NM WRRI Student Water Research Grant Final Report

Temporal and climatic analysis of the Rio Peñasco in New Mexico

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Problem

Little is known on how to characterize ephemeral and intermittent streams or how they can be integrated in regional water budgets. Most classification systems use perennial streams as the basis for analysis making standard classifications of ephemeral and intermittent streams difficult.

Objectives

This study will identify, define, and analyze three gages on the Rio Peñasco in New Mexico in order to analyze and describe the stream, and ultimately to determine what impact climate change or anthropogenic alterations such as diversions are having on hydrological trends and variability. I hope to discover any interannual or decadal temporal trends in streamflow data including what impact large-scale climate drivers such as El Niño-Southern Oscillation (ENSO) have on HIE streamflow. Streamflow will be quantified in order to better integrate the Rio Peñasco into the larger surface water budget of the state. The goal of this research is to define the impact that future climate change could have on HIE streams.

Methods

Streamflow data, including daily means, and annual peak streamflow, were obtained from United States Geological Survey (USGS) continuous gage 08398500 for the Rio Peñasco at Dayton, NM from 1951-2012. The number of days with flow was calculated along with the mean and median of the daily discharge rates. The streamflow exceedance probability was calculated based on the Weibull probability distribution method which is commonly employed by the U.S. Geological Survey for regional flood frequency analyses (Dalrymple 1960; Interagency Advisory Committee on Water Data 1982). P is the probability of exceedance in percentage, n is the number of years of record, and m is the rank of that year’s flood event.

$$P = \left(\frac{m}{n+1}\right) * 100 \quad (1)$$

The complete data set were plotted on a hydrograph to discover any temporal trends. Mean monthly streamflow was calculated and plotted on bar graphs to discover any seasonal trends. The streamflow rates were converted to total volumes (Equation 2) in order to assess the overall change in total water volume and compare the results to discharge rates.

$$Total\ flow = flow\ increment * s \quad (2)$$

$$Flow\ increment = \frac{Current\ discharge\ rate - previous\ discharge\ rate}{12\ hours\ x\ 60\min x\ 60\ sec}$$

$$s = \frac{n(n+1)}{2}$$

The monthly mean flows were used to discover if ENSO affects the seasonality of the streamflow. The months of October, September, and November were classified as El Niño, La Niña, or ENSO-Neutral using the Oceanic Niño Index (ONI) which uses a three month running mean of extended reconstructed sea surface temperatures in the Niño 3.4 region provided by the National Weather Service Climate Prediction Center (NWS 2014). The following winter and spring were labeled using the classification of the previous Oct-Nov. The monthly discharges were averaged and plotted on a bar graph. Each peak streamflow was also assigned ENSO values using the same method above and then plotted to see how peak streamflow was affected by ENSO.

Precipitation data from 1951-2012 was obtained from National Oceanic and Atmospheric Administration's National Climatic Data Center for Artesia, NM station 290600. The total snowfall was converted to precipitation values using the average snow to precipitation ratio of 11:1 where 11 units of snow equals 1 unit of precipitation (Baxter, Graves, & Moore 2005). The snow equivalent precipitation was summed with regular precipitation amounts. Each month was labeled as either El Niño, La Niña, or ENSO-Neutral using the same method that was used for streamflow. The results were plotted on bar graph. The data were separated into seasons in order to ascertain how ENSO influences precipitation.

Results and Discussion

The streamflow of the Rio Peñasco at gage 08398500 has a total record of 22,646 days with only 912 of those days experiencing streamflow. The daily discharge has a mean of 0.108 m^3/s and a median of 0.000 m^3/s signifying that this is an intermittent or ephemeral stream. Besides qualitatively confirming that a stream is intermittent, the mean and median are not very good descriptors of HIE streams. The probability of flow was calculated and is displayed in Table 1.

