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REFERENCE CONDITIONS FOR LOS ALAMOS NATIONAL LABORATORY STREAMS USING BENTHIC MACROINVERTEBRATE ASSESSMENT IN UPPER PAJARITO CANYON

RALPH E. FORD-SCHMID

New Mexico Environment Department, Department of Energy Oversight Bureau, 2044 A Galisteo St., Santa Fe, N M 87502

Abstract—Benthic macroinvertebrates and water samples were collected at three stations in upper Pajarito Creek and at one station in each of two first-order tributaries to Pajarito Creek at Los Alamos National Laboratory (LANL). A total of 63 taxa were identified from the five stations. Number of taxa per study location ranged from 25 to 35 and standing crop ranged from 2351 (no/m^2) to 11,212 (no/m^2). EPT/EPT + Chironomid ratios, a measure of community balance, ranged from 0.17 to 0.84, while another measure of community balance, the Shannon-Weaver's index of diversity, ranged from 2.48 to 3.53. The Winget and Mangum CTQd index, a measure of non-organic perturbations, ranged from 72.5 to 89.1, and the Hilsenhoff Biotic Index (HBI), a measure of the presence of organic perturbation, ranged from 4.20 to 6.92. Habitat assessments indicate that four of the five stations were comparable, whereas the station farthest downstream in Pajarito Canyon displayed effects of embeddedness, channel alteration, scouring and reduced flow. The HBI = 6.92, calculated for Starmer Spring station (ST 0.5), indicates fairly poor water quality with substantial organic pollution likely. The complete absence of the scraper functional feeding group, the dominance of the community by one tolerant midge, and the presence of mats of filamentous algae at Starmer Spring indicate a community structure that is tolerant of nutrient enrichment. The State of New Mexico water-quality standards for livestock watering and wildlife habitat were met at all stations, while the fisheries acute standard for aluminum (750 µg/L) was exceeded at the station farthest downstream in Pajarito Canyon. The 11 metrics used to compare sites indicate that the farthest upstream station in Pajarito Canyon (PA 9.0) is appropriate for use as the reference condition for future comparisons of streams at LANL.

INTRODUCTION

As part of a program to monitor water and habitat quality at Los Alamos National Laboratory (LANL), New Mexico Environment Department (NMED), Department of Energy Oversight Bureau (DOE OB) personnel collected benthic macroinvertebrate and water samples in upper Pajarito Canyon and two of its perennial tributaries, between July 1 and August 9, 1994. The five locations studied (Fig. 1) are: Station PA 9.0 - Pajarito Creek, 5 m below its confluence with Starmer Gulch; Station PA 8.7 - Pajarito Creek, 5 m below its confluence with Bulldog Gulch; Station PA 6.7 - Pajarito Creek, 10 m above its confluence with Two Mile Canyon; Station BU 0.01 - Bulldog Gulch, approximately 23 m upstream from its confluence with Pajarito creek; Station ST 0.5 - Starmer Gulch, approximately 800 m upstream from its confluence with Pajarito Canyon, 2 m upstream from Starmer Spring.

One purpose of this monitoring was to determine baseline conditions that could be used as a reference for future surface-water quality monitoring studies at LANL. Surveys conducted in most of the canyon systems at LANL have located springs and short perennial reaches that support macroinvertebrate communities. The quantity and quality of aquatic habitat is limited in the majority of these canyons, with the exception of upper Pajarito Canyon. Surveys indicate that upper Pajarito Canyon has optimum habitat consisting of gravel/rubble riffles, plunge pools, stable-vegetated undercut banks, healthy riparian vegetation, and perennial flows supplied by numerous springs.

General setting

LANL is located west of the Rio Grande in Los Alamos County, approximately 40 km northwest of Santa Fe, New Mexico. Geologically, LANL is located on the Pajarito Plateau, an area of deeply dissected Quaternary volcanic deposits and Tertiary fill of the Española Basin (Stone et al., 1993). The volcanics belong to the Bandelier Tuff, largely rhyolitic ash flows and pumice falls that were derived from the Valles caldera in the Jemez Mountains (Purtymun, 1980). The basin fill is represented by the Puye and Tesuque Formations. Perennial, interrupted, and ephemeral streams flowing easterly to the Rio Grande dissect the plateau into many narrow, finger-like mesas separated by narrow deep canyons. The average elevation of the mesas is approximately 2134 m. From an elevation of approximately 1890 m at White Rock, the plateau ends in sheer cliffs, dropping to 1646 m at the Rio Grande (Cross, 1994). The major canyons that cut across the plateau are Guaje, Rendija, Barrancas, Bayo, Pueblo, Los Alamos, Sandia, Mortandad, Pajarito, Water, Ancho, and Frijoles.

Springs at elevations between 2408 m and 2713 m on the eastern slopes of the Sierra de Los Valles supply perennial base flow to the headwaters of Guaje, Los Alamos, Pajarito and Water canyons (Abeele et al., 1981). These springs are located west of LANL property. Other springs and perennial reaches located in the western one third of LANL property have received little attention and are the subject of this report.

Study area

The vegetation of this study's canyon systems are generally of a mixed-conifer type, consisting of Douglas fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), ponderosa pine (*Pinus ponderosa*), and Gambels oak (*Quercus gambelii*). The mixed-conifer community prevails on north-facing slopes, while the south-facing slopes are drier and support a ponderosa pine/Gambel's oak community. The average annual precipitation in the vicinity is 475 mm. Summer rain showers during July and August account for 36% of the area's annual precipitation. (Anonymous, 1992a).

