LA-13741-T
Thesis

Estimates of Radionuclide Loading to Cochiti Lake from Los Alamos Canyon Using Manual and Automated Sampling

Los Alamos
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Table of Contents

List of Figures

List of Tables

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Estimates of Radionuclide Loading To Cochiti Lake From Los Alamos Canyon Using Manual And Automated Sampling

Christopher T. McLean

1. ABSTRACT

Los Alamos National Laboratory has a long-standing program of sampling storm water runoff inside the Laboratory boundaries. In 1995, the Laboratory started collecting the samples using automated storm water sampling stations; prior to this time the samples were collected manually. The Laboratory has also been periodically collecting sediment samples from Cochiti Lake. This paper presents the data for Pu-238 and Pu-239 bound to the sediments for Los Alamos Canyon storm water runoff and compares the sampling types by mass loading and as a percentage of the sediment deposition to Cochiti Lake. The data for both manual and automated sampling are used to calculate mass loads from Los Alamos Canyon on a yearly basis. The automated samples show mass loading 200-500 percent greater for Pu-238 and 300-700 percent greater for Pu-239 than the manual samples. Using the mean manual flow volume for mass loading calculations, the automated samples are over 900 percent greater for Pu-238 and over 1800 percent greater for Pu-239. Evaluating the Pu-238 and Pu-239 activities as a percentage of deposition to Cochiti Lake indicates that the automated samples are 700-1300 percent greater for Pu-238 and 200-500 percent greater for Pu-239. The variance was calculated by two methods. The first method calculates the variance for each sample event. The second method calculates the variances by the total volume of water discharged in Los Alamos Canyon for the year.

2. INTRODUCTION

Los Alamos National Laboratory is located on a unique mesa-top canyon environment. The canyons have an east-to-west orientation and are cut by intermittent or ephemeral streams. The mesa tops range in elevation from 7800 feet close to the mountains to about 6200 feet above the Rio Grande Canyon. Most of the canyon streams are ephemeral in nature. The total area of the Laboratory is 43 square miles.

Los Alamos National Laboratory has sampled the storm water runoff emanating from within the Laboratory boundaries since the 1960s. Prior to 1995, sampling personnel visited the sampling sites during rainfall-runoff events to collect storm water samples manually. Due to the large area of the Laboratory the sampling personnel were forced to select a particular location to sample. Storms are very localized within the Laboratory boundaries. A storm might be concentrated in one part of the Laboratory while other areas are not experiencing rain. Thus, the sampling area visited by the sampler may not have received enough rain to produce discharge. The sampler would have to relocate to an area where the rainfall intensity is enough to generate flow. At this point, the sampler would have already missed the leading edge of the storm; therefore, the sample would not be fully representative of the storm.

Since 1991 the Laboratory has installed more than fifty automated sampling and flow measurement stations inside the Laboratory boundaries. These stations take flow readings at five-minute intervals. Once flow is detected, at any of these stations, the automated sampler activates and starts collecting samples. This allows for the "first flush" of the storm water to be sampled. Sampling the "first flush" of the storm is generally the peak of the hydrograph. In the ephemeral flash-flood type of system prevalent at the Laboratory, the sediments deposited on the floodplains have the highest probability of being mobilized during this segment of the hydrograph.

The focus of this study is the automated storm water sampling station E042 termed Los Alamos (LA) Canyon near LA and the manual sample point termed LA Canyon at State Road 4 (SR 4). The manual sampling station lies about one-quarter of a mile downstream from the automated sampling site. There are no stream inputs or radiological sources located between the two sampling points. The proximity of and similarity between the sites allow analytical data comparison. These sampling points lie near the edge of the discharge point off the Laboratory boundary. The data collected and evaluated in this study will be used to estimate the discharge of Pu-238 and Pu-239 leaving the boundary of the Laboratory.

Figures 1-3 are shown to illustrate the geography and drainage basins of the Laboratory. Figure 1 illustrates the location of the Laboratory. In this figure, the general site orientation of the Laboratory is shown. Figure 2 illustrates areas of historical releases of Pu-238 and Pu-239. In Figure 2, the relationship between the Rio Grande and Cochiti Lake is shown. Figure 3 illustrates the stream channels of the Laboratory and the associated automated storm water monitoring stations.

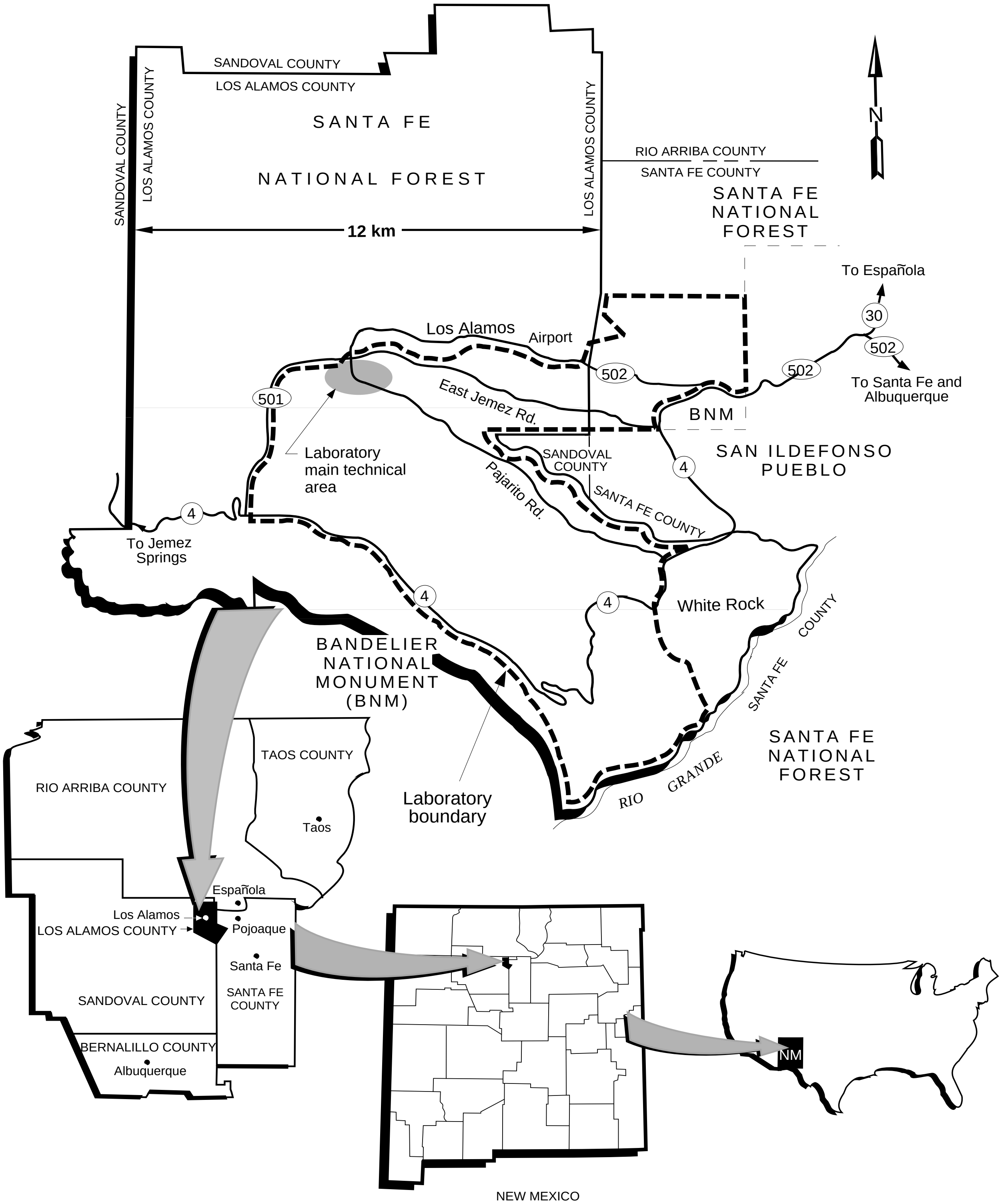

Figure 1. Location of Los Alamos National Laboratory

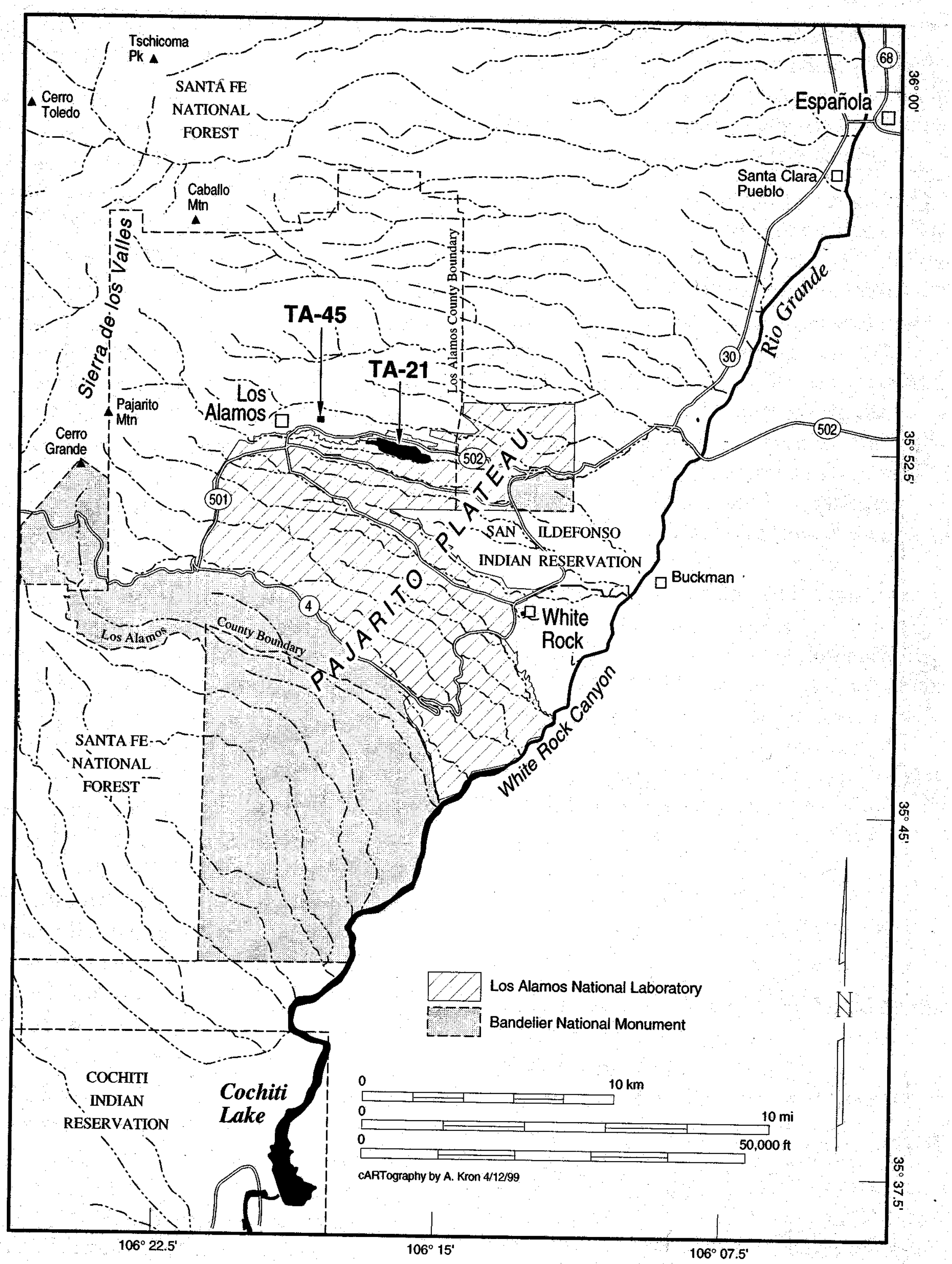

Figure 2. Map showing the Laboratory (TA-45 and TA-21) Drainages and the Rio Grande to Cochiti Lake

