Arid West Water Quality Research Project

Aquatic Communities of Ephemeral Stream Ecosystems

FINAL REPORT

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Directed by:

Pima County Wastewater Management Department

Prepared by:

URS

GEI Consultants
Chadwick Ecological Division

November 2006

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prepared by URS Corporation, Albuquerque, New Mexico and
Chadwick Ecological Consultants, Littleton, Colorado

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cover photo: Santa Cruz River, near Tubac, Arizona
Linwood Smith, photographer

FOREWORD

The Arid West Water Quality Research Project (AWWQRP or "Project") was established in 1995 as a result of a federal appropriation (Public Law 103-327) and the establishment of an Assistance Agreement between the U.S. Environmental Protection Agency (USEPA) and Pima County Wastewater Management (PCWMD), Tucson, Arizona. The establishment of this Agreement provided a significant opportunity for western water resource stakeholders to (1) work cooperatively to conduct scientific research to recommend appropriate water quality criteria, standards and uses for effluent-dependent and ephemeral waters in the arid and semi-arid regions of the West ("arid West"), and (2) improve the scientific basis for regulating wastewater and stormwater discharges in the arid West. Effluent-dependent waters are created by the discharge of treated effluent into ephemeral streambeds or streams that in the absence of effluent discharge would have only minimal flow.

With the establishment of the AWWQRP, a management infrastructure was created to support the development of peer-reviewed research products. From within the Environmental Planning Division of PCWMD, the AWWQRP Project Director, Program Manager and support staff administer the Project. A Regulatory Working Group (RWG), comprised of 15 stakeholders representing both public and private interests, works to ensure that Project research has a sound regulatory basis and that research activities focus on important regulatory concerns. The Scientific Advisory Group (SAG), comprised of scientists with experience in water quality research, makes certain that project research has a sound scientific basis and that studies are properly designed and technically sound.

This report represents the fifth in a series of research reports produced by the AWWQRP, and builds upon already completed work. The first report in the series, *Pre-Research Survey of Municipal NPDES Dischargers in the Arid and Semi-Arid West*, resulted from an RWG recommendation that the Project survey arid West wastewater facilities to compile information about their effluent discharges and associated water quality concerns.

The second report, the *Habitat Characterization Study*, utilized the findings of the Discharger Survey. Recognizing that an understanding of the attributes of effluent-dependent waters was critical to the development of appropriate water quality criteria and standards for these waters, the RWG recommended that the AWWQRP commission a major study to describe the physical, chemical, and biological characteristics of effluent-created habitats.

The *Habitat Characterization Study* evaluated the physical, chemical and biological characteristics of effluent-dependent habitats at ten case study sites in the arid West: Santa Cruz River below Nogales and below Tucson, Arizona; Salt River below Phoenix, Arizona; Santa Ana River below San Bernardino, California; Fountain Creek below Colorado Springs, Colorado; South Platte River below Denver, Colorado; Las Vegas Wash below Las Vegas, Nevada; Santa Fe River below Santa Fe, New Mexico; Carrizo Creek below Carrizo Springs, Texas; and Crow Creek below Cheyenne, Wyoming (Figure F-1). The primary objectives of this effort were to (1) review existing physical, chemical and biological data; (2) conduct a site reconnaissance to characterize habitats using established protocols and protocols adapted for arid West conditions; (3) identify similarities and differences among sites; (4) discuss potential approaches to protect these habitats in the context of existing regulatory programs; and (5) recommend areas for additional study. The final report may be downloaded from the AWWQRP website, www.co.pima.az.us/wwm/wqrp, or obtained from the AWWQRP Office in a CD hyperlinked format.

Figure F-1. *Habitat Characterization Study* Case Study Sites.

The AWWQRP's third report, *Extant Criteria Evaluation*, evaluated the applicability of national water quality criteria, as well as the methods to modify those criteria, to effluent-dependent and ephemeral waters in the arid West. This work built upon the findings presented in the *Habitat Characterization Study* using the expertise of national water quality criteria researchers. The AWWQRP used the findings and recommendations contained in the *Extant Criteria Evaluation* as the primary driver for the selection and execution of three subsequent research projects, including evaluations of (1) the Biotic Ligand Model of copper toxicity in arid west streams, (2) use of the EPA recalculation procedure in effluent-dependent streams, and (3) potential hardness-modifications to ammonia toxicity and their implications for use of the water-effect ratio.

The fifth report, *Evaluation of EPA Recalculation Procedure in Arid West Effluent Dependent Waters* ("Recalculation Procedure Study"), evaluated the use of the Recalculation Procedure on selected water quality criteria with different modes of toxicity in specific arid West waters. In addition, based on the findings from this evaluation, a *User's Guide for Development of Site-Specific Water Quality Standards in Arid West Effluent-dependent Streams Using USEPA's Recalculation Procedure* was also prepared as a practical guide for water quality standards practitioners regarding use of the Recalculation Procedure for developing site-specific water quality standards.

This sixth and final report, *Aquatic Communities of Ephemeral Stream Ecosystems*, examined the aquatic communities found at three ecosystems in the arid West, defined by state designation as ephemeral streams. Macroinvertebrate, microinvertebrates, and vertebrate biota were counted at several sites, including tributaries with no upstream source of water and ephemeral reaches of streams that were intermittent or perennial. The streams were located in three distinct bioregions, including the high plains of Colorado, the Colorado Plateau of New Mexico and the Sonoran Desert of southern Arizona. Sampling occurred at two sites over an extended part of the receding limb of a 2- to 3-year recurrence interval flow event. In these cases USGS flow gaging stations in the watershed gave an indication of the flow hydrograph at the site.

The SAG provided a technical review of the findings from the Ephemeral Streams Study. After the SAG comments were addressed, the report was submitted to the RWG and USEPA for additional technical and regulatory review. Comments of a technical nature were covered in a response matrix, with major comments addressed in the report, as necessary. Many comments were more directly related to policy and implementation issues, rather than to the scientific content and recommendations in the report. As such, even though the findings of this study have received both technical and regulatory reviews, it is strongly recommended that local state and regional USEPA staff should be consulted prior to using these findings to support or propose regulatory change.

The AWWQRP has made a significant effort to share Project results and their implications in a variety of technical, regulatory, industry and public interest forums, including publication in the primary scientific literature. This outreach effort is designed to create a broader understanding of water quality issues unique to the arid West and provide scientific and regulatory data in support of a regional approach to the development of water quality criteria, standards and uses. Heightened interest in arid West water quality issues has been fueled by the recognition that treated effluent can have a valuable role in the support and enhancement of riparian ecosystems, particularly in light of increasingly limited water resources. The AWWQRP looks forward to continuing its support of research that not only provides critical data to address unique western water quality issues, but also supports the development of innovative solutions.

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This study was conducted as part of the Arid West Water Quality Research Project (AWWQRP) under the direction of the Pima County Wastewater Management Department in Tucson, Arizona. Funding for the AWWQRP was provided by USEPA Region IX under Assistance Agreement #XP-99926701. The AWWQRP is administered by the following individuals:

- Michael Gritzuk, P.E., Director, Pima County Wastewater Management Department
- Paul M. Bennett, P.E., Deputy Director, Pima County Wastewater Management Department
- Edward F. Curley, Project Director, Pima County Wastewater Management Department
- Karen Ramage, Program Manager, Pima County Wastewater Management Department
- Richard D. Meyerhoff, Ph.D., Research Manager, Camp Dresser & McKee
- Robyn Stuber, EPA Project Officer, EPA Region IX, San Francisco, California

REGULATORY WORKING GROUP

The Regulatory working Group (RWG) was established by the AWWQRP to assist in the identification of regulatory issues needing to be addressed by scientific research. The RWG includes representatives from State and regulatory agencies, municipalities, Indian Tribes, industry, environmental organizations, consulting firms, and universities. The RWG also provided critical review of draft reports and project presentations. Currently, the RWG consists of the following individuals:

- Michael Gritzuk, P.E., Pima County Wastewater Management, Tucson, Arizona
- Edward C. Anton, California State Water Resources Control Board, Sacramento, California
- Rodney W. Cruze, Riverside Regional Water Quality Control, Riverside, California
- Steve Davis, P.E., Malcolm Pirnie, Inc., Tucson, Arizona
- Paul D. Frohardt, Colorado Water Quality Control Commission, Denver, Colorado
- Robyn Stuber, USEPA, Region IX, San Francisco, California
- Andy Laurenzi, The Nature Conservancy, Marana, Arizona
- Patrick J. Maley, Mining Industry Representative, Boise, Idaho

- Lynn Wellman, U.S. Fish & Wildlife Service, Albuquerque, New Mexico
- James F. Pendergast, USEPA, Office Science and Technology, Washington, D.C.
- Sam Rector, Arizona Department of Environmental Quality, Phoenix, Arizona
- Eric Rich, EPA – Navajo Nation, Tuba City, Arizona
- Daniel Santantonio, Ph.D., City of Las Cruces, Utility/Water Division, Las Cruces, New Mexico
- Gary Ullinskey, City of Phoenix Water Services, Phoenix, Arizona

SCIENTIFIC ADVISORY GROUP

The Scientific Advisory Group (SAG) was established to provide technical oversight and peer review of ongoing and planned research for the AWWQRP. The SAG provided critical review for all sections of this report. SAG members include:

- Paul Adamus, Ph.D., Corvallis, Oregon (Oregon State University)
- Gary Chapman, Ph.D., Paladin Water Quality Consulting, Corvallis, Oregon
- Karmen King, Colorado Mountain College, Leadville, Colorado
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- Robert Gray, Ph.D., Richland, Washington
- Carlton Sims White, Ph.D., University of New Mexico, Albuquerque, New Mexico

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

All AWWQRP research products were also reviewed to ensure compliance with the project QAQC plan. This review was provided by:

- Frederick A. Amalfi, Ph.D., Aquatic Consulting and Testing, Tempe, Arizona

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1.0 Introduction

1.1 Introduction

The Arid West Water Quality Research Project (AWWQRP) was established to generate scientific data applicable to the protection of arid West water quality, especially ephemeral and effluent-dependant ecosystems. The AWWQRP was instituted in 1995 as a result of a federal appropriation (Public Law 103-327) and the establishment of an Assistance Agreement between the U.S. Environmental Protection Agency (US EPA) and Pima County, Arizona. The AWWQRP provides a mechanism for arid West stakeholders to work cooperatively to conduct scientific research on a variety of issues relevant to the establishment of beneficial uses and water quality criteria necessary to protect those uses. These efforts will ultimately improve the scientific basis for regulating wastewater and stormwater discharges in the arid West. (Note: references to the arid West include the arid and semi-arid areas of the United States; i.e., all or part of 17 western states).

Findings from previously funded AWWQRP research projects (AWWQRP 2002) and discussions among AWWQRP advisory groups have identified the need to conduct studies to characterize the aquatic communities of ephemeral stream ecosystems and collect data to better evaluate the basis for application of chronic aquatic life criteria to these waters. For the purposes of this study, an ephemeral stream is defined as a surface water with a channel that is at all times above the water table and flows only in direct response to precipitation or snowmelt.

Research on the aquatic biological communities that inhabit ephemeral stream systems of the arid West is limited. Much of this work has concentrated on "interrupted" streams – those with reaches of perennial flow (due to intrusion of bedrock) separated by vast stretches of dry streambed (Reid 1961, Fisher et al. 1982). These ephemeral stream systems have relatively diverse aquatic communities in the perennial reaches, with those portions "reset" with each storm event or flash flood. However, previous studies did not address the potential aquatic communities of the reaches lacking perennial flow.

Most states apply the same national ambient, acute, and chronic aquatic life water quality criteria to perennial and ephemeral waters without taking into account differences in aquatic communities or potential differences in the default exposure assumptions associated with these criteria. For example, national water quality criteria are derived using both fish and invertebrate toxicity data. However, ephemeral stream fish communities are expected to be highly limited, and in most cases, nonexistent. To aid states with the development of appropriate criteria, it is necessary to have an acceptable aquatic species list.

Accordingly, a primary outcome of this project was the preparation of an aquatic taxa list for ephemeral stream communities. Given the significant lack of published literature on the aquatic communities of ephemeral streams, we conducted field studies to successfully achieve this project outcome.

A second area of research interest is an evaluation of the applicability of chronic aquatic life criteria to ephemeral streams or the applicability of chronic toxicity tests to temporary discharges to ephemeral streams. The duration of chronic toxicity tests for deriving federally recommended chronic aquatic life criteria ranges from about seven days to more than 28 days. However, the in situ exposure duration in an ephemeral stream is likely to be much shorter, often on the order of only a few days. Under this project, we also conducted field studies to evaluate exposure duration in the context of the basis for the derivation of chronic aquatic life criteria.

1.2 Literature Review

Ephemeral streams have been studied extensively for their hydrologic connections within arid watersheds (Coes and Pool 2005), riparian effects on the surrounding landscapes (Cockman and Pieper 1997), and as habitat corridors for migratory animals such as birds and mammals (Jorgensen et al. 1995). However, ephemeral streams themselves have not been well studied in regard to their function as aquatic habitats and the aquatic biota that they support. This can be largely attributed to the fact that ephemeral streams do not lend themselves well to being studied, having short torrential flow periods during extreme weather and lasting for unpredictable periods thereafter.

Although ephemeral pools (playas, pans, etc.) can occur throughout the arid West absent of ephemeral stream reaches (Williams 2001), we are concerned specifically with flowing waters and the resulting pools, which occur in conjunction with ephemeral stream channels.

Here we review the current understanding of the aquatic organisms found living within ephemeral streams of the arid southwestern United States during their brief flow periods following extreme precipitation events. There is a paucity of published literature on this particular type of ecosystem, with most studies focusing on interrupted streams (streams with limited reaches of perennial flow [due to intrusion of bedrock] separated by vast stretches of dry stream bed, e.g., Fisher et al. 1982), summer-dry winter-wet semi-perennial streams, or isolated (i.e., not associated with a stream channel) pools such as alpine vernal pools. Interrupted streams have been shown to support relatively diverse aquatic invertebrate communities in the perennial reaches, with those portions “re-set” with each storm event or flash flood (Fisher et al. 1982). However, those studies generally did not address the potential aquatic communities of the ephemeral reaches without perennial flow.

In the only study directly comparable to the present effort, Graham (2002) conducted a survey of aquatic macroinvertebrates and amphibians that occurred within the temporary pools (not the flowing sections) of arroyos and other catchments in Wupatki National Monument, Arizona, USA. He sampled three pools in August, four pools in September, and three pools in both August and September within a single year. There were 22 taxa found in different combinations within the 13 pools used for the study (Table 1-1), including 5 taxa of Branchiopoda, 5 taxa of Coleoptera, 5 taxa of Hemiptera, 3 taxa of Diptera, and 1 taxon each of Odonata and Ephemeroptera. In addition, he found 2 taxa of Amphibia.

Table 1-1: Taxa collected in temporary pools within arroyos in Wupatki National Monument, Arizona, USA. Data from Graham (2002) based on surveys of 13 pools

Taxa	Number of Pools/Taxon
INSECTA	
EPHEMEROPTERA	
Callibaetis sp.	2
ODONATA	
Pantala sp.	1
HEMIPTERA	
Buenoa sp.	2
Callicorixa sp.	4
Cenocorixa sp.	1
Gerris sp.	2
Notonecta sp.	4
COLEOPTERA	
Berosus sp.	1
Dibolocelus sp.	3
Hydrochus sp.	3
Hydrophilus sp.	1
Rhantus sp.	1
DIPTERA	
Chironomidae	4
Culex sp.	2
Psorophora sp.	6
CRUSTACEA	
ANOSTRACA	
Branchinecta lindahli	1
Streptocephalus dorothae	5
Thamnocephalus platyurus	4
DIPLOSTRACA	
Eulimnadia cylindrova	1
NOTOSTRACA	
Triops newbarryi	3
AMPHIBIA	
ANURA	
Bufo punctatus	2
Spea multiplicatus	5

The primary focus of the study was to assess the factors affecting species richness within the communities of these temporary pools. The study found that pools in closer proximity to permanent waters contained a greater number of aquatic species than those that were further away, that pools cut into sandstone experienced the greatest disturbance and therefore contained the fewest species of all the pools sampled, that the basin size did not correlate with community composition but the actual amount of water present did, and that the community composition of the pools changed over time, reflecting the phenology of some of the inhabitants.

A study in the African country of Namibia (Curtis et al. 1998) was conducted to assess the biodiversity of freshwater macroinvertebrates, fish, and amphibians. Namibia is an arid high-desert country that is comparable to the southwestern United States and contains much of the same ephemeral aquatic habitats. The surface water of the entire western and southern third of the country occurs as ephemeral rivers and ephemeral pans or pools.

The biota of the Namibian temporary waters are adapted to long periods of dormancy during dry phases and have rapid life cycles during the brief wet periods. The taxa richness found in the ephemeral rivers comprised 2 taxa of Mollusca, 34 taxa of Crustacea, 90 taxa of Insecta, 8 species of amphibians, and 6 species of fish. The ephemeral pads and pools contained 11 taxa of Mollusca, 60 taxa of Crustacea, 72 taxa of Insecta, 15 species of amphibians, and 49 species of fish. In most cases, species, genera, and even families from Africa were different from taxa collected in the arid western United States.

In Morocco, a study of biotic components of ephemeral streams within the Zegzel-Cherraa watershed was conducted (Melhaoui 2004), including streams that are almost always dry, containing water only sporadically. The characteristics of ephemeral streams in the upper reaches of this particular watershed system are similar to the arid southwestern United States ephemeral streams. When these streams do have water in them they are dominated by Hemiptera, Coleoptera, Hydracarina, Chironomidae, Diptera, Odonata, and Ephemeroptera. Temporary pools were often covered with filamentous algae, and it was noted that crustaceans do not normally occur.

A study conducted in northwestern Oregon focused on invertebrates within summer-dry streams and included some ephemeral streams as well (Dieterich and Anderson 2000). The taxa richness of the ephemeral streams was found to be roughly 35 taxa, and the duration of flow, exposure (shade or open), riffle-pool structure, and summer drought conditions were found to be the key factors in shaping the community structures of the different streams.

The combined emergent and benthic taxa found within the ephemeral stream reaches included Plecoptera, Trichoptera, Coleoptera, Diptera, and some other minor taxa. The ephemeral areas supported very few stoneflies and caddisflies, being primarily dominated by

Diptera and Coleoptera. A total of 13 taxa were found to have a high affinity to ephemeral sites.

McCormick (1990) conducted a study on the effects of consumers on benthic algae within isolated pools of an ephemeral stream. The study used both artificial and natural pools from a summer-dry ephemeral stream to add grazers and adjust the nitrogen and/or phosphorous content in the water. The study looked into the factors affecting the aquatic food-webs within these small temporary pools and does not list any biota other than the algal grazers such as crayfish and snails.

Adams (2000) conducted a study of ephemeral stream macroinvertebrates in Portland, Oregon, for the purpose of developing scoring criteria for biological monitoring. Insects were identified to the genus level with a few exceptions, and most of the non-insect macroinvertebrates were classified at higher taxonomic levels. Because this study was intended for developing scoring criteria for ephemeral streams and the results were inadequate to do so, the raw data from the study were not included in the paper. There is, however, an appended data sheet listing the taxa present.

From these few studies, it is apparent that the primary species within the small temporary wet reaches of ephemeral streams are active colonizers who have good powers of aerial dispersal, such as beetles, true bugs, dragonflies and true flies (Williams 2001). However, flow permanency can greatly affect colonization such that summer-dry streams can be colonized by poor aerial dispersers during periods of extended precipitation simply because water is present for a longer period of time (Williams 1977, Dieterich and Anderson 2000).

Further study is needed to determine to a greater degree just how extensively ephemeral streams support different colonizing species due to their varied and unpredictable nature. Especially in the arid southwestern United States, ephemeral stream conditions can only be predicted on a very general basis – until sufficient data are available to make reliable models of ephemeral stream conditions, each one must be dealt with on an individual basis since proximity to permanent waters, soil conditions, and geographic location appear to greatly affect how ephemeral streams flow and function (Williams 1977, Ruegg and Robinson 2004).

1.3 Colonization Mechanisms

Invertebrate colonization in streams is mediated by four primary processes: drift from sources upstream, migration from sources downstream or from near channel sources, migration from the substrate below, and aerial sources (Williams and Hynes 1976, Williams 1977, Bilton et al. 2001). Fish and amphibian larvae can colonize new locations primarily by migration from upstream sources, lateral sources, or downstream sources (Schlosser 1987, Fausch and Young 1995, Li et al. 1995); colonization from the substrate or aerial sources is rare. Amphibian adults can live in water and come from upstream, lateral, or downstream sources, as well as from terrestrial sources (Stebbins 1985). Each of the four processes may be important in the colonization of streams, particularly after a stream has been depopulated by drought, flood, or toxic chemicals. Additionally, the processes appear to have different importance in different kinds of streams. Each of the processes can be found in ephemeral stream ecosystems (Adams 2000, Graham 2002, Melhaoui 2004).

Drift refers to the movement of organisms from an upstream source to a downstream site and can be either passive (behavioral) or catastrophic (Waters 1964, 1972, Brittain and Eikeland 1988, Allan 1995). Passive drift involves the voluntary entrance of an organism into the flow for the purpose of being transported to a different place. Catastrophic drift occurs when a flood or other disturbance removes organisms and transports them downstream. Drift is expected to be an important colonization process for ephemeral portions of streams with upstream sources of potential colonizers. In true ephemeral streams, there is no upstream source of potential colonizers; however, in interrupted streams, ephemeral stream reaches generally have an upstream source.

Behavioral drift is an important life history strategy for organisms that live in upstream, perennial reaches of streams (Brittain and Eikeland 1988). Some organisms, such as the longfin dace (*Agosia chrysogaster*), actively participate in drift, even in flash floods, to disperse to new areas (Arizona Game and Fish Department 2006). Others, such as the amphipod *Hyalella azteca*, are passively carried by drift because of naturally poor long-distance swimming capabilities (Thorp and Covich 2001).

Organisms can also migrate into a site from downstream or lateral sources (Söderström 1987). Upstream migration is mostly observed in slower-moving streams, since the organisms have to fight the current to move upstream. Because of the high flows associated with the flash floods and the typically long distances to downstream sources of potential colonizers, we do not anticipate that upstream migration is a likely source of colonizers in ephemeral streams.

Lateral migration from isolated backwaters, disconnected pools, or off-channel ponds is more common. In many cases, these lateral sources serve as important areas of refuge for stream-dwelling organisms when adverse environmental conditions exist. Lateral migration is important when calmer backwaters exist along a stream or when there are disconnected pools that could overtop and allow organisms to escape into the stream. These kinds of pools can occur in manmade impoundments near ephemeral streams and ephemeral stream reaches.

Organisms that take advantage of off-channel pools and backwaters include many poor swimmers and sestonic (water-surface) dwellers. These include the water striders (Gerridae and Veliidae), some lentic forms (such as the mayfly *Callibaetis*), or beetles. Fish frequently use backwaters as a refuge during flooding or are stocked in off-channel pools (Kohler and Hubert 1993, Brown et al. 2001, Leibowitz 2003).

In addition to off-channel pools, stream flows in the channel can subside and result in isolated pools within the channel. Lentic organisms may begin colonization of these water bodies, generally from aerial sources. The complexity of the resulting aquatic community often depends on the size and longevity of the flows and the pools, how frequently the community is disturbed or "reset" by repeated high flows, and distance to permanent water as a corollary of dispersal mechanisms of the organisms (Dieterich and Anderson 2000, Graham 2002). These pools can also serve as upstream sources for stream colonization if flows resume.

Some organisms can migrate upward from refugia deeper in the sediment. This can be within the hyporheic zone (i.e., water flowing through sediment under the stream bed), as aestivating or resting forms, or from cryptobiotic (defined below) stages that have settled into the sediment. In ephemeral streams, there is, by definition, no hyporheic zone (the water table is too far below the surface to be a source of fauna). However, there are organisms that utilize an aestivating or cryptobiotic life history strategy.

Cryptobiosis is the term for any of several stages of life that are characterized by temporary reduction or cessation of metabolism, temporary cessation of growth and/or reproduction, and enhanced resistance to environmental extremes. These states include encystment, anoxybiosis, cryobiosis, osmobiosis, and anhydrobiosis (Nelson and Higgins 1990), of which anhydrobiosis (life without water) is of extreme importance in the arid West. A common habitat of anhydrobiotic organisms is in dried-up pools, where the cryptobiotic form lies latent in soil until liquid water returns in the form of precipitation or runoff. Alternatively, some cryptobiotic stages of some organisms are very light weight and can be dispersed by wind to other waters (Bilton et al. 2001).

Organisms that can survive for long periods of time in a cryptobiotic state include the Tardigrada, Nematoda, and Crustacea. Although these groups are technically aquatic (active when submerged in at least a thin film of water), the vast majority of Nematoda and Tardigrada are primarily considered to be terrestrial organisms, which, if conditions require, can spend a considerable portion of their lives in a "cryptobiotic" state (Freckman and Baldwin 1990, Nelson and Higgins 1990, Thorp and Covich 2001).

Aestivation is similar to cryptobiosis, except that it is more of a "resting" period or period of change than a complete repression of life processes. For example, some leeches are known to burrow into the substrate and secrete a protective mucus layer, which can allow them to withstand several months of dry conditions (Wiggins et al. 1980, Klemm 1985, Thorp and Covich 2001).

The final process for colonization is from aerial sources, and it is an important process in almost every stream ecosystem (Williams and Hynes 1976, Williams 1977). This can be either the adult stages of aquatic organisms which themselves are aquatic (e.g., many

Hemiptera and Coleoptera) or the progeny of the adult, aerial stages of aquatic organisms (e.g., Ephemeroptera and Diptera). Frequently, the occurrence of younger instar larvae is an indication that they recently hatched from eggs laid by aerial adults. In ephemeral streams, aerial dispersers and their progeny are likely to be the most common organisms collected. Organisms that do not have an aerial life stage (e.g., Crustacea), must rely on other methods of colonization.

There are variations of aerial colonization. First, most amphibian adults, although they are not aerial, are terrestrial and can survive away from water; however, they do return to water to reproduce (Stebbins 1985). Secondly, passive transport by other animals, such as birds and mammals, has been shown to be effective for colonization by such animals as leeches and snails (Klemm 1985, Bilton et al. 2001). Similarly, game and bait fish are sometimes transported by anglers to novel locations (Kohler and Hubert 1993).

1.4 Sampling Strategy

Findings from previously funded AWWQRP research projects (AWWQRP 2002) and discussions among AWWQRP advisory groups have identified the need to conduct studies to characterize the aquatic communities of ephemeral stream ecosystems and collect data to better evaluate the basis for application of ambient water quality criteria to these waters. An ephemeral stream is defined, for these purposes, as a surface water with a channel that is at all times above the water table and flows only in direct response to precipitation or snowmelt (Williams 2001, AWWQRP 2002).

Research on the aquatic biological communities that inhabit ephemeral stream systems of the arid West is limited. Much of the previous research has been conducted on perennial reaches of interrupted streams and vernal pools. However, because the former has a water table above the channel for at least some portions (and, therefore, perennial water is available) and because the latter has no connection to flowing water, these systems are not appropriate surrogates for ephemeral streams.

In this project, we were concerned with the fauna in ephemeral streams (or ephemeral reaches of intermittent streams) that colonize in response to flows from monsoonal thunder-storms. Monsoon is a term that describes the meteorological pattern of wind change and precipitation in mid to late summer in Southeast Asia and the southwestern United States (Hanson 1962). Monsoons in North America are characterized by scattered, intense rain-storms, which are formed over the Pacific Ocean and cross from southwest to northeast over southern California, Arizona, New Mexico, and Colorado. These thunderstorms are generally intense, bringing precipitation on the order of multiple inches per hour, and causing flash flooding in low-lying areas, including the ephemeral streams that are the subject of this study.

