by a series of ladders. The visitor complex in the canyon is accessible by motor vehicle; Bandelier is otherwise a hiker's park. Three large canyons cross the monument, with a complex system of mesas and secondary canyons separating them. Much of the monument has been designated a unit of the National Wilderness Preservation System. **2.6**

30.7 Meadows with abundant small pine trees on left have replaced the burned areas of the 1977 La Mesa forest fire. This area is now a National Environmental Research Area set aside to observe nature's reclamation process. **0.6**

31.3 Technical Area 49 on right. **0.3**

31.6 Good view into Water Canyon on right. **0.4**

32.0 Trailhead to Burnt Mesa on left. **1.0**

33.0 Contact between Tshirege units E and F (Rogers, 1995) on right. **0.1**

33.1 Good view of Pajarito fault scarp at 12:00 (Fig. 3.16). **0.7**

33.8 Road descends into shallow graben east of Pajarito fault. **0.2**

34.0 Junction with NM-501; **continue straight ahead** (uphill) on NM-4. The following minipaper summarizes the numerous springs present to the north of NM-4 and east of NM-501 on the western side of the Pajarito Plateau. **0.1**

CHARACTERISTICS OF SPRINGS IN THE WESTERN PAJARITO PLATEAU, LOS ALAMOS NATIONAL LABORATORY, NEW MEXICO

Michael R. Dale and Steve Yanicak

New Mexico Environment Department, DOE Oversight Bureau,
35 Rover Blvd., White Rock, NM 87544

Historically, drainages that dissect the Pajarito Plateau have been thought to contain only ephemeral streams produced from snow-melt and storm-water runoff. However, recent investigations by the New Mexico Environment Department, Department of Energy Oversight Bureau (NMED, DOE OB) indicate that perennial and ephemeral springs, emanating from the Bandelier Tuff and alluvium, supply perennial flow to several canyons along the western boundary of the Pajarito Plateau. Here, we briefly summarize the characteristics of these springs. A more detailed report is in preparation through the NMED DOE OB (Dale and Yanicak, unpubl. 1996).

The area studied (in 1994 and 1995) encompasses 3 mi^2, and is located entirely within the western region of Los Alamos National Laboratory (Fig. 3.17). Spring elevations vary from 7389 to 7481 ft, with springs at the northern edge of the study area occurring at slightly higher elevations. All observed springs discharged from gray tuff associated with units D or E of the Tshirege Member of the Bandelier Tuff (Rogers, 1995), or canyon alluvium. We made no attempt to correlate these units with Bandelier Tuff nomenclature for the Laboratory's Environmental Restoration Project (Broxton and Reneau, 1995), but recommend that future correlative studies be conducted.

Flow was determined at culverts and temporary diversion structures by the bucket-and-stop-watch method. Measurements were made downstream from the springs in order to focus on the amount of water contributed to the stream. Mean flow values (Fig. 3.17) were calculated using multiple measurements (7 to 12 replications).

Field work led to the discovery of 12 perennial springs, two in the Twomile Canyon area, six in the Pajarito Canyon area, and four in the Canon de Valle area (Fig. 3.17). With few exceptions, these springs discharge from north-facing canyon walls or slopes and occur along a 1.5-mi long, NNE-SSW-trending zone that subparallels major segments of the Pajarito fault system. The estimated flow of perennial springs during 1994 and 1995 was fairly consistent, ranging from 0.06 to 1.20 L/sec. Additional observations made periodically during 1994 and 1995 showed that perennial flow in Pajarito Canyon extended east from Homestead Spring for at least 2.2 mi. During 1995, perennial flow in Canon de Valle was observed from Peter Spring to the east for approximately 1.2 mi.

Field measurements for specific conductance, pH and temperature for the perennial springs ranged from 80 to 323 µS/cm, 6.07 to 7.79 S.U. and 8.0 to 12.7°C, respectively. The water is predominately a calcium-sodium-bicarbonate type with total dissolved solids (TDS) ranging from