	January	February	March	April	May	June	July	August	September	October	November	December
# of Days with flow	0	0	0	9	18	64	122	197	244	147	79	32
Probability (w/ flow)	0	0	0	0.986842	1.973684	7.017544	13.37719	21.60088	26.75438596	16.11842	8.662280702	3.50877193
Probability mn (all days)	0	0	0	0.483871	0.936524	3.44086	6.347555	10.24974	13.11827957	7.648283	4.247311828	1.664932362
Days w/sf per month	0	0	0	0.145161	0.290323	1.032258	1.967742	3.177419	3.935483871	2.370968	1.274193548	0.516129032
Total days in series	1922	1752	1922	1860	1922	1860	1922	1922	1860	1922	1860	1922

Table 1. Streamflow probability statistics.

The first row displays the number of days with flow by month showing that the period of July-October contains the majority of streamflow days when there is flow. The second row shows the probability of each month receiving streamflow using only the days with non-zero streamflow. The third row shows the overall probability that each month will have flow when looking at the entire data series. The fourth row shows the daily probability of streamflow by month. This shows the monsoonal influence on streamflow with one exception: peak precipitation due to monsoonal rain generally occurs in August with September showing the influence of tropical storms (Higgins et al 1997).

Figure 2 shows the precipitation seasonality. This also shows that September receives the highest total amount of precipitation indicating that Artesia, NM is influenced by both monsoonal storms and tropical storms. Figure 4 shows the streamflow seasonality. While September has the highest number of days with streamflow, August has the highest mean discharge rate. This could indicate that while September has more days with precipitation, the intensity of the precipitation is less than the intensity of precipitation events in August.

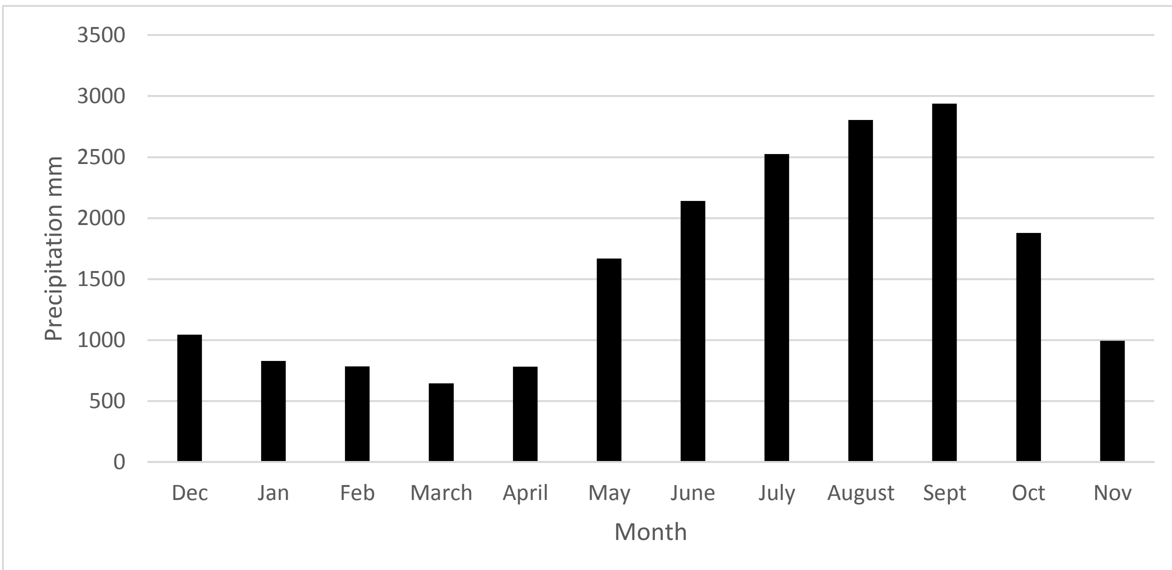

Figure 1. Seasonality of precipitation using monthly totals Artesia, NM.