Springs, at elevations between 2225 m and 2286 m, supply base flow to Cañon de Valle, Starmer Gulch and Pajarito Canyon. Riparian vegetation and algal growth noted in 1992 (Anonymous, 1993) indicate that the springs in Starmer Gulch and Pajarito Canyon are perennial. Springs, at elevations between 2252 and 2255 m, supply base flow to another southern tributary to Pajarito Canyon. These springs are referred to as Keiling and Bulldog Springs, and the tributary is referred to as Bulldog Gulch. Bulldog Gulch joins with Pajarito Canyon at 35°51'23" N lat.; 106°19'53" W long. (approximately 500 m downstream from the Starmer Gulch junction). These springs discharge from units D or E of the Tshirege Member of the Bandelier Tuff (Rogers, 1995). This study documents water-quality parameters and the benthic macroinvertebrate communities present below these springs and in the perennial reaches of Starmer Gulch and upper Pajarito Canyon.

Station designations

All sample stations in major canyons are designated by incorporating the first two letters of the canyon name and the distance in miles from them to the Rio Grande, as determined from USGS topographic maps (scale 1:24000). For tributaries to major canyons, the station designation is the first two letters of that canyon name and the distance from its junction with the main canyon. For example, station PA 9.0 is located in Pajarito Canyon, 9.0 mi upstream from the Rio Grande, at the confluence of Starmer Gulch and Pajarito Creek. A sample collected in Starmer gulch, 16 m above the confluence with Pajarito Creek, would be designated ST 0.01. A sample collected in Pajarito Creek, below the confluence of Starmer Gulch would be designated PA 9.0.

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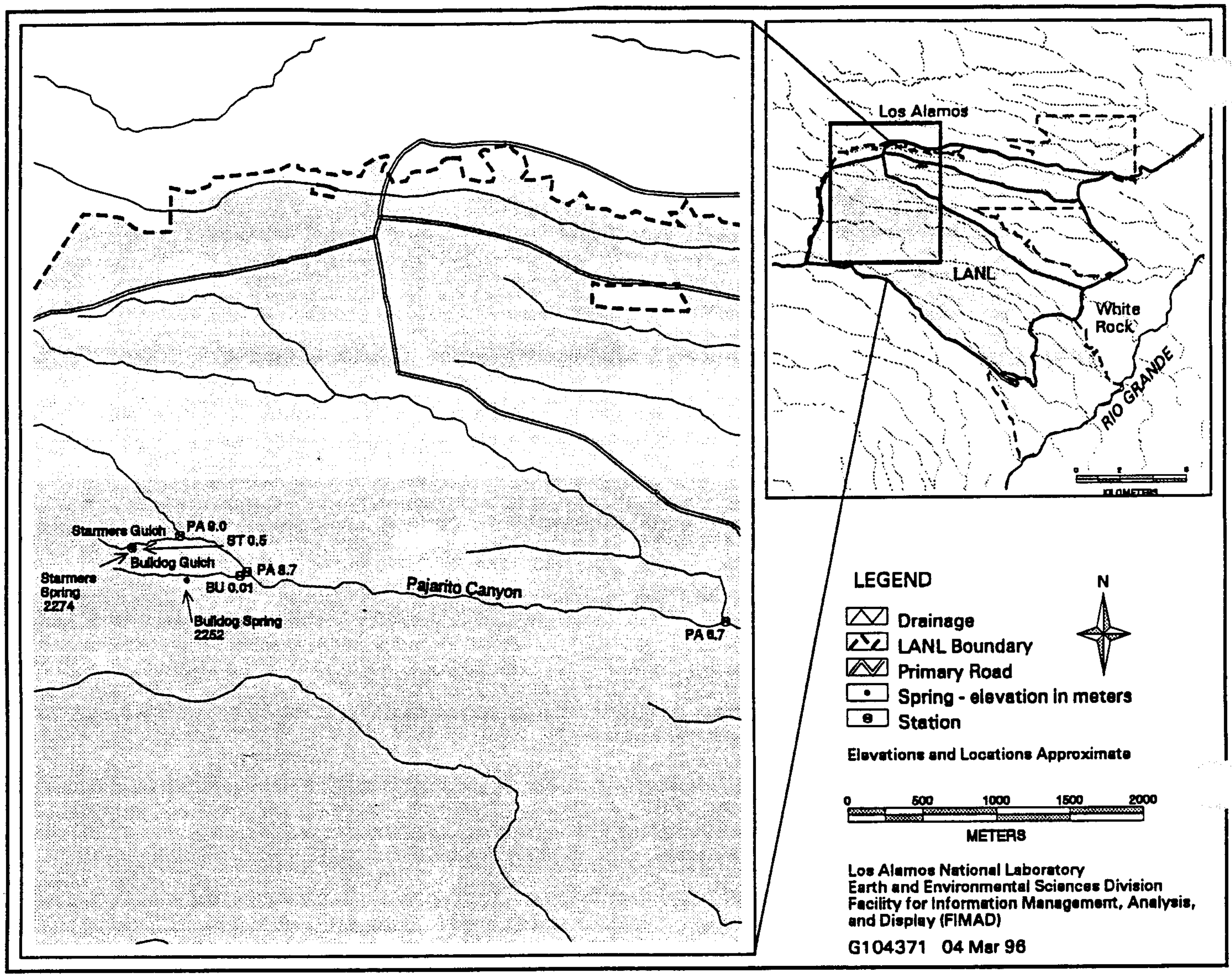

FIGURE 1. Location of upper Pajarito Creek, Bulldog Gulch and Starmer Gulch stations.

