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Snowmelt and Storm Water Runoff at Los Alamos National Laboratory in 2001

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by

Richard J. Koch, Bruce M. Gallaher, and David A. Shaull

ABSTRACT

This report describes precipitation and fire-related snowmelt and storm water runoff events that occurred during 2001 at the Los Alamos National Laboratory (LANL) one year after the Cerro Grande Fire. Snowmelt and storm water runoff events are described from data obtained from stream gaging stations where runoff samples were collected during the 2001 runoff season. The report incorporates available information pertaining to the location of significant precipitation events, precipitation amounts, and resulting storm water flow rates and flow volumes and summarizes the storm water runoff samples that were collected at LANL in 2001. The report is intended to provide the background information necessary to assist in the understanding of the runoff characteristics at LANL and the water quality data obtained from the storm water runoff samples.

Snowmelt runoff in 2001 was significantly higher than observed during the previous six years of record. About 570 ac-ft of snowmelt runoff entered LANL at upstream gages and about 531 ac-ft of snowmelt runoff flowed downstream from LANL, indicating that overall, about 39 ac-ft of runoff was lost to infiltration or evapotranspiration at LANL. The snowmelt runoff in 2001 is about 1.5 times higher than previously observed at upstream gages and about 2.0 times higher than previously observed at downstream gages.

The largest runoff event at LANL in 2001 occurred on July 2 when a short-duration (60-minute) relatively high-intensity thunderstorm occurred over the western part of the Los Alamos town site. This event caused a flood in Pueblo Canyon that totaled about 90 ac-ft of runoff. The total downstream storm water runoff at LANL in 2001 was 388 ac-ft, significantly higher than in 2000, primarily due to the large runoff event in Pueblo Canyon on July 2. The total downstream runoff in 2001 was 1.5 times higher than in 2000 after the Cerro Grande Fire and about 3.6 times higher than the prefire average annual runoff (106 ac-ft), even though the seasonal precipitation in 2001 (6.94 in.) was less than received in 2000 and less than the prefire average seasonal precipitation (12.4 in.). The total storm water runoff from Rendija Canyon was 94 ac-ft and from Guaje Canyon above Rendija Canyon was 74 ac-ft, for a total storm water runoff from the Guaje Canyon watershed of at least 168 ac-ft.

1.0 Introduction

Los Alamos National Laboratory (LANL) is located on 43 mi^2 of the Pajarito Plateau on the east flank of the Jemez Mountains (the Sierra de los Valles) of north-central New Mexico (Figure 1-1). Bandelier National Monument is located south of LANL, and the Santa Fe National Forest is located on the slopes of the Sierra de los Valles west and north of LANL.

The Pajarito Plateau slopes to the east-southeast and changes in elevation from west to east from about 7600 ft to about 6300 ft, for a total change in elevation of about 1300 ft; canyons and mesas extend along the entire slope of the plateau. Significant larger-scale topographic features exist in the vicinity of the plateau, such as the broad north-south trending Rio Grande Valley to the east and the Sierra de los Valles to the west, which extend to over 10,000 ft, up to 3000 ft above the plateau. The local and regional topographical features contribute to the meteorological complexity of the site and significantly influence the local meteorology of the Laboratory (Baars et al. 1998).

This report describes precipitation events and snowmelt and storm water runoff events that occurred during 2001 at LANL, which were primarily related to runoff from fire-impacted areas associated with the Cerro Grande Fire of May 2000 (for a description of the Cerro Grande Fire see Webb and Carpenter, 2001). Snowmelt and storm water runoff events are described for stream gaging stations where runoff samples were collected during the 2001 runoff season. The report incorporates available information pertaining to the location of significant precipitation events, precipitation amounts, and snowmelt and storm water flow rates and flow volumes and the significant storm water runoff samples that were collected in major drainages at LANL in 2001. Descriptions of storm water runoff samples that were not influenced by the Cerro Grande Fire, such as storm water samples routinely collected at Technical Area (TA) 54, Material Disposal Area (MDA) G, TA-55, and other mesa-top sites, are not included in this report. The report is primarily intended to provide the background information necessary to assist in the understanding of the runoff and water quality characteristics associated with runoff from fire-related areas at LANL.

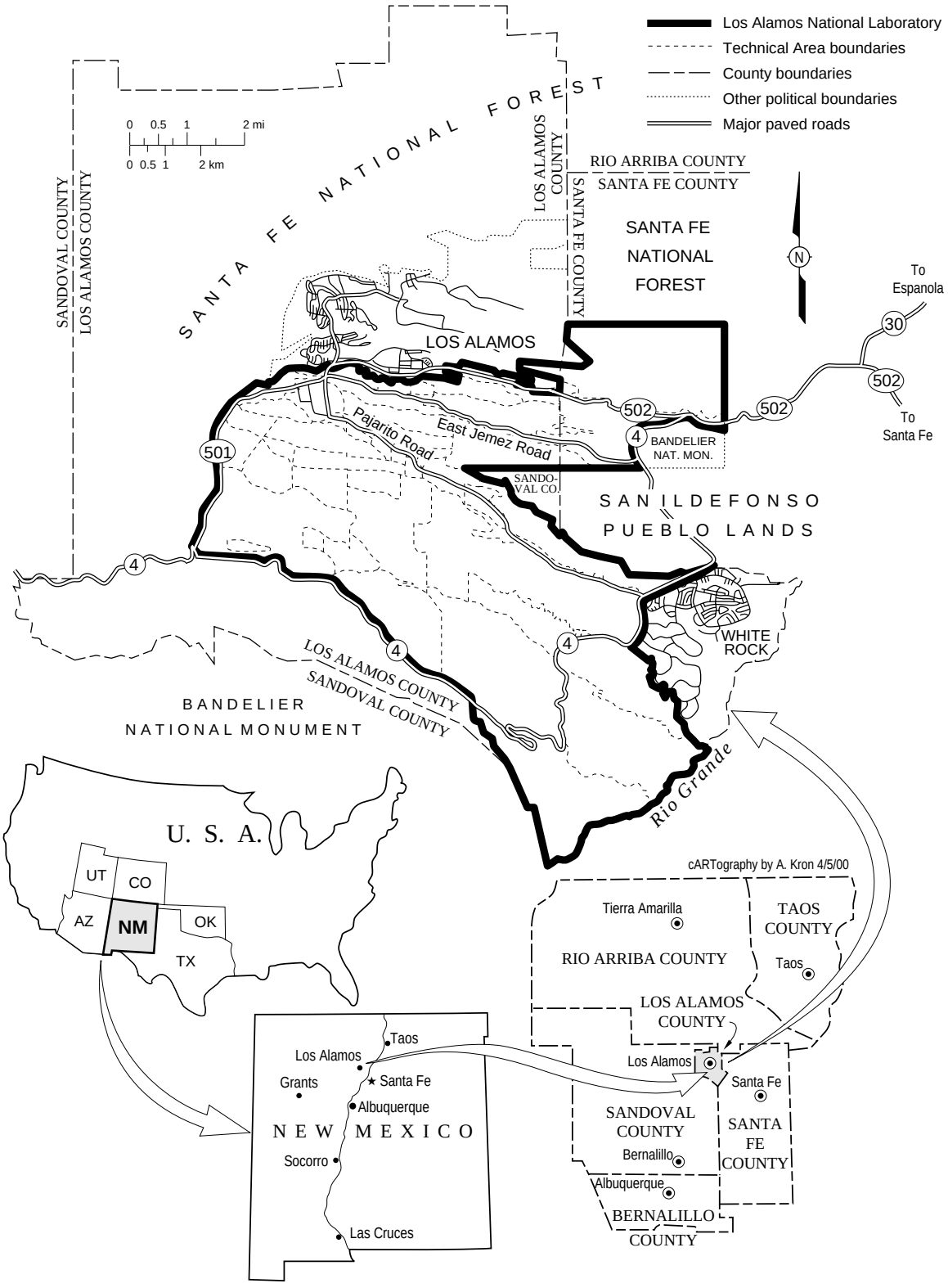


Figure 1-1. Regional location of Los Alamos National Laboratory.

2.0 Brief Climatology of the Pajarito Plateau

The Pajarito Plateau has a temperate, semiarid mountain climate that is largely influenced by elevation. Large temperature and precipitation differences are observed across the Laboratory because of the 1000-ft elevation change across the Pajarito Plateau. General information about the climate of the Laboratory area is provided in the annual environmental surveillance reports (e.g., Environmental Surveillance Program [2001]). Bowen (1990) provides detailed data compilations and extensive statistical summaries, including projected probabilities for climate. Much of the following summary of climate is from the LANL Weather Machine on the following Laboratory web site: http://weather.lanl.gov/. General weather conditions for Los Alamos and the Laboratory are reported from data collected at the meteorological tower located at TA-6.

Four distinct seasons occur on the Pajarito Plateau. Spring is usually windy and dry. Summer begins with warm, usually dry conditions in June, followed by a two-month rainy season in July and August when afternoon convection thunderstorms containing hail and lightning are common. Autumn is the end of the rainy season when the climate returns to drier, cooler, and calmer weather. Winters are generally mild with occasional winter storms that contain large snows and cause frigid temperatures. Mid-latitude winter storms drop far enough to the south to keep the ground covered with snow for about two months each winter.

Meteorological variables at LANL are measured at five towers located on the Pajarito Plateau. Four of the towers are located on mesas and one tower is located in Los Alamos Canyon, which is one of the larger canyons on the plateau. The meteorological observation stations and information about the stations are listed in Table 2-1. A sixth tower was recently installed on Pajarito Mountain to help predict wind shifts across the plateau below.

Data collected at the observation stations include wind, temperature, pressure, relative humidity and dew point, and solar and terrestrial radiation. Wind variables are measured at different heights above ground levels on the meteorological towers, including 37.5 ft, 75 ft, and 150 ft, and at the TA-6 tower at 300 ft. The atmospheric state variables, precipitation, and radiative energy fluxes are measured at 5 ft above the ground surface. The data are obtained through direct measurement or calculation from most sites every 15 minutes, and some variables such as precipitation are totaled for each 24-hr period (Baars et al. 1998).

In addition to the period of record available for the active stations listed in Table 2-1, precipitation data are available from meteorological stations located at Bandelier National Monument. Data from two sites in particular—Cerro Grande, located in the Sierra de los Valles in the western part of the monument, and Frijolito, located near the park headquarters in the eastern part of the monument—were used in the construction of precipitation pattern figures in Appendix A. After the Cerro Grande Fire in May 2000, nine remote automated weather stations (RAWS) were installed in the Sierra de los Valles north and west of Los Alamos. RAWS locations are shown in figures in Appendix A. Data from these weather stations were also used in construction of figures in this document.

Table 2-2 lists the average daily climate variables for each of the active meteorological stations at the Laboratory. The highest average daily wind speed is recorded at TA-49, and the lowest average wind speed is at TA-41 in Los Alamos Canyon. The highest average daily maximum temperature is recorded at TA-54, and the lowest minimum temperature is recorded at TA-41. The highest average annual precipitation is at TA-6, and the lowest average annual precipitation is at TA-54. The average surface soil moisture (0- to 3-in. depth) is highest at TA-6 (25.65%), but the highest average soil moisture to a depth of 6 in. is at TA-54.

Table 2-1. Meteorological Observation Stations at Los Alamos National Laboratory.

Station Name	Location	Elevation (ft)	Period of Record	Comment
Meteorological Towers				
TA-6	South of TA-3, upper Pajarito Plateau	7424	2/90 to present	Official meteorological station for LANL and Los Alamos
TA-41	Los Alamos Canyon south of town site	6914	11/93 to present	Provides information about meteorology in the canyons
TA-49	Frijoles Mesa	7045	6/87 to present	Provides information for Bandelier National Monument
TA-53	Los Alamos Neutron Science Center	6990	2/92 to present	
TA-54	MDA-G, White Rock	6548	1/92 to present	MDA-G observation station, previous station record at MDA-G from 1979 to 1992
Pajarito Mt.	Pajarito Mountain	10360	8/97 to present	Installed in 1994, reconfigured in 1997
SODAR	TA-6	7414	2/90 to present	Sound detection and ranging
Precipitation-Only Stations				
TA-16	S-Site	7635	1/77 to present	Precipitation measurement
TA-74	State Road (SR) 4/ SR 501 Intersection	6370	7/81 to present	Near Test Well 1 in Pueblo Canyon
North Community	Los Alamos town site	7420	1/86 to present	Northwest side of Los Alamos

Adapted from Baars et al. (1998) p. 7-8.

Table 2-2. Average Daily Climate Variables at LANL Meteorological Stations.

	Units	TA-6	TA-41	TA-49	TA-53	TA-54
Atmospheric Variables						
Average Wind Speed	m/s	2.49	1.66	3.16	2.90	2.74
Maximum Temperature	Degree-C	15.03	15.61	16.18	16.58	17.58
Minimum Temperature	Degree-C	1.77	0.66	3.44	4.36	0.99
Average Relative Humidity	%	50.83		47.30	49.02	52.01
Average Dew Point	Degree-C	-2.80			-2.05	-2.15
Average Precipitation	In./yr	19.69		18.68	15.97	14.57
Radiative Energy Variables						
Short Wave Irradiance (incoming)	mJ/m^2	18.87	14.49	19.14	18.94	19.23
Net Radiation	mJ/m^2	7.04				5.72
Sensible Heat Energy	mJ/m^2	3.23				5.45
Latent Heat Energy	mJ/m^2	2.32				0.99
Subsurface/Ground Variables						
Average Soil Moisture – 3 in.	%	25.65				12.32
Average Soil Moisture – 6 in.	%	29.84				31.02
Ground Heat Flux	mJ/m^2	0.85				0.15

Source: LANL Weather Machine

Several factors influence the temperature of the Pajarito Plateau, however, elevation is the primary influence; and at elevations of the mesas that are generally over 7000 ft, the plateau is cooler in the summer than nearby locations that are at lower elevation. The changes in elevation of the plateau are reflected in the sloping nature of the plateau and the configuration of the mesas and canyons, which combine to cause daily temperature changes. In the evening and at night, cooled air drains off the plateau and flows down the canyons; thus, nighttime temperatures on the mesas are often warmer than in the canyons and at lower elevations.

Another factor affecting the temperature is the lack of moisture in the atmosphere. With less moisture, there is less cloud cover, which allows a significant amount of solar heating during the daytime and radiative cooling during the nighttime. This heating and cooling often cause a wide range of daily temperatures, which averages 56^{o}F. July is the warmest month of the year with an average daily high of 81^{o}F. January is the coldest month when the temperatures range from an average daily high of 40^{o}F to a low of 17^{o}F.

Relative humidity varies considerably over daily periods, but monthly average values vary little during the year. Relative humidity ranges from a low of 39% in June to a high of 56% in December and averages 51% over the entire year. Absolute humidity ranges from a low of 2.4 g of water/m^3 of air in January to a high of 8.7 g/m^3 in July and August, when moist subtropical air invades the region during the rainy season. Fog in the Pajarito Plateau area is very rare, occurring less than five times a year on average.

The average annual precipitation from rainfall and the water-equivalent from frozen precipitation is 18.7 in. However, the annual total fluctuates considerably from year to year, with the standard deviation of the fluctuation being 4.8 in. The lowest recorded annual precipitation is 6.8 in., and the highest is 30.3 in. The maximum precipitation recorded for a 24-h period is 3.5 in., and the maximum 15-minute precipitation in the period of record is 0.9 in.

Because of the eastward slope of the Pajarito Plateau terrain, there is a large east-to-west gradient in precipitation across the plateau. White Rock often receives 5.1 in. less annual precipitation than does the official observing station at TA-6, and the eastern flanks of the Sierra de los Valles often receive an equivalent amount of additional precipitation. About 36% of the annual precipitation is received during the July and August rainy season.

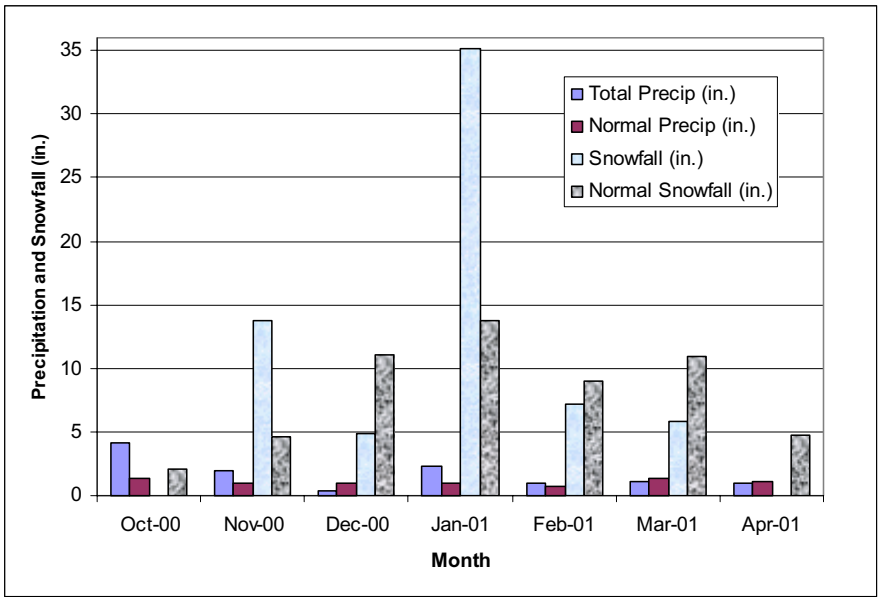
The Pajarito Plateau experiences on average 61 thunderstorm days each year, about twice the national average. Lightning and hail frequently accompany the thunderstorms. Hailstones 0.25 in. in diameter are common, and stones as large as 1 in. have been reported. Hail has caused significant damage to property and vegetation and localized accumulations of 3 in. have been observed.

Winter precipitation occurs mostly as snow. The snow is generally dry with, on average, 20 units of snow equivalent to one unit of water. The annual snowfall averages 59 in., but, from year to year, the amount of snow is quite variable. The standard deviation of annual snowfall is 28 in. The highest recorded snowfall for one season is 153 in., and the highest recorded snowfall for a 24-h period is 22 in. In a typical winter season there are 14 days containing snowfall exceeding 1 in. and 4 days of snowfall exceeding 4 in. The extreme single-storm snowfall on record is 48 in.

Wind conditions on the Pajarito Plateau are generally light, having an average annual wind speed of 5.5 mph. However, the windy period from mid-March to early June sustains wind speeds exceeding 8.8 mph 20% of the time during the daytime, and the daily maximum wind gust exceeds 31 mph about 20% of the time. The highest wind gust on record is 77 mph. High winds are associated with the passage of weather fronts, thunderstorms, and mid-latitude storm systems. Tornadoes have not touched the ground in the Pajarito Plateau area, however, funnel clouds have been observed in Los Alamos and Santa Fe Counties.

2.1 Precipitation in the Winter of 2000–2001

Northern New Mexico, as well as much of the Southwestern US, had been in a drought during 1999 and the early months of 2000. The total annual rainfall for 2000 recorded at the TA-6 meteorological station was 13.80 in., 73% of the normal annual precipitation of 18.95 in. However, precipitation in the fall and winter of 2000–2001 was above normal for most months. Figure 2-1 shows the pattern of total monthly precipitation and snowfall recorded at the TA-6 meteorological station during the winter of 2000–2001. Normal monthly snowfall and precipitation are also shown for comparison. Snowfall during the 2000–2001 season was 66.9 in., 115% of the seasonal normal snowfall of 58.2 in.



Source: http://Weather.lanl.gov

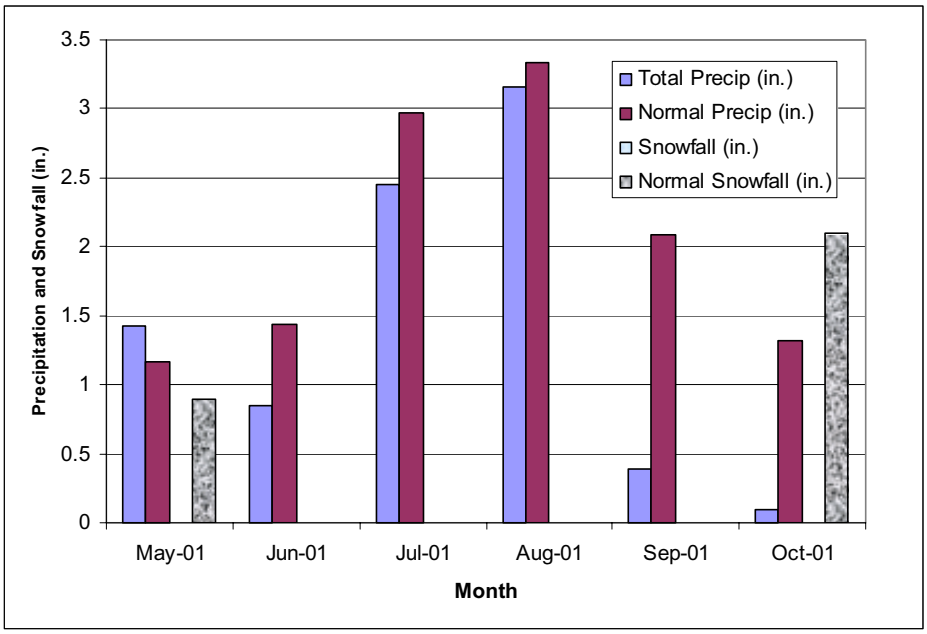
Figure 2-1. Total monthly precipitation and snowfall recorded at TA-6 October 2000 through April 2001.

Meteorological stations at LANL received above-normal precipitation during October and November 2000 and January and February 2001. Most other months had near-normal precipitation, except for December 2000, which had about 30% of normal precipitation. Snowfall was significantly above normal in November 2000 and January 2001 and less than normal for the other winter months. The winter snowpack for the 2000–2001 season was above normal, enabling the local Pajarito Mountain Ski Area to open on the Thanksgiving holiday weekend and remain open throughout the entire 2000–2001 winter season. The snowpack in the Jemez Mountains on March 6, 2001, was 104% of normal (NWS 2001a). However, an unusually warm and windy April allowed for significant sublimation of the snowpack, which, combined with normal melting, caused the snowpack in the Jemez Mountains to decrease to only 8% of normal by the beginning of May 2001.

With the increased moisture during the winter, the Palmer Drought Index for early May 2001 indicated that northern New Mexico was “Near Normal” with respect to drought condition (Palmer Index between -1.9 and +1.9) (NWS 2001b).

2.2 Precipitation in the 2001 Runoff Season

Figure 2-2 shows the total monthly precipitation and snowfall recorded at the official LANL TA-6 meteorological station from May through October 2001. Normal monthly precipitation and snowfall amounts are also shown for comparison.



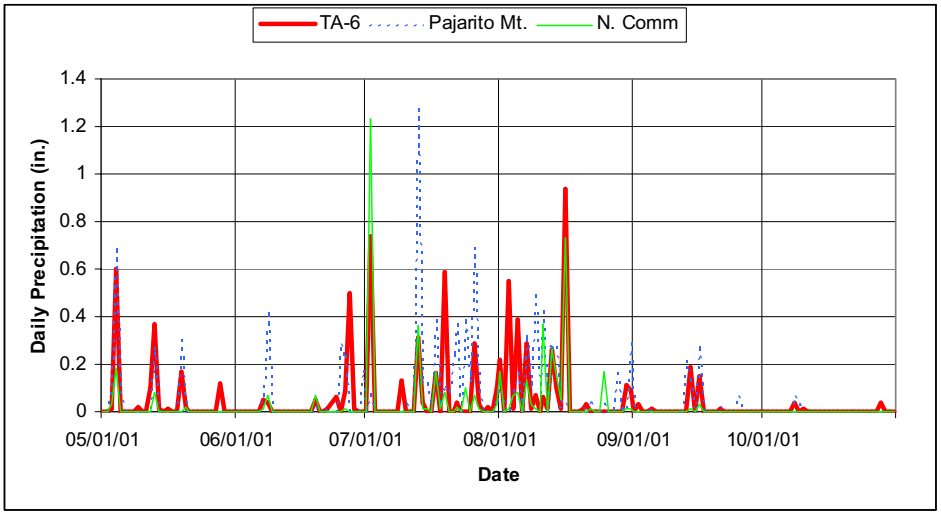
Source: **http://Weather.lanl.gov**

Figure 2-2. Total monthly precipitation recorded at TA-6 May through October 2001.

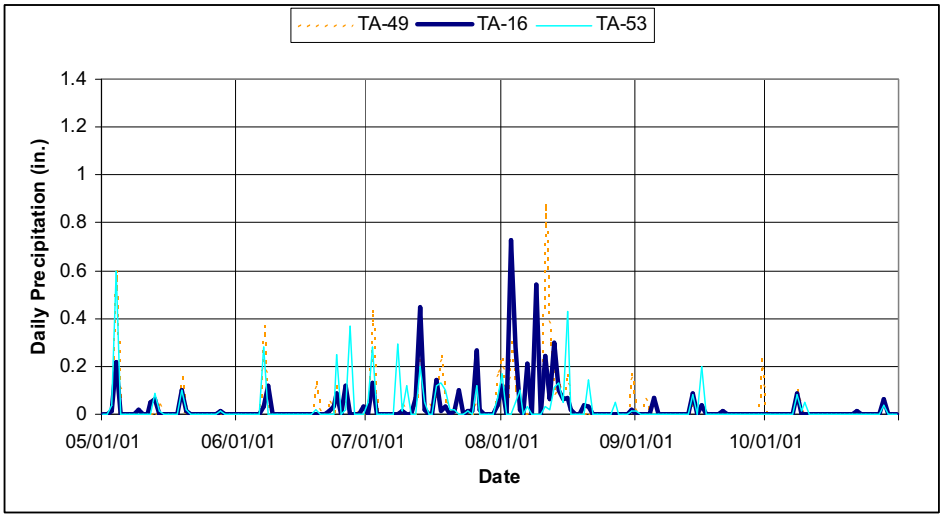
Precipitation received in May was 1.43 in., slightly above the average May precipitation of 1.17 in. Precipitation in all other months during the summer of 2001 was below normal. Precipitation in the months of June, July, September, and October was significantly below normal, with about 50% of normal precipitation received in June, 19% of normal precipitation received in September, and only 7% of normal precipitation in October. Precipitation in July and August was slightly below normal, when 82% and 95% of normal amounts were received, respectively.

Precipitation recorded at individual LANL meteorological stations from May 1 through October 31 is shown in Figures 2-3a, -3b, and -3c. These figures show the total daily precipitation recorded at stations north and west of LANL (Figure 2-3a: North Community, TA-6, and Pajarito Mountain stations), stations in the southern and central portions of LANL (Figure 2-3b: TA-16, TA-49, and TA-53), and stations in the eastern part of LANL (Figure 2-3c: TA-54 and TA-74). Precipitation isopleth maps in Appendix A show the pattern of precipitation received on the Pajarito Plateau on specific days when storm water runoff samples were collected. Further descriptions of individual precipitation events are in Section 3.

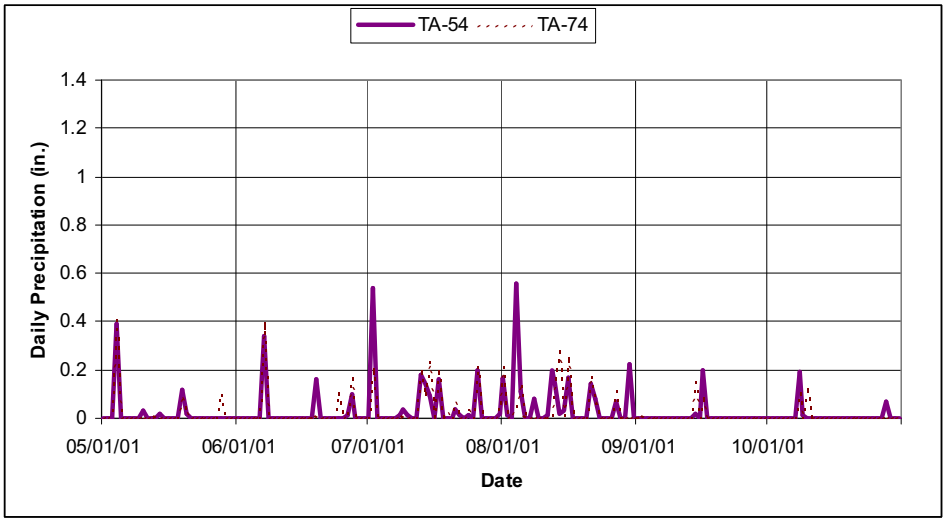
The general pattern of precipitation received on the Pajarito Plateau during the summer of 2001 can be interpreted from Figure 2-3. The higher precipitation amounts generally were received at the higher-elevation stations along the western part of the plateau and in the Sierra de los Valles (Figure 2-3a). The highest daily precipitation amount was recorded at Pajarito Mountain where 1.27 in. was received on July 13. The highest daily precipitation amount on the Pajarito Plateau was recorded in Los Alamos at the North Community gage where 1.23 in. was received on July 2, 2001. Except for isolated thunderstorms that occasionally impact portions of the Pajarito Plateau, lower precipitation amounts were generally received at meteorological stations in the middle and eastern parts of the Pajarito Plateau, with noticeably less precipitation occurring at the TA-74 station, which is the lowest elevation meteorological station and is located near the confluence of Pueblo and Los Alamos Canyons.



2-3a



2-3b



2-3c

Figure 2-3. Precipitation recorded at individual LANL meteorological stations, June 1 to October 31, 2000.

Most precipitation events in 2001 appear to have been thunderstorms that were relatively localized and brief in nature. These events are represented on Figure 2-3 by highly variable amounts of precipitation at different meteorological stations on a given day. During June, July, and August, thunderstorms likely occurred in response to diurnal heating of the ground causing localized thunderstorms to form, usually over higher terrain. Some precipitation events in early May and in August and September appear to have uniformly impacted meteorological stations on the Pajarito Plateau, which indicates a larger-scale precipitation event rather than a localized thunderstorm event.

In July of each year, the summer monsoon rains begin as tropical moisture moves northward into New Mexico from Mexico. Precipitation events in July and August are more numerous compared with those in June, September, and October and precipitation amounts tend to increase in July in response to the monsoon rains. In 2001, the highest precipitation recorded was in July and August at the meteorological stations located along the western part of the Pajarito Plateau. The highest amounts of precipitation occurred at Pajarito Mountain on July 13 (1.27 in.) and at North Community on July 2 (1.23 in.). Monsoon rains continued into mid-August, when precipitation events were usually spread across the entire Pajarito Plateau. In 2001, monsoon rains ended abruptly on August 16 and only light, scattered rains occurred during the second half of August, September, and October.

The most destructive precipitation and runoff event of 2001 occurred on July 2 when a short-duration (60-minute) relatively high-intensity thunderstorm occurred over the western part of the Los Alamos town site (see Appendix Figure A-4). Rainfall recorded at the North Community rain gage site was 1.23 in., and a private resident on Alabama Street in western Los Alamos reported a total rainfall of 1.75 in. (Los Alamos Monitor 2001). Although not historically significant rainfall amounts, the resulting runoff from the areas burned by the Cerro Grande Fire was significant and heavily impacted portions of Pueblo Canyon.

September and October were relatively dry months with no significant precipitation events. The highest precipitation in September was on September 16 at Pajarito Mountain where 0.27 in. was received. The highest precipitation in October was 0.19 in. at TA-54 on October 8. Less than 0.2 in. daily precipitation was received at other meteorological stations during these two months.

Lower-elevation meteorological stations at TA-54 and TA-74 recorded higher precipitation than did higher-elevation gages on a few days in 2001, including June 7, June 19, August 4, August 12, August 30, and October 8. Precipitation pattern maps (see Appendix A) show the different patterns of precipitation that occurred over the Pajarito Plateau in the summer of 2000.

3.0 Runoff Monitoring at Los Alamos National Laboratory

In 1991, LANL began regularly monitoring runoff from storm events on Laboratory property in Pueblo and Los Alamos Canyons. The number of monitoring locations (stream gages) was augmented from 1995 to 2000 and the stream gages were equipped with automated runoff samplers. By 2001, the sampling network comprised more than 70 sampling stations. Figure 3-1 shows the locations of the runoff sampling stations on the Pajarito Plateau. Runoff sampling at LANL is routinely performed to provide compliance with environmental permits and approvals (e.g., ESP 2000).

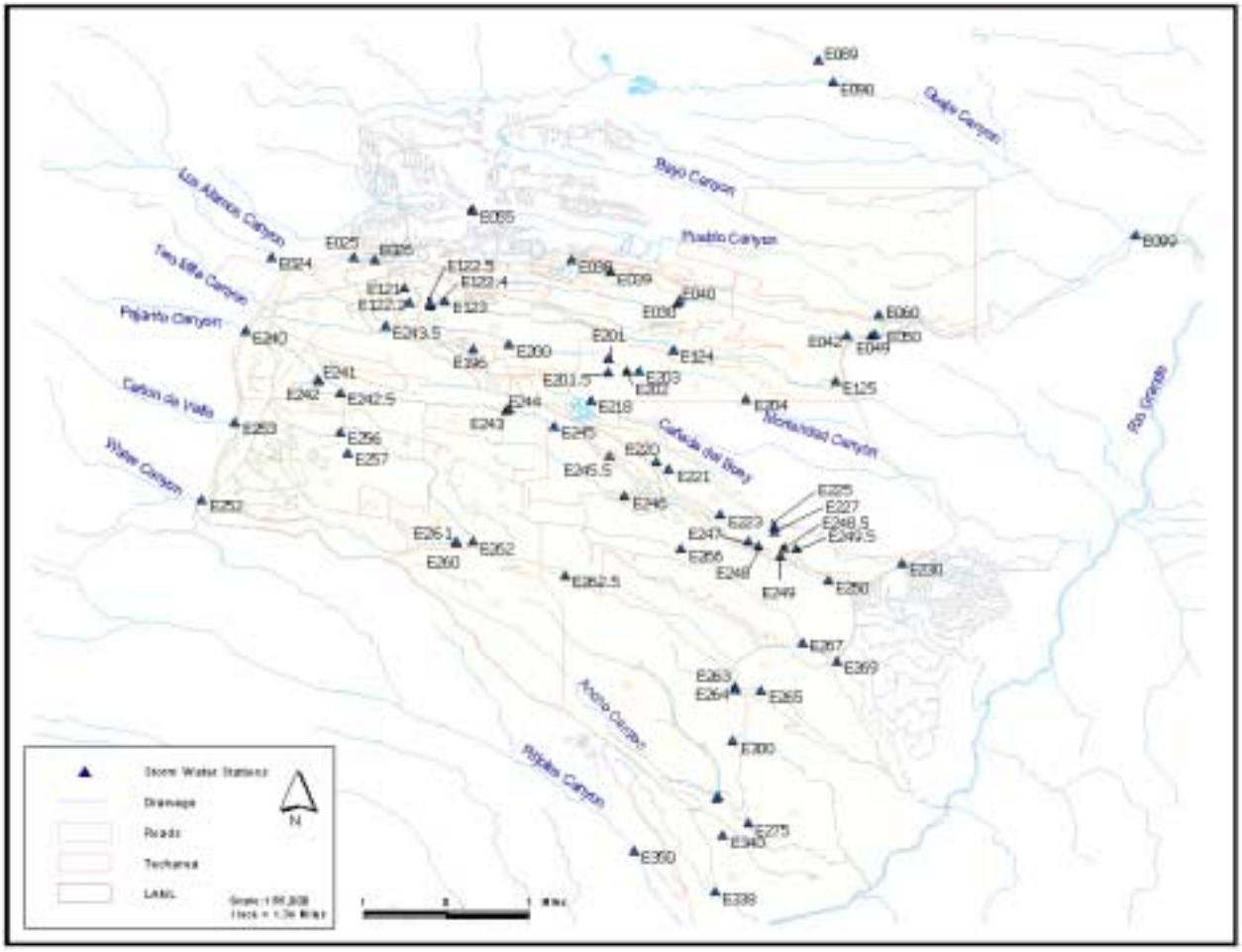


Figure 3-1. Runoff sampling stations on the Pajarito Plateau.

In 2000, LANL conducted an extensive environmental monitoring and sampling program to evaluate the effects of the Cerro Grande Fire at LANL and especially to evaluate if the Laboratory may have impacted public and worker health and the environment as a result of the fire (Koch et al. 2001, Gallaher et al. 2002). These monitoring and sampling activities continued throughout 2001 to evaluate the extended impacts from the fire and to monitor impacts to storm water from LANL operations. Snowmelt and storm water runoff sampling activities are conducted according to the *Institutional Monitoring and Sampling Plan for Evaluating Impacts of the Cerro Grande Fire* (LANL 2000) and according to the procedure for *Operation of Stream Gaging Stations and Collection of Storm Water Runoff Samples* (LANL 2001).

Using the automated flow monitoring stations and visual inspections of runoff conditions, LANL personnel collect samples at the following sites:

- upstream of LANL operational areas as storm water moves onto Laboratory property from the Sierra de los Valles,
- on LANL property at
    - specific mesa-top sites where LANL operations occur, and
    - in watercourses as storm water originates and moves through LANL,
- on the downstream side of the Laboratory near the eastern boundary, and
- in Rendija Canyon and Guaje Canyon north of LANL and downstream of historic LANL operations.

At times, runoff samples are also collected manually at specific locations where stream gages and automatic samplers are not located. These samples are designated as manual, or grab, runoff samples.

A list of the stream gage sampling stations and manual collection sites that were sampled during the 2000 season is in Table 3-1. This table shows the canyon where the sample collection sites are located, the common name of the collection site, and whether automated or manual runoff samples were collected at each site.

3.1 Snowmelt Runoff

Snowpack in the Jemez Mountains was above normal in early March 2001, but, by the first part of May (see Section 2.1), snowpack was significantly below normal. Above normal temperatures and winds in late March and April contributed to the demise of the snowpack, and, combined with the effects to soil and vegetation caused by the Cerro Grande Fire, contributed to higher than normal snowmelt runoff at LANL in 2001.

Stream gages in upper Pajarito Canyon, Cañon de Valle, and Water Canyon were destroyed by floodwaters during the June 28, 2000, flood event. These gages were replaced and/or repaired during the winter and spring of 2000–2001; however, these gages were not in operating condition at the beginning of the 2001 snowmelt runoff season, but were operating before the end of snowmelt runoff in the spring of 2001.

3.1.1 Snowmelt Runoff in 2001

Table 3-2 summarizes the snowmelt runoff characteristics at LANL in 2001, and Figures 3.1-1, 3.1-2, and 3.1-3 show the snowmelt hydrographs for gaging stations in Los Alamos and Pueblo Canyons, Pajarito Canyon, and Water Canyon and Cañon de Valle, respectively. Warmer than normal temperatures on March 20 and 21 caused the snowpack in the Jemez Mountains and on the Pajarito Plateau to begin melting and significant volumes of snowmelt runoff began flowing throughout the canyons on March 21. Small amounts of flow were present in upper Los Alamos Canyon (gage E025) and middle Pajarito Canyon (gage E245) and Three-mile Canyon (gage E246) before March 21 that was likely associated with discharge from springs and/or local snowmelt runoff.

Some stream gages, such as gage E030 in middle Los Alamos Canyon and gage E253 in upper Cañon de Valle, were apparently frozen at the beginning of snowmelt runoff and did not record the initial snowmelt runoff. Gages located at lower elevations, such as gage E042 in lower Los Alamos Canyon and gage E265 in lower Water Canyon, began registering the first local snowmelt runoff on March 8, but significant snowmelt runoff did not begin at the downstream gages until March 21. Gage E060 in lower Pueblo Canyon recorded flow from discharge from the Los Alamos County Sewage Treatment Plant but significant flow from snowmelt runoff did not extend to the gage in lower Pueblo Canyon (see Figure 3.1-1).

Table 3-1. Snowmelt and Storm Water Runoff Collection Sites at LANL in 2001.

Gage/ Site	Canyon	Location	Collection Method
E024	Los Alamos	Los Alamos Reservoir	Manual
E025	Los Alamos	Los Alamos Canyon above ice rink	Automated
E026	Los Alamos	Los Alamos Canyon below ice rink	Automated
E030	Los Alamos	Los Alamos Canyon above DP Canyon	Automated
E038	DP	DP Canyon above TA-21	Automated
DPS-1	DP	DP Canyon Site 1	Manual
E039	DP	DP Canyon below meadow at TA-21	Automated
E040	DP	DP Canyon above Los Alamos Canyon	Automated
E042	Los Alamos	Los Alamos Canyon above SR 4	Automated
E049	Los Alamos	Los Alamos Canyon Weir	Manual
E050	Los Alamos	Los Alamos Canyon below LA Weir	Automated
E055	Pueblo	Pueblo Canyon above Acid Canyon	Automated
E056	Acid	Acid Canyon above Pueblo Canyon (Acid Weir)	Automated
Pueblo 1R	Pueblo	Pueblo Canyon Site 1R	Manual
Pueblo 2	Pueblo	Pueblo Canyon Site 2	Manual
E060	Pueblo	Pueblo Canyon above SR 502	Automated
E089	Guaje	Guaje Canyon above Rendija Canyon	Automated
E090	Rendija	Rendija Canyon above Guaje Canyon	Automated
E099	Guaje	Guaje Canyon below SR 502	Automated
LA at RG	Los Alamos	Los Alamos Canyon at Rio Grande	Manual
E122.2	Sandia	Sandia Canyon tributary at Sigma Building	Automated
E122.4	Sandia	Sandia Canyon tributary at Motor Pool	Automated
E122.5	Sandia	Sandia Canyon tributary at Salvage Yard	Automated
E123	Sandia	Sandia Canyon below Wetlands	Automated
E125	Sandia	Sandia Canyon above SR 4	Automated
E196	Mortandad	Mortandad Canyon tributary at TA-55	Automated
E200	Mortandad	Mortandad Canyon at GS-1	Automated
E218	Cañada del Buey	Cañada del Buey at TA-46	Automated
E221	Cañada del Buey	TA-54 MDA-J	Automated
E223	Cañada del Buey	TA-54 below MDA-L	Automated
E227	Cañada del Buey	TA-54 MDA-G-6	Automated
E230	Cañada del Buey	Cañada del Buey above SR 4 at White Rock	Automated
E240	Pajarito	Pajarito Canyon above SR 501	Automated
E241	Pajarito	Pajarito Canyon at TA-22	Automated
E242	Pajarito	Starmers Gulch at TA-22	Automated
E245	Pajarito	Pajarito Canyon above TA-18	Automated
E246	Three-Mile	Three-Mile Canyon at TA-18	Automated
Pajarito Canyon	Pajarito	Pajarito Canyon below TA-18	Manual
E247	Pajarito	TA-54 MDA-G-1	Automated
E248	Pajarito	TA-54 MDA-G-2	Automated
E248.5	Pajarito	TA-54 MDA-G-3	Automated
E249.5	Pajarito	TA-54 MDA-G-4	Automated
E250	Pajarito	Pajarito Canyon above SR 4	Automated
E252	Water	Water Canyon above SR 501	Automated
E253	Cañon de Valle	Cañon de Valle above SR 501	Automated
E260	Water	Water Canyon above S-Site Canyon	Automated
E261	Water	S-Site Canyon above Water Canyon	Automated
E262	Cañon de Valle	Cañon de Valle above Water Canyon	Automated
Water at Beta	Water	Water Canyon at MDA-B	Manual
E262.5	Water	Water Canyon below MDA-AB	Automated
E263	Water	Water Canyon above SR 4	Automated
E264	Water	Indio Canyon at SR 4	Automated
E265	Water	Water Canyon below SR 4	Automated
E267	Potrillo	Potrillo Canyon above SR 4	Automated
E269	Potrillo	Potrillo Canyon tributary below SR 4	Automated
E273	Ancho	Ancho Canyon above SR 4	Automated
E275	Ancho	Ancho Canyon below SR 4	Automated
E300	Ancho	Ancho Canyon Spring below SR 4	Automated

Table 3-2. Summary of Snowmelt Runoff in 2001.

