Western Region Technical Attachment
No. 07-06
May 14, 2007

Flood and Precipitation Frequency of the September 13, 2006 Flash Flood in Railroad Wash through Indirect Discharge Estimates

Glenn Lader, NOAA/NWS Forecast Office Tucson, Arizona

Introduction

On September 13, 2006 a flash flood occurred at Railroad Wash near Franklin, Arizona. Railroad Wash is a tributary to the Gila River in Southern Greenlee County, Arizona. The Railroad Wash watershed is approximately 200 square miles located in Southern Greenlee County, Arizona, and Western Hidalgo County, New Mexico (Figure 1), with a mean basin elevation approximately 4000 feet MSL. The flash flood affected five to ten residences near the wash and overtopped the U.S. Highway 70 Bridge. The wash has a history of flash flooding with three people killed in an event in September, 1980. Railroad Wash is an ungaged site and there were no direct measurements taken after the event. The purpose of this project is to obtain an indirect discharge estimate at Railroad Wash, then use that data to determine the flood frequency and evaluate the discharge relative to the United States Geological Survey (USGS) gage several miles downstream in the Gila River. Precipitation frequency estimates were also determined for this event using radar data and cooperative observer reports.

Event and Radar Overview

The flash flood occurred at the end of a very active summer monsoon season across Southeast Arizona. September 13th was the second consecutive active thunderstorm day over the Railroad Wash watershed. NWS Tucson Doppler radar estimates from September 12th indicated 0.50” to 1.00” of storm total rainfall (Figure 2). However, the Tucson Doppler radar is located approximately 100 miles away from the Watershed. This immediately raises several issues. The first issue is that of beam blockage over the northern half of the watershed which can clearly be seen from the September 12th storm rainfall total. In this case with widespread rainfall, there was at least a 50 percent reduction in the radar derived rainfall total within the beam blocked area compared to the non beam blocked area. In addition, the location of the watershed puts the lowest 0.5 ^{o} radar beam approximately 10,000ft-12,000ft Above Ground Level which misses lower level precipitation processes. An NWS COOP observer located in Duncan, Arizona, within the beam-blocked area reported 0.96” of rain on September 12th. The radar Storm Total Precipitation estimated that less than 0.2” occurred in Duncan on this date.

Regardless, the rainfall from September 12th probably set the stage for the flash flooding event by saturating the soils, thus reducing the infiltration on September 13th and increasing runoff.

The meteorological setup proved favorable for thunderstorms on September 13th with an upper level low located across Central Arizona and surface dew point values in the upper 50's ºF, precipitable water of 1.15" and a lifted index of -4ºC on the 12Z KTUS sounding (Figure 3). One disturbance on the southeast side of the aforementioned upper low moved toward the Railroad Wash watershed and initiated thunderstorms across Southern Greenlee County after 1 PM MST. These thunderstorms continued for the next several hours, with one small area of thunderstorms remaining nearly stationary just west and southwest of Franklin, AZ, between 2:00PM and 4:45 PM MST (Figure 4). Although these thunderstorms encompassed only a small percentage of the watershed, they were located within 15 miles of the flash flood site. Local unofficial reports from Greenlee County Emergency Management indicated 2.5 to 3 inches of rain on the afternoon of September 13th. NWS Tucson Doppler radar only estimated 1 to 1.5 inches of rainfall with this cluster of thunderstorms. However, this is within the beam-blocked area and most likely underestimated the amount of rainfall (Figure 5). This area of thunderstorms was the most likely culprit for the flash flood in Railroad Wash. At 4:30 PM MST, the first report was received with one home already flooded and the Arizona Department of Transportation closing Highway 70 due to water overtopping the bridge at Railroad Wash.

Discharge Estimation Method

Discharge estimates were made within Railroad Wash several hundred feet downstream of the Highway 70 Bridge. This site is 1.5 miles upstream of the outlet of the wash into the Gila River. The two main methodologies used for determining discharge estimates at an ungaged site are the slope-area method and a step-backwater model. The slope area method is often used by the USGS to obtain a post event peak discharge. It requires a stable reach and useful high water marks and was chosen for this study. The secondary method is a step-backwater model which utilizes a balanced energy equation computed from one cross section to the next. The result is a velocity calculation, and thus a water surface elevation for the next upstream cross section (Schaffner, 2004).

Slope-Area Computation

Since a suitable reach was found with useful high water marks, the USGS slope-area method was used to compute a peak discharge for this flash flood event (Dalrymple and Benson, 1967). At Railroad Wash, appropriate locations were first determined to use as cross sections. Using the slope-area method, the distance between each cross section should be at least as wide as the channel. In this case an estimate was made that the channel reach was 400 feet long and 100 feet wide. As a result, there were four cross sections placed 100 feet apart (Figure 6.) Once the cross sections are determined a common benchmark should be found and used as a reference point for all the cross sections. This enables the surveyor to determine the height difference between the high water marks which also approximates the water surface slope at peak discharge. Within each cross section, the wetted perimeter, or distance between high water marks (Figure 7) averaged 125 feet. It is best to take distance measurements relative to the high water mark along the channel bed often, especially at natural breaks in the channel (Figure 8). Depth at each break in the channel is calculated using survey equipment. The high water marks were generally 10 feet above the low flow channel at each cross section with a gentle slope of 0.3 feet/100 feet distance between cross sections. A determination of Manning's Roughness Coefficient must also be determined at each cross section. Given that the channel characteristics were nearly identical at each cross section, with 80% mostly sand and small cobble matrix with the other 20% consisting of denser vegetation, a weighted Manning's Roughness value (N) of 0.037 was used at all cross sections (Phillips and Tadayon, 2006).

