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TECHNIQUE FOR ANALYZING HEAVY RAIN EVENTS AND ASSOCIATED STREAM RESPONSES CASE STUDY: 23 FEBRUARY 1998

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The Problem

Historical correlations between observed rainfall and resulting stream responses in a river basin are useful for forecasting floods. However, without the benefit of local analysis tools, the development of these correlations can be difficult and tedious.

To get a comprehensive view of a heavy rainfall event, a dense network of precipitation and stream gages is necessary. In addition to NWS sensors, local data sets in southern California include ALERT and DCP sensors. At the present time, the archive of these data for local research purposes is via Hydromet 4 which requires a separate file for each sensor, for each month. For studies requiring dozens of sensors, the data processing task can become unwieldy; especially if the data requires any manual analysis. Therefore, previous studies were either reduced in scope to make them more manageable, or simply not conducted because they were too time-consuming.

The Solution

To make these vital correlation studies more manageable, we developed several computer programs. These programs create formatted data files in a fraction of the time compared to manual analysis. A single program, PROC_DATA.CSH, runs a suite of programs consisting of four PERL scripts. Resulting data files are comma delimited, have a date/time stamp and a sensor ID, and can easily be imported into a spreadsheet to produce graphs, charts, and statistics for further analysis. While the programs include gross error checks to eliminate bad data, some bad data can make it through and require manual correction. However, since the data files are plotted on a spreadsheet, errors are easy to detect and manual corrections simple to make.

The programs are as follows:

a. PROC_RAWDATA.PL – This program inputs ASCII tabular data from the Hydromet 4 monthly archives for all desired sensors. These files may contain either aperiodic or 1 hour data reports. Rainfall data is produced with hourly totals while the stream data output is the maximum level during a fifteen minute period. In addition, the program produces files containing cumulative precipitation for sensors that report in that manner.

b. PROC_BASIN.PL – This program uses delimited data files and collates the sensors into individual river basin data files. Each file contains all of the rainfall and river data for the respective basin.

c. PROC_MAX_EVENT.PL – This program uses the river basin data files and generates other files containing the maximum 1 hour, 6 hour, and storm total rainfall amounts for a user specified time period--such as an individual storm event. This program also determines the time of occurrence of the 1 hour and 6 hour periods. Data is arranged by storm event with all three rainfall parameters included in the file.

d. PROC_MAX_PARAMETER.PL – This program uses the maximum rainfall data files and reformats them with data arranged by parameter. All events are given for each separate maximum parameter.

Case Study: 23 February 1998

In the "El Nino" winter season of 1997-1998, severe Pacific storms brought heavy rains to much of coastal Southern California. Widespread flooding occurred with these storms producing extensive property damage and several fatalities. The analysis technique described in this paper will play a key part in a more comprehensive study of all these storms and the flooding that resulted. However, the purpose of this paper is merely to demonstrate the technique looking specifically at a flood event that occurred on the 23rd of February in the Calleguas Creek River Basin. The amount, intensity, and duration of the rainfall were studied to determine which characteristics and values may be useful for forecasting floods in this particular basin. Stream response times were assessed qualitatively with examples provided in the paper. In follow-on studies, these specific basin characteristics will be compared with those of other river basins.

<u>The Calleguas Creek River Basin</u>

The Calleguas Creek River Basin is located in southeastern Ventura County at the extreme west end of the Santa Monica Mountains (Fig. 1). It is a small basin covering only 325 square miles with elevations running from sea level to about 2800 feet. Flooding in this basin threatens not only the farmlands of Oxnard and Camarillo, but also the Pacific Missile Test Center at the Point Mugu Naval Air Station, located near the rivers mouth. Other than levees on the lower reaches of the river and around the Navy Base, there are no major flood controls in the watershed.

After a near record drought–only a quarter inch of rain measured at Point Mugu between 1 February and 1 November 1997–soil moisture in the basin was very low. However, by the 23rd of February the area had received almost 23 inches of rain since the first of November–with almost 15 inches in just the preceding three weeks. Therefore, the soil was saturated. As will be shown in Fig. 1, stream response times began with the onset of heavy rains with the peak stream levels occurring within a few hours after the heaviest rain episode.

Synoptic Situation on February 23

The basic characteristics of the February 23 storm were very similar to the storms that had already raked the area more than a half dozen times since the first of November 1997. Model forecasts from the 0300 GMT run of the 29km Meso-Eta model are used to depict the situation. The key characteristics of this storm were as follows:

> Figure 2 is a 500 mb height and vorticity chart for the 23rd of February at 2100 GMT which shows a vigorous upper-level low with several vorticity maxima located several hundred miles offshore of California. Figure 3 is a time-height profile of winds, relative humidity, and vertical velocity for Oxnard, CA for the period of the storm. Note the large values of upward vertical velocity and high values of relative humidity throughout the lower and middle atmosphere. Note, also, the strong southerly winds which create tremendous orographic lift when encountering the east-west oriented mountains of Southern California. This orographic lift is also depicted in Figs. 4 and 5 which are 850 and 700 mb charts showing the region inundated with 90+ percent relative humidity and vertical velocity patterns that clearly reflect the influence of the east-west mountain ranges. Although not depicted, at 250 mb there was a jet max of 180 knots to the southwest of Southern California which produced strong diffluence in the upper atmosphere–further supporting upward motion over the entire region.

Model Forecast Precipitation

Previous studies have shown that the highest resolution models usually produce the best rainfall forecasts in complex terrain (Martin 1998). The 29km Meso-Eta model had the best resolution of all the operational models available to local forecasters on February 23.

> Figure 6 shows the Meso-Eta 6-hour precipitation forecast for the period 1500 GMT to 2100 GMT. It was this 6-hour time period where the model forecast the greatest 6-hour rainfall. The total 6-hour amount forecast for this time period is over 1.75 inches centered along the lower Santa Clara River Valley in Ventura County. The amount forecast over the Calleguas Creek River Basin was 1.0 to 1.5 inches. Figure 7 shows the 33-hour storm total for the event of February 23. The total 33 hour amount forecast is over 4.25 inches–again centered over the lower Santa Clara River Basin-with 3.0 to 3.5 forecast over the Calleguas Creek River Basin.

As comparison with actual rainfall amounts will show, the performance of the Meso-Eta model for this event was fairly typical. The model did reasonably well in timing the heaviest rainfall, but poorly in quantifying and locating the actual rainfall maxima.