Canyon/Gage	Date Flow Began	Date of Peak Flow	Peak MD Flow (cfs)	Date Flow Ended	Flow Volume (ac-ft)	Drainage Area (mi^2)	Yield (ac-ft/mi^2)	Comment
Los Alamos Canyon								
E025	20-Feb	27-Mar	5.1	30-May	331	7.12	46.4	Spring-fed reach
E026	21-Mar	27-Mar	4.8	31-May	328	7.20	45.6	Estimated record from E025
E030	21-Mar	27-Mar	5.1	30-May	392	8.58	45.6	Frozen until Mar 23
E042	07-Mar	25-Mar	5.2	29-May	385	9.08	42.3	Peak on 5/4 aided by storm runoff
Pajarito Canyon								
E240	N/A	N/A	N/A	22-May	75**	1.90	39.2	Gage setup May 8, partial record
E245	15-Feb	23-Mar	4.5	19-Jun	123	7.84	15.6	Spring-fed reach at times
E246	10-Mar	22-Mar	0.6	18-Apr	11.7	1.53	7.6	Three-mile Canyon
E250	21-Mar	23-Mar	3.1	24-May	83	10.9	7.6	
Water Canyon – Cañon de Valle								
E252	N/A	N/A	N/A	23-May	86**	3.39	25.4	Gage setup Apr 18, partial record
E253	28-Mar	04-Apr	0.7	07-May	30.1	2.46	12.3	Frozen until Mar 28, partial record
E265	08-Mar	26-Mar	3.3	13-Apr	63.3	13.0	4.9	

*MD Flow = mean daily flow; cfs = cubic feet per second; N/A = not available; ** Estimated flow data
Drainage area data from Shaull et al. 2002.

The total seasonal snowmelt runoff (in acre-feet) at each gage is shown in Table 3-2. Los Alamos Canyon had significantly more snowmelt runoff than other canyons. Approximately 390 ac-ft of snowmelt runoff passed through middle Los Alamos Canyon at LANL, about three times more than in middle Pajarito Canyon, where 123 ac-ft passed through gage E245. The increased snowmelt runoff in Los Alamos Canyon is probably the result of a larger watershed area at higher elevations (see Table 3-2).

When the major snowmelt runoff began in Los Alamos Canyon on March 21, flow was similar at each gaging station in the canyon until about mid-April when local snowmelt caused increased runoff at the middle and downstream stations, after which, flows at gage E042 more closely matched flows at gage E030 for a time. After May 8, flow at gage E042 was less than flow at the upstream gages, probably resulting from streambed thawing and infiltration and/or evapotranspiration of some flow in the lower reaches of Los Alamos Canyon. Several increases in runoff in Los Alamos Canyon were from small precipitation events that occurred on April 5 and May 4 and 13 that appear to have temporarily increased flow more at the downstream gage than at the upstream gages (see Figure 3.1-1). The total snowmelt runoff from DP Canyon (gage E040) was about 1.3 ac-ft. Snowmelt runoff ceased at the downstream gage (E042) on May 29 and at the middle and upstream gages (E030 and E025) on May 30.

Snowmelt runoff in Pajarito Canyon (Figure 3.1-2) was measured primarily at gages E245 in the middle part of the canyon and gage E250 in the lower canyon. The upstream gage (E240) was not operational until May 8; the snowmelt runoff for this gage before May 8 is estimated. A total of 123 ac-ft of runoff passed through gage E245 and a total of about 83 ac-ft passed through gage E250, indicating that about 40 ac-ft were either lost to evapotranspiration or infiltration in the middle and lower reaches of Pajarito Canyon. Snowmelt runoff ceased at the upstream gage E240 on May 22 and at downstream gage E250 on May 24. Snowmelt runoff at the middle-canyon gage E245 lasted until about May 30; however, a small amount of flow continued at this gage until June 19, likely supported by springs. Gage E242, located in lower Starmers Gulch, records flow from several springs. Base flow at gage E242 before snowmelt runoff began was about 0.15 cubic feet per second (cfs), which increased to a maximum mean daily flow of 0.36

cfs on March 21 during snowmelt runoff. Flow at gage E242 returned to base-flow conditions during the last week of April.

Snowmelt runoff in Water Canyon (Figure 3.1-3) began at gage E253 in upper Cañon de Valle on March 28, about one week after snowmelt runoff began in other canyons; this gage may have been frozen before March 28. Gage E252 in upper Water Canyon was not operational until April 18 and did not record the beginning of the snowmelt runoff; most snowmelt runoff for this gage has been estimated. Gage E265 in lower Water Canyon recorded a small amount of local snowmelt runoff on March 8 and 17 but the major runoff from upstream areas began on March 21 and ended on April 13. Total snowmelt runoff at gage E265 was 63 ac-ft. Flow ceased in upper Cañon de Valle (gage E253) on May 7, and in upper Water Canyon (gage E252) on May 23. Total runoff at gage E253 was about 30 ac-ft, and the estimated runoff at gage E252 was about 86 ac-ft.

Figure 3.1-4 shows the total snowmelt runoff at upstream and downstream gages in each canyon system at LANL and the total runoff for all upstream and downstream LANL gages. The runoff data for each gage are shown in Table 3-2. About 570 ac-ft of snowmelt runoff entered LANL at upstream locations, and about 531 ac-ft of snowmelt runoff flowed downstream from LANL, indicating that overall, about 39 ac-ft of runoff was lost to infiltration or evapotranspiration at LANL. The best record of data is from Los Alamos Canyon where about 331 ac-ft of runoff occurred at the upstream gage (E025) and about 385 ac-ft of runoff flowed downstream (gage E042), indicating that about 54 ac-ft of snowmelt runoff originated on LANL within the Los Alamos Canyon watershed. (About 1 ac-ft of snowmelt runoff occurred from March 17 until April 26 in lower DP Canyon at gage E040). Snowmelt runoff at the upstream gages in the Pajarito Canyon and Water Canyon/Cañon de Valle watersheds was greater than at the downstream gages. In these canyons, a combined total of 93 ac-ft of snowmelt runoff was lost to infiltration and/or evapotranspiration.

The snowmelt runoff yield was calculated for each gage by dividing the total runoff in ac-ft by the watershed area in square miles (mi^2). The yield for each gage is shown in Table 3-2 and in Figure 3.1-5. In Los Alamos Canyon, the yield ranged from 42 ac-ft/mi^2 at gage E042 to 46 ac-ft/mi^2 at gage E025. The decrease in yield at the downstream gage may be attributed to less snowfall at lower elevations and infiltration and/or evapotranspiration of runoff in the lower reaches of the canyon.

In Pajarito Canyon, the yield at gage E240 was estimated to be 39 ac-ft/mi^2, at gage E245 in the middle part of the canyon the yield was 15.6 ac-ft/mi^2, where runoff is augmented by spring discharge. The yield at gage E246 in lower Three-mile Canyon was 7.6 ac-ft/mi^2, similar to the yield at gage E250 in lower Pajarito Canyon, which was 7.6 ac-ft/mi^2. The lower yield at the downstream location is likely the result of infiltration and evapotranspiration in the lower reaches of Pajarito Canyon. Gage E240 in the upper part of the canyon did not begin recording flow until May 8 near the end of snowmelt runoff; the estimated yield was 39.2 ac-ft/mi^2.

The yield at gage E253 in upper Cañon de Valle was 12.3 ac-ft/mi^2, the upper Water Canyon gage E252 did not record most snowmelt runoff; the estimated yield was 25.4 ac-ft/mi^2. The yield at gage E265 in lower Water Canyon was 4.9 ac-ft/mi^2.

The higher snowmelt runoff yields observed in the Los Alamos Canyon watershed may result from differences in snowpack conditions, canyon morphology, burn severity from the Cerro Grande Fire, and watershed management practices (retention structures, etc.). The Los Alamos Canyon Reservoir in upper Los Alamos Canyon temporarily retains some runoff, but is not expected to contribute to increased snowmelt runoff and yield.

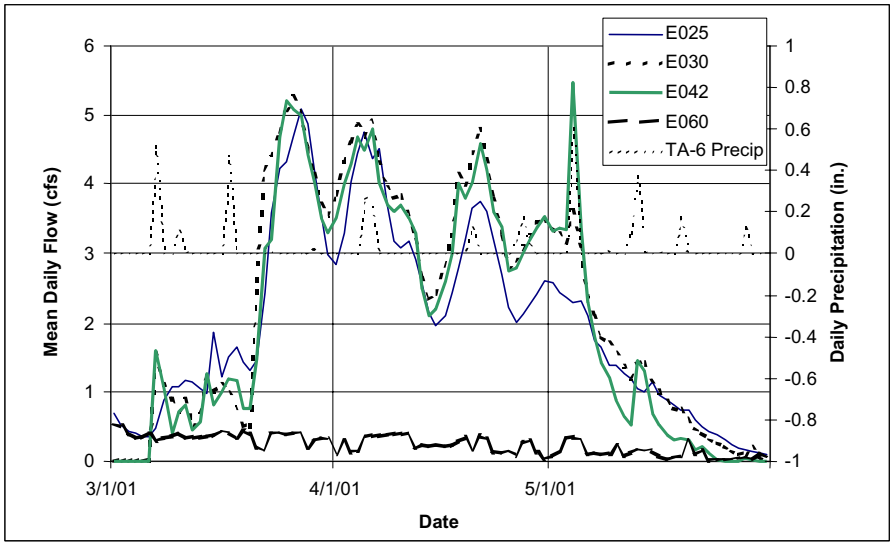


Figure 3.1-1. Snowmelt runoff in Los Alamos and Pueblo Canyons in 2001.

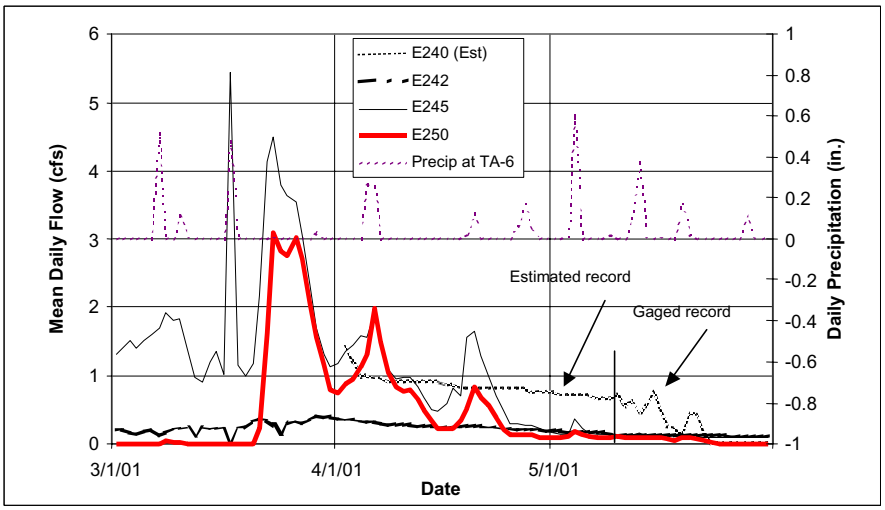


Figure 3.1-2. Snowmelt runoff in Pajarito Canyon in 2001.

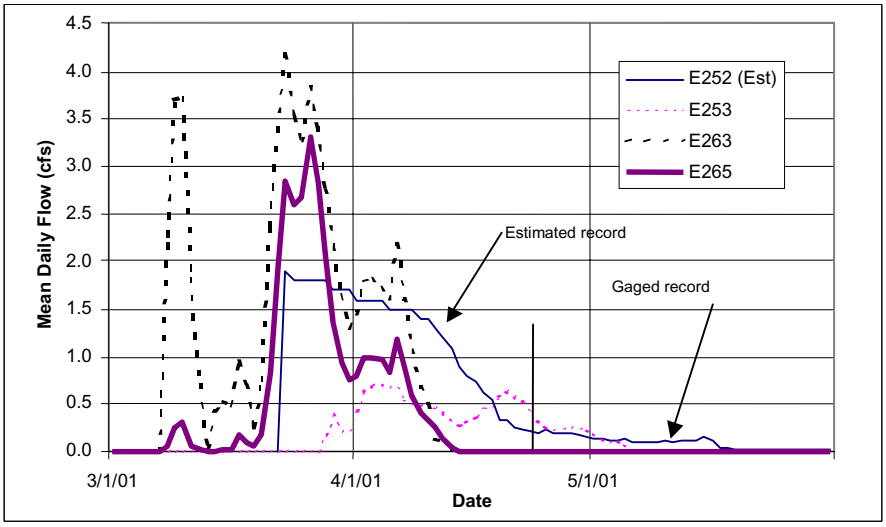


Figure 3.1-3. Snowmelt runoff in Water Canyon and Cañon de Valle in 2001.

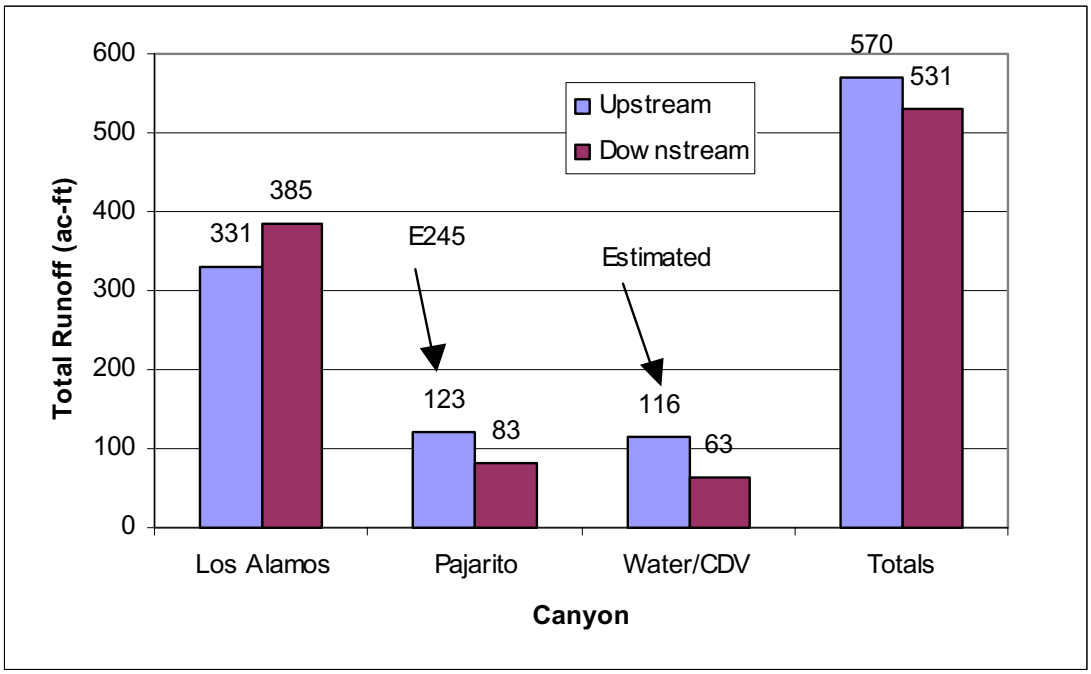


Figure 3.1-4. Total snowmelt runoff at upstream and downstream locations.

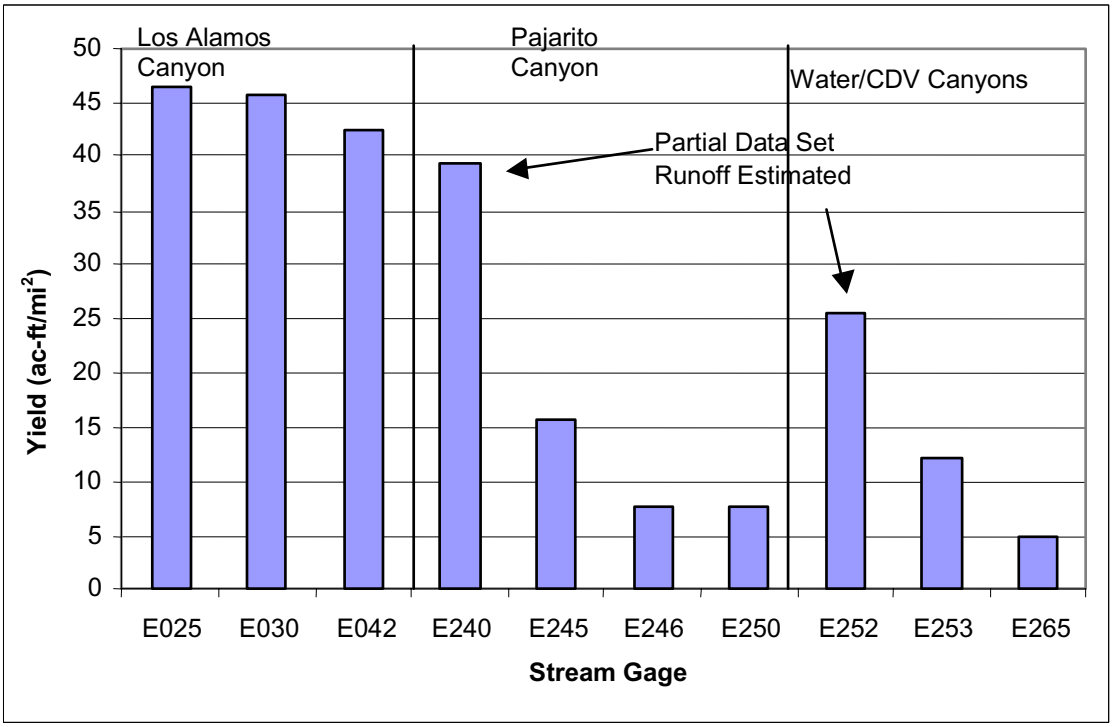
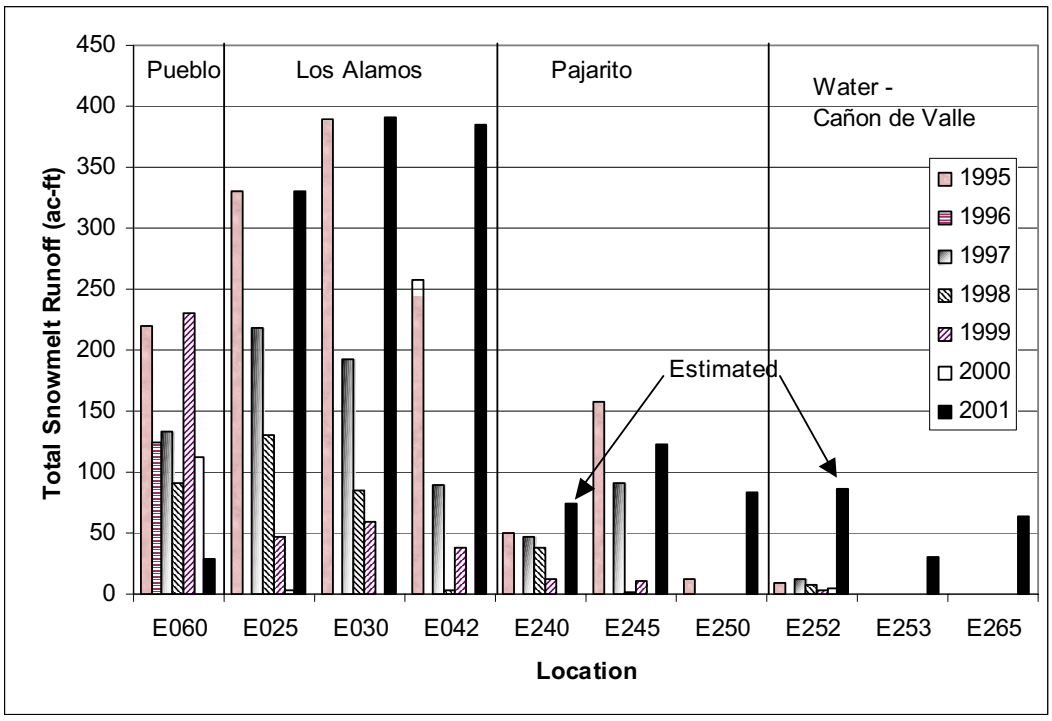


Figure 3.1-5. Snowmelt runoff yield at LANL gages.

3.1.2 Historical Snowmelt Runoff at LANL

Figure 3.1-6 shows the total snowmelt runoff measured at gaging stations in Pueblo, Los Alamos, Pajarito, and Water Canyons in the months of March, April, and May from 1995 through 2001. The most snowmelt runoff has typically been in Los Alamos Canyon where runoff in previous years at gage E042 ranged from 0 ac-ft in 1996 to 257 ac-ft in 1995, primarily the consequence of the amount of snowfall and snowpack during the previous winter. The highest volume of snowmelt runoff observed in Los Alamos Canyon before 2001 was in 1997 when 331 ac-ft passed through gage E025, 389 ac-ft through gage E030, and 257 ac-ft through gage E042. Snowmelt runoff in Los Alamos Canyon in 2001 was 331 ac-ft at gage E025, 392 ac-ft at gage E030 (both similar to runoff in 1995), and 385 ac-ft at gage E042, about 1.5 times higher than previously recorded. Runoff in lower Pueblo Canyon at gage E060 is primarily from discharge from the Los Alamos County Sewage Treatment Plant; in 2001, snowmelt runoff was not evident at this gage (see Figure 3.1-1).



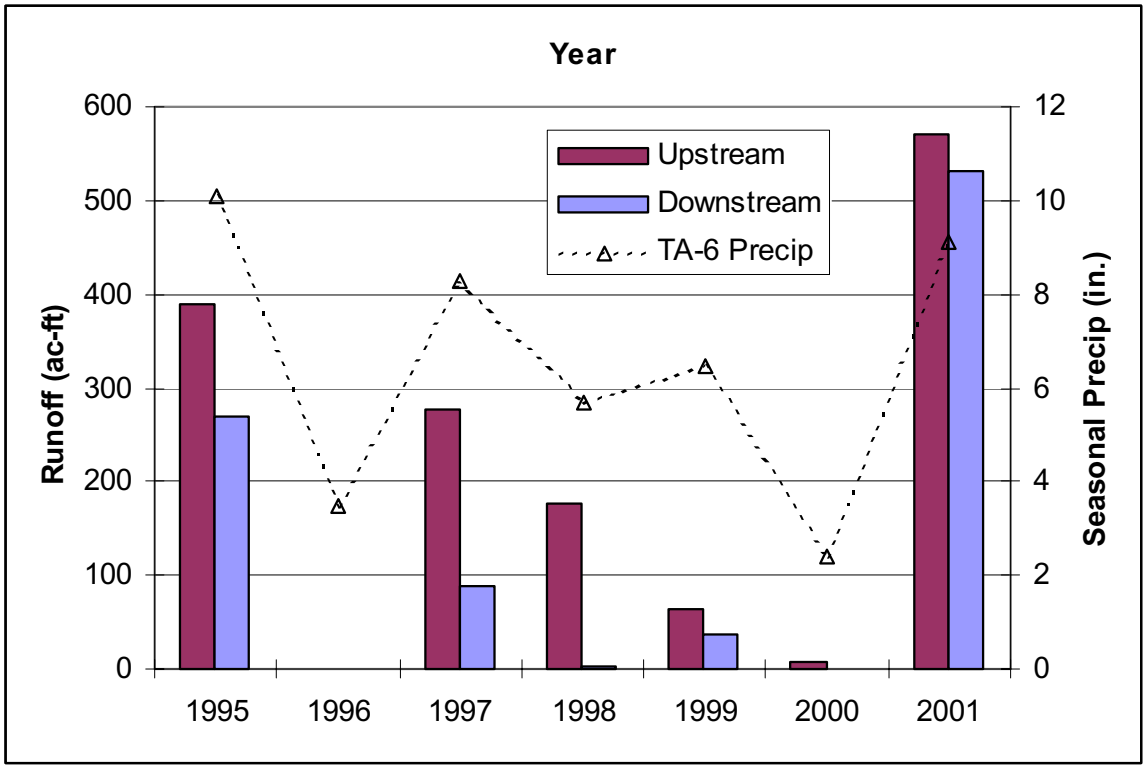
Data from Shaull et al. 1996a, 1996b, 1998, 1999, 2000, 2001, and 2002.

Figure 3.1-6. Snowmelt runoff in 2001 compared with previous years.

The estimated snowmelt runoff at the upstream gage (E240) in Pajarito Canyon in 2001 was 75 ac-ft, 1.5 times higher than the historic high runoff of 50 ac-ft observed in 1995 and 1997. Runoff in middle Pajarito Canyon at gage E245 was 123 ac-ft, less than the historic high runoff of 158 ac-ft in 1995 (runoff at E245 could be impacted by the Pajarito Canyon Retention Structure). Snowmelt runoff at gage E250 in 2001 was 83 ac-ft, significantly higher than the previous maximum snowmelt runoff (12.1 ac-ft) recorded in 1995.

Snowmelt runoff in upper Cañon de Valle at gage E253 had not previously been observed, but in 2001 the runoff was 30 ac-ft. The estimated runoff at gage E252 in upper Water Canyon in 2001 was 86 ac-ft, about seven times higher than previously recorded (12.1 ac-ft) in 1997. Snowmelt runoff had not previously been observed at gage E265 in lower Water Canyon; in 2001, the snowmelt runoff at gage E265 was 63 ac-ft, significantly higher than previously observed.

Figure 3.1-7 shows the total annual snowmelt runoff at upstream and downstream gages at LANL (excluding gage E060 in lower Pueblo Canyon) and the November through May seasonal precipitation for each year. The snowmelt runoff in 2001 was significantly higher than observed during the previous six years of record. The previously high snowmelt runoff was in 1995 when runoff totaled 390 ac-ft at upstream gages and 269 ac-ft at downstream gages. The runoff in 2001 is about 1.5 times higher than previously observed at upstream gages and about two times higher than previously observed at downstream gages, although the seasonal precipitation in 2001 (9.1 in.) was about 10% less than that received in 1995 (10.1 in.). The increased snowmelt runoff in 2001 was likely due in part to the effects of the Cerro Grande Fire.



Data from Shaull et al. 1996a, 1996b, 1998, 1999, 2000, 2001, and 2002.

Figure 3.1-7. Historic total annual snowmelt runoff at upstream and downstream LANL gages.

3.1.3 Snowmelt Runoff Samples Collected in 2001

Table 3-3 summarizes the snowmelt runoff samples that were collected at LANL in 2001. A total of 44 samples were collected from 18 collection sites on eight days during the snowmelt runoff period. The samples collected on March 7 and 15 at upstream gages E025 and E252 are associated with early small volumes of snowmelt runoff (see Figures 3.1-1 and 3.1-3). The samples collected on March 20 at upstream gages in Los Alamos Canyon (E025), Pajarito Canyon (E240), and Water Canyon (E252) are the result of the first significant warming period and represent the initial phase of significant snowmelt runoff. Samples were collected at downstream gages in Los Alamos Canyon (E042 and E050), Pajarito Canyon (E250), and Water Canyon (E265) on March 21 when the first runoff from upstream snowpack areas arrived. Subsequent snowmelt runoff samples were collected from upstream and downstream locations at two-week intervals, on April 4, April 18, and May 2, where snowmelt runoff persisted. One sample was collected from Guaje Canyon above Rendija Canyon (E089) on April 18 (because this new gage was installed in 2001, flow records for this location are not available until mid-June).

Table 3-3. Dates and Locations of Snowmelt Runoff Samples Collected in 2001.

Sample Date	E025	E026	E030	E042	E050	DPS-1	Acid Weir	Pueblo 1 R	Pueblo 2	E089	LA at RG	E240	Pajarito Canyon	E250	E252	E253	Water at Beta	E265
07-Mar-01	X																	
15-Mar-01	X			X	X										X			
20-21-Mar-01	X			X	X							X		X	X			X
26-28-Mar-01			X	X		X					X							
03-04-Apr-01	X			X	X				X			X	X	X	X	X		X
11-Apr-01							X	X										
17-18-Apr-01		X		X	X					X		X		X	X	X	X	
02-May-01	X			X	X							X		X	X	X		

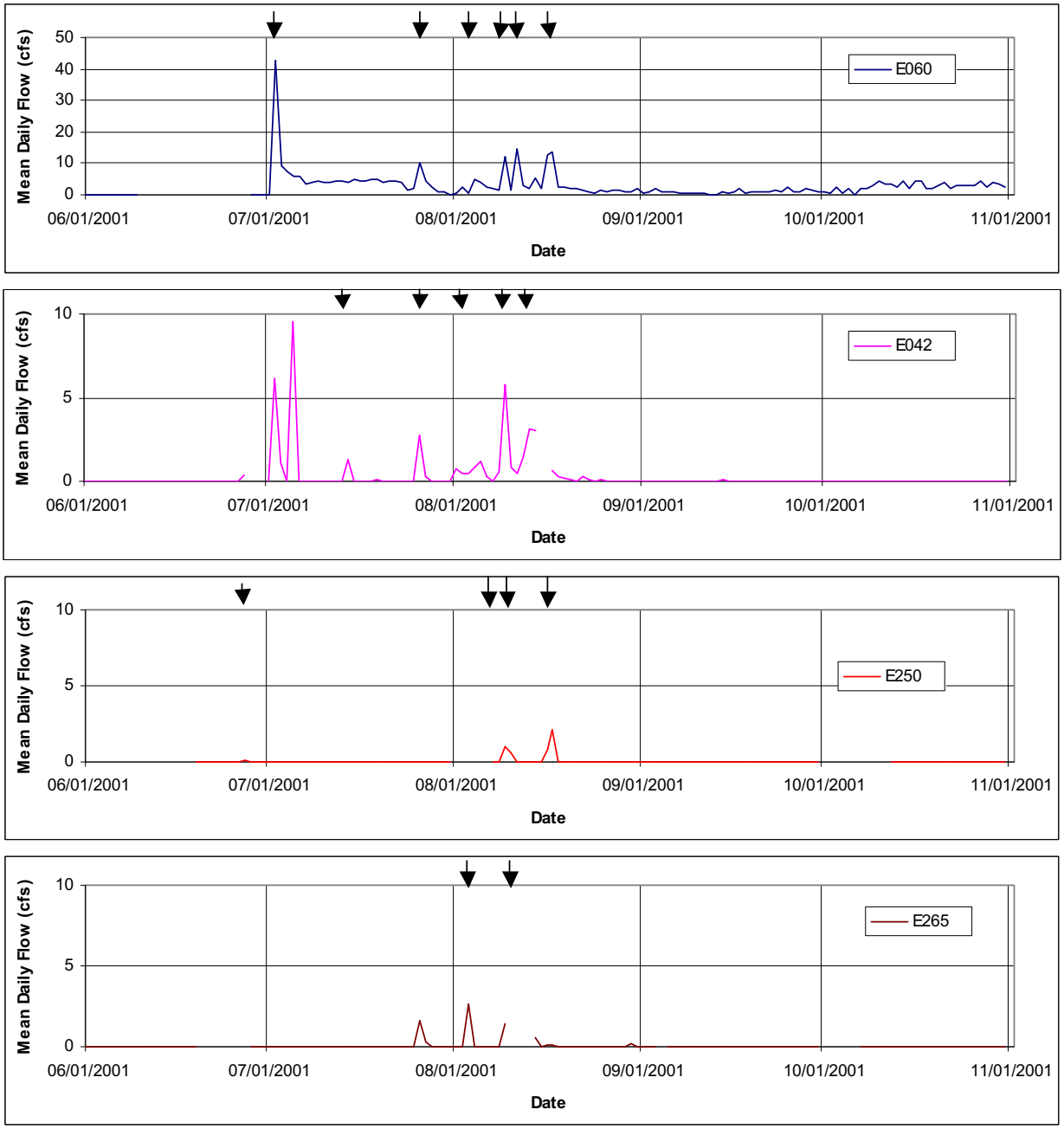
3.2 Storm Water Runoff

One of the notable effects of the Cerro Grande Fire was increased runoff from precipitation events during the summer of 2000. When thunderstorms occurred over the higher elevations of the Sierra de los Valles, runoff from burned slopes was significantly higher in canyons downstream of the precipitation than before the fire. Storm water runoff in 2000 after the Cerro Grande Fire was described by Shaull et al. (2001), Koch et al. (2001), and Gallaher et al. (2002). Generally, most storm water runoff events at LANL in 2001 were less intense than in 2000, partially due to below-normal amounts of precipitation during the summer thunderstorm season, and possibly due to partial recovery of fire-impacted areas in the watersheds. In 2001, however, record peak flows from fire-impacted areas occurred in Pueblo Canyon, Los Alamos Canyon, and Rendija Canyon, and the total volume of storm water runoff was higher than in 2000.

Stream gages in upper Pajarito Canyon, Cañon de Valle, and upper Water Canyon were destroyed by floodwaters on June 28, 2000. These gages were replaced and/or repaired and were in operating condition at the beginning of the 2001 storm water runoff season. Stream gages were also added north of Los Alamos in Rendija Canyon and Guaje Canyon. In 2001, storm water runoff was monitored at over 70 stream gage stations at LANL and runoff samples were collected from 34 automated samplers. Figure 3-1 shows the locations of the stream gage stations and Table 3-1 lists the gage stations where samples were collected in 2001. For the summary purposes and discussion in this report, the storm water runoff season is considered to be from June through October of each year.

3.2.1 Storm Water Runoff in 2001

Figure 3.2-1 shows the daily mean runoff at downstream gages at LANL during the storm water runoff season in 2001 (June through October), and indicates the runoff events where samples were collected. Storm water runoff in 2001 was primarily the result of monsoonal thunderstorms in July and August. Significant runoff events occurred from July 2 to August 16 and total fewer than 10 events. Very little precipitation and runoff occurred in June, the last two weeks of August, and in September and October in 2001.



Note scale change on E060 chart. Arrows indicate runoff events where storm water runoff samples were collected.

Figure 3.2-1. Mean daily storm water runoff at downstream stations at LANL in 2001.

The major storm water runoff event of 2001 occurred in Pueblo Canyon on July 2, 2001, when a flood event totaling about 90 ac-ft rushed through the canyon. This record high runoff event resulted from a 60-minute thunderstorm that occurred west of Los Alamos town site on the afternoon of July 02, 2001. Utility structures in Pueblo Canyon were extensively damaged by the runoff. Base flow in lower Pueblo Canyon at gage E060 is from discharge from the Los Alamos County Sewage Treatment Plant; base flow does not normally occur at other downstream gages at LANL, where flow is usually associated with runoff events.

Table 3-4 summarizes the storm water runoff at LANL in 2001 from June through October and historical runoff data for this period from previous years, and Figure 3.2-2 shows the volumes of storm water runoff at upstream (where present) and downstream gages in each canyon at LANL. The highest seasonal flow volume at any gage in 2001 was 721 ac-ft at gage E060 in lower Pueblo Canyon. However, most of this flow was from discharge from the Los Alamos County Sewage Treatment Plant rather than from storm water runoff, which in 2001 is estimated to be approximately 250 ac-ft or about 35% of the total flow in lower Pueblo Canyon.

Table 3-4. Summary of Storm Water Runoff (June through October) at LANL in 2001.

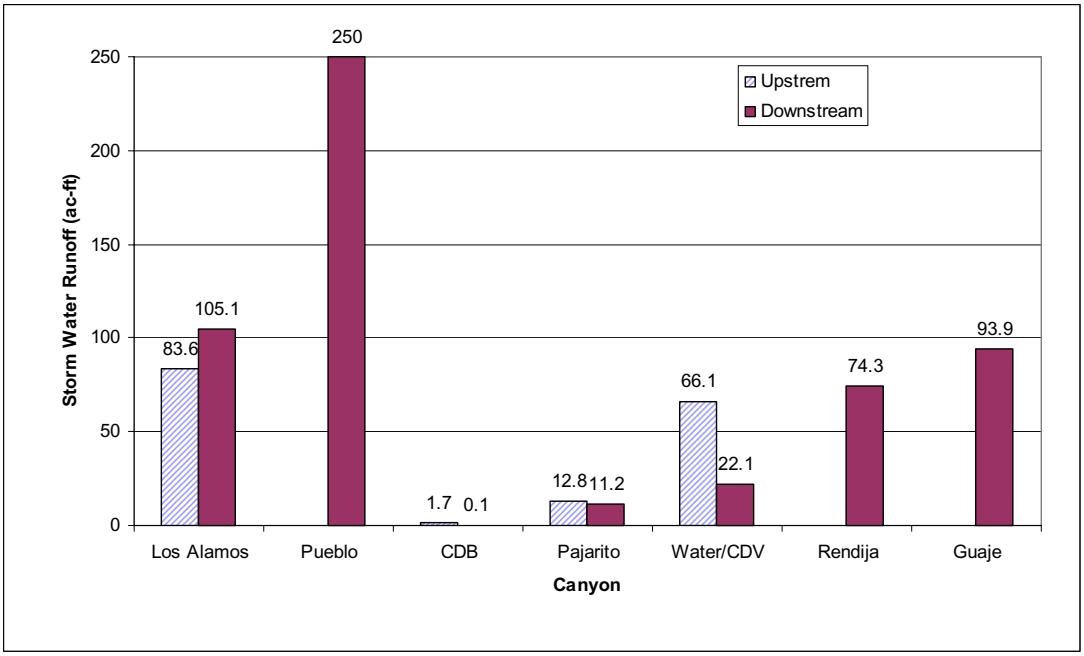
Canyon	Gage	1995–1999 Average Annual Runoff (ac-ft)	2000 Runoff Volume (ac-ft)	2001 Runoff Volume (ac-ft)	Drainage Area (mi^2)	2001 Storm Water Runoff Yield (ac-ft/mi^2)
Pueblo Canyon*	E060	51	71.8	250*	6.94	36
Guaje Canyon	E089	ND**	ND	74.3	14.6	5.1
Rendija Canyon	E090	ND**	ND	93.9	9.58	9.8
Los Alamos Canyon	E025/E026	48	137	83.6	7.12	11.7
	E030	35	56	46.9	8.58	5.5
	E042	40	51.7	105.1	9.08	11.6
Cañada del Buey	E230	12	4.7	0.12	2.14	0.1
Pajarito Canyon	E240	40	65.8	12.8	1.9	6.7
	E245	39		28.1	7.84	3.6
	E250	3.2	11.9	11.2	10.9	1.0
Potrillo Canyon	E267	2.1	5.5	0	2.25	0.0
Water Canyon/Cañon de Valle	E252	2.4	68.8	62.7***	3.39	18.5
	E253	0.0	59.3	3.4	2.46	1.4
	E265	0.4	90.8	22.1	13.0	1.7
Ancho Canyon	E275	6.0	12.0	0	4.55	0.0

*The total flow at gage E060 in lower Pueblo Canyon in 2001 was 721 ac-ft. Of this approximately 250 ac-ft or 35% is estimated to be storm water runoff, based on runoff being all flow >6 cfs. The majority of flow at gage E060 is discharge from the Los Alamos County Sewage Treatment Plant. Flow at other stream gages is predominantly storm water runoff. Historical data from 1995–1999 for E060 are estimated for runoff and do not represent total runoff at gage E060.
** ND = No Data.
*** Estimated runoff, base flow from spring discharge not included.

Total runoff at the downstream gage E042 in Los Alamos Canyon in 2001 was about 105 ac-ft, compared with 0.1 ac-ft in Cañada del Buey, 11.2 ac-ft at gage E250 in lower Pajarito Canyon, and 22.1 ac-ft at gage E265 in Water Canyon, for a total downstream runoff from LANL (excluding Pueblo Canyon) of approximately 138 ac-ft. The total storm water runoff from LANL, including Pueblo Canyon, was approximately 388 ac-ft. The runoff in lower Rendija Canyon was 94 ac-ft and, in Guaje Canyon above Rendija Canyon, the runoff was 74 ac-ft, for a total runoff of at least 168 ac-ft from the Guaje Canyon watershed.

Upstream gages were not operational the entire season in Pueblo Canyon and would have been overwhelmed or destroyed by the July 2 flood event. Approximately 90 ac-ft of runoff occurred as a result of the July 2 flood event in Pueblo Canyon (see Section 4.5). In Los Alamos Canyon about 84 ac-ft of runoff occurred at the upstream gage (E026) and about 8.1 ac-ft of runoff came from DP Canyon at gage E040.

The upstream gage in Pajarito Canyon (E240) was relocated downstream of SR 501 after the large flood event in June 2000 destroyed the gage. In 2001, gage E240 was operational throughout the storm water runoff period and recorded 12.8 ac-ft of storm water runoff. The downstream gage in Pajarito Canyon (E250) recorded 11.2 ac-ft of runoff.



Note: The total flow at gage E060 in lower Pueblo Canyon was 721 ac-ft. Of this approximately 250 ac-ft or 35% is estimated to be storm water runoff, based on runoff being flow >~6 cfs. The majority of flow at gage E060 is discharge from the Los Alamos County Sewage Treatment Plant. Flow at other downstream gages is predominantly storm water runoff.

Figure 3.2-2. Storm water runoff at upstream and downstream gages in canyons at LANL in 2001.

A total of 75.8 ac-ft of storm water runoff and spring base flow passed through the upstream gage in Water Canyon (gage E252), of which approximately 62.7 ac-ft was from runoff (base flow was approximately 0.1 cfs for approximately 13.1 ac-ft). Runoff in upper Cañon de Valle (gage E253) was 3.6 ac-ft, for a total of 66.3 ac-ft at the upstream Water Canyon/Cañon de Valle gages. Before the Cerro Grande Fire, most spring flow in upper Water Canyon seeped into the alluvium before reaching gage E252, but after the flood of June 28, 2000, much of the alluvium was scoured from the canyon floor, and in 2001 spring-supported flow was present much of the time at gage E252.

Storm water runoff at gage E265 in lower Water Canyon totaled approximately 22.1 ac-ft. No significant storm water runoff occurred in lower Potrillo Canyon (gage E267) or Ancho Canyon (gage E275) in 2001. Only one small runoff event totaling 0.1 ac-ft occurred at gage E230 in lower Cañada del Buey in 2001.

