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TITLE: HYDROLOGIC CHARACTERISTICS OF THE ALLUVIAL AQUIFERS IN MORTANDAD, CANADA DEL BUEY AND PAJARITO CANYONS

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SUBMITTED TO: New Mexico Enviornmental Improvement Division

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HYDROLOGIC CHARACTERISTICS OF THE ALLUVIAL AQUIFERS IN MORTANDAD, CAÑADA DEL BUEY AND PAJARITO CANYONS

by

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INTRODUCTION

This report documents previous geologic and hydrologic studies conducted in Mortandad Canyon, and discusses the applicability of these studies to Cañada del Buey and Pajarito Canyons. The canyons trend to the southeast and are cut into the Bandelier Tuff that forms the Pajarito Plateau (Fig. 1). The purpose of this report is to document that the aquifers are confined to alluvium in the canyons and do not extend beneath the adjacent mesas. It was prepared to comply with Paragraph 25 of a Compliance Order/Schedule issued to Los Alamos National Laboratory on May 7, 1985. The Compliance Order/Schedule (Docket Number 001007), attached, was issued by the New Mexico Environmental Improvement Division (EID) under authority of New Mexico's Hazardous Waste Management Act. Paragraph 25, Task 6, requires the Laboratory to submit a report "summarizing the applicability of research in Mortandad Canyon" to EID by November 30, 1985.

The Laboratory is seeking a waiver from the interim status ground water monitoring requirements of the New Mexico Hazardous Waste Management Regulations (NM HWMR). Section 206.C.1.a(3) specifically allows for a waiver if the following requirements are met: "All or part of the ground water monitoring requirements of 206.C.1. may be waived if the owner or operator can demonstrate that there is a low potential for migration of hazardous waste constituents form the facility...to water supply wells or to surface water." This demonstration must include an evaluation of: (1) water balance; (2) unsaturated zone characteristics; (3) saturated zone characteristics; and (4) proximity of facility to wells or surface water. The NM HWMR ground water monitoring requirements, and hence the waiver demonstration, apply to waste disposal sites, Areas L and G, on Mesita del Buey.

The EID determined that the Laboratory's original waiver documentation, submitted July 26, 1984, was inadequate with respect to the requirements of the above regulations. EID's response was a Notice of Violation issued to the Laboratory on October 25, 1985. The Laboratory submitted additional waiver documentation on November 1, 1984. EID's response to that submittal, and remaining inadequacies in the Laboratory's ground water monitoring waiver documentation, are addressed in the May 7, 1985 Compliance Order/Schedule.

I. GENERAL GEOLOGY

Los Alamos National Laboratory and the communities of Los Alamos and White Rock are located on the Pajarito Plateau. The plateau is 10 to 15 miles wide and 25 to 30 miles long, lying on the eastern flank of the Jemez Mountains (Fig. 1). The plateau slopes eastward from an altitude of about 7800 ft along its western margin to about 6200 ft to the east where it terminates above the Rio Grande at the Puye Escarpment and the rim of White Rock Canyon. The surface of the plateau is cut into numerous narrow "finger-like" mesas by southeast-trending intermittent streams (Fig. 2). The dissected eastern margin of the plateau stands 300 to 1000 ft above the Rio Grande.

Volcanic and sedimentary rocks cropping out near or found in the subsurface of the Pajarito Plateau are the (from oldest to youngest) Tesuque Formation, Puye Conglomerate, Basaltic Rocks of Chino Mesa, Tschicoma Formation, and Bandelier Tuff. A brief description of the rock units and formations is in several references (Griggs, 1964; Spiegel and Baldwin, 1963). Not all units are present in all locations beneath the plateau (Fig. 3) due to the nature of their deposition.

The Tesuque Formation is composed of siltstones and sandstones with lenses of clay deposited as basin fill sediments in the Rio Grande depression. The thickness of the Tesuque Formation exceeds 2600 ft. It underlies the Pajarito Plateau and crops out along White Rock Canyon of the Rio Grande (Fig. 3).

The Puye Conglomerate consists of a thin (approximately 50 ft) layer of well-rounded pebbles, cobbles, and small boulders derived from granitic terrain. It is overlain by angular fragments of cobble to boulder size volcanics in an ash matrix. The thickness exceeds 700 ft beneath the plateau. The conglomerates interfinger with basalt flows to the east and the Tschicoma Formation to the west.

Basaltic Rocks of Chino Mesa form the steep walls of White Rock Canyon and cap the high mesas to the east of the Rio Grande.

The Tschicoma Formation consists of volcanic flow rocks: andesites, dacites, rhyodacites, and quartz latites. The Tschicoma Formation interfingers and overlies the Tesuque Formation along the western part of the plateau and forms the mountain mass of the Sierra de los Valles (Fig. 3). The thickness of this formation is variable.

The Bandelier Tuff caps the Pajarito Plateau. The tuff ranges from 50 to 1000 ft in thickness and is divided into three members. The lowest member is the Guaje, composed of gravel-size pumice. The next member, the Otowi, is a massive pumiceous tuff breccia of ash-flow origin as much as 300 ft thick. The upper member, the Tshirege (detailed description in Koopman and Purtymun, 1965), is a succession of cliff-forming welded and non-welded ash flows as much as 500 ft in thickness.

The tuff laps onto the flanks of the Sierra de los Valles and slopes gently to the east, where it terminates in cliffs or steep slopes along White Rock Canyon or as isolated outcrops above the Puye Escarpment. The surface of the plateau formed by tuff has been dissected by southeastward-trending intermittent streams into a number of long narrow mesas.