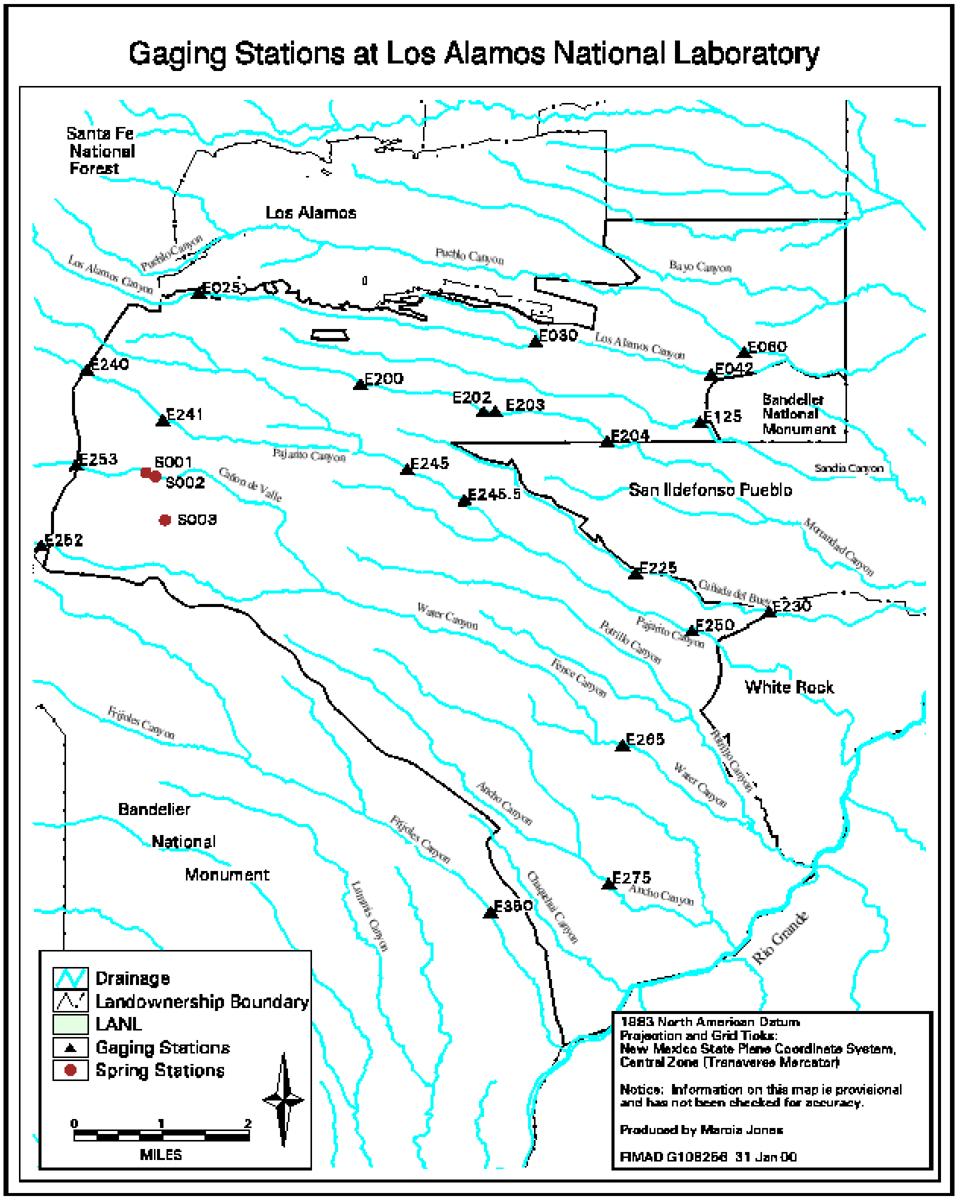

Figure 3. Stream Channel and Associated Automated Storm Water Monitoring Stations in the Los Alamos Area

3. LOS ALAMOS CANYON HISTORY

3.1.1 Geology

Sedimentary and volcanic rocks underlie LA Canyon. The canyon walls are composed of pumiceous tuff breccia and nonwelded tuff. When weathered these materials yield stream sediments that are dominated by sand-sized particles (Graf, 1996). The streams in LA Canyon are intermittent or ephemeral. Runoff is restricted to snowmelt in spring and rainfall in summer; however, snowmelt rarely reaches the sampling points used in this study. The upper reaches of LA Canyon are steeper in gradient and do not allow for continued deposition of sediment. The lower reaches, near the sampling points in this study, have a gentler gradient that allows for sediment deposition. A larger runoff event is required to move sediment in this area due to the lower gradient and the wider floodplain.

3.1.2 Historical Disposal Practices

Between 1956 and 1985 an estimated 2 to 12 grams of Pu were released into DP Canyon, which is a tributary to upper LA Canyon (Gallaher et al., 1999). This Pu quickly became adsorbed onto the sediments in the stream channels. Since the deposition, the plutonium inventory has been moving down the LA Canyon during runoff events. Much of the Pu-238 and Pu-239 sediment-bound inventory has been deposited in the lower reaches of LA Canyon. Because of this movement, the plutonium inventory has migrated out of the channel and into the floodplains. To mobilize the sediments in the floodplains a high volume runoff event is required (Graf, 1996). Through long-term monitoring by the

Laboratory it has been determined that mean plutonium concentrations are approximately 10 pCi/g near the discharge areas to 0.10 pCi/g near the confluence with the Rio Grande. A small portion of this inventory has been washed down more than 20 km where it has been deposited in Cochiti Lake since its construction in 1973.

4. STUDY OBJECTIVES

There are three distinct but interrelated objectives to be determined from the study.

1. Show rainfall variations that illustrate the inability of the sampling person to choose the site where storm water runoff will occur.

2. Show the short peak duration of the storm water runoff in the area allowing the sampler an extremely short time frame to collect the “first flush” sample.

3. Determine if estimates of radionuclide loading to Cochiti Lake are a function of the type of sampling technique, manual or automated.

Manually collecting samples raises an issue of adequate representation of the storm event over the hydrograph. The automated samples can be shown to represent the storm event over the hydrograph; therefore, the automated samples should estimate the radionuclide loading to Cochiti Lake better than the manual. The automated and manual analytical samples are analyzed and the percentage by mass loading calculated with respect to Cochiti Lake. The estimates are determined for each sampling type.

5. RAINFALL AND RUNOFF DATA

5.1 Rainfall Data

Los Alamos National Laboratory's meteorological group ESH-17 in the Environmental Safety and Health (ESH) Division has a large network of stations that collects rainfall data in 15-minute increments (LANL, 2000). The stations are situated throughout the Laboratory area and give a spatial representation of the rainfall. The station data used to show the variability of the rain over the Laboratory are Technical Area (TA)-6, TA-16, TA-49, TA-53, TA-54, and TA-74. Figure 4 illustrates the location of the rain gauging stations on the Laboratory. Figures 5-10 illustrate the variability of the rain over the Laboratory area.