METHODS

Benthic macroinvertebrates

Three replicate, modified-Hess circular (Jacobi, 1978) samples (0.059 m^2) were collected from rubble substrate that represented the best habitat quality at each location. Samples were stored individually in 70% ethyl alcohol for analysis by Dr. Gerald Z. Jacobi of New Mexico Highlands University. Samples were sorted in their entirety and macroinvertebrates, with the exception of Chironomidae, were enumerated and identified to the lowest taxonomic level possible using available keys (Merritt and Cummins, 1984; Pennak, 1989; Usinger, 1956; Wiggins, 1978 and Baumann et al., 1977). Chironomidae were enumerated and identified to the genus level by Daniel L. McGuire of McGuire Consulting, Española, NM, using available keys (Coffman and Ferrington, 1984; Hilsenhoff, 1981; Oliver et al., 1978 and Wiederholm, 1983).

Habitat assessment

Benthic invertebrate habitat quality was rated using the U. S. EPA's Rapid Bioassessment Protocol III (RBP III) (Plafkin et al., 1989). This method rates nine habitat parameters (Table 1) and weights the scores according to their degree of importance to benthic macroinvertebrate communities. Habitat parameters are assigned to one of three categories: primary (substrate and instream cover), secondary (channel morphology), and tertiary (riparian and bank structure). The range of scores for parameters is 0–20 for primary, 0–15 for secondary, and 0–10 for tertiary. All nine parameter scores are totaled and the maximum score a site can receive is 135.

In the EPA-RBP III, flow is considered a primary habitat parameter and is scored from 0 to 20 for flows ranging from <0.5 cfs (14.2 L/sec) to >2 cfs (56.6 L/sec). The flow scoring range was modified to account for flows normally encountered at LANL because base flows in LANL streams are normally <15 L/sec and resulted in a score of 0 for all streams. Flows of 0.31–1.6 L/sec were scored 0–5; flows of 1.61–3.2 L/sec - 5–10, flows of 3.21–9.5 L/sec - 10–15; and flows of 9.51–15.7 L/sec - 15–20. Flow was measured monthly from February through November, 1995 with a bucket and stopwatch at natural waterfalls. Three to five such measurements were averaged for each station and the lowest monthly value was considered base flow for the purpose of habitat assessment. Where there were no natural falls, flow was visually estimated. Flow data used in this report will be presented in a forthcoming NMED report detailing water quality and flow characteristics of LANL springs and streams.

Water quality sampling

To aid in assessing the suitability of each location for colonizatio macroinvertebrates, field parameters (pH, dissolved oxygen, specific conductance, and temperature) were measured at each station. Water samples were collected for analysis by the Scientific Laboratory Divi-

TABLE 1. Habitat quality assessment for upper Pajarito Creek, Bulldog Gulch and Starmer Gulch stations.

HABITAT PARAMETER	LANL REFERENCE FOR STREAMS PA 9.0	PA 8.7	PA 6.7	BU 0.01	ST 0.5
Date	22-Jul-94	22-Jul-94	22-Jul-94	9-Aug-94	22-Jul-94
Latitude	35 51 31	35 51 23	35 51 14	35 51 23	35 51 31
Longitude	106 21 20	106 19 53	106 17 46	106 19 53	106 20 21
Elevation	2243 m	2225 m	2164 m	2231 m	2271 m
Bottom substrate instream cover	15	15	10	14	11
Embeddedness	16	19	6	11	16
Flow	8	9	6	3	4
Channel alteration	12	15	7	12	11
Bottom scouring and deposition	9	15	7	12	9
Pool/riffle, run/bend ratio	12	11	10	15	15
Upper bank stability	10	10	10	10	10
Bank vegetative protection	10	10	10	10	9
Streamside cover	9	9	9	8	10
Total Score	*101*	*113*	*75*	*95*	*95*

sion (SLD) of the New Mexico Department of Health for total and dissolved metals, nutrients, and general water chemistry. Samples analyzed for dissolved metals were passed through a 0.45 micron filter prior to shipment to SLD. Samples analyzed for total and dissolved metals were preserved with nitric acid. Samples analyzed for nutrients were preserved with sulfuric acid. All samples were stored on ice at 4°C until analyzed at SLD. Water quality sampling methods were in accordance with the U. S. EPA-approved Quality Assurance Project Plan for Water Pollution Control Programs (Anonymous, 1992b).

Data analysis

This assessment modified metrics (calculations used for comparisons in biological assessments) found in the EPA-RBP III for use in streams and rivers. Taxonomic data were entered into a computer program (BASICA, developed by M. D. and G. Z. Jacobi), which incorporates a data base of over 550 macroinvertebrate taxa found in New Mexico streams. This program calculated the metrics used in this report. A complete description of these common metrics can be found in (Klemm et al., 1990; Plafkin et al., 1989, or Garn and Jacobi, in press). The following metrics were used in this report (G. Z. Jacobi, unpubl. report for Camp, Dresser McKee, 1994).

