TR 1737-17

A Guide to Managing, Restoring, and Conserving Springs in the Western United States (2001)

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RIPARIAN AREA MANAGEMENT

A Guide to Managing, Restoring, and Conserving Springs in the Western United States

Technical Reference 1737-17 2001

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I. Introduction

Springs have played an important role in the human occupation of the Western United States. Emigrants who crossed and settled in arid regions of the country were dependent upon springs for water. Though these vital water sources were comparatively small, they were commonly developed to provide water for livestock, mining, and the burgeoning human population.

Springs have also provided important habitat for many species of wildlife and plants, and in fact, are vital to a number of unique plant and animal communities in the Western U.S. Early studies by Gilbert (1893), Wales (1930), Hubbs (1932), Hubbs and Kuhne (1937), Hubbs and Miller (1948a) and Miller (1943, 1948) described many unique fishes from springs, and studies since the mid-1980's have described a number of endemic spring-dwelling macroinvertebrates (primarily mollusks and aquatic insects) (Hershler 1998; Schmude 1999). Erman (1997) and Wiggins and Erman (1987) identified distinctive caddisflies of subalpine springs in the Sierra Nevada, along the western edge of the Great Basin. Surveys in other regions also document endemic mammals, amphibians, and plants from spring-fed wetlands (Sada et al. 1995) and Forester (1991) and Holsinger (1974) cited the importance of springs to ostracodes and amphipods, respectively.

Unfortunately, as springs have been developed to enhance water availability for livestock, game animals such as chukar (*Alectoris graeca*) and bighorn sheep (*Ovis canadensis*), and humans, the associated riparian and aquatic habitats frequently have been altered due to trampling, diversion, channelization, and impoundment. Springs have also been affected by excessive ground-water use, as well as by the invasion and establishment of nonnative plants and animals. As a result, the current physical and biological characteristics of many springs bear little resemblance to their historical, unaltered conditions. Additionally, populations of plants and animals that rely on spring habitat have declined and many are now on the Federal list of threatened or endangered species.

Evidence showing the biological importance of springs continues to increase and general guidance is available to assist agencies in developing springs while maintaining biological diversity. However, these small wetlands have received limited management priority. Degraded habitat conditions (Sada et al. 1992), recent population declines, and species extinctions (Sada and Vinyard in press) all indicate that management changes are necessary to restore habitat integrity and prevent future extinctions and wetland deterioration (Williams et al. 1985; Erman and Erman 1990; Naiman et al. 1993; Shepard 1993).

The purpose of this technical reference is to provide information on the characteristics of springs in the Western

KEY FEDERAL POLICIES AND REGULATIONS DIRECTING SPRING ECOSYSTEM MANAGEMENT

All major Federal policies, Executive orders, and legislation to direct management of aquatic and riparian habitats are more fully described in USDI (1991). A number of additional State regulations are also applicable (e.g., water quality standards, water rights, etc.). Following are several key Federal policies and regulations:

- ✦ The Taylor Grazing Act of 1934 directs the Secretary of the Interior to end degradation of public lands (including riparian areas) by preventing overgrazing and soil deterioration and requiring orderly use, development, and improvement of natural resources on grazing lands.
- ✦ The Federal Land Policy and Management Act of 1976, 43 U.S.C. 1701 (FLPMA) provides overall guidance to the Bureau of Land Management for managing riparian and aquatic systems. Implementation of this guidance is to be accomplished through land use plans.
- ✦ The Federal Water Pollution Control Act of 1977 (Clean Water Act) provides for protection and improvement of water quality, including wetland areas.
- ✦ A 1992 Bureau of Land Management policy states that the goal of riparian-wetland area management is to maintain, restore, improve, protect, and expand these areas so they are in proper functioning condition for their productivity, biological diversity, and sustainability. The overall objective is to achieve an advanced ecological status, except where resource management objectives, including proper functioning condition, would require an earlier successional stage (USDI 1992).
- ✦ Interior Department Manual 520, *Protection of the Natural Environment*, directs preservation, protection, and acquisition of riparian-wetland areas, as necessary.

U.S. and to identify techniques for managing spring habitats that will allow use, maintain biological integrity, and rehabilitate or restore degraded habitats. Spring management goals are outlined and methods for prioritizing management actions are discussed.