Rainfall versus Stream Response

The February 23 storm provided an excellent case study for looking at a basin's response to a heavy rain event. The three reporting stream gages had significantly different response times depending on their location. One sensor (622) is located on the lower part of the main stem near the river's mouth, a second (627) is located on the Arroyo Simi at the upper headwaters of the river, and a third (617) is located on a tributary of the lower main stem. This tributary is an improved channel with concrete sides and bottom which contribute to a fast response. Therefore, sensor 617 showed the quickest and sharpest response to heavy rains, while site 622 near the mouth of the river had the slowest response. Likewise, the recovery time for the tributary gage was the quickest while the gage near the mouth of the river was the slowest. Note that, while there were two periods of heavy rainfall, the heaviest rains did fall in the 6 hour period between 1500 and 2100 GMT (7 AM to 1 PM PST) in good agreement with the Meso-Eta forecast.

Besides being an important learning tool, the ability to quickly plot all data for a basin, as in Fig. 8, has several advantages. First, instead of manually trying to determine which sensors are key to the event, you get to see all the sensors plotted at once–making it easy to identify the most important contributors. In addition, data quality control is simplified by these same comparisons. In this example, note how easy it is to identify the bad data value of 0.9 inches at 2000 local (24/0400 GMT) when compared to other gages that showed no precipitation.

Event Comparisons

While it is useful to know the amount, duration and intensity of the rainfall that caused flooding in a watershed for a particular event, it is even more useful for forecasters to understand how the watershed reacts to different types of rainfall events. The "El Nino" winter of 1997-1998 provided a variety of different types of flooding events to study and the technique described in this paper allows us to quickly and easily make these comparisons.

Figures 9, 10, and 11 look at the maximum 1 hour, 6 hour and storm total rainfalls, respectively, for a half dozen heavy rain producing storms that hit the Calleguas Creek River Basin in the winter of 1997-1998. The type of event ranged from short-duration, high intensity events like February 6, (6 hours, up to 1.6" per hour) to long duration, continuous, high rainfall total events like December 5 (over 6 inches in 24 hours). The technique described in this paper will be used to conduct basin response studies for each of these storms for every major flood basin in the local county warning area.

Summary

This case study looked at only one of the major "El Nino" storms that produced record flooding in Southern California during the winter of 1997 to 1998. The purpose of the study was to demonstrate a valuable technique for quickly processing Hydromet 4 data files into a format useful to the forecast staff. Specifically, the study looked at a major flood producing event that occurred in Southern California on the 23rd of February 1997. A suite of locally developed computer programs was used to process Hydromet 4 rainfall and stream gage data and generate delimited output files. These files were then fed to a spreadsheet program for analysis and display.

The generated graphs of hourly rainfall amounts and 15 minute maximum stream levels are extremely useful in assessing the amount, intensity, and duration of rainfall, as well as the associated stream response. Model data was included to describe the synoptic conditions that led to the heavy rains and subsequent widespread flooding. The resulting study is a powerful tool for training forecasters who need to understand the complexities involved in producing accurate river forecasts and flood warnings.

However, many such studies are needed because the study of one basin's response to one storm is still of limited value. The power of this technique is its efficiency. To study all of the flood events in the winter of 1997-1998 for the Calleguas Creek River Basin, data files consisting of 23 METAR and ALERT stations containing rainfall and stream data had to be formatted. Although this required sifting through over 1500 raw data files, using the computer programs described in this study, it took just a few minutes to organize these into just 14 formatted river basin files. It is our intent to use this technique to conduct follow-on studies of all the flooding events of 1997-1998 for all basins and to construct a compendium that will prove useful to forecasters for years to come.

Finally, although the programs developed are somewhat dependant on the format of the archived output, it should not be too difficult to adjust the program to use AWIPS instead of Hydromet 4. Someone with a basic understanding of the PERL and C-SHELL programming languages and familiar with basic UNIX commands could implement these programs at their own WFO which could then be run by other users. To obtain these programs, please contact the authors at NWSFO LOX.

References

Martin, Greg, 1998: An Outstanding Performance by the ETA-10 for the Southern California Storm of 23 February 1998, *Western Regional Technical Attachment 98-36* [Available from the National Weather Service, 125 S. State St., Salt Lake City, UT 84138].