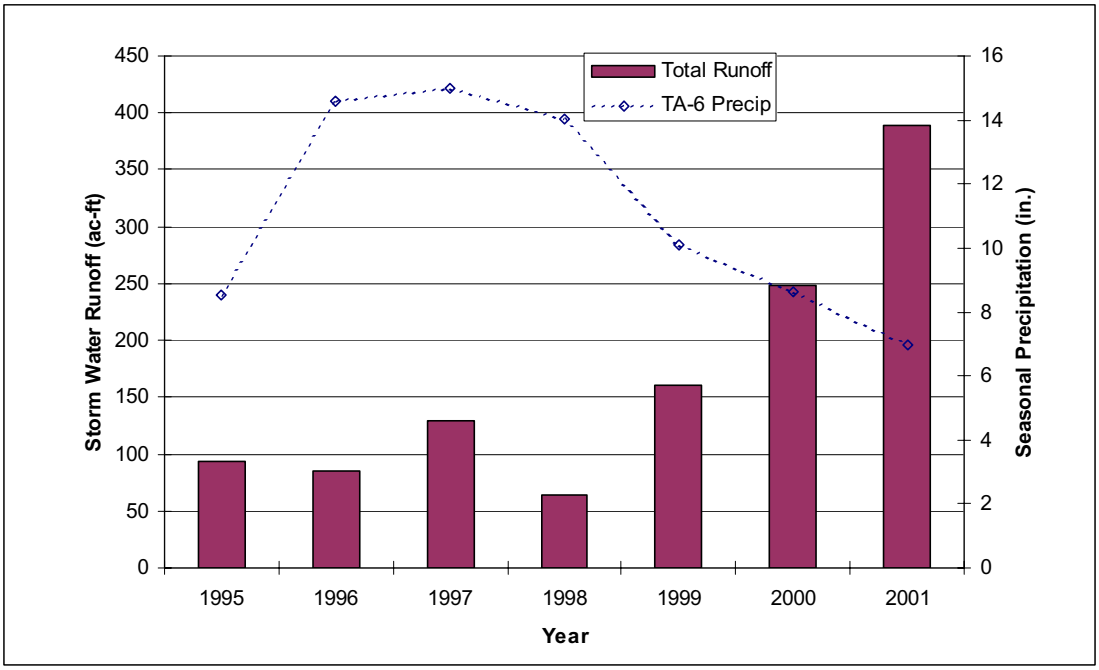
The summary of all storm water runoff events at LANL in 2001 is in Appendix B. The date and time of the beginning of the runoff event, the instantaneous peak flow in cfs, the time of the peak flow, the date and time of the end of the runoff event, the runoff volume, and the runoff yield are summarized for each significant runoff event in the Appendix B table.

3.2.2 Historical Storm Water Runoff at LANL

Figure 3.2-3 shows the seasonal storm water runoff measured at the downstream gages at LANL (including Pueblo Canyon) for the period 1995 through 2001. The seasonal storm water runoff for each year is the sum of runoff at each downstream gage from June 1 through October 31 of each year. Also

shown on Figure 3.2-3 is the seasonal precipitation received at the TA-6 meteorological station each year from June 1 through October 31. Because flow at gage E060 in lower Pueblo Canyon is primarily discharge from the Los Alamos County Sewage Treatment Plant, annual storm water runoff at this gage was estimated based on daily flow records that exceeded the running average of sewage treatment plant discharges, which is usually less than 6 cfs.

The total downstream runoff at LANL in 2001 was 388 ac-ft, significantly higher than in 2000, primarily due to the large runoff event in Pueblo Canyon on July 2, which comprised about 90 ac-ft. The total downstream runoff in 2001 was 1.5 times higher than the runoff in 2000 after the Cerro Grande Fire and about 3.6 times higher than the prefire average annual runoff (106 ac-ft), even though the seasonal precipitation in 2001 (6.94 in.) was less than received in 2000 and less than the prefire average seasonal precipitation (12.4 in.). For perspective, the largest runoff event in 2000 after the Cerro Grande Fire occurred on June 28, 2000, primarily in the upper reaches of Pajarito Canyon and Water Canyon. This runoff event produced much smaller volumes of runoff at downstream stations, only 2.75 ac-ft at gage E250 in Pajarito Canyon and 21.8 ac-ft at gage E265 in Water Canyon (Koch et al., 2001, p. 18).



Note: Downstream gages include E060, E042, E125, E230, E250, E265, E267, and E275.

Figure 3.2-3. Annual seasonal precipitation and storm water runoff at downstream gages at LANL.

Table 3-5 shows the peak flow data for the prefire period of record and the postfire years 2000 and 2001. Runoff data are shown for 14 stream gages, of which peak flows at five gages were higher in 2001 than in 2000 and historical peak flow records were set at four of the gages in 2001.

The peak flow at gage E060 on July 2, 2001, was 1440 cfs, significantly higher than the previous peak flow at E060 of 11 cfs, which was set on July 9, 1999. Peak flow records were established at two gages in Los Alamos Canyon on August 9, 2001, when the peak flow at gage E026 was 185 cfs and the peak flow at gage E030 was 59.6 cfs. The peak flow at gage E042 in lower Los Alamos Canyon on August 9 was 146 cfs, which did not surpass the historical peak flow of 171 cfs set on August 22, 1997. The peak flow at gage E250 in lower Pajarito Canyon in 2001 was 21.6 cfs on August 16, slightly higher than the historical record of 20 cfs set on June 17, 1999. The peak flow records established in Pueblo Canyon and Los Alamos Canyon in 2001 are primarily the result of localized thunderstorm events that occurred in fire-impacted upper watershed areas of each canyon (see Sections 4.5 and 4.14). The new gages installed in

Guaje Canyon (E089) and Rendija Canyon (E090) began operating in mid-June 2000. Peak runoff at these gages occurred on August 11 when the peak runoff in Guaje Canyon was 644 cfs and the peak runoff in Rendija Canyon was 2120 cfs, which established a new peak record for the Pajarito Plateau.

The ratio of peak flows recorded at each gage in 2001 to the peak flows recorded in 2000 is shown in Table 3-5. Peak flows in 2001 were higher at gages in Pueblo Canyon (E060), Los Alamos Canyon (E026, E030, and E042), and lower Pajarito Canyon (E250); all other peak flows in 2001 were less than in 2000. Table 3-5 also shows the ratio of peak flows recorded after the Cerro Grande Fire with those recorded before the fire. Most stations experienced higher peak flows after the fire, except for gage E042 in lower Los Alamos Canyon and gages in lower Potrillo Canyon (E267) and lower Ancho Canyon (E275), which are in watersheds that were not significantly impacted by the fire. The Los Alamos Canyon Reservoir in upper Los Alamos Canyon probably provides a buffer to runoff, reducing the impact of the fire to storm water runoff in Los Alamos Canyon.

Table 3-5. Peak Flows at LANL in Prefire and Postfire Years of 2000 and 2001.

		Prefire Peak		2000 Peak		2001 Peak		Peak Ratios		
Gage/Canyon	Period of Record Start	Date of Peak Flow	Peak Flow (cfs)	Date of Peak Flow	Peak Flow (cfs)	Date of Peak Flow	Peak Flow (cfs)	2001/ 2000	Postfire /Prefire peak	Comment
E025/E026 LA	10/1/93	5/4/95	10	7/18/00	60	8/9/01	185	3.1	18.5	
E030 LA	7/1/94	7/9/99	13	6/2/00	13	8/9/01	60	4.6	4.6	
E042 LA	10/1/91	8/22/97	171	6/2/00	17	8/9/01	146	8.6	0.9	
E060 Pueblo	1/1/92	7/9/99	11	10/24/00	139	7/2/01	1440	10.1	128.1	
E089 Guaje	6/14/01					8/11/01	644			Gage installed in 2001
E090 Rendija	6/19/01					8/11/01	2120			Gage installed in 2001
E230 CDB	10/1/91	6/17/99	210	8/9/00	33	8/4/01	5.8	0.2	0.2	
E240 Pajarito	10/1/93	6/21/64	2.4	6/28/00	1020	8/9/01	155	0.2	425.0	
E241 Pajarito	3/1/99	9/16/99	0.21	6/28/00	300	8/9/01	109	0.4	1428.6	
E245 Pajarito	11/1/93	8/17/97	30	6/28/00	517	6/27/01	141	0.3	17.2	
E250 Pajarito	11/1/93	6/17/99	20	6/28/00	14	8/16/01	22	1.5	1.1	
E252 Water	10/1/94	3/23/97	0.29	6/28/00	840	7/22/01	242	0.3	2896.6	
E253 CDV	10/1/94		0	6/28/00	740	8/9/01	19	0.0		No flow before fire
E265 Water	10/1/93	8/29/95	21	6/28/00	274	8/3/01	92	0.3	13.0	
E267 Potrillo	10/1/93	8/29/95	63	8/9/00	7	3/8/01	0.06	0.0	0.1	Snowmelt is peak in 2001
E275 Ancho	10/1/93	6/29/95	520	8/6/00	348	8/12/01	0.05	0.0	0.7	

Data from Shaull et al. 2000; Shaull et al. 2001; peak flow refers to instantaneous 5-minute peak flow.

Figure 3.2-4 shows the instantaneous peak flows observed at stream gages in 2000 and 2001 compared with prefire peak flow rates. In 2000, nine stream gages experienced record peak runoff, and in 2001, four gages (E060, E026, E030, and E250) experienced record peak runoff. The highest peak runoff observed in 2000 after the Cerro Grande Fire was 1020 cfs at gage E240 in upper Pajarito Canyon while other peak flows in 2000 ranged from 274 to 840 cfs. In 2001, peak flows at LANL were usually less than 200 cfs, except at gage E252 in upper Water Canyon, where the peak flow was 242 cfs, and at gage E060 in Pueblo Canyon, where the peak flow was 1440 cfs. Peak flows in 2001 at gage E089 in Guaje Canyon was 644 cfs, and the peak flow in Rendija Canyon at gage E090 was 2120 cfs.

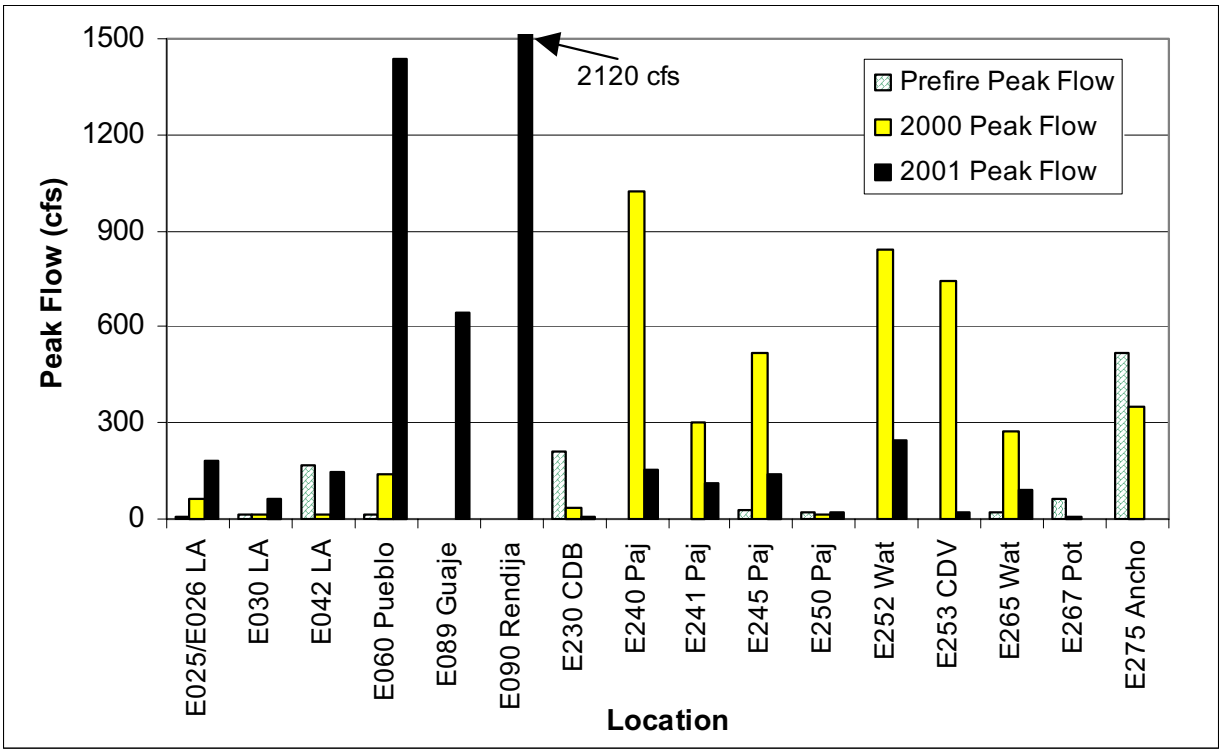


Figure 3.2-4. Peak runoff recorded in 2000 and 2001 compared with historical peak flows.

3.2.3 Storm Water Runoff Samples Collected in 2001

Storm water runoff samples were collected on 30 days during the 2001 runoff season. A list of the dates when runoff samples were collected and the locations that were sampled is in Table 3-6. Some runoff samples were collected on days following the precipitation and initial runoff events; descriptions of specific runoff events are in Section 4.

Some of the storm water runoff samples are collected from mesa-top gage sites at LANL to provide compliance with Clean Water Act and National Pollutant Discharge Elimination System permits (e.g., ESP 2000, p. 22). These mesa-top samples are not associated with flow in a watercourse but are collected to determine if specific sites at LANL may be contributing contaminants to a watercourse. Table 3-7 lists the non-water course runoff samples that were collected at LANL in 2001. These samples are usually collected in response to local rainfall at a specific site and may or may not be associated with runoff samples collected in nearby watercourses, depending on the rainfall intensity and the extent of runoff from mesa tops. In 2001 the first mesa-top runoff samples were collected at TA-54 and TA-55 (gages E223 and E196, respectively) on April 6 and at TA-55 again on April 20; no watercourse samples were collected on these dates and many of the other dates when mesa-top runoff samples were collected due to the limited extent of runoff from the mesa-top sites. Specific descriptions of runoff from these mesa-top sites are not provided in the following descriptions of runoff events.

Table 3-6. Storm Water Runoff Samples Collected in 2001.

Collection Date	Locations Sampled [a]
April 6	E223, E249.5
April 7	E196
April 20	E196
April 27	E223
May 13	E038, E040, E196
May 28	E038, E040, E196, E223
June 07	E223, E248.5, E249.5
June 27	E038, E039, E040, E122.5, E196, E249.5, E250
July 02	E026, E030, E038, E039, E042, E060, E090, E196, E223, E245, E248.5, E249.5
July 13	E026, E196, E248.5, E249.5
July 14	E030, E042
July 17	E223, E249.5
July 19	E196
July 21	E223
July 22	E252, E253, E260
July 26	E030, E042, E050, E060, E122.5, E223, E240, E241, E249.5, E253, E262.5, E263
Aug 01	E026, E038, E042, E122.5, E196, E248.5, E249.5
Aug 03	E056, E061, E262.5, E263, E265
Aug 04	E038, E039, E040, E042, E060, E248.5, E249.5
Aug 05	E030, E123, E241, E245, E247, E262, E269
Aug 06	E250
Aug 08	E042, E089, E262.5
Aug 09	E026, E030, E042, E050, E060, E089, E240, E250, E262, E263, E265
Aug 11	E060, E089, E241, E269
Aug 12	E300
Aug 13	E055
Aug 14	E089
Aug 16	E030, E038, E042, E050, E060, E089, E250
Aug 30	E248, E248.5, E269
Oct 05	E223, E249.5

a. See Table 3-1 for location names of sampling stations.

Table 3-7. Storm Water Runoff Samples Collected from Mesa-Top Sites in 2001.

	Sandia Canyon Tributary	TA-55	TA-54 MDA-L	TA-54 MDA-G-1	TA-54 MDA-G-2	TA-54 MDA-G-3	TA-54 MDA-G-4
Sample Date	E122.5	E196	E223	E247	E248	E248.5	E249.5
06-Apr-01			X				X
07-Apr-01		X					
20-Apr-01		X					
27-Apr-01			X				
13-May-01		X					
28-May-01		X	X				
07-Jun-01			X			X	X
27-Jun-01	X	X					X
02-Jul-01		X	X			X	X
13-Jul-01		X				X	X
17-Jul-01			X				X
19-Jul-01		X					
21-Jul-01			X				
26-Jul-01	X		X				X
01-Aug-01	X	X				X	X
04-Aug-01						X	X
05-Aug-01				X			
30-Aug-01					X	X	
05-Oct-01			X				X

See Table 3-1 for location names of sampling stations

4.0 Description of Storm Water Runoff Events in 2001

The descriptions of runoff events that are provided in following sections are primarily focused on providing details for runoff events and sampling activities that occurred in main watercourses. Descriptions of runoff are not provided for dates when only mesa-top samples were collected.

4.1 May 13, 2001

The first watercourse storm water runoff samples collected in 2001 were collected from DP Canyon on May 13 when a small rain shower occurred during the afternoon between 14:30 and 15:30. Precipitation at TA-53 was 0.09 in. and at TA-6 was 0.06 in. The pattern of precipitation received on May 13 is shown in Appendix Figure A-1. The hourly precipitation at TA-53 and the average hourly runoff in DP Canyon at gage E038 and in Los Alamos Canyon at E030 and E042 are shown in Figure 4-1. Runoff began at gage E038 in upper DP Canyon at 16:00 when the peak flow was 176.4 cfs. The runoff at gage E038 continued until 17:35 and the total amount of runoff was about 3.9 ac-ft.

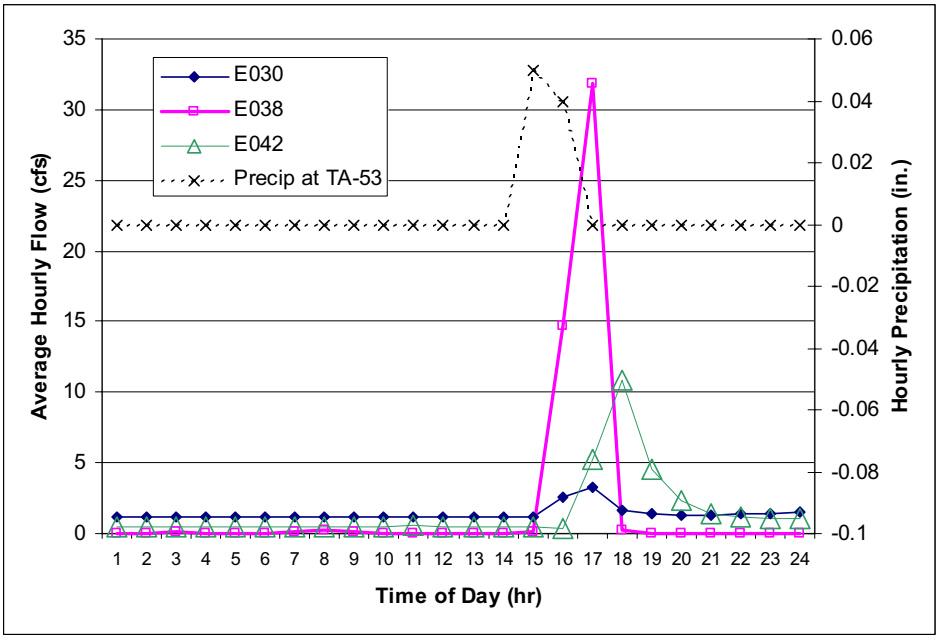


Figure 4-1. Precipitation and runoff in DP and Los Alamos Canyons on May 13, 2001.

Runoff samples were collected at gages E038 and E040 in DP Canyon on May 13. The sites sampled, the sample identification numbers, field preparation information (filtered [F] or unfiltered [UF] samples), and analytical suites are listed in Table 4-1.

Table 4-1. Storm Water Runoff Samples Collected on May 13, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite*
05-13-01	E038	GU01051E038	16:00	UF	TSS, Rad
05-13-01	E040	GU01051E040	16:44	UF	TSS, Gen, Metals, Rad

*TSS = total suspended solids; Rad = radionuclides; Gen = general inorganics

4.2 May 28, 2001

Watercourse storm water runoff samples were again collected on May 28 in DP Canyon after a small local rain shower occurred over the western and central part of the Pajarito Plateau between 16:00 and 17:00. Precipitation at TA-6 was 0.12 in. and at TA-74 was 0.09 in. The pattern of precipitation received on May 28 is shown in Appendix Figure A-2. The hourly precipitation at TA-6 and the average hourly flow at gage E040 in lower DP Canyon and at gages E030 and E042 in Los Alamos Canyon are shown in Figure 4-2. Runoff began at gage E040 in lower DP Canyon at 19:00 when the peak flow was 4.3 cfs. The runoff at gage E040 continued until 23:00 and the total amount of runoff was about 0.3 ac-ft (13,000 cubic feet).

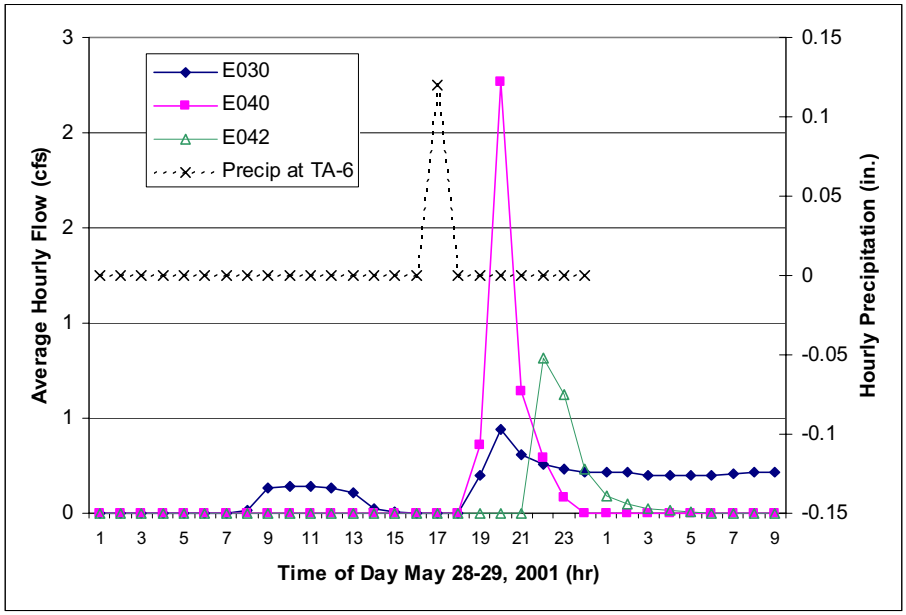


Figure 4-2. Precipitation and runoff in DP and Los Alamos Canyons on May 28, 2001.

Runoff samples were collected at gages E038 and E040 in DP Canyon on May 28. Table 4-2 lists the samples that were collected.

Table 4-2. Storm Water Runoff Samples Collected on May 28, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
05-28-01	E038	GU01052E038	16:55	UF	TSS, Metals, Gen
05-28-01	E038	GF01052E038	16:55	F	Metals, Gen
05-28-01	E040	GU01052E040	19:09	UF	TSS, Metals, Gen
05-28-01	E040	GF01052E040	19:09	F	Metals, Gen

4.3 June 15, 2001

In preparation for the summer storm water runoff season, the Los Alamos Canyon Reservoir was drained in mid-June. Flow in Los Alamos Canyon at gages E025 and E030 that resulted from the draining of the reservoir is shown in Figure 4-3. Flow began at 12:30 at gage E025 and at 16:35 at gage E030 on June 14. The flow was not recorded at gage E042 in lower Los Alamos Canyon due to a malfunction of the

instrument. The peak flow at gage E025 was 4.3 cfs at 17:10 on June 14 and peak flow at gage E030 was 3.5 cfs at 08:30 on June 15. The total flow at gage E030 resulting from the reservoir draining was approximately 7.4 ac-ft. Significant precipitation was not recorded on the Pajarito Plateau in the first two weeks of June prior to draining the Los Alamos County Reservoir.

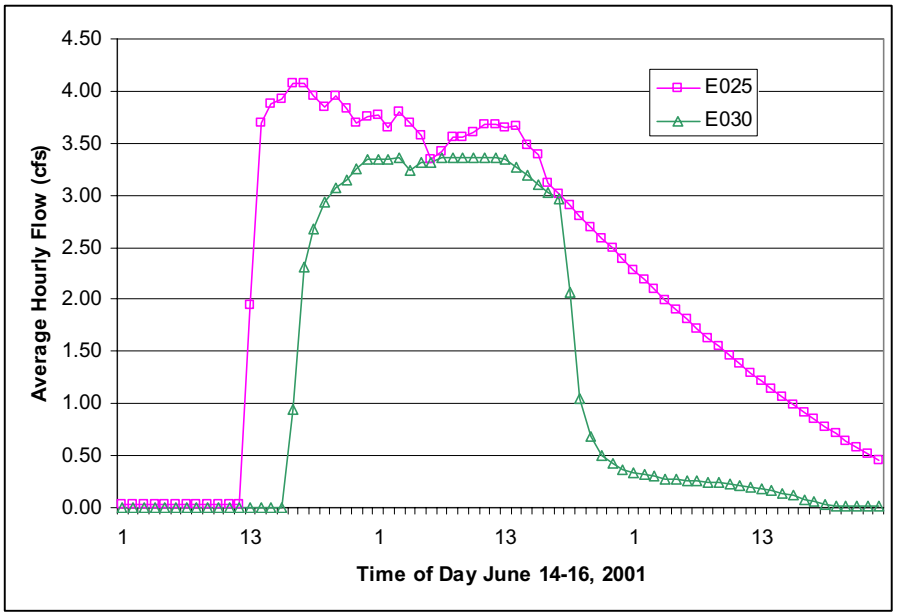


Figure 4-3. Runoff in Los Alamos Canyon June 14–16, 2001, while draining reservoir.

Surface water samples were collected at gage E042 in lower Los Alamos Canyon at 10:30 on June 15 when the gage height was 1.69 ft as recorded by the sampling personnel. Table 4-3 lists the samples that were collected.

Table 4-3. Surface Water Samples Collected on June 15, 2001.

Date	Gage	Sample ID	Time (hr)	Sample Type	F/UF	Suite*
06-15-01	E042	GU01061E042	10:30	Manual	UF	TSS, Metals, Gen, Rad, H-3, HE, CN, ClO_4, Dioxan/Furan, PCB, SVOC

* H-3 = tritium; CN = cyanide; ClO_4 = perchlorate; PCB = polychlorinated biphenyls; SVOC = semivolatile organic compounds

4.4 June 27, 2001

The first significant precipitation and storm water runoff event in 2001 occurred on June 27. The official LANL meteorological station at TA-6 received 0.5 in. of rain between 11:30 and 12:00. Other meteorological stations around the Pajarito Plateau recorded rainfall ranging from 0.1 in. at TA-54 to 0.37 in. at TA-53, with most other gaging stations receiving less than 0.1 in.; rainfall was not recorded at stations in the Sierra de los Valles. The pattern of precipitation that was recorded on the Pajarito Plateau on June 27 is shown in Appendix Figure A-3. The precipitation was from a local thunderstorm that occurred over the western part of LANL about midday.

Figure 4-4 shows the hourly precipitation received at TA-6 and TA-54 and the average hourly flow at stream gages E038, E039, E040, and E042 in Los Alamos Canyon on June 27. Flow began in upper DP Canyon at gage E038 at 12:45 with a peak flow of 208 cfs; runoff continued until 15:45 during which time approximately 4.5 ac-ft passed through the upper DP Canyon gage. Runoff began in middle DP Canyon at gage E039 at 12:50 and the peak flow was 77 cfs at 13:00; runoff continued until about 16:00 and approximately 5.2 ac-ft passed through gage E039. Runoff began in lower DP Canyon at gage E040 at 13:35 when the peak flow was 19 cfs; flow continued until 18:15 and the total runoff was approximately 0.9 ac-ft. The stream gage data indicate that approximately 4 ac-ft of runoff was lost to infiltration or evapotranspiration in lower DP Canyon between gages E039 and E040.

Flow began at gage E042 in lower Los Alamos Canyon at 14:50 and the peak flow was 11 cfs at 14:55. Flow continued at gage E042 in declining volumes until 20:15 and the total runoff volume was approximately 0.8 ac-ft. During the June 27 runoff event, storm water flowed in Los Alamos Canyon throughout the length of the canyon on Laboratory property and continued to flow off Laboratory property for a distance.

The precipitation event on June 27 also caused a small amount of runoff in Mortandad Canyon at gage E200 and in lower Pajarito Canyon at gage E250. The hydrograph of flow at gage E200 in Mortandad Canyon and gage E250 in lower Pajarito Canyon is shown in Figure 4-4. Runoff began at gage E200 in Mortandad Canyon at 12:35 and the peak flow was 49 cfs at 12:50; runoff continued until about 20:00 and the total runoff was approximately 2.5 ac-ft. Runoff began at gage E250 in Pajarito Canyon at 19:25 and peak flow was 1.55 cfs at 19:55. Runoff continued in small volumes until about 14:25 on June 28 and approximately 0.4 ac-ft passed through gage E250.

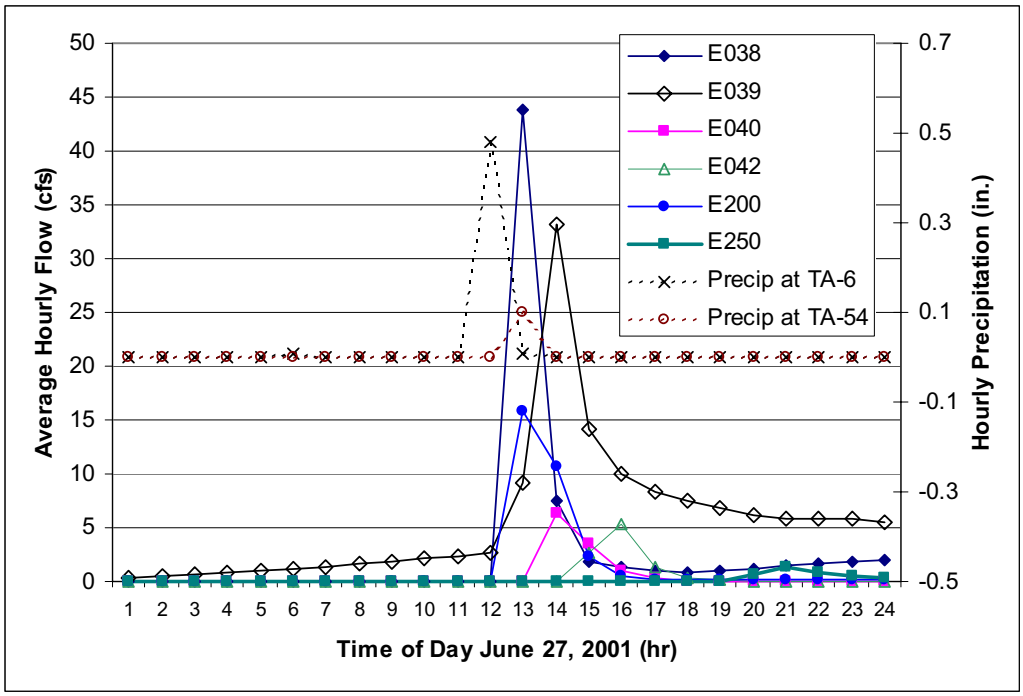


Figure 4-4. Precipitation at TA-6 and TA-54 and average hourly streamflow at gages in DP, Los Alamos, and Pajarito Canyons on June 27, 2001.

Personnel of the Water Quality and Hydrology Group (RRES-WQH) collected runoff samples from three automated sampling stations in DP Canyon and from lower Pajarito Canyon on June 27. The sites sampled on June 27, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-4.

Table 4-4. Storm Water Runoff Samples Collected on June 27, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
06-27-01	E038	GU01063E038	11:41	UF	TSS, Gen, Metals, CN
06-27-01	E038	GF01063E038	11:41	F	Gen, Metals
06-27-01	E039	GU01061E039	13:00	UF	TSS, Gen, Metals, CN
06-27-01	E039	GF01061E039	13:00	F	Gen, Metals
06-27-01	E040	GU01063E040	13:35	UF	TSS, Gen, Metals, Rad, H-3, ClO_4, CN
06-27-01	E040	GF01063E040	13:35	F	Gen, Meals, Rad
06-27-01	E122.5	GU010611122.5	12:30	UF	TSS, Gen, Metals, CN
06-27-01	E122.5	GF01061122.5	12:30	F	Gen, Metals
06-27-01	E249.5	GU01064249.5	13:26	UF	TSS, Gen, Metals, Rad, CN
06-27-01	E249.5	GF01064249.5	13:26	F	Metals
06-27-01	E250	GU01061E250	18:27	UF	TSS, Gen, Metals, Rad, H-3, ClO_4, CN
06-27-01	E250	GF01061E250	18:27	F	Gen, Metals, Rad

4.5 July 2, 2001

The largest precipitation and storm water runoff event at LANL in 2001 occurred on July 2. The official LANL meteorological station at TA-6 received 0.74 in. of rain and the North Community station received 1.23 in. of rain. Other meteorological stations around the Pajarito Plateau recorded rainfall ranging from 0.13 in. at TA-16 to 0.54 in. at TA-54, with an average rainfall of about 0.5 in. A private residence on Alabama Street in western Los Alamos reported receiving 1.75 in. of rainfall (Los Alamos Monitor 2001). The pattern of precipitation that was recorded on the Pajarito Plateau on July 2 is shown in Appendix Figure A-4. The precipitation was from a localized heavy thunderstorm that occurred over the western part of the Pajarito Plateau during the late afternoon from 16:00 to about 18:00.

Figure 4-5 shows the hourly precipitation received at TA-6 and the North Community meteorological stations on July 2 and the hydrograph of stream flow at stream gages E026, E038, E039, E040, and E042 in Los Alamos Canyon, gage E060 in Pueblo Canyon, and gage E090 in Rendija Canyon on July 2 and 3. Flow began at gage E038 in upper DP Canyon at 17:25 and the peak flow was 127 cfs at 17:30. Runoff continued at gage E038 until 20:20; the total runoff was approximately 7.7 ac-ft. Flow began in middle DP Canyon at gage E039 at 17:45 with a peak flow of 42.5 cfs; runoff continued at gage E039 until 04:25 on the morning of July 3 during which time approximately 5.6 ac-ft passed through the middle DP Canyon gage. Runoff began in lower DP Canyon at gage E040 at 18:20 and the peak flow was 33 cfs at 19:15. Runoff continued at gage E040 until 23:35 and the total runoff in the lower part of DP Canyon was approximately 2.5 ac-ft. The runoff data from DP Canyon indicate that about 3.1 ac-ft were lost to infiltration and/or evapotranspiration between gages E039 and E040.

Runoff began in upper Los Alamos Canyon at gage E026 at 18:15 and the peak flow was 173 cfs at 18:30; runoff continued until about 22:00 and approximately 3.6 ac-ft passed through gage E026. Flow began at gage E042 in lower Los Alamos Canyon at 19:30 and the peak flow was 91 cfs at 20:40. Flow continued at gage E042 in declining volumes until 11:55 on the morning of July 3 and the total runoff in lower Los Alamos Canyon was approximately 14.2 ac-ft for a runoff yield of about 1.6 ac-ft/mi^2.

Runoff from the storm event began in lower Pueblo Canyon at gage E060 at 19:55 with the peak flow of 1440 cfs occurring at 20:00. Flow from the runoff event continued in Pueblo Canyon until about 07:00 on July 3 (flow at gage E060, supported by discharges from the Los Alamos County Sewage Treatment Plant, continued beyond this time) and the total runoff in Pueblo Canyon was approximately 91 ac-ft, for a yield of about 13 ac-ft/mi^2. The peak flow computation at gage E055 in Pueblo Canyon above Acid Canyon obtained after the July 2 runoff event was 1600 cfs. The peak flow at gage E060 on July 2 set a

peak flow record for this site. This runoff event caused extensive damage to utilities and roads in Pueblo Canyon (Los Alamos Monitor 2001).

Runoff in lower Rendija Canyon at gage E090 began at 19:10 with a peak flow of 66 cfs. Flow continued for 20 minutes in lower Rendija Canyon where the total runoff volume was 0.6 ac-ft. Flow at gage E089 in middle Guaje Canyon above Rendija Canyon began at 18:40 and the peak flow was 19.3 cfs at 19:30. Small amounts of flow continued in Guaje Canyon until 12:00 on July 3 and the total flow in middle Guaje Canyon was about 1 ac-ft. During the July 2 runoff event, storm water flowed in Pueblo and Los Alamos Canyons throughout the length of the canyons on Laboratory property and continued to flow off Laboratory property to the Rio Grande.

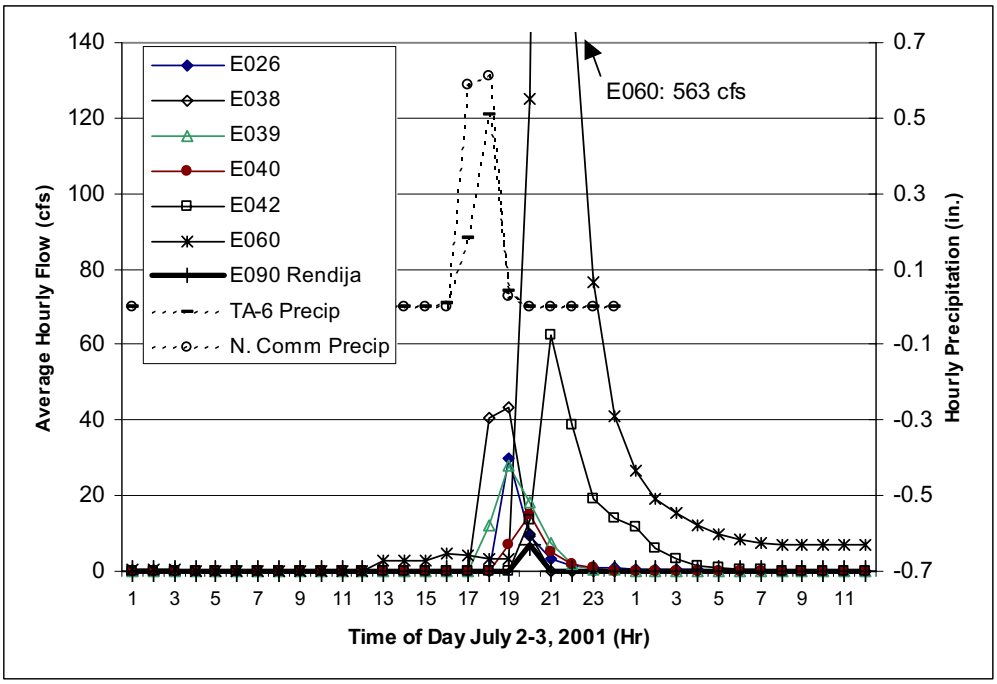


Figure 4.5. Precipitation at TA-6 and North Community and flow in Los Alamos, Pueblo, and Rendija Canyons on July 2 and 3, 2001.

The precipitation event on July 2 also caused a small amount of runoff in middle Pajarito Canyon at gage E245. The gage is located downstream of the Pajarito Canyon Retention Pond and does not record flow until water discharges from the retention pond. Flow triggered the sampling device at gage E245 at 19:09 on the evening of July 2 but the gage did not begin recording until midnight on the morning of July 3. Runoff continued in small volumes at gage E245 until 02:00 on July 3; peak flow recorded at gage E245 was 0.085 cfs and the apparent total volume of runoff associated with the runoff event at gage E245 was about 2000 gallons (0.006 ac-ft). Runoff from the July 2 precipitation event did not occur at gage E240 in upper Pajarito Canyon or at gage E250 in lower Pajarito Canyon.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in DP Canyon, Los Alamos Canyon, Guaje Canyon, and middle Pajarito Canyon on July 2. The sites sampled on July 2, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-5.

Table 4-5. Storm Water Runoff Samples Collected on July 2, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite*
Los Alamos Canyon					
07/02/01	E026	GF01071E026	18:30	F	Metals
07/02/01	E026	GU01071E026	18:30	UF	TSS, Gen, Metals, Rad, ClO_4
07/02/01	E030	GF01071E030	19:25	F	Metals
07/02/01	E030	GU01071E030	19:25	UF	TSS, Gen, Metals
07/02/01	E038	GF01074E038	17:23	F	Metals
07/02/01	E038	GU01074E038	17:23	UF	TSS, Metals
07/02/01	E039	GF01072E039	17:42	F	Gen, Metals
07/02/01	E039	GU01072E039	17:42	UF	TSS, Metals
07/02/01	E042	GF01072E042	19:26	F	Gen, Metals
07/02/01	E042	GU01072E042	19:26	UF	Gen, Metals, Rad, CN
Pueblo Canyon					
07/02/01	E060	GF01071E060	19:49	F	Gen, Metals, Rad, Hg
07/02/01	E060	GU01071E060	19:49	UF	Gen, Metals, Rad, Hg
Rendija Canyon					
07/02/01	E090	GF01071E090	19:22	F	Gen, Metals, Hg
Pajarito Canyon					
07/02/01	E245	GF01071E245	19:09	F	Gen, Metals, Rad
07/02/01	E245	GU01071E245	19:09	UF	TSS, Metals, Rad, H-3
07/02/01	E090	GU01071E090	19:22	UF	TSS, Metals, Rad, CN
Mesa-Top Sites					
07/02/01	E196	GF01076E196	17:59	F	Gen, Metals, Rad
07/02/01	E196	GU01076E196	17:59	UF	TSS, Metals, Rad
07/02/01	E223	GU01075E223	18:00	UF	Gen, Metals, Rad, PCB
07/02/01	E248.5	GF01072E248.5	17:42	F	Gen, Metals, Rad
07/02/01	E248.5	GU01072E248.5	17:42	UF	Gen, Metals, Rad, SVOC, H-3, ClO_4
07/02/01	E249.5	GF01075E249.5	17:58	F	Gen, Metals, Rad
07/02/01	E249.5	GU01075E249.5	17:58	UF	TSS, Metals, Rad, PCB

* Hg = Mercury

4.6 July 13, 2001

A rainstorm occurred mainly over the higher elevations of the Pajarito Plateau and the Sierra de los Valles during the late evening hours on July 13. Pajarito Mountain received 1.27 in. and upper Quemazon Canyon received 1.78 in. The TA-6 meteorological station received 0.31 in. and the average precipitation received on the Pajarito Plateau was about 0.3 in., most of the precipitation was received from 20:00 to 22:00. The pattern of precipitation received on July 13 is shown in Figure A-5.

Figure 4-6 shows the hourly precipitation received at TA-6 and Pajarito Mountain and the average hourly flow at gages E026 and E042 in Los Alamos Canyon on July 13 and 14. Flow began at gage E026 in upper Los Alamos Canyon at 23:40 and continued until about 10:00 on the morning of July 14. The peak flow was 87 cfs at 00:05 on the morning of July 14 and the total runoff was approximately 8.5 ac-ft. Flow began at gage E030 in middle Los Alamos Canyon at 01:15 on the morning of July 14 and continued until about 12:00. The peak flow was 9 cfs at 01:20 and the total runoff at gage E030 was approximately 1.5 ac-ft. Flow began at gage E040 in lower DP Canyon at 00:25 on the morning of July 14 and continued until about 04:00. The peak flow at gage E040 was 3.3 cfs at 00:35 and the total runoff from DP Canyon was approximately 0.3 ac-ft.

Flow began at gage E042 in lower Los Alamos Canyon at 02:10 on the morning of July 14 and continued in decreasing volumes until 12:50. The peak flow was 29 cfs at 02:10 and the total runoff at gage E042 was approximately 2.5 ac-ft. The gage data indicate that approximately 6 ac-ft of runoff was lost to evapotranspiration and infiltration in middle and lower Los Alamos Canyon.

Personnel of the RRES-WQH collected runoff samples from the automated sampling station E026 in upper Los Alamos Canyon on July 13. The sites sampled on July 13, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-6.