In addition, this guidance is intended to facilitate implementation of a memorandum of understanding (MOU) pertaining to the U.S. Department of the Interior's Species at Risk Program for springsnail conservation. This MOU was prepared to facilitate cooperation and participation among The Nature Conservancy, Bureau of Land Management (BLM), Smithsonian Institution, National Park Service, Fish and Wildlife Service, and U.S. Department of Agriculture, Forest Service, to conserve springsnails and their habitats on Federal and TNC lands. The MOU was formally signed by representatives from these agencies during 1998.

The information presented focuses on habitats managed by BLM in the Western United States, excluding Alaska. It is intended to assist biologists, range conservationists, and other natural resource specialists in the development of conservation or land use plans. It does not, however, make specific water development recommendations. When water developments are constructed, the guidance in this document should be integrated with the recommendations in BLM Handbook H-1741-2, *Water Developments* (USDI 1990).

II. *What is a Spring?*

A spring is where water flows naturally from a rock or soil upon the land or into a body of surface water (Meinzer 1923).[1] Many springs exhibit a unique combination of physical, chemical, and biological conditions (Hynes 1970; Garside and Schilling 1979). Spring ecosystems include aquatic and riparian habitats that are similar to those associated with rivers, streams, lakes, and ponds. They are distinctive habitats because they provide relatively constant water temperature, they depend on subterranean flow through aquifers, and on occasion, they provide refuge for species that occur only in springs (Hynes 1970; Erman and Erman 1995; Hershler 1998; O'Brien and Blinn 1999).

Figure 1. Types of Springs.

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Springs are replenished by precipitation that percolates into aquifers. The precipitation seeps into the soil and enters fractures, joints, bedding planes, or interstitial pore space in sedimentary rocks. Springs occur where water flowing through aquifers discharges at the ground surface through fault zones, fractures, or by flow along an impermeable layer (Figure 1A-F). They can also occur where water flows from large orifices that result when the water dissolves carbonate rock, enlarging fractures or joints to create a passage. Characteristics of regional and local

[1] This guidance is applicable to seeps as well as to springs. There is a fine distinction between seeps and springs. The term spring refers to an intersection of the ground-water table and the ground surface resulting in a spring. Sepps to not have an obvious localized spot from which water flows, but they are a subset of springs. Therefore, although the term "spring" is used alone thoughout this document, it implies both springs and seeps.

geology influence spring occurrence and flow rates. Springs are generally classed as gravity springs and artesian springs, with thermal springs typically being considered a type of artesian spring. Gravity springs are created by water that moves along an elevation gradient emerging at the surface. Depression springs, contact springs, and fracture and tubular springs are different types of gravity springs. These types of springs occur where the movement of water through permeable material is interrupted by an impermeable layer that directs water to the surface. This situation often creates a perched aquifer, with springs flowing along the contact with an impermeable layer (Figure 2). Artesian springs occur where the potentiometric level of the ground-water flow system is above the land surface and the water flows at the land surface under pressure either at the aquifer outcrop (Figure 3) or from fractures or faults (Figure 4). Water is sometimes forced to the surface along a fault from deep sources by thermal and pressure gradients. Aquifer outcrop springs and fault springs are the two main types of artesian springs.

Springs can be regional (long flow paths that are often interbasin) or local discharge points (short flow paths). Local springs are comparatively small, can have low flow, and are typically from shallow aquifers. The discharge from these springs often fluctuates either seasonally or in greater cycles, sometimes in response to local

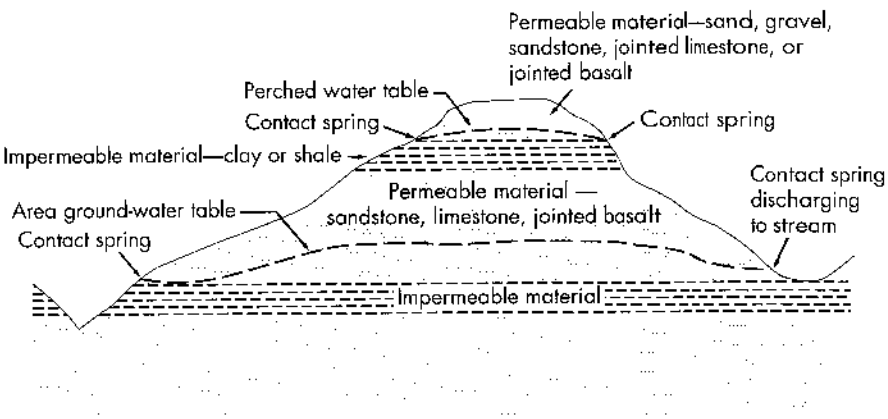

FIGURE 2. Typical contact spring.