The Bandelier Tuff is the most important geologic unit of this report, since all the waste disposal sites are located on top or in this geologic formation. Tuff thickness is in excess of 1000 ft in the western part of the Pajarito Plateau and thins to less than 50 ft toward the east above the Rio Grande. It is exposed along canyon walls and is covered by a thin mantle of soil on mesa surfaces. Tuff is composed of quartz and sanidine crystals; crystal fragments; and small rock fragments of pumice, rhyolite, dacite, and latite; in a fine ash matrix.

Ashfalls and ashflows are described as nonwelded, moderately welded, and welded tuff. Nonwelded tuff has a high porosity of 40% to 60% by volume, slight cohesion of glassy fragments, and crumbly fracture. Moderately welded tuff has a lesser degree of porosity, ranging from 30% to 55% by volume. It has moderate cohesion with slight deformation of glassy fragments, and somewhat brittle fracture. Welded tuff has a low porosity of 15% to 40% by volume, good cohesion, a high degree of deformation by flatting of glassy fragments, and a brittle fracture. The physical and hydrologic characteristics of the individual ash flow tuff units are related to the degree of welding.

II. GENERAL HYDROLOGY

Surface flow in the canyons of the Pajarito Plateau is intermittent. Springs on flanks of the Sierra de los Valles supply base flow to upper reaches of some canyons (Environmental Surveillance Group, 1984), but the amount is insufficient to maintain surface flows across the plateau before it is depleted by evaporation, transpiration, and infiltration. Sixteen drainage areas, with a total area of 52,500 acres, pass through or originate within the Laboratory boundaries. Streamflow in these canyons is intermittent. Only runoff from heavy thunderstorms or unusually heavy snowmelt will reach the Rio Grande.

Intermittent streamflows in canyons of the Plateau have deposited alluvium that ranges from less than 3 ft to 100 ft in thickness. The alluvium is quite permeable, in contrast to the underlying volcanic tuff and sediments. Intermittent runoff in canyons infiltrates the alluvium until its downward movement is impeded by less permeable tuff and volcanic sediment. This results in a shallow alluvial ground water body. As water in the alluvium moves downgradient, it is depleted by evapotranspiration and movement into underlying volcanic tuff (Purtymun et al, 1977). The proportions of evapotranspiration, infiltration of ground water into the tuff, or suspension of soil moisture above the perched aquifer were quantified in Mortandad Canyon using a tritium tracer (Purtymun, 1974). This report demonstrated that the perched aquifer is not hydraulically connected to the main aquifer.

The main aquifer in the Los Alamos area is located within the Tesuque Formation beneath the entire plateau and Rio Grande valley. The lower part of the Puye Conglomerate, as well as the Tesuque Formation, is within the main aquifer beneath the central and western portions of the plateau (Purtymun and Cooper, 1969). The depths to water below the mesa tops range from about 1200 ft along the western margin of the plateau to about 600 ft along the eastern part of the plateau (Kelly, 1974). The hydraulic gradient of the aquifer averages about 60 ft/mi within the Puye Conglomerate, but increases to about 100 ft/mi along the eastern edge of the plateau as water in the aquifer enters less permeable sediments of the Tesuque Formation. The average movement rate within the aquifer is about 1 ft/day toward the Rio Grande (Theis and Conover, 1962).

The major recharge area for the main aquifer is in intermountain basins formed by the Valles Caldera (Fig. 1). Saturated sediments and volcanics in the caldera are highly permeable and recharge the main aquifer in sediments of the Tesuque Formation and Puye Conglomerate. Movement of water in the main aquifer is eastward toward the Rio Grande, where a part is discharged through springs and seeps into the river. It is estimated that the 11.5 mi reach through White Rock Canyon below Otowi Bridge receives a discharge from the aquifer of 4,300 to 5,500 acre-ft annually (Purtymun, 1966).

III. MORTANDAD CANYON

Mortandad Canyon is a southeast-trending canyon about 10 mi long cut into the Pajarito Plateau. The upper 4 mi of the canyon is within Laboratory boundaries. The drainage area of Mortandad Canyon, to the eastern Laboratory boundary, is 2.86 sq mi (Environmental Studies Group, 1973). The canyon is a tributary to the Rio Grande in White Rock Canyon.

Mortandad Canyon is cut into the Tshirege Member of the Bandelier Tuff, underlain by the Otowi and Guaje Members of the Bandelier. Alluvium in the canyon is derived from erosion and weathering of tuff. It consists mainly of silts, sands and gravels. The alluvium thickens from less than 3 ft in the head of the canyon (eastward into the middle and lower canyons) to about 120 ft at the Laboratory boundary (Fig. 4).

Two ground water bodies are present--water of the main aquifer, which is in the Puye Conglomerate more than 965 ft beneath the canyon floor , and water perched in the alluvium at shallow depth in Mortandad Canyon. No water has been found between the base of the alluvium and the top of the main aquifer (Purtymun, 1964). The main aquifer was discussed in Section II of this report.

The hydrology of Mortandad Canyon has been studied in some detail. This section summarizes results of some of these studies related to the alluvial perched aquifer. A number of these studies was conducted by the U. S. Geological Survey.

Mortandad Canyon has no natural perennial stream flow. However, alluvium in the canyon contained a small perched water body prior to the release of industrial effluents (Baltz et al, 1963). Since 1963, treated industrial effluents, along with periodic snowmelt and summer runoff, have contributed to recharge of this aquifer. Effluents released into Mortandad Canyon have caused perennial flow in the upper reach of the canyon (Purtymun et al, 1983). This surface flow recharges the perched aquifer in the alluvium.

