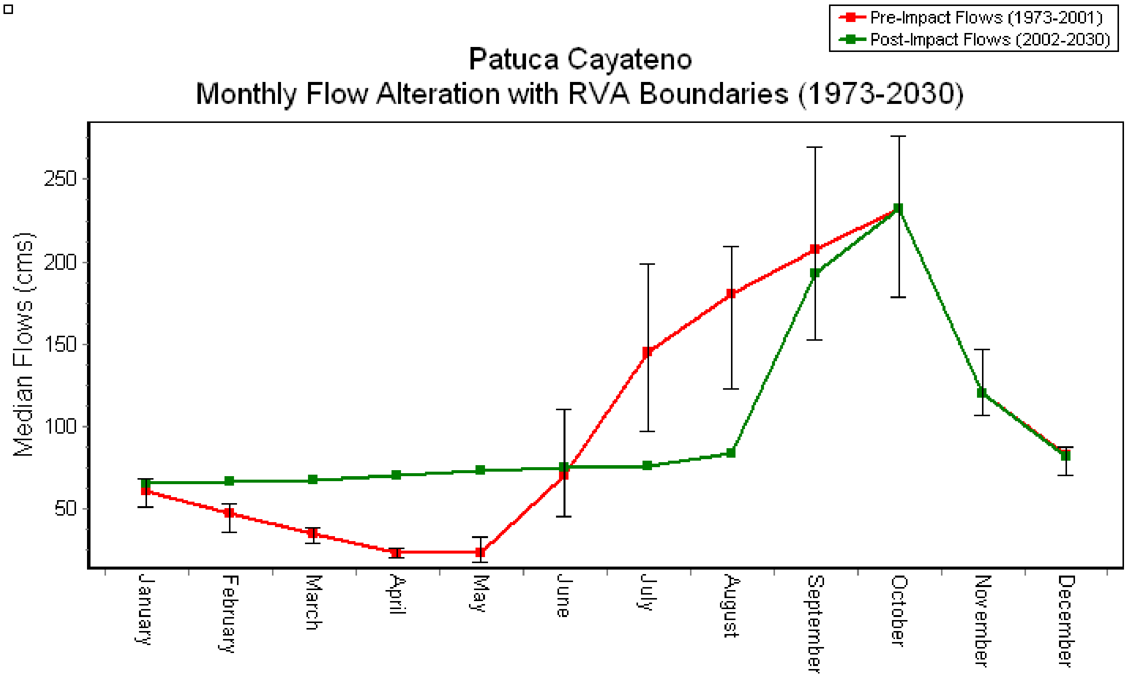


Figure 3. Monthly flows for April, Cayetano.

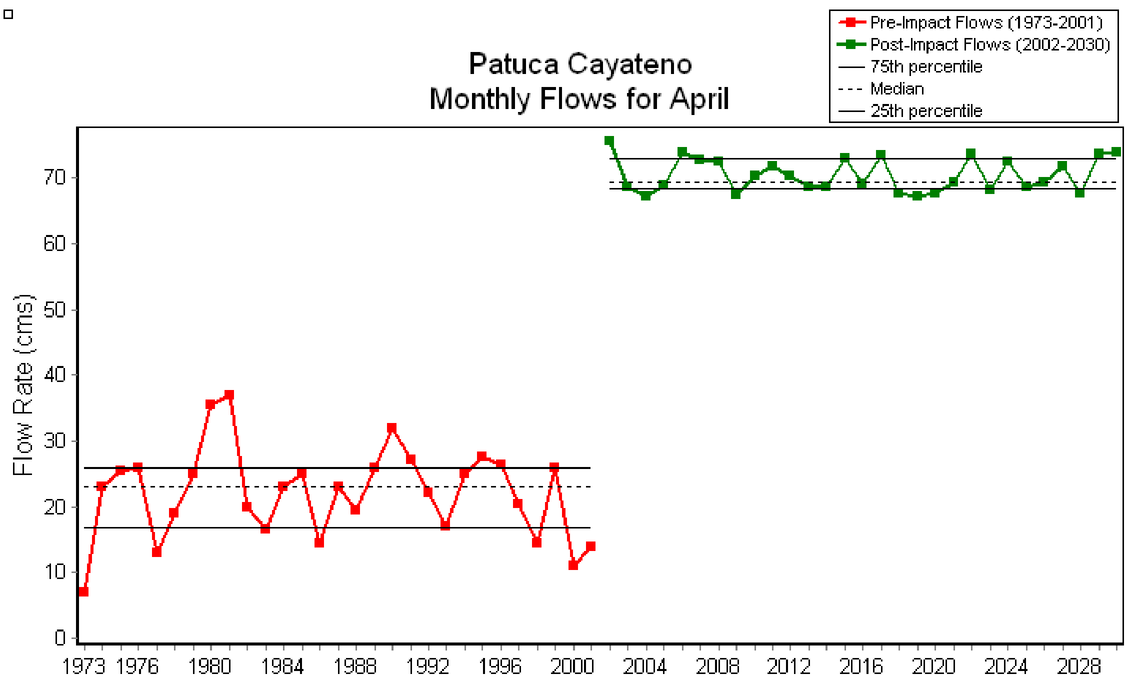


Figure 4. Monthly low flows for April, Cayetano.

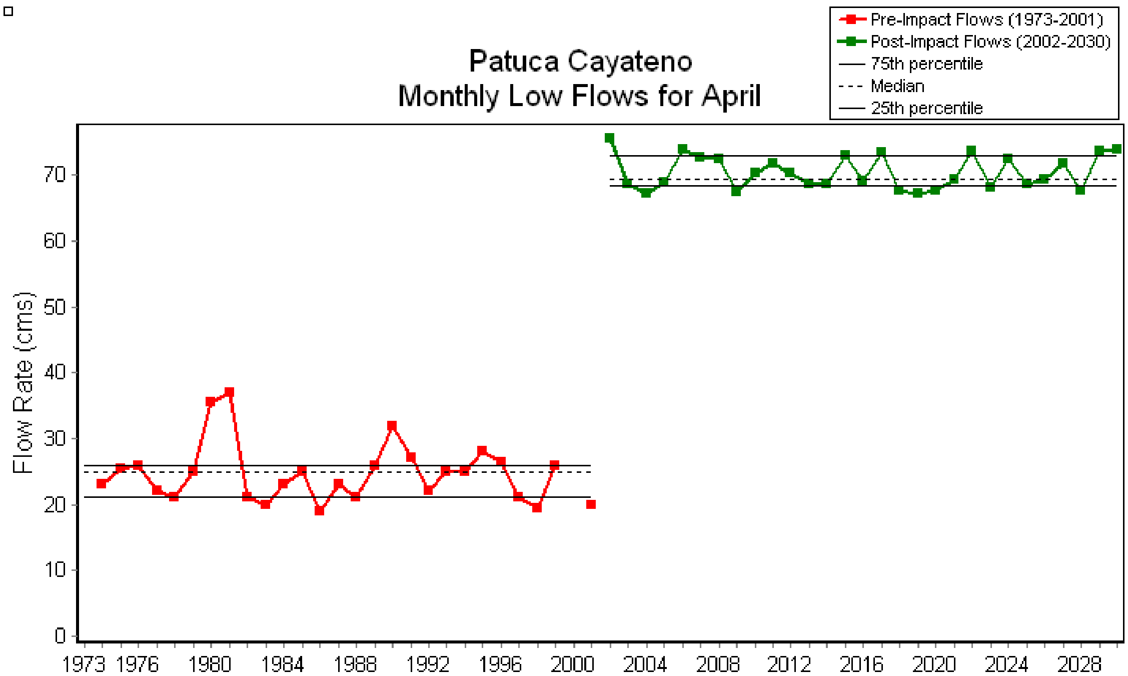


Figure 5. Extreme low flows (magnitude), Cayetano.