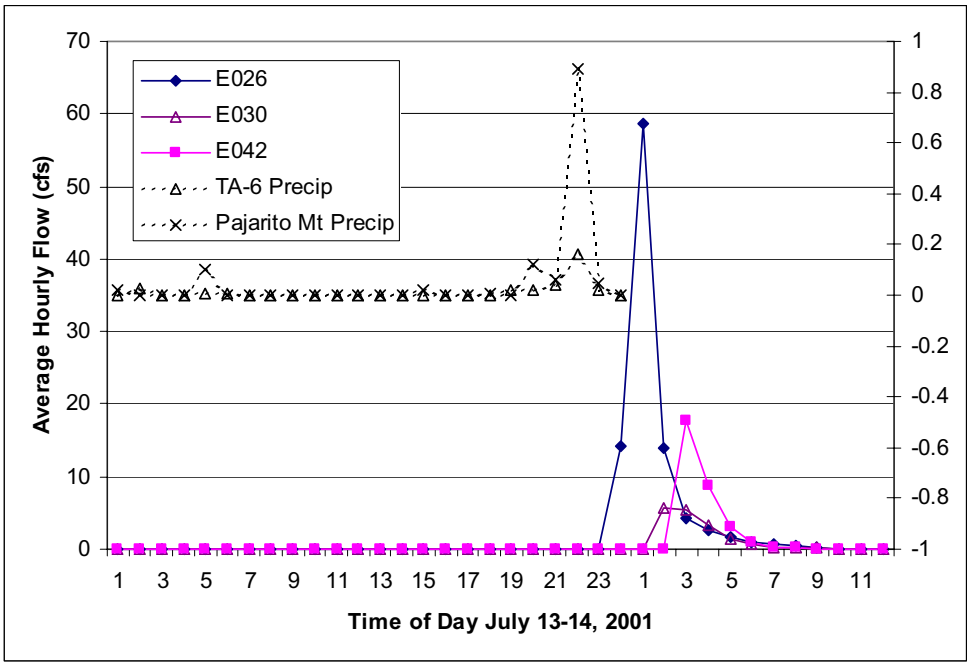


Figure 4-6. Precipitation at TA-6 and Pajarito Mountain and flow in Los Alamos Canyon on July 13 and 14, 2001.

Table 4-6. Storm Water Runoff Samples Collected on July 13 and 14, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
07/13/01	E026	GF01072E026	23:36	F	Gen, Metals, Rad
07/13/01	E026	GU01072E026	23:36	UF	TSS, Gen, Metals, Rad, ClO_4, H-3
07/14/01	E030	GF01072E030	01:13	F	Gen, Metals, Rad
07/14/01	E030	GU01072E030	01:13	UF	TSS, Meals, Rad, CN, H-3
07/14/01	E042	GF01073E042-1	02:07	F	Hg
07/14/01	E042	GU01073E042-1	02:07	UF	TSS, Metals, Rad, CN

4.7 July 22, 2001

A mid-day and early-afternoon thunderstorm occurred in the Sierra de los Valles west of LANL on July 22. The maximum amount of precipitation (0.59 in.) was received at the Cerro Grande gage on Bandelier National Monument. The Water Canyon RAWS received 0.53 in. and Pajarito Mountain received 0.37 in. The TA-6 meteorological station received 0.04 in. and most of the Pajarito Plateau received less than 0.1 in. The higher amounts of precipitation occurred in the upper Water Canyon and Cañon de Valle watersheds. The pattern of precipitation that was received on July 22 is shown in Figure A-6.

Figure 4-7 shows the hourly precipitation at the Water Canyon and Pajarito Canyon RAWS and the average hourly runoff at stream gages in Cañon de Valle and upper Water Canyon on July 22. Flow began at gage E252 in upper water canyon at 14:10 and the peak flow was 255 cfs at 14:25. Flow continued at the upper Water Canyon gage until 10:45 on the morning of July 23 and the total runoff was approximately 8 ac-ft. Flow began at gage E253 in upper Cañon de Valle at 14:35 and the peak runoff was 2.3 cfs at 14:40. Flow continued at gage E253 in small volumes until 19:00 and the total runoff was approximately 0.15 ac-ft. Increased flow from runoff began at gage E262.5 in middle Water Canyon at MDA-AB at 15:05 and the peak flow was 3.5 cfs at 15:45. Runoff continued in middle Water Canyon until about 04:00 on the morning of July 23 and the total runoff was approximately 0.36 ac-ft. Runoff was not recorded at gages E262 in lower Cañon de Valle or at gages E263 and E265 in lower Water Canyon on July 22, however, peak flow computation from runoff gage height at gage E265 was 96 cfs (Shaull et al. 2002, p. 85).

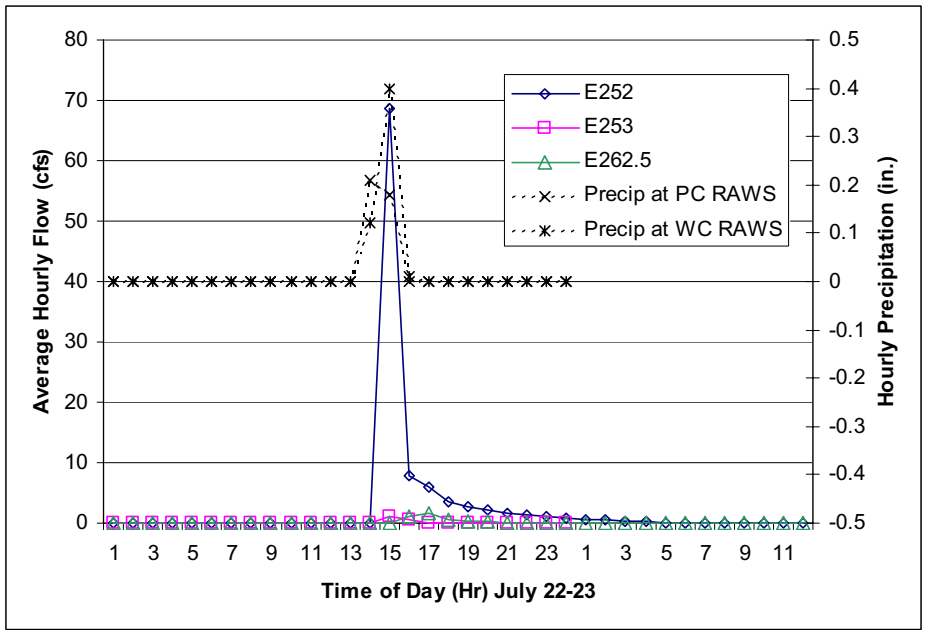


Figure 4-7. Precipitation at Pajarito Canyon and Water Canyon RAWS and flow in Water Canyon and Cañon de Valle at gages E252, E253, and E262.5 on July 22 and 23, 2001.

Personnel of the RRES-WQH collected runoff samples from the automated sampling stations at gages E252, E253, and E260 in upper Water Canyon and Cañon de Valle on July 22. The sites sampled on July 22, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-7.

Table 4-7. Storm Water Runoff Samples Collected on July 22, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
07/22/01	E252	GF01071E252	14:25	F	Gen, Metals
07/22/01	E252	GU01071E252	14:25	UF	TSS, Metals, H-3
07/22/01	E253	GF01071E253	14:35	F	Rad
07/22/01	E253	GU01071E253	14:35	UF	TSS, Rad
07/22/01	E260	GU01071E260	15:20	UF	TSS, pH

4.8 July 26, 2001

A thunderstorm occurred over the Pajarito Plateau and the Sierra de los Valles late on the afternoon of July 22. The highest precipitation amounts were received in the mountains west of LANL where 0.6 to 0.8 in. of rain fell, whereas stations on the Pajarito Plateau received between 0.1 and 0.3 in. The TA-6 meteorological station received 0.29 in. and TA-54 received 0.2 in. The Pueblo Canyon RAWS received 0.51 in. The pattern of precipitation that was received on July 26 is shown in Figure A-7.

Figure 4-8 shows the hourly precipitation at TA-6 and the Pajarito Canyon RAWS and the average hourly runoff at stream gages E026, E030, and E042 in Los Alamos Canyon and gage E060 in lower Pueblo Canyon on July 26 and 27. Flow began at gage E026 at 18:00 where the peak flow was 65 cfs at 18:20. Flow continued in declining volumes until 23:30 on July 27 and the total runoff was approximately 6 ac-ft. Flow began at gage E030 at 19:40 where the peak flow was 16.8 cfs at 20:00. Flow continued at gage E030 until 10:10 on July 27 and the total runoff was approximately 2.6 ac-ft. Flow began at gage E042 in lower Los Alamos Canyon at 20:30 when the peak flow was 50 cfs. Flow continued at gage E042 until 09:25 on July 27 and the total runoff was approximately 6 ac-ft. Flow began at gage E060 in lower Pueblo Canyon at 20:10 where the peak flow was 114 cfs at 20:15. Runoff continued at gage E060 until about 11:00 on the morning of July 27 and the total runoff during this time was approximately 21 ac-ft.

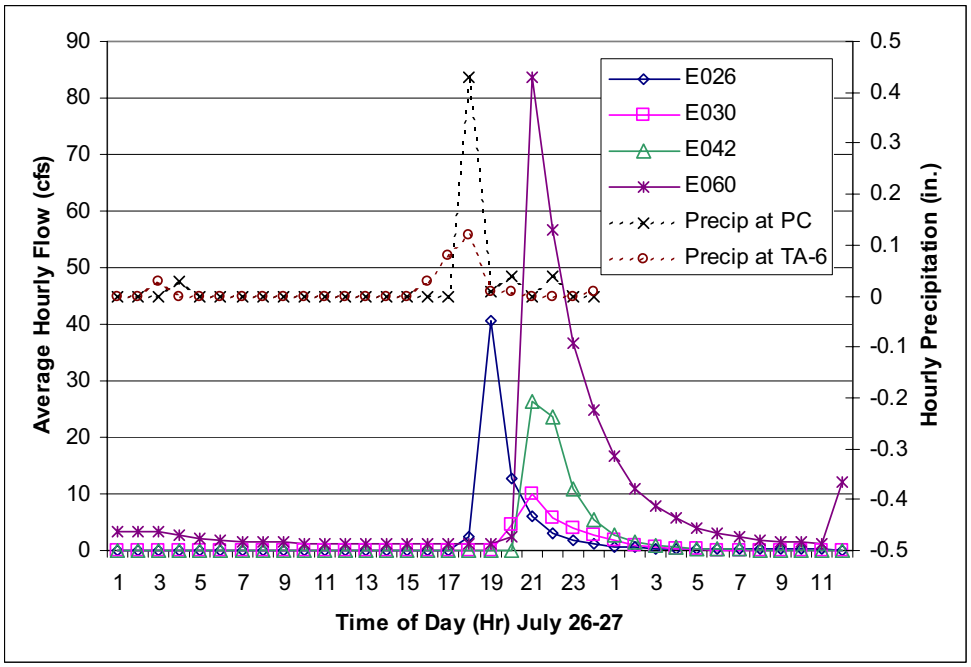


Figure 4-8. Precipitation at Pajarito Canyon RAWS and TA-6 and flow in Los Alamos Canyon on July 26 and 27, 2001.

Figure 4-9 shows the hourly precipitation at the upper Pajarito Canyon RAWS and at TA-6 and the average hourly flow at gages E240 and E245 in upper and middle Pajarito Canyon on July 26 and 27. Runoff at gage E240 in upper Pajarito Canyon began at 17:40 when the peak flow was 54 cfs. Runoff continued until 03:15 and the total runoff was 8.2 ac-ft. Runoff samples were collected at gage E241 in Pajarito Canyon at TA-22 but the stream gage apparently did not record the runoff event. Runoff began at gage E245 in middle Pajarito Canyon at 19:40 and the peak flow was 24 cfs at 19:45. The runoff event at gage E245 continued until about 01:30 on the morning of July 27 and flow continued in small volumes until 16:35 on the afternoon of July 27, probably supported by spring discharge to the saturated stream channel. The total flow during the runoff event was approximately 2.3 ac-ft. The runoff data in Pajarito Canyon indicate that approximately 5.9 ac-ft of runoff was retained in the Pajarito Canyon Retention Pond and/or lost to infiltrations and evapotranspiration in the upper and middle reaches of the canyon. Runoff was not recorded at gage E250 in lower Pajarito Canyon on July 26 and 27.

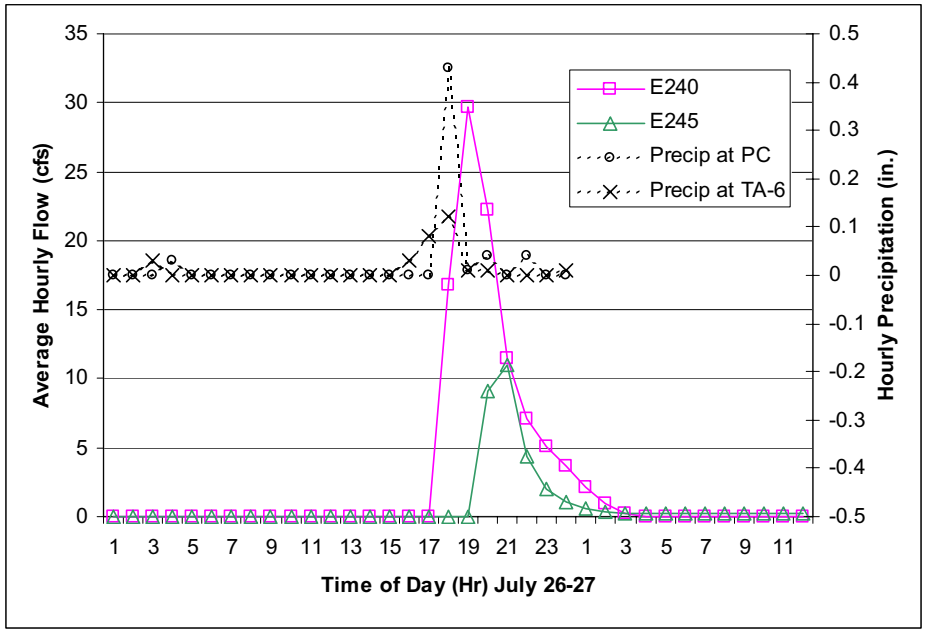


Figure 4-9. Precipitation at Pajarito Canyon RAWS and TA-6 and flow in Pajarito Canyon on July 26 and 27, 2001.

Figure 4-10 shows the average hourly runoff at stream gages in Cañon de Valle and Water Canyon and precipitation at the upper Water Canyon and Pajarito Canyon RAWS. Runoff began at gage E252 in upper Water Canyon at 17:35 when the peak flow was 80 cfs. Runoff continued at gage E252 in declining amounts until about 11:00 on the morning of July 27, during which time the total runoff was approximately 13 ac-ft. Runoff began at gage E253 in upper Cañon de Valle at 17:45 and the peak flow was 9.7 cfs at 17:50. Small volumes of flow continued at gage E253 for about five hours, until 23:05, and the total flow was approximately 0.35 ac-ft. Runoff began at gage E262.5 in middle Water Canyon at MDA-AB at 19:15 when the peak flow was 12.6 cfs. Runoff continued in middle Water Canyon until about 11:00 on the morning of July 27 and the total runoff at gage E262.5 was approximately 1.7 ac-ft. Runoff began at gage E263 in lower Water Canyon at SR 4 at 20:25 with a peak flow of 13.8 cfs. Runoff continued at gage E263 until 03:25 on the morning of July 17 and the total runoff was approximately 2.2 ac-ft. Runoff began at gage E265 in lower Water Canyon at 20:35 when the peak flow was 31.9 cfs. Runoff continued at gage E265 until 10:20 on the morning of July 27 and the total runoff was approximately 3.7 ac-ft. The runoff data in Water Canyon indicate that approximately 9.3 ac-ft of runoff was lost to infiltration and/or to evapotranspiration in Water Canyon as a result of the runoff event on July 26 and 27.

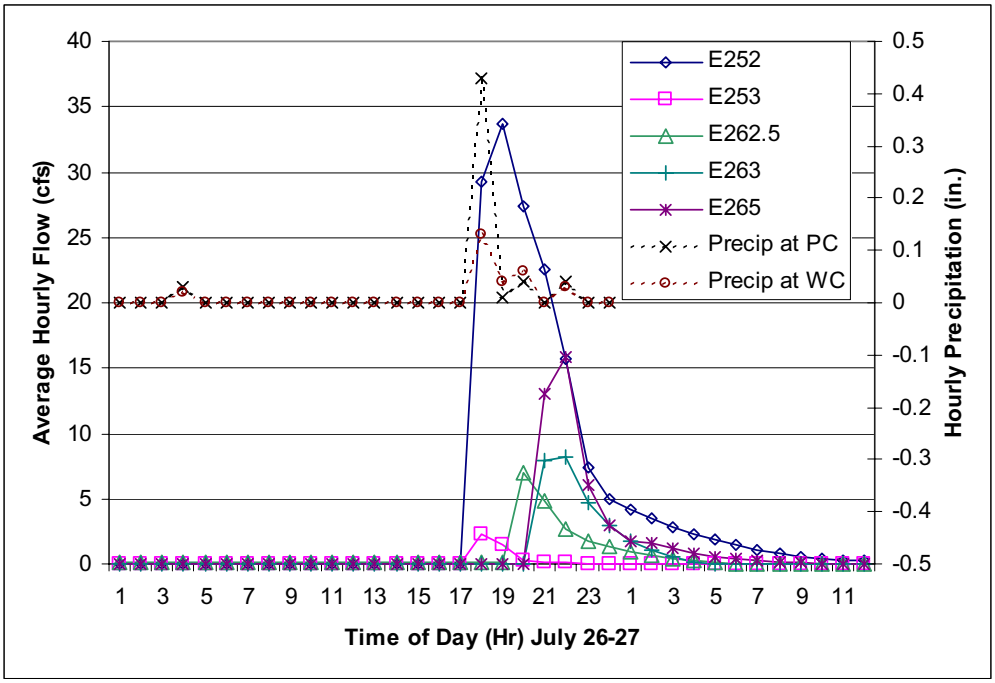


Figure 4-10. Precipitation at Pajarito Canyon and Water Canyon RAWS and flow in Cañon de Valle and Water Canyon on July 26 and 27, 2001.

Personnel of the RRES-WQH collected runoff samples from the automated sampling stations in Los Alamos Canyon, Pueblo Canyon, Sandia Canyon, Pajarito Canyon, and Water Canyon and Cañon de Valle on July 26. The sites sampled on July 26, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-8.

Table 4-8. Storm Water Runoff Samples Collected on July 26, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Los Alamos/Pueblo Canyon					
07/26/01	E030	GF01073E030	19:38	F	Gen, Metals, Rad
07/26/01	E030	GF01073E030	19:38	UF	Gen, Metals, Rad, ClO_4, H-3
07/26/01	E042	GU01073E042	20:27	UF	TSS, Metals, H-3
07/26/01	E050	GF01071E050	21:05	F	Gen, Metals
07/26/01	E050	GU01071E050	2105	UF	TSS, Gen, Metals
07/26/01	E060	GF01072E060	19:10	F	Gen, Rad
07/26/01	E060	GF01072E060	19:10	UF	TSS, Gen, Rad
Sandia Canyon					
07/26/01	E122.5	GF01072E122.5	17:10	F	Hg
07/26/01	E122.5	GU01072E122.5	17:10	UF	TSS, CN, Hg, H-3
Pajarito Canyon					
07/26/01	E240	GU01071E240	17:40	UF	TSS, Rad
07/26/01	E241	GF01071E241	16:12	F	Rad
07/26/01	E241	GU01071E241	16:12	UF	TSS, Rad
Water Canyon /Cañon de Valle					
07/26/01	E253	GF01072E253	17:43	F	Gen, Metals
07/26/01	E253	GU01072E253	17:43	UF	TSS, Gen, Metals
07/26/01	E262.5	GF01071E262.5	19:11	F	Gen, Metals, Rad
07/26/01	E262.5	GF01071E262.5	19:11	UF	TSS, Metals, Rad
07/26/01	E263	GF01071E263	21:27	F	Gen, Metals
07/26/01	E263	GU01071E263	21:27	UF	TSS, Gen, Metals

4.9 August 1 and 2, 2001

A precipitation event occurred over the Pajarito Plateau and the Sierra de los Valles on the afternoon of August 1. Most areas received from 0.15 to 0.2 in. of rain beginning at around 16:00 and continuing for about two hours. The highest precipitation was on the southern part of the Pajarito Plateau where up to 0.23 in. was received at TA-49. The TA-6 meteorological station received 0.20 in. and TA-54 received 0.17 in. The pattern of precipitation that was received on August 1 is shown in Figure A-8 and the hourly precipitation at TA-6 and TA-53 is shown in Figure 4-11. The precipitation appears to have moved westward as time progressed from TA-6 to upper Los Alamos Canyon to Quemazon Canyon.

Figure 4-11 shows the hourly precipitation at TA-6 and TA-53 and the average hourly runoff at stream gages in Los Alamos Canyon on August 1. The Los Alamos Canyon reservoir was being dredged during early August and surface water from the reservoir was pumped from the reservoir daily. Discharged flow from the reservoir (about 5 cfs) began at gage E026 at 08:35 and continued until 16:00 when runoff from the precipitation event began. The peak runoff was 9.1 cfs at 17:05, 18:30, and 19:25. The runoff event continued until about 02:35 on the morning of August 2. Discharged flow from the reservoir began at gage E030 in middle Los Alamos Canyon at 13:30 and runoff began at about 18:00. The peak flow at gage E030 was 3.1 cfs at 19:45 and flow continued until 07:45 on the morning of August 2; the total flow at gage E030 was approximately 1.5 ac-ft.

Runoff at gage E038 in upper DP Canyon began at 18:10 and the peak flow was 27 cfs at 18:15. Runoff continued at gage E038 until 18:55 and the total flow was approximately 0.7 ac-ft. Runoff at gage E040 in lower DP Canyon above Los Alamos Canyon began at 19:55 when the peak flow was 2 cfs. Runoff continued until 21:20 and the total runoff at gage E040 was approximately 0.1 ac-ft.

A small amount of local runoff began at gage E042 in lower Los Alamos Canyon at 16:50 but runoff from the upper part of the canyon began at about 20:00. The peak flow was 9.4 cfs at 20:55 and runoff continued until 05:05 on the morning of August 2, and the total runoff at gage E042 was approximately 1.6 ac-ft.

Additional discharge from the Los Alamos Canyon reservoir occurred on the morning of August 2 and on subsequent days. Surface water flow at gage E026 began at 09:20 on August 2 and peak flow was 8.6 cfs at 17:30. Flow continued at gage E026 until 07:00 on the morning of August 3 and the total flow on August 2 was approximately 7.4 ac-ft.

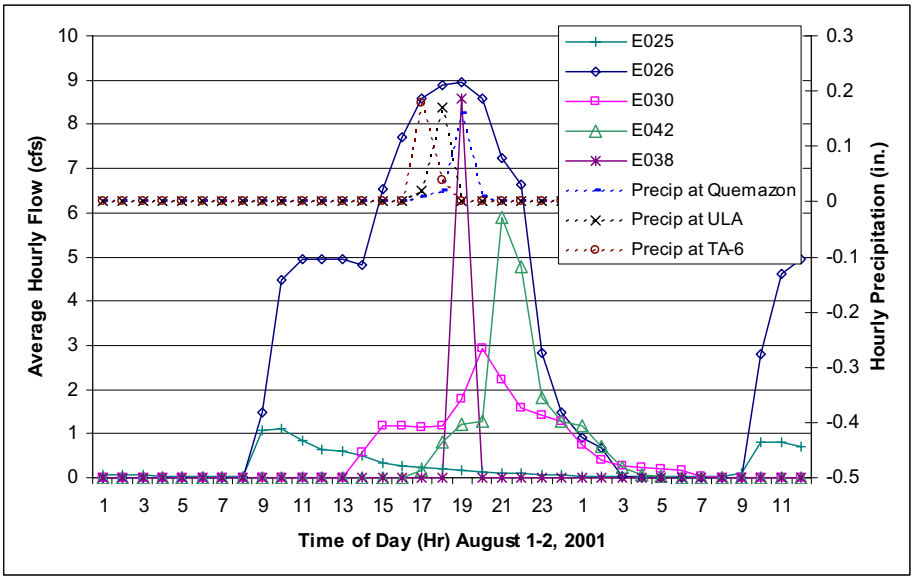


Figure 4-11. Precipitation at TA-6 and in upper Los Alamos Canyon and flow in Los Alamos and DP Canyons on August 1 and 2, 2001.

Personnel of the RRES-WQH collected runoff samples from the automated sampling stations in Los Alamos Canyon and DP Canyon on August 1. The sites sampled on August 1, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-9. The samples collected at gage E026 on August 1 and 2 were not related to a runoff event but was surface water released from the Los Alamos Canyon Reservoir.

Table 4-9. Storm Water Runoff Samples Collected on August 1 and 2, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Los Alamos/DP Canyon					
08/01/01	E026	GF01083E026	08:33	F	Gen, Metals, Rad
08/01/01	E026	GU01083E026	08:33	UF	Gen, Metals, Rad, H-3, ClO_4
08/01/01	E038	GF01085E038	18:10	F	Gen, Metals
08/01/01	E038	GU01085E038	18:10	UF	TSS, Gen, Metals
08/01/01	E042	GF01084E042	20:48	F	Gen, Metals
08/01/01	E042	GU01084E042	20:48	UF	TSS, Gen, Metals
08/02/01	E026	GF01084E026	09:16	F	Gen, Metals, Rad
08/02/01	E026	GU01084E026	09:16	UF	Gen, Metals, Rad, H-3, ClO_4
Sandia Canyon					
08/01/01	E122.5	GF01083E122.5	17:56	F	Gen, Metals
08/01/01	E122.5	GU01083E122.5	17:56	UF	TSS, Gen, Metals
Pajarito Canyon					
08/01/01	E249.5	GF01089E249.5	17:24	F	Rad
08/01/01	E249.5	GU01089E249.5	17:24	UF	TSS, Rad, HE
08/01/01	E248.5	GF01084E248.5	18:24	F	Gen, Metals, Rad
08/01/01	E248.5	GU01084E248.5	18:24	UF	TSS, Gen, Metals, Rad, H-3, CN, Dioxan
Mortandad Canyon					
08/01/01	E196	GF010810E196	17:52	F	Rad
08/01/01	E196	GU010810E196	17:52	UF	TSS, Rad, Metals

4.10 August 3, 2001

A local precipitation event occurred over the western Pajarito Plateau on the morning of August 3. The highest precipitation recorded was 0.73 in. at TA-16, 0.55 in. at TA-6, and 0.3 in. at TA-49. Most other meteorological stations on the Pajarito Plateau and in the Sierra de los Valles received less than 0.1 in. and TA-53 and TA-54 stations did not receive any measurable precipitation. The pattern of precipitation received on August 3 is shown in Figure A-9.

Figure 4-12 shows the hourly precipitation at TA-6, TA-16, and TA-49 and the average hourly runoff at stream gages in Water Canyon on August 3. A small amount of surface water (about 0.75 cfs) was present at gage E252 in upper Water Canyon on the morning of August 3. The surface water is the result of discharge from the Water Canyon Gallery spring and residual runoff from light rains received on August 1. Runoff associated with the precipitation event on August 3 began at gage E252 at about 10:00 and the peak flow was 14 cfs at 12:00. Runoff continued in small amounts until about 17:00 during which time the total runoff was approximately 1.8 ac-ft. The majority of the precipitation and runoff, however, occurred in the Water Canyon watershed downstream of gage E252 (see Figure A-9).

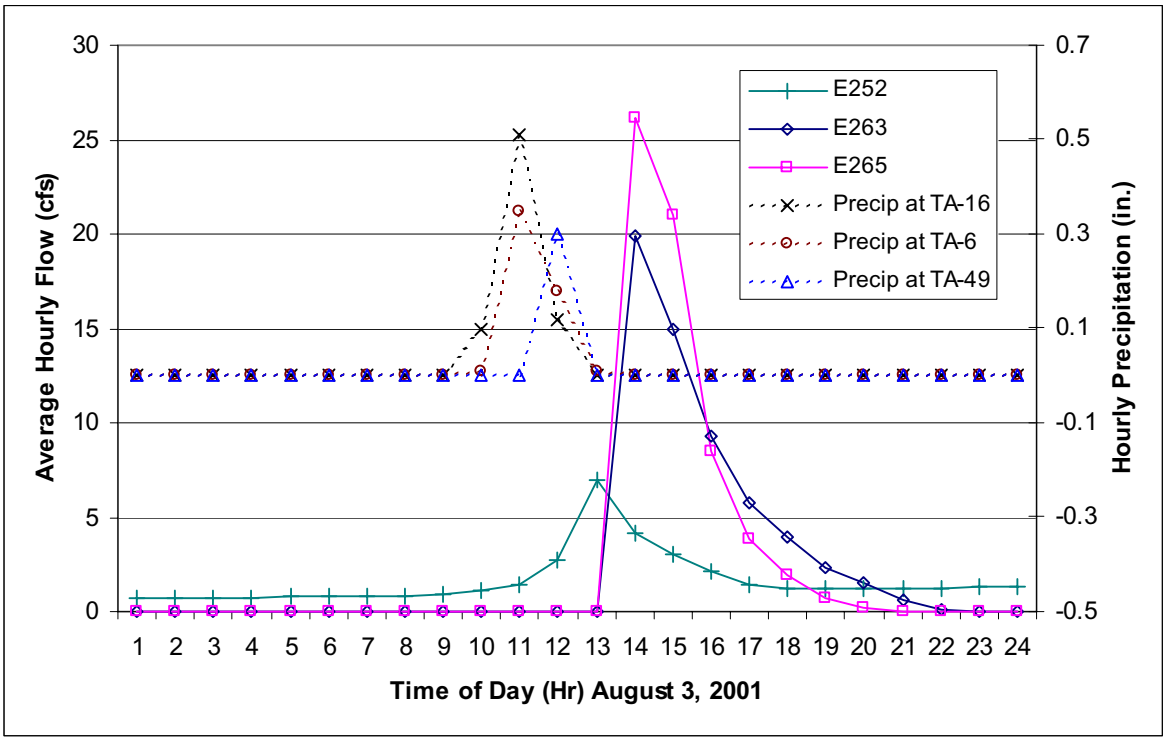


Figure 4-12. Precipitation at TA-16, TA-6, and TA-49 and flow in Water Canyon on August 3, 2001.

Runoff in lower Water Canyon at gage E263 began at SR 4 at 13:40 when the peak flow was 72 cfs. Runoff at this gage continued until 21:20 and the total runoff was approximately 4.7 ac-ft. Runoff samples were collected twice during the runoff event, once at 13:34 and again at 16:14. Runoff began at gage E265 in lower Water Canyon below SR 4 at 13:45 when the peak flow was 92.3 cfs. Runoff continued until 20:15 and the total runoff was approximately 5.1 ac-ft. Runoff samples were collected twice at this gage during the runoff event, once at 13:41 and again at 15:54.

The precipitation and runoff event on August 3 was apparently quite localized within the Water Canyon drainage; flow was not recorded at stream gage E275 in lower Ancho Canyon and only a small amount of flow (less than 0.2 cfs) was measured at gage E245 in middle Pajarito Canyon.

Personnel of the RRES-WQH collected runoff samples from the automated sampling stations in Water Canyon on August 3. The sites sampled on August 3, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-10. Runoff samples from Acid Canyon were collected during a small runoff event in that canyon, but stream gage data are not currently available for this gage.

4.11 August 4, 2001

A precipitation event occurred on the eastern part of the Pajarito Plateau on the afternoon of August 4. The highest precipitation was received at the TA-54 meteorological station where 0.56 in. was received from 12:45 to 13:30. The TA-16 station received 0.28 in. and the TA-6 station received 0.1 in. Other stations on the Pajarito Plateau generally received less than 0.1 in. except for upper Los Alamos Canyon and Quemazon Canyon where 0.2 in. was received. The pattern of precipitation received on the Pajarito Plateau on August 4 is shown in Figure A-10.

Table 4-10. Storm Water Runoff Samples Collected on August 3, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Acid Canyon					
08/03/01	E056	GF01081E056	10:30	F	Gen, Metals
08/03/01	E056	GU01081E056	10:30	UF	TSS, Gen, Metals
Water Canyon					
08/03/01	E262.5	GF01082E262.5	12:54	F	Gen, Metals, Rad
08/03/01	E262.5	GU01082E262.5	12:54	UF	TSS, Gen, Metals, Rad, CN, ClO_4, H-3
08/03/01	E261	GF01081E261	13:30	F	Gen, Metals
08/03/01	E261	GU01081E261	13:30	UF	TSS, Metals
08/03/01	E263	GU01083E263	13:36	UF	TSS, Metals, Rad
08/03/01	E263	GF01082E263	16:14	F	Gen, Metals
08/03/01	E263	GU01082E263	16:14	UF	TSS, Gen, Metals, CN, H-3
08/03/01	E265	GF01082E265	13:41	F	Gen, Rad
08/03/01	E265	GU01082E265	13:41	UF	TSS, Gen, CN, H-3, ClO_4
08/03/01	E265	GF01081E265	15:54	F	Gen, Metals
08/03/01	E265	GU01081E265	15:54	UF	TSS, Metals, Rad, ClO_4, H-3

Figure 4-13 shows the hourly precipitation received at the upper Los Alamos Canyon RAWS and the flow in Los Alamos Canyon, DP Canyon, and Pueblo Canyon on August 4. A small amount of flow (about 3.5 cfs) was present in upper Los Alamos Canyon at gage E026 on the morning of August 4; the result of discharge from the Los Alamos Canyon Reservoir. Runoff at gage E026 began at 13:50 with a peak flow of 6.4 cfs. The runoff event continued at gage E026 until about 15:00 during which time the total runoff was approximately 0.4 ac-ft. Runoff began at gage E030 in middle Los Alamos Canyon above DP Canyon at 14:55 when the peak flow was about 3 cfs. Flow supported by discharge from the reservoir continued at gage E030 throughout the day on August 4, but the runoff event ended about 18:30; the total runoff was approximately 0.3 ac-ft.

Runoff began at gage E038 in upper DP Canyon at 13:40 when the peak flow was 160 cfs. Runoff continued until 15:00 during which time the total runoff was approximately 2.8 ac-ft. Runoff began at gage E040 in lower DP Canyon above Los Alamos Canyon at 14:35 when the peak runoff was 11.5 cfs. Runoff continued at E040 until 18:15 and the total runoff was approximately 0.8 ac-ft.

Runoff began at gage E042 in lower Los Alamos Canyon at 15:35 when the peak flow was 21.3 cfs. Flow continued in small volumes until about 02:40 on the morning of August 5; the total runoff at gage E042 was approximately 1.7 ac-ft. A small volume of local runoff (about 1 cfs) began at gage E060 in lower Pueblo Canyon at 15:10 but the major runoff event began at 17:00. The peak flow was 61.6 cfs at 17:15 and runoff continued until about 10:00 on the morning of August 5, possibly supported by discharges from the Los Alamos County Sewage Treatment Plant. The total runoff at gage E060 in Pueblo Canyon was approximately 9.8 ac-ft.

A small amount of runoff resulting from the precipitation event at TA-54 occurred at gage E230 in lower Cañada del Buey on August 4. Runoff began at 14:15 and the peak flow was 5.8 cfs at 14:35. Runoff continued until 15:40 and the total runoff was approximately 0.1 ac-ft. Records of runoff at gage E250 in lower Pajarito Canyon for August 4 are not available.

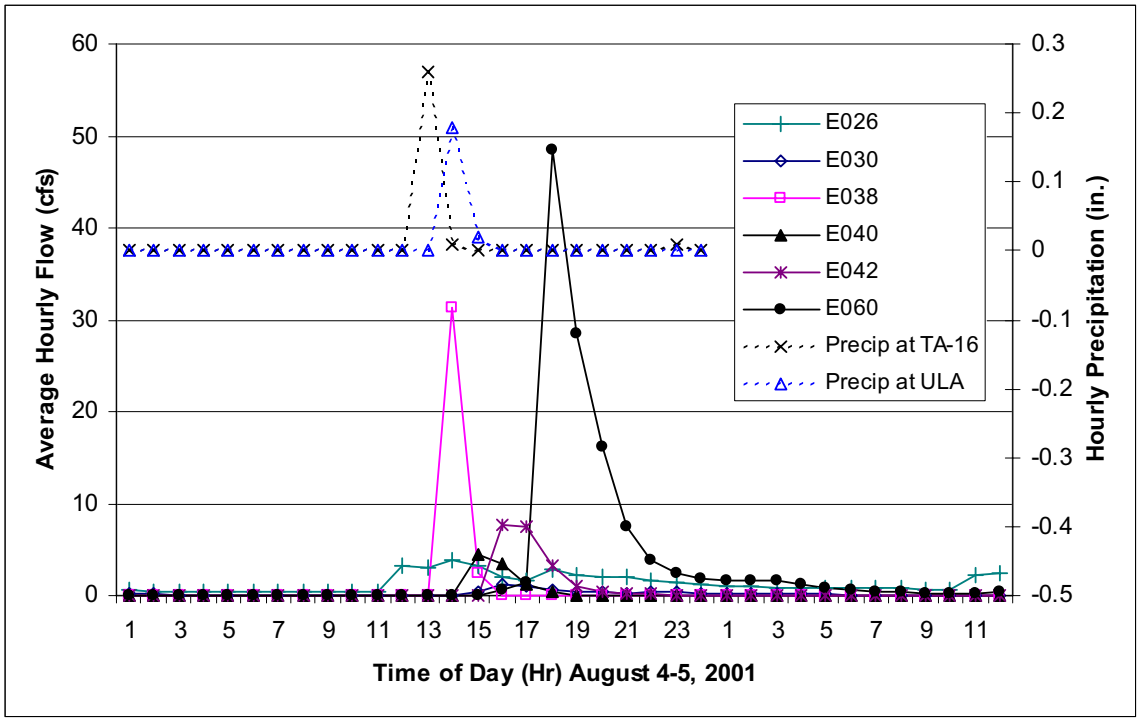


Figure 4-13. Precipitation at the upper Los Alamos Canyon RAWS and flow in Los Alamos, DP, and Pueblo Canyons on August 4, 2001.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in Los Alamos Canyon, DP Canyon, and Pueblo Canyon on August 4. The sites sampled on August 4, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-11.

Table 4-11. Storm Water Runoff Samples Collected on August 4, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
DP Canyon					
08/04/01	E038	GF01086E038	12:36	F	Gen, Hg
08/04/01	E038	GU01086E038	12:36	UF	TSS, Gen, CN, H-3
08/04/01	E039	GU01083E039	13:54	UF	TSS, Gen
08/04/01	E040	GF01084E040	14:27	UF	Gen, Metals
08/04/01	E040	GU01084E040	14:27	F	TSS, Metals
Los Alamos Canyon					
08/04/01	E042	GF01085E042	15:31	F	Gen, Metals, Rad
08/04/01	E042	GU01085E042	15:31	UF	TSS, Gen, Metals, Rad, H-3, CN
Pueblo Canyon					
08/04/01	E060	GU01083E060	16:06	UF	TSS, Rad, H-3
Cañada del Buey					
08/04/01	E248.5	GF01085E248.5	14:11	F	Gen, Metals, Rad
08/04/01	E248.5	GU01085E248.5	14:11	UF	Gen, Metals, Rad, CN, H-3
08/04/01	E249.5	GF010810E249.5	22:34	F	Gen, Metals, Rad
08/04/01	E249.5	GU010810E249.5	22:34	UF	TSS, Metals, Rad

4.12 August 5, 2001

Two precipitation events occurred on the Pajarito Plateau on August 5. The first thunderstorm occurred during the afternoon over the western part of the plateau and the Sierra de los Valles from about 14:30 to 15:30. The highest precipitation was at TA-6 where 0.33 in. was received. During the afternoon precipitation event, the Pajarito Canyon RAWS received 0.19 in., the upper Los Alamos Canyon RAWS received 0.24 in., and the Pueblo Canyon RAWS received 0.11 in., while TA-53 received only 0.04 in. and TA-54 did not receive precipitation. The pattern of precipitation received on the afternoon of August 5 is shown in Figure A-11a.

The second precipitation event occurred on the evening of August 5 from about 19:30 to 20:00; this event occurred mainly over the eastern part of the Pajarito Plateau. TA-54 received 0.11 in. while other meteorological stations received less than 0.06 in. The pattern of precipitation received during the evening hours of August 5 is shown in Figure A-11b.

Figure 4-14 shows the precipitation at TA-6 and the upper Los Alamos Canyon RAWS and flow at stream gages in Los Alamos Canyon on the afternoon of August 5. A small volume of flow (1 to 2 cfs) was present in upper Los Alamos Canyon at gage E026 during the morning and early afternoon, the result of discharges from the Los Alamos Canyon Reservoir. Runoff associated with the precipitation event began at gage E026 at 16:15 and the peak runoff was 15.2 cfs at 16:50 and 17:10. This initial runoff event continued in decreasing volumes until 20:10 when a second smaller runoff event resulting from the second precipitation event occurred. The peak flow during the second runoff event was 3.5 cfs at 20:25 and runoff continued at gage E026 until about 23:00. The total runoff during the initial runoff event at gage E026 was approximately 1.8 ac-ft and the total runoff during the second event was approximately 0.6 ac-ft for a total runoff of about 2.4 ac-ft.

Runoff from the afternoon precipitation event began at gage E030 at 17:40 when the peak flow was 9 cfs. Runoff continued in decreasing amounts until 22:45 when runoff increased to a peak of 2 cfs as a result of the evening precipitation event; small volumes of runoff continued until about 03:00 on the morning of August 6. The total flow during the initial runoff event was approximately 1.1 ac-ft and during the second event was approximately 0.2 ac-ft for a total runoff of about 1.3 ac-ft.

Runoff at gage E042 in lower Los Alamos Canyon began at 18:40 and the peak flow was 29.4 cfs at 18:45. Runoff continued in decreasing amounts until 00:10 on the morning of August 6 when runoff increased to a peak of 4.3 ac-ft after the evening precipitation event. Runoff continued until 11:50 on the morning of August 6 and the runoff during the initial event was approximately 2.3 ac-ft and runoff during the second event was approximately 0.5 ac-ft for a total runoff of about 2.8 ac-ft.

Figure 4-15 shows the precipitation at TA-6 and the upper Los Alamos Canyon RAWS and flow at stream gage E123 in Sandia Canyon on August 5. A small volume of flow (about 1 cfs) was present in Sandia Canyon at gage E026 during the morning and early afternoon, the result of discharges from the LANL sanitary wastewater systems (SWS) at TA-3. Runoff began at gage E123 at 16:15 and the peak runoff was 45.9 cfs at 17:00. The runoff from the initial runoff event continued until about 20:30 and the total initial runoff was approximately 2.8 ac-ft. A second runoff event began at 22:00 and the peak flow was 2.7 cfs at 22:20; flow continued until about 00:30 on the morning of August 6 and the runoff during the second event was approximately 0.2 ac-ft. The total runoff in Sandia Canyon at gage E123 on August 5 was approximately 3 ac-ft.

Figure 4-16 shows the precipitation at TA-6 and TA-54 and flow at stream gages in Pajarito Canyon on August 5 and 6. Flow began in upper Pajarito Canyon at gage E240 at 16:30 and the peak flow was 4.4 cfs at 17:00. Runoff continued for a short time until 18:10 and the total runoff was approximately 0.2 ac-ft. A small amount of base flow (about 0.02 cfs) at gage E241 in Pajarito Canyon is supported by spring discharge. Runoff at gage E241 began at 16:15 and the peak runoff was 4.3 cfs at 17:45. Runoff continued at gage E241 until about 22:00 and the total runoff (supported by spring flow) was approximately 0.4 ac-ft. Runoff at gage E242 in Starmers Gulch began at 17:10 and the peak flow was 103 cfs at 17:20; runoff continued until about 20:30 and the total runoff was approximately 2.6 ac-ft.

