Pima County Regional FLOOD CONTROL DISTRICT

MEMORANDUM

Director's Office
Regional Flood Control District

THE SEAL OF PIMA COUNTY ARIZONA

DATE: September 26, 2006

TO: C.H. Huckelberry
County Administrator

FROM: Suzanne Shields, P.E.
Director

SUBJECT: 2006 Monsoon Season and the July 27, 2006 to July 31, 2006 Flood Event

The Regional Flood Control District (District) is continuing to evaluate storm events and flooding during this 2006 monsoon season, especially the flooding that occurred from July 27, 2006 through July 31, 2006. This memorandum is intended to provide updated information on these events including flood damages and subsequent mitigation activities.

2006 Monsoon Season

The 2006 summer monsoon season has turned out to be a record year for rainfall and stream flow in eastern Pima County. The total rainfall received in June, July, and August was 8.6 inches at the Tucson International Airport (Airport). This rainfall total is 2 inches more than the average rainfall for the same time period. As of September 18, 2006, 10.2 inches have been received at the Airport.

Rainfall in mid-July created saturated soil conditions in the upper watersheds especially the Rillito-Tanque Verde-Pantano River system. In late July, moisture from the Gulf of California caused by Tropical Storm Emilia created a period of intense rainfall in eastern Pima County starting on July 27 and ending on July 31, 2006. During this five-day period, rainfall totals ranged between 5 to 11 inches in the Catalina and Rincon Mountains and from 1 to 6 inches in the valley with many locations receiving over 50% of their average annual rainfall (see Table 1).

Rainfall on the morning of July 31, 2006 was especially intense over the Tanque Verde Creek Watershed where 4 to 6 inches of rainfall occurred between midnight and 7:00 a.m.

July 27, 2006 – July 31, 2006 Flood Event

The U.S. Geological Survey's (USGS) preliminary estimate of the flood peak in the Rillito River is 32,900 cubic feet per second (cfs) and the flood peak on the Santa Cruz River at Continental is 42,000 cfs. By comparison, the Federal Emergency Management Agency's (FEMA) estimate for the 100-year flood on the Rillito River is 32,000 cfs and the 50-year flood on the Santa Cruz River is 48,000 cfs.

The most intense flood damages occurred in the Tanque Verde Creek Watershed including Sabino Canyon and other mountain washes along the southern Catalina Mountains where heavy rains on the weekend of July 27, 2006 to July 31, 2006 deposited 6.97 to 10.28 inches of rain. Only preliminary flood estimates are available for the mountain canyon washes; however, initial indications are that the flows in many of the mountain washes exceeded the 100-year event. For example, the 100-year estimate for Bear Canyon Wash is 1,940 cfs and the estimate for July 31st is 2,400 cfs. Preliminary estimates of the flood flows on July 31, 2006 are provided in Table 2 and Table 3.

While flood damages were relatively light given the magnitude of the storms and floods (see map of Pima County flood damage), there were some areas where there were significant damages caused by floodwaters and, in some cases, debris flows

including:

- Flooding of 35 residential structures, the most severely damaged were along Rincon Creek.

  Debris flows and rockslides that damaged the Sabino Canyon Recreation Area, Catalina Highway and Mt. Lemmon Short Road.

- Erosion damage and 8 feet of channel bed lowering along the Pantano Wash downstream of Speedway Boulevard.

- Significant accumulation of sediment and debris in the Rillito River that in one case backed up local drainage into the adjacent Lazy Creek subdivision.

The most unique feature of the storms and flooding are the debris flows along the southern Catalina Mountains. The USGS has identified over 200 debris flow locations in the Catalina Mountains in the area from Esperero Canyon to Solider Canyon. The Sabino Canyon Recreation Area was impacted by 18 debris flows that the USGS is currently evaluating (see Exhibit A). The USGS is classifying the storm and subsequent debris flows as an extreme event. There has been no evidence of similar debris flow activity in historic times and they estimate that debris flows in the Catalina Mountains have not taken place in the past 10,000 years. The majority of the debris flows were along the steep sidewalls of the canyons. However, in three canyons the debris flow traveled some distance down the canyon. In the Sabino Canyon Recreational Area, the Rattlesnake Canyon debris flow traveled more than 2 miles down to the main Sabino Creek. Similar debris flows occurred in Bird Canyon and Soldier Canyon. The Soldier Canyon debris flow damaged the Catalina Highway at Milepost 1, the Mount Lemmon Short Road, and some of the surrounding homes (see Exhibit B).

Repair and Mitigation Activities

Along the major rivers, the floods caused significant erosion or deposition in some areas that have changed the channel profile and capacity beyond what might be expected by normal fluctuation in the channel bed. To evaluate the major rivers, inspections of all flood control infrastructures are being conducted to assess any damages or maintenance requirements such as debris removal. Surveys are also underway to take cross sections along the Santa Cruz River at Continental, Rillito River and Pantano Wash. These cross sections will be used to better assess where channel bed degradation and sedimentation occurred, develop scopes for maintenance activities and develop long-term mitigation strategies.

The following is a summary of conditions following the July flooding and subsequent August storms and key areas where maintenance or repairs will be evaluated. More detailed information is provided in the attached exhibits.

Tanque Verde Creek and Tributaries

Along the southeast side of the Catalina Mountains, the July 31, 2006 storm event resulted in significant flooding as well as rockslides and debris flows. Similarly, the Mount Lemmon Highway and Mount Lemmon Short Road were damaged by rockslides and debris flows (see Exhibit C). With the damage to the Mount Lemmon Short Road, the area north of Snyder Road and east of Catalina Highway does not have all-weather access. The USGS and the Natural Resources and Conservation Service (NRCS) are assisting in evaluating the damage at the Mount Lemmon Short Road. The District applied for and received $400,000 in emergency repair funding from the NRCS under their Emergency Watershed Protection Program. The Pima County Department of Transportation is coordinating with the U.S. Forest Service and Federal Highway Administration for funding to make repairs to Catalina Highway.

Rincon Creek
The County's stream gauge on the Rincon Creek reported flow depths of 9 feet before the stream gauge was washed away. Severe flooding along the Rincon Creek damaged four residential structures (see Exhibit D). These properties have been appraised for acquisition under the Floodprone Land Acquisition Program.

Pantano Wash
The erosion and failure of rock gabion bank protection occurred on the Pantano Wash from Tanque Verde Road upstream approximately 4,150 feet to a soil cement grade control structure. This reach of the Pantano Wash has unprotected banks, areas with old rock gabion or rock and rail protection, and soil cement bank protection. At the upstream grade control, the channel bed has degraded approximately 8 feet. This degradation could potentially undermine the soil cement bank protection along the Mullen Landfill on the east bank. The flow in the Pantano Wash also eroded the west bank at the Kolb Road Executive Park undercutting the stacked gabion bank protection and the existing rock and rail bank protection at the Pantano Townhomes (see Exhibit E). For temporary protection, large rocks were dumped along the bank adjacent to the Kolb Road Executive Park. The long-term solution will require new bank protection and additional grade control structures along this segment upstream of the Tanque Verde Road Bridge. The preliminary estimate for the new bank protection and grade control structures is $4,000,000. We will be working with NRCS on funding for erosion protection in this area.

Rillito River
The soil cement bank protection constructed by Pima County and the U.S. Army Corps of Engineers (Corps) protected all of the public infrastructure and private property along the Rillito River. The only damage to the bank protection occurred along the south bank of the Rillito River next to the University of Arizona Agricultural Extension (approximately 1,200 feet east of the Campbell Avenue Bridge). Approximately 225 linear feet of soil cement bank protection was damaged (see Exhibit F). Visual inspection of the site indicates that the damage likely occurred due to undercutting of the toe of the soil cement bank protection followed by the soil cement delaminating and falling into the scour hole. Preliminary repair costs are estimated at $310,000.

Santa Cruz River
In the 1993 flood, the Santa Cruz River degraded in the Continental Ranch area. We will be surveying cross sections of the Santa Cruz River through Continental Ranch to determine if this degradation trend has continued and to determine if there are any significant changes in channel capacity. There is a 100-foot stretch of bank protection in the low flow channel that was undermined and will require repair (see Exhibit G).

SS/tj
Attachments

cc: John Bernal, Deputy County Administrator – Public Works
Chris Cawein, Deputy Director – Regional Flood Control District

TABLE 1: RAINFALL FOR THE STORM EVENTS – JULY 27 TO JULY 31, 2006

Reporting at 8:00 am on the Day of:	7/27/06	7/28/06	7/29/06	7/30/06	7/31/06	Totals
	Rainfall in inches					
Canada del Oro Watershed						
Samaniego Peak	1.65	0.39	2.99	1.50	1.26	**7.79**
Oracle Ridge	1.89	0.79	3.23	0.67	0.87	**7.45**
Pig Spring	1.34	0.59	3.58	1.02	1.61	**8.14**
Mt. Lemmon						
Mt. Lemmon @ Radio Tower	1.85	1.46	3.66	2.01	1.69	**10.67**
Palisades Ranger Station	0.67	1.65	2.48	1.77	1.73	**8.30**
Tanque Verde - Sabino Canyon						
Sabino Canyon Dam	0.43	0.47	2.68	2.28	2.01	**7.87**
Bear Canyon	0.28	0.51	2.52	1.73	1.38	**6.42**
Molina Basin	0.28	0.55	1.10	2.60	3.94	**8.47**
Rincon Creek						
Mannings Camp	1.85	0.63	1.46	1.30	0.94	**6.18**
Rincon Creek X-9 Ranch	0.82	0.20	0.55	1.54	1.89	**5.00**
Pantano - Cienega Creek						
Colossal Cave	0.67	0.21	0.94	1.50	0.55	**3.87**
Davidson Canyon	1.50	0.08	2.17	1.57	0.79	**6.11**

TABLE 2: JULY 31, 2006 FLOW ESTIMATES (cfs)