"Eleven metrics were selected as indices of comparison because individual taxa as well as total communities respond to stress (flow regime, sediment loading, organic and toxic pollutants, thermal variation, etc.) in different ways. The selected metrics, which encompass a wide range of benthic macroinvertebrate sensitivity to environmental perturbation, included (1) Standing crop (macroinvertebrate density, No/m^2); (2) Taxa richness (number of taxa per study location); (3) CTQ$_d$ - community tolerance dominance quotient, from Winget and Mangum (1979) BCI - biotic condition index methodology; (4) HBI - Hilsenhoff's biotic condition index (Hilsenhoff, 1988); (5) EPT Index (the number of Ephemeroptera, Plecoptera and Trichoptera taxa present); (6) EPT/EPT + Chironomidae (total number of organisms in Ephemeroptera, Plecoptera, and Trichoptera/EPT +Chironomidae); (7) Community loss (the number of taxa at a reference location minus the number of common taxa/the number of taxa at the comparison location) which is related to similarity between sample locations; (8) Percent dominant taxon (the taxon which contained the greatest number of organisms at each study location); (9) Diversity index (d) which reflects the number of specimens in the various taxa and the richness of the taxa; (10) Scrapers/scrapers + filtering collectors feeding groups; and (11) Shredders/total number of organisms in the sample."

These criteria (Table 2) were used to assign scores for characterizing macroinvertebrate communities at a particular location (Garn and Jacobi, in press). The individual scores for each station were totaled to obtain the Biological Condition score and compared to the reference location total Biological Condition score. The reference location was selected to best represent the least perturbed stream or spring brook reach within LANL.

The categories defined by the Hilsenhoff Biotic Index (Table 3) were originally intended to evaluate samples collected in spring and fall. Samples collected from organically enriched streams during the summer tend to have much higher HBI values (Hilsenhoff, 1987). All data used in this study were collected in July and August and therefore may overestimate the degree of organic pollution. Adequate seasonal correctional factors have yet to be developed; therefore, I have used the next lower (better) assessment category of the HBI for determining the degree of organic pollution present. Macroinvertebrate samples, collected in April 1995 will be used to verify the results of this study.

RESULTS AND DISCUSSION

Biological assessment of upper Pajarito Creek, Bulldog Gulch and Starmer Gulch stations

Results of the benthic macroinvertebrate survey and the analysis of these data from upper Pajarito Creek, Bulldog Gulch, and Starmer Gulch are listed in Tables 4 and 5. The habitat analysis results are listed in Table 1. It should be noted that three genera of Chironomidae, identified from Starmer Gulch and upper Pajarito Creek, are uncommon in New Mexico,

TABLE 2. Metric scoring criteria (based on those of Garn and Jacobi, in press).

	Scoring Criteria			
score:	6	4	2	0
Standing Crop(No/m2)[a]	50-149%	35-49% or 150-199%	20-345% or 200-249%	<20% or >250%
No. of Taxa [a]	>80%	60-79%	40-59%	<40%
CTQ$_d$ [b]	>85%	70-84%	50-69%	<50%
HBI[a]	>85%	70-84%	50-69%	<50%
EPT Index [a]	>90%	80-89%	70-79%	<70%
EPT/EPT+Chironomidae[a]	>75%	50-74%	25-49%	<250%
Community Loss[c]	<0.5	0.5-1.4	1.5-3.9	>4.0
Dominant Taxon[d]	<20%	20-29%	30-39%	>40%
Diversity[d]	>3.0	2.00-2.99	1.00-1.99	<1.00
Sc./Sc. + Fl. Cl.[a]	>50%	35-49%	20-34%	<20%
Shredders/Total[a]	>50%	35-49%	20-34%	<20%

[a] score is a ratio of study site to reference site x 100.
[b] score is a ratio of reference site to study site x 100.
[c] range of values obtained-comparison to reference station.
[d] actual % composition for study and reference station.

TABLE 3. Evaluation of water quality using the family-level biotic index (Hilsenhoff, 1988, table 2).

Biotic Index	Water Quality	Degree of Organic Pollution
0.00 - 3.75	Excellent	Organic pollution unlikely
3.76 - 4.25	Very Good	Possible slight organic pollution
4.26 - 5.00	Good	Some organic pollution probable
5.01 - 5.75	Fair	Fairly substantial pollution likely
5.76 - 6.50	Fairly Poor	Substantial pollution likely
6.51 - 7.25	Poor	Very substantial pollution likely
7.26 - 10.00	Very Poor	Severe organic pollution likely

TABLE 4. Metric calculations for upper Pajarito Creek, Bulldog Gulch and Starmer Gulch stations.

Metric	Stations PA 9.0 reference	PA 8.7	PA 6.7	BU 0.01	ST 0.5
Calculated Value					
Standing Crop (No./m2)	2589	6562	2913	2351	11212
No. of Taxa	25	25	32	25	35
BCI (CTQd)	80.0	77.9	89.1	72.5	85.5
HBI	4.38	4.95	4.20	4.66	6.92
EPT Index	10	11	8	8	8
EPT/EPT + Chiron.	0.84	0.79	0.78	0.60	0.17
Community Loss	0	0.24	0.38	0.52	0.23
% Dominant Taxon	21	39	55	24	59
Diversity	3.53	2.67	2.63	3.52	2.48
Scra./Scra.+Filt. Coll.	0.948	0.961	0.975	0.637	0.000
Shredders/Total	0.051	0.023	0.139	0.012	0.171
Percent of Reference					
Standing Crop (No./m2)	100	253	112	90	433
No. of Taxa	100	100	100	100	100
BCI (CTQd)	100	100	89	100	93
HBI	100	88	100	93	63
EPT Index	100	100	80	80	80
EPT/EPT + Chiron.	100	94	93	71	20
Scra./Scra.+Filt. Coll.	100	100	100	67	0
Shredders/Total	100	44	100	24	100
Score					
Standing Crop (No./m2)	6	0	6	6	0
No. of Taxa	6	6	6	6	6
BCI (CTQd)	6	6	6	6	6
HBI	6	6	6	6	2
EPT Index	6	6	4	4	4
EPT/EPT + Chiron.	6	6	6	4	0
Community Loss	6	6	6	4	6
% Dominant Taxon	4	2	0	4	0
Diversity	6	4	4	6	4
Scra./Scra.+Filt. Coll.	6	6	6	6	0
Shredders/Total	6	4	6	2	6
Biological Condition					
Total	64	52	56	54	34
% of Reference	100	81	87	84	53
Condition		NI	NI	NI	MI
Habitat Condition					
Total	101	113	75	95	95
% of Reference	100	100	74	94	94
Condition		C	PS	C	C

and restricted to springs and first-order streams. They are listed as Chironomidae A, B, and C in Table 5.