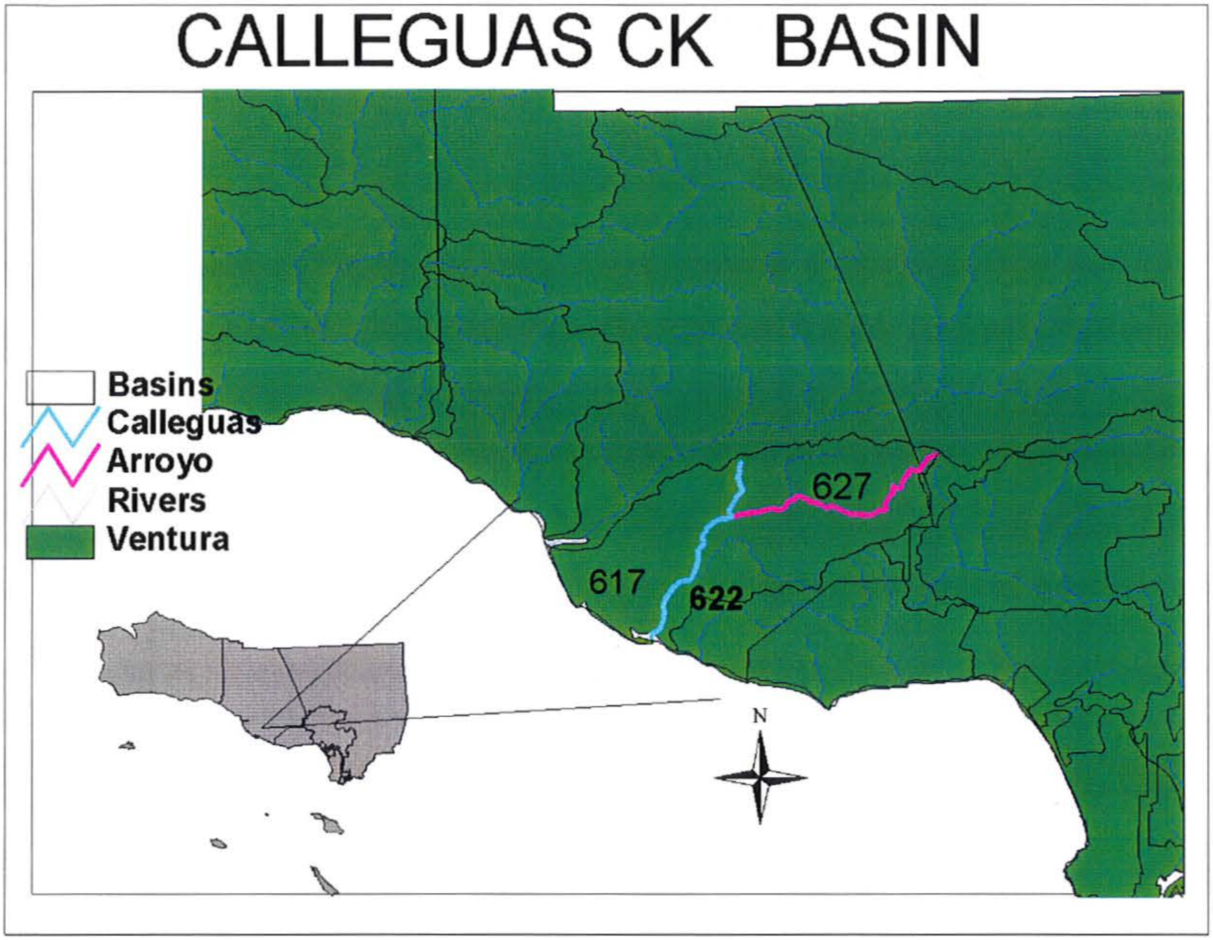


Fig. 1 - Basin Map for the Calleguas Creek River Basin

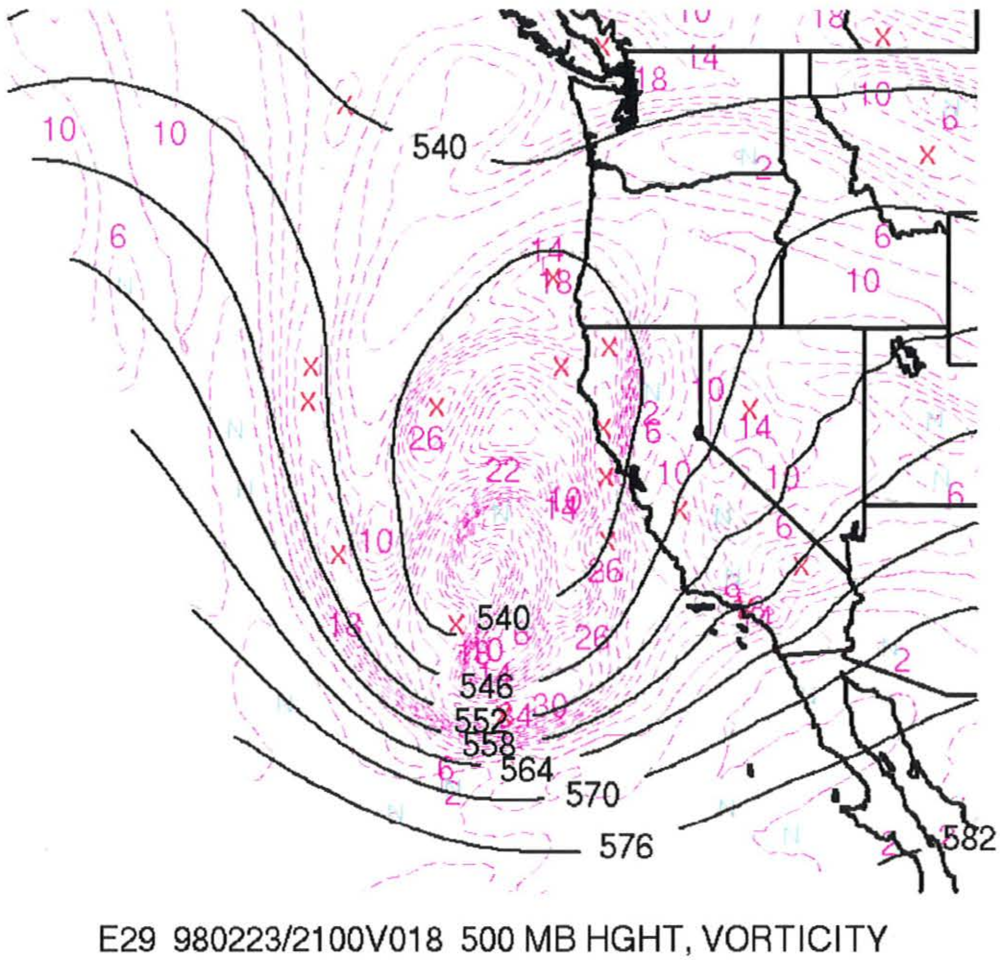


Fig. 2 - Vorticity and Heights at 500 Mb (2/23/98 21z)