River	cfs
Rincon Creek*	7,881
Pantano Wash	25,600
Agua Caliente Wash	9,756
Sabino Creek	16,389
Tanque Verde Creek	11,508
Rillito River	30,000 – 40,000
Santa Cruz River	42,000

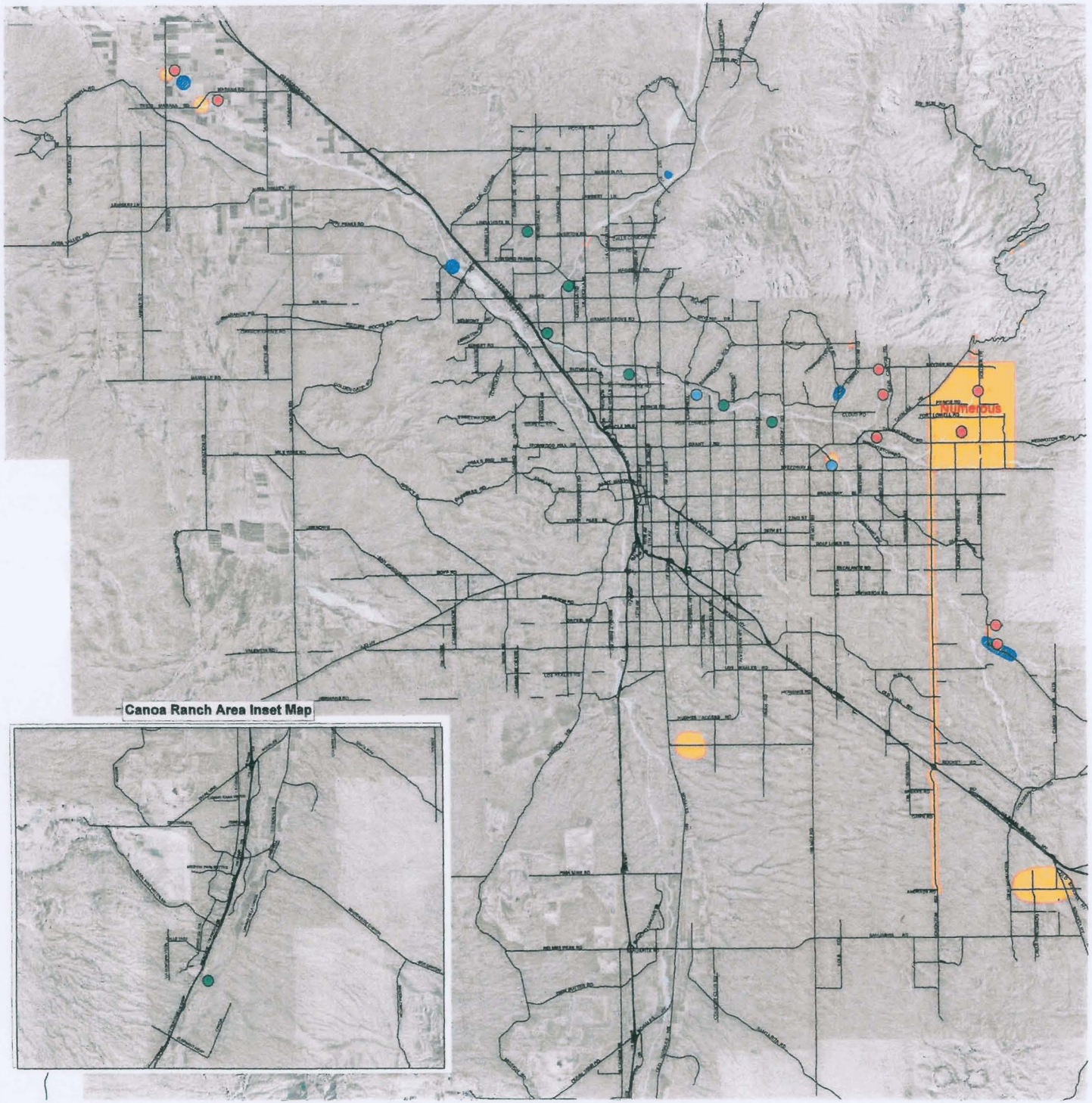
Note: Flow before the stream gauge washed out.

By comparison the peaks for the 1983, 1993, and 2006 floods were:

TABLE 3: PEAK FLOW ESTIMATES (cfs)

River	1983	1993	2006
Rillito River	29,700	28,000	30,000 – 40,000
Santa Cruz River @ Cortaro	65,000	40,000	42,000

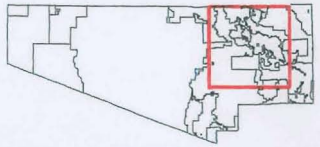
Pima County
Flood Damage
July 27- August 4, 2006



Flood Damage

- Bank Protection
- Park Damage
- Private Property
- Major Streets
- Wastewater Facilities
- Pima County, Road Infrastructure
- Washes, Greater than 10,000 CFS

Pima County Index Map



Inset Map Scale 1:1,500,000

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Department of Transportation Technical Services Division makes no claims regarding the accuracy of the information depicted herein.

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Scale 1:84,000

Pima County Department of Transportation

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9/25/2006

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EXHIBIT A

Sabino Canyon Recreation Area

PORTRAIT OF AN EXTREME EVENT:
The Sabino Canyon, Arizona Debris Flows and Flood of July 31, 2006

Statement of Problem. Sabino Canyon is a south-facing canyon draining the southern Santa Catalina Mountains north of Tucson, Arizona. Sabino Creek, a perennial stream that flows through this canyon, is a U.S. Forest Service recreation area, and the canyon is a valued riparian resource in Pima County. In 2003, the Aspen Fire, which coursed over much of the higher-elevation of the Santa Catalina Mountains, burned the headwaters of Sabino Creek, leading to concerns about increased flood hazards in this watershed.

A low-pressure system centered over northern New Mexico steered moisture-laden air into southern Arizona from July 28-31, 2006. Unlike monsoonal storms that are typical during the summer months in southern Arizona, thunderstorms developed in the late evening or early morning hours and were steered by a combination of low-level winds, the upper-level low, and topography. Rainfall was particularly heavy in the Tucson basin (fig. 1), resulting in a series of floods that culminated records set at several gaging stations on July 31 (fig. 2).

A Next-Generation Radar (NEXRAD) Doppler radar station on Empire Mountain southeast of Tucson documented storm precipitation for the entire event (fig. 3). Storm totals predicted by the radar returns for the 1 x 2 km pixels show a maximum of 6-8 inches of rainfall fell in the middle part of the Sabino Creek watershed. No precipitation gages are in this part of the watershed, which is critical because NEXRAD typically overestimates storm precipitation. A graph of cumulative storm rainfall for Molino Basin, just east of Sabino Canyon and representative of the area where debris flows occurred, shows that successive storms resulted in more than 4.5 inches of rainfall in a 6-hr period (fig. 4) in an area where mean annual precipitation is 12-15 inches per year.

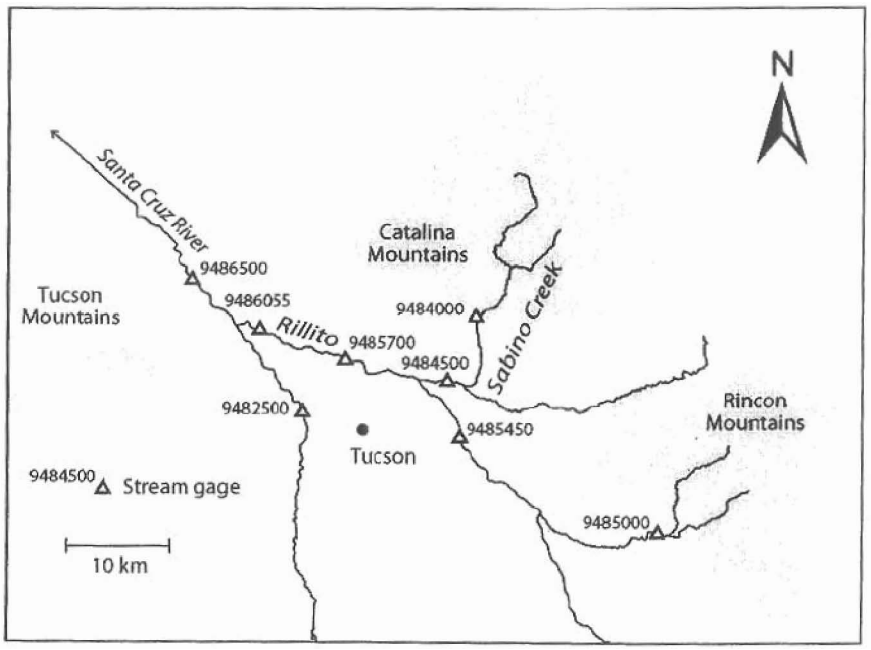


Figure 1. Map of the Tucson basin showing the locations of selected gaging stations.

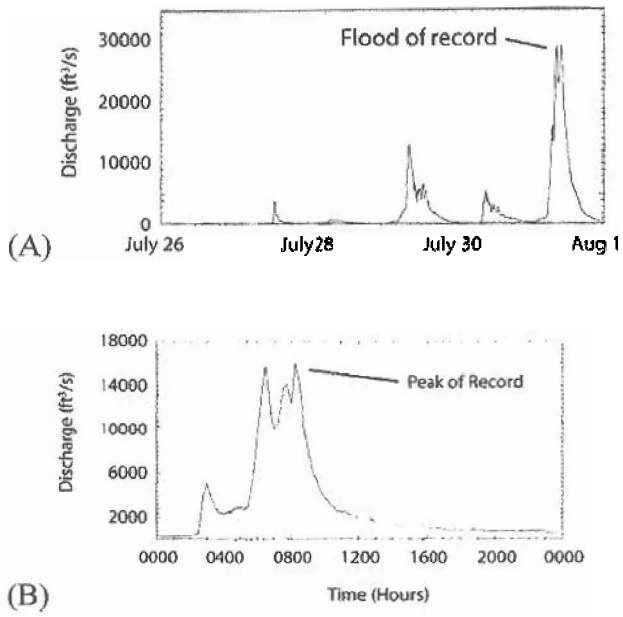


Figure 2. Hydrographs of the floods of late July 2006. (A) The six-day hydrograph of Rillito Creek at La Cholla Road near Tucson [9485700]. The flood of record, with a preliminary peak of about 30,000 ft^3/s, occurred at about 10:00 AM. (B) The hydrograph of Sabino Creek near Tucson for July 31, 2006 [9484000]. The data in these hydrographs are preliminary and subject to revision.

