Evaluation of Aquatic Macroinvertebrate Communities and Habitats in Los Alamos and Pueblo Canyons

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Introduction

This evaluation of aquatic macroinvertebrate communities and habitats was part of the biological investigations planned by the Los Alamos National Laboratory (LANL or the Laboratory) Risk Reduction and Environmental Stewardship Division Remediation Services Project for Los Alamos and Pueblo Canyons, as documented in Katzman (2002). This plan indicated that rapid bioassessments using US Environmental Protection Agency (EPA) protocols (Barbour et al. 1999) would be conducted at the end of the rainy season (September-October 2002) at sites in Los Alamos and Pueblo Canyons with persistent flow. The habitat assessments provide background information about physical aspects of site condition, while the aquatic macroinvertebrate community structure evaluations provide information about biological responses to site condition.

Methods

We performed habitat assessments and sampled aquatic macroinvertebrates at six sites at which flow volume could potentially support the development of aquatic invertebrate communities. The study sites included four locations in Los Alamos Canyon, one in DP Canyon (a tributary to Los Alamos Canyon), and one in Pueblo Canyon (Table 1). Reach LA-0 in Los Alamos Canyon was identified *a priori* as a reference site for the study due to its location upstream of Laboratory influences. However, although LA-0 is an appropriate upstream reference site from the standpoint of contaminants and Laboratory impacts, it is not used in this evaluation as a reference site for determining the biotic potential or optimal habitat for the test sites. A set of objective criteria such as land use, impoundment, degree of channel alteration, human and livestock activity, and vegetation cover should be used for identifying "minimally impacted" reference sites for evaluating ecological condition (Reynoldson et al. 1997, Hughes 1995, Barbour and Jacobi 2004, personal communication). LA-0 would be unlikely to meet these criteria for a reference site due to impoundment upstream and other human impacts in the site's watershed.

Table 1. Reach locations, descriptions, and dates for habitat assessments and macroinvertebrate sampling.

Location and description of reach	Reach ID	Date Sampled
Los Alamos Canyon upstream of Skating Rink; persistent, discontinuous flow	LA-0	09/30/02
Los Alamos Canyon near cattail wetlands; not representative of reach, but ecologically significant	LA-1FW	09/30/02
Los Alamos Canyon downstream of Basalt Spring, in area of perennial flow	LA-4W	10/02/02
Los Alamos Canyon, just downstream of Guaje Canyon confluence; increased flow in post-fire regime	LA-5W	09/17/02
Upper DP Canyon bedrock pools, potential for DP Tank Farm plus town site effects	DP-1C	10/03/02
Pueblo Canyon downstream of Bayo Wastewater Treatment Plant, near well PAO-1; representative area with incised channel in wetland	P-3E	10/03/02

Ideally, test sites would be compared to a *reference condition*, which comprises characteristics representative of a group of reference sites that are physically, chemically, and biologically similar to the test sites and that account for the natural variability among “minimally impacted” sites (Reynoldson et al. 1997, Hughes 1995). Reference conditions are currently being established for New Mexico streams by the New Mexico Environment Department (NMED) but are not yet available (Barbour and Jacobi 2004, personal communication). Because we do not yet have a reference condition for habitat and aquatic macroinvertebrate community characteristics, we compare the study sites only to each other and do not attempt to designate the extent to which they deviate from the “minimally impacted” condition.

For habitat evaluations, we sampled in a 50 m reach at each site using the US EPA Rapid Bioassessment Protocol (RBP) for high gradient streams (Barbour et al. 1999). The RBP habitat assessment involves scoring each site based on 10 parameters related to habitat quality, including watershed characteristics, riparian vegetation, instream features, aquatic vegetation, and benthic substrate (Appendix A). The scores for each parameter are summed to arrive at an overall habitat assessment score for a site. We also used portions of the Arizona Department of Environmental Quality’s (ADEQ) site assessment protocol (Appendix B) to provide complementary information about physical characteristics and habitat at the sites. Areas of overlap between the RBP and the ADEQ protocol allowed us to confirm or reconsider our ratings for certain parameters, while substantive differences between the protocols provided additional information about the sites. Again, because we do not know the range of scores that “minimally impacted” reference sites would receive using this protocol, we did not assign qualitative condition categories (e.g., optimal, suboptimal, marginal, and poor) to the overall habitat assessment scores. We instead considered only the numerical scores for each site.