Once the necessary data is obtained from the field, the USGS Slope-Area computation program (SAC) was used to calculate the peak discharge using Manning's discharge equation (Fulford, J.M., 1994). The SAC calculations from each cross section indicated there was a range in estimated discharge from 5785 cfs to 8996 cfs. Taking an average of the values from these cross sections yields a discharge of 6916 cfs. This value seems reasonable based on the cruder slope-conveyance method.

Flood Frequency

Regression equations to determine flood frequency in ungaged watersheds have been developed by the USGS for every state and for the different hydrologic regions within each state. Watershed size is input into the National Flood Frequency visual basic program which uses the regression equations to determine a recurrence interval (USGS Fact Sheet 111-98, June 1999). In this case, 6916 cfs for Arizona in USGS Hydrologic region four, the recurrence interval is about 27 years (Figure 9). Since part of the Railroad Wash watershed is in New Mexico, the data was compared to the proper New Mexico regression equation and the results were nearly identical. Even assuming up to a 20% plus or minus error on the determination of peak discharge the recurrence interval would range from 15 years to 40 years, thus signifying that this flow was significant.

Precipitation Frequency

One of the main goals of this project is to correlate the amount of rainfall that occurred prior to the event, find its recurrence interval, and compare it to the flood frequency recurrence interval. Although flood frequency does not correlate to precipitation frequency, it is important to review this precipitation data to see just how significant the event was. NOAA Atlas 14 was used to determine precipitation frequency near Railroad Wash (Figure 10). Knowing that the radar derived rainfall estimates over the watershed are poor with limited knowledge of official rainfall tallies, this is a difficult task. Taking a strict watershed average of radar derived storm total precipitation, which generally occurred in less than 3 hours, yields perhaps half an inch. Considering that the radar is missing lower level precipitation processes in addition to beam blockage issues, it will be assumed that rainfall watershed 3-hour totals were one inch. The result of this is a recurrence interval about 1 in every 2 years. However, much of the input likely came from a single nearly stationary cluster of thunderstorms covering a smaller portion of the watershed which reportedly dropped two to three inches in a two to three hour time period. Knowing this, and considering that radar derived rainfall from September 12th was also about one half inch, and assuming it was, at least one inch, the 24 hour basin average rainfall was probably closer to around two inches. This yields a precipitation frequency of only about once in every five years. Furthermore, if the authors estimate of watershed rainfall was too low and the 24 hour amount was 3.00", then the precipitation frequency recurrence interval jumps to about 37 years. Although the exact precipitation amount and recurrence interval will never be known, this range provides a spectrum of possibilities for forecasters to use in determining what amount of rainfall will cause a flash flood in Railroad Wash.

Comparison to USGS Gages on Gila River

About 3 miles downstream from the mouth of Railroad Wash at the Gila River, there is a USGS stream gage on the Gila in Duncan, Arizona. Hydrograph data from the stream gage at Duncan was examined to determine whether a spike from the flash flood in Railroad Wash could be seen (Figure 11). The Duncan hydrograph did indeed show a clear rise after 5 PM MST jumping from 2180 cfs to 3450 cfs in a 15 minute time period between 5:30 PM and 5:45 PM. It is likely that this was a rise partially attributed to Railroad Wash. The attenuation of the hydrograph from the Railroad Wash site to the USGS Gage on the Gila River at Duncan is the primary reason that the rise on the Gila was much reduced compared to the 6916cfs estimated flow at Railroad Wash. The peak discharge at Duncan was 5670 cfs at 8:30 PM MST. Much of this peak flow on the Gila came from upstream as a typical flow takes 4-6 hours to reach Duncan, Arizona, from the Virden, New Mexico, gage upstream.

Conclusions and Discussion

The September 13th, 2006 Flash Flood at Railroad Wash near Franklin, Arizona stemmed primarily from a cluster of nearly stationary thunderstorms across Southern Greenlee County. One day prior to the event on September 12th, 2006, thunderstorms across the same region completely saturated the ground and set the stage for the flash flood event. Using the USGS slope-area method it was estimated that this Flash Flood was 6916 cfs. Based on the USGS regional regression equations for ungaged watersheds, this flow has a recurrence interval of every 27 years. The field survey was completed approximately 6 months after the event, with rather well defined high water marks proving once again that useful data can be obtained well after an event.

A methodology of using radar derived rainfall total data and correlating it to precipitation frequency was attempted. This process would be best suited for a rainfall event with a smaller watershed and close to the radar. A lack of good rainfall data away from the radar is a significant problem, especially in the Western U.S. with larger distance between radars with considerable beam blocking and overshooting issues. This case clearly shows that there are issues with radar Quantitative Precipitation Estimates (QPE) and proves once again that skywarn spotters are especially useful far away from radar to get "ground truth" rainfall amounts.

