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U.S. National Park Service Mojave Inventory and Monitoring Network Spring Survey Protocols: Level I and Level II

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INTRODUCTION

Thousands of springs scatter a variety of landscapes throughout the western U.S. They have been a focus of human activity for thousands of years because they often provide the only reliable source of water. Their importance as aquatic and riparian habitats for wildlife has also become increasingly apparent (Hubbs 1995), and they are now known as “biodiversity hotspots” that support a large proportion of the aquatic and riparian species in arid regions (Fisher et al. 1972, Williams and Koenig 1980, Gubanich and Panik 1986, Myers and Resh 1999). Several hundred species or subspecies of fishes, mollusks, crustaceans, aquatic insects, and plants are endemic to western U.S. springs, which shows that they are also important to a wide variety of rare plants and animals (e.g., Hubbs and Miller 1948, Hubbs et al. 1974, Williams et al. 1985, Minckley et al. 1986, Wiggins and Erman 1987, Hershler and Sada 1987, Shepard 1990, Hershler 1998 & 1999, Schmude 1999, Hershler and Frest 1996, Baldinger et al. 2000, Polehmus and Polhemus 2002, Sada and Vinyard 2002, Smith et al. 2002).

Although discharge rates, aquifer sources, and the presence of rare species (e.g., fishes, aquatic macroinvertebrates, rare plants, etc.) have been assessed at some springs, basic information describing physical and biological characteristics of arid land springs is very limited. This paucity of knowledge has often resulted in permitting activities that adversely affect spring aquatic and riparian biota (Shepard 1993). Management is challenged to respond to these issues because many uses and management activities have adversely affected biodiversity and resulted in status declines of rare species (Sada and Vinyard 2002). At this time, assessing the efficacy of management is often difficult because springs are unique systems, spring survey and monitoring methods are largely unknown, and spring resources are often unknown to most resource managers.

The U.S. National Park Service, Mojave Inventory and Monitoring Network (Mojave I&M Network), is responding to these deficiencies by working with the Desert Managers Group to prepare a series of inventory and monitoring protocols that are specific to spring systems within their jurisdictions. These protocols are consistent with a planning process that accumulates information at several different quantitative levels and reviews issues at differing scales of resource challenge. They also provide a broad base of information that can be compiled by all public and private agencies to characterize springs and monitor for long-term changes in their biota and physicochemical environment. Using consistent data collection methods will allow cooperating agencies to compile and disseminate information and facilitate assessments of spring resources across a broad geographic area.

Gathering information for this spring inventory and monitoring program is accomplished by data mining and two hierarchical field surveys. A database is then created to archive information. Data mining is conducted to compile information from agency files that document historical work on springs in a management area. This may include wildlife surveys, water chemistry data, etc. This is followed by Level I field studies that inventory all springs or water features (the types of water sources included in these surveys may vary with resource needs within a management area) by visiting all water sources within a defined geographic area (e.g., within a national park). This inventory records the spring location, and characteristics of the spring that include its size and morphology, basic water chemistry, the presence of important plants and animals, and natural and anthropogenic factors stressing the aquatic and riparian systems. This information can be used to generally assess the biotic integrity of springs and conditions resulting from existing management practices. If conditions do not meet existing management goals and guidelines, Level I surveys should be followed by Level II surveys, which quantify temporal variation in aquatic and riparian communities, characteristics of the aquatic habitat, and water chemistry to document how the spring system changes over time. This level of investigation provides more rigorous insight into the environmental and biotic responses to changes in management. A third level of surveys may also be conducted to more accurately quantify spatial and temporal variability in water chemistry and aquatic and riparian habitats and communities. This information may also quantify the age of water, relatively precise assessment of water age and sources, seasonal and annual variability in biotic and physiochemical factors, and specific microhabitats that are required by aquatic and riparian species,. This level of work is included in these protocols. In summary, the four elements to the hierarchical assessment of springs through Level I and Level II are:

1. Data mining to review existing information, protocols, and databases related to inventory of spring-fed water features within a designated management area.
2. Level I surveys to inventory isolated water features that include 1) natural springs and seeps (groundwater that flows onto the land surface through natural processes), 2) hand and mechanically dug wells (groundwater that flows onto the land surface because of vertically oriented human excavation), and 3) artificial surface water expressions or qanats, and water

troughs (groundwater that flows onto the land surface because of horizontally oriented human excavation). The purpose of Level I surveys is to characterize salient aspects of each spring's aquatic and riparian environments. These surveys are reconnaissance-level observations that focus on locating springs and generally assessing biotic potential that can be used to facilitate management and prioritize the importance of individual springs within the park ecosystem. This information is neither highly detailed nor accumulated in a rigorous manner that allows statistical analysis. It is a tool that characterizes spring resources and provides information that can be used to assess management needs and prioritize spring resources. Collection of highly quantified data requires much more detail, time, and substantially greater funding than is necessary for Level I surveys.

3. Level II surveys that are the basis of a long-term monitoring program that quantifies temporal variation in biotic and physicochemical characteristics of individual springs. These surveys should be conducted annually for three to five years to determine baseline conditions. Sampling frequency may be reduced to every three to five years once baseline conditions are accurately quantified. The number of springs, duration of surveys, and goals and purposes of Level II surveys should be developed by a team of managers, ecologists, and hydrologists. These surveys include water chemistry analyses, quantitative description of aquatic habitats, and the identification and enumeration of riparian and aquatic taxa to species or genus, respectively. Information provided by these surveys will 1) quantify baseline conditions at the beginning of a monitoring program and 2) quantify changes in biotic and abiotic characteristics of springs under existing or newly implemented management strategies. Level II surveys may include only springs where the effects of altered management strategies should be documented, and they may be implemented to determine landscape changes in biotic and abiotic condition of springs.
4. Compilation of survey and monitoring information into a Microsoft Access® database.

The foundation for these protocols is provided by a number of hydrological and biological studies of springs in the western U.S. and elsewhere (e.g., Ferrington 1995, Botosaneau 1998, Meffe and Marsh 1983, Williams and Danks 1991, Thomas et al. 1996, Sada et al. 2005, and many other references that are cited herein) that have examined spring physicochemical conditions and their influence on aquatic and riparian systems.

This document includes a number of sections that educate surveyors about physicochemical and biological characteristics of springs, describes collection methods for Level I and Level II surveys, defines terms used in the protocols (Appendix I), recommends field forms, describes how to identify important animals, and provides an example of how information from Level I surveys can be used to prioritize management and restoration activities. Guidelines are also provided to prevent translocating animals among springs while conducting surveys. These protocols include minimum information that should be compiled at each spring for Level I and Level II surveys. Individual agencies or jurisdictions may wish to include other variables to customize these assessments for specific management needs.

WHAT ARE SPRING SYSTEMS?

Aquifer Sources

Springs are relatively small aquatic and riparian systems that are maintained by groundwater flowing onto the land surface through natural processes (Meizner 1923, Hynes 1970). They are distinct from other aquatic systems because their water temperature is relatively constant (at least near their source), they depend on subterranean flow through aquifers, they provide the only water over vast areas and are therefore “biodiversity hotspots” (Myers and Resch 1999), and many support obligatory, spring-dwelling species (crenobiontic species) (Hynes 1970, Erman and Erman 1995, Myers and Resch 1999).

Springs are supported by precipitation that seeps into the soil and accumulates in aquifers where it is stored. They occur where subterranean water reaches the earth’s surface through fault zones, rock cracks, or orifices that occur when water creates a passage by dissolving rock. Spring hydrology is influenced by characteristics of regional and local geology, and how water moves through an aquifer. The size of an aquifer depends on regional and local geology and climate, and water chemistry is strongly influenced by aquifer geology. Perched, local, and regional aquifers are the basic types of aquifers in the western U.S. These aquifers differ primarily in their transmissivity, and hence their water chemistry and persistence. In general, water in highly transmissive aquifers (e.g., perched aquifers) contains fewer dissolved chemical constituents than water in aquifers with low transmissivity (e.g., regional aquifers).

Perched Aquifers

In the western U.S., springs at high elevations (> 1,800 m [~6,000 ft]) and on mountain blocks are generally supplied by perched aquifers. These aquifers are small and fed by precipitation covering a small area (e.g., a drainage basin, small portion of a mountain range, or series of hills). Perched springs are cool (<10^{o}C), usually small, and often dry during periods of low precipitation. Seasonal and annual variability in discharge may also be large.

Local Aquifers

Local aquifers are fed by precipitation from a larger area (e.g., a mountain range) and springs they support are located between valley floors and the base of mountains. Flow through these aquifers is generally deeper (< 500 m) and springs are usually cool, but warmer than perched aquifer springs (< 20^{o}C). Geothermal springs (> 40^{o}C) are also supported by local aquifers that circulate near magma that heats water to temperatures that dissolve rocks to increase the concentration and number of chemicals. Discharge from springs fed by these aquifers may also change seasonally and annually in response to precipitation, but most of these springs dry only during extended droughts.

Regional Aquifers

Springs fed by regional aquifers are warm (>20^{o}C) and supplied from recharge extending over vast areas. Flow through these aquifers is complex, controlled by fractures, and may extend beneath valleys and topographic divides (Mifflin 1968, Winograd and Thordarson 1975, Thomas et al. 1996). The movement of water through these aquifers is slow compared to perched and local aquifers. Water in regional aquifer springs may also contain elevated chemical concentrations and TDS level because the long residence of time and elevated temperatures facilitate the dissolving of rock and minerals. In contrast to springs supported by perched and local aquifers, discharge from regional springs is constant over long periods of time (often >1,000 years, and exceeding 50,000 years; Winograd et al. 1992).

Physical and Chemical Characteristics of Springs

Springs and seeps occur in many sizes and shapes, and the complex influences of aquifer geology, morphology, discharge rates, and regional precipitation and vegetation dictate that environmental characteristics of most springs are unique (see Hynes 1970, Garside and Schilling

1979). They can be cold (near or below mean-annual air temperature), thermal (>5°C and <10 °C above mean-annual air temperature [van Everdingen 1991]), or hot (water temperature >10°C above mean-annual air temperature [Peterken 1957]). They may also be chemically harsh. Many hot springs are highly acidic and springs flowing through limestone and basalt may be alkaline. Dissolved oxygen concentrations are frequently very low (< 2 milligrams/liter [mg/l]) in hot springs, and high (> 5 mg/l) in cooler springs. At spring sources, dissolved oxygen concentrations are frequently low and increase downstream with exposure to the atmosphere (Hynes 1970). Electrical conductance may also range from very low (near 0 microsiemens/centimeter/second [µmhos]) in springs supported by perched aquifers to very high (>10,000 µmhos) in some harsh environments. Also, cooler and smaller springs may freeze during winter, while larger and warmer springs do not.

Spring size is generally a function of its discharge. Seeps are small springs that support vegetation that is adapted to drier conditions (e.g., upland and facultative wetland species), and seeps that are dry on a regular basis. Springs may also be small but they support larger aquatic habitats, dry less frequently, and they are generally surrounded by more robust riparian zones with species that rely on moist soils (e.g., obligatory and facultative wetland species). Springs may be broadly categorized by the morphology of their source. *Limnocrenes* are springs with water flowing from a deep pool, *helocrenes* are marshy and bog-like, and *rheocrenes* have a well-defined source that flows directly into a confined channel.

Springs occur singly and in provinces that include many sizes and morphologies. Most springs below approximately 2,100 m (7,000 ft) in western North America are isolated and flow a short distance before drying (Deacon and Minckley 1974). Many springs in this region also dry periodically, while few flow into rivers, lakes, or streams, and spring provinces may support extensive wetlands.

Biological Characteristics of Springs

Physical and chemical features are dominant factors influencing spring-fed riparian and aquatic plant and animal communities (van der Kamp 1995, Sada et al. 2005). Plant and animal assemblages in springs may be similar to aquatic and riparian assemblages associated with regional streams and ponds (with the exception of crenobiontics). However, arid land spring communities exhibit unique compositional and structural characteristics that are attributed to their distinctive environments and to colonization/extirpation dynamics that characterize small, isolated habitats. Riparian and aquatic communities at hot springs are distinct from other spring systems and from all other biotic systems in the western U.S. (Milligan et al. 1966, Garside and Schilling 1979).

Although abiotic and biotic characteristics of most arid land springs are distinctive, a number of general factors are known about ecological relationships. Riparian vegetation at cool water springs and springs with lower thermal temperatures is generally comprised of species associated with regional streams, lakes, and marshes (e.g., willows, mesquites, sedges, and grasses). This vegetation may be dense at springs that are minimally disturbed, but springs that are disturbed by natural (e.g., scouring floods, fire, avalanche) and cultural activities usually have less diverse riparian communities that include more non-native and upland species (Fleishman et al. in press). Riparian vegetation may be restricted to the immediate boundaries of a spring's aquatic habitat, or it may extend outward for substantial distances where water seeps outward from aquatic habitats and moistens hydric soils (e.g., in spring provinces). The structure of riparian communities varies considerably with many factors, including discharge, spring elevation, soil type, and disturbance levels. Vegetation associated with thermal springs is usually tolerant of soils with elevated salinity and alkalinity (Kristijansson and Hreggvidsson 1995). Vegetation at larger and minimally disturbed springs is dominated by sedges, rushes, grasses, and woody phreatophytes (e.g., willows at middle to higher elevations, mesquite at lower elevations). Vegetation at seeps is typically limited to grasses and rushes.

Smaller springs are generally autotrophic aquatic systems with little dependence on allochothonous carbon sources (Minshall 1978, Cushing and Wolf 1984). In larger springs, energy may enter the system during periodic floods that flush carbon from the surrounding landscape. As a consequence, most spring environments are less variable than other aquatic habitats (e.g., streams, rivers, and lakes), which causes variability in population size and assemblage structure to be comparatively low (Minckley 1963, van der Kamp 1995). Within a spring system, environmental variation is typically lowest near the source, where environments are comparatively stable, and greatest downstream, where variability in temperature, discharge, dissolved oxygen concentration, and other factors is much greater (Deacon and Minckley 1974). As a result, the composition of source and downstream communities is usually different, and many species that occupy the source are frequently absent from downstream habitats (Hayford et al. 1995, Hershler 1998, O'Brien and Blinn 1999). Many taxa occupying source habitats do not occur downstream where temporal fluctuations in water temperature and flow are greater and may exceed the physiological tolerance of source-dwelling species (Erman and Erman 1990, Erman 1992). Resh (1983) found more species near the source of a Mendocino County, California spring, but higher animal density in downstream reaches. In a small New Mexico spring, Noel (1954) found that highest density was near the source and during the period January through September.

A number of studies have also observed that abundance differs throughout the year in response to food availability, temperature, reproduction, and migration of species along a springbrook (Minckley 1963, Glazier and Gooch 1987, Varza and Covich 1995). Aquatic life is also influenced by morphology. Species that inhabit rheocrenes prefer flowing water and species in limnocrenes and helocrenes are better adapted to lentic environments (Sada et al. 2000).

Crenobiontics appear to be specifically adapted to their home environment. Although additional information is needed to identify habitats preferred by most crenobiontics, it appears that they are most abundant within 50 m of a spring source, and scarce or absent from the downstream-most reaches of spring brook. It also appears that each species also prefers a specific microhabitat. Springsnails in the genus *Pyrgulopsis* generally prefer gravel substrate and flowing water, whereas species in the genus *Tryonia* occur in sand substrate that is typically found along banks in slow current (Hershler 1998, Hershler and Sada 1987, Sada and Herbst 1999). Sada and Herbst (1999) found that habitat partitioning among three springsnail species (*Pyrgulopsis avernalis*, *Pyrgulopsis carinifera*, and *Tryonia clathrata*) was based on water depth, current velocity, and substrate composition. O'Brien and Blinn (1999) showed that *P. montezumensis* preferred specific levels of CO_2 that were restricted to a short portion of spring brook. Endemic beetles (e.g., *Stenelmis* sp. and *Microcylleopus* sp.) and true bugs (e.g., *Ambrysus* sp. and *Limnocoris* sp.) are most common where gravel substrate occurs with high current velocities (Sada and Herbst 1999). The Devil's Hole pupfish (*Cyprinodon diabolis*) also selects specific habitat for spawning (Deacon and Deacon 1979).

Because of the relative isolation of many arid land springs, plant diversity and endemism are frequently higher than communities in other aquatic systems and uplands. Sada and Nachlinger (1996) documented 250 species of plants and animals associated with springs in the Spring Mountains of southern Nevada. Comparatively high species diversity (126 to 150 species) was also recorded at springs along the southwestern edge of the Great Basin in Owens

Valley, California (DeDecker 1980, Ferren and Davis 1991). Springs in both of these regions also support rare plant populations (Skinner 1994, Sada and Nachlinger 1998).

Spring systems also may exhibit unusual hydrologic and edaphic characteristics that are associated with plant rarity. For example, soils near many Great Basin springs are highly alkaline with high levels of calcium, an element frequently associated with rare plants in the genus *Astragalus* (milk vetch) (Ferren et al. 1991). In Nevada, approximately 15 wetland plants are on Sensitive or Watch Lists (Nevada Natural Heritage 1998), and in the Great Basin region of eastern California (Mono and Inyo Counties) approximately 35 wetland plants are considered rare (Skinner 1994).

Comparatively little information has been compiled showing the value of spring-fed riparian habitats to western North American birds, reptiles, amphibians, and mammals. However, extensive work in riparian habitats along streams and rivers indicates that they are important habitats for roosting, food, and shelter (e.g., Warner and Hendrix 1984, Johnson et al. 1985, Naiman and Rogers 1997). Quality riparian habitat has high structural diversity created by dense undergrowth of tangled vegetation and debris. In quality habitat, vegetation at mid-level is less dense and there is a comparatively open canopy provided by large trees. In many of western North America's riparian zones, structure provided by a dense undergrowth of shrub willow and debris, willows at mid-level, and a willow and cottonwood tree canopy. Mesquite (*Prosopis* spp.) woodlands are also common at lower elevations and latitudes in arid lands (Hendrickson and Minckley 1984). Riparian habitat has been reduced at many western U.S. springs by diversion, burning, vegetation control, and excessive ungulate grazing (Shepard 1993). As a result, suitable riparian habitat along springs has been eliminated or degraded so that invasive species such as Brown-Headed Cowbirds (*Molothrus ater*) can more easily establish nesting areas and displace native species (Gaines 1977).

The amount that birds depend on water for drinking appears related to their dietary habits and behavior. Granivorous birds drink more than carnivorous or insectivorous birds (Fisher et al. 1972). Williams and Koenig (1980) suggested that Western Tanagers (*Piranga ludoviciana*) in central California depend on springs during migration but Gubanich and Panik (1986) rarely recorded this species drinking from springs in western Nevada. Gubanich and Panik (*ibid*) did, however, observe insectivorous species such as the American Robin (*Turdus migratorius*), Townsends Solitare (*Myadestes townsendi*), Mountain Bluebird (*Sailia currocoides*), Northern

Flicker (*Colaptes cafer*), Horned Lark (*Eremophila alpestris*), and five species of warbler drinking from springs. Both of these studies suggested that the stresses of migration may cause insectivorous and frugivorous species to be at least seasonally dependent on spring water.