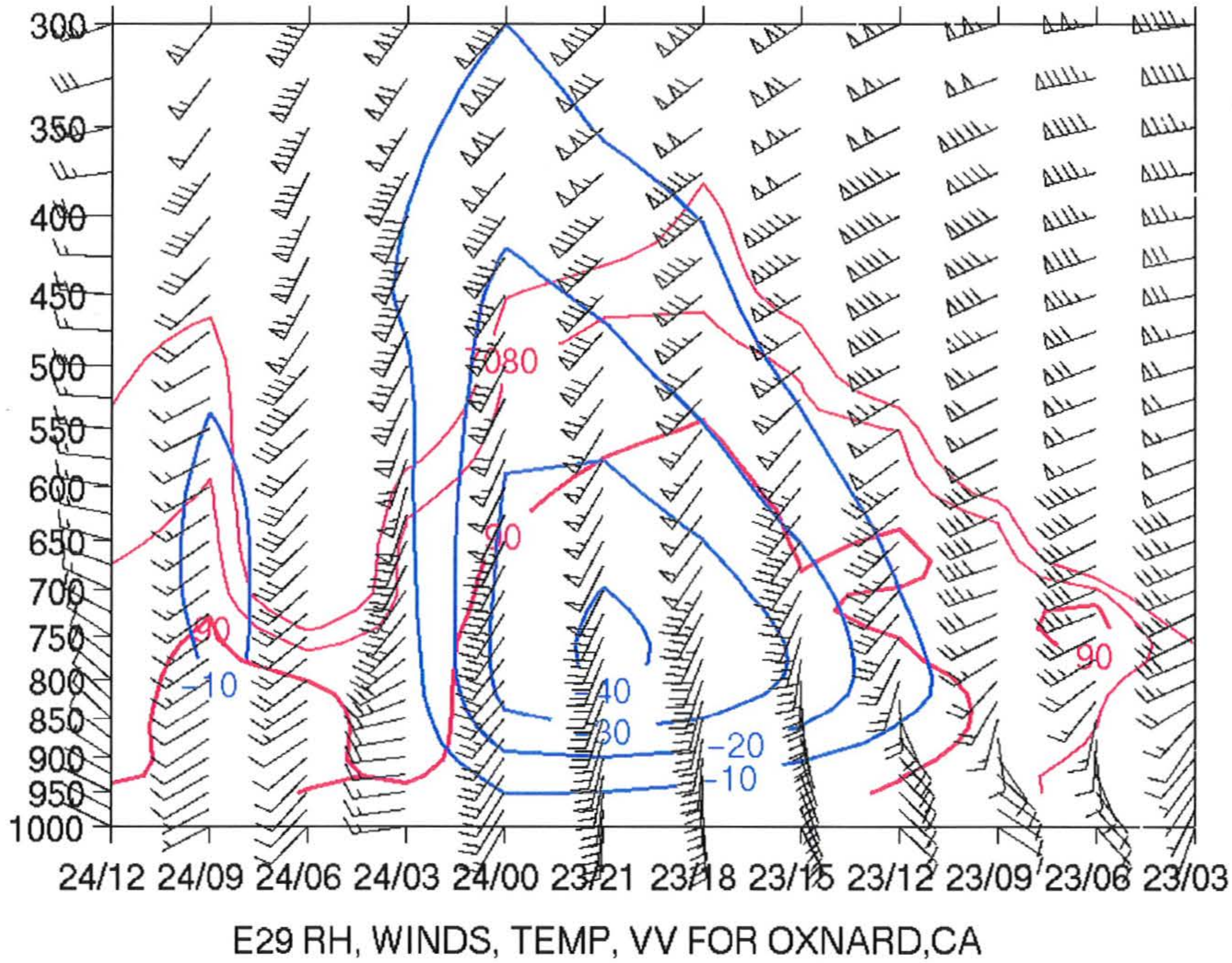
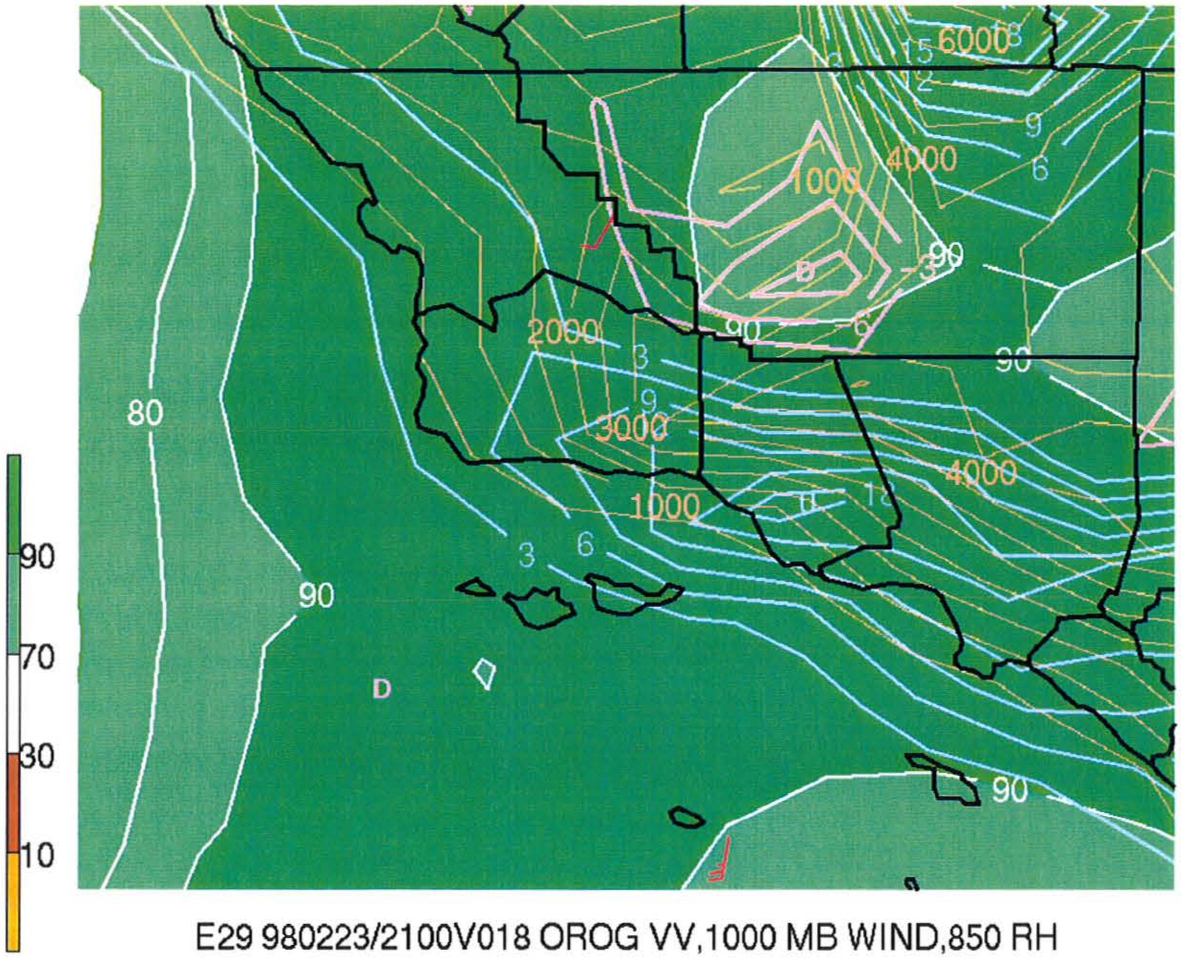


Fig. 3 - Vertical Profile at Oxnard (2/23/98 03z - 2/24/98 12z)



E29 980223/2100V018 OROG VV,1000 MB WIND,850 RH

Fig. 4 - 850 Mb Rh, Orographic Vv, 1000 Mb Winds (2/23/98 (21z)