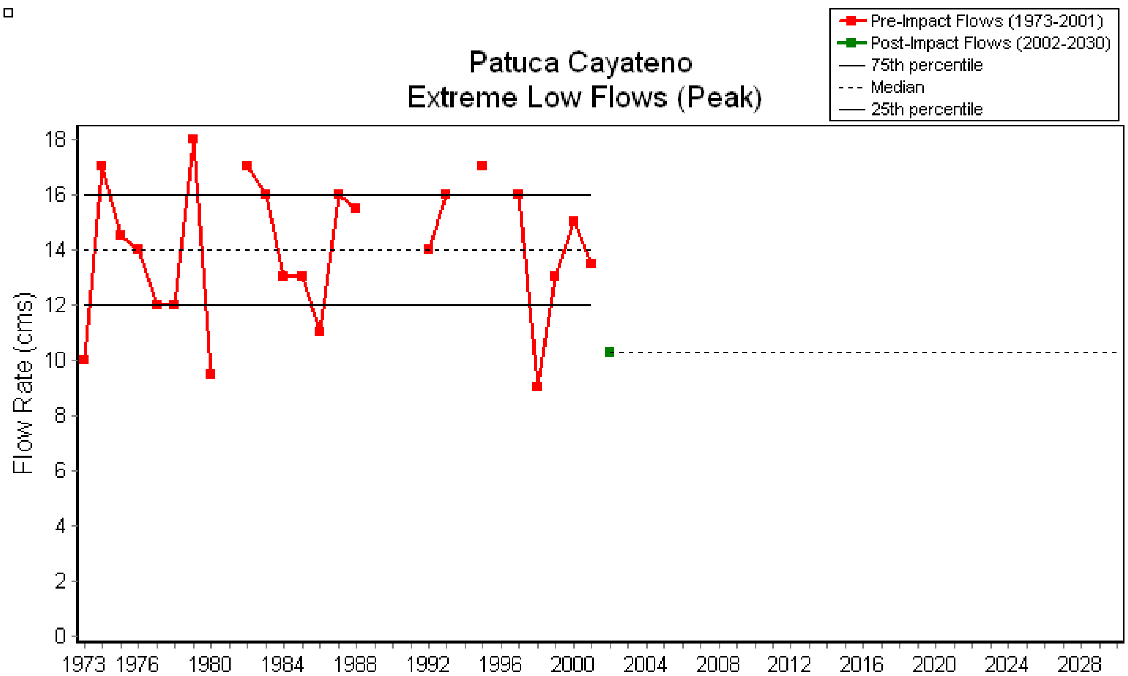


Figure 6. Extreme low flows (duration), Cayetano.

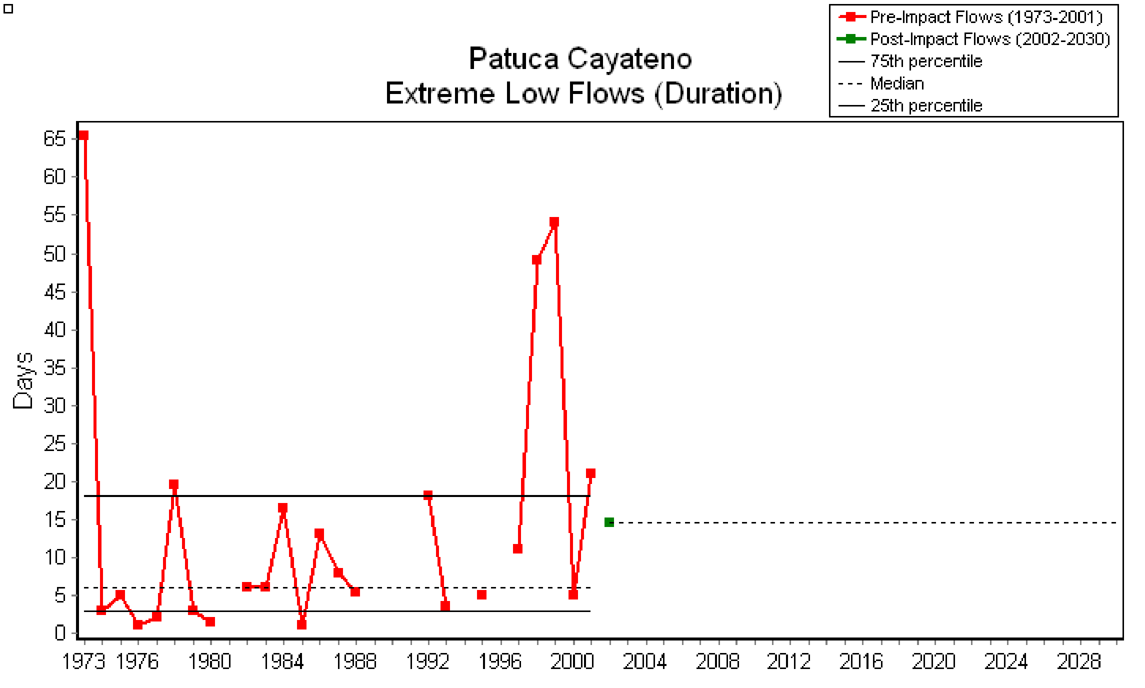


Figure 7. 30-day minimum flow magnitude, Cayetano.

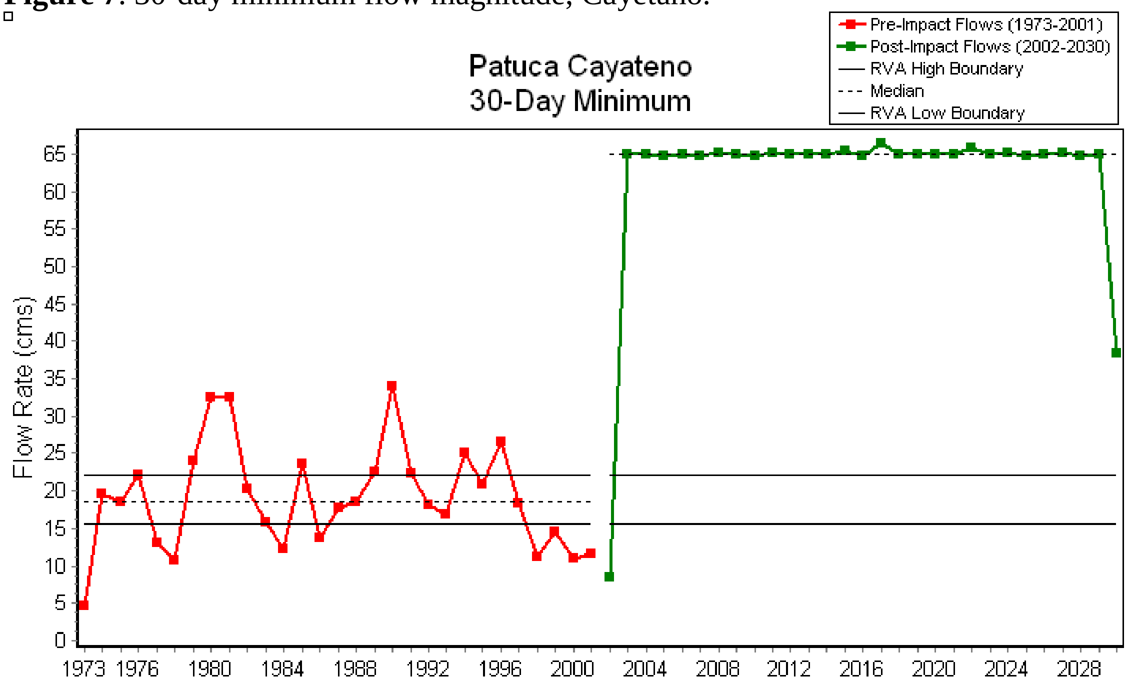


Figure 8. Monthly flows for August, Cayetano.