Station PA 9.0

Station PA 9.0 was selected as the reference site for this analysis. The habitat at this site rated "good", though it was moderately impacted by bottom scouring and deposition. This station had the highest benthic diversity (3.53), the lowest percent dominant taxon (21% *Baetis tricaudatus*), a moderately tolerant mayfly, and the highest EPT/EPT + Chironomid ratio (0.84). These metrics indicate a well-balanced, diverse community. The Winget & Mangum CTQd index of 80.0 indicates a community that is moderately tolerant to inorganic perturbations (sedimentation, low flows, habitat degradation). Sampling conducted by the LANL Ecological Studies Team obtained similar values at their upper Pajarito and Starmer Gulch stations (Cross, 1995). Wilhm's biodiversity index values ranged from 2.20–3.03 and CTQ values ranged from 70.4–87.5 (Cross, 1995). The standing crop values reported by Cross (1995) are generally lower than those reported here and may be attributable to the use of a Surber sampler instead of a circular sampler (Jacobi, 1978). The HBI index (4.38) indicates "very good" water quality with "possible slight organic pollution" (Table 3).

Station PA 8.7

The habitat at this site was comparable, though it rated slightly higher than the reference site. The substrate was less embedded, and displayed fewer effects from scouring and deposition. The standing crop of 6562 was 2.5 times the standing crop of the reference station. Diversity (2.67) was lower due to the dominance of three taxon, *Simulium* sp.(39%), *Optioservus* sp. (24%), and *Baetis tricaudatus* (18%). The Winget & Mangum CTQd (77.9) was lower, primarily due to the presence of seven intolerant EPT taxa. The HBI index (4.95) indicates "very good" water quality with "possible slight organic pollution" (Table 3). Overall, the biological condition at this site scored 81% of the reference condition and was considered non-impaired (Table 4).

TABLE 5. Taxa represented at upper Pajarito Creek, Bulldog Gulch and Starmer Gulch stations.

	Stations PA 9.0 reference	PA 8.7	PA 6.7	BU 0.01	ST 0.5
PLECOPTERA - stoneflies					
Amphinemura banksi Baumann and Gaufin	6	51	352	0	1361
Isoperla sp.	0	0	17	0	0
Sweltsa sp.	193	40	0	0	0
Alloperla severa (Hagen)	0	85	0	45	62
Hesperoperla pacifica (Banks)	266	62	0	51	40
EPHEMEROPTERA - mayflies					
Ameletus sp.	79	6	0	0	6
Baetis tricaudatus Dodds	539	1162	34	232	295
Centroptilum sp.	0	0	6	0	0
Paraleptophlebia sp.	0	0	0	0	6
TRICHOPTERA - caddisflies					
Rhyacophila sp.	0	0	0	0	11
Rhyacophila brunnea complex	0	108	0	11	0
Glossosoma sp.	6	102	0	0	0
Ceratopsyche oslari sp. (Banks)	23	68	40	312	0
Hydroptila sp.	6	6	198	11	0
Hesperophylax sp.	57	51	6	0	85
Psychoglypha sp.	0	0	0	6	0
Ecclisomyia sp.	11	0	0	0	0
Lepidostoma sp.	0	0	17	23	0
DIPTERA - true flies					
Tipulidae	0	6	0	0	0
Pedicia sp.	0	0	0	51	0
Antocha monticola Alexander	0	6	0	323	11
Dicranota sp.	57	0	23	125	34
Tipula sp.	0	0	0	6	6
Maruina sp.	0	0	0	11	0
Pericoma sp.	6	0	0	11	57
Simulium sp.	227	2529	6	79	119
Chironomidae A Paramerina sp.	0	0	0	0	17
Chironomidae B Boreochlus sp.	0	0	0	0	23
Chironomidae C Chaetocladius sp.	0	6	23	0	0
Diamesa sp.	51	159	0	0	0
Pagastia sp.	119	221	17	289	6645
Thienemannimyia sp.	0	0	11	0	0
Pseudodiamesa sp.	0	0	0	0	340
Orthocladius sp.	6	0	6	11	45
Brillia sp.	11	6	23	0	136
Eukiefferiella sp.	0	28	28	40	68
Parametriocnemus sp.	6	0	11	0	57
Tvetenia sp.	6	45	28	17	306
Cricotopus sp.	0	0	6	0	318
Corynoneura sp.	34	0	0	11	40
Rheocricotopus sp.	0	0	6	0	40
Rheotanytarsus sp.	0	0	6	0	0
Micropsectra sp.	0	0	23	57	
Paraphaenocladius sp.	0	0	0	45	
Ceratopogonidae	0	0	6	17	
Ephydra sp.	0	0	0	0	
HEMIPTERA - true bugs					
Gerris sp.	0	0	11	0	0
Rhagovelia sp.	0	0	6	0	0
Circadellidae	0	0	6	0	0
COLEOPTERA - beetles					
Dytiscidae	0	0	6	0	0
Helichus sp.	6	6	0	0	0
Heterelmis sp.	0	0	255	0	62
Narpus sp.	57	34	0	0	6
Optioservus sp.	414	1559	1588	556	0
Curculionidae	0	0	0	0	6
COLLEMBOLA - springtails					
Poduridae	0	0	0	0	6
ASCHELMINTHES					
Nematoda	0	0	0	0	6
MOLLUSCA - snails/clams					
Sphaeriidae	0	0	0	11	0
ANNELIDA - segmented worms					
Tubificidae	0	0	6	0	0
Naididae	0	0	68	0	0
Lumbricidae	352	210	0	0	11
Lumbiculidae	0	0	74	0	0
PLATYHELMINTHES - flatworms					
Turbellaria	51	6	0	0	119
Total (numbers/m2)	2589	6562	2913	2351	11212