Weather Forecast Offices should be encouraged to engage in this concept of flash flood study using indirect discharge estimates. In addition to field personnel familiarization with a flash flood site, useful discharge data yielding flood frequency intervals can be obtained to provide a frame of reference for event significance and comparison. This data is helpful to forecasters in future warning situations, state and local emergency managers and flood control districts.

Acknowledgements

Special thanks to the USGS Tucson Field office for the use of their survey equipment in this study, USGS Tucson water resources division for their input and assistance with the slope-area computation program. WFO Binghamton, NY Senior Service Hydrologist (and former Tucson, AZ Service Hydrologist) Mike Schaffner for assisting in the field study and reviewing this paper. CBRFC Senior Hydrologist Bill Reed for reviewing the paper, providing input and making suggestions.

References

Dalrymple, T. and Benson, M.A., 1967: Measurement of peak discharge by the slope-area method. USGS *Techniques of Water-Resources Investigations,* Chap. A2, Book 3.

Fulford, J.M., 1994, User's guide to SAC, a computer program for computing discharge by the slope-area method: U.S. Geological Survey Open-File Report 94-360, 31 p.

The National Flood-Frequency Program—Methods for Estimating Flood Magnitude and Frequency in Arizona, *U.S. Geological Survey Fact Sheet 111-98 June, 1999*

NOAA Atlas 14 Precipitation Frequency Estimates for Arizona. Available online: http://hdsc.nws.noaa.gov/hdsc/pfds/sa/az_pfds.html

Phillips, J., Tadayon, S., 2006: Selection of Manning's Roughness Coefficient for Natural and Constructed Vegetated and Non-Vegetated Channel, and Vegetation Maintenance Plan Guidelines for Vegetated Channels in Central Arizona, *USGS Scientific Investigations Report 2006-5108.*

Schaffner, M., 2004: The Rucker Canyon Flash Flood of July 21, 2002: Estimating Discharge for an Ungaged Site. *NWS-WR TA No. 04-07*

USGS Slope-Area Computation Program. Available online: http://water.usgs.gov/software/sac.html