Initial studies conducted from October 1960 through June 1961 are summarized in a 1963 report (Baltz et al, 1963). The study area included the upper section of Mortandad Canyon having a drainage area of 2 sq mi. Thirty-three test holes, each less than 100 ft deep, were drilled in Mortandad Canyon in 10 lines perpendicular to the channel from the western margin of the study area to just west of the Los Alamos-Santa Fe County line. Ten of the test holes were cased for observation wells to allow for measuring water levels and collecting water samples from the alluvium. Twenty-three of the test holes were used to provide access for neutron moisture probes for determining moisture content of the alluvium and tuff. Each line includes one observation well and two or more moisture access holes (Fig. 4).

The 10 observation wells and 23 moisture access holes across the canyon covered the lateral and horizontal extents of the aquifer in the alluvium. The perched aquifer was determined to be confined to the alluvium, extending as a narrow body of water eastward in the alluvium below the stream channel. It was also determined that it was perched in the alluvium on the tuff (Baltz et al, 1963).

Water level and soil moisture measurements defined a body of perched water in the alluvium from snowmelt runoff in part of Mortandad Canyon (Abrahams et al, 1962). The main source of recharge for this ground water body is infiltration from intermittent streamflow in reaches of the canyon west of Well Number MCO-6 (Fig. 4).

A deep test well (bottomed at 1065 ft) was drilled in Mortandad Canyon near the middle of the area studied. The top of the main aquifer in the well was at a depth of 965 ft below the canyon bottom. Data from this well indicate that perched water does not exist between the alluvium in the canyon and the top of the main aquifer in the Puye Conglomerate (Fig. 2) (Baltz et al, 1963).

Nine additional observation wells and nine moisture holes were installed in the canyon in 1963 (Purtymun, 1964). These and an additional study in 1967 indicated that the perched water in the alluvium was confined to the canyon (Purtymun, 1967).

A study (Purtymun, 1974) of dispersion and movement of tritium (20 Ci of tritium were discharged with 9145 cu ft of water as a result of equipment decontamination in November 1969) in the perched aquifer of Mortandad Canyon found that water was confined to the alluvium. It formed a shallow ground water body confined to the canyon floor. Using tritium and chloride as tracers, the velocity of water in the perched aquifer ranged from about 6 ft/day in a silty section of the aquifer in the lower reaches of the canyon (below Well Number MCO-6) to 60 ft/day in the sand-gravel section of the perched aquifer in the upper reach of the canyon.

A recent report (Purtymun et al, 1983) further substantiates the presence of a perched shallow aquifer in the alluvium (Fig. 5). As shown in previous studies, this report also found that the aquifer is confined to the alluvium in the canyon and does not extend under the adjacent mesas. This study found that the shallow aquifer in the alluvium occupies less than 10% of the volume in the alluvium. (The alluvium thickens eastward from about 3 ft at the gaging station to more than 79 ft at Well Number MCO-8.)

Another study (Environmental Surveillance Group, 1983) reports results of an investigation to determine the distribution of infiltration (moisture) in the alluvium and underlying tuff in a section of Mortandad Canyon. This study indicated some infiltration of water into the tuff beneath the aquifer. It also indicates that the aquifer is confined to the alluvium (Fig. 6). Note the alluvium-tuff interface; the depth of alluvium decreases with distance from the stream channel, shown in Fig. 6. The alluvial-tuff contact, defined with distance from the stream channel, was also previously documented (Abrahams et al, 1962; Baltz et al, 1963).

Results from three core holes (in same line across the canyon as Well Number MCO-6) indicated that the moisture content approaches 30% by volume from 3 to 10 ft above the top of the alluvial aquifer (see Fig. 6). Moisture content of the aquifer material ranged from 20 to 25% by volume. There is some infiltration of water into tuff beneath the aquifer, but this decreases dramatically with greater distance from the stream channel. [In the stream channel (core hole 1, Fig. 6) the moisture content ranges from 10 to 27% to a depth of 24 ft below the base of the aquifer; 18 ft from the stream channel it ranges from 10 to 18% at the same depth; 36 ft from the stream channel it ranges from 5 to 10% at the same depth.] These holes also indicated the perched water was confined to the aquifer in the alluvium and did not extend into tuff adjacent to the stream channel (Environmental Surveillance Group, 1983).

IV. CAÑADA DEL BUEY

Mesita del Buey is a narrow southeastward-trending mesa that contains waste disposal sites (Areas L and G, Fig. 7). The mesa is located along the eastern margin of the Pajarito Plateau (Purtymun and Kennedy, 1971). The mesa is bounded on the north by Cañada del Buey and on the south by Pajarito Canyon (Fig. 7).

Cañada del Buey heads on the Pajarito Plateau and has a relatively small drainage area (3.40 sq mi to the eastern

Laboratory boundary) as compared to that of Pajarito Canyon to the south (10.61 sq mi to the eastern Laboratory boundary). Streamflow in the canyon is intermittent and occurs as an occasional snowmelt runoff or as runoff from heavy summer thundershowers. Alluvium in the canyon is derived from the weathering of the Bandelier Tuff and is composed of silts, sands, and gravels. The alluvium is confined to the stream channel and does not extend under the adjacent mesas. The stream channel is not well defined, braiding out in places along the canyon floor. This lack of definition indicates only limited runoff in the canyon.

Four test holes (CDBO series, Fig. 7) were drilled in the canyon in 1985 to determine if there was water perched in the alluvium as in Mortandad Canyon. All the test holes penetrated the alluvium and were completed into the top of the tuff. All holes were dry. Cuttings from the holes contained little or no moisture (estimated less than 10% by volume by visual observation). This is due to the small drainage area of the canyon that results in little or no surface runoff to form a body of water in the alluvium.