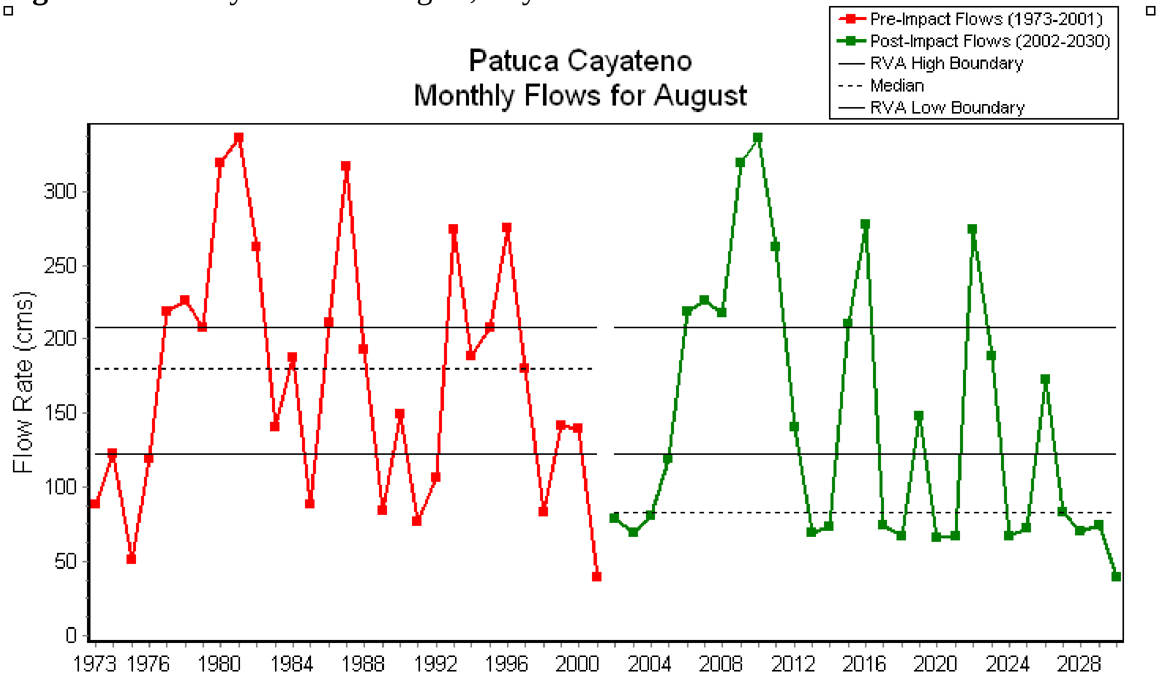


Figure 9. Monthly flows for October, Cayetano.

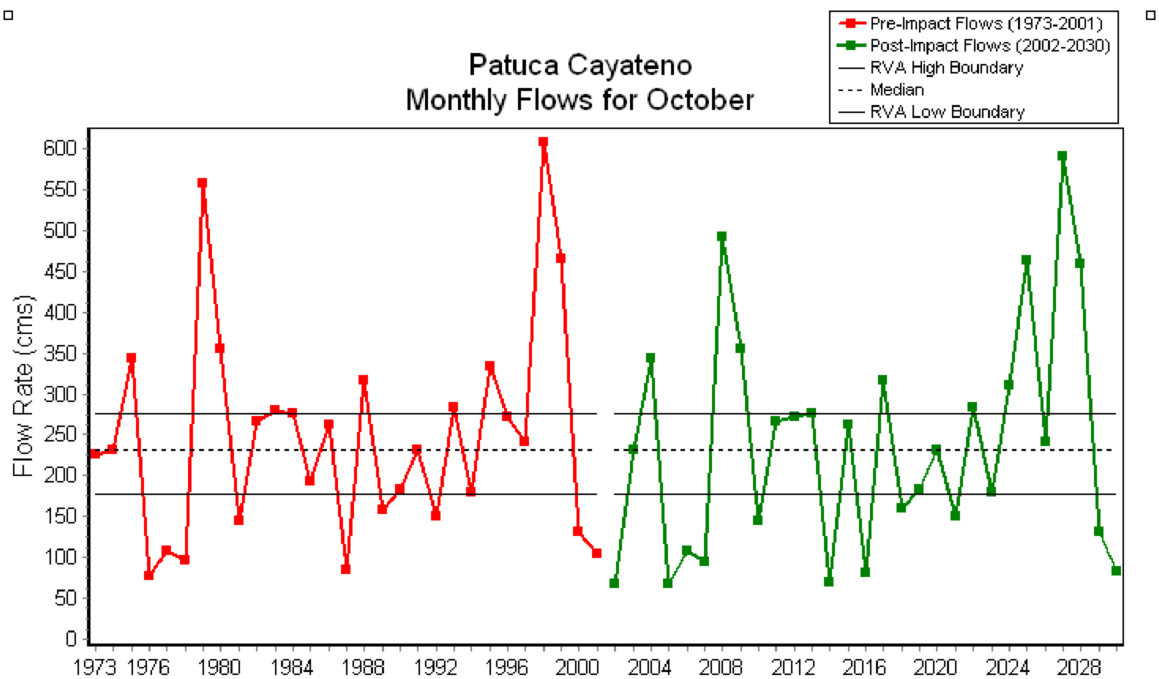


Figure 10. Frequency of high flow pulses, Cayetano.

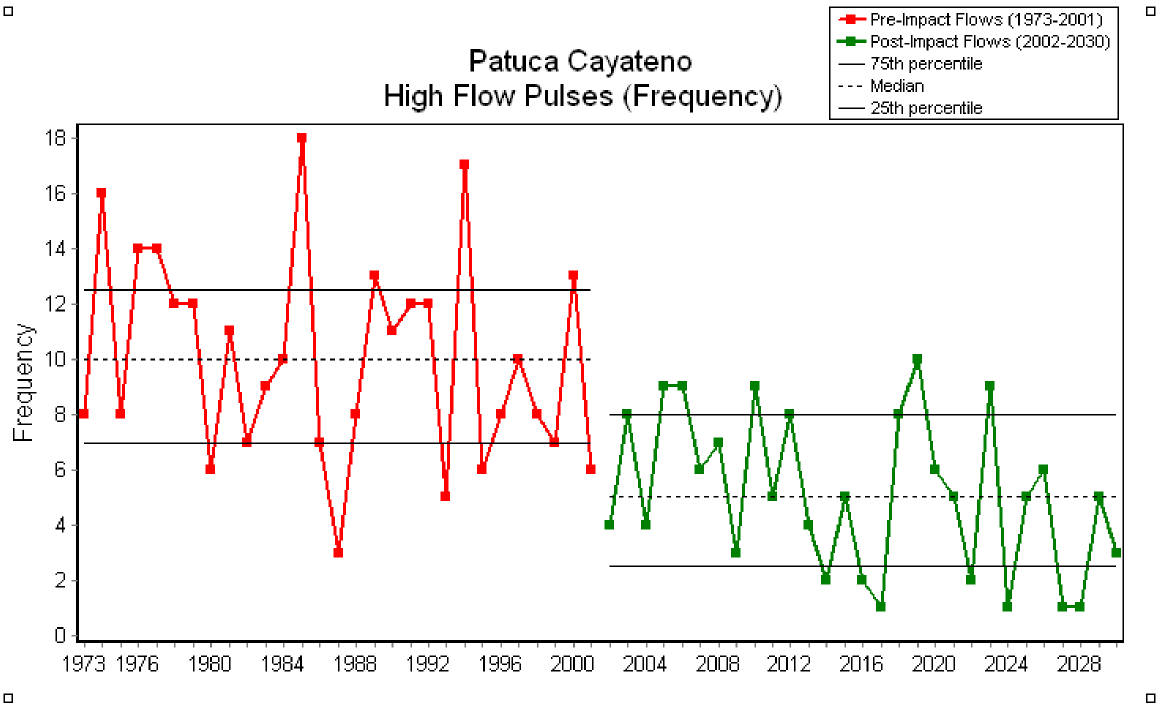


Figure 11. Magnitude of high flow pulses, Cayetano.