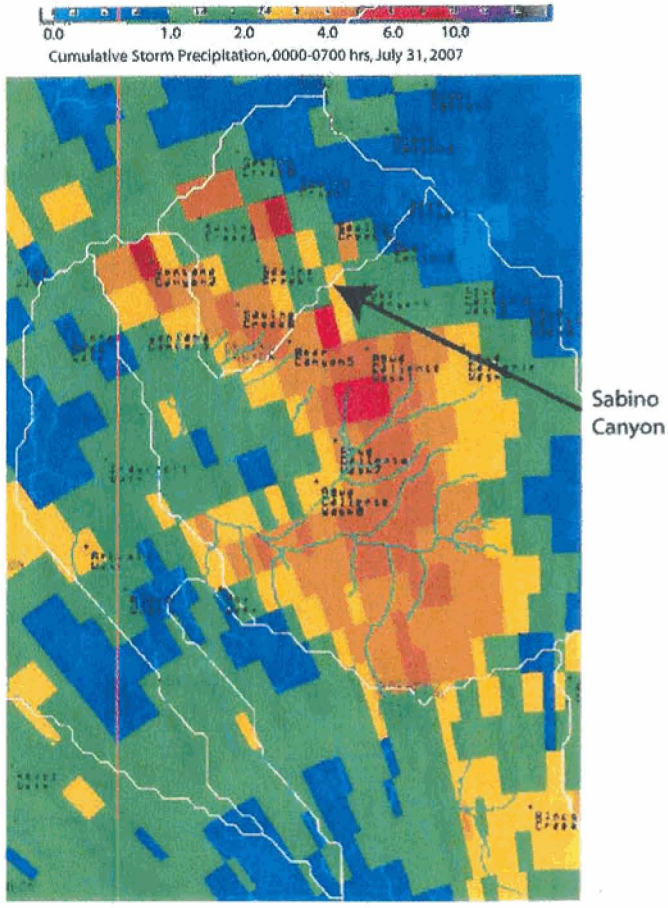


Figure 3. Cumulative storm precipitation for the eastern part of the Tucson Basin, including Sabino Canyon, for the period of 0000 to 0700 hours on July 31, 2006. Pixel size is 1 x 2 km. Precipitation units are in inches and shown in the explanation.

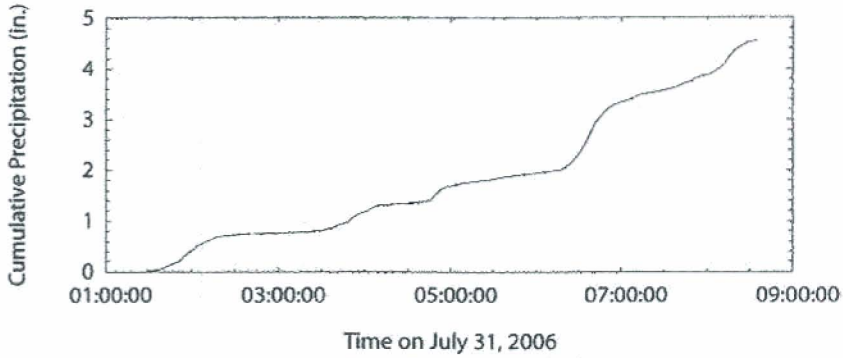


Figure 4. Cumulative storm precipitation from the tipping bucket rain gage in Molino Basin, east of Sabino Canyon. This precipitation gage is probably the most representative record of rainfall in the area of Sabino Canyon where debris flows occurred.

Debris flows and floods devastated Sabino Canyon (figs. 5 and 6) in the reaches downstream from the area burned by the Aspen Fire. As shown in fig. 2B, the flood in Sabino Canyon had several peaks, probably resulting from non-synchronous tributary additions to the

main channel. A post-flood survey on August 8 revealed that tributaries had produced at least 14 debris flows in the reach of Sabino Canyon formerly accessible by paved road; more debris flows occurred upstream from where the road ends. Considering just the boulder size fraction of the debris flows, the typical particles deposited on or near the roadway were about 1-m b-axis diameter with the largest particles upwards of 3 m in diameter.

Considerable historical photography is available for Sabino Canyon; the earliest photographs were taken in the 1890s. These photographs have been repeatedly matched for other projects dealing with long-term landscape change in the Sonoran Desert. The most recent match, in 2003 (fig. 6A), shows a river corridor as it appeared four years after the then-flood of record, which occurred in August 1999. As apparent in the photograph taken in early August 2006 (fig. 6B), the canyon bottom is scoured nearly clean of riparian vegetation that made Sabino Canyon a desirable recreation destination.

Considerable change occurred in the creek channel, home to the Gila chub (*Gila intermedia*), a federally listed endangered species. Immediately following the Aspen Fire, Gila chub were removed from Sabino Creek over fears of the effects of high-concentration ash-laden flows on the habitat of this species. Subsequently, this species was restocked in Sabino Creek. The effect of the July 31 event on Gila chub is not yet known, but the habitat changes are considerable.

Figure 5. Debris flow tentatively named "Ocho Grande" in Sabino Canyon that resulted from the July 31, 2006, storm. The extreme damage to the roadway in Sabino Canyon is apparent from the exposed and destroyed culvert at left center; a 2-m tall figures stands in the destroyed roadway. This debris flow was one of 14 identified in an area of the canyon where debris flows had not occurred historically.

In summary, the extreme flood event that occurred in Sabino Canyon on July 31 had extremely large impacts on the geomorphology, riparian vegetation, and (probably) the aquatic ecology of Sabino Creek. Considerable hydrologic data exist for reconstruction of the flood events of July 31. Rarely are data available that so thoroughly document, in fine detail, the nature of an extreme event.

Objective. The purpose of this proposal is to collect time-sensitive data that thoroughly document debris flows, flood stages, and flood impacts in Sabino Canyon and to collate and analyze the existing hydrologic data on this extreme event. We also propose to examine nearby flood-affected watercourses in northeastern Pima County, Arizona, and secure time-sensitive data from those areas as well.

Collaborations. This project will be conducted in collaboration with the National Weather Service, Tucson office, and the Arizona Water Science Center. Additional funding support will be sought from the U.S. Fish and Wildlife Service and Pima County Regional Flood Control District.

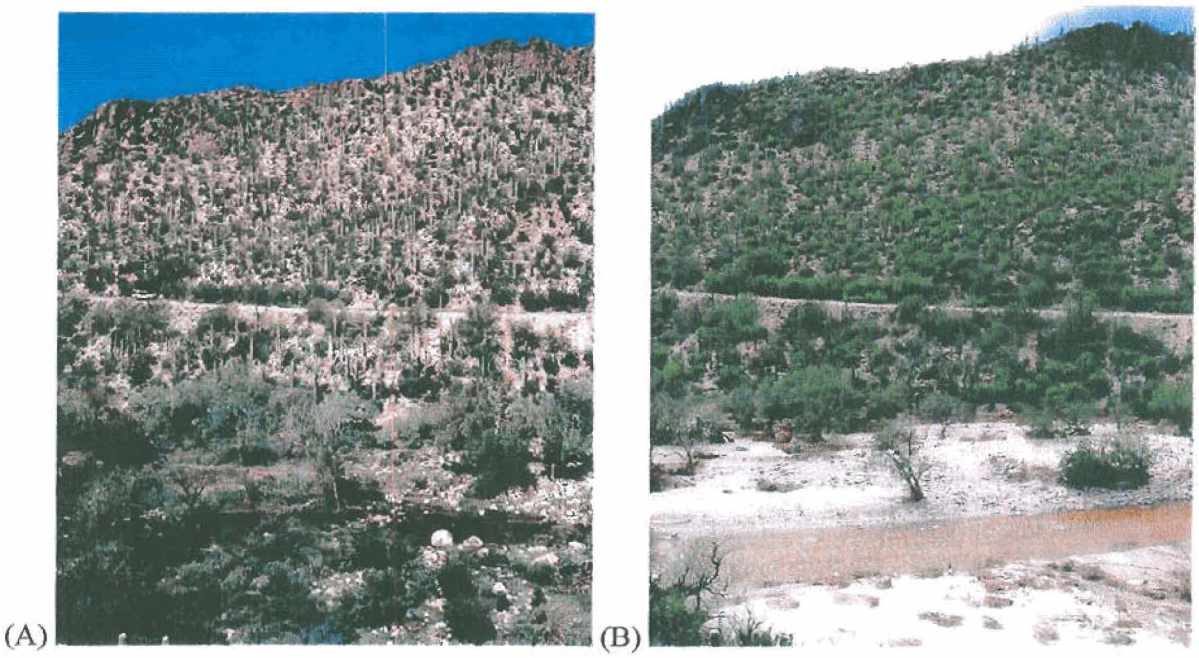


Figure 6. Views across lower Sabino Canyon, with Sabino Creek in the foreground. (A) Photos taken on 9/26/2003 and (B) on 8/8/2006. The peak discharge of the July 31 flood was more than 15,000 ft^3/s.

Approach. This project will collate and analyze all relevant meteorological and climatic data available for the July 31, 2006 storm including the time series of water vapor maps, the time series of integrated water-vapor columns for the vicinity of Sabino Canyon, the NEXRAD 1x2 km storm precipitation estimates, data from tipping-bucket rain gages in and adjacent to the watershed, and streamflow data. The storm was unusual enough that NWS Tucson is planning collaboration with our project for a presentation on this event in early November to describe the event and its hydrological consequences at a national meeting.

