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Title

Biological and Water Quality Assessments for the Material Disposal Area P Project Area, March 1995—August 1997

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TABLE OF CONTENTS

ABSTRACT 1

I. GENERAL ENVIRONMENT 2

1.1 General Setting 2

1.2 Description of the Project Area 5

II. PROJECT DESCRIPTION 9

III. VEGETATION OF THE VICINITY 12

IV. WILDLIFE OF THE VICINITY 13

4.1 Invertebrates 14

4.2 Fish 14

4.3 Reptiles and Amphibians 14

4.4 Birds 14

4.5 Mammals 14

V. THREATENED AND ENDANGERED SPECIES 15

VI. WATER QUALITY AND AQUATIC INVERTEBRATES 18

6.1 Introduction 18

6.1.1 Water Quality Concerns 18

6.1.2 Physical and Chemical Parameters 18

6.1.3 Aquatic Invertebrates 20

6.2 Sampling Sites and Methodology 21

6.2.1 Sampling Sites 21

6.2.2 Habitat Assessment 23

6.2.3 Water Quality Parameters 24

6.2.4 Aquatic Macroinvertebrate Sampling 24

6.2.5 Aquatic Macroinvertebrate Analysis 25

6.2.5.1 Rapid Bioassessment Protocols 25

6.2.5.2 Other Measures of Macroinvertebrate Communities 29

6.3 Water Quality Sampling Results 31
6.3.1 Habitat Assessment 31
6.3.2 Physical and Chemical Parameters 31
6.3.2.1 Water Temperature 31
6.3.2.2 pH 34
6.3.2.3 DO 34
6.3.2.4 Conductivity 34
6.3.3 Aquatic Macroinvertebrate Sampling Results and Analysis 34
6.3.3.1 Standing Crops and Taxa Collected 35
6.3.3.2 Biodiversity 36
6.3.3.3 Community Compositions by Functional Feeding Group 37
6.3.3.4 RBP Metrics 37
VII. RECOMMENDED BEST MANAGEMENT PRACTICES 40
7.1 T&E Species 40
7.2 Erosion Control and Water Quality 41
7.3 Restoration of the Area Following Clean Closure 42
VIII. CONCLUSIONS 42
IX. ACKNOWLEDGMENTS 43
X. GLOSSARY OF ACRONYMS AND TECHNICAL TERMS 45
XI. CITATIONS 48

LIST OF FIGURES

Fig. 1. Location of Los Alamos National Laboratory, New Mexico. 3
Fig. 2. LANL Technical Areas. 4
Fig. 3. 1995 monthly precipitation totals for the MDA-P project area. 6
Fig. 4. 1996 monthly precipitation totals for the MDA-P project area. 7
Fig. 5. 1997 monthly precipitation totals for the MDA-P project area. 8

Fig. 6. Water sources near MDA-P. 10

Fig. 7. Locations of the aquatic invertebrate sampling stations. 22

Fig. 8. Community composition by functional feeding group. 38

LIST OF TABLES

Table 1. USFWS T&E Species List for Los Alamos County. 16

Table 2. Aquatic Insect Functional Feeding Groups. 28

Table 3. Interpretative Chart for the Total Biological Condition Scores and Associated Impairment Categories (Plafkin et al. 1989). 30

Table 4. Habitat Assessment Scores. 32

Table 5. Physical and Chemical Water Quality Measurements. 33

Table 6. Aquatic Invertebrate Population Measurements. 36

Table 7. Biological Condition Scores for Cañon de Valle. 39

Table 8. Summary of Total RBP Biological Condition Scores for Cañon de Valle. 39

APPENDICES

Appendix A. Aquatic Invertebrates Collected from Los Alamos County and Adjacent Watersheds 53

Appendix B. Aquatic Invertebrate Taxa Collected in Cañon de Valle and Starmer's Gulch 65

Appendix C. Functional Feeding Groups of Collected Aquatic Insects 68

Appendix D. Tolerance Quotients of Collected Invertebrates 71

Appendix E. Rapid Bioassessment Protocol Worksheets 73

BIOLOGICAL AND WATER QUALITY ASSESSMENTS FOR THE MATERIAL DISPOSAL AREA P PROJECT AREA, MARCH 1995 – AUGUST 1997

ABSTRACT

The Biology Team of Los Alamos National Laboratory's Ecology Group has monitored the vicinity of the Material Disposal Area (MDA) P since 1995. MDA-P contains a waste pile that is scheduled to undergo a clean closure soon. The Biology Team has addressed threatened and endangered species concerns and conducted species-specific surveys for the Mexican spotted owl, which is known to nest in the general vicinity of the project area. Resident Mexican spotted owls have been located near the MDA-P site and detailed best management practices discussed in this report will ensure that clean closure activities do not disturb or otherwise negatively affect the owls.

Since 1995, the Biology Team has monitored water quality in a small stream flowing through Cañon de Valle and along the base of the MDA-P waste pile. Prior to the commencement of remediation activities, physical and chemical measurements were recorded and resident aquatic invertebrates were sampled to evaluate baseline conditions within the stream. Comparisons were made with a similar stream flowing through the nearby Starmer's Gulch. All physical and chemical measurements taken within the Cañon de Valle stream were within the ranges set by the State of New Mexico for high-quality cold-water fisheries. In terms of habitat assessment measurements and resident aquatic invertebrate communities, the Cañon de Valle stream is slightly to moderately impaired relative to the Starmer's Gulch stream. Site-specific erosion control and remediation measures to contain wastes on-site and to protect the Cañon de Valle stream from potential clean-up activity impacts are discussed.

Author's note: This report updates and expands on a previous report entitled "Biological and Water Quality Assessments for the Material Disposal Area - P Project Area, 1995 and 1996" by Saul Cross (Cross 1996a).

1. GENERAL ENVIRONMENT

1.1 General Setting

The Material Disposal Area (MDA) P project area occurs within the boundaries of Los Alamos National Laboratory (LANL). The Laboratory is owned by the U.S. Department of Energy (DOE) and is jointly operated by DOE and the University of California. The 111-km^2 (43-mi^2) Laboratory site is located in north-central New Mexico on the Pajarito Plateau, approximately 120 km (80 mi) north of Albuquerque and 40 km (25 mi) west of Santa Fe (Fig. 1). In the LANL region, the eastern edge of the Pajarito Plateau descends to the Rio Grande in White Rock Canyon. The Rio Grande flows in a southwesterly direction along the easternmost boundary of LANL.

Most LANL industrial developments are confined to the mesa tops, which range in elevation from a maximum of 2,400 m (7,800 ft) asl (above sea level) along the western boundary to about 1,900 m (6,200 ft) asl at their eastern terminus above the Rio Grande. The canyons within LANL boundaries can be as deep as 300 m (1,000 ft) below the mesa top. Technical areas (TAs) contain administration and support function buildings, experimental and research areas, waste disposal areas, roads, and utility corridors (Fig. 2). However, these components use only a small part of LANL's total land area, and the remainder is reserved as buffer zones and potential sites for future development (EPG 1996).

Most of the mesas in the Los Alamos area are formed from Bandelier Tuff, which includes ash fall, ash fall pumice, and rhyolite tuff. The tuff, ranging from nonwelded to welded, is more than 300 m (1,000 ft) thick in the western portion of the Plateau and thins to about 80 m (260 ft) above the Rio Grande. It was deposited as a result of major eruptions in the Jemez Mountains about 1,200,000–1,600,000 years ago. The tuff overlaps onto the Tschicoma Formation, which consists of older volcanics that form the Jemez Mountains. Along its central and eastern edges above the Rio Grande, the tuff is underlain by the conglomerate of the Puye Formation. Chino Mesa basalts also intermix with the conglomerate along the river. These formations overlay the sediments of the Santa Fe Group, which extend across the Rio Grande Valley and are more than 1,000 m (3,300 ft) thick (EPG 1996).

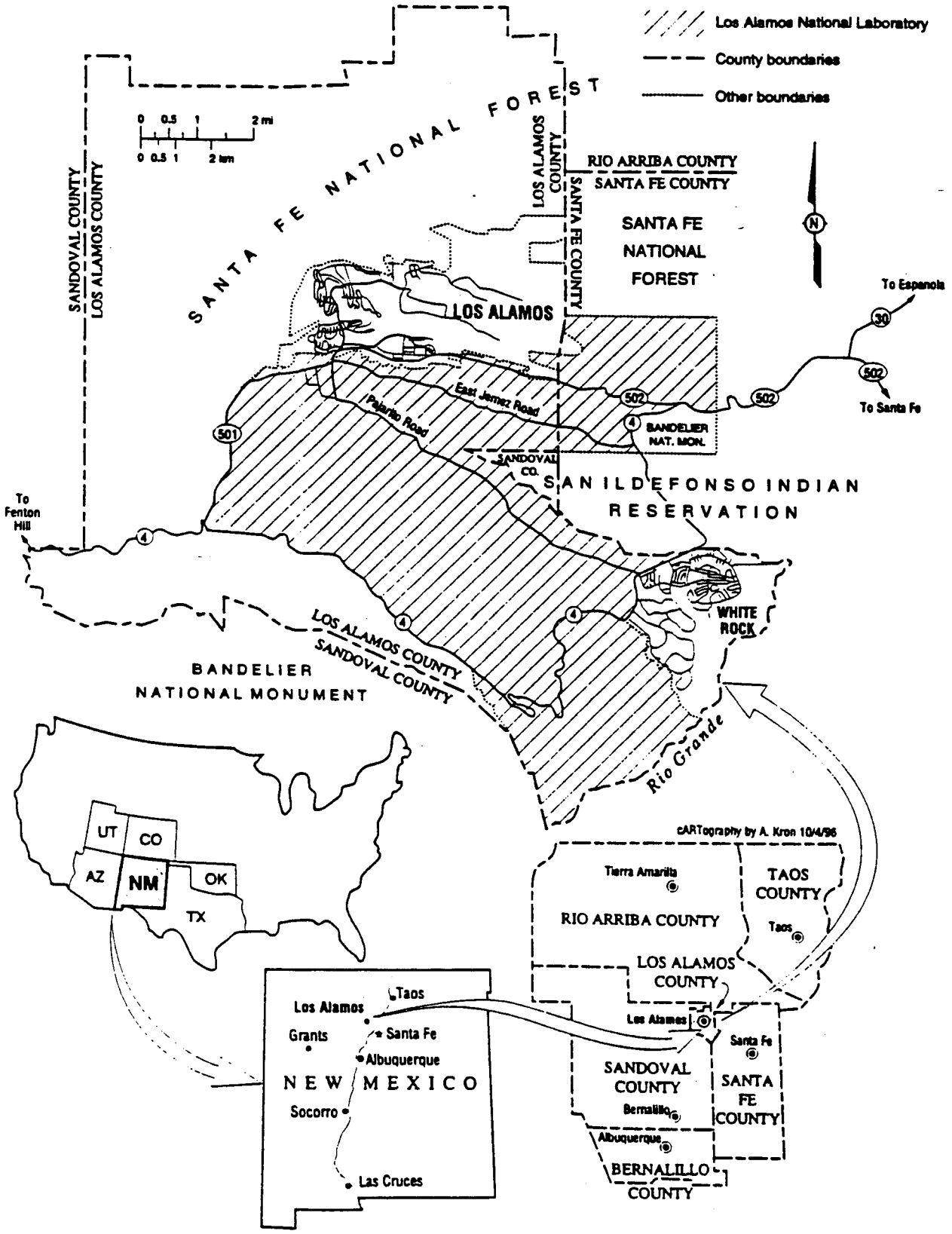

Fig. 1. Location of LANL, New Mexico.

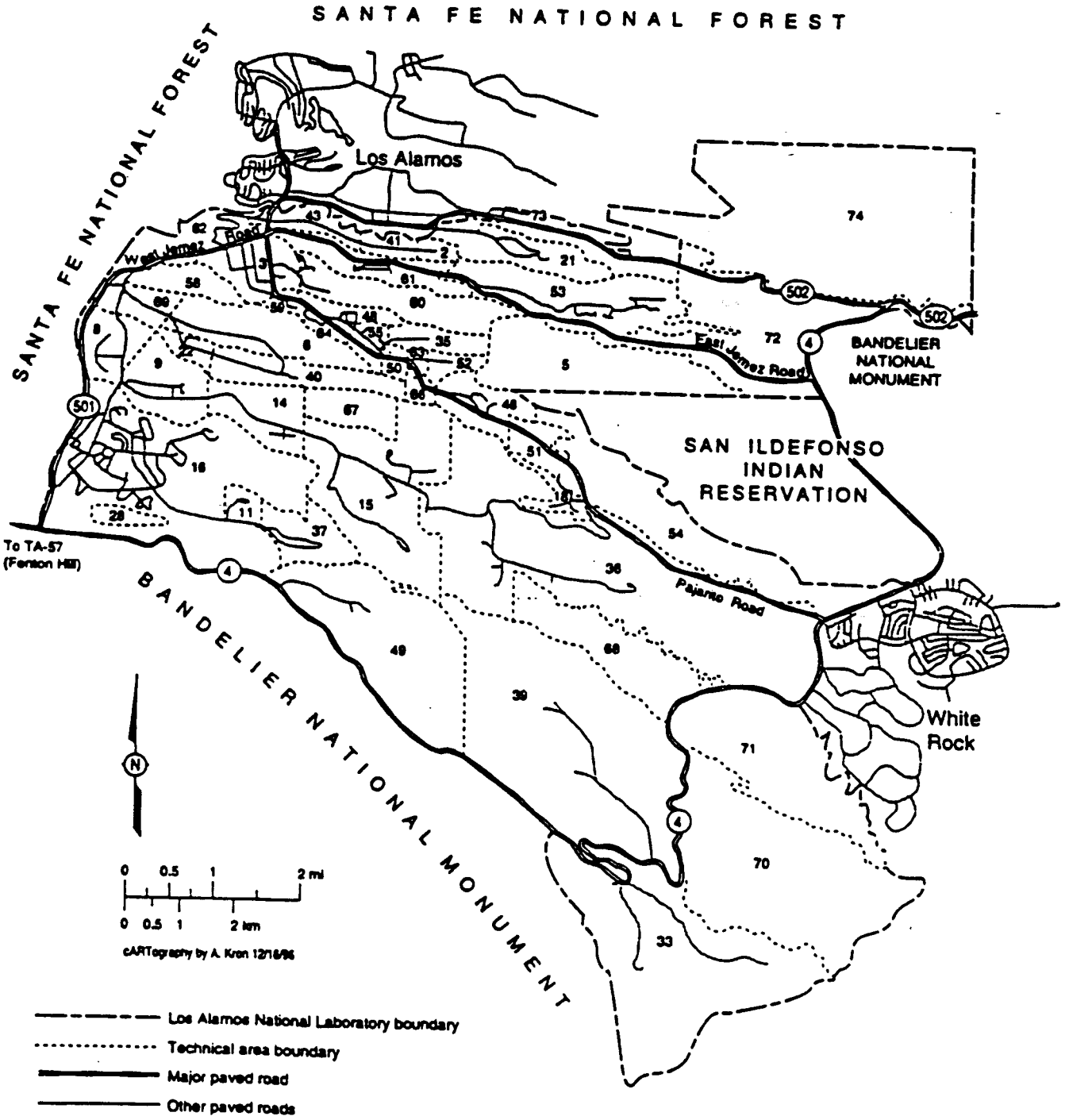

Fig. 2. LANL Technical Areas.

LANL has a semiarid, temperate mountain climate. However, its climate is strongly influenced by elevation, and local topography produces large temperature and precipitation differences. Winter temperatures range from –1°C to 10°C (30°F to 50°F) during the daytime, to –9°C to –4°C (15°F to 25°F) during the nighttime. Winter is usually not particularly windy, so extreme wind chills are uncommon at Los Alamos. Summer temperatures range from 21°C to 37°C (70°F to 88°F) during the daytime, to 10°C to 15°C (50°F to 59°F) during the nighttime. Occasional temperatures over 32°C (90°F) are recorded, and the highest temperature ever recorded in Los Alamos was 35°C (95°F) (EPG 1996).

The average annual precipitation (including both rain and the water equivalent of frozen precipitation) at LANL is 48 cm (18.7 in.). The summer rainy season accounts for 48% of the annual precipitation. Runoff from late summer thundershowers flows towards the east through the various canyons, supplementing ground water in the shallow alluvium. Winter precipitation falls primarily as snow with accumulations of about 150 cm (59 in.) (EPG 1996). The lowest recorded annual precipitation in Los Alamos County was 17.3 cm (6.8 in.), and the highest was 77.0 cm (30.3 in.) (Alexander 1996). Figures 3, 4, and 5 display monthly precipitation totals from the LANL meteorological station nearest to upper Cañon de Valle for 1995–1997.

Surface water in Los Alamos County occurs primarily as intermittent streams. Springs supply base flow into the upper reaches of some of the canyons, including Cañon de Valle and Pajarito Canyon. However, the volumes of water are usually insufficient to maintain year-round surface flow. Runoff from heavy thunderstorms or heavy snowmelt reaches the Rio Grande several times a year in some drainages (Purtymun 1995).