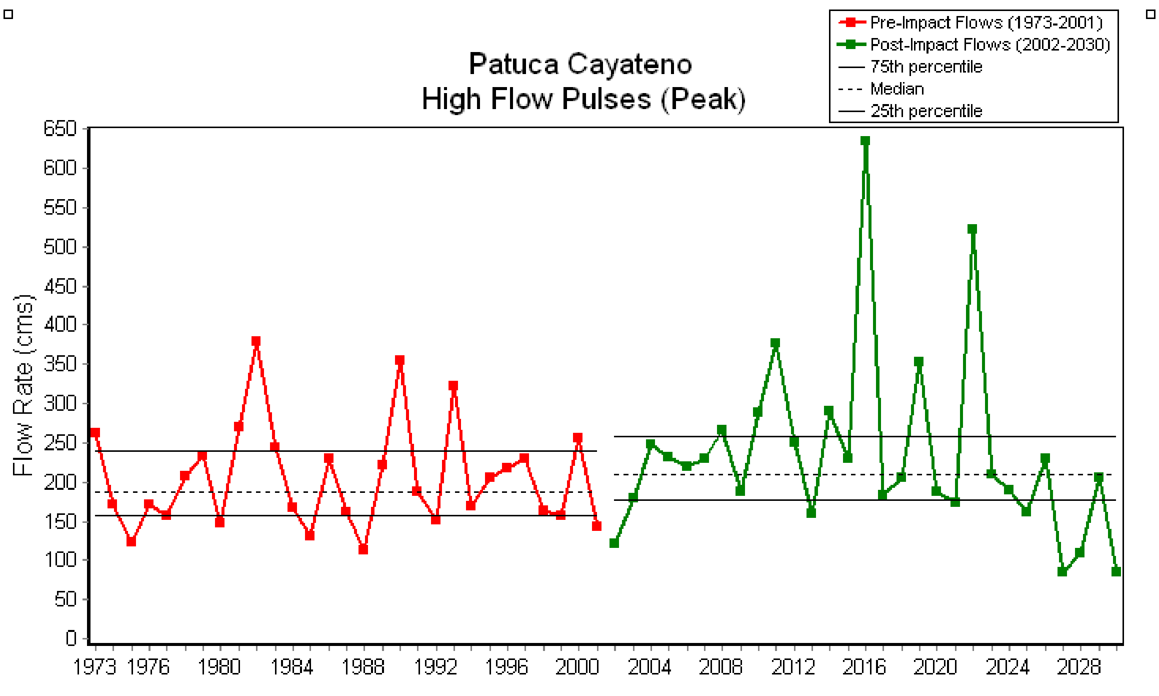


Figure 12. Duration of high flow pulses, Cayetano.

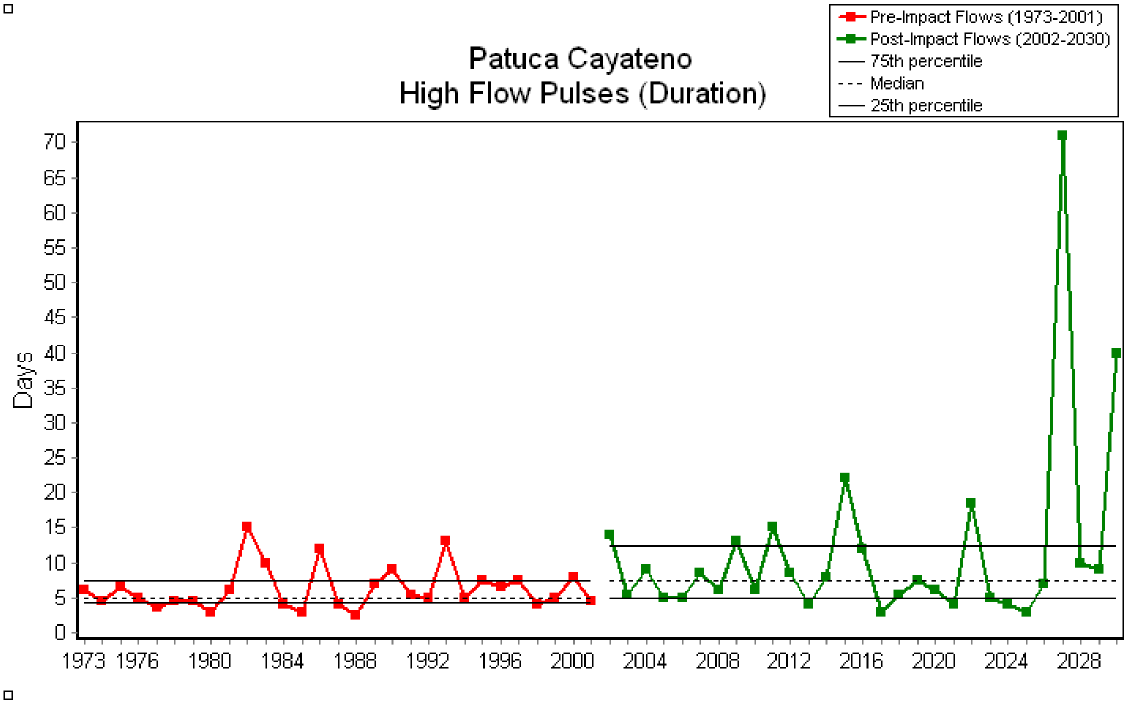


Figure 13. Timing of high flow pulses, Cayetano.

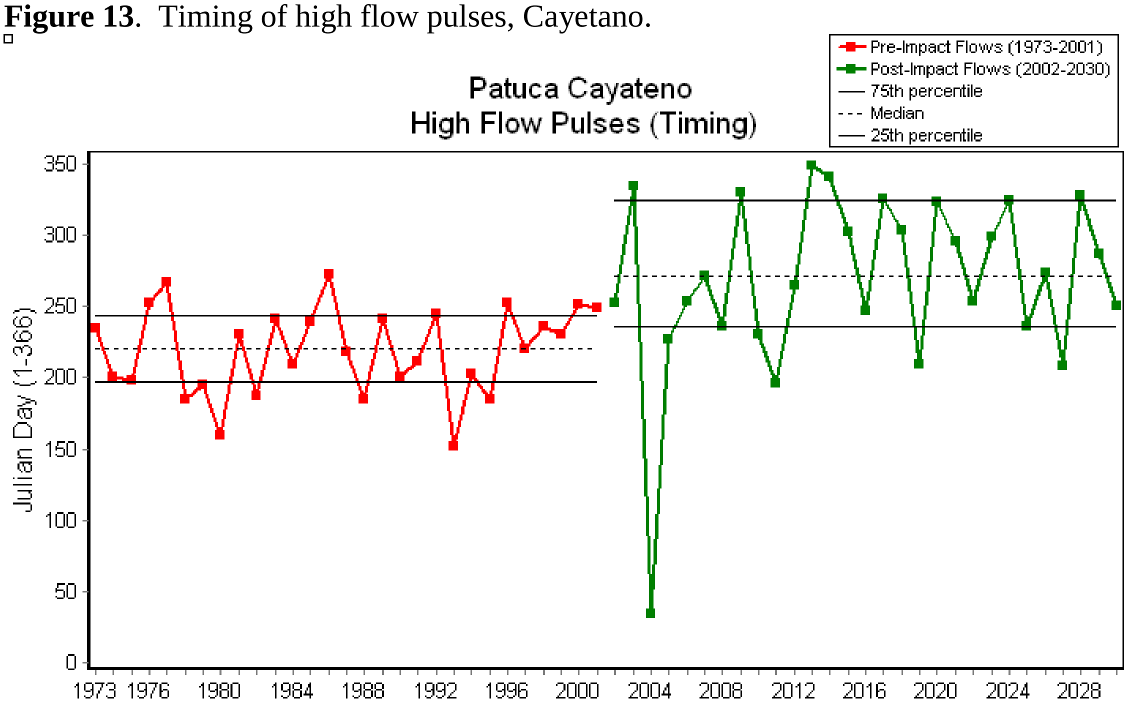


Figure 14. 7-day maximum flows, Cayetano.