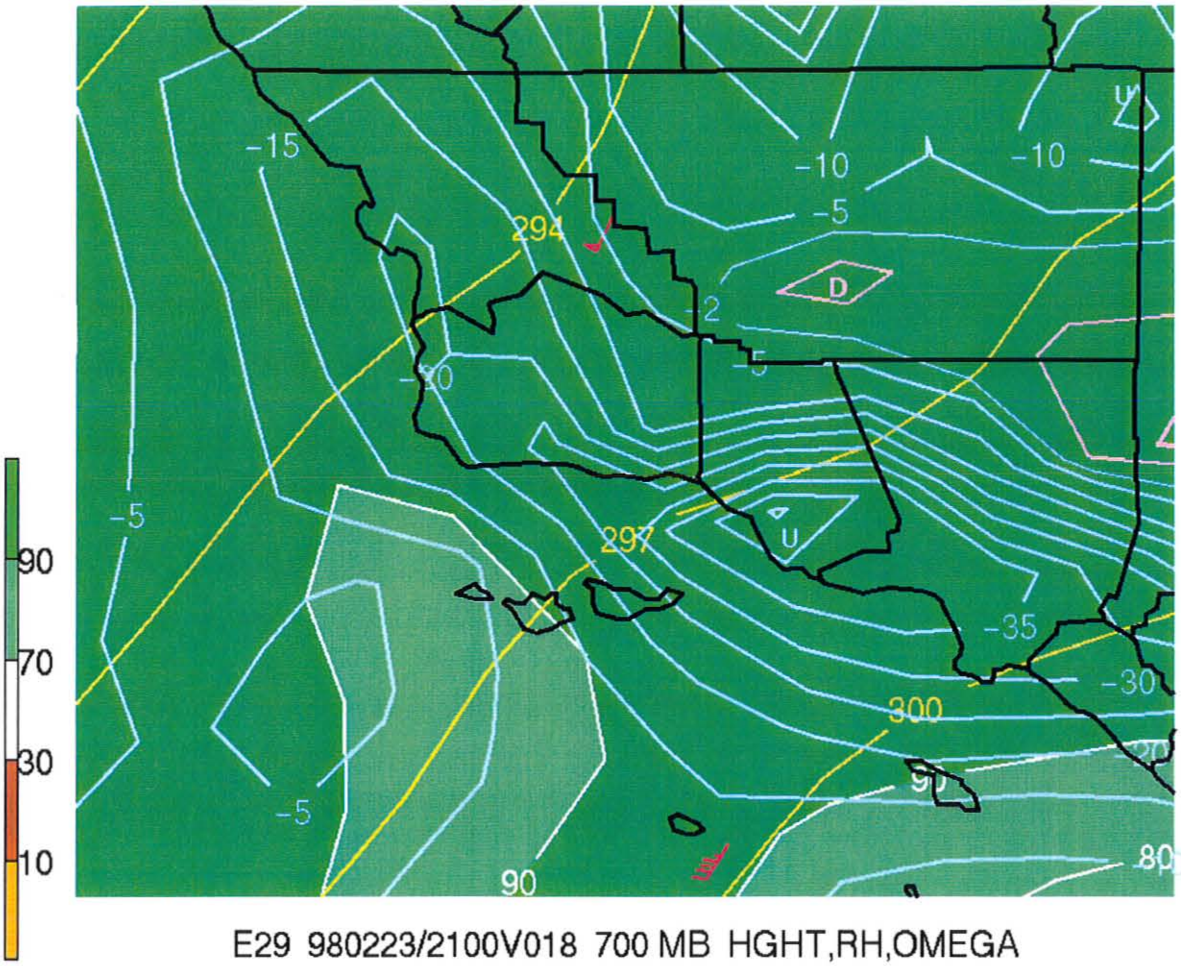


Fig. 5 - 700 Mb Omega and Rh (2/23/98 21z)