1.2 Description of the Project Area

The MDA-P waste pile occurs along a slope on the southern rim of Cañon de Valle, just north of the TA-16 thermal treatment area's pad TA-16-387. The waste pile almost extends to a small stream in the bottom of the canyon, approximately 45 m (150 ft) below the summit of the waste pile. The elevation of the waste pile is approximately 2,245–2275 m (7,365–7,460 ft) asl, while the stream is approximately 2,237 m (7,340 ft)

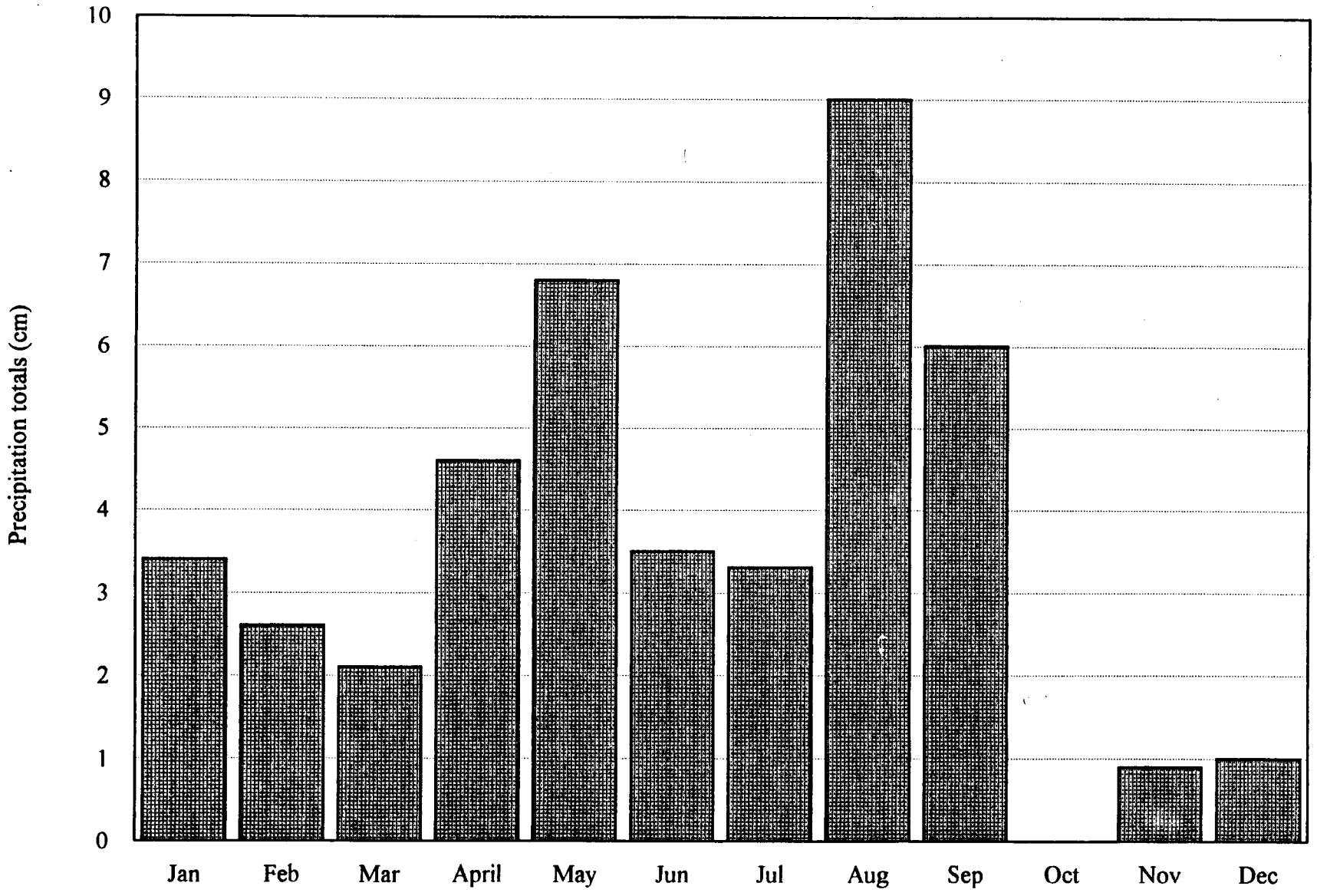

Fig. 3. 1995 monthly precipitation totals for the MDA-P project area.

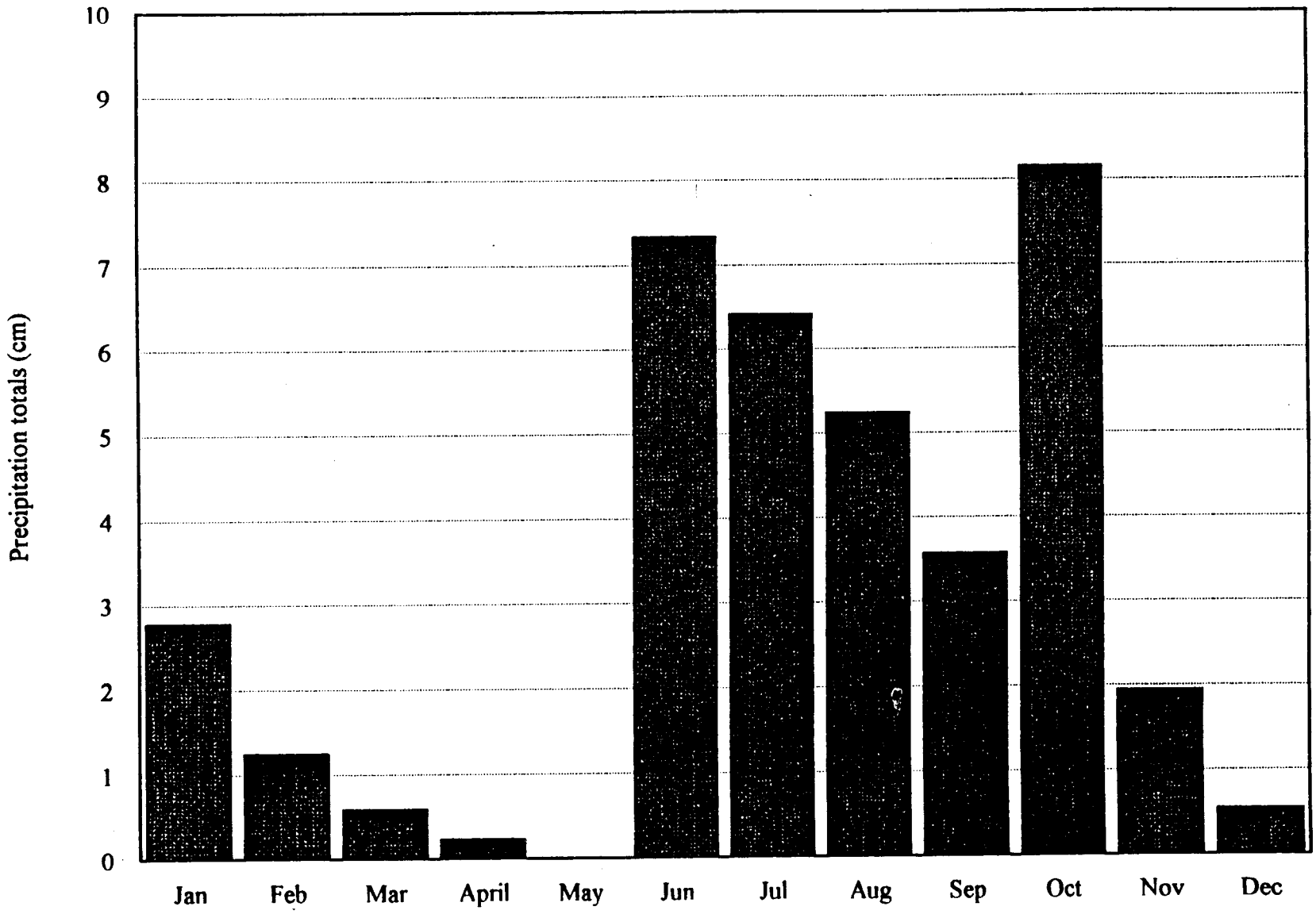

Fig. 4. 1996 monthly precipitation totals for the MDA-P project area.

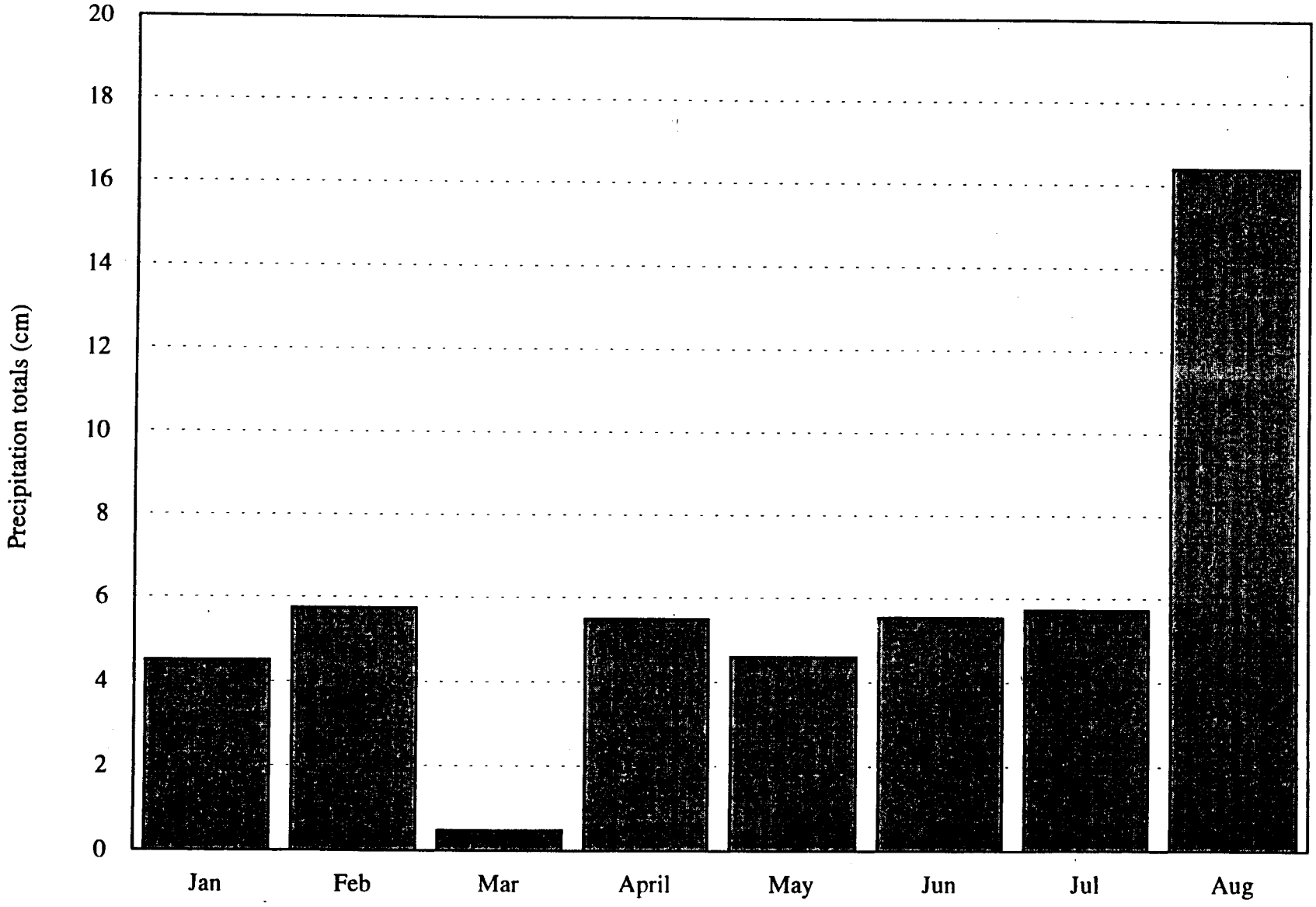

Fig. 5. 1997 monthly precipitation totals for the MDA-P project area.

asl. TA-16 soils are classified as mesic rock outcrop with a soil pH from 6.6 to 7.8. The potentiometric surface of the main aquifer at MDA-P is approximately 260 m (850 ft) below the mesa surface (Alexander 1996). The MDA-P waste pile occurs within the 100-year floodplain boundary. These floodplains are protected under Executive Order 11988 ("Floodplain Management") and 10 CFR 1022, which outlines DOE compliance.

The National Wetlands Inventory conducted by the U.S. Fish and Wildlife Service (Cowardin et al. 1979) found no wetlands within Cañon de Valle (Fig. 6). These surveys were performed with aerial photography and were not field checked. The Biology Team of ESH-20 (LANL's Ecology Group) walked the entire length of the canyon to confirm its wetlands status. Riparian vegetation occurs along the stream banks, but this vegetation is patchy and poorly developed due to the stream's low flow regime.

The stream bed is known to be contaminated with constituents similar to those in the waste pile from known sources located upstream from MDA-P. These include drainage from burn pads, MDA-R and its waste disposal area, and outfall effluent from Building 16-260 (Alexander 1996).

The waste pile slope supported native understory and several small trees. In 1996, the Biology Team approved the removal of the trees, mostly ponderosa pine, to facilitate access to the project area. All trees were removed before the start of the Mexican spotted owl nesting season.

II. PROJECT DESCRIPTION

MDA-P is located within LANL's TA-16 whose chief activities are high explosives (HE) production and development. This area was previously designated TA-13, which was located at the eastern end of the current TA-16 explosives manufacturing area. In 1944, TA-13 was designed principally as a site for counter x-ray diagnostics of HE lens configuration. By the 1950s, most of the original buildings had been removed. The remaining buildings were absorbed into the TA-16 S-Site Complex when TA-13 was decommissioned. These buildings are currently used for HE machining safety studies.

The MDA-P waste pile was used from the early 1950s until 1984. It was used as a landfill for rubble and debris resulting from burning operations conducted at adjacent burn pads. The debris is very heterogeneous, consisting of burned HE-contaminated

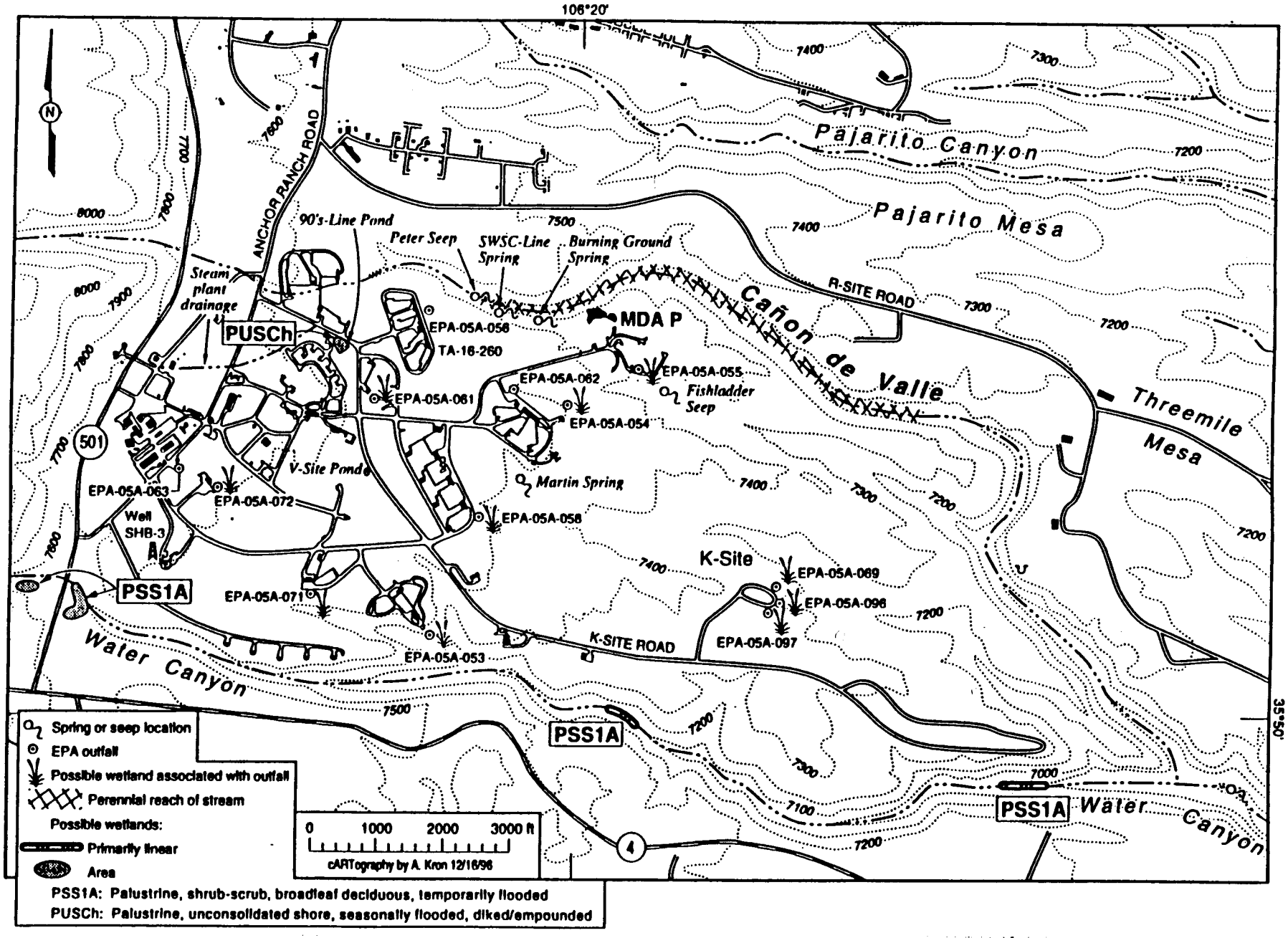

Fig. 6. Water sources near MDA-P.

equipment, building materials including structural steel, empty drums and bottles, and trash. After burning, the waste materials and the original sand burn pads were pushed over the edge of the mesa immediately south of upper Cañon de Valle. Waste materials include metals (barium, beryllium, cadmium, chromium, copper, cobalt, lead, manganese, mercury, nickel, vanadium, zinc, aluminum, calcium, iron, magnesium, sodium, potassium, silver, selenium, antimony), arsenic, nitrates, and HE residue, and may include polycyclic aromatic hydrocarbons, asbestos, solvents, and depleted uranium. In 1984, the waste pile was covered with 2 m (6 ft) of earth. A surface run-on control trench of asphalt was subsequently constructed around the upper perimeter.

The area impacted by the waste pile is approximately 52 m (170 ft) by 122 m (400 ft), and the total surface area encompasses approximately 0.81 ha (2 ac). The depth of the waste is approximately 3.5 m (12 ft) to 4 m (14 ft), and it is not underlain by a liner or a leachate collection system. The existing MDA-P waste pile contains an estimated 22,935 m^3 (30,000 yd^3) of waste materials and debris. It is assumed that an additional 380 m^3 (500 yd^3) of waste soil below the waste pile will also require stabilization. The majority of these wastes should be uncontaminated and will be disposed of at an approved Subtitle D facility.

A closure plan for the MDA-P (ICF Kaiser Engineers 1994) was submitted to the New Mexico Environment Department (NMED). This plan was designed to meet requirements of the New Mexico Hazardous Waste Regulations (20 NMAC 4.1), the federal Resource Conservation and Recovery Act (RCRA), and a NMED compliance order. The entire waste pile, including hazardous and nonhazardous waste and soil, will be removed to achieve closure. Excavation of the waste will be performed with heavy equipment including a backhoe, front-end loader, and dump trucks.

Phase I sampling will be conducted during removal of the waste pile to characterize the waste for appropriate disposal. As sections of the pile are removed, the waste will be treated or disposed of within 90 days from excavation. For safety reasons, the debris will be decontaminated using steam, hot water, or other substances such as ammonium sulfate. If HE materials cannot be effectively removed from the debris, the debris will be flashed at the TA-16 burn pad. After decontamination and/or flashing, most

of the debris is expected to be designated as nonhazardous. Soil, decontamination wastes (i.e., liquids and sludges), or free liquids (i.e., those liquids found in pockets in the waste pile) that contain HE materials or exceed the regulatory levels for toxic metals (e.g., barium, chromium, and lead) will be treated on-site if a permit modification for the existing RCRA permit is approved by NMED.