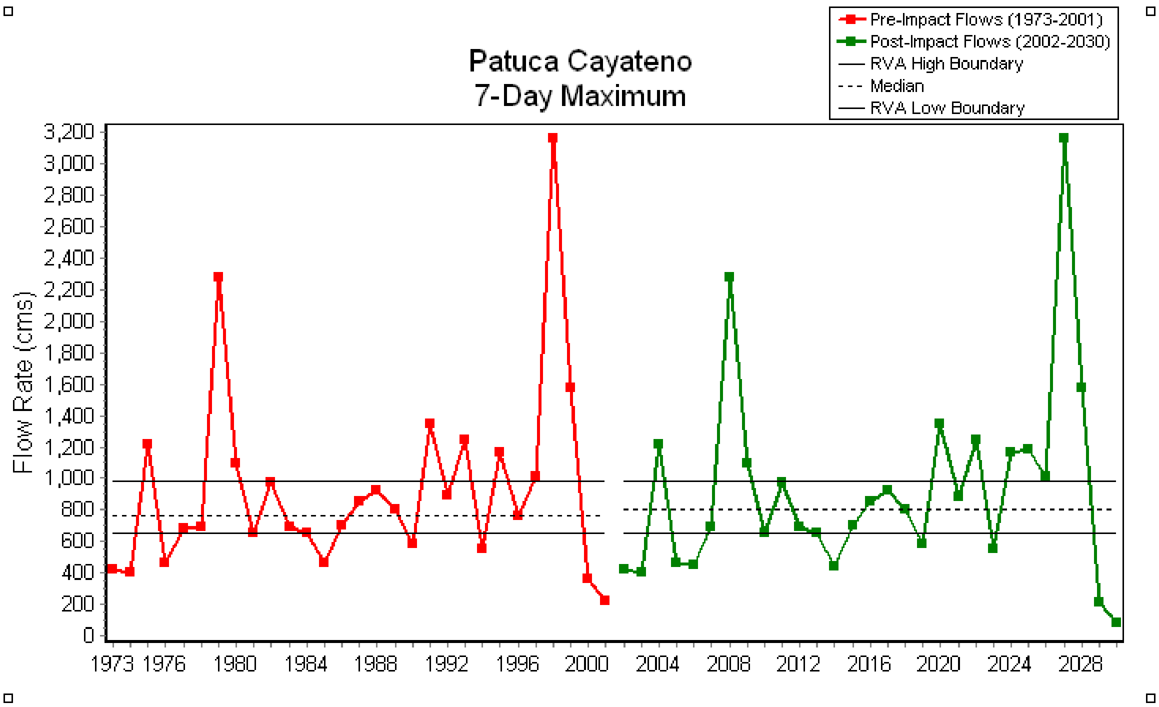


Figure 15. Pre-dam flows (flows above 440 cms not shown) at Cayetano, 1989 – 1991.

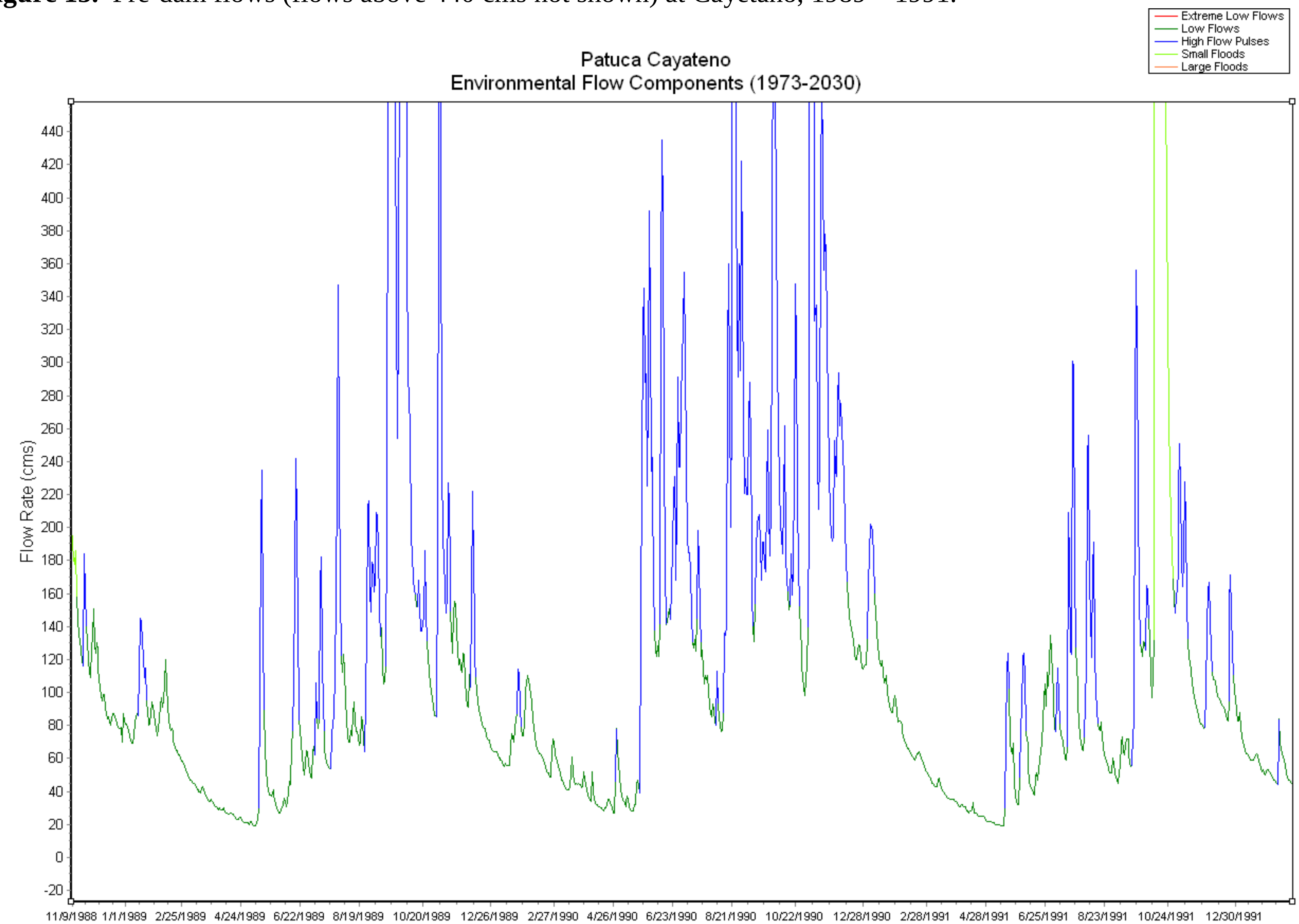
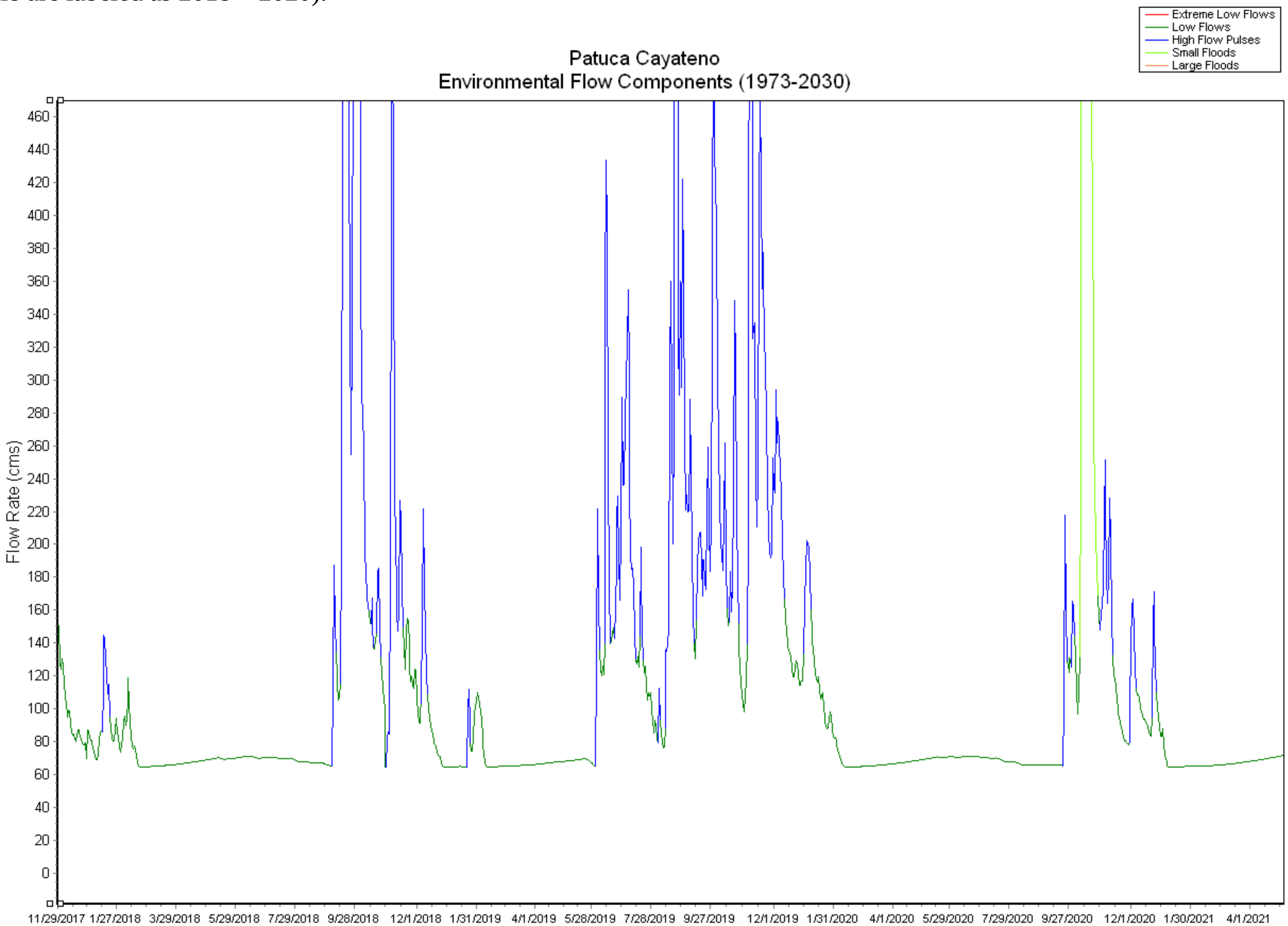


