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W. J. Smith, II
E. B. Fowler
R. G. Stafford

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

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OFFICE MEMORANDUM

TO : Holders of LA-6731-MS

DATE: March 30, 1977

FROM : ISD-6

SUBJECT : Errata

SYMBOL :

Page 2. The scale for Fig. 1 is 90 m/cm.
Page 7. The scale for Fig. 2 is 10 m/cm.
Page 8. The scale for Fig. 3 is 6 m/cm.
Page 9. Replace Fig. 4 with the attached figure.
Page 11. The scale for Fig. 6 is 7 m/cm.

EXPERIENCE IN THE CLEANUP OF PLUTONIUM-CONTAMINATED LAND

by

W. J. Smith, II, E. B. Fowler* and R. G. Stafford**

ABSTRACT

During the summer of 1974, two accidental releases from a radioactive liquid-waste line at the Los Alamos Scientific Laboratory (LASL) resulted in plutonium contamination of a small area of land, a portion of a Laboratory parking lot, and a strip along an adjacent street. This report documents the immediate control actions and radiation surveys made in response to these leaks, and the subsequent exhumation and decontamination processes, including the physical operations, operational health physics, and soil sample analyses. The cost and results of the decontamination and restoration are also covered.

I. INTRODUCTION

The term "cleanup," as defined for this report, means the removal and proper disposal of radioactive materials from a contaminated site. Implicit in this definition is the existence of a contamination level below which the area is considered clean, and a prescribed means for measuring this level. For the operations described in this report, the background gross-alpha radioactivity level of local soils was used as the cleanup criterion. A zinc sulfide (ZnS) alpha scintillation system was used in conjunction with soil radionuclide chemical analyses to determine the effectiveness of the cleanup activities.†

Radioactive liquid wastes from several areas of the Los Alamos Scientific Laboratory (LASL) flow through collection lines to a lift station, from which they are periodically pumped to a liquid waste treatment facility. The pipeline from the lift station has two major segments. The first is a cast-iron force main through which the waste is pumped to a high point in the system. The second is a vitrified clay-tile, gravity-flow line which descends to the waste treatment facility. The system collects wastes of variable radionuclide content; however, in recent years wastes have contained predominantly ^{238}Pu, with lesser concentrations of ^{239}Pu, $^{89,90}Sr$, and ^{137}Cs. In 1974, average yearly concentrations in the waste were 3×10^5 dis/min/ℓ for gross alpha and 5×10^6 dis/min/ℓ for gross beta; typical volumes were about 3×10^6 ℓ/month. Figure 1 is a map showing the major features of this system.

In the past, the pipeline has been subject to surveillance at irregular intervals by personnel walking its length and monitoring the cleanout risers and

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*LASL Group H-8, Environmental Studies
**LASL Group H-1, Health Physics
†Each instrument and analytical procedure is described in Appendix A.

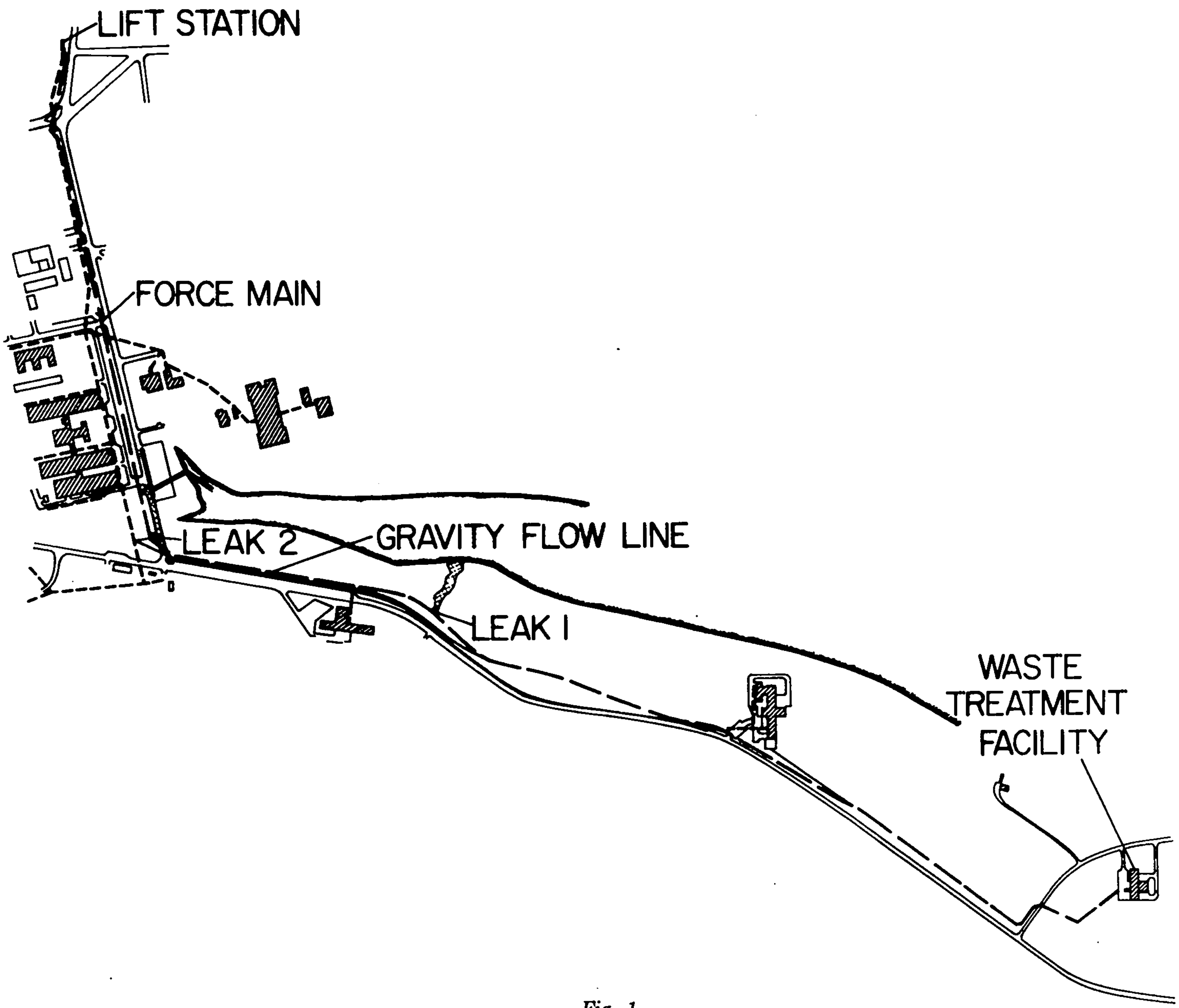

Fig. 1.
A portion of the liquid waste handling system at Los Alamos.

caps. Surveillance had been conducted less than a year before the discovery, in late June 1974, of damage to cleanout risers near a new construction site. No releases resulted from the damage, but its discovery prompted a subsequent inspection of the entire line that resulted in a July 9, 1974, discovery of a leak at a separate cleanout riser (indicated as "Leak 1," in Fig. 1). This leak was the first observed from this line since its construction in 1962.