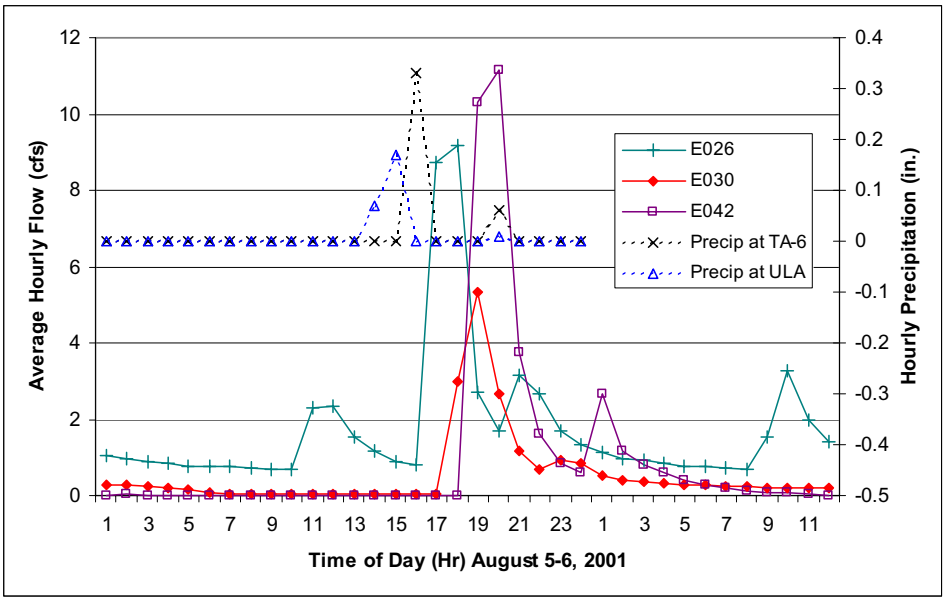


Figure 4-14. Precipitation at TA-6 and the upper Los Alamos Canyon RAWS and flow in Los Alamos Canyon on August 5 and 6, 2001.

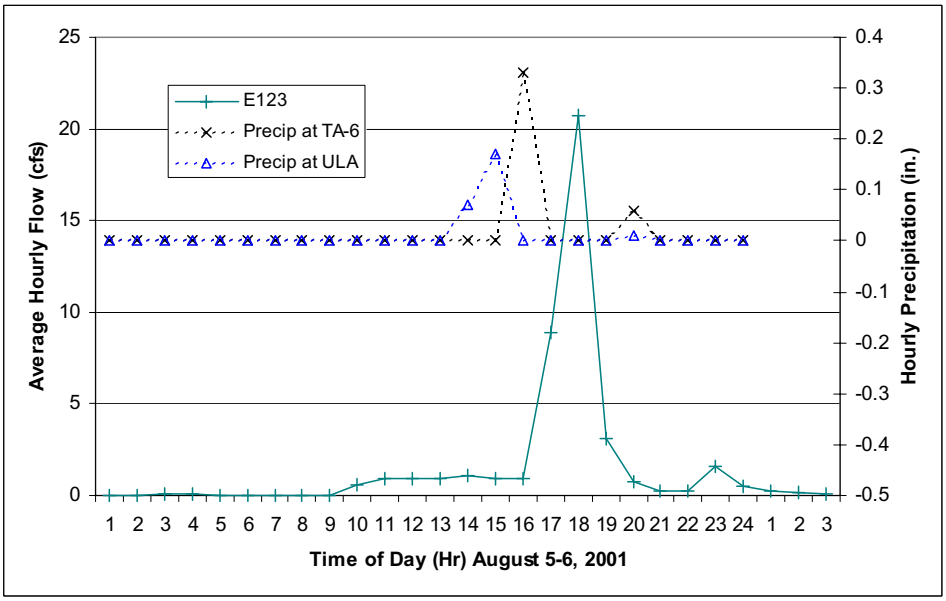


Figure 4-15. Precipitation at TA-6 and the upper Los Alamos Canyon RAWS and flow in Sandia Canyon on August 5 and 6, 2001

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Runoff began at gage E245 in middle Pajarito Canyon below the Pajarito Canyon Retention Pond at 17:05 and the peak flow was 50.7 cfs at 17:10. Runoff continued until 15:10 on the afternoon of August 6, partially supported by spring flow. The total runoff at gage E245 was approximately 7 ac-ft. The higher

flow at gage E245 was largely the result of the location of the afternoon precipitation event, which was approximately centered between gages E241 and E245 (see Figure A-11a). The evening precipitation event was apparently not of adequate amount in the watershed upstream of gage E245 to result in an increase in flow during the evening hours (buffered by the Pajarito Canyon Retention Pond), although runoff at gage E245 was likely sustained by the evening precipitation.

Runoff at gage E250 in lower Pajarito Canyon began at 03:25 on the morning of August 6 and the peak flow was 1.1 cfs at 03:45. Runoff continued until 21:35 on the evening of August 6 and the total runoff was approximately 0.36 ac-ft. Based on previous similar precipitation events, it is doubtful if the afternoon precipitation event at TA-6 (0.33 in.) would have caused runoff in Pajarito Canyon as far downstream as gage E250. However, due to the previous several days of precipitation causing elevated moisture conditions in soils and sediments and to the evening precipitation event at TA-54 (0.11 in.), conditions were apparently sufficient to produce a small amount of runoff in lower Pajarito Canyon at gage E250.

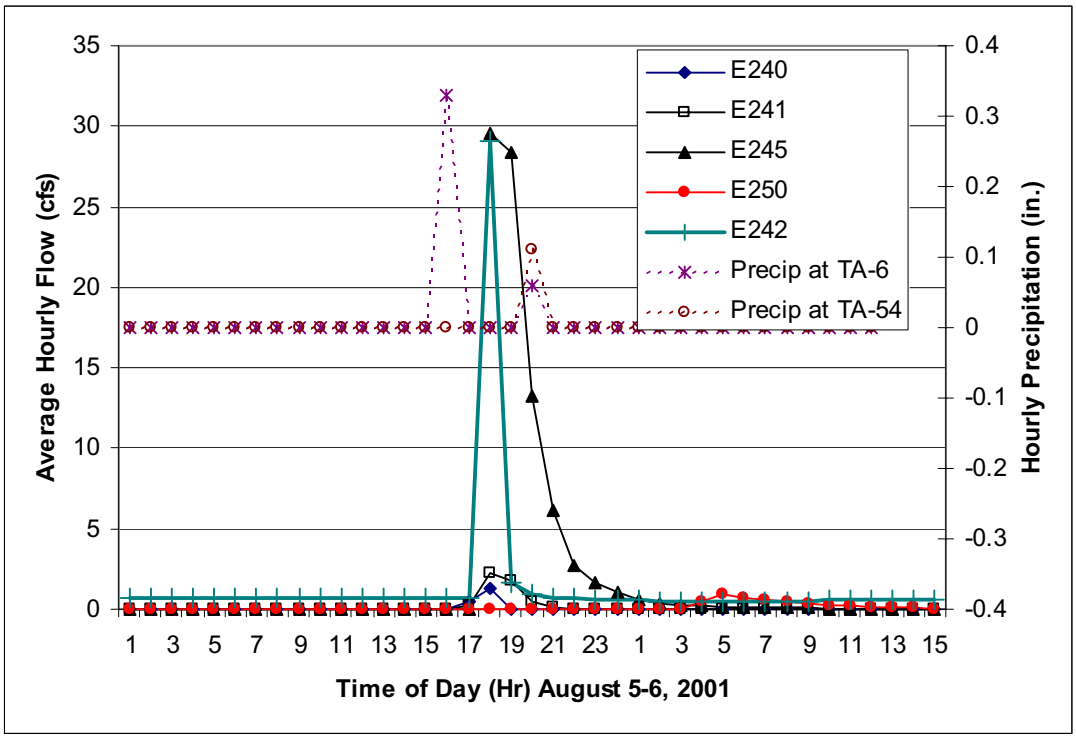

Figure 4-16. Precipitation at TA-6 and TA-54 and flow in Pajarito Canyon on August 5 and 6, 2001.

Figure 4-17 shows the precipitation at TA-6 and TA-54 and flow at stream gages in Water Canyon and Cañon de Valle on August 5 and 6. Base flow in upper Water Canyon at gage E252 from spring discharges from the Water Canyon Gallery on the morning of August 5 was 1.5 to 2 cfs. Runoff began at gage E252 at 18:05 and peak runoff was 14.5 cfs at 18:30. Runoff continued until about 23:00 and the total runoff at gage E252 was approximately 1.9 ac-ft.

Runoff began in upper Cañon de Valle at gage E253 at 17:10 when the peak flow was 15.8 cfs. Runoff continued until 21:20 and the total runoff was approximately 0.6 ac-ft. Runoff began at gage E262 in lower Cañon de Valle above the confluence with Water Canyon at 20:10 when the peak flow was 3.7 cfs. Runoff continued until 02:50 on the morning of August 6 and the total runoff was approximately 0.5 ac-ft.

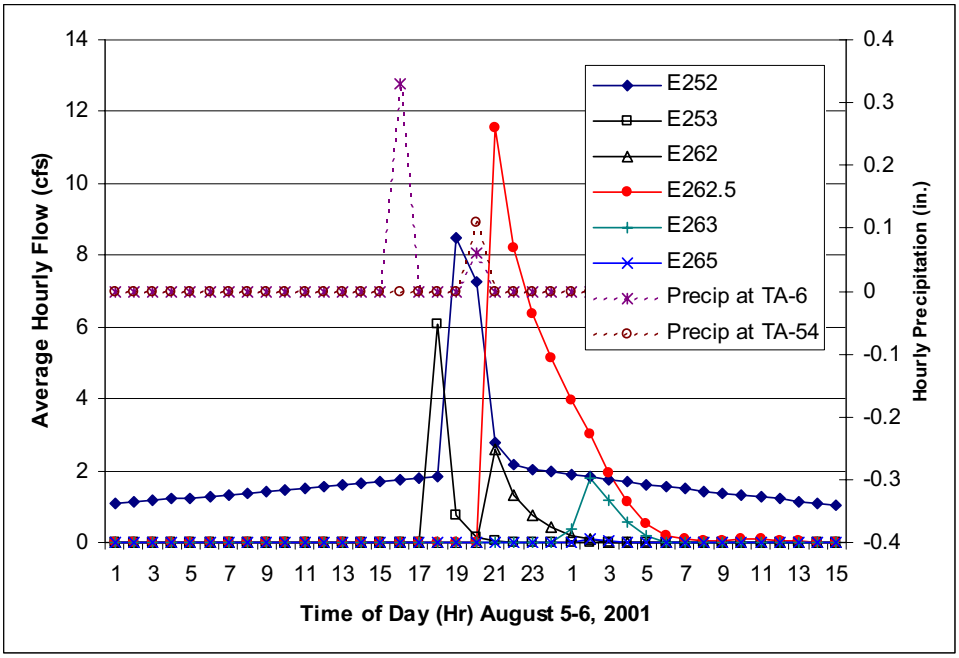

Figure 4-17. Precipitation at TA-6 and TA-54 and flow in Water Canyon and Cañon de Valle on August 5 and 6, 2001.

Runoff began in middle Water Canyon at gage E262.5 at 20:10 when the peak flow was 15.4 cfs. Runoff continued until 16:05 on the afternoon of August 6 and the total runoff was approximately 3.5 ac-ft. Runoff began in lower Water Canyon at gage E263 at 00:55 on the morning of August 6 when the peak flow was 2.2 cfs. Runoff continued until 04:40 and the total runoff at gage E263 was approximately 0.3 ac-ft. Runoff at gage E265 in lower Water Canyon began at 01:30 when the peak flow was 0.3 cfs. Flow continued for about an hour until 02:40 during which time the total flow was approximately 0.01 ac-ft.

Runoff in the lower part of Water Canyon on August 5 was probably the result of the evening precipitation event rather than from runoff from the upper and middle portions of the canyon that occurred earlier in the day. The evening precipitation event was augmented by rains received earlier in the day, and over the previous several days, which caused increased moisture conditions in the soil and sediments.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in Los Alamos Canyon, Sandia Canyon, Pajarito Canyon, Potrillo Canyon, and Water Canyon on August 5 and 6. The sites sampled on August 5 and 6, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-12.

4.13 August 7 and 8, 2001

Two precipitation events occurred in the Pajarito Plateau area on August 7. A thunderstorm occurred over the Sierra de los Valles in the mid-afternoon of August 7 and light intermittent rainfall was received across the western Pajarito Plateau on the evening of August 7 from about 18:00 to midnight. The highest daily rainfall amounts were received at the Pajarito Canyon RAWS, which received 0.32 in., and at Pajarito Mountain, which received 0.31 in. The Water Canyon RAWS received 0.18 in., the Quemazon Canyon RAWS received 0.27 in., the upper Los Alamos Canyon RAWS received 0.29 in., and TA-16 received 0.21 in. The TA-6 meteorological station received 0.29 in., while the eastern part of the Pajarito Plateau did not receive significant precipitation on August 7. The pattern of precipitation received on August 7 is shown in Figure A-12.

Table 4-12. Storm Water Runoff Samples Collected on August 5 and 6, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Los Alamos Canyon					
08/05/01	E030	GF01084E030	17:37	F	Gen, Metals, Rad
08/05/01	E030	GU01084E030	17:37	UF	TSS, Gen, Metals, Rad, CN, H-3
Sandia Canyon					
08/05/01	E123	GF01081E123	15:40	F	Gen, Metals
08/05/01	E123	GU01081E123	15:40	UF	TSS, Metals, Rad
Pajarito Canyon					
08/05/01	E247	GU01081E247	13:12	UF	TSS, Metals, Rad
08/05/01	E241	GF01082E241	16:42	F	Gen, Metals
08/05/01	E241	GU01082E241	16:42	UF	TSS, Gen, Metals, Rad, ClO_4, H-3
08/05/01	E245	GF01083E245	17:04	F	Gen, Metals
08/05/01	E245	GU01083E245	17:04	UF	TSS, Metals
08/06/01	E250	GF01082E250	01:34	F	Gen, Metals, Rad
08/06/01	E250	GU01082E250	01:34	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3
Potrillo Canyon					
08/06/01	E269	GF01081E269	02:22	F	Rad
08/06/01	E269	GU01081E269	02:22	UF	TSS, Rad
Water Canyon/Cañon de Valle					
08/05/01	E262	GF01081E262	07:52	F	Gen, Metals
08/05/01	E262	GU01081E262	07:52	UF	TSS, Gen, Metals, Rad

The hourly precipitation received at the Quemazon Canyon and upper Los Alamos Canyon RAWS and at TA-6 and flow at gages in Los Alamos Canyon on August 7 and 8 are shown in Figure 4-18. Base flow at gage E026 in Los Alamos Canyon from spring discharge and flow from the Los Alamos Canyon Reservoir was about 0.6 cfs on the morning of August 7. Runoff from the afternoon precipitation in the Sierra de los Valles began at gage E026 at 13:40 and peak flow was 4.3 cfs at 13:50. This runoff event continued at gage E026 until about 20:00 and the total runoff during this event was approximately 0.8 ac-ft. A second runoff event occurred at gage E026 at 22:10 in response to the evening precipitation event. The peak flow during the second runoff event was 1.7 cfs at 22:20 and runoff continued until about 03:00 on the morning of August 8. The runoff at gage E026 during the second runoff event was approximately 0.4 ac-ft and the total runoff at gage E026 from the two events was approximately 1.2 ac-ft.

Stream flow at gage E030 in middle Los Alamos Canyon began at 18:20 in response to saturation of the stream channel due to upstream runoff and spring flow. The peak flow was 0.3 cfs at 18:25 and flow continued in decreasing volumes until 23:25 when runoff began in response to the evening precipitation event. Peak runoff at gage E030 was 2 cfs at 23:25 and runoff continued until about 06:00 on the morning of August 8, although base flow continued at about 0.2 cfs. The total runoff at gage E030 was approximately 0.3 ac-ft.

Runoff at gage E042 in lower Los Alamos Canyon began at 00:45 on the morning of August 8 when the peak flow was 8.2 cfs. Runoff continued until 08:30 and the total runoff in lower Los Alamos Canyon was approximately 0.8 ac-ft.

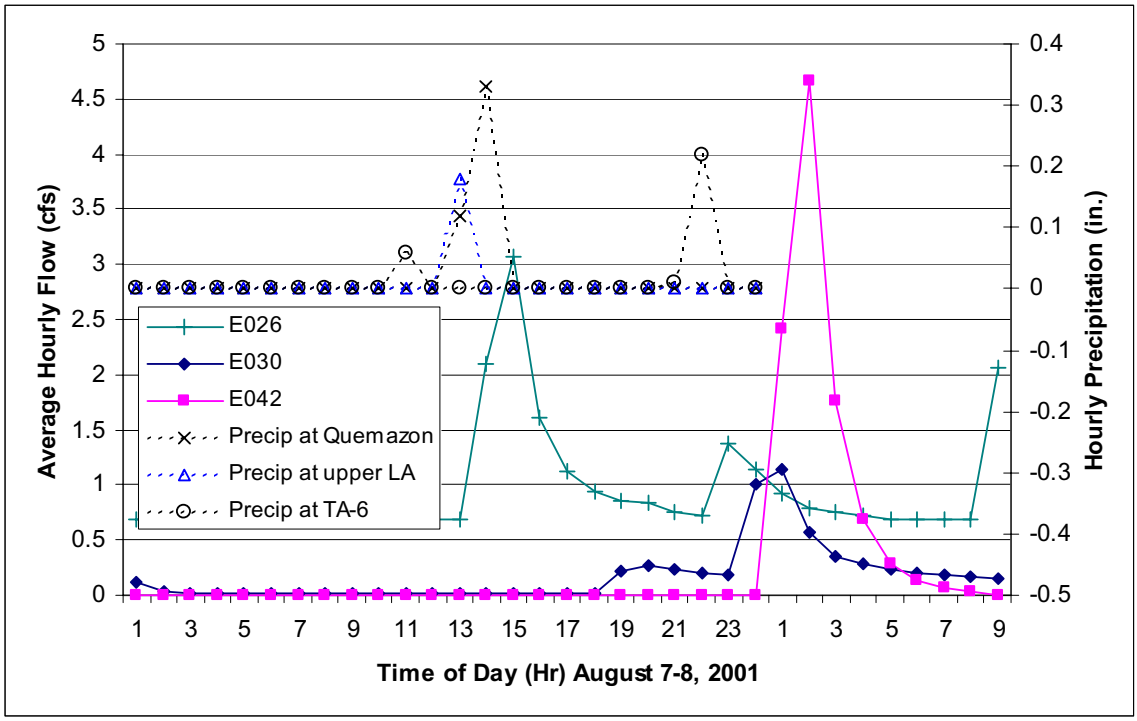

Figure 4-18. Precipitation at TA-6, Quemazon Canyon, and upper Los Alamos Canyon RAWS and flow in Los Alamos Canyon on August 7 and 8, 2001.

Another rainstorm occurred mainly over the higher elevations of the northern Sierra de los Valles during the early afternoon on August 8. The highest precipitation was at the Quemazon Canyon RAWS, which received 0.45 in., and the Garcia Canyon RAWS, which received 0.24 in. The upper Los Alamos Canyon RAWS received 0.18 in. and the Guaje Canyon RAWS received 0.19 in. The TA-6 meteorological station received 0.01 in. and the TA-54 station received 0.08 in. The pattern of precipitation received on August 8 is shown in Figure A-13.

Figure 4-19 shows the precipitation at the Garcia Canyon and Guaje Canyon RAWS and flow at gage E089 in Guaje Canyon on August 8. Runoff at gage E089 began at 14:45 and the peak flow was 4 cfs at 14:50. Runoff continued until about 18:00 and the total runoff at gage E089 was approximately 0.4 ac-ft.

The hourly precipitation received at TA-6 and the Water Canyon RAWS and runoff at gages in Water Canyon on August 7 and 8 is shown in Figure 4-20. Runoff was not recorded in Cañon de Valle at gages E253 and E262 or in middle Water Canyon at gage E262.5 on the evening of August 7 or on the morning of August 8, however, runoff was recorded at gages E263 and E265 in lower Water Canyon on the morning of August 8. Runoff began at gage E263 at 06:15 on the morning of August 8 when the peak flow was 1.9 cfs. Flow continued at gage E263 until 10:15 and the total flow was approximately 0.4 ac-ft. Runoff began at gage E265 at 06:50 when the peak flow was 0.2 cfs. Flow continued for a short time at gage E265 until 08:05 and the total runoff was approximately 0.01 ac-ft.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in Water Canyon and Guaje Canyon on August 8. The sites sampled, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-13.

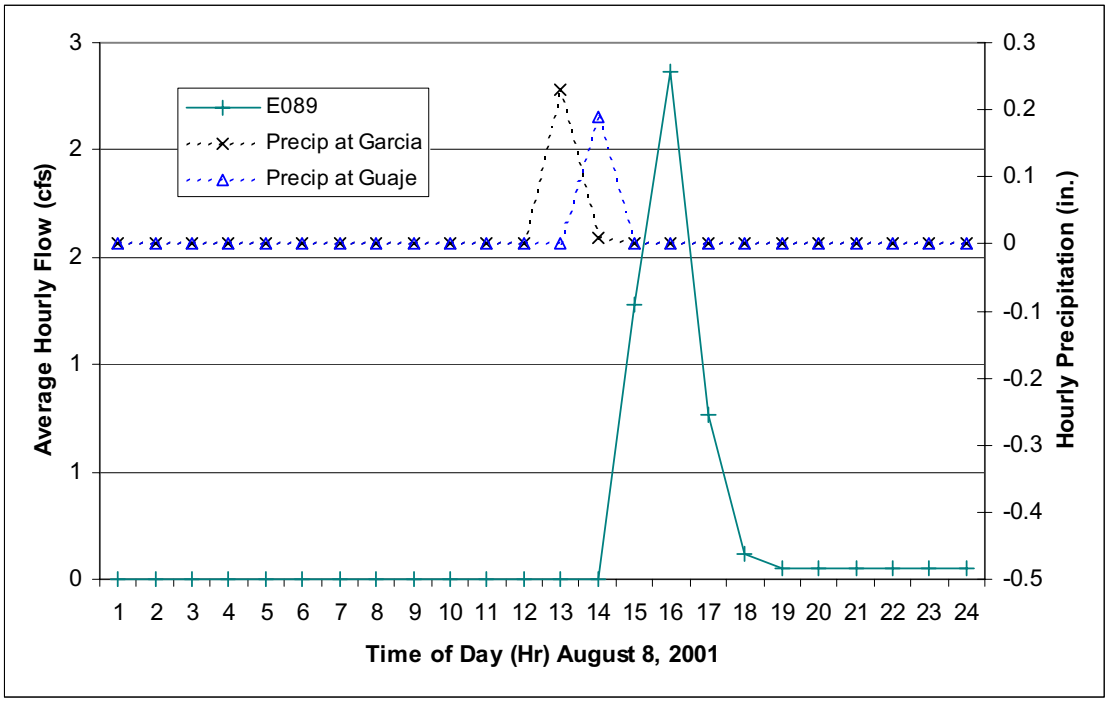

Figure 4-19. Precipitation at Quemazon and Guaje Canyon RAWS and flow in Guaje Canyon on August 8, 2001.

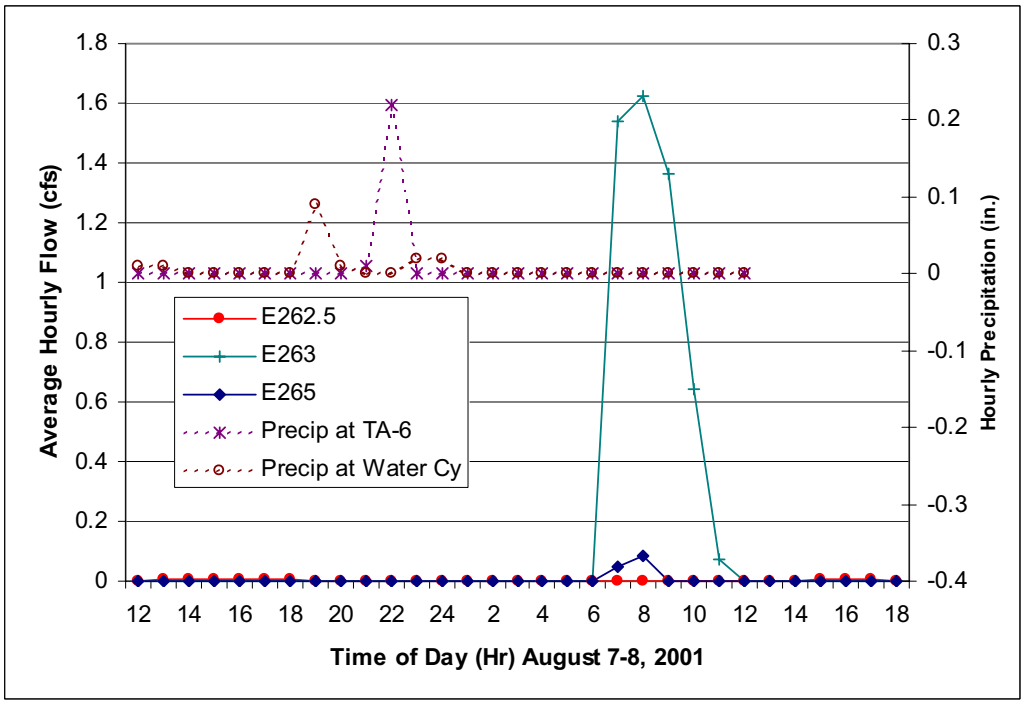

Figure 4-20. Precipitation at TA-6 and the Water Canyon RAWS and flow in Water Canyon on August 7 and 8, 2001.

Table 4-13. Storm Water Runoff Samples Collected on August 8, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Guaje Canyon					
08/08/01	E089	GF01082E089	14:45	F	Gen, Metals
08/08/01	E089	GU01082E089	14:45	UF	TSS, Gen, Metals, Rad

4.14 August 9, 2001

A relatively large thunderstorm event occurred over the Sierra de los Valles on the afternoon of August 9. The highest precipitation was received at the upper Los Alamos Canyon RAWS, where 1.24 in. of rain was received within a two-hour period from about 13:00 to 15:00. The Quemazon Canyon RAWS received 1.18 in., the Pajarito Canyon RAWS received 0.8 in., and the Water Canyon RAWS received 0.72 in. The highest precipitation at LANL was at TA-16, where 0.54 in. was received; TA-6 received 0.07 in., but the TA-49, TA-53, and TA-54 meteorological stations did not receive any precipitation on August 9. The pattern of precipitation received on August 9 is shown in Figure A-14.

The hourly precipitation at the Quemazon, upper Los Alamos, and Pueblo Canyon RAWS and flow at gaging stations in Los Alamos, Pueblo, and Guaje Canyons is shown in Figure 4-21. Runoff at gage E026 in upper Los Alamos Canyon began at 15:20 and the peak flow was 185 cfs at 15:45. Runoff continued at gage E026 until about 21:00 and the total runoff was approximately 9.2 ac-ft. Runoff at gage E030 in middle Los Alamos Canyon began at 16:55 and the peak runoff was 59.6 cfs at 17:05. Runoff continued until about 03:00 on the morning of August 10 and the total runoff was approximately 4.9 ac-ft. Runoff at gage E042 in lower Los Alamos Canyon began at 17:40, where the peak flow was 146 cfs at 17:45. Runoff continued until about 01:30 on the morning of August 10 and the total runoff at gage E042 was approximately 11.6 ac-ft. The peak runoff at gages E026 and E030 on August 9 surpassed previous historical peak records at these sites (see Section 3.2.2).

Runoff began at gage E060 in lower Pueblo Canyon at 17:10 when the peak flow was 244 cfs. Runoff continued until about 06:00 on the morning of August 10 and the total runoff in lower Pueblo Canyon was approximately 23.6 ac-ft.

Runoff at gage E089 in Guaje Canyon began at 15:35 when the peak flow was 21 cfs. Runoff continued in small volumes until 04:20 on the morning of August 10 and the total runoff was approximately 1.8 ac-ft.

Figure 4-22 shows the hourly precipitation at the Pajarito Canyon and upper Los Alamos Canyon RAWS and average hourly flow at gages E240, E241, and E250 in Pajarito Canyon on August 9 and 10. Runoff began in upper Pajarito Canyon at gage E240 at 15:00 with a peak flow of 155 cfs. A small amount of runoff continued until 22:20 on the evening of August 9 during which time the total runoff was approximately 2.6 ac-ft. Runoff began at gage E241 at 15:00 when the peak flow was 109 cfs. Runoff continued until about 19:15 and the total runoff was approximately 1.2 ac-ft.

Flow records for gage E245 in middle Pajarito Canyon are not available for August 9. Runoff began in lower Pajarito Canyon at gage E250 at 21:05 on the evening of August 9 and continued in declining volumes until 15:20 on the afternoon of August 11. The peak flow was 11.5 cfs at 21:45 on August 9 and the total runoff in lower Pajarito Canyon was approximately 3.2 ac-ft.

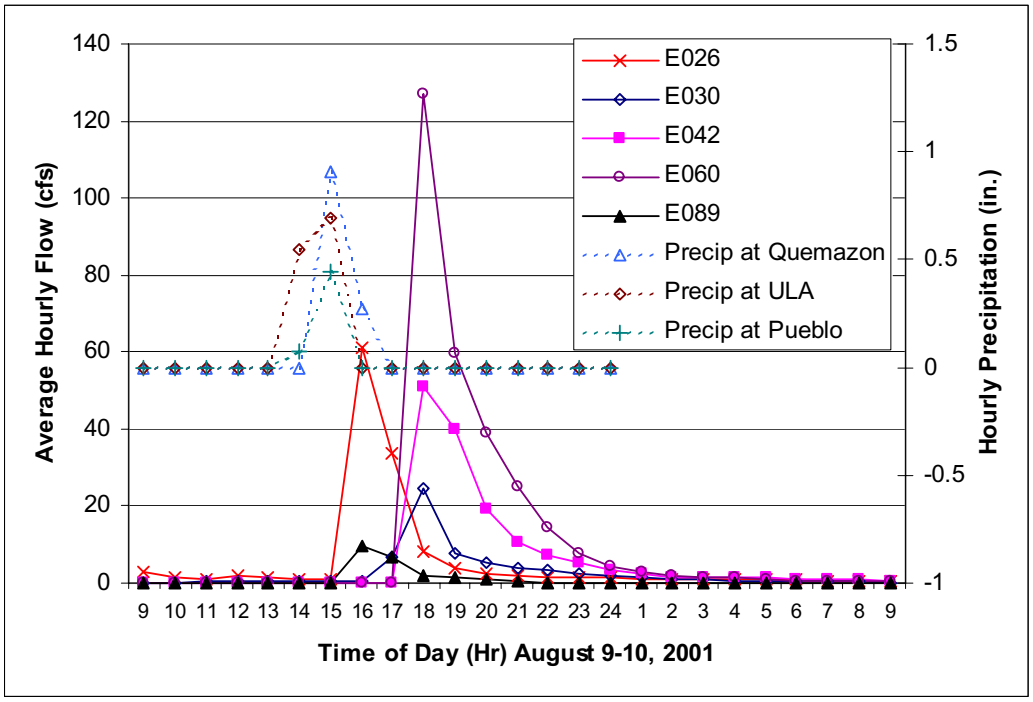

Figure 4-21. Precipitation at Quemazon, upper Los Alamos, and Pueblo Canyon RAWS and flow in Los Alamos, Pueblo, and Guaje Canyons on August 9 and 10, 2001.

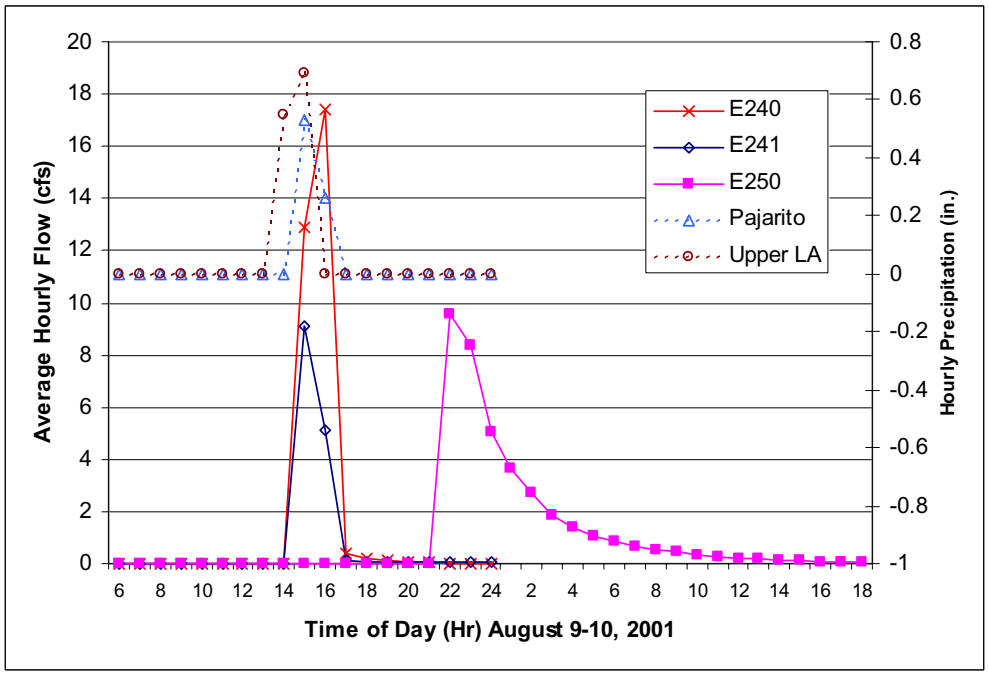

Figure 4-22. Precipitation at Pajarito Mountain and upper Los Alamos Canyon RAWS and flow in Pajarito Canyon on August 9 and 10, 2001.

Figure 4-23 shows the hourly precipitation at the Pajarito Canyon and Water Canyon RAWS and average hourly flow at gages in Water Canyon and Cañon de Valle on August 9 and 10. Runoff began at gage E253 in upper Cañon de Valle at 14:10 and the peak flow was 16.9 cfs at 14:55. Runoff continued until about 23:00 on the evening of August 9 and the total runoff was approximately 1.2 ac-ft. Gage E252 in upper Water Canyon did not record the runoff event. Runoff began at gage E262 in lower Cañon de Valle at 16:55 and the peak flow was 25.7 cfs at 17:00. Runoff continued until 07:00 on the morning of August 10 and the total runoff in lower Cañon de Valle was approximately 2.0 ac-ft.

Runoff began at gage E262.5 in middle Water Canyon at 16:55 and the peak flow was 50 cfs at 17:00. Runoff continued until 22:45 and the total runoff at gage E262.5 was approximately 5.1 ac-ft. Runoff began at gage E263 in lower Water Canyon at 18:10 and the peak flow was 25.2 cfs at 18:15. Runoff continued until 00:15 on the morning of August 10 and the total runoff was approximately 3.1 ac-ft. Runoff began at gage E265 in lower Water Canyon at 18:20 and the peak flow was 22.2 cfs at 18:25. Runoff continued at gage E265 until 07:55 on the morning of August 10 and the total runoff was approximately 3.1 ac-ft.

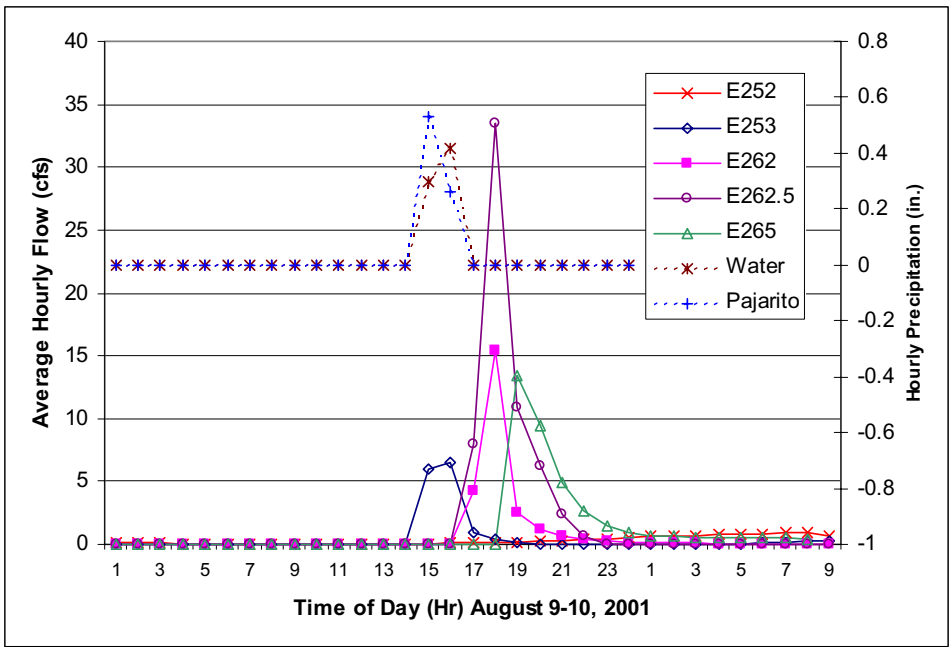

Figure 4-23. Precipitation at the Pajarito and Water Canyon RAWS and flow in Water Canyon and Cañon de Valle on August 9 and 10, 2001.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in Water Canyon and Guaje Canyon on August 9. The sites sampled, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-14.

4.15 August 11, 2001

Two thunderstorms occurred concurrently during the middle of the day on August 11. One thunderstorm was located over the foothills of the Sierra de los Valles west of the town of Los Alamos, where the Pueblo Canyon RAWS received 0.66 in. between 11:00 and 13:00. Another thunderstorm was located over the southern part of the Pajarito Plateau at TA-49, which received 0.49 in. between noon and 13:00. TA-16 received 0.24 in., TA-54 received only 0.01 in., and TA-6 received 0.06 in. The pattern of precipitation received on the Pajarito Plateau on August 11 is shown in Figure A-15.

Table 4-14. Storm Water Runoff Samples Collected on August 9, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Los Alamos Canyon					
08/09/01	E026	GF01085E026	13:37	F	Gen, Metals, Rad
08/09/01	E026	GU01085E026	13:37	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3
08/09/01	E030	GF01085E030	16:52	F	Gen, Metals, Rad
08/09/01	E030	GU01085E030	16:52	UF	Gen, Metals, Rad, ClO_4, CN, H-3
08/08/01	E042	GF01086E042	00:39	F	Gen, Metals
08/08/01	E042	GU01086E042	00:39	UF	TSS, Gen, Metals
08/09/01	E050	GF01082E050	17:58	F	Gen, Metals
08/09/01	E050	GU01082E050	17:58	UF	Gen, Metals, CN, H-3
Pueblo Canyon					
08/09/01	E060	GF01084E060	16:09	F	Gen, Metals, Rad
08/09/01	E060	GU01084E060	1609	UF	Gen, Metals, Rad, ClO_4, CN, H-3
Guaje Canyon					
08/09/01	E089	GF01081E089	16:07	F	Rad, Hg
08/09/01	E089	GU01081E089	16:07	UF	TSS, Rad, Metals, CN, H-3
Pajarito Canyon					
08/09/01	E240	GF01082E240	15:18	F	Gen, Metals
08/09/01	E240	GU01082E240	15:18	UF	TSS, Gen, Metals
08/09/01	E250	GF01083E250	19:58	F	Gen, Metals, Rad
08/09/01	E250	GU01083E250	19:58	UF	Gen, Metals, Rad, ClO_4, CN, H-3
Water Canyon/Cañon de Valle					
08/09/01	E262	GF01082E262	16:54	F	Gen, Metals, Rad
08/09/01	E262	GU01082E262	16:54	UF	Gen, Metals, Rad, ClO_4, CN, H-3
08/09/01	E262.5	GF01083E262.5	16:55	F	Gen, Metals, Rad
08/09/01	E262.5	GU01083E262.5	16:55	UF	TSS, Metals, Rad, CN, ClO_4, H-3
08/09/01	E263	GF01084E263	18:05	F	Gen, Metals, Rad
08/09/01	E263	GU01084E263	18:05	UF	Gen, Metals, Rad, CN, H-3
08/09/01	E265	GF01083E265	18:15	F	Gen, Metals
08/09/01	E265	GU01083E265	18:15	UF	Gen, Metals, Rad

The hourly rainfall at the Quemazon, Pueblo, and Guaje Canyon RAWS and the average hourly flow at gaging stations in Rendija, Guaje, and Pueblo Canyons are shown on Figure 4-24. Runoff at gage E089 in Guaje Canyon began at 13:20 and the peak flow was 644 cfs at 13:30. Runoff continued until 14:15 on the afternoon of August 12 and the total runoff in Guaje Canyon was approximately 15.5 ac-ft. Runoff at gage E090 in Rendija Canyon began at 13:45 and the peak flow was 2120 cfs at 13:50. Runoff continued until 01:35 on the morning of August 12 and the total runoff in Rendija Canyon was approximately 57 ac-ft. The peak flow of 2120 cfs at gage E090 established a new record peak runoff for the Pajarito Plateau.

Runoff at gage E060 in lower Pueblo Canyon began at 14:55 and the peak flow was 248 cfs at 15:00. Runoff continued until about 05:00 on the morning of August 12 and the total runoff in Pueblo Canyon was approximately 31 ac-ft.

Figure 4-25 shows the precipitation at TA-49 and flow in a tributary to Potrillo Canyon at gage E269 on August 11. Runoff at gage E269 began at 13:30 and the peak flow was 0.87 cfs at 13:40. Runoff continued until 22:15 and the total runoff at gage E269 was approximately 1130 cubic feet (0.03 ac-ft).

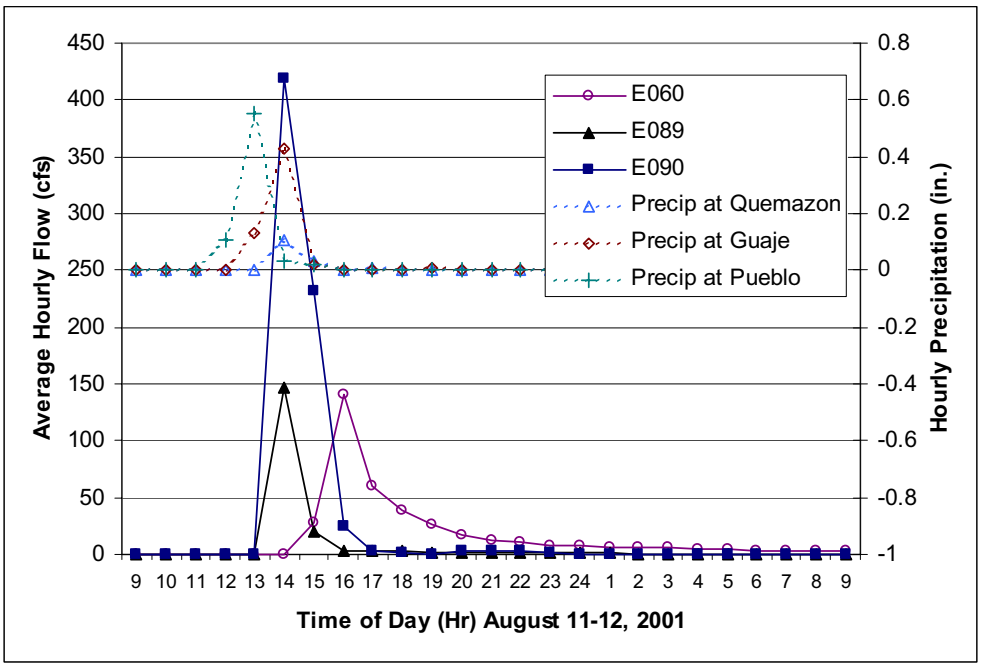

Figure 4-24. Precipitation at the Quemazon, Pueblo, and Guaje Canyon RAWS and flow in Rendija, Guaje, and Pueblo Canyons on August 11 and 12, 2001.