Birds are highly vulnerable to predation while drinking and traveling to and from water (Fisher et al. 1972). Gubanich and Panik (1986) compared use at two springs with different amounts of cover, and concluded that birds more frequently used the site with greater tree and shrub cover. Species such as Rufous-Sided Tohee (*Pipilo erythrophthalmus*), Red-Breasted Nuthatch (*Sitta canadensis*), Mountain Chickadee (*Parus gambeli*), Shrub Jay (*Aphelocoma coerulescens*), and Steller's Jay (*Cyanocitta stelleri*) were never observed drinking away from cover. They also observed many instances of birds seeking cover in trees and shrubs near springs when avian predators appeared.

Many species of bats also use water and insects at springs (O'Farrell and Bradley 1970, 1977).

<u>Rare and Other Important Species</u>

A number of important species are associated with springs. These include rare species that may require specific management and introduced species that may adversely affect biotic integrity.

Taxonomic studies over the past 120 years have found a large number of endemic plants, vertebrates, and macroinvertebrates associated with arid land springs throughout western North America (see Miller 1958; Taylor 1966, 1985; Minckley 1977; Skinner 1994; Hershler 1998; Schmude 1999). Early studies focused on lotic habitats and large, valley floor springs that were inhabited by unique fishes. More recent studies have examined macroinvertebrates in small springs. A diverse crenobiontic fauna is now known from isolated habitats throughout much of the western U.S. These species represent relict populations that have persisted in isolated habitats for thousands of years. They are unable to live outside of an aquatic environment for long periods and most of them are restricted to springs with good water quality. They do not inhabit springs that periodically dry. Therefore, extant populations are in aquatic habitats that have persisted (possibly in conditions similar to those we see today) for long periods of geological time (Taylor 1985, Polhemus and Polhemus 2002).

While there have been few descriptions of new fish taxa in the western U.S. within the past

20 years, more than 100 species of spring-dwelling aquatic mollusks, crustaceans, and insects have been recently described from smaller springs that are not occupied by native fishes (e.g., Hershler and Sada 1987; Shepard 1990; Polhemus and Polhemus 1994; Hershler 1998, 1999; Schmude 1999; Hershler and Frest 1996; Weaver and Myers 1998; Baldinger et al. 2000). Descriptions of new springsnail species are notable among recent taxonomic work because their diversity is surprisingly high (e.g., Hershler 1998). Importance of this fauna was formalized in a Memorandum of Understanding for Great Basin springsnail conservation, which was signed by The Nature Conservancy, Smithsonian Institution, U.S. Department of Interior (U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, U.S. National Park Service, and U.S. Geological Survey), and U.S. Forest Service during 1998. Finger clams (*Pisidium* spp.) and amphipods (*Hyalella* spp. and *Gammarus* spp.) also occur in many springs. Taxonomy of these groups is poorly understood, and future studies may result in description of new species.

Surveys for rare fishes have been comparatively extensive and their distributions are well understood. These surveys have included most large spring habitats and streams, and opportunities for finding new populations are comparatively small. Macroinvertebrate surveys have been uncommon, however. The number of recently described aquatic macroinvertebrates from single localities and the number of habitats that have not been surveyed both suggest that additional populations and new species will be discovered during future surveys. The paucity of information about these species suggests that future spring surveys will provide substantial new information about their distribution, biogeography, and status. Table 1 shows taxonomic groups of native crenobiontic macroinvertebrates that are most likely to be found during spring surveys in the western U.S. (see Myers and Resh 1999; Hershler 1998, 1999; Schmude 1999, Polhemus and Polhemus 2002). Many of these animals are illustrated in Appendix IV.

Spring-fed riparian habitats are also used by vertebrates that are endemic to small areas. Hall (1946) and Ingles (1965) identified voles endemic to spring-fed mesic alkali wetlands in desert regions, and Myers (1942) and Schuierer (1963) identified endemic toad populations in the southwestern Great Basin.

Table 1. Taxonomic groups of crenobiontic aquatic macroinvertebrates that most commonly occur in western North America springs.

Aquatic Insects
Order Coleoptera
Family Elmidae (riffle beetles)
Order Hemiptera
Family Naucoridae (naucorid bugs)
Order Trichoptera
Family Lepidostomatidae (caddisflies)
Mollusks
Family Hydrobiidae (springsnails)
Family Lymnaeidae
Crustaceans
Order Amphipoda (scuds)
Order Ostracoda

Table 2. Common non-native species known from arid land springs.

Fishes
Mosquito fish (*Gambusia affinis*)
Guppy (*Poecillia reticulata*
Goldfish (*Carassius auratus*)
Mollies (*Poecilia* spp., *Xiphophorus* spp.)
Cichlids (Family Cichlidae)
Large mouth bass (*Micropeterus salmoides*)
Amphibians
Bullfrog (*Rana catesbeiana*)
Mollusks
Red-rimmed melania (*Melanoides tuberbulata*)
New Zealand mudsnail (*Potamopyrgus antipodarum*)
Crustaceans
Order Decapoda (crayfish)
Vegetation
Salt cedar (*Tamarisk* sp.)
Palm tree (Family Arecaceae)
White top (*Cardaria pubescens*)
Arundo (*Arundo donax*)
Rabbit's foot grass (*Polypogon monspeliensis*)
Russian knapweed (*Acroptilon repens*)

Non-Native Species

A number of non-native species of animals and plants also occur at springs. Fishes occur mostly in larger habitats, while macroinvertebrates occupy a wide variety of spring sizes and types. Although non-native vegetation occurs primarily at disturbed sites, these species also occur over broad areas. The most common non-native plant and animal species that are associated with arid land springs are shown in Table 2. Refer to Bossard et al. (2000) and Whiston et al. (1992) to identify these plants. Common non-native animals found in springs are illustrated in Appendix IV.

Important Stress Factors Structuring Biotic Communities

Stresses attributed to environmental harshness and anthropogenic disturbance overlay and supplement hydrologic factors that influence spring ecosystems. These factors may act singly or simultaneously and the aquatic and riparian communities are usually structured by the factor that causes the greatest stress. As in other systems, the ecological effects of these factors are a function of their frequency, duration, and severity. Spring systems are relatively unaffected and they will recover quickly from infrequent and slight stresses, and they typically support species that are intolerant of harsh conditions. In contrast, severely stressed systems are occupied by tolerant species and recovery to pre-stress conditions will occur over a long time. Natural stress factors include disturbances from periodic drying, fire, avalanche, scouring floods, and trampling by native ungulates (e.g., elk), and aquifers that provide high water temperatures and chemical concentrations. A number of anthropogenic stress factors also disturb springs. These include diversion (ground water pumping, spring box capture and piping to troughs, channelization, etc.), impoundment, nutrient pollution, introduction of non-native plants and animals, and trampling by humans and non-native ungulates (Shepard 1993, Minckley and Unmack 2000, Sada 2001, Sada and Vinyard 2002). In a survey of 505 springs throughout northern Nevada, Sada et al. (1992) found greater than 85 percent of springs were moderately or highly disturbed by livestock and diversion. Less than five percent of springs were unaffected by human disturbances.

Highly stressed springs (e.g., high water temperatures, high concentrations of dissolved solids, subject to scouring floods or periodic drying, etc.) are biologically depauperate in comparison to springs with cooler, purer water. Life in these environments is adapted to conditions where osmoregulation and respiration are difficult (Brock 1994, McCabe 1998). Flies (Diptera) are the most common animals in harsh environments and bluegreen algae (Cyanobacteria) frequently dominate the periphyton community of hot springs. In cooler habitats where conditions are moderate, stoneflies (Plecoptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera) are common, and communities are most structured by other physical and chemical factors such as spring size and environmental heterogeneity. In montane Sierra Nevada springs, Erman and Erman (1995) found aquatic macroinvertebrate diversity was correlated with spring permanence, calcium concentration, specific conductance, pH, magnesium, and alkalinity. Aquatic communities in permanent springs generally include more species and more individuals than communities in ephemeral springs and seeps (Erman and Erman 1995). Ephemeral springs and springs with harsh environments generally have low species richness, and aquatic species in ephemeral habitats are typically vagile (animals that can fly or crawl long distances) and well adapted to colonizing intermittent habitats. Sada et al. (2005) and Fleishman et al. (in press) found that spring size and condition influenced spring biodiversity.

Sada et al. (2005) and Fleishman et al. (in press) also qualitatively assessed stress levels in relation to functional characteristics of aquatic and riparian communities at springs. They observed biotic characteristics varying along a gradient of disturbance. As stress increased, the richness in aquatic and riparian communities declined, the abundance of tolerant macroinvertebrates increased. Obligatory and facultative wetland vegetation declined and was replaced by upland species. There were also similarities between their response to natural and human-induced stresses. Drying by diversion (groundwater pumping, spring box capture, etc.) and natural drought both eliminated aquatic communities and increase upland species in the riparian zone. Scouring by flood and trampling by humans, elk, and livestock all eliminate riparian vegetation and create autotrophic conditions where highly tolerant aquatic species dominate communities. These similarities show that identifying and estimating the magnitude of stress factors is critical to defining ecological status and potential, and management goals. Aquatic and riparian communities at springs that were stressed by only anthropogenic factors differ substantially from those that are unaffected by these activities. The biotic integrity of these disturbed springs is also diminished. Changes in management can ameliorate these stresses and allow biotic integrity to be restored. This is in contrast with springs that are stressed by natural factors because their biotic integrity is comparatively unaffected by management or anthropogenic stresses.

Natural Stress Factors

Springs occur across all landforms, elevations, and aspects of the western U.S. landscape. Springs in areas with greater, and less variable, precipitation and on valley floors are usually less disturbed by natural factors than springs in drier regions and gullies and springs affected by stochastic weather events. Some of the most common natural factors that stress springs are:

- Scouring. Springs that are most susceptible to scour occur in the bottom of gullies where they are exposed to high flows during spring runoff or thundershowers. Aquatic and riparian communities that are located in gullies range from being depauperate where scouring is frequent to relatively rich where scouring is infrequent, short-termed, or minor. Springs located on the sides of gullies and washes may be unaffected by scouring, but these events may have a strong influence on their spring brook communities that are located in the gully bottom.
- Drought. Some springs are more susceptible to drying during drought than others. Compared to persistent springs, riparian communities at springs that dry include more upland and drought-tolerant species, and aquatic communities include vagile, tolerant species that rapidly colonize ephemeral systems. At springs that dry, both of these communities are depauperate in comparison with persistent springs.
- Water Chemistry. Harsh chemical conditions occur in hot springs (temperature > 20^{o}C above mean annual air temperature) and springs supported by aquifers carrying high mineral concentrations. Under these types of conditions, physiological and osmoregulatory pathways of most aquatic life breaks down and survival is not possible. Harsh water chemistry also influences the chemical composition of riparian soil, which may create harsh conditions that are poorly tolerated by many riparian plant species. Springs with harsh water chemistry have fewer species, and species that are tolerant of harsh conditions, than springs with benign water chemistry. High temperature springs are usually supported by local aquifers where groundwater is buoyed upward by hot magma that is near the surface.
- Fire. Fires are common across the western U.S., and many springs are burned frequently. Fires affect springs in a manner that is similar to their affect on lotic systems. Fires often remove large quantities of riparian vegetation and stress aquatic systems by elevating water temperature, increasing siltation, and altering pH levels through the introduction of ashes.

Spring systems recover from fire through a series of successional stages where invasive and tolerant species comprise early communities. These communities are replaced by woody vegetation and less tolerant species over time. These changes occur over a long period, and they may be interrupted if fires are frequent. Springs that are frequently affected by fires will support many invasive plant species, little woody vegetation, and depauperate aquatic communities that consist mostly of tolerant macroinvertebrates.

- Avalanche. Avalanches affect only mountain springs that are on the floor of gullies at high elevations. Springs in avalanche paths are disturbed during winter and support willow or moss vegetation. Larger woody vegetation (e.g., aspen) is absent. Where water is persistent, macroinvertebrate communities may be comparatively diverse because water is cold, high quality, and the aquatic habitat is comparatively heterogeneous due to larger substrates and substantial quantities of interstitial space. Springs in avalanche paths that dry are influenced more by this factor than by stress from avalanches.

Anthropogenic Stress Factors

Human activities have altered the physical and biological condition of most springs in western North America (Shepard 1993). Early changes were made by native peoples and settlers, who often relied on springs as water sources. It appears that activities of native peoples minimally affected springs in most areas because they lacked equipment necessary to dredge, store, or transport large quantities of water. While some arid land springs were altered by native people for agriculture (e.g., Mehringer and Warren 1976, Fowler and Fowler 1990), these activities appear to be focused on streams along the Wasatch and Sierra Nevada ranges and larger spring systems (e.g., Steward 1933, Madsen 1989). The activities of native peoples probably affected more springs in drier portions of the intermountain region (e.g., Mojave Desert) where they improved access to water by excavating shallow wells to pool water in a qanat. These springs now appear to be highly disturbed, and they are more accurately classified as wells, but these ‘springs’ are often the only water over large areas and it is difficult to determine which qanats were developed from persistent springs and which were intermittent seeps with occasional surface flow.

Settlers developed springs for homes and livestock by dredging, impounding, and often piping water to distant locations. As the population of settlers increased, changes in spring condition followed, including introductions of non-native plants and animals, and more extensive alterations that channelized spring brooks, and dried springs by diversion and excessive groundwater withdrawal. These activities affected spring biota by decreasing habitat size (both incrementally and completely) and vegetative cover, and changing aquatic and riparian community composition. This caused the loss of native species through habitat alteration, and competition and predation (see Miller 1961, Dudley and Larson 1976, Miller et al. 1989, Hershler 1998, Sada and Vinyard 2002). Changes in riparian vegetation composition and density also altered aquatic system energy budgets (changing the aquatic system from allochthonous to autochthonous) and reduced larval food and reproductive habitats for terrestrial phases of aquatic insects. These changes probably decreased food availability for many bird species (Erman 1984, 1987). These activities continue, and springs that have not been altered by these activities are few (Sada et al. 1992). The most common anthropogenic activities affecting springs are:

- <u>Trampling.</u> Most arid land springs have altered by livestock, and wild horse and burro grazing and trampling. Sada (2001) documented how trampling by recreationists affected the abundance and distribution of spring-dwelling mollusks in Death Valley, California. The impact on springs is similar to those caused by excessive grazing in riparian and aquatic systems where it has degraded riparian vegetation, and increased water temperature, the amount of fine substrates, and nutrient loading (Kauffman and Krueger 1984, Fleischner 1994).
- <u>Diversion.</u> Springs diversions include spring brook channelization and redirection, delivering water through pipes and concrete channels to tanks and reservoirs, excavating and installing spring boxes, impounding spring sources, and decreasing discharge from excessive groundwater pumping. Diversions that remove very small amounts of water may minimally affect spring biota. Activities that occur infrequently and involve small disturbances may also minimally affect biota if sufficient time passes for the spring to naturalize after each disturbance (it may take decades for a spring to naturalize after these types of disturbances). Effects of diversion are similar to the consequences of drought that dry springs or greatly reduce discharge. In general, species richness declines as diversion increases, and there are functional shifts in the structure of aquatic and riparian communities. As diversion increases, intolerant aquatic species (e.g., mayflies, caddisflies,

crenobiontics) are replaced by tolerant taxa (e.g., midges, beetles, corixids, etc.) and non-native and upland vegetation become dominant members of the riparian community.

- Non-Native Species. Many non-native plant species are detrimental to spring systems,and many of these are classified as noxious weeds. These species pose a significant impact to the ecological function of spring systems by reducing overall plant and animal diversity and by altering site hydrology. Salt cedar (*Tamarix* spp.), purple loostrife (*Lythrum salicaria*), Canada thistle (*Cirsium arvense*), knapweeds (*Centaurea* spp.), and perennial pepperweed (*Lepidium latifolium*) are the most common non-native plants affecting western wetlands. Seed germination and dissemination, and physiological characteristics of these species make them competitively superior to native vegetation, and adept at displacing native vegetation at sites that have been disturbed by water impoundments, excessive grazing and recreation. By displacing native vegetation they reduce habitat that formerly provided critical nesting, feeding and spawning habitat for wildlife species.

  A number of non-native vertebrates and invertebrates have also been introduced into springs in western North America. Mosquito fish (*Gambusia affinis*) is probably the most widely introduced vertebrate because it has been used as a biological control agent for mosquitoes throughout the world (Courtenay et al. 1984). Many species of aquarium fish have been introduced, primarily into thermal springs (e.g., goldfish, *Carassius auratus*; sailfin molly, *Poecilia latipinna;* shortfin molly, *Poecilia mexicana*). Bullfrogs (*Rana catesbeiana)* have also been widely introduced for sport. A number of self-sustaining populations of sport species of fish (e.g., rainbow trout, *Onchorynchus mykiss*, and large mouth bass, *Micropterus salmoides*) are also established in springs. Crayfish (usually *Pacifastacus lenusculus*) and red-rimmed melanoides (*Melanoides tuberculata*) (an aquatic snail) are believed to be the most commonly introduced invertebrates in western springs. Populations of aquatic species have either been reduced or extirpated as a result of these and other species being introduced into western spring systems (Schoenherr 1981, Moyle 1984, Taylor et al. 1984, Hershler 1998, Sada and Vinyard 2002).

- Pollution. Springs are susceptible to pollution from a number of activities. Pollutants may be toxic, which may exterminate aquatic and riparian life. They may also increase nutrient concentrations (e.g., nitrogen, phosphorus, etc.) that increase the growth of aquatic vegetation and bacterial abundance and lower dissolved oxygen concentrations. These changes may change intolerant macroinvertebrate communities to communities that characterize polluted aquatic systems (see Rosenberg and Resh 1993). The most common sources of pollution affecting springs are:

- Non-native ungulate activity. Wild horses and burros, cattle, and sheep often congregate around springs. This activity tramples vegetation, which diminishes riparian vegetation and eliminats a buffer that prevents silt and elevated levels of nutrients from entering the aquatic system. Fecal material is often deposited in and around aquatic systems, which elevates nutrients.
- Refuse Disposal. Disposal of solid and liquid waste in landfills and industrial and municipal waste in holding ponds produces pollutants that may leach into the groundwater and move to springs along a hydraulic gradient. Materials that most frequently enter groundwaters are chemicals from mine stockpiles and tailings, landfills, sewage treatment ponds, fertilizers and pesticides, hazardous waste disposal, and accidental spills of hazardous chemicals and waste.
- Groundwater and Injection Wells. Groundwater contamination may occur from material leaking from abandoned or improperly constructed wells. Surface water injected into the ground may enter an aquifer that supports spring discharge, causing pollution. Springs may also be affected by injection of cool water that change thermal characteristics of spring discharge.