V. PAJARITO CANYON

Pajarito Canyon lies south of Mesita del Buey (Fig. 7). The canyon has a large drainage area (10.61 sq mi) that heads on the flanks of the Sierra de los Valles to the west of the Pajarito Plateau. The canyon contains a stream that is perennial on the flanks of the mountains and across the western half of the plateau and intermittent across the eastern half of the plateau to the Rio Grande. Alluvium in the canyon is derived from the Bandelier Tuff and Tschicoma Formation. It consists of silts and clays, sand and gravels, and large boulders. The alluvium is underlain by the

Bandelier Tuff. The alluvium ranges from 10 to 20 ft in thickness in the canyon; it does not extend under the adjacent mesas. Gravels and sand have been removed from the eastern section of the canyon leaving large pits that at times are filled with water when there is a large volume of surface runoff in the canyon.

Seven test holes (PCO and PCM series, Fig. 7) were completed through the alluvium into the top of the tuff in 1985. Since the spring (March to May) precipitation was above normal (estimated 8.3 in., compared with a 30-yr average of 2.6 in.; Bowen, Laboratory climatological data) and surface runoff very high, water was encountered in the four test holes (PCO-1, PCO-2, PCO-3, and PCO-4) in the alluvium. During construction of these four test holes, it was noted that cuttings from underlying tuff packed against the auger were dry, indicating little infiltration of water from the alluvium into the underlying tuff. The remaining three test holes, drilled at the flank of the canyon, were dry. The test holes document that perched water in Pajarito Canyon, adjacent to Mesita del Buey, is confined to the alluvium in the stream channel, and does not extend to the flank of the canyon.

Two test holes (T-series) were drilled in the canyon in 1947 to look for water. The holes were blank cased through the alluvium (Figs. 7 and 8). The holes, about 300 ft deep, encountered no water in the underlying tuff and volcanic sediments (Griggs, 1964). The holes were also dry when measured in the spring of 1985. Also a test hole (ST-1, Fig. 7) drilled at the east end of Area G on Mesita del Buey through 160 ft of tuff and completed into the top of a basalt contained no water (Purtymun et al, 1978).

Two supply wells located west of Area L were completed into the main aquifer (Well Numbers PM-2 and PM-4, Fig. 7). Well Number PM-2 was drilled in 1965 to a depth of 2600 ft. The depth to the main aquifer was 823 ft (Cooper et al, 1965). Well Number PM-4 was drilled to a depth of 2920 ft in 1980. The depth to the main aquifer was 1060 ft (Purtymun et al, 1983). No perched water above the top of the main aquifer was found in either Well Number PM-2 or Well Number PM-4.

Test holes were drilled on the top of Mesita del Buey at Areas L (10 holes) and G (6 holes) during the summer of 1985 (Fig. 9). They were drilled to depths between 100 and 150 ft. None of these holes encountered any water. For example, a hole at Area L drilled to a depth of 150 ft was dry. This hole extended 10 ft below the base of Pajarito Canyon. All holes at Area G, ranging in depth from 100 to 125 ft, were below the base of the canyon and were also dry (Environmental Surveillance Group, 1985). These findings further substantiate that the perched aquifer is confined to Pajarito Canyon and does not extend below Mesita del Buey.

VI. CONCLUSIONS

Water in the alluvium in Mortandad and Pajarito Canyons is perched on the underlying tuff. Both are recharged from surface flow from upper reaches of their watersheds and/or effluent flows into the canyon. Occurrence of water in both of the canyons is similar. The alluvium is confined to the stream channel and does not extend under the adjacent mesas. No water is found between the base of the alluvium and the top of the main aquifer. Studies made in Mortandad Canyon indicate that the water is confined to the alluvium and does not extend under the mesas adjacent to the canyon bottom. Based on data from test holes drilled in Cañada del Buey (dry), in Pajarito Canyon into the alluvium, and from those holes drilled below the alluvium into underlying volcanic sediments, water in the alluvium in Pajarito Canyon does not extend under adjacent mesas.

This report has summarized the applicability of research in Mortandad Canyon to Cañada del Buey and Pajarito Canyons, as required in Task 6, Paragraph 25 of the Compliance Order/Schedule issued to the Laboratory by the EID on May 7, 1985. Cañada del Buey and Pajarito Canyons are adjacent to Mesita del Buey where the Laboratory;s waste disposal sites, Areas G and L, are located. This report further substantiates the Laboratory's ground water monitoring waiver application because it documents, as required by NM HWMR Section 206.C.1.a(3), that there is no, or at worst, low potential for migration of hazardous waste or hazardous waste constituents from the waste disposal facilities on top of the mesa to water supply wells or to surface water.