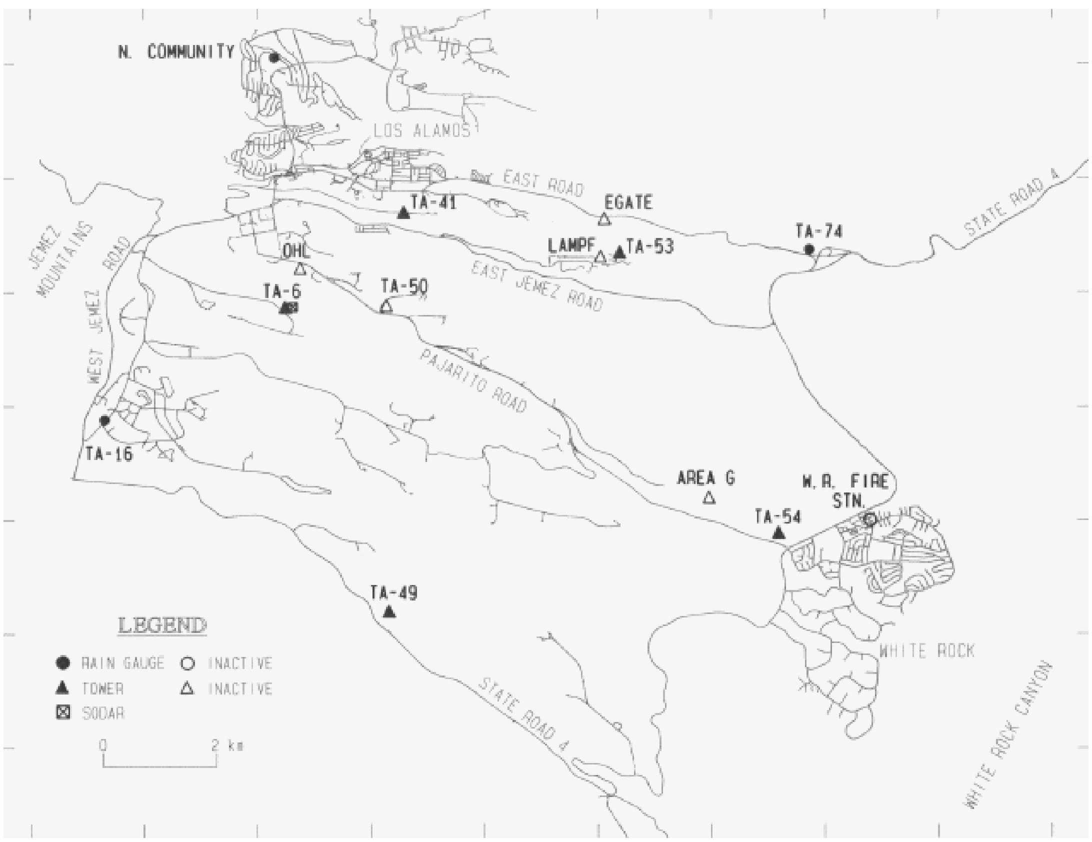

Figure 4. Location of Rain Gauging Stations at Los Alamos National Laboratory

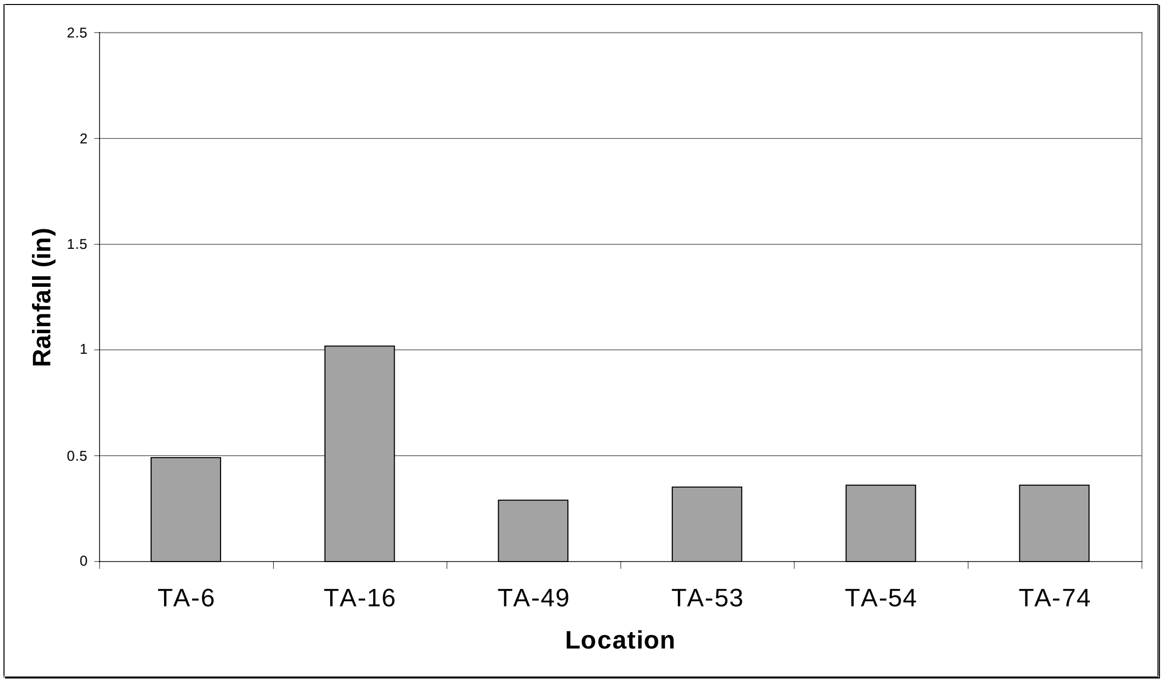

Figure 5. Rainfall April 30, 1999

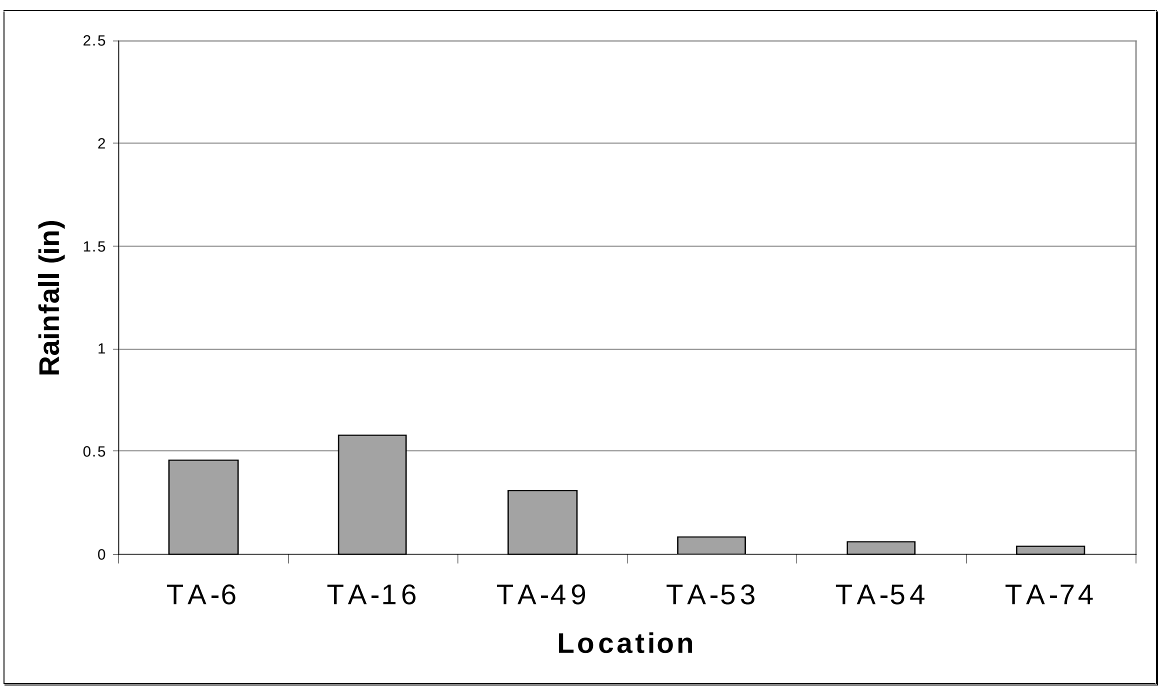

Figure 6. Rainfall May 28, 1999

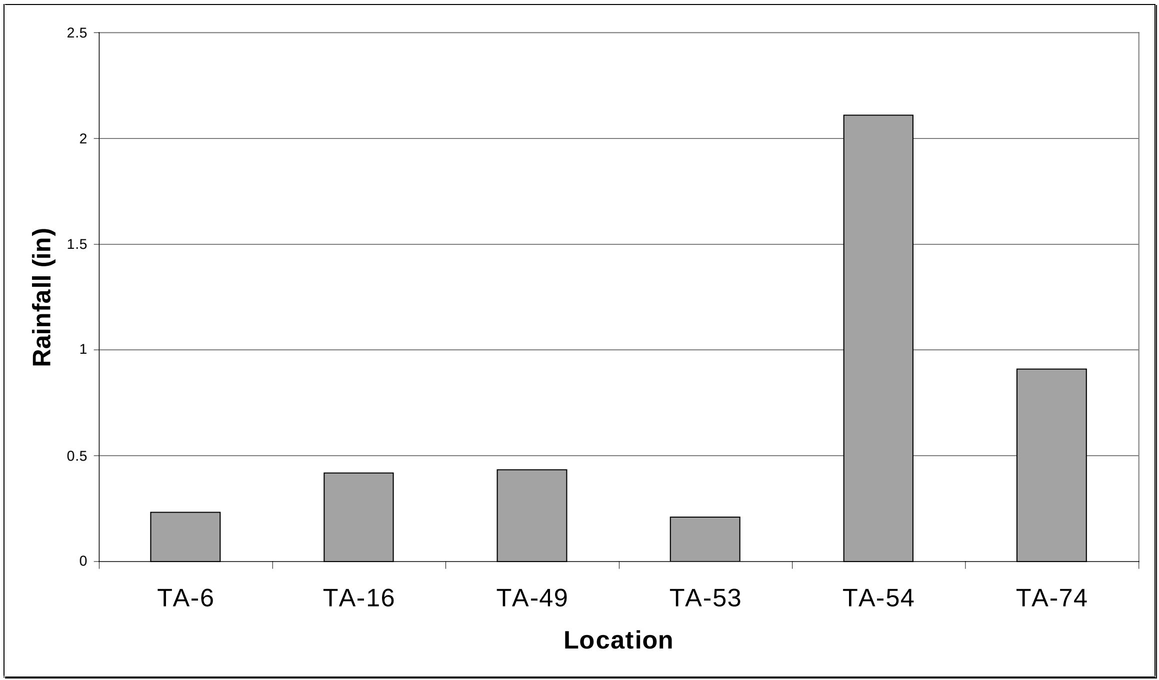

Figure 7. Rainfall June 17, 1999

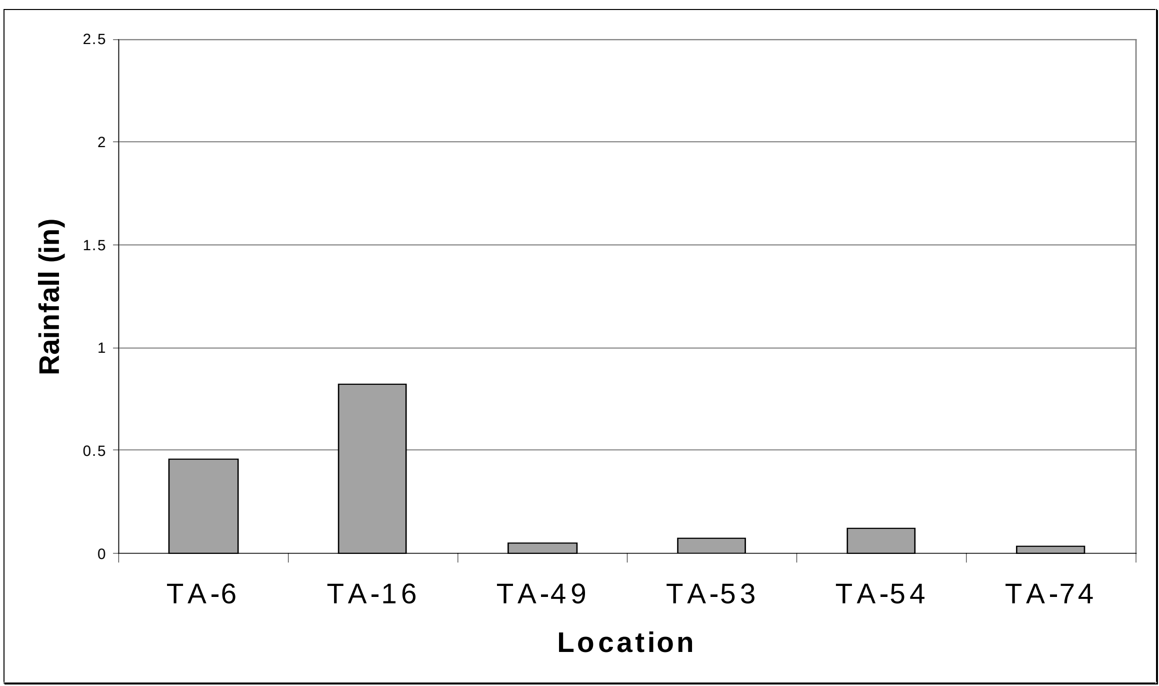

Figure 8. Rainfall July 6, 1999

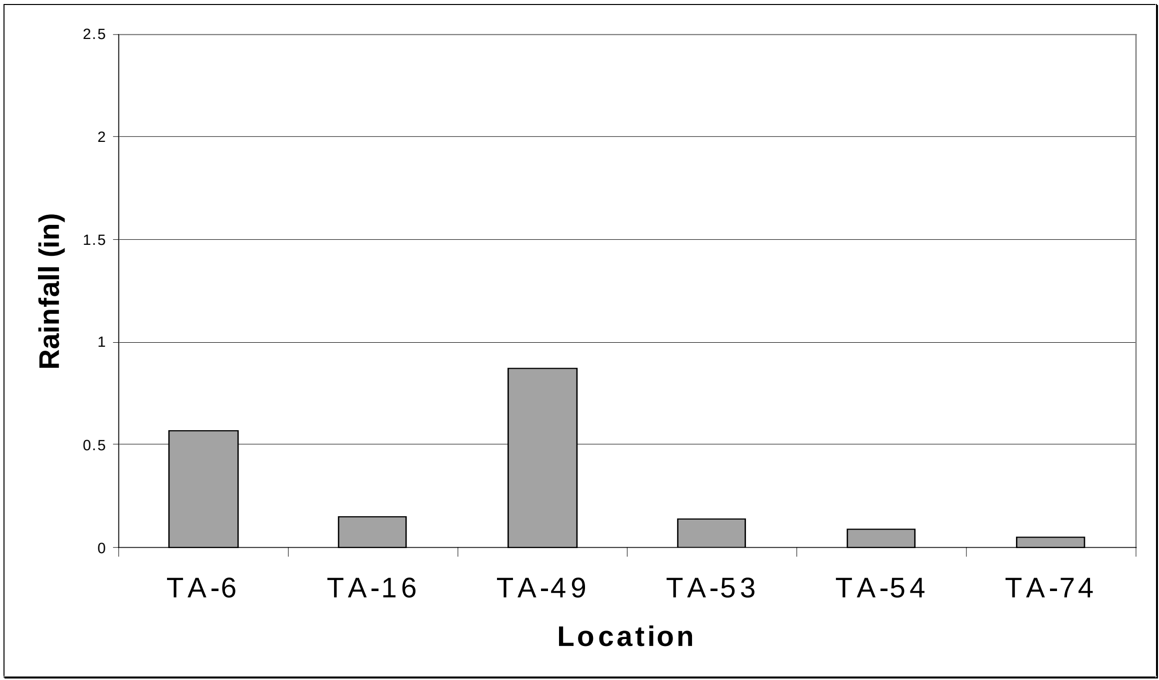

Figure 9. Rainfall August 10, 1999

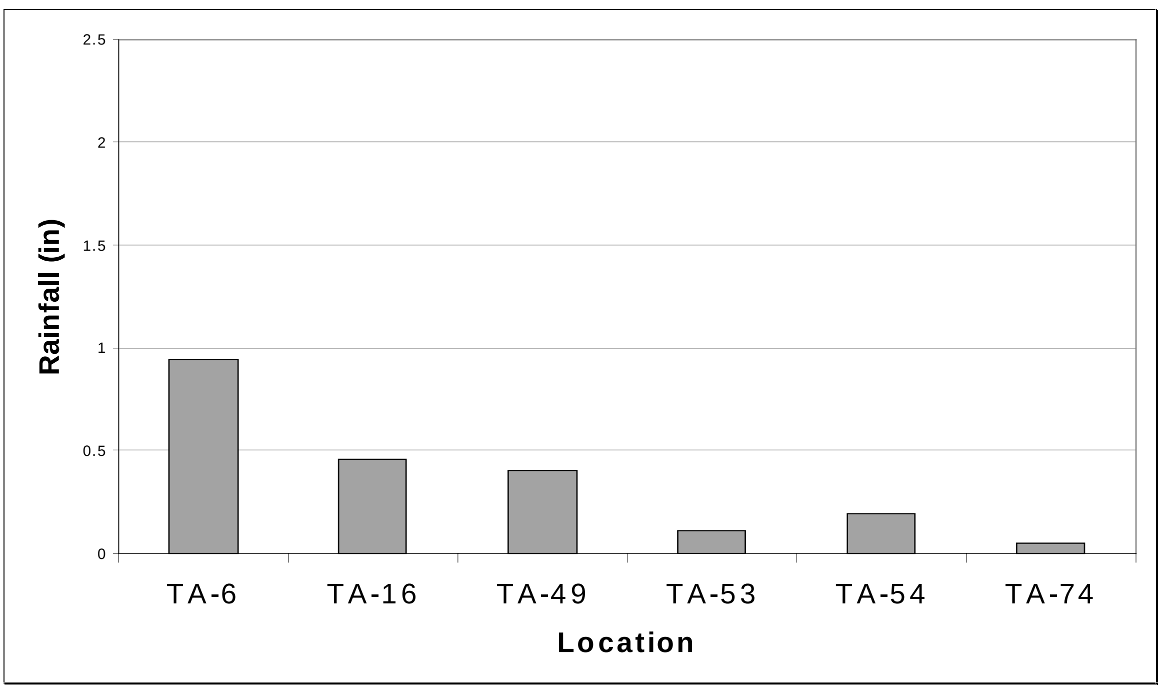

Figure 10. Rainfall September 14, 1999

These figures illustrate the variability of rainfall events around the Laboratory and the ensuing difficulty sample personnel have determining which area to visit. To collect a representative sample from the storm the sampler must be in the area at the beginning of the rainfall event. The problem is determining the area where the rain will be concentrated. Due to the variability of the rainfall patterns throughout the Laboratory, it is difficult for the sample personnel to collect a representative sample over the entire storm event.

5.2 Runoff Data

The Water Quality and Hydrology Group (ESH-18) is tasked with monitoring the groundwater and surface water at the Laboratory. ESH-18's Storm Water Team collected the flow data for the event illustrated by Figure 11. Figure 11 shows the sample times plotted and the corresponding flow values over the hydrograph for a storm event on 8/14/1999. The flow data is from a stilling-well type recorder that takes flow readings at five-minute intervals. An automated ISCO sampler collected the samples. These samples were also collected at five-minute intervals to correlate with the sample times. Five-minute collection intervals are generally representative of the sample over the hydrograph.

The automated flow station E042 LA Canyon near LA was installed in October of 1991 and operated by the United States Geological Survey (USGS) until September of 1995. The 1992 through 1995 flow values were taken from the USGS Water-Data Reports (USGS, 1994-1995). ESH-18 operated the station after September of 1995 and all subsequent flow values are from the Surface Water Data at Los Alamos National

Laboratory Water Year Reports (Shaull et al., 1996-2000). All the yearly flow volumes used in the report are for the water year from October 1 to September 30.