SURVEY PROTOCOLS

The hierarchical elements that comprise the Mojave I&M Network spring inventory and monitoring program are described below. First, an office assessment is conducted to compile information about springs within the area to be surveyed (which is usually a defined management unit such as a national park, national forest, etc.). The second survey element (Level I) is a qualitative inventory to locate and characterize springs within a management unit. These surveys describe spring characteristics, spring condition attributed to natural factors and current management practices, and guidance for future management. Level I surveys may be conducted periodically to qualitatively determine temporal changes in biotic and abiotic characteristics of a spring, but Level II surveys should be conducted when quantitative monitoring and assessment information is needed. Level II surveys quantitatively measure water chemistry, aquatic habitat characteristics, and aquatic and riparian communities. These surveys are limited to priority springs in a management unit that have been identified as important sites for detailed monitoring during Level I surveys. Level II surveys are the core of spring monitoring programs because they quantitatively document temporal variability in biological and physicochemical features of a spring. They should be conducted on a regular basis to determine temporal variation in biotic communities, physicochemical aspects of the environment, and the response of springs to changes in management. These surveys require highly trained personnel to analyze water chemistry and to identify plants and animals. Selection of sites and the frequency of Level II surveys may differ as a function of management questions and funding. They may be conducted annually for several years to quantify temporal variation in their biota and environments, then reduced to once every five years if variability is low and the status of conditions is relatively secure. Level II surveys may also assess long-term changes in spring conditions over a large management area by including randomly selected springs and springs that are important to management within a management area. The number of springs surveyed to examine landscape changes in springs should be determined with input from a statistician.

Background Assessment (Data Mining)

Springs are valuable arid land resources to the public and many resource management agencies. As a result, they have been the subject of a wide variety of resource management programs. Wildlife management agencies developed many into guzzlers, and land management agencies and the public have developed many springs for recreation (e.g., picnic and camping, roadside facilities, etc.), and to support municipalities and livestock management. Water chemistry data have been collected at numerous springs during groundwater studies, and many springs have been modified for conservation of rare crenobiontic species. As a result, records showing location, development features, water chemistry, etc., may be held by several state and federal agencies. This ‘data mining’ exercise compiles and organizes this information into a database before field studies are initiated.

Level I Surveys

Level I surveys inventory isolated water features that include 1) natural springs and seeps (groundwater that flows onto the land surface through natural processes), 2) hand and mechanically dug wells (groundwater that flows onto the land surface because of vertically oriented human excavation), and 3) artificial surface water expressions or qanats, and water troughs (groundwater that flows onto the land surface because of horizontally oriented human excavation). Level I surveys are inventories that accurately locate springs, characterize salient aspects of their aquatic and riparian environments, and record the presence of important species. These are reconnaissance-level observations that focus on assessing biotic potential to facilitate management and prioritize the relative importance of individual springs within a management area. This information is neither highly detailed nor accumulated in a rigorous manner that allows statistical analysis. Collection of highly quantified data requires much more detail, time, and substantially greater funding than is necessary for Level I surveys.

These spring monitoring protocols are based on ecological studies of southern Nevada springs by Sada et al. (2005), Fleishman et al. (in press), and Bradford et al. (2003), work by R. Hershler and D. Sada during Great Basin spring surveys from 1991 to 2002, and studies conducted in the intermountain west (e.g., Meffe and Marsh 1983; Anderson and Anderson 1995, Sada et al. 2000; Sada 2000; Sada and Herbst 2005). Basic elements of Level I surveys recognize that:

- Few springs have been visited by resource managers and there are few data that describe either biotic or abiotic characteristics of individual springs.
- Springs are often difficult to locate, and existing map coordinates may be inaccurate.
- General biotic and abiotic characteristics of a spring can often be determined with relative ease, and without accumulating highly detailed information.
- Compiling this information can be accomplished quickly. Travel time to a spring is the greatest amount of time spent gathering this information.
- Biotic and abiotic characteristics of springs are influenced by elevation, spring size, aquifer affinities, disturbance stressors (natural and anthropogenic), and physicochemical characteristics of aquatic and riparian environments. It is not necessary to quantify these features with detailed accuracy to determine the ecological characteristics of a spring.
- Generally speaking, the taxonomic richness of aquatic and riparian communities is correlated with spring size (larger springs have greater discharge, deeper and wider aquatic habitat, and longer spring brooks and support more aquatic and riparian species than small springs). Ephemeral springs support a distinct, fishless and depauperate aquatic

macroinvertebrate community and riparian communities with low diversity. Persistent springs support aquatic and riparian communities that are more diverse.

- Taxonomic richness and functional characteristics of riparian and aquatic communities are correlated with the amount of environmental stress. Springs highly stressed by anthropogenic disturbances (including excessive livestock grazing, diversion, impoundment, etc.) or natural factors (e.g., affected by scouring floods, periodically dry, naturally high water temperatures or elevated solute concentrations) have fewer species, and more species that are tolerant of harsh conditions (often non-native riparian species and pollution tolerant aquatic macroinvertebrates) than minimally disturbed springs.

Field Survey Preparation

Surveyors must be trained by qualified personnel to accurately conduct Level I surveys. This can be accomplished during a 2-day training course of classroom and field studies that expose surveyors to a wide diversity of spring sizes, types, and disturbances. Surveyors must be supervised to ensure data are being properly collected, recorded, and filed. Training must also include safety instruction to prepare surveyors for working in remote regions where water is scarce.

A tremendous amount of planning and preparation are necessary to conduct Level I surveys. Before fieldwork, all equipment must be organized and tested, spare equipment purchased (e.g., batteries), and field forms printed and placed in a protective binder. Additional planning and preparation are necessary if many springs are to be surveyed over several days before returning to the office. Preliminary work should also include studying maps and filling the field form with information that can be compiled before the beginning of a field trip (e.g., spring name, map location, county, state, etc.).

Field Equipment

Limited equipment is needed for Level I surveys. All equipment should be sturdy and able to tolerate rugged conditions of being carried in a backpack or exposed to dust. All equipment should be checked prior to beginning a field trip. Extra batteries and directions and tools to calibrate instruments should be carried into the field. Calibration frequency and methods should follow manufacturer recommendations. Records must be recorded in a metadata file describing the manufacturer and model of all equipment used during field surveys. Upon returning from field work, instruments must be cleaned, and compiled data in database that includes all elements described above and shown on the field survey form (Appendix II). Key equipment necessary for a Level I survey includes:

- Survey form. At least 12 blank copies of the Level I survey form should be carried into the field each day. The forms should be printed onto ‘write in the rain’ paper.
- Maps. Locating springs requires using maps of different scales. Road maps are needed to direct travel on paved roads that lead to remote areas. The greater detail provided by USGS topographic maps is necessary to locate dirt roads and geographic features that may be important for navigation to a specific site. While it is often convenient to use 7.5 minute topographic maps, the number required for broad surveys often makes using these burdensome. The 1:100,000 scale maps are often sufficient. Maps should be reviewed prior to field work to maximize survey efficacy.
- GPS unit. This should include a hand-held data logging system to minimize recording error.
- Dissolved oxygen, pH, conductivity, and temperature meters. Meters manufactured by YSI are preferred because they are rugged, easy to calibrate, and a single instrument can measure multiple parameters.
- Watch and container of known volume (no larger than 2 liters).

<u>Field Surveys</u>

In the field, extreme care is required to protect data, and calibrate and maintain instruments. All Level I information should be compiled at the spring source, and include the upper 50 m of aquatic habitat (at larger springs). All of the aquatic habitat should be included at springs with spring brooks less than 50 m long. Although there are a number of individual elements recorded in Level I surveys, they fall into five categories, which are: 1) Recording survey date and spring location, 2) water chemistry parameters, 3) physical characteristics of the aquatic and riparian environment (e.g., spring brook length, discharge, water depth, vegetative cover, and substrate composition, etc.), 4) natural and anthropogenic factors that may be stressing the aquatic and riparian systems, and 5) the presence or absence of important animals and plants. There is error associated with all measurements and estimates. While these are often difficult to quantify, the magnitude of error anticipated for each measured or estimated value is discussed below for each parameter. It is also important to recognize that Level I surveys are qualitative, not quantitative, and designed to characterize springs at a single point in time. Compilation of rigorous quantitative data is the focus of Level II surveys, which should be conducted by specialists who are qualified in specific sampling techniques and can deliver samples to water chemistry laboratories and laboratories where plant, vertebrate, and macroinvertebrate species can be preserved, identified, enumerated, and archived.

A Level I survey form is shown in Appendix II, standard operating procedures to prevent translocation of foreign material between springs are summarized in Appendix III, and Appendix IV is a guide to assist with identifying selected important animals that may occur in springs. An example of how Level I survey information can be used to prioritize spring management and restoration is presented in Appendix V.

Level I Data Elements

The following elements comprise a Level I survey and are recorded on the data sheet shown in Appendix II:

- Date the survey is conducted. Record this in the 'month/day/year' format.
- Lead Person (Surveyor) conducting the spring survey by first letters of their given and middle names and surname (e.g., JDSmith).
- Field Note Number. Standardize the number by including the initials of the person recording data followed by the last two digits of the year the survey is conducted, then, after a hyphen, followed sequentially by the number of the spring that has been surveyed by the lead surveyor during the year (e.g., for the 21st and 22nd springs surveyed during the year 2003, JS03-21, JS03-22, etc.).
- The State where the spring is located. Record as the standardized abbreviation used by the U.S. Postal Service (e.g., CA = California, NV = Nevada).
- The County where the spring is located. This information is on maps, which can be reviewed in the office or the field.
- Locality, which is the spring name. If unnamed, record it as 'unnamed' with a brief geographical description of its approximate location, e.g., 'unnamed spring in Willow Canyon'.

- Location ID, which is an identification number for each spring within a National Park. Each Park has a standardized format for this number, such as DEVA_SPINV_ONE_01.
- Drainage Basin where the spring is located. If the spring is located within a river drainage, list the river drainage basin. If it occurs in an endorheic basin, identify the valley. This information must be compiled from maps, and it may be done while in the field or in the office. This information is important because of its relevance to aquatic and semi-aquatic species that may occur at springs.
- Township, Range, and Quarter-section Coordinates. Record from USGS topographic maps.
- 1:100,000 scale USGS map that includes the spring/seep location. Finer scale maps may be used, but 1:100,000-scale maps have greater utility because they include a greater portion of the landscape and efficiently show the array of roads that provide access to sites.
- Global Positioning System (GPS) location, and the datum of the spring/seep source. Record the UTM zone in the North American Datum of 1983 (NAD83) unless otherwise specified. Document GPS files in a gps log. All geographic information system (GIS) data layers created from GPS files must include FGDC Geospatial and Biological Profile (NBII) compliant metadata. Record PDOP or '±' the number of meters as metrics indicating accuracy of the GPS reading.
- Access. Record the ease at which the public could visit a spring. Categories 1 through 5. Category 1 = inaccessible sites, access only by cross-country hiking; Category 2 = sites that can be accessed only by arduous trail hike (e.g., > 5 miles); Category 3 = sites accessed by easy trail hike (e.g., 1 to 5 miles) and four-wheel drive vehicle; Category 4 = sites easily accessed by walking less than 1 mile or a two-wheel drive, high clearance vehicle; and Category 5 = sites immediately adjacent to high-quality gravel road or a paved road.
- Photos. These photos should be taken to show the spring and its landscape context. One should overview the spring source and looking downstream, and the second from the spring brook's end looking upstream. At larger springs, take one photo of the source and a second from a distant area that encompasses as much of the riparian area as possible. Photos should be labeled by site ID number, date, site name, Township, Range, quarter-Section location, and GPS coordinates of the point where the photo was taken. Photos

should be taken using a digital camera. Maintain a photo log with digital photograph number and description using the Location ID. Note on the field form that photos were taken.

- Spring elevation, in meters using a Thommen hand-held meter, GPS system, or interpolated from a USGS topo map. There may be substantial error in all of these measurements, but these data are adequate to 'characterize' site elevation. For more accurate elevations, estimate them from a 10-m Digital Elevation Model. Record methods used for elevation in notes section.
- Land ownership, as U.S. National Park Service, U.S. Forest Service, U.S. Bureau of Land Management (BLM), tribal, military, private, or other (e.g., State lands, U.S. Fish and Wildlife Service, municipality, etc., write out the name of the owner). This information is most easily determined using BLM Surface Management Maps (1:100,000 scale).
- Spring Type, as: **Rheocrene** (a spring that discharges into a defined channel), **Limnocrene** (a spring that discharges into a ponded or pooled habitat before flowing into a defined channel), **Helocrene** (similar to a Limnocrene, but marshy and comparatively shallow, not an open pond or pool), or unknown. In some areas, springs have been altered by native peoples or settlers by excavating the source to create a **Qanat**, which is a type of hand-dug well. Where these occur, water is regionally scarce and where surface water is scarce. Also record if a site is a mechanically dug **Well** (usually with rock, metal, or plastic casing). Record **Other** when the source is something else, such as a cliff face, boil, etc. Record spring type as **Unknown** at highly disturbed sites where no semblance of natural characteristics of a spring remains, or where the spring is dry. Examples of disturbances that prevent identifying spring type include impoundment by dikes, sources in a spring box, or dredging and filling to capture water in a pipe leading to a trough. Spring alterations and spring condition are assessed, and recorded, in the Site Condition section below. If further description is necessary, it can be summarized in the Notes Section.
- Spring Discharge, estimated in liters/minute. It is difficult to estimate the discharge of most arid land springs because they are small, water is usually shallow and broadly and unevenly spread over a wide area, and areas with moving water are often very limited. Accuracy is also a relative term because discharge often changes throughout the day, seasonally, or annually, which minimizes the effectiveness of single measurements to

precisely quantify long-term discharge characteristics. Highly quantitative discharge recording is a component of Level III surveys.

- Preferably For Level I surveys, measure discharge by recording the length of time required to fill a container with a known volume. Unfortunately, it is usually not possible to use this method because most arid land springs are very small and it is difficult to capture water in a container (their small size also prevents using a water current velocity meter to measure discharge). While these factors limit the precision of most discharge estimates, the amount of water issuing from spring sources should be estimated in liters/minute. These estimates combined with water width, depth, and spring brook length provide sufficient information to characterize spring discharge rates.
- Spring Brook Length, measured in meters. Use a tape to measure distance from the spring source (upstream limit of surface water) to the downstream limit of surface water.
- Average Water Depth. This is a qualitative estimate of the vertical distance from substrate to water surface (in centimeters) that is found throughout the aquatic habitat.
- Estimate the average Water Width. This is a qualitative estimate of the distance covered by water (and perpendicular to its flow) that lies between banks of the spring brook, less islands, emergent rocks, etc., in centimeters. (This is formally described as the length of wetted contact between flowing or standing water and the spring brook bank in a vertical plane at right angles to the direction of flow.)
- Dissolved Oxygen Concentration, (D.O., in mg/liter) using a field meter (e.g., YSY, Oakton, etc.). The meter should be kept clean, have fresh batteries, and calibrated daily following the manufacture's recommendation. All water chemistry parameters should be measured as close to the spring source as possible and in flowing water if available. The location of the measurements not taken at the source should be noted.
- Water Temperature. Water temperature is an important factor structuring aquatic communities, and may give insight into source waters. This measurement (record in degrees Centigrade) is easily taken with a meter used to measure dissolved oxygen or conductivity, and it is necessary to calibrate some analytical meters (e.g., conductivity). Field measurements can be easily made using a high quality meter. Calibration is not necessary for temperature measurements using a high quality meter.

- Conductivity (also called electrical conductance). Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. This ability is dependent on the amount of dissolved ions, and is therefore an indicator of total dissolved solids in the solution. Conductivity provides insight into water sources and it is important to aquatic life because of requirements to maintain osmoregulatory balance. Conductivity is measured using a field meter (e.g., YSY Model 30, Oakton Acorn CON 5, etc.) and recorded in mhos, µmhos, or microsiemens. The meter should be kept clean, have fresh batteries, and calibrated daily following the manufacturer's recommendation. Most high-quality meters do not require frequent calibration. Salinity may also be measured, but the greatest amount of information regarding a spring's ability to conduct an electrical current is provided by measuring conductance.
- pH. pH is the measure of hydrogen activity, which indicates the acid/basic qualities of water. It can be measured using a hand-held field meter that can be calibrated (such as Oakton Model, pHtestr2). Low (<6.5) and high (>8.0) pH environments are stressful to aquatic life. The meter should be kept clean, have fresh batteries, and calibrated daily following the manufacturer's recommendation. These meters generally have a limited life, and a backup meter should always be carried.
- Emergent Cover. Estimate to the nearest 10 percent the vegetative, debris, or other material that arises within the water width and covers the water surface.
- Vegetative Bank Cover. Estimate to the nearest 10 percent the proportion of spring brook banks that is covered by live vegetation.
- Substrate Composition. Qualitatively estimate using a Wentworth particle scale analysis, which describes the substrate by the proportional composition of materials, where materials are classified as: fines (<1 mm), sand (1 mm - 5 mm), gravel (>5 mm - 80 mm), cobble (>80 mm - 300 mm), boulder (>300 mm), or bedrock. Size is defined as the minimum particle size of substrate as measured on a two-dimensional axis, as would pass through a substrate sieve.
- Important animals and plants. Note the presence of important animal (see Tables 1 & 2, & Appendix IV) and plant species. Important species are those that occupy or use the aquatic or riparian environments, and noted during the survey. This list may differ among management areas, and it should be compiled accordingly. It should include: 1) rare

species (crenobiontics, amphibians, bats, birds, mammals, etc.), 2) species that are indicative of spring characteristics (e.g., species of woody vegetation, obligatory and facultative wetland vegetation, crenobiontics), and 3) non-native species. Species should be identified, if possible (many surveyors will be unable to identify species). If a species cannot be identified, the presence of plants and animals within any of the important groups should be recorded (e.g., native fish and trees, mollusks, aquatic insects, non-native species, etc.). Also note the presence of important terrestrial species, such as bats, if seen. Noting the presence of these types of species provides information that assists with identifying management issues and can be used to determine management priorities.

Important species occupy a wide variety of habitats, and they may be very scarce or abundant. Most aquatic macroinvertebrates can be readily captured with a kitchen sieve (~ 1 mm mesh) that is used to collect animals from aquatic vegetation, debris, or substrate. Each species prefers a distinct microhabitat, and sampling must include all habitat types that occur in a spring (e.g., sand, gravel, & cobble substrates, all types of emergent and submerged vegetation, all current velocities, mid-channel, backwater, and lateral habitats). Crenobiontic macroinvertebrates are generally common in specific habitats, but they may be scarce remaining areas within the aquatic system. Time required to survey for crenobiontics varies with spring size, but crenobiontic surveys should focus on upstream reaches of a spring brook because crenobiontic abundance decreases downstream. Large springs usually require more sampling than small springs because they support a greater diversity of aquatic habitat types. In small springs (spring brook < 100 m long), sample for a minimum of 15 minutes, in larger springs sample for a minimum of 25 minutes. Create a list of important plant and animal species that are likely to occur within a survey area on the Level I survey form.