Figure 16. "Post-dam flows" (flows above 440 cms not shown) at Cayetano, 1989 – 1991 (note that, for the purposes of the IHA, these years are labeled as 2018 – 2020).



Figure

Figure 17. Post-dam flows" (flows above 440 cms not shown) at Cayetano, 1989 – 1991 (note that, for the purposes of the IHA, these years are labeled as 2018 – 2020). Where the red line disappears, it lies directly behind the green line.

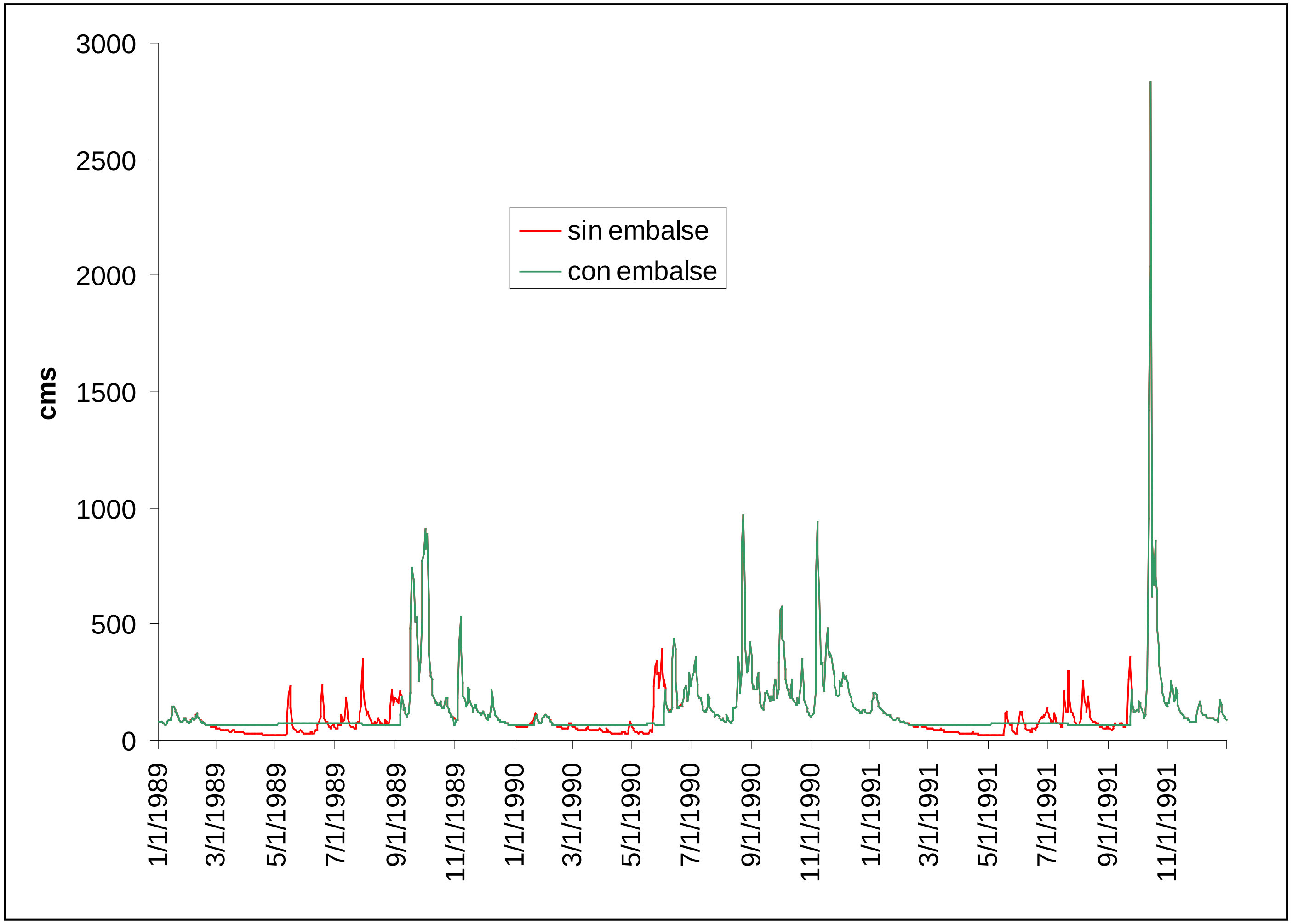


Figure 18. Post-dam flows" (flows above 500 cms not shown) at Cayetano, 1989 – 1991 (note that, for the purposes of the IHA, these years are labeled as 2018 – 2020). Where the red line disappears, it lies directly behind the green line.