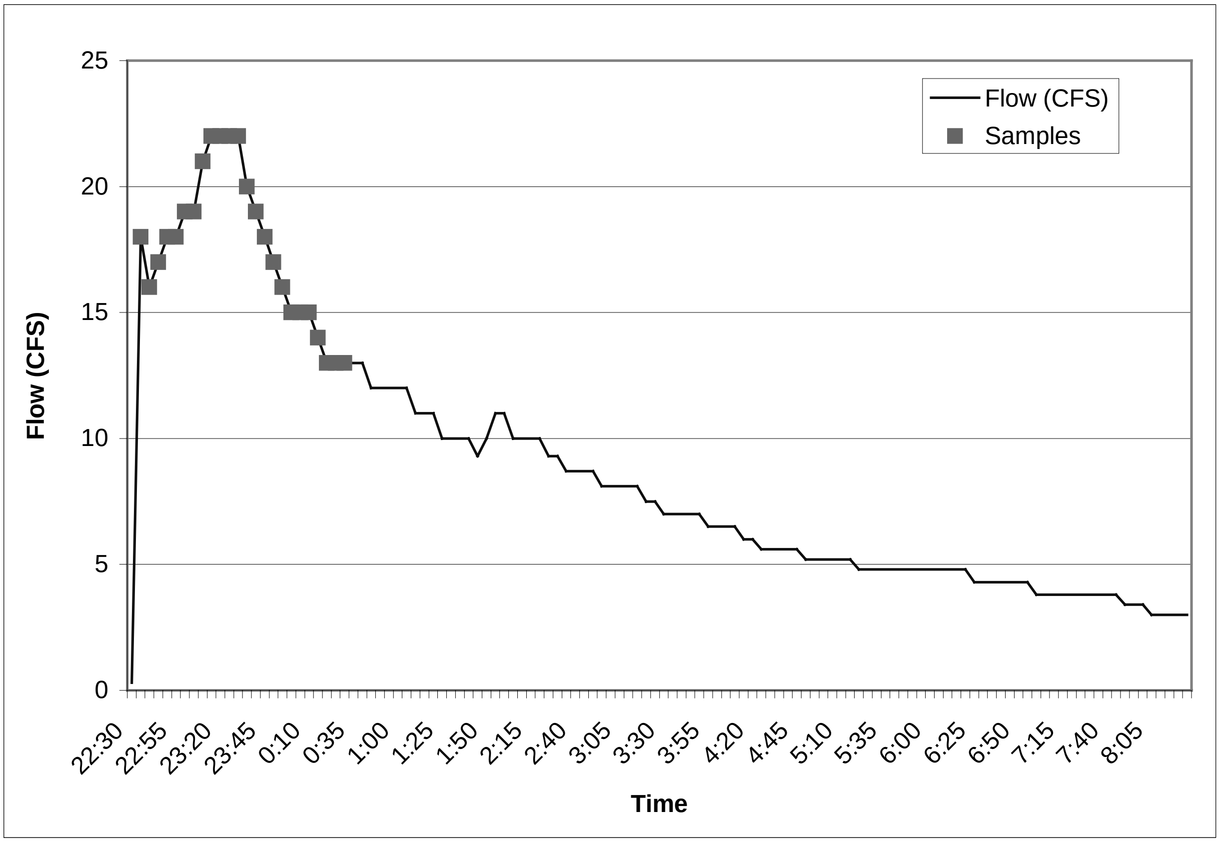

Figure 11. Hydrograph with Samples for E042 LA Canyon Near LA on 8/14/1999

From the hydrograph, it can be seen that the sample points represent the leading, peak, and trailing edge of the storm. Due to the long duration of this storm the sample interval could have been longer; quite often, the storms are of shorter duration. If the sampling interval were set to a longer period many of the representative samples would not be collected for many of the storms with shorter periods of flow.

6. MANUAL SAMPLING

6.1 Manual Sample Collection and Submittal

Water flowing at the manual sampling site LA Canyon at SR 4 during the spring and summer months can be assumed to be due to rainfall-runoff events. The site is generally dry except when there is rainfall-induced runoff. The exception would be for years with an abnormally heavy snow pack and unseasonably warm spring days. To obtain a sample the sample personnel would first pre-label the sample bottles. If filtering of the sample was necessary this would occur in the field. New polyethylene bottles are used for each sample. Samples are collected from the bank by dipping the sample container into the flow (Mullen and Naranjo, 1996b). Once the sample is collected all chain-of-custody procedures are followed (Gallaher, 1993). The sample is placed in a cooler until transfer to the Chemical Science and Technology (CST) Division's Sample Receiving Facility Group (CST-3). At this time chain-of-custody transfers to CST-3.

6.2 Flow Calculation for Manual Samples by Event

The automated flow monitoring station E042 LA Canyon near LA began operation October 1, 1991. Flow values prior to October 1, 1991 were not available for sample points used in the study for 1991, so a relationship was needed to calculate flow for these sampling points in 1991. Since the rainfall and runoff were known, this relationship could be established. Error in the calculation will be due to the limited spatial coverage of the rain gauges over the sampling area and the assumption of a linear relationship between rainfall and runoff. There are areas providing inputs to the basin that do not contain a rain gauge; therefore, there could be flows that will not have rain associated with the flow. Also, some of the flow is due to snowmelt. Some of the outlying data points were not used to calculate the relationship between rainfall and runoff. The flows are reported in Cfs-day. Cfs-day is the volume of water represented by the flow of one cubic foot per second for 24 hours, or 646,317 gallons.

The storm on 8/6/91 produced only 0.03 inches of rain. This amount of rain is insufficient to produce runoff; therefore, the date reported for the analytical result in the database is in all probability incorrect. The 0.52 inches of rain reported for 8/7/91, was used for the calculation for the analytical sample reported as 8/6/91. The date is left reported as 8/6/91 to correspond with the analytical report date entered in the database.

Figures 12 and 13 show the rainfall-runoff relationship by day for the months of August and September using data separately for each month from 1992 to 1999. Table 1 shows the calculations for the days of flow needed for the manual samples in 1991. These calculations were made using the rainfall-runoff equation generated from the plot.

A total runoff for the 1991 water year was not available. This was calculated using the months of May through September. These months represent the rainfall-induced storms that produced runoff for the year, with little input from snowmelt. Figure 14 determines the rainfall-runoff relationship yearly by using the rainy season months of April-September for 1992-1999. Table 1 shows the total flow calculations for the 1991 water year.

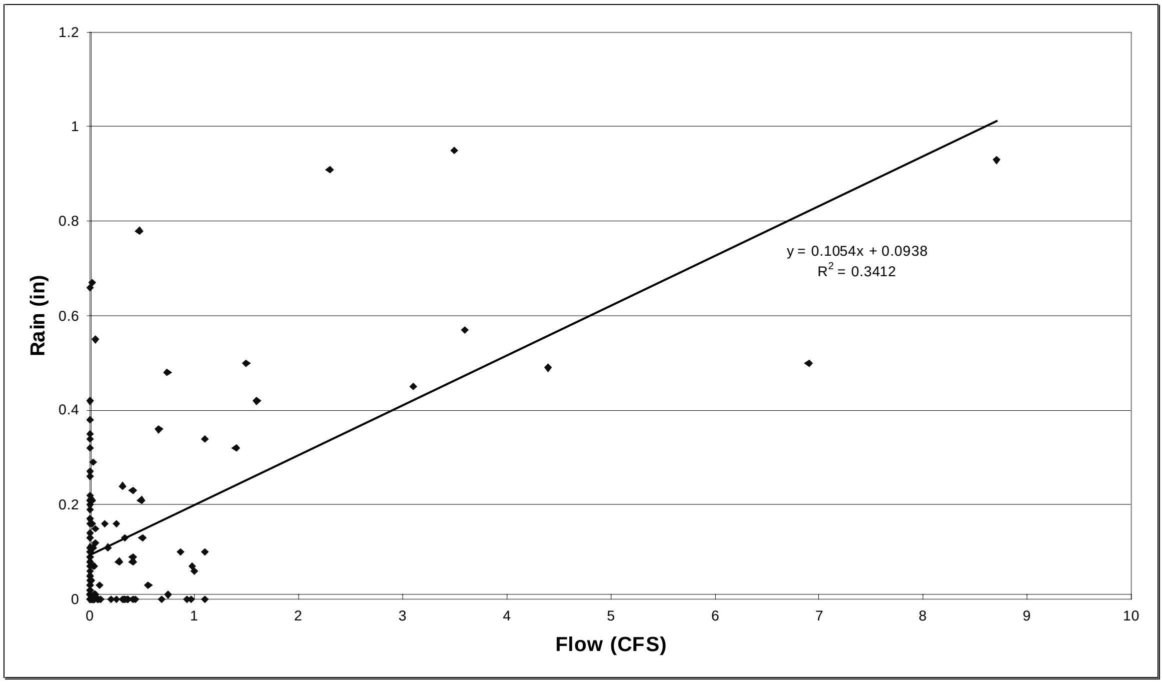

Figure 12. August Rainfall-Runoff Relationship 1992-1999

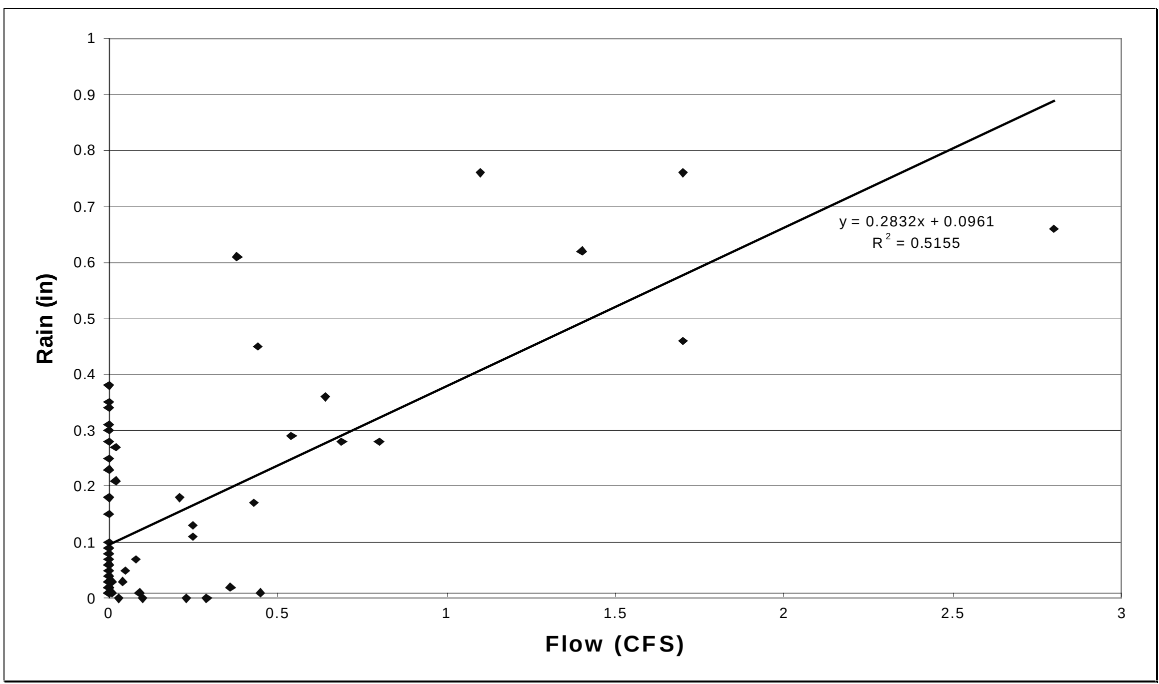

Figure 13. September Rainfall-Runoff Relationship 1992-1999

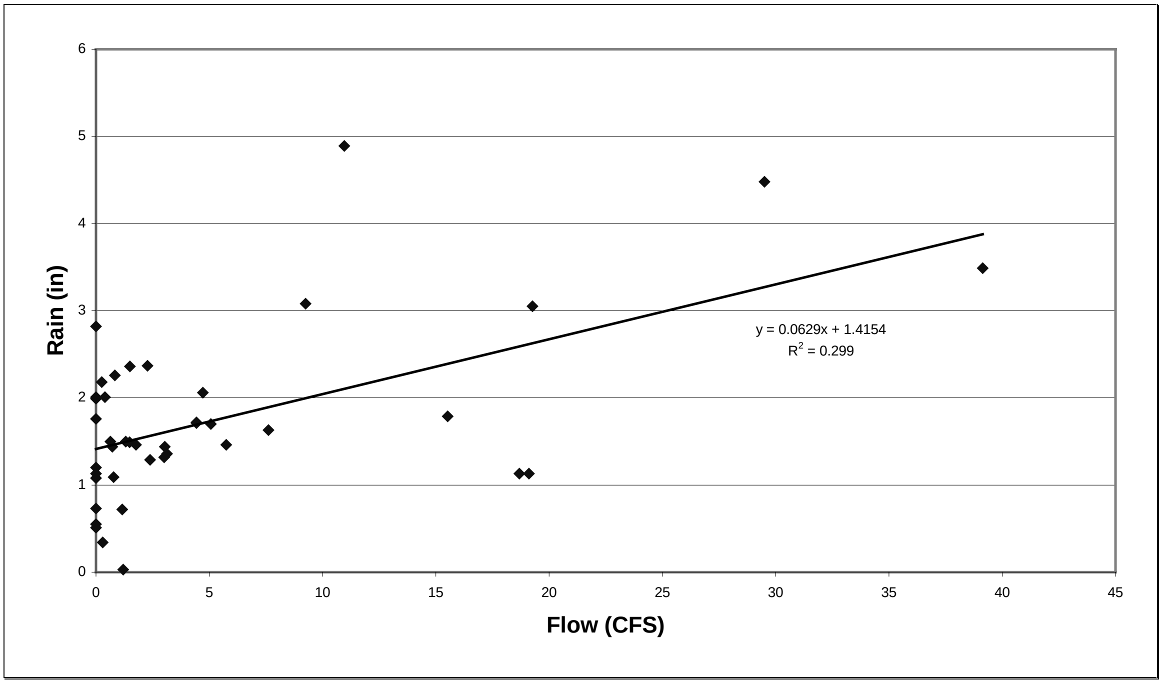

Figure 14. April-September Rainfall-Runoff Relationship 1992-1999

Table 1. Rainfall-Runoff Calculations for Manual Samples

Date of Sample	Rain (in)	Calculated Flow (Cfs-day)
8/6/91	0.52	4.0
8/13/91	0.21	1.1
9/6/91	1.04	3.3
9/12/91	0.17	0.3
Flow Calculation Equation for August y=0.1054x + 0.0938		
Flow Calculation Equation for September y=0.2832x + 0.0961		
y=Rain (in) x=Unknown Flow (Cfs-day)		