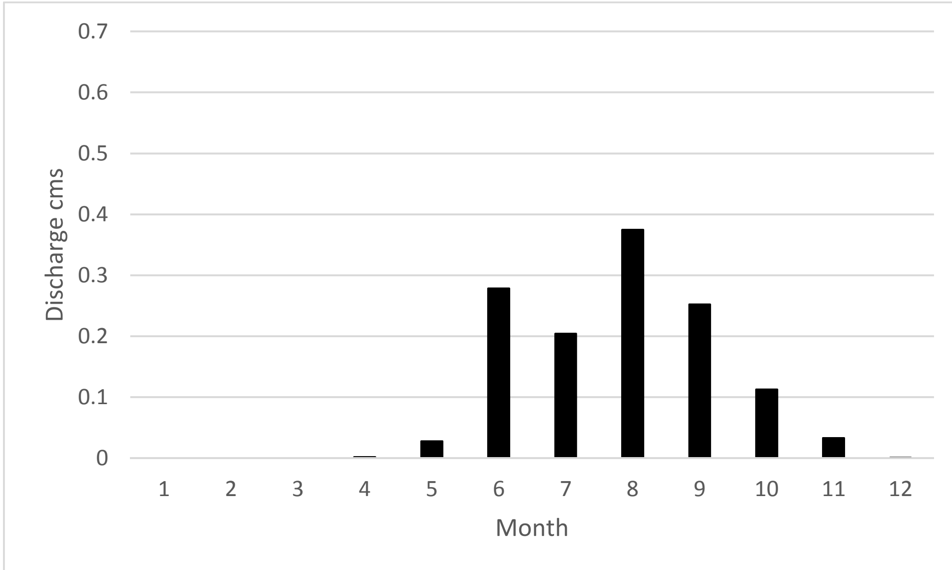

Figure 2. Seasonality of streamflow using mean monthly discharge rates.

In the past 62 years, there has been zero streamflow during the months of January, February, and March. While the headwaters of the Rio Peñasco are located in the Sacramento Mountains and may experience snowmelt events, those melt events do not impact the lower reaches of the stream. Of the 912 days with streamflow, 26% of streamflow occurred during September. July-October accounts for 77.85% of all streamflow days with non-zero flow recorded. 13% of days in September have experienced streamflow. When broken down into a single month, September has 4 days of streamflow per year. The probability of exceeding zero flow on any given day is 1.12% (Fig. 3).

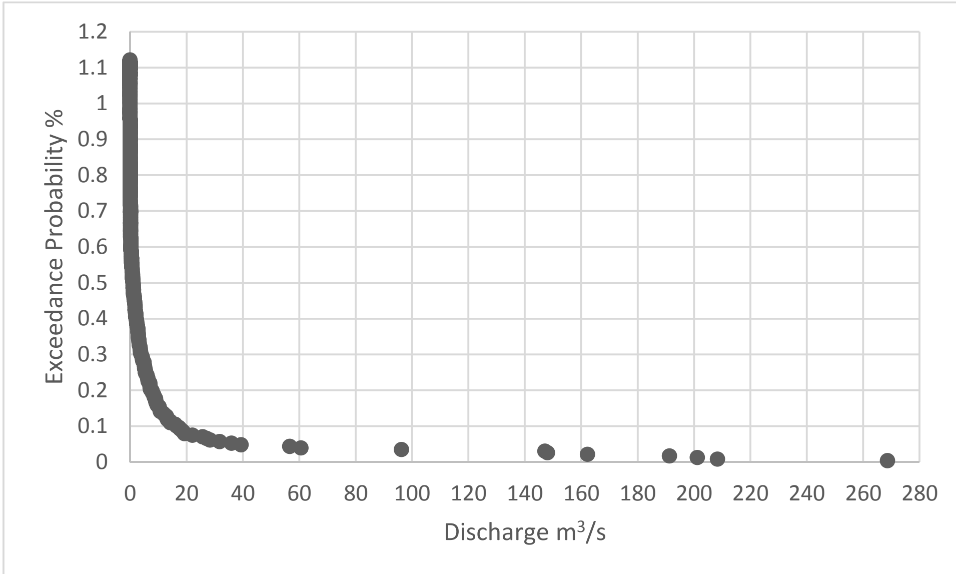

Figure 3. Probability of exceedance plotted with mean daily discharge.