For the purposes of this project, seasonal weather patterns were analyzed to anticipate the formation of monsoonal thunderstorms. The thunderstorms were monitored via remote access to National Weather Service radar images (http://radar.weather.gov) and responsive streamflows were monitored using U.S. Geological Survey (USGS) stream hydrographs (http://waterdata.usgs.gov). When it was deemed that potential runoff-producing conditions had occurred and that flows were expected to continue for several days, a team of biologists traveled to each study area to initiate sampling of the potential aquatic biota.

Three broad types of biological samples were collected at each site within each study area to account for all potential aquatic biota. Water column samples were collected to account for the potential for transient microinvertebrates (i.e., zooplankton). Benthic samples were collected to account for the potential for the presence of macroinvertebrates (e.g., aquatic insects, amphipods, and isopods). Vertebrate samples were collected to account for the potential of presence of fishes and amphibians.

In addition to accounting for which potential aquatic biota exist within these ephemeral streams (i.e., a "taxa list"), we also attempted to elucidate the "succession" of these fauna within the streams as related to the duration of the flow events. A succession study investigates which organisms arrive in a given habitat, when they arrive, and how long they stay, up until a stable, climax community is established or the habitat disappears (Hanson 1962). For ephemeral streams, this contrasts from typical colonization studies, which would be based on an assumption that the organisms that arrive are able to establish reproducing, resident populations. In the ephemeral streams we are investigating, the habitat is expected to disappear and a classical "climax aquatic community" never forms.

Flow events in response to monsoon thunderstorms are generally characterized by a sharp increase and then a decrease in flow – i.e., a "flash flood." As part of our study, sampling was not conducted as flows were rising or at their peak because the system, at that point, is flushing and restricting voluntary movement of the biota. Those flood events also present safety hazards to field personnel. Instead, sampling was initiated when flows had declined to a point at which biota movement was not restricted, safety of personnel was not compromised, and succession (colonization) activities could potentially have begun. Sites were generally visited and sampled daily until no surface water remained.

2.0 Study Areas

Three regions for community characterization were chosen from the arid southwestern United States, based on ecological studies of arid West streams, including past AWWQRP investigations (AWWQRP 2002). These regions each have their own distinct patterns of precipitation, stream flows, stream substrates, and dependant ecology. The study included sites in three southwestern regions:

- Hot Desert – similar to the Chihuahuan, Sonoran, and Mojave deserts of Arizona and California
- Cool Desert/Great Basin – similar to the Colorado Plateau near Grand Junction, Colorado, the Rio Grande Rift near Albuquerque, New Mexico, and the high desert of Nevada, Utah, and Oregon)
- High Plains – similar to central Colorado east of the Front Range

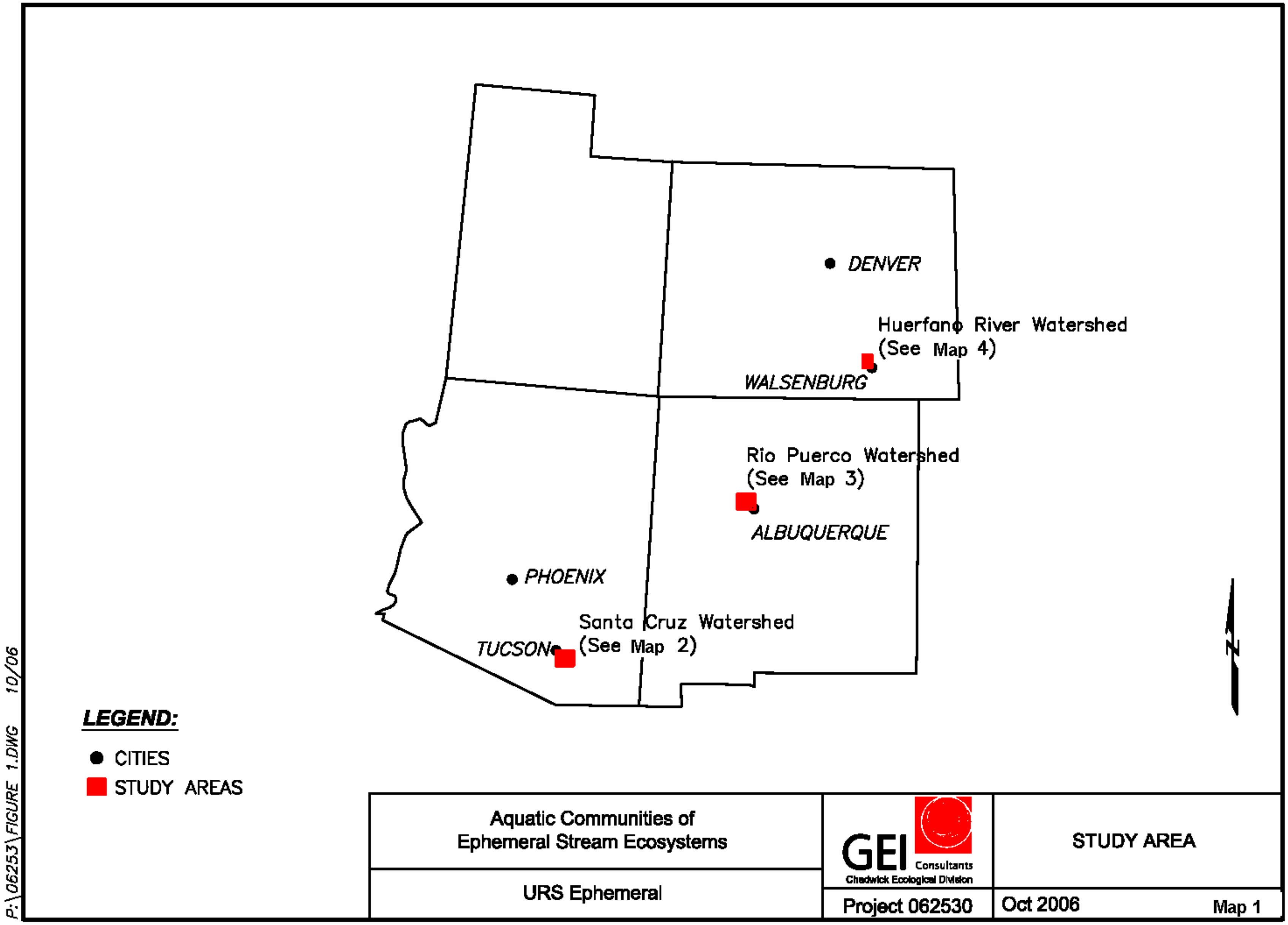
One representative watershed within each region was chosen for sampling in conjunction with this study (Map 1). The Hot Desert region was represented by sites in the Santa Cruz River Watershed in southern Arizona. The Cool Desert/Great Basin region was represented by sites in the Rio Puerco Watershed in northwestern New Mexico. Lastly, the High Plains region was represented by a site in the Huerfano River Watershed in southeastern Colorado. Several potential sites were identified within each watershed to provide multiple opportunities for data collection, depending on precipitation and flow conditions.

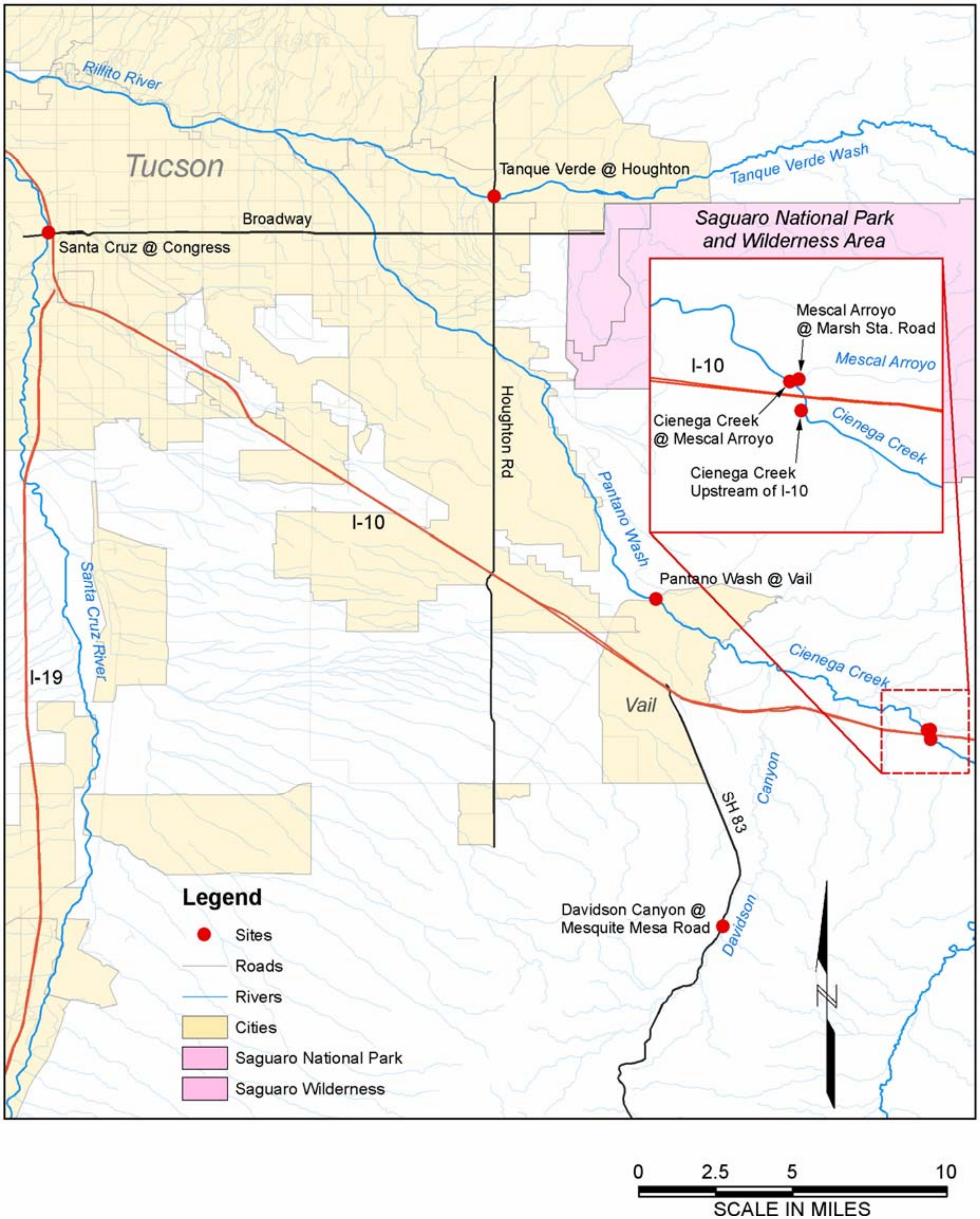
2.1 Santa Cruz Watershed, Arizona

A total of seven sites were established in the Santa Cruz Watershed (Map 2). Detailed descriptions of the physical aspects of each site, Global Positioning System (GPS) coordinates, and photographs of each site with no/little water present and with higher flows present during sampling are provided. Details of the dates each site was visited (including the day of succession following initial subsidence of high flows), types of samples collected, and sampling effort are presented in tabular form.

2.1.1 Santa Cruz River at Congress

The Santa Cruz River originates in the Patagonia and Huachuca Mountains of southeastern Arizona, loops through northern Sonora, Mexico, and reenters the United States near Nogales. It flows northward from Nogales, through Tucson, and is a tributary to the Gila River. The site sampled was at the Congress Street (= Broadway Street) crossing near downtown Tucson. USGS gage 09482500 (Santa Cruz River at Tucson) is located at the site, with a drainage area of 5,755 km^2. This site had a broad channel with fine, silty substrate


DENVER
Huerfano River Watershed
(See Map 4)
WALSENBURG
Rio Puerco Watershed
(See Map 3)
ALBUQUERQUE
PHOENIX
Santa Cruz Watershed
(See Map 2)
TUCSON
N
LEGEND:
CITIES
STUDY AREAS
Aquatic Communities of
Ephemeral Stream Ecosystems
URS Ephemeral
GEI Consultants
Chadwick Ecological Division
Project 062530
STUDY AREA
Oct 2006
Map 1
P:\06253\FIGURE 1.DWG 10/06



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Aquatic Communities of Ephemeral Stream Ecosystems	GEI Consultants Chadwick Ecological Division	COLLECTING LOCALITIES IN SANTA CRUZ WATERSHED, ARIZONA
URS Ephemeral	Project 062530	Oct 2006 Map 2

and some gravel and boulders (Figures 2-1 and 2-2). Vegetation was primarily mesquite. The west bank was steep and reinforced. This site was chosen as an alternate sampling site during the site reconnaissance visit in May 2006. GPS coordinates for this site are N32°13'16.8" W110°58'54.5".

From the headwaters to approximately 48 km downstream of the Nogales Wastewater Treatment Plant (a little downstream of Tubac), the Santa Cruz maintains perennial flows. In addition to the in-channel flow from the headwaters and the effluent-dependant flow from Nogales to near Tubac, there are multiple off-channel ponds in golf courses, gravel pits, and irrigated fields near Green Valley, which could also have contributed water, and, potentially, aquatic organisms if they were overtopped during the rainstorm events. Therefore, this site has known upstream sources of potential colonizers. This site was visited on July 30 and August 1-5, 2006 (Table 2-1).

Figure 2-1: Santa Cruz River at Congress with flow during sampling, July 30, 2006

Figure 2-2: Santa Cruz River at Congress with residual pools, August 6, 2006

Table 2-1: Sampling effort at the Site Santa Cruz River at Congress, Santa Cruz River Watershed, Arizona, 2006

Parameter	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6
Day of Succession					0	1	2	3	
Flowing Water	Not visited	High flows – no samples collected	Not visited	High flows – no samples collected	No	No	No	No	Dry – no samples collected
Total Area (m^2)					--	--	--	--	
Standing Water					1 pool	1 pool	1 pool	1 pool	
Total Area (m^2)					724	244	116	3.4	
Microinvertebrates					40 liters	40 liters	40 liters	20 liters	
Macroinvertebrates					20 jabs	20 jabs	20 jabs	10 jabs	
Fish & Amphibians									
Area Seined (m^2)					724	--	--	--	
Area Electrofished (m^2)					--	244	116	--	

2.1.2 Pantano Wash at Vail

Pantano Wash originates at the base of the Rincon Mountains southeast of Tucson and flows generally to the northwest. It is a tributary to the Rillito River, formed at the junction with Tanque Verde Wash, which it joins in northeast Tucson. We sampled the site on Pantano Wash where it crosses the Old Spanish Trail / Colossal Cave Road in Vail. This site is within the *Ciénega Creek Conservation Area*, and USGS gage 09484600 (Pantano Wash near Vail) is located immediately downstream of the site with a drainage area of 1,184 km^2. Pantano Wash at this site has a broad channel, steep and incised on the south bank, with a sand/gravel substrate (Figures 2-3 and 2-4). GPS coordinates for the site are N32°2'58.0" W110°41'47.2".

This site was chosen as an alternate site during the site reconnaissance in April 2006. Ciénega Creek is a tributary to Pantano Wash upstream of this site and has perennial reaches of stream further upstream in the *Ciénega Creek Conservation Area.* Therefore, the Pantano Wash site is considered to be a stream with known upstream sources of potential colonizers. This site was visited July 29 – August 6, 2006 (Table 2-2). Field observations of this stream indicated that it went from high flows to no surface water overnight on August 1-2; this was not accurately reflected by the USGS gage (cf. Figure 4-2).

Figure 2-3: Pantano Wash at Vail with high flows, July 31, 2006

Figure 2-4: Pantano Wash at Vail with no flow, August 6, 2006

Table 2-2: Sampling effort at the Site Pantano Wash at Vail, Santa Cruz River Watershed, Arizona, 2006

Parameter	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6
Day of Succession							0	1	
Flowing Water	High flows – no samples collected	High flows – no samples collected	High flows – no samples collected	High flows – no samples collected	Dry – no samples collected	Dry – no samples collected	Low	Low	Dry – no samples collected
Total Area (m^2)							1,976	678	
Standing Water							No	No	
Total Area (m^2)							--	--	
Microinvertebrates							40 liters	40 liters	
Macroinvertebrates							20 jabs	20 jabs	
Fish & Amphibians									
Area Seined (m^2)							1,182	521	
Area Electrofished (m^2)							795	--	

2.1.3 Davidson Canyon at Mesquite Mesa Road

Davidson Canyon is a tributary to Pantano Wash upstream of Tucson and flows off the northeast side of the Santa Rita Mountains. Access at this site was off Mesquite Mesa Road. During site reconnaissance in April 2006, the channel in this area was dry, but there were indications of scour holes and other potential habitats that would potentially hold water following rain events (Figures 2-5 and 2-6). GPS coordinates for this site are N31°53'44.8" W110°39'54.1". The drainage area at this site is approximately 131 km^2.

An area upstream of this site was noted on USGS topographical maps as having a spring; however, no flow was observed at that location or in Davidson Canyon for another 7-8 km upstream. This study site was deemed to not have any upstream sources of potential colonizers from sections with perennial flow. This site was visited July 29 – August 6, 2006 (Table 2-3). Note that on two successive days, flows in Davidson Canyon ceased while the research team was on site, leaving only small, isolated pools.

Figure 2-5: Davidson Canyon at Mesquite Mesa Road with flows, July 31, 2006

Figure 2-6: Davidson Canyon at Mesquite Mesa Road with no flow, August 2, 2006

Table 2-3: Sampling effort at the Site Davidson Canyon at Mesquite Mesa Road, Santa Cruz River Watershed, Arizona, 2006

Parameter	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6
Day of Succession	0	1	2	3					
Flowing Water	No	Dried during sampling	Dried during sampling	No	Dry – no samples collected	Dry – no samples collected	Dry – no samples collected	Dry – no samples collected	Dry – no samples collected
Total Area (m^2)	--	3.1	46	--					
Standing Water	24 pools	24 pools	7 pools	1 pool					
Total Area (m^2)	12	22	13	0.2					
Microinvertebrates	20 liters	20 liters	20 liters	0.5 liter					
Macroinvertebrates	20 jabs	20 jabs	20 jabs	--					
Fish & Amphibians									
Area Seined (m^2)	--	--	--	--					
Area Electrofished (m^2)	--	--	--	--					

2.1.4 Mescal Arroyo at Marsh Station Road

Mescal Arroyo is a tributary to Ciénega Creek, flowing roughly east to west paralleling I-10 between the southern borders of the Rincon Mountains and the northern borders of the Whetstone Mountains. The reach between the Marsh Station Road crossing and the confluence with Ciénega Creek was sampled. Characteristics of a typical ephemeral stream that were present included a sand/gravel substrate with scour holes (Figures 2-7 and 2-8). Riparian vegetation included mesquite and grasses. One large scour hole was present along bedrock outcroppings just upstream of the confluence with Ciénega Creek and this was the only place within the site that had residual surface water during our visits, although patterns in the shifted sand and riparian grasses indicated that flows had come through Mescal Arroyo overnight on multiple occasions. GPS coordinates for this site are N31°59'17.3" W110°34'3.3". The drainage area at this site is approximately 99 km^2. We were unable to locate any upstream sources of potential colonizers on Mescal Arroyo. This site was visited July 29 – August 6, 2006 (Table 2-4).

Figure 2-7: Mescal Arroyo at Marsh Station Road, residual pool, July 30, 2006

Figure 2-8: Mescal Arroyo at Marsh Station Road with dry pool, August 6, 2006

Table 2-4: Sampling effort at the Site Mescal Arroyo at Marsh Station Road, Santa Cruz River Watershed, Arizona, 2006

Parameter	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6
Day of Succession	0	1	2	3					
Flowing Water	No	No	No	No	Dry – no samples collected	Dry – no samples collected	Dry – no samples collected	Dry – no samples collected	Dry – no samples collected
Total Area (m^2)	--	--	--	--					
Standing Water	1 pool	1 pool	1 pool	2 pools					
Total Area (m^2)	21	21	21	10					
Microinvertebrates	20 liters	20 liters	20 liters	20 liters					
Macroinvertebrates	20 jabs	20 jabs	20 jabs	20 jabs					
Fish & Amphibians									
Area Seined (m^2)	--	--	--	--					
Area Electrofished (m^2)	--	--	--	--					

2.1.5 Ciénega Creek Upstream of I-10

Two sites were sampled on Ciénega Creek. This site was about 0.8 km upstream of the crossing of Interstate 10, accessed from the Marsh Station Road Exit. This reach of Ciénega Creek has the characteristics of an ephemeral stream, with sand/gravel substrate and presence of scour holes along the banks (Figures 2-9 and 2-10). GPS coordinates for this site are N31°59'1.3" W110°34'2.1". Drainage area for this site and the next downstream site is approximately 749 km^2.

This portion of Ciénega Creek is downstream of a flowing portion in the *Ciénega Creek Conservation Area* and provides information on an ephemeral stream reach with a known upstream source of potential colonizers. Even though this site was not visited on July 31, August 1, and August 3 due to logistic concerns (i.e., sampling intensively elsewhere in the Santa Cruz River Watershed), information from the next downstream site on Ciénega Creek indicated that flows had begun subsiding on July 30 and peaked again on the evening of August 2; thus, dates for biotic succession reflect the passage of time since high flow subsidence began. Missing data for these dates may have introduced some unspecified error (missing one or two taxa) into the analyses. This site was visited July 29, August 2, and August 4-6, 2006 (Table 2-5).

Figure 2-9: Ciénega Creek Upstream of I-10 with high flows, July 29, 2006

Figure 2-10: Ciénega Creek Upstream of I-10 with no flow, August 6, 2006

Table 2-5: Sampling effort at the Site Ciénega Creek Upstream of I-10, Santa Cruz River Watershed, Arizona, 2006

Parameter	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6
Day of Succession					2		1	2	
Flowing Water	High flows – no samples collected	Not visited	Not visited	Not visited	No	Not visited	Low	Dried during sampling	Dry – no samples collected
Total Area (m^2)					--		n/m	n/m	
Standing Water					1 pool		No	4 pools	
Total Area (m^2)					1.4		--	94	
Microinvertebrates					20 liters		40 liters	40 liters	
Macroinvertebrates					5 jabs		20 jabs	20 jabs	
Fish & Amphibians									
Area Seined (m^2)					--		53	94	
Area Electrofished (m^2)					--		--	--	

2.1.6 Ciénega Creek Downstream of Mescal Arroyo

This site is further downstream than the previous site on Ciénega Creek, near the confluence with Mescal Arroyo. This reach of Ciénega Creek also has the characteristics of an ephemeral stream, with sand/gravel substrate and presence of scour holes along the banks (Figures 2-11 and 2-12). GPS coordinates for this site are N31°59'16.1" W110°34'7". This portion of Ciénega Creek is also downstream of the flowing portion in the *Ciénega Creek Conservation Area* and likewise can provide information on an ephemeral stream reach with a known upstream source of potential colonizers. This site was visited July 29 – August 6, 2006 (Table 2-6).

Figure 2-11: Ciénega Creek Downstream of Mescal Arroyo with high flows, July 30, 2006

Figure 2-12: Ciénega Creek Downstream of Mescal Arroyo with no flow, August 2, 2006

Table 2-6: Sampling effort at the Site Ciénega Creek Downstream of Mescal Arroyo, Santa Cruz River Watershed, Arizona, 2006

Parameter	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6
Day of Succession			0	1	2	0	1	2	
Flowing Water	High flows – no samples collected	High flows – no samples collected	Mod	Low	Dry – no samples collected	Low	Low	Low	Dry – no samples collected
Total Area (m^2)			358	566		n/m	939	n/m	
Standing Water			No	No		No	No	No	
Total Area (m^2)			--	--		--	--	--	
Microinvertebrates			40 liters	40 liters		40 liters	40 liters	40 liters	
Macroinvertebrates			20 jabs	20 jabs		20 jabs	20 jabs	20 jabs	
Fish & Amphibians									
Area Seined (m^2)			358	566		565	939	363	
Area Electrofished (m^2)			--	--		--	374	--	

2.1.7 Tanque Verde Wash at Houghton Road

Tanque Verde Wash originates in the Rincon Mountains north of the eastern unit of Saguaro National Park, east of Tucson. The study site is located where Houghton Road crosses Tanque Verde Wash in northeast Tucson. The site has a broad channel with sand substrate, incised channels within the channel, and deep scour holes along the banks (Figures 2-13 and 2-14). Riparian vegetation included mesquite, palo verde, and some cottonwood trees. GPS coordinates for the site are N32°14'17.4" W110°46'20.9". Drainage area at this site is approximately 567 km^2. This site was chosen as an alternate site during the site reconnaissance in April 2006.

We observed perennial flow in reaches of Tanque Verde Wash 8 km upstream of the site near Saguaro National Park. In addition, Tanque Verde Wash experienced record flows in the days preceding the sampling event, and it is possible that water and biota from numerous adjacent stock ponds, golf course ponds, and other off-channel pools could have entered Tanque Verde Wash as water levels rose both in the ponds and in Tanque Verde Wash itself. Therefore, we consider that this site has known upstream sources of potential colonizers. This site was visited August 1-6, 2006 (Table 2-7).