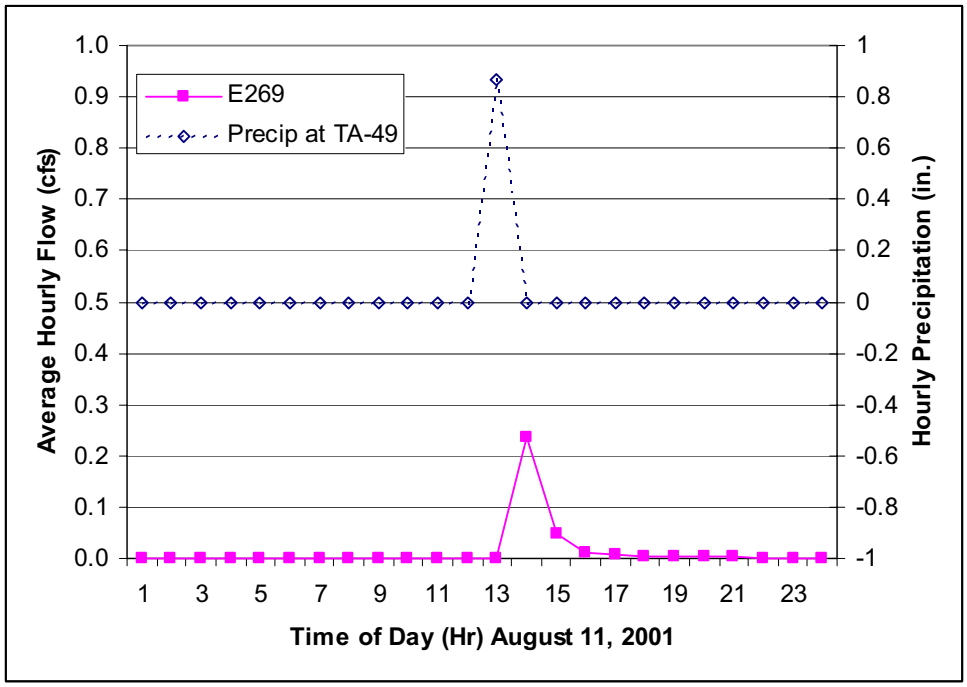

Figure 4-25. Precipitation at TA-49 and flow at gage E269 in Potrillo Canyon on August 11, 2001.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in Guaje Canyon, Pueblo Canyon, Pajarito Canyon, and a tributary to Potrillo Canyon on August 11. The sites sampled, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-15. Runoff samples were collected at gage E241 in Pajarito Canyon at TA-22 on August 11; however, flow data are not available for this gage on this date.

Table 4-15. Storm Water Runoff Samples Collected on August 11, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Pueblo Canyon					
08/11/01	E060	GF01085E060	14:56	F	Gen, Metals, Rad
08/11/01	E060	GU01085E060	14:56	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3
Guaje Canyon					
08/11/01	E089	GF01083E089	13:37	F	Gen, Metals, Rad
08/11/01	E089	GU01083E089	13:37	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3
Pajarito Canyon					
08/11/01	E241	GF01083E241	15:30	F	Gen, Metals
08/11/01	E241	GU01083E241	15:30	UF	TSS, Gen, Metals, Rad, CN
Potrillo Canyon					
08/11/01	E269	GF01082E269	13:30	F	Gen, Metals, Rad
08/11/01	E269	GU01082E269	13:30	UF	TSS, Metals, Rad

4.16 August 12 through 14, 2001

A precipitation event occurred over the southern part of the Pajarito Plateau on the afternoon of August 12, 2001. The highest precipitation on August 12 was at the Bandelier National Monument Frijolito meteorological station where 0.33 in. was received and at TA-49, which received 0.29 in. TA-54 received 0.2 in. and TA-6 received 0.01 in. The pattern of precipitation received on August 12 is shown in Figure A-16. Runoff samples were collected at gage E300 in the Ancho Spring tributary to Ancho Canyon on the afternoon of August 12. Flow records for this gage are not currently available.

A relatively prolonged precipitation event occurred over the Pajarito Plateau and the Sierra de los Valles on the night of August 13-14 between 20:00 and 02:00. The highest amount of precipitation during this period was at the higher elevations in the Sierra de los Valles, where the upper Santa Clara Canyon RAWS received 0.73 in. and the Quemazon Canyon RAWS received 0.61 in. TA-6 received 0.35 in., while the eastern part of LANL received less than 0.2 in. The pattern of precipitation recorded on the night of August 13-14 is shown in Figure A-17.

Precipitation at the Quemazon Canyon, Guaje Canyon, and Pueblo Canyon RAWS on the night of August 13-14 and flow at gages in Los Alamos, Pueblo, and Guaje Canyons is shown in Figure 4-26. Hourly precipitation amounts of up to 0.25 in. occurred over the Sierra de los Valles at about 20:00 on the evening of August 13 and again at about 02:00 on the morning of August 14. Prior to the precipitation events, stream gages in Los Alamos and Pueblo Canyons were flowing small volumes from rains received over the previous several days.

Flow at gage E042 in lower Los Alamos Canyon on the evening of August 13 was about 1 cfs. Runoff associated with the evening precipitation began at 22:15 and slowly increased through the night to a peak runoff of 10.9 cfs at 04:55 on the morning of August 14. Runoff associated with the precipitation event continued in decreasing volumes at gage E042 until about 10:15 on the morning of August 14 but flow

continued at about 2 cfs throughout the day. The total runoff at gage E042 in lower Los Alamos Canyon was approximately 4 ac-ft.

Flow at gage E060 in lower Pueblo Canyon is primarily from discharges from the Los Alamos County Sewage Treatment Plant and was about 2.0 to 2.5 cfs on the evening of August 13. Runoff from local precipitation began at about 21:15 on the evening of August 13 and, in response to different precipitation events, slowly increased to peak flows of 3.6 cfs at 00:20 and 4.8 cfs at 02:40 on the morning of August 14. Runoff from upstream areas in Pueblo Canyon began at 06:00 on the morning of August 14 and the peak flow was 29.6 cfs at 06:30. The runoff continued in lower Pueblo Canyon until about 10:35 and the total runoff in lower Pueblo Canyon was approximately 6.5 ac-ft.

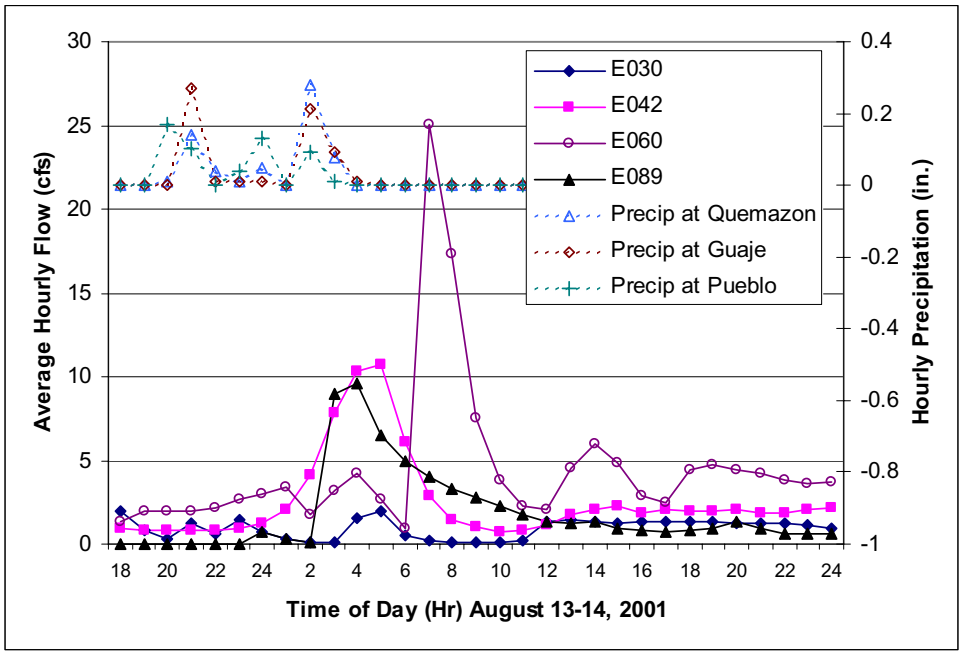

Figure 4-26. Precipitation at northern RAWS and flow at gages in Los Alamos, Pueblo, and Guaje Canyons on the night of August 13 and 14, 2001.

Runoff from local precipitation at gage E089 in Guaje Canyon above Rendija Canyon began at 22:55 and the peak flow was 1.1 cfs at 23:10. Runoff from the second precipitation event began at 02:30 and the peak flow from upstream areas was 32 cfs at 02:45. Runoff continued at gage E089 in Guaje Canyon throughout August 14 and 15 and the total runoff was approximately 4.8 ac-ft.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in a tributary to Ancho Canyon on August 12 and from Guaje Canyon and Pueblo Canyon on August 13 and 14. The sites sampled, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-16. Runoff samples were collected at gage E300 in a tributary to Ancho Canyon on August 12, however flow data are not available for this gage on this date.

4.17 August 16, 2001

Two precipitation events occurred on August 16, one in the morning from about 01:00 to 03:00 and another in the evening from about 17:00 to 20:00. The morning precipitation event occurred primarily north and northwest of Los Alamos where the Guaje Canyon RAWS received 0.13 in. and the upper Santa Clara Canyon RAWS received 0.18 in. TA-6 received 0.08 in. and TA-53 received 0.13 in., while

the southern LANL meteorological stations received less than 0.05 in. The pattern of precipitation received during the morning of August 16 is shown in Figure A-18a. Runoff samples were collected at gage E042 at 05:55 on the morning of August 16; however, flow records are not available for gage E042 during this runoff event.

Table 4-16. Storm Water Runoff Samples Collected on August 12 through 14, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Ancho Canyon					
08/12/01	E300	GF01081300	16:24	F	Gen, Metals
08/12/01	E300	GU01081300	16:24	UF	TSS, Gen, Metals
Pueblo Canyon					
08/13/01	E055	GU01081E055	14:57	UF	TSS, Rad
Guaje Canyon					
08/14/01	E089	GF01084E089	02:41	F	Gen, Metals, Rad
08/14/01	E089	GU01084E089	02:41	UF	TSS, Gen, Metals, Rad, CN, ClO_4, H-3

The evening precipitation event occurred mainly from the western part of LANL northward to the Garcia Canyon RAWS station, where the highest precipitation was 1.88 in. TA-6 received 0.86 in., TA-53 received 0.3 in., the Pueblo Canyon RAWS received 0.42 in., and the Guaje Canyon RAWS received 0.47 in. The pattern of precipitation received on the evening of August 16 is shown in Figure A-18b.

Figure 4-27 shows precipitation at meteorological stations within the Los Alamos Canyon watershed and flow at gaging stations in Los Alamos Canyon and DP Canyon. Runoff began at gage E030 in middle Los Alamos Canyon at 19:15 and the peak flow was 28.4 cfs at 19:20. Runoff continued at gage E030 until about 02:00 on the morning of August 17 and the total runoff was approximately 2.7 ac-ft.

Runoff began at gage E039 in middle DP Canyon at 18:45 and the peak flow was 23.8 cfs at 18:50. Runoff continued in small quantities until about 23:00 and the total runoff at gage E039 was approximately 2.3 ac-ft. Runoff began at gage E040 in lower DP Canyon at 19:30 and the peak flow was 9.3 cfs at 19:35. Runoff continued until 02:00 on the morning of August 17 and the total runoff in lower DP Canyon was approximately 0.8 ac-ft. Samples were collected in upper DP Canyon at gage E038 at 17:23, but flow records are not available for this gage on this date.

Runoff began at gage E042 in lower Los Alamos Canyon at 19:55 and the peak flow was 107 cfs at 20:00. Runoff continued in declining volumes until about 06:00 on the morning of August 17 and the total runoff was approximately 9.2 ac-ft. A small volume (<1 cfs) of flow continued at gage E042 in lower Los Alamos Canyon throughout the day on August 17, possibly the result of spring discharge in the upper part of the canyon and saturated conditions in the stream channel from several preceding days of precipitation. Flow continued in small volumes at gage E042 until about 06:00 on the morning of August 19.

Figure 4-28 shows the precipitation at the Pueblo Canyon and Guaje Canyon RAWS and at the North Community rain gage and flow in Pueblo, Rendija, and Guaje Canyons on August 16 and 17. Runoff began in Guaje Canyon at gage E089 at 18:20 and the peak flow was 171 cfs at 18:25. Runoff continued until about midnight and the total runoff was approximately 16.2 ac-ft. Runoff began in Rendija Canyon at gage E090 at 18:50 and the peak flow was 631 cfs at 19:20. Runoff continued in declining volumes until 23:50 and the total runoff in lower Rendija Canyon was approximately 35 ac-ft.

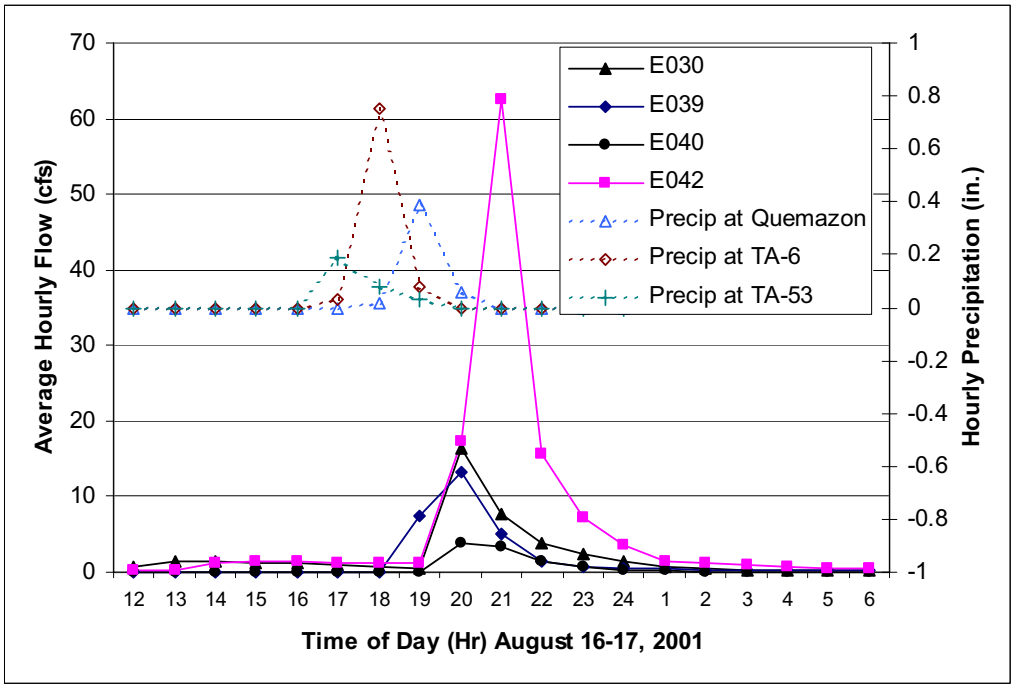

Figure 4-27. Precipitation at TA-6, TA-53, and Quemazon Canyon and flow at gages in Los Alamos Canyon and DP Canyon on August 16 and 17, 2001.

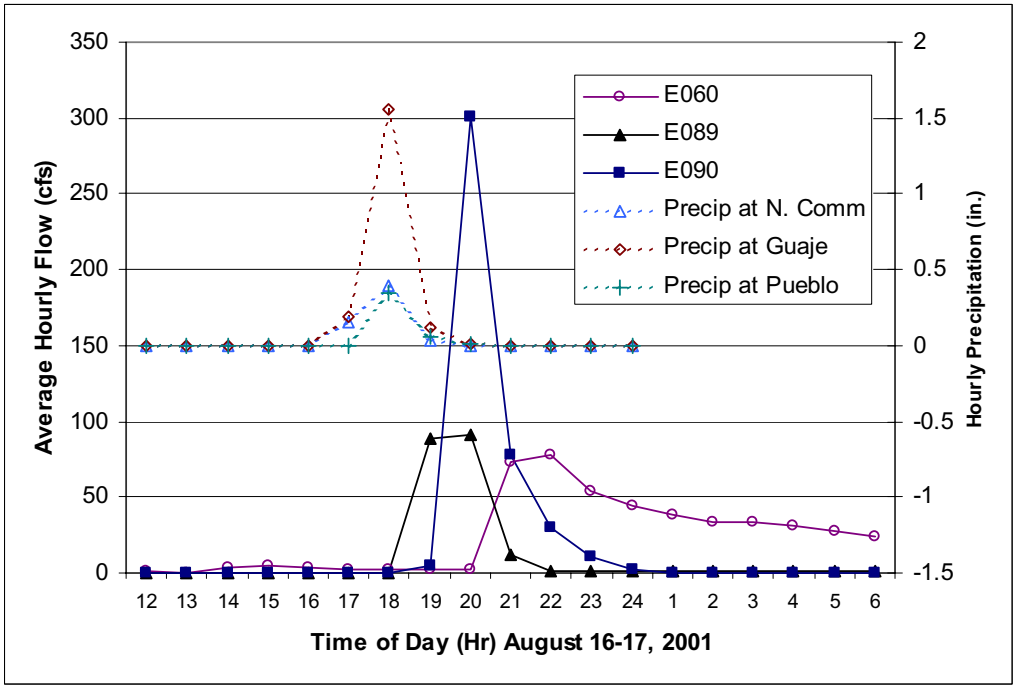

Figure 4-28. Precipitation at Quemazon, Guaje, and Pueblo Canyon RAWS and flow at gages in Pueblo, Rendija, and Guaje Canyons on August 16 and 17, 2001.

Runoff began at gage E060 in lower Pueblo Canyon at 20:30 and the peak flow was 174 cfs at 20:35. Runoff continued until about 02:00 on the morning of August 17 and the total runoff was approximately 27 ac-ft. Flow continued in lower Pueblo Canyon at about 10 cfs until about 16:00 on the afternoon of August 17, probably supported by discharge from the Los Alamos County Sewage Treatment Plant.

Figure 4-29 shows the hourly precipitation at TA-6 and TA-53 and the average hourly flow in Sandia Canyon at gage E123 on August 16. Flow at gage E123 began at 18:05 and the peak flow was 50 cfs at 18:50. Runoff continued at gage E123 until about 04:00 on the morning of August 17 and the total runoff was approximately 5 ac-ft. Small volumes of effluent-supported flow from outfalls at TA-3 continued at gage E123. The pattern of daily effluent discharges and flow in Sandia Canyon at gage E123 are shown on Figure 4-29.

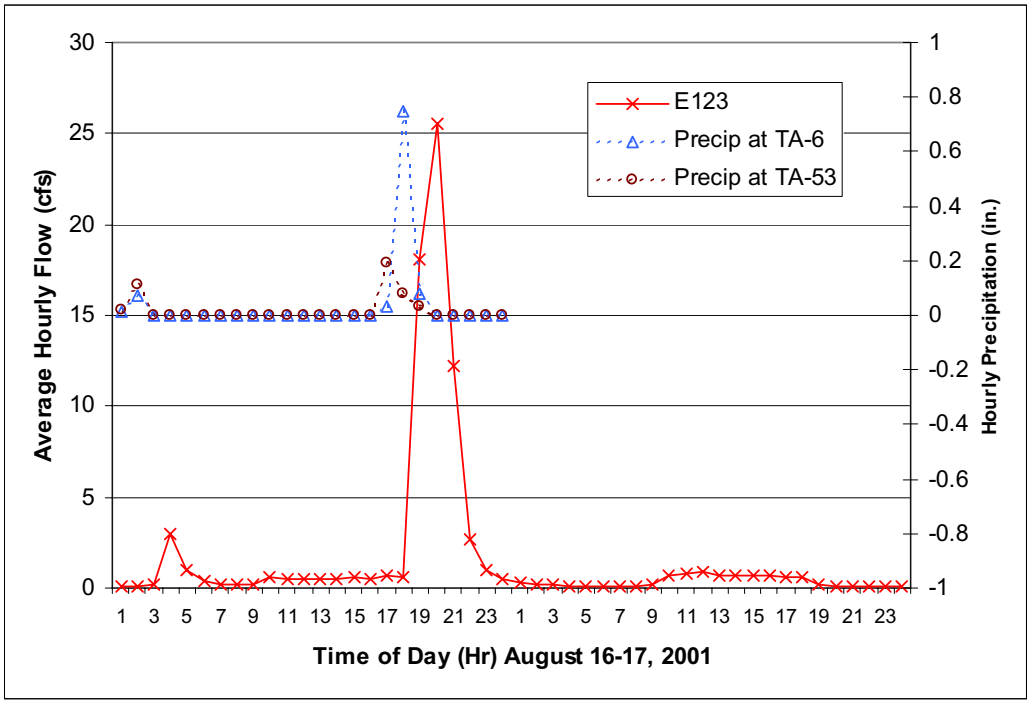

Figure 4-29. Precipitation at TA-6 and TA-53 and flow in Sandia Canyon at gage E123 on August 16 and 17, 2001.

Figure 4-30 shows hourly precipitation at TA-6 and TA-54 on the evening of August 16 and flow at gages in Pajarito Canyon on August 16 and 17. The evening precipitation event was primarily located over the western Pajarito Plateau where TA-6 received 0.86 in., whereas meteorological stations in the Sierra de los Valles at Pajarito Mountain received only 0.02 in. and the Pajarito Canyon RAWS received only 0.06 in (see Figure A-18b). Runoff was not recorded at gages E240 in upper Pajarito Canyon and E245 in middle Pajarito Canyon after the precipitation event. Runoff began at gage E250 in lower Pajarito Canyon at 22:55 on the evening of August 16 and the peak flow was 21.6 cfs at 23:35. Runoff continued in lower Pajarito Canyon in small volumes until 20:35 on the evening of August 18 and the total runoff was approximately 5.7 ac-ft. The peak runoff at gage E250 on August 16 surpassed the historical peak runoff at this site (see Section 3.2.2).

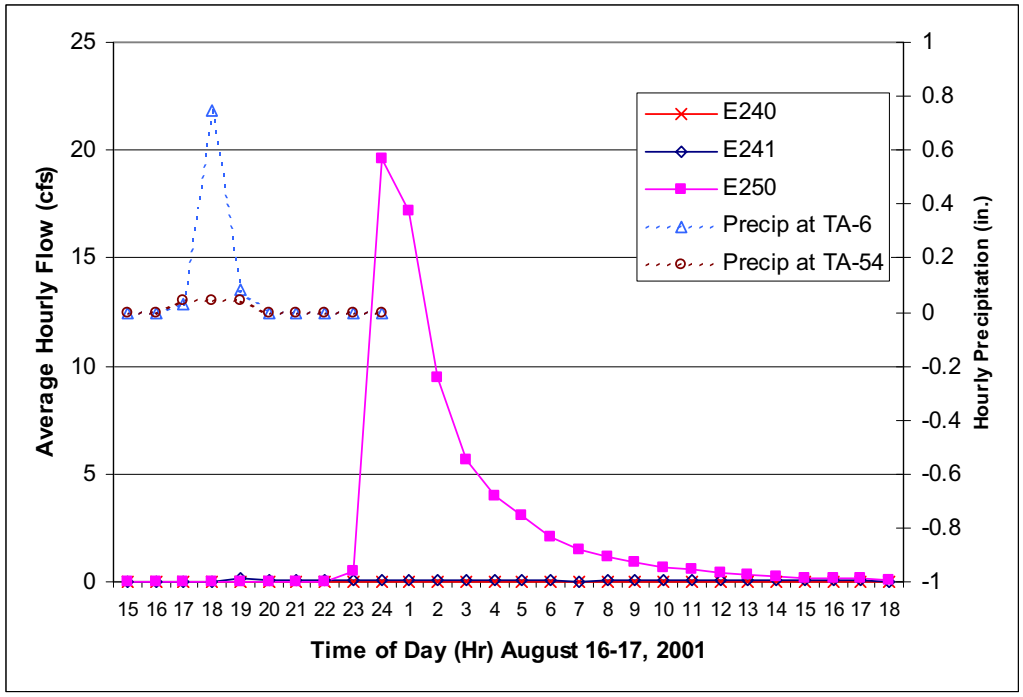

Figure 4-30. Precipitation at TA-6 and TA-54 and flow at gages in Pajarito Canyon on August 16 and 17, 2001.

Figure 4-31 shows the precipitation at TA-16, TA-49, and the Water Canyon RAWS and flow at gages in Water Canyon on August 16 and 17. Flow at gage E252 in upper Water Canyon ranged from about 1 to 1.5 cfs in response to spring flow in the upper part of the canyon, but runoff was not recorded at this gage or at gage E253 in Cañon de Valle on August 16. Runoff at gage E262 in lower Cañon de Valle began at 20:45 where the peak flow was 0.13 cfs at 20:55. Runoff continued in lower Cañon de Valle until 22:55 and the total runoff was approximately 500 cubic ft (0.01 ac-ft).

Runoff began at gage E262.5 in middle Water Canyon at 20:40 and the peak flow was 3.1 cfs at 20:55. Runoff continued in middle Water Canyon until 00:55 on the morning of August 17 and the total runoff was approximately 0.5 ac-ft. Runoff began at gage E263 in lower Water Canyon at SR 4 at 19:30 in response to local precipitation. The peak flow was 3.7 cfs at 19:45, after which time flow decreased until 00:45 on the morning of August 17, when runoff from upstream arrived at gage E263 and the flow increased to a peak of 1.25 cfs. Runoff continued until 03:10 on the morning of August 17 and the total runoff at gage E263 was approximately 0.78 ac-ft.

Runoff from local precipitation began at gage E265 in lower Water Canyon at 21:10 when the peak flow was 1.8 cfs. Local flow declined until runoff from upstream arrived at gage E265 at 01:05 on the morning of August 17 and the peak flow was 0.8 cfs at 01:10. Runoff continued at gage E265 until 10:05 on the morning of August 17 and the total runoff was approximately 0.5 ac-ft.

The runoff data in Water Canyon on August 16 indicate that the evening precipitation event must have moved quickly from east to west, causing local runoff to occur in the lower part of the canyon before runoff occurred in the upper and middle part of the canyon.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in Los Alamos, DP, Pueblo, Guaje, and Pajarito Canyons on August 16. The sites sampled, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-17.

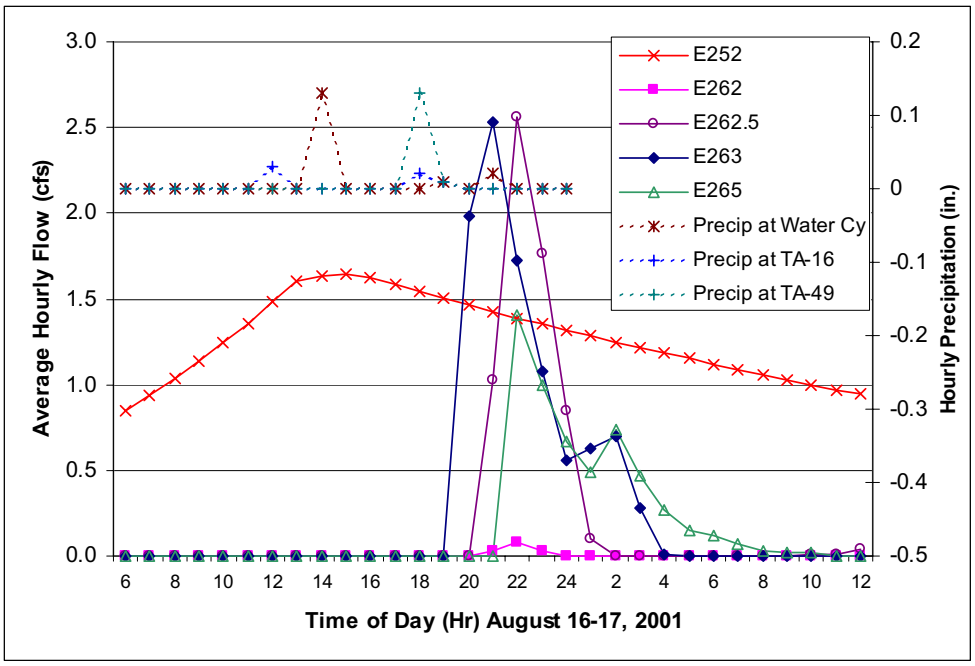

Figure 4-31. Precipitation at TA-16, TA-49, and the Water Canyon RAWS and flow at gages in Water Canyon on August 16 and 17, 2001.

Table 4-17. Storm Water Runoff Samples Collected on August 16, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Los Alamos Canyon					
08/16/01	E042	GF01087042	05:50	F	Gen, Metals
08/16/01	E042	GU01087042	05:50	UF	TSS, Metals
08/16/01	E030	GF01086E030	19:09	F	Gen, Metals, Rad
08/16/01	E030	GU01086E030	19:09	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3
08/16/01	E042	GF01088E042	19:50	F	Gen, Metals, Rad
08/16/01	E042	GU01088E042	19:50	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3
08/16/01	E050	GF01083E050	20:10	F	Gen, Metals
08/16/01	E050	GU01083E050	20:10	UF	TSS, Gen, Metals
DP Canyon					
08/16/01	E038	GF01087E038	17:23	F	Gen, Metals
08/16/01	E038	GU01087E038	17:23	UF	TSS, Metals, CN, H-3
Pueblo Canyon					
08/16/01	E060	GF01086E060	19:32	F	Gen, Metals, Rad
08/16/01	E060	GU01086E060	19:32	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3
Guaje Canyon					
08/16/01	E089	GF01085E089	18:15	F	Gen, Metals, Rad
08/16/01	E089	GU01085E089	18:15	UF	TSS, Metals, Rad
Pajarito Canyon					
08/16/01	E250	GF01084E250	22:50	F	Gen, Metals, Rad
08/16/01	E250	GU01084E250	22:50	UF	TSS, Gen, Metals, Rad, CN, ClO_4, H-3

4.18 August 30, 2001

A relatively small precipitation event occurred over the eastern Pajarito Plateau on the afternoon of August 30. TA-54 received 0.22 in., TA-6 received 0.11 in., and the Bandelier National Park Frijolito station received 0.08 in.; other stations received less than 0.02 in. on August 30. The pattern of precipitation received on August 30 is shown in Figure A-19.

Figure 4-32 shows the precipitation at TA-6 and TA-54 and flow at gages in Water Canyon on August 30. Runoff began at gage E263 in lower Water Canyon at 15:45 and the peak flow was 7.5 cfs at 15:50. Runoff continued until 17:15 and the total runoff was approximately 0.35 ac-ft. Local runoff began at gage E265 at 15:30 and the peak flow was 7.2 cfs at 16:00. Runoff continued until 18:05 and the total runoff was approximately 0.35 ac-ft.

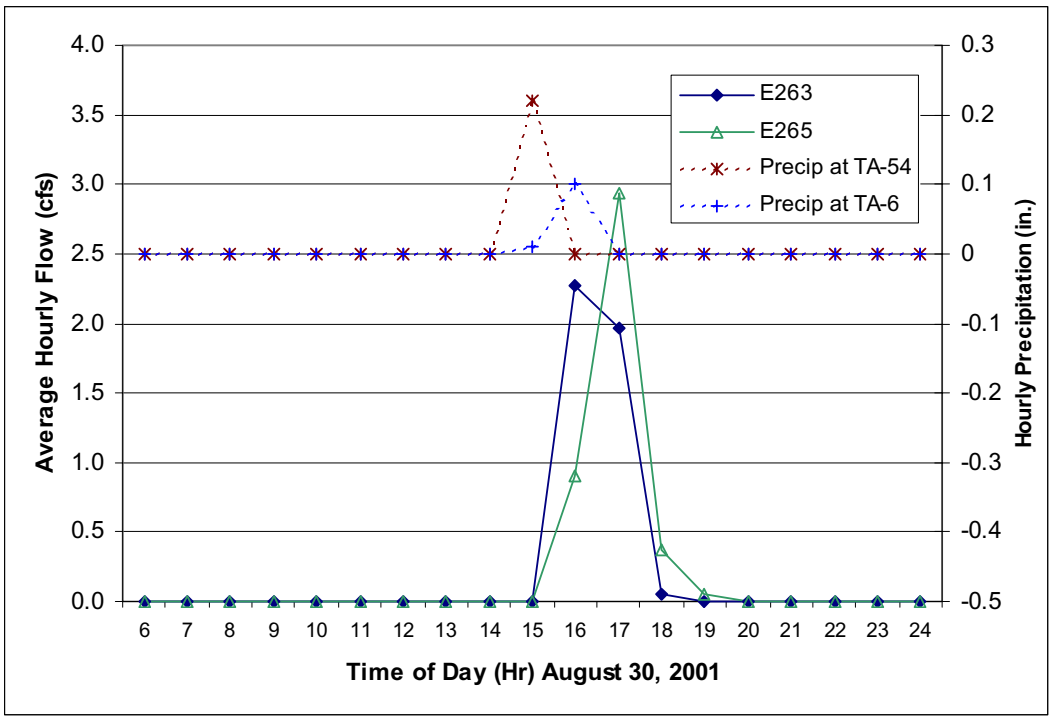

Figure 4-32. Precipitation at TA-6 and TA-54 and flow at gages in Water Canyon on August 30, 2001.

Personnel of the RRES-WQH collected runoff samples from automated sampling stations in Potrillo Canyon and at TA-54 on August 30. The sites sampled, the sample identification numbers, field preparation information (filtered or unfiltered samples), and analytical suites are listed in Table 4-18. Samples were collected at gage E269 in a tributary to Potrillo Canyon on August 30 but flow records are not available for the runoff event.

Table 4-18. Storm Water Runoff Samples Collected on August 30, 2001.

Date	Gage	Sample ID	Time (hr)	F/UF	Suite
Pajarito Canyon					
08/30/01	E248	GF01091E248	15:15	F	Gen, Metals, Rad
08/30/01	E248	GU01091E248	15:15	UF	TSS, Metals, Rad
08/30/01	E248.5	GF01096E248.5	00:31	F	Gen, Metals, Rad
08/30/01	E248.5	GU01096E248.5	00:31	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3
Potrillo Canyon					
08/30/01	E269	GF01093E269	15:55	F	Gen, Metals
08/30/01	E269	GU01093E269	15:55	UF	TSS, Gen, Metals, Rad, ClO_4, CN, H-3

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Appendix A. Figures Showing the Pattern of Precipitation in 2000 on Days of Significant Runoff

Daily precipitation data used to create the following precipitation isopleth maps were obtained from the following sources.

- The Laboratory Air Quality Group maintains precipitation data for several Los Alamos National Laboratory area meteorological stations at their web page at www.weather.lanl.gov

- The Desert Research Institutes (DRI) Remote Area Weather Stations (RAWS) that are provided though interagency cooperation of the Bureau of Land Management, National Interagency Fire Center, and the Western Region Climate Center. The data are available at the DRI web site at http://www.wrcc.dri.edu/losalamos/

- The Bandelier National Monument provided precipitation data for two stations, one at Cerro Grande and another at the main monument headquarters, called Frijolito. Thanks to Kay Beeley of the National Park Service for providing these data.

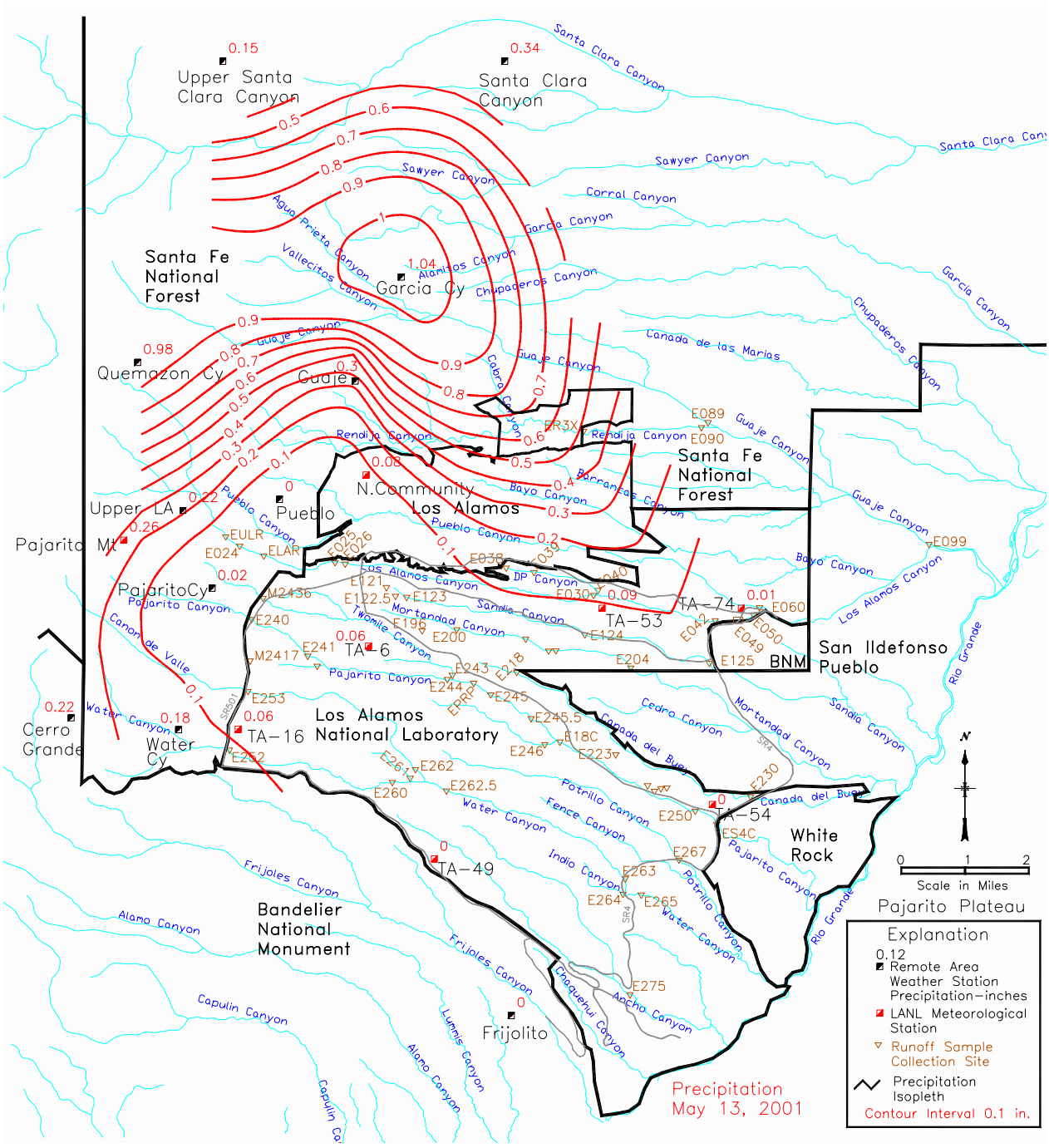

Figure A-1. Pattern of precipitation recorded on the Pajarito Plateau on May 13, 2001.

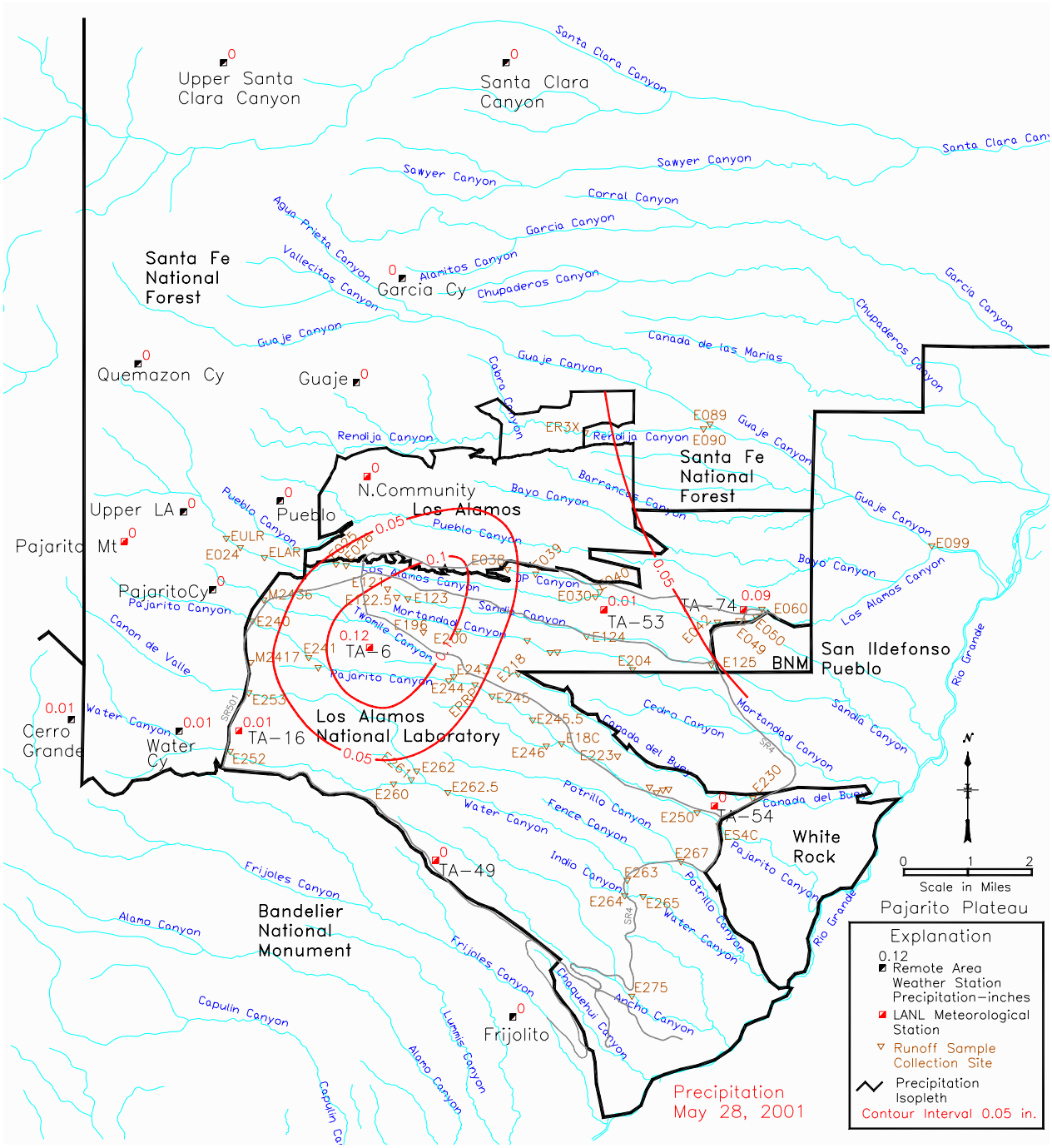

Figure A-2. Pattern of precipitation recorded on the Pajarito Plateau on May 28, 2001.