After the waste pile has been removed, remaining soil and tuff may be left in place if Phase 2 sampling determines that contamination is below allowable levels and if NMED approves the action. At this point, it is unclear if waste contaminants have migrated into the upper vadose zone. After the waste materials have been removed and decontaminated, the underlying soil will be over-excavated by approximately 0.6 m (2 ft). Following over-excavation, Phase 2 sampling of the upper vadose will be conducted at a depth of 0–15 cm (0–6 in.) and 15–30 cm (6–12 in.) below the post-excavation grade to assess whether contaminant migration has occurred. Based upon upper vadose zone sampling, the closure may be certified as complete or additional waste may be removed.

III. VEGETATION OF THE VICINITY

Located in a semiarid environment, New Mexico is characterized by plant communities ranging from Chihuahuan desert scrub to alpine tundra (Brown 1980). North-central New Mexico contains a variety of vegetative complexes that are directly influenced by the wide range of elevation zones. Upland (nonriparian) mountainous areas contain two climatic zones consisting of three plant communities: the Rocky Mountain Subalpine Conifer Forest and Woodland, the Rocky Mountain Montane Conifer Forest, and the Great Basin Conifer Woodland (Brown 1980). Lower elevations encompass two grassland climatic zones, which contain at least three different upland communities: the Plains Grassland, the Great Basin Shrub Grassland, and the Rocky Mountain Montane Grassland.

In addition to the upland communities, numerous wetland (riparian) plant communities occur in association with most of the previously mentioned uplands. Due to the large number of wetland communities, a more general description of the climatic zones in which these communities are located, is given. These wetland communities are located within five different climatic zones and include the Cold Temperate Swamp and Riparian

Forest, the Arctic-Boreal Swamp-Scrub, the Arctic-Boreal Marshland, the Arctic-Boreal Strand (streams, lakes), and the Cold Temperate Strand (streams, lakes).

The Rio Grande floodplain contains the lowest elevations in or near Los Alamos County and is characterized by a Plains and Great Basin Riparian-Deciduous Forest with cottonwood and willow within its boundaries. Salt cedar (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*), both introduced species, are also present. Juniper (*Juniperus* spp.) and piñon pine (*Pinus edulis*) are the typical upland overstory species at elevations ranging from about 1,705–1,890 m (5,600–6,200 ft). Both of these species are typical of the Great Basin Conifer Woodland; and both are also common at higher elevations (1,890–2,105 m or 6,200–6,900 ft) where they occupy large areas on the mesa tops. In the western portion of Los Alamos County, the woodland community intergrades with species of the Rocky Mountain Montane Conifer Forest. Ponderosa pine (*Pinus ponderosa*) is a common species at about 2,105–2,285 m (6,900–7,500 ft) on the higher mesa tops and along many of the north-facing canyon slopes. White fir (*Abies concolor*) also occurs along the higher north-facing slopes intermixing with ponderosa pine in a mixed-conifer community. Species of the Rocky Mountain Subalpine Conifer Forest and Woodland occur along the extreme western edge of the county and are more prevalent in higher elevations of the nearby Jemez Mountains.

Most streams within Los Alamos County are ephemeral (flowing only during and shortly after precipitation and runoff events). However, permanent flow from springs and LANL facility discharges create a small number of perennial or near-perennial stream flows within short stretches of certain canyons. Many of these streams and other wetlands are characterized by vegetation of the Rocky Mountain Riparian Deciduous Forest and the Plains Interior Marshland.

IV. WILDLIFE OF THE VICINITY

The wide range of plant communities in the Los Alamos County area contain a correspondingly wide range of micro- and macrohabitats. This diversity of habitat results in a relatively wide diversity of wildlife species, including both invertebrates and vertebrates.

4.1 Invertebrates

Numerous surveys for terrestrial and aquatic invertebrates have been conducted at LANL and Bandelier National Monument. However, the results from these surveys are restricted to localized areas and are limited in regional application. Members of the Biology Team have found 4 genera of aquatic mollusks and 15 genera of terrestrial mollusks on LANL property. Researchers have found 216 genera of aquatic insects and 20 other aquatic non-insects taxa in the waterways on and adjacent to LANL property (Appendix A). At least 89 families of terrestrial insects and 45 families of terrestrial non-insect arthropods have been identified on the Laboratory property.

4.2 Fish

Due to the ephemeral nature of the waterways, no fish have been found on Laboratory property. Fish have been observed in nearby Guaje Canyon, Los Alamos Canyon on U.S. Forestry Service lands, and at the confluence of White Rock Canyon and the Rio Grande. A current U.S. Fish and Wildlife study will determine if fish can survive within LANL canyons, including Cañon de Valle and upper Pajarito Canyon.

4.3 Reptiles and Amphibians

A variety of reptiles are common throughout much of the county and include at least 14 species of skinks, lizards, and snakes. The presence of wetlands adds additional habitat for water-associated species. At least 7 species of amphibians are found in the county.

4.4 Birds

Birds are the most diverse group of wildlife found in the area due in part to the wide range of habitats. This group includes a variety of nesting and migrating raptors that occupy some of the relatively undisturbed areas and the steeper canyon walls. Over 200 bird species have been recorded in Los Alamos County, including at least 112 species of breeding birds (Travis 1992), most of them migratory summer residents.

4.5 Mammals

At least 29 species of small ground-dwelling mammals (i.e., mice, wood rats, voles, squirrels, chipmunks) occur in the area, some of which are specific to particular elevation ranges. Deer mice (*Peromyscus* spp.), wood rats (*Neotoma mexicana*), and

least chipmunks (*Tamias minimus*) inhabit most areas of the region. Piñon mice (*Peromyscus truei*) are found primarily in piñon-juniper woodlands; the red-backed vole (*Clethrionomys californicus*) occurs in the higher elevations; the western harvest mouse (*Reithrondontomys megalotis*) and long-tailed voles (*Microtus longicaudus*) are found in moist canyon bottoms; and shrews (*Sorex* spp.) occur near flowing water. Thirteen species of bats have been recorded within LANL boundaries.

The most commonly seen large mammals in Los Alamos County are mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*). These species generally winter in the lower elevations of the Pajarito Plateau, including mesas and canyons along the central and eastern portions of the county and surrounding areas, and spend their summers at higher elevations of the Jemez Mountains. However, recent surveys in the Los Alamos County area indicate growing population numbers of these species residing year-round at lower elevations. Little population data is available for the other large and medium size mammals of the area, but also present are at least 12 species of carnivores, including mountain lion (*Felis concolor*), bobcat (*Lynx rufus*), fox (*Vulpes vulpes*), and coyote (*Canis latrans*).

V. THREATENED AND ENDANGERED SPECIES

As of this writing (September 1997), the U.S. Fish and Wildlife Service (USFWS) lists 7 federal threatened and endangered (T&E) animals and no T&E plants as occurring in or potentially occurring in Los Alamos County. The potential occurrences are based on preferred habitats of the species and the presence of those habitats within or near Los Alamos County. Table 1 lists all T&E wildlife species occurring or potentially occurring in the County, their listing status, and their preferred habitat. Due to previous disturbance, the MDA-P site does not contain potential habitat for many T&E species that may occur in the general vicinity.

The stream in upper Cañon de Valle may provide suitable riparian habitat for a New Mexico-endangered plant, the wood lily (*Lilium philadelphicum* var. *andium*). This plant is protected by the New Mexico Endangered Plant Species Act. The plant occurs in upland riparian areas, and upper Cañon de Valle may provide suitable habitat. The Biology Team will conduct species-specific surveys for wood lilies in Cañon de Valle during each

Table 1. USFWS T&E Species List for Los Alamos County.

Common Name	Scientific Name	Status*	Habitat Description
Black-footed ferret	*Mustela nigripes*	E	Prairies, usually in prairie dog towns.
American peregrine falcon	*Falco peregrinus anatum*	E	Ponderosa and piñon; nests in cliffs and rock outcrops on cliffs, known to breed locally.
Arctic peregrine falcon	*Falco peregrinus tundrius*	T (S/A)	Nests in Alaska and northern Canada, migrates along coasts to southern U.S. and Mexico.
Bald eagle	*Haliaeetus leucocephalus*	T	Riparian areas, wetlands, and open water for wintering and migrating eagles.
Mexican spotted owl	*Strix occidentalis lucida*	T w/CH	Mixed conifer in uneven-aged and multistoried forests with closed canopies, mountains and canyons; known to breed locally.
Southwestern willow flycatcher	*Empidonax traillii extimus*	E w/PCH	Nesting habitat includes shrubs and trees in willow thickets, shrubby mountain meadows, and deciduous woodlands along streams, lakes, and bogs.
Whooping crane	*Grus americana*	E	Nests in Canada, winters along Rio Grande where it roosts near water.

* Status Index

E	=	Endangered
PE	=	Proposed endangered
T	=	Threatened
PCH	=	Proposed critical habitat
PT	=	Proposed threatened
PT w/CH	=	Proposed threatened with critical habitat
S/A	=	Similarity of appearance

year of the project. These surveys would preferably be conducted during July, when the plant is in flower and is easiest to identify. The Biology Team searched the Cañon de Valle streamside below the MDA-P project area for wood lilies on 5 August 1997 and found none. If any wood lilies are located in the area, suitable protective measures will be developed to ensure that project operations do not threaten the plant or its habitat.

The project area may also contain foraging and/or nesting habitat for a federal-threatened raptor, the Mexican spotted owl, protected by the 1973 Federal Endangered Species Act. Mexican spotted owls are known to nest and successfully fledge chicks in the general vicinity of MDA-P. The presence of Mexican spotted owls within the immediate vicinity of the project area must be assumed unless annual surveys are conducted to establish their absence. Nesting is the most sensitive period for the spotted owl, and this extends from March 1 to September 1 in New Mexico. If these raptors are found to be nesting within 0.46 km (0.25 mi) of the MDA-P site, heavy equipment use will be restricted during the nesting period.

David Keller is a LANL staff biologist with ESH-20, a certified Mexican spotted owl expert, and a holder of a current U.S. Fish and Wildlife permit to survey Mexican spotted owls. Species-specific surveys are conducted within all areas of potential habitat. A walking route is planned to survey all available habitat within 0.8 km (0.5 mi) of the route. Recorded spotted owl calls are played at intervals from approximately 2:00 AM until sunrise. During the breeding season, male owls become very territorial and should respond to the call if they are present. The surveyor waits for a response after the call is played at an appropriate volume level. If a Mexican spotted owl does respond, intensive nest surveys are initiated.

In 1995, Keller found a pair of nesting Mexican spotted owls within 3.2 km (2.0 mi) of the MDA-P site. Keller conducted owl surveys during the early springs of 1996 and 1997 within the general MDA-P project area. He found that the nest site was occupied and successfully fledged chicks all 3 years. The nest was farther than 1.6 km (1 mi) from the project area, although the owls may forage nearby. These owls are very territorial, and the presence of an owl so close to the MDA-P site eliminates the possibility of a different pair nesting in the same vicinity. Work practices to minimize potential disturbance to

Mexican spotted owls are discussed in the "Best Management Practices" section of this report.

VI. WATER QUALITY AND AQUATIC INVERTEBRATES

6.1 Introduction

To establish baseline conditions, the Biology Team characterized the Cañon de Valle stream prior to site remediation. This effort will document the condition of the stream before excavation is initiated and will provide a basis of comparison for evaluating water quality during and after clean closure activities. We will monitor potential impacts to the stream from contaminants, sediment loading, and chemical changes by determining the composition of the resident aquatic invertebrate community. Unlike chemical testing, the use of biological indicator species provides detection of stream disturbances that occurred much earlier than the sampling date.

6.1.1 Water Quality Concerns

The MDA-P waste pile covers a steep slope immediately above a spring-fed stream flowing through Cañon de Valle, and clean-up activities pose an extremely high potential for erosion. Special precautions discussed in the "Best Management Practices" section of this report must be closely followed to ensure that disturbed debris and/or contaminants do not tumble or migrate into the stream. Sampling of the stream is necessary to ensure and document compliance with the New Mexico Standards for Interstate and Intrastate Streams (State of New Mexico 1995).

6.1.2 Physical and Chemical Parameters

In a report for the Bureau of Reclamation (Battelle 1972), Battelle Columbus Laboratories outlined a comprehensive and interdisciplinary Environmental Evaluation System (EES). This EES uses physical, chemical, and biological parameters to assess possible environmental impacts of water resource projects. To accurately evaluate water quality parameters, this report refers to many of the environmental quality ratings developed by Battelle. The Biology Team measured water temperature, dissolved oxygen, pH, and conductivity at each sampling site when an aquatic invertebrate sample was collected.

Water temperature directly influences aquatic organisms' physiological functions such as metabolism, growth, emergence, and reproduction (Wallace and Anderson 1996). Temperature is inversely related to oxygen solubility because water absorbs greater amounts of oxygen at lower temperatures. While aquatic organisms can tolerate wide fluctuations in pH and conductivity, a change in water temperature of a single degree Celsius can be significant (Lehmkuhl 1979).

Depressed oxygen environments often indicate the presence of organic wastes. The amount of dissolved oxygen (DO) in water has direct and immediate effect on invertebrates using tracheal gills for respiration (such as the larvae of dragonflies, mayflies, caddisflies, and stoneflies). Oxygen is present in air at levels greater than 200,000 ppm, but its maximum value at saturation in water is only 15 ppm (Eriksen et al. 1996). Although aquatic insects require more oxygen for metabolism at elevated temperatures, less is available due to decreased solubility (Gaufin et al. 1974). Certain stages in the life cycle of aquatic invertebrates, such as emergence, will not occur unless sufficient oxygen is present (Bell 1971). Cold-water mayflies and stoneflies cannot tolerate DO concentrations much below 5 mg/l (Nebeker 1972). Since oxygen absorption in water is temperature dependent, a useful means of viewing DO concentration is the percent DO saturation present in the sample.

Acidic waters are characterized by low species diversity and low productivity. Acidity and basicity of water are measured by the logarithmic pH scale, with low standard unit (su) values (0–6) indicating acidity, middle values (around 7) indicating neutrality, and high values (8–14) indicating basicity. Some aquatic organisms, such as mayflies, are extremely sensitive to low pH, which can be caused by accidental acid spills or acid rain deposition. The normal pH of natural surface waters in the United States ranges from 6.5 to 9.0 (Canter and Hill 1979).

Conductivity measures the ability of water to carry an electrical current, and it reflects the concentrations of ionized substance in water. The conductivity of potable water in the United States ranges from 50 to 1,500 micro-mhos per centimeter (μmhos/cm), and the conductivity of industrial waste may be as high as 10,000 μmhos/cm.

A rough approximation of the total dissolved solids of freshwater in mg/l is obtained by multiplying the conductivity in µmhos/cm by 0.66.

6.1.3 Aquatic Invertebrates

Aquatic macroinvertebrates (water-dwelling invertebrates visible to the unaided eye) are extensively utilized as water quality indicators. This report uses the terms macroinvertebrate, aquatic macroinvertebrate, invertebrate, and aquatic invertebrate interchangeably. These organisms, especially the stream-dwelling insects, are well suited as water quality indicators due to their

- small size and total immersion in the aquatic environment;
- relatively sedentary nature;
- abundance in virtually all streams;
- range of sensitivities to stress and contaminants;
- life cycles, which are frequently at least one-year in duration, allowing long-term detection of past disturbance; and
- relative ease of collection and identification to family or genus level.

In general, monitoring only the physical and chemical characteristics of waters provides little information of conditions prior to the sampling date. In contrast, changes in macroinvertebrate communities indicate water quality over a much longer period (Rosenberg et al. 1986). Failure of chemical criteria to protect aquatic life has necessitated the incorporation of biological criteria into water resource management planning (Karr 1991). Shifts in the numbers of individuals and community species composition indicate disturbance to the stream environment. These disturbances could result from infrequent discharges of waste that might remain undetected through a water quality monitoring program that did not incorporate biological data (Weber 1973).

Biological assessments facilitate the comprehension of ecosystem processes and health, allowing management to make informed decisions and to take appropriate actions (ITFMWQ 1994). According to the Intergovernmental Task Force on Monitoring Water Quality (1992), objectives of an aquatic biological monitoring program should include

- defining status and trends,
- identifying existing and emerging problems,

- providing information to support development and implementation of policies and programs for water-resource management,
- evaluation of program effectiveness, and
- response to emergencies.

6.2 Sampling Sites and Methodology

6.2.1 Sampling Sites

The Cañon de Valle stream is fed by springs approximately 0.4 km (0.25 mi) to the west of the MDA-P project site. Stream flow is augmented by precipitation and runoff from the surrounding hillsides and mesa tops. The Biology Team desired to sample the Cañon de Valle waterway upstream and downstream from the project site to determine if project work impaired water quality. However, it is not possible to collect aquatic invertebrates with a Surber sampler from the upstream reach in Cañon de Valle because the stream has poorly defined banks as it flows through a grassy meadow. It was decided to collect invertebrates and water quality parameters immediately downstream from MDA-P and to compare these measurements with those taken at a similar site in nearby Starmer's Gulch (Fig. 7). At all locations, macroinvertebrate samples were collected at riffle areas, which provide the best available habitat. Water quality parameters were measured concurrently with invertebrate collections.