- Important native plant species. Note the presence of important native plant species (e.g., rushes [Family Juncaceae], cattails [*Typha* sp.], reeds [*Scirpus* sp.], watercress [*Rorippa* sp.], spikerush (*Eleocharis* sp.), sedges [*Carex* sp.], yerba mansa (*Anemopsis californica*), mesquite (*Prosopis* sp.), wild rose (*Rosa* sp.), cottonwood (*Populus freemontii*), willow (*Salix* sp.), or other large woody vegetation in spring brook or riparian zone. Identify if possible; most species will be willow, cottonwood, mesquite, spikerush, or rushes. Circle species on the list provided on the survey form.

Modify the list to include taxa that the management believes are important, if necessary.

- Important native animals. Note the presence of important native animal species (e.g., crenobiontics, amphibians, fishes, ostracodes, amphipods, finger clams, etc.).
- Important non-native plants and animals. Note the presence of non-native species (Table 2). Non-native plants that most likely occur at arid land springs include salt cedar (*Tamarisk* sp.), palm trees (Family Arecaceae), arundo (*Arundo donax*), and white top (*Cardaria pubescens*). The most likely non-native animals include mosquito fish (*Gambusia affinins*), bass (*Micropterus* sp.), trout, crayfish, and red-rimmed melania (*Melanoides tuberculata*).

- Site Condition. This evaluation qualitatively identifies 1) disturbance factors stressing a spring and 2) the amount of stress of each factor on the spring environment. Harsh chemical conditions are not noted in this section, but can be easily determined from water quality and conductance measurements. Determine factors causing stress by looking for evidence of natural and human caused disturbances. Influences of flooding are indicated by location of a spring in the bottom of a gully, presence of a naturally incised channel, and usually a paucity of vegetation. The presence of pipes, dikes, or spring box indicates modifications for diversion. Abundance of hoof prints and droppings, and evidence of grazing indicates ungulate use of a spring. The presence of campsites and trash indicates recreation. The most common stressing factors are listed on the field form, and the appropriate factor(s) affecting a spring should be circled. Disturbance may be influenced by multiple factors such as trampling by intensive livestock and diversion into a trough; recreation use along a spring brook that tramples vegetation and the spring brook is channelized away from areas used for picnicking. Circle each appropriate factor. If other factors are evident, circle Other and briefly describe in the Notes Section.

- Categorize each spring as undisturbed, slightly, moderately, or highly disturbed, and circle the appropriate category on the survey form. When entering data into a database, identify these categories as: 1 = undisturbed, 2 = slightly disturbed, 3 = moderately disturbed, and 4 = highly disturbed for easier data analysis. Springs with these levels of disturbance appear as:

- **Undisturbed** springs have been unaffected by recent or historical factors or activities. All evidence of trampling, diversion, fire, or drying is absent. Since most springs have been altered by humans, drought, fire, or flood, these types of springs are rare and most undisturbed springs are naturalizing from past disturbances.

- **Slightly Disturbed** springs exhibit little evidence that vegetation or soil have been disturbed. Vegetation shows slight signs of browsing and foraging, and animal footprints and scat are present by not prominent. Recreation may be evident, but its impact on riparian or aquatic environments is minimal. Evidence of fire or flooding in the distant past may be visible but these events occur infrequently; riparian vegetation is vigorous.
- **Moderately Disturbed** springs exhibit evidence of recent, comparatively high disturbance. Use by native and non-native ungulates, and recreation has reduced vegetation height and coverage from natural conditions. Vegetation covers, hoof prints, footprints, and scat are common. Where there has been diversion, a spring box may be present but at least 50% of natural discharge remains within the natural spring brook. Neither the spring nor spring brook has been impounded. Where flooding or fire is apparent, > 50% of the spring brook banks are covered by vegetation; flood and fire are infrequent and the spring is naturalizing.
- **Highly Disturbed** springs have little similarity to undisturbed springs. Less than 50% of their banks are covered by vegetation, their spring brooks contain < 50% of natural discharge, they are impounded or dredged, or spring boxes collect water. All impounded springs are highly disturbed because flow has been interrupted and functional characteristics of the aquatic system have been highly altered. Hoof prints and scat are abundant where ungulate use is heavy, and campsites are large, trashy, and vehicle use evident. These activities have decreased vegetative cover of spring brook banks to < 50%. Springs affected by drought (springs that are dry when sampled or experience seasonal or annual drying) should also be categorized as highly disturbed. These springs can be identified by the presence of upland riparian species and absence of obligatory wetland plants. Riparian vegetation is sparse at

springs recently affected by fire or flooding, there is recent evidence of elevated discharge, and spring brooks are usually incised.

- Notes, to include additional pertinent information. This may include observations further describing site condition, use of the spring by other animals (e.g., bats, wild horses, etc.), clarification of difficulties in accessing the spring, etc.
- Sketch, of the spring if necessary. This may be very important in spring provinces where sample sites may be close to one another and map/GPS coordinates weakly describe the relative location of sample sites.

Level I Quality Assurance

Training is needed for field crews to gain experience necessary to conduct a Level I survey. The accuracy of measurements and estimates made during these surveys are described above for each data element, but additional evaluation is needed to determine if additional training is needed to ensure survey accuracy. Approximately 2 weeks after a crew begins Level I surveys, the trainer should spend additional time in the field to answer questions, evaluate how data are being accumulated, and determine if there is consistency between crew members. This evaluation should occur in the management area that is being surveyed and it should be conducted on springs not previously visited by the crew or the trainer. The evaluation is conducted by 1) comparing forms for a single spring that have been completed independently by each crew member and 2) completing an audit form (Appendix VI) for each crew member. No additional training is needed if agreement between the records of each crew member are within confidence limits described above for each Level I survey element, and if there is an affirmative answer to all questions on the audit form. Training should continue until these two conditions are met.

Level II Surveys

Level II surveys quantify biotic and physicochemical characteristics and provide the basic elements of long-term spring monitoring programs. As such, the number of springs, duration of surveys, and goals and purposes of monitoring should be developed by a team of managers, ecologists, and hydrologists. Funding may limit the number of springs included in Level II surveys, and managers will be challenged to implement monitoring programs that consider specific management issues. These surveys include water chemistry analyses, quantitative description of aquatic habitats, and the identification and enumeration of riparian and aquatic taxa to species or genus, respectively. Information provided by these surveys will: 1) quantify baseline conditions at the beginning of a monitoring program and 2) quantify changes in biotic and abiotic characteristics of springs under existing or newly implemented management strategies. Level II surveys may include only springs where the effects of altered management strategies needs documenting, and they may be implemented to determine changes in biotic and abiotic condition of springs across the landscape. For landscape monitoring programs, temporal changes in condition are monitored at a number of randomly selected springs within a management area. A statistician should be consulted to determine the number of springs included in this type of monitoring program. Aquatic habitat data, benthic macroinvertebrates (BMIs), vertebrates, and water samples may be collected by minimally trained personal, but highly trained personnel are required to measure water chemistry parameters, identify BMIs, vertebrates, and plant species, and interpret data. Taxonomic identifications should be verified and submitted to taxonomic specialists for quality assurance and quality control. Analysis and interpretation of ecological and chemical information should be conducted by ecologists and groundwater geochemists, respectively.

Level II surveys should be conducted annually and when the accuracy of plant and BMI identification is maximized (i.e., during summer). Annual sampling should continue until the bounds of temporal variation in physicochemical and biotic characteristics are documented, which should be within three to five years. After this period, monitoring goals and purposes should be reassessed and the frequency of monitoring changed accordingly. The frequency of monitoring is a function of threats to the system (frequency should be correlated with the level of threat to a system), requiring a need to understand how biological and physicochemical characteristics of a spring respond to natural factors and to changes in management.

Trends in temporal variability in biotic and physicochemical components of the aquatic and riparian systems should be assessed using community metrics (e.g., Kendall tau, Spearman's rank correlation, community index of similarity, species richness [Margalef's *d*, Shannon H], eveness, etc.), and non-parametric statistical methods (e.g., Kruskal-Wallis analysis of variance, chi square test, etc.). A statistician or qualified ecologist should be consulted to determine appropriate analyses that can be used to fulfill goals and purposes of monitoring.

Guidelines for Level II surveys are described below under categories for water chemistry, biota (aquatic and riparian vegetation), and aquatic habitat characteristics. A basic Level II survey form is shown in Appendix VII. Level I and Level II survey forms have a number of common elements that record location, spring name, etc. These common elements are measured or estimated and recorded following guidelines for Level I surveys. All elements of the Level II form need not be completed by each type of survey nor during frequently conducted surveys. For instance, it is not necessary to collect water chemistry during riparian surveys and geological information needs to be recorded only during the first survey conducted by a team. Unique elements of the Level II form include:

- Identifying the type of survey being conducted (e.g., water chemistry, aquatic habitat, aquatic macroinvertebrates, or riparian vegetation).
- Identifying collections made and where they are deposited (e.g., in a museum or archives that are affiliated with the management area being studied).
- For water chemistry analyses and BMI identification, recording the name and location of the analytical laboratory.
- Recording several features that more fully describe characteristics of spring physiography and disturbance. These are:
    - The percent spring brook slope using a hand-held inclinometer, or a comparable sight level. Accuracy of these estimates should be $\pm$ 1 percent.
    - Spring brook aspect, using a compass to record the direction of flow in the spring brook in degrees from magnetic north (e.g., if it flows southeastward its aspect would be approximately 135^{o}).
    - Basic characteristics of local geology, by identifying the type of rocks that are exposed near the spring source (e.g., granite, basalt, limestone, etc.).
    - Type of ungulate use at a spring. If dung is present, estimate how recently the animal visited the spring by recording it as being fresh (within the past 2 days), recent (within the past month), or old (greater than one month). Also estimate its abundance within 5 m of both sides of the spring brook as light (< 1% soil coverage), moderate (> 1% < 10% coverage), and heavy (>10% soil coverage).

    - Use of the spring for recreation. Record the type of use (e.g., picnicking, camping, etc.) and if trash is light, medium, or heavy.
    - Diversion of the spring. Record if the diversion is a spring box, trough/tank, pipe, and if the spring brook is channelized, ditched, or impounded. Diversions at a spring may include several development features.
- Notes, as appropriate to more fully describe the spring or other factors that may be important.

Level II Spring Monitoring: Water Chemistry

Determining the water chemistry of a spring is important because it indicates aquifer geology and the origin of water, and chemicals that structure biotic communities and affect human health. A number of common measurements are important to assess each of these characteristics in a spring, and some unique determinations are necessary to assess aquifer characteristics and water quality. Programs that examine spring/aquifer relationships measure water geochemistry (ergo ionic concentrations and ratios, and isotopes). These analyses can be used to determine geological characteristics of an aquifer and identify the source and residence time of water. Assessments that focus on ecological relationships measure factors that stress aquatic life and riparian vegetation (e.g., water temperature, electrical conductance, pH, dissolved oxygen, alkalinity, nutrients, etc.). Water quality programs are concerned with toxic compounds, nutrients, and harmful bacteria. Important determinants for each Level II assessment are shown in Table 3, and the relevance of each compound to monitoring is summarized in Appendix IIX.

Chemical analyses for Level II surveys should address specific management issues within a region or at individual springs, and focus on the goals and purposes of monitoring. For example, programs monitoring the effects of groundwater pumping should focus on analyses that provide insight into aquifer geology (anions and cations), groundwater provenance (stable isotopes), and circulation time and groundwater renewability (radioisotopes and cholorfluorocarbons). Water quality monitoring should focus on surface pollution and groundwater contamination issues. Although resource managers may accurately identify potential resource issues, specialists should be consulted to design a monitoring program.

Groundwater geochemists, water quality specialists, and ecologists should be consulted for programs to monitor aquifer dynamics, water quality, and ecology, respectively.

Some water chemistry measurements may be accurately made in the field and others should be made by a certified laboratory. Analyses using field kits are much less accurate than laboratory analyses for many compounds, which limit their usefulness for providing information that accurately documents temporal variability. Their utility may also be limited by their large size (which makes transport to remote sites difficult) and errors attributed to the number of different people taking measurements. Water temperature, dissolved oxygen, electrical conductance, and pH can be accurately measured in the field using high-quality instruments that can be easily calibrated. Recommendations for these meters are the same for Level I and II surveys. For all other measurements, water should be collected and delivered to a laboratory. Water should be analyzed by a laboratory that is certified by the U.S. Environmental Protection Agency and follows standard Chain of Custody (COC), standard operating procedures. And quality assurance/quality control procedures that are within acceptable error limits.

Field Methods

Trained technicians can collect water samples if they exercise the precision necessary to prevent contamination and deliver samples to the laboratory. General guidance for collecting samples is provided below and detailed information is in Wilde et al. (1999). Due to frequent changes in techniques and requirements of individual laboratories, the laboratory that is selected to analyze samples should be contacted to determine preferred sampling procedures, sample volumes, and equipment. Table 4 provides general guidelines for collecting water samples to be used for geochemical analysis. In general, 500 ml of sample is sufficient to determine the complete list of major ion parameters. If samples have high concentrations of dissolved ions or if sampling a smaller volume is desirable, 250 ml will generally suffice. Collections for nitrite should be made in an individual, 50 ml bottle.

Table 3. Chemical compounds and biological indicators (determination) that should be included in Level II surveys for assessing spring/aquifer affinities, chemical factors structuring biotic communities, and water quality. The list of determinations for a monitoring program will differ in response to the goals and purposes of the monitoring program, and whether monitoring is conducted to assess aquifer characteristics, biotic communities, and/or water quality.

Determination	Aquifer Characteristics	Biotic Communities	Water Quality
--------------------------	--------------------	-----------------------	-----------------
Water Temperature	X	X	X
Dissolved Oxygen (DO)	X	X	X
Electrical Conductance (EC)	X	X	X
pH	X	X	X
Alkalinity	X	X	X
Chloride	X	X	X
Sulfate	X	X	X
Major Cations			
Sodium (Na)	X	X	
Potassium (K)	X	X	
Calcium (Ca)	X	X	
Magnesium (Mg)	X	X	
Silica Dioxide (SiO_2)	X	X	
Iron (Fe)	X	X	
Deuterium ($^2H_2$)	X		
Oxygen-18 (^{18}O)	X		
Chloroflorocarbons (CFCs)	X		
Nitrate (NO_3)		X	X
Fecal Indicator Bacteria		X	X

Table 4. Field sampling and preservation protocols for major ion analysis of water samples.

Determination	Standard/Minimum Sample Size (ml)	Preservation	Maximum Storage
----------------	----------------	-----------------------	-------------------------
Alkalinity	200/100	Refrigerate	14 days
Chloride	50/25	< 25ºC	Indefinite
Sulfate	50/25	Refrigerate	28 days
Major Cations Na, K, Ca, Mg, Fe	100/50	< 25ºC, add HNO_3 to pH < 2 in lab	6 months
SiO_2	50/25	Refrigerate	28 days
NO_3*	50/25	Refrigerate/Acidify	48 hours/28 days
$^2H_2$	30/30	None	Indefinite
^{18}O	30/30	None	Indefinite

*Preserving sample up to 28 days without refrigeration requires collecting the NO_3 sample in a separate bottle and acidify to pH 2.0 using sulfuric (H_2SO_4) or nitric acid (HNO_3) solution of 1 ml/l or 2 ml/l concentrated acid, respectively. Prorate the quantity of acid to add in relation to the water sample size.

Glassware/Plastic

Type of plastic sample bottle should be considered. Fluorocarbon polymers may not be appropriate because they are a potential source of fluoride to samples. Polypropylene and polyethylene are suitable. Bottles should be triple rinsed with sample before filling. The volume to be sampled (i.e., bottle size) is usually determined by the laboratory. All glassware and plastic used during fieldwork should be cleaned according to a standard procedure that is recommended by the laboratory that analyzes water chemistry. The following cleaning process is recommended when possible for bottles that will be used for trace element sampling or bottles that will be reused for any sampling: scrub bottles with detergent; triple rinse with tap water; soak 10 to 15 minutes in liquid detergent bath; scrub; triple rinse with tap water; triple rinse with deionized water (DI); soak 10 to 15 minutes in 6 N hydrochloric acid (Certified ACS Plus Grade) bath; triple rinse with tap water; and triple rinse with DI. The acid stock solution should be 12 N and diluted 1:1 with DI. A blank (sample bottled filled with DI) should be analyzed to verify cleanliness of sample bottles for trace element samples (note, a sample of the DI water is required to determine what is from the bottle).

Bottle Labeling

It is extremely important that bottles be properly labeled, since information on labels is carried over onto field data forms. To avoid smudging, use a waterproof label and a fine-tipped permanent marker. If possible, pre-label the sample bottles before entering the field. On the label, include site name, sample date, field note number, name of surveyor/sampler, GPS sample location, sample preparation, and analyses to be conducted. A suggested label format is shown in Appendix IX.

Collecting Samples

Collect water samples from the spring source and carefully avoid collecting debris, vegetation, or animals in the bottle. Triple rinse collection bottles and caps with spring water before filling with sample. If acidifying, use a dropper and ultra-pure sulfuric (H_2SO_4) or nitric acid (HNO_3). Label each sample (Appendix IX) and store in an ice-chest with cold packets or ice until it is delivered to the laboratory.

Blank and Control Samples

Blank and control samples should be collected for each series of samples collected within a management area. A blank sample is a bottle of DI that is given to the laboratory. This serves to verify results and methodology, and it provides additional insight into cleanliness of equipment, awareness of operator error, and problems with field kits. A control campale is a solution of known ion concentrations that is submitted to the laboratory as a field sample. This sample is analyzed to verify laboratory results.

Field Equipment

Meters

- pH meter and calibration standards
- EC meter and calibration standards
- DO meter

Bottles

- For major cations and anions (sample size depends on laboratory methods)
- For dissolved metals (acid-cleaned bottles; sample size depends on laboratory methods)
- Labels printed on waterproof paper

Other Equipment

- Ice-chest with re-freezable ice packs
- DI water
- Extra batteries (size as necessary for each meter)
- Ultrex nitric acid in a bottle with a dropper (for sample preservation)
- Pens/pencils/permanent ink markers
- Tools (screwdrivers, wrenches, pliers, etc.)

Level II Spring Survey and Monitoring: Aquatic Habitat Characteristics

This sampling is conducted to describe the physical habitat characteristics occurring in a spring and spring brook through quantitative measurements and qualitative assessments. These sampling strategies follow general guidelines used to quantify characteristics of the aquatic habitat in streams. Parameters measured for this sampling are shown in Tables 5 and 6.