Within two days of the discovery of the leak, the affected length of line was unearthed and cleaned with a sewer rooter. A number of cracks were found in the line, and the leak was attributed to plant roots entering and clogging the line. A radiation survey of the vicinity indicated that the contaminated area was large enough to require an extensive excavation effort. Since the pipeline was now considered of questionable integrity for prolonged use, it was decided to proceed with a cleanup of a limited portion of the area to permit installation of a replacement gravity-flow line.

By the end of August, a butt-welded polyethylene waste line had been installed, and on September 3, 1974, it was subjected to a pumping test. The flow capacity of the new line was inadvertantly exceeded during the test, causing waste to back up and flow out of a manhole at the junction of the cast-iron and polyethylene lines. The location of the point of overflow is marked as "Leak 2" in Fig. 1. Leak 2 contaminated a portion of a street and parking lot, and a storm drain leading to a nearby canyon. Within the day, the contamination on paved areas was fixed by applying a layer of asphalt, and the canyon flow was blocked by an earthen dam. A small area around the manhole was excavated, backfilled with clean soil, and surrounded with an earthen berm as a precaution against subsequent overflows. The efforts to contain and prevent the spread of contamination from Leak 2 were followed by excavations to clean up the contaminated material, and restoration of the affected areas was begun by the end of September.

Immediately thereafter, attention was given to the excavation of the major portion of the area contaminated by Leak 1. This work was completed by late October and restoration of the area was finished in mid-November 1974.

II. THE CLEANUP MISSION

Leak 1 was located in an area which could be isolated for controlled access. Soil, tuff (the principal rock-type outcrop occurring in the area, consisting of a welded volcanic ash), and vegetation were contaminated. Time was needed, and could safely be taken, to make extensive preliminary surveys and to design an effective cleanup. The cleanup mission was defined in three parts:

1. Determine the extent, in three dimensions, of the contaminated land;

2. clean up the area to the level of gross-alpha radioactivity of surrounding, uncontaminated land; and

3. determine the plutonium inventory associated with the release.

Leak 2 was associated with a Laboratory parking lot and a road used by the general public, and required immediate action. The urgency of the situation required positive action without the benefit of extensive preliminary work. The mission was again defined in three steps:

1. Clean up the area observed to be contaminated by the liquid radioactive waste, plus a 2-3 m safety zone on all sides;

2. effect a contamination level not exceeding the gross-alpha level found beneath the paved road and parking lot; and

3. restore the area with the least delay consistent with a thorough and complete cleanup.

III. IMMEDIATE CONTROL ACTIONS

The immediate responses to both of the leak incidents were: (1) to establish safety measures for the protection of personnel and the public, (2) to perform radiation surveys to determine the extent and severity of the contamination, and (3) to prevent the migration of the contaminant by containment actions until cleanup procedures could be started.

A. Leak 1

As people would not normally frequent the area of Leak 1, it was deemed sufficient to fence the area and post it with warning signs. The first barrier was erected on the day the leak was discovered; the perimeter was subsequently adjusted as radiation surveys more accurately determined the extent of the area. Health physics measures to ensure adequate personnel protection included using booties, coveralls, and gloves for workers in the area, and monitoring hands, shoes, and clothing when workers left the area. Nose swipes were taken for analysis for inhaled radionuclides. Four hi-vol continuous air samplers were set in operation around the periphery on the day following the discovery of the leak. A portable, low-volume air sampler was used as an operational air monitor close to the breathing zone of workers engaged in the preliminary excavation work.

The survey of the cleanout riser, which disclosed the leak, was made with an alpha survey instrument which indicated alpha radioactivity up to 50 000 counts/min. Up to 10 000 counts/min were observed as far as 10 m from the riser, along the natural drainage path of the area. Preliminary soil samples taken at that time and analyzed subsequently by rough chemical procedures indicated 10 000 to 130 000 dis/min/g of gross alpha radioactivity.

Initial investigations following the discovery of the leak, were intended to pinpoint the cause of the leaking riser and to determine whether the source of the leak was below the surface or through the riser cap. A plastic bag was secured over the clean-out riser and waste was pumped into the line. About 20 min later, liquid was observed at the top of the riser and in the plastic cover. This required at least 0.6 m of hydrostatic head in the line, indicating an obstruction downstream in the gravity-flow line.

It was observed during the test that the riser pipe was loose. Excavation revealed a broken joint from which waste also was seeping. The joint was repaired and a small sewer "snake" was introduced into the line in order to remove the obstruction causing the leak. The snake removed some roots in the line, and a large sewer rooter was later used to clean the line over its entire length. An excavated trench along the waste line extended for approximately 15 m upstream and 10 m downstream of the leak. Data showing the radioactivity observed on the walls of the trench are presented in Tables I and II. A total of 6 m^3 of contaminated soil was removed from the area and buried in twenty-nine 210-ℓ steel drums.

Plastic-lined cardboard cartons, 210-ℓ mild steel drums, and dump trucks were used for collection of radioactive materials at various stages in the cleanup operations. The selection was generally based on the mode of excavation; manual excavation made use of the former two containers, while mechanized excavation required dump trucks as containers. In general, although not always, steel drums were used for the higher radioactivity materials removed in manual excavations.

Surveys were made of the land surface around the leak using a FIDLER* probe and the Los Alamos Field Pulse Height Analyzer (LAFPHA). The observed radioactivity profiles are shown on the Fig. 2 map of the area.

Considering the time required for excavation of the contaminated area indicated by this survey and the questionable integrity of the waste line for prolonged use, it was proposed that a limited cleanup be undertaken sufficient for the laying of a new waste line. These cleanup procedures are discussed in detail in Section IV.

Since there was no apparent hazard from the soilbound radioactivity of Leak 1, no immediate actions for imposing additional containment were taken. Transport of radionuclides away from the leak occurred in two phases; first the liquid waste percolated through the soil until absorbed, and secondly the soil with its sorbed radionuclides was moved by summer rain runoff. Movement of the plutonium by wind resuspension was not discernable by continuous air sampling, presumably due to the moist condition of the soil during the late summer.

B. Leak 2

The location of Leak 2 required immediate action for the protection of personnel and the public. Activities were concerned primarily with the redirection of people and vehicles, removal of the released liquid, and containment of any residual radioactivity. The waste primarily flowed along a curb gutter provided for storm runoff, and puddled in the

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*Field Instrument for Detecting Low-Energy Radiation.