Station PA 6.7

The habitat at this site scored 74% of the reference site and was rated as partially supporting. Effects from scouring and deposition resulted in reduced instream cover, increased channel alteration, and increased embeddedness. This site had the highest number of taxa (32) of the three sites studied in upper Pajarito Creek, primarily due to an increased number of tolerant Diptera. The community was dominated by the moderately tolerant riffle beetle *Optioservus* sp. (55%). The EPT index (80% of the reference site) and the CTQd of 89.1 indicate a shift toward a community more tolerant of the reduced habitat quality. However the HBI index (4.20) indicates "excellent water quality" with "organic pollution unlikely" (Table 3). Overall the biological condition score was 87% of the reference site and was rated non-impaired (Table 4).

Station BU 0.01

The habitat score of 95 at station BU 0.01 was comparable to the reference site. The high number of taxa (25), diversity (3.52) and EPT/EPT + Chironomid index (0.60) indicate a reasonably well balanced macroinvertebrate community, though 24% of the sample consisted of the moderately tolerant riffle beetle, *Optioservus* sp. The low CTQd (72.5) indicates a high percentage of intolerant taxa, (11 of 25), six of which were intolerant Diptera. The HBI (4.66) indicates "very good water quality" with "possible slight organic pollution" (Table 3). Overall the biological condition score was 84% of the reference site and was rated non-impaired (Table 4).

Station ST 0.5

The habitat score of 95 at station ST 0.5 was comparable to the reference site, indicating that differences in the macroinvertebrate communities are probably attributable to water quality. Heavy growths of filamentous algae were present at this station, indicating possible nutrient enrichment. The standing crop at this station was 4.3 times higher than the reference site. Despite the high number of taxa (35), the diversity of 2.48 is the lowest of all five stations sampled. This is primarily due to the dominance of the macroinvertebrate community by the tolerant, collector-gatherer midge *Pagastia* sp. (59%), which is indicative of a community under stress (D. L. McGuire, personal commun., 1996). A shift in community structure to a high standing crop (11,212 no/m^2) dominated by one or few genera is common with eutrophication, or nutrient enrichment. The moderately elevated CTQd (85.5) is influenced by the sixteen tolerant Dipteran taxa which compose 80% of the total population. The EPT/EPT + Chironomid index (0.17) indicates a disproportionate number of tolerant midges. The HBI (6.92) generated from this station indicates "fairly poor water quality" with "substantial organic pollution likely" (Table 3). The Scraper/Scraper + Filtering Collectors feeding group metric reflects the riffle community food-base. Scrapers increase with increased diatom abundance and decrease as filamentous algae and aquatic mosses, (which scrapers cannot efficiently harvest) increases (Plafkin et al., 1989). Filamentous algae provide good attachment sites for filtering collectors, and the organic enrichment often responsible for overabundance of filamentous algae provide Fine Particulate Organic Matter (FPOM) utilized by the filterers (Klemm et al., 1990). The complete absence of the scraper functional feeding group and presence of mats of filamentous algae indicate a community structure tolerant of nutrient enrichment. Overall the biological condition score (34) is 53% of the reference station and ST 0.5 is considered moderately impaired (Table 4).

Water-quality data collected in 1994 for nutrient analysis did not indicate high nutrient levels (samples did not meet holding time). Surveys conducted in spring 1995 located an ephemeral spring, discharging approximately 3.8 L/min, approximately 10 m upstream from ST 0.5 (see Dale and Yanicak, this volume). Water samples collected on April 28, 1995, yielded 29 mg/L NO_3–N, 2.0 mg/L Kjeldahl–N, and 0.13 mg/L Total Phosphorus (see Dale and Yanicak, this volume). When the spring was resampled on May 24, 1995, the flow had dropped to less than 1 L/min, and the nutrient levels had dropped significantly to 0.1 mg/L NO_3–N, <0.5 mg/L Kjeldahl–N, and 0.09 mg/L Total Phosphorus (see Dale and Yanicak, this volume). This indicates that there may be a seasonal input, during the spring snowmelt, of nutrient-rich waters. The presence of algal growth at Starmer Spring, noted in 1992 (Anonymous, 1993), indicates this may be an annual or semi-annual occurrence.