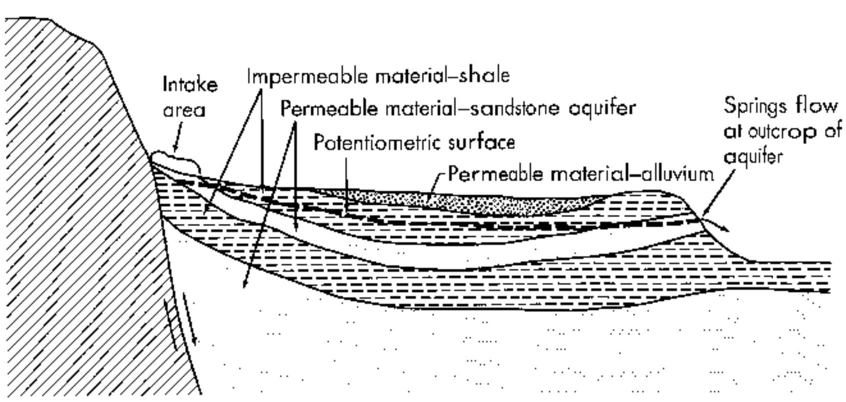

FIGURE 3. Artesian spring at outcrop of aquifer.

precipitation. Local aquifers are quickly recharged and water movement through them is comparatively rapid, resulting in waters that are low in mineralization. Springs supported by local aquifers are more likely to periodically stop flowing than springs supported by regional aquifers.

Regional springs are more typically high-flowing and are discharge points for aquifers covering hundreds of square miles. In the Great Basin, the majority of the high-flowing springs occur within the intermontane basins of the carbonate rock province and are often closely associated with outcrops of carbonate rock (i.e., limestone) (Mifflin 1988). Regional springs are typically of nearly constant discharge and can be more mineralized than local springs due to their long flow paths. Their temperatures can be cold or warm depending on the depth of circulation. Seasonal and annual variations in discharge from regional aquifer springs are usually limited, and they are comparatively stable aquatic environments. Regional springs rarely stop flowing, even during long droughts.

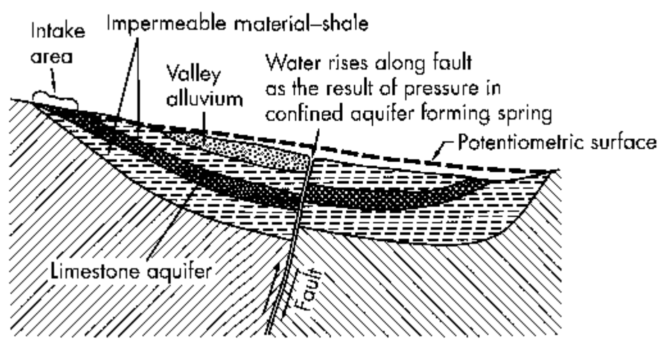

FIGURE 4. Artesian spring occurring along a fault.

Physical Environment of Springs

Springs occur in many sizes, types of discharge points, and locations with respect to topography. They occur in the highest elevations of mountainous areas to valley floors. Many springs found on lands managed by the BLM are small, provide limited aquatic habitat, and are intermittent in flow. They generally support limited amounts of riparian vegetation. However, some small springs do provide greater amounts of aquatic habitat, are permanent, and support larger riparian zones with greater species diversity. Springs are frequently categorized by the morphology of their source: *limnocrenes* are sources where water flows from large deep pools, *helocrenes* are marshy bogs, and *rheocrenes* flow into a confined channel (Hynes 1970). It is often difficult to categorize springs because morphology can be a combination of features from more than one of these categories.

Springs vary in their physical and chemical conditions (see Hynes 1970; Garside and Schilling 1979). They can be cold (near or below mean annual air temperature), thermal (5 to 10 °C above mean annual air temperature) (van Everdingen 1991), or hot (more than 10 °C above mean annual air temperature) (Peterken 1957). The temperature of spring water is also an indicator of the flow path of water discharging to the spring and its recharge area. Shallow circulating ground water has temperatures generally within a few degrees of the mean annual ambient air temperature (Mifflin 1988).