Figure 2-13: Tanque Verde Wash at Houghton Road with moderate flows, August 1, 2006

Figure 2-14: Tanque Verde Wash at Houghton Road with no flow, August 5, 2006

Table 2-7: Sampling effort at the Site Tanque Verde Wash at Houghton Road, Santa Cruz Watershed, Arizona, 2006

Parameter	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6
Day of Succession				0			0		
Flowing Water	Not visited	Not visited	Not visited	Mod	Dry – no samples collected	Dry – no samples collected	Low	Dry – no samples collected	Dry – no samples collected
Total Area (m^2)				1,325			336		
Standing Water				No			No		
Total Area (m^2)				--			--		
Microinvertebrates				40 liters			40 liters		
Macroinvertebrates				20 jabs			20 jabs		
Fish & Amphibians									
Area Seined (m^2)				419			--		
Area Electrofished (m^2)				--			336		

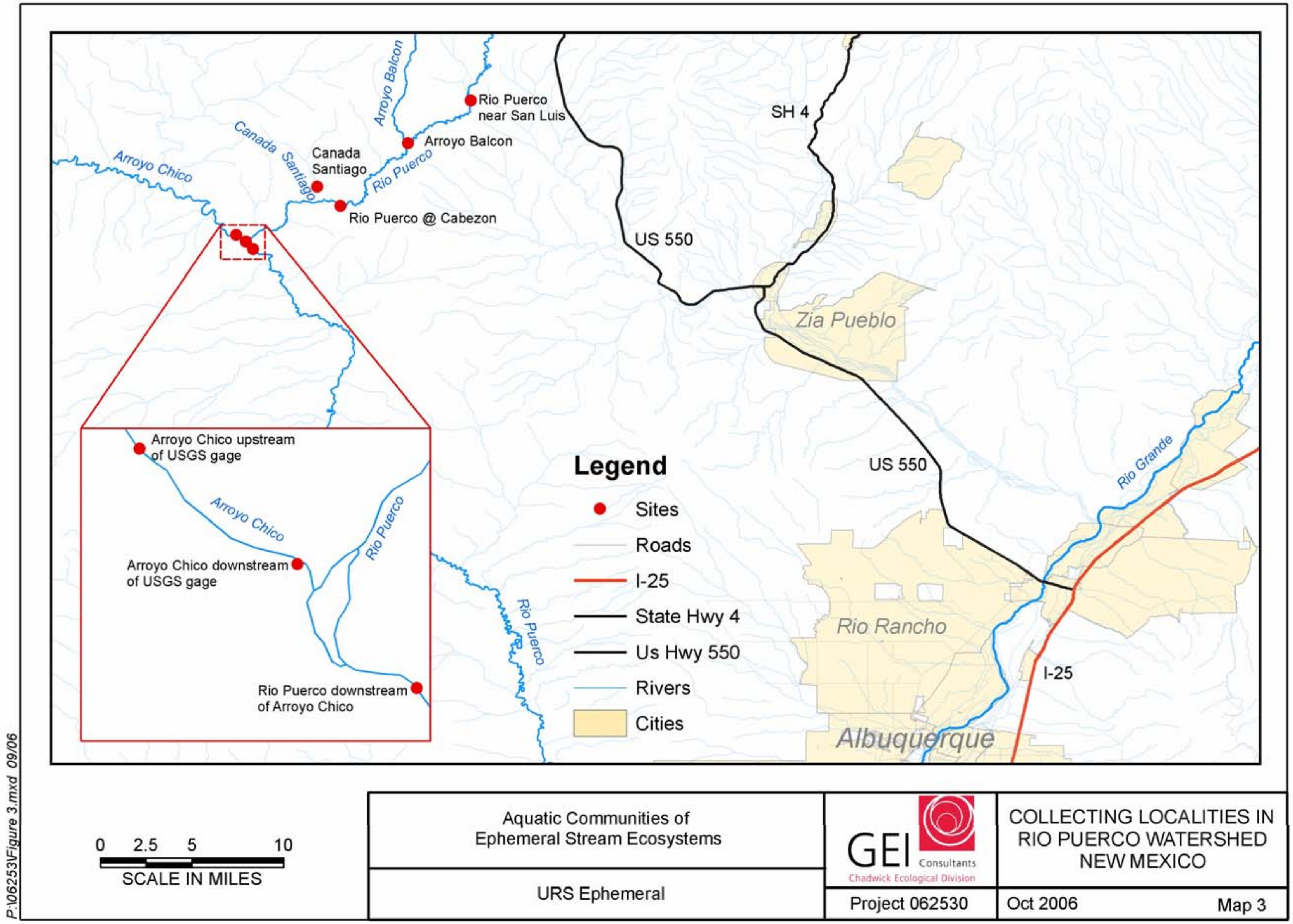
2.2 Rio Puerco Watershed, New Mexico

A total of seven sites were established in the Rio Puerco Watershed (Map 3), again described in detail, with photographs, below.

2.2.1 Rio Puerco near San Luis

The headwaters of the Rio Puerco are in the San Pedro Mountains north of Cuba, and the stream flows southward to its confluence with the Rio Grande near Socorro. We sampled three sites on the Rio Puerco. The most upstream site was located near the town of San Luis, just outside of the Jemez Indian Reservation. This site was narrower than the other Rio Puerco sites, and riparian vegetation consisted primarily of cottonwood, salt cedar, and Russian olive trees. Evidence of past beaver activity exists. There was very low flow in the channel in June, but there were deeply incised channels and deep scour holes downstream of the road (Figures 2-15 and 2-16). Substrate was primarily silt, but there was also cobble and slate in the stream. GPS coordinates for this site are N35°42'12.6" W107°00'35.9". Because there are perennial flows in the Rio Puerco upstream near the town of Cuba (New Mexico Environment Department [NMED] 2006), we considered this site to have known upstream sources of potential colonizers. This site was visited August 8-14, 2006 (Table 2-8).

Figure 2-15: Rio Puerco near San Luis with high flow, August 10, 2006


Rio Puerco near San Luis
Arroyo Balcon
Arroyo Balcon
Canada Santiago
Canada Santiago
Rio Puerco
Arroyo Chico
Rio Puerco @ Cabezon
SH 4
US 550
Zia Pueblo
US 550
Rio Grande
Rio Rancho
I-25
Albuquerque
Rio Puerco
Arroyo Chico upstream of USGS gage
Arroyo Chico
Rio Puerco
Arroyo Chico downstream of USGS gage
Rio Puerco downstream of Arroyo Chico
Legend
Sites
Roads
I-25
State Hwy 4
Us Hwy 550
Rivers
Cities
0 2.5 5 10
SCALE IN MILES
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Aquatic Communities of Ephemeral Stream Ecosystems
URS Ephemeral
GEI Consultants
Chadwick Ecological Division
Project 062530
COLLECTING LOCALITIES IN RIO PUERCO WATERSHED NEW MEXICO
Oct 2006
Map 3

Figure 2-16: Rio Puerco near San Luis with low flow, August 10, 2006

Table 2-8: Sampling effort at the Site Rio Puerco near San Luis, Rio Puerco Watershed, New Mexico, 2006

Parameter	8/8	8/9	8/10	8/11	8/12	8/13	8/14
Day of Succession	0	1	2	3	4	5	6
Flowing Water	Low	Low	Mod	Low	Low	Low	No
Total Area (m^2)	53	179	198	138	91	119	31
Standing Water	No	No	No	No	No	No	1 pool
Total Area (m^2)	--	--	--	--	--	--	72
Microinvertebrates	40 liters	40 liters	40 liters	40 liters	40 liters	40 liters	40 liters
Macroinvertebrates	20 jabs	20 jabs	20 jabs	20 jabs	20 jabs	20 jabs	20 jabs
Fish & Amphibians							
Area Seined (m^2)	53	179	--	138	91	--	--
Area Electrofished (m^2)	--	--	--	--	--	89	24

2.2.2 Rio Puerco at Cabezón

This site is located about 16 km downstream of the previous site, near the ghost town of Cabezón. At this site, the substrate was primarily silt and mud, with a small riffle containing cobble-sized pieces of clay. There were incised channels and scour holes for pooling water (Figures 2-17 and 2-18). Riparian vegetation included mesquite, salt cedar, and Russian olive trees. Access was off a side road from the main road following the Rio Puerco. GPS coordinates for this site are N35°37'12.1" W107°6'46.7". Drainage area at this site is 1,028 km^2. This site was also considered to have known upstream sources of potential colonizers. This site was visited August 8-14, 2006 (Table 2-9).

Figure 2-17: Rio Puerco at Cabezón with high flow, August 9, 2006

Figure 2-18: Rio Puerco at Cabezón with low flow, August 8, 2006

Table 2-9: Sampling effort at the Site Rio Puerco at Cabezón, Rio Puerco Watershed, New Mexico, 2006

Parameter	8/8	8/9	8/10	8/11	8/12	8/13	8/14
Day of Succession	0		0	1	2	3	4
Flowing Water	Low	High flows – no samples collected	Low	Low	Low	Low	Low
Total Area (m^2)	135		306	275	221	292	186
Standing Water	No		No	No	No	No	No
Total Area (m^2)	--		--	--	--	--	--
Microinvertebrates	40 liters		40 liters	40 liters	40 liters	40 liters	40 liters
Macroinvertebrates	20 jabs		20 jabs	20 jabs	20 jabs	20 jabs	20 jabs
Fish & Amphibians							
Area Seined (m^2)	--		306	275	221	--	--
Area Electrofished (m^2)	135		--	--	--	219	140

2.2.3 Rio Puerco Downstream of Arroyo Chico

The lowest site on the Rio Puerco was below its confluence with Arroyo Chico, approximately 11 km downstream from the Site Rio Puerco at Cabezón. Riparian vegetation included mesquite, salt cedar, and Russian olive trees on the bench above the stream channel. Channel characteristics included a short riffle, incised channels, bank debris, and scour holes; substrate was primarily silt, sand, and cobble-sized pieces of clay (Figure 2-19). USGS gage 08334000 (Rio Puerco Upstream of Arroyo Chico near Guadalupe) is located approximately 4 km upstream of the confluence, with a drainage area of 1,088 km^2. GPS coordinates for this site are N35°35'28.2" W107°11'11.8".

As with the other two sites on the Rio Puerco, this site was also deemed to have known upstream sources of potential colonizers. Even though this site was not visited on August 8-11 due to excessive flows, information from another site on Arroyo Chico indicated that flows had begun subsiding on August 8; thus, dates for biotic succession reflect the passage of time since high-flow subsidence began. Missing data from these dates may have introduced some unspecified error (missing one or two taxa) into the analyses. This site was visited August 12-14, 2006 (Table 2-10).

Figure 2-19: Rio Puerco Downstream of Arroyo Chico, August 12, 2006

Table 2-10: Sampling effort at the Site Rio Puerco Downstream of Arroyo Chico, Rio Puerco Watershed, New Mexico, 2006

Parameter	8/8	8/9	8/10	8/11	8/12	8/13	8/14
Day of Succession					3	4	5
Flowing Water	Not visited	Not visited	Not visited	Not visited	Low	Low	Low
Total Area (m^2)					376	425	499
Standing Water					1 pool	No	No
Total Area (m^2)					48	--	--
Microinvertebrates					40 liters	40 liters	40 liters
Macroinvertebrates					20 jabs	20 jabs	20 jabs
Fish & Amphibians							
Area Seined (m^2)					--*	--	--
Area Electrofished (m^2)					--*	181	181

* Not sampled for fish and amphibians due to technical difficulties

2.2.4 Cañada Santiago

Cañada Santiago is a tributary to the Rio Puerco, with the confluence being approximately 5 km downstream of the Site Rio Puerco at Cabezón. Riparian vegetation included salt cedar and Russian olive trees. The substrate was fine silt over sand, with some cobbles and bedrock present. Cañada Santiago was unique compared to the other sites in the Rio Puerco Watershed in that a greater percentage of channel substrate was bedrock, creating plunge pools that persisted longer than pools associated with streams of similar size (Figures 2-20 and 2-21). GPS coordinates for this site are N35°38'7.4" W107°11'15.3". Drainage area of this site is unknown.

This site was not surveyed during the site reconnaissance and was added during field sampling. Cañada Santiago is located in the vicinity of a small impoundment, but potential connection with the impoundment or overflow of the impoundment during precipitation events is not known. We considered this site to have no known upstream sources of potential colonizers. This site was visited August 8-14, 2006 (Table 2-11).

Figure 2-20: Cañada Santiago main channel with flow, August 9, 2006

Figure 2-21: Cañada Santiago pool, August 9, 2006

Table 2-11: Sampling effort at the Site Cañada Santiago, Rio Puerco Watershed, New Mexico, 2006

Parameter	8/8	8/9	8/10	8/11	8/12	8/13	8/14
Day of Succession	0	1	2	3	4	5	6
Flowing Water	Low	Low	No	No	No	No	No
Total Area (m^2)	44	88	--	--	--	--	--
Standing Water	No	No	2 pools	1 pool	1 pool	1 pool	1 pool
Total Area (m^2)	--	--	83	16	4.6	4.1	3.1
Microinvertebrates	40 liters	40 liters	20 liters				
Macroinvertebrates	18 jabs	20 jabs	10 jabs	20 jabs	20 jabs	20 jabs	20 jabs
Fish & Amphibians							
Area Seined (m^2)	44	88	83	16	4.6	4.1	3.1
Area Electrofished (m^2)	--	--	--	--	--	--	--

2.2.5 *Arroyo Balcón*

Arroyo Balcón runs parallel to Torreón Road for several kilometers. Near its confluence with the Rio Puerco, the substrate is fine silt over sand with some cobbles present (Figures 2-22 and 2-23). In June 2006, the lowest 10 m of the arroyo was wetted with backwaters from the Rio Puerco. GPS coordinates for this site are N35°40'10.4" W107°3'34.5". Drainage area at this site is unknown. There are no sections of perennial stream upstream in Arroyo Balcón; therefore, there are no known upstream sources of potential colonizers. This site was visited August 9-14, 2006 (Table 2-12).

Figure 2-22: Arroyo Balcón with high flow, August 9, 2006

Figure 2-23: Arroyo Balcón with low flow, August 12, 2006

Table 2-12: Sampling effort at the Site Arroyo Balcón, Rio Puerco Watershed, New Mexico, 2006

Parameter	8/8	8/9	8/10	8/11	8/12	8/13	8/14
Day of Succession		0	1	2	3	4	5
Flowing Water	Not visited	Low	Low	Low	Low	No	No
Total Area (m^2)		95	42	33	36	--	--
Standing Water		No	No	No	No	3 pools	3 pools
Total Area (m^2)		--	--	--	--	4.3	1.6
Microinvertebrates		40 liters	40 liters	40 liters	40 liters	40 liters	40 liters
Macroinvertebrates		20 jabs	20 jabs	20 jabs	20 jabs	20 jabs	20 jabs
Fish & Amphibians							
Area Seined (m^2)		96	42	33	36	4.3	1.6
Area Electrofished (m^2)		--	--	--	--	--	--

2.2.6 Arroyo Chico Upstream of the USGS Gage

We sampled two sites on Arroyo Chico, a tributary to the Rio Puerco that has its headwaters along the south side of Chaco Mesa and the Continental Divide and along the north side of San Mateo Mesa. The furthest upstream site we sampled was downstream of the confluence with Arroyo Empedrado. The channel is very wide with small, incised channels, scour holes, stagnant pools in the flood plain, and large, connected backwater areas (Figures 2-24 and 2-25). Substrate is primarily silt, with some cobbles; vegetation is primarily mesquite and Russian olive trees. USGS gage 08340500 is downstream of this site, although monitoring of this site by USGS ceased in 1986; drainage area at the gage is 3,600 km^2. GPS coordinates for this site are N35°35'48.3" W107°11'46.1". Given the elevation and location of their headwaters, there are reaches of Arroyo Chico and San Miguel Creek (a tributary to Arroyo Chico) that are likely to have perennial flows; therefore, we consider this site to have likely upstream sources of potential colonizers. This site was visited August 9-14, 2006 (Table 2-13).

Figure 2-24: Arroyo Chico Upstream of the USGS Gage main channel, August 14, 2006

Figure 2-25: Arroyo Chico Upstream of the USGS Gage floodplain pond, August 10, 2006

Table 2-13: Sampling effort at the Site Arroyo Chico Upstream of the USGS Gage, Rio Puerco Watershed, New Mexico, 2006

Parameter	8/8	8/9	8/10	8/11	8/12	8/13	8/14
Day of Succession		0	1	2	3	4	5
Flowing Water	Not visited	High	Low	Low	Low	Low	Low
Total Area (m^2)		n/m	572	502	513	465	527
Standing Water		pools	pools	pools	pools	pools	pools
Total Area (m^2)		57	57	46	40	40	29
Microinvertebrates		40 liters	40 liters	40 liters	40 liters	40 liters	40 liters
Macroinvertebrates		20 jabs	20 jabs	20 jabs	20 jabs	20 jabs	20 jabs
Fish & Amphibians							
Area Seined (m^2)		57	315	--	--	--	--
Area Electrofished (m^2)		--	--	274	277	252	278

2.2.7 Arroyo Chico Downstream of the USGS Gage

This site on Arroyo Chico was sampled between the USGS gage and the confluence with the Rio Puerco. The channel is very wide with a short riffle, bank debris jams, scour holes, and disconnected pools in the flood plain (Figure 2-26). Substrate is primarily silt with some cobble–sized pieces of clay; vegetation is primarily mesquite, salt cedar, and Russian olive trees. There is a concrete drop structure just downstream of the USGS gage, resulting in scour holes; however, we specifically did not sample those scour holes as they represent atypical arroyo/ephemeral stream characteristics. GPS coordinates for this site are N35°35'29.4" W107°11'15.3".

This site also was considered to have known upstream sources of potential colonizers. Even though this site was not visited on August 8-11 due to high flows, information from the other site on Arroyo Chico indicated that flows had begun subsiding on August 8; thus, dates for biotic succession reflect the passage of time since high flow subsidence began. Missing data from these dates might have introduced some unspecified error (missing one or two taxa) into the analyses. This site was visited August 12-14, 2006 (Table 2-14).

Figure 2-26: Arroyo Chico Downstream of the USGS Gage, August 14, 2006

Table 2-14: Sampling effort at the Site Arroyo Chico Downstream of the USGS Gage, Rio Puerco Watershed, New Mexico, 2006

Parameter	8/8	8/9	8/10	8/11	8/12	8/13	8/14
Day of Succession					3	4	5
Flowing Water	Not visited	Not visited	Not visited	Not visited	Low	Low	Low
Total Area (m^2)					496	438	511
Standing Water					2 pools	2 pools	2 pools
Total Area (m^2)					36	21	17
Microinvertebrates					40 liters	40 liters	40 liters
Macroinvertebrates					20 jabs	20 jabs	20 jabs
Fish & Amphibians							
Area Seined (m^2)					--	--	--
Area Electrofished (m^2)					76*	202	198

* experienced technical difficulties

2.3 Huerfano River Watershed, Colorado

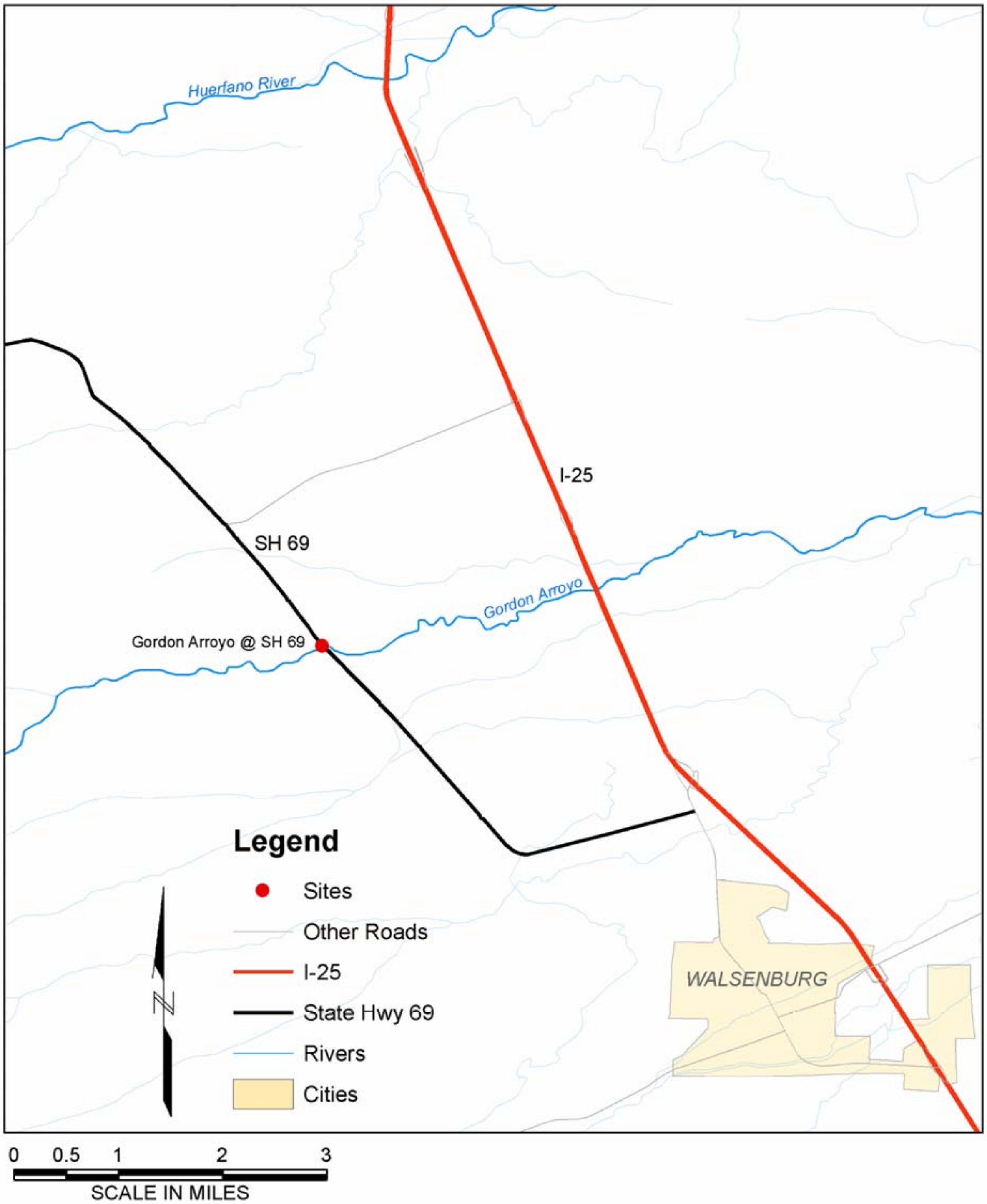
Only one site was established in the Huerfano River Watershed (Map 4), described in detail, with photographs, below. Twenty-four other possible sites were visited in the area, including those identified in the site reconnaissance in July 2006. However, each was found to be dry or to be a perennial stream. Monsoonal rainfall events were apparently not as prevalent in this region, as compared to the sites in the Santa Cruz River and Rio Puerco watersheds, resulting in little available sampling habitat. Photographs from the site reconnaissance show wet soils from a storm two days prior to the visit; they should not be construed as permanent flows as these stream channels are usually dry, except in response to storm runoff.

2.3.1 Gordon Arroyo at State Highway 69

Gordon Arroyo is a tributary to the Huerfano River near Walsenburg, Colorado. We sampled one site on Gordon Arroyo where it crosses State Highway (S.H.) 69. There is an incised channel with scour holes, especially near the road bridge pilings (Figure 2-27). The scour holes near the bridge were not sampled, as that was not considered to be natural ephemeral stream habitat. Substrate was sand and gravel, and riparian vegetation was primarily grasses. During sampling, this site consisted only of five disconnected pools. GPS coordinates for this site are N37°40'34.2" W104°50'40.7". Drainage area at this site is unknown.

This site has no known upstream sources of potential colonizers. Flow records from the nearby Cucharas River indicate that a storm event and high flows occurred on the evening of August 12, 2006, with flows beginning to subside by morning; thus, dates for biotic succession reflect the passage of time since high flow subsidence in Gordon Arroyo probably began. Missing data from these dates might have introduced some unspecified error (missing one or two taxa) into the analyses. This site was visited August 15-17, 2006 (Table 2-15).

Figure 2-27: Gordon Arroyo at State Highway 69 pool, August 17, 2006



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Aquatic Communities of Ephemeral Stream Ecosystems	GEI Consultants Chadwick Ecological Division	COLLECTING LOCALITIES IN HUERFANO RIVER WATERSHED, COLORADO
URS Ephemeral	Project 062530	Oct 2006 Map 4

Figure 2-28: Gordon Arroyo at State Highway 69 with no flow, July 11, 2006

Table 2-15: Sampling effort at the Site Gordon Arroyo at State Highway 69, Huerfano River Watershed, Colorado, 2006

Parameter	8/15	8/16	8/17
Day of Succession	2	3	4
Flowing Water	No	No	No
Total Area (m^2)	--	--	--
Standing Water	5 pools	5 pools	5 pools
Total Area (m^2)	87	65	46
Microinvertebrates	40 liters	40 liters	40 liters
Macroinvertebrates	20 jabs	20 jabs	20 jabs
Fish & Amphibians			
Area Seined (m^2)	87	65	46
Area Electrofished (m^2)	--	--	--

3.0 Methods

3.1 Hydrology Characterization

The study watersheds and sampling sites were chosen to give a general representation of the physical geography that would be broadly representative of the ephemeral stream habitats of the three ecoregions. Within these geographic areas, attempts were made to match these physical characteristics with gaged streams, preferably monitored by or in cooperation with the USGS. This allowed the investigators to use the USGS Web-based data network (National Water Information System, NWIS) to monitor the development of streamflow in a watershed when rainfall was reported by the National Weather Service.

In the case of two of the sites, the proximity of USGS gages allowed for the development of a hydrograph for the events. This was helpful in that these were also the sites chosen for temporal (as opposed to grab) sampling. In both cases, the gage used was on the main stem (Rio Puerco and Pantano Wash) and did not reflect the actual flow and duration experienced by the site or the tributary streams. However, the data are useful to understand some of the general streamflow patterns experienced by the watersheds during the sampling events. The scope and schedule of the project did not allow for the construction of gages at each site. Because no appropriate local stream gaging station was available for the Huerfano River Watershed, the discussion of that site is less detailed.

At the two sites selected for temporal sampling, USGS records were used to plot an average flow discharge curve in order that the sampling event could be compared to similar events of the period of record and to evaluate events antecedent to the sampled flow. A Log Pearson, Type III flood frequency curve was developed to determine the recurrence period of the flows sampled.

3.2 Field Methods

3.2.1 Sampling Reach Measures

Sampling reaches varied from region to region, depending on physical habitat, access, and safety issues. Mean reach lengths were 104 m in the Santa Cruz River Watershed, 30 m in the Rio Puerco Watershed, and 91 m in the Huerfano River Watershed and were designated at each site on the first day of sampling. All biota samples were collected from within the designated reach unless noted otherwise.

To estimate total available aquatic habitat, we also measured wetted width at four locations within each reach in flowing water and measured total area of isolated pools within each reach. Mean depth and maximum depth were also measured within each reach and pool. If a stream site became dry (no surface water), longer reaches were surveyed at most sites (up to 1.6 km) at least once to find additional possible sample sites.

3.2.2 Microinvertebrates

Microinvertebrate samples were collected first so that other sampling activities did not suspend excess sediment into the water column before taking the microinvertebrate sample. Using small buckets, we filled a larger bucket to 10 liters, and then filtered the water through a planktonic tow net with a 63-micron (63-µm) mesh (American Public Health Association et al. 1998). This was repeated along a transect across the stream until we had filtered up to 40 liters of water. In large pools and flowing portions of the stream channel, we filtered a total of 40 liters of water. However, if only multiple small pools were available, we used several pools as sources of the water and usually filtered a smaller volume of water, generally 20 liters or, in one case, 0.5 liter of water, based on available habitat. Samples were transferred into individual, labeled plastic jars and preserved using 95% ethanol and submitted to the laboratory for processing.

Care was taken during sampling to collect only pelagic microinvertebrates and to not disturb riparian vegetation or bottom sediments. Nevertheless, the considerable load of suspended sediment in the water column of both flowing and pooled water following the rain events often tended to clog the tow net during sampling. During laboratory processing it was found that ≥10 ml sediment (≥20% of entire sample) was present in 11/60 (18.3%) of the microinvertebrate samples. Thus, some samples presented difficulties in analysis due to the large amount of sediment present.

3.2.3 Aquatic Macroinvertebrates

Aquatic macroinvertebrate samples were collected from the designated stream reach within each site on every visit when sufficient water was available. Samples were collected consistent with the US EPA Rapid Bioassessment Protocols for the multihabitat approach (Barbour et al. 1999), with a composite of 20 "jabs" or "kicks" with a modified kick net sampler (mouth 305 mm × 508 mm, 500-µm mesh) in all available instream habitats, such as riffles, runs, pools, banks, snags, and overhanging vegetation. As flow decreased or smaller pools were encountered, lesser efforts (10 jabs, 5 jabs, etc.) were necessary and were documented as such. All samples were collected into individual, labeled plastic sample jars and preserved in the field using 95% ethanol and submitted to the laboratory for processing.

3.2.4 Vertebrates (Fish and Amphibians)

Collection of fish and amphibians was conducted using seines and/or backpack electrofishing gear. Multiple passes using appropriate equipment were conducted through available habitat within the designated reach, including open water, scour holes, snags, and submerged vegetation. All areas seined or electrofished were measured for areal extent of sampling effort. All fish and most amphibians, except voucher specimens, were identified, counted, measured for length, and released. Some incidental captures of amphibian tadpoles in the microinvertebrate and benthic macroinvertebrate samples were also identified and included in the analyses.