We collected macroinvertebrate samples in the 50 m reach using a D-frame aquatic dip net (0.3 m wide with a 500 µm mesh). Per Barbour et al. (1999), sampling was semi-quantitative with effort standardized by taking 20 sweeps or “jabs” of the dip net at each site. In order to avoid bias in the types of substrates sampled, we first visually identified the types of habitats present (riffles, runs, pools, submerged vegetation) and estimated their percentage in the reach. We then sampled those habitats in proportion to their occurrence. Macroinvertebrate samples were preserved in the field in 99% isopropyl alcohol and returned to the laboratory for sorting. The sorted samples were submitted to a taxonomist with expertise in aquatic macroinvertebrates of New Mexico (Dr. Gerald Jacobi) for identification and enumeration. We then calculated macroinvertebrate community metrics for samples containing at least 100 total individuals. A minimum sample size of 100 specimens is required for macroinvertebrate metrics, with most aquatic monitoring programs requiring a minimum of 200 or 300 specimens (EPA 2001).

Macroinvertebrate metrics are measures of community composition (e.g., diversity, tolerance, richness, habit, and habitat) that change predictably in response to environmental degradation. There are numerous metrics that have been shown to be useful for specific watersheds or geographic areas, but these metrics vary in their robustness and cannot be used reliably in other geographic areas without first being validated. The NMED (with Tetra Tech, Inc.) has performed a preliminary statistical analysis of numerous potential macroinvertebrate metrics and identified six metrics (Table 2) as being the most likely to be responsive to environmental disturbance in New Mexico streams (Barbour and Jacobi 2004, personal communication). We used these six metrics for our evaluation because the NMED/Tetra Tech, Inc., analysis provides the best information available at this time about which macroinvertebrate metrics have the greatest utility for this area. The finalized set of validated metrics for New Mexico will not be available until the analysis has been completed by the NMED and Tetra Tech, Inc., later this year.

Table 2. Metrics used in this study and their hypothesized response to increases in environmental perturbation.

Metric	Definition	Hypothesized response to environmental perturbation
Richness		
# Ephemeroptera taxa	Number of taxa in the insect order Ephemeroptera (mayflies)	Decrease
# Plecoptera taxa	Number of taxa in the insect order Plecoptera (stoneflies)	Decrease
# Trichoptera taxa	Number of taxa in the insect order Trichoptera (caddisflies)	Decrease
Diversity		
Shannon-Weiner index	Incorporates richness and evenness in a measure of general diversity and composition	Decrease
Tolerance		
# intolerant taxa	Taxa richness of organisms considered to be sensitive to perturbation (tolerance values 0 to 3)	Decrease
Habit		
# clinger taxa	Percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water	Decrease

Results

<u>Los Alamos Canyon upstream of the Skate Rink (Reach LA-0):</u> The habitat assessment score of 141/200 was the highest of the sample locations (Table 3; see Appendix C for scores for each parameter). Moderately stable banks, benthic substrate in a mix of size classes from sand to medium-sized cobble, energy inputs of coarse particulate organic matter from riparian vegetation, and the presence of medium- to large-sized organic debris in the channel indicated that this site could provide high-quality habitat for aquatic life. Width, structural complexity, and estimates of aerial coverage of vegetation in the riparian zone indicated good buffer potential, although to a lesser extent on the left bank (facing downstream) due to the proximity (approximately 10 m) of the road paralleling the stream. The habitat parameters for velocity/depth regime and flow status were scored low due to nearly absent flow on the day of sampling.

Macroinvertebrate abundance in this reach was sufficient for metric calculations, with 116 individuals in the sample (see Appendix D for sample data, and Appendix E for taxa attributes used in metric calculations). Of the three sampling locations that had macroinvertebrate abundance sufficient for metric calculation, the sample from this reach had the highest (best) metric values for diversity, tolerance, and habit.

<u>Los Alamos Canyon near Cattail Wetlands (Reach LA-1FW):</u> Habitat quality received a score of 107/200. Benthic substrate was unstable and dominated by sand and gravel, with substantial sediment deposition. The velocity/depth regime lacked complexity, consisting of approximately 50% very shallow riffle and 50% shallow run. Most of the available riffle substrate was exposed due to low flow. Bank stability was moderate on the left bank but poor on the right bank, with many eroded areas. Width, structural complexity, and estimates of aerial coverage of vegetation

in the riparian zone indicated moderate to good buffer potential.

Macroinvertebrate abundance in this reach was sufficient for metric calculations, with 167 individuals in the sample. Metric values for this site were similar to values for LA-0 but tended to be slightly lower.