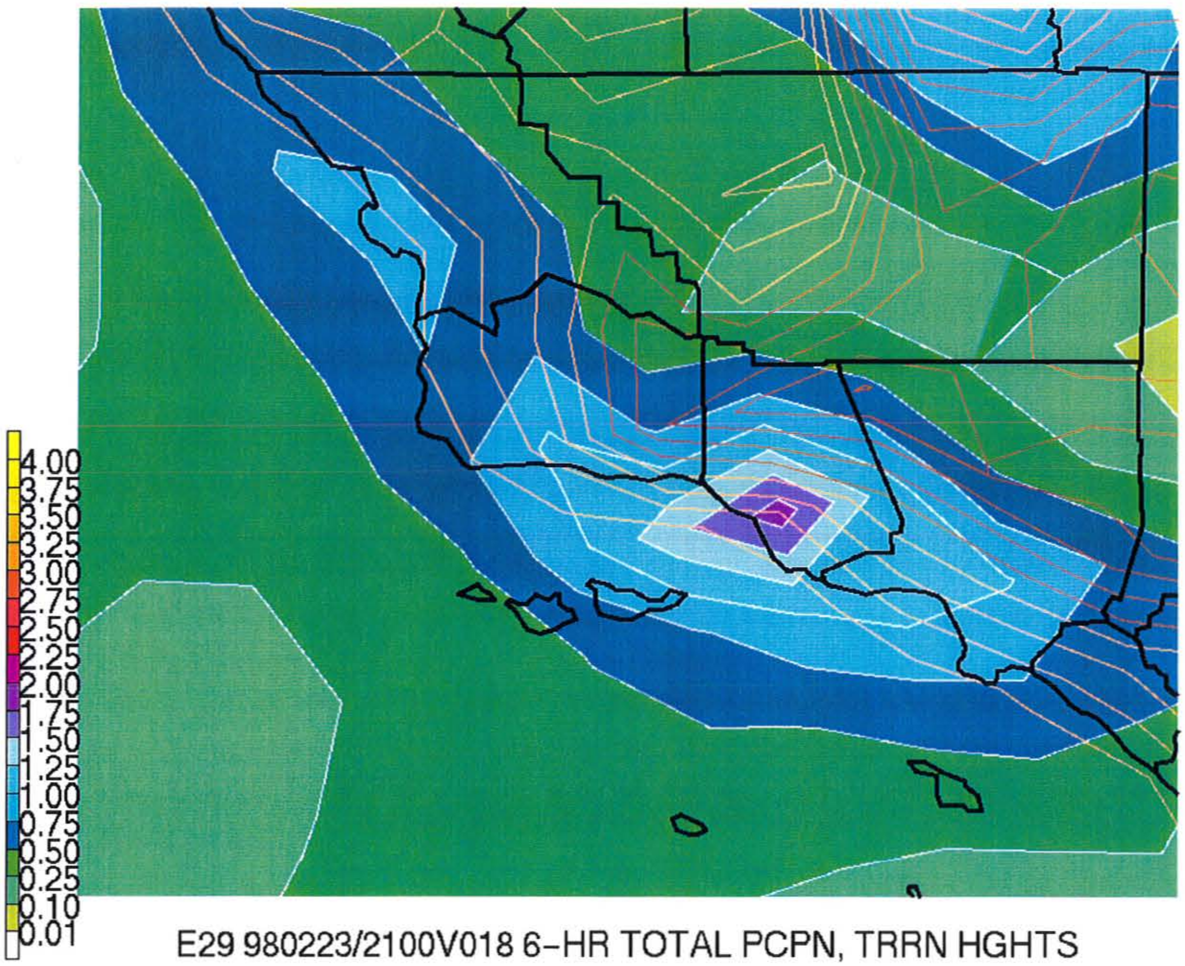


Fig. 6 - Meso-eta 6-hour Total Precipitation

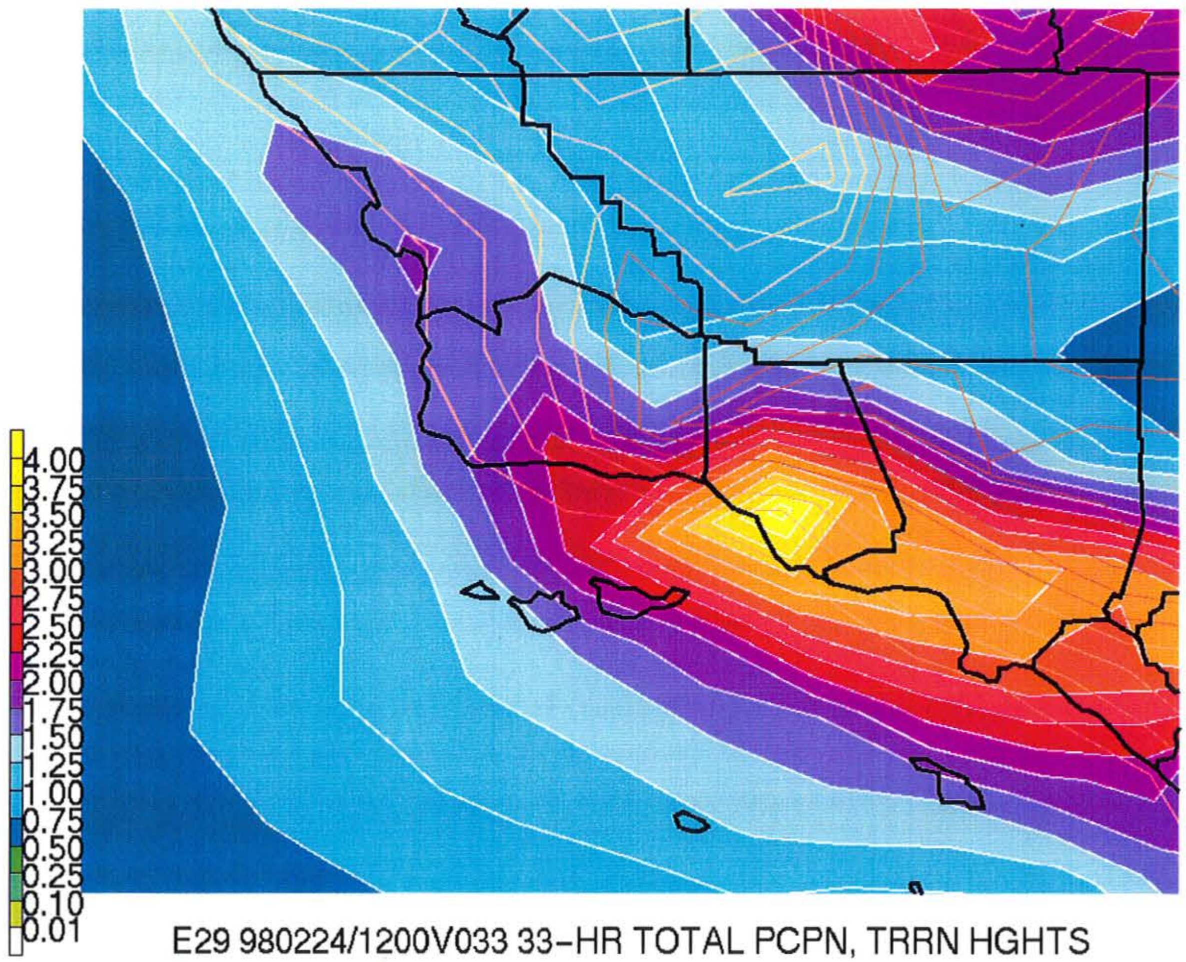


Fig. 7 - Meso-eta 33-hour Total Precipitation

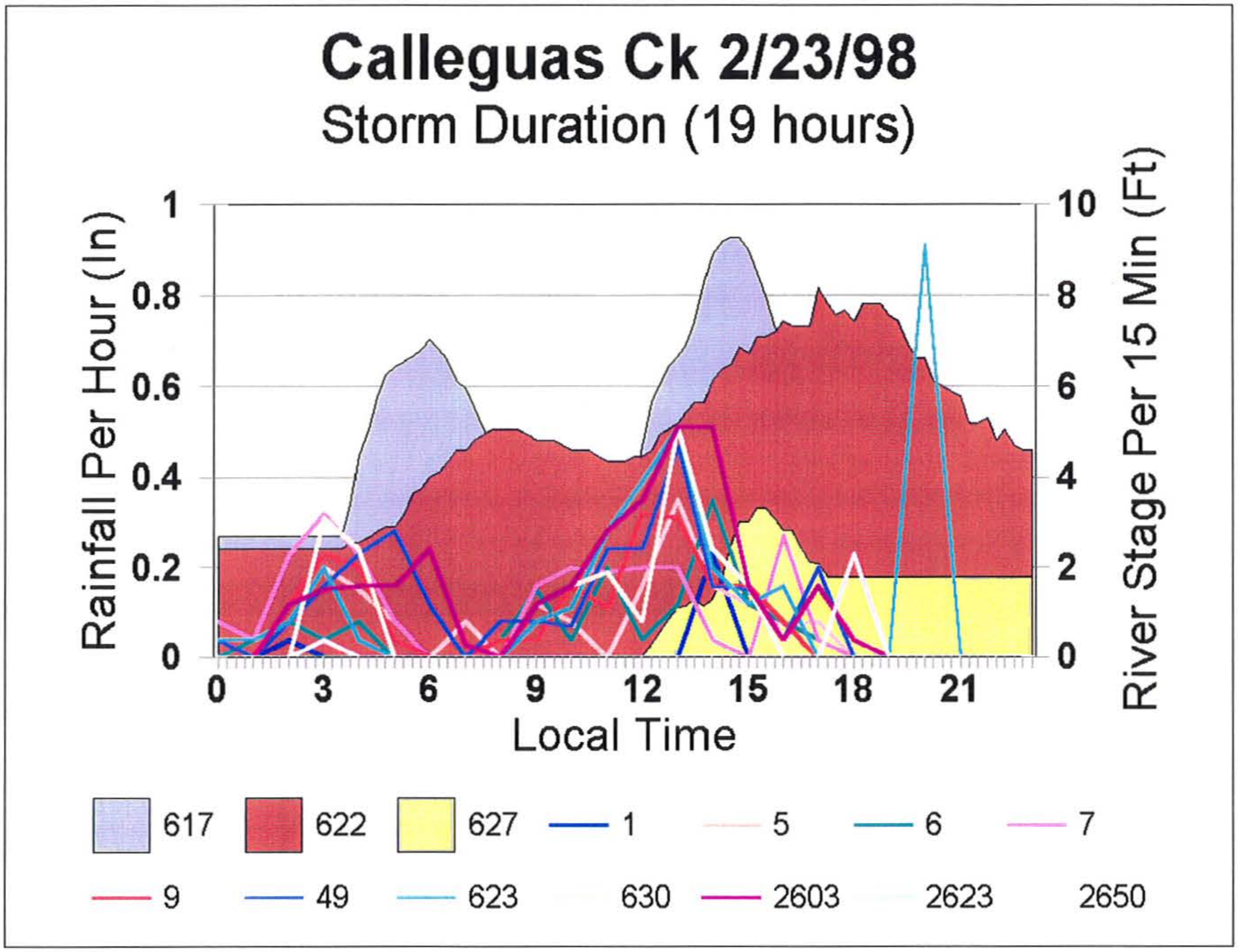