TABLE I

ACTIVITY MEASURED ALONG WALL OF TRENCH EXCAVATED ALONG ACID WASTE LINE AT LEAK 1[a,b]

North Wall — Clean out riser, Leak 1

Ground Surface	-	-	-	-	-	-	-	-	2k	1.5k	1.5k	-	-
1 ft	-	-	-	-	-	-	-	-	2k	1.5k	1.5k	-	-
2 ft	-	-	-	-	-	-	-	-	2.5k	1k	1.5k	-	-
2.5 ft	-	15k	20k	2k	2k	-	-	-	1.5k	1k	2k	-	-
3 ft (pipe level)	-	-	100k	15k	15k	-	-	-	1k	1k	1k	-	-

South Wall

Ground Surface	-	-	-	-	-	-	-	-	-	2k	2k	-	-
1 ft	-	-	-	-	-	-	-	-	-	-	-	-	-
2 ft	-	-	-	-	-	-	-	1k	1k	-	-	-	-
2.5 ft	-	2k	2k	25k	5k	2k	2k	-	2k	-	-	-	-
3 ft (pipe level)	-	2k	2k	25k	7k	3k	3.5k	-	3k	-	-	-	-
Meters[c]	6	4.9	4.3	3.7	3	2.4	1.5	1.2	0.3	0.3	1.2	1.5	3

[a]All readings are in counts/min on the alpha survey meter.

[b]Blank boxes indicated readings of <100 counts/min.

[c]Measured up- and down-grade from the cleanout riser.

TABLE II

ACTIVITY MEASURED ALONG WALL OF TRENCH EXCAVATED ALONG ACID WASTE LINE AT LEAK 1[a,b]

North Wall — Clean out riser, Leak 1

Ground Surface	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	1.5		3.0	0.9	-	-
1 ft	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5		3.0	0.9	-	-
2 ft	0.2	0.2	0.2	0.7	0.5	0.5	0.5	0.5	0.5		3.0	0.9	-	-
2.5 ft	0.2	10	0.7	1.5	0.2	0.2	0.2	0.5	0.5		2.5	1.0	-	-
3 ft (pipe level)	0.2	40	45	8	1.0	0.5	0.5	0.5	0.5		1.0	0.7	-	-

South Wall

Ground Surface	-	-	-	-	-	-	-	-	1.0		0.5	-	-	-
1 ft	-	-	-	-	-	-	-	-	1.0		0.5	-	-	-
2 ft	-	-	-	-	-	-	-	-	1.0		0.5	-	-	-
2.5 ft	6	5	40	8	0.2	0.2	0.5	1.0	0.7		0.5	-	-	-
3 ft (pipe level)	6	50	60	43	0.3	3.5	1.1	60	0.5		0.5	-	-	-
Meters[c]	6	4.9	4.3	3.7	3	2.4	1.5	1.2	0.3		0.3	1.2	1.5	3

[a]All readings are in mr/hr on the beta-gamma survey instrument.

[b]Blank boxes indicate readings of 0 mr/hr.

[c]Measured up- and down-grade from the cleanout riser.

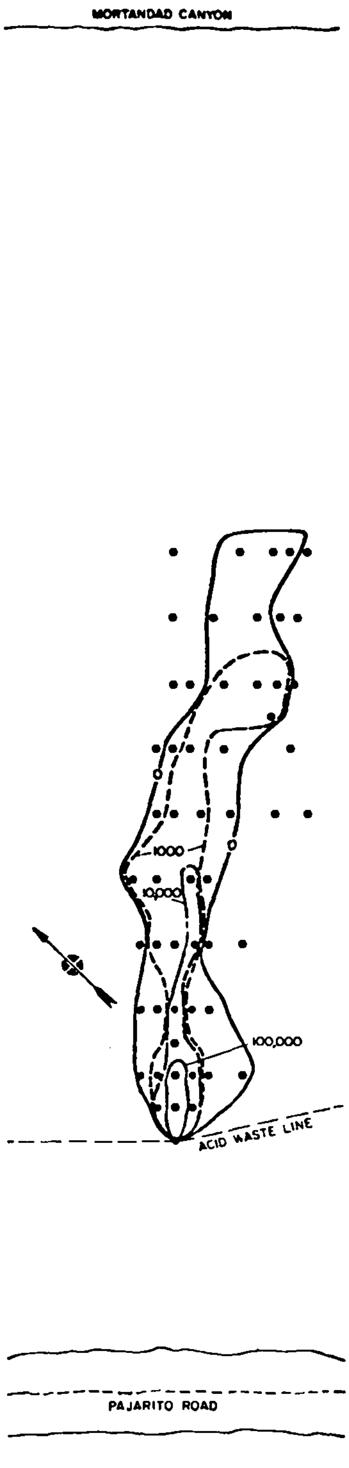

Fig. 2.
FIDLER/LAFPHA survey of Leak 1. Values are net counts/min in 17-keV channel. Points show locations of some soil core and surface samples.

entrance and exit to a Laboratory parking lot. A small puddle also formed in the entrance to a technical area adjacent to the parking lot. Movement through those areas was curtailed by closing the gate at the guard station and preventing vehicular movement into or out of the parking lot. Southbound traffic along Diamond Drive was directed into the inner lane, providing a safety zone for workers and preventing accidental vehicle contact with the waste water in the gutter. A wooden ramp was constructed spanning the contaminated gutter, which permitted vehicles to leave the parking lot at the close of the business day. Pedestrians entering the area were routed along the far side of the street. Figure 3 is a map of the area of Leak 2.

Protective clothing was provided for personnel involved in cleanup operations. Other health physics measures included monitoring hands, shoes and clothing of personnel leaving the area, and taking nose swipes as a check for possible inhalation exposures.

Initial radiation surveys were coupled with actions to control and contain the released liquid waste. These efforts began with mopping and sweeping the water to prevent it from spreading. Subsequently, the standing liquid was absorbed with cheesecloth or collected using wet-dry vacuum cleaners and placed in 210-ℓ drums. As the paved road and parking lot surfaces were dried, areas observed to have been contaminated were roped at a perimeter established using the alpha survey instruments. Two coats of hot asphalt mix were applied as a seal over the contaminated paved surfaces. No radioactivity was detectable after application of the first coat.

An area immediately around the manhole from which the waste was released was surveyed with both the alpha survey instruments and the FIDLER/LAFPHA System. Soil was excavated from that area to a depth of about 0.3 m, and clean backfill was applied as a temporary containment for residual subsurface soil radioactivity. Data before and after the excavation are presented in Fig. 4. A total of 13.4 m^3 of contaminated absorbents and soil was removed and buried in steel drums and plastic-lined cardboard cartons.