Los Alamos Canyon downstream of Basalt Spring (Reach LA-4W): Habitat quality at this site received a score of 97/200. Although the stream rated high for bank stability, the benthic substrate was almost exclusively sand over bedrock, with very little cobble or organic debris for colonization by macroinvertebrates. The velocity/depth regime consisted of almost 100% shallow run. Discharge on the day of sampling was very low, but there was evidence of recent flooding to an estimated width of 20 m in the sample reach. Width, structural complexity, and estimates of aerial coverage of vegetation in the riparian zone indicated moderate to good buffer potential.

Macroinvertebrate abundance in this reach was insufficient (26 individuals) for metric calculation.

Los Alamos Canyon downstream of confluence with Guaje Canyon (Reach LA-5W): The habitat assessment score of 54/200 was the lowest among the study locations. The water had a slight odor of sewage. During one site visit, flow from Los Alamos Canyon upstream of the Guaje Canyon confluence approximately tripled and was accompanied by foaming and an increase in turbidity. The active stream channel was very shallow, unstable, and braided, with low flow and a velocity/depth regime consisting of primarily runs with a few riffles and occasional small, isolated pools. The benthic substrate consisted of primarily sand with very little gravel or cobble. Both banks were severely eroded, with raw, vertical walls at a height of up to 3 m above the streambed. Width, structural complexity, and estimates of aerial coverage of vegetation in the riparian zone suggested moderate buffer potential on the left bank and poor buffer potential on the right bank.

Macroinvertebrate abundance in this reach was insufficient (20 individuals) for metric calculation.

Upper DP Canyon (Reach DP-1C): The habitat at this sited received a score of 130/200. The relatively high score was due primarily to parameters pertaining to bank stability, degree of channel alteration, vegetative protection, and vegetative zone width. The channel had very low flow and consisted of a series of isolated bedrock pools separated by boulders. The benthic substrate in the pools was composed of a thin layer of coarse sand and gravel, with no aquatic vegetation and little organic debris, providing little potential for colonization by macroinvertebrates. Refuse was common in the reach. Width, structural complexity, and estimates of aerial coverage of vegetation in the riparian zone indicated moderate to good buffer potential.

Macroinvertebrate abundance in this reach was insufficient (7 individuals) for metric calculation.

Pueblo Canyon (Reach P-3E): Habitat quality at this site received a score of 105/200. Our sampling visit coincided with the approximately daily discharge from the Bayo wastewater treatment plant. The water was turbid and light brown, with foaming and a sewage odor. The velocity/depth regime consisted of 100% shallow run, with an homogeneous, poor-quality benthic substrate consisting of fine sediments and decayed organic material. Width, structural complexity, and estimates of aerial coverage of vegetation in the riparian zone indicated moderate buffer potential and evidence of nutrient enrichment.

Although macroinvertebrate abundance was sufficient for metrics calculation (175 individuals), the sample was composed entirely of individuals belonging to the Tubificidae (sewage worm) family, and none of the metrics scored above zero.

Table 3. Habitat assessment scores, macroinvertebrate sample abundance, and macroinvertebrate metrics.

	Reach ID					
	LA-0	**LA-1FW**	**LA-4W**	**LA-5W**	**DP-1C**	**P-3E**
Habitat Assessment Score	141/200	107/200	97/200	54/200	130/200	105/200
Macroinvertebrate Sample Abundance	116	167	26	20	7	175
Number of Taxa	12	11	4	6	3	1
Macroinvertebrate Metrics						
Richness						
# Ephemeroptera taxa	1	2	-	-	-	0
# Plecoptera taxa	0	0	-	-	-	0
# Trichoptera taxa	0	0	-	-	-	0
Diversity						
Shannon-Weiner index (base 2)	2.44	1.91	-	-	-	0.00
Tolerance						
# intolerant taxa	2	1	-	-	-	0
Habit						
# clinger taxa	3	1	-	-	-	0

Discussion

The habitat assessment score for LA-0 indicated that this site had higher habitat quality than the test sites included in this study. However, it received a lower habitat assessment score than other LANL sites sampled recently using the same protocol. Three of the five habitat assessments performed by personnel with LANL's Water Quality and Hydrology Group (RRES-WQH) in 2001 received higher habitat assessment scores than LA-0: Sandia Canyon just downstream of Diamond Drive (166/200), Sandia Canyon downstream of the wetlands (155/200), and Pajarito Canyon downstream of the confluence of Starmer's Gulch (155/200) (Buckley et al. 2003). In spite of having higher habitat assessment scores than LA-0, all three of these sites are significantly impacted by human activities (Sandia Canyon) or fire (Pajarito Canyon) in their watersheds and are not considered to be reference sites. These results support our assertion that although LA-0 can serve as a reference site for LANL-source contaminants, it is not a "minimally-impacted" reference site from the standpoint of aquatic habitat quality.