Fig. 8 - Calleguas Creek River Basin: Rainfall vs Stream Response

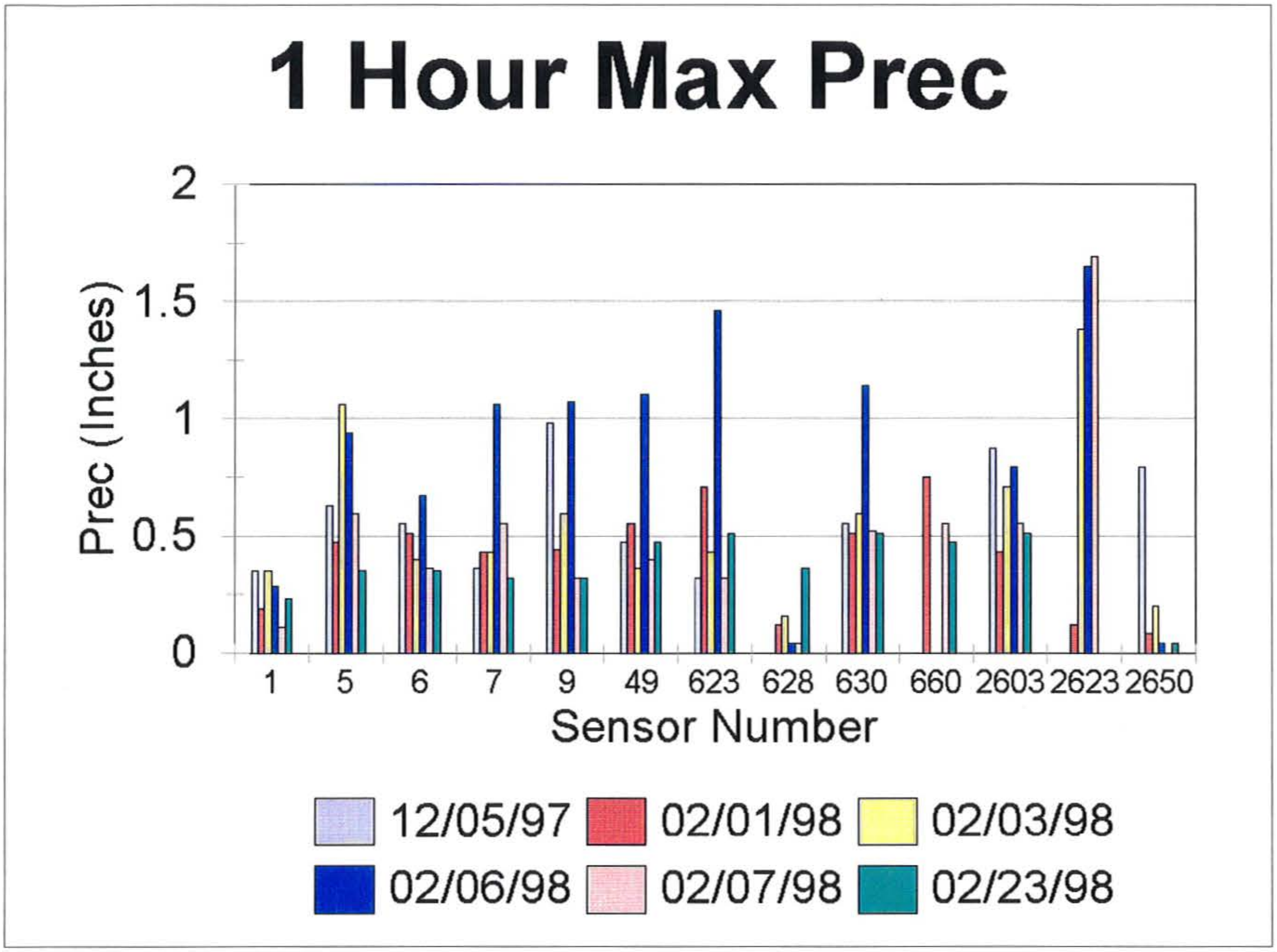


Fig. 9 - Calleguas Creek River Basin 1-hour Maximum Precipitation