Water-quality assessment

In accordance with Section 1105 of the State of New Mexico Standards for Interstate and Intrastate Streams, the current designated use for surface waters occurring at LANL is "livestock watering" and "wildlife habitat" (Anonymous, 1995). The water-quality data collected during this study indicate that the livestock watering and wildlife habitat standards are being attained. A comparison of the water-quality data and the fishery standards is provided in Tables 6 and 7 for discussion purposes only. While not applicable, the fishery "acute standard" for aluminum (750 μg/L) was exceeded at the most downstream station (PA 6.7), and the "chronic standard" for aluminum (87 μg/L) was exceeded at all stations. Chronic criteria are applicable only to the arithmetic mean of four samples collected on each of four consecutive days. The water quality of upper Pajarito Canyon, Starmer Gulch and Bulldog Gulch meets all applicable water-quality standards.

CONCLUSIONS

Conditions at station PA 9.0 in upper Pajarito Creek are the appropriate reference conditions with which to compare other LANL streams and spring brooks. Upper Pajarito Creek supports a diverse, well-balanced, moderately tolerant macroinvertebrate community. Habitat quantity and quality is high at the junction of Starmer Gulch and Pajarito Creek, displaying some degradation 2.6 km downstream due to scouring, deposition and reduced flows, which result in reduced instream cover and increased embeddedness. Water quality is good, though there may be periodic inputs of elevated nutrient levels 800 m upstream (near ST 0.5). Aluminum concentrations are elevated and are probably attribut-

TABLE 6. General water chemistry results and coldwater fishery standards (Anonymous, 1995).

UPPER PAJARITO SAMPLING STATIONS / WATER CHEMISTRY	DATE / TIME / UNITS	ST 0.5 22-Jul-94 1420	ST 0.0 1-Jul-94 1320	PA 9.0 22-Jul-94 1445	BU 0.01 22-Jul-94 1300	PA 6.7 22-Jul-94 1117	COLD WATER FISHERIES STANDARDS
AIR TEMP	(C)						
WATER TEMPERATURE (FIELD)	(C)	11.7	12.5	14.3	14.6	16.5	< 20 C
CONDUCTIVITY (FIELD)	(uhmo)	120	122	138	200	120	
O2 DISSOLVED (FIELD)	(mg/L)	8.8	7.4	8.8	8.4	7.8	> 6.0mg/L
pH (FIELD)	(S.U.)	7.45	8.00	8.45	7.98	7.81	6.6 > pH < 8.8
NITRATE+ITE	(mg/L)	0.20Q	0.20	0.20Q	0.40Q	0.10KQ	
AMMONIA	(mg/L)	0.10Q	0.10Q	0.10Q	0.30Q	0.10KQ	
KJELDAHL N	(mg/L)	0.30Q	0.30Q	0.10Q	0.20Q	0.40Q	
TOTAL PHOSPHORUS	(mg/L)	0.09KQ	0.09KQ	0.09KQ	0.09KQ	0.09KQ	
Ca	(mg/L)	10.00Q	8.60Q	10.00Q	16.00Q	12.00Q	
Mg	(mg/L)	3.20Q	6.40Q	3.10Q	4.20Q	3.40Q	
K	(mg/L)	4.00Q	5.00Q	4.00Q	4.00Q	4.00Q	
Na	(mg/L)	9.00Q	9.00Q	10.00Q	18.00Q	13.00Q	
HARDNESS	(mg/L)	38.00Q	35.00Q	38.00Q	58.00Q	44.00Q	
ALKALINITY	(mg/L)	41.00Q	38.00Q	42.00Q	65.00Q	52.00Q	
BICARBONATE	(mg/L)	50.00Q	46.00Q	52.00Q	79.00Q	64.00Q	
CARBONATE	(mg/L)	0.00Q	0.00Q	0.00Q	0.00	0.00Q	
CHLORIDE	(mg/L)	8.00	8.00	8.00	12.00	9.00	
FLOURIDE	(mg/L)	0.10	0.10K	0.10	0.30	0.20	
SULFATE	(mg/L)	7.00	6.00	7.00	9.00	6.00	
COLOR TEST	(units)	15	25.00	20.00	15.00	50.00L	
CONDUCTIVITY (LAB)	(uS/cm)	120	113.00Q	120.00	197.00	153	
pH (LAB)	(S.U.)	7.28Q	7.90Q	6.95Q	7.34Q	6.81Q	
TDS	(mg/L)	142	154	122	174	162	
TSS	(mg/L)	18	5	4	3K	3K	

K = Less Than Q = Did Not Meet Holding Time NA = Not Analyzed For

TABLE 7. Total and dissolved metals results and water quality standards (Anonymous, 1995).