VII. ACKNOWLEDGEMENTS

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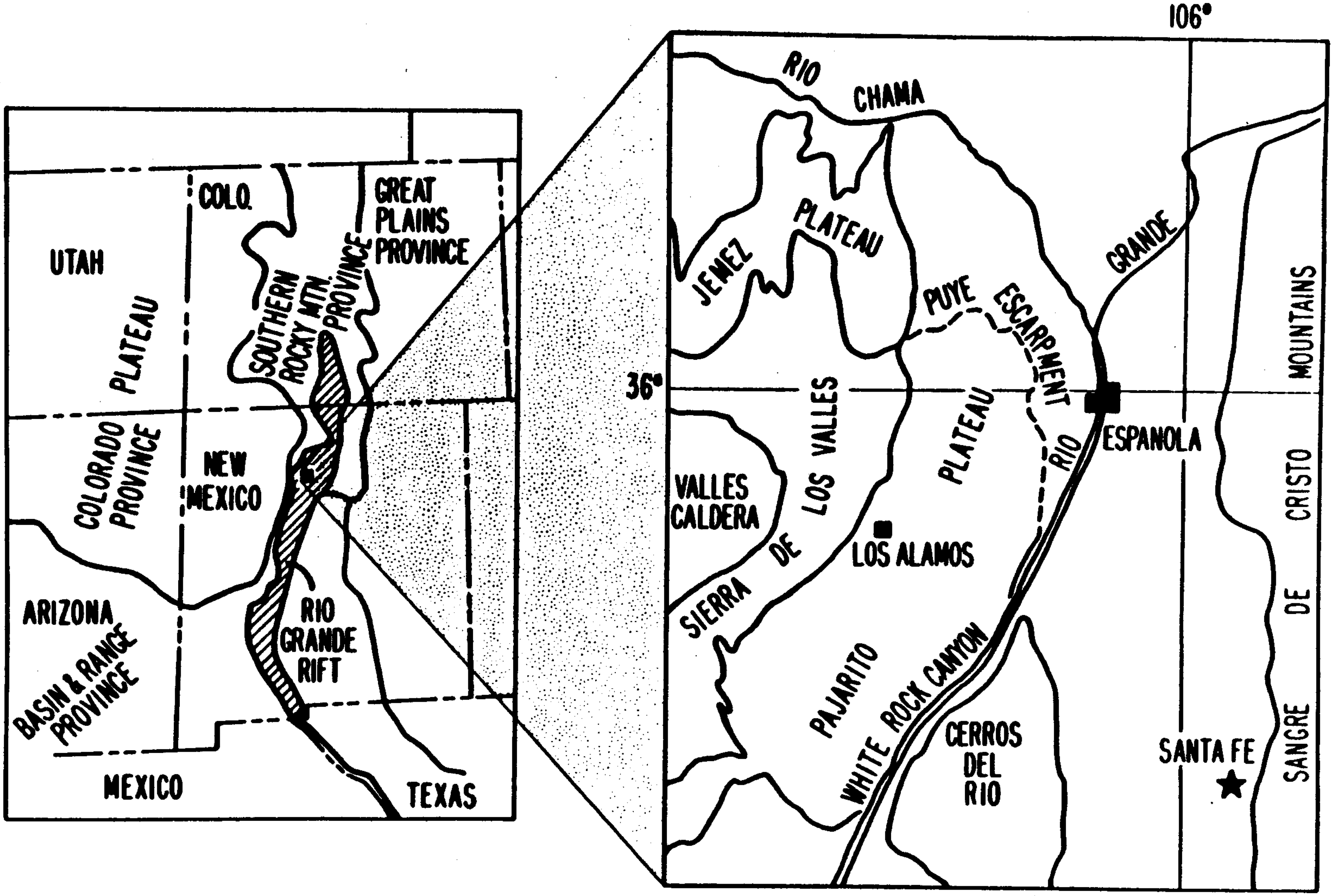