Approximately 20 previously established camera stations in Sabino Canyon documented riverine conditions prior to the July 31 event. We proposed to replicate all of the extant repeat photography to document the changes in riparian vegetation and channel morphology that occurred. In addition, approximately 5-10 additional unmatched photographs will be used to assess changes. Our overall goal of the repeat photography is to determine a potential return period for the debris flows that occurred on July 31. In addition to repeat photography, we will assess the potential for other retrospective measures of past debris-flow activity, including but not limited to radiocarbon dating of debris-flow deposits and cosmogenic dating of debris-flow terraces in and downstream from Sabino Canyon.

Considerable aerial photography and other digital topographic data is available to bracket the dates of the floods. Pima County Regional Flood Control District contracted for 1:6000 aerial photography immediately following the July 31 event; stereographic coverage at about 2-foot resolution is available from 2002 and non-stereo color imagery is available for May 2006. In addition, airborne LIght Detection And Ranging (LIDAR) data is available for the lower reaches of Sabino Creek.

Given the time-sensitive nature of flood damage, and particularly given the pending clean-up of roadway deposition and damage in the canyon, we propose to use a reflectorless total station to survey and assess sediment volumes transported by debris flows. We also propose to use high-resolution photogrammetry of existing aerial photography of Sabino Canyon to calculate a higher-resolution local digital-elevation model (the best existing data is 10 m resolution) to aid in the estimation of debris flow volume.

In October 2006, we propose to collaborate with the California Water Science Center to use tripod-mounted LIDAR (1) to survey, in fine detail (5-10 cm accuracy) a half-kilometer reach of Sabino Creek for the purpose of peak-discharge reconstruction and (2) to survey hillslopes to assess changes in debris-flow initiation points, channels, and deposition areas in or near Sabino Creek. High-water marks for the 2006 peak discharge have already been flagged, and we will install discrete, semi-permanent markings at those sites to allow capture by LIDAR.

Products. This project would involve no written products for FY06. Instead, this project would acquire data that would require considerable analysis in FY07, leading to several potential publications.

Benefits. State-of-the-art documentation of the meteorological circumstances that led to an extreme event, combined with a hydrological reconstruction of the aftermath, provides an extremely unusual opportunity that would greatly contribute to an understanding of flood hazard in Pima County, Arizona, as well as other arid and semiarid regions of the western United States.

EXHIBIT B

Soldier Canyon Debris Flow

Pima County Regional
FLOOD CONTROL
DISTRICT

MEMORANDUM

Floodplain Management
Regional Flood Control District

DATE: September 13, 2006

TO: Suzanne Shields, P.E.
Director

FROM: Evan Canfield, P.E., PhD
Planning and Development

SUBJECT: **Soldier Canyon Debris Flows**

BACKGROUND

You asked me to look into the debris flows at Soldier Canyon Wash to determine its implication for flood control and floodplain management. This memorandum characterizes what is known about the debris flows that occurred at the base of the Catalina Mountains (Catalinas) and lists some questions to answer about the potential impact these may have on future flooding.

SUMMARY

USGS Observations

The Following are observations about the debris flows along the Catalinas described by Bob Webb from the U.S. Geological Survey (USGS) and Eric Ptylak from the National Weather Service (NWS) during a talk on August 25, 2006.

1. Existing debris flow deposits are present all along the base of the Catalinas at the transition to alluvial fans.

2. There has been no evidence of similar debris flow activity in historic times. Bob Webb believes that this kind of activity has not taken place since the Pleistocene (i.e., approximately 10,000 years ago).

3. Two separate fronts hit the Sabino Canyon area on July 31, 2006 between approximately 2:00 a.m. and 6:00 a.m. with an hour between the two events.

4. Radar data indicates that up to six inches was dumped on lower Sabino Canyon (see attached radar map).

5. It was an 'impressive rain' — but the primary trigger for the debris flows was the saturated condition of the watershed from the previous week of rainfall, including July 27th on which three separate events deposited a total of 1.07 inches at the dam in Sabino Canyon.

6. The debris flows were widespread across the watershed and occurred in both burned and unburned areas, which makes Bob Webb believe that the fire effect was minimal.

7. The debris flows started very near the watershed divide with virtually no contributing area. This is much different than the kind of activity Bob Webb has seen in the Grand Canyon area where larger areas are required to initiate a debris flow.

8. The debris flows initiated at colluvium/bedrock interface in most cases.

9. Debris flows are about 80% solids and behave more like concrete slurry than water. Virtually no sorting occurs, and huge boulders can ride on the top of the slurry mixture.

10. Two different types of activity were observed:

    a. Debris flows/rock slides that flow down a steep slope face, which may reach the canyon floor. In Sabino Canyon, debris flows went down the canyon sides and were subsequently reworked by flowing water.
    b. Debris flows down the canyon channel. In Rattlesnake Canyon debris flows combined and traveled as debris flow slurry down the canyon channel.

11. The alluvium in some tributary channels is 'entirely cleaned out' which might increase flooding because there is no material to absorb the initial runoff. In other words, they eliminate transmission losses that can occur.

12. The destabilized tributaries may be further destabilized by subsequent flows.

Aerial Photographs – Soldier Canyon
Cooper Aerial delivered aerial photography of Soldier Canyon/Agua Caliente. The original purpose of the flight had been to catch high water marks. However, during a later flight, Cooper had learned of our interest in debris flows and took photos of Soldier Canyon. The following are a series of examples showing before and after photos comparing the Cooper photos with the 2002 and 2005 images.

Extent of Debris Flows in Soldier Canyon
Field reconnaissance of Soldier Canyon was done by a colleague of Bob Webb, Peter Griffiths, who indicated that most of the sedimentation could be attributed to debris flows including the sediment in the vicinity of the Mount Lemmon Short Rd (se Map E). Since flooding also occurred, much of these debris flows, which traveled as slurry, were subsequently re-worked by water. Some of the characteristics that indicate debris flow are:

1. Creation of new flow patterns. Because the debris flows have the capability to both scour and deposit, they have the capability to rearrange flow patterns move the stream channel as the debris flow did at the Mt. Lemmon Short Road.

2. Extremely poorly sorted (well graded) material with many angular boulders. Sediment deposited exclusively by water would exhibit layering, sorting, and rounding of rock.

3. Coarsest material traveling in front of the debris flow. The coarsest sediment rides on the front of the slurry. The coarsest material along the Mt Lemmon Short Road is at the front and is finer further up the channel. This is indicated on the following map where photo locations 1 and 2 are indicated.

Questions to be addressed:

1. ***Are there other areas that are at risk for debris flows and subsequent flooding or rockslides?*** Debris flow material is present across the front of the Catalinas. However, in the recent event not all watersheds experienced debris flows. In the first set of photos (Map A), the watershed west of Soldier Canyon is shown to be without debris flows, while Soldier Canyon itself has numerous debris flows, though they tend to be more active on Western slopes (i.e., east-facing slopes). This could be due to a number of factors including vegetative cover, underlying geology, availability of colluvium, etc.

2. *Will the areas destabilized in the debris flows continue to be unstable and thus be sources of further debris flows?* Bob Webb, who has studied debris flows, did not have an answer to this question because the debris flows in the Catalinas behaved differently than the ones he has studied in the past.

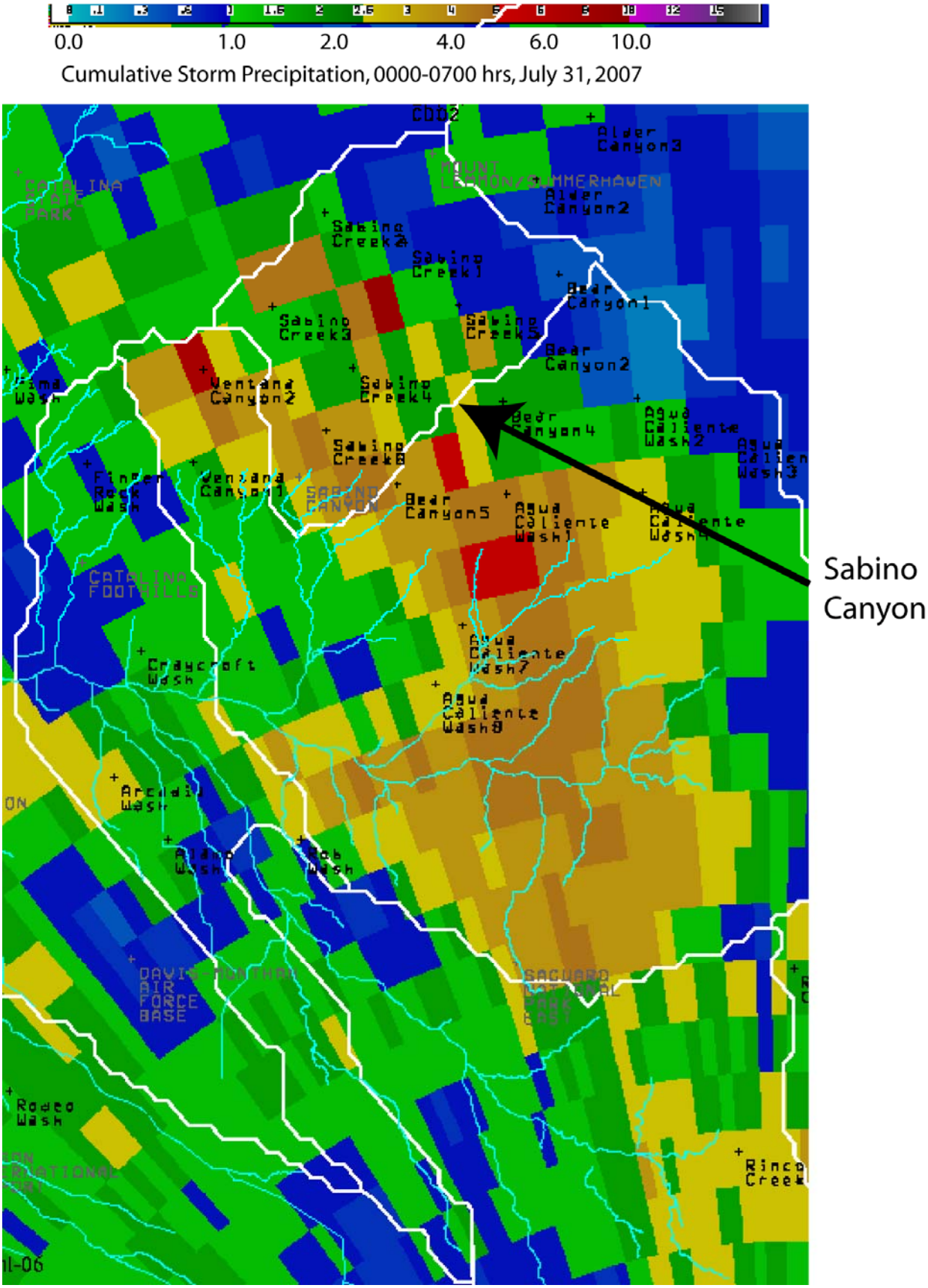
3. *By removing rock and other sediment from channels, will these canyons be at risk for increased flooding because there is no alluvium to hold runoff in the upper end, or at a decreased risk of flooding because more sediment is in place in the channels further down the mountain?* The transmission losses associated with the changed alluvium are likely to impact the flooding characteristics of the streams. The flood peaks could potentially be greater closer to the mountain front, and then reduced to pre-debris flow discharges further down in the channel where the new sediment results in increased infiltration. At some point downstream, there should be little change in peak discharge from pre-debris flow conditions.