The hydrograph shows a downward trend in annual peak streamflow (Fig. 5). This trend is not significant, but the hydrograph does show a stark decline in discharge around 1986/1987. Because of the stark decrease in flow around 1986/1987, the data were separated into two periods: 1951-1986 and 1987-2012. When the hydrograph is separated into two periods, you can see that each separate period has a slight upward trend although the trend is not significant (Fig. 6).

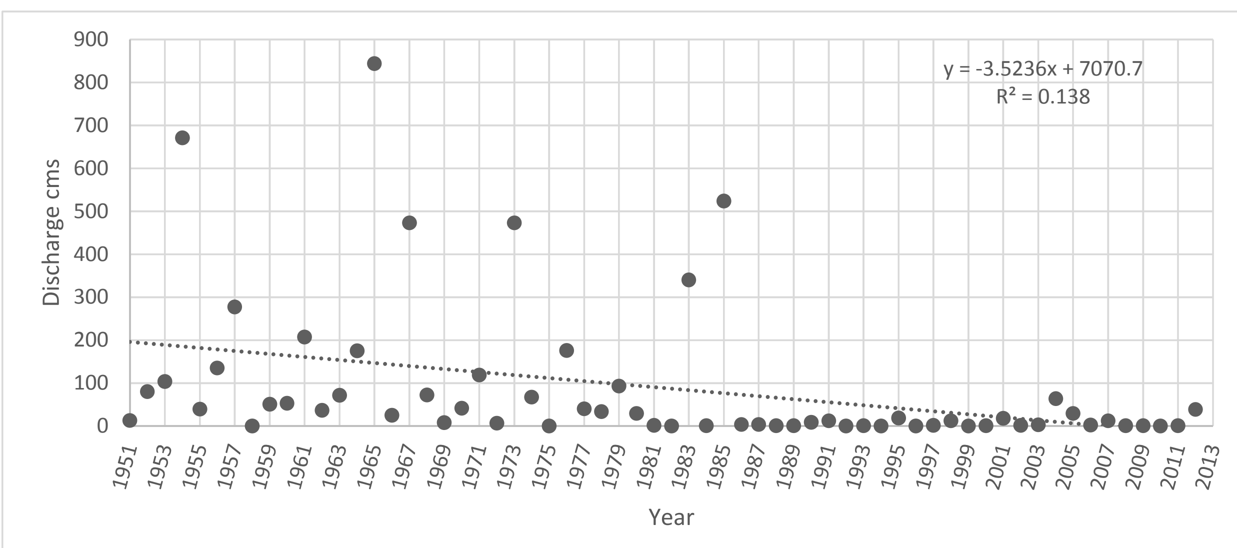

Figure 4. Hydrograph of peak annual streamflow.