Fig. 1. Physiographic features near Los Alamos (U.S. Department of Energy, 1979

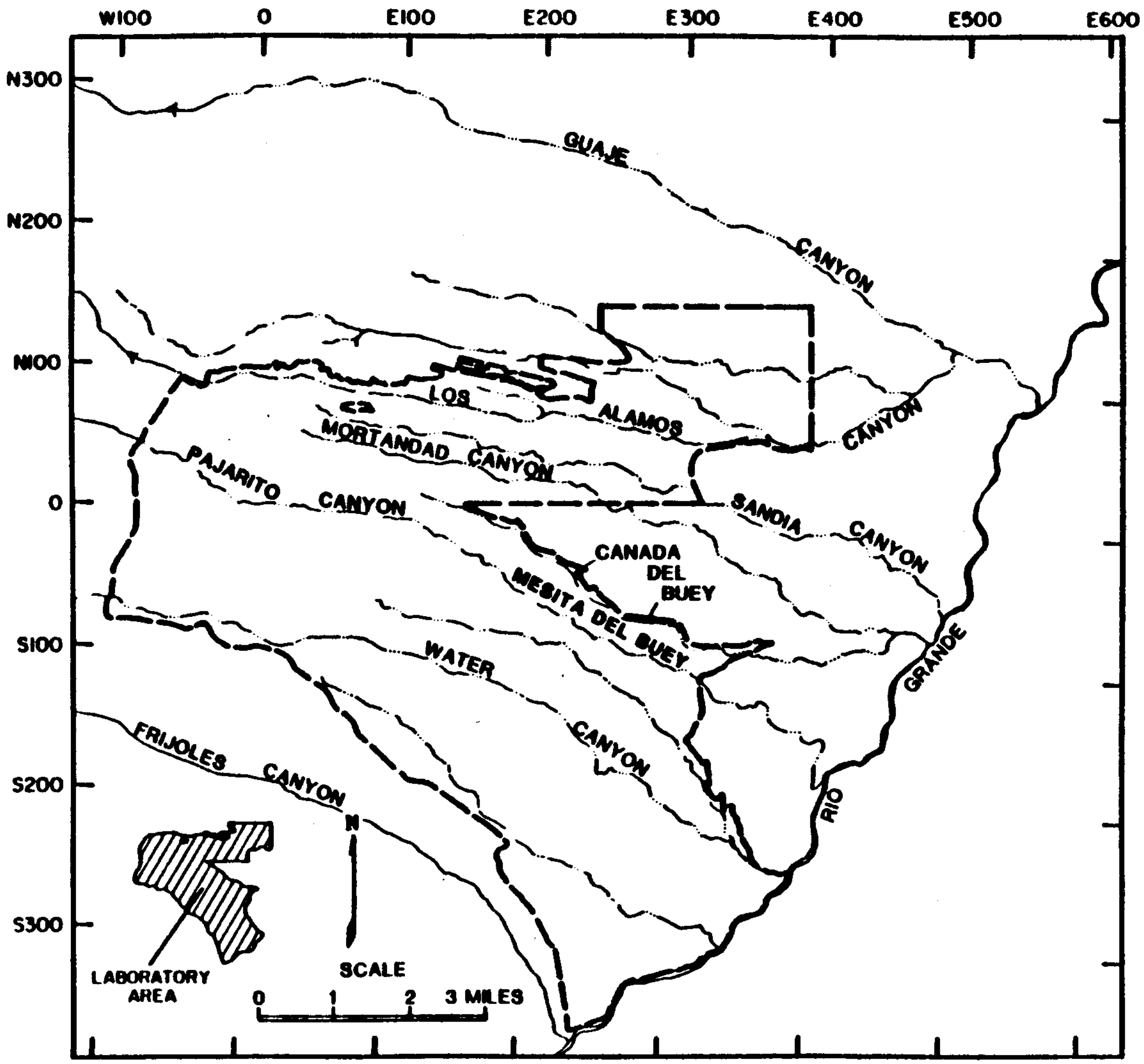

Fig. 2. Map of Los Alamos Area showing locations of Mortandad, Canada del Buey, and Pajarito Canyons

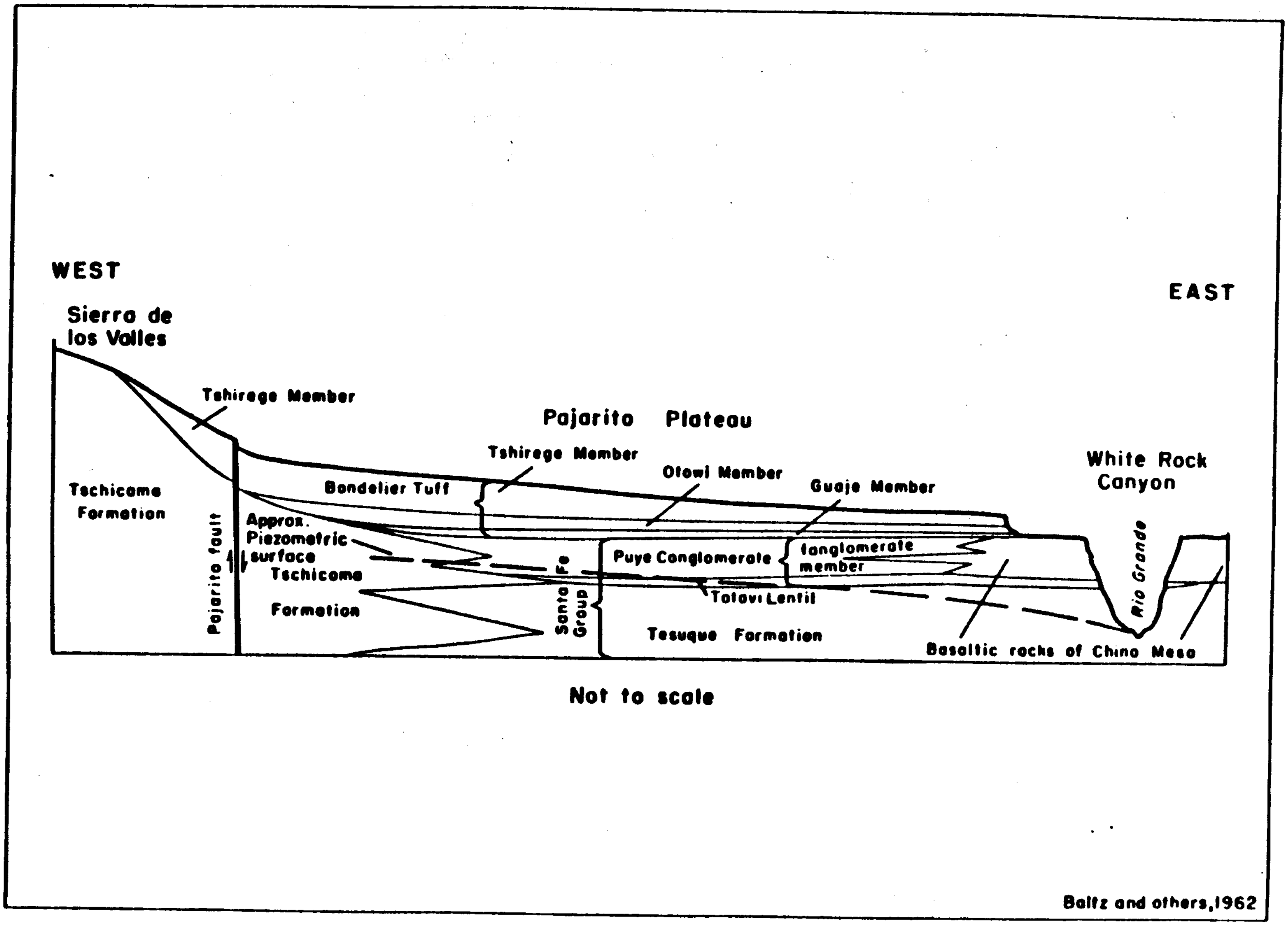

Fig. 3. Diagrammatic cross section (East-West) across the Pajarito Plateau showing the stratigraphic relation of geologic units (Baltz et al., 1963)