4. *Will the floodplains need to be remapped because the sedimentation is significant enough to change the mapping of the inundated areas?* The sediment introduced into the channels can expect to be reworked over time. The magnitude of the sedimentation is not yet known. By comparing the elevation between the pre-flood and post-flood photogrammetry, it should be possible to make a better estimate of how floodplain mapping will change (see maps D and E).

If you have any questions, please see me.

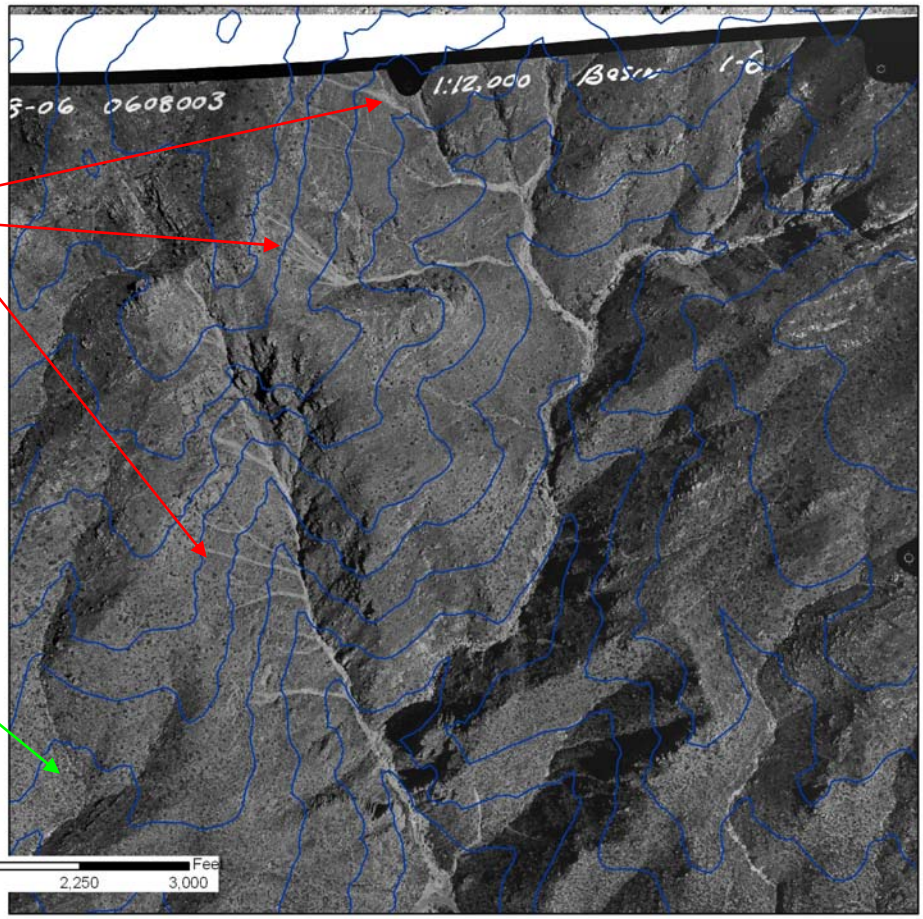
EC/tj
Attachments

cc: Chris Cawein, Deputy Director – Regional Flood Control District
Jerry Curless, Manager – Planning and Development Division
Terry Hendricks, Chief Hydrologist – Mapping and Studies Section

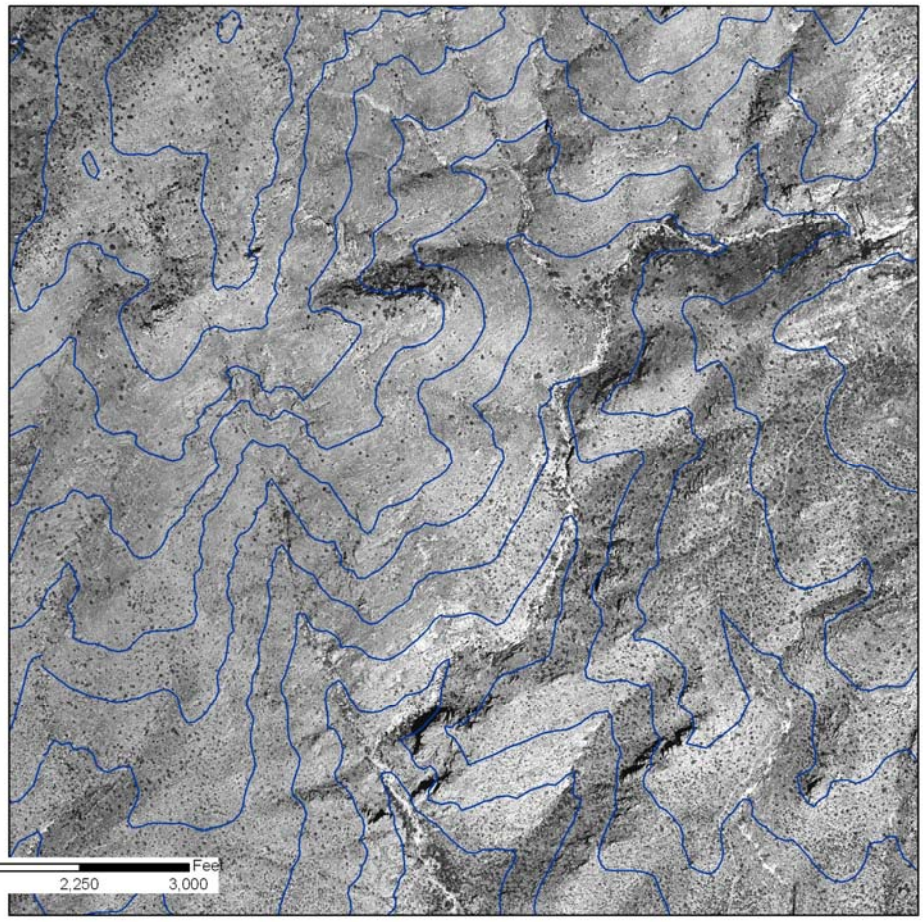

0.0
1.0
2.0
4.0
6.0
10.0
Cumulative Storm Precipitation, 0000-0700 hrs, July 31, 2007
Alder Canyon3
Alder Canyon2
Sabino Creek2
Sabino Creek1
Bear Canyon1
Sabino Creek3
Sabino Creek5
Bear Canyon2
Ventana Canyon2
Sabino Creek4
Bear Canyon4
Agua Caliente Wash2
Sabino Creek6
Finger Rock Wash
Ventana Canyon1
Bear Canyon5
Agua Caliente Wash1
Agua Caliente Wash4
Agua Caliente Wash7
Agua Caliente Wash8
Craycroft Wash
Arcadia Wash
Rodeo Wash
Sabino Canyon