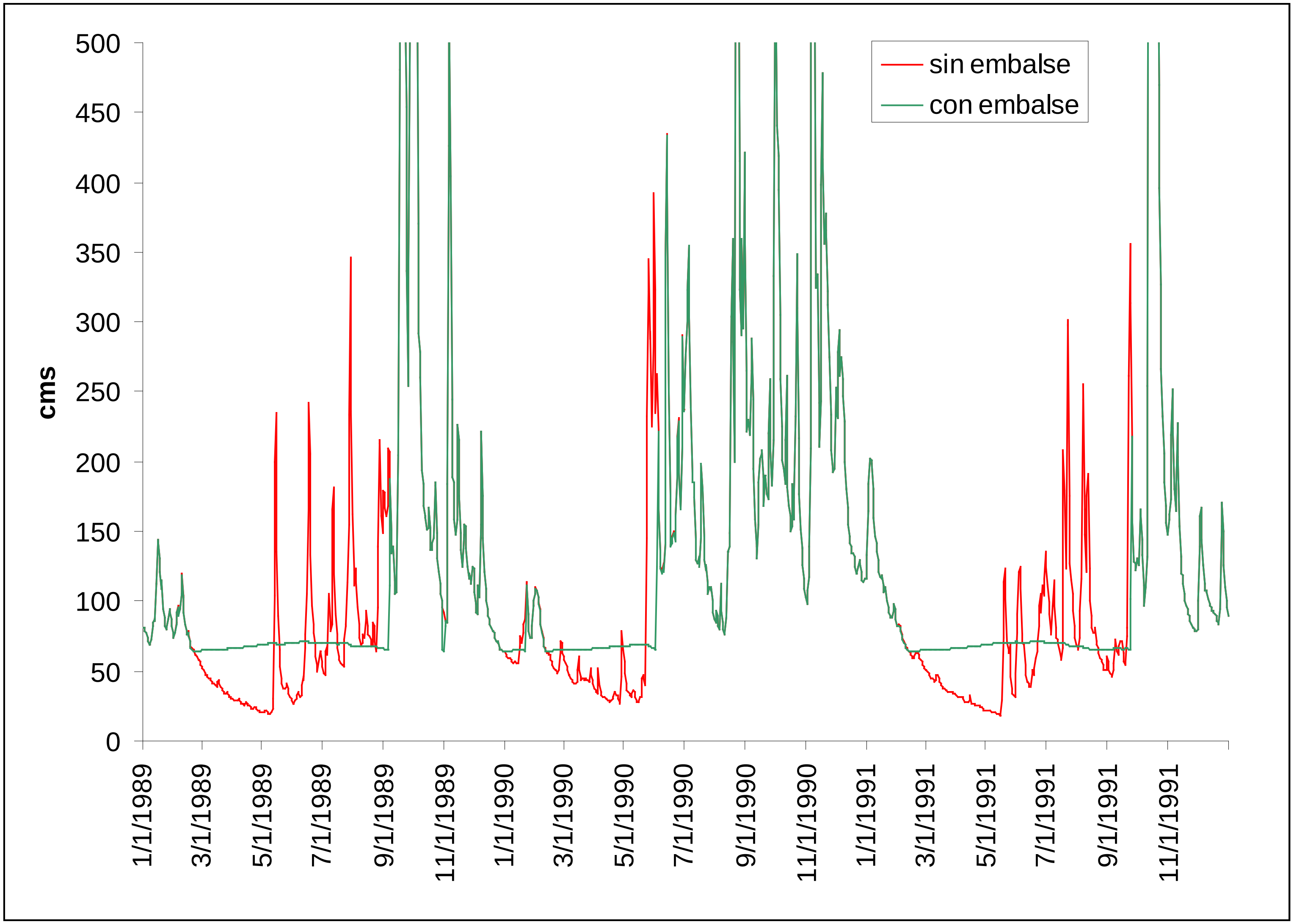


Figure 19. Hydrologic alteration values for Kurpha.

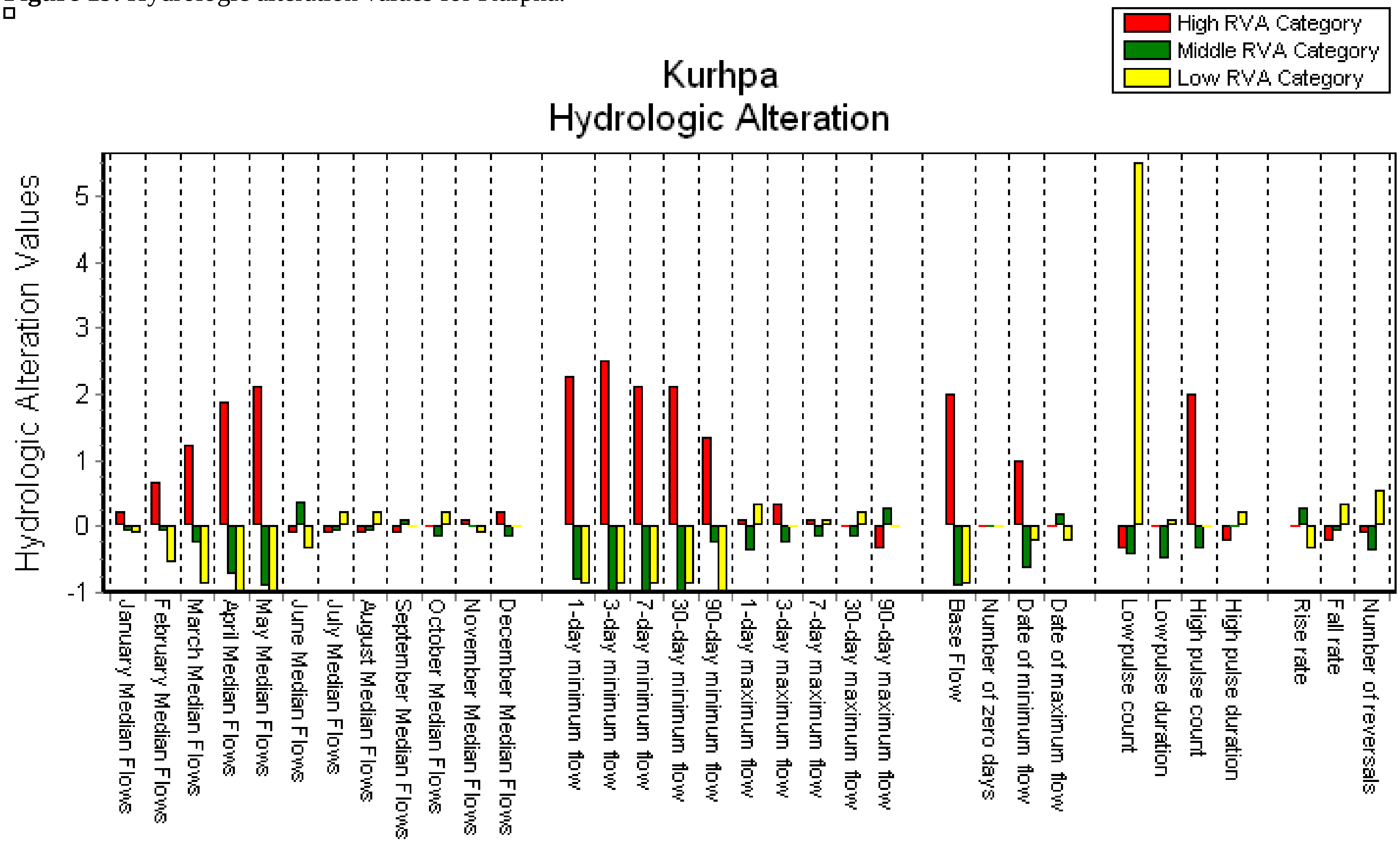


Figure 20. Monthly flows at Kurpha before (red) and after (green) the Patuca Dam.