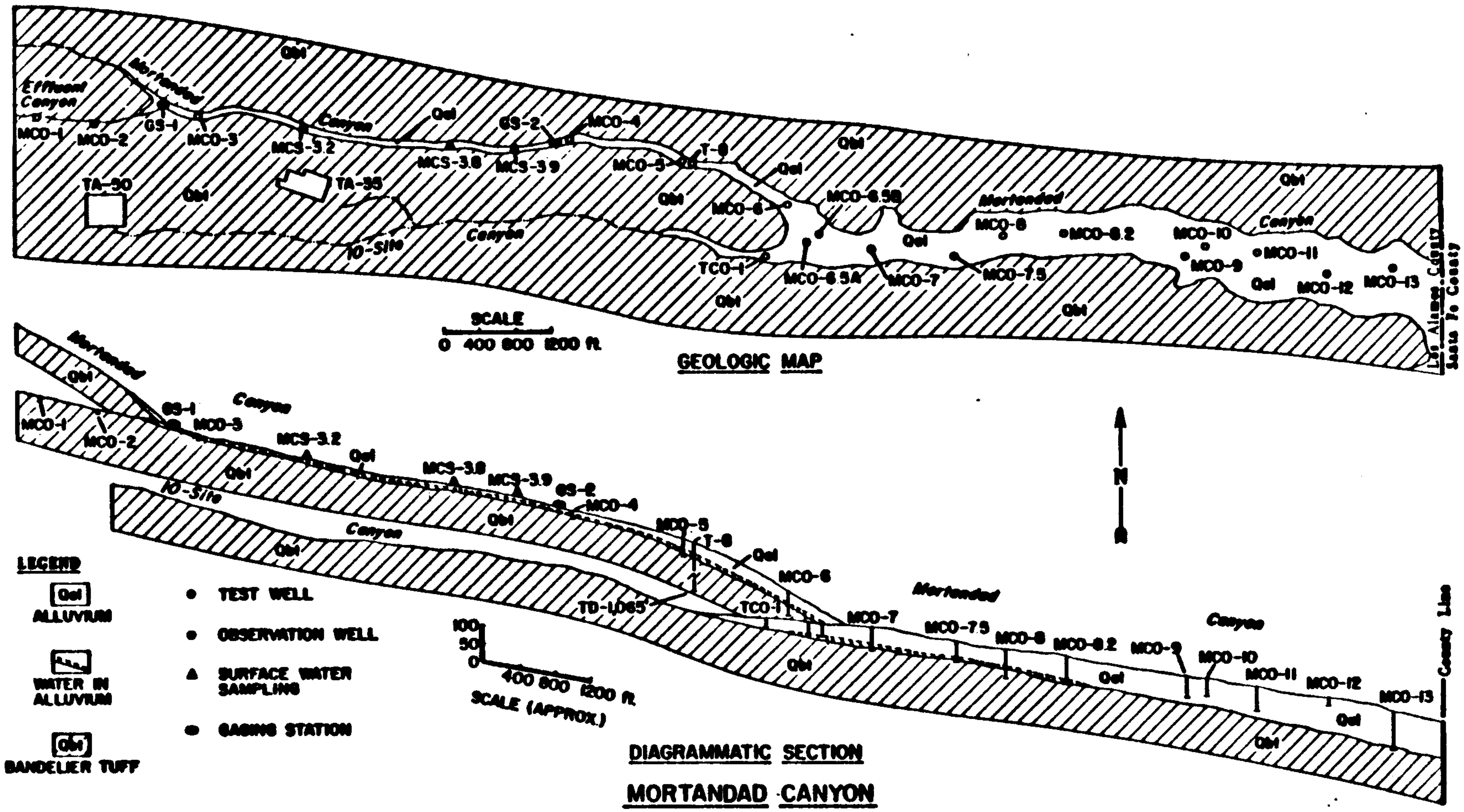

Fig. 4. Plan view and geologic section showing geology and hydrology of Mortandad Canyon