Map A

Post Flood Soldier Canyon Watershed

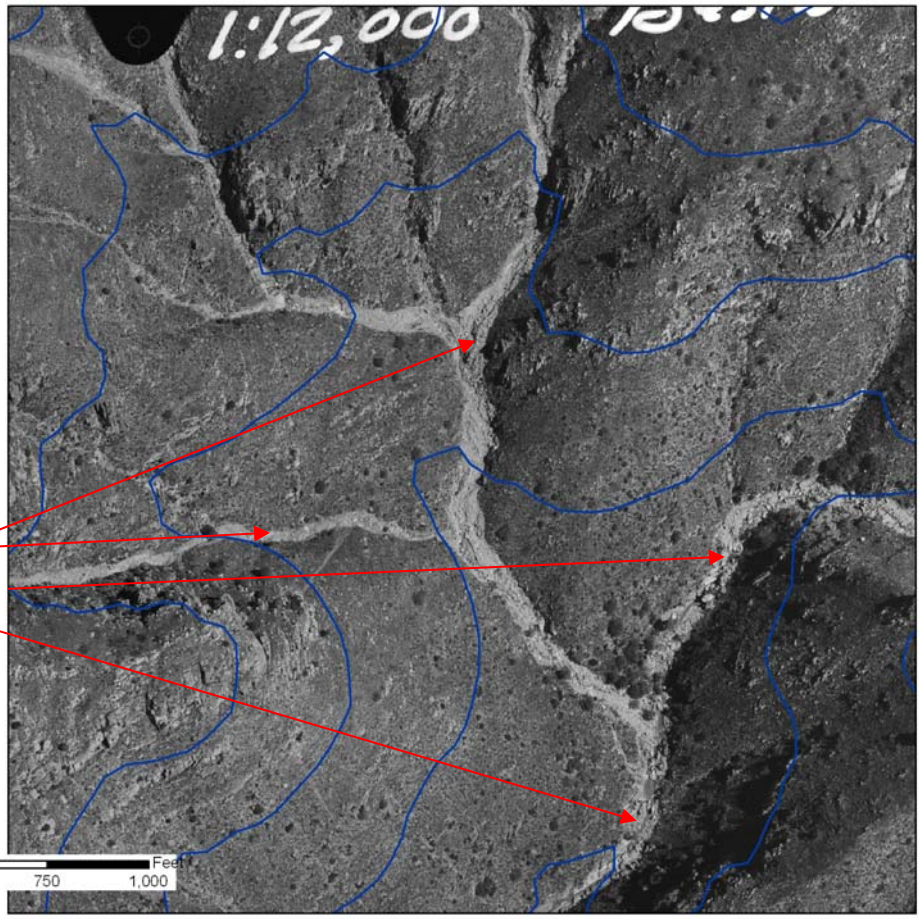


Pre Flood Soldier Canyon Watershed 2002 Orthophoto



Map B

Post Flood Soldier Canyon Watershed 8-18-06 Photo



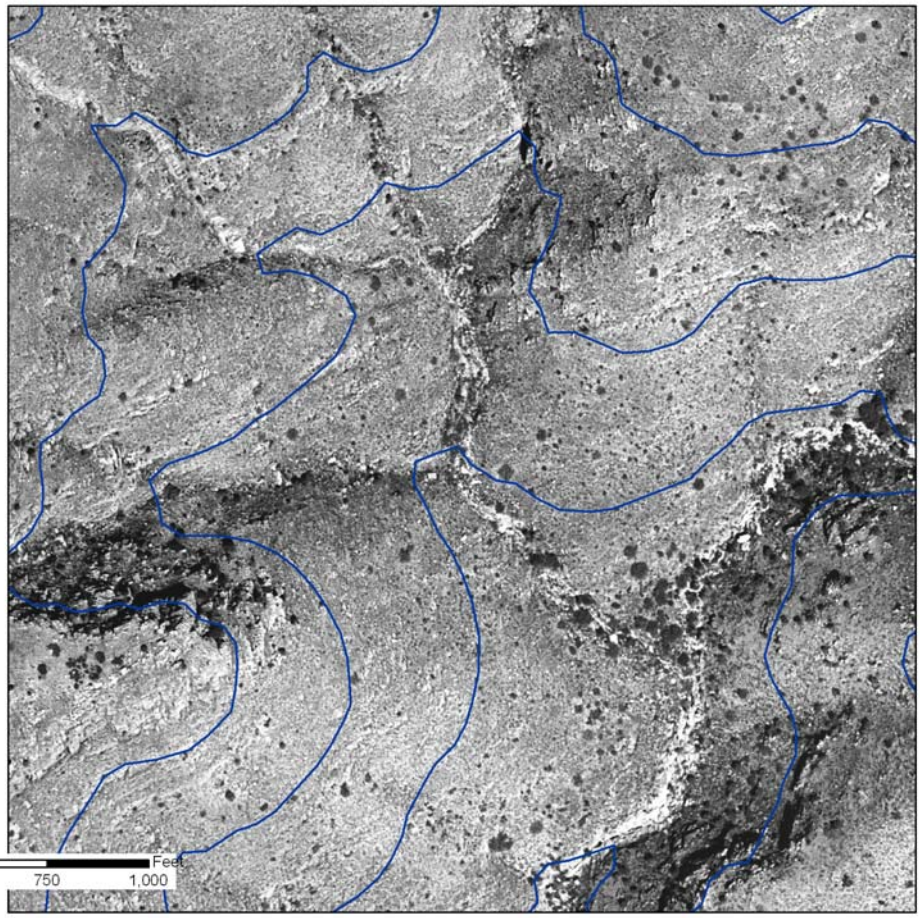
N

Channels with significant change related to debris-flows

Contours are 100' intervals

0 125 250 500 750 1,000 Feet

Pre Flood Soldier Canyon Watershed 2002 Orthophoto



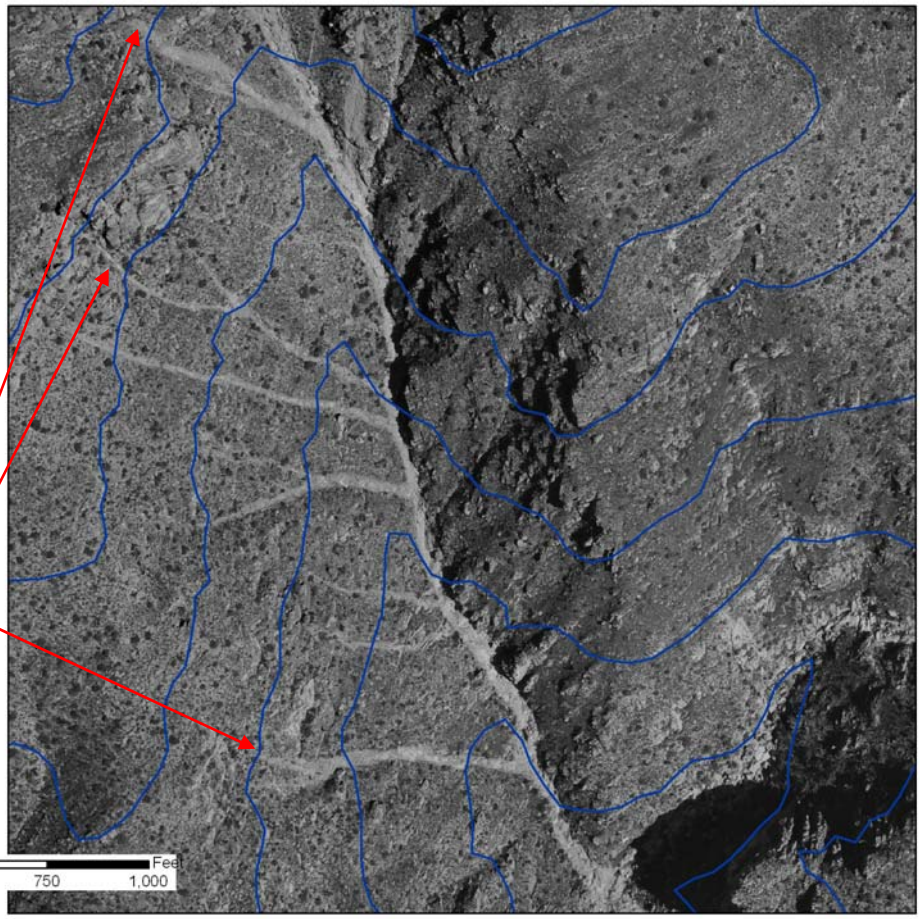
N

Contours are 100' intervals

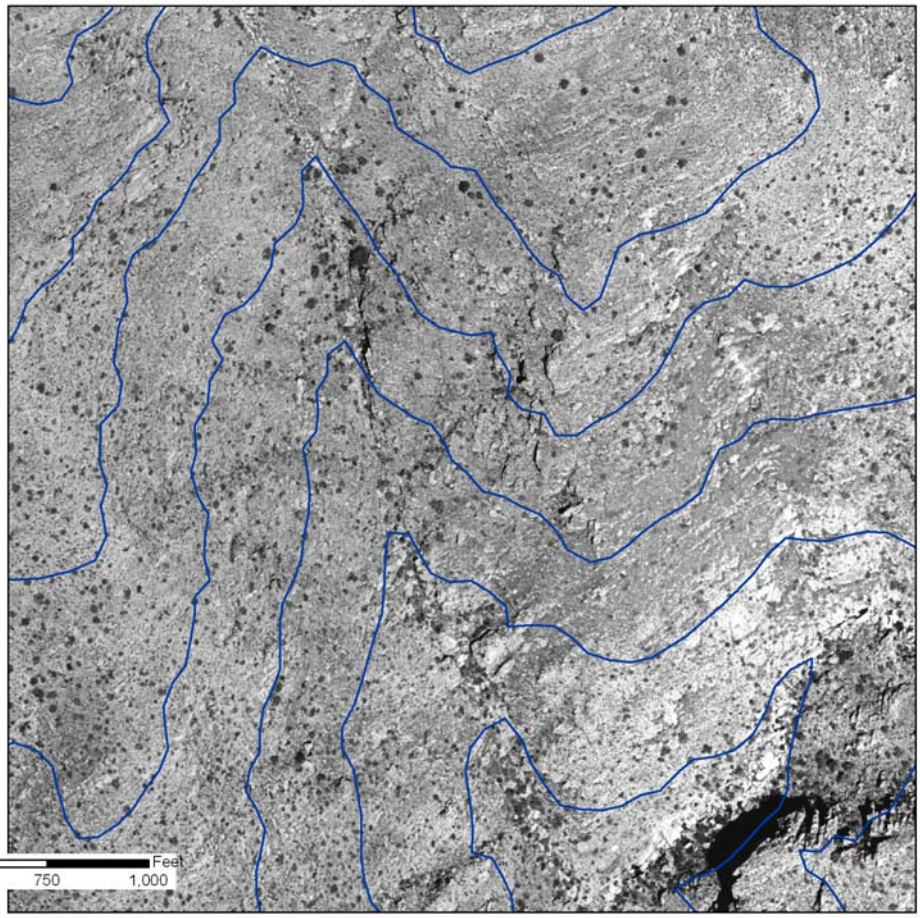
0 125 250 500 750 1,000 Feet

Map C

Post Flood Soldier Canyon Watershed 8-18-06 Photo



Post Flood Soldier Canyon Watershed 2002 Orthophoto



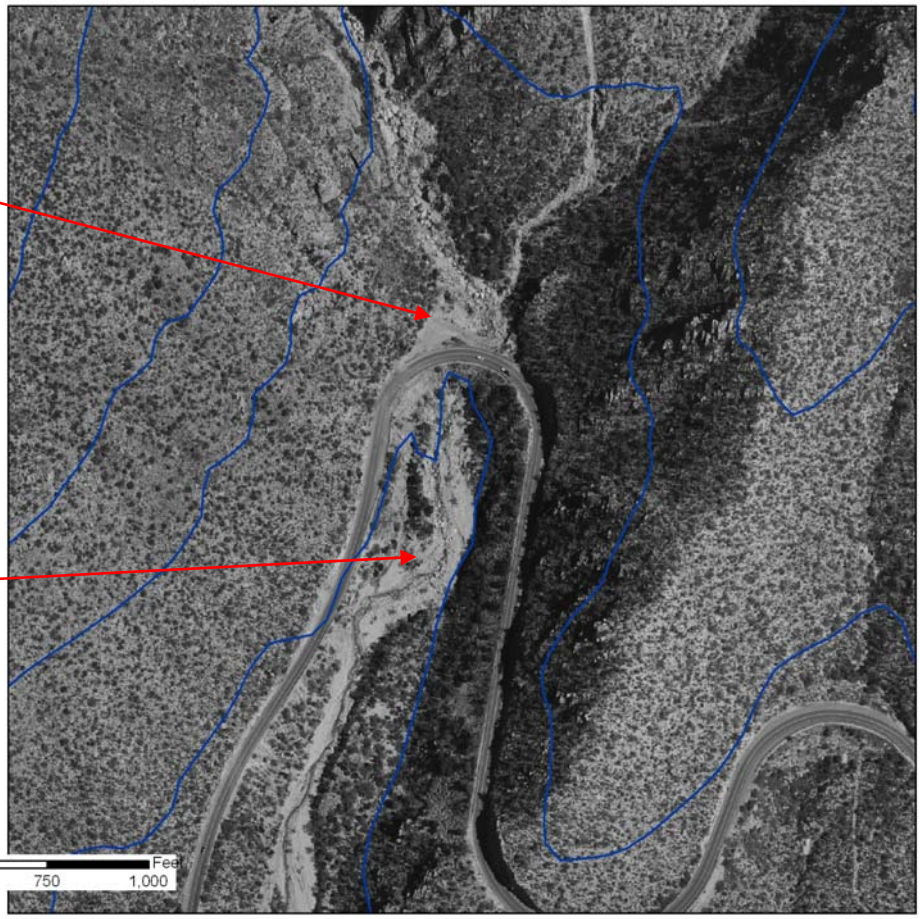
Map D
Soldier
Canyon Watershed
8-18-06 Photo