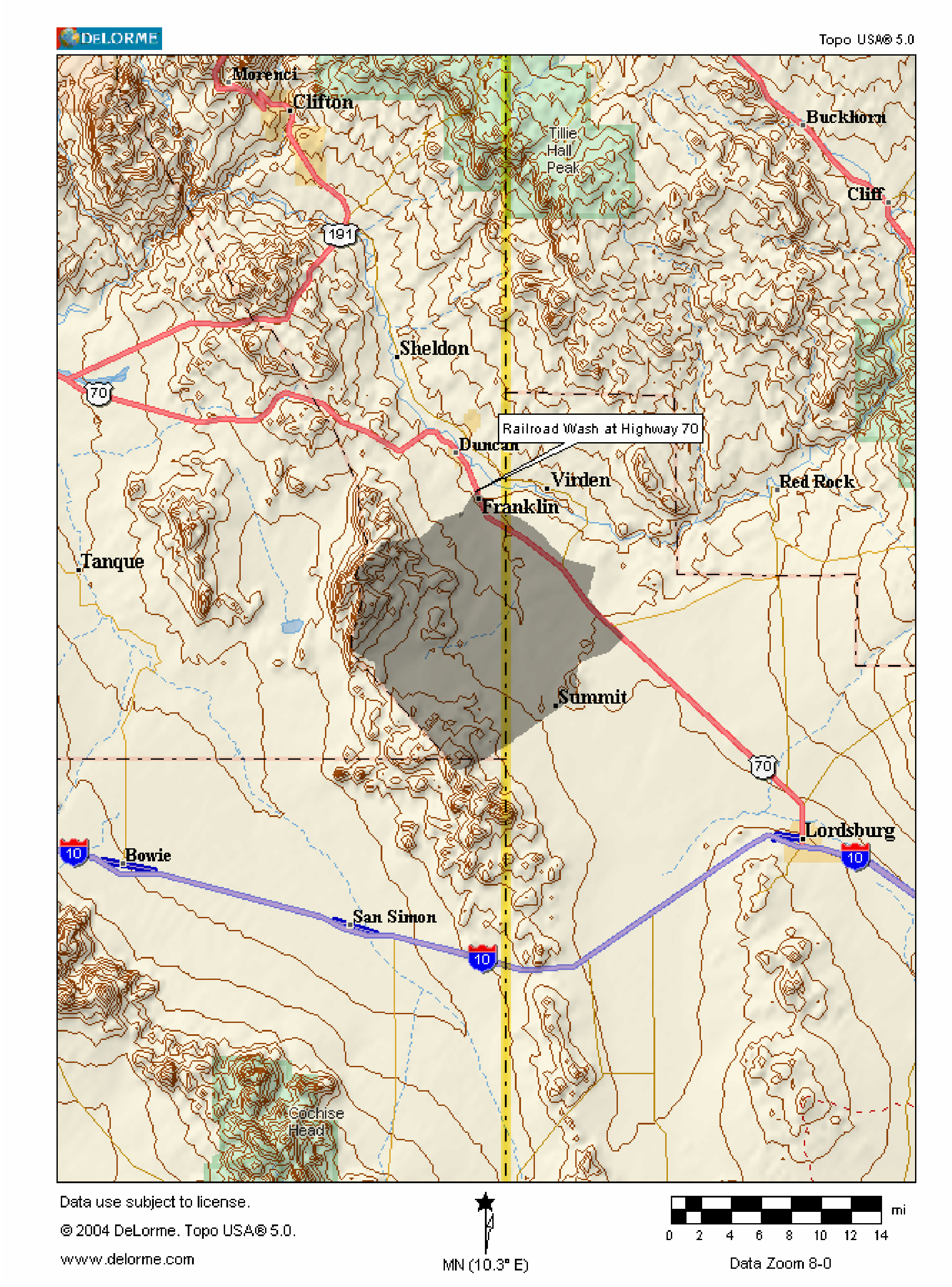

Figure 1: Watershed boundary for Railroad Wash (in opaque black) overlaid over USGS topographic map. Flash Flood event and survey occurred at northernmost point within the watershed. Map courtesy DeLorme, © 2004 DeLorme (www.delorme.com) Topo USA®

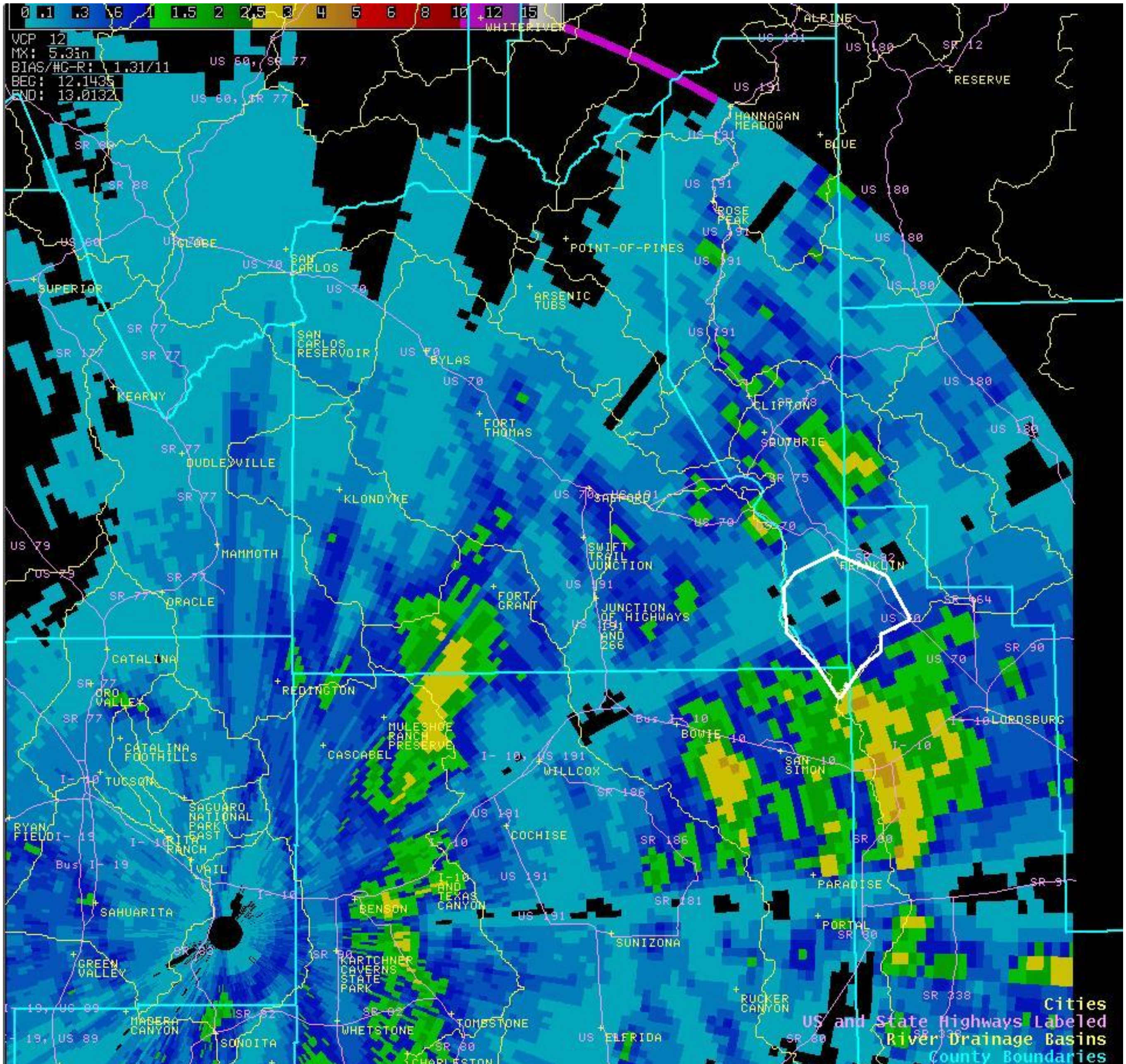

Figure 2: Storm total precipitation from Tucson WSR-88D ending September 12th, 2006 at 6:30PM MST. Note the beam blockage near Franklin, Arizona which covers the northern half of the watershed which is outlined in white.