Higher temperatures are usually indicative of deeper, regional circulation, although some cool regional springs exist. Thermal springs gain their temperature increases when water comes in contact with or in close proximity to recently emplaced igneous masses, such as at Steamboat Springs, Nevada; Yellowstone National Park; and Geyser, California (Wood and Fernandez 1988). Thermal and hot springs are due to deep seated thermal sources, and are classed as volcanic springs or fissure springs (Milligan et al. 1966), which are types of artesian springs. Fault-related springs can also be thermal if they are from a deep source of water. This type of spring is common in the Great Basin, where mountain blocks are faulted along the margins, allowing water from deep sources to rise along the fault.

Springs may occur singly or in groups that can include dozens of habitats in various sizes and morphologies. Many springs are tributaries to rivers, lakes, and streams. A few are even the major source for a river, lake, or stream. However, most single springs below approximately 7,000 feet (2,100 m) on BLM lands in the Western U.S. are isolated from other wetlands and frequently flow a short distance on the surface before drying (Hendrickson and Minckley 1984). Many springs in this region stop flowing periodically on a seasonal basis or during times of drought. Some groups of mid- to low-elevation springs can support wetland areas with unique habitat and species (e.g., Ruby Marsh in northeastern Nevada, Ash Meadows in southern Nevada, Fish Springs in northwestern Utah, and San Bernardino Ranch in southern Arizona) (Hendrickson and Minckley 1984; Dudley and Larson 1976). Springs at higher elevations generally display greater fluctuations in flow rates and dry more frequently than regional springs or springs at lower elevations. However, they are generally less susceptible to impacts from dewatering at agriculture and mining operations. Some springs support mid- to low-elevation fens in the watershed, usually in large open areas or parks such as South Park in south-central Colorado. Some springs are the source for streams high in a watershed and provide a perennial water supply to lower elevation streams.

Water Chemistry of Springs

Springs may be highly mineralized, especially thermal springs and sometimes regional springs that have a very long flow path. Thermal springs in Utah have pH values ranging from 7.2–7.6 (Milligan et al. 1966). Springs in the Great Basin likely have similar pH values. Dissolved oxygen concentration is primarily a function of temperature and pressure; as temperature increases, the dissolved oxygen concentration decreases (Hem 1992). As a result, dissolved oxygen concentrations are frequently very low [less than 2 parts per million (ppm)] in hot springs and high (greater than 5 ppm) in cold springs. Electrical conductance may range from very low (near 0 microsiemens per centimeter) to very high (greater than 10,000 microsiemens per centimeter). Local low-flowing springs may freeze during winter, while the larger and warmer regional springs do not.

Biotic Characteristics of Springs

Ecological aspects of spring-fed aquatic and riparian systems in the Western U.S. have been studied less than lentic and lotic systems in the region. Spring ecology is described briefly here; a more thorough summary is presented in Appendix A.

Studies of springs in other regions indicate that these wetlands are habitat for aquatic plants and animals, a water source for terrestrial animals, and a source of food and cover for birds, reptiles, amphibians, and mammals. Many of these habitats are also occupied by endemic vertebrates and/or macroinvertebrates. Riparian communities are generally composed of species associated with regional streams, rivers, wetlands, and lakes, and aquatic communities include species that are closely related to other regional wetlands. The aquatic biota of a spring is regulated by its chemical, biological, and morphological characteristics (van der Kamp 1995). Species that inhabit rheocrenes prefer flowing water and species in limnocrenes are more closely related to species that occupy lakes and ponds. Water temperature, dissolved oxygen concentrations, and other water chemistry components change downstream from the spring source. As a result, animal communities that occupy spring sources typically differ from communities in habitats further downstream. Many spring source species do not occupy downstream habitats where temporal fluctuations in water temperature and flow are greater (Erman and Erman 1990; Erman 1992), and endemic macroinvertebrates are usually more abundant near spring