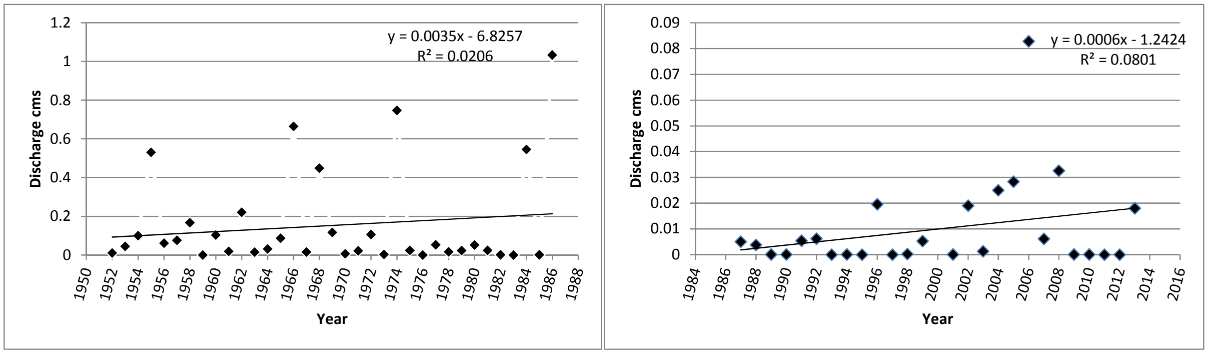

Figure 5. Left: Hydrograph of peak annual discharge 1951-1986. Right: Hydrograph of peak annual discharge 1987-2012.

By calculating the percent decline in streamflow rate, it is possible to determine the decline in water volume from 1951-1986 to 1987-2012. The total water volume was also calculated for comparison (Table 2). The flow rate at this gage on the Rio Peñasco has decreased by 93% while the total volume output has decreased by 91%. The seasonality bar graphs in Figure 7 visually show the same trend. The upper stream has been moved out of its natural channel several times to facilitate flood irrigation (Surface Water Quality Bureau 2007) which may explain why there has been a significant decrease in discharge rates near Artesia, NM.

Years	1951-2013	1951-1986	1987-2012
Total days	22646	13149	9497
Days w/flow	913	668	245
% days w/flow	4.03	5.08	2.58
Mean flow rate	3.82	6.25	0.41
Reduction in flow			93%
Avg total flow vol		117614.3	10986.75
Reduction in flow			91%

Table 2. Total decrease in mean flow rate versus reduction in flow volume in m^3/s.

By assigning monthly mean streamflow rates to ENSO values, it is possible to see how ENSO may affect the seasonality of the streamflow. When looking at the impact of ENSO on peak streamflow values, it appears that peak streamflow is less influenced by El Niño years, but this trend needs to be tested for significance (Fig. 8). Of the 61 years of peak streamflow data, 28 years were during ENSO-Neutral periods with a total discharge of 2998.12 m^3/s, 18 years were during El Niña with a total discharge of 1828.03 m^3/s, and 16 years were during El Niño with a total discharge of 665.03 m^3/s. The average discharge during El Niño years was half (41.56 m^3/s) of the average discharge during La Niña (101.56 m^3/s) and ENSO-Neutral (107.08 m^3/s) years.