Debris flows forced to west side of channel

N

Deposition of sediment across floodplain

Contours are 100' intervals

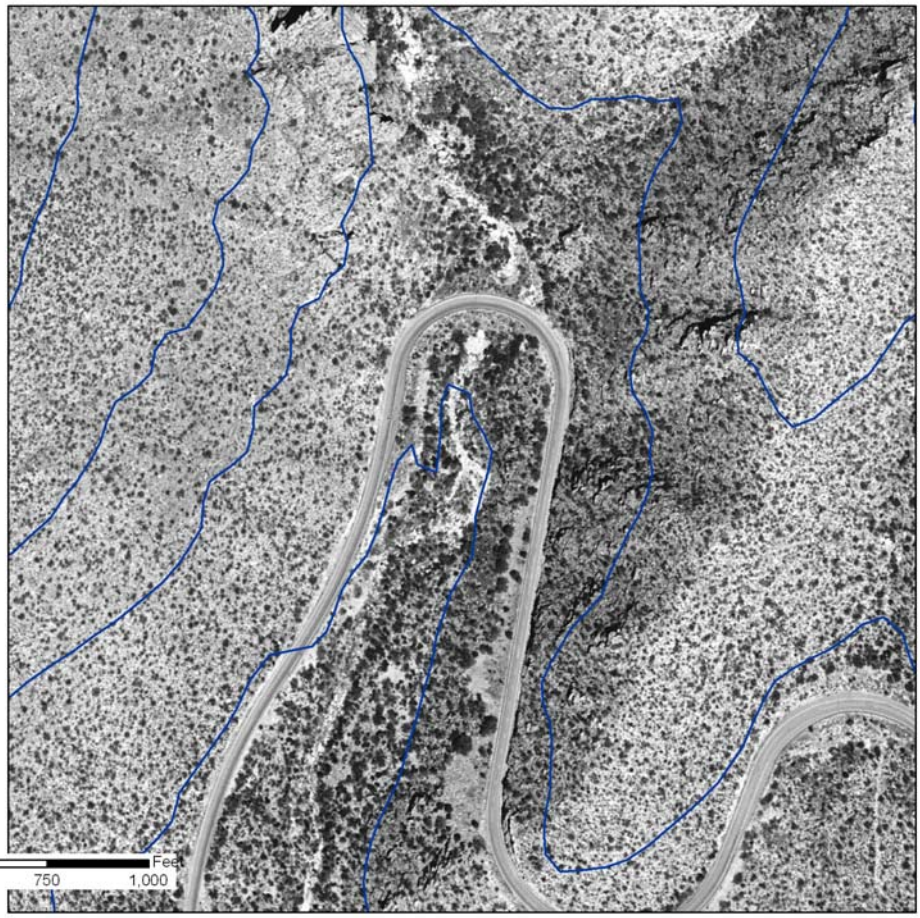


0 125 250 500 750 1,000 Feet

Soldier
Canyon Watershed
2002 Orthophoto

N

Contours are 100' intervals

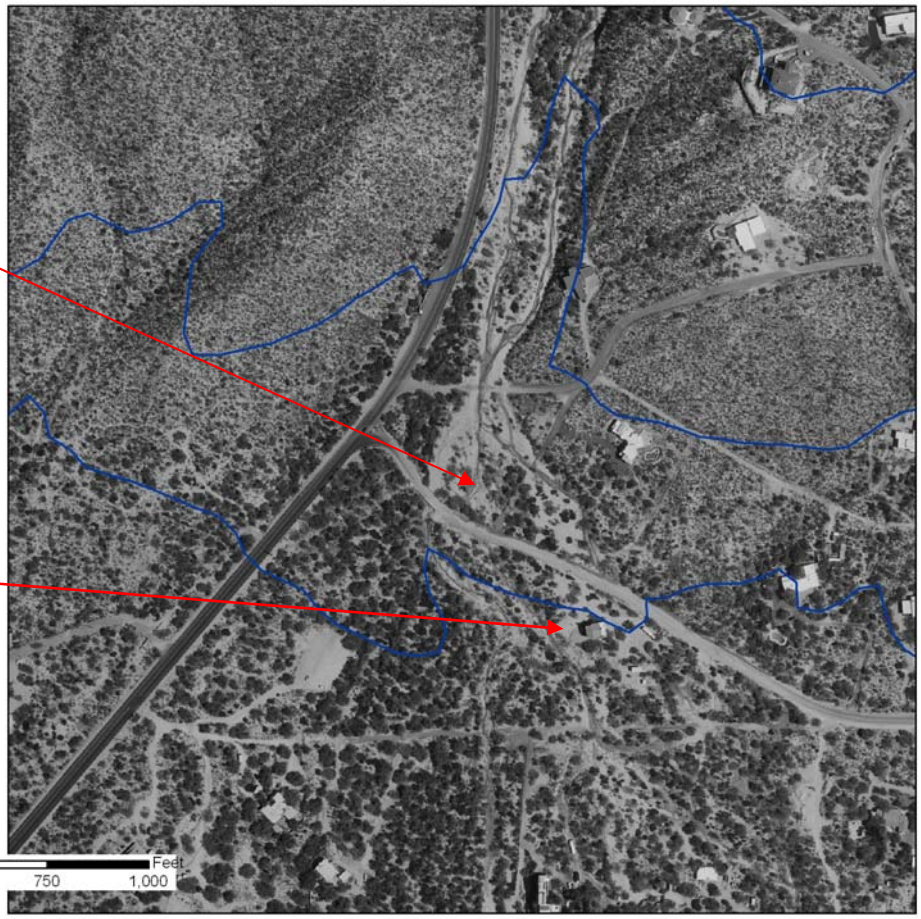


0 125 250 500 750 1,000 Feet

Soldier
Canyon Wash
8-18-06 Photo

Deposition of sediment along north side of Mt. Lemmon Short Rd

N

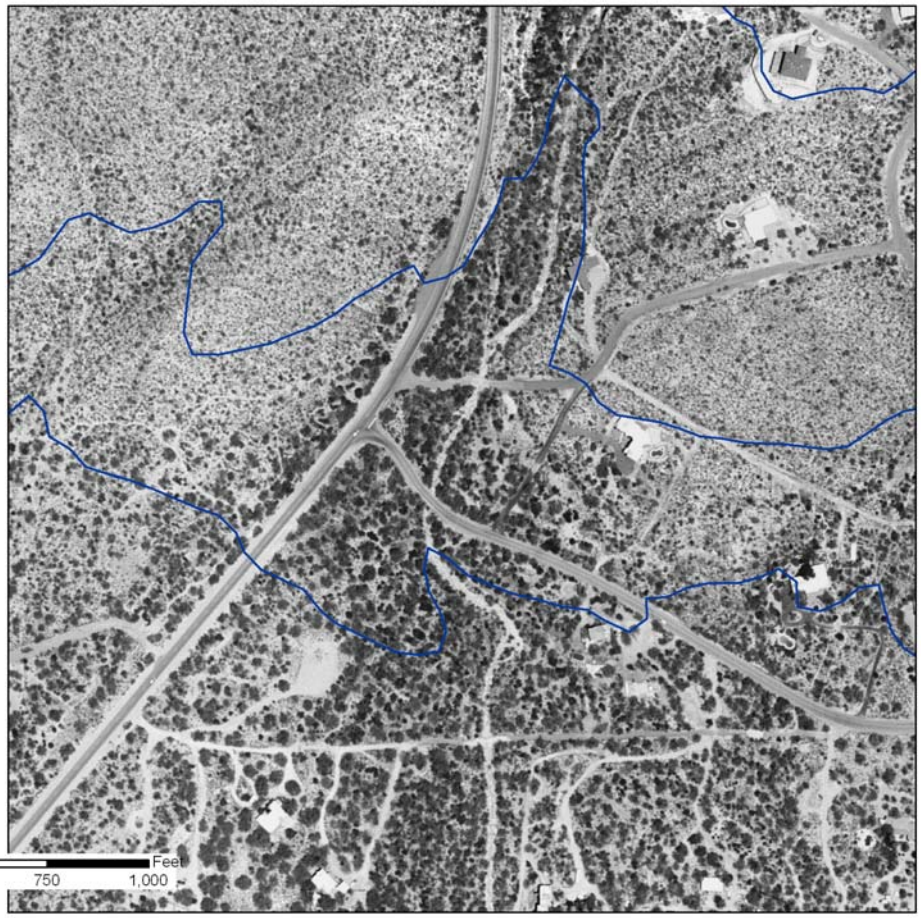


Contours are 100' intervals

0 125 250 500 750 1,000 Feet

Soldier
Canyon Wash
2002 Orthophoto

N



Contours are 100' intervals

0 125 250 500 750 1,000 Feet

Soldier
Canyon Wash
8-18-06

0 12.5 25 50 75 100 Feet

Photo Location 1:

Poorly sorted, Coarse material at the debris flow front

Photo Location 2:

Poorly sorted, finer material back from the debris flow front

Pima County Regional FLOOD CONTROL DISTRICT

MEMORANDUM

Director's Office
Regional Flood Control District

THE SEAL OF PIMA COUNTY ARIZONA

DATE: September 26, 2006

TO: C.H. Huckelberry
County Administrator

FROM: Suzanne Shields, P.E.
Director

SUBJECT: 2006 Monsoon Season and the July 27, 2006 to July 31, 2006 Flood Event

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The Regional Flood Control District (District) is continuing to evaluate storm events and flooding during this 2006 monsoon season, especially the flooding that occurred from July 27, 2006 through July 31, 2006. This memorandum is intended to provide updated information on these events including flood damages and subsequent mitigation activities.

2006 Monsoon Season

The 2006 summer monsoon season has turned out to be a record year for rainfall and stream flow in eastern Pima County. The total rainfall received in June, July, and August was 8.6 inches at the Tucson International Airport (Airport). This rainfall total is 2 inches more than the average rainfall for the same time period. As of September 18, 2006, 10.2 inches have been received at the Airport.

Rainfall in mid-July created saturated soil conditions in the upper watersheds especially the Rillito-Tanque Verde-Pantano River system. In late July, moisture from the Gulf of California caused by Tropical Storm Emilia created a period of intense rainfall in eastern Pima County starting on July 27 and ending on July 31, 2006. During this five-day period, rainfall totals ranged between 5 to 11 inches in the Catalina and Rincon Mountains and from 1 to 6 inches in the valley with many locations receiving over 50% of their average annual rainfall (see Table 1).