Voucher specimens were collected and preserved in 95% ethanol when field identification was not possible. Identification and confirmation of identification for fish voucher specimens was conducted in the laboratory.

3.3 Laboratory Methods

3.3.1 Microinvertebrates

Sample processing in the laboratory involved concentrating the sample to 20 ml in 70% ethanol, subsampling it into three 1-ml aliquots, and identifying the taxa to the taxonomic levels described in Table 3-1. Identifications were conducted using a 1 ml Sedgewick-Rafter counting cell under a compound microscope at a magnification of 100x. These analyses produced taxa lists and estimates of density (number of organisms/40 liters). If there were excessive organisms in a subsample (i.e., >100 individuals of any given taxon), only a single 1-ml subsample was identified; this occurred in only one sample. All individuals (i.e., both aquatic and terrestrial organisms) in each subsample were identified and enumerated. Raw data are reported in Appendix A.

Table 3-1: Standard taxonomic effort for microinvertebrates

Taxon	Common Name	Taxonomic Effort
INSECTA	Insects	Order and Family
ACARI	Mites	Order
CRUSTACEA	Crustaceans	Class and Order (Family for Daphnidae)
GASTROTRICHA	Gastrotrichs	Phylum
TARDIGRADA	Water bears	Phylum
ROTIFERA	Wheel animals	Phylum
NEMATODA	Roundworms	Phylum
ANNELIDA	Segmented worms	Class and Family

3.3.2 Aquatic Macroinvertebrates

In the laboratory, aquatic macroinvertebrate samples were sorted in their entirety and the organisms identified to the lowest practical taxonomic level (depending on age and condition of specimens and available literature) under a stereo dissecting microscope at magnifications of 7x – 40x. Chironomidae and Oligochaeta were cleared and mounted on glass microscope slides for identification and enumeration under a compound microscope. Chironomidae were submitted to Dr. Leonard Ferrington, Jr., University of Minnesota, for identification. The standard taxonomic effort for aquatic macroinvertebrates is described in Table 3-2; however, the taxonomy of very immature specimens, pupae, and specimens in extremely poor condition was left at higher taxonomic levels, usually at the level of Family. These analyses produced species lists and estimates of relative abundance (number of organisms/sample). Terrestrial organisms were removed during sorting or identification procedures and were not counted. Raw data are reported in Appendix B.

Table 3-2: Standard taxonomic effort for aquatic macroinvertebrates

Taxon	Common Name	Taxonomic Effort
INSECTA	**Insects**	
EPHEMEROPTERA	Mayflies	Genus
ODONATA	Dragonflies, damselflies	Genus
HEMIPTERA	True bugs	Genus
COLEOPTERA	Beetles	Genus/species
DIPTERA	True flies	Family, except as follows
Chironomidae	Non-biting midges	Genus
Ceratopogonidae	Biting midges	Subfamily
Culicidae	Mosquitoes	Genus
Chaoboridae	Phantom midges	Genus
Tabanidae	Horse flies, deer flies	Genus
HYDRACARINA (ACARI)	Water mites	Genus
CRUSTACEA	**Crustaceans**	
ANOSTRACA	Fairy shrimp	Genus
NOTOSTRACA	Fairy shrimp	Genus
AMPHIPODA	Scuds	Genus/species
ANNELIDA	**Segmented worms**	
OLIGOCHAETA	Oligochaetes	Family
HIRUDINEA	Leeches	Genus/species
MOLLUSCA	**Molluscs**	
GASTROPODA	Snails	Genus

3.4 Quality Assurance/Quality Control

Quality assurance and quality control of data were ensured through steps aimed at maintaining data integrity throughout the collection process. These procedures were utilized for field sampling, laboratory processing of samples, and data entry operations.

3.4.1 Field QA/QC

Field collection techniques used in the study were based on standard routine techniques (American Public Health Association et al. 1998, Barbour et al. 1999, Murphy and Willis 1996) that are commonly used by other agencies and have been used extensively by us in previous projects throughout the western United States. All field biologists had extensive training in the sampling of the biota of streams, with experience specifically geared for the expected macroinvertebrate and fish communities. Crew leaders held at least a master's degree in the biological or environmental sciences.

Although the intention of the sampling plan was to sample every site every day starting from peak flows to no surface water remaining, this was not always possible due to logistical constraints. Sampling each site intensively took time and did not always allow the teams to access each site every day. Missing data from streams and dates that were not sampled may have introduced some unspecified error into the results of this study. Based on results, errors would primarily have consisted of only a few taxa which were not collected and which might otherwise have been collected.

Collection of fish and amphibians using electrofishing gear and seines was constrained by high turbidity and behavior (e.g., the ability to burrow in loose sand), lowering efficiency of these methods in these streams. Habitats were sampled extensively using both methods (Tables 2-1 – 2-15) when possible, and alternative methods (i.e., individually dip netting specimens observed swimming near the surface) were applied when necessary.

3.4.2 Laboratory QA/QC

Quality control procedures in the laboratory were implemented for aquatic macroinvertebrate, fish, and amphibian samples. Due to the type of samples taken and the availability of experts, quality control procedures were not implemented for identification of microinvertebrates (identified by a taxonomist with experience in terrestrial microinvertebrates, recognizing that the majority of individuals were likely from terrestrial sources), Chironomidae (submitted to Dr. Leonard Ferrington, Jr., University of Minnesota, for identification), or Oligochaeta (few organisms encountered).

3.4.2.1 Microinvertebrates

Although quality control procedures were not implemented for identification of microinvertebrates, we did utilize quality control procedures for data entry. Data entry quality control procedures involved the use of Taxonomic Serial Numbers as assigned by the Integrated Taxonomic Information System of the U.S. Department of Agriculture (http://www.usda.itis.gov), ensuring correct spelling of all scientific names. All data entry reports were checked against original bench sheets by a taxonomist for both nomenclatural and enumeration accuracy as well as format before the final report was produced. Representatives of both aquatic and terrestrial forms were reported since all individuals (both aquatic and terrestrial) were identified.

3.4.2.2 Aquatic Macroinvertebrates

For sorting of aquatic macroinvertebrate samples, all samples were checked by a taxonomist or experienced technician. If more than 5% of the original technician's count of organisms was found in the QA check, the technician was instructed to continue sorting until the QA check found <5% of the original count. This process was documented on 10% of the samples, randomly selected.

For identification of the aquatic macroinvertebrate samples, all samples were checked by a taxonomist with experience in both terrestrial and aquatic fauna, since terrestrial biota comprised a considerable portion of the collected specimens. Terrestrial organisms were removed during sorting or identification, so only aquatic taxa were reported; however, it is possible that some taxa (esp. some annelids) were misinterpreted as aquatic taxa when they were actually terrestrial forms. Quality assurance checks on the enumeration of the aquatic biota were documented on 10% of the samples, randomly selected.

As with the microinvertebrate data entry procedures, data entry QA procedures for aquatic macroinvertebrates also involved the use of Taxonomic Serial Numbers as assigned by the Integrated Taxonomic Information System of the U.S. Department of Agriculture (http://www.usda.itis.gov), ensuring correct spelling of all scientific names. All data entry reports were checked against original bench sheets by a taxonomist for both nomenclatural and enumeration accuracy as well as format before the final report was produced.

3.4.2.3 Vertebrates

For vertebrates, voucher specimens were collected, where allowed in the scientific collecting permits. Fish identifications were verified by fish biologists in the laboratory. Identification of amphibian voucher specimens was conducted in the laboratory and results confirmed by Dr. Anthony Gendusa, Camp Dresser & McKee, Spokane, Washington.

3.5 Succession Patterns

Succession patterns were defined for this project basically as the colonization by aquatic biota of the stream sites over the duration of the flows/sampling. These patterns were analyzed for aquatic macroinvertebrates and vertebrates. We did not look at broad succession patterns for the microinvertebrates because we determined that almost all of the organisms collected were derived from terrestrial sources. We did analyze briefly the succession of truly aquatic forms of microinvertebrates (i.e., microcrustaceans).

For the purposes of investigating patterns of succession, we defined the start of succession as the subsidence of high flows in the streams. Colonization would be precluded by high flushing flows with substantial bedload movement. Thus, Day 0 included the first 24 hours after high flows began to subside, and the stream was deemed to be safe for sampling activities by the field crews. If a stream channel dried to the point at which there was no surface water present and was rewetted by another storm runoff event, succession activities were assumed to be reset by flushing flows from this new storm runoff event. Subsequent sampling for the succession was also reset to Day 0.

It was anticipated that there might be different aquatic macroinvertebrate and fish succession patterns on streams which had known or likely upstream sources of potential colonizers when compared to streams which did not have known upstream sources of potential colonizers. For the purposes of this study, we divided the streams into two groups to reflect these possibilities and analyzed the succession patterns separately in each group. Stream segments with upstream sources of potential colonizers in the Santa Cruz River Watershed included Pantano Wash at Vail, Ciénega Creek (both sites), Tanque Verde Wash at Houghton Road, and Santa Cruz River at Congress, in the Rio Puerco Watershed at Arroyo Chico (both sites), and the Rio Puerco (all three sites). Stream segments without upstream sources of potential colonizers in the Santa Cruz River Watershed included Mescal Arroyo at Marsh Station Road and Davidson Canyon at Mesquite Mesa Road, in the Rio Puerco Watershed at Arroyo Balcón and Cañada Santiago, and in the Huerfano River Watershed at Gordon Arroyo at State Highway 69.

Cañada Santiago had an off-channel impoundment upstream of the sampling site, but it is unknown if water levels overtopped the banks of this impoundment and allowed water and potential colonizing organisms to enter the stream. Some study sites from each of the Santa Cruz River and Rio Puerco watersheds were allocated to the groups of sites with or without upstream sources. We were able to collect data on succession patterns through Day 6 on streams where there was a possible upstream source of potential colonizers and through Day 6 on streams where there was not a known upstream source of potential colonizers.

We did not distinguish between streams with known upstream sources of potential colonizers and streams without known upstream sources of potential colonizers for analysis of the amphibian succession patterns. Because the adult stage is terrestrial for most of the amphibians we collected, an upstream source of potential colonizers is not requisite for their presence.

4.0 Results

4.1 Hydrologic Characterization of Regions

4.1.1 Flows in the Santa Cruz Watershed

The stream gage used to monitor flows in the Santa Cruz Watershed is USGS station number 09484600, Pantano Wash near Vail, Arizona (Map 2). The stream drains 1,184 km² of Upper Sonoran desert scrub and semi-desert grassland (Brown and Lowe 1980) within Pima, Cochise, and Santa Cruz Counties, Arizona, at an elevation of 977 m above mean sea level. Average annual rainfall is 34 cm (Period of record = 1992 to 2005).

The period of record for daily discharge data at the gaging station is from 1/1/1959 to 10/8/2006 and for annual peak data, from 8/11/1958 to 9/9/2005. Average daily discharge values (Figure 4-1) suggest that flows usually begin at the end of June and continue into late September with the highest concentration of large events occurring in August. This is typical of the southern Arizona annual monsoon and represents the only sustained pattern of flow in the annual cycle.

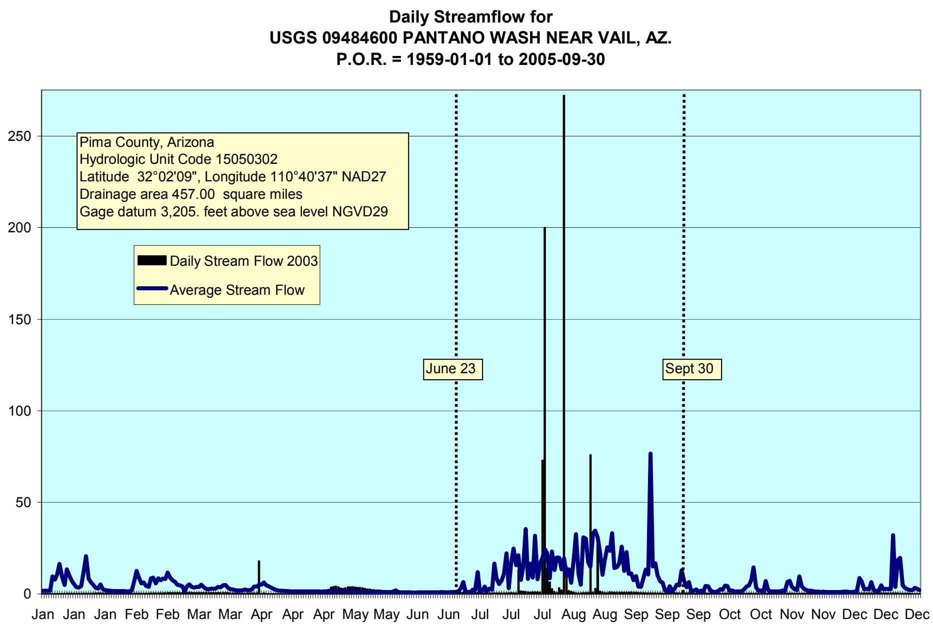

Figure 4-1: Daily streamflow for USGS 09484600 Pantano Wash near Vail, Arizona

In 2006, large events in the Pantano Wash Watershed began in the last week of July and continued into the first week of August (Figure 4-2). Peak flows exceeded 37,000 cfs (1,047 m^3/s) in the Rillito River, 4,000 cfs (113 m^3/s) in Pantano Wash, and 26,000 cfs (736 m^3/s) in Tanque Verde Wash (http://waterdata.usgs.gov). Three large events preceded sampling of the stream community and sampling occurred within the receding limb of the event of 31 July. Comparing these three events to the entire period of record indicates that the recurrence interval for them ranged between 1.75 and 3.45 years (Figure 4-3). This suggests that the flows were slightly greater than the effective discharge recurrence interval of 1.15-1.4 years for Southwestern streams, as suggested by Graf (2002).

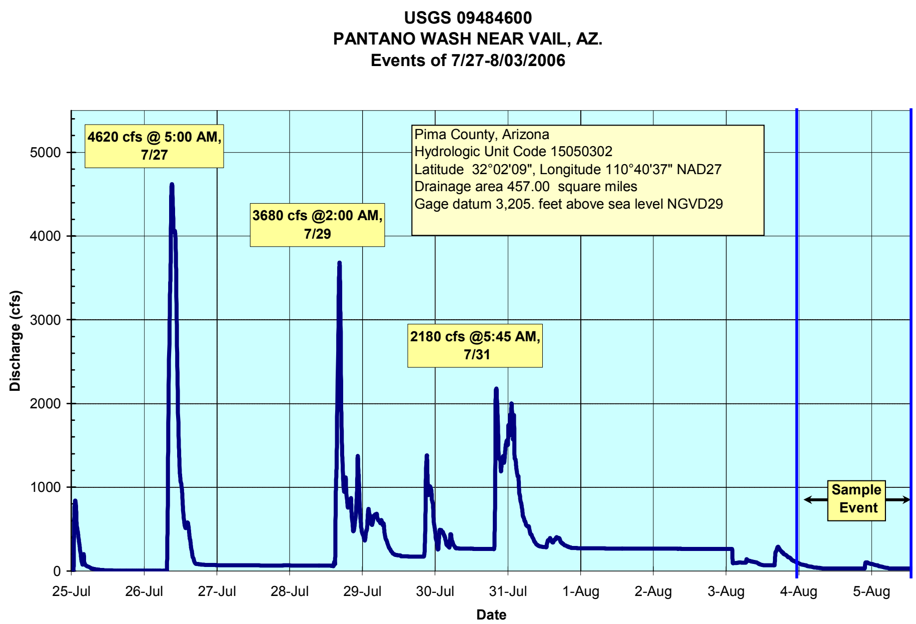

Figure 4-2: Events of July 27- August 3, 2006, for USGS 09484600 Pantano Wash near Vail, Arizona

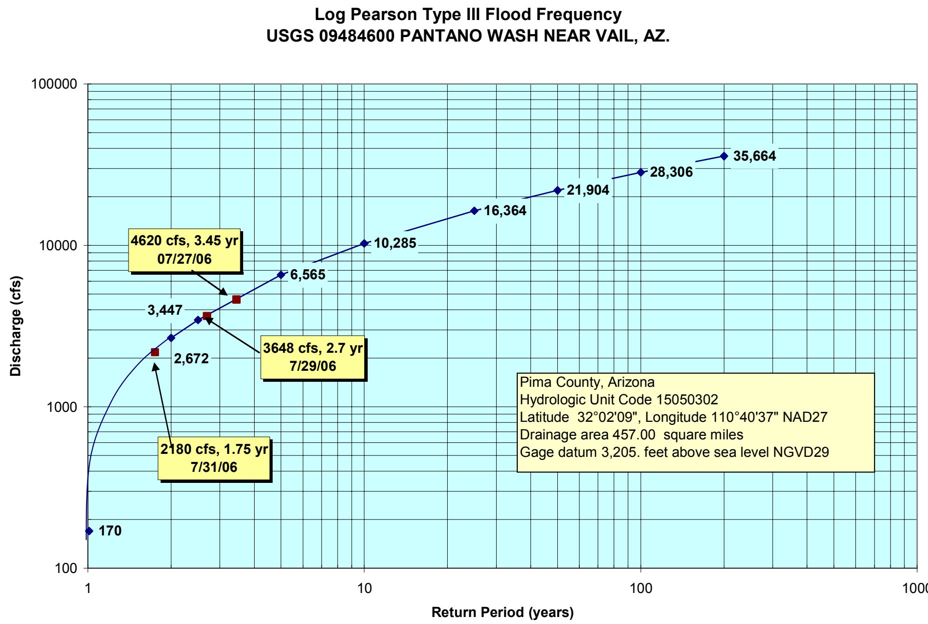

Figure 4-3: Log Pearson Type III Flood Frequency for USGS 09484600 Pantano Wash near Vail, Arizona

Despite the high flows, water levels receded quickly, and all sites were dry (no surface water) within nine days following commencement of flow. Several sites had overnight flow events, which did not even persist until the site could be sampled the next day. In three instances, flows ceased (leaving isolated pools) while the research team was on site.

4.1.2 Flows in the Rio Puerco Watershed

In the Rio Puerco Watershed, the USGS stream gage used was station 08334000 on the Rio Puerco above Arroyo Chico near Guadalupe, NM (Map 3). Streams sampled included the main stem (three locations), Arroyo Chico (two locations), and two other ephemeral tributaries. The gage itself includes discharge from a 1,088 km² watershed in Sandoval and McKinley Counties, New Mexico, consisting of Great Basin grassland and conifer woodland in the eastern Colorado Plateau (Brown and Lowe 1980). The gage elevation is 1,813 m above mean sea level. Rainfall measured at nearby Torreon Navajo Mission averages 26 cm over a period of record from 1961 to 2005. The Arroyo Chico Watershed, confluencing below the gage, is much bigger, comprising 3,600 km² but is at the same elevation and includes the same general plant community.

The Rio Puerco Watershed has two periods of ephemeral flow (Figure 4-4). High discharges are experienced by the streams from spring snowmelt beginning in late April and extending to late June, including both the San Juan Basin to the west and the Naciamento Mountains on the east, which rise to 2,888 m above sea level. A second, higher peak in runoff occurs in response to the summer monsoonal events, beginning in July and ending in September, similar to southern Arizona. This runoff pattern is typical of the margins of the Colorado Plateau.

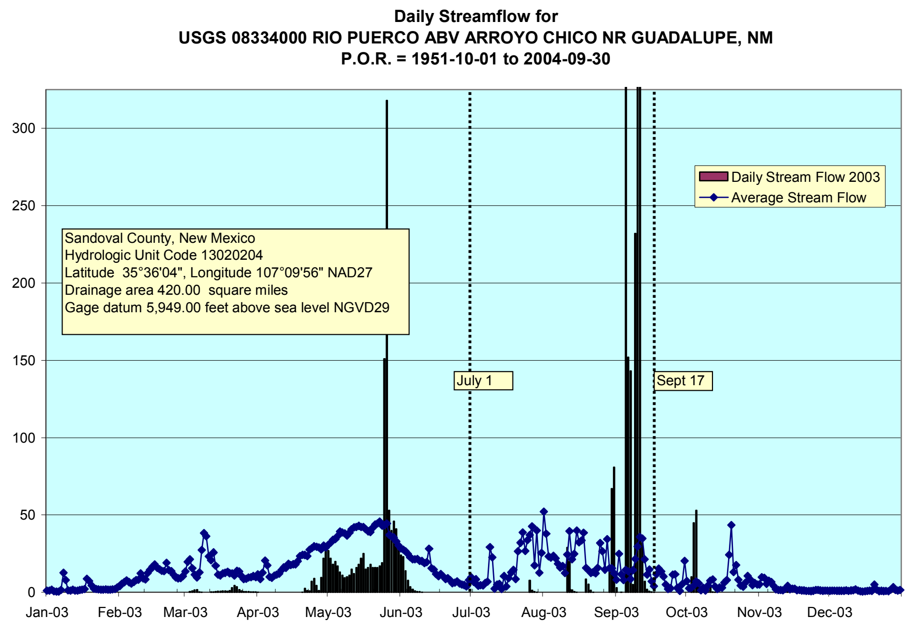

Figure 4-4: Daily streamflow for USGS 08334000 Rio Puerco above Arroyo Chico near Guadalupe, New Mexico

As expected, watershed-wide streamflow events began in 2006 on the Rio Puerco/Arroyo Chico watershed (Figure 4-5). Three large flow-producing events occurred in the first week of August and sampling began on the receding limb of the last (August 7, 2006) event. The antecedent flows had a recurrence interval of between 2.30 and 2.45 years, similar to the Pantano Wash events and, again, slightly greater than a typical effective discharge recurrence interval for arid West ephemeral streams (Figure 4-6).

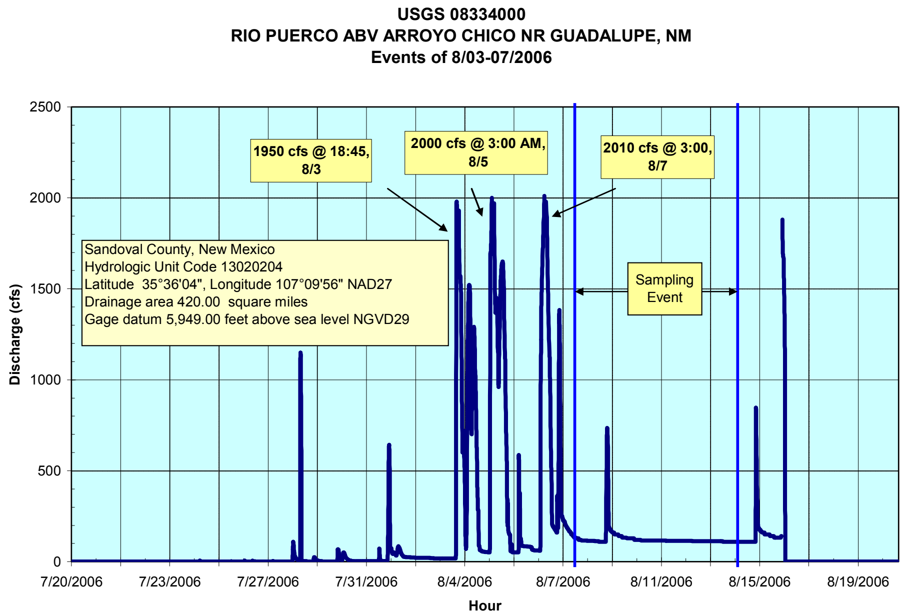

Figure 4-5: Events of August 3-7, 2006, for USGS 08334000 Rio Puerco above Arroyo Chico near Guadalupe, New Mexico

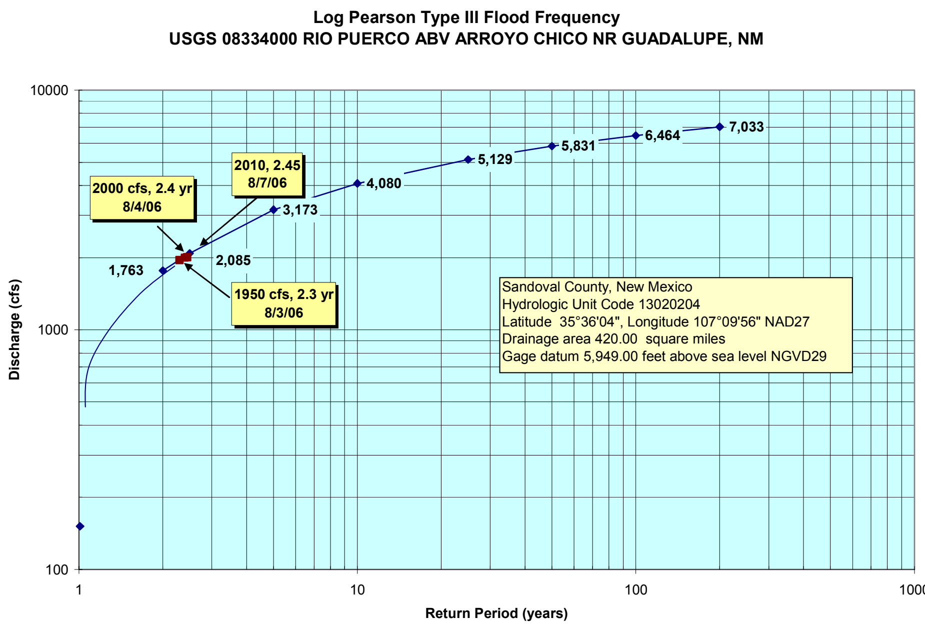

Figure 4-6: Log Pearson Type III Flood Frequency for USGS 08334000 Rio Puerco above Arroyo Chico near Guadalupe, New Mexico

4.1.3 Flows in the Huerfano River Watershed

In the Huerfano River Watershed, only Gordon Arroyo had surface water, despite recent precipitation. This site also was restricted to five pools without flowing water. The research team also investigated 24 additional arroyos throughout the region from Colorado Springs to Trinidad and found no other arroyos with surface water.

4.2 Aquatic Community Composition – Taxa Lists

4.2.1 Microinvertebrates

We collected a total of 21 taxa of microinvertebrates from the analysis of 1,380 organisms (Table 4-1). Microinvertebrate taxa included specimens from phyla, which have both aquatic and terrestrial representatives (Dindal 1990, Smith 2001). We were unable to determine if most of the organisms collected (e.g., Nematoda, Acari) originated from upstream aquatic sources or from inundated terrestrial sources.

We suspect that the majority of organisms (approximately 60%) came from terrestrial sources, since the taxa in many of these groups are primarily terrestrial as opposed to being truly aquatic. For example, organisms in the Family Campodeidae (insect Order Diplura) are entirely terrestrial (Ferguson 1990), and most Collembola are also terrestrial in origin (Christiansen 1990, Christiansen and Snider 1996).

Terrestrial organisms were likely moved into the sites from the vast amount of riparian land area inundated and/or flushed by high flows resulting from the monsoonal rain events (particularly in the Santa Cruz River Watershed). Flash floods like those experienced by these streams are frequently characterized by high sediment loads from eroded bank material (Fisher and Minckley 1978), and high rates of bank erosion (i.e., terrestrial soils) were documented in several streams. For example, up to six feet of bank was washed away in areas of Pantano Wash (Figure 4-7). This material also clogged the sampling gear, such as the zooplankton net that we used for collecting samples of microinvertebrates (Figure 4-8). Due to the amount of suspended sediment in the streams, over 18% of the microinvertebrate samples submitted to the laboratory consisted of ≥20% sediment, further illustrating the amount of sediment in these streams. During sample processing, we also encountered a large (>25 mm) tenebrionid beetle in a sample from the Rio Puerco Watershed; this terrestrial beetle was also likely washed in from inundated terrestrial areas.