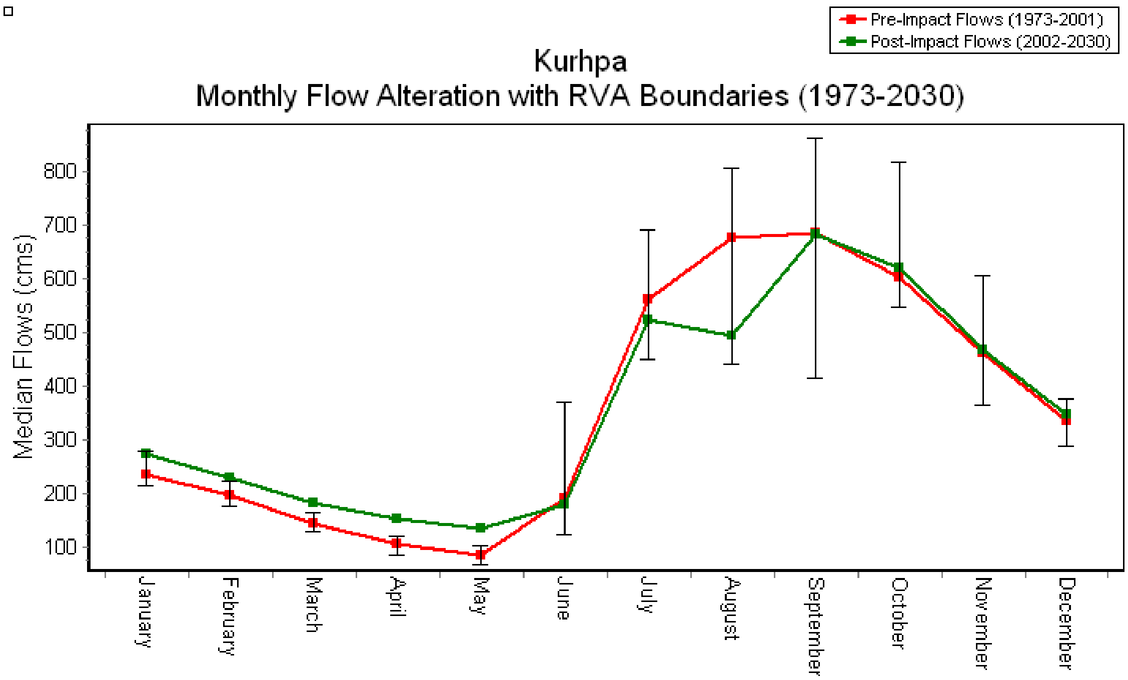


Figure 21. . 30-day minimum flows, Kurpha.

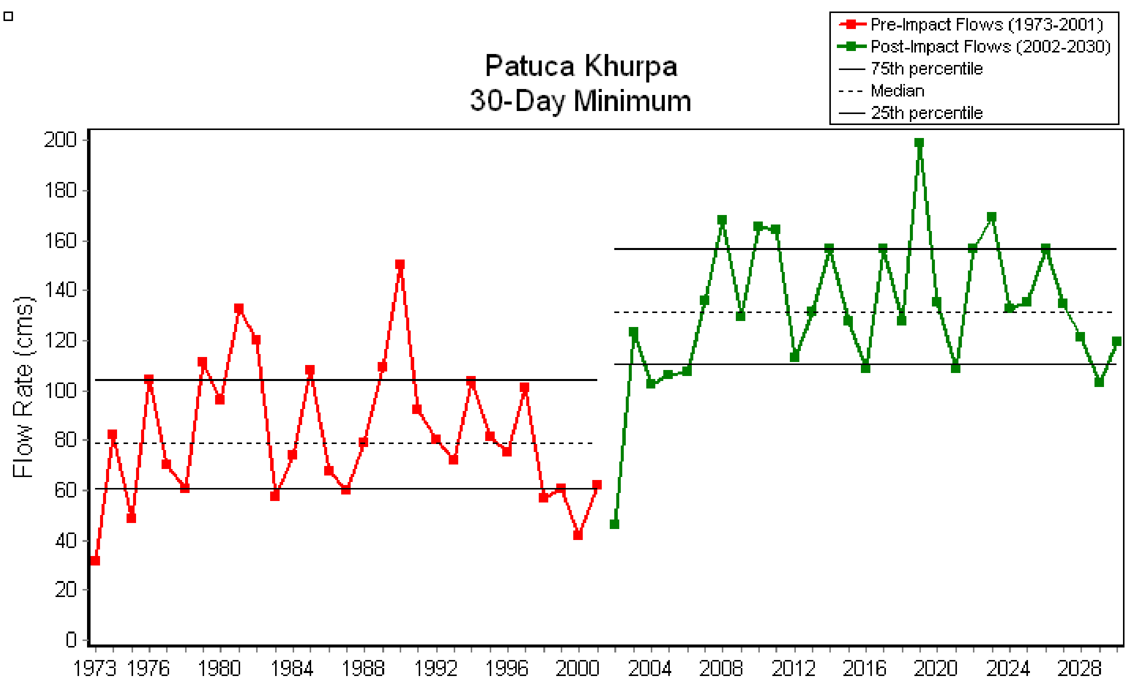


Figure 22. Monthly flows for May, Kurpha.

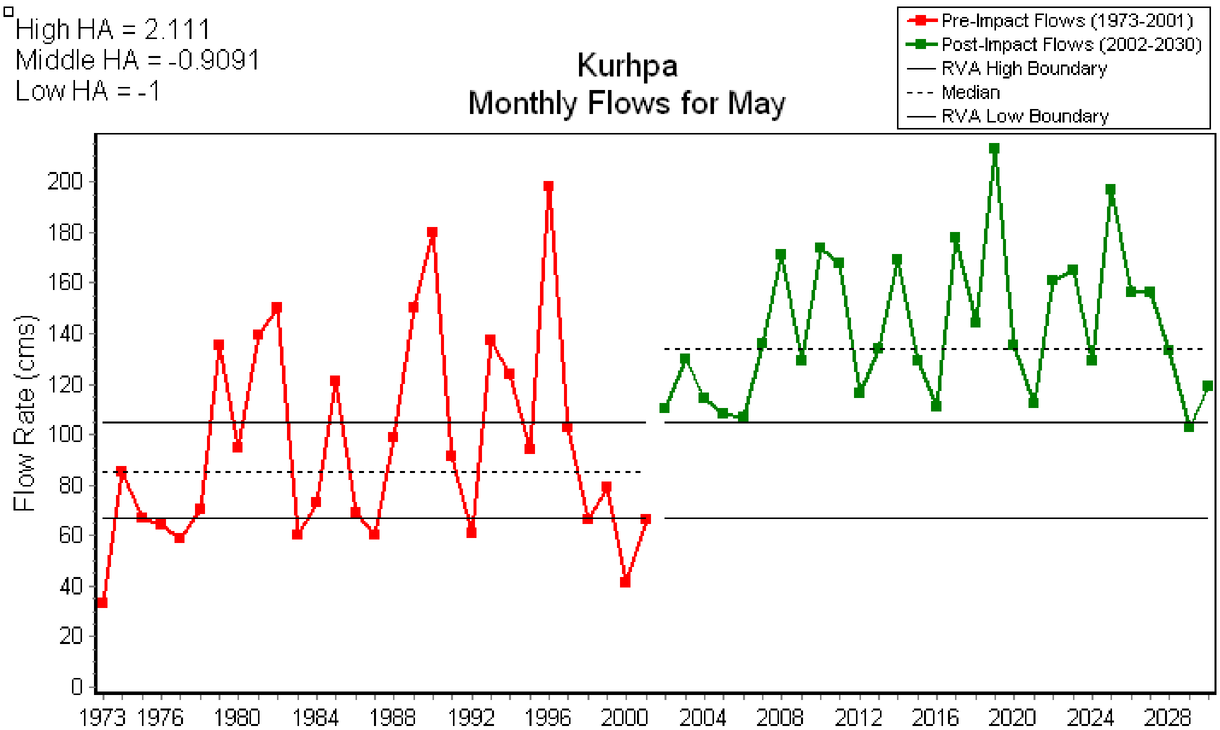


Figure 23. Monthly flows for August, Kurpha.