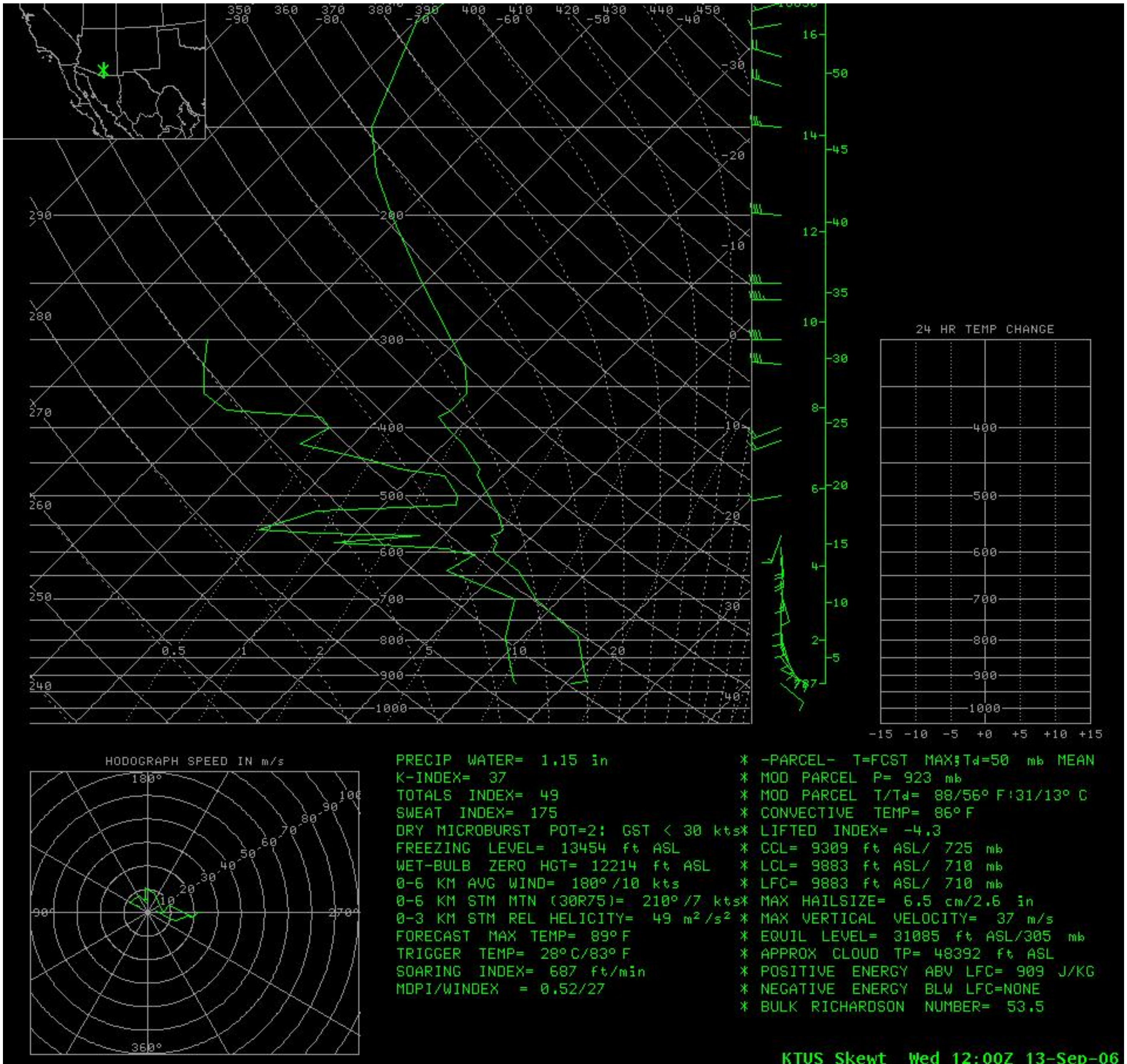

Figure 3: 12Z September 13th, 2006 KTUS Sounding.