The MDA-P sample site is located within the Cañon de Valle stream, approximately 43 m (140 ft) downstream from the northeast corner of a fence surrounding the project area. This site has a relatively consistent flow although a severe drought throughout northern New Mexico precluded sample collection throughout most of the summer of 1996. During 1995 and 1996, flow measurements taken and estimations made by members of the NMED averaged 36 gallons/min (gpm) for the Cañon de Valle stream near MDA-P. The estimated base flow is 0.023 ft^3/sec at upper Cañon de Valle. The collection area is partially shaded by a southern hillside and coniferous trees. Dominant overstory trees in the immediate area include white fir, ponderosa pine, Douglas-fir (*Pseudotsuga menziesii*), and gambel oak (*Quercus gambelii*). Fine sediments of sand and small gravel are carried into the sampling site from the upstream grassy meadow, and

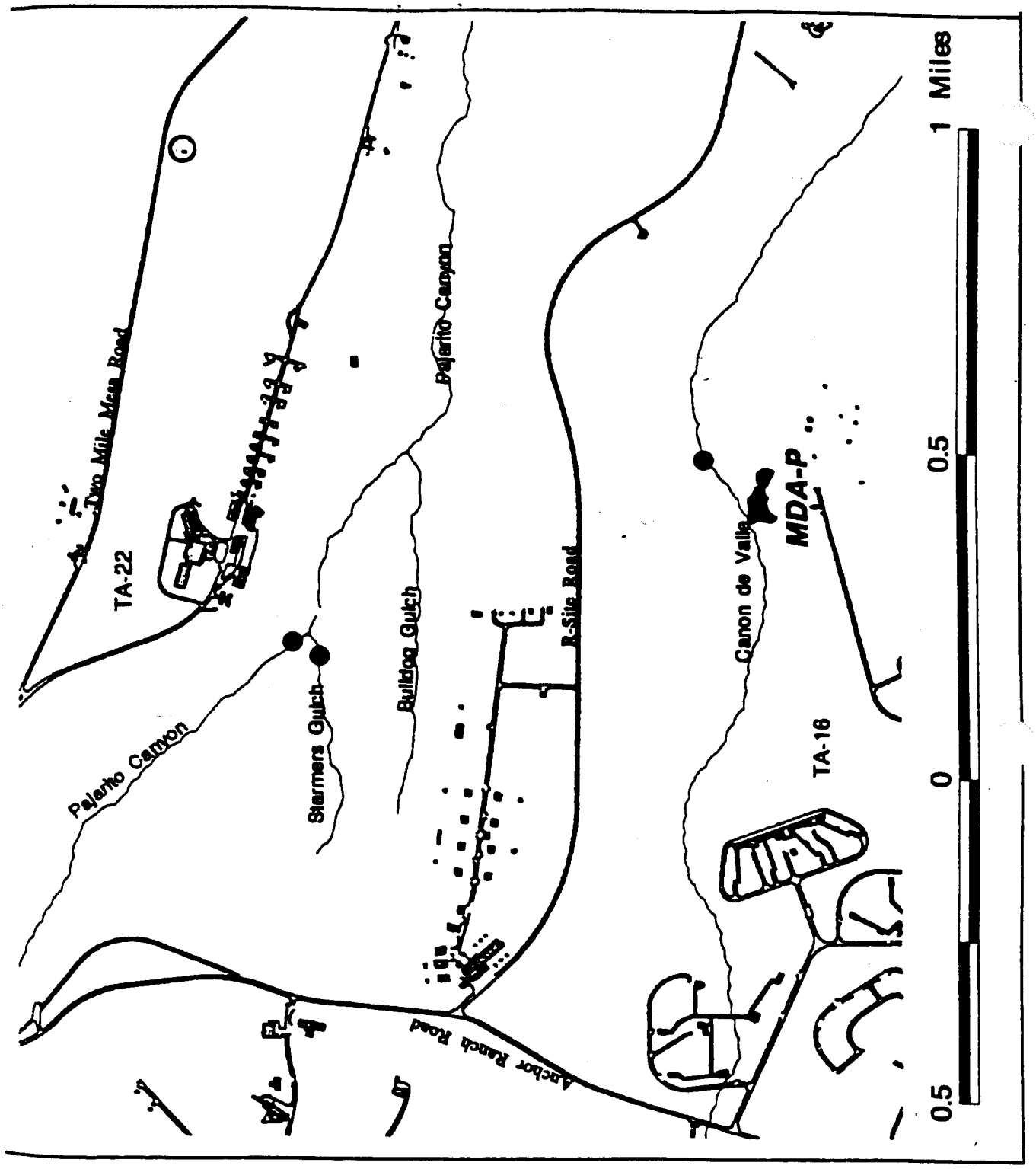

Fig. 7. Locations of the aquatic invertebrate sampling stations.

these limit available invertebrate habitat. Occasional stacked rocks within the stream provide some good habitat for a variety of invertebrates. Starmer's Gulch is a perennial tributary of upper Pajarito Canyon within TA-22. The Biology Team sampled the stream approximately 15 m (50 ft) upstream from its confluence with Pajarito Canyon. Flow measurements and estimations made by members of NMED during 1994 and 1995 averaged 140 gpm for Starmer's Gulch. The estimated base flow is 0.04 ft^3/sec at Starmer's Gulch. This site is shaded by a large rock wall to the south and is bordered by a small grassy expanse to the north. The upstream overstory consists of the same species found in Cañon de Valle, but tree cover is much denser along the stream at Starmer's Gulch. At times, Starmer's is heavily sedimented, but it usually provides good quality aquatic habitat. Personnel from the NMED have suggested that Starmer's Gulch be used as an aquatic reference site for the Laboratory.

6.2.2 Habitat Assessment

The US EPA (Environmental Protection Agency) has developed a series of measures to assess the quality of aquatic habitat in stream riffle and run areas (Plafkin et al. 1989). These parameters assess conditions at specific sampling sites and along larger stream reaches. The habitat parameters are divided into three groups:

- primary — #1 bottom substrate instream cover, #2 embeddedness, and #3 canopy cover (shading);
- secondary — #4 channel alteration, #5 bottom scouring and deposition, and #6 pool riffle and run ratio;
- tertiary — #7 upper bank stability, #8 bank vegetative protection, and # 9 streamside cover.

The groups are scored so that primary parameters receive the greatest weight and tertiary parameters the least. Each parameter is assigned a score from a table of values, with higher scores reflecting higher quality habitat. The scores are then summed to yield an overall numerical habitat assessment score, and the highest possible total score is 135. The sum is not intended to directly translate into narrative categories of habitat quality. Instead, the score provides a means of combining several habitat parameters into a single value that provides a basis of comparison to evaluate stream habitat.

EPA recommends that a single individual perform all comparative habitat assessments to standardize any prejudices and/or preferences that may influence the scoring. I, therefore, personally conducted all habitat assessments in both canyons.

6.2.3 Water Quality Parameters

The Biology Team measured the water temperature, pH, DO, and conductivity in upper Cañon de Valle and Starmer's Gulch. All measurements were taken with instruments in accordance with all provided manufacturer's specifications. Each instrument was calibrated on the same day that it was used in the field. All measurements were taken three times, and the average value was used in computations.

All pH measurements were taken with an Orion model 230A pH meter or an Oakton pH/mV/°C meter. Temperature measurements were taken with a Yellow Springs Instrument model 57 DO meter in degrees Celsius. DO was measured with the same Yellow Springs Instrument model 57. The DO meter was calibrated by multiplying the reading by a factor of 0.78 to compensate for the elevation. Conductivity measurements were taken with a Van Waters Rogers digital conductivity meter which displays conductivity in units of μmhos/cm. Total dissolved solids were estimated by multiplying the conductivity readings by 0.66 (Battelle 1972).

6.2.4 Aquatic Macroinvertebrate Sampling

Aquatic macroinvertebrates were collected seasonally at the same time that water quality parameters were measured. Most samples were collected in spring, summer, and fall because snowpack limits access to the canyons during winter. The Biology Team used a 0.09-m^2 (1- ft^2) Surber sampler to collect macroinvertebrates because it allows density calculations. The sampler consists of a square metal frame that supports two side-flaps with a conical net between them. The frame was positioned firmly against the substrate in a riffle area that was subjectively judged to provide the best available habitat in the vicinity. The net trailed downstream and captured dislodged invertebrates that the current swept into it. Large rocks within the metal frame were shaken and then scrubbed with a brush to remove clinging macroinvertebrates. The substrate was agitated to a depth of several inches so that burrowing invertebrates would also be collected.

All captured aquatic invertebrates were placed in labeled Nalgene bottles containing 70% ethanol. Collection data were logged into the Biology Team Aquatic Data Book upon return to the invertebrate lab. Trained sorters separated invertebrates from associated debris, placing the collected invertebrates in labeled scintillation vials containing 70% ethanol to await identification. Macroinvertebrates were identified by Saul Cross and Dan McGuire, an expert in the Chironomidae (midge) family and non-insect aquatic invertebrates.

Organisms were identified with an American Optics Stereo-star-zoom dissecting microscope and an American Optics Model 150 compound microscope for slide samples. Identification of specimens was accomplished using taxonomic references for North American macroinvertebrates including Baumann et al. 1977, Edmunds et al. 1976, Merritt and Cummins 1996, Thorpe and Covich 1991, and Wiggins 1978. Organisms were identified to species- or genus-level when possible and archived in the permanent Biology Team invertebrate collection.

6.2.5 Aquatic Macroinvertebrate Analysis

Many early water quality investigators compiled extensive indicator lists to measure species-specific tolerances to pollution. This method is prone to erroneous interpretations since species-level identification is difficult to ascertain, tolerances of some species vary greatly under different environmental conditions, and "intolerant" species may occur in polluted waters due to drift, i.e. transport by water currents.

More recent studies have emphasized the importance of community structure in evaluating water quality (Hilsenhoff 1977; Schwenneker and Hellenthal 1984; Rosenberg and Resh 1993). Diversity indices have been developed to allow numerical comparisons of entire macroinvertebrate communities. Unpolluted environments have higher taxa diversity index values than polluted environments, which tend to be dominated by a relatively few tolerant species.

6.2.5.1 Rapid Bioassessment Protocols. The U.S. EPA published the *Rapid Bioassessment Protocols for Use in Streams and Rivers* (Plafkin et al. 1989) to standardize biological aquatic sampling methodologies. These nationally-used protocols are a series of integrated analytical measures or "metrics" for utilizing

macroinvertebrate data to assess the degree of stream impact. This multimetric approach measures a variety of parameters to provide an overall evaluation of community health. A primary goal of the Rapid Bioassessment Protocols (RBPs) is to allow nationwide comparisons of streams and stream conditions. In 1996, 42 states used multiple metric assessments to evaluate water quality, and 6 other states were in the process of developing similar protocols (Davis et al. 1996).

Rapid assessment approaches differ from traditional scientific studies in that they compare summations of multimetrics to predetermined thresholds rather than relying on statistical comparisons of individual measures (Resh et al. 1995). This study uses the RBP III metrics, which require genus-level identifications for most specimens. Seven quantitative metrics of the aquatic environment were computed and analyzed. In all metrics except "percent contribution of dominant taxon," the study site (Cañon de Valle) is compared to a reference site (Starmer's Gulch). The *Rapid Bioassessment Protocols for Use in Streams and Rivers* emphasizes that these measures may require modification for use in a particular area; and the current study modified Metric 2. A brief explanation of the RBP III metrics follows:

Metric 1: Taxa Richness

This metric reflects the health of the community by measuring the numbers of taxa, or distinctly different types of invertebrates, present. Taxa richness generally increases with improving water quality, habitat diversity, and/or habitat suitability. The Biology Team attempted to ensure that taxa were not counted twice; and if a counting error occurred, it was due to under-counting rather than over-counting. Therefore, we counted only one taxon in a sample for the following cases:

- different life stages of a taxon present,
- specimen(s) keyed to the family level and another specimen(s) in the same family identified to a lower level, and
- possible different instars of a genus assigned separate descriptive, rather than taxonomic, identifications.

Metric 2: Modified Hilsenhoff Biotic Index (Community Tolerance Quotient)

The Hilsenhoff biotic index (HBI) was developed for higher-order streams of Wisconsin and may have little applicability to first-order streams of New Mexico. Hilsenhoff's tolerance values range from 0 to 10, increasing as water quality decreases. The formula for the index is

$$HBI = \Sigma(xt)/n,$$

where x = number of individuals within a species,
t = tolerance value of a taxon (found in a published table of values), and
n = total number of organisms in the sample.

Instead of using the HBI, we included a community tolerance quotient (CTQ), which was developed to assess the impacts of nonpoint source pollution in the western United States (Winget and Mangum 1979). This system has been previously used to effectively evaluate stream quality in the Jemez Mountains (Jacobi 1989, 1990, and 1992; Cross 1994, 1995a, and 1995b). Tolerance quotients (TQs) for aquatic macroinvertebrate taxa range from 6 (the most stress sensitive) to 108 (the least stress sensitive) and are based upon tolerances to alkalinity, sulfates, and sedimentation. The CTQ is computed using the HBI formula with Winget and Mangum's list of tolerances. The scoring criteria developed for the HBI are then used to assign a biological condition score. The mayfly genus *Baetis* is assigned a tolerance quotient of 72, which is deemed too low a score for the members of that genus found in the vicinity of Los Alamos. Instead of recording values believed to be inaccurate, members of *Baetis* were rejected from the computation of all CTQs.

Metric 3: Ratio of Scrapers to Filtering Collectors

When feeding, aquatic insects select organic particles primarily due to particle size rather than their origin. Thus, the familiar trophic (feeding) categories of herbivore, carnivore, and omnivore have little application in aquatic macroinvertebrate studies. To better describe the trophic relations of aquatic insects, a series of functional feeding groups, or trophic categories, has been developed (Cummins and Merritt 1996). These categories are determined by feeding mechanism (Table 2).

Table 2. Aquatic Insect Functional Feeding Groups.

Functional Group	Dominant Food
Filtering collectors	Water-borne fine particulate organic matter
Gathering collectors	Sedimentary fine particulate organic matter
Shredders	Coarse particulate organic matter
Scrapers	Attached algae and associated material
Predators	Engulfers or piercers feeding on living animal tissue

The proportion of these feeding groups is important because predominance of a particular feeding type may indicate an unbalanced community responding to an overabundance of a particular food source. Scrapers increase with increased diatom abundance and decrease as filamentous algae and aquatic mosses increase. However, filamentous algae and aquatic mosses provide good attachment sites for filtering collectors. In addition, the organic enrichment often responsible for overabundance of filamentous algae provides fine particulate organic matter used by the filterers. Therefore, sites subjected to organic pollutants have lower Metric 3 values than undisturbed sites.

Metric 4: Ratio of EPT to EPT + Chironomidae Abundances

The Ephemeroptera, Plecoptera, Trichoptera (EPT) and Chironomidae abundance ratio uses relative abundance of these indicator groups as a measure of community balance. Skewed populations with a disproportionate number of the generally tolerant Chironomidae relative to the more sensitive EPT groups may indicate environmental stress.

Metric 5: Percent Contribution of Dominant Taxon

This metric is a good measure of community balance. A community dominated by a relatively few species usually indicates environmental stress. Habitat requirements of the dominant taxon may indicate specific conditions within the stream reach.

Metric 6: EPT Index

The EPT Index is the total number of distinct taxa within the pollution-intolerant EPT orders. This metric summarizes taxa richness within the insect orders that are generally considered to be pollution sensitive. The index value generally increases with increasing water quality.

Metric 7: Community Loss Index

The Community Loss Index (CLI) measures the loss of benthic species between a reference station and a study station. Plafkin (1989) offers three methods of computing community dissimilarity. Based on previous data analysis, the CLI (Courtemanch and Davies 1987) provided greater discrimination between sites than Jaccard's Coefficient of Community (Jaccard 1912, Boesch 1977) or the Index of Similarity (Klemm et al. 1990). The CLI is calculated as follows:

$$CLI = (d-a)/e,$$

where a = number of taxa common to both samples,
d = total number of taxa present at reference station, and
e = total number of taxa present at study station.

Biological Condition Score

Each metric is calculated independently of the others. In most cases, the computed value for the study site is divided by the computed value for the reference site to yield a percent similarity value. This percent value is assigned a biological condition score of either 0, 2, 4, or 6 from a reference chart that evaluates each metric separately. The biological condition score assesses the degree of community impairment. A score of 6 signifies no impairment, while a score of 0 signifies severe impairment.

The biological condition scores from all metrics are totaled and compared to the total possible. Study site totals are compared to reference site totals to provide an overall bioassessment of the study site (Table 3). In order to provide more general comparisons and conclusions, we also reported averages of the biological condition totals.

6.2.5.2 Other Measures of Macroinvertebrate Communities. In addition to computation of the 7 RBP metrics, the Biology Team included 3 other standard measures of aquatic communities:

Standing Crop

Standing crop is a measure of macroinvertebrate density expressed as the number of macroinvertebrates/m^2. The use of a Surber sampler, a quantitative sampling device, permits accurate density computations:

$$\text{individuals/ft}^2 \times 10.76\ \text{m}^2/\text{ft}^2 = \text{individuals/m}^2.$$

Table 3. Interpretative Chart for Total Biological Condition Scores and Associated Impairment Categories (Plafkin et al. 1989).

Percentage Comparison to Reference Score	Biological Condition Category	Attributes
>83%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.
54–79%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
21–50%	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<17%	Severely impaired	Few species present. If high densities of organisms, then domination by 1 or 2 taxa.

Biodiversity Index

A biodiversity index was calculated for each station using the equation discussed by Wilhm (1967):

$$D = (S-1)/\ln N,$$

where D = the taxa diversity index,
S = the number of taxa, and
N = the number of individuals.

Despite the simplicity of Wilhm's equation, this diversity index usually provides an accurate measure of a site's taxa richness (number of taxa present) and evenness (distribution of individuals in differing taxa). A diversity index less than 1 usually indicates heavy pollution, between 1 and 3 usually indicates moderate pollution, and greater than 3 usually indicates clean water. However, biodiversity values for low-order montane streams are notoriously low and should not be compared to higher-order or lower elevation streams.

Community Functional Feeding Group Compositions

Several RBP metrics require analysis of functional feeding groups. This classification of feeding groups distinguishes aquatic insect taxa performing different functions within aquatic ecosystems with respect to processing nutritional resource

categories. Populations are regulated in part by interactions between habitat and food suitability and availability. An undisturbed aquatic ecosystem would be expected to support diverse functional feeding groups, which allow aquatic insects to utilize a variety of nutritional sources. Some taxa have more than one feeding group, reflecting diversity of species or feeding behaviors within the taxon. Only primary functional feeding groups were used to determine community percent compositions

6.3 Water Quality Sampling Results

6.3.1 Habitat Assessment

In 1997, habitat assessments for riffle and run stream areas were conducted in Cañon de Valle and Starmer's Gulch at the aquatic invertebrate sampling sites (Table 4). The habitat was assessed at both locations each time that aquatic invertebrates were collected during 1997. The aquatic habitat at Cañon de Valle had only 82% of the quality found at Starmer's Gulch. The greatest differences occurred in bottom substrate instream cover, embeddedness, bottom scouring and deposition, and pool riffle to run ratios.

6.3.2 Physical and Chemical Parameters

The physical and chemical parameter measurements and averages from Cañon de Valle and Starmer's Gulch are presented in Table 5. These are compared to values published in the most recent New Mexico water quality standards (State of New Mexico 1995). The applicable use standards for these stream reaches have not yet been defined, but comparisons are made to those of high-quality cold-water fisheries, the strictest nonpotable water standards. A cold-water fishery is defined as "a stream reach, lake, or impoundment where the water temperature and other characteristics are suitable for the support or propagation or both of cold-water fishes such as but not limited to longnose dace, roundtail chub, Rio Grande chub, Rio Grande sucker, brown, Gila, cutthroat (including the native Rio Grande cutthroat), brook or rainbow trout, or speckled dace" (State of New Mexico 1995). It should be noted that specific water chemistry tests may reveal the presence of contaminants believed to be in the area that could negatively impact the stream biota.