Human activities and other potential impacts on a stream can be identified relatively easily through watershed reconnaissance and site assessments. Determining the extent to which habitat quality deviates from the optimum is more difficult. This is particularly problematic in arid and semi-arid regions of the US because most habitat assessment protocols have been developed for mesic regions. We have attempted to address some of these issues by not assigning qualitative scores (e.g., marginal or poor) to the sample sites, but this accounts only for the possibility that the parameters are scaled inappropriately for these sites and not for the possibility that some of the habitat parameters are inapplicable, or that important data are being omitted. Development of habitat assessment protocols that are specific to arid and semi-arid regions will greatly improve our ability to evaluate habitat quality using appropriate benchmarks.

The presence of almost exclusively Tubificidae (sewage worm) specimens in Pueblo Canyon (P-3E) is consistent with sites receiving outfalls from sewage treatment plants, as this taxon is particularly tolerant of low oxygen conditions and sedimentation. Extremely low abundance of macroinvertebrates in Los Alamos Canyon downstream of Basalt Spring (LA-4W), DP Canyon (DP-1C), and Los Alamos Canyon near the Guaje confluence (LA-5W) was probably due to poor benthic substrate. Benthic substrates at LA-4W and DP-1C were composed of a thin layer of sand or gravel over bedrock, which had little potential for colonization by macroinvertebrates. Los Alamos Canyon near Guaje (LA-5W) had very unstable substrate composed primarily of sand, which is unsuitable for colonization by many macroinvertebrate taxa. Similar to the results of this study, Buckley et al. (2003) also found that sites with relatively low habitat assessment scores tended to also have low macroinvertebrate abundance. Even when overall habitat assessment scores are relatively high, such as with DP-1C, very low scores for critical parameters such as flow status or epifaunal substrate have potential to be limiting factors for aquatic life. With the exception of streams that have effluent-dependent flow (e.g., Pueblo Canyon), the structures of the aquatic communities at all of these sites are probably stressed by habitat changes due to drought and fire impacts in the watershed, including post-fire floods that have scoured the channels in LA-4W and LA-5W, and frequent floods and scouring generated by urban runoff into DP-1C.

Other historical data from LANL are inappropriate for direct comparison to data from this study because of inconsistencies in locations, sampling methods, and the sampling season. For example, a sample collected in Los Alamos Canyon downstream of the reservoir spillway in June 1993 (NMED 1993, unpublished data) is the best candidate for comparison with LA-0 and LA-4W because of the proximity of the sites. However, the aquatic communities and habitats at the NMED site are more impacted by the reservoir and spillway than the Los Alamos Canyon sites downstream. An additional limitation is that the NMED used a modified Hess sampler to sample macroinvertebrates from exclusively riffle habitats, while we used a D-frame net and sampled multiple habitats for this study. Direct comparison of macroinvertebrate data that were collected using different gear and sampled from different habitats is not recommended (Myerhoff 2003, personal communication; Barbour and Jacobi 2004, personal communication). Comparing data collected in different seasons (mid June vs. late September) is also problematic. A recent analysis of a large number of samples collected in New Mexico indicated that samples collected during summer months are highly variable compared to samples collected in the spring and fall (Barbour and Jacobi 2004, personal communication). Our ability to detect and evaluate environmental stressors with macroinvertebrates will improve when validated macroinvertebrate metrics and reference conditions become available.

While single “snap-shot” assessments provide useful information about habitat quality and the structure of the aquatic community, the greatest value with macroinvertebrate and habitat assessments comes from repeating sampling at the same locations over time in order to detect trends and evaluate temporal variability in the data. Given the limitations in our knowledge of reference conditions for habitats and macroinvertebrates in arid and semi-arid streams, trend detection is also more appropriate than designating biological status or assigning qualitative judgments about site condition. If conducted in tandem with other independent data sources such as watershed surveys and studies of water quality parameters and contaminants, ongoing assessments would improve our understanding of macroinvertebrate community response to environmental stressors.