SELECTED RARE PLANT SPECIES ASSOCIATED WITH SPRING SYSTEMS

STATE and SPECIES	COMMON NAME
ARIZONA	
Lilaeopsis schaffneriana	Huachuca water umbel
Spiranthes delitescens	Canelo Hills ladies tresses
CALIFORNIA	
Calochorthus excavatus	Inyo County mariposa lily
Carex albida	White sedge
Cirsium fontinale var. obispoense	Chorro Creek bog thistle
Cirsium hydrophilum var. hydrophilum	Suisun thistle
Sidalcea covillei	Owens Valley checkerbloom
COLORADO	
Aquilegia chrysantha var. rydbergii	Golden columbine
Botrypus virginianus ssp. europaeus	Rattlesnake fern
Epipactis gigantea	Giant hellborine
Mimulus eastwoodiae	Eastwood monkey flower
IDAHO/MONTANA	
Howellia aquatilis	Water howellia
Spiranthes diluvialis	Ute ladies tresses
MAINE	
Pedicularis furbishiae	Furbish lousewort
Platanthera leucophaea	Eastern prairie fringed orchid
NEVADA	
Centaurium namophilum	Spring-loving centaury
OREGON	
Ilamna rivularis var. rivularis	Streambank hollyhock
UTAH	
Asclepias welshii	Welsh's milkweed
Carex specuicola	Navajo sedge
VIRGINIA	
Cardamine micranthera	Small-anthered bittercress
Platanthera leucophaea	Eastern prairie fringed orchid
WASHINGTON	
Arenaria paludicola	Marsh sandwort
Sidalcea nelsoniana	Nelson's checker mallow
WISCONSIN	
Aconitum noveboracense	North wild monkshood
Iris lacustris	Dwarf lake iris
WYOMING	
Spiranthes diluvialis	Ute ladies tresses

sources than they are in downstream habitats (Hershler 1998; Erman and Erman 1995). Communities in permanent springs generally include more species and more individuals than communities in ephemeral springs (Erman and Erman 1995). Species in ephemeral habitats are generally highly mobile (animals that can fly or crawl long distances) and adapted to establishing in impermanent and comparatively harsh habitats. Springs occupied by endemic species do not dry and they have persisted for thousands of years.

The physical habitat of a spring is the most important factor influencing its riparian and aquatic plant and animal communities. Riparian vegetation may be narrowly restricted to immediate boundaries of the aquatic habitat or may extend outward for substantial distances. Narrow riparian zones are typically dominated by sedges, grasses, and woody phreatophytes (e.g., willows, mesquite, etc.). Wider riparian systems are generally associated with spring provinces where water seeps outward from aquatic habitats, which saturates and creates hydric soils. In these provinces, riparian systems are characterized by marsh vegetation or expansive mesic alkali meadows. Riparian vegetation surrounding coolwater springs and springs with lower thermal temperatures consists of species typically found near regional streams, lakes, and marshes (e.g., willows, mesquites, sedges, and grasses). This vegetation may be dense at sites that have been minimally changed by impacting uses.

Sites that have been highly modified generally have less diverse riparian communities, and they may include nonnative species and many species that are typically associated with upland plant communities. Aquatic vegetation in these systems is also similar to vegetation that occurs in streams, lakes, and marshes (e.g., green algae, duckweed, cattail, giant reed, etc.). Vegetation near hot springs is more distinctive because it consists of plants that are tolerant of highly alkaline and salty soils. Cyanobacteria (photosynthetic bacteria) is typically the most abundant aquatic vegetation in the springs. Habitat condition also affects aquatic vegetation communities. Green algae is frequently the dominant aquatic vegetation in degraded habitats. Habitats in better condition usually support a more diverse community that consists mostly of flowering plants, ferns, and calcareous algae.

Aquatic animal communities in springs consist of species that are closely related to those commonly occurring in other regional wetlands, as well as a diversity of endemic fishes, mollusks, and aquatic insects. Species that occur in these communities also vary in response to environmental conditions. Some species occupy only cool habitats while others occur only in thermal springs. Habitats with swiftly flowing water are preferred by some species and other species occur only in placid water. As in streams, substrate composition is an important habitat component. Some species prefer gravel and others prefer silt, sand, or cobbles.

III. Uses that Affect Springs

Springs in the Western U.S. have been physically and biologically modified from historical conditions that existed when settlers first entered the region. Spring ecosystems have been functionally changed by modifications that decrease water volume and soil moisture and by impoundments that inundate spring brooks. These functional changes have increased abundance of nonnative and upland vegetation within riparian zones, replaced taxa that require flowing water with taxa that occupy pond/lake habitats, and caused extirpation of populations and species extinctions (Sada and Vinyard in press).