Table 4-1: Microinvertebrate taxa collected in 2006 in ephemeral stream ecosystems of the arid southwestern United States

The Santa Cruz Watershed in Arizona was sampled July 29 – August 6, the Rio Puerco Watershed in New Mexico was sampled August 8-14, and the Huerfano River Watershed in Colorado was sampled August 15-17. "Unid." = unidentified species in the taxon.

Taxa	Santa Cruz River Watershed							Rio Puerco Watershed							Huerfano River Watershed
	Santa Cruz River @ Congress	Pantano Wash @ Vail	Davidson Canyon @ Mesquite Mesa Rd.	Mescal Arroyo @ Marsh Sta. Rd.	Ciénega Cr. US of I-10	Ciénega Cr. @ Mescal Arroyo	Tanque Verde Cr. @ Houghton Rd.	Rio Puerco nr. San Luis	Rio Puerco @ Cabezon	Rio Puerco DS of Arroyo Chico	Cañada Santiago	Arroyo Balcón	Arroyo Chico US of USGS gage	Arroyo Chico DS of USGS Gage	Gordon Arroyo @ S.H. 69
Anthropoda															
Insecta															
Diplura															
Campodeidae	X		X												
Collembola															
Entomobryidae	X														
Poduridae	X		X	X			X								
Sminthuridae			X												
Diptera															
Ceratopogonidae				X	X								X		
Chironomidae	X			X	X		X								
Tipulidae			X												
Acari															
Mesostigmata	X			X										X	
Oribatei	X	X	X	X	X	X	X		X		X			X	
Crustacea															
Copepoda															
*Calanoida	X	X													
*Cyclopoida	X													X	
*Harpactacoida											X				
Cladocera															
*Daphniidae	X									X					
*Unid. Cladocera	X						X								
Ostracoda															
*Unid. Ostracoda	X								X						
Rotifera															
*Unid. Rotifera	X		X	X	X										
Nematoda															
Unid. Nematoda	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tardigrada															
Unid. Tardigrada	X	X	X	X					X					X	
Annelida															
Oligochaeta															
Enchytraeidae			X	X			X								
Naididae			X		X	X									
Gastrotricha															
*Unid. Gastrotricha	X														

An asterisk (*) indicates taxa considered to be truly aquatic microinvertebrates (zooplankton).

Figure 4-7: Bank erosion in Pantano Wash upstream of the sampling site, August 3, 2006

Figure 4-8: Clogged zooplankton net

The 572 organisms which most likely came from aquatic sources (i.e., few, if any, terrestrial representatives are known) include the Copepoda, Ostracoda, Cladocera, Rotifera, and Gastrotricha (Smith 2001). All aquatic taxa except the copepods were rarely collected, and 94.6% of the aquatic microinvertebrates were copepods collected only at the Site Santa Cruz River at Congress. These groups primarily occur in lentic bodies of water, although some can encyst themselves in a "cryptobiotic" state (e.g., as resting eggs) to persist in stream channels during environmental stress, such as drought (Smith 2001, Thorp and Covich 2001). Even though the insects and annelids actually represent macroinvertebrate forms, they were collected in the microinvertebrate samples and are included in the discussion later.

4.2.2 Aquatic Macroinvertebrates

Within the entire project, we collected a total of 86 distinct taxa of aquatic macroinvertebrates (Table 4-2). The taxa included representatives of the Insecta, Hydracarina, Crustacea, Oligochaeta, Hirudinea, and Gastropoda. Insects were the most diverse group, with 74 distinct taxa, including the Orders Collembola, Ephemeroptera, Odonata, Hemiptera, Coleoptera, and Diptera. All but 15 taxa (82.6%) have aerially dispersing adults, which may account for their presence in these ephemeral stream sites (Merritt and Cummins 1996). The remaining taxa, including two collembolan taxa and all of the non-insects, could have come from upstream perennial sources of water, terrestrial sources (esp. Collembola, Enchytraeidae, Hydracarina), and/or cryptobiotic stages from previous inundations (esp. Anostraca, Notostraca).

Table 4-2: Aquatic macroinvertebrate taxa collected in 2006 in ephemeral stream ecosystems of the arid southwestern United States

The Santa Cruz Watershed in Arizona was sampled July 29 – August 6, the Rio Puerco Watershed in New Mexico was sampled August 8-14, and the Huerfano River Watershed in Colorado was sampled August 15-17. "Unid." = unidentified species in the taxon.

Taxa	Santa Cruz River Watershed							Rio Puerco Watershed							Huerfano River Watershed
	Santa Cruz R.iver@ Congress	Pantano Wash @ Vail	Davidson Cyn @ Mesquite Mesa Rd.	Mescal Arroyo @ Marsh Sta. Rd.	Ciénega Cr. US of I-10	Ciénega Cr. @ Mescal Arroyo	Tanque Verde Cr. @ Houghton Rd.	Rio Puerco nr. San Luis	Rio Puerco @ Cabezon	Rio Puerco DS of Arroyo Chico	Cañada Santiago	Arroyo Balcón	Arroyo Chico US of Gage	Arroyo Chico DS of Gage	Gordon Arroyo @ S.H. 69
Anthropoda															
Insecta															
Collembola															
Sminthuridae															
Unid. minthuridae								X							
Unid. Collembola								X							

Taxa	Santa Cruz River Watershed							Rio Puerco Watershed							Huerfano River Watershed
	Santa Cruz R.iver@ Congress	Pantano Wash @ Vail	Davidson Cyn @ Mesquite Mesa Rd.	Mescal Arroyo @ Marsh Sta. Rd.	Ciénega Cr. US of I-10	Ciénega Cr. @ Mescal Arroyo	Tanque Verde Cr. @ Houghton Rd.	Rio Puerco nr. San Luis	Rio Puerco @ Cabezon	Rio Puerco DS of Arroyo Chico	Cañada Santiago	Arroyo Balcón	Arroyo Chico US of Gage	Arroyo Chico DS of Gage	Gordon Arroyo @ S.H. 69
Ephemeroptera															
Baetidae															
Unid Baetidae								X	X	X		X	X	X	X
Callibaetis sp.						X		X	X					X	
Odonata															
Coenagrionidae															
Coenagrion/Enallagma	X							X		X					
Unid. Coenagrionidae							X	X					X		
Libellulidae															
Unid. Libellulidae	X														
Hemiptera															
Naucoridae															
Ambrysus mormon										X	X		X		
Gerridae															
Aquarius sp.								X							
Rheumatobates sp.								X							
Unid. Gerridae								X							
Belostomatidae															
Belostoma sp.	X														
Corixidae															
Corisella sp.	X														
Hesperocorixa sp.						X									
Sigara sp.								X	X		X			X	X
Unid. Corixidae								X	X	X				X	
Hebridae															
Lipogomphus sp.								X			X	X	X		
Veliidae															
Microvelia sp.					X										
Unid. Veliidae						X									
Notonectidae															
Notonecta sp.															X
Unid. Notonectidae								X		X					
Coleoptera															
Dytiscidae															
Agabus sp.											X				
Eretes occidentalis	X														
Laccophilus sp.						X		X							
Laccophilus maculosus	X														
Liodessus obscurellus	X					X									X
Neoporus dimidiatus											X		X		
Oreodytes sp.								X							
Stictotarsus striatellus								X	X	X					
Unid. Dytiscidae						X									
Hydrophilidae															
Berosus sp.	X					X		X	X	X			X		X
Enochrus sp.	X										X				
Laccobius sp.											X				
Paracymus sp.												X			

Taxa	Santa Cruz River Watershed							Rio Puerco Watershed							Huerfano River Watershed
	Santa Cruz R.iver@ Congress	Pantano Wash @ Vail	Davidson Cyn @ Mesquite Mesa Rd.	Mescal Arroyo @ Marsh Sta. Rd.	Ciénega Cr. US of I-10	Ciénega Cr. @ Mescal Arroyo	Tanque Verde Cr. @ Houghton Rd.	Rio Puerco nr. San Luis	Rio Puerco @ Cabezon	Rio Puerco DS of Arroyo Chico	Cañada Santiago	Arroyo Balcón	Arroyo Chico US of Gage	Arroyo Chico DS of Gage	Gordon Arroyo @ S.H. 69
Tropisternus sp.															X
Dryopidae															
Helichus sp.										X					
Postelichus sp.	X				X	X		X	X						
Helophoridae															
Helophorus sp.															X
Hydrochidae															
Hydrochus sp.	X														
Elmidae															
Microcylloepus pusillus									X						
Hydraenidae															
Ochthebius sp.								X	X		X	X	X		X
Haliplidae															
Peltodytes sp.					X	X									
Salpingidae															
Unid. Salpingidae								X	X						X
Diptera															
Culicidae															
Aedes sp.											X				
Psorophora sp.											X				
Unid. Culicidae	X							X	X		X				
Chironomidae															
Apedilum sp.							X								
Bryophaenocladius sp.				X	X								X		
Chironomus sp.	X							X	X	X			X		
Conchapelopia/ Thienemanniella													X	X	
Endotribelos sp.													X	X	
Goeldichironomus sp.	X														
Larsia sp.													X		
Paramerina sp.														X	
Polypedilum sp.														X	
Procladius sp.										X	X			X	
Pseudosmittia sp.							X								
Smittia sp.				X					X						
Stictochironomus sp.										X					
Unid. Orthocladiinae	X	X	X	X	X	X		X	X	X	X	X	X	X	
Unid. Chironomidae		X													
Ceratopogonidae															
Unid. Ceratopogoninae					X	X	X		X		X		X	X	
Unid. Ceratopogonidae		X						X			X				
Chaoboridae															
Chaoborus sp.	X														
Dolichopodidae															
Unid. Dolichopodidae	X												X		
Empididae															
Unid. Empididae				X				X	X				X		

Taxa	Santa Cruz River Watershed							Rio Puerco Watershed							Huerfano River Watershed
	Santa Cruz R.iver@ Congress	Pantano Wash @ Vail	Davidson Cyn @ Mesquite Mesa Rd.	Mescal Arroyo @ Marsh Sta. Rd.	Ciénega Cr. US of I-10	Ciénega Cr. @ Mescal Arroyo	Tanque Verde Cr. @ Houghton Rd.	Rio Puerco nr. San Luis	Rio Puerco @ Cabezon	Rio Puerco DS of Arroyo Chico	Cañada Santiago	Arroyo Balcón	Arroyo Chico US of Gage	Arroyo Chico DS of Gage	Gordon Arroyo @ S.H. 69
Ephydridae															
Unid. Ephydridae				X	X			X	X						X
Muscidae															
Unid. Muscidae									X						
Stratiomyiidae									X						
Nemotelus sp.					X										
Stratiomys sp.							X								
Tipulidae															
Ormosia sp.									X						
Unid. Tipulidae			X					X	X	X			X		
Syrphidae															
Unid. Syrphidae		X													
Tabanidae															
Tabanus sp.	X							X			X			X	
Acari															
"Hydracarina"															
Hydryphantidae															
Hydryphantes sp.	X														
Limnesiidae															
Tyrellia sp.								X							
Crustacea															
Anostraca															
Chirocephalidae															
Eubranchipus sp.											X				
Notostraca															
Triopidae															
Triops sp.										X			X		
Amphipoda															
Hyalellidae															
Hyalella azteca cx.	X	X								X					
Annelida															
Oligochaeta															
Megdrili															
Enchytraeidae															
Unid. Enchytraeidae			X						X	X	X				
Lumbriculidae															
Unid. Lumbriculidae				X	X		X	X	X				X		
Tubificdae															
UIT w/CC*								X							
Unid. Megadrili								X	X				X		X
Hirudinea															
Hirudinoidea															
Erpobdellidae															
Erpobdela punctata punctata	X					X			X		X				

Taxa	Santa Cruz River Watershed							Rio Puerco Watershed							Huerfano River Watershed
	Santa Cruz R.iver@ Congress	Pantano Wash @ Vail	Davidson Cyn @ Mesquite Mesa Rd.	Mescal Arroyo @ Marsh Sta. Rd.	Ciénega Cr. US of I-10	Ciénega Cr. @ Mescal Arroyo	Tanque Verde Cr. @ Houghton Rd.	Rio Puerco nr. San Luis	Rio Puerco @ Cabezon	Rio Puerco DS of Arroyo Chico	Cañada Santiago	Arroyo Balcón	Arroyo Chico US of Gage	Arroyo Chico DS of Gage	Gordon Arroyo @ S.H. 69
Mollusca															
Gastropoda															
Eulamellibranchia															
Planorbidae															
Helisoma sp.														X	
Lymnaeidae															
Stagnicola sp.											X				

* Unidentified Immature Tubificidae with Capilliform Chaetae

4.2.3 Fish

We collected a total of four species of fish (Table 4-3), including two members of the Family Cyprinidae (minnows), one of the Family Centrarchidae (sunfish and bass), and one of the Family Poeciliidae (livebearers). In addition to fish specimens collected as part of the sampling (seining and electroshocking) or kept as voucher material, we also noted the presence of fish when they were observed but not collected.

Table 4-3: Fish species collected in 2006 in ephemeral stream ecosystems of the arid southwestern United States

The Santa Cruz Watershed in Arizona was sampled July 29 – August 6, the Rio Puerco Watershed in New Mexico was sampled August 8-14, and the Huerfano River Watershed in Colorado was sampled August 15-17.

Taxa	Santa Cruz River Watershed							Rio Puerco Watershed							Huerfano River Watershed
	Santa Cruz River @ Congress	Pantano Wash @ Vail	Davidson Canyon @ Mesquite Mesa Rd.	Mescal Arroyo @ Marsh Sta. Rd.	Ciénega Cr. US of I-10	Ciénega Cr. @ Mescal Arroyo	Tanque Verde Cr. @ Houghton Rd.	Rio Puerco nr. San Luis	Rio Puerco @ Cabezon	Rio Puerco DS of Arroyo Chico	Cañada Santiago	Arroyo Balcón	Arroyo Chico US of Gage	Arroyo Chico DS of Gage	Gordon Arroyo @ S.H. 69
Centrarchidae															
Lepomis cyanellus							X								
Cyprinidae															
Agosia chrysogaster					X	X									
Pimephales promelas								X			X		X		
Poeciliidae															
Gambusia affinis							X								

4.2.4 Amphibians

We collected six taxa of amphibians, including one species of the Order Salientia (salamanders) and five species of the Order Anura (frogs and toads) (Table 4-4). Some of the anuran species identifications are tentative because of immature specimens (small tadpoles and recently metamorphosed adults), darkened coloration upon preservation, or decomposition/poor condition after being collected in microinvertebrate or aquatic macroinvertebrate samples. In addition to the specimens retained as voucher material, we also frequently noted the presence of tadpoles at the sites.

Table 4-4: Amphibian taxa collected in 2006 in ephemeral stream ecosystems of the arid southwestern United States

The Santa Cruz Watershed in Arizona was sampled July 29 – August 6, the Rio Puerco Watershed in New Mexico was sampled August 8-14, and the Huerfano River Watershed in Colorado was sampled August 15-17.

Taxa	**Santa Cruz River Watershed**							**Rio Puerco Watershed**							**Huerfano River Watershed**
	Santa Cruz R.iver @ Congress	**Pantano Wash @ Vail**	**Davidson Canyon @ Mesquite Mesa Rd.**	**Mescal Arroyo @ Marsh Sta. Rd.**	**Ciénega Cr. US of I-10**	**Ciénega Cr. @ Mescal Arroyo**	**Tanque Verde Cr. @ Houghton Rd.**	**Rio Puerco nr. San Luis**	**Rio Puerco @ Cabezon**	**Rio Puerco DS of Arroyo Chico**	**Cañada Santiago**	**Arroyo Balcón**	**Arroyo Chico US of Gage**	**Arroyo Chico DS of Gage**	**Gordon Arroyo @ S.H. 69**
Salientia															
Ambystomatidae															
Ambysoma tigrina															X
Anura															
Bufidae															
Bufo punctatus	X						X						X	X	
Bufo sp.										X					
Ranidae															
Rana catesbieana							X								
Pelobatidae															
Scaphiopus couchii				X				X			X	X	X	X	
Spea bombifrons										X					

4.3 Aquatic Community Composition – Regional Patterns in Taxa

4.3.1 Santa Cruz River Watershed

4.3.1.1 Microinvertebrates

A total of 20 distinct taxa of microinvertebrates were collected in the Santa Cruz River Watershed (Table 4-1). The average number of taxa per site was 8 taxa, ranging from 3 taxa in samples collected from Ciénega Creek at Mescal Arroyo to 15 taxa in samples collected from the Santa Cruz River at Congress. Fewer taxa were found in flowing waters (i.e., Ciénega Creek, Tanque Verde Wash, Pantano Wash) than at sites where the water had pooled and the pools persisted for a few days (i.e., Davidson Canyon, Mescal Arroyo, Santa Cruz River).

Of the 20 taxa collected in the Santa Cruz River Watershed, 7 taxa were collected at only a single site, and only 2 taxa (mites in the Order Oribatei and nematode round worms) were collected at all seven sites. The specimens from both Oribatei and Nematoda were probably from terrestrial sources (Dindal 1990), and the insects had been washed in from terrestrial sources (e.g., Collembola, Diplura), drifted in from upstream sources, or were hatched from eggs recently laid by aerial adults (Diptera).

The largest densities of truly aquatic macroinvertebrates occurred in the Santa Cruz River at Congress, with large numbers of copepods present. These organisms also increased in density over time at that site. Many copepods have a cryptobiotic life stage in which they encyst in response to adverse environmental conditions, such as drought, and can re-animate in response to the presence of water (Smith 2001). Unidentified Cladocera (not Daphniidae) were also collected in Tanque Verde Wash at Houghton Road. Both of these sites have known possible upstream sources of potential colonizers, including instream flows and off-channel impoundments, which likely overtopped during the high flows.

4.3.1.2 Aquatic Macroinvertebrates

A total of 44 distinct taxa of aquatic macroinvertebrates were collected in the Santa Cruz River Watershed. Average number of taxa per site was 9 taxa, ranging from 3 taxa in samples collected from Davidson Canyon to 21 taxa in samples collected from the Santa Cruz River at Congress. Fewer taxa were found at sites where flows following flood events were reduced primarily to isolated pools (e.g., Davidson Canyon, Mescal Arroyo) than at sites in which water was flowing (e.g., Ciénega Creek). Fewer taxa were also found at sites where samples were taken infrequently because flows were either too high or nonexistent (e.g., Pantano Wash, Tanque Verde Wash) than at sites where water was present more consistently (e.g., Ciénega Creek, Santa Cruz River).

While no single taxon was collected at every site, one taxon (Unidentified Orthacladiinae) was found at six of the seven sites. This taxon represents an entire subfamily of Chironomidae and individuals from different species or genera could be represented in this broad grouping. The identification of these specimens was necessarily left at the subfamily level primarily because the specimens were too immature to be identified with precision to a finer taxonomic level. The immature state of these specimens suggests that they probably had recently hatched from eggs laid by an aerial adult. A total of 33 taxa were collected at only a single site in the Santa Cruz River Watershed, 7 taxa were collected at two sites, and 3 taxa were collected at three sites.

It is not uncommon for large proportions (i.e., up to 33%) of taxa to be collected only at a single site (Resh et al. 2005); however, this proportion (75%) suggests strongly that most species entered from random, aerial sources outside of the site and did not come from source populations upstream. Generally, upstream source populations would have had established aquatic invertebrate assemblages, which would have flushed representative individuals down to these ephemeral stream segments from each of the taxa. Given that most of the taxa were collected only at single sites, it appears that this was not the case. In fact, 39 of the 44 taxa (88.6%) collected at these sites have aerially dispersing adults.

4.3.1.3 Vertebrates

4.3.1.3.1 Fish

Three species of fish were collected in the Santa Cruz River Watershed. They included *Agosia chrysogaster* (the longfin dace), *Lepomis cyanellus* (the green sunfish), and *Gambusia affinis* (the western mosquitofish). These species represent three different families of fish.

Longfin dace (Figure 4-9) were collected at two sites (Ciénega Creek at Mescal Arroyo and Ciénega Creek upstream of I-10) in the Santa Cruz River Watershed. Seven specimens were captured at the Ciénega Creek at Mescal Arroyo site. Subsequently, this site was dry and then stream flows resumed. Four additional specimens were captured the second day after flows resumed. One specimen was captured in the Ciénega Creek Upstream of I-10 site; however, the site had been dry (except for a single, small pool) two days prior.

Figure 4-9: Longfin dace, *Agosia chrysogaster*, collected in Ciénega Creek at Mescal Arroyo, August 1, 2006

There is a known perennial reach of Ciénega Creek upstream of these sites within the *Ciénega Creek Conservation Area*, and longfin dace have previously been reported from those perennial reaches of this stream (Arizona Game and Fish Department 2006). Longfin dace were not captured at the Tanque Verde Wash at Houghton Road site, even though we observed minnows (probably longfin dace) at upstream perennial reaches of Tanque Verde Wash just west of the Saguaro National Park boundary.

Green sunfish (Figure 4-10) were collected only in Tanque Verde Wash and were represented by desiccated specimens following cessation of flow. This species is not native to Arizona; however, it has been heavily introduced, particularly for sport fishing (Minckley 1973, Schade and Bonar 2005). There are many small impoundments off-channel near Tanque Verde Wash, in the form of backyard ponds, ranch ponds, golf course ponds, stock tanks, etc., which may have contributed fish to the stream if these waterbodies were flooded during high flows. We believe impoundments such as these were the likely source of the green sunfish found in Tanque Verde Wash. Although we were unable to collect any specimens because flows were too high to seine effectively when the stream was flowing, we did observe fish in the flowing water in Tanque Verde Wash the day before it dried up. Based on the specimens we collected, we believe that those fish were probably green sunfish, as well.

Figure 4-10: Green sunfish, *Lepomis cyanellus*, collected in Tanque Verde Wash at Houghton Road, August 2, 2006

Western mosquitofish (Figure 4-11) were also collected only from desiccated specimens in Tanque Verde Wash. As with the green sunfish, this species is not native, has been frequently introduced (for biological control of mosquitoes), and likely originated in off-channel impoundments flooded during the high flows (Minckley 1973, Schade and Bonar 2005).

Figure 4-11: Western mosquitofish, *Gambusia affinis*, collected in Tanque Verde Wash at Houghton Road, August 2, 2006

In regard to both green sunfish and mosquitofish, it has been noted that native fishes are adapted to handle extreme flow events, whereas populations of introduced species tend to be poorly adapted, and populations can be decimated by flood events (Greenfield et al. 1970, Deacon and McKinley 1974, Minckley 1981, Meffe 1984, Minckley and Meffe 1987, Dudley and Matter 1999). Since over 66% of streams in Arizona have nonnative fish species present (Schade and Bonar 2005), their collection in the present effort is not surprising.

4.3.1.3.2 Amphibians

Three taxa of amphibians, all of which were anurans, were collected in the Santa Cruz River Watershed. These included *Rana catesbieana* (the bullfrog), *Bufo punctatus* (the red-spotted toad), and *Scaphiopus couchii* (the Couch's spadefoot toad). These species represent three different families in the Order Anura. In addition to the specimens collected, we also observed tadpoles on multiple dates.

Bullfrogs (Figure 4-12) are not native to Arizona and have been implicated in declines in other amphibian species within the state. We collected two adult specimens at the site on Tanque Verde Wash. One specimen was found dead (and had been preyed upon by, presumably, a small avian raptor, since its legs were missing), and the other specimen was found alive.

Figure 4-12: Bullfrog, *Rana catesbieana*, collected in Tanque Verde Wash at Houghton Road, August 4, 2006

Red-spotted toads (Figure 4-13) are common throughout the southwestern United States, with their range extending south through Baja California and mainland Mexico to the state of Hidalgo (Stebbins 1985). This species was collected at two sites. One red-spotted toad tadpole was collected at the Tanque Verde site; other specimens were found scattered on the sand, dried, along with the green sunfish and mosquitofish, discussed above. One red-spotted toad tadpole was also collected at the Santa Cruz River at Congress site, and thirteen tadpoles were also collected in the aquatic macroinvertebrate samples from that site.

Figure 4-13: Red spotted toad, *Bufo punctatus*, tadpole collected in Arroyo Chico Downstream of the USGS Gage, August 12, 2006

Couch's spadefoot toad was collected from only one site in the Santa Cruz River Watershed, with one tadpole collected from the pool in Mescal Arroyo. Additional tadpoles were observed on the next day. After the pool dried, dead tadpoles were found on the surface of the mud, and ants were observed scavenging their carcasses.

4.3.2 Rio Puerco Watershed

4.3.2.1 Microinvertebrates

A total of 9 taxa of microinvertebrates were collected in the Rio Puerco Watershed. Average number of taxa per site was 3 taxa, ranging from 1 taxon in samples collected at Arroyo Balcón and in the Rio Puerco near San Luis to 5 taxa in samples collected in Arroyo Chico downstream of the USGS gage.

This taxa richness is lower than taxa richness in the Santa Cruz River watershed, possibly because of the finer sediments present in the Rio Puerco Watershed. Since many of the microinvertebrates we collected reside in interstitial spaces between sediment grains, they might prefer the coarser sediments of the Santa Cruz River Watershed.

One taxon (Nematoda) was found at every site, and six taxa were collected at only a single site within the watershed. Most taxa were probably terrestrial in origin; however, the crustaceans (cyclopoid and harpacticoid copepods, ostracods, and daphniid cladocerans) probably came from upstream sources of perennial water. The Cyclopoida, Ostracoda, and Daphniidae were collected from Arroyo Chico and the Rio Puerco downstream of Arroyo Chico, both of which have known possible upstream sources of potential colonizers. The Harpacticoida were collected from Cañada Santiago, which does not have a known source of potential colonizers upstream, except possibly from a small, off-channel impoundment. The copepods collected in Cañada Santiago could have originated from cryptobiotic stages in the streambed sediments, either within the site itself or from a scoured section upstream (Smith 2001) or even from wind-blown sediments from other drainages (Bilton et al. 2001).

4.3.2.2 Aquatic Macroinvertebrates

A total of 63 distinct taxa of aquatic macroinvertebrates were collected in the Rio Puerco Watershed. The average number of taxa per site was 19 taxa, ranging from 5 taxa in samples collected in Arroyo Balcón to 32 taxa in samples collected in the Rio Puerco near San Luis. As in the Santa Cruz River Watershed, fewer taxa were found at sites in which post-flood flows were primarily represented by isolated pools when we sampled (e.g., Arroyo Balcón) than at sites in which water was flowing when we sampled (e.g., Arroyo Chico).

Only one taxon (Unidentified Orthocladiinae) was found at every site, and, as stressed above, this taxon could represent multiple taxa that were unidentifiable because of their immature development. A total of 31 taxa were found only at one site each, with 12 taxa collected at two sites, 11 taxa collected at three sites, and 6 taxa collected at four sites. Adult *Ochthebius* sp., a hydraenid beetle, was found at five of the seven sites, and unidentified baetid mayflies were found at six of the seven sites. The immature state of the mayflies suggests that they might have originated from eggs laid recently by an aerial adult.

As in the Santa Cruz River Watershed, this proportion (49%) of taxa collected at only a single site suggests that the majority of the organisms may have come in from outside sources and not from upstream source populations. Of the 63 taxa collected in this watershed, 51 taxa (80.9%) have aerially dispersing adults.

4.3.2.3 Vertebrates

4.3.2.3.1 Fish

We collected only one species of fish in the Rio Puerco Watershed. The fathead minnow, *Pimephales promelas* (Figure 4-14), was collected at three sites: Cañada Santiago, the Rio Puerco near San Luis, and Arroyo Chico upstream of the USGS gage. This species is native to the western United States, including this study area. Their fast generation time and tolerance of a wide variety of environmental conditions allows them to adapt to the rapidly changing landscape of the arid western United States. There are known populations of this species in the upstream reaches of the Rio Puerco near Cuba (NMED 2006) which could have been transported downstream with the high flows and potentially migrated upstream into Cañada Santiago and Arroyo Balcón during receding flows.