6.3.2.1 Water Temperature. State standards for high-quality cold-water fisheries state that water temperature shall not exceed 20°C (69°F). No water temperature measurements

Table 4. Habitat Assessment Scores.

Stream Canyon	Sampling Date	Habitat Parameter*									
		1	2	3	4	5	6	7	8	9	Total
Cañon de Valle	17 March 1997	13	11	16	3	4	9	8	9	8	81
Cañon de Valle	13 June 1997	10	10	16	6	5	7	7	8	8	77
Cañon de Valle	6 Aug 1997	9	11	16	6	5	7	8	9	8	79
Cañon de Valle	**Average**	**11**	**11**	**16**	**5**	**5**	**8**	**8**	**9**	**8**	**79**
Starmer's Gulch	17 March 1997	11	10	16	4	7	10	9	10	8	85
Starmer's Gulch	12 June 1997	17	14	16	10	7	10	9	7	8	98
Starmer's Gulch	6 Aug 1997	16	17	17	7	9	12	9	9	8	104
Starmer's Gulch	**Average**	**15**	**14**	**16**	**7**	**8**	**11**	**9**	**9**	**8**	**96**

* see Section 6.2.2 for a listing of each habitat parameter by number

Table 5. Physical and Chemical Water Quality Measurements.

Site	Date	Water temp (°C)	pH (su) *	DO (mg/l)	DO (saturation)	Conductivity (µmho/cm)
Cañon de Valle	March 1995	7.5	NA	9.62	80.2	248
Cañon de Valle	Feb 1996	0.8	7.2	9.63	67.7	255
Cañon de Valle	Aug 1996	16.2	8.1	7.66	77.6	225
Cañon de Valle	March 1997	5.6	7.85	9.85	78.1	232
Cañon de Valle	June 1997	15.9	7.9	7.45	75.5	193
Cañon de Valle	Aug 1997	16.8	7.9	7.48	77.4	218
Cañon de Valle	**Average**	**10.5**	**7.8**	**8.62**	**77.2**	**228.5**
Starmer's Gulch	June 1995	10.9	7.3	8.70	78.9	186
Starmer's Gulch	Feb 1996	3.2	7.2	9.89	73.5	203
Starmer's Gulch	Aug 1996	11.5	8.6	8.93	81.9	167
Starmer's Gulch	March 1997	8.1	7.5	9.55	80.6	197
Starmer's Gulch	June 1997	10.2	7.6	7.97	70.6	132
Starmer's Gulch	Aug 1997	11.0	8.1	10.70	97.0	143
Starmer's Gulch	**Average**	**9.15**	**7.7**	**9.29**	**80.4**	**171**

* = standard unit

exceeded the maximum value. The highest recorded water temperature of 16.8°C° (62.2°F) occurred at Cañon de Valle in August 1997. The range of recorded temperatures was greater at Cañon de Valle (16.0°C or 60.8°F) than at Starmer's Gulch (8.3°C or 46.9°F), probably due to its lower flow rates and relative lack of protective plant cover upstream. In the colder months (March 1995, February 1996, and March 1997), water temperatures were always colder at Cañon de Valle and averaged 2.8°C (5.9°F) lower than at Starmer's Gulch. In the warmer months (August 1996, June 1997, and August 1997),

water temperatures were always warmer at Cañon de Valle and averaged 5.4°C (11.4°F) higher than at Starmer's Gulch.

6.3.2.2 pH. The pH range for high-quality cold-water fisheries is between 6.6 and 8.8 su. All measurements taken at Cañon de Valle and Starmer's Gulch were within the acceptable range. The highest recorded pH (8.6 su) occurred at Starmer's Gulch in August 1996. The lowest recorded pH (7.2 su) occurred at both sites in February 1996. Of the five sampling dates when pH was measured at both sites, it was highest at Cañon de Valle twice, highest at Starmer's Gulch twice, and equal at both sites once.

6.3.2.3 DO. State standards for high-quality cold-water fisheries state that DO shall not be less than 6.0 mg/l. None of the DO measurements were below this minimum value, and the lowest recorded DO (7.45 mg/l) occurred at Cañon de Valle in June 1997. The lowest percent DO saturation (67.7%) occurred at Cañon de Valle in February 1996, and the highest value (97.0%) occurred at Starmer's Gulch in August 1997. The averaged DO saturation percentages are higher than the averages recorded at high-quality sampling stations in Guaje Canyon during 1994 (Cross 1995b) and 1995 (Cross 1995b).

6.3.2.4 Conductivity. State standards for high-quality cold-water fisheries state that conductivity "shall not exceed a limit varying between 300 µmhos/cm and 1,500 µmhos/cm depending on the natural background in particular stream reaches (the intent of this standard is to prevent excessive increases in dissolved solids which would result in changes in stream community structure)" (State of New Mexico 1995). All conductivity measurements were less than the lowest acceptable maximum of 300 µohms/cm, and the highest recorded conductivity (255) occurred at Cañon de Valle in February 1996. Each month's conductivity readings were higher at Cañon de Valle than at Starmer's Gulch, but the average value was only 57.5 µmhos/cm higher.

6.3.3 Aquatic Macroinvertebrate Sampling Results and Analysis

Several attempts were made to collect aquatic invertebrates from Cañon de Valle during the summer of 1996, but a prolonged drought precluded Surber sample collection, which requires a 0.09-m^2 (1-ft^2) sample area. NMED personnel recommended that Starmer's Gulch be utilized as a reference site for comparable LANL waterways, and the RBP metrics were calculated by comparing Cañon de Valle to Starmer's Gulch.

In 1997, 13 new genera were collected at the sampling sites:

Ephemeroptera, Baetidae, *Centroptilum*;

Ephemeroptera, Leptophlebiidae, *Paraleptophlebia*;

Plecoptera, Chloroperlidae, *Suwallia*;

Plecoptera, Nemouridae, *Malenka*;

Plecoptera, Nemouridae, *Prostoia*;

Hemiptera, Gerridae, *Gerris*;

Trichoptera, Glossosomatidae, *Agapetus*;

Diptera, Chironomidae, *Corynoneura*;

Diptera, Chironomidae, *Paratendipes*;

Diptera, Chironomidae, *Zavrelimyia*;

Diptera, Psychodidae, *Maruina*;

Diptera, Tabanidae, *Chrysops*; and

Diptera, Tipulidae, *Tipula*.

The discovery of so many new taxa in these waters underscores the need for continued monitoring to fully describe the resident aquatic communities within Cañon de Valle and Starmer's Gulch.

6.3.3.1 Standing Crops and Taxa Collected. A total of 3,074 aquatic invertebrates of 73 different taxa (Appendix B) were collected, identified, and analyzed for this study. The greatest numbers of aquatic invertebrates were collected in Cañon de Valle (Table 6). Average densities of invertebrates/m^2 showed the same pattern with Starmer's Gulch having 2,203 and Cañon de Valle having 3,311. These densities are roughly comparable to those recorded during 1993-1995 in Guaje Canyon and upper Los Alamos Canyon, relatively undisturbed sites in the Santa Fe National Forest (Cross 1995b).

The mayfly *Baetis tricaudatus* was the dominant taxon in 6 of 12 samples. The dominant taxon for the February 1996 Cañon de Valle sample is listed as the Chironomid (midge) family rather than a single genus or genus and species. This family of true flies is very stress-tolerant, and its abundance may indicate prior disturbance to the stream. It is noteworthy that this February sample contained 11 genera of Chironomids, and if the

Table 6. Aquatic Invertebrate Population Measurements.

Site	Date	Number of Individuals	Number of Taxa	Wilhm's Biodiversity	Percentage Contribution of Dominant Taxon
Cañon de Valle	Oct 95	349	27	4.44	33.5% (*Baetis tricaudatus*)
Cañon de Valle	Feb 96	328	25	4.14	69.5% (Chironomidae)
Cañon de Valle	Aug 96	422	29	4.63	38.6% (*Amphinemura*)
Cañon de Valle	March 97	556	23	3.48	56.8% (*Simulium*)
Cañon de Valle	June 97	170	13	2.34	42.4% (*Simulium*)
Cañon de Valle	Aug 1997	21	9	2.63	33.3% (*Baetis tricaudatus*)
Cañon de Valle	**Average**	**308**	**21**	**3.61**	**45.7%**
Starmer's Gulch	Oct 95	247	20	3.49	32.0% (*Zapada cinctipes*)
Starmer's Gulch	Feb 96	341	27	4.46	32.0% (*Baetis tricaudatus*)
Starmer's Gulch	Aug 96	137	16	3.05	51.8% (*Baetis tricaudatus*)
Starmer's Gulch	March 97	119	11	2.09	32.8% (*Baetis tricaudatus*)
Starmer's Gulch	June 97	187	20	3.63	74.9% (*Baetis tricaudatus*)
Starmer's Gulch	Aug 1997	199	20	3.59	67.8% (*Simulium*)
Starmer's Gulch	**Average**	**205**	**19**	**3.38**	**48.5%**

single dominant genus was considered, the percent contribution would fall to 25.6%, causing the average for Cañon de Valle to drop to 38.4%.

6.3.3.2 Biodiversity. Wilhm's biodiversity averages are higher at Cañon de Valle than at Starmer's Gulch (Table 6). Biodiversities at both sites are slightly lower than those recorded in Guaje Canyon and upper Los Alamos Canyon, relatively undisturbed sites in the Santa Fe National Forest (Cross 1995b). However, the biodiversities recorded at

Cañon de Valle and Starmer's Gulch are characteristic of healthy but low-flow streams in the area.

6.3.3.3 Community Compositions by Functional Feeding Group. Appendix C lists the functional feeding groups of insects collected during this study. We compared the groups found at Starmer's Gulch and Cañon de Valle by totaling the numbers collected on all 6 sampling dates (Fig. 8).

Overall, the communities have a balance of functional feeding groups, although no scrapers were collected at Cañon de Valle. Numbers of collector-gatherers were similar within the 2 streams, and this category contained the greatest number of taxa (17). Starmer's Gulch samples contained some scrapers (5.5% of the total), but Cañon de Valle had none, possibly due to the presence of filamentous algae and organic enrichment in the Cañon de Valle stream. Numbers of shredders and predators were similar in both streams despite more abundant food supplies for shredders at Starmer's Gulch. The greater number and percentage (38.0% as compared to 17.7%) of collector-filterers in Cañon de Valle is interesting in terms of toxicants. Most water-borne toxicants are readily absorbed by fine particulate organic matter that collector-filterers feed on. However, the relatively high numbers of this functional feeding group in Cañon de Valle indicate that such pollutants have not recently impacted the resident aquatic community. Almost all of the filterer-collectors at both sites were members of the fly genus *Similium*.

6.3.3.4 RBP Metrics. Primary and secondary functional feeding groups were used to determine Metric 3, which compares the numbers of scrapers and collector-filterers in a sample. Only aquatic insects are used in functional feeding group comparisons, but non-insects are included in the computation of other metrics (such as taxa richness, percentage contribution of dominant taxon, and CLI). The TQs for collected invertebrates are listed in Appendix D.

Table 7 lists the RBP III biological condition scores and totals (more complete data is included in Appendix E). Cañon de Valle scored 6, indicating no impairment in that metric, in 42.9% of the calculations. However, Cañon de Valle also scored 0, indicating severe impairment in that metric, in 21.4% of the calculations. The highest scores were recorded in Metrics 1 (taxa richness), 4 (EPT and Chironomid abundances), and 7

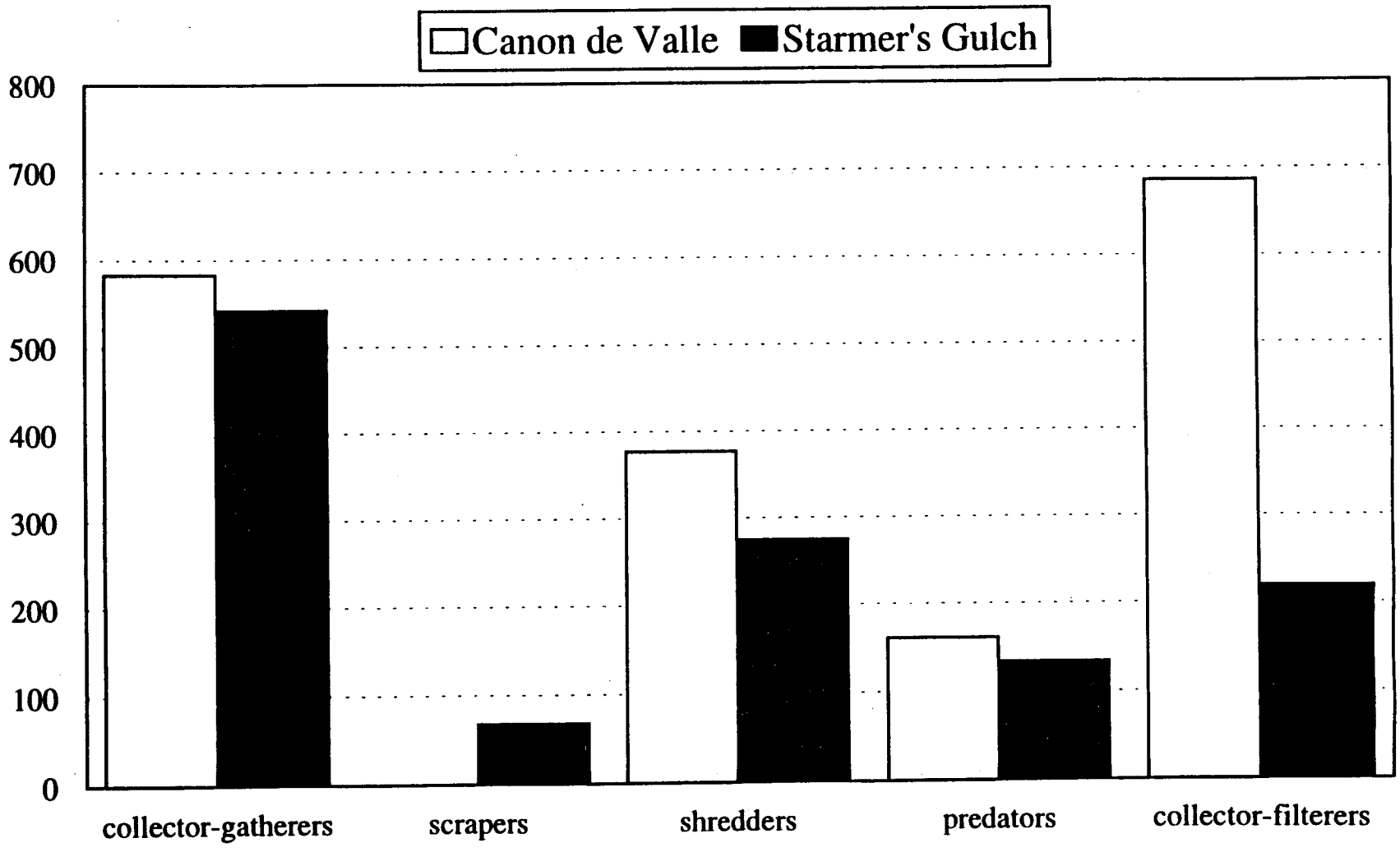

Fig. 8. Community composition by functional feeding group.

Table 7. Biological Condition Scores for Cañon de Valle.

Date	Metric 1	Metric 2	Metric 3	Metric 4	Metric 5	Metric 6	Metric 7	Total score
10/95	6	2	6	6	2	2	6	30
2/96	6	2	6	0	0	0	4	18
8/96	6	6	2	6	2	2	6	30
3/97	6	0	0	6	0	6	6	24
6/97	4	4	2	6	0	0	4	20
8/97	2	6	6	6	2	0	2	24
Average	**5.0**	**3.3**	**3.7**	**5.0**	**1.0**	**1.7**	**4.7**	**24.4**

(Community Loss Index). The lowest scores were recorded in Metrics 5 (percent contribution of dominant taxa) and 6 (EPT Index). Although Cañon de Valle supports many aquatic invertebrate taxa, the community has disproportionate numbers of dominant taxa and comparatively few pollution-tolerant taxa.

The aquatic community in Cañon de Valle was slightly impaired on 4 of 6 sampling dates, and moderately impaired on the other 2 sampling dates (Table 8). The average score of all sampling dates ranks Cañon de Valle as slightly impaired. This impairment may be due to a combination of stressors in the environment including unstable hydrology, reduced habitat in the sampling area, impoverished upstream habitat limiting food sources and potential colonization, and pollutant inputs from upstream outfalls and the MDA-P site. This report seeks to document baseline conditions in the Cañon de Valle stream, not to identify all past and present impacts on the stream.

Table 8. Summary of Total RBP Biological Condition Scores for Cañon de Valle.

Sample Date	Total Biological Condition Score	Percentage Score	Assessment
Oct 95	30	71.4%	Slightly impaired
Feb 96	18	42.9%	Moderately impaired
Aug 96	30	71.4%	Slightly impaired
March 97	24	57.1	Slightly impaired
June 97	20	47.6	Moderately impaired
Aug 97	24	57.1	Slightly impaired
Average	**24**	**57.1**	**Slightly impaired**

VII. RECOMMENDED BEST MANAGEMENT PRACTICES

The categorical exclusion granted to the MDA-P project states, "Mitigation measures, discussed in the DEC [DOE Environmental Checklist] and supporting biological and archaeological assessment reports, must be implemented and adhered to over the course of the proposed project in order for the categorical exclusion determination to remain applicable" (DOE 1995). Beverly Larson, a LANL staff archeologist with ESH-20, identified no archeological issues requiring further action.

Biological best management practices (bmps) for the project may be divided into several areas of concern:

7.1 T&E Species

Mexican spotted owl surveys must be conducted and completed in the spring of each year of the cleanup before heavy equipment can be used in the area. If no Mexican spotted owls are found nesting within 0.4 km (0.25 mi) of the project area, the work may proceed if the restrictions discussed below are followed. If Mexican spotted owls are found to be nesting within 0.4 km (0.25 mi) of the project area, heavy equipment use will be restricted at the clean up site from March 1 through September 1 of that year. If species-specific surveys are not conducted, the owls will be assumed to be nesting within the immediate project area, and all heavy equipment restrictions will apply.

During the Mexican spotted owl's nesting season (March 1 through September 1), work noise should be kept to a minimum, all machinery must be maintained to reduce unnecessary noise, no night operations are allowed, and elaborate site lighting should not be used at night without advance approval from the Biology Team. Project personnel should be restricted to the immediate project area, and no unauthorized personnel are permitted to walk in the surrounding canyons or along the mesa tops.