Field Methods

Parameters are measured along transects that are oriented perpendicular to the direction of streamflow. Parameters in Table 5 describe channel characteristics and those in Table 6 describe aquatic habitat features within the wetted width. These parameters are defined in Appendix X, and a field form for this sampling is in Appendix XI. At springs where spring brook length exceeds 100 m, channel morphology parameters are measured along transects that are spaced at equal intervals from the spring source to 100 m downstream. At springs where spring brooks are less than 100 m, transects should be evenly spaced along the entire length of spring brook. The number of transects that are measured at a spring is relative to the wetted width of the spring brook, such that parameters in Table 6 are measured at a minimum of 50 points. In narrow spring brooks (< 25 cm), parameters in Table 6 should be measured at three equally spaced points across each transect. In wider spring brooks (> 25 cm), parameters in Table 6 should be measured at five equally spaced points across each transect. As such, the number of transects measured at a spring will vary in relation to the wetted width of a spring brook (e.g., 14 transects in narrow spring brooks and 10 in wide spring brooks). Varying the number of measurements taken across transects in narrow and wide spring brooks is necessary because the interval between equally-spaced points across the wetted width is exceedingly small in narrow spring brooks and it is difficult to distinctly measure the depth, velocity, etc., of separate points. Parameters shown in Table 5 are measured either on both stream banks (e.g., bank overhang) or across the transect (e.g., wetted width and canopy cover). Measure canopy cover using a concave densiometer following techniques of Platts et al. (1987). Measure current velocity at 60 percent water depth using a 20-second average with top-setting wading rod and a Marsh-McBirney Model 2000 portable current meter.

Table 5. Parameters, units of measure, or estimates, to describe spring brook channel characteristics. Wetted width and canopy cover are to be measured along each transect across the spring brook. Bank overhang and bank angle are assessed at points where each transect intersects a spring brook bank. Sample size shows the number of measurements to be made in each spring brook during each sample date. cm = centimeters. A description of parameters is in Appendix X.

Parameter	**Units**	**Sample Size**
----------------------------------	------------	-----------------
Wetted Width	cm	10
Spring Brook Bank Canopy Cover	Percent	10
Spring Brook Bank Overhang	cm	20

Table 6. Parameters and units of measure to describe characteristics of the wetted width (mm = millimeters, cm = centimeters, cm/sec = centimeters per second). Measured each parameter at evenly-spaced points along transects described in Table 1. Sample size shows the number of measurements made in each spring brook during each sample date. ** indicates estimated parameters. Description of parameters is in Appendix X.

Parameter	**Units**	**Sample Size**
----------------------------------	-----------	-----------------
Water depth	cm	30
Mean water column velocity	cm/sec	30
Substrate size	mm	30
Embeddedness	percent	30
Aquatic vegetation depth	cm	30
Submerged detritus depth	cm	30

Collect aquatic habitat data by first walking the spring brook, estimating its width, and determining if data in Table 6 will be collected from three or five points across the wetted width. If average width is < 25 cm, three measurements will be made across 14 transects and if > 25 cm, five measurements will be made across 10 transects. Use the tape measure to measure spring brook length. Determine spacing between transects by dividing spring brook length by the number of transects to be measured. Use the tape measure as a transect by securing both ends and suspending the tape at least 3 cm, but no more than 10 cm, above the surface of water. Locate the first transect approximately 1 m downstream from the upper limit of water at the spring source. Measure the wetted width as the length of water (to the nearest 5 cm) lying under the tape. Islands and emergent rocks are not included in this measurement. Measure bank overhang where the tape intersects each bank, and estimate cover using the densiometer. Determine spacing between measurement points along the wetted width (Table 6) by dividing the wetted width by the number of points to be measured along the transect. Begin at the left bank (looking upstream) and locate the first measurement point at a distance from the bank that is one-half of the interval between the equally spaced points across the transect. Space all other points at the necessary interval. At each point, measure mean water column velocity (60 percent of depth as determined using a top-setting wading rod), water depth, substrate size (measure by picking up the substrate and holding it against the tape for measurement; after measurement, replace substrate in the spring brook), and the depth of aquatic vegetation and submerged detritus. Continue taking these measurements along equally spaced transects down the entire length of spring brook. Record measurements that are shown on the form in Appendix XI.

Field Equipment

- Metric fiberglass tape measure, 30 m minimum
- Plastic ruler with metric measurements
- Model 2000 Marsh-McBirney portable current meter with top-setting wading rod
- Clipboard
- Level II survey form and data form shown in Appendix XI
- Concave densitometer
- Pocket calculator to calculate distance between equally spaced transects and points across the wetted width

Level II Spring Survey and Monitoring: Aquatic Biota

The size and environmental characteristics of most springs require unique sampling methods to collect biological data. Gear must be modified to accommodate small habitats, and vegetation surveys must describe vegetation laterally (on both sides of the spring brook) and along the gradient from source to terminus. Additionally, sampling (particularly in the aquatic systems) must be conducted in a manner that causes minimal disturbance. Contrary to sampling in larger systems where samples usually disturb a small portion of the environment (e.g., several riffles in a stream or river), springs are small systems where a relatively large portion of the environment can be easily disturbed by sampling. Spring sampling must involve a comparatively small portion of the habitat so that it does not inadvertently alter the aquatic environment and concomitantly alter community structure or decrease the abundance of individual species.

Level II aquatic surveys are designed to compile a taxonomic list and quantify structure of vertebrate and BMI communities. Basic tools to sample these communities are also used in lentic and lotic environments (e.g., Barbour et al. 1999), but the small size of most springs often requires using equipment that is designed for small habitats. Whereas BMIs are sampled using a D-frame net in lotic systems, they are too large for most springs and should be replaced with a 4 in to 6 in aquarium-size net with 250-micron mesh.

Field Equipment

In addition to equipment necessary to conduct Level I surveys, Level II surveys require materials to collect and preserve specimens for laboratory analysis. Key equipment necessary for Level II surveys includes:

- Nets. The wide diversity and size of springs requires that several net sizes should be taken into the field. To collect invertebrates, the mesh size of nets should not exceed 250 microns to ensure that small invertebrates are collected. A D-frame net should be included (to sample larger springs) and smaller aquarium nets (‘brine shrimp’ nets are preferred) included for sampling small springs. The D-frame net may be used to collect fish from some springs, but seines (approximately 5 m long, 1 m high, and ¼ in mesh) and minnow traps should also be taken to collect fish from larger springs.
- Preservative. Aquatic invertebrates should be preserved in 90% ethyl alcohol (EtOH). Fish should be fixed in 10% formalin for approximately 48 hours then transferred to 75% EtOH for preservation. All preservation materials must be in metal or plastic containers. The chemicals must be handled and stored following health standard operating procedures that are provided by the agency funding the surveys or from the laboratory analyzing water samples.
- Collection bottles. Biological samples should be preserved in wide-mouth plastic bottles with a minimum capacity of 250 milliliters.
- Sample labels. Labels for individual samples should be prepared before conducting field work. They should be prepared on ‘write-in-the-rain’ paper and include: sample date, field note number, lead surveyor, sample location (state, county, township/range/quarter-section coordinates, and UTMs), and spring name.
- Buckets. Several plastic buckets should be taken for field processing of invertebrates and fish.

Field Methods

Macroinvertebrate Samples

Collect ‘grab’ samples of aquatic macroinvertebrates by roiling substrates and capturing material that washes downstream into a 250-micron mesh net. The type of net used is relative to spring size. A D-frame net is suitable for larger springs and a small, aquarium-size net is suitable for small springs. All of the available aquatic habitat types (e.g., banks, mid-channel, gravel, sand, cobble, boulder, and bedrock, emergent and submerged aquatic vegetation) should be sampled in a spring for approximately 20 minutes (small springs will require less time to sample than large springs). Immediately preserve samples in 90 % EtOH in plastic bottles, usually 250 ml bottles are sufficient. Return samples to a qualified laboratory for sorting, identification, and enumeration.

Label each sample with internal tags written on write-in-the-rain paper.

Vertebrate Samples

Collect aquatic vertebrates using seines, minnow traps, dipnet, or electrofisher. Record species, count the number of individuals captured for each species, record the amount of effort expended for capture (e.g., time spent sampling, number of minnow traps used, etc.), and preserve voucher specimens. Preserve a minimum of three individuals of each species by immediately placing them in a plastic bottle with 10% formalin. Label each sample with internal tags written on write-in-the-rain paper. These specimens should be deposited in a regional natural history museum.

BMI Laboratory Procedures

Processing BMIs requires training and diligent attention to standardized procedures that provide for quality assurance and quality control. Laboratory procedures for Level II surveys should follow general processing and BMI identification guidelines that have been developed for bioassessment studies (e.g., Barbour et al. 1999). While each individual laboratory follows slightly different guidelines, the laboratory involved with Level II studies should operate under standardized procedures that are similar to those summarized below:

Chain of Custody

A COC form must be maintained to track vertebrate and BMI samples from the field to the laboratory and then to their final storage area. The following procedures should be employed for the COC:

- A COC must accompany all samples accepted into the laboratory. Upon delivery, a Laboratory Number must be assigned to each sample. This number must be recorded on the COC and cross-referenced to each individual sample.
- When all samples listed on the COC are accounted for, then the individual delivering the samples must sign the “Released By” portion and the laboratory personnel must sign the “Received By” portion of the COC. The original COC must remain at the laboratory, and a copy retained by the project supervisor.

- Samples and COCs must be kept in a safe depository until BMI processing, identification, and enumerations are complete. The COC must also be processed, maintained, and accompany voucher specimens and samples submitted for verification, and for final curation by a qualified repository. A copy of each COC must also be maintained in permanent laboratory records.
- Samples should be released from the laboratory only when the COC is properly completed and samples are accounted for release.

Data Handling and Management

Taxonomic information must be recorded on a Macroinvertebrate Laboratory Bench Sheet. The bench sheet must include the following information: watershed or project name; sampling date; sample identification number; date of subsampling; name of subsampler; remnant jar number; taxonomy completion date; name of taxonomist; taxonomic list of organism and enumeration; total number of organisms; total number of taxa; list of unknowns and problem groups and comments.

Taxonomic information must be transcribed from the Bench Sheet into an electronic database that is compatible with the Ecological Data Application System. Transcriptions for each sample must be reviewed by no fewer than two additional people to verify that information in the database is the same as information on the Bench Sheet.

Macroinvertebrate Sample Processing

The following materials must be maintained in the laboratory while processing all samples. Dissecting microscopes, standard size sieve (0.5 mm), griddled picking trays, wide-mouth glass jars, glass petri dishes, vials, standardized taxonomic lists, taxonomic keys, 70% EtOH/5% glycerol, fine dissecting forceps, waterproof paper, pencils, laboratory bench sheets, random numbers table, and COC form.

All BMI samples accepted into a laboratory must be examined using the following procedures:

Step 1. Record receipt of all samples into the laboratory on the BMI Long-in sheet. Data on this sheet must contain all information from the sample container label.

Step 2. Retrieve the sample from the sample depository and cross-check the sample number with the bioassessment laboratory number on the COC.

Step 3. Empty the contents of the sample jar into the # 35 sieve (0.5 mm mesh) and thoroughly rinse with water.

Step 4. Once the sample is rinsed, clean and remove debris larger than 2 inches. Remove and discard green leaves, twigs, and rocks. Do not remove filamentous algae and skeletonized leaves.

Step 5. [A number of methods can be used to split samples and select BMIs for identification and enumeration. The technique shown below is an example of one method.] After cleaning the sample, place the material into a plastic tray marked with equally sized, numbered grids (approximately 2 in by 2 in). Do not allow any excess water into the tray. Spread the moist, cleaned debris on the bottom of the tray using as many grids necessary to obtain an approximate thickness of 2 in. Make an effort to distribute the material as evenly as possible.

Step 6. Remove and count macroinvertebrates from randomly chosen grids until 300 BMIs are removed (or all organisms have been removed from samples where BMIs are scarce). Place the BMIs in a clean petri dish containing 70% ethanol / 5% glycerin. Completely count the remaining organisms in the last grid but do not include them with the 300 used for identification. The final count should be recorded on the bench sheet for eventual abundance calculations.

Step 7. Conduct a rare-large search to identify taxa not included in the sample of 300 BMIs.

Step 8. The debris from processed grids should be put in a clean Aremnanti jar and the remaining contents of the tray should be placed back into the original sample jar. Both jars should be filled with fresh 70% ethanol, labeled (bioassessment laboratory number and either Aoriginal® or Aremnant®), and returned to the sample depository.

Step 9. Identify each BMI to the standardized level identified in Appendix XII using appropriate taxonomic keys.

Step 10. Place identified BMIs in individual glass vials for each taxon. Each vial must contain a label with taxonomic name, bioassessment laboratory number, spring, county, collection date, and collector's name. This voucher collection should be labeled and returned to the Sample Depository.

Step 11. Record taxonomic information on a Macroinvertebrate Laboratory Bench Sheet. The bench sheet should include the following information: watershed or project name; sampling date; sample ID number; bioassessment laboratory number; date of subsampling; name of subsampler; remnant jar number; taxonomy completion date; name of taxonomist; taxonomic list of organism and enumeration; total number of organisms; total number of taxa; list of unknowns and problem groups and comments.

Step 12. Maintain a reference collection of representative specimens of all accurately identified BMI taxa.

Quality Assurance

The laboratory should follow a Standard Operating Procedures (SOP) manual that provides detailed instructions for BMI processing, personnel duties, qualified QA taxonomists, and bench sheets for each phase of sampling, subsampling, and identification. The SOP manual is to be maintained for all laboratory operations and updated regularly.

When samples arrive, laboratory staff must inspect the samples for a sufficient volume of EtOH and labels for pertinent information including waterbody name, sample date and time, location, transect number, and sampler name. The steps discussed for COC forms should be followed. Sample description information must be recorded in the Laboratory Sample Inventory Log and each sample given a unique identification number. Written and electronic records must be maintained to trace each sample from entry into the laboratory through final analysis. Samples must be stored in the Sample Repository until processing and returned after processing.

Subsampling - Subsampling involves removing 300 organisms from each sample, or all organisms if the entire sample contains fewer than 300. The subsampling technician systematically transfers organisms from the sample to a collection vial then transfers the processed sample debris (remnant) into a remnant jar. At least 10% of the remnant samples must be examined by the QA taxonomist for organisms that may have been overlooked during subsampling. After laboratory processing is complete for a given sample, all sieves, pans, trays, etc., that have come into contact with the sample must be rinsed thoroughly, examined carefully, and picked free of organisms or debris. Organisms found during this process must be added to the sample residue.

Taxonomic Identification and Enumeration - All organisms must be identified to the standardized taxonomic level shown in Appendix XII, using established taxonomic keys and references. The QA taxonomist must check at least 10% of the samples for taxonomic accuracy and enumeration of individuals within each taxon. Sample numbers that were selected randomly for the subsampling quality control must be used for this procedure. Misidentifications and/or taxonomic discrepancies as well as enumeration errors should be noted on the laboratory bench sheets. The laboratory supervisor determines if the errors warrant corrective action.

Organism Recovery - During the sorting and identification process, organisms may be lost, miscounted, or discarded. Taxonomists must record the number of organisms discarded and a justification for discarding on the laboratory bench sheets. Organisms may be discarded for several reasons including: 1) subsampler mistakes (e.g., inclusion of terrestrial or semi-aquatic organisms or exuviae), 2) small size (< 0.5 mm), 3) poor condition, or 4) fragments of organisms. The number of organisms recovered at the end of sample processing must also be recorded and a percent recovery determined for all samples. Concern is warranted when organism recoveries fall below 90%. Samples with recoveries below 90% should be checked for counting errors and laboratory bench sheets should be checked to determine the number of discarded organisms. If the number of discarded organisms is high, then the technician who performed the subsampling should be informed and retrained if necessary.

Corrective Action - Any quality control parameter that is considered out of range must be followed by a standard corrective action that includes two levels. Level I corrective action includes an investigation for the source of error or discrepancy derived from the quality control parameter. Level II corrective action includes checking all samples for the error derived from the quality control parameter but is initiated only after the results of the Level I process justify it. The decision to initiate Level II corrective action and reanalyze samples or conduct quality control on additional samples should be made by the laboratory supervisor.

Interlaboratory Taxonomic Validation - An external laboratory or taxonomic specialist must be consulted on a regular basis to verify taxonomic accuracy. External validation can be performed on selected taxa to help the laboratory taxonomists with problem groups of BMIs and to verify representative specimens of all taxa assembled in a reference collection.

Bioassessment Validation – At least 10% bioassessment validation must be conducted where whole samples of 300 identified BMIs are randomly selected from all samples either for a particular project or for all samples processed within a set time period such as every 6 months or a year. The labels must be removed from the vials and replaced with a coded label that does not show the taxonomic name of the MIs. The validation laboratory or specialist should be instructed to identify and enumerate all specimens in each vial and produce a taxonomic list. There must inevitably be some disagreements between the bioassessment and the external laboratory on taxonomic identification. These taxa should be re-examined by both parties and a resolution reached before a final QA report is written.

Voucher Material – A series of collections must be maintained as voucher material that can be used to confirm taxonomic identification.

Level II Spring Survey and Monitoring: Riparian Vegetation

Spring-fed riparian systems are distinctive, and unique sample methods are required to quantify species richness, and their biotic and physical structure. Recently developed methods to sample plant communities provide a foundation for sampling (e.g., Elzinga et al. 1998, Cowley and Burton 2005), but alterations are needed to understand riparian boundaries, and longitudinal and lateral gradients in community composition, cover, and physical structure. Sampling strategies for Level II riparian surveys that are outlined below were developed by Stanton and Pavlik (2003) while working in southern Nevada springs. Level II riparian surveys quantify the spatial and temporal distribution and variability of vegetation at individual springs and to accurately quantify unique aspects of spring-fed riparian systems. This is accomplished by employing several methods that sample vegetation along a series of transects that: 1) provide a list of species, 2) profile vegetation along lateral and longitudinal gradients, 3) assess vegetation structure, and 4) determine composition and cover for all levels of canopy. Sampling occurs at two primary sites at each spring, the source and the spring brook. Springs that are dry when sampling occurs (hence ephemeral) should be sampled in a similar manner; vegetation at the highest elevation functions as an indicator of the spring source and vegetation distributed down the fall line functions as an indicator of the spring brook. These surveys focus on communities nearest the spring source because this area provides the most persistent, reliable water, it is least influenced by variable discharge rates, and is typically most affected by anthropogenic activities.

Level II riparian surveys should be conducted by plant ecologists that are familiar with quantitative sample methods and the local flora.

Field Equipment

- Metric fiberglass tape measure, 30 m minimum
- Metric cloth tape, 5 m maximum (to measure diameter at breast height [DBH])
- Plant press to collect plants for museum or for identification
- Clipboard
- Survey forms as necessary for the type of sampling (either Appendix XII, XIV, XV or XVI)
- GPS
- 1:100,000-scale USGS map

Field Methods

Riparian sampling and monitoring examines physiographic and disturbance characteristics of the spring source, and incorporates four sampling strategies to record salient elements of plant communities and vegetation structure. These strategies are:

Strategy I—Physiographic and Disturbance Characteristics and Vegetation Context

This sampling provides a vegetation profile that is associated with the spring source and the upstream-most reach of spring brook. It is designed to assess the context of the vegetation along a gradient extending across the riparian zone from upland (xeric) to riparian (mesic/hydric) that lies along both sides of spring brook. Sampling occurs along four 20 m transects that are oriented perpendicular to the spring brook thalweg. Transects are placed at the upstream-most extent of water (or 1 m downgradient from the highest extent of riparian species occurring at dry springs), and at 5 m, 15 m, and 30 m downstream from the spring source (or from the highest transect at dry springs). Along each transect, linear dimensions of the zones (e.g., 5 m upland, 8 m riparian, 7 m upland) and the three dominant species (by visual abundance and size) in each zone are recorded. These data produce four profiles for each spring system that can later be reduced to quantitative metrics (e.g., percent riparian, percent upland). Physiographic and disturbance characteristics are recorded on the basic Level II survey form (Appendix VII) and vegetation context is recorded on the form shown in Appendix XIII (guidelines to fill out this form are also shown in Appendix XIII).