Year	Rain	Calculated Flow (Cfs-day)
1991	14.12	202.0
Flow Calculation Equation for 1991 y=0.0629x + 1.4154		
y= Rain (in) x= Unknown Flow (Cfs-day)		

7. AUTOMATED SAMPLING

7.1 Automated Station Overview

Station E042 LA Canyon near LA, shown in Figure 15, was originally installed and operated by the USGS in October 1991. Figure 16 shows the terrain surrounding station E042. Since October of 1995, ESH-18 has been operating the station. It is located at Lat 35°52’1.3”, Long 106°13’25.8”, in SW ¼ sec. 20, T. 19 N, R. 7 E, Santa Fe County, on right bank, ¼ mile upstream from NM State Highway 4, 2.7 mi NW of White Rock, NM, 3.9 mi E of Los Alamos, and 13.5 mi SW of Espanola. The drainage area is 9.08 mi^2. The period of record for the station is from November 1970 to June 1971, and October 1991 to present. It is equipped with a data logger including cellular telemetry and a concrete control. It is powered by a solar panel that charges a sealed lead acid battery. The elevation of the gage is 6383 ft above mean sea level. The water discharge records are fair. The extremes for the period of record include a maximum discharge of 171 cfs on August 22, 1997 at a gage height of 2.95 ft. There is no flow most of the time.

Figure 15. Automated Storm Water Station E042 LA Canyon Near LA

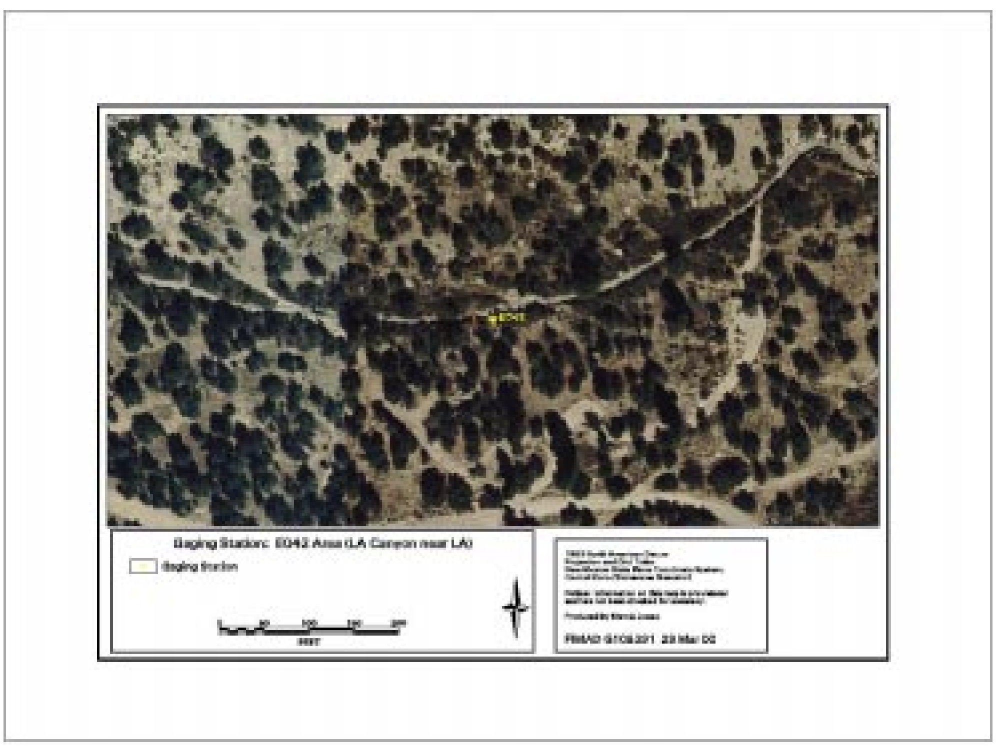

Figure 16. Aerial Overview of Automated Storm Water Station EO42

7.2 Automated Sample Collection

Station E042 LA Canyon near LA is equipped with an automated ISCO sampler. The sampler is housed in the small box-like shelter, seen in Figure 15. From here plastic tubing extends into the stream where it is attached to a debris strainer. The strainer is placed at a level where it will be completely submerged in the discharge. When the gauge height reaches 1.70 in., which corresponds to 4.80 CFS, the ISCO sampler is activated. A sample is collected every five minutes until the sampler finishes filling all twenty-four bottles or the gauge height drops below 1.70 in. Once all the bottles have been filled or the flow drops below the sampler trip level the sampling team will visit the site to retrieve the samples (Reynolds, 1997). The samples will be transferred from the sampler directly to a cooler for transport to the storm water laboratory. At this time all chain of custody procedures will be followed (Gallaher, 1993).

7.3 Automated Sample Submittal

Once the samples are at the storm water laboratory, the samples are prepared for submittal to the analytical laboratory. For radiochemical analysis the analytical laboratory needs a gallon of sample volume. The automated sampler fills 24 liter bottles. To obtain a gallon of sample volume the samples are transferred to a churn splitter where they are mixed to homogenize the sample. The samples are split into separate filtered and unfiltered bottles. These samples are then delivered to the CST-3. At this point chain of custody transfers to the analytical laboratory. All radiochemical analyses for storm water samples have been analyzed by CST-3.

8. SEDIMENT SAMPLING

8.1 Stream Channel Sediment Sample Collection and Submittal

All stream channel sediment samples were collected by ESH-18. The samples were collected through a cross section of the stream channel. Samples were collected from the upper 0.5-0.75 inch of the stream channel sediments. An effort has been made to collect the finer-grained sediments. The samples were collected using disposable scoops and trowels that are used once and then discarded. Each sample collected is 100g of sediment. Once collected and placed in a pre-labeled sample bottle, the samples are stored for submittal to the CST-3 Analytical Laboratory (Mullen and Naranjo, 1996a).

8.2 Cochiti Lake Sediment Sampling and Submittal

The Cochiti Lake sediments used in this study have been collected by ESH-18 using a Ponar Grab, which is a clamshell type scoop that is activated by a messenger weight. The Ponar Grab is mounted on a boat to obtain samples from depth in the lake. To collect a sample, the shell must be opened and latched in place. The shell is slowly lowered to the bottom and is then closed by the messenger weight. Once the messenger weight has closed the jaws, the sample is slowly brought to the surface. There are 1000g of sediment collected for each sample. The sample is then transferred to a pre-labeled bottle. The samples are stored until they are submitted to the CST-3 Analytical Laboratory (Mullen and Naranjo, 1996a).

9. SEDIMENT AND STORM WATER DATA COMPARISON

9.1 Sediment and Storm Water Data Presentation

The data for Figures 17-20 were collected by ESH-18, and are for the period from 1991-1999. These figures illustrate the sediment and storm water concentrations for Pu-238 and Pu-239 with the associated error bars. The breaks in the lines represent the change from manual to automated sampling. The samples are from the sediment and manual sampling point LA Canyon at SR 4, and the automated sampling point LA Canyon near LA.

9.2 Sediment and Storm Water Data Analysis

The sediment and manual samples for LA Canyon were collected at the same location. The storm water automated sampling point is just upstream from the other two sampling points. The manual storm water data points do not extend past 1995. The automated storm water data comprise the data points after 1995. An increase in the values is seen in the storm water samples for the period corresponding to the automated sampling. The sediment samples show a decrease in the values during the automated sampling period. Thus if the sampling techniques demonstrated a comparable representative sample, there should be a decrease for the storm water samples during the automated sampling period. Therefore it can be inferred that the automated sampling technique is gathering a more representative sample of the Pu-238 and Pu-239 bound to the sediments that are flowing through the system.