The upper Cañon de Valle riparian area may provide suitable habitat for a State of New Mexico-endangered plant, the wood lily. The Biology Team must conduct a species-specific survey for this plant each year that excavations occur at the waste pile. These surveys would preferably be conducted during July, when the lily is in flower and easiest to identify. If the plant is found in the area, suitable mitigation measures will be developed to ensure that project operations do not threaten the plant or its habitat.

7.2 Erosion Control and Water Quality

The Biology Team will continue to collect baseline data from the upper Cañon de Valle area and other comparable sites in the vicinity to establish pre-project conditions. Water quality testing and aquatic invertebrate sampling should continue during each year of the project and the first year after clean closure has been attained to document conditions within the adjacent stream.

All recommendations contained within the Storm Water Pollution Prevention Plan (Alexander 1996) developed for the area must be closely followed. This plan was developed specifically for the MDA-P clean closure and is the key to controlling pollutants in storm water discharges (EPA 1992).The greatest potential source of pollutants are the soils and burned debris within the waste pile and excavated materials stored in staging and decontamination areas. Prior to beginning remediation, run-on and run-off controls must be installed to prevent the migration of contaminants downslope and/or into the stream channel. The asphalt trench at the top of the waste pile must be kept clear of obstructions. All excavated areas should be covered with secured tarps during storm events or when work is delayed to limit precipitation and/or runoff from reaching the exposed areas.

Water run-off from on-site sources should be collected in trenches at the bottom of the project excavation and along the entire length of the waste pile base. Collected liquids from the lower trenches should be pumped into containers, sampled, analyzed for waste constituents, and managed appropriately based on the analytic findings. All storm water control measures should be inspected daily and after significant storm water events for structural integrity. All deficiencies found during inspections should be documented and corrected immediately. Due to the steepness of the slope and the attendant high erosion potential, it may be necessary to erect additional erosion barriers to prevent soil, debris, and/or contaminants from entering the stream channel. The stream should be monitored before, during, and after remediation to ensure that containment of disturbed materials within the waste pile has been achieved.

Heavy equipment must not be used within the stream channel. A crane or other similar equipment should be used to lift out and remove debris that threatens to enter the channel. Heavy equipment to be used in remediation activities and on-site contaminant

storage containers must be inspected daily for leaks, and any leaks or spills must be repaired or collected immediately. Individual chunks of debris currently in the stream should be removed with minimal disturbance to the stream channel.

7.3 Restoration of the Area Following Clean Closure

The project area must be restored to its approximate natural contours with backfill. Care must be taken to ensure that the backfill is spread and compacted to minimize erosion potential. Subsoil will be prepared to eliminate uneven surfaces and low spots. Topsoil will be applied during dry weather on a dry unfrozen subgrade, added to a minimum depth of 10 cm (4 in.), and raked smooth (Alexander 1996).The area should be monitored for two years following clean closure to document that restoration, replanting, and reseeding efforts have been successful and that loose material does not migrate into the Cañon de Valle stream.

ESH-20's Biology Team approved several tree removals in the project area prior to the initiation of excavation. Any subsequent tree removals must be approved in advance by the Biology Team. Once the waste pile has been removed, ponderosa pine or other native trees and shrubs should be replanted. Revegetation stabilizes soils by holding the particles in place and reducing the volume of runoff. Vegetation also filters sediments, increases infiltration, improves wildlife habitat, and enhances site aesthetics (EPA 1992).

The entire MDA-P slope will require reseeding with a mix of native grasses and forbs to prevent sheet flow erosion. The Biology Team can provide a list of appropriate seeds to use for revegetation. Other soil stabilization practices such as spreading straw or mulch may be used during the nongrowing seasons to limit erosion.

VIII. CONCLUSIONS

All measured water quality parameters (temperature, pH, DO, and conductivity) taken in the Cañon de Valle stream were within the ranges set by the State of New Mexico for high-quality cold-water fisheries. These measurements demonstrate that the water is of high quality for these parameters that directly affect resident aquatic invertebrates. However, water chemistry tests may reveal the presence of contaminants believed to be in the area that could negatively impact the stream biota, especially in pulses following precipitation and runoff.

Higher densities of aquatic invertebrates and greater biodiversities were recorded in Cañon de Valle than in Starmer's Gulch. Nonetheless, the abundance of pollution-tolerant taxa imply that the Cañon de Valle stream may be subjected to periodic stress. Starmer's Gulch also had a more evenly balanced aquatic community in terms of functional feeding groups.

A series of 7 RBP metrics was used to compare the waterways in Cañon de Valle (the study site) and Starmer's Gulch (the reference site). The aquatic community in Cañon de Valle was slightly impaired on 4 of 6 sampling dates and moderately impaired on the other 2 sampling dates. The average score of all sampling dates ranked Cañon de Valle as slightly impaired as compared to Starmer's Gulch. This impairment may be due to a combination of stressors in the environment including unstable hydrology, reduced habitat in the sampling area, impoverished upstream habitat limiting food sources and potential colonization, and pollutant inputs from upstream outfalls and the MDA-P site.

A federal-endangered T&E species known to inhabit the area is discussed as are project restrictions due to species and habitat requirements. A New Mexico-endangered plant may occur in the area, and the Biology Team will search for it each summer of the project and develop suitable protective measures if it is found in the project area. Site-specific bmps addressing biological concerns have been designed for the MDA-P project. These bmps are presented in terms of T&E species, erosion control and water quality, and restoration of the area following clean closure.

IX. ACKNOWLEDGMENTS

Much of the project description information was taken from a 1994 report on the MDA-P clean closure prepared by ICF Kaiser Engineers. Information included in the vegetation and wildlife sections was condensed from a report by ESH-20 biologist James Biggs (Biggs 1995). David Keller led all T&E surveys and assisted with the compilation of background materials. ESH-20 staff assisted with invertebrate collections and provided necessary sampling equipment. Saul Cross and Dan McGuire identified all aquatic invertebrates, while Saul Cross performed all analytical work and compiled the report. Hector Hinojosa reviewed the manuscript and made editorial suggestions. I wish to

personally thank Ken Bostick, MDA-P project leader, for his support of this work and his strict adherence to all necessary environmental restrictions.

X. GLOSSARY OF ACRONYMS AND TECHNICAL TERMS

aquifer – a water-bearing stratum of permeable rock, sand, or gravel.

asl – above sea level.

biota – the various life forms of a particular area.

bmp – best management practice.

CLI – Community Loss Index.

CTQ – Community Tolerance Quotient.

DEC - DOE Environmental Checklist

DO – dissolved oxygen.

DOE – Department of Energy.

EES – Environmental Evaluation System.

EPA – Environmental Protection Agency.

EPT – the pollution-sensitive aquatic insect order Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

ESH-20 – a division of LANL's Environment, Health, and Safety Division; LANL's Ecology Group, which includes the Biology Team.

gpm – gallons per minute.

groundwater – water in wholly saturated ground.

HBI – Hilsenhoff Biotic Index

HE – high explosives.

LANL – Los Alamos National Laboratory.

MDA – Material Disposal Area.

metric – a comparative measure of an aquatic community.

NMED – New Mexico Environmental Department.

Phase 1 sampling – sampling designed to establish background and baseline concentrations of contaminants and also to ensure proper disposition of excavated wastes.

Phase 2 sampling – sampling designed to measure whether clean closure criteria have been met.

Potentiometric – relating to electromotive forces.

ppm – parts per million.

RBPs – Rapid Bioassessment Protocols; a series of aquatic community measures developed by the U.S. EPA.

RCRA – Resource Conservation and Recovery Act.

standing crop – the density of aquatic invertebrates.

su – standard unit, referring to the units of the pH scale.

TA – technical area.

taxon (plural taxa) – a distinct group of living creatures.

taxa richness – the number of taxa of invertebrates in a sample.

T&E - threatened and endangered, referring to a species protected under State of New Mexico or federal environmental law.

TQ – Tolerance Quotient; a measure of a taxon's stress-sensitivity.

Vadose – water or solutions above the permanent groundwater level.

XI. CITATIONS

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Appendix A.

Aquatic Invertebrates Collected from Los Alamos County and Adjacent Watersheds

Aquatic Insects Collected

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
Collembola (Springtails)				S,SG
	Poduridae			SG
Ephemeroptera (Mayflies)	Baetidae	*Acentrella*	*insignificans*	F
	Baetidae	*Baetis*	*bicaudatus*	F
	Baetidae	*Baetis*	*tricaudatus*	A,B,CV,D,F, G,L,PS,RS,S, SG,UP
	Baetidae	*Baetis*		A,C,F,G,H,L, P,PS,S,SG, 128
	Baetidae	*Callibaetis*		G,L,P,PS,S, RS,48
	Baetidae	*Centroptilum*		CV, UP
	Baetidae	*Diphenor*	*hageni*	SG
	Ephemerellidae	*Drunella*	*coloradensis*	G,L
	Ephemerellidae	*Drunella*	*doddsi*	F,G
	Ephemerellidae	*Drunella*	*grandis grandis*	F,G
	Ephemerellidae	*Ephemerella*	*inermis*	F,G,L
	Ephemerellidae	*Ephemerella*	*infrequens*	F,G
	Ephemerellidae	*Ephemerella*		F
	Heptageniidae	*Cinygmula*		F,G,L,UP
	Heptageniidae	*Epeorus*	*longimanus*	F,G,L
	Heptageniidae	*Epeorus*		F,G,L
	Heptageniidae	*Heptagenia*		G
	Heptageniidae	*Nixe*	*simplicoides*	L
	Heptageniidae	*Rhithrogena*		F,G
	Leptophlebiidae	*Paraleptophlebia*		F,G,L,UP, CV,SG
	Siphlonuridae	*Ameletus*		F,G,L,S,SG, UP
	Siphlonuridae	*Siphlonurus*	*occidentalis*	F,L
	Siphlonuridae	*Siphlonurus*		F

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Siphlonuridae			A,L
	Tricorythidae	*Tricorythodes*	*minutus*	G,PS,RS,S
	Tricorythidae	*Tricorythodes*		A,CV,F
Odonata				
suborder Anisoptera (Dragonflies)	Aeshnidae	*Aeshna*		A,C,F,I,S
	Aeshnidae	*Anax*		H,P,S,48
	Aeshnidae	*Boyeria*		CV,L,S
	Aeshnidae	*Oplonaeschna*		CV
	Cordulegastridae	*Cordulegaster*		CV,F,S
	Corduliidae	*Belonia*?		A,C,P
	Corduliidae	*Neurocordulia*		RS
	Gomphidae			L,P
	Libellulidae	*Leuchorrhina*		I
	Libellulidae	*Libellula*		PS
	Libellulidae	*Pantala*		A,C
	Libellulidae	*Platyhemis*?		P
	Libellulidae	*Sympetrum*?		PS
	Libellulidae			A,F,PS
suborder Zygoptera (Damselflies)	Agriidae	*Argion*		A
	Agriidae (Calopterygidae)	*Hetaerina*		A,PS,RS
	Coenagrionidae	*Argia*		A,C,CV,F,P, RS,S,PS
	Coenagrionidae	*Enallagma*		I,S
	Coenagrionidae	*Hyponeura*		F
	Coenagrionidae	*Ishmura*	*perparua*	F
	Coenagrionidae	*Ishmura*		H,S
	Coenagrionidae	*Zoniagrion*		S
	Lestidae	*Archilestes*		PS,RS,S
Plecoptera (Stoneflies)	Capniidae	*Capnia*		F
	Capniidae			CV,F,L
	Chloroperlidae	*Alloperla*	*severa*	UP,SG
	Chloroperlidae	*Chloroperla*		F
	Chloroperlidae	*Paraperla*	*frontalis*	G,L
	Chloroperlidae	*Paraperla*		F
	Chloroperlidae	*Sweltsa*	*coloradensis*	F

	LOCATION **
	A,L
	G,PS,RS,S
	A,CV,F
	A,C,F,I,S
	H,P,S,48
	CV,L,S
	CV
	CV,F,S
	A,C,P
	RS
	L,P
	I
	PS
	A,C
	P
	PS
	A,F,PS
	A
	A,PS,RS
	A,C,CV,F,P, RS,S,PS
	,S
	F
	F
	H,S
	S
	PS,RS,S
	F
	CV,F,L
	UP,SG
	F
	G,L
	F
is	F

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Chloroperlidae	*Sweltsa*	*lamba*	F
	Chloroperlidae	*Sweltsa*		CV,F,G,SG, UP
	Chloroperlidae	*Suwallia*		CV,G,L
	Chloroperlidae			F,G,L,SG
	Leuctridae	*Despoxia*		G
	Leuctridae	*Paraleuctra*	*vershina*	F
	Nemouridae	*Amphinemura*		CV,F,G,SG
	Nemouridae	*Amphinemura*	*banksi*	CV, F,G,L,P, SG, UP
	Nemouridae	*Malenka*	*coloradensis*	F
	Nemouridae	*Malenka*		CV,G,L,SG
	Nemouridae	*Nemoura*		F,G
	Nemouridae	*Podmosta*	*delicatula*	G,L,S
	Nemouridae	*Prostoia*		CV
	Nemouridae	*Zapada*	*cinctipes*	CV,F,L,SG, UP
	Nemouridae	*Zapada*	*frigida*	L
	Perlidae	*Acroneuria*	*abnormis*	F
	Perlidae	*Hesperoperla*	*pacifica*	B,F,L,SG,UP
	Perlodidae	*Cultus*	*aestivalis*	GL
	Perlodidae	*Cultus*		G
	Perlodidae	*Isoperla*	*fulva*	F
	Perlodidae	*Isoperla*	*quinquepunc-tata*	F
	Perlodidae	*Isoperla*		CV,F,G,L, UP,S
	Perlodidae	*Kogotus*	*modestus*	G,L
	Perlodidae	*Skwala*	*parallela*	G
	Pteronarcyidae	*Pteronarcella*	*badia*	F,G
	Pteronarcyidae	*Pteronarcella*		F
	Pteronarcyidae	*Pteronarcys*	*californica*	G
	Pteronarcyidae	*Pteronarcys*		G
	Taeniopterygidae	*Taenionema*		F
Hemiptera (True bugs)	Cicadellidae			UP
	Corixidae	*Corisella*		F
	Corixidae	*Sigara*		F
	Corixidae	*Trichocorixa*		A,P,S
	Gerridae	*Gerris*	*marginatus*	F
	Gerridae	*Gerris*	*notabilis*	F

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Gerridae	*Gerris*		A,CV,D,F,G, H,I,L,PS,RS, S,UP
	Gerridae	*Metrobates*		PS
	Gerridae	*Trepobates*		H,S
	Naucoridae	*Ambrysus*	*mormon*	A,C,PS,RS
	Notonectidae	*Notonecta*	*undulata*	F
	Notonectidae	*Notonecta*		C,S
	Salididae			RS
	Veliidae	*Microvelia*		A,F,G,L
	Veliidae	*Rhagovelia*		A,S,UP
	Veliidae			A,PS
Megaloptera (Nerve-wings)	Corydalidae	*Neohermes?*		G,L
Trichoptera (Caddisflies)	Brachycentridae	*Amiocentrus*		F
	Brachycentridae	*Brachycentrus*	*americanus*	F
	Brachycentridae	*Brachycentrus*		F
	Brachycentridae	*Micrasema*		F,G,L
	Calamoceratidae	*Phylloicus*		F
	Glossosomatidae	*Agapetus*		G,SG
	Glossosomatidae	*Anagapetus*		G
	Glosssosomatidae	*Glossosoma*		F,G,L,SG,UP
	Helicosychidae	*Helicopsyche*	*borealis*	A,F,G,L,PS, RS
	Helicopsychidae	*Helicopsyche*		F
	Hydropsychidae	*Arctopsyche*	*grandis*	A,F,G,L,S,PS
	Hydropsychidae	*Ceratopsyche*	*oslari*	B,CV,SG,UP
	Hydropsychidae	*Cheumatopsyche*		G,PS,RS
	Hydropsychidae	*Hydropsyche*	*occentalis*	PS
	Hydropsychidae	*Hydropsyche*	*oslari*	A,CV,F,RS,S, SG,UP
	Hydropsychidae	*Hydropsyche*		F,G,PS,L,S, SG
	Hydroptilidae	*Alisotrichia*		PS
	Hydroptilidae	*Hydroptila*		A,B,CV,P,PS, RS,S,UP
	Hydroptilidae	*Leucotrichia*		PS
	Hydroptilidae	*Ochrotrichia*		F,G,L,RS
	Hydroptilidae	*Stactobiella*		A,CV,L,PS, RS

LOCATION **
,CV,D,F,G, H,I,L,PS,RS, S,UP
PS
H,S
A,C,PS,RS
F
C,S
RS
A,F,G,L
A,S,UP
A,PS
G,L
F
F
F
F,G,L
F
G,SG
G
F,G,L,SG,UP
A,F,G,L,PS, RS
F
,F,G,L,S,PS
,CV,SG,UP
G,PS,RS
PS
A,CV,F,RS,S, SG,UP
F,G,PS,L,S, SG
PS
A,B,CV,P,PS, RS,S,UP
PS
F,G,L,RS
A,CV,L,PS, RS

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Lepidostomatidae	*Lepidostoma*		B,F,G,L,S, SG,UP
	Lepidostomatidae			G
	Leptoceridae	*Oecetis*?		G,L,P,S
	Limnephilidae	*Ecclisomyia*		UP
	Limnephilidae	*Dicosmoecus*		F
	Limnephilidae	*Hesperophylax*		CV,G,L,P,RS, S,SG,UP
	Limnephilidae pupae	*Hesperophylax*		G,L,SG,UP
	Limnephilidae	*Limnephilus*		F,G,L,PW, RS,S
	Limnephilidae	*Oligophlebodes*		F,G,L,P,S,SG
	Limnephilidae	*Psychoglypha*		B
	Limnephilidae	*Psychoronia*		F,G
	Limnephilidae			G,L,PW
	Odontoceridae	*Namamyia*		G
	Philopotamidae	*Chimarra*		A,PS,RS
	Philopotamidae	*Dolophilodes*	*aequalis*	F
	Philopotamidae	*Dolophilodes*	*sortosa*	F,G
	Philopotamidae	*Dolophilodes*		G,L
	Philopotamidae	*Wormaldia*		F,PS,RS
	Polycentropidae	*Polycentropus*		F,RS
	Rhyacophilidae	*Rhyacophila*	*acropedes*	F,G
	Rhyacophilidae	*Rhyacophila*	*brunnea* complex	B,F,G,L,SG, UP
	Rhyacophilidae	*Rhyacophila*	*coloradensis*	F
	Rhyacophilidae	*Rhyacophila*	*hyalinata*	F,G
	Rhyacophilidae	*Rhyacophila*	*valuma*	F,G
	Rhyacophilidae	*Rhyacophila*		F,SG
	Rhyacophilidae			A
	Sericostomatidae	*Gumaga*		RS
Lepidoptera (Butterflies and moths)	Noctuidae			G,L,PS
	Pyralidae			G,S
	Pyralidae	*Paraponyx*		PS
	Pyralidae	*Parargyractis*	*kearfottalis*	F,PS
	Pyralidae	*Petrophila*		PS,RS,S
Coleoptera (Beetles)	Amphizoidae	*Amphizoa*		G