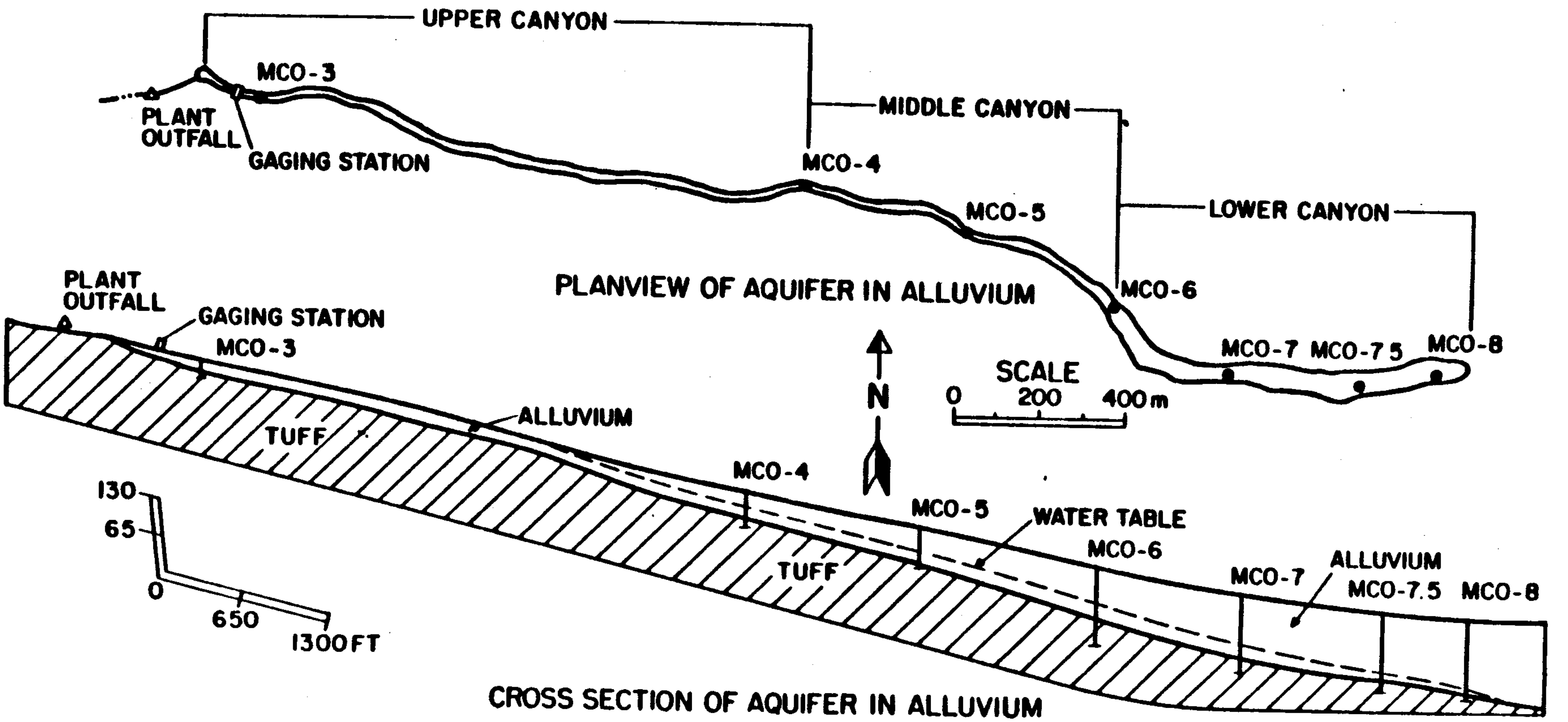

Fig. 5. Plan view and cross section of aquifer in alluvium of Mortandad Canyon (Purtymun, 1974)

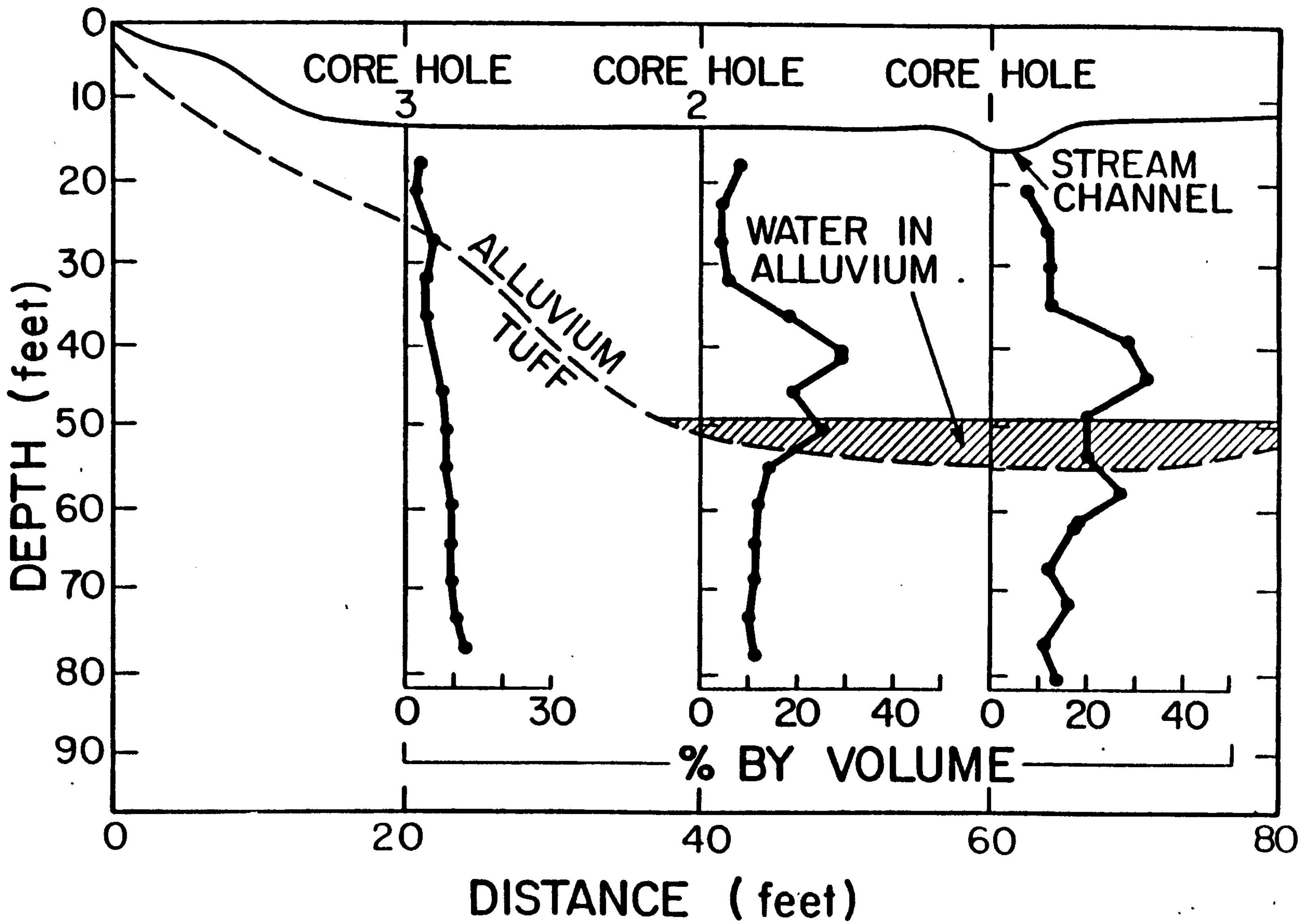

Fig. 6. Locations of core holes in cross section of Mortandad Canyon showing aquifer in alluvium and distribution of moisture (Environmental Surveillance Group, 1983)