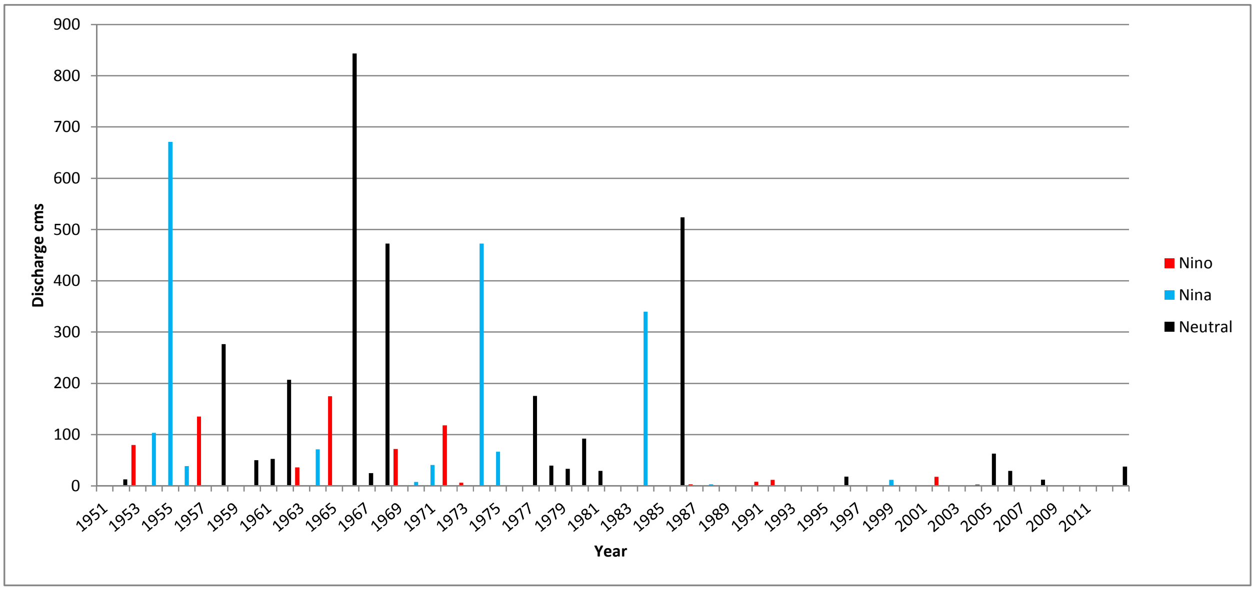

Figure 8. ENSO impact on peak streamflow.

While there was no apparent ENSO trend when looking at annual peak streamflows, a trend began to emerge when looking at monthly averages. ENSO directly impacts winter and early spring precipitation which should also affect winter streamflow (Ropelewski & Halpert 1987). However, the Rio Peñasco has no winter streamflow. It has been hypothesized that ENSO can also impact spring precipitation as well as alter monsoon precipitation totals. When looking at the monthly averages (Fig. 9), it can be seen that when the previous winter was impacted by El Niño, total streamflow is decreased and streamflow events occur later in the year when compared to La Niña years or years with no ENSO influence. This trend also needs to be tested for statistical significance before it can be declared as an actual trend.

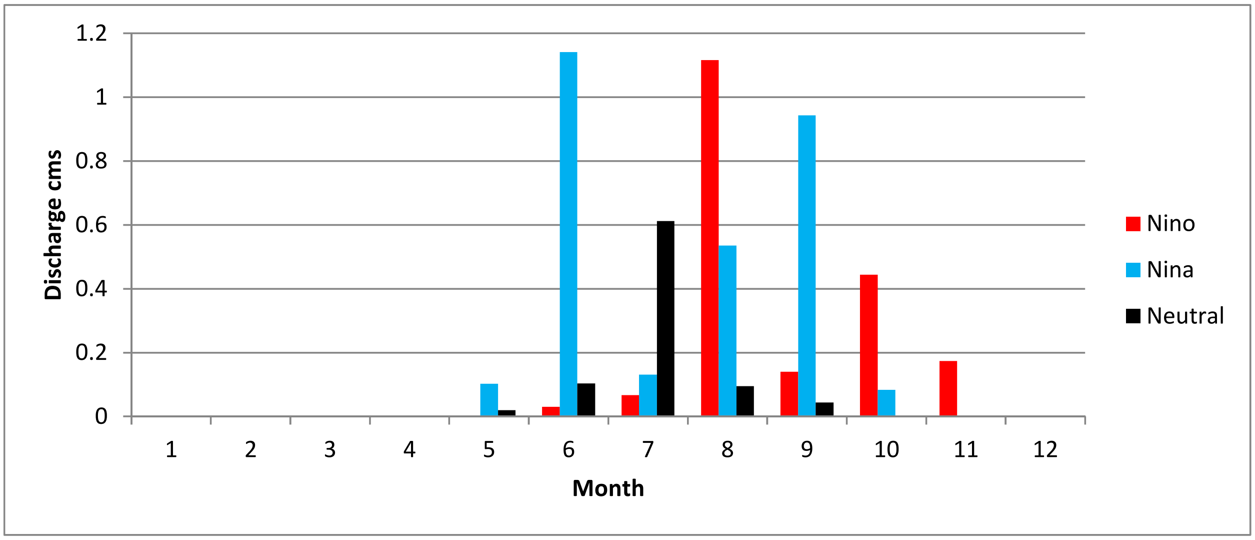

Figure 9. ENSO impact on monthly mean discharge rates.