A portion of the released waste had been conducted through a storm drain into a nearby canyon. Concurrent with the above actions, efforts were applied to impounding the flow through the canyon by

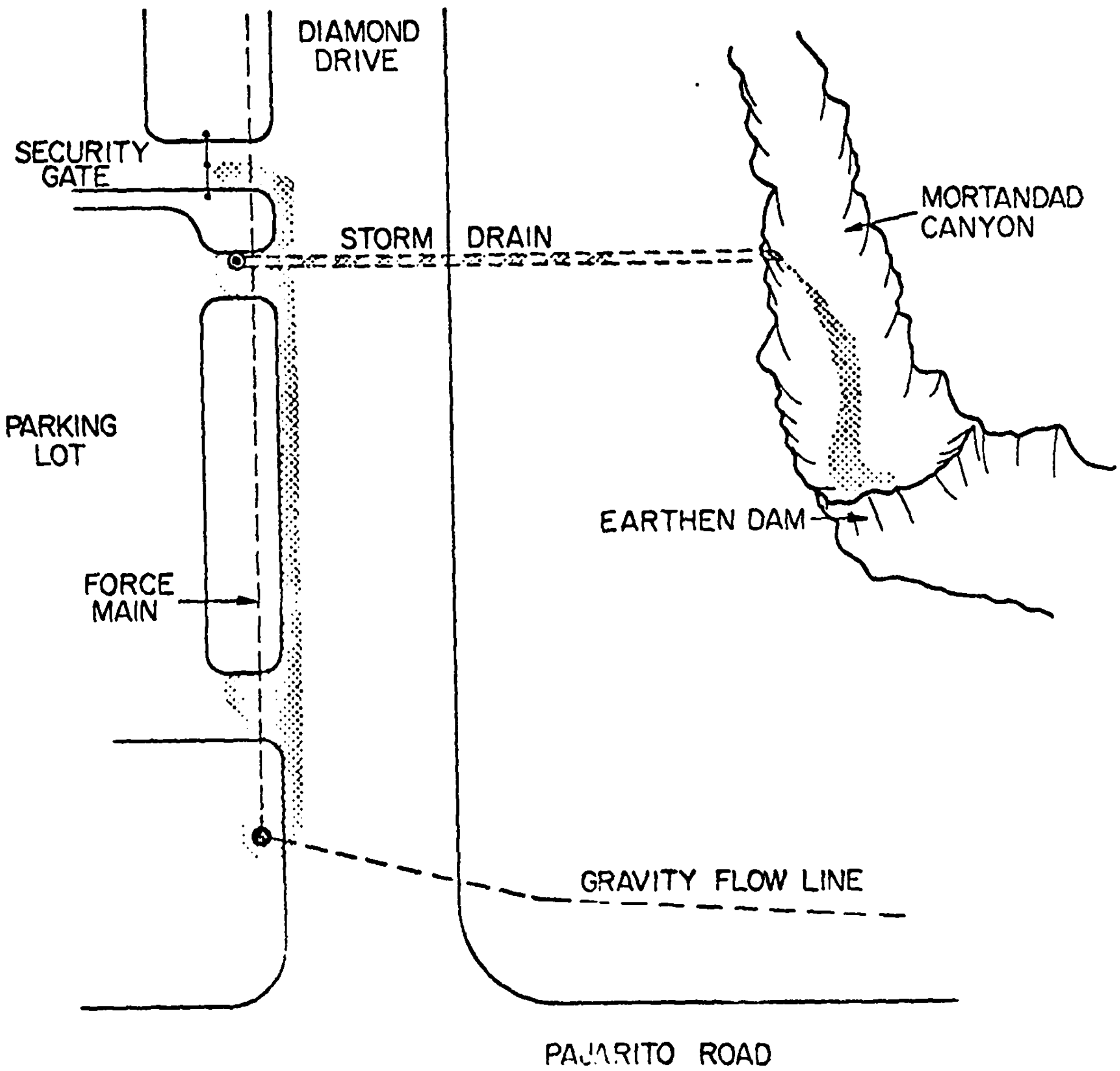

Fig. 3.
The area of Leak 2.

constructing a small earthen dam a short distance below the drain's outfall. Surveys with alpha survey instruments indicated count rates of 800 to 1200 counts/min along the stream bed above the dam.

IV. EXCAVATION AND DECONTAMINATION PROCEDURES

A. Leak 1

The full-scale cleanup of Leak 1 was effected in two stages. A small trench across the area was prepared for the laying of a temporary, butt-welded polyethylene waste line. The trench (approximately 12 m long and 1 to 4 m wide) was excavated by pick and shovel to depths of 30 to 100 cm. The most highly contaminated sections of soil were removed; however, since both the old waste line and the temporary line are expected to be excavated when a proposed new line is installed, a complete cleanup was not attempted. A total of 43.4 m^3 of soil was removed, packaged in plastic-lined cardboard cartons and buried. Figure 5 diagrams the area of the excavation and indicates levels of residual radioactivity.