Recommendations

Future aquatic habitat and macroinvertebrate studies could be improved by building on prior research. However, decentralized data storage and inefficient indexing of LANL reports containing aquatic data (particularly if the aquatic studies were embedded in a larger project) have made it difficult to define LANL's historical dataset. Inconsistencies in field sampling methods and locations have also reduced the utility of the Laboratory's historical dataset. Personnel with LANL's Ecology Group (RRES-ECO) have begun addressing this issue by customizing a database that was developed specifically for the storage and analysis of aquatic data (Ecological Data Application System; Tetra Tech 2003) and compiling data from of all aquatic sampling that has been conducted on or near the Laboratory since the early 1990s, including data from this study. This database contains information such as sampling locations and dates, sampling methods, personnel, habitat assessment data, macroinvertebrate sample data, and macroinvertebrate taxa attributes used to derive macroinvertebrate metrics. Macroinvertebrate metric calculation can be performed very quickly using built-in or customized queries. The database will eventually be linked to a geographic information system and other data layers (such as land use), and will greatly enhance the ability of LANL staff to design new aquatic studies that build on prior research, combine data sets from compatible studies, or reanalyze data from earlier studies.

For future studies, we recommend consulting the aquatics database during the study design stage to ensure that sampling locations, times, and methods are compatible with other studies that could provide useful temporal or spatial comparisons. For example, LANL's RRES-WQH has instituted an aquatic monitoring program that involves sampling with a Hess sampler at six fixed locations in the spring and fall, and began sampling with artificial substrates in 2003 (see discussion below). Data from the RRES-WQH program could be very useful for providing information about recent conditions in Laboratory streams. In some cases, the use of multiple, side-by-side sampling methods might be needed to maximize comparability with more than one other study in which different sampling methods were used.

Regardless of the macroinvertebrate sampling method that is chosen, it can be difficult to determine whether changes in the aquatic community structure are related to habitat quality (particularly sedimentation) or water quality. In order to better distinguish habitat limitations from water quality issues, RRES-WQH and RRES-ECO staff are collaborating on a study comparing aquatic macroinvertebrate samples collected from artificial substrate samplers to macroinvertebrate samples collected from natural substrates at the same sites. The artificial substrate samplers are made up of 5 to 10 cm cobble enclosed in 2.5 cm mesh wire baskets, with an approximate overall volume of 2500 cm^3 ($22 \times 22 \times 5$ cm). The cobble substrate provides habitat that could potentially support taxa that are intolerant of sedimentation. The samplers are left in the sample reach to colonize for 4 to 6 weeks and are then collected at the same time that the Hess samples are collected. Results from this study are pending. If the study finds that there are consistent differences between the natural and artificial substrate samples, and if an ability to distinguish among habitat and water quality impacts is desired for future contaminant studies, we would recommend collecting macroinvertebrate samples using both artificial samplers and natural substrates.

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Appendix A. US EPA Habitat Assessment Field Data Sheets

HABITAT ASSESSMENT FIELD DATA SHEET - HIGH GRADIENT STREAMS

STREAM NAME	LOCATION
STATION # ________ RIVERMILE ________	STREAM CLASS
LAT ________ LONG ________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE ________ TIME ________ AM PM | REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal		Poor
1. Epifaunal Substrate & Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).		Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of > 25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score

Adapted from EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition, 1999.

Appendix B. Arizona Department of Environmental Quality Field Data Forms

LANL Bioassessment Field Data Sheet

SAMPLE LOCATION

Date:(dy/mo/yr): ______________________ Sample Time: ______________

Stream Name: ______________________ Site Name: ______________________

Site Description ____

Field Crew: ______________________ Program: ______________________

SITE INFORMATION

USGS 7.5' Quadrangle: ______________ Ownership: ______________

Watershed Name: ______________ Elev.(ft): ________

HUC - Reach: ______________ County: ____________ State: ______ Aspect: __________

Site Id Latitude (DMS): ____________ Site Id Longitude (DMS): ____________ Method: ____________

Watershed Area (mi²): ______________

Most Recent Flood Event (Date; Discharge): ______________________________

Designated Uses: ____

POST SAMPLING RECOMMENDATIONS

(Notes about flow regime, relocating site, site access, sample types, analysis parameters, etc.)

GENERAL SITE CHARACTERISTICS

General Appearance in the Stream Reach (Check all that apply)

No refuse visible
Small volume refuse (e.g., cans, paper) rare
Small volume refuse common
Large volume refuse (e.g., tires, carts) rare
Large volume refuse common

General Appearance of the Streambank along the Reach (Check all that apply)

No refuse visible
Small volume refuse (e.g., cans, paper) rare
Small volume refuse common
Large volume refuse (e.g., tires, carts) rare
Large volume refuse common

Water Appearance (Check all that apply)

Clear	Light brown	Reddish
Milky	Dark Brown	Greenish
Turbid	Oily Sheen	Other _

Water Odor (Check all that apply)