Strategy II—Tree Canopy, Count Method (See Appendix XIV for the field form)

This strategy focuses on riparian trees by identifying species, tallying the number of individuals, and measuring the height and diameter at breast height (dbh) of all trees present on both sides of the spring brook and within 10 m of a 30 m long centerline (centered on the source and downstream at the center of the spring brook). These data yield species composition and density information for trees within 600 m^2 of the riparian zone. A tree is defined as vegetation that is at least 2 m tall, provides canopy cover over the spring or spring brook, and has a single main trunk. This generally includes pine (*Pinus* sp.), juniper (*Juniperus* sp.), mesquite (*Prosopis* spp.), willow (*Salix* sp.), ash (*Fraxinus* sp.), and cottonwood and aspen (*Populus* sp.) at arid land springs. Multi-stemmed, lower-growing forms (including small individuals of the tree species shown above) are not considered to be trees, but are measured and tallied during the line intercept and quadrat sampling methods that are discussed below.

Strategy III—All Canopies, Line Intercept Method (See Appendix XV for the field form)

Species composition and cover on all canopy levels is compiled using the line intercept method along a single 15 m long centerline in small springs (spring brook < 30 m long) and a 30 m long centerline in springs with spring brooks > 30 m. Collect data along the transect formed by a fiberglass tape that is laid from a point at the water source and runs down the center of the spring brook (parallel to the banks) for either 15 m or 30 m, whichever is appropriate. Beginning at 0 m, identify every plant species that intersects the plane of the tape at each 1 m point along the transect. This includes all vegetation canopies, from overhanging trees and shrubs, down to herbs and emergent or submerged aquatics. Also record the presence of open water, bare ground, litter, or rock at each 1 m point.

Strategy IV—Shrub and Herb Canopies, Quadrat Method (See Appendix XVI for the field form)

Quadrat sampling is conducted to more rigorously quantify spatial variation in distribution and community composition along a spring brook. The number of measurements for each spring should be comparable as much as possible to standardize methods and minimize the affect of spring size on inter-spring comparisons. This is difficult when a wide variety of small and large springs occur in a sample area. Therefore, inter-spring comparisons may be possible only within size-classes of springs in an area (e.g., springs $\leq$ 30 m long, > 30 m $\leq$ 100 m, and > 100 m). This selection of size-classes is reasonable for most arid land springs in western North America (where aquatic habitat and riparian vegetation are typically less than 50 m long), but they can be modified as appropriate when the range of spring size differs. Quadrat sampling for these size classes occurs along transects 15 m and 30 m long for spring brooks $\leq$ 30 m long and > 30 $\leq$ 100 m long, respectively. For spring brooks > 100 m long, 30 m long transects should be sampled beginning at 0 m, then at 60 m.

For each 15 m segment, sample four 0.25 m^2 square quadrats that are placed every 3 m along the spring brook and alternate from being "near" and "far" from each bank. Place each quadrat along a transect that extends perpendicular from a tape that is stretched downstream from the spring source and marks the spring brook centerline. At the centerline point lying 3 m from the source, place a "near" quadrat on the left bank, and at 6 m, place a "far" quadrat on the left bank . At the centerline point lying 9 m from the source, place a "near" quadrat on the right bank and at 12 m, place a "far" quadrat on the right bank. Place "near" and "far" quadrats 0.5 m and 3 m from the tape, respectively. Repeat this procedure for each 15m segment. Identify all shrub and herb species that provide cover in each quadrat (do not include trees) and the cover of each taxon to one of seven cover classes: 1 <1%, 2) 1 to 5%, 3a) 5 to 15%, 3b) 15 to 25%, 4) 25 to 50%, 5) 50 to 75%, and 6) >75%. These cover classes are used by the California Native Plant Society and the Terrestrial Ecological Unit Inventory (TEUI) assessments conducted by the USFS.

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APPENDIX I. Glossary

abiotic – non-living, factors of the environment including light, temperature, and atmospheric gases; physical and chemical characteristics of a site

abundance – the number of individuals counted at a single site and time

alkaline–soil or water with high concentrations of mineral salts; strongest concentrations can be caustic

allochothonous – originating from another place, as opposed to originating in place

anthropogenic –caused by human activities

aquifer – an underground layer of rock, sand, etc. containing water

autochthonous – originating in place, as opposed to being brought in from another place

autotrophic – making its own food by photosynthesis (green plants) or chemosynthesis (some bacteria)

bosque – a grove of trees; woodland

cohorts – associated plants, animals, etc.

crenobiontic –species that dwell only in springs

edaphic – pertaining to the physical and chemical characteristics of soil

endemic – native to a particular geographical area as a county, state, region

ephemeral – short-lived, transitory

extant – still existing, not extinct

extinct – no longer in existence; having no living descendant

extirpate – to completely remove or destroy

Facultative – capable of living under varying conditions

fault zone – a fracture or zone of fractures in rock strata

feral – untamed, wild

frugivorous – fruit-eating

granivorous – seed-eating

helocrene – a spring originating from a marsh or bog

indigenous – native to a particular geographical area

insectivorous – insect-eating

limnocrene –a spring originating from a large, deep pool of water

lotic –living in flowing water, as in a river or stream

macroinvertebrate – insects, snails, clams and other animals without backbones that can be seen without magnification

mesic – moderately moist, as in between very dry (xeric) and wet (hydric)

morphology – the form and structure of plants, animals, landforms

non-native – a plant or animal that occurs outside of its native or natural range

obligatory – limited to specific conditions of temperature, moisture, habitats, etc.

orifice –opening of a tube, cavity, etc.

osmoregulation – control of flow of fluids through a membrane

perturbations – disturbances

pH – the measure of acidity/alkalinity

phreatophytes – deep-rooted plants that absorb water from the water table or groundwater layers, like tamarisk

pluvial – pertaining to 1) substrates, landforms, etc. formed as a result of rain or ephemeral streams, 2) climatology: relating to former periods of abundant rains

ppm – parts per million

qualitative – identifying the different elements or components of a mixture; such as the different kinds of species in a habitat

quantitative – finding the amounts of components; determining the relative amounts of a mixture; such as the relative numbers of different species in a habitat, etc.

relict – a plant, animal, or habitat surviving as a remnant and persisting in isolation from earlier populations and time

rheocrene – a spring that flows from a defined opening into a confined channel

richness – the number of different species of an area

riparian – associated with the edges of a spring, stream, lake, or river, such as a riparian species, landowner, etc.

scouring – erosion by moving water; where flowing water moves and/or removes silt, mud, gravel, stones

seep – a place where water oozes from the ground or rock through small openings

spatial – the distribution of organisms, springs, etc., over an area

spring – a place where water naturally flows from the ground or rock upon the land to form a stream or into a body of water

temporal – time

terrestrial – living on the land, as different from living in water

vagile - animals that can disperse over long distances by flying, walking, or swimming

xeric – dry or desert-like conditions

APPENDIX II. Level I Spring Survey Field Form

U.S. National Park Service - Mojave Inventory and Monitoring Network

FIELD NOTE #: _____________ SURVEYOR: ____________ DATE: __________________

STATE: ______ COUNTY: ____________ LOCALITY: _______________________________

LOCATION ID: ____

DRAINAGE: _________________________ T_______ R_______¼ SEC_________

1:100,000 USGS QUAD:______________________ GPS ZONE: _____ ±m ________

PDOP: _______ DATUM: NAD:___ ACCESS:___________________ ELEVATION (M):______

SOURCE GPS POINT: PHOTO #1: NORTHING:______________EASTING:_______________

DOWNSTREAM PHOTO #2: NORTHING:______________ EASTING:___________________

UPSTREAM PHOTO #3: NORTHING:__________________ EASTING:___________________

__________________PHOTO #4: NORTHING: ______________ EASTING: ________________

Vegetation ______________________

Willow	*Salix* sp.
Mesquite	*Prosopis* sp.
Cattails	*Typha* sp
Rushes	Juncaceae
Spikerush	*Eleocharis* sp.
Reeds	*Scirpus* sp.
Salt Grass	*Distichlis spicata*
Phragmytes	*Phragmytes australis*
Wild Rose	*Rosa woodsii*
Grapevine	*Vitis sp.*
Cottonwood	*Populous freemontii*
Watercress	*Rorippa* sp
Palm Tree	Arecaceae
White Top	*Cardaria pubescens*
Salt Ceder	*Tamarix* sp.
Arundo	*Arundo donax*
Sedge	*Carex* sp.

__________________PHOTO #5: NORTHING:____________________________ EASTING:______________________________

OWNER: NPS USFS BLM TRIBAL MILITARY PRIVATE OTHER_________________

SPRING TYPE: HELOCRENE RHEOCRENE LIMNOCRENE DRY QANAT CASED WELL UNKN OTHER__________

ESTIMATED DISCHARGE (L/MIN.) :_______________ SPRING BROOK LENGTH (M): ___________________________

AVERAGE WATER DEPTH (CM): _____________ AVERAGE WATER WIDTH (CM): __________ DO (MG/L:) _____________

TEMPERATURE (°C) :____________ SALINITY (PPT) :_____________ CONDUCTIVITY (µS OR mS): _______________

pH _____ EMERGENT COVER (%): ____________ VEGETATIVE BANK COVER (%): ______________

SUBSTRATE (%): fines (<1 mm):___________ sand (1 mm - 5 mm):__________ gravel (>5 mm – 80 mm):_______________

cobble (>80 mm - 300 mm):_________________ boulder (>300 mm):______________ bedrock:___________________

IMPORTANT ANIMALS: NONE SPRINGSNAILS (Scarce; Common; Abundant) FISH CLAMS AMPHIPODS

COLLECTIONS MADE: ____ MUSEUM DEPOSITED: _______________________

OTHER NON-NATIVE SPECIES: ____

OTHER VEGETATION: ____

OTHER FAUNA: ____

SITE CONDITION: undisturbed slight moderate high

DISTURBANCE: livestock recreation diversion residence drying fire flooding dredging other_______________________

NOTES:____

____

____

____

____

SKETCH OF AREA ON BACK

APPENDIX III. Preventing Inter-Wetland Translocation of Foreign Material

Each isolated, arid land wetland is occupied by a distinctive aquatic community. While inter-wetland translocation of vertebrates and invertebrates may occur via natural factors, such as transport via waterfowl and mammals, it is also caused by human activities such as recreational bathing, wildlife management, release of aquarium life, and scientific investigation. When caused by humans, translocation frequently results in establishment of non-native species, which has typically been detrimental to native fauna and ecosystem health. Preventing translocation of vertebrates is relatively easy because it requires a conscious effort to provide suitable habitat during transport (ergo sufficient amounts of water to permit respiration and prevent overheating). Translocation of macroinvertebrates and disease may occur more readily because many forms are able to live outside of water for extended periods of time.

This standard operating procedure describes mechanical and chemical methods to prevent accidental translocations that may occur during Levels I and II spring surveys in the Mojave Network. These methods must be employed upon completion of surveys at each isolated site and before additional surveys are conducted. During these surveys, there are two types of isolated sites: 1) individual, isolated springs, and 2) spring provinces where there is either continuous or periodic (e.g., seasonal) connectivity between springs that naturally permits inter-spring movement of life. These methods must be used following the survey of each of these wetland types, therefore, between surveys of isolated springs or, if springs are connected, before surveys of springs that are outside of the immediate province.

<u>Equipment</u>

- 10 % chlorine bleach solution
- Leak-proof, plastic bottle (approximately 250 ml that can be carried to remote sites, or 1 L that can be carried in a vehicle) to contain the chlorine bleach.
- Toothbrush
- Scrub brush. Size is relatively unimportant, but the bristles should be stiff and durable. A small brush (e.g., 2 cm X 7 cm) may be carried to remote sites, and larger brushes may be used when there is vehicle support.

<u>Methods</u>

Every precaution should be taken to avoid wading and getting shoes wet, which should be easily accomplished during Level I surveys because most arid land springs are small and extensive biological sampling is not an element of the protocol. Additional caution is necessary during Level II surveys because it may be necessary to enter water while collecting BMIs and aquatic habitat information. When wading is necessary, rubber boots must be worn (either hip boots or ‘irrigator boots’). Upon completing the survey, boots should be rinsed in water from the surveyed spring to remove mud, vegetation, and all other material. Dry the boots, then wash boots in the Chlorine bleach solution, and dry again before entering another spring. Precautions should also be taken when shoes are kept dry and wading does not occur. This can be accomplished by using a small scrub brush to buff the soles and sides of shoes and remove all material that may have been gathered from the spring.

Equipment used to collect biological samples is the most likely translocation vector. After completing surveys at each isolated site, all equipment must be: 1) vigorously shaken to remove as much material as possible, 2) treated with Chlorine bleach by either dipping into a container and/or using a toothbrush scrub surfaces and clean crevices where macroinvertebrates may be hidden, and 3) dried in the sun before initiating subsequent spring surveys.

APPENDIX IV. Aquatic Animal Identification

A Field Guide to Important Taxonomic Groups of Animals in Springs

Important taxonomic groups that occur in springs are those with species that have the greatest implication for management. For restoration and rare species management, the most common groups include crenobiontic species; for resource protection or non-native species management, species that are known to demonstrably influence aquatic and riparian systems are important. A substantial amount of training is needed to identify many of these species, but identifying most groups of animals, and many non-native species, may be accomplished with minimal training. This field guide provides text and illustrations to facilitate identification of important organisms that can be used by a minimally trained person for a Level I survey.

For Level I surveys, the presence or absence of important species or groups is an important goal (if possible the relative abundance [e.g., scarce, common, or abundant] should also be recorded as a note). If a species cannot be identified (e.g., whether the fish is native such as tui chub [*Siphatales bicolor*], speckled dace [*Rhinichthys osculus*], etc.), it is less important than recording that fish occur at a spring. Noting the presence of fish will allow the species to be identified later by someone familiar with fishes. In many instances, field identification may be comparatively easy and the species should be recorded (e.g., identifying goldfish [*Carassius auratus*], mosquitofish [*Gambusia affinis*]). Groups of important organisms are shown in Table 1-Appendix IV, and representative drawings of many groups are shown after the table.

Table 1-Appendix IV. Groups of organisms that are important for spring management and that can be identified during Level I surveys, with minimal technical training.

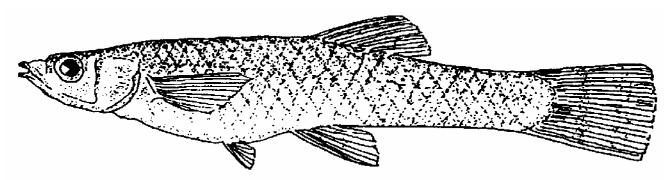
Groups
Amphipods
Pisidium sp. Clams
Springsnails
Red-rimmed thiara (*Melanoides tuberculata*)
Ostracodes
Goldfish (*Carassius auratus*)
Mosquitofish (*Gambusia affinis*)
Unknown Fish
Riffle Beetles (Family Elmidae)
Bullfrog (*Rana catesbeiana*)
Unknown Amphibian
Crayfish

Fish

Record 'unknown fish' if the species cannot be identified. Mosquito fish and goldfish are the most common non-native fish in springs, and they are comparatively easy to identify. Most people are familiar with goldfish from aquaria, but the mosquito fish is less well known. The mosquito fish is illustrated below.

Mosquito fish (*Gambusia affinis*)

Mosquito fish are native to the southeastern U.S. and they have been introduced throughout the world as a biological control agent for mosquitoes. They are hardy, highly predatory, and feed on macroinvertebrates as well as fish eggs and larvae. While they occur throughout the water column, they are usually near the water surface. They are small (< 3 cm), gray, and easily identified because of their flattened head.



The Mosquito fish body form

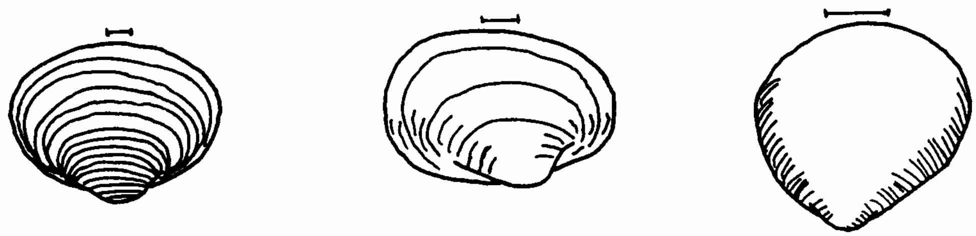
Amphibians

A number of amphibians are known from springs, but they are often difficult to identify without training, and adults are typically seen only during nocturnal sampling. It is very difficult to identify amphibians by examining tadpoles. Record 'unknown amphibian' if identification is not possible. If tadpoles are seen, record 'unknown amphibian' and 'tadpoles present' in the notes. Bullfrogs occupy only larger springs, and adults are large and comparatively easy to see and identify. No amphibians are illustrated in this field guide.

Mollusks

Clams (Finger clams, Family Sphaeriidae)

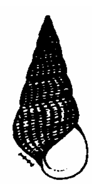
Finger clams are small and from 2 mm to 5 mm wide. They usually occur in habitats with fine sediment and low current velocity. They may be colored tan, but they are usually white and often translucent. Magnification is needed to differentiate species, which precludes the identification of species in the field. When present, they are usually common and comparatively easy to find.