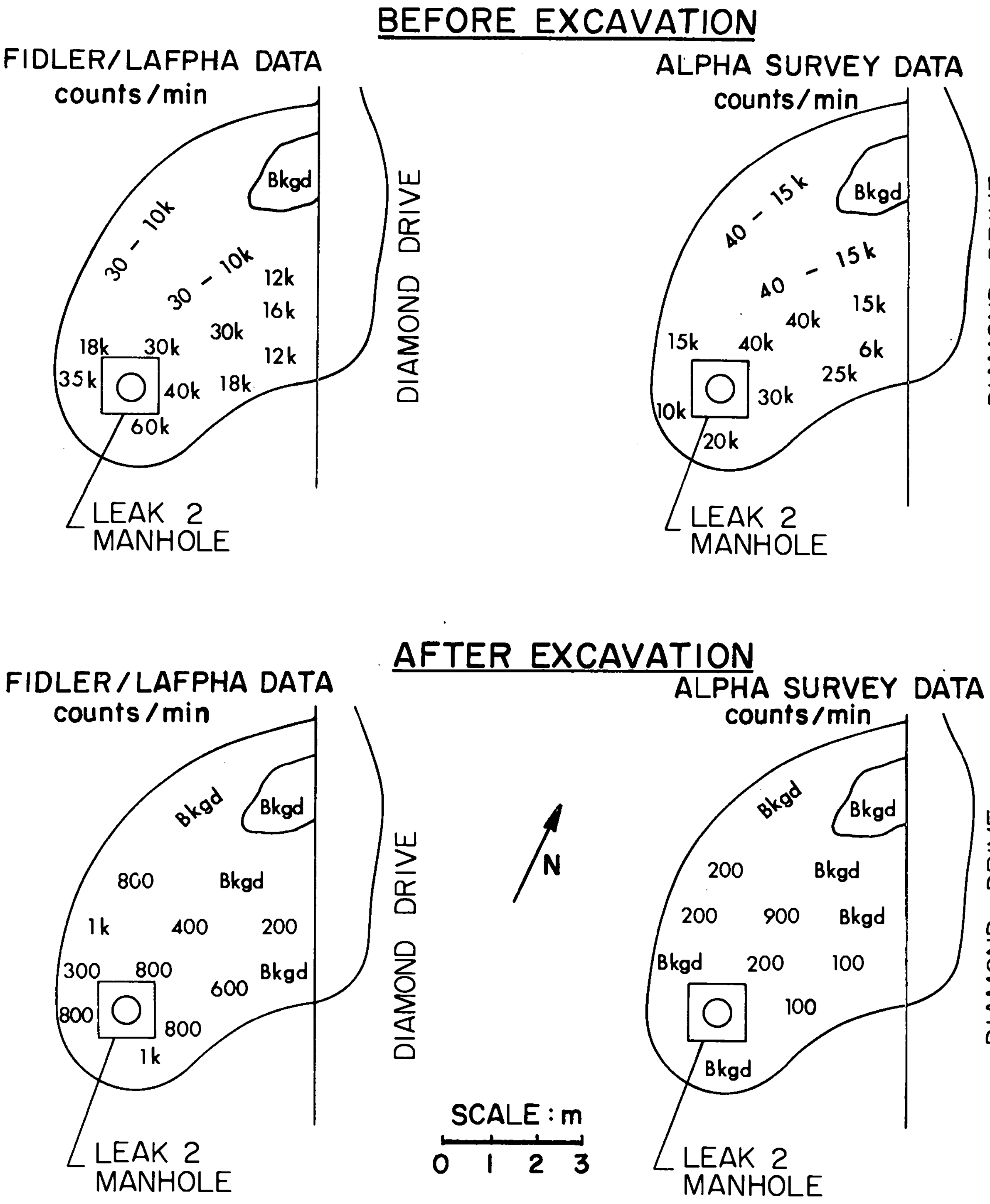

Fig. 4.
Leak 2 manhole area before and after excavation.

FIRST SAMPLES (pCi/g)

Bkgd	100	1000	3000	300	Bkgd	Bkgd	Bkgd
		100	7000	1000			
		400	1100	500			

FINAL SAMPLES (pCi/g)

Bkgd	50	50	100	Bkgd	Bkgd	Bkgd	Bkgd
		100	Bkgd	150			
			Bkgd	50			

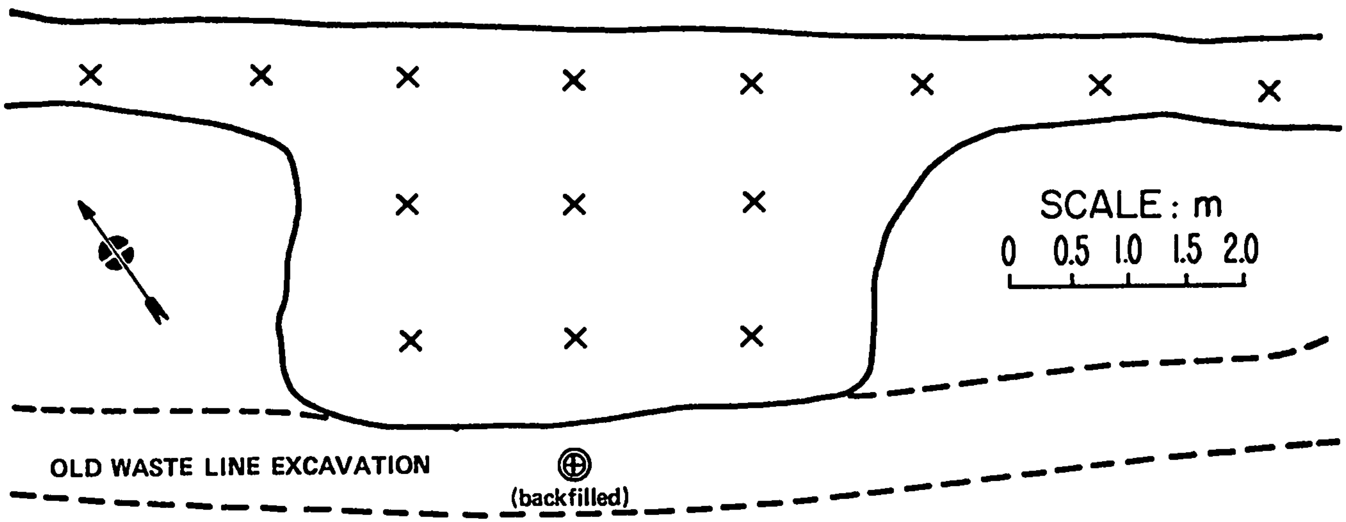

Fig. 5.
Before and after soil sample data from the replacement waste line excavation (aerial view).

The cleanup of the major portion of Leak 1 was begun after the installation of the temporary waste line, and the occurrence and cleanup of Leak 2. A preliminary analysis was made of surface soil samples, soil cores, and background soil samples. Surface soil samples were taken using a location pattern based on the preliminary FIDLER/LAFPHA survey. Sampling procedures and data are described in Appendix B.

The results of soil core sample analysis indicated that the radioactivity decreased rapidly with depth near the source of the leak, but that substantial radioactivity could be expected at depths of 60 to 100 cm. At distances of 20 m and more from the leak the radioactivity was found to be more uniformly distributed in the soil profile, presumably due to its having been laid down as silt deposits from the runoff of frequent summer storms.

Background surface soil samples were taken at several distant points within Los Alamos County. A number of background samples were also taken at distances of a few hundred meters from the contaminated area. No background cores were taken. The average value obtained for the gross-alpha radioactivity of the background samples was defined as the level to which the area would be cleaned. With the ZnS system, the defined level equaled a measurement of <25 pCi/g; for the acid-leaching chemistry procedure the level was found to be <12 pCi/g.

A map of Leak 1, showing isopleths of concentration as determined by soil samples, is given in Fig. 6. The periphery of the area was determined according to the background for area soils and represented the minimum area to be excavated in fulfillment of the designated mission. The minimum depth to be cleaned was estimated as 60 cm or more on the basis of soil cores showing substantial radioactivity at their 30 cm maximum depth. The actual depth of the excavation was to be determined by sampling the newly exposed surfaces after each excavation.

Calculations of the quantity of released plutonium were made using Fig. 6, soil core data, and data on the volumes and concentrations removed in the original excavations of the waste line and for the temporary line. Estimates using various methods of averaging land areas, soil concentations, and summing over depth profiles ranged from 150 to 300 mCi, which was believed to be satisfactory considering the uncertainties involved in the measurements and estimates.