None	Chlorine	Rotten eggs
Sewage	Fishy	Other ____

Appearance at Water's Edge (Check one)

_____ No evidence of salt crusts
_____ White crusty deposits rare
Numerous white crusty deposits localized
Banks covered with white crusty deposits

Fish (Based on observation)

1. Abundant Comments: ______________________________
2. Rare Comments: ______________________________
3. Absent Comments: ______________________________

Crayfish (Based on observation)

1. Abundant Comments: ______________________________
2. Rare Comments: ______________________________
3. Absent Comments: ______________________________

Recent (past 2 months) flood or long term drought evidence (Check all that apply)

No recent flood evidence
Fresh debris line
Grasses laid over
Recent flood event greater than baseflow:
< bankfull width
> bankfull width - estimated width ______

_____ Fresh debris suspended in bushes/trees
_____ Other_____________________
_____ Drought Conditions Prevailing

Flow Regime (Check one)

Perennial stream channel. Surface water persists all year long.
Intermittent stream channel. One which flows only seasonally or sporadically. Surface sources include springs, snow melt and flows that reappear along various locations of a reach, then run subterranean (interrupted).
Subterranean stream channel. Flows parallel to and near the surface for various seasons; a subsurface flow which follows the stream bed.
Ephemeral stream channel. Flows only in response to precipitation.

Flow Variability (Check one)

Seasonal variation in stream flow dominated primarily by **snowmelt** runoff.
Seasonal variation in stream flow dominated primarily by **stormflow** runoff.
Uniform stage and associated stream flow due to **spring fed condition**.
Regulated stream flow due to diversions, dam release, dewatering, etc.
Altered flows due to development such as urban streams, cut-over watersheds, vegetation conversions (e.g. forested to grassland) that changes flow response to precipitation events.

AQUATIC PLANTS

Filamentous Algae

Estimated percent of filamentous algae covering stream bed throughout study reach: ____________________% cover

Floating Algae

Are any detached clumps or mats of algae floating downstream?

1. Abundant Comments: ______________________________
2. Rare Comments: ______________________________
3. Absent Comments: ______________________________

Algal Slime (not filamentous)

‹re the submerged rocks, bedrock, woody material in the stream coated with a layer of algal slime? May be slippery to the touch, but not readily visible.

Abundant - thick-coating Comments: ______________________________

Rare - thin-coating Comments: ______________________________

Absent Comments: ______________________________

Percent macrophytes covering stream bed throughout the reach: ____________________ % cover

Description of algae/macrophytes in reach (emergent and submergent):

CHANNEL/HABITAT COMPLEXITY

(Reach length equals 2 meander lengths or 20-30 times bankfull width of the stream) Use a minimum of 100 m reach to 'entify habitat types for large streams.

Habitat	Number of Paces	%	
Pool			
Riffle			
Run			Riffle/Pool Ratio
Total			

EMBEDDEDNESS

(Estimate the percent Embeddedness of 10 cobbles along each of three riffle transects. Select three different riffles within the reach wherever possible. Begin and end transect at edges of riffle, don't include edge particles of the wetted width. Count sand and fines as 100% embedded and bedrock and hardpan as 0% embedded. Gravel that is selected from a patch of gravel is considered 100% embedded)

											Average % Embeddedness
Transect #1											
Transect #2											
Transect #3											

ORGANIC DEBRIS/CHANNEL BLOCKAGES (IN ACTIVE CHANNEL)

Mark single most appropriate description

No organic debris or channel blockages

Infrequent debris, what's present consists of small, floatable organic debris.

Moderate frequency, mixture of small to medium size debris affects less than 10% of active channel area.

Numerous debris mixture of medium to large sizes - affecting up to 30% of the area of the active channel.

Debris dams of predominantly large material affecting over 30% to 50% the channel area and often occupying the total width of the active channel.

Extensive, large debris dams either continuous or influencing over 50% of channel area. Forces water onto flood plain even with moderate flows. Generally presents a fish migration blockage.

Beaver dams. Few and/or infrequent. Spacing allows for normal stream/flow conditions between dams.

Beaver dams - Frequent. Back water occurs between dams - stream flow velocities reduced between dams.

Beaver dams - abandoned where numerous dams have filled in with sediment and are causing channel adjustments of lateral migration, avulsion, and degradation etc.

Man made structures - diversion dams, low dams, controlled by-pass channels, baffled bed configuration with gabions, etc.