Body forms of several species of finger clams (measurement lines = 1 mm)

Red-rimmed melania (*Melanoides tuberculata*)

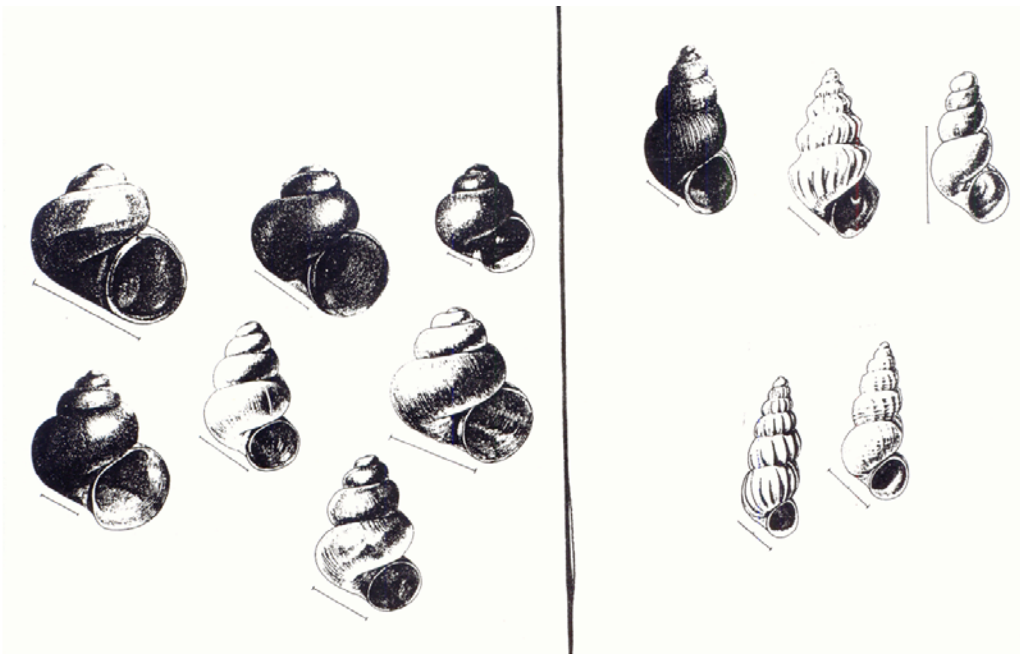
This mollusk was introduced into North America by the aquarium trade, and it has become widespread throughout the western U.S. It is native to Asia, parthenogenic (reproduces asexually), and can survive long periods out of water. It can be easily transplanted, is tolerant of harsh conditions, and prefers warm water. It prefers fine substrates and slow water. It is easy to identify because its shape and color are distinctive and very different from all other mollusks in the western U.S. It is long (up to 2.5 cm) and conical, with body whirls terminating at a sharp point. Its shell is slightly sculptured and its coloration is an attractive and distinct mottled, reticulated mixture of tan and brown. Since these mollusks are easily transplanted, care should be taken to completely clean and inspect field gear to ensure they are not carried and introduced into other springs.



The generalized body form of the red-rimmed melania (measurement line = 1mm)

Springsnails

Springsnails are small (< 1mm to 5mm) crenobiontic species that occur in two general body forms. Most species in southern U.S. deserts are in the genus *Pyrgulopsis* or genus *Tryonia*. Most *Pyrgulopsis* species are round and slightly inflated and most *Tryonia* spp. are elongate (see figure below). All springsnails are usually black or brown. *Pyrgulopsis* spp. generally occur on gravel and cobble substrates, and on watercress (*Rorippa nasturtium-aquaticum*) in areas with higher water velocity. *Tryonia* spp. are usually found in slow currents where there are fine substrates.



Body forms of several *Pyrgulopsis* spp. Body forms of several *Tryonia* spp.

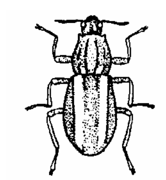
Measuement lines = 1 mm

Aquatic Insects

A number of aquatic insects are crenobiontic species. These are all small and difficult to identify without training. Riffle beetles are the most common crenobiontic aquatic insect in southern California and Nevada arid lands, and the group is comparatively easy to identify.

Beetles (riffle beetles, Family Elmidae)

A large number of beetles occur in aquatic habitats, but there are comparatively few crenobiontic species. In the western U.S., most crenobiontic beetles are in two genera, *Stenelmis* and *Microcylloepus*. Identifying each species, and differentiating between these genera, is difficult in the field because all of these species are small (< 3 mm long) and difficult to examine without magnification. They are easy to see in samples, however. These beetles are black or dark brown with long, spindly legs. They move slowly by crawling and they have weak swimming ability.

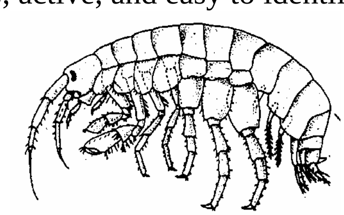


The generalized body form of a riffle beetle

Crustaceans

Amphipods (Family Hyalellidae)

Amphipods occur in many springs, and they are usually very numerous. They are comparatively large (up to 10 mm long), active, and easy to identify in a macroinvertebrate sample.

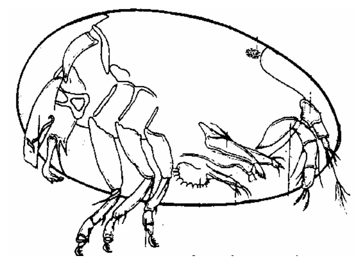


Generalized amphipod body form

Crustaceans (continued)

Ostracodes

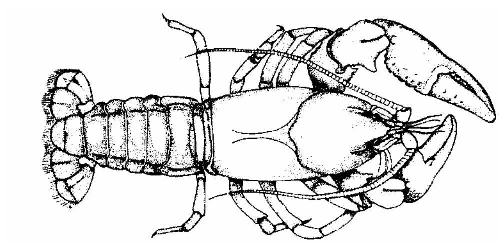
Ostracods are the oldest know microfauna, and they have been extensively used in paleoclimate studies. They are small (usually < 2 mm long), flattened animals with a calcitic shell with an external morphology that is similar to a plant seed. They are brown to pale olive green or gray, active, and they are usually easy to see in a sample because they constantly move. They may be floating, or on the substrate, and they are usually abundant in springs where they occur.



Schematic drawing of an Ostracode

Crayfish

Crayfish are not native to the southwestern U.S., but they have been introduced into many springs. They occur only in large springs that do not dry.



Schematic drawing of a Crayfish

APPENDIX V. Setting Management and Restoration Priorities

Management goals can be integrated with descriptions of biological and physical characteristics to prioritize spring management and restoration programs. This is possible because most land management agencies have developed 'resource targets' (or goals of resource management) to maintain values such as biodiversity, watershed productivity, vegetation vigor, etc., and information compiled during Level I surveys provides insight into the condition and biotic potential of individual springs.

An example of this integration comes from recent work to prioritize the management and restoration of individual springs in Clark County, Nevada (Sada et al. 2003). This effort prioritized springs using matrix analyses by ranking biotic and abiotic elements of each spring (compiled during Level I and Level II surveys), and considering factors important to management. In Clark County, the long term goal of management is to: 1) design management strategies to restore springs to ecological conditions that are maintained by natural processes; 2) maintain springs in natural ecological conditions; and 3) protect, restore, and maintain rare species. Matrix elements used to evaluate the management priority of individual springs in Clark County are shown in Table 1-Appendix V and elements to prioritize restoration are shown in Table 2-Appendix V. These examples are provided as one means to prioritize management and restoration. This method could be easily modified to evaluate priorities where other goals are guiding resource management. Although this exercise provides a prioritized list of springs for management and restoration, the list should not be considered as definitive, absolute guidance because differences between needs at individual springs may vary only slightly. It is more appropriate to use the matrix analyses as a process to reveal the relative importance of springs along a gradient of resource values and needs. In context of this gradient, additional planning is usually necessary to prioritize specific implementation programs within constraints such as funding and public involvement.

Matrix Analysis

Matrix I (Table 1-Appendix V) ranks the relative importance of each spring's resources to values at other springs in the Clark County. Elements in this matrix included rare species, factors indicating taxonomic richness (e.g., spring size, amount of disturbance [cultural and natural]), the rarity of spring habitats across the landscape, land ownership, and the potential of conflicting uses that may affect biotic integrity. In this analysis, higher priority springs had higher matrix and resource values, and included larger springs (that generally do not dry during droughts), springs supporting covered species (in Clark County these are crenobiontic species) and high species richness. Higher priority springs were also in public ownership where management activities can be conducted, and springs where uses did not affect biotic integrity. Lower priority springs had lower matrix values and did not support covered species, had lower taxonomic richness (because they were small, subjected to scouring floods, etc.), periodically dried, occurred on private lands, and were affected by overwhelming uses that degraded their biotic integrity and minimized chances of restoring to natural character.

Matrix II (Table 2-Appendix V) ranks restoration priorities by considering habitat condition in addition to the elements used in Matrix I. Higher restoration priority is indicated by higher matrix values, which are given to springs with higher resource values and where restoration programs can achieve more rapid and effective success. Therefore, moderately disturbed springs with high resource values are given higher restoration priority than minimally disturbed springs with high resource values, and highly degraded springs with low resource value. Lower priority is assigned to the springs with lower resource values and higher disturbance where restoration may have minimal influence on riparian and aquatic communities.

Management priority rankings ranged from a maximum of 65 down to 20 in Clark County. Highest management priority springs were occupied by covered species, and they were relatively large, persistent, and in relatively good condition. Lower priority springs were small (many were ephemeral), not occupied by covered species, and highly disturbed by natural and anthropogenic factors.

Table 1-Appendix V. Elements and ranking values for Matrix I to rank the relative value of resources at springs. Each spring is ranked by evaluating each matrix element and summing the ranking values for all elements. Elements are described below.

Matrix I Criteria	**Ranking Value**
Presence of Rare Aquatic Species [1]	Present = 10, Absent = 0
Rarity Across Landscape [2]	Rare = 10, Sparse = 5, Common = 2
Spring Brook Length [3]	> 500 m = 10, ≤ 500 > 200 = 7, ≤ 200 ≥ 50 = 5, < 50 = 2
Scouring [4]	None = 10, Occasional = 5, Frequent = 2
Aquatic Habitat Persistence [5]	Persistent = 10, Ephemeral = 2
Resource Threats [6]	High = 2, Medium = 10, Low = 7
Land Ownership [7]	Public = 10, Private = 3
Conflicting Uses [8]	≤ 1 = 10, 2-3 = 5, >3 = 2

[1] Springs with rare plants or crenobiontic species are ranked 10, springs without rare species are ranked 0.

[2] Spring rarity is a subjective scale of density across the landscape. In southern Nevada, density is comparatively high in spring provinces, moderate along much of the east side of the Spring Mountains, and scarce in areas such as the west side of the Spring Mountains, in the McCullough Range, and Muddy Mountains.

[3] Length is the distance in meters of the spring brook from the source to the end of contiguous flowing surface water.

[4] Scouring is based on the potential of scouring due to flooding. Frequent scouring may have a lower resource value and recovery potential.

[5] Persistence is the long-term presence of surface water. It is indicated by riparian systems with obligate wetland species and macroinvertebrate communities that include large numbers of Ephemeropterans, Plectopterans, or Trichopterans. Riparian vegetation associated with non-persistent waters include more facultative wetland and upland species and macroinvertebrate communities are dominated by water boatman (corixids), diving beetles, and other highly vagile, invasive species. If spring snails are present, the spring has long-term persistence. Springs that dry have low recovery potential as aquatic habitats, but they may be important to amphibians.

[6] Threat is a subjective evaluation of the likelihood that current activities will further degrade spring resource quality or keep it in a degraded condition. High threats usually mean a spring will be more difficult to restore. Low threats suggest that land managers may wish to keep the spring in its existing condition.

[7] Ownership is either private, state, or federal (public land).

[8] Conflicting Uses is a subjective ranking of how current uses conflict with management objectives. In the Spring Mountains, there are three primary types of conflicting uses: 1) introduced grazing, 2) diversions, and 3) recreation. If none of these is occurring the ranking is 0. If one of these conflicting uses is present the ranking is 7. If two conflicting uses are present, the ranking is 5, and if three are present the ranking is 2.

Table 2-Appendix V. Elements and ranking values for Matrix II to rank the restoration priority of springs. Each spring is ranked by evaluating each matrix element and summing the ranking values for all elements. Elements are as described for Matrix I, and below for elements used in only Matrix II.

Matrix II Criteria	**Analysis Scale**
Presence of Rare Aquatic Species [1]	Present = 10, Absent = 0
Rarity Across Landscape [2]	Rare = 10, Sparse = 5, Common = 2
Spring Brook Length [3]	> 500 m = 10, ≤ 500 > 200 = 7, ≤ 200 ≥ 50 = 5, < 50 = 2
Scouring [4]	None = 10, Occasional = 5, Frequent = 2
Aquatic Habitat Persistence [5]	Persistent = 10, Ephemeral = 2
Resource Threats [6]	High = 2, Medium = 10, Low = 7
Land Ownership [7]	Public = 10, Private = 3
Conflicting Uses [8]	≤ 1 = 10, 2-3 = 5, >3 = 2
Habitat Condition [9]	Slight/Unmodified = 5, Moderate = 10, High = 2
Recoverability [10]	High = 10, Medium = 5, Low = 2

1 through 8—refer to Table 1-Appendix V.

[9] Habitat condition ratings are described in Level I protocol guidelines. Moderately disturbed springs receive higher ranking because restoration activities are more necessary than at slightly and undisturbed springs. Highly disturbed springs receive lower ranking because many of them are so badly disturbed that restoration is a very long-term process that requires substantial resources.

[10] Recoverability includes the physical and biological aspects necessary to recover a spring. It does not include cost, feasibility, staffing needs, or political considerations.

APPENDIX VI. Level I Survey Audit Form

National Park Service-Mojave Inventory and Monitoring Network

Auditors and Field Crew

Date: ____
Field Note No.: ____
Crew Leader: ____
Crew Member(s): ____
Auditor(s): ____

General

Crew operates safely / follows safety measures
Yes No
Crew uses and maintains equipment properly
Yes No
Crew communicates effectively with each other
Yes No
Crew uses time efficiently
Yes No
Crew uses written protocols to solve problems
Yes No

Level I Data Elements

Field Note Number

1. Did the crew use the correct format for the field note number?
   Yes No
2. Did crew 1 use numbers 1-250 and/or crew 2 use numbers 251 – 500?
   Yes No
3. If site was a spring province, were all springs identified?
   Yes No
4. If site was a spring province, were all springs numbered correctly?
   Yes No

Lead Person (Surveyor)

5. Was the lead surveyor's name described correctly (e.g., JDSmith)?
   Yes No

Date and Time

6. Was a correct EventID entered (e.g., SPINV_ONE_20040108_1100)?
   Yes No

State, County, and Locality

7. Were the state, county and locality entered correctly on the data sheet?
   Yes No

Location ID

8. Was a correct LocationID entered on the data sheet? (e.g. DEVA_SPINV_ONE_0001)?
   Yes No

Drainage Basin

9. Was the drainage basin correctly identified by the field crew?
   Yes No
10. If it was an endorheic basin (ergo enclosed), did they identify the valley?
   Yes No

Township, Range, and Quarter-Section Coordinates, USGS Map

11. Were the T/R/¼S correctly identified from the USGS topographic maps?
   Yes No
12. Was the name of the USGS map correctly identified?
   Yes No

GPS Location and Datum

13. Did the crew use the NAD83 datum?
   Yes No
14. Were the GPS coordinates correctly transferred from the GPS meter?
   Yes No
15. Did the crew record the PDOP or ± meters?
   Yes No

Access

16. Did the crews understand the access categories?
   Yes No
17. Did they select the correct category for this spring?
   Yes No

Spring elevation

18. Did the crew accurately describe the elevation of the spring?
   Yes No
19. Did they record the method used to determine elevation in the notes section?
   Yes No

Photos

20. Did the crew select the most appropriate locations for the photos? Yes
   No
21. Were the photos described in a photo log?
   Yes No

Land Ownership

22. Did the crew record the correct land ownership (National Park Service)?
   Yes No

Spring Type:

23. Did the crew demonstrate an understanding of how to distinguish the differences between rheocrene, limnocrene, or helocrene spring types?
   Yes No

24. If the spring had been dug out, was it described correctly?
    Yes No

Spring Discharge

25. Was the crew's estimate for spring discharge (in liters/minute) acceptable?
    Yes No
26. Did the crew use appropriate means for estimating the discharge?
    Yes No

Spring Brook Length

27. Did the crew select the correct starting and ending points for the measurement of spring brook length?
    Yes No
28. If springs in a spring province joined, were the correct locations chosen for ending points?
    Yes No

Average Water Depth and Width

29. Was the average water depth and width estimated near the source?
    Yes No
30. Were these measurements made in centimeters?
    Yes No

Dissolved Oxygen Concentration

31. Was the DO meter clean, have fresh batteries, and calibrated?
    Yes No
32. Was the DO measured as close to the spring source as possible?
    Yes No
33. Was the DO probe submerged and in flowing water?
    Yes No
34. Does the crew understand how to address difficult situations (pipes, helocrenes, etc.)?
    Yes No
35. If DO measurements could not be taken at the source, was this noted?
    Yes No

Water Temperature

36. Was sufficient time allowed for an accurate reading of temperature?
    Yes No
37. Was the temperature probe submerged and in flowing water?
    Yes No

Conductivity

38. Was the conductivity meter clean, have fresh batteries, and calibrated?
    Yes No
39. Was the conductivity probe submerged and in flowing water?
    Yes No
40. If the salinity exceeds the meter's calibration, does the crew know what to do?
    Yes No

pH

41. Was the pH meter clean, have fresh batteries, and calibrated?
    Yes No
42. Does the crew have a backup pH meter?
    Yes No
43. Was the pH probe submerged and in flowing water?
    Yes No

Percent of Emergent Cover

44. Was the crew's estimate of emergent cover acceptable?
    Yes No

Percent of Vegetative Bank Cover

45. Was the crew's estimate of vegetative cover acceptable?
    Yes No

Substrate Composition

46. Does the crew understand the size differences between fines, sand, gravel, cobble, boulder, and bedrock?
    Yes No
47. Was the crew's estimate of the substrate composition taken near the spring source?
    Yes No
48. Was the crew's estimate of the components of the substrate composition acceptable?
    Yes No
49. Does the total composition add up to 100%?
    Yes No

Important Groups of Animals

50. Did the crew use correct procedures when searching for species?
    Yes No
51. Did the crew correctly identify the presence and abundance of important groups of spring animals (e.g., springsnails, amphipods, fish, clams, amphibians, non-native species)?
    Yes No
52. Did the crew clean and dry the sampling equipment to prevent spreading biota from one spring to another?
    Yes No

Trees or Large Woody Vegetation

53. Did the crew note the presence of trees and large woody vegetation?
    Yes No
54. Were the species or common names correctly identified in the notes section?
    Yes No

Non-Native Species

55. Did the crew note the presence of non-native species (e.g., salt cedar, palm trees, mosquito fish, bass, and arundo)?
    Yes No
56. Were the non-native species correctly identified in the notes section?
    Yes No

Site Condition

57. Does the crew understand the differences between the various spring site condition (undisturbed, slightly disturbed, moderately disturbed, or highly disturbed)?
    Yes No
58. Was the site condition correctly described?
    Yes No

Disturbance Factors

59. Were all disturbance factors correctly identified?
    Yes No

Notes

60. Was the crew careful to include additional important information in the notes?
    Yes No
61. Did the crew prepare a map of the spring(s)?
    Yes No
62. Was the field note number written on the map?
    Yes No

Comments

APPENDIX VII. Basic Level II Survey Form

The Level II survey form is comparatively short and it has many elements in common with the Level I form. Elements of the form should be completed each time a Level II survey is conducted by any group of specialists, with exception of descriptions of physiography. These features should not differ between surveys. This form is distinct from the Level I form by its inclusion of information that briefly describes physiographic and disturbance characteristics of the spring. Physiography is described as the geological setting, and the aspect and slope of the spring brook. Disturbance characteristics more fully describe factors by indicating the extent of ungulate use through the amount of dung present, etc.