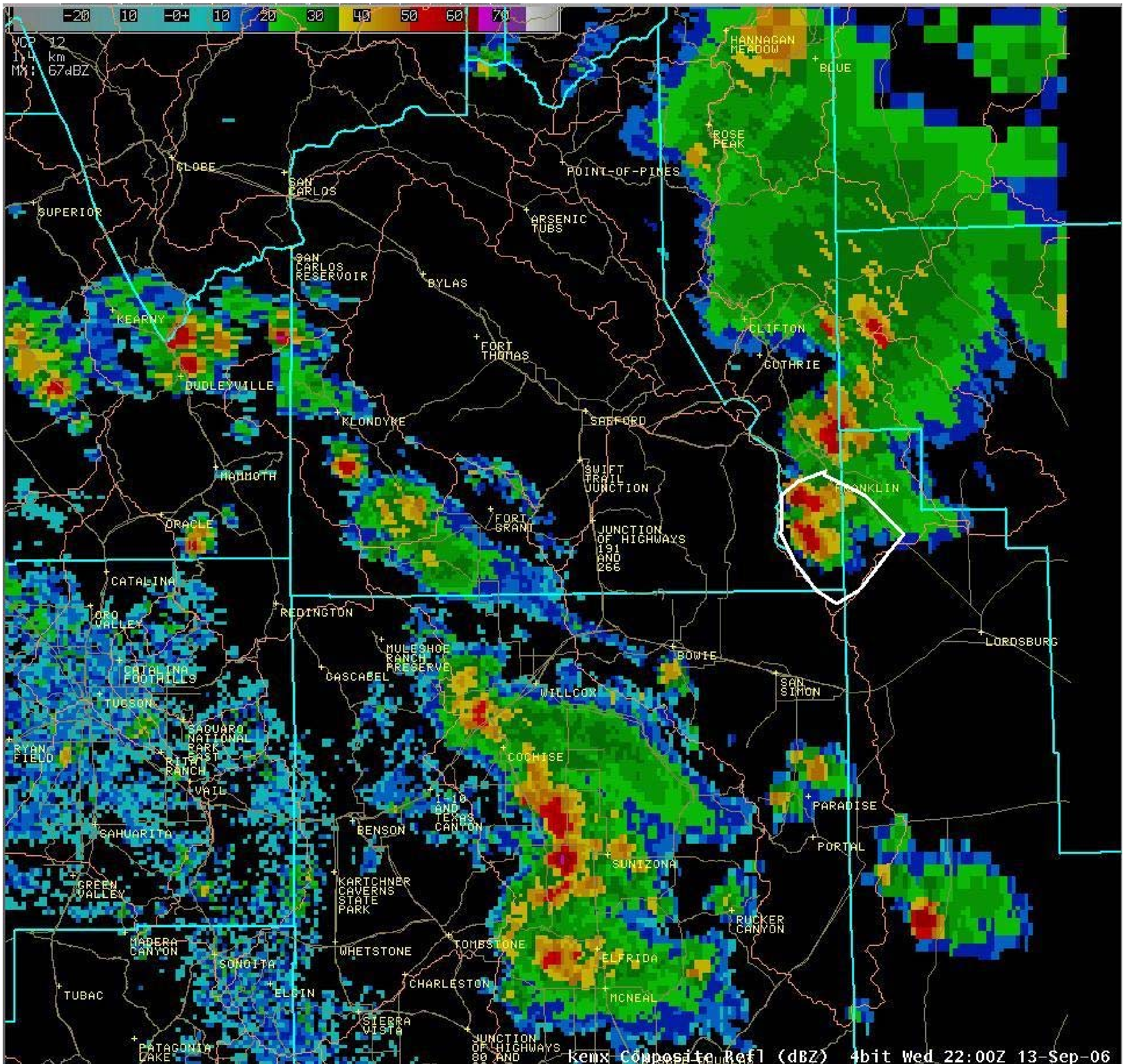

Figure 4: Tucson WSR-88D Composite reflectivity image from September 13th, 2006 at 3:00PM MST. The Railroad Wash watershed is outlined in white.