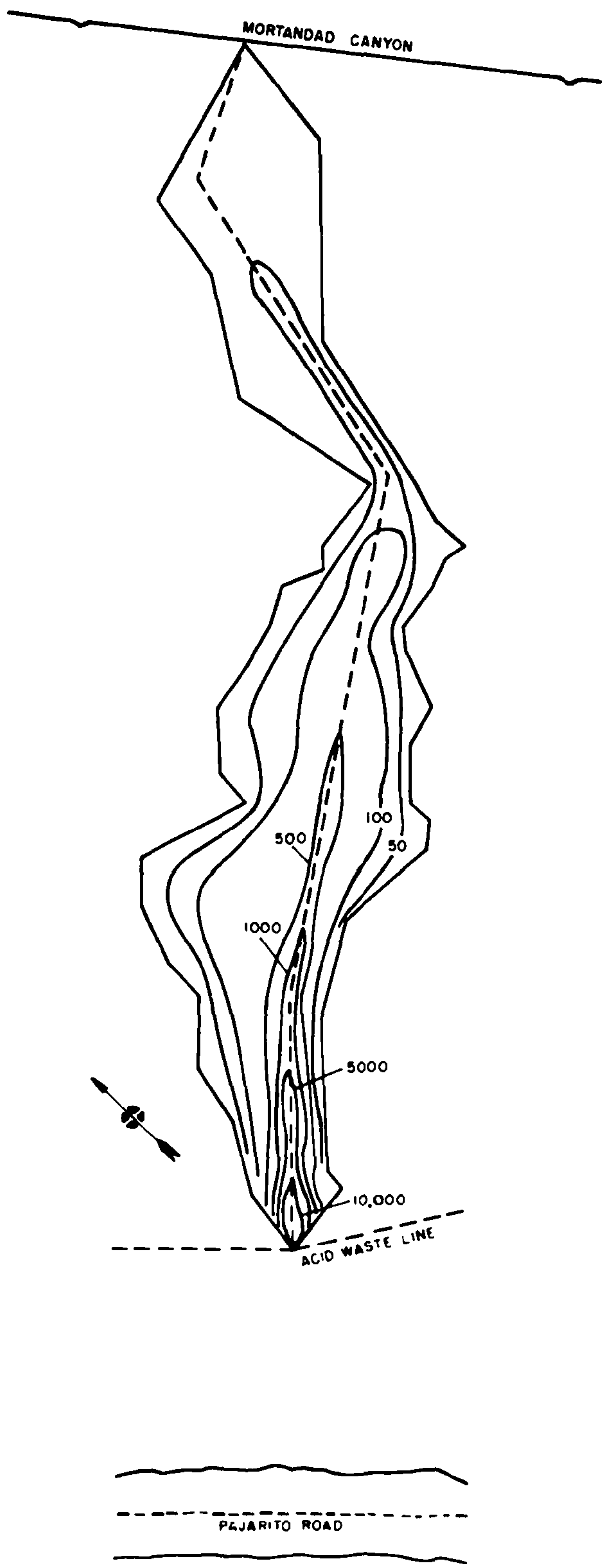

Fig. 6.
Soil sample data map of Leak 1. Values are pCi/g. Perimeter line is at background gross-alpha level.

The cleanup was accomplished using heavy equipment, *i.e.*, front-end loaders and dump trucks. Work progressed from the least contaminated areas inward to the more contaminated areas, with extreme care being taken to ensure that no contamination was carried outward by the moving vehicles. The dump truck beds were sealed with heavy plastic sheeting; soil was loaded no higher than the top of the bed, and the load was covered with heavy tarpaulins for the trip to the waste disposal area. Convoys of several trucks were escorted by radio-equipped vehicles maintaining a speed of 35 mph. After disposing of the load, each vehicle was monitored externally for contamination and decontaminated, if necessary, before its return to the work site.

As the heavy equipment cleaned out an area and moved further inward, health physics monitors and soil sampling personnel followed. Each area was thoroughly surveyed with the alpha survey instruments and the FIDLER/LAFPHA. Soil samples from the fresh surface were taken on the original sampling pattern and analyzed using the ZnS system and the chemical analysis procedures.

Three passes of the equipment, over consecutively smaller areas, were made as soil analyses verified the cleanup of some areas and detected residual contamination of others. The maximum depth excavated was 1-1.5 m at the most highly contaminated end of the area. A final decontamination was made of four small areas by pick and shovel; contaminated liquid had seeped into crevices of the underlying rock and had become absorbed by the clay deposits in these areas. A total of about 283 m^3 of soil was removed in 74 truckloads and buried.

Hi-vol air samplers were operated during the entire cleanup, but indicated no airborne radioactivity above normal background. All personnel wore protective clothing and were monitored for contamination upon leaving the site.

B. Leak 2

Cleanup of Leak 2 began the day following its occurrence. A collection and pumping system was set up to allow flushing of the contaminated storm drain and collection of the water for pumping to tank trailers for later processing as liquid waste. The drain was flushed three times using a dispersant followed by water. The initial flushing carried a large amount of the alpha contamination out of the drain; less was observed in samples taken from subsequent flushings. Samples of the drain water taken on the following days showed background levels of gross-alpha radioactivity.

Initial canyon soil and sediment samples showed that the waste had moved about 50 m down the canyon to where the earthen containment dam had been erected on the day of the leak. The cleanup of the canyon area also began the day following the leak, while the water from the storm drain was being contained. Prior to excavation, the stream channel was filled with bentonite to absorb standing water. The stream bed was then excavated using a backhoe and front-end loader. All alluvial material showing radioactivity above background was removed, for a total of about 192 m^3 of waste materials transported to the radioactive waste dump in 35 truck loads.

The aim for the decontamination of the paved areas was initially stated as the gross-alpha level determined from a sample of base-course material currently used in road construction. However, when excavation was begun, it was found that the base-course underlying the excavated pavement had significantly lower background radioactivity (presumably due to the absence of fallout radionuclides). Thus the gross-alpha background of that material was used as the cleanup criterion.

The pavement to be excavated was cut, outside of the sealed area, using a cutting edge attached to the blade of a road grader. The asphalt was cut to the depth of the base-course, and front-end loaders were used to break up and lift out the pavement. Activity progressed along Diamond Drive from both ends, with the areas where liquid formed puddles in the parking lot entrances taken out as they were encountered. About 176 m^3 of material were removed in 46 truck loads and buried.

As pavement was removed and loaded into the trucks for disposal, all newly exposed surfaces were monitored with the alpha survey instruments. Radioactivity was found only on one segment of curbing; that segment was subsequently removed. Following the removal of all pavement, a thorough survey was made with the FIDLER/LAFPHA system. No radioactivity above background was observed in or around the excavated area. Samples were then taken of the exposed base course, and analysis of these by the ZnS system and chemical procedures revealed no radioactivity above the decontamination criterion.

V. RESTORATION METHODS

Restoration of the Leak 1 excavation site consisted of backfilling to grade with top soil and reseeding the land with native grass species. The reseeding was successful, producing a growth comparable to that of similar open areas and preventing any extensive erosion of the new soil.

Restoration of Leak 2 was predominantly a repaving project. This effort required replacing curbs and pavement and took about three weeks. No restoration actions were taken for the small section of canyon that was involved, since it had been previously disturbed and was not adversely affected. The area around the manhole remained enclosed in an earthen berm paved with asphalt as a temporary safety measure for protection against any future leaks until engineering measures could be taken to prevent waste overflow. These measures included instrumentation to detect a rise of the liquid level in the manhole, with resulting shut down of the pumping operations. A secondary safeguard was the installation of piping to return excess waste to the waste holding tank.