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Curculionidae	*Phytonomus*		G,L,S
	Curculionidae			D,F,SG
	Curculionidae adult			G
	Dryopidae	*Helichus*	*suturalis*	F
	Dryopidae	*Helichus*	*striatus*	F
	Dryopidae	*Helichus*		F,G,L,P,PS, RS,S,UP
	Dryopidae			S
	Dytiscidae	*Agabus*	*cordatus*	F
	Dytiscidae	*Agabus*	*tristus*	F
	Dytiscidae	*Agabus*		A,C,CV,D,L, P,RS,S
	Dytiscidae	*Agabinus*		CV
	Dytiscidae	*Deronectes*	*striatellus*	F
	Dytiscidae	*Deronectes*		L
	Dytiscidae	*Dytiscus*		F
	Dytiscidae	*Hydaticus*		G,L,PS,S
	Dytiscidae	*Hydroporus*	*vilis*	F
	Dytiscidae	*Hydroporus*		S
	Dytiscidae	*Hygrotus*		S
	Dytiscidae	*Rhantus*		RS
	Dytiscidae			G,L,PS,RS,S, UP
	Elmidae	*Cleptelmis*	*addenda*	F
	Elmidae	*Cylloepus*		F
	Elmidae	*Dubiraphia*		G
	Elmidae	*Heterelmis*		A,RS,SG,UP
	Elmidae	*Heterlimnius*	*corpulentis*	F,G,L,PS,RS, S,SG
	Elmidae	*Microcylloepus*		PS,RS
	Elmidae	*Narpus*	*concolor*	F
	Elmidae	*Narpus*		F,G,L,SG,UP
	Elmidae	*Optioservus*	*castanipennis*	F
	Elmidae	*Optioservus*	*divergens*	F
	Elmidae	*Optioservus*		B,CV,D,F,L, PS,S,SG,UP
	Elmidae	*Rhizelmis*		F
	Elmidae	*Zaitzevia*	*parvula*	D,F,L
	Elmidae	*Zaitzevia*		C,F,G,L,RS,S
	Elmidae			C,SG,L,P,S

	LOCATION **
	G,L,S
	D,F,SG
	G
	F
	F
	F,G,L,P,PS, RS,S,UP
	S
	F
	F
	A,C,CV,D,L, P,RS,S
	CV
	F
	L
	F
	G,L,PS,S
	F
	S
	S
	RS
	G,L,PS,RS,S, UP
	F
	F
	L,RS,SG,UP
	F,G,L,PS,RS, S,SG
	PS,RS
	F
	F,G,L,SG,UP
s	F
	F
	B,CV,D,F,L, PS,S,SG,UP
	F
	D,F,L
	C,F,G,L,RS,S
	C,SG,L,P,S

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Gyrinidae	*Gyrinus*		A,F,S,PS,RS
	Haliplidae	*Haliplus*		IC
	Haliplidae	*Peltodytes*		G
	Haliplidae			S
	Helodidae			P
	Helodidae	*Prionocyphon*		G
	Hydrophilidae	*Ametor*	*scabrosus*	F
	Hydrophilidae	*Ametor*		A,C,G,L,S
	Hydrophilidae	*Berosus*	*styliferous*	F
	Hydrophilidae	*Crenitis*		F
	Hydrophilidae	*Cymbiodyta*	*dorsalis*	F
	Hydrophilidae	*Enochrus?*		G
	Hydrophilidae	*Helphorus*		L
	Hydrophilidae	*Hydrobius*		L
	Hydrophilidae	*Hydrochus*		G
	Hydrophilidae			CV,G,L,P,RS, S,SG
	Psephenidae	*Psephenus?*		C,P,48
	Psephenidae			G
	Staphylinidae			CV
Diptera (Flies)	Blephariceridae			F
	Ceratopogonidae (Heleidae)	*Bezzia*		G,L,RS,S
	Ceratopogonidae (Heleidae)	*Culicoides?*		RS
	Ceratopogonidae (Heleidae)			B,CV,F,G,P, S,PS,UP
	Chironomidae	*Ablabesmyia*		F,RS
	Chironomidae	*Boreochlus*		SG
	Chironomidae	*Brillia*		CV,F,G,L,S, SG,UP
	Chironomidae	*Cardiocladius*		F,G,S
	Chironomidae	*Chaetocladius*		S,UP
	Chironomidae	*Chironomus*		F
	Chironomidae	*Corynoneura*		A,B,G,L,PS, RS,SG,UP
	Chironomidae	*Cricotopus*		A,CV,F,G,PS, RS,S,SG,UP
	Chironomidae	*Cryptochironomus*		F
	Chironomidae	*Cryptotendipes*		A

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Chironomidae	*Diamesa*		CV,S,UP
	Chironomidae	*Eukiefferiella*		A,B,F,G,L,S, SG,UP
	Chironomidae	*Labrundinia*		RS
	Chironomidae	*Macropelopia*		CV
	Chironomidae	*Micropsectra*		A,B,CV,F,L, PS,RS,SG,UP
	Chironomidae	*Microtendipes*		D,F
	Chironomidae	*Nanocladius*		F
	Chironomidae	*Nostocladius*		A,F,G,PS
	Chironomidae	*Nostococladius*		A,F,G,PS
	Chironomidae	*Orthocladius*		A,B,CV,F,PS, RS,S,SG,UP
	Chironomidae	*Pagastia*		B,CV,L,S,SG, UP
	Chironomidae	*Parametriocnemus*		L,RS,S,SG, UP
	Chironomidae	*Paraphaenocladius*		B,CV,S,SG
	Chironomidae	*Paramerina*		SG
	Chironomidae	*Paratendipes*		CV
	Chironomidae	*Parochlus*		CV
	Chironomidae	*Pentaneura*		CV,SG,UP
	Chironomidae	*Phaenopsectra?*		RS
	Chironomidae	*Polypedilum*		A,F
	Chironomidae	*Procladius*		F,RS
	Chironomidae	*Psectrocladius*		CV,SG
	Chironomidae	*Pseudochironomus*		A,RS
	Chironomidae	*Pseudodiamesa*		CV,SG,UP
	Chironomidae	*Pseudosmittia*		G
	Chironomidae	*Rheocricotopus*		SG,UP
	Chironomidae	*Rheotanytarsus*		A,F,PS,RS, UP
	Chironomidae	*Robackia*		CV
	Chironomidae	*Stempellina*		G
	Chironomidae	*Stempellinealla?*		L
	Chironomidae	*Tanytarsus*		CV
	Chironomidae	*Thienemannimyia*		A,CV,L,RS,S, UP
	Chironomidae	*Thienemanniella*		A
	Chironomidae	*Tvetenia*		B,CV,F,L,PS, S,SG,UP

LOCATION **
V,S,UP
A,B,F,G,L,S, SG,UP
RS
CV
A,B,CV,F,L, PS,RS,SG,UP
D,F
F
A,F,G,PS
A,F,G,PS
A,B,CV,F,PS, RS,S,SG,UP
B,CV,L,S,SG, UP
L,RS,S,SG, UP
B,CV,S,SG
SG
CV
CV
CV,SG,UP
RS
A,F
F,RS
CV,SG
RS
V,SG,UP
G
SG,UP
A,F,PS,RS, UP
CV
G
L
CV
A,CV,L,RS,S, UP
A
B,CV,F,L,PS, S,SG,UP

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Chironomidae	*Zavrelia*		F
	Chironomidae	*Zavrelimyia*		CV,RS,SG
	Chironomidae, Macropelopini			L,RS
	Chironomidae, Orthocladiinae			A,L,PS,RS
	Culicidae	*Aedes*		F
	Culicidae	*Chaoborus*		I,48
	Culicidae	*Culex*		F,H,RS,128
	Culicidae	*Culiseta*		D,H,G,L,M, 48,128
	Culicidae			S
	Dixidae	*Dixa*	*californica*	F
	Dixidae	*Dixa*		F,G,L,PS,RS
	Dolichopodidae			CV
	Empididae	*Chelifera*		CV,F,G,L,RS, S
	Empididae	*Oreogeton*		C,F,G,L,P,S
	Empididae	*Hemerodromia*		G,S
	Empididae			A,H
	Ephydridae	*Brachydeutera*		S
	Ephydridae	*Ephydra*		SG
	Muscidae	*Limnophora*	*aequifrons*	F
	Muscidae	*Limnophora*		A,D,L,S,SG
	Muscidae			RS,S
	Psychodidae	*Maruina*		B,G,L,PS,RS, S,SG
	Psychodidae	*Pericoma*		B,F,G,L,SG, UP
	Ptychopteridae	*Bittacomorpha*		A,G,L,S
	Ptychopteridae	*Ptychoptera*		G,UP
	Ptychopteridae			F
	Simuliidae	*Prosimilium*		A,F,G,L,S
	Simuliidae	*Simulium*		A,B,CV,F,G, L,PS,RS,S, SG, UP
	Simuliidae			D,F,G,L,S,SG
	Stratiomyidae	*Eulalia*		F
	Stratiomyidae	*Odontomyia*		G,PS,S
	Stratiomyidae			A,F,G,RS
	Syrphidae	*Tubifera*	*bastardii*	F

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Siphlonuridae			A,L
	Tricorythidae	*Tricorythodes*	*minutus*	G,PS,RS,S
	Tricorythidae	*Tricorythodes*		A,CV,F
Odonata				
suborder Anisoptera (Dragonflies)	Aeshnidae	*Aeshna*		A,C,F,I,S
	Aeshnidae	*Anax*		H,P,S,48
	Aeshnidae	*Boyeria*		CV,L,S
	Aeshnidae	*Oplonaeschna*		CV
	Cordulegastridae	*Cordulegaster*		CV,F,S
	Corduliidae	*Belonia*?		A,C,P
	Corduliidae	*Neurocordulia*		RS
	Gomphidae			L,P
	Libellulidae	*Leuchorrhina*		I
	Libellulidae	*Libellula*		PS
	Libellulidae	*Pantala*		A,C
	Libellulidae	*Platyhemis*?		P
	Libellulidae	*Sympetrum*?		PS
	Libellulidae			A,F,PS
suborder Zygoptera (Damselflies)	Agriidae	*Argion*		A
	Agriidae (Calopterygidae)	*Hetaerina*		A,PS,RS
	Coenagrionidae	*Argia*		A,C,CV,F,P, RS,S,PS
	Coenagrionidae	*Enallagma*		I,S
	Coenagrionidae	*Hyponeura*		F
	Coenagrionidae	*Ishnura*	*perparua*	F
	Coenagrionidae	*Ishnura*		H,S
	Coenagrionidae	*Zoniagrion*		S
	Lestidae	*Archilestes*		PS,RS,S
Plecoptera (Stoneflies)	Capniidae	*Capnia*		F
	Capniidae			CV,F,L
	Chloroperlidae	*Alloperla*	*severa*	UP,SG
	Chloroperlidae	*Chloroperla*		F
	Chloroperlidae	*Paraperla*	*frontalis*	G,L
	Chloroperlidae	*Paraperla*		F
	Chloroperlidae	*Sweltsa*	*coloradensis*	F

S	LOCATION **
	A,L
	G,PS,RS,S
	A,CV,F
	A,C,F,I,S
	H,P,S,48
	CV,L,S
	CV
	CV,F,S
	A,C,P
	RS
	L,P
	I
	PS
	A,C
	P
	PS
	A,F,PS
	A
	A,PS,RS
	A,C,CV,F,P, RS,S,PS
	,S
	F
	F
	H,S
	S
	PS,RS,S
	F
	CV,F,L
	UP,SG
	F
	G,L
	F
s	F

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Chloroperlidae	*Sweltsa*	*lamba*	F
	Chloroperlidae	*Sweltsa*		CV,F,G,SG, UP
	Chloroperlidae	*Suwallia*		CV,G,L
	Chloroperlidae			F,G,L,SG
	Leuctridae	*Despoxia*		G
	Leuctridae	*Paraleuctra*	*vershina*	F
	Nemouridae	*Amphinemura*		CV,F,G,SG
	Nemouridae	*Amphinemura*	*banksi*	CV, F,G,L,P, SG, UP
	Nemouridae	*Malenka*	*coloradensis*	F
	Nemouridae	*Malenka*		CV,G,L,SG
	Nemouridae	*Nemoura*		F,G
	Nemouridae	*Podmosta*	*delicatula*	G,L,S
	Nemouridae	*Prostoia*		CV
	Nemouridae	*Zapada*	*cinctipes*	CV,F,L,SG, UP
	Nemouridae	*Zapada*	*frigida*	L
	Perlidae	*Acroneuria*	*abnormis*	F
	Perlidae	*Hesperoperla*	*pacifica*	B,F,L,SG,UP
	Perlodidae	*Cultus*	*aestivalis*	GL
	Perlodidae	*Cultus*		G
	Perlodidae	*Isoperla*	*fulva*	F
	Perlodidae	*Isoperla*	*quinquepunc-tata*	F
	Perlodidae	*Isoperla*		CV,F,G,L, UP,S
	Perlodidae	*Kogotus*	*modestus*	G,L
	Perlodidae	*Skwala*	*parallela*	G
	Pteronarcyidae	*Pteronarcella*	*badia*	F,G
	Pteronarcyidae	*Pteronarcella*		F
	Pteronarcyidae	*Pteronarcys*	*californica*	G
	Pteronarcyidae	*Pteronarcys*		G
	Taeniopterygidae	*Taenionema*		F
Hemiptera (True bugs)	Cicadellidae			UP
	Corixidae	*Corisella*		F
	Corixidae	*Sigara*		F
	Corixidae	*Trichocorixa*		A,P,S
	Gerridae	*Gerris*	*marginatus*	F
	Gerridae	*Gerris*	*notabilis*	F

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Gerridae	*Gerris*		A,CV,D,F,G, H,I,L,PS,RS,S ,UP
	Gerridae	*Metrobates*		PS
	Gerridae	*Trepobates*		H,S
	Naucoridae	*Ambrysus*	*mormon*	A,C,PS,RS
	Notonectidae	*Notonecta*	*undulata*	F
	Notonectidae	*Notonecta*		C,S
	Salididae			RS
	Veliidae	*Microvelia*		A,F,G,L
	Veliidae	*Rhagovelia*		A,S,UP
	Veliidae			A,PS
Megaloptera (Nerve-wings)	Corydalidae	*Neohermes?*		G,L
Trichoptera (Caddisflies)	Brachycentridae	*Amiocentrus*		F
	Brachycentridae	*Brachycentrus*	*americanus*	F
	Brachycentridae	*Brachycentrus*		F
	Brachycentridae	*Micrasema*		F,G,L
	Calamoceratidae	*Phylloicus*		F
	Glossosomatidae	*Agapetus*		G,SG
	Glossosomatidae	*Anagapetus*		G
	Glosssosomatidae	*Glossosoma*		F,G,L,SG,UP
	Helicosychidae	*Helicopsyche*	*borealis*	A,F,G,L,PS, RS
	Helicopsychidae	*Helicopsyche*		F
	Hydropsychidae	*Arctopsyche*	*grandis*	A,F,G,L,S,PS
	Hydropsychidae	*Ceratopsyche*	*oslari*	B,CV,SG,UP
	Hydropsychidae	*Cheumatopsyche*		G,PS,RS
	Hydropsychidae	*Hydropsyche*	*occentalis*	PS
	Hydropsychidae	*Hydropsyche*	*oslari*	A,CV,F,RS,S, SG,UP
	Hydropsychidae	*Hydropsyche*		F,G,PS,L,S, SG
	Hydroptilidae	*Alisotrichia*		PS
	Hydroptilidae	*Hydroptila*		A,B,CV,P,PS, RS,S,UP
	Hydroptilidae	*Leucotrichia*		PS
	Hydroptilidae	*Ochrotrichia*		F,G,L,RS
	Hydroptilidae	*Stactobiella*		A,CV,L,PS, RS

LOCATION **
,CV,D,F,G, H,I,L,PS,RS,S ,UP
PS
H,S
A,C,PS,RS
F
C,S
RS
A,F,G,L
A,S,UP
A,PS
G,L
F
F
F
F,G,L
F
G,SG
G
F,G,L,SG,UP
A,F,G,L,PS, RS
F
,F,G,L,S,PS
B,CV,SG,UP
G,PS,RS
PS
A,CV,F,RS,S, SG,UP
F,G,PS,L,S, SG
PS
A,B,CV,P,PS, RS,S,UP
PS
F,G,L,RS
A,CV,L,PS, RS

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Lepidostomatidae	*Lepidostoma*		B,F,G,L,S, SG,UP
	Lepidostomatidae			G
	Leptoceridae	*Oecetis?*		G,L,P,S
	Limnephilidae	*Ecclisomyia*		UP
	Limnephilidae	*Dicosmoecus*		F
	Limnephilidae	*Hesperophylax*		CV,G,L,P,RS, S,SG,UP
	Limnephilidae pupae	*Hesperophylax*		G,L,SG,UP
	Limnephilidae	*Limnephilus*		F,G,L,PW, RS,S
	Limnephilidae	*Oligophlebodes*		F,G,L,P,S,SG
	Limnephilidae	*Psychoglypha*		B
	Limnephilidae	*Psychoronia*		F,G
	Limnephilidae			G,L,PW
	Odontoceridae	*Namamyia*		G
	Philopotamidae	*Chimarra*		A,PS,RS
	Philopotamidae	*Dolophilodes*	*aequalis*	F
	Philopotamidae	*Dolophilodes*	*sortosa*	F,G
	Philopotamidae	*Dolophilodes*		G,L
	Philopotamidae	*Wormaldia*		F,PS,RS
	Polycentropidae	*Polycentropus*		F,RS
	Rhyacophilidae	*Rhyacophila*	*acropedes*	F,G
	Rhyacophilidae	*Rhyacophila*	*brunnea* complex	B,F,G,L,SG,U P
	Rhyacophilidae	*Rhyacophila*	*coloradensis*	F
	Rhyacophilidae	*Rhyacophila*	*hyalinata*	F,G
	Rhyacophilidae	*Rhyacophila*	*valuma*	F,G
	Rhyacophilidae	*Rhyacophila*		F,SG
	Rhyacophilidae			A
	Sericostomatidae	*Gumaga*		RS
Lepidoptera (Butterflies and moths)	Noctuidae			G,L,PS
	Pyralidae			G,S
	Pyralidae	*Paraponyx*		PS
	Pyralidae	*Parargyractis*	*kearfottalis*	F,PS
	Pyralidae	*Petrophila*		PS,RS,S
Coleoptera (Beetles)	Amphizoidae	*Amphizoa*		G