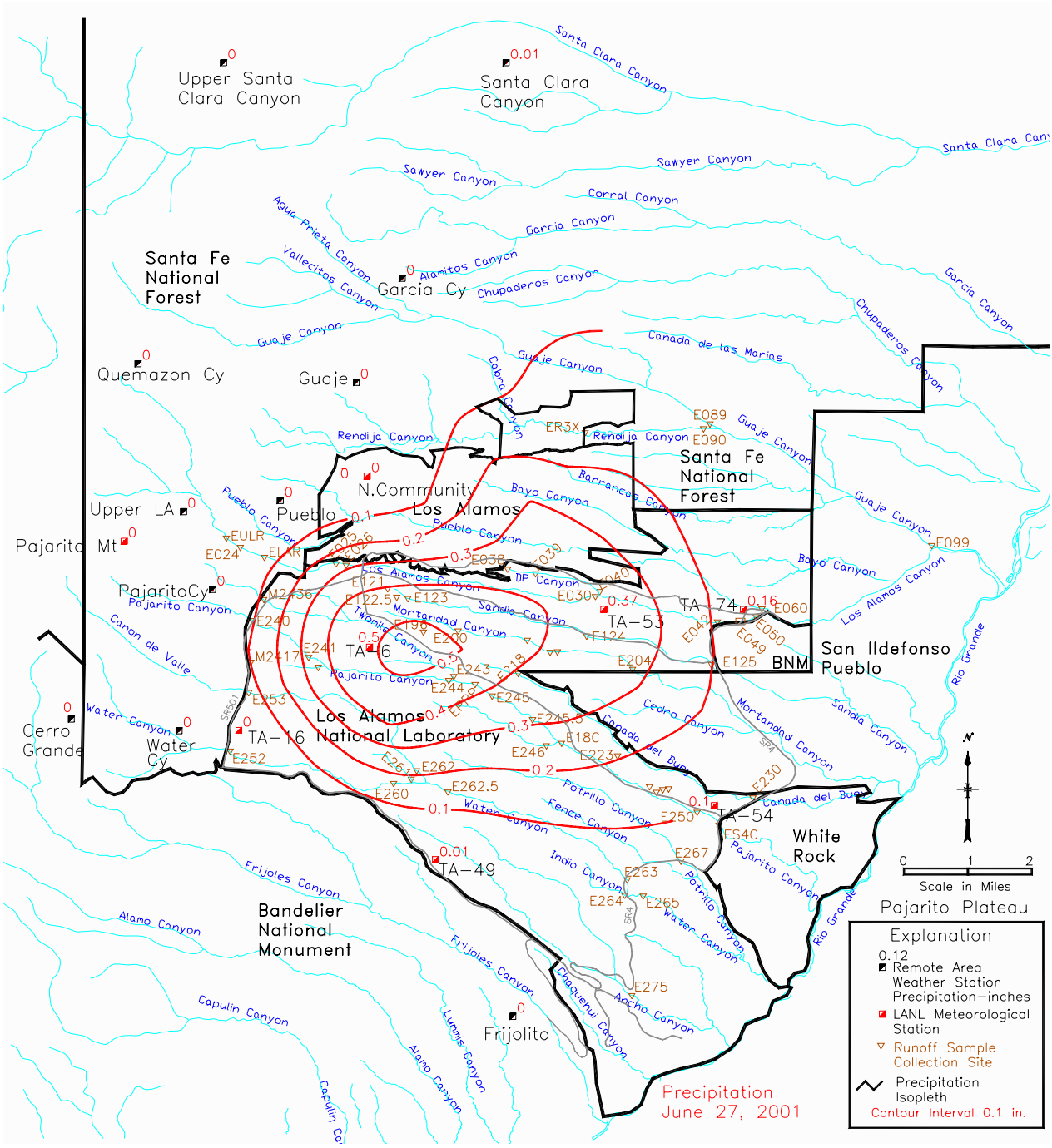

Figure A-3. Pattern of precipitation recorded on the Pajarito Plateau on June 27, 2001.

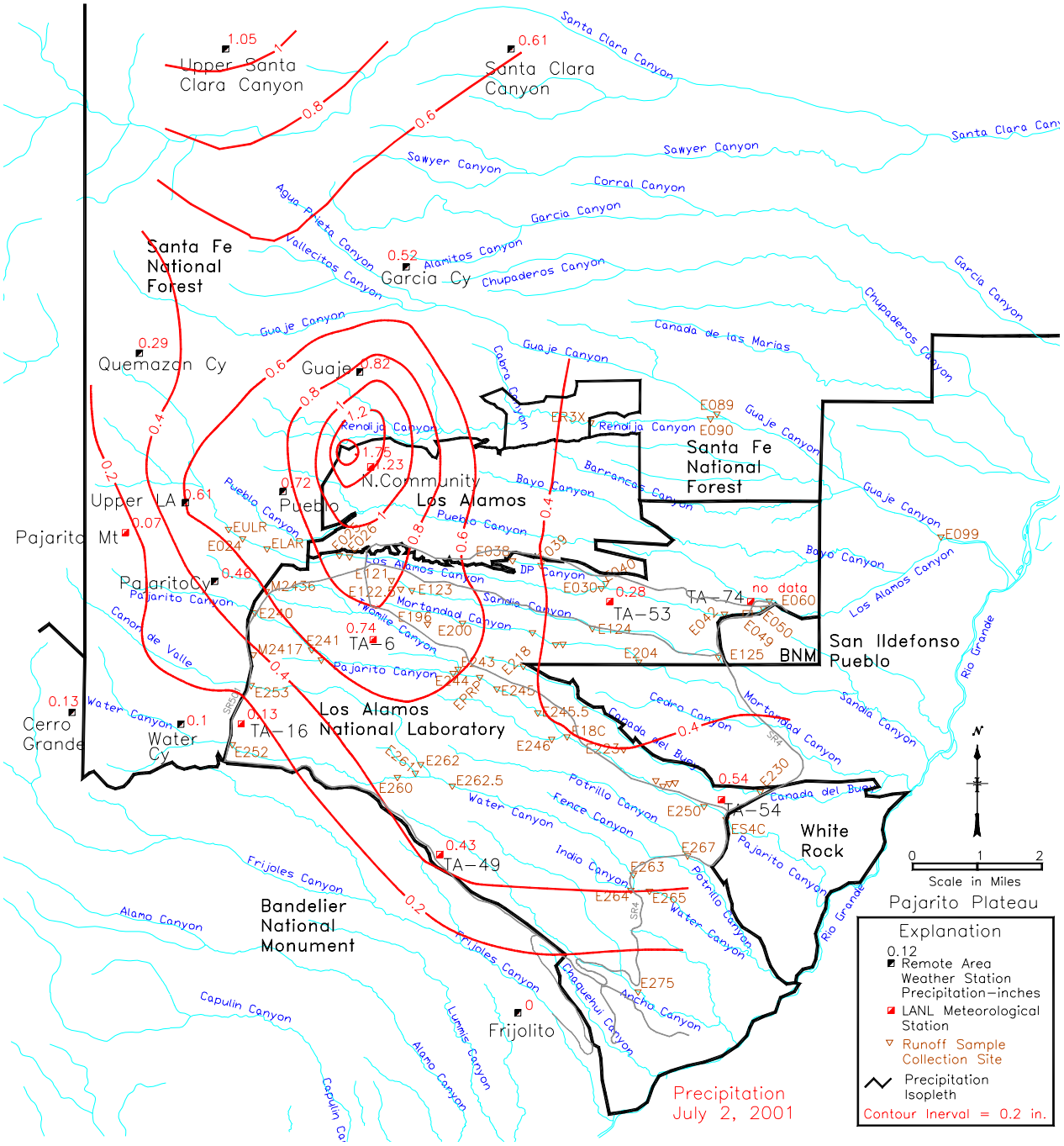

Figure A-4. Pattern of precipitation recorded on the Pajarito Plateau on July 2, 2001.

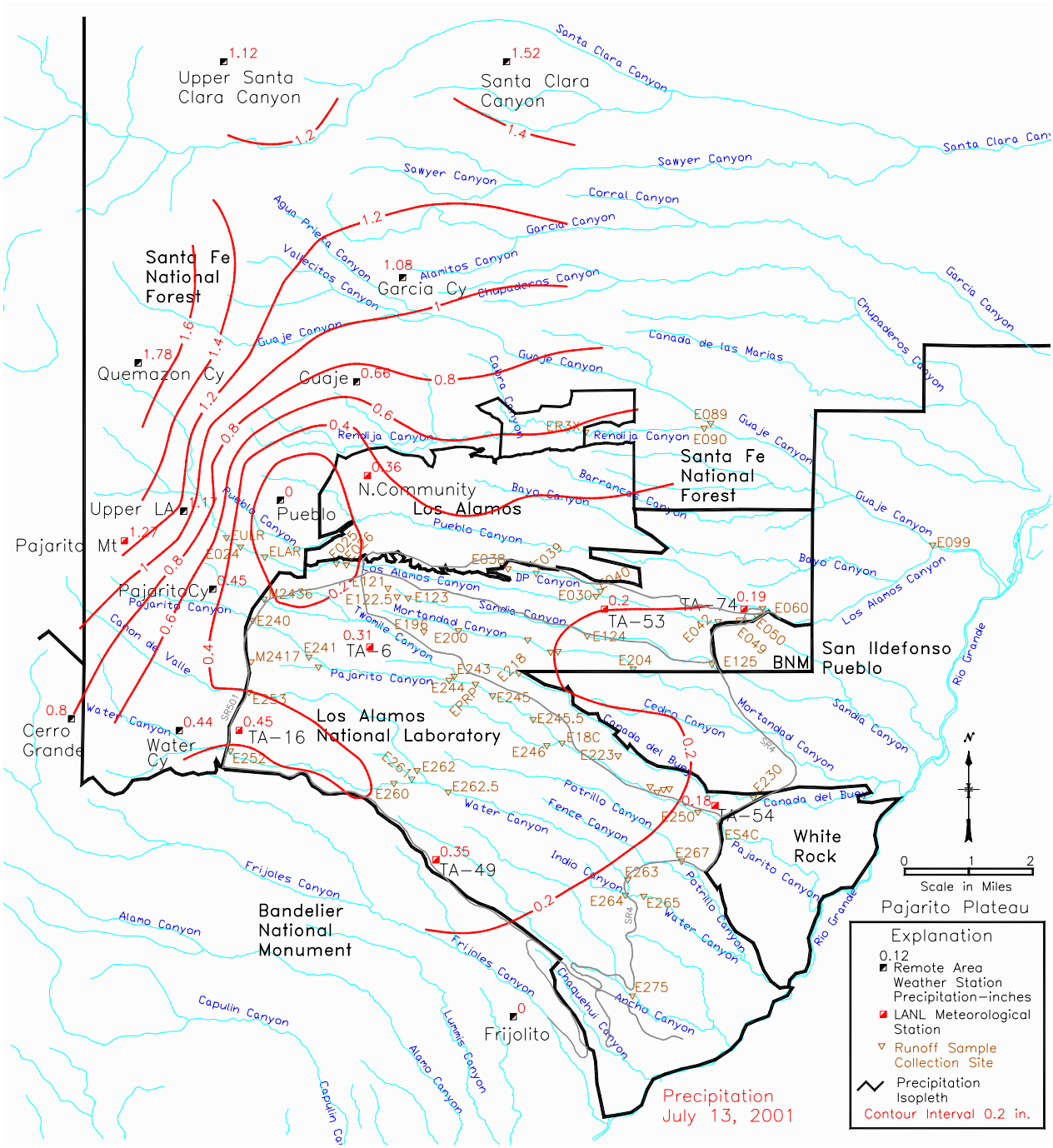

Figure A-5. Pattern of precipitation recorded on the Pajarito Plateau on July 13, 2001.

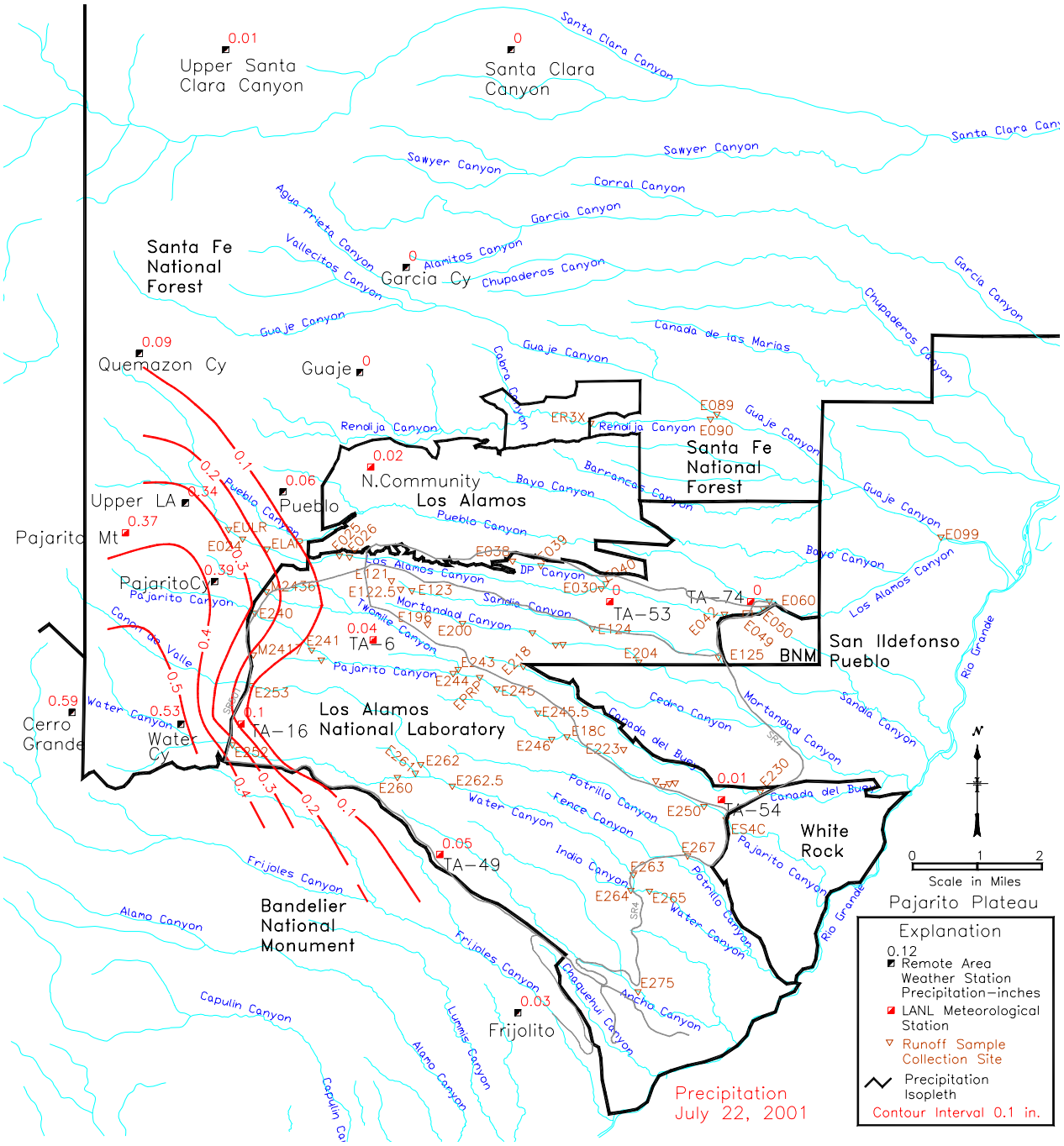

Figure A-6. Pattern of precipitation recorded on the Pajarito Plateau on July 22, 2001.

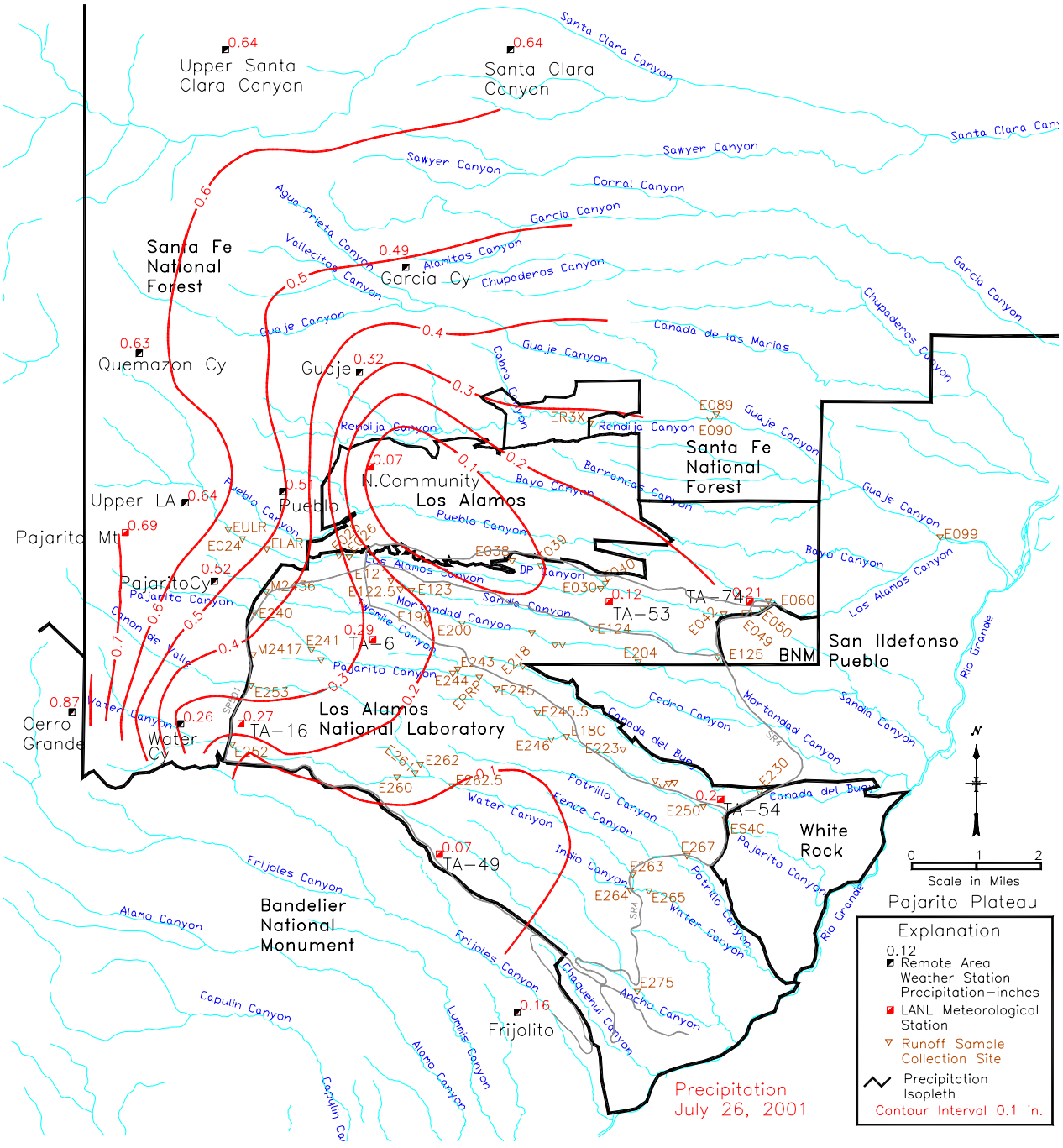

Figure A-7. Pattern of precipitation recorded on the Pajarito Plateau on July 26, 2001.

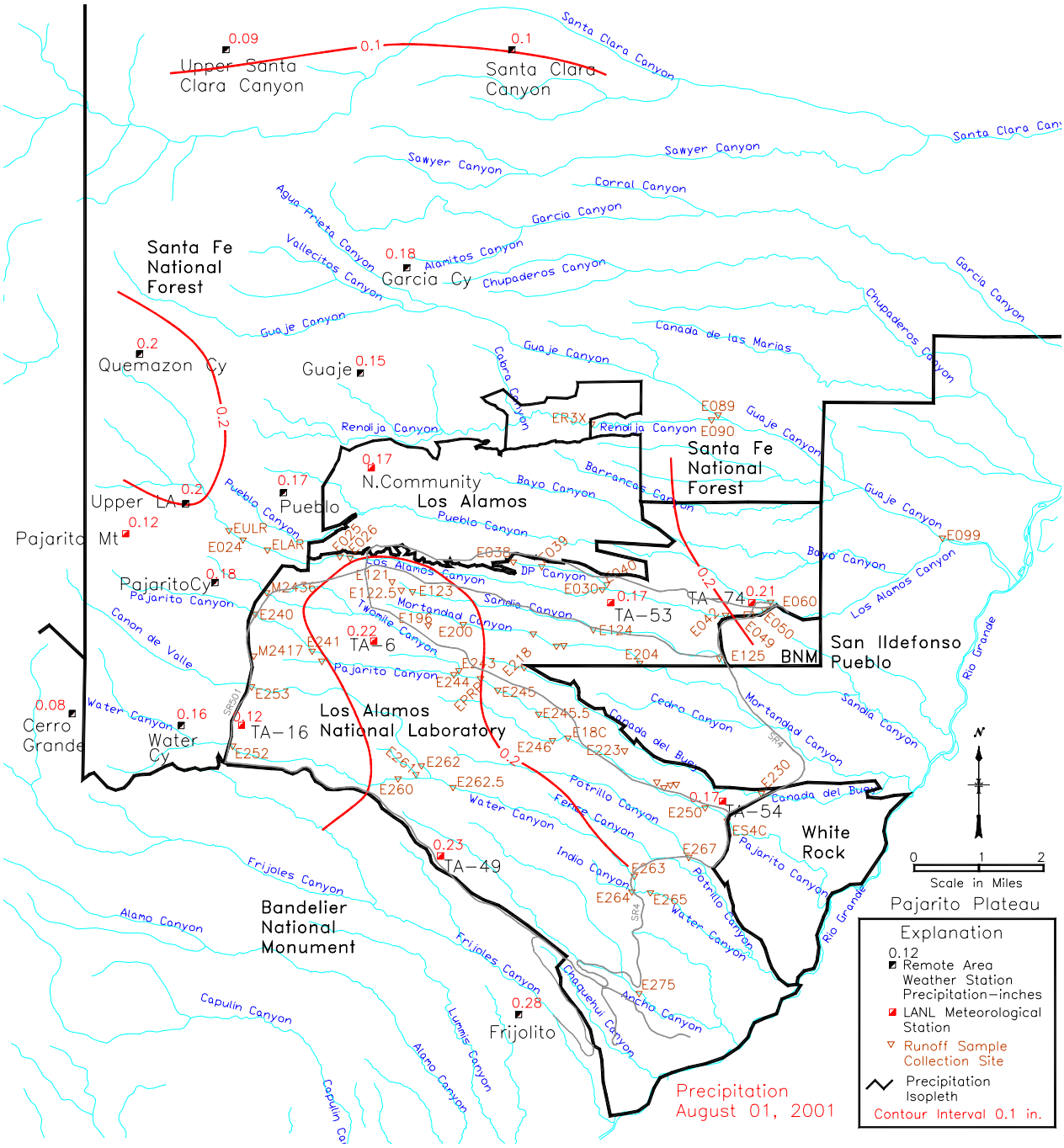

Figure A-8. Pattern of precipitation recorded on the Pajarito Plateau on August 1, 2001.

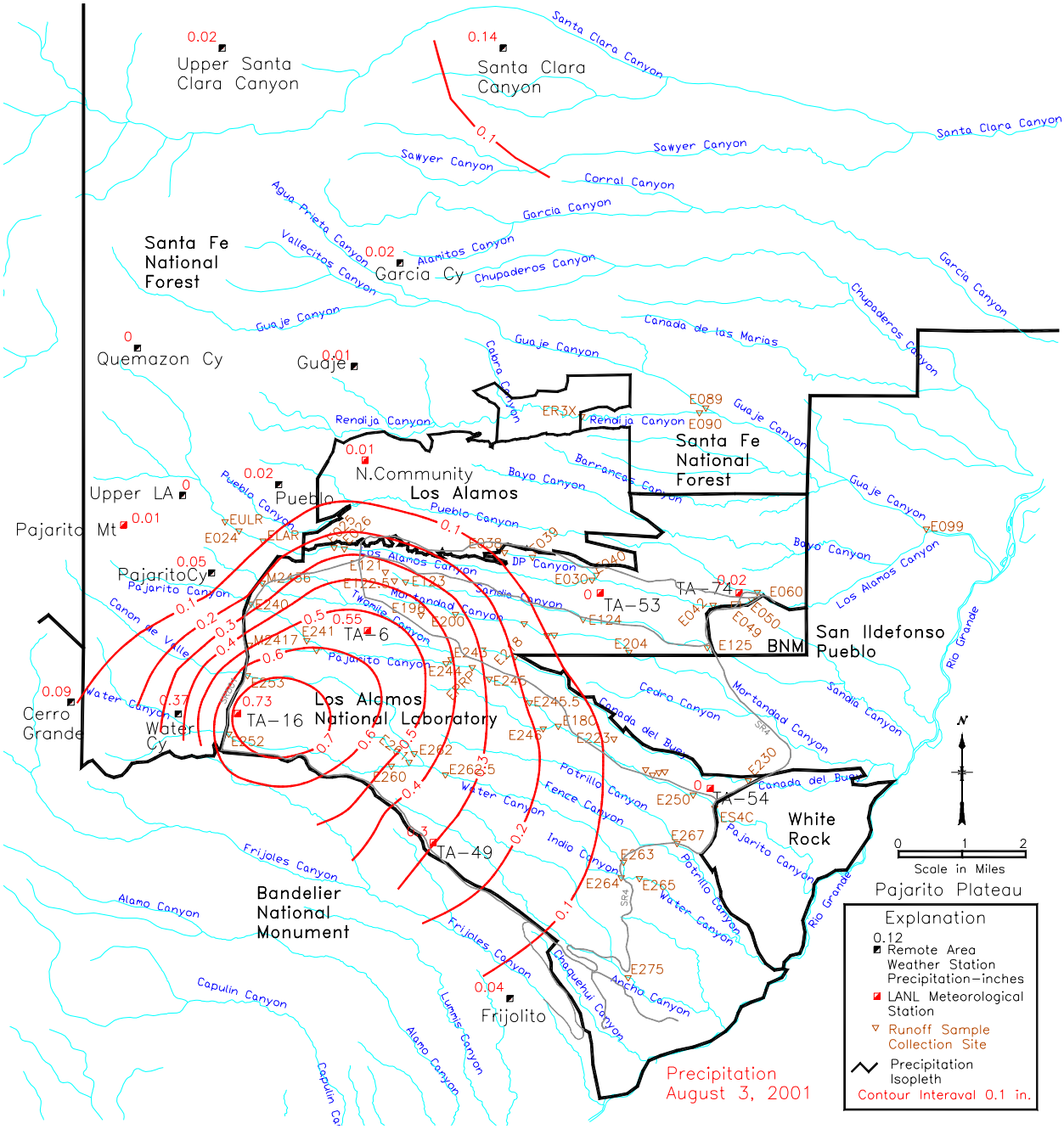

Figure A-9. Pattern of precipitation recorded on the Pajarito Plateau on August 3, 2001.

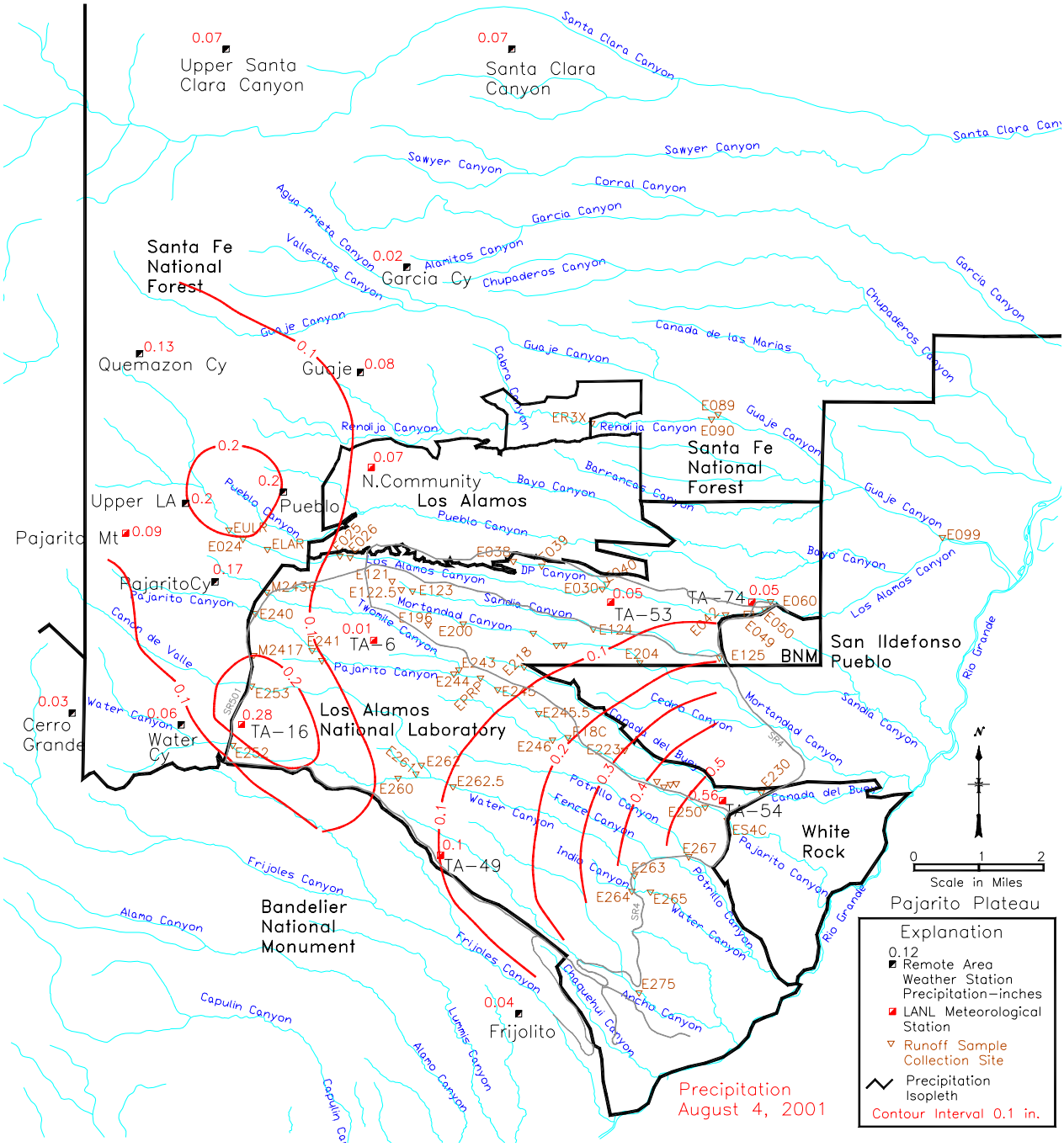

Figure A-10. Pattern of precipitation recorded on the Pajarito Plateau on August 4, 2001.

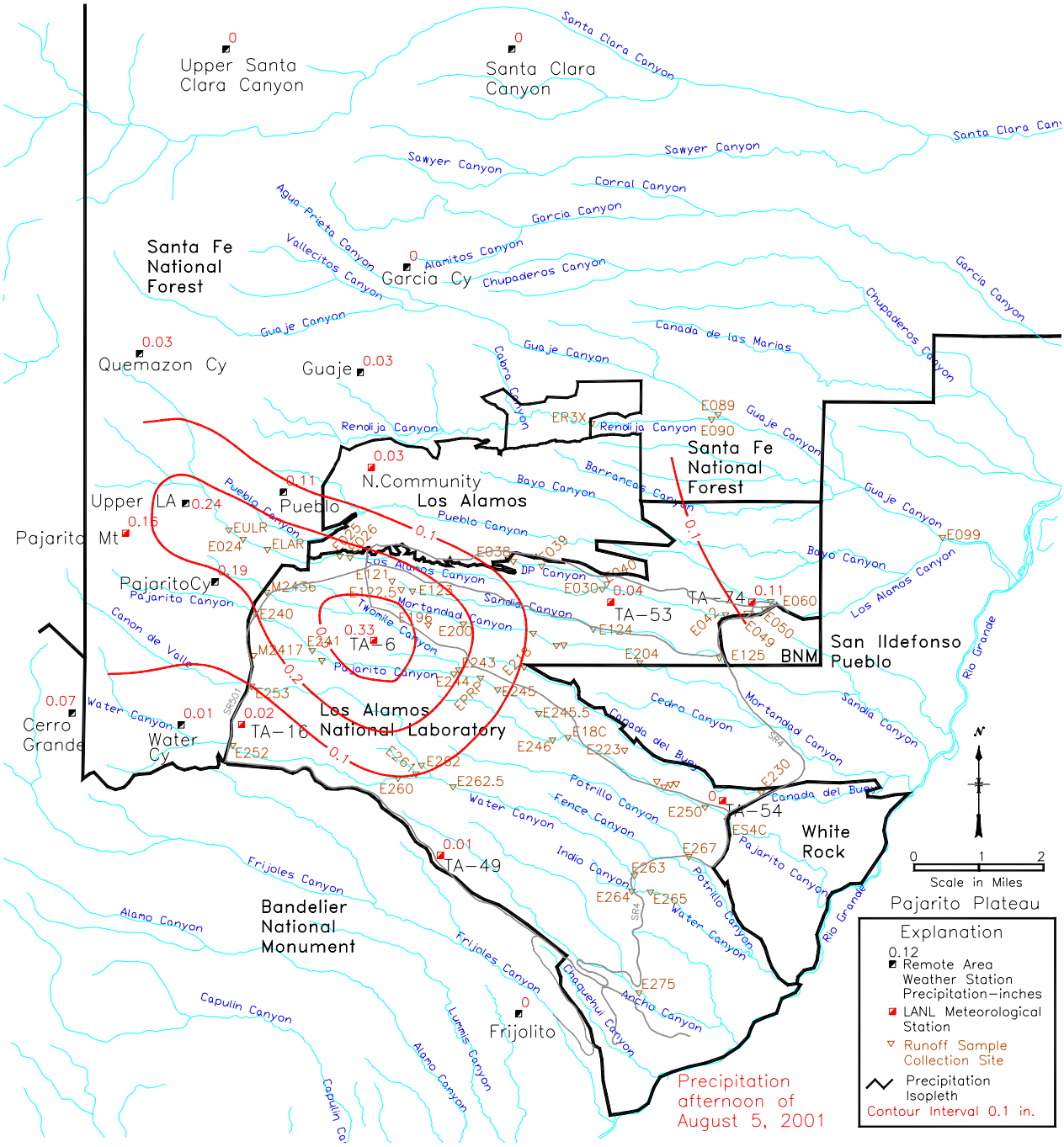

Figure A-11a. Pattern of precipitation recorded on the Pajarito Plateau on the afternoon of August 5, 2001.

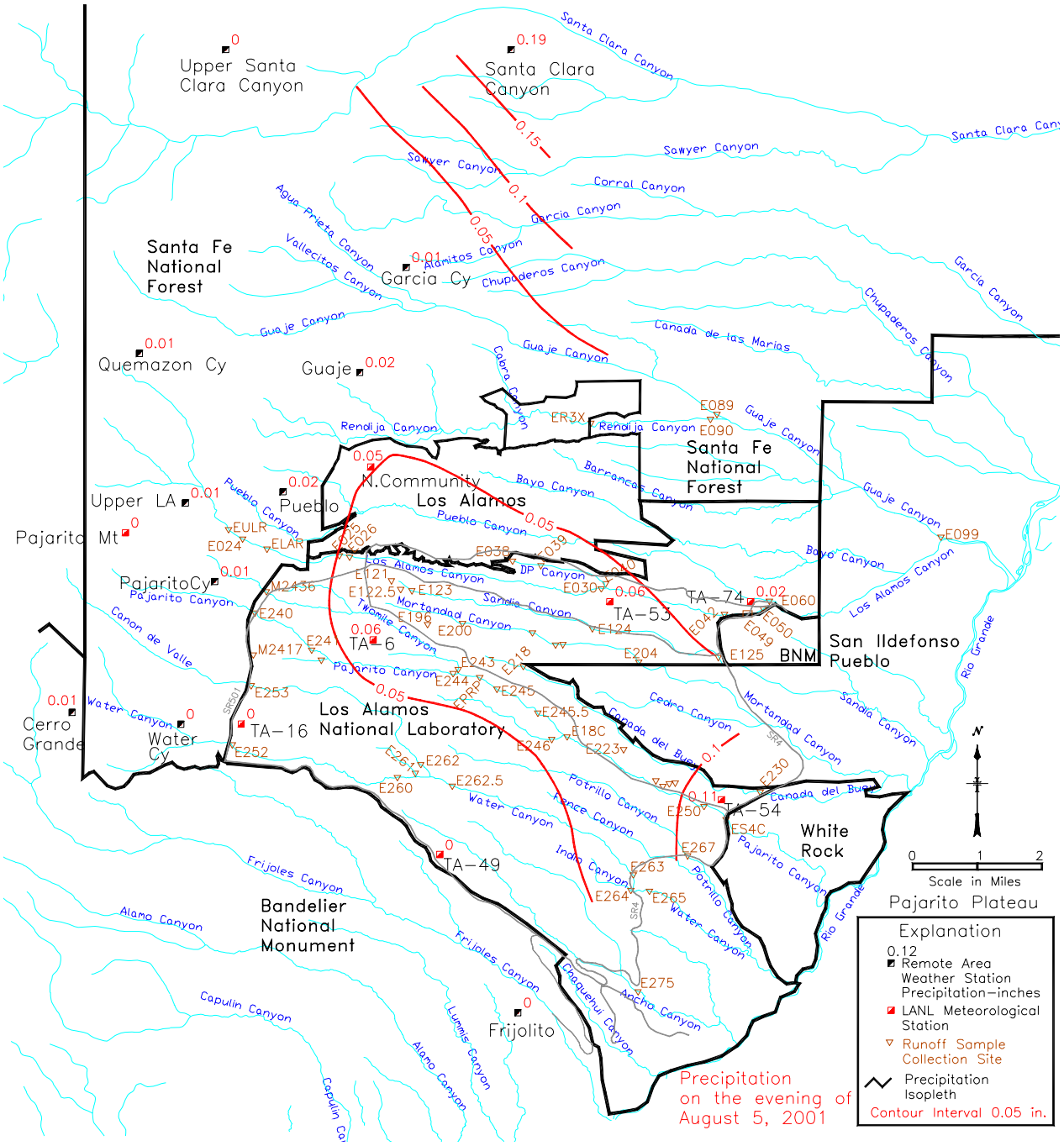

Figure A-11b. Pattern of precipitation recorded on the Pajarito Plateau on the evening of August 5, 2001.

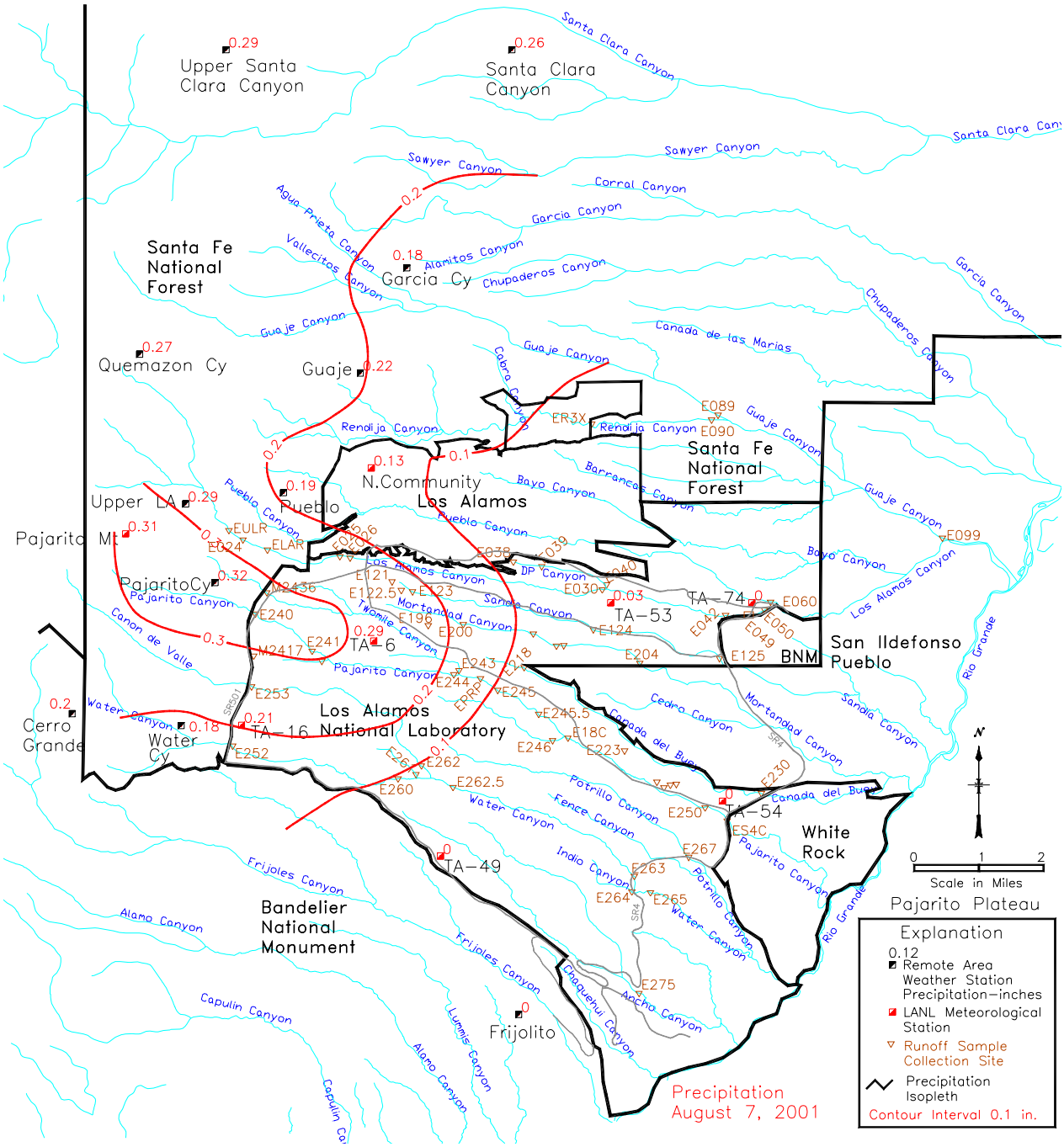

Figure A-12. Pattern of precipitation recorded on the Pajarito Plateau on August 7, 2001.