Figure 4-14: Fathead minnow, *Pimephales promelas*, collected in Cañada Santiago, August 11, 2006

4.3.2.3.2 Amphibians

Three distinct species of anurans were collected at sites in the Rio Puerco Watershed. We collected *Bufo punctatus* (the red-spotted toad), *Scaphiopus couchii* (the Couch's spadefoot toad), and *Spea bombifrons* (the plains spadefoot toad). In an aquatic macroinvertebrate sample, we also collected one additional tadpole in the genus *Bufo*, which was too decomposed to be able to identify beyond the genus level – but was probably a red-spotted toad.

One red-spotted toad tadpole was collected from Arroyo Chico upstream of the USGS gage. Other tadpoles were observed at this site on multiple dates, although we do not know the specific identity of those organisms.

We collected one tadpole and one tentatively identified adult of Couch's spadefoot toad (Figure 4-15) in Cañada Santiago. Additionally, seven tadpoles of this species were also collected in Cañada Santiago in the aquatic macroinvertebrate sample the following day. Other tadpoles were observed at this site on multiple dates, although we do not know the specific identity of those individuals. The adult was tentatively identified as Couch's spadefoot toad because it was recently metamorphosed and bears only some of the characteristics of that species.

Figure 4-15: Couch's spadefoot toad, *Scaphiopus couchii*, collected in Cañada Santiago, August 11, 2006

The plains spadefoot toad is also a common inhabitant of the central United States, with a range extending across the Great Plains from Alberta, Canada, south to Chihuahua, Mexico. Its distribution continues across New Mexico to include the study area. The sole tadpole of plains spadefoot toad we encountered was incidentally collected in an aquatic macroinvertebrate sample from the Rio Puerco downstream of Arroyo Chico. This individual was of a predaceous form of the tadpole, having a large, hardened beak among its mouthparts.

4.3.3 Huerfano River Watershed

4.3.3.1 Microinvertebrates

Only one taxon of microinvertebrate was collected in samples from Gordon Arroyo in the Huerfano River Watershed. That taxon was the Nematoda, which, as discussed above, probably represent terrestrial forms that had been washed into the stream and resulting pools.

4.3.3.2 Aquatic Macroinvertebrates

A total of 11 distinct taxa of aquatic macroinvertebrates were collected in samples from Gordon Arroyo in the Huerfano River Watershed. Ten of the eleven taxa (90.9%) collected at this site have aerially dispersing adults.

4.3.3.3 Amphibians

We collected one amphibian species, *Ambystoma tigrinum* (the tiger salamander) (Figure 4-16), from Gordon Arroyo. This species has nearly a transcontinental distribution, being absent only from the Great Basin and the Appalachian mountain chain (Stebbins 1985). There are numerous subspecies, but we did not identify the specimens we collected to the subspecific level. Since at the time of sampling rainfall events were sparse and no flowing water was present, Gordon Arroyo consisted only of a couple pools, with the same individuals captured in the seine every day. Due to the distinctive appearance of this species, no voucher specimens were collected.

Figure 4-16: Tiger salmander, *Ambystoma tigrinum*, collected in Gordon Arroyo, August 16, 2006

4.4 Aquatic Community Composition – Succession Patterns

4.4.1 Flow Duration and Succession of Aquatic Communities

As discussed in the Methods section, we anticipated different succession patterns on streams with or without known upstream sources of potential colonizers. Streams with known or likely upstream sources of colonizers have more potential for long-lived aquatic organisms and lentic organisms than streams without upstream sources of potential colonizers. This could result in a different fauna utilizing these stream reaches.

Although the intention of the sampling plan was to sample every site every day starting from peak flows to no surface water remaining, this was not always possible due to logistical constraints. Sampling each site intensively took time and did not always allow the teams to access each site every day. Missing data from streams and dates that were not sampled may have introduced some unspecified error into the results of this study. Based on these results, errors would primarily have consisted of only a few taxa which were not collected and which might otherwise have been collected.

4.4.1.1 Microinvertebrates

Because the majority of the organisms in the microinvertebrate samples likely came from terrestrial sources, we did not examine trends in the succession of the entire assemblage of microinvertebrates in the ephemeral stream ecosystems. We did, however, examine succession of Crustacea in these systems, because it is likely that they came from aquatic sources. Microcrustaceans were primarily collected in the Santa Cruz River at Congress. The communities included both calanoid and cyclopoid copepods, but only the cyclopoid copepods seemed to persist. Their densities increased considerably over time until the site dried up (Appendix B). In addition to possibly originating from cryptobiotic stages, the resulting community could also have entered cryptobiotic stages, such as cysts or resting eggs, in preparation for the drying up of the pools.

4.4.1.2 Aquatic Macroinvertebrates

4.4.1.2.1 Streams with known or likely upstream sources of potential colonizers

A total of 77 aquatic macroinvertebrate taxa were evaluated in the 7-day succession period (Days 0-6) on streams with a known or likely upstream source of potential colonizers (Table 4-5). Of these, 33 taxa were collected on only a single day. The remaining 44 taxa were collected on multiple days, although not necessarily at the same sites each day.

Table 4-5: Succession pattern of aquatic macroinvertebrate taxa collected in ephemeral stream ecosystems of the arid southwestern United States with known or likely upstream sources of potential colonizers (Santa Cruz River Watershed, Arizona, and Rio Puerco Watershed, New Mexico), 2006

Succession is defined as beginning after high flows start to subside (first 24 hours = Day 0). "Unid." = unidentified species in that taxon. An "X" in the "Aerial Dispersal" column indicates that the taxon has an aerially dispersing life stage; an "XX" indicates that the stage collected in this study was in that life stage.

Taxa	Aerial Dispersal (General / Stage)	Day of Succession (with possible upstream sources of colonizers)[1]						
		0	1	2	3	4	5	6
Apedilum sp.	X	X						
Eretes occidentalis	XX	X						
Hesperocorixa sp.	XX	X						
Microcylloepus pusillus	XX	X						
Unid. Muscidae	X	X						
Pseudosmittia sp.	X	X						
Stratiomys sp.	X	X						
Unid. Veliidae	X	X						
Belostoma sp.	XX	X	X					
Chaoborus sp.	X	X	X					
Ormosia sp.	X	X	X					
Unid. Dolichopodidae	X	X		X				
Laccophilus maculosus	XX	X	X	X				
Peltodytes sp.	XX	X	X	X				
Corisella sp.	XX	X			X			
Unid. Culicidea	X	X		X	X			
Chironomus sp.	X	X	X	X	X	X		
Lipogomphus sp.	X	X				X		
Unid. Salpingidae	X	X		X	X	X		
Unid Tipulidae	X	X		X	X	X		
Berosus sp.	X	X	X			X	X	
Unid. Ceratopogoninae	X	X		X	X		X	
Unid. Ceonagrionidae	X	X			X		X	
Hyalella azteca cx.		X	X	X	X		X	
Unid. Lumbriculidae		X	X	X	X	X	X	
Unid. Megadrili		X	X	X			X	
Stictotarsus striatellus	XX	X		X	X	X	X	
Tabanus sp.	X	X					X	
Callibaetis sp.	X	X			X			X
Coenagrion/Enallagma	X	X				X		X
Unid. Corixidae	X	X			X	X		X
Postelichus sp.	XX	X	X	X	X	X	X	X
Unid. Orthocladiinae	X	X	X	X	X	X	X	X
Aquarius sp.	XX		X					
Unid. Chironomidae	X		X					
Unid. Dytiscidae	X		X					
Hydrochus sp.	XX		X					
Hydryphantes sp.			X					
Smittia sp.	X		X					
Unid. Syrphidae	X		X					
Unid. Ephydridae	X		X	X				
Unid. Ceratopogonidae	X		X		X			
Unid. Empididae	X		X		X			
Enochrus sp.	XX		X		X			
Erpobdella punctata punctata			X	X	X			
Goeldichironomus sp.	X		X	X	X			
Liodessus obscurellus	XX		X	X	X			
Sigara sp.	XX		X	X	X			
Bryophaenocladius sp.	X		X	X	X	X		
Unid. Enchytraeidae			X		X	X		
Unid. Baetidae	X		X	X	X	X	X	
Microvelia sp.	XX			X				
Nemotelus sp.	X			X				
Unid. Notonectidae	X			X				
Unid. Collembola				X				

	Aerial Dispersal	Day of Succession						
Taxa	**(General / Stage)**	**(with possible upstream sources of colonizers)[1]**						
		0	**1**	**2**	**3**	**4**	**5**	**6**
***Laccophilus* sp.**	**XX**			**X**	**X**			
***Ochthebius* sp.**	**XX**			**X**	**X**	**X**		
Unid. Libellulidae	**X**				**X**			
***Paramerina* sp.**	**X**				**X**			
***Procladius* sp.**	**X**				**X**			
Unid Sminthuridae					**X**			
Conchapelopia/Thienemannimyia	**X**				**X**	**X**		
***Helichus* sp.**	**XX**				**X**	**X**		
Ambrysus mormon	**XX**				**X**		**X**	
***Endotribelos* sp.**	**X**				**X**		**X**	
***Triops* sp.**					**X**		**X**	
UIT w/CC[2]					**X**	**X**		**X**
***Helisoma* sp.**						**X**		
Neoporus dimidiatus	**XX**					**X**		
Unid. Notonectidae	**X**					**X**		
***Oreodytes* sp.**	**XX**					**X**		
***Rheumatobates* sp.**	**X**					**X**		
Unid. Gerridae	**X**						**X**	
***Larsia* sp.**	**X**						**X**	
***Polypedilum* sp.**	**X**						**X**	
***Stictochironomus* sp.**	**X**						**X**	
***Tyrellia* sp.**							**X**	

1. Streams include Pantano Wash at Vail, Ciénega Creek Upstream of I-10, Ciénega Creek at Mescal Arroyo, Tanque Verde Wash at Houghton Road, Santa Cruz River at Congress, Arroyo Chico Upstream of USGS Gage, Arroyo Chico Downstream of USGS Gage, Rio Puerco near San Luis, Rio Puerco at Cabezón, and Rio Puerco Downstream of Arroyo Chico.
2. Unidentified Immature Tubificidae with Capilliform Chaetae.

Within the first 24 hours (Day 0), 33 taxa of aquatic macroinvertebrates were collected in these streams. Eighteen taxa were first collected on Day 1, six taxa were first collected on Day 2, ten taxa were first collected on Day 3, five taxa were first collected on Day 4, and five taxa were collected first and only on Day 5. Total taxa richness decreased over time, with 33 taxa being collected on Day 0, but only 6 taxa being collected on Day 5.

The dryopid beetle *Postelichus* sp. and the unidentified Orthocladiinae were collected on every day of succession; however, as noted before, unidentified Orthocladiinae is a relatively broad taxon and could potentially comprise multiple taxa. Other taxa, which were collected on both Day 0 and Day 6 (suggesting that they could possibly be present throughout succession), included the mayfly *Callibaetis* sp., the damselfly *Coenagrion/Enallagma*, and immature waterboatmen (Corixidae). Eight of the 33 taxa that were collected within the first 24 hours were not collected later.

Twelve of the 77 taxa do not have aerially dispersing life stages. Although these taxa could have come from upstream perennial water sources, they could also have come from other sources, such as cryptobiotic states (e.g., the fairy shrimp *Triops* sp.) or as transients on birds and other wildlife (e.g., the leech *Erpobdella punctata punctata* and the snail *Helisoma* sp.) Conversely, some taxa, such as the Collembola and the enchytraeid worms, could also have been terrestrial forms, misinterpreted as aquatic forms, which were incidentally collected in the samples. The *H. azteca* were almost certainly from upstream sources, given their limited dispersal ability.

Although most of the taxa collected have aerially dispersing life stages and were represented in the samples by small, immature larvae (as would be expected from recently laid and hatched eggs), a few taxa were represented by older larvae. These taxa included the mayfly *Callibaetis* sp., the predaceous midge *Chaoborus* sp., and the hydrophilid beetle *Berosus* sp. Additionally, *Callibaetis* sp. and *Chaoborus* sp. are primarily lentic forms, being found in lakes and ponds, and rarely in flowing water, suggesting they were washed into the stream from off-channel ponds, rather than intermittent flowing sections of the stream.

4.4.1.2.2 Streams without known upstream sources of potential colonizers

A total of 35 aquatic macroinvertebrate taxa were involved in the 7-day succession period (Days 0-6) on streams with no known upstream source of potential colonizers (Table 4-6). Of these, 16 taxa were collected on only one day, and the remaining 19 taxa were collected on multiple days, although not necessarily at the same sites each day.

Table 4-6: Succession pattern of aquatic macroinvertebrate taxa collected in ephemeral stream ecosystems of the arid southwestern United States without upstream sources of potential colonizers (Santa Cruz River Watershed, Arizona, Rio Puerco Watershed, New Mexico, and Huerfano River Watershed, Colorado), 2006

Succession is defined as beginning after high flows start to subside (first 24 hours = Day 0). "Unid." = unidentified species in that taxon. An "X" in the "Aerial Dispersal" column indicates that the taxon has an aerially dispersing life stage; an "XX" indicates that the stage collected in this study was in that life stage

	Aerial Dispersal	**Day of Succession**						
	(General / Stage)	**(with possible upstream sources of colonizers)[1]**						
		0	**1**	**2**	**3**	**4**	**5**	**6**
Unid. Tipulidae	X	X						
Aedes sp.	X	X		X				
Unid. Ephydridae	X	X	X	X	X			
Unid. Orthocladiinae	X	X	X	X	X	X		
Unid. Culicidae	X		X			X		
Berosus sp.	X			X				
Helophorus sp.	XX			X				
Notonecta sp.	XX			X				
Unid. Salpingidae	X			X				
Agabus sp.	XX			X				
Neoporus dimidiatus	XX			X				
Paracymus sp.	XX			X				
Smittia sp.	X			X				
Tabanus sp.	X			X				
Bryophaenocladius sp.	X			X	X			
Unid. Enchytraeidae				X	X			
Eubranchipus sp.				X	X			
Unid. Lumbriculidae				X	X			
Psorophora sp.	X			X	X			
Stagnicola sp.				X	X			
Unid. Megadrili				X		X		
Sigara sp.	XX			X	X	X		
Erpobdella punctata punctata				X	X	X	X	X
Ochthebius sp.	XX			X	X	X	X	X
Procladius sp.	X			X	X	X	X	X

	Aerial Dispersal	Day of Succession			
	(General / Stage)	(with possible upstream sources of colonizers)[1]			
Tropisternus sp.	XX	X			
Unid. Empididae	X	X			
Enochrus sp.	XX	X			
Laccobius sp.	XX	X			
Unid. Baetidae	X	X	X		
Unid. Ceratopogoninae	X	X		X	
Liodessus obscurellus	XX		X		
Lipogomphus sp.	XX		X	X	
Unid Coenagrionidae	X		X		X
Ambrysus mormon	XX			X	

1. Streams include Mescal Arroyo at Marsh Station Road, Davidson Canyon at Mesquite Mesa Road, Arroyo Balcón, Cañada Cantiago, and Gordon Arroyo at State Highway 69.

Within the first 24 hours (Day 0), four taxa of aquatic macroinvertebrates were collected in these streams, and only one of those taxa (an unidentified Tipulidae) was not collected again during the course of the study. Three taxa were first collected on Day 1, twenty taxa were first collected on Day 2, six taxa were first collected on Day 3, three taxa were first collected on Day 4, and one taxon was first collected on Day 5. Although four taxa were collected on Day 6, none of those was collected for the first time. Daily taxa richness was highest on Day 2 and Day 3, with 23 taxa and 16 taxa, respectively.

As opposed to the streams with known possible sources of potential colonizers, no taxon was collected on every day in these streams. The unidentified Orthocladiinae were collected every day through Day 4, and the leech *E. p. punctata*, the hydraenid beetle *Ochthebius* sp., and the midge *Procladius* sp. were collected every day from Day 2 to the end of the study.

While most of the taxa do have aerially dispersing life stages, six taxa collected in these streams do not. These include the fairy shrimps in the genus *Triops*, three taxa of annelid worms, the leech *E. p. punctata*, and the snail *Stagnicola* sp. It was not until Day 2 of succession that taxa without aerially dispersing life stages were collected. Since these streams do not have known upstream sources of potential colonizers, these organisms likely came from alternate sources. As discussed above, they might have been terrestrial representatives of these groups (misinterpreted as aquatic forms, e.g., worms in the Family Enchytraeidae and the Family Lumbriculidae), originated in cryptobiotic states (e.g., *Triops* sp.), or as transients on wildlife (leeches and snails). As expected, given the lack of upstream sources of potential colonizers, there were no *H. azteca* individuals collected in samples from these streams.

4.4.1.3 Vertebrates

4.4.1.3.1 Fish

Because the green sunfish and the mosquitofish are not native species within the stream systems where they were collected and because they were collected only as dried specimens in the middle of a dry streambed after flows disappeared, these two species are not included in the discussion of succession on these streams. They seem not to survive in these streams. The other two fish species collected, the longfin dace and fathead minnows, are native to the stream systems in which they were found and have adaptations that allow them to survive.

Longfin dace were found only on Day 1 of succession and only in Ciénega Creek. Populations of longfin dace are known to exist in perennial reaches of Ciénega Creek within the *Ciénega Creek Conservation Area* (Arizona Game and Fish Department 2006). Furthermore, this species is adapted to take advantage of flash floods for downstream dispersal, entering the flow when it starts and being carried downstream to other perennial reaches for colonization (Minckley 1973, Arizona Game and Fish 2006). If flows do not transport them to suitable habitat, they are also known to burrow under logs, stones, and algal mats in wet sand to await another high flow event (or die trying!) We also observed this species burrowing in loose sand as we tried to seine them in Ciénega Creek. After flows disappeared, we did look in wet sand and mud under rocks and vegetation mats in Ciénega Creek to determine if this behavior was occurring in the study streams, but we were unable to locate any fish.

Fathead minnows were collected on Day 3 in Cañada Santiago and on Day 5 in the Rio Puerco near San Luis. It is unknown where the specimen came from in Cañada Santiago, because that stream does not have a known upstream source of potential colonizers, except for an off-channel impoundment. It is possible that the impoundment had overflowed and the fish we collected in Cañada Santiago came from that impoundment. There are known populations of fathead minnows in the Rio Puerco near Cuba (NMED 2006), and it is possible that the fish we collected in the Rio Puerco near San Luis originated in those populations.

These data indicate that longfin dace can be present in ephemeral stream ecosystems within 1 day after flows begin to subside, but do not persist in these ephemeral reaches. Rather, it is their normal behavior to use these ephemeral reaches as corridors to disperse to other suitable habitats. Fathead minnows can be present in these ephemeral stream ecosystems within 3 to 5 days after high flows begin to subside. As flows had not fully disappeared at the cessation of sampling, we do not know how long these fish would persist.

4.4.1.3.2 Amphibians

Most adult amphibians are terrestrial and do not require an upstream source population to potentially colonize a stream segment; therefore, we did not split the amphibian succession data into streams with and without known or likely upstream sources of potential colonizers. Two species of amphibians were found on Day 0 of succession, and one species (red-spotted toad) was found on every day of succession through Day 5. Spadefoot toads (*Spea bombifrons* and *Scaphiopus couchii*) were not observed or collected until Days 4-5 of succession.

Table 4-7: Succession pattern of amphibians observed/collected in ephemeral stream ecosystems in the arid southwestern United States (Santa Cruz River Watershed, Arizona, Rio Puerco Watershed, New Mexico, and Huerfano River Watershed, Colorado), 2006

Succession is defined as beginning after high flows start to subside.

Species	Day of Succession						
	0	1	2	3	4	5	6
Rana catesbieana, bullfrog	X(A)						
Bufo punctatus, red-spotted toad	X(L)	X(L)	X(L)	X(L)	X(L)	X(L, A)	
Ambystoma tigrinum, tiger salamander			X(A)	X(A)	X(A)		
Scaphiopus couchii, Couch's spadefoot toad					X(L)	X(L)	
Spea bombifrons, plains spadefoot toad						X(L)	
Bufo sp., unid. toad						X(L)	

Note: (first 24 hours = Day 0). All streams included. "L" = larval specimens, "A" = adult specimens

These data indicate that amphibians can be present in these ephemeral stream ecosystems almost as soon as high flows begin to subside and remain in the streams until adulthood, if surface water persists. The adult stage of the life cycle of most of the amphibian species we collected is well able to survive without pools or streams, but the other life stages need water to survive. On several occasions, we observed dead tadpoles being scavenged by ants in pools, which had dried.

5.0 Discussion

5.1 Regional Similarities and Differences in Communities

5.1.1 Microinvertebrates

As previously discussed, the majority of the microinvertebrates collected were probably from terrestrial sources or were the immature life stages of macroinvertebrates. The potential aquatic exceptions included the Crustacea, Rotifera, Gastrotricha, and the Naididae. None of the aquatic microinvertebrate groups were collected in the Huerfano River Watershed. In all sites, most of the taxa were represented in small densities.

Cyclopoid copepods were collected in both the Santa Cruz River Watershed and the Rio Puerco Watershed. While there were larger populations of cyclopoid copepods at the Site Santa Cruz River at Congress, they were uncommon elsewhere (Appendix A). Only a few individuals of calanoid copepods were collected, all in the Santa Cruz River Watershed. Similarly, harpactacoid copepods were collected only at one site in the Rio Puerco Watershed. Their presence in these watersheds is likely a function of their ability to withstand desiccation through their encysted resting stage, described earlier

Daphniid cladocerans were collected in both the Santa Cruz River Watershed and the Rio Puerco Watershed in very low numbers, with the unidentified Cladocera (which were not daphniids) collected only in the Santa Cruz River Watershed. Unidentified Ostracoda were also collected in each of the two watersheds. Gastrotricha and Naididae were each collected only in the Santa Cruz River Watershed.

Although some of the truly aquatic microinvertebrates occurred in both watersheds, they were only encountered in any significant densities in the remnant pools following cessation of flows in the Santa Cruz River. Based on these studies, while aquatic microinvertebrates were found at many of the sites, their relative abundance was generally fairly low. These organisms were primarily able to inhabit the sites as a result of specialized life history mechanisms.

5.1.2 Aquatic Macroinvertebrates

The Rio Puerco Watershed had the highest taxa richness of the three areas studied, with 63 distinct taxa identified. The Huerfano River Watershed had the lowest, with only 11 distinct taxa. However, that finding was strongly influenced by the fact that only one site was found with any residual water, compared to the multiple sites in the other two watersheds – a reflection of the lack of monsoon-related flow events in the Huerfano River Watershed.

Only 2 of the 88 taxa collected were common to all three study areas: the hydrophilid beetle *Berosus* sp. and the brine fly family Ephydridae. The latter was identified at the family level because of its immature age and may not necessarily represent identical species between the three regions. Between the Santa Cruz River and the Rio Puerco watersheds, there were 25 taxa in common. A total of 55 taxa were collected only within one study area. Again, nearly all of the taxa collected were widespread geographically, and all but 14 taxa have good dispersal mechanisms (Merritt and Cummins 1996).

Interestingly, despite the low number of taxa collected in the Huerfano River Watershed, three taxa (27.3%) were collected only within that watershed. Those taxa were the backswimmer *Notonecta* sp., the beetle *Helophorus* sp., and the hydrophilid beetle *Tropisternus* sp. Unidentified notonectids were collected at two sites in the Rio Puerco Watershed. They could only be identified to the family level because of the immature age of the specimens, but they are likely to be the same genus, *Notonecta*.

To determine similarities between the macroinvertebrate fauna of the three watersheds, cluster analysis of the sites was conducted, based on species composition (i.e., presence/absence) data (Hintze 2004). This analysis indicated that the sites do appear to group within and between study areas, with an overall similarity between watersheds of about 5% (Figure 5-1). However, even within each of the study areas, overall taxa similarity was not very high. The Sites Rio Puerco near San Luis and Rio Puerco at Cabezón showed the highest similarity at only 25%. The sole Huerfano River Watershed site, Gordon Arroyo at State Highway 69, clustered amid the Rio Puerco Watershed sites, although its similarity to the closest site (Arroyo Balcón) remained at only about 7% (Figure 5-1). A similar cluster analysis based on species composition data in Graham (2002) yielded a dendrogram with similarity between closest sites of approximately 29%. Six of his thirteen pool “sites” were the same three pools sampled twice only one month apart, and all sites were within 18 km of each other.

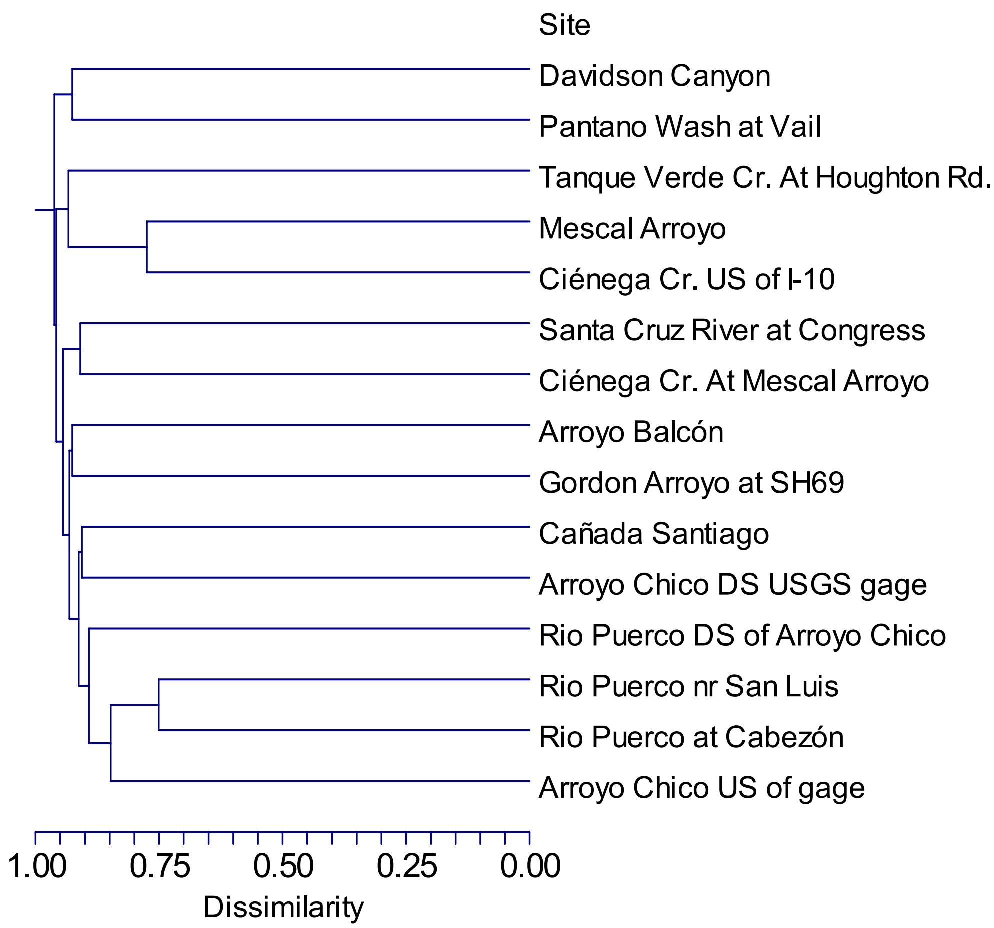

Figure 5-1: Presence/absence cluster analysis of aquatic macroinvertebrate communities at sites in the Santa Cruz River Watershed, Arizona, the Rio Puerco Watershed, New Mexico, and the Huerfano River Watershed, Colorado

These extensive regional differences are likely a result of biogeographic patterns in the distribution of the taxa. Nearly all of the taxa we collected are geographically widespread at the genus and family levels (Merritt and Cummins 1996, Thorp and Covich 2001, Smith 2001), but the distribution of individual species might limit their capture at these sites. Not only is there the difference in type of arid West ecosystems sampled (Hot Desert vs. Cold Desert/Great Basin vs. High Plains), but there are also differences in latitude, substrate, and riparian vegetation, as well, which could be influencing patterns.