FIELD NOTE #: _____________ SURVEYOR(S): _______________________________________ DATE: __________________

STATE: ______ COUNTY: ____________ LOCALITY: _______________________________

TYPE OF SURVEY: WATER CHEMISTRY AQUATIC HABITAT BMIs RIPARIAN VEGETATION

COLLECTIONS MADE:____

MUSEUM DEPOSITED: ________________________ ANALYTICAL WATER LABORATORY: ____________________________

T_______ R_______¼ SEC_________ 1:100,000 USGS QUAD:____________________

GPS ZONE: ________ ±m ________ PDOP: _______ DATUM: NAD_______

SOURCE GPS POINT: PHOTO #1: NORTHING:______________EASTING:_______________

PHOTO #2: NORTHING:__________________ EASTING:______________________

PHOTO #3: NORTHING:__________________ EASTING:______________________

PHOTO #4: NORTHING: __________________ EASTING: ______________________

PHOTO #5: NORTHING:___________________ EASTING:_______________________

SPRING BROOK SLOPE %: ________ SPRING BROOK ASPECT: ________________

GEOLOGY: SANDSTONE LIMESTONE GRANITE VOLCANIC METAMORPHIC UNCONSOLIDATED

SPRING TYPE: HELOCRENE RHEOCRENE LIMNOCRENE DRY QANAT CASED WELL UNKN OTHER__________

SPRING BROOK LENGTH (M) :___________________________ DO (MG/L): _____________

TEMPERATURE (°C) :____________ CONDUCTIVITY (µS OR mS): _______________ pH :_____

SITE CONDITION: undisturbed slight moderate high

DISTURBANCE: livestock recreation diversion residence drying fire flooding dredging other_______________________

UNGULATES: HORSE BURRO ELK CATTLE DEER DUNG (LIGHT, MEDIUM, HEAVY): FRESH RECENT OLD

TYPE OF RECREATION: PICNIC AREA HIKING TRAIL CLIMBING CAMPING TRASH (LIGHT, MEDIUM, HEAVY)

TYPE OF DIVERSION: SPRING BOX TROUGH/TANK PIPE CHANNELIZED IMPOUNDED

NOTES:____

APPENDIX VIII. Description of Chemical Compounds Measured during Level I and II Surveys (* = measurements for Level I surveys only)

Temperature*

Temperature is an important factor structuring aquatic and riparian communities, and may give insight into source waters. This measurement is also necessary to calibrate some analytical meters (e.g., pH and conductance). Field temperature measurements can be accurately made with a high-quality meter (e.g., YSI model 55 meter)

Dissolved Oxygen (DO)*

DO is a measure of how much oxygen is dissolved in the water. For groundwater, DO indicates if the groundwater is under reducing or oxidizing conditions, and low DO at night can indicate poor water quality. DO is also important to aquatic life; springs with low DO are stressful aquatic environments. DO is measured with a DO meter (e.g., YSI Model 55).

Electrical Conductance (EC)*

EC is a measurement of the ability of an aqueous solution to carry an electrical current. This ability is dependent on the amount and charge of ions dissolved in water, and as such, is a general indicator of total dissolved solids (TDS). EC is measured using an EC meter (e.g., YSI Model 30 meter). EC provides insight into water sources and chemical reactions in the aquifer, and it is important to aquatic life. High EC (e.g., >1,000 microsiemens/centimeter) waters are stressful to aquatic life.

pH*

pH is the measurement of hydrogen ion activity, which indicates acidic/basic qualities of water. It should be measured in the field using a pH meter. Low (< 6.5) and high (> 8.0) pH environments are stressful to aquatic life. pH can be accurately measured in the field using high-quality meters that are calibrated daily (e.g., Oakton pHTester and Model 300 and 310 meters, YSI Model 60 pH meter, and numerous other brands).

Alkalinity

Alkalinity is a measure of the amount of acid (sulfuric acid) neutralized in a water sample. In most waters, organic compounds are not present in high concentrations, so this is a measure of dissolved carbonate in the water. The measurement is generally reported in terms of calcium carbonate ($CaCO_3$) alkalinity and as the ions bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}). Alkalinity is accurately measured in the laboratory by titrating samples collected in the field.

Chloride (Cl)

Primary sources of chloride in groundwater are evaporates and salty water, which indicate the possibility the aquifer has a marine origin or that it includes salt strata. Low chloride levels suggest the aquifer may include igneous rocks, granite, or limestone geology.

Sulfate (SO_3)

Sulfate is formed by oxidation of pyrite and other sulfides that occur in igneous rocks and dissolution of gypsum and anhydrite in sedimentary rocks. In arid regions, sulfate may also leach from the soil, resulting in sulfate being the principal anion in groundwater.

Sodium (Na)

Nitrate is measured because it indicates high nutrient concentrations that may adversely affect aquatic life. High concentrations also pose risks to human health.

Potassium (K)

Potassium is more abundant in volcanic and sedimentary rocks and is often dissolved from potassium feldspars. It is less concentrated in igneous rocks, where it is also less common than sodium.

Calcium (Ca)

Calcium is generally a principal cation in groundwater. Low calcium concentrations are indicative of aquifers flowing through igneous or metamorphic rock, or waters that have undergone ionic exchange with clay minerals. High concentrations are indicators that the aquifer includes sedimentary rock such as carbonates.

Magnesium (Mg)

Most groundwater contains small quantities of Mg, except where they have been in contact with dolomite (where concentrations of Mg and Ca are similar) or with Mg-rich evaporites. It is derived from ferromagnesian minerals in igneous rocks, and other compounds in sedimentary and metamorphic rocks.

Iron (Fe)

The common form of iron in groundwater is the soluble ferrous ion Fe^{2+}. Concentrations are normally in the 1 mg/l to 10 mg/l range. When exposed to the atmosphere, Fe^{2+} is oxidized to Fe^{3+}, which is insoluble and precipitates as a reddish/brown deposit. Iron concentrations are high in aquifers that contain iron strata.

Silica Dioxide (SiO_2)

Silica is the second most common element (after oxygen) in the earth's upper crust. In groundwater, it is an indicator that the groundwater flows through volcanic rocks.

Hydrogen Sulfide (H_2S)

Hydrogen sulfide is stressful to aquatic life. It is most commonly present if DO is low (<1.0). This measurement is made if odor is present (rotten egg smell). Hydrogen sulfide is measured using a field kit.

Fecal Indicator Bacteria

Fecal bacteria occur in springs that are susceptible to human waste, usually caused by recreationists or seepage from septic tank leach lines. High fecal bacteria counts pose a serious threat to human health.

Deuterium (^2H)

Deuterium is part of the water molecule, so it can be used to identify water sources, mixing of different waters, and physical processes such as evaporation.

Oxygen 18 (O^{18})

Oxygen, like deturium, is part of the water molecule, so it can be used to identify water sources, mixing of different waters, and physical processes such as evaporation.

Chlorofluorocarbons (CFCs)

Many chlorofluorocarbons exist in the atmosphere from human production of solvents, refrigerants and propellants. Hydrogeologists use CFCs as tracers because they equilibrate with water to form a dating tool for groundwater that is <50 years old. They are also indicators of sewage contamination.

Carbon-14 and Carbon-13 (^{14}C and ^{13}C)

Carbon isotopes can be used to calculate the age of water discharging from a spring if the water does not contain any measurable tritium. Corrected groundwater ages can be modeled using these isotopes. The corrected ages can span a range of approximately 1,000 to 40,000 years.

Uranium (U)

The radioactive decay of uranium and thorium produces a series of isotopes that display a broad array of half-lives (10^5 to 10^9 years). These characteristics make them useful to evaluate mixing between aquifers, trace groundwater movement, investigate geochemical processes, and measure groundwater-surface water interactions.

Strontium (Sr)

The isotopic composition of strontium (Sr) in groundwater depends on the $^{87}Sr/^{86}Sr$ ratios of the rocks within an aquifer. In basins containing several aquifers with differing rock types, these ratios may help distinguish the portion of an aquifer that is supporting an individual spring.

Tritium (^3H)

The radioactive isotope tritium provides a semi-quantitative means for dating groundwater with residence times of several decades or less (Mazor 1991). Groundwaters having tritium concentrations < 5pCi/l are considered to be derived primarily from recharge prior to the onset of atmospheric nuclear bomb testing in 1952, while groundwaters having concentrations > 5pCi/l are considered to have at least some component of recharge after 1952. Due to its short half-life (12/3 years), tritium concentrations in atmospheric precipitation have declined since the period of maximum testing in 1962.

APPENDIX IX. Suggested Label for Bottles Containing Water Chemistry Samples

SITE NAME: ____________________ FIELD NOTE NUMBER:______________

ZONE:_____ NORHTHING: ______________ EASTING:___________________

Datum:______ Date:_________ Time:________________

Laboratory analysis to be conducted (e.g., cations, anions, NO_3, etc.)
____

SAMPLE INFO: acidified, raw, etc.

PERSON(S) COLLECTING SAMPLE:__________________

APPENDIX X. Definition of Parameters Measured during Level II Survey—Aquatic Habitat Assessment

Definition of parameters measured for aquatic habitat monitoring as presented in U.S. Forest Service (1990)[1] and Pfankuch (1978)[2], and modified for spring assessments[3].

Wetted Width[1]-The length of wetted contact between a stream of flowing water and the spring brook bottom in a vertical plane at right angles to the direction of flow, measured as the distance between banks less the distance of islands, emergent rocks, or peninsulas.

Mean Water Column Velocity[1]--The average velocity of the water measured on an imaginary vertical line at any point in a stream. A measurement at 60% of depth, measured from the surface, closely approximates the average velocity for the water column. In water greater than 76 cm in depth, calculate the average velocity from measurements made at 20% and 80%.

Spring Brook Canopy Cover[1]--The density of vegetation that projects over the stream, measured as percentage of total cover using a concave densitometer and following methods of Platts et al. (1987).

Stream Bank Overhang[3]--The horizontal distance that the spring brook bank extends over flowing water along the water surface and perpendicular to spring brook flow.

Water Depth[3]--Vertical distance from the substrate to the water surface.

Substrate Size[3]--Minimum particle size of substrate as measured on a two-dimensional axis, as would pass through a substrate sieve.

Aquatic Vegetation Depth[3]--The vertical depth of submerged aquatic vegetation in the water column.

Submerged Debris Depth[3]--The vertical depth of submerged vegetative debris that covers the rock substrate.

APPENDIX XI. Field Survey Form for Parameters Measured during Level II Survey—Aquatic Habitat Assessment

Record spring name (Locality), Surveyor name(s), sample Date, State, and County where the spring is located, and UTM coordinates of the spring source, following directions for Level I surveys. This data sheet is organized with the transect number listed in the left column with the number of each equally spaced point across the wetted width next to them. Water depth (WD), water velocity (WV), substrate size (SUB), and depth of aquatic vegetation (VEG) and debris (DETR) are recorded at each equally spaced point. WW = the length wetted width across the transect, BOH = bank overhang measured at each point where the transect intersects the spring brook bank (recorded in centimeters for each bank looking upstream, e.g., 3/0, where the overhang is 3 cm on the left bank and 0 on the right bank). Cover is the number of points intersected on a concave densitometer looking upstream, downstream, to the right, and to the left along a transect (e.g., recorded as 5/2/6/11 for counts made for each of these orientations, respectively). The percent cover is calculated by summing these values and multiplying by 1.5 (Platts et al. 1987). A partial sheet with some data recorded is shown below. Surveys at a spring will require several sheets to record data for the requisite number of transects and equally spaced points.

Level II Spring Aquatic Habitat Assessment

LOCALITY: ______________________________ SURVEYOR(S): ______________________________________

DATE: _________________ STATE: ______ COUNTY: ____________ T_______ R_______¼ SEC_________

GPS ZONE: ________ ±m ________ PDOP: _______ DATUM: NAD______

SOURCE GPS POINT: PHOTO #1: NORTHING:______________EASTING:_______________

Transect	Point	WW	BOH	Cover	WD	WV	SUB	DETR	VEG
---------	------	-------	-------	-------	-----	------	------	-------	-------
1	1	60	0/0	5/2/6/11	3	2	1	0	3
1	2				5	7	5	0	1
1	3				3	2	20	0	0
1	4				5	0	10	1	0
1	5				7	3	50	0	3
2	1	75	0/0		etc.				
2	2								
2	3								
2	4								
2	5								
3	1								
3	2								
3	3								
3	4								
3	5								

APPENDIX XII. Recommended Lowest Taxonomic Level for Aquatic Macroinvertebrate Identifications during Level II Spring Surveys

PHYLUM ARTHROPODA	Taxonomic Level
Class Insecta	
Coleoptera	Genus
Diptera	Genus except in the following cases:
Canacidae	Family
Chironomidae	Subfamily or Tribe
Dolichopodidae	Family
Phoridae	Family
Scathophagidae	Family
Syrphidae	Family
Hemiptera	Genus
Megaloptera	Genus
Odonata	Genus
Lepidoptera	Genus
Ephemeroptera	Genus
Plecoptera	Genus
Trichoptera	Genus
Subphylum Chelicerata	
Class Arachnoidea	
Acari	Family
Class Brachiopoda	
Notostraca	Genus
Cladocera	Family
Class Copepoda	Subclass
Class Malacostraca	
Amphipoda	Genus
Decapoda	Genus
Isopoda	Genus
Mysidacea	Genus
Class Ostracoda	
Ostracoda	Family
PHYLUM COELENTERATA	
Class Hydrozoa	Genus
PHLYUM MOLLUSCA	
Class Gastropoda	Genus expect in the following cases:
Hydrobiidae	Species
Physidae	Genus except for *Physa* / *Physella*
Class Bivalvia	Genus
PHYLUM NEMATODA	Phylum

PHYLUM TARDIGRADA	Phylum
PHYLUM PLATYHELMINTHES	Family
PLYLUM ANNELIDA	
Class Hirudinea	Genus
Class Branchiobdellida	Genus
Class Oligochaeta	Family
Class Polychaeta	Genus
PLYLUM NEMERTEA	
Class Enopla	Genus

APPENDIX XIII. Field Survey Form for Level II Riparian Surveys—Vegetation Context

This form is used to record dimensions of upland and riparian types of vegetation near the spring source (a component of riparian sampling Strategy I). The length of each type of vegetation is measured along 20 m transects that are centered on the spring brook and oriented perpendicular to its thalweg. Transects are placed at the source and 5 m, 15 m, and 30 m downstream. This form also includes spring name (Locality), Surveyor name(s), sample Date, State, and County where the spring is located, and UTM coordinates of the spring source, following directions for Level I surveys.

Spring Riparian Surveys: Vegetation Context

LOCALITY: ______________________________ SURVEYOR(S): ______________________________________

DATE: _________________ STATE: _____ COUNTY: ___________ T______ R______ ¼ SEC________

GPS ZONE: ________ ±m ________ PDOP: _______ DATUM: NAD_______

SOURCE GPS POINT: PHOTO #1: NORTHING:_____________EASTING:______________

Location	Upland Vegetation	Riparian Vegetation	Upland Vegetation
-----------	-----------------	-----------------	-----------------
0			
5			
15			
30			

APPENDIX XIV. Field Survey Form for Level II Riparian Surveys—Tree Canopy (Count Method)

This form is used to record tree canopy by identifying, estimating the height, and diameter at breast height (Dbh) of all trees present within 10 m of both sides of the centerline along the upper 30 m length of spring brook (riparian sampling Strategy II). Measure Dbh in cm using a flexible tape measure. Estimate height in m. This form also includes spring name (Locality), Surveyor name(s), sample Date, State, and County where the spring is located, and UTM coordinates of the spring source, following directions for Level I surveys.

Spring Riparian Surveys: Tree Canopy Count

LOCALITY: ________________________________ SURVEYOR(S): ____

DATE: ___________________ STATE: ______ COUNTY: ____________ T_______ R_______ ¼ SEC_________

GPS ZONE: ________ ±m ________ PDOP: _______ DATUM: NAD_______

SOURCE GPS POINT: PHOTO #1: NORTHING:______________EASTING:_______________

Species	Dbh	Height
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APPENDIX XV. Field Survey Form for Level II Riparian Surveys—All Canopies (Line Intercept Method)

This form is used to record species composition and cover data of all canopy levels along the spring brook bank. Record the identity of all species extending over the water at every 1m point (Point) along the length of a 30m transect for long spring brooks and 15m for shorter spring brooks. If no vegetation is present at a point, record OP = open water, BG = bare ground, LI = litter, or RO = rock. This form also includes spring name (Locality), Surveyor name(s), sample Date, State, and County where the spring is located, and UTM coordinates of the spring source, following directions for Level I surveys. Use a tape to measure spring brook length.

Spring Riparian Surveys: All Canopies—Line Intercept Method

LOCALITY: ______________________________ SURVEYOR(S): ______________________________________ DATE: _________________

STATE: ______ COUNTY: ____________ T_______ R_______¼ SEC_________ SPRING BROOK LENGTH: ___________________________

GPS ZONE: ________ ±m ________ PDOP: _______ DATUM: NAD_______ SOURCE GPS POINT: PHOTO #1: NORTHING:______________EASTING:_______________

Point	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														

APPENDIX XVI. Field Survey Form for Level II or III Riparian Surveys—Shrub and Herb Canopies (Quadrat Method)

This form is used to record the vegetative cover of species within four quadrats that are placed within each 15 m of spring brook. Quadrats are located 3 m, 6 m, 9 m, and 12 m from the upper limit of each 15 m length and placed near (0.5 m) and far (3 m) from alternate spring brook banks such that near quadrats are placed at 3 m and 9 m from right and left banks, respectively, and far quadrats are placed at 6 m and 12 m from right and left banks, respectively. Circle the segment of spring brook being sampled (e.g., 0 to 15, 15 to 30, etc.). Number the upstream most quadrat within a 15 m segment as 1 downstream through the segment to 6. Circle 'N' for quadrats 0.5 m from the spring brook and 'F' for quadrats 3m from the spring brook. Identify and list all species providing ground cover in each quadrat (with the exception of overstory trees) and categorize the coverage by each species as: 1—<1%, 2—1%-5%, 3a—5%-15%, 3b—15%-25%, 4—25%-50%, 5—50%-75%, or 6—>75%.

Spring Riparian Surveys: Shrub and Herb Canopies—Quadrat Method

LOCALITY: ______________________________ SURVEYOR(S): ______________________________________

DATE: _________________ STATE: ______ COUNTY: ____________ T_______ R_______¼ SEC_________

GPS ZONE: ________ ±m ________ PDOP: _______ DATUM: NAD______

SOURCE GPS POINT: PHOTO #1: NORTHING:______________EASTING:_______________

Segment **0-15 15-30 30-45 45-60**			
Quad #	Location	Species	Cover
---------	----------	----------	--------
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		

Segment **0-15 15-30 30-45 45-60**			
Quad #	Location	Species	Cover
---------	----------	----------	--------
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		
	N F		