This same trend can be seen in the precipitation records. Figure 10 shows the ENSO influence on precipitation at the nearby gage in Artesia. The precipitation gage shows a strong ENSO influence on winter precipitation amounts. Most of the largest winter precipitation events are influenced by El Niño. This trend continues in the spring, but it does start to break down. During the standard monsoon season (July-November), El Niño years have much lower precipitation totals compared to La Niña and no ENSO event years which supports earlier research (Gutzler and Preston 1997).

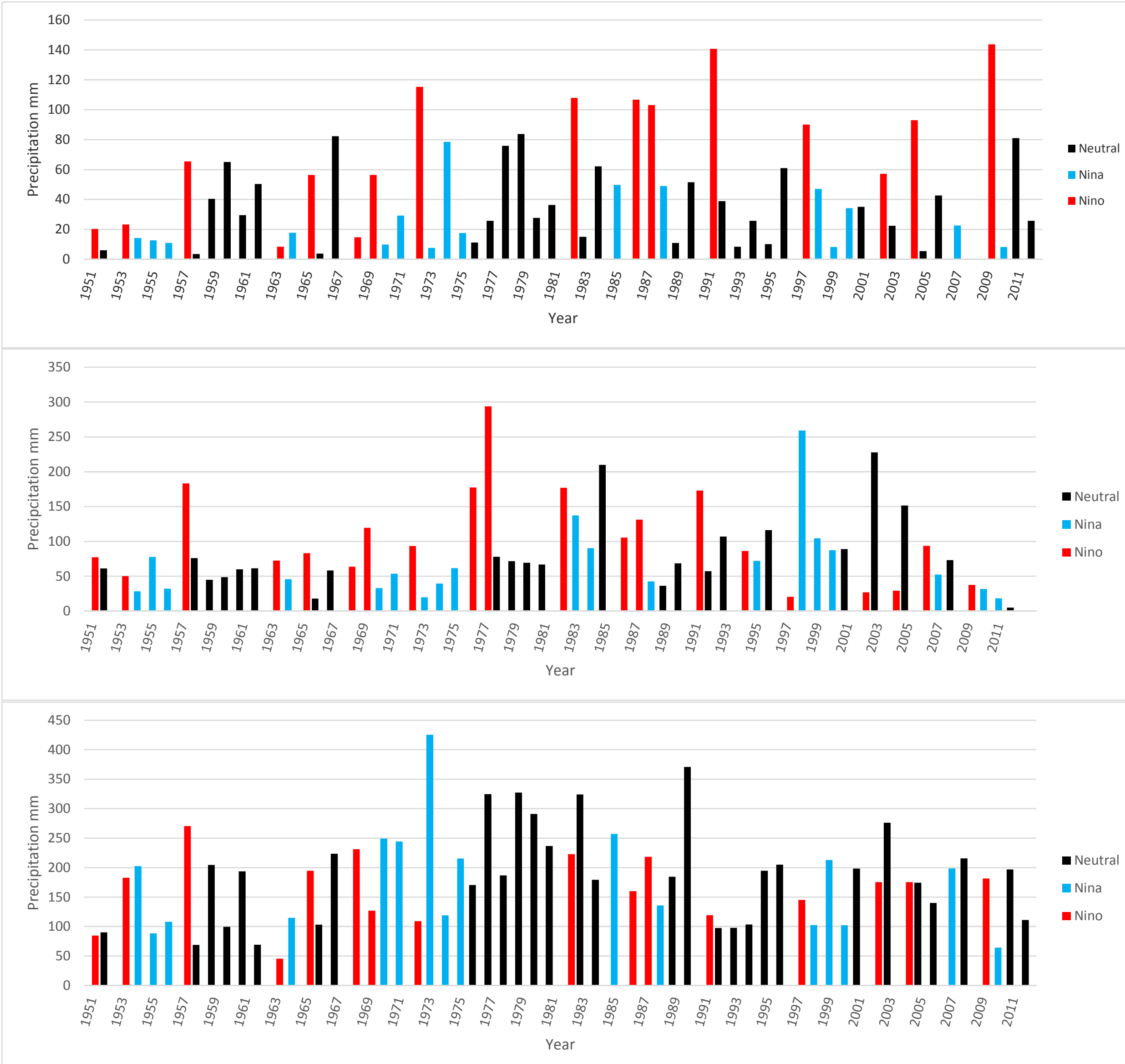

Figure 10. Top: ENSO impact on monthly precipitation totals December-February. Middle: ENSO impact on monthly precipitation totals March-June. Bottom: ENSO impact on monthly precipitation totals July-November

Conclusion

The Rio Peñasco gage near Artesia, NM is an ephemeral stream that is dry in the spring and most active during the monsoon months. The statistical analysis of this stream shows that there is an inadequacy of traditional metrics for the average and variance of HIE streams. Exceedance probability calculations and return intervals are very useful for perennial streams, but it is obvious that these metrics are not as useful when the mean of the data is zero. Models for intermittent streams must be more complex and have a larger number of variables (Aksoy & Bayazit 2000) so it would follow that traditional statistical metrics should also be developed based solely on HIE streams instead of using metrics from perennial streams.

The temporal analysis of the entire series shows a downward trend that is not significant. The downward trend is primarily due to a decline in discharge rates due to anthropogenic influences (including damming and diversions) which can be seen in the change in discharge rates in the 1980s. It is also possible that the decrease in the hydrograph could be due to changes in groundwater. Future research could address the changing water table in the areas of Artesia in order to identify if groundwater could be a factor. When the data is divided into two separate time periods, a slight upward trend (that is also not significant) can be seen. This does not follow the overall drying trend that is currently happening in the Southwest.