Lastly, the overall dissimilarity between sites – even those in close proximity to each other – might be indicative of a random pattern of colonization, supported by both this study and Graham (2002). The chance of any given organism occurring in the ephemeral stream resource may simply be related to the chance that it happened to fly in the vicinity of the stream. Chance may be the natural pattern for ephemeral streams, even with an upstream source of potential colonizers (Diamond 1975).

When compared to a previous taxa list compiled by the AWWQRP from effluent-dependent streams in the arid West (AWWQRP 2002), we found that only 35 taxa collected in these ephemeral stream sites in 2006 were common also to the arid West effluent-dependent stream taxa list at the genus level. A total of 167 taxa were included in that taxa list which were not collected in the present study. Furthermore, 50 taxa were collected in the present study that were not included in the taxa list from effluent-dependent streams. The taxa list generated in the present study had only seven taxa in common with the twenty taxa listed by Graham (2002). In addition to illustrating how poorly known these arid West stream communities are, these results also highlight what is probably the random pattern of colonization described above. Even if the colonizers had come from upstream sources, the taxa lists do not reflect those upstream sources very well.

5.1.3 Vertebrates

Each study area had its own fish populations with no overlap. Green sunfish and western mosquitofish have been introduced all over the western United States, including New Mexico, even though we did not collect any in the Rio Puerco Watershed sites. Fathead minnows, likewise, occur in Arizona (Minckley 1973), but we did not collect any in the Santa Cruz River Watershed sites. The longfin dace is restricted in distribution to desert streams of southern and central Arizona and northern Sonora, Mexico (Minckley 1973). As this distribution excludes New Mexico and Colorado, it is not surprising that the species was not collected in the study areas in those two states.

Of the six taxa of amphibians collected, none were collected in all three watersheds, and only two, the red-spotted toad and Couch's spadefoot toad, were collected in both the Santa Cruz River Watershed and the Rio Puerco Watershed. Graham (2002) reported collection of red-spotted toads and New Mexico spadefoot toads (*Spea multiplicatus*) from ephemeral pools in Arizona.

Biogeographic patterns do not restrict the amphibians as clearly as they do for the longfin dace (above), since all of the taxa collected are widespread among the sample areas with a semi-terrestrial life stage and ability to withstand long periods of no water.

5.2 Effects of Duration of Flow on Succession Patterns

Within the study sites, the amount of aquatic habitat available did not necessarily decrease over time (Figure 5-2). While the amount of aquatic habitat available decreased rapidly in the Santa Cruz River Watershed sites, and decreased slowly in the Huerfano River Watershed site, it actually increased over time in the Rio Puerco Watershed sites, perhaps reflecting the continued rainfall pattern at the time of sampling in that system.

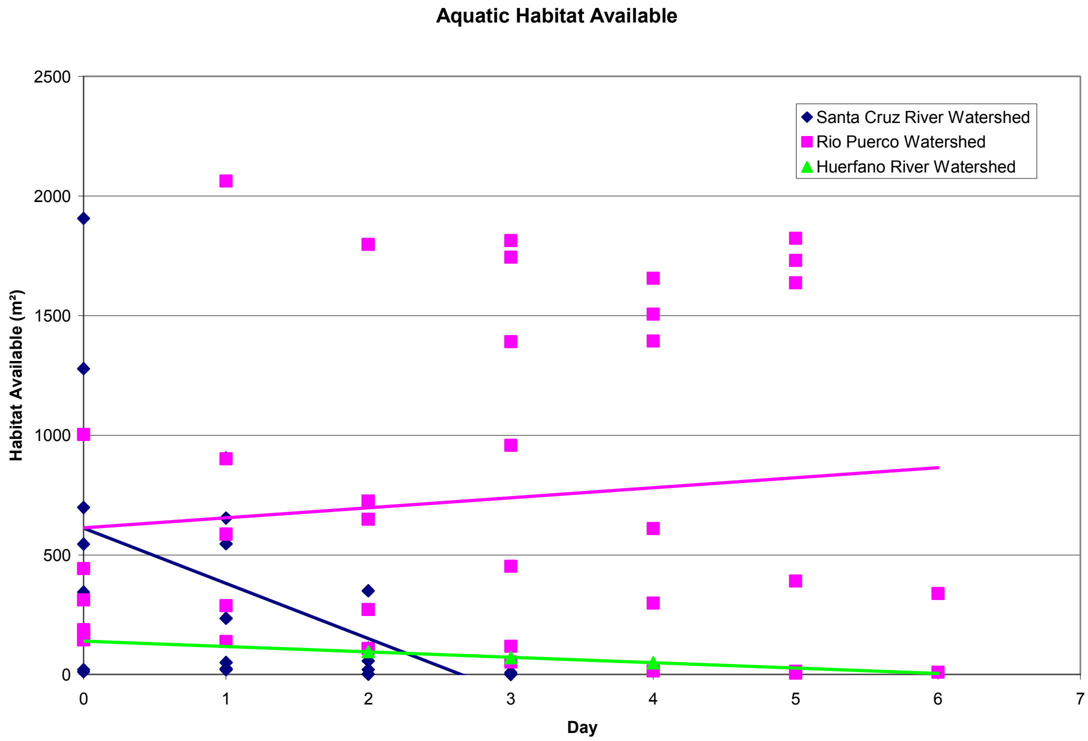

Figure 5-2: Aquatic habitat measured (standardized to a representative 100–m reach) each day in ephemeral streams and ephemeral stream reaches in the Santa Cruz River Watershed, Arizona (blue diamonds), Rio Puerco Watershed, New Mexico (pink squares), and the Huerfano River Watershed, Colorado (green triangles)

**Data collected after monsoon thunderstorms in 2006;
Day 0 is the first 24 hours after high flows begin to subside.**

One reason behind the differences appears to lie mainly in the types of sediment present in the channels and stream banks. In the Santa Cruz River Watershed sites, the primary substrate and source material in the banks was large-grained sand. This allowed rapid penetration of water into the stream bottom, resulting in loss of surface flow rapidly following cessation of rain.

In the Rio Puerco Watershed sites, the primary substrate and source material was fine silts and clays, which tend to seal the stream bottom, precluding rapid penetration of the water into the stream bottom. Furthermore, we observed that the banks in the Rio Puerco Watershed retained water much longer than the sandy soils in the Santa Cruz River Watershed, releasing it slowly over time into the channel, actually adding to the flows and making additional aquatic habitat available. In the Huerfano River Watershed site, the fine silt sediment did not allow rapid penetration of the water into the stream bottom, but lack of hydrological connections to any external water sources (i.e., upstream sources or bank-held water) prevented flows and aquatic habitat from increasing in the absence of rainfall.

5.2.1 Microinvertebrates

Although microinvertebrates were collected during the entire succession study, the only aquatic microinvertebrates sufficiently abundant to analyze for the effects of flow duration were the cyclopoid copepods. These organisms were present primarily in the Santa Cruz River at Congress Road, and the densities increased exponentially over time – until the pond in which they were living dried up. Density of these taxa increased due to two mechanisms: 1) additional organisms exiting their resting stages with water being present, and 2) increased reproduction while the water existed. Whatever progeny resulted from the reproduction then apparently formed their own cryptobiotic stages to withstand desiccation after the water disappeared, since they do not have aerially dispersing life stages.

5.2.2 Aquatic Macroinvertebrates

Overall, the patterns of succession we observed in both streams with known or likely upstream sources of potential colonizers and streams without upstream sources of potential colonizers were typical of succession patterns on ephemeral habitats. In the terrestrial realm, many studies have been conducted on the ephemeral resources of decomposing animal and plant material (e.g., Putman 1983). These studies have generally found that, within the first two or so days, many organisms arrive and begin to utilize the resource. Some actively alter the resource, making it more accessible to other organisms, and others sequester the resource, making it unavailable to other organisms. However, over time, the resource quantity (and, often, quality) usually diminish, and fewer organisms are able to utilize it. Eventually, the resource disappears, and the associated community disappears as well (Putman 1983).

Although we did not observe the end of the resource (in this case, water) in all of the study areas, we did have no surface water remaining at the sites in the Santa Cruz River Watershed on the last day of sampling. As expected, there were also no aquatic organisms remaining at the sites.

As flows and amount of aquatic habitat decrease, we generally see a decrease in the number of aquatic macroinvertebrate taxa utilizing the available habitat (Figure 5-3). However, in the Santa Cruz River Watershed, we actually observed a slight increase in the number of taxa in response to decreasing available habitat. This is probably because the aquatic habitat was generally small and only available for such a very short period of time, concentrating the number of organisms and number of aquatic macroinvertebrate taxa that could utilize it.

In contrast to the pattern observed in the copepods, it appears that most of the aquatic macroinvertebrates utilized the ephemeral stream resources as a temporary "stop-over" as they moved from one small waterbody to the next (e.g., Coleoptera). Some taxa (e.g., Ephemeroptera and Diptera) used the ephemeral streams as habitat for their larvae, and the progeny would leave the water as soon as they reached the aerially dispersing adult life stage. The individuals that did not finish their development by the time the water disappeared likely died. Finally, some aquatic macroinvertebrate taxa that did not have aerially dispersing life stages either entered their own cryptobiotic stages (e.g., most crustaceans, some worms, etc.) or also died. Graham (2002) also found positive correlations between taxa richness and available aquatic habitat in ephemeral pools in Wupatki National Monument, Arizona.

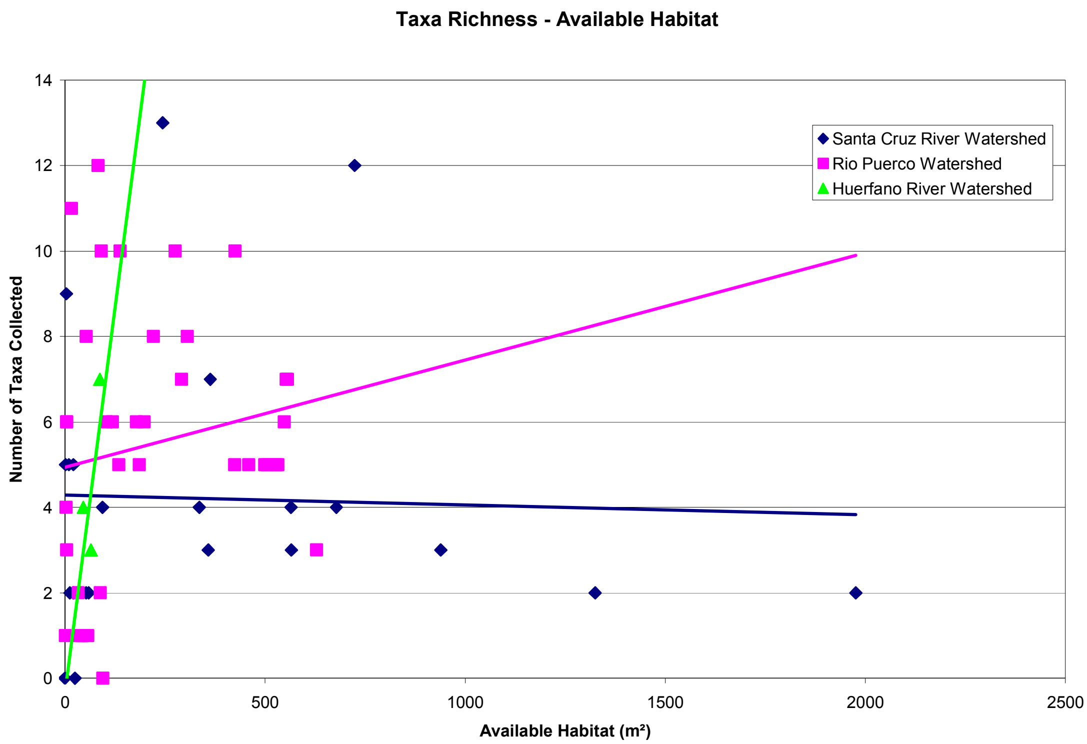

Figure 5-3: Relationship between aquatic macroinvertebrate taxa collected and available habitat measured each day in ephemeral streams in the Santa Cruz River Watershed, Arizona (blue diamonds), the Rio Puerco Watershed, New Mexico (pink squares), and the Huerfano River Watershed, Colorado (green triangles)

Samples collected after monsoon thunderstorms in 2006.

5.2.3 Vertebrates

As reviewed in AWWQRP (2002), we found that vertebrate species that are native to the arid West are adapted to the conditions and are able to tolerate the vagaries of stream flow, whereas nonnative species are subject to higher mortality. For example, the green sunfish and western mosquitofish were actually found stranded and desiccated, lying on the sand mid-channel, after flows subsided in Tanque Verde Wash at Houghton Street. Longfin dace were apparently able to utilize the flows in Ciénega Creek to transport them from suitable habitats upstream into the study sites, perhaps in an attempt to locate suitable habitats downstream, as is their normal behavior pattern (Minckley 1973). Reduced flow had a substantial impact on the green sunfish and mosquitofish in Tanque Verde Wash.

Several populations of amphibians also enjoyed sufficient duration of flow that they would have survived to adulthood, since some toads collected in the Rio Puerco Watershed sites were already beginning to metamorphose into adults by the end of the sampling effort. This was not always the case, as we also observed tadpole carcasses on the mud in Mescal Arroyo being scavenged by ants.

5.3 Potential Implications for Water Quality Standards

National ambient water quality criteria (AWQC) developed by the US EPA provide the starting point for many state water quality standards. These criteria are intended to protect aquatic life inhabiting all aquatic habitat types on a nationwide basis. Many states adopt the national US EPA recommendations exactly as they are published, if deemed appropriate, and then address specific aquatic life and water quality considerations on a site-specific basis. Given the wide geographic area the national AWQC are intended to protect, toxicity data for a wide variety of aquatic life must be included to provide adequate protection. Although appropriate on a nationwide basis, the community composition of many aquatic ecosystems may differ substantially from the databases used to derive national criteria or even state standards.

The US EPA recognized this potential and has provided guidelines for the derivation of site-specific standards. The three primary methods that may be used include the recalculation procedure, water-effects ratios, and the resident species procedure. As part of the AWWQRP, a study was conducted resulting in a report titled *Evaluation of U.S. EPA Recalculation Procedures in Arid West Effluent-Dependent Waters* (Recalc Report) (AWWQRP 2006). This report specifically addressed the utility of the recalculation procedure for effluent-dependent/dominated streams located in arid regions. Sites evaluated in this effort included the following:

- South Platte River, Colorado
- Fountain Creek, Colorado
- Santa Ana River, California
- Salt-Gila Rivers, Arizona
- Santa Cruz River, Arizona

An initial step of the recalculation procedure requires the derivation of resident species lists. For the purposes of the recalculation procedure evaluation, "resident species" were defined as organisms that inhabit a site and use the site for reproduction, foraging, and/or refuge, including migratory species (AWWQRP 2006). With regard to the concept of "resident species," we would expect ephemeral and perennial streams to be different – which, in turn, would affect the resulting calculations or even application of chronic standards.

Resident species lists were compiled for the streams in the Recalc Report from a literature review of data collected downstream of wastewater treatment plant discharges. Although the resident species lists in the Recalc Report accurately describe the aquatic life expected to occur when perennial flow from treatment plants is present, these lists would not characterize the expected condition in the absence of the discharge (i.e., ephemeral streams).

The species composition lists derived in the present effort can be used as a starting point for characterization of the expected condition of the biological communities of ephemeral streams in the arid West. Here we compare species present in the list derived from effluent-dependent/dominated sites to the species lists derived from the ephemeral streams. We then evaluate how these differences could affect water quality standards if the expected conditions are used to establish the level of protection applied in such segments.

Based on the limited abundance of truly aquatic microinvertebrates, omitting planktonic crustaceans (such as many of the cladocerans in the toxicity databases) from the resident species lists may be appropriate. Databases should retain copepods, another microcrustacean group, given their relative abundance in one of the study streams and presence in three other sites.

In general, for the macroinvertebrate communities, there was little similarity between ephemeral stream species composition databases and effluent-dependent stream species composition databases. Despite an overlapping geographic range, the ephemeral sites had only 35 taxa in common with the effluent-dependent taxa list of >200 taxa (AWWQRP 2006). In addition, the ephemeral sites included 50 taxa which were not included in the effluent-dependent stream taxa list. A striking example of this limited overlap in species composition is the general paucity of amphipods and isopods in the ephemeral stream study. In fact, no isopods were collected from the ephemeral streams. Amphipods were collected in low numbers at only three of the 15 sites, all of which had known upstream sources of potential colonizers. They were present in most of the recalculation databases from effluent-dependent/dominated streams. The amphipod *H. azteca* is frequently one of the more sensitive invertebrates to a wide variety of toxicants.

A key component of the fish portion of the resident species list and site-specific toxicity databases from the Recalc Report is the Family Centrarchidae (sunfish and bass). This family was commonly found in effluent-dependent/dominated streams, but is apparently not resident to ephemeral streams. These nonnative species were also unable to tolerate the variability of flow, being stranded mid-channel as flows quickly receded and subjected to desiccation. In fact, fish were rarely found in the ephemeral streams, even when flowing. Limited presence of fish indicates that these fish are not resident to the streams, but rather transient during flow events. When present, the Family Cyprinidae (minnows and dace) was the primary group.

The immature, tadpole life stage of amphibians was the most consistently represented vertebrate group in ephemeral ecosystems. However, there is little toxicity data on amphibians, and what data do exist are primarily for nonnative species, and, as such, would normally be deleted from a recalculation of site-specific standards (Stephan et al. 1985). Sensitivity data that are available suggest that amphibians are relatively tolerant of toxic chemicals, but more data are needed to determine the appropriate level of protection.

Based on these data and data from the Habitat Characterization Study (AWWQRP 2002), resident species lists for effluent-dependant/dominated streams, ephemeral reaches of interrupted streams, and truly ephemeral streams do not meet the EPA minimum data requirements, also known as "the eight family rule" (AWWQRP 2006). In short, the eight family rule stipulates that criteria can be developed if appropriate toxicity data on organisms in eight particular families are represented in the criteria database (Stephan et al. 1985).

After demonstrating that this "rule" could not be met by species lists generated from extensive sampling of arid West effluent-dependent/dominated streams, an alternative "eight family rule" specific to perennial streams of the arid West was proposed (AWWQRP 2006). In that proposal, Centrarchidae replaced Salmonidae, Cyprinidae replaced the second fish family, and a second insect family replaced the planktonic crustacean family. The question then remains for the present study as to whether or not these recommendations can also apply to ephemeral reaches of interrupted streams or to truly ephemeral streams.

In fact, the results from the present study indicate that additional modifications to the minimum data requirements (proposed eight family rule) are warranted for ephemeral streams. For vertebrates, this may result in less of an emphasis on sensitivity of fish species and more of an emphasis on sensitivity of amphibian species to toxic conditions. For invertebrates, this may involve removal of the requirement for a benthic crustacean family, given the general absence of this group, replacing it with a microcrustacean copepod family (whether benthic or not).

The resident species list in these ephemeral streams differs substantially from the national databases and even from the resident species list from effluent-dependent/dominated streams. Based on the findings of this study, it could be argued that a different level of protection may be warranted for the flowing portions of effluent-dependent streams, if the expected condition is set to resident communities of ephemeral stream reaches more representative of conditions upstream of wastewater treatment plant discharges. Differences in these species lists would result in standards for some toxicants that are substantially different from national, state, and site-specific standards for sites with perennial flow, while still being protective of the expected biological communities in ephemeral streams.

In addition to the resident species lists, other considerations to be made regarding “resident” status and the applicability of chronic AWQC to these ephemeral streams include habitat use, connectivity to perennial aquatic habitats, and duration of flow. Nearly all of the organisms we collected are not necessarily “resident,” but rather “transient” in these streams as they are usually only passively moving through the sites, given the life stages collected, the duration of time they spent in the water (role in succession), the duration of stream flow, and their ultimate fates. Nevertheless, in discussion of water quality criteria applicability, we have assumed that the taxa represented in the generated taxa lists are indeed resident (except where we determined they were of terrestrial origin). This assumption could potentially be tested for specific sites with targeted studies.

When perennial waters were located downstream of the sites, it is possible that the organisms could have remained suspended in the high flows long enough to arrive at those perennial reaches. If no perennial reaches were located downstream or the organisms were trapped in a pool, which then dried up, most organisms likely died anyway. A few organisms, particularly certain microcrustaceans, could be able to enter cryptobiotic states and survive the lack of water, while most others would have to rely on aerially dispersing life stages (if they arrived as such or attained that life stage) to reach other sources of water.

Natural limitations in flow duration would certainly limit applicability of water quality standards based on chronic criteria. Acute standards and the period of exposure in acute whole effluent toxicity tests (2-4 days, Stephan et al. 1985) more closely resemble the flow duration conditions in arid West ephemeral streams. With regard to applicability of chronic criteria, most chronic test endpoints require measures of growth or reproduction, particularly for vertebrate species (Stephan et al. 1985). These endpoints would rarely be realized within the short duration of flow at the study sites (generally ≤7 days – see discussion above). Additionally, the EPA required test duration for chronic whole effluent toxicity (WET) compliance testing is 7 days (US EPA 2002). Most sites that we studied had <7 days of surface flow. Those sites which did have >7 days of surface “flow” were actually not flowing, but represented sites reduced to isolated pools within a short time.

Historically, surface flows do not persist long in these drainages. For example, using data from the same gages used for the hydrologic characterization (Pantano Wash and Rio Puerco), we found that both streams experienced seven flow events each in 2005. In Pantano Wash, one event occurred in January and a second in May—the rest were associated with monsoonal thunderstorms. Average flow duration for all events was 4 days, with only one flow event lasting longer than 7 days. (In that case, the flow lasted 18 days, a result of monsoon-related rain storms continually adding water to the system every few days.) In the Rio Puerco, three runoff events were associated with snowmelt, the longest lasting 88 days.

Average flow duration for all events (including snowmelt) was 18 days, but runoff from the four monsoon thunderstorms alone lasted an average of only 6 days.

Even when pooled water is unaffected by anthropogenic influences, water quality can deteriorate (Webb et al. 2006). Standing pools in the arid West are subject to high evaporation rates and can experience high salinity, high dissolved solids concentrations, high temperature, low dissolved oxygen concentrations, etc. These poor water quality conditions have been shown to be deleterious not only to aquatic organisms but also to wildlife, which subsequently might use the water resources (Webb et al. 2006).

Outside of the realm of this report, yet of substantial importance to arid West water quality governance, lies yet another underlying conceptual question: Are the standards in the context of ephemeral streams intended to protect the expected condition of these ephemeral systems (limited taxa list, flow duration of <7 days, flows present only in response to precipitation events or snowmelt, etc.) or the altered expected condition of the created use (e.g., habitat in downstream effluent-dependant/dominated stream ecosystems)?

6.0 Summary and Recommendations

Findings from previously funded AWWQRP research projects (AWWQRP 2002) and discussions among AWWQRP advisory groups identified the need to conduct studies to characterize the aquatic communities of ephemeral stream ecosystems and collect data to better evaluate the basis for application of ambient water quality criteria to these waters. An ephemeral stream is defined, for these purposes, as a surface water with a channel that is at all times above the water table and flows only in direct response to precipitation or snowmelt. (Williams 2001, AWWQRP 2002)

Much of the limited previous research on ephemeral streams has been conducted on perennial reaches of interrupted streams and vernal pools. However, because the former has a water table above the channel for at least some portions (and, therefore, perennial water available) and because the latter has no connection to flowing water, these systems are not appropriate surrogates for ephemeral streams.

In this project, we were concerned with the fauna in ephemeral streams (or ephemeral reaches of intermittent streams) that colonize in response to flows from monsoonal thunderstorms. Fifteen study sites within three broad geographic regions (Hot Desert, Cool Desert/Great Basin, and High Plains) were identified, visited, and sampled over the course of up to 10 days Seasonal weather patterns were analyzed to anticipate the formation of monsoonal thunderstorms. When it was deemed that potential runoff-producing conditions had occurred and that flows were expected to continue for several days, a team of biologists traveled to each study area to initiate sampling of the potential aquatic biota.

Water column samples were collected to account for the potential for transient microinvertebrates (i.e., zooplankton). Benthic samples were collected to account for the presence of macroinvertebrates (e.g., aquatic insects, amphipods, and isopods). Vertebrate samples were collected to account for the presence of fishes and amphibians. In addition to accounting for which potential aquatic biota exist within these ephemeral streams (i.e., a "taxa list"), we also attempted to elucidate the "succession" of these fauna within the streams as related to the duration of the flow events. Sites were generally visited and sampled daily after peak flows began to subside until no surface water remained.

We collected a total of 21 distinct taxa of microinvertebrates; however, it was concluded that most of the taxa and most of the individuals were from terrestrial sources or were the immature stages of aquatic macroinvertebrates. The few truly aquatic microinvertebrates (i.e., zooplankton) included microcrustaceans, rotifers, and gastrotrichs. Most microinvertebrates were collected in very small densities, except for the cyclopoid copepods, which were abundant at only one site.

We collected a total of 86 distinct taxa of aquatic macroinvertebrates, including Insecta, Hydracarina, Crustacea, Oligochaeta, Hirudinea, and Gastropoda. Most of the taxa had aerially dispersing life stages and were present either in that form or as immature larvae recently hatched from eggs deposited by the aerial life stage. The remaining taxa likely came from upstream perennial water sources, terrestrial sources, and or cryptobiotic life stages. Succession patterns of the aquatic macroinvertebrates, both with and without known or likely upstream sources of potential colonizers, were similar to patterns seen on other ephemeral resources. Although many taxa were collected repeatedly throughout succession, some taxa were collected only once or a few times, suggesting that they were using the ephemeral resource only as a "stop-over" between other aquatic habitats. Generally, taxa richness was highest in the first few days after flows began to recede, and decreased as available habitat diminished.

Four species of fish were collected, although two nonnative species were collected only as desiccated specimens from the middle of a dry streambed. The native species were collected in small numbers at only a few sites, apparently arriving within 1 day (longfin dace) to 3 to 5 days (fathead minnows) after high flows begin to recede. We do not know at this time how long the latter species would have persisted, as flows had not fully disappeared at the cessation of sampling.

Six species of amphibians were collected, including one Salientia and five species of Anura. Both adult and tadpole life stages of the anurans were collected, with many individuals in the process of metamorphosis from tadpole to adult. Amphibians were collected throughout succession and apparently can remain in the streams until they reach adulthood, if surface water persists.

There was very little similarity between the communities collected in the three study areas. Our analysis indicated that the sites do appear to group within and between study areas, and the overall similarity between watersheds was about 5%. Based on the aquatic macroinvertebrate data, the closest similarity between any two individual sites was only 25%, likely a result of biogeographic patterns and differences in latitude, substrate, riparian vegetation, and the apparently random pattern of colonization.

Areal extent of aquatic habitat tended to decrease with time after high flows began to recede. Similarly, number of taxa tended to decrease as available aquatic habitat diminished, a natural result of less habitat being available.