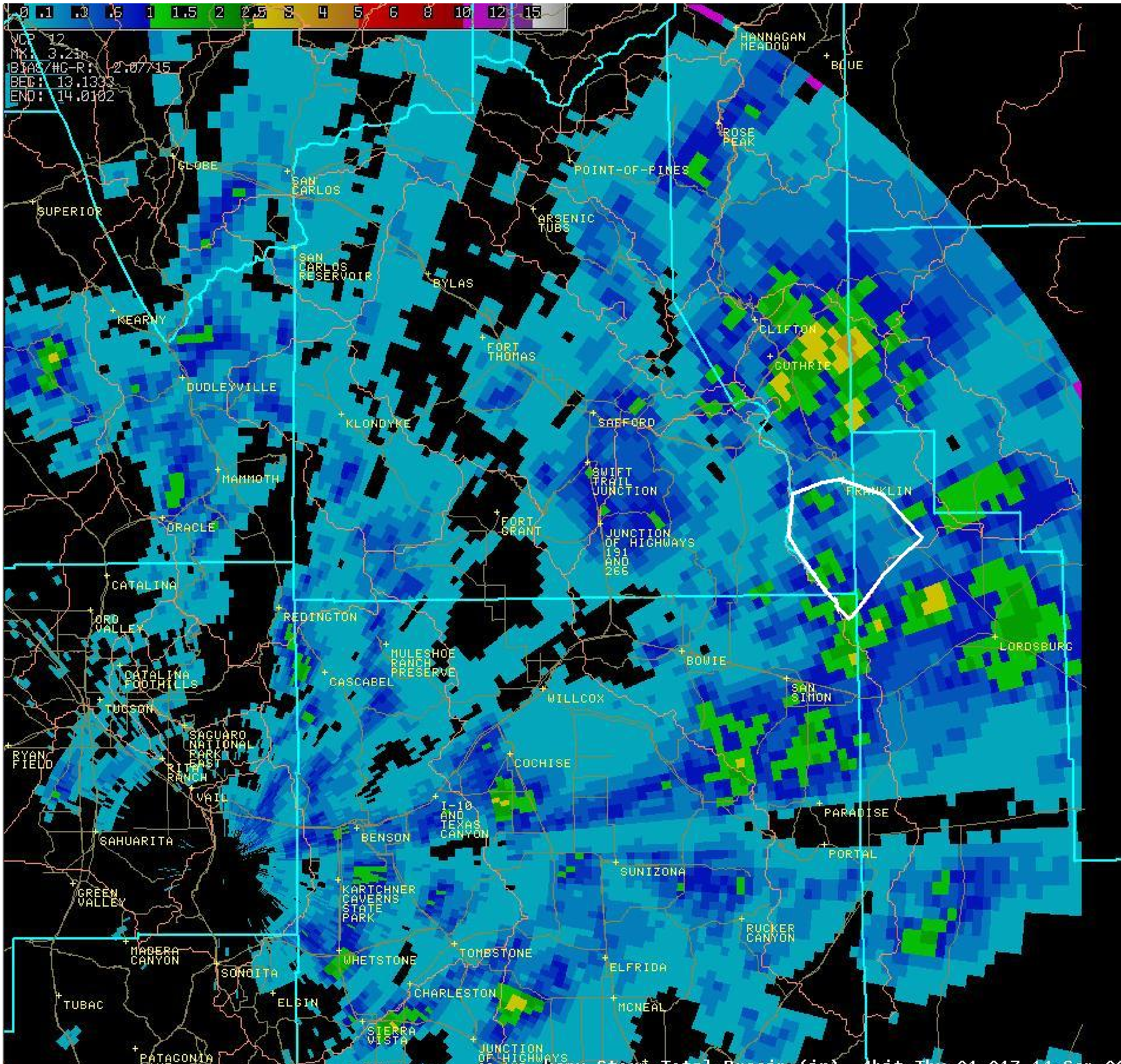

Figure 5: Storm total precipitation on September 13th, 2006 ending at 6PM MST. Note the area of 1.5" storm totals just southwest of Franklin, Arizona within the beam blocked area. Local unofficial reports indicated 2.5" to 3" of rain with this storm. The Railroad Wash watershed is outlined in white.

Figure 6: View looking downstream in low flow channel of Railroad Wash. Distance between cross sections was 100 feet, the same distance between the survey equipment as shown in the foreground and the survey rod in the distance. This was also the methodology used to determine channel slope.

Figure 7: Example of high water mark on right bank of Railroad Wash. Note debris pushed up against tree on left side of picture.

Figure 8: Survey equipment placed at high water mark on left bank of Railroad Wash. There were numerous breaks in the channel where distance measurements were made. The right bank featured a steep embankment on which the high water marks were above the bank at each cross section.

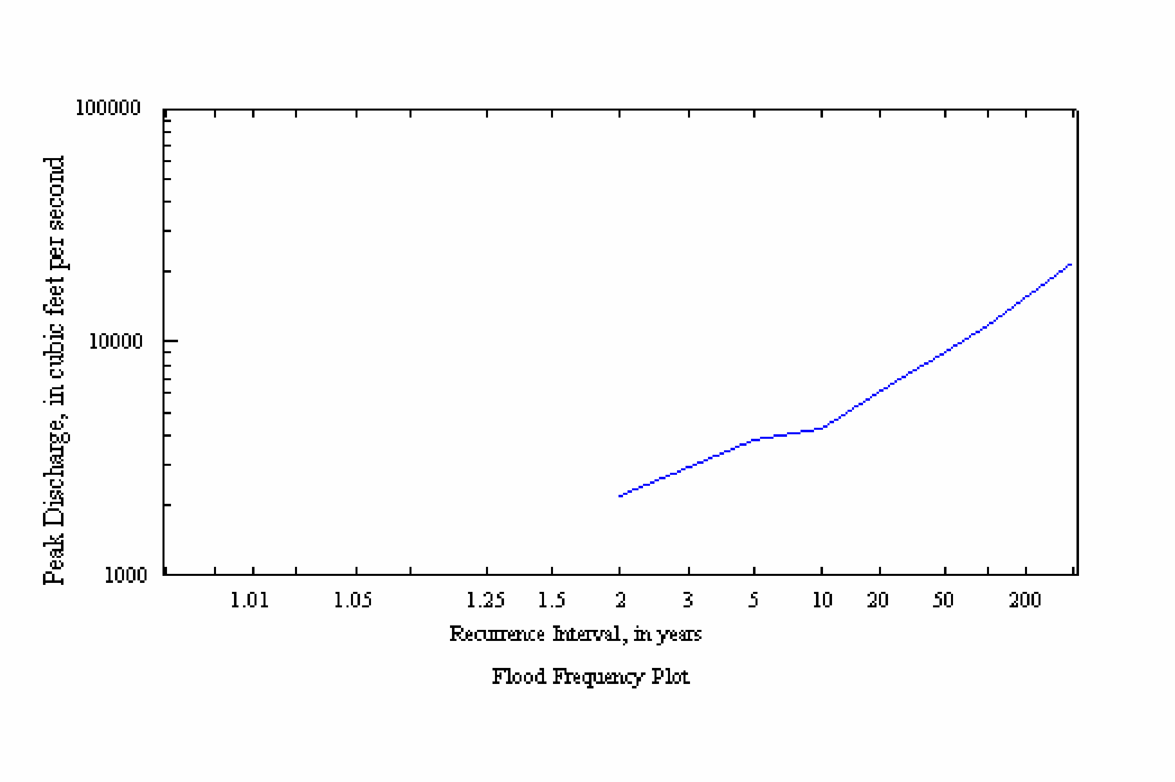

Figure 9: Flood Frequency plot using appropriate USGS regression equation for the Railroad Wash watershed.