This stream showed a seasonal trend with ENSO. Previous research has shown that ENSO impacts streamflow timing when looking at watersheds (Redmond & Koch 1991), but this trend has not been observed when looking at a single intermittent or ephemeral stream. ENSO impacted the timing of the onset of streamflow during monsoonal months. During La Niña years, there was an early onset of streamflow and during El Niño years, streamflow occurred later in the year. This relationship shows that climate signals can be detected when looking at HIE streams.

While this paper provides an introductory look at the statistics of flow at one gage of an ephemeral stream in New Mexico, much more work needs to be completed in order to form a complete assessment of streamflow in NM as well as determine the overall influence of climate on HIE streams. This next logical step for this project would be to investigate other HIE streams nearby to determine if the same ENSO influence can be seen. Other climate drivers such as Pacific Decadal Oscillation (PDO) and North Atlantic Oscillation (NAO) could be examined to determine whether they impact streamflow on HIE streams. Streamflow could also be quantified based on the primary climate driver of that streamflow to determine future changes that could occur due to anthropogenic climate change by looking at weather maps and isolating the primary cause of the precipitation event that caused flow.

Benefits

This research is a useful first step in building a picture of intermittent and ephemeral streams in the Southwest. Analysis used on the Rio Peñasco can also be applied to additional streams. Intermittent and Ephemeral streams can then be compared with perennial streams. It is already obvious that conventional metrics that are used on perennial streams are not accurate for intermittent and ephemeral streams.

Presentations

NM WRRI 59th Annual Water Conference in Santa Fe, NM

Special Recognition/Notable Achievements

I was awarded the NSF GRFP for the overall goal of analyzing all intermittent and ephemeral streams in the Southwest. Being awarded the NM WRRI grant definitely helped my application as well as improved my research statements.