Riffle Pebble Count (Transect method; do 100 pebble counts in riffle habitat only; measure particles at equal increments across multiple line transects within the wetted width of available riffle habitat throughout the reach)

Size Class	Size Range(mm)	Tally	Count	Percent	Cumulative Percent
Silt/Clay*	<0.062				
Sand**	0.063-2				
Very Fine Gravel	3-4				
Fine Gravel	5-8				
Medium Gravel	9-16				
Coarse Gravel	17-32				
Very Coarse Gravel	33-64				
Small Cobble	65-96				
Medium Cobble	97-128				
Large Cobble	129-180				
Very Large Cobble	181-256				
Small Boulder	257-512				
Medium Boulder	513-1024				
Large Boulder	1025-2048				
Very Large Boulder	2049-4096				
Bedrock	>4097				
	Totals				

Comments: (record # of transects and increment size)		
	%Fines (<2mm)	
	# Size Classes	
	D15	
	D50	
	D84	

* Particles feel slick when rubbing between thumb and forefinger
** Particles feel gritty when rubbing between thumb and forefinger

RIPARIAN VEGETATION COVER: (Record the % cover of each vegetation type. Consider each vegetative layer separately with a score of 0-100% for each)

Riparian Vegetation Cover	**Percent Cover**
Canopy of riparian trees (>5m high)	
Understory of woody shrubs, saplings, herbs, grasses & forbs (0.5 to 5 m high)	
Ground cover of woody shrubs seedlings, herbs, grasses & forbs (<0.5 m high)	
Barren, bare dirt	

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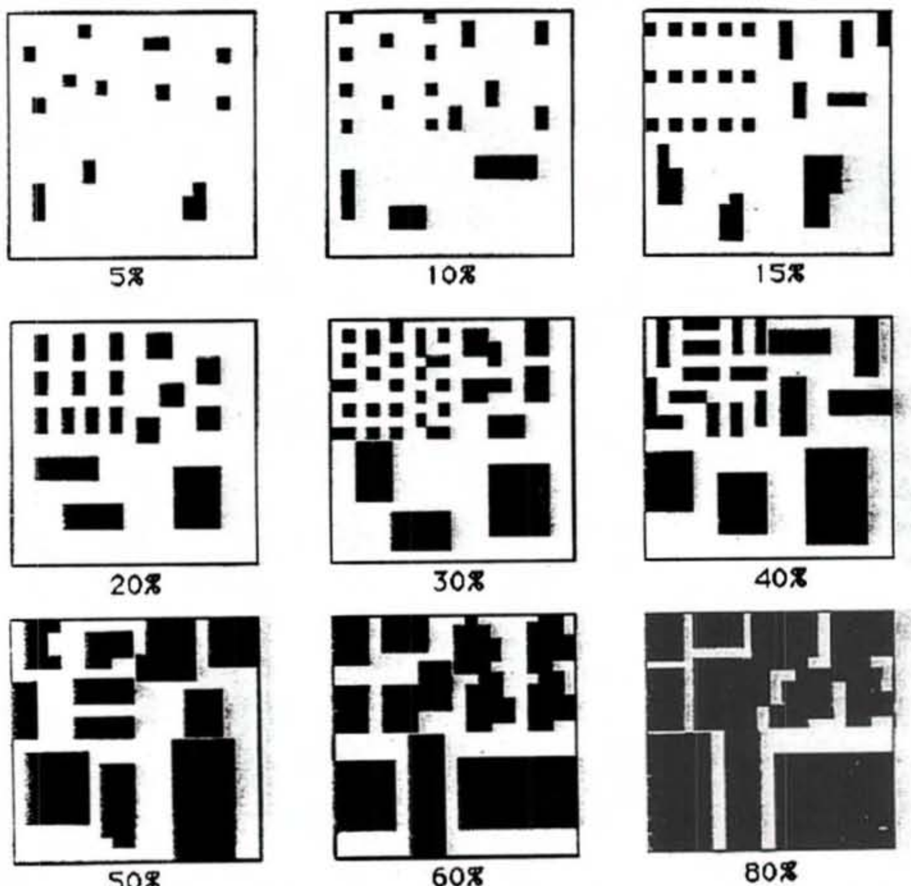

Figure 5.9. Chart for visual estimation of areal coverage. Modified from Northcote (1979) by permission of Rellim Technical Publications

ADDITIONAL FIELD NOTES: (Note How stream is confined, geomorphic features, streambed structure, habitat variety, sedimentation, flood/drought evidence, fish, frogs, other wildlife, channel modifications etc.)