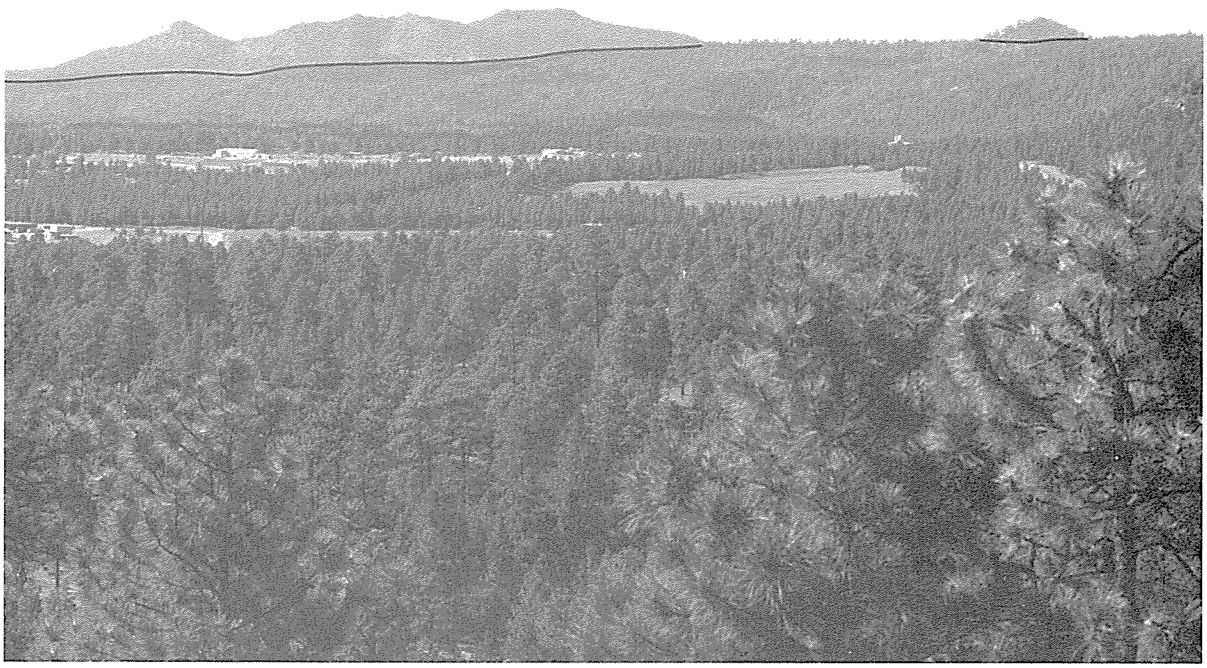

FIGURE 3.16. View, looking south, of the Pajarito fault scarp in Bandelier National Monument. Black line highlights the top of the scarp where it does not form the skyline. The Pajarito fault exhibits over 400 ft of displacement on marker horizons within the Bandelier Tuff. Pointed mountain at left is Boundary Peak, to the right is St. Peter's Dome, and at the far right is Rabbit Hill.

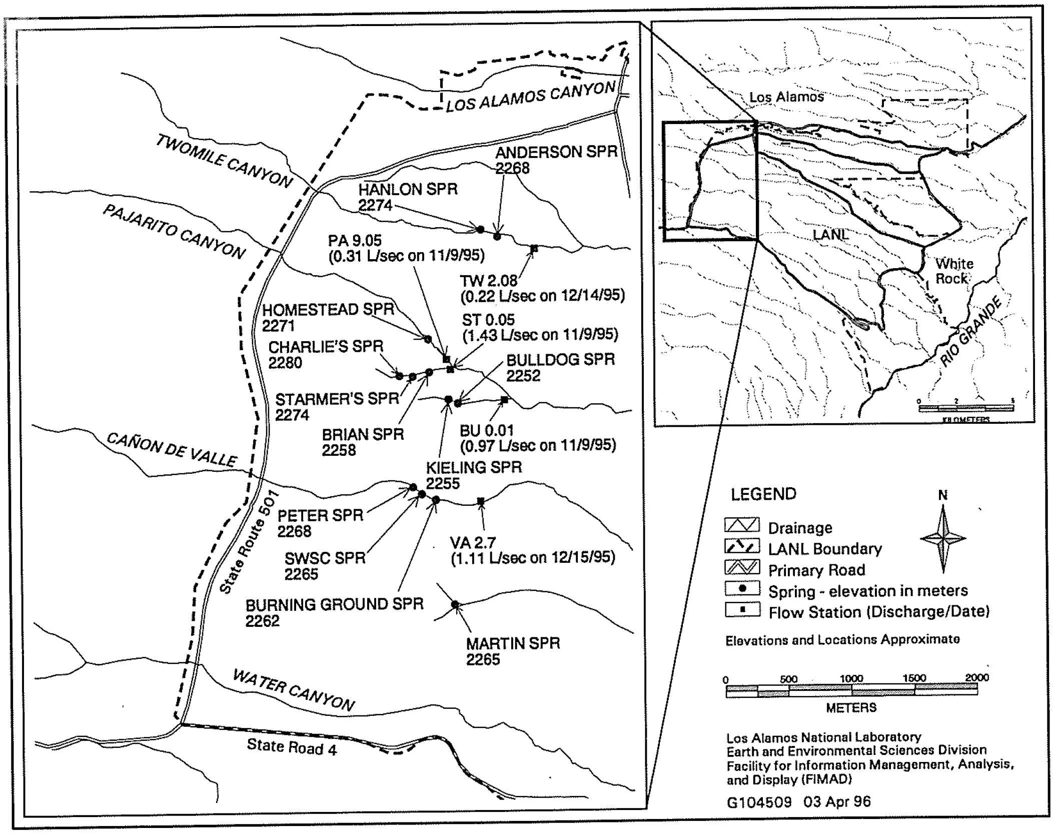

FIGURE 3.17. Locations of springs and flow-measurement stations along the western region of the Pajarito Plateau, Los Alamos National Laboratory, New Mexico.