Precipitation Frequency Estimates (inches)

AEP* (1-in-Y)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr
2	0.24	0.37	0.46	0.62	0.76	0.89	0.94	1.09	1.25	1.47	1.62
5	0.34	0.52	0.65	0.87	1.08	1.24	1.30	1.49	1.69	1.98	2.18
10	0.41	0.62	0.77	1.04	1.28	1.48	1.55	1.77	2.00	2.33	2.56
25	0.49	0.75	0.93	1.25	1.55	1.80	1.88	2.16	2.42	2.80	3.07
50	0.56	0.85	1.05	1.41	1.75	2.05	2.15	2.47	2.75	3.16	3.46
100	0.62	0.95	1.17	1.58	1.96	2.32	2.42	2.80	3.09	3.53	3.85
200	0.69	1.05	1.30	1.75	2.16	2.59	2.71	3.15	3.46	3.91	4.26
500	0.77	1.18	1.46	1.97	2.44	2.96	3.12	3.64	3.97	4.45	4.82
1000	0.84	1.28	1.59	2.14	2.65	3.26	3.45	4.04	4.38	4.88	5.26

Figure 10: Precipitation frequency estimate for point near Franklin, AZ from NOAA Atlas 14.

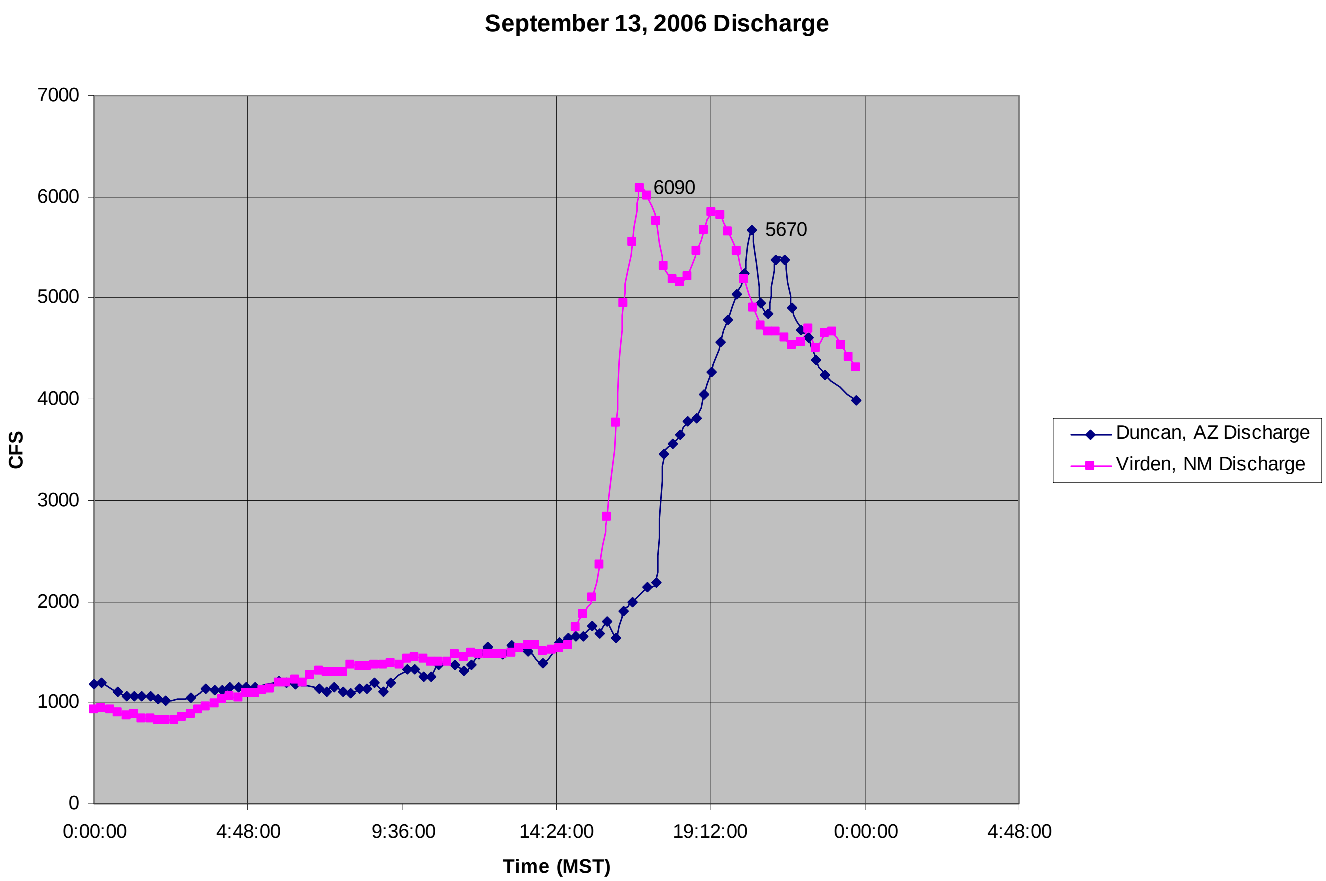

Figure 11: Stream discharge on September 13th, 2006 from USGS gages on the Gila River at Duncan, Arizona and Virden, New Mexico.