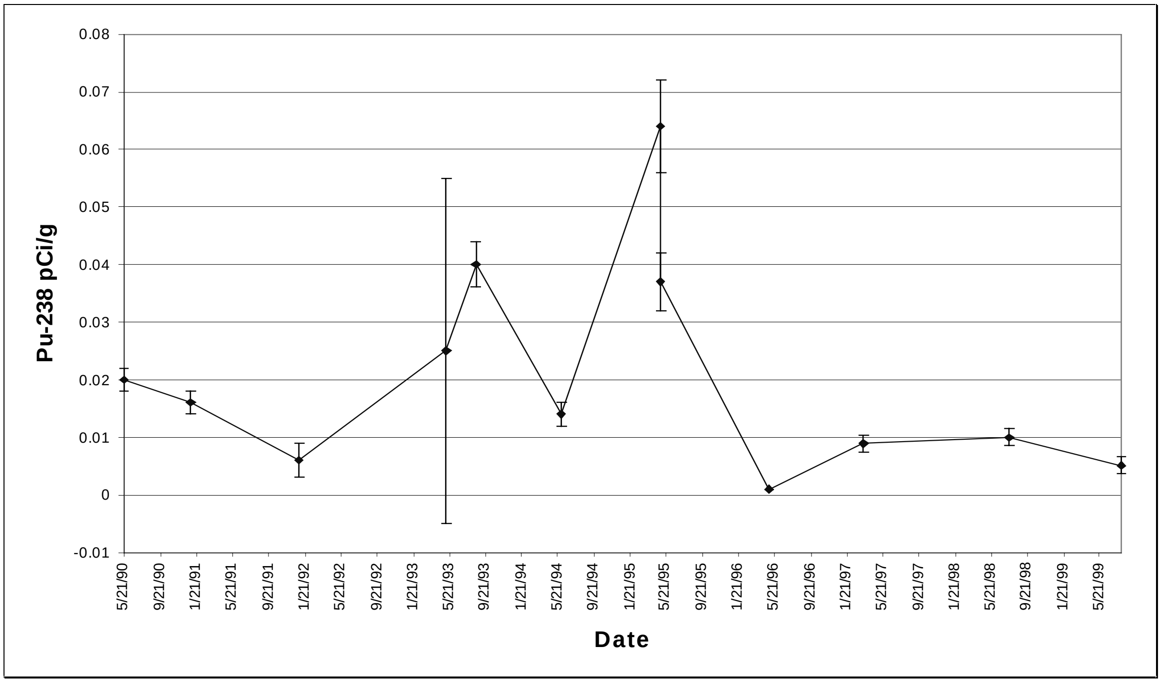

Figure 17. Pu-238 Sediment Concentrations for LA Canyon at SR4

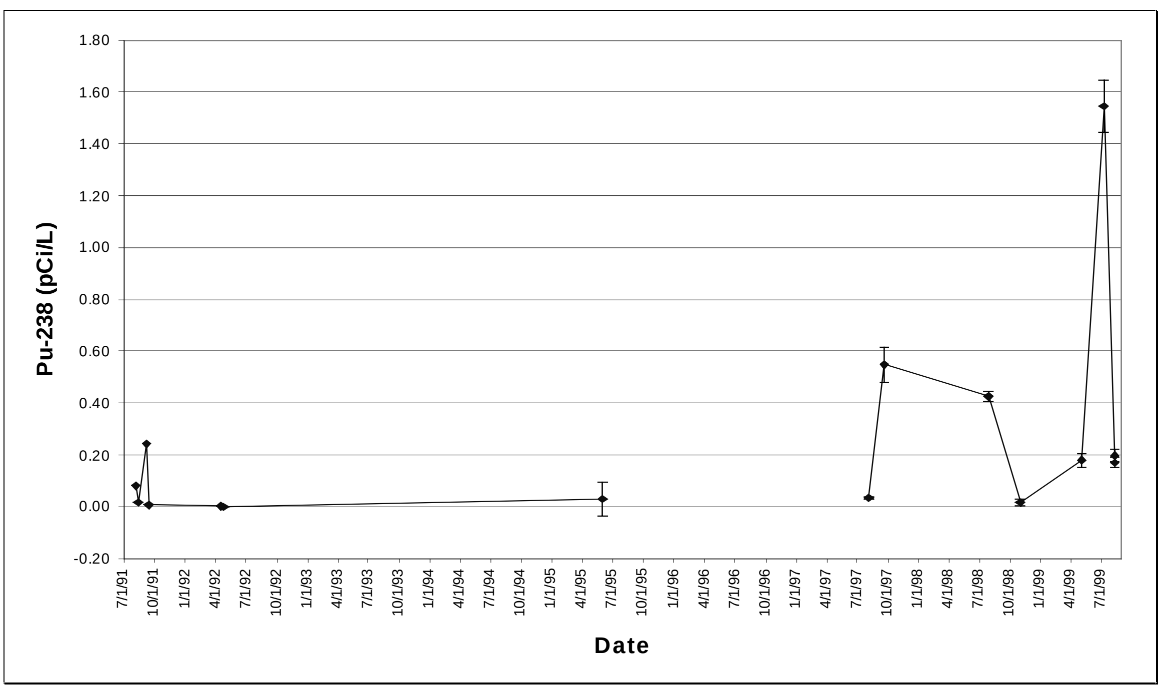

Figure 18. Pu-238 Manual and Automated Storm Water Concentrations

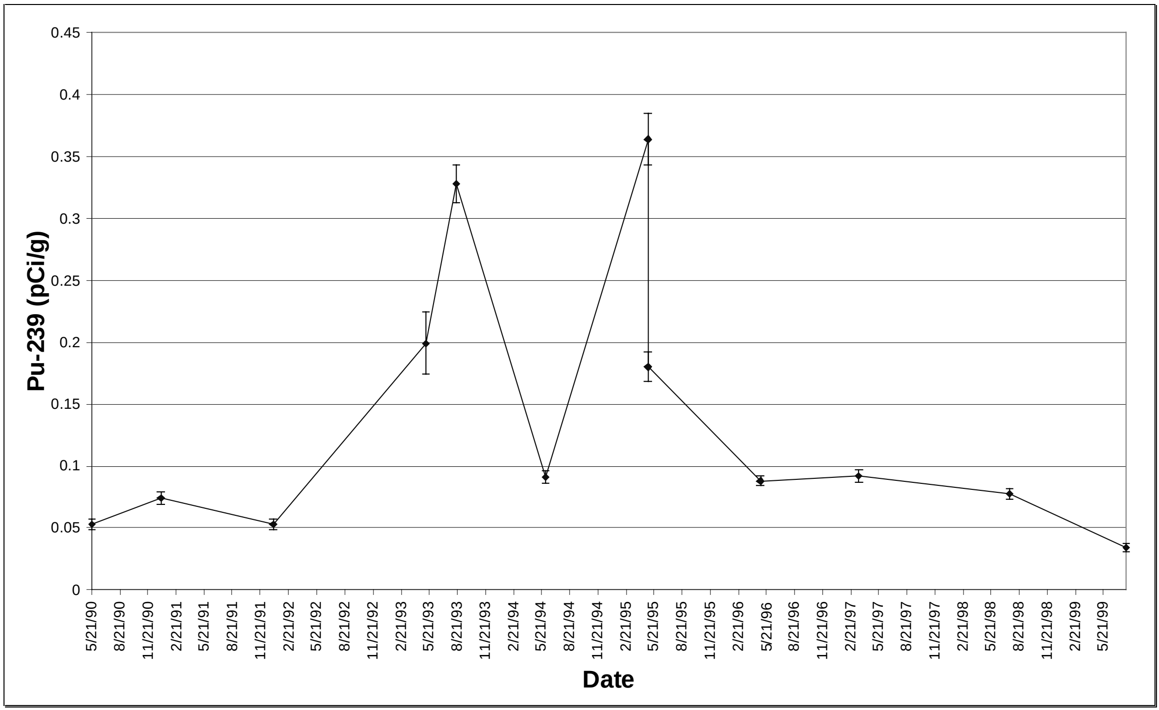

Figure 19. Pu-239 Sediment Concentrations for LA Canyon at SR 4

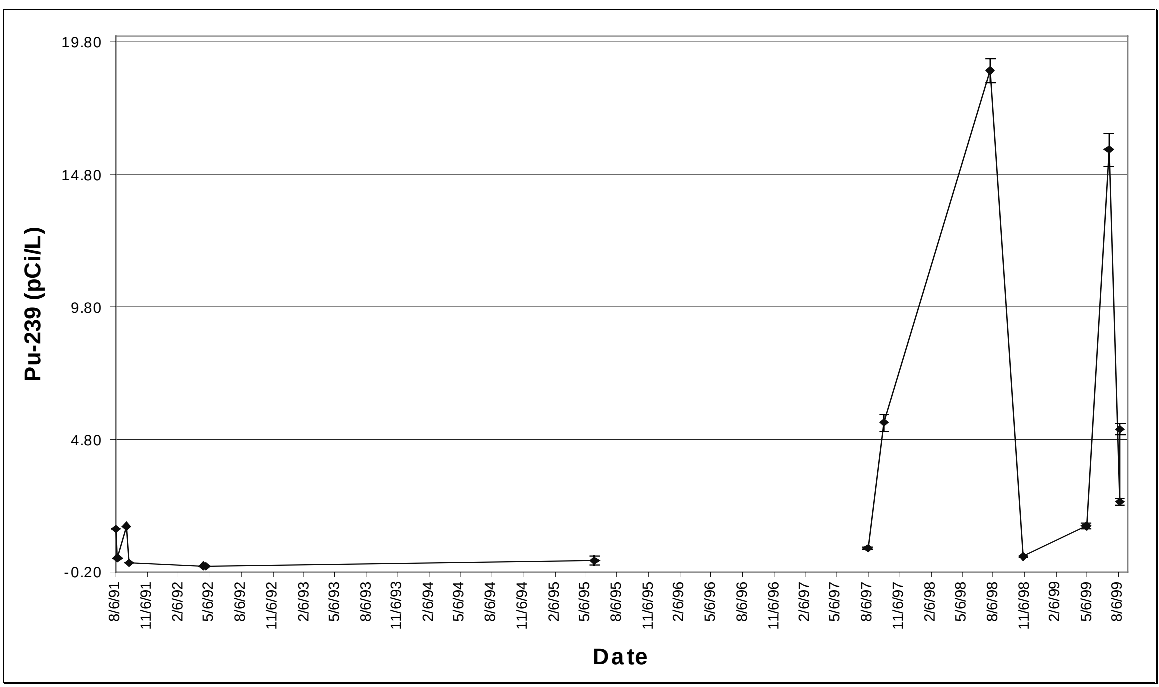

Figure 20. Pu-239 Manual and Automated Storm Water Concentrations

10. COCHITI LAKE DATA

10.1 Cochiti Lake Sampling

Samples for the upper, middle, and lower sediment sampling sites are taken for each year at Cochiti Lake (LANL, 1993-1999). These sampling locations are shown in Figure 21. The numbers were averaged to obtain a yearly mean number for Cochiti Lake sediments. The mean number is used in the calculations to determine a total activity for the lake sediments.

10.2 Cochiti Lake Sediments

The amount of sediment deposited used for the calculations was obtained from the Corps Of Engineers survey of Cochiti Lake (U.S. Army Corps of Engineers, 1999). This survey is done every five to seven years. The survey involves a hydrographic sonar survey with boat-mounted equipment to determine cross sections throughout Cochiti Lake (D. Gallegos, personal communication, 1999). The large boat mounted with the hydrographic sonar equipment is unable to pass the sediment berm at the upper end of the lake. Thus in the 1998 survey, the upper end of the lake above the sediment berm was floated using small inflatable rafts to further determine the total sediment deposition to Cochiti Lake. Once the cross sections were developed, the total sediment load to the lake was calculated for the period following the last hydrographic sonar survey. The sediment deposited was determined to be 1265 acre-feet from 1991 to 1998.The value used for the weight of sediment, 109 lb/ft^3, is for the dry weight of sand dense and mixed (Lindberg, 1989). Sand-sized particles were determined to be the dominant weathering product in

LA Canyon (Graf, 1996). The calculations to determine the total activity in Cochiti Lake are shown in Table 2. The 1999 sediment deposited number was taken directly from the previous years. The analytical lab has not yet calculated the Pu-238 and Pu-239 activities for 1999. Due to the large amount of sediment collected, 1000g per sample for Cochiti Lake, and the high-accuracy analytical technique used, it takes approximately a year to digest the large sample volume of sediment. The Pu-238 and Pu-239 activities for 1999 are calculated means of the previous years.

The Pu loading equation for Cochiti Lake is:

Activity pCi/g*1265 ac-ft *109 lb/ft^3 * 0.45 kg/lb * 43560 ft^3/ac-ft *1000g/kg=Total pCi

Table 2. Pu-238 and Pu-239 Sediment Activity in Cochiti Lake

Year	Pu 238 pCi/g	Pu 238 uncert. pCi/g	Pu 239 pCi/g	Pu 239 Uncert. pCi/g	Total Pu 238 µCi	Total Pu 238 Uncert. µCi	Total Pu 239 µCi	Total Pu 239 Uncert. µCi
1991	0.0002	0.0001	0.0041	0.0004	5.5E+02	2.7E+02	1.1E+04	1.1E+03
1992	0.0019	0.0002	0.0134	0.0000	5.2E+03	5.5E+02	3.7E+04	0
1993	0.0041	0.0004	0.0305	0.0004	1.1E+04	1.1E+03	8.3E+04	1.1E+03
1994	0.0004	0.0001	0.0093	0.0004	1.1E+03	2.7E+02	2.5E+04	1.1E+03
1995	0.0076	0.0014	0.0125	0.0018	2.1E+04	3.8E+03	3.4E+04	4.9E+03
1996	0.0009	0.0000	0.0181	0.0010	2.5E+03	0	4.9E+04	2.7E+03
1997	0.0006	0.0001	0.0132	0.0003	1.6E+03	2.7E+02	3.6E+04	8.2E+02
1998	0.0007	0.0001	0.0115	0.0003	1.9E+03	2.7E+02	3.1E+04	8.2E+02
1999	0.0021	0.0015	0.0141	0.0022	5.7E+03	4.0E+03	3.8E+04	6.0E+03