Rainfall on the morning of July 31, 2006 was especially intense over the Tanque Verde Creek Watershed where 4 to 6 inches of rainfall occurred between midnight and 7:00 a.m.

July 27, 2006 – July 31, 2006 Flood Event

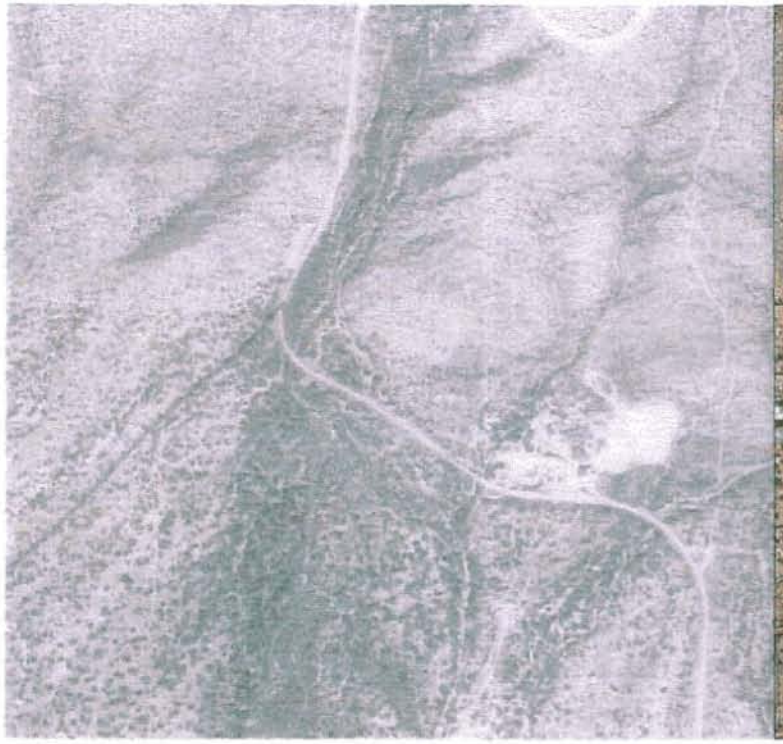
The U.S. Geological Survey's (USGS) preliminary estimate of the flood peak in the Rillito River is 32,900 cubic feet per second (cfs) and the flood peak on the Santa Cruz River at Continental is 42,000 cfs. By comparison, the Federal Emergency Management Agency's (FEMA) estimate for the 100-year flood on the Rillito River is 32,000 cfs and the 50-year flood on the Santa Cruz River is 48,000 cfs.

The most intense flood damages occurred in the Tanque Verde Creek Watershed including Sabino Canyon and other mountain washes along the southern Catalina Mountains where heavy rains on the weekend of July 27, 2006 to July 31, 2006 deposited 6.97 to 10.28 inches of rain. Only preliminary flood estimates are available for the mountain canyon washes; however, initial indications are that the flows in many of the mountain washes exceeded the 100-year event. For example, the 100-year estimate for Bear Canyon Wash is 1,940 cfs and the estimate for July 31st is 2,400 cfs. Preliminary estimates of the flood flows on July 31, 2006 are provided in Table 2 and Table 3.

While flood damages were relatively light given the magnitude of the storms and floods (see map of Pima County flood damage), there were some areas where there were significant damages caused by floodwaters and, in some cases, debris flows

EXHIBIT C

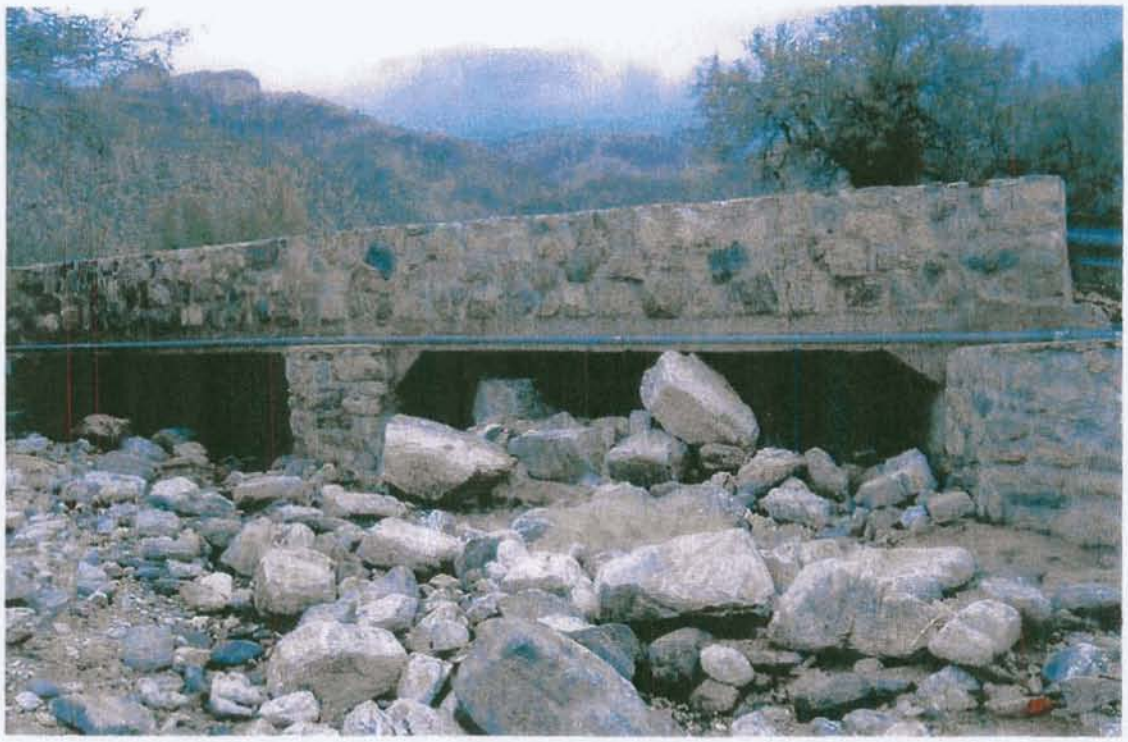
Mt. Lemmon Short Road



1936 Aerial Photograph of the Mt. Lemmon Short Road
Solider Canyon Wash Fans Out at the Bottom of the Mountain Front.

2005 Aerial Photograph of the Mt. Lemmon Short Road
Soldier Canyon Wash is Incised and Channeled Through the Bridge.

Upstream of Bridge on Mt. Lemmon Short Road - 6 to 8 Feet of Rock & Debris



Downstream of Bridge on Mt. Lemmon Short Road - Bridge Plugged by Boulders

East End of Bridge on Mt. Lemmon Short Road - 2 to 3 Feet of Scour

Looking East from the Bridge on Mt. Lemmon Short Road