Physical and Chemical Disturbances

Diversion

Springs have been diverted in many ways to provide water for many uses. Pipes have been installed to deliver water for livestock, agriculture, recreation, and homes, and many springs have been dried by ground-water pumping (Brune 1975; Dudley and Larson 1976). Sada and Vinyard (in press) concluded that water diversion was the most common threat to fishes and other aquatic species from the Great Basin.

USDI (1990) describes a number of water development techniques, including some for developing springs. Most of these techniques involve excavating a box into a spring to capture water and pipe it to impoundments, troughs, or other storage reservoirs. There are a number of different spring box designs, but most are constructed either from culverts, concrete, or wood. Some spring developments are designed to capture all the flow, while others let some of it pass into natural channels.

Many springs have been modified by these developments. Indications of the magnitude of impacts from spring development were quantified during surveys of 505 springs in northern Nevada by Sada et al. (1992). They observed that approximately 60 percent of these springs had been modified by diversion. Sada and Vinyard (in press) concluded that approximately 50 percent of the aquatic taxa endemic to the Great Basin (78 percent of which occupy springs) had declined because of diversion impacts. There is comparatively little information that quantifies biological impacts of spring developments. However, Sada and Nachlinger (1996, 1998) found that biological diversity was greater in larger and undisturbed springs and that nonnative taxa comprised a greater proportion of the riparian vegetation at disturbed springs. They concluded that diversions decreased biological diversity by reducing aquatic habitat and reducing soil moisture in riparian zones. Altering riparian vegetation may alter energy budgets (changing the aquatic system from being allochthonous to autochthonous) and reduce larval food and reproductive habitats for terrestrial phases of aquatic insects (Erman 1984, 1987). Similar results may occur following establishment of nonnative species. Sada and Nachlinger (1996) also reported loss of springsnail populations (*Pyrgulopsis deaconi* and *P. turbatrix*) from recent diversions. Hershler (1998) attributed extinction of a springsnail (*P. ruinosa*) to diversion. Stromberg et al. (1992, 1993) and Stromberg and Patten (1990) found that stand structure, species composition, and leaf area in southwestern U.S. riparian zones were decreased by diversion and ground-water removal. Differences in source and downstream aquatic communities indicate that diversion may also affect the distribution of species. Decreased flow is likely to result in greater water temperature variation, causing a decrease in habitat for spring source species and a relative increase in habitat of downstream species.

Functional changes in spring biota also occur when flowing habitats are impounded. Under these circumstances, species that require lotic habitats are extirpated and replaced by lentic taxa. Hershler (1989) documented local extirpation of the Fish Slough springsnail (*Pyrgulopsis perturbata*) following impoundment of a spring source.

Recreation

Recreational use of spring systems for bathing (most common in thermal springs) can cause a significant decline in the ecological function of these sites. The primary impacts of recreational use include: soil compaction, removal of vegetation, and resulting erosion from camping along the edges of springs; manipulation of spring flow from installing "tubs" and water diversions; and elimination of aquatic biota from using bleach and soap.

Mining

Springs have been affected by mining in several ways. In the late 19th century they were most affected by diversions that captured water for delivery to mining operations and to towns for municipal use. Frequently, the spring sources were captured in a box and either all or part of the discharge was diverted into a pipe for use. These diversions decreased the amount of water flowing across the land and changed aquatic and riparian habitat conditions. Recent use of spring flow at mining operations is rare. More often, spring discharge has been affected by high-capacity pumping that dewaters aquifers to prevent flooding in open pit mines. Because dewatering lowers the water levels in the regional aquifer or decreases the potentiometric surface (artesian pressure), it affects artesian springs and low-elevation springs that have the regional aquifer as their source more than high-elevation springs where water sources are above the regional aquifer system. However, depression springs can also be affected in this situation when the regional water table is lowered, thereby lowering the water table below the depression and drying the spring.

Pollution

Springs are susceptible to pollution because they are often supplied by shallow aquifers that can easily become polluted if spilled chemicals percolate from the surface through rock fractures or joints. Pollutants may be toxic (affecting aquatic and riparian biota if the source of contaminants is very close to the spring) and may increase nutrient concentrations (e.g., nitrogen, phosphorus, etc.), which may cause changes in chemical habitat characteristics. Such changes may increase bacterial abundance and lower dissolved oxygen concentrations, which frequently cause macroinvertebrate communities to change from taxa typically found in unpolluted systems to taxa that occupy polluted water (Rosenberg and Resh 1993). The most common sources of pollution that affect springs are:

- Refuse Disposal and Hazardous Materials: Sources for springs on BLM lands are rarely affected by landfills. More frequently, ground waters near springs are contaminated by illegal dumping, chemicals from abandoned mining operations, leachates, or runoff from abandoned mine waste and tailings. Other possible source of ground-water contamination near springs are sewage treatment lagoons in mountain communities, herbicides and pesticides, hazardous waste disposal, and accidental spills of hazardous chemicals.