Appendix C. Habitat Assessment Scores

	Reach ID					
Habitat Parameters (maximum score)	**LA-0**	**LA-1FW**	**LA-4W**	**LA-5W**	**DP-1C**	**P-3E**
Epifaunal Substrate/Available cover (20)	18	8	0	2	11	0
Embeddedness (20)	13	12	6	2	18	0
Velocity/Depth Regime (20)	8	6	8	6	3	3
Sediment Deposition (20)	14	5	2	4	15	13
Channel Flow Status (20)	7	7	8	6	0	20
Channel Alteration (20)	18	13	20	15	20	18
Frequency of Riffles or Bends (20)	18	13	3	3	3	3
Bank Stability						
Left bank (10)	7	5	8	0	10	9
Right bank (10)	7	1	8	0	10	9
Vegetative Protection						
Left bank (10)	7	10	7	0	10	6
Right bank (10)	9	10	7	0	10	6
Riparian Vegetative Zone Width						
Left bank (10)	5	10	10	8	10	10
Right bank (10)	10	7	10	8	10	8
Habitat Assessment Score	**141/200**	**107/200**	**97/200**	**54/200**	**130/200**	**105/200**

Appendix D. Macroinvertebrate Sample Data

Taxa name	Reach ID					
	LA-0	**LA-1FW**	**LA-4W**	**LA-5W**	**DP-1C**	**P-3E**
Ephemeroptera – Mayflies						
Baetis tricaudatus	21			6		
Calibaetis sp.		8				
Tricorythodes sp.		1				
Trichoptera – Caddisflies						
Oxyethira sp.				3		
Diptera – True Flies						
Chironomdae	43	99	5	5		
Dicranota sp.	2					
Ephydra sp.		32				
Limnophora sp.		2				
Pedicia sp.	1					
Simulium sp.	1	5		3		
Tipula sp.	2				3	
Odonata – Dragon flies/Damselflies						
Argia sp.	8					
Boyeria sp.	30	1				
Hemiptera –True Bugs						
Ambrysus mormon				1		
Coleoptera – Beetles						
Dytiscidae	1	1				
Helichus sp.	1					
Hydrophilidae	1	2				
Collembola – Springtails						
Poduridae						
Annelida – Segmented Worms						
Tubificidae	5	15	16	2	2	175
Lumbriculidae			3		2	
Isopoda – pill bugs						
Caecidotea sp.		1				
Mollusca – Clams/snails						
Physella sp.			2			
TOTAL	**116**	**167**	**26**	**20**	**7**	**175**

Appendix E. Taxa Attributes and Tolerance Values

Taxa Name	Habitat	Habit	Feeding Group	Tolerance Value	Tolerance Value Source
Ephemeroptera					
Baetis tricaudatus	Eros/Dep	Swimmer	Collector	7	Wisseman (1996)
Callibaetis		Swimmer	Collector	9	Wisseman (1996)
Tricorythodes sp.	Depositional	Sprawler	Collector	8	Wisseman (1996)
Trichoptera					
Oxyethira sp.	Eros/Dep	Climber	Collector	9	Wisseman (1996)
Diptera					
Chironomidae				6	Wisseman (1996)
Dicranota	Eros/Dep	Sprawler	Predator	6	Wisseman (1996)
Ephydra	Depositional	Sprawler	Shredder	9	Parent's TV
Limnophora	Erosional	Burrower	Predator	8	Wisseman (1996)
Pedicia sp.		Burrower	Predator	3	Wisseman (1996)
Simulium	Erosional	Clinger	Collector	7	Wisseman (1996)
Tipula	Eros/Dep	Burrower	Shredder	7	Wisseman (1996)
Odonata					
Argia	Eros/Dep	Clinger	Predator	7	ID DEP (Barbour et al. 1999)
Boyeria	Eros/Dep	Climber	Predator	3	Parent's TV
Hemiptera					
Ambrysus mormon	Erosional	Clinger	Predator	5	Parent's TV
Coleoptera					
Dytiscidae	Depositional	Diver	Predator	8	Wisseman (1996)
Helichus	Erosional	Clinger		5	WI DNR (Barbour et al. 1999)
Hydrophilidae	Depositional	Diver	Collector	7	Wisseman (1996)
Collembola					
Poduridae		Skater	Collector	10	ID DEP (Barbour et al. 1999)
Isopoda					
Caecidotea sp.		Swimmer		8	ID DEP (Barbour et al. 1999)
Annelida					
Lumbriculidae				8	ID DEP (Barbour et al. 1999)
Tubificidae		Burrower	Collector	8	Wisseman (1996)
Mollusca – Clams/snails					
Physella sp.		Clinger	Scraper	9	Wisseman (1996)