IV. EXPOSURES

All evidence indicates that there were no exposures to the public or working personnel attributable to these leaks. Air samples were taken continuously at both sites until the cleanup operations were completed; no positive alpha radioactivities were detected. Monitoring of personnel leaving the contaminated areas was rigidly enforced, but no positive alpha radioactivities were detected on shoes, coveralls or hands of the personnel. In the early cleanup period, several booties were found to have alpha contamination ranging from 500-2000 c/m. A total of 155 nose swipes were taken in conjunction with all operations for Leak 1, and 89 were taken as a result of Leak 2; all nose swipes were negative for alpha contamination.

VII. COSTS

A breakdown of the total costs for each of the two incidents is given in Table III. The figures are estimates, based on the best available information. Each heading includes costs for manpower, supplies, and materials, but does not include baseline items such as required instrumentation and laboratory facilities.

TABLE III

ESTIMATED COSTS

	Leak 1 $K	Leak 2 $K
Clean/Repair Waste Line	5.4	---
Spill Containment	---	12.3
H.P. Surveillance	13.0	5.1
Environmental Surveillance	4.6	1.2
Environmental Sample Analysis	14.6	8.6
Excavations and Restoration	10.4	19.0
Waste Disposal	1.6	1.8
TOTAL	49.6	48.0

VIII. RESIDUAL ACTIVITY

A. Leak 1

Two incompletely cleaned areas remain. Some plutonium contamination remains beneath the original clay-tile waste line for a length of about 35 m; contaminant levels of 30 nCi/g might be found in certain portions of that area. (This value was roughly estimated from the data of Table I, using arbitrary assumptions of a 2π geometry and a 50% detection probability for an alpha particle emitted in the proper direction.) Small portions of the trench excavated for the installation of the temporary polyethylene line are known to have plutonium concentrations of as much as 0.05 nCi/g (from Fig. 5). Both of those areas currently exist under clean backfill at a depth of 1 to 2 m, and will be subject to further cleanup when a proposed new waste line is built.

The major portion of the Leak 1 area is well documented as being at or below the ambient soil background. Radioactivity was removed by pick and shovel from three small rock fractures and clay deposits in the last pass over the area. At one small fracture, 7.5 m from the leak, radioactivity in the final sample was about 30 pCi/g; all others were at background. The area is now covered by 1 to 2 m of clean backfill.

B. Leak 2

The only known residual contamination is that remaining around the manhole (see Fig. 4), where a complete cleanup was not attempted. Gross-alpha concentrations in soil on the order of 15 nCi/g (roughly estimated) may still exist at isolated points below the clean earth backfill and asphalt cover. However, data indicate that the area is, in general, below 0.5 nCi/g gross alpha.

The cleanup of the roadway and puddle areas is well documented as having been complete. Indeed, the average alpha radioactivity after cleanup was found to be lower than the ambient soil background. It may be expected that some residual radioactivity could have been bound within the storm drain leading to the canyon, but the contamination remaining in this culvert, if any, is such that effluent water is at background levels for alpha radioactivity. The strip of narrow stream bed which was contaminated was sampled after cleanup and the radioactivity content was found to be background.

APPENDIX A
INSTRUMENTATION AND ANALYTIC PROCEDURES

The characteristics and applications of the instruments and sample analysis procedures used in the Leak 1 and 2 cleanups are briefly described here, in order of their mention in the text.

A-1. Zinc Sulfide (ZnS) Alpha Scintillation Probe

This system, consisting of a zinc sulfide alpha detector and single-channel analyzer, was used as the main means for rapid alpha radioactivity analysis of bulk soil samples. Soil preparation consisted of mixing, breaking apart of aggregates, and drying under heating lamps. Sample counting was done using 1.5-cm high by 10-cm-diam petri dishes filled with soil. System calibration was made with a standard petri dish filled with a prepared 2 nCi/g (^{239}Pu) soil sample. Samples were counted for 5-min periods, and the detection sensitivity was found to be about 25 pCi/g above ambient gross-alpha background at the 99.7% confidence level.

A-2. Chemical Analysis

Two different chemical analyses were performed. The first, an "acid leaching" process, was performed on almost all of the soil samples. In this process, soil samples of known dry weight were extracted with a hot concentrated nitric acid-hydrofluoric acid mixture. The extract was reduced to dryness, dissolved in 0.1 M nitric acid, and 10 mℓ was plated on a 7-cm-diam stainless steel plate. Samples were counted in a gas-flow proportional counter for the period of time required to obtain acceptable counting statistics. The method was sensitive to soil gross-alpha concentrations at the several pCi/g level. The time required for analysis was on the order of 8 h.

The second chemical process was a "complete" analysis for plutonium. It was used on approximately 15% of the collected soil samples for the purpose of confirming other methods and for determining plutonium-alpha to gross-alpha ratios. This chemistry was followed by pulse height analysis using silicon-barrier, solid-state detectors and a multichannel analyzer. Again, counting times were as long as necessary to obtain acceptable counting statistics. The method was sensitive to plutonium concentrations at the fractional pCi/g level. The time required for analysis was on the order of 12 h.

A-3. High-Volume Air Sampler

The high-volume air sampler operated on 110-120 VAC power and pulled approximately 32 cfm across a 6-in. by 9-in. HV-70 filter media. The flow rate was measured by a visi-float flow meter attached to the discharge side of the sampler. The filter media were analyzed using "wide-beta" counters. These samplers are mounted in pairs on two wheeled trailers along with a gasoline powered electrical generator.

A-4. Portable Air Sampler

This air sampler is a small, semi-portable device with adjustable volume control operating on 110-120 VAC power. It was generally used with a 5.4-cm diam HV-70 filter media and sampled at 2 cfm. The entire device may be moved by a two-wheel dolly assembly attached to the motor housing. The flow rate is measured by a magnehelic meter attached to an orifice meter on the discharge side of the sampler. The filter media are analyzed using "wide-beta" counters.

A-5. Alpha Survey Instrument

This alpha survey instrument using a LASL-designed, two-wire air proportional probe, was used by health physics surveyors for field monitoring for alpha contamination. It has scales of 0-1000, 0-10 000, 0-100 000, and 0-1 000 000 counts/min. Earphones allow the operator to hear individual pulses. On its most sensitive scale, it is used to determine the presence of personnel or equipment contamination.

A-6. FIDLER/LAFPHA

This system consists of a commercial Field Instrument for Detecting Low-Energy Radiation probe coupled to the Los Alamos Field Pulse Height Analyzer. The former is a thin NaI crystal (1.5 × 130 mm) optimized for the detection of low-energy x- and gamma-rays. The latter is a portable, 7-channel analyzer with variable channel capabilities suitable for field x- and gamma-ray spectroscopy on a gross level. Resulting data are reported as net counts per minute in a channel centered on the plutonium 17-keV x ray. From the data obtained during these cleanup operations, it appears that the FIDLER/LAFPHA is capable of distinguishing radioactivity above soil background at a level on the order of 0.1 to 0.2 nCi/g.