UPPER PAJARITO SAMPLING STATIONS DISSOLVED METALS	DATE TIME UNITS	Starmer Spring 22-Jul-94 1420	ST 0.0 1-Jul-94 1320	PA9.0 22-Jul-94 1445	BU 0.01 22-Jul-94 1300	PA 6.7 22-Jul-94 1117	Fisheries Acute Hardness-Dependent Criteria Hardness (35)	Fisheries Chronic Hardness-Dependent Criteria Hardness (35)	Livestock Watering Standards	Wildlife Habitat Standards
Al	(ug/l)	700	500	700	400	800	750	87	5000	
Ba	(ug/l)	100K	100K	100K	100K	100K				
Be	(ug/l)	100K	100K	100K	100K	100K	130	5.3		
B	(ug/l)	100K	100K	100K	100K	100K			5000	
Ca	(ug/l)	9600	9600	10,000	16,000	12,000				
Co	(ug/l)	50K	50K	50K	50K	50K			1000	
Cu	(ug/l)	10KQ	10KQ	10K	10KQ	10KQ	7	5	500	
Fe	(ug/l)	300	300	1,000	200	500				
Mg	(ug/l)	3200	2900	3400	4300	3600				
Mn	(ug/l)	50K	50K	50K	50K	50K				
Mo	(ug/l)	100K	1KQ	100K	100K	100K				
Ni	(ug/l)	100K	100K	100L	100K	100K	600	60		
Si	(ug/l)	20,000	19,000	NA	21,000	18,000				
Ag	(ug/l)	100K	100K	100K	100K	100K	0.7			
Sr	(ug/l)	100K	100K	100K	100K	100K				
Sn	(ug/l)	100K	100K	100K	100K	100K				
V	(ug/l)	100K	100K	100K	100K	100K			100	
Zn	(ug/l)	20Q	10KQ	10	20Q	1KQ	50	40	2500	
U	(ug/l)	NA	1KQ	NA	NA	NA				
As	(ug/l)	1KQ	1KQ	1K	2Q	2Q			200	
Cd	(ug/l)	1KQ	1KQ	1K	1KQ	1KQ	1.2	0.5	50	
Cr	(ug/l)	1KQ	1KQ	1K	1KQ	1KQ	700	90	1000	
Pb	(ug/l)	1KQ	1KQ	1K	1KQ	1KQ	21	0.8	100	
Hg	(ug/l)	0.5K	0.5K	0.5K	0.5K	0.5K				
Se	(ug/l)	5K	5K	5K	5K	5K			50	

UPPER PAJARITO SAMPLING STATIONS TOTAL METALS	DATE TIME UNITS	Starmer Spring 22-Jul-94 1420	ST 0.0 1-Jul-94 1320	PA9.0 22-Jul-94 1445	BU 0.0 22-Jul-94 1300	PA 6.7 22-Jul-94 1117	Fisheries Acute Hardness-Dependent Criteria Hardness (35)	Fisheries Chronic Hardness-Dependent Criteria Hardness (35)	Livestock Watering Standards	Wildlife Habitat Standards
Al	(ug/l)	600	1000	700	900	2400				
Ba	(ug/l)	100K	100K	100K	100K	100K				
Be	(ug/l)	100K	100K	NA	NA	100K				
B	(ug/l)	100K	100K	NA	NA	100K				
Ca	(ug/l)	9800	16,000	NA	NA	12,000				
Co	(ug/l)	50K	50K	50K	50K	50K				
Cu	(ug/l)	10KQ	10KQ	10K	10KQ	10K				
Fe	(ug/l)	300	500	500	600	1,400				
Mg	(ug/l)	3300	3100	3100	4300	3700				
Mn	(ug/l)	50K	50K	50K	50K	50K				
Mo	(ug/l)	100K	1KQ	100K	100K	100K				
Ni	(ug/l)	100K	100K	100K	100K	100K				
Si	(ug/l)	20,000	19,000	20,000	19,000	1200				
Ag	(ug/l)	100K	100K	100K	100K	100K				
Sr	(ug/l)	100K	100K	100K	100K	100K				
Sn	(ug/l)	100K	100K	100K	100K	100K				
V	(ug/l)	100K	100K	100K	100K	100K				
Zn	(ug/l)	10KQ	10KQ	10K	10Q	1				
U	(ug/l)	NA	1KQ	NA	NA	NA				
As	(ug/l)	1KQ	1KQ	1K	4Q	2				
Cd	(ug/l)	1KQ	1KQ	1K	1KQ	1K				
Cr	(ug/l)	1Q	1Q	1K	3Q	3				
Pb	(ug/l)	1KQ	1K	1K	2Q	2				
Hg	(ug/l)	0.5K	0.5K	0.5K	0.5K	0.5K	2.4	0.012	10	0.012
Se	(ug/l)	5K	5K	5K	5K	5K	20	2	50	2

K = Less than Q = Did not meet holding time NA = Not analyzed for

able to the abundance of aluminum oxides in the rhyolitic ash-flow tuffs and pumice which make up much of the Pajarito Plateau.

Bulldog Gulch supports a diverse, well-balanced, moderately-intolerant macroinvertebrate community. Habitat quality is high, though limited in quantity. Low flow in Bulldog Gulch (45-57 L/min) is a major limiting factor affecting habit availability.

Starmer Gulch, near Starmer Spring (ST 0.5), supports an unbalanced, tolerant, macroinvertebrate community, indicative of nutrient enrichment. The distance downstream from ST 0.5 that is affected by the nutrient enrichment has not been determined, but the effects do extend to Pajarito Creek, 800 m downstream. The ephemeral natu springs discharging into Starmer Gulch emphasizes one of the adva... tages of biological assessment. An important value of using macroinvertebrates as an index to water quality lies in the long-term effects that invertebrates will reflect. Water samples offer a snapshot of the water quality at the time of collection, but give little insight to the streams' water-quality history. Water samples collected after a pulse of nutrient-rich spring discharge may not reveal nutrient enrichment, whereas the growth of filamentous algae and the macroinvertebrate community response to the organic enrichment will persist for some time after nutrient input has ceased.

Studies will be undertaken in 1996 to determine the flow characteristics and water-quality trends at ephemeral springs in Starmer Gulch, and the extent downstream that these flows influence the resident macroinvertebrate community. It is not yet understood whether the elevated nutrient levels are a natural phenomenon or due to anthropogenic causes. In view of the proximity of these ephemeral springs to a Solid Waste Management Unit (Material Disposal Area M), additional studies to determine the source of these nutrients are warranted.

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Travertine mound spring, in the reeds between the bathhouse in Jemez Springs and the Jemez River, issues at 72°C, and is the hottest spring outside the caldera depression. It is reported to contain an extremely rare species of alga.