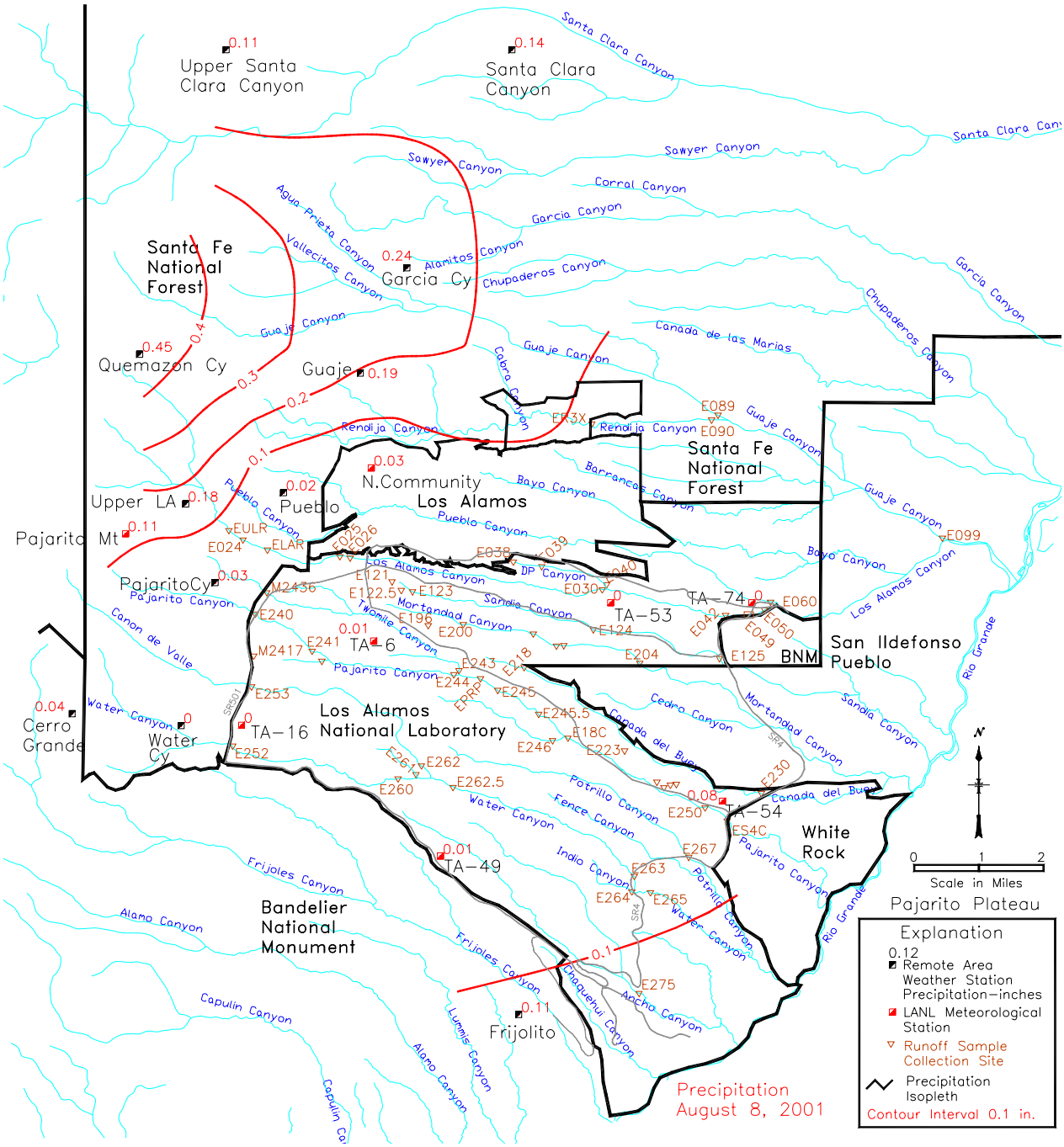

Figure A-13. Pattern of precipitation recorded on the Pajarito Plateau on August 8, 2001.

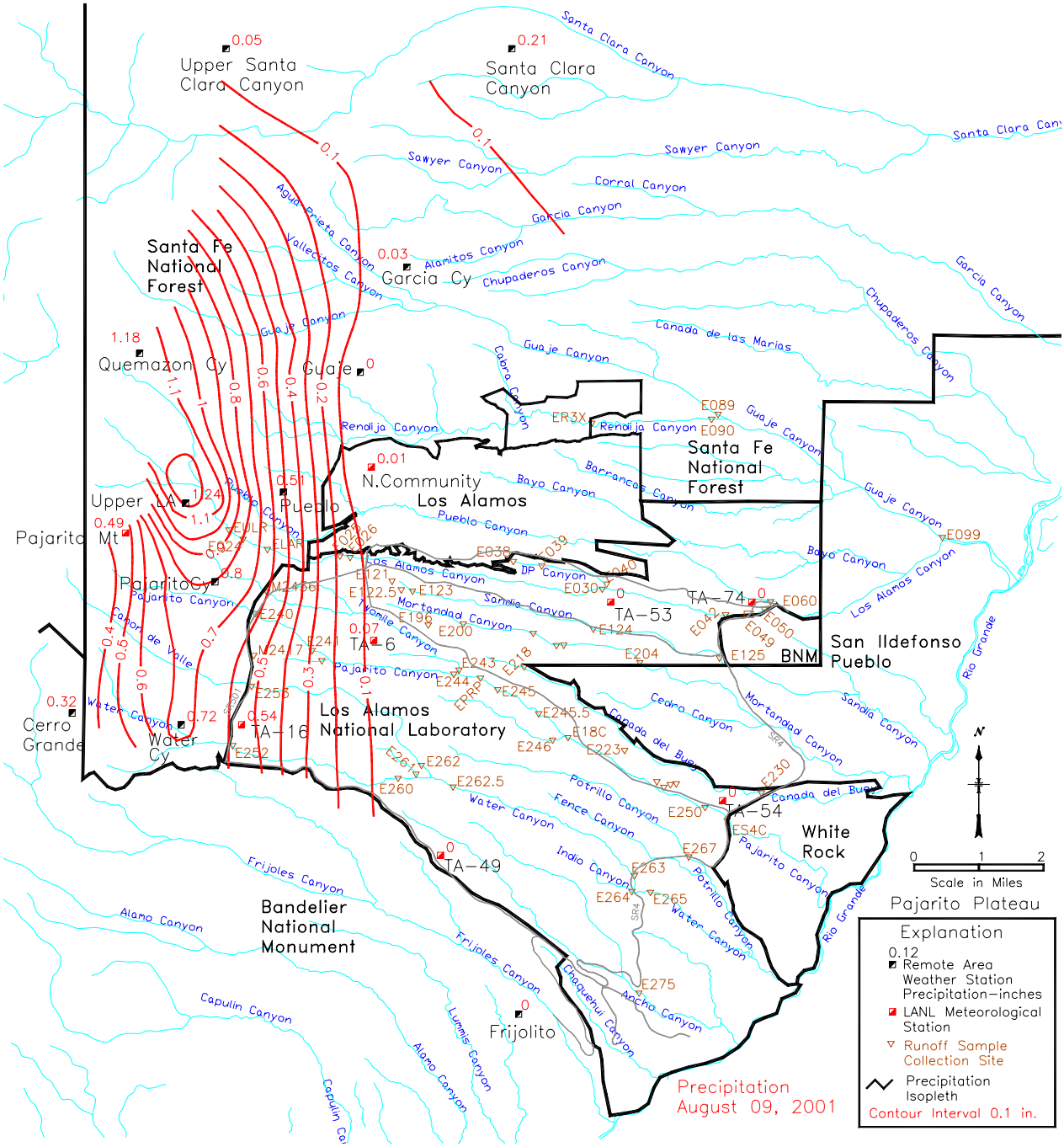

Figure A-14. Pattern of precipitation recorded on the Pajarito Plateau on August 9, 2001.

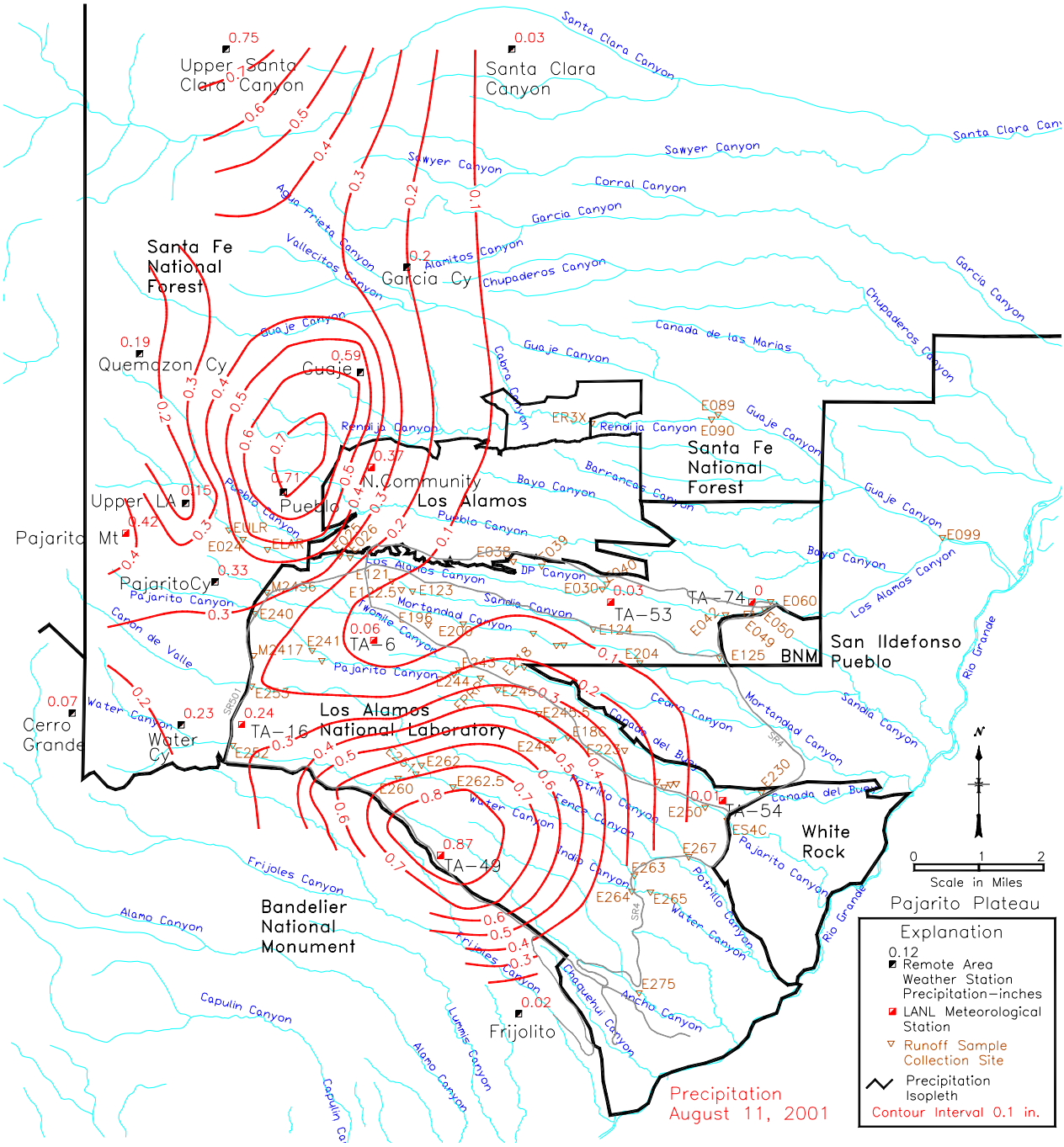

Figure A-15. Pattern of precipitation recorded on the Pajarito Plateau on August 11, 2001.

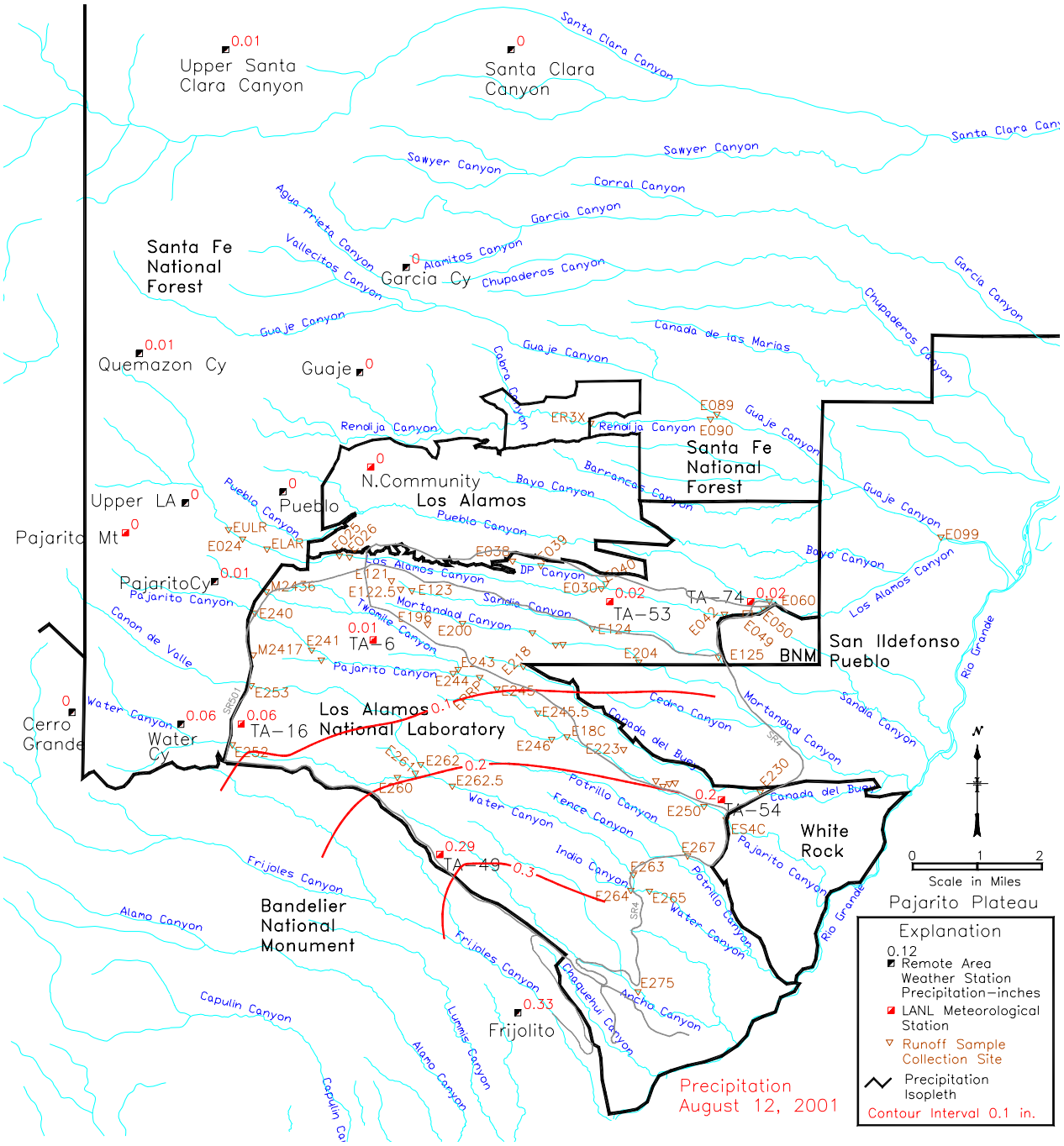

Figure A-16. Pattern of precipitation recorded on the Pajarito Plateau on August 12, 2001.

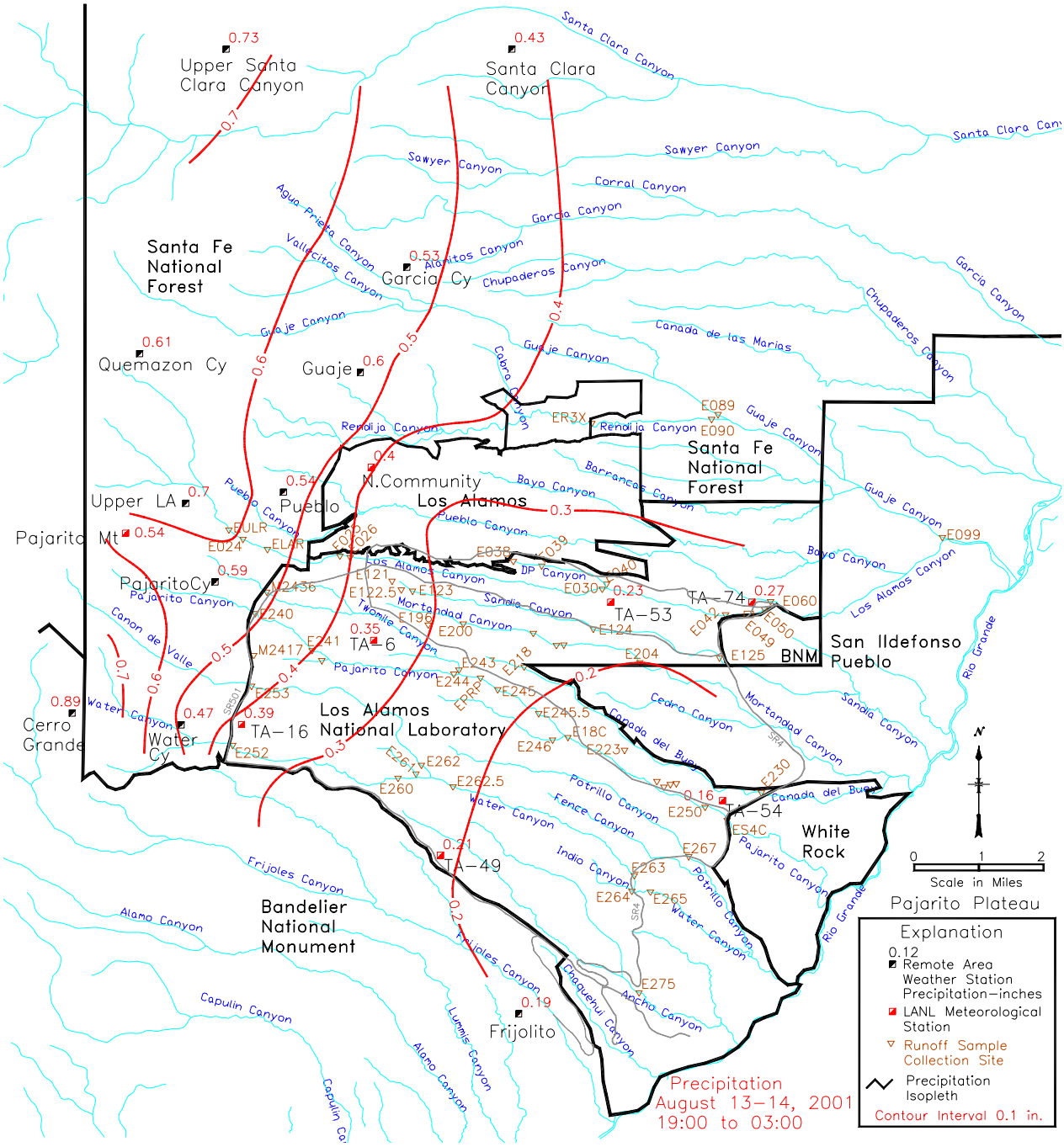

Figure A-17. Pattern of precipitation recorded on the Pajarito Plateau on the night of August 13 and 14, 2001 from 19:00 to 03:00.

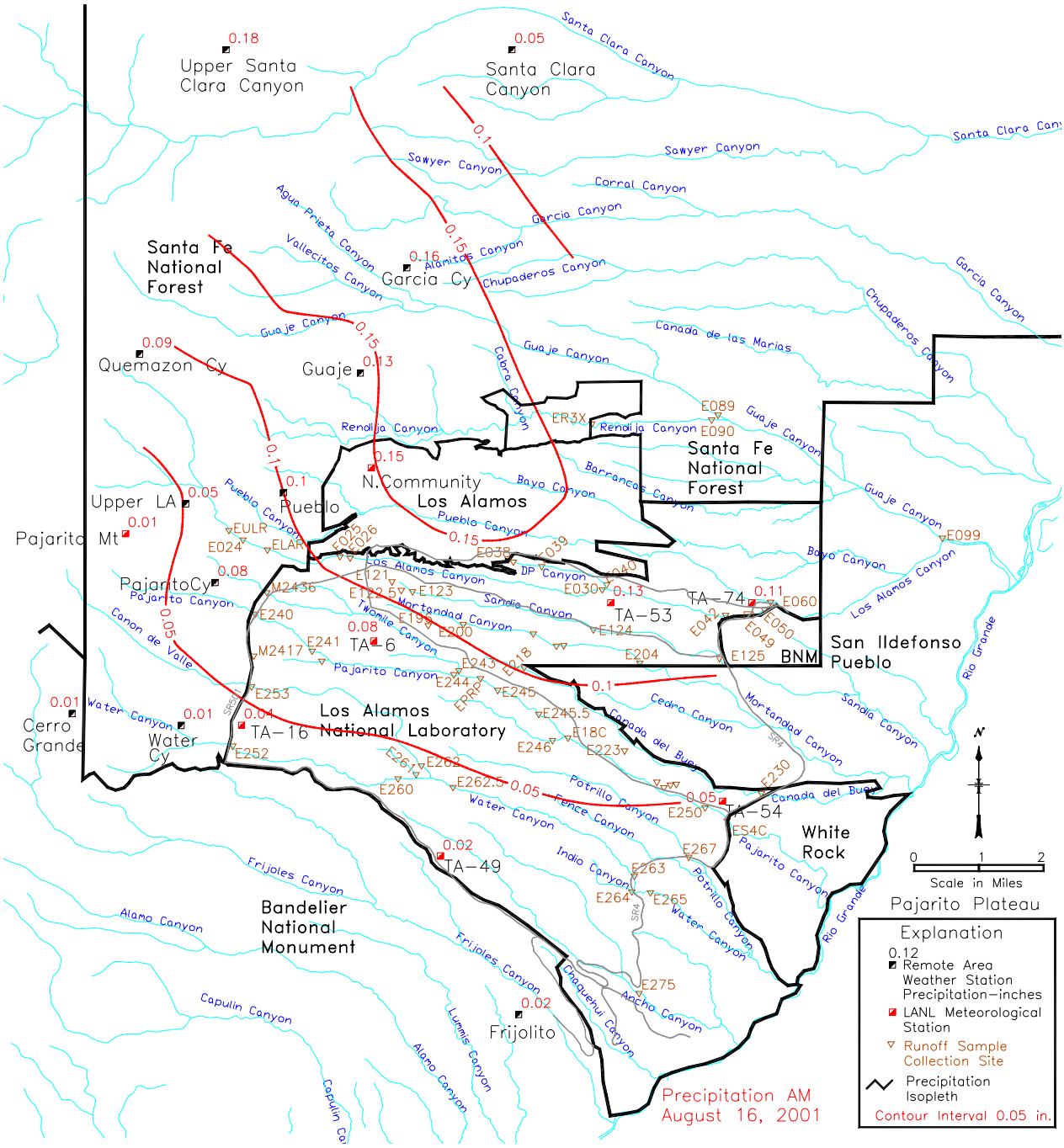

Figure A-18a. Pattern of precipitation recorded on the Pajarito Plateau on the morning of August 16, 2001.

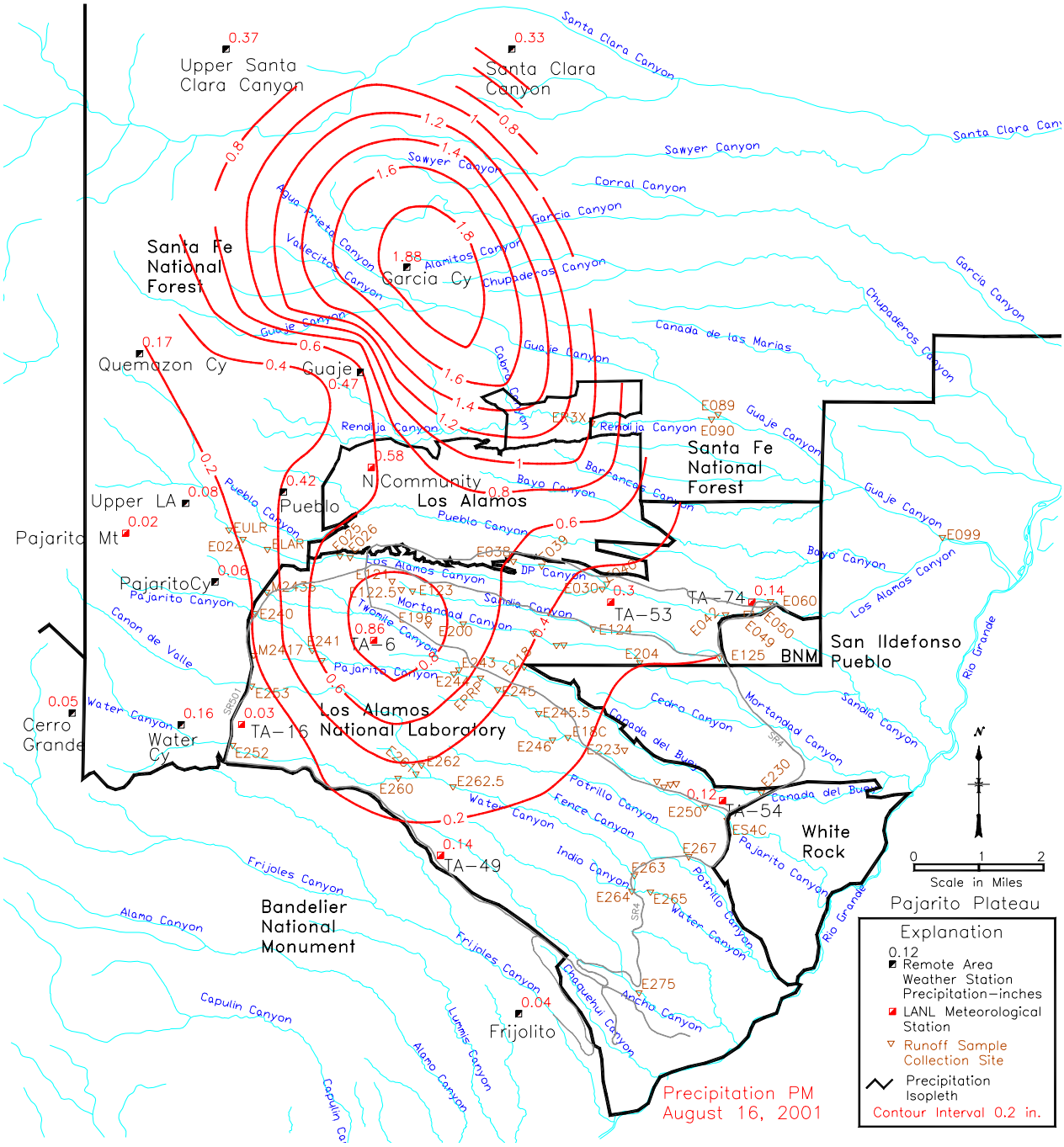

Figure A-18b. Pattern of precipitation recorded on the Pajarito Plateau on the evening of August 16, 2001.

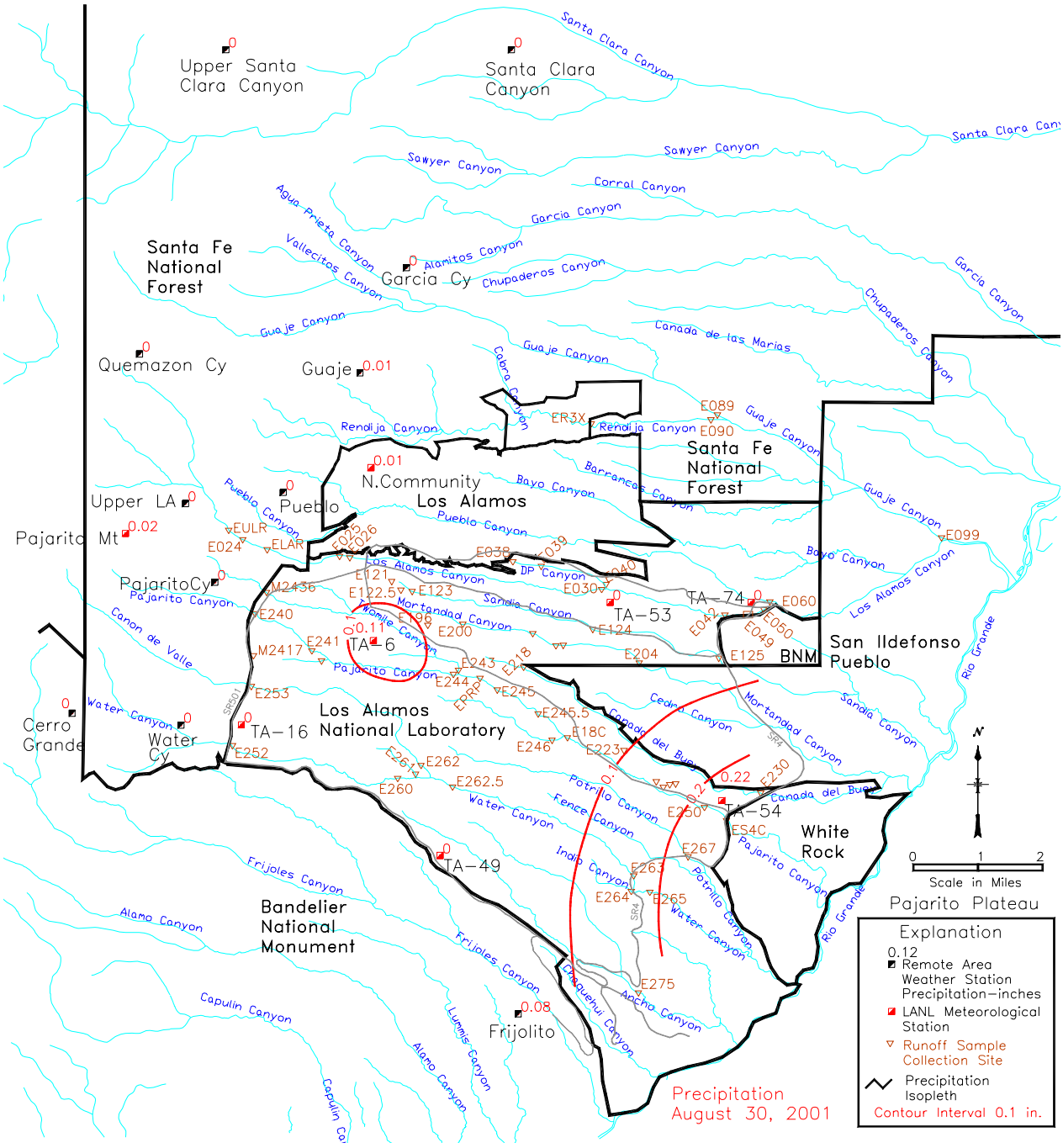

Figure A-19. Pattern of precipitation recorded on the Pajarito Plateau on August 30, 2001.

Appendix B. Summary of Storm Water Runoff Events at LANL in 2001

Gage	Date Time Start	Instant Peak Flow (cfs)	Time Peak Flow	Date Time End	Flow Volume (ac-ft)	Drainage Area (mi^2)	Runoff Yield (ac-ft/mi^2)	Comment
E038	05/13/2001 16:00	176	16:00	05/13/2001 17:35	3.9	0.207	18.84	
E040	05/28/2001 19:00	4.3	19:00	05/28/2001 23:00	0.3	0.57	0.53	
E200	06/27/2001 12:35	49	12:50	06/27/2001 20:00	2.5	0.49	5.10	
E038	06/27/2001 12:45	208	12:45	06/27/2001 15:45	4.5	0.207	21.74	
E039	06/27/2001 12:50	77	13:00	06/27/2001 16:00	5.2	0.315	16.51	
E218	06/27/2001 13:05	20	13:20	06/27/2001 15:35	0.7	0.31	2.26	
E040	06/27/2001 13:35	19	13:35	06/27/2001 18:15	0.9	0.57	1.58	
E042	06/27/2001 14:50	11	14:55	06/27/2001 20:15	0.8	9.08	0.09	
E245	06/27/2001 12:50	137	13:15	06/27/2001 23:55	13.3	7.84	1.70	
E250	06/27/2001 19:25	1.55	19:55	06/28/2001 14:25	0.4	10.9	0.04	
E038	07/02/2001 17:25	127	17:30	07/02/2001 20:20	7.7	0.207	37.20	
E039	07/02/2001 17:45	42.5	17:45	07/03/2001 4:25	5.6	0.315	17.78	
E026	07/02/2001 18:15	173	18:30	07/02/2001 22:00	3.6	7.12	0.51	
E040	07/02/2001 18:20	33	19:15	07/02/2001 23:35	2.5	0.57	4.39	
E089	07/02/2001 18:40	19	19:30	07/03/2001 12:00	1	14.6	0.07	
E090	07/02/2001 19:10	66	19:10	07/02/2001 19:30	0.6	9.58	0.06	
E042	07/02/2001 19:30	91	20:40	07/03/2001 11:55	14.2	9.08	1.56	
E060	07/02/2001 19:55	1440	20:00	07/03/2001 7:00	91	6.94	13.11	record peak flow
E026	07/13/2001 23:40	87	07/14/2001 0:05	07/14/2001 10:00	8.5	7.12	1.19	
E040	07/14/2001 0:25	3.3	0:35	07/14/2001 4:00	0.3	0.57	0.53	
E038	07/14/2001 1:15	9.0	1:20	07/14/2001 12:00	1.5	207	0.01	
E042	07/14/2001 2:10	29	2:10	07/14/2001 12:50	2.5	9.08	0.28	
E252	07/22/2001 14:10	255	14:25	07/23/2001 10:45	8	3.39	2.36	
E253	07/22/2001 14:35	2.3	14:40	07/22/2001 19:00	0.15	2.46	0.06	
E262.5	07/22/2001 15:05	3.5	15:45	07/23/2001 4:00	0.36	11.3	0.03	
E252	07/26/2001 17:35	80	17:35	07/27/2001 11:00	13	3.39	3.83	
E240	07/26/2001 17:40	54	17:40	07/27/2001 3:15	8.2	1.9	4.32	
E253	07/26/2001 17:45	9.7	17:50	07/26/2001 23:05	0.35	2.46	0.14	
E026	07/26/2001 18:00	65	18:20	07/27/2001 23:30	6	7.12	0.84	
E262.5	07/26/2001 19:15	13	19:15	07/27/2001 11:00	1.7	11.3	0.15	
E030	07/26/2001 19:40	16.8	20:00	07/27/2001 10:10	2.6	8.58	0.30	
E245	07/26/2001 19:40	24	19:45	07/27/2001 1:30	2.3	7.84	0.29	
E060	07/26/2001 20:10	114	20:15	07/27/2001 11:00	21	6.94	3.03	
E263	07/26/2001 20:25	13.8	20:25	07/27/2001 3:25	2.2	12.3	0.18	
E042	07/26/2001 20:30	50	20:30	07/27/2001 9:25	6	9.08	0.66	
E265	07/26/2001 20:35	32	20:35	07/27/2001 10:20	3.7	13	0.28	
E026	08/01/2001 16:00	9.1	17:05	08/02/2001 2:35		7.12	0.00	runoff volume indeterminate
E042	08/01/2001 16:50	9.4	20:55	08/02/2001 5:05	1.6	9.08	0.18	
E030	08/01/2001 18:00	3.1	19:45	08/02/2001 7:45	1.5	8.58	0.17	
E038	08/01/2001 18:10	27	18:15	08/01/2001 18:55	0.7	207	0.00	
E040	08/01/2001 19:55	2.0	19:55	08/01/2001 21:20	0.1	0.57	0.18	
E026	08/02/2001 9:20	8.6	17:30	08/03/2001 7:00	7.4	7.12	1.04	surface water flow
E252	08/03/2001 10:00	14	12:00	08/03/2001 17:00	1.8	3.39	0.53	supported by spring flow
E263	08/03/2001 13:40	72	13:40	08/03/2001 21:20	4.7	12.3	0.38	
E265	08/03/2001 13:45	92.3	13:45	08/03/2001 20:15	5.1	13	0.39	
E038	08/04/2001 13:40	160	13:40	08/04/2001 15:00	2.8	207	0.01	
E026	08/04/2001 13:50	6.4	13:50	08/04/2001 15:00	0.4	7.12	0.06	
E230	08/04/2001 14:15	5.8	14:35	08/04/2001 15:40	0.1	2.14	0.05	
E040	08/04/2001 14:35	12	14:35	08/04/2001 18:15	0.8	0.57	1.40	
E030	08/04/2001 14:55	3.0	14:55	08/04/2001 18:30	0.3	8.58	0.03	supported by surface water
E060	08/04/2001 15:10	61.6	17:15	08/05/2001 10:00	9.8	6.94	1.41	supported by surface water
E042	08/04/2001 15:35	21	15:35	08/05/2001 2:40	1.7	9.08	0.19	
E026	08/05/2001 16:15	15	16:50	08/05/2001 20:10	1.8	7.12	0.25	first runoff event
E123	08/05/2001 16:15	45.90	17:00	08/05/2001 20:30	2.8	0.45	6.22	first runoff event
E241	08/05/2001 16:15	4.3	17:45	08/05/2001 22:00	0.4	3.97	0.10	
E240	08/05/2001 16:30	4.4	17:00	08/05/2001 18:10	0.2	1.9	0.11	

Gage	Date Time Start	Instant Peak Flow (cfs)	Time Peak Flow	Date Time End	Flow Volume (ac-ft)	Drainage Area (mi^2)	Runoff Yield (ac-ft/mi^2)	Comment
E245	08/05/2001 17:05	51	17:10	08/06/2001 15:10	7	7.84	0.89	supported by spring flow
E242	08/05/2001 17:10	103	17:10	08/05/2001 20:30	2.6	0.82	3.17	supported by spring flow
E253	08/05/2001 17:10	16	17:10	08/05/2001 21:20	0.6	2.46	0.24	
E030	08/05/2001 17:40	9.0	17:40	08/05/2001 22:45	1.1	8.58	0.13	first runoff event
E252	08/05/2001 18:05	15	18:30	08/05/2001 23:00	1.9	3.39	0.56	
E042	08/05/2001 18:40	29	18:45	08/06/2001 0:10	2.3	9.08	0.25	first runoff event
E026	08/05/2001 20:10	3.5	20:25	08/05/2001 23:00	0.6	7.12	0.08	second runoff event
E262	08/05/2001 20:10	3.7	20:10	08/06/2001 2:50	0.5	4.14	0.12	
E262.5	08/05/2001 20:10	15	20:10	08/06/2001 16:05	3.5	11.3	0.31	
E123	08/05/2001 22:00	2.7	22:20	08/06/2001 0:30	0.2	0.45	0.44	second runoff event
E030	08/05/2001 22:45	2.0	22:45	08/06/2001 3:00	0.2	8.58	0.02	second runoff event
E042	08/06/2001 0:10	4.3	0:10	08/06/2001 11:50	0.5	9.08	0.06	second runoff event
E263	08/06/2001 0:55	2.2	0:55	08/06/2001 4:40	0.3	12.3	0.02	
E265	08/06/2001 1:30	0.3	1:30	08/06/2001 2:40	0.01	13	0.00	
E250	08/06/2001 3:25	1.1	3:45	08/06/2001 21:35	0.36	10.9	0.03	
E026	08/07/2001 13:40	4.3	13:50	08/07/2001 20:00	0.8	7.12	0.11	first runoff event
E030	08/07/2001 18:20	0.3	18:25	08/07/2001 23:25		8.58	0.00	stream flow
E026	08/07/2001 22:10	1.7	22:20	08/08/2001 3:00	0.4	7.12	0.06	second runoff event
E030	08/07/2001 23:25	2.0	23:25	08/08/2001 6:00	0.3	8.58	0.03	
E042	08/08/2001 0:45	8.2	0:45	08/08/2001 8:30	0.8	9.08	0.09	
E263	08/08/2001 6:15	1.9	6:15	08/08/2001 10:15	0.4	12.3	0.03	
E265	08/08/2001 6:50	0.2	6:50	08/08/2001 8:05	0.01	13	0.00	
E089	08/08/2001 14:45	4.0	14:50	08/08/2001 18:00	0.4	14.6	0.03	
E253	08/09/2001 14:10	17	14:55	08/09/2001 23:00	1.2	2.46	0.49	
E240	08/09/2001 15:00	155	15:00	08/09/2001 22:20	2.6	1.9	1.37	
E241	08/09/2001 15:00	109	15:00	08/09/2001 19:15	1.2	3.97	0.30	
E026	08/09/2001 15:20	185	15:45	08/09/2001 21:00	9.2	7.12	1.29	record peak flow
E089	08/09/2001 15:35	21	15:35	08/10/2001 4:20	1.8	14.6	0.12	
E030	08/09/2001 16:55	60	17:05	08/10/2001 3:00	4.9	8.58	0.57	record peak flow
E262	08/09/2001 16:55	26	17:00	08/10/2001 7:00	2	4.14	0.48	
E262.5	08/09/2001 16:55	50	17:00	08/09/2001 22:45	5.1	11.3	0.45	
E060	08/09/2001 17:10	244	17:10	08/10/2001 6:00	23.6	6.94	3.40	
E042	08/09/2001 17:40	146	17:45	08/10/2001 1:30	11.6	9.08	1.28	
E263	08/09/2001 18:10	25	18:15	08/10/2001 0:15	3.1	12.3	0.25	
E265	08/09/2001 18:20	22	18:25	08/10/2001 7:55	3.1	13	0.24	
E250	08/09/2001 21:05	12	21:45	08/11/2001 15:20	3.2	10.9	0.29	
E089	08/11/2001 13:20	644	13:30	08/12/2001 14:15	15.5	14.6	1.06	record peak flow
E269	08/11/2001 13:30	0.87	13:40	08/11/2001 22:15	0.03			
E090	08/11/2001 13:45	2120	13:50	08/12/2001 1:35	57	9.58	5.95	record peak flow
E060	08/11/2001 14:55	248	15:00	08/12/2001 5:00	31	6.94	4.47	
E253	08/13/2001 21:00	19	21:00	08/13/2001 23:35	0.3	2.46	0.12	
E060	08/13/2001 21:15	30	08/14/2001 6:30	08/14/2001 10:35	6.5	6.94	0.94	
E042	08/13/2001 22:15	11	08/14/2001 4:55	08/14/2001 10:15	4	9.08	0.44	
E089	08/13/2001 22:55	32	08/14/2001 2:45	08/15/2001 0:00	4.8	14.6	0.33	multiple runoff events
E123	08/16/2001 18:05	50	18:50	08/17/2001 4:00	5	0.45	11.11	
E089	08/16/2001 18:20	171	18:25	08/16/2001 23:55	16.2	14.6	1.11	
E039	08/16/2001 18:45	24	18:50	08/16/2001 23:00	2.3	0.315	7.30	
E090	08/16/2001 18:50	631	19:20	08/16/2001 23:50	35	9.58	3.65	
E030	08/16/2001 19:15	28	19:20	08/17/2001 2:00	2.7	8.58	0.31	
E040	08/16/2001 19:30	9.3	19:35	08/17/2001 2:00	0.8	0.57	1.40	
E263	08/16/2001 19:30	3.7	19:45	08/17/2001 3:10	0.78	12.3	0.06	
E042	08/16/2001 19:55	107	20:00	08/17/2001 6:00	9.2	9.08	1.01	
E060	08/16/2001 20:30	174	20:35	08/17/2001 2:00	27	6.94	3.89	
E262.5	08/16/2001 20:40	3.1	20:55	08/17/2001 0:55	0.5	11.3	0.04	
E262	08/16/2001 20:45	0.13	20:55	08/16/2001 22:55	0.01	4.14	0.00	
E265	08/16/2001 21:10	1.8	21:10	08/17/2001 10:05	0.5	13	0.04	
E250	08/16/2001 22:55	22	23:35	08/18/2001 20:35	5.7	10.9	0.52	record peak flow
E265	08/30/2001 15:30	7.2	16:00	08/30/2001 18:05	0.35	13	0.03	
E263	08/30/2001 15:45	7.5	15:50	08/30/2001 17:15	0.35	12.3	0.03	

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