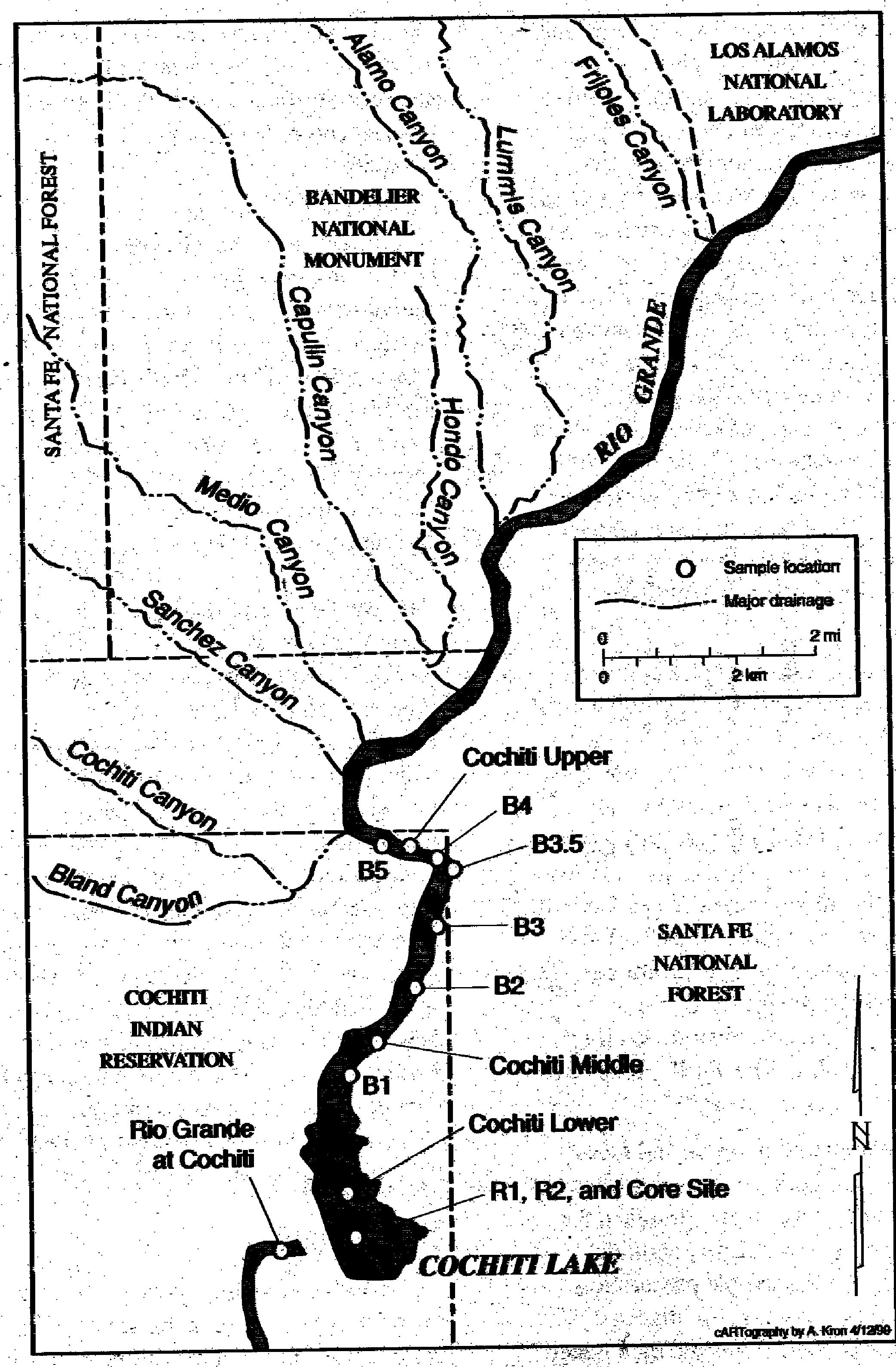

Figure 21. Cochiti Lake Sampling Locations

11. COMPARISON OF LOADING TO COCHITI LAKE BY MANUAL AND AUTOMATED SAMPLING TECHNIQUES

11.1 Comparison by Storm Event

Table 3 shows the activities bound in the sediment for the manual samples. The original analytical values in pCi/g were multiplied by the Total Suspended Solids (TSS) value in g/L. This gives the Pu-238 and Pu-239 activities for the sediment in pCi/L. The Pu-238 and Pu-239 values are multiplied by the total volume of water measured at the sampling point for the storm event. Table 4 sums the calculated loads by sample event from Table 3 to obtain a total activity for the year. The uncertainty for the amount bound on the sediments was calculated by multiplying the uncertainty by pCi/g and the TSS value in g/L to get the uncertainty in pCi/L. This value was then multiplied by the volume of water in liters of water measured for the storm event to get an uncertainty for the total volume in pCi. No uncertainties were reported for 1991 or 1992 (LANL, 1993-1994).

The activity levels shown in Table 5 for the automated sample on 7/28/98 were calculated using the same methods as the manual samples. For the other automated samples the unfiltered value was subtracted from the filtered value to obtain a value for the activity bound on the sediments for Pu-238 and Pu-239. Each analytical value for a specific storm event was multiplied by the volume of discharge for that event to get a total activity for the sample. The unfiltered minus filtered uncertainty value was calculated by taking the square root of the sum the squares. Table 6 sums the values per sample event from Table 5 to obtain a total activity for the year.

Table 3. Activity Level for LA at SR 4 Manual Samples

Sample Date	Pu-238 (pCi/g)	Pu-238 Uncert (pCi/g)	Pu-239 (pCi/g)	Pu-239 Uncert (pCi/g)	TSS (g/L)	Total Pu-238 (pCi/L)	Total Pu-238 Uncert (pCi/L)	Total Pu-239 (pCi/L)	Total Pu-239 Uncert (pCi/L)	Storm Flow Volume (L)	Pu-238 result (µCi)	Pu-238 Uncert result (µCi)	Pu-239 result (µCi)	Pu-239 Uncert result (µCi)
8/6/91	0.0970		1.7400		0.8200	0.0795		1.4268		9.9E+06	0.7861		14.1012	
8/12/91	0.0380		0.8310		0.3900	0.0148		0.3241		2.7E+06	0.0399		0.8721	
9/6/91	0.4650		2.9300		0.5200	0.2418		1.5236		8.1E+06	1.9698		12.4116	
9/13/91	0.0940		2.0700		0.0600	0.0056		0.1242		6.4E+05	0.0036		0.0790	
4/16/92	0.0140		0.2210		0.1280	0.0018		0.0283		3.0E+07	0.0530		0.8373	
4/24/92	0.0000		0.0000		0.0358	0.0000		0.0000		8.1E+06	0.0000		0.0000	
6/1/95	0.1910	0.0670	1.4480	0.1690	0.1530	0.0292	0.0103	0.2215	0.0259	3.5E+06	0.1009	0.0354	0.7651	0.0893

Table 4. Total Activity by Sample Event for Manual Samples

Year	Total Load (µCi)
1991 Pu-238	2.80
1991 Pu-238 Uncertainty	
1991 Pu-239	27.46
1991 Pu-239 Uncertainty	
1992 Pu-238	0.05
1992 Pu-238 Uncertainty	
1992 Pu-239	0.84
1992 Pu-239 Uncertainty	
1995 Pu-238	0.10
1995 Pu-238 Uncertainty	0.04
1995 Pu-239	0.77

Table 5. Activity Levels for E042 LA near LA Automated Samples

Sample Date	Pu-238 (UF) pCi/L	Pu-238 (UF) Uncert	Pu-238 (F) pCi/L	Pu-238 (F) Uncert	Pu-239 (UF) pCi/L	Pu-239 (UF) Uncert	Pu-239 (F) pCi/L	Pu-239 (F) Uncert	Pu-238 (UF-F) pCi/L	Pu-238 (UF-F) pCi/L Uncert	Pu-239 (UF-F) pCi/L	Pu-239 (UF-F) pCi/L Uncert	Storm Flow Volume (L)	Pu-238 result (µCi)	Pu-238 Uncert result (µCi)	Pu-239 result (µCi)	Pu-239 Uncert result (µCi)
8/5/97	0.1592	0.0312	0.1243	0.0275	1.7053	0.1223	1.0114	0.0829	0.0349	0.0416	0.6939	0.1477	2.4E+06	0.0854	0.1017	1.6975	0.3614
9/20/97	0.5605	0.0768	0.0135	0.0094	5.4795	0.3356	0.0489	0.0143	0.5470	0.0774	5.4306	0.3359	3.4E+06	1.8734	0.2650	18.5989	1.1504
10/31/98	0.0545	0.0294	0.0379	0.0154	0.5148	0.0643	0.1428	0.0252	0.0166	0.0332	0.3720	0.0691	1.5E+07	0.2437	0.4871	5.4602	1.0137
5/3/99	0.1837	0.0379	0.0043	0.0108	1.5680	0.1161	0.0383	0.0186	0.1794	0.0394	1.5297	0.1176	3.2E+06	0.5705	0.1253	4.8648	0.3739
7/8/99	1.5308	0.1219	-0.0143	0.0197	15.7777	0.6380	0.0473	0.0245	1.5451	0.1235	15.7304	0.6385	4.9E+06	7.5596	0.6041	76.9629	3.1238
8/9/99	0.2220	0.0404	0.0515	0.0219	2.4705	0.1493	0.0275	0.0159	0.1705	0.0460	2.4430	0.1501	5.6E+06	0.9593	0.2586	13.7456	0.8448
8/10/99	0.2199	0.0395	0.0227	0.0145	5.2913	0.2350	0.1122	0.0231	0.1972	0.0421	5.1791	0.2361	8.3E+06	1.6402	0.3500	43.0769	1.9640

Sample Date	Pu-238 (pCi/g)	Pu-238 (UF) Uncert	Pu-239 (pCi/g)	Pu-239 (UF) Uncert	TSS (g/L)	Total Pu-238 (pCi/L)	Total Pu-238 (pCi/L) Uncert	Total Pu-239 (pCi/L)	Total Pu-239 (pCi/L) Uncert	Storm Flow Volume (L)	Pu-238 result (mCi)	Pu-238 Uncert result (mCi)	Pu-239 result (mCi)	Pu-239 Uncert result (mCi)
7/28/98	0.0816	0.0038	3.5876	0.0869	5.2170	0.4257	0.0198	18.7165	0.4534	1.7E+06	0.7394	0.0344	32.5083	0.7874

UF = Unfiltertered
F = Filtered
UF – F = Unfiltered minus filtered

Table 6. Total Activity for Automated Samples by Water Year

Year	Total Load (µCi)
1997 Pu-238	1.96
1997 Pu-238 Uncertainty	0.37
1997 Pu-239	20.30
1997 Pu-239 Uncertainty	1.51
1998 Pu-238	0.98
1998 Pu-238 Uncertainty	0.52
1998 Pu-239	37.97
1998 Pu-239 Uncertainty	1.80
1999 Pu-238	10.73
1999 Pu-238 Uncertainty	1.34
1999 Pu-239	138.65
1999 Pu-239 Uncertainty	6.31

11.2 Comparison by Total Water Year Budget

A mean value for each year was calculated to compare manual and automated sampling by total water year budget. The sample points for all years were averaged separately for Pu-238 and Pu-239. The mean values for 1991, 1992, and 1995 are shown in Table 4. These values were calculated using the manual sampling values for the activity bound to the sediments shown in Table 3. The mean values shown for 1997, 1998, and 1999 in Table 6 correspond to the automated sampling years. These automated sample mean values were calculated using the values shown in Table 5 for specific sample events for the activity bound to the sediments. The uncertainties for the years were calculated by taking the square root of the sum of the years sampling points for Pu-238 and Pu-239. No uncertainties were reported for 1991 or 1992 (LANL, 1993-1994).

Table 7. Calculated Mean for LA Canyon 1991-1999

Sample Type	Year	Mean Value Pu-238 (pCi/L)	Mean Value Pu-239 (pCi/L)	Mean Uncert Pu-238 (pCi/L)	Mean Uncert Pu-239 (pCi/L)
Manual	1991	0.0855	0.8497		
	1992	0.0009	0.0141		
	1995	0.0292	0.2215	0.0103	0.0259
Automated	1997	0.2910	3.0622	0.0879	0.3669
	1998	0.2211	9.5443	0.0387	0.4586
	1999	0.5231	6.2206	0.1439	0.6971

Table 8 uses the mean value calculated in Table 7 and multiplies it by a known flow volume for the year. This allows a total mass loading from the canyon to be calculated based on a known total amount of flow volume for the year. The calculations by sample event provide a mass loading using the known volume of flow for each event and not the total volume of flow for the year. Not all flows in the water year are sampled in LA Canyon. Using the mean value calculated from all sampling events and a known flow volume gives an estimate of the total load for the year.

Table 8. Activity Level Calculated by Year for LA Canyon

Sample Type	Year	Pu-238 (pCi/L)	Pu-238 Uncert (pCi/L)	Pu-239 (pCi/L)	Pu-239 Uncert (pCi/L)	Flow (L)	Pu-238 result (µCi)	Pu-238 Uncert (µCi)	Pu-239 result (µCi)	Pu-239 Uncert (µCi)
Manual	1991	0.0855		0.8497		4.9E+08	42.25		419.84	
	1992	0.0009		0.0141		6.1E+08	0.55		8.67	
	1995	0.0292	0.0103	0.2215	0.0259	4.0E+08	11.83	4.17	89.69	10.49
Automated	1997	0.2910	0.0879	3.0622	0.3669	2.1E+08	62.17	18.78	654.36	78.40
	1998	0.2211	0.0387	9.5443	0.4586	1.1E+07	2.46	0.43	106.00	5.09
	1999	0.5231	0.1439	6.2206	0.6971	1.3E+08	69.71	19.18	829.04	92.91

By evaluating Table 8 it can be ascertained that the flow volumes during the manual sampling years are much larger than during the automated sampling years. The mean flow volume for the manual years of 5.0E+08 liters was used in Table 8. This allowed a total load for the year to be calculated approximating the higher flow volumes recorded during the manual sampling years.

Table 9. Activity Level Calculated by Year for LA Canyon Using Mean Manual Flow Volume for Automated Flows

Sample Type	Year	Pu-238 (pCi/L)	Pu-238 Uncert (pCi/L)	Pu-239 (pCi/L)	Pu-239 Uncert (pCi/L)	Flow (L)	Pu-238 result (µCi)	Pu-238 Uncert (µCi)	Pu-239 result (µCi)	Pu-239 Uncert (µCi)
Manual	1991	0.0855		0.8497		4.9E+08	42.25		419.84	
	1992	0.0009		0.0141		6.1E+08	0.55		8.67	
	1995	0.0292	0.0103	0.2215	0.0259	4.0E+08	11.83	4.17	89.69	10.49
Automated	1997	0.2910	0.0879	3.0622	0.3669	5.0E+08	145.91	44.08	1535.70	184.00
	1998	0.2211	0.0387	9.5443	0.4586	5.0E+08	110.91	19.41	4786.38	229.98
	1999	0.5231	0.1439	6.2206	0.6971	5.0E+08	262.31	72.16	3119.57	349.59
Total Manual	All						54.63		518.20	
Total Automated	All						519.12		9441.65	
Percent Automated is greater							950		1822	

When using the mean flow volume from the manual sampling years to calculate the yearly loads, the automated sampling is over 900 percent greater for Pu-238 and over 1800 percent greater for Pu-239. This shows that if manual sampling is used the loads calculated using the analytical data from the manual sampling could be underestimated by 900 to 1800 percent if the flow volumes are similar.