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Curculionidae	*Phytonomus*		G,L,S
	Curculionidae			D,F,SG
	Curculionidae adult			G
	Dryopidae	*Helichus*	*suturalis*	F
	Dryopidae	*Helichus*	*striatus*	F
	Dryopidae	*Helichus*		F,G,L,P,PS, RS,S,UP
	Dryopidae			S
	Dytiscidae	*Agabus*	*cordatus*	F
	Dytiscidae	*Agabus*	*tristus*	F
	Dytiscidae	*Agabus*		A,C,CV,D,L, P,RS,S
	Dytiscidae	*Agabinus*		CV
	Dytiscidae	*Deronectes*	*striatellus*	F
	Dytiscidae	*Deronectes*		L
	Dytiscidae	*Dytiscus*		F
	Dytiscidae	*Hydaticus*		G,L,PS,S
	Dytiscidae	*Hydroporus*	*vilis*	F
	Dytiscidae	*Hydroporus*		S
	Dytiscidae	*Hygrotus*		S
	Dytiscidae	*Rhantus*		RS
	Dytiscidae			G,L,PS,RS,S, UP
	Elmidae	*Cleptelmis*	*addenda*	F
	Elmidae	*Cylloepus*		F
	Elmidae	*Dubiraphia*		G
	Elmidae	*Heterelmis*		A,RS,SG,UP
	Elmidae	*Heterlimnius*	*corpulentis*	F,G,L,PS,RS, S,SG
	Elmidae	*Microcylloepus*		PS,RS
	Elmidae	*Narpus*	*concolor*	F
	Elmidae	*Narpus*		F,G,L,SG,UP
	Elmidae	*Optioservus*	*castanipennis*	F
	Elmidae	*Optioservus*	*divergens*	F
	Elmidae	*Optioservus*		B,CV,D,F,L, PS,S,SG,UP
	Elmidae	*Rhizelmis*		F
	Elmidae	*Zaitzevia*	*parvula*	D,F,L
	Elmidae	*Zaitzevia*		C,F,G,L,RS,S
	Elmidae			C,SG,L,P,S

	LOCATION **
	G,L,S
	D,F,SG
	G
	F
	F
	F,G,L,P,PS, RS,S,UP
	S
	F
	F
	A,C,CV,D,L, P,RS,S
	CV
	F
	L
	F
	G,L,PS,S
	F
	S
	S
	RS
	G,L,PS,RS,S, UP
	F
	F
	G
	A,RS,SG,UP
	F,G,L,PS,RS, S,SG
	PS,RS
	F
	F,G,L,SG,UP
is	F
	F
	B,CV,D,F,L, PS,S,SG,UP
	F
	D,F,L
	C,F,G,L,RS,S
	C,SG,L,P,S

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Gyrinidae	*Gyrinus*		A,F,S,PS,RS
	Haliplidae	*Haliplus*		IC
	Haliplidae	*Peltodytes*		G
	Haliplidae			S
	Helodidae			P
	Helodidae	*Prionocyphon*		G
	Hydrophilidae	*Ametor*	*scabrosus*	F
	Hydrophilidae	*Ametor*		A,C,G,L,S
	Hydrophilidae	*Berosus*	*styliferous*	F
	Hydrophilidae	*Crenitis*		F
	Hydrophilidae	*Cymbiodyta*	*dorsalis*	F
	Hydrophilidae	*Enochrus?*		G
	Hydrophilidae	*Helphorus*		L
	Hydrophilidae	*Hydrobius*		L
	Hydrophilidae	*Hydrochus*		G
	Hydrophilidae			CV,G,L,P,RS, S,SG
	Psephenidae	*Psephenus?*		C,P,48
	Psephenidae			G
	Staphylinidae			CV
Diptera (Flies)	Blephariceridae			F
	Ceratopogonidae (Heleidae)	*Bezzia*		G,L,RS,S
	Ceratopogonidae (Heleidae)	*Culicoides?*		RS
	Ceratopogonidae (Heleidae)			B,CV,F,G,P, S,PS,UP
	Chironomidae	*Ablabesmyia*		F,RS
	Chironomidae	*Boreochlus*		SG
	Chironomidae	*Brillia*		CV,F,G,L,S, SG,UP
	Chironomidae	*Cardiocladius*		F,G,S
	Chironomidae	*Chaetocladius*		S,UP
	Chironomidae	*Chironomus*		F
	Chironomidae	*Corynoneura*		A,B,G,L,PS, RS,SG,UP
	Chironomidae	*Cricotopus*		A,CV,F,G,PS, RS,S,SG,UP
	Chironomidae	*Cryptochironomus*		F
	Chironomidae	*Cryptotendipes*		A

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Chironomidae	*Diamesa*		CV,S,UP
	Chironomidae	*Eukiefferiella*		A,B,F,G,L,S, SG,UP
	Chironomidae	*Labrundinia*		RS
	Chironomidae	*Macropelopia*		CV
	Chironomidae	*Micropsectra*		A.B.CV.F.L. PS.RS.SG.UP
	Chironomidae	*Microtendipes*		D.F
	Chironomidae	*Nanocladius*		F
	Chironomidae	*Nostocladius*		A.F.G.PS
	Chironomidae	*Nostococladius*		A,F,G,PS
	Chironomidae	*Orthocladius*		A,B,CV,F.PS. RS,S.SG.UP
	Chironomidae	*Pagastia*		B,CV,L,S.SG. UP
	Chironomidae	*Parametriocnemus*		L,RS,S.SG. UP
	Chironomidae	*Paraphaenocladius*		B,CV,S.SG
	Chironomidae	*Paramerina*		SG
	Chironomidae	*Paratendipes*		CV
	Chironomidae	*Parochlus*		CV
	Chironomidae	*Pentaneura*		CV,SG,UP
	Chironomidae	*Phaenopsectra?*		RS
	Chironomidae	*Polypedilum*		A,F
	Chironomidae	*Procladius*		F,RS
	Chironomidae	*Psectrocladius*		CV.SG
	Chironomidae	*Pseudochironomus*		A.RS
	Chironomidae	*Pseudodiamesa*		CV,SG,UP
	Chironomidae	*Pseudosmittia*		G
	Chironomidae	*Rheocricotopus*		SG.UP
	Chironomidae	*Rheotanytarsus*		A,F,PS,RS, UP
	Chironomidae	*Robackia*		CV
	Chironomidae	*Stempellina*		G
	Chironomidae	*Stempellinealla?*		L
	Chironomidae	*Tanytarsus*		CV
	Chironomidae	*Thienemannimyia*		A,CV,L,RS,S, UP
	Chironomidae	*Thienemanniella*		A
	Chironomidae	*Tvetenia*		B,CV,F,L,PS, S,SG,UP

S	LOCATION **
	CV,S,UP
	A,B,F,G,L,S, SG,UP
	RS
	CV
	A,B,CV,F,L, PS,RS,SG,UP
	D,F
	F
	A,F,G,PS
	A,F,G,PS
	A,B,CV,F,PS, RS,S,SG,UP
	B,CV,L,S,SG, UP
	L,RS,S,SG, UP
	B,CV,S,SG
	SG
	CV
	CV
	CV,SG,UP
	RS
	A,F
	F,RS
	CV,SG
	A,RS
	V,SG,UP
	G
	SG,UP
	A,F,PS,RS, UP
	CV
	G
	L
	CV
	A,CV,L,RS,S, UP
	A
	B,CV,F,L,PS, S,SG,UP

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Chironomidae	*Zavrelia*		F
	Chironomidae	*Zavrelimyia*		CV,RS,SG
	Chironomidae, Macropelopini			L,RS
	Chironomidae, Orthocladiinae			A,L,PS,RS
	Culicidae	*Aedes*		F
	Culicidae	*Chaoborus*		I,48
	Culicidae	*Culex*		F,H,RS,128
	Culicidae	*Culiseta*		D,H,G,L,M, 48,128
	Culicidae			S
	Dixidae	*Dixa*	*californica*	F
	Dixidae	*Dixa*		F,G,L,PS,RS
	Dolichopodidae			CV
	Empididae	*Chelifera*		CV,F,G,L,RS, S
	Empididae	*Oreogeton*		C,F,G,L,P,S
	Empididae	*Hemerodromia*		G,S
	Empididae			A,H
	Ephydridae	*Brachydeutera*		S
	Ephydridae	*Ephydra*		SG
	Muscidae	*Limnophora*	*aequifrons*	F
	Muscidae	*Limnophora*		A,D,L,S,SG
	Muscidae			RS,S
	Psychodidae	*Maruina*		B,G,L,PS,RS, S,SG
	Psychodidae	*Pericoma*		B,F,G,L,SG,U P
	Ptychopteridae	*Bittacomorpha*		A,G,L,S
	Ptychopteridae	*Ptychoptera*		G,UP
	Ptychopteridae			F
	Simuliidae	*Prosimilium*		A,F,G,L,S
	Simuliidae	*Simulium*		A,B,CV,F,G, L,PS,RS,S, SG, UP
	Simuliidae			D,F,G,L,S,SG
	Stratiomyidae	*Eulalia*		F
	Stratiomyidae	*Odontomyia*		G,PS,S
	Stratiomyidae			A,F,G,RS
	Syrphidae	*Tubifera*	*bastardii*	F

ORDER	FAMILY	GENUS	SPECIES	LOCATION **
	Tabanidae	*Chrysops*		CV,H,M
	Tabanidae	*Tabanus*		128,PW,S
	Tabanidae			F,G,L,S
	Tanyderidae	*Protanyderus*		F
	Tipulidae	*Antocha*	*monticola*	B,F,G,SG,UP
	Tipulidae	*Antocha*		G,L,S
	Tipulidae	*Dicranota*		B,F,CV,G,L, PS,S,SG,UP
	Tipulidae	*Hexatoma*		F,L,RS
	Tipulidae	*Holorusia*	*grandis*	F
	Tipulidae	*Holorusia*		RS
	Tipulidae	*Limonia*		CV,F,RS,S, UP
	Tipulidae	*Ormosia*		SG
	Tipulidae	*Pedicia*		B,F,L,SG
	Tipulidae	*Tipula*		B,CV,D,F,G, L,PS,RS,S, SG,UP
	Tipulidae			G,RS,UP

Non-Insect Aquatic Invertebrates Collected

PHYLUM or SUBPHYLUM	CLASS, ETC	COMMON NAME	LOCATION *
Annelida (Segmented worms)	Hirudinea	Leeches	A,F
	Oligochaeta, Lumbricidae *Eiseniella tetraedra*	Aquatic earthworms	F
	Oligochaeta, Lumbricidae	Aquatic earthworms	A,F,G,L,PS, RS,S,SG,UP
	Oligochaeta, Lumbriculidae	Aquatic earthworms	UP
	Oligochaeta, Naididae	Coil worms	F,G,L,RS,S, UP
	Oligochaeta, Tubificidae	Tubifex worms	RS,S,SG,UP
Arthropoda, Arachnoidea (Spiders, ticks, and mites)	Hydracarina	Water mites	C,F,G,L,PS,S
Aschelminthes (Round worms and hairworms)	Nematomorpha	Horsehair worm	C,F,G,L,P,S,

LOCATION **
CV,H,M
128,PW,S
F,G,L,S
F
B,F,G,SG,UP
G,L,S
B,F,CV,G,L, PS,S,SG,UP
F,L,RS
F
RS
CV,F,RS,S, UP
SG
B,F,L,SG
B,CV,D,F,G, L,PS,RS,S, SG,UP
G,RS,UP

NAME	LOCATION **
	A,F
worms	F
worms	A,F,G,L,PS, RS,S,SG,UP
worms	UP
	F,G,L,RS,S, UP
s	RS,S,SG,UP
	C,F,G,L,PS,S
m	C,F,G,L,P,S,

PHYLUM or SUBPHYLUM	CLASS, ETC	COMMON NAME	LOCATION **
	Nematomorpha, Gordioidea,Gordiidae, *Gordius*	Horsehair worm	F,G
	Nematoda	Free-living roundworm	F,G,L,PS,RS, S,SG
Crustacea (Crustaceans)	Amphipoda, Gammaridae, *Gammarus*	Scuds	RS
	Amphipoda, Talidridae, *Hyatella azteca*	Scuds	A,C,PS,RS
	Cladocera	Water fleas	O
	Copepoda	Copepods	S
	Ostracoda	Seed shrimp	C,RS,S,SG
Mollusca (Mollusks)	Lymnaeidae, *Lymnaea*	Snails	A,G,L,P, RS,S
	Physidae, *Physella gyrina*	Snails	A,F,RS
	Physidae, *Physella*	Snails	A
	Physidae, *Physa*	Snails	F,S
	Planorbidae, *Gyralus parvus*	Snails	G,IC,S
	Sphaeriidae, *Pisidium casertanum*	Fresh-water clams	F,G,L,PS,RS
	Sphaeriidae, *Pisidium compressa*	Fresh-water clams	H
	Sphaeriidae, *Pisidium*	Fresh-water clams	CV,UP
	Sphaeriidae	Fresh-water clams	B
	Gastropoda	Snails	SG
Platyhelminthes (Flatworms)	Turbellaria	Planaria	A,C,CV,F,G, L,PS,RS,S, SG,UP

Locations:

A = Ancho Canyon
B = Bulldog Gulch
C = Chaquehui Canyon
CV = Cañon de Valle
D = DP Canyon
F = Rio Frijoles and Frijoles Canyon
G = Guaje Canyon
H = High Explosives wastewater stream
I = Ice House pond, off West Jemez Road
L = Los Alamos Canyon
O = Otowi firestation pond
M = Mortandad
PW = Pajarito Wetlands
PS = Pajarito Springs
RS = Rio springs
S = Sandia Canyon
SG = Starmer's Gulch
UP = Upper Pajarito
48 = TA-48 pond
128 = outfall 128

Appendix B.

Aquatic Invertebrate Taxa Collected in Cañon de Valle and Starmer's Gulch

Aquatic Insects:

Order	Family	Genus (species)	Location*
Collembola			SG
Ephemeroptera	Baetidae	*Baetis (tricaudatus)*	CV, SG
	Baetidae	*Diphetor (hageni)*	SG
	Baetidae	*Centroptilum*	CV
	Leptophlebiidae	*Paraleptophlebia*	CV
	Siphlonuridae	*Ameletus*	SG
	Tricorythidae	*Tricorythodes*	CV
Plecoptera	Capniidae	*Capnia?*	CV
	Chloroperlidae	*Suwallia*	SG
	Chloroperlidae	*Sweltsa*	CV, SG
	Nemouridae	*Amphinemura*	CV, SG
	Nemouridae	*Malenka*	CV, SG
	Nemouridae	*Prostoia*	CV
	Nemouridae	*Zapada (cinctipes)*	CV, SG
	Perlidae	*Hesperoperla (pacifica)*	SG
	Perlodidae	*Isoperla*	CV
Hemiptera	Gerridae	*Gerris*	CV
Trichoptera	Glossosomatidae	*Agapetus*	SG
	Glossosomatidae	*Glossosoma*	SG
	Hydropsychidae	*Ceratopsyche (oslari)*	CV, SG
	Hydroptilidae	*Hydroptila*	CV
	Hydroptilidae	*Stactobiella*	CV
	Lepidostomatidae	*Lepidostoma*	SG
	Limnephilidae	*Hesperophylax*	CV, SG

Order	Family	Genus (species)	Location*
	Limnephilidae	*Oligophlebodes*	SG
	Rhyacophilidae	*Rhyacophila (brunnea)*	SG
Odonata	Aeshnidae	*Boyeria*	CV
	Aeshnidae	*Oplonaeschna*	CV
	Coenagrionidae	*Argia*	CV
	Cordulegastreridae	*Cordulegastor*	CV
Coleoptera	Curculionidae		SG
	Dytiscidae	*Agabus*	CV
	Dytiscidae	*Agabinus*	CV
	Elmidae	*Heterlimnius*	SG
	Elmidae	*Narpus*	SG
	Elmidae	*Optioservus*	CV, SG
	Hydrophilidae		CV, SG
	Staphylinidae		CV
Diptera	Ceratopogonidae		CV
	Chironomidae	*Brillia*	CV
	Chironomidae	*Corynoneura*	SG
	Chironomidae	*Cricotopus*	CV
	Chironomidae	*Diamesa*	CV
	Chironomidae	*Macropelopia*	CV
	Chironomidae	*Micropsectra*	CV, SG
	Chironomidae	*Orthocladius*	CV, SG
	Chironomidae	*Pagastia*	CV, SG
	Chironomidae	*Parochlus*	CV
	Chironomidae	*Paraphaenocladius*	CV, SG
	Chironomidae	*Paratendipes*	CV
	Chironomidae	*Pentaneura*	CV, SG
	Chironomidae	*Psectrocladius*	CV, SG

ıtion*
SG
SG
SG
SG
SG
SG
SG
SG

Order	Family	Genus (species)	Location*
	Chironomidae	*Pseudodiamesa*	CV, SG
	Chironomidae	*Robackia*	CV
	Chironomidae	*Tanytarsus*	CV
	Chironomidae	*Thienemannimyia*	CV
	Chironomidae	*Tvetenia*	CV, SG
	Chironomidae	*Zavrelimyia*	CV, SG
	Dolichopodidae		CV
	Empididae	*Chelifera*	CV
	Psychodidae	*Maruina*	SG
	Psychodidae	*Pericoma*	SG
	Simulidae	*Simulium*	CV, SG
	Tabanidae	*Chrysops*	CV
	Tipulidae	*Dicranota*	CV, SG
	Tipulidae	*Limonia*	CV
	Tipulidae	*Ormosia*	SG
	Tipulidae	*Pedicia*	SG
	Tipulidae	*Tipula*	CV, SG

Non-insect invertebrates:

Phylum	Class	Family	Location
Annelida	Oligochaeta	Lumbricidae	SG
	Oligochaeta	Tubificidae	SG
Mollusca	Pelecypoda	Sphaeridae, genus *Pisidium*	CV
Platyhelminthes	Turbellaria		CV, SG

* Location Abbreviations:

CV = Cañon de Valle

SG = Starmer's Gulch