- Injection Wells: Brines or other poor-quality water may enter an aquifer that supports spring discharge, possibly contaminating the spring source. Springs may also be affected by the injection of cool water, which causes a change in temperature of the spring discharge. These effects can sometimes be observed in springs several miles away from an injection field, depending on geological conditions.

- Oil and Gas Development: Ground-water contamination may occur when petroleum leaks from abandoned or improperly constructed wells. Hydrocarbons can discharge at springs as a result of transport along fractures or faults. Leaking pipelines in oil or gas fields can also be a source of petroleum hydrocarbons in ground water. Pits containing produced water can contain high total dissolved solids (TDS) and some hydrocarbons, and could potentially affect water quality if there are nearby springs that are fed by shallow ground water.

- Ungulate Activity: Wild horses and burros, cattle, sheep, and sometimes wildlife congregate around springs. This results in trampling of vegetation, eliminating a buffer that prevents silt and elevated levels of nutrients from entering the aquatic system. Additionally, fecal material is often deposited in and around aquatic systems, which elevates nutrients (Kauffman and Krueger 1984; Fleischner 1994; Thomas and Toweill 1982).

Biological Disturbances

Introduced Species

Vegetation

Introduced plant species, many of which are recognized as noxious weeds, can be detrimental to spring systems. These species can have a significant impact on the ecological function of spring systems by reducing overall plant and animal diversity and altering site hydrology. Saltcedar (*Tamarix* spp.), purple loosestrife (*Lythrum salicaria*), Canada thistle (*Cirsium arvense*), knapweed (*Centaurea* spp.), and perennial pepperweed (*Lepidium latifolium*) are the most common introduced plants affecting western wetlands. Seed germination and dissemination and physiological characteristics make these species competitively superior to native vegetation. They are adept at displacing native vegetation at sites that have been disturbed by water impoundments, excessive grazing, and recreation, which reduces critical nesting, feeding, and reproductive habitat for wildlife and fish species.

Aquatic Animals

A number of vertebrates and invertebrates have been introduced into springs throughout the Western U.S. The mosquito fish (*Gambusia affinis*,) which has been used as a biological control agent for mosquitoes throughout the world (Courtenay et al. 1984), is probably the most widely introduced vertebrate. Many species of aquarium fish have been introduced [e.g., goldfish (*Carassius auratus*), sailfin molly (*Poecilia latipinna*), shortfin molly (*Poecilia mexicana*)], primarily into thermal springs. Bullfrogs (*Rana catesbeiana*) have also been widely introduced for sport. In addition, a number of sport species of fish have been introduced into springs [e.g., rainbow trout (*Oncorhynchus mykiss*) and largemouth bass (*Micropterus salmoides*)]. Crayfish (usually *Pacifastacus lenusculus*) and red-rimmed thiara (*Thiara tuberculata*) (an aquatic snail) are believed to be the most commonly introduced invertebrates in western springs. Populations of native aquatic species have either been reduced or extirpated as a result of these and other species being introduced into western spring systems (Miller 1961; Schoenherr 1981; Moyle 1984; Taylor et al. 1984; Miller et al. 1989; Hershler 1998).

Terrestrial Animals

Spring-fed aquatic and riparian systems are also impacted by introduced terrestrial animals. As in lotic systems, excessive use by terrestrial vertebrates frequently causes trampling that decreases riparian and aquatic diversity (Kauffman and Krueger 1984; Fleischner 1994). There are a number of variables that influence the degree of impact to springs from large ungulate use such as local topography, soils, and the ungulate causing the disturbance.

Cattle are widespread throughout the Western U.S. and springs are frequently their only source of water. Cattle probably impact more springs in the region than other ungulates. Without proper grazing, cattle will utilize spring riparian vegetation until it is virtually eliminated. Only then will they utilize surrounding areas. This creates a concentric ring effect with the spring being the most heavily utilized area and areas further from the spring being utilized at decreasing levels. Since the spring is often the primary watering source, additional use occurs even after livestock have removed all