11.3 Sources of Error in the Calculations

Much of the remaining contaminant inventory is bound in the floodplain sediments. These sediments are only mobilized during very large storm events. Not all storms were sampled; therefore, depending upon if the storms were large or small the analytical value could be greatly influenced. There was poor correlation in the rainfall-runoff calculations for the flows in 1991. Global fallout was not taken into account. The transport lag to Cochiti Lake was unaccounted for; this study infers instant transport from LA Canyon to Cochiti Lake. Finally, the activity bound to the sediments below the sampling point in LA Canyon is not taken into account in the calculations.

12. DETERMINATIONS OF PERCENTAGES

12.1 Determinations of Percentages by Sample Event

Table 10 uses the values in Table 4 for the manual samples and in Table 6 for the automated samples. This table shows percentages using the sum of the activity for each sample event, which could be one event as in 1995 or 4 events as in 1991 or 1999. There are no uncertainties presented for percentage of activity. No uncertainties were reported for 1991 or 1992 (LANL, 1993-1994).

Table 10. Percentage Activity Calculations by Sample Event

	Manual (µCi)	Cochiti Lake (µCi)	Percentage of Activity
1991 Pu-238 result	2.80	546	0.5127
1991 Pu-238 Uncertainty result		273	
1991 Pu-239 result	27.46	11192	0.2454
1991 Pu-239 result Uncertainty		1092	
1992 Pu-238 result	0.05	5187	0.0010
1992 Pu-238 Uncertainty result		546	
1992 Pu-239 result	0.84	36580	0.0023
1992 Pu-239 Uncertainty result		0	
1995 Pu-238 result	0.10	20747	0.0005
1995 Pu-238 Uncertainty result	0.04	3822	
1995 Pu-239 result	0.77	34123	0.0022
1995 Pu-239 Uncertainty result	0.09	4914	
Pu-238 all years result	2.95	26480	0.0112
Pu-238 Uncertainty all years result	0.04	3870	
Pu-239 all years result	29.07	81895	0.0355
Pu-239 Uncertainty all years result	0.09	5034	
	Automated (µCi)	Cochiti Lake (µCi)	Percentage of Activity
1997 Pu-238 result	1.96	1638	0.1196
1997 Pu-238 Uncertainty result	0.37	273	
1997 Pu-239 result	20.30	35952	0.0565
1997 Pu-239 Uncertainty result	1.51	819	
1998 Pu-238 result	0.98	1911	0.0514
1998 Pu-238 Uncertainty result	0.52	273	
1998 Pu-239 result	37.97	31393	0.1209
1998 Pu-239 Uncertainty result	1.80	819	
1999 Pu-238 result	10.73	5733	0.1872
1999 Pu-238 Uncertainty result	1.34	4049	
1999 Pu-239 result	138.65	38412	0.3610
1999 Pu-239 Uncertainty result	6.31	6043	
Pu-238 all years result	13.67	9281	0.1473
Pu-238 Uncertainty all years result	1.48	4067	
Pu-239 all years result	196.92	105758	0.1862
Pu-239 Uncertainty all years result	6.73	6153	

12.2 Determinations of Percentages by Water Year

Table 11 uses the values calculated in Table 7 to determine a percentage of activity in Cochiti Lake for Pu-238 and Pu-239 from LA Canyon. Table 11 calculates a percentage of the amount of activity in the sediments deposited in Cochiti Lake by year. The percentage is based on the mean of the sum of the activity by year for manual and automated sampling. The calculated mean value is multiplied by the total volume of water discharged past the sampling point for the year. Also calculated is the difference between automated and manual sampling by mass loading. There are no uncertainties presented for percentage of activity. No uncertainties were reported for 1991 or 1992 (LANL, 1993-1994).

The annual values calculated are higher for the samples collected automatically. In 1991 the manual samples show a high value. The correlation for the flow volume calculations was poor for 1991 and could be a factor of the high values. The data, when separated by manual and automated sampling for all years, show a higher percentage for the automated sampling.

Table 11. Percentage Activity Calculations by Water Year

	Manual (μCi)	Cochiti Lake (μCi)	Percentage of Activity
1991 Pu-238 result	42	546	7.7378
1991 Pu-238 Uncertainty result		273	
1991 Pu-239 result	420	11192	3.7512
1991 Pu-239 result Uncertainty		1092	
1992 Pu-238 result	1	5187	0.0106
1992 Pu-238 Uncertainty result		546	
1992 Pu-239 result	9	36580	0.0237
1992 Pu-239 Uncertainty result		0	
1995 Pu-238 result	12	20747	0.0570
1995 Pu-238 Uncertainty result	4	3822	
1995 Pu-239 result	90	34123	0.2628
1995 Pu-239 Uncertainty result	10	4914	
Pu-238 all years result	55	26480	0.2063
Pu-238 Uncertainty all years result	4	3870	
Pu-239 all years result	429	81895	0.5232
Pu-239 Uncertainty all years result	10	5034	
	Automated (μCi)	Cochiti Lake (μCi)	Percentage of Activity
1997 Pu-238 result	62	1638	3.7958
1997 Pu-238 Uncertainty result	19	273	
1997 Pu-239 result	654	35952	1.8201
1997 Pu-239 Uncertainty result	78	819	
1998 Pu-238 result	2	1911	0.1285
1998 Pu-238 Uncertainty result	0	273	
1998 Pu-239 result	106	31393	0.3377
1998 Pu-239 Uncertainty result	5	819	
1999 Pu-238 result	70	5733	1.2160
1999 Pu-238 Uncertainty result	19	4049	
1999 Pu-239 result	829	38412	2.1583
1999 Pu-239 Uncertainty result	93	6043	
Pu-238 all years result	72	9281	0.7775
Pu-238 Uncertainty all years result	27	4067	
Pu-239 all years result	1589	105758	1.5029
Pu-239 Uncertainty all years result	122	6153	

13. COMPARISON OF LOADING TO COCHITI LAKE BY WATER YEAR USING BACKGROUND ACTIVITY LEVELS

13.1 LA Canyon Background Data

In Tables 12, 13, and 14 no uncertainties were reported for the background values (LANL, 1993-1998). The values for Pu-238 and Pu-239, shown in Table 12 and 13, represent the upper limit for background from sediment samples from 1974 to 1986. The flow numbers are the same numbers used for calculation of samples from LA Canyon for manual and automated samples by year.

Table 12. Background Calculations for LA Canyon

Sample Type	Year	Mean Pu-238 Background (pCi/L)	Mean Pu-239 Background (pCi/L)	Flow (L) by Water Year	Yearly Activity Pu-238 (µCi)	Yearly Activity Pu-239 (µCi)
Manual	1991	0.006	0.023	4.94E+08	2.96	11.36
	1992	0.006	0.023	6.13E+08	3.68	14.10
	1995	0.006	0.023	4.05E+08	2.43	9.31
Automated	1997	0.006	0.023	2.14E+08	1.28	4.91
	1998	0.006	0.023	1.11E+07	0.07	0.26
	1999	0.006	0.023	1.33E+08	0.80	3.07

13.2 Cochiti Lake Background Data

Cochiti Lake has a large input from background radioactivity. Table 13 presents the calculation for background concentrations for Pu-238 and Pu-239 activity levels in Cochiti Lake. The 1999 sediment-deposited number was taken directly from the previous years' numbers. Since the calculated value will be same for all years the calculation will only be illustrated once.

Table 13. Background Calculations for Cochiti Lake

Pu 238 pCi/g	Pu 239 pCi/g	Sed. Depos. (ac-ft)	Sed. Weight (lb/ft^3)	1kg/ 2.2lb	43560 ft^3/ ac-ft	1000 g/kg	Total Pu 238 (µCi)	Total Pu 239 (µCi)
0.0060	0.0230	1265	109	0.4545	43560	1000	16379	62787

13.3 Determination of Percentage Using Background

The percentage of activity from background attributable to LA Canyon in Cochiti Lake is shown in Table 14. The values are taken directly from Tables 12 and 13. No uncertainties were reported for the background values (LANL, 1991-1998).

Table 14. Percentage Activity Calculations Using Background Levels

	Manual (µCi)	Cochiti Lake (µCi)	Percentage of Activity
1991 Pu-238 result	2.96	16379	0.0181
1991 Pu-239 result	11.36	62787	0.0181
1992 Pu-238 result	3.68	16379	0.0225
1992 Pu-239 result	14.10	62787	0.0225
1995 Pu-238 result	2.43	16379	0.0148
1995 Pu-239 result	9.31	62787	0.0148
Pu-238 all years result	9.07	49137	0.0185
Pu-239 all years result	34.77	188360	0.0185
	Automated (µCi)	Cochiti Lake (µCi)	Percentage of Activity
1997 Pu-238 result	1.28	16379	0.0078
1997 Pu-239 result	4.91	62787	0.0078
1998 Pu-238 result	0.07	16379	0.0004
1998 Pu-239 result	0.26	62787	0.0004
1999 Pu-238 result	0.80	16379	0.0049
1999 Pu-239 result	3.07	62787	0.0049
Pu-238 all years result	2.15	49137	0.0044
Pu-239 all years result	8.24	188360	0.0044

The percentage calculations are very small when compared to the numbers for discharges from LA Canyon. Note the smaller numbers calculated for the automated sampling in comparison to the manual. This is an inverse relationship to what is seen by examining the manual to automated storm water data. It can be assumed the background data would correlate to the relationship seen between the manual and automated values for the different years. The disparity in the relationship could be due to the lag time required for transport from LA Canyon to Cochiti Lake.

14. CONCLUSIONS

14.1 Conclusions by Sampling Event

The activity values shown in Table 15 for Pu-238 and Pu-239 are a mean value calculated separately using all the sample points for the manual sampling and automated sampling. The sum of the volume of water measured for all sampling events is used in the calculations. The uncertainties were calculated by taking the square root of the sum of the squares. The chart illustrates the percent difference between the automated sampling and manual sampling for mass loading. Also illustrated is the mass loading to Cochiti Lake by manual sampling as a percentage of automated sampling.

Table 15. Difference in Sample Types by Sampling Event

	LA Canyon (μCi)	Cochiti Lake (μCi)	Percentage of Activity
Pu-238 all years manual result	2.95	26480	0.01
Pu-238 Uncertainty all years manual result	0.04	3870	
Pu-239 all years manual result	29.07	81895	0.04
Pu-239 Uncertainty all years manual result	0.09	5034	
Pu-238 all years automated result	13.67	9281	0.15
Pu-238 Uncertainty all years automated result	1.48	4067	
Pu-239 all years automated result	196.92	105758	0.19
Pu-239 Uncertainty all years automated result	6.73	6153	
Percent Auto is greater than Man Pu-238	463		1321
Percent Auto is greater than Man Pu-239	677		525

Due to the lag time in transport in LA Canyon the sediments being sampled in Cochiti Lake do not correlate to the same time period as the storm water samples collected during the same year. The transport of sediments bound with historical Pu-238 and Pu-239 has decreased as the sediments have been deposited in the floodplains. The small numbers calculated per sample event would not raise the activity to the levels measured in Cochiti Lake. The Cochiti Lake sediment values were greater for the samples collected during the years the manual samples were collected. If the values were held constant for the Cochiti Lake sampling, the percentage would be even greater for the automated sampling.

14.2 Conclusions by Water Year

The activity values shown in Table 16 for Pu-238 and Pu-239 are mean values calculated separately using all the sample points for the manual sampling and automated sampling. The sum of the total volume of water measured at the sampling point for the corresponding years of manual and automated sampling was used for the calculations. The uncertainties were calculated by taking the square root of the sum of the squares.

Table 16 illustrates the difference between the automated sampling and the manual sampling for mass loading. Also illustrated is the mass loading to Cochiti Lake by manual sampling as a percentage of automated sampling.

Table 16. Difference in Sample Types by Water Year

	LA Canyon (μCi)	Cochiti Lake (μCi)	Percentage of Activity
Pu-238 all years manual result	55	26480	0.21
Pu-238 Uncertainty all years manual result	4	3870	
Pu-239 all years manual result	518	81895	0.63
Pu-239 Uncertainty all years manual result	10	5034	
Pu-238 all years automated result	134	9281	1.45
Pu-238 Uncertainty all years automated result	27	4067	
Pu-239 all years automated result	1589	105758	1.50
Pu-239 Uncertainty all years automated result	122	6153	
Percent Auto is greater than Man Pu-238	246		702
Percent Auto is greater than Man Pu-239	307		238

The analytical numbers for the manual samples are lower than the values reported for the automated samples. The flow volumes for these years were significantly higher than for the years with the automated samples. This has made the values for the manual samples inflated for total activity when compared to the automated samples.

15. RECOMMENDATIONS

This is an initial study of mass loading to Cochiti Lake. The historical data have not been consistently analyzed for parameters allowing a mass balance study. The plutonium analysis has become more consistent in the parameters analyzed in the recent years. This is noted by the fact that mass loading was calculated consistently for 1997, 1998, and 1999. With the continuation of sampling, allowing for mass loading calculations this study can be repeated in the future. This would allow determination of trends in Pu transport. If limited precipitation years continue a good comparison to the automated sampling can be made. If wet years prevail, with larger yearly flow volumes, this study could be repeated using water years that are more closely matched to the volume of runoff recorded in to the manually sampled years.

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