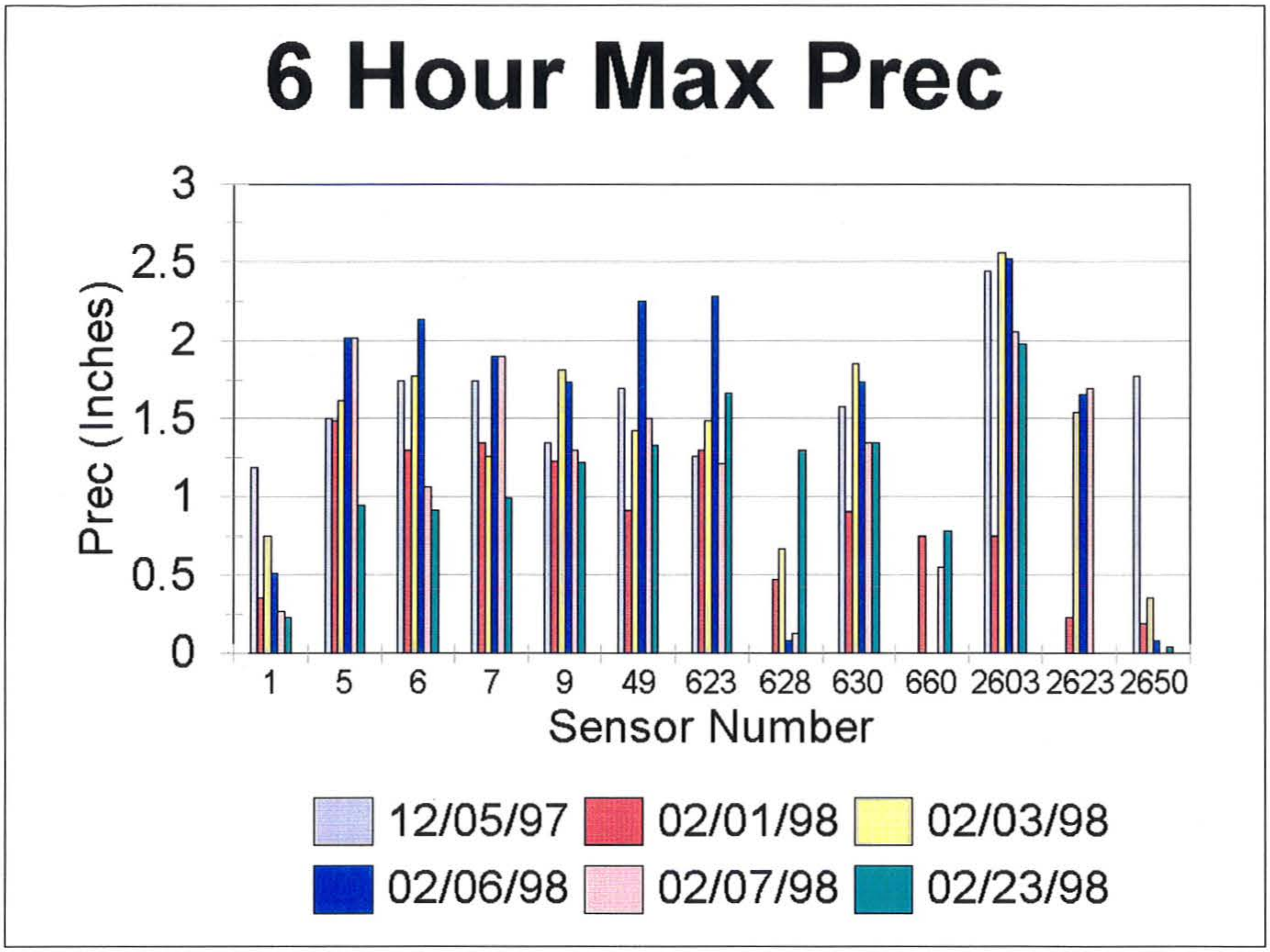


Fig. 10 - Calleguas Creek River Basin 6-hour Maximum Precipitation

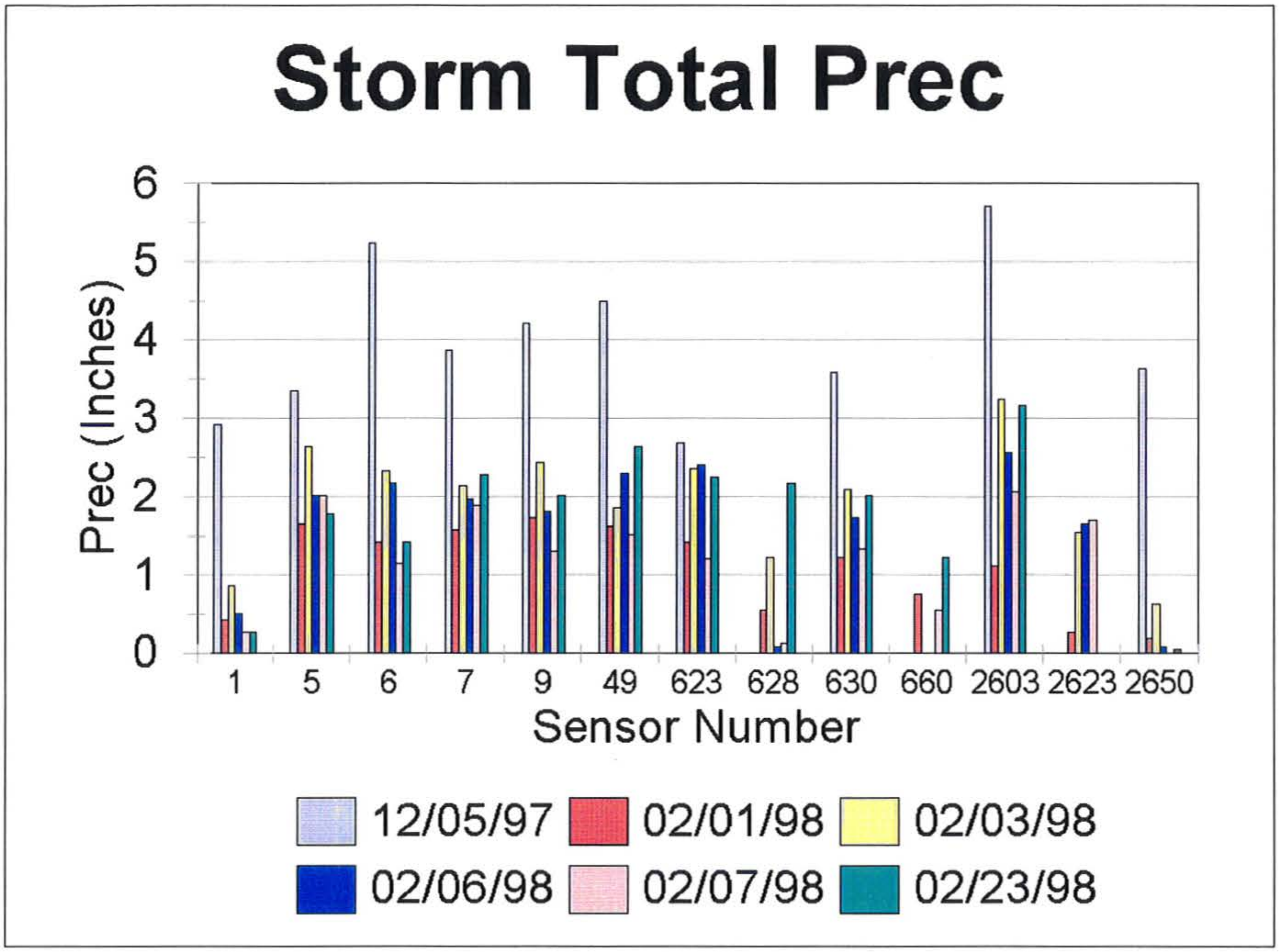


Fig. 11 - Calleguas Creek River Basin Storm Total Precipitation