This instrument was used in three modes during the cleanup. It was hand carried, at ~30 cm above the ground, at a slow walking pace to define gross patterns of radioactivity and to detect residual hot spots. It was set on a stationary tripod, at 30-cm height, to determine "wide-area" contamination levels. It was used on a stand at 5 cm height to give "small-area" measurements.

A-7. Beta-Gamma Survey Instrument

The beta-gamma portable survey instrument is a five-scale ionization meter capable of measuring beta-gamma radiation. The following full-scale ranges are available: 0-3, 0-10, 0-30, 0-100, and 0-300 mrem/h.

APPENDIX B
SOIL SAMPLING TECHNIQUES

Surface soils were taken at Leak 1 using a location pattern based on the preliminary FIDLER/LAFPHA survey (see Fig. 2). Samples were also taken along the drainage path of the area out to the edge of the canyon; Fig. 6 shows the isopleth map of the area as determined from the soil samples. The surface soil samples were taken using a simple hand scoop to half fill a 20 × 20 cm self-sealing plastic bag with soil from no deeper than 5 cm. The sampling scoop was cleaned with alcohol and distilled water between samples. Six hundred surface samples were collected and analyzed with the zinc sulfide system and the chemical procedures described in Appendix A.

Correspondence between results was generally acceptable, most falling within a factor of two of each other. Differences are attributable to inhomogeneities in the bulk sample from which the two separate aliquots were taken. Some sample data are given in Table B-I. In a recent cleanup operation using the same instruments and similar chemical procedures, the discrepancies were reduced by taking the aliquot for chemical analysis from the ZnS-counted sample.[1]

Two techniques were used for determining the depth distribution of the contaminant within the soil profile. Core samples were taken by hammering a 30-cm long, 2.4-cm diam, bevel-ended PVC pipe into the soil. The depth of the core was determined by subtracting the length of empty pipe remaining. Taking these samples required about 5 min per core. This method raised some question concerning the possibility of smearing surface contamination over

TABLE B-I

COMPARISON OF VALUES FROM THE ZnS SYSTEM WITH THOSE OF THE ACID-LEACHING PROCESS AND THE TOTAL PLUTONIUM CHEMICAL ANALYSIS

Sample	pCi/g (Gross alpha) ZnS	pCi/g (Gross Alpha) Acid-Leaching Process	pCi/g (Pu-238 and 239) Total Plutonium Chemical Analysis
1	<24	6	3
2	<24	5	6
3	<24	6	4
4	<24	35	39
5	24	5	0
6	25	13	1
7	25	32	34
8	27	9	37
9	34	33	33
10	34	43	43
11	44	14	18
12	47	15	38
13	54	23	20
14	54	61	62
15	62	3	13
16	67	36	45
17	94	19	22
18	98	25	36
19	98	34	83
20	110	75	77
21	110	52	124
22	110	151	203
23	120	87	112
24	130	93	155
25	130	37	104
26	150	187	220
27	160	69	76
28	170	112	189
29	180	56	77
30	190	85	132
31	230	198	190
32	240	127	107
33	290	120	256
34	290	326	405
35	350	95	154
36	840	2010	2890
37	920	404	655
38	930	564	300
39	930	1060	1090
40	1750	1045	1177
41	3340	1030	2030
42	3600	1670	2950
43	4000	3350	4450
44	4520	3450	4239
45	13400	12900	12200
46	28700	26260	36600
47	403000	372000	500000

the entire length of the core by the passage of the pipe. The problem was investigated using a trench-profile sampling technique. Basically, a soil profile was exposed by cutting a trench, then layers of the soil were carefully sampled, removing one layer to expose the next after each sample. The procedure required about 40 min per trench profile.

Comparative data are offered in Table B-II. Larger increments of depth are reported for the core samples since smaller quantities of sample were available per unit depth. In most cases the core data do not reflect the same depth as the trench profile data, due to the difficulty in driving the core successfully through the rocky soil. The two sets of data compare well enough so that for the purpose of determining the presence of subsurface contamination over wide areas the easier and much faster coring method was acceptable.

Eighty cores were taken and analyzed to determine the distribution of the contaminants with depth. In general, less than the full 30 cm sample was obtained. In areas close to the leak, the radioactivity was observed to decrease rapidly with depth, but substantial radioactivity still remained at 30 cm, indicating that a considerable depth of soil would have to be removed. In areas further from the source the cores showed more or less uniform concentrations over the depth of the core, indicating that the radioactivity had probably been laid down by silt deposited from runoff from frequent summer storms.

Finally, in the main drainage channel at fairly large distances from the source, cores showed anomalous high concentrations separated by layers of low concentration. This was attributed to deposition from storm runoff where only the largest storms could carry the most radioactive soils that far from the source. Small storms accounted for the deposition of the less radioactive soils.

REFERENCE

1. A. J. Ahlquist, A. K. Stoker and C. J. Umbarger, "Recent Developments for Field Monitoring of Alpha-Emitting Contaminants in the Environment," to be published.

TABLE B-II

SOIL PROFILE DATA FOR COMPARISON OF SAMPLING METHODS

Cores			Trenches	
PVC Pipe Core pCi/g[a]	Sample Depth (cm)	Location Number	Sample Depth	Trench Profile pCi/g[a]
4	0- 8.5	1	0- 2.5	5
			2.5- 5.0	3
			5.0- 7.5	3
13	0- 7	2	0- 2.5	4
			2.5- 5.0	14
58	0- 5	3	0- 2.5	21
			2.5- 5.0	64
29	5-10		5.0- 7.5	30
			7.5-10.0	60
53	10-15		10.0-12.5	63
			12.5-15.0	55
			15.0-17.5	26
			17.5-20.0	5
			20.0-22.5	6
			22.5-25.0	12
54	0- 6	4	0- 2.5	173
			2.5- 5.0	33
			5.0- 7.5	13
			7.5-10.0	5
			10.0-12.5	3
			12.5-15.0	6
			15.0-17.5	3
37	0- 5	5	0- 2.5	34
			2.5- 5.0	22
80	5-10		5.0- 7.5	21
			7.5-10.0	20
60	10-14		10.0-12.5	18
			12.5-15.0	28
			15.0-17.5	41
513	0- 6.5	6	0- 2.5	1300
			2.5- 5.0	175
			5.0- 7.5	53
4	0- 5	7	0- 2.5	8
			2.5- 5.0	18
4	5-10		5.0- 7.5	15
			7.5-10.0	9
3	10-15		10.0-12.5	11
			12.5-15.0	20
6572	0-5	8	0- 2.5	4640
			2.5- 5.0	14100
			5.0- 7.5	11700
			7.5-10.0	3000
			10.0-11.0	2400

[a]Data are the average of the zinc sulfide and acid leach values.