Representative resident taxa lists from the arid West region, as compiled from previous AWWQRP projects, were supplemented by an additional 50 taxa collected in this study, and only 35 taxa overlapped between the two lists. It is expected that the lack of resident fish (particularly centrarchids) and elimination of key water quality indicator organisms such as cladocerans and isopods from the resident species lists will have a considerable effect on water quality criteria as applied to ephemeral streams.

In summary, when evaluating standards for effluent-dependent/dominated streams, a different level of protection may be warranted, if the expected condition is set to resident communities of ephemeral streams more representative of upstream conditions. Differences in aquatic communities sampled from the ephemeral stream sites in this study as well as resident species lists derived for effluent-dependent/dominated streams would result in standards for some toxicants that are substantially different from national, state, and site-specific standards for sites with perennial flow, while still being protective of those communities.

Recommendations for further study in the ephemeral stream ecosystems include the following types of research projects:

- Further studies on ephemeral stream ecosystems, either expanding the geographic area or investigating each of the study areas more intensively. This could involve more streams and more stream sites, more storm events, and snowmelt runoff, where applicable, with the result of better characterization of these ecosystems.
- Better characterization of watershed hydrology through sites located at or near gages on gaged streams. This can result in attempts to relate watershed morphology, size, and geology to biological diversity, succession patterns, and duration of aquatic habitat.
- Life-history studies on various aquatic macroinvertebrate taxa collected to determine longevity of the aquatic stages (i.e., can they actually complete the life stages from egg to adult – or maybe a semi-terrestrial pupa – in the time frame that the water is present?) Results could help address applicability of chronic criteria to sites with flows lasting <7 days and "resident" status of these organisms.
- Studies to determine fate of organisms suspected of having cryptobiotic life stages (i.e., did they really enter a cryptobiotic life stage or did they just die?) Results could help address the "resident" status of these organisms.
- Studies to determine the fate of native fishes (i.e., did the longfin dace and fathead minnows actually make it downstream to another perennial stream reach or did they just die?) Results could help address applicability of chronic criteria to sites with flows lasting <7 days and "resident" status of these organisms.
- Development of whole effluent toxicity test protocols for taxa typical of ephemeral stream ecosystems (e.g., aquatic insects, copepods, toads).
- Subsequent whole effluent toxicity tests on some of the more important taxa (i.e., collected at four or more sites), such as *Callibaetis* sp., *Sigara* sp., *Lipogomphus* sp., *Berosus* sp., *Postelichus* sp., *Ochthebius* sp., *Chironomus* sp., *Tabanus* sp., *Erpobdella punctata punctata*, red-spotted toads, and Couch's spadefoot toad.

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Appendix A

Microinvertebrate Data

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Santa Cruz at Congress
Santa Cruz River Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
INSECTA	Not visited	High flows- no samples collected	Not visited	High flows- no samples collected					Dry- no samples collected
DIPLURA									
Campodeidae					--	--	7	--	
COLLEMBOLA									
Entomobryidae					--	7	--	--	
Poduridae					--	20	--	--	
DIPTERA									
Chironomidae					--	--	--	40	
ACARI									
Mesostigmata					--	7	13	--	
Oribatei					7	--	33	40	
CRUSTACEA									
COPEPODA									
Calanoida					76	--	--	--	
Cyclopoida					611	920	127	11680	
OSTRACODA									
Unid. Ostracoda					--	--	13	--	
CLADOCERA									
Daphniidae					7	--	--	40	
Unid. Cladocera					7	--	--	40	
ROTIFERA									
Unid. Rotifera					7	--	7	--	
GASTROTRICHA									
Unid. Gastrotricha					--	--	13	--	

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Santa Cruz at Congress
Santa Cruz River Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
NEMATODA									
Unid. Nematoda					13	40	47	--	
TARDIGRADA									
Unid. Tardigrada					--	7	--	--	
TOTAL (#/40L)	--	--	--	--	728	1001	260	11840	--
TOTAL NUMBER OF TAXA	--	--	--	--	7	6	8	5	--

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Pantano Wash at Vail
Santa Cruz River Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
	High flows- no samples collected	High flows- no samples collected	High flows- no samples collected	High flows- no samples collected	Dry- no samples collected	Dry- no samples collected			Dry- no samples collected
ACARI									
Oribatei							--	20	
CRUSTACEA									
COPEPODA									
Calanoida							--	7	
NEMATODA									
Unid. Nematoda							400	180	
TARDIGRADA									
Unid. Tardigrada							14	--	
TOTAL (#/40L)	--	--	--	--	--	--	414	207	--
TOTAL NUMBER OF TAXA	--	--	--	--	--	--	2	3	--

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Davidson Canyon at Mesquite Mesa Road
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
INSECTA					Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected
DIPLURA									
Campodeidae	54	--	14	--					
COLLEMBOLA									
Poduridae	--	--	120	--					
Sminthuridae	506	--	--	--					
DIPTERA									
Tipulidae	14	--	--	--					
ACARI									
Oribatei	54	--	14	--					
ROTIFERA									
Unid. Rotifera	--	--	14	--					
NEMATODA									
Unid. Nematoda	294	120	94	18160					
TARDIGRADA									
Unid. Tardigrada	226	14	54	1040					
OLIGOCHAETA									
Enchytraeidae	94	--	14	--					
Naididae	66	--	--	--					
TOTAL (#/40L)	1308	134	324	19200	--	--	--	--	--
TOTAL NUMBER OF TAXA	8	2	7	2	--	--	--	--	--

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Mescal Arroyo at Marsh Station Road
Santa Cruz River Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
INSECTA					Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected
COLLEMBOLA									
Poduridae	40	--	14	--					
DIPTERA									
Ceratopogonidae	--	--	--	26					
Chironomidae	--	--	--	54					
ACARI									
Mesostigmata	26	--	--	--					
Oribatei	14	--	14	66					
ROTIFERA									
Unid. Rotifera	14	--	--	14					
NEMATODA									
Unid. Nematoda	80	426	94	414					
TARDIGRADA									
Unid. Tardigrada	26	14	--	40					
ANNELIDA									
OLIGOCHAETA									
Enchytraeidae	--	--	14	40					
TOTAL (#/40L)	200	440	136	654	--	--	--	--	--
TOTAL NUMBER OF TAXA	6	2	4	7	--	--	--	--	--

MICROINVERTEBRATES
CLIENT: AWWQRP Ehemeral Stream Study
SITE: Ciénega Creek Upstream of I-10
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
	High flows- no samples collected	Not visited	Not visited	Not visited		Not visited			Dry- no samples collected
INSECTA									
DIPTERA									
Ceratopogonidae					--		--	13	
Chironomidae					--		--	13	
ACARI									
Oribatei					--		7	20	
ROTIFERA									
Unid. Rotifera					--		--	7	
NEMATODA									
Unid. Nematoda					--		87	113	
ANNELIDA									
OLIGOCHAETA									
Naididae					--		--	7	
TOTAL (#/40L)	--	--	--	--	0	--	94	173	--
TOTAL NUMBER OF TAXA	--	--	--	--	0	--	2	6	--

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Ciénega Creek at Mescal Arroyo
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
ACARI	High flows- no samples collected	High flows- no samples collected			Dry- no samples collected				Dry- no samples collected
Oribatei			--	--		13	13	--	
NEMATODA									
Unid. Nematoda			240	247		340	187	87	
ANNELIDA									
OLIGOCHAETA									
Naididae			--	--		--	7	--	
TOTAL (#/40L)	--	--	240	247	--	353	207	87	--
TOTAL NUMBER OF TAXA	--	--	1	1	--	2	3	1	--

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Tanque Verde Creek at Houghton Road
Santa Cruz River Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
INSECTA	Not visited	Not visited	Not visited		Dry- no samples collected	Dry- no samples collected		Dry- no samples collected	Dry- no samples collected
COLLEMBOLA									
Poduridae				7			--		
DIPTERA									
Chironomidae				--			13		
ACARI									
Oribatei				--			33		
CRUSTACEA									
CLADOCERA									
Unid. Cladocera				--			7		
NEMATODA									
Unid. Nematoda				113			47		
ANNELIDA									
OLIGOCHAETA									
Enchytraeidae				7			--		
TOTAL (#/Sample)	--	--	--	127	--	--	100	--	--
TOTAL NUMBER OF TAXA	--	--	--	3	--	--	4	--	--

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Rio Puerco near San Luis
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
NEMATODA							
Unid. Nematoda	20	13	20	20	--	--	147
TOTAL (#/40L)	20	13	20	20	0	0	147
TOTAL NUMBER OF TAXA	1	1	1	1	0	0	1

MICROINVERTEBRATES
CLIENT: AWWQRP Rphemeral Stream Study
SITE: Rio Puerco at Cabezón
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
ACARI		High flows- no samples collected					
Oribatei	--		--	--	13	--	--
CRUSTACEA							
OSTRACODA							
Unid. Ostracoda	7		--	--	--	--	--
NEMATODA							
Unid. Nematoda	20		27	7	13	7	47
TARDIGRADA							
Unid. Tardigrada			--	--	--	7	--
TOTAL (#/40L)	27	--	27	7	26	14	47
TOTAL NUMBER OF TAXA	2	--	1	1	2	2	1

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Rio Puerco Downstream of Arroyo Chico
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
CRUSTACEA	Not visited	Not visited	Not visited	Not visited			
CLADOCERA							
Daphniidae					--	7	--
NEMATODA							
Unid. Nematoda					93	27	67
TOTAL (#/40L)	--	--	--	--	93	34	67
TOTAL NUMBER OF TAXA	--	--	--	--	1	2	1

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Cañada Santiago
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
ACARI							
Oribatei	--	7	--	--	--	--	--
CRUSTACEA							
COPEPODA							
Harpactacoida	--	--	14	--	--	--	--
NEMATODA							
Unid. Nematoda	93	7	54	--	--	--	--
TOTAL (#/40L)	93	14	68	0	0	0	0
TOTAL NUMBER OF TAXA	1	2	2	0	0	0	0

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Arroyo Balcón
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
NEMATODA	Not visited					Sample compromised	
Unid. Nematoda		100	20	--	27		--
TOTAL (#/40L)	--	100	20	0	27	--	0
TOTAL NUMBER OF TAXA	--	1	1	0	1	--	0

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Arroyo Chico Downstream of USGS Gage
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
ACARI	Not visited	Not visited	Not visited	Not visited			
Mesostigmata					13	--	--
Oribatei					20	--	7
CRUSTACEA							
COPEPODA							
Cyclopoida					7	--	--
NEMATODA							
Unid. Nematoda					93	33	40
TARDIGRADA							
Unid. Tardigrada					13	--	--
TOTAL (#/40L)	--	--	--	--	146	33	47
TOTAL NUMBER OF TAXA	--	--	--	--	5	1	2

MICROINVERTEBRATES
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Gordon Arroyo at S.H. 69
Huerfano River Watershed, Colorado

TAXA	08/15/06	08/16/06	08/17/06
NEMATODA			
Unid. Nematoda	7	13	--
TOTAL (#/40L)	7	13	0
TOTAL NUMBER OF TAXA	1	1	0

Appendix B

Aquatic Macroinvertebrate Data

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Santa Cruz River at Congress
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
INSECTA	Not visited	High flows- no samples collected	Not visited	High flows- no samples collected					Dry- no samples collected
ODONATA									
Coenagrion/Enallagma					1	--	--	--	
Libellulidae					--	--	--	2	
HEMIPTERA									
Belostoma sp.					1	1	--	--	
Corisella sp.					1	--	--	1	
COLEOPTERA									
Berosus sp.					1	1	--	--	
Enochrus sp.					--	1	--	2	
Eretes occidentalis					1	--	--	--	
Hydrochus sp.					--	1	--	--	
Laccophilus maculosus					5	1	15	--	
Liodessus obscurellus					--	1	--	2	
Postelichus sp.					--	11	--	--	
DIPTERA									
Chaoborus sp.					4	2	--	--	
Chironomus sp.					20	29	23	25	
Culicidae					--	--	2	5	
Dolichopodidae					1	--	--	--	
Goeldichironomus sp.					--	1	3	1	
Tabanus sp.					1	--	--	--	
Unid. Orthocladiinae					1	--	2	1	
HYDRACARINA									
Hydryphantes sp.					--	1	--	--	

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Santa Cruz River at Congress
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
CRUSTACEA									
AMPHIPODA									
Hyalella azteca cx.					4	8	60	164	
ANNELIDA									
HIRUDINEA									
Erpobdella punctata punctata					--	1	--	--	
TOTAL (#/Sample)	--	--	--	--	41	59	105	203	--
TOTAL NUMBER OF TAXA	--	--	--	--	12	13	6	9	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Pantano Wash at Vail
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
	High flows- no samples collected	High flows- no samples collected	High flows- no samples collected	High flows- no samples collected	Dry- no samples collected	Dry- no samples collected			Dry- no samples collected
INSECTA									
DIPTERA									
Ceratopogonidae							--	11	
Chironomidae							--	1	
Syrphidae							--	2	
Unid. Orthocladiinae							4	--	
CRUSTACEA									
AMPHIPODA									
Hyalella azteca cx.							3	14	
TOTAL (#/Sample)	--	--	--	--	--	--	7	28	--
TOTAL NUMBER OF TAXA	--	--	--	--	--	--	2	4	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Davidson Canyon at Mesquite Mesa Road
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
INSECTA				Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected
DIPTERA									
Tipulidae	1	--	--						
Unid. Orthocladiinae	3	--	2						
ANNELIDA									
OLIGOCHAETA									
Enchytraeidae	--	--	3						
TOTAL (#/Sample)	4	0	5	--	--	--	--	--	--
TOTAL NUMBER OF TAXA	2	0	2	--	--	--	--	--	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Mescal Arroyo at Marsh Station Road
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
INSECTA					Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected	Dry- no samples collected
DIPTERA									
Bryophaenocladius sp.	--	--	2	3					
Empididae	--	--	--	3					
Ephydridae	1	1	8	21					
Smittia sp.	--	--	1	--					
Unid. Orthocladiinae	4	1	24	83					
ANNELIDA									
OLIGOCHAETA									
Lumbriculidae	--	--	1	1					
TOTAL (#/Sample)	5	2	36	111	--	--	--	--	--
TOTAL NUMBER OF TAXA	2	2	5	5	--	--	--	--	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Ciénega Creek Upstream of I-10
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
	High flows- no samples collected	Not visited	Not visited	Not visited		Not visited			Dry- no samples collected
INSECTA									
HEMIPTERA									
Microvelia sp.					--		--	1	
COLEOPTERA									
Peltodytes sp.					--		--	4	
Postelichus sp.					--		2	1	
DIPTERA									
Bryophaenocladius sp.					1		--	--	
Ceratopogoninae					3		--	--	
Ephydridae					5		--	1	
Unid. Orthocladiinae					4		2	--	
ANNELIDA									
OLIGOCHAETA									
Lumbriculidae					1		--	--	
TOTAL (#/Sample)	--	--	--	--	14	--	4	7	--
TOTAL NUMBER OF TAXA	--	--	--	--	5	--	2	4	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Ciénega Creek at Mescal Arroyo
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
	High flows- no samples collected	High flows- no samples collected			Dry- no samples collected				Dry- no samples colected
INSECTA									
EPHEMEROPTERA									
Callibaetis sp.			1	--		--	--	--	
HEMIPTERA									
Hesperocorixa sp.			1	--		--	--	--	
Veliidae				--		1	--	--	
COLEOPTERA									
Berosus sp.			--	1		--	--	--	
Dytiscidae			--	1		--	--	--	
Laccophilus sp.			--	--		--	--	2	
Liodessus obscurellus			--	--		--	1	2	
Peltodytes sp.			--	--		1	4	2	
Postelichus sp.			1	--		--	2	1	
DIPTERA									
Ceratopogoninae			--	--		2	--	--	
Nemotelus sp.			--	--		--	--	1	
Unid. Orthocladiinae			--	1		3	--	1	
ANNELIDA									
HIRUDINEA									
Erpobdella punctata punctata			--	--		--	--	1	
TOTAL (#/Sample)	--	--	3	3	--	7	7	10	--
TOTAL NUMBER OF TAXA	--	--	3	3	--	4	3	7	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Tanque Verde Creek at Houghton Road
Santa Cruz Watershed, Arizona

TAXA	07/29/06	07/30/06	07/31/06	08/01/06	08/02/06	08/03/06	08/04/06	08/05/06	08/06/06
INSECTA	Not visited	Not visited	Not visited		Dry- no samples collected	Dry- no samples collected		Dry- no samples collected	Dry- no samples collected
ODONATA									
Coenagrionidae				1			--		
DIPTERA									
Apedilum sp.				--			1		
Ceratopogoninae				--			1		
Pseudosmittia sp.				--			1		
Stratiomys sp.				1			--		
ANNELIDA									
OLIGOCHAETA									
Lumbriculidae				--			3		
TOTAL (#/Sample)	--	--	--	2	--	--	6	--	--
TOTAL NUMBER OF TAXA	--	--	--	2	--	--	4	--	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Rio Puerco near San Luis
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
INSECTA							
COLLEMBOLA							
Sminthuridae	--	--	--	1	--	--	--
Unid. Collembola	--	--	1	--	--	--	--
EPHEMEROPTERA							
Baetidae	--	--	1	--	18	1	--
Callibaetis sp.	6	--	--	12	--	--	74
ODONATA							
Coenagrion/Enallagma	--	--	--	--	1	--	2
Coenagrionidae	1	--	--	1	--	--	--
HEMIPTERA							
Aquarius sp.	--	1	--	--	--	--	--
Corixidae	--	--	--	1	--	--	2
Gerridae	--	--	--	--	--	1	--
Lipogomphus sp.	--	--	--	--	1	--	--
Notonectidae	--	--	1	--	--	--	--
Rheumatobates sp.	--	--	--	--	1	--	--
Sigara sp.	--	--	2	--	--	--	--
COLEOPTERA							
Berosus sp.	--	--	--	--	1	1	--
Laccophilus sp.	--	--	--	1	--	--	--
Ochthebius sp.	--	--	--	1	1	--	--
Oreodytes sp.	--	--	--	--	2	--	--
Postelichus sp.	2	1	--	--	1	1	1
Salpingidae	--	--	2	--	--	--	--
Stictotarsus striatellus	12	--	--	3	8	4	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Rio Puerco near San Luis
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
DIPTERA							
Ceratopogonidae	--	--	--	1	--	--	--
Chironomus sp.	--	--	--	1	--	--	--
Culicidae	2	--	--	--	--	--	--
Empididae	--	2	--	--	--	--	--
Ephydridae	--	3	--	--	--	--	--
Tabanus sp.	1	--	--	--	--	--	--
Tipulidae	--	--	1	--	--	--	--
Unid. Orthocladiinae	1	3	--	--	--	--	1
HYDRACARINA							
Tyrellia sp.	--	--	--	--	--	1	--
ANNELIDA							
OLIGOCHAETA							
Lumbriculidae	1	--	--	--	--	--	--
Megadrili	--	2	--	--	--	--	--
Unid. Immature Tubificidae w/ Capilliform Chaetae	--	--	--	1	5	--	1
TOTAL (#/Sample)	26	12	8	23	39	9	81
TOTAL NUMBER OF TAXA	8	6	6	10	10	6	6

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Rio Puerco at Cabezón
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
INSECTA		High flows- no samples collected					
EPHEMEROPTERA							
Baetidae	--		--	1	1	--	5
Callibaetis sp.	9		--	--	--	--	--
HEMIPTERA							
Corixidae	--		1	--	--	1	--
Sigara sp.	--		--	1	2	--	--
COLEOPTERA							
Berosus sp.	--		1	--	--	--	--
Microcylloepus pusillus	--		1	--	--	--	--
Ochthebius sp.	--		--	--	1	--	--
Postelichus sp.	2		--	6	1	1	7
Salpingidae	2		--	--	1	1	1
Stictotarsus striatellus	--		--	--	1	--	--
DIPTERA							
Ceratopogoninae	--		--	--	--	6	--
Chironomus sp.	--		--	--	1	--	--
Culicidae	1		--	--	--	--	--
Empididae	--		--	1	--	--	--
Ephydridae	--		--	3	--	--	--
Muscidae	--		1	--	--	--	--
Ormosia sp.	--		1	1	--	--	--
Smittia sp.	--		--	1	--	--	--
Tipulidae	--		1	--	--	--	--
Unid. Orthocladiinae	1		3	1	--	1	1

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Rio Puerco at Cabezón
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
ANNELIDA							
OLIGOCHAETA							
Enchytraeidae	--		--	5	--	2	1
Lumbriculidae	--		--	1	3	--	--
Megadrili	--		6	--	--	--	--
HIRUDINEA							
Erpobdella punctata punctata	--		--	--	--	1	--
TOTAL (#/Sample)	15	--	15	21	11	13	15
TOTAL NUMBER OF TAXA	5	--	8	10	8	7	5

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Rio Puerco Downstream of Arroyo Chico
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
INSECTA	Not visited	Not visited	Not visited	Not visited			
EPHEMEROPTERA							
Baetidae					3	8	--
ODONATA							
Coenagrion/Enallagma					--	1	--
HEMIPTERA							
Ambrysus mormon					1	--	2
Corixidae					--	1	--
Notonectidae					--	1	--
COLEOPTERA							
Berosus sp.					--	--	1
Helichus sp.					1	1	--
Stictotarsus striatellus					--	1	--
DIPTERA							
Chironomus sp.					--	2	--
Procladius sp.					1	--	--
Stictochironomus sp.					--	--	1
Tipulidae					--	3	--
Unid. Orthocladiinae					--	3	1
CRUSTACEA							
NOTOSTRACA							
Triops sp.					3	--	--
AMPHIPODA							
Hyalella azteca cx.					--	--	1

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Rio Puerco Downstream of Arroyo Chico
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
ANNELIDA							
OLIGOCHAETA							
Enchytraeidae					--	1	--
TOTAL (#/Sample)	--	--	--	--	9	22	6
TOTAL NUMBER OF TAXA	--	--	--	--	5	10	5

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Cañada Santiago
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
INSECTA							
HEMIPTERA							
Ambrysus mormon	--	--	--	--	--	1	--
Lipogomphus sp.	--	--	--	--	--	1	--
Sigara sp.	--	--	1	--	--	--	--
COLEOPTERA							
Agabus sp.	--	--	1	--	--	--	--
Enochrus sp.	--	--	--	2	--	--	--
Laccobius sp.	--	--	--	1	--	--	--
Neoporus dimidiatus	--	--	1	--	--	--	--
Ochthebius sp.	--	--	3	30	45	16	5
DIPTERA							
Aedes sp.	1	--	5	--	--	--	--
Ceratopogonidae	--	--	--	--	2	--	2
Ceratopogoninae	--	--	--	10	--	2	--
Culicidae	--	2	--	--	1	--	--
Procladius sp.	--	--	8	67	10	3	1
Psorophora sp.	--	--	83	16	--	--	--
Tabanus sp.	--	--	1	--	--	--	--
Unid. Orthocladiinae	--	1	--	9	2	--	--
CRUSTACEA							
ANOSTRACA							
Eubranchipus sp.	--	--	62	6	--	--	--

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Cañada Santiago
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
ANNELIDA							
OLIGOCHAETA							
Enchytraeidae	--	--	1	4	--	--	--
HIRUDINEA							
Erpobdella punctata punctata	--	--	2	33	10	16	11
MOLLUSCA							
GASTROPODA							
Stagnicola sp.	--	--	8	1	--	--	--
TOTAL (#/Sample)	1	3	176	179	70	39	19
TOTAL NUMBER OF TAXA	1	2	12	11	6	6	4

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Arroyo Balcón
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
INSECTA	Not visited						
EPHEMEROPTERA							
Baetidae		--	--	--	--	1	--
HEMIPTERA							
Lipogomphus sp.		--	--	--	--	1	--
COLEOPTERA							
Ochthebius sp.		--	--	6	3	14	2
Paracymus sp.		--	--	2	--	--	--
DIPTERA							
Unid. Orthocladiinae		--	1	--	--	--	--
TOTAL (#/Sample)	--	0	1	8	3	16	2
TOTAL NUMBER OF TAXA	--	0	1	2	1	3	1

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Arroyo Chico Upstream of USGS Gage
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
INSECTA	Not visited						
EPHEMEROPTERA							
Baetidae		--	--	--	--	1	--
ODONATA							
Coenagrionidae		--	--	--	--	--	1
HEMIPTERA							
Ambrysus mormon		--	--	--	--	--	2
Lipogomphus sp.		1	--	--	--	--	--
COLEOPTERA							
Berosus sp.		--	--	--	--	--	1
Neoporus dimidiatus		--	--	--	--	2	--
Ochthebius sp.		--	--	1	--	1	--
DIPTERA							
Bryophaenocladius sp.		--	1	1	1	1	--
Ceratopogoninae		--	--	--	4	--	--
Chironomus sp.		--	1	--	--	--	--
Conchapelopia/Thienemannimy		--	--	--	2	--	--
Dolichopodidae		--	--	2	--	--	--
Empididae		--	--	--	1	--	--
Endotribelos sp.		--	--	--	1	--	--
Larsia sp.		--	--	--	--	--	2
Tipulidae		--	--	2	1	--	--
Unid. Orthocladiinae		--	--	1	--	--	--
CRUSTACEA							
ANOSTRACA							
Triops sp.		--	--	--	--	--	1

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Arroyo Chico Upstream of USGS Gage
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
ANNELIDA							
OLIGOCHAETA							
Lumbriculidae		--	1	--	2	1	1
Megadrili		--	--	1	--	--	2
TOTAL (#/Sample)	--	1	3	8	12	6	10
TOTAL NUMBER OF TAXA	--	1	3	6	7	5	7

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Arroyo Chico Downstream of USGS Gage
Rio Puerco Watershed, New Mexico

TAXA	08/08/06	08/09/06	08/10/06	08/11/06	08/12/06	08/13/06	08/14/06
INSECTA	Not visited	Not visited	Not visited	Not visited			
EPHEMEROPTERA							
Baetidae					--	2	--
Callibaetis sp.					1	--	--
HEMIPTERA							
Corixidae					--	3	--
Sigara sp.					1	--	--
DIPTERA							
Ceratopogoninae					--	--	1
Conchapelopia/Thienemannimy					--	1	--
Endotribelos sp.					--	--	1
Paramerina sp.					2	--	--
Polypedilum sp.					--	--	1
Procladius sp.					1	--	--
Tabanus sp.					--	--	1
Unid. Orthocladiinae					2	5	3
MOLLUSCA							
GASTROPODA							
Helisoma sp.					--	1	--
TOTAL (#/Sample)	--	--	--	--	7	12	7
TOTAL NUMBER OF TAXA	--	--	--	--	5	5	5

MACROINVERTEBRATE DENSITY
CLIENT: AWWQRP Ephemeral Stream Study
SITE: Gordon Arroyo at S.H. 69
Huerfano River Watershed, Colorado

TAXA	08/15/06	08/16/06	08/17/06
INSECTA			
EPHEMEROPTERA			
Baetidae	--	1	--
HEMIPTERA			
Notonecta sp.	2	--	--
Sigara sp.	1	3	6
COLEOPTERA			
Berosus sp.	1	--	--
Helophorus sp.	2	--	--
Liodessus obscurellus	--	--	1
Ochthebius sp.	--	--	1
Salpingidae	2	--	--
Tropisternus sp.	--	1	--
DIPTERA			
Ephydridae	1	--	--
ANNELIDA			
OLIGOCHAETA			
Megadrili	4	--	2
TOTAL (#/Sample)	13	5	10
TOTAL NUMBER OF TAXA	7	3	4