99 to 250 mg/L. Concentrations of dissolved inorganic constituents (mg/L) ranged from 8 to 24 for calcium, 6 to 25 for sodium, 3 to 6 for magnesium, 2 to 5 for potassium, 29 to 104 for bicarbonate, 6 to 31 for chloride, <0.1 to 0.3 for fluoride, 6 to 31 for sulfate and 0.01 to 1.1 for nitrate/nitrite as total nitrogen. The high-range concentrations are predominately associated with springs in the Canon de Valle area. Springs in Pajarito and Twomile Canyons generally show lower TDS concentrations, but seasonal variations in concentration appear to be occurring. Sampling on April 28, 1995, showed an increase in specific conductance and TDS for perennial springs in the Pajarito Canyon area.

Some perennial springs were analyzed for high-explosive compounds (HE), volatile-organic compounds (VOC) as well as the radionuclides ^{90}Sr, $^{239/240}$Pu, ^{238}Pu, ^{241}Am, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U and gross alpha/beta in dissolved phase. HEs and VOCs were detected at some springs in the Canon de Valle area. The concentration for the HE compounds 2-amino-4,6-dinitrotoluene and 2-amino-2,6-dinitrotoluene ranged from 2.3 to 3.3 μg/L; that for octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) ranged from 5.5 to 11.0 μg/L; and that for hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) ranged from 83 to 100 μg/L. The concentration for the VOC tetrachloroethene ranged from 2.3 to 15 μg/L and that for trichloroethene ranged from 0.9 to 3.1 μg/L. Additionally, cis-1,2-dichloroethene at 21 μg/L was detected at Peter Spring. HEs and VOCs were not detected at springs in the Pajarito Canyon area. Gross beta, ^{234}U, ^{235}U, and ^{238}U were detected above the method detection limits for all springs. It is unknown if these levels are within the background range for these types of waters. Activity (pCi/L) ranged from 3.49 to 10.1 for gross beta, 0.06 to 0.77 for ^{234}U, 0.02 to 0.03 for ^{235}U and 0.09 to 0.70 for ^{238}U.

Four ephemeral springs were flowing on April 28, 1995, in the Pajarito Canyon tributary where Starmer's Spring discharges (Fig. 3.17). All springs discharged from the south-facing canyon wall. The initial estimated flow ranges from <0.06 to 0.12 L/sec. Flow of these springs gradually ceased during the summer. Field measurements for specific conductance, pH and temperature for the ephemeral springs ranged from 82 to 169 μS/cm, 6.24 to 6.98 S.U. and 8.1 to 10.6°C, respectively. TDS ranged from 70 to 148 mg/L. Concentrations of dissolved inorganic constituents (mg/L) ranged from 6 to 10 for calcium, 5 to 11 for sodium, 2 to 4 for magnesium, 2 to 3 for potassium, 37 to 40 for bicarbonate, <5 to 6 for chloride, <0.5 for fluoride, 17 to 20 for sulfate and <0.1 to 29 for nitrate/nitrite as total nitrogen.

At most discharge points, tuff beds are moderately welded and show vertical fractures common to the Tshirege Member, but horizontal fractures with aperture widths of up to 0.5 in. or more are also abundant. Spring water discharges mainly from fractures, contacts, or parting surfaces between tuff beds of similar lithology but varying competency (e.g., surge beds). Because ephemeral springs ceased flow during summer, we theorize that these springs may have some connection to surface-water infiltration during snow-melt runoff.

As flow measurements were made at some distance below the springs, they may not adequately represent spring discharge. The values may be low due to losses associated with infiltration, or high due to contributions by interflow or runoff. Since measurements were made during extremely dry conditions, the former is most likely and the data probably represent minimum spring discharge.

Preliminary chemical and benthic-invertebrate data (see Ford-Schmid, this volume) indicate that ground-water impacts, via anthropogenic sources (e.g., outfall, landfill), may be occurring in the western region of the Pajarito Plateau. Furthermore, the perennial reaches supported by the springs described herein support a saturated zone within the canyon alluvium that could transport contaminants over a wider area. Thus, additional work on the source of such contaminants is recommended.

[redacted] te El Cajete Pumice exposed in soil on left. **0.5**
[redacted] point on left in sharp bend of road provides excellent [redacted] of the Pajarito Plateau, Pajarito fault, Rio Grande [redacted] and Sangre de Cristo range (Fig. 3.18). **0.8**
[redacted] road to American and Armisted cold springs on [redacted]. **1.7**
[redacted] ndary to Bandelier National Monument. **2.9**
40.0 Intersection of NM-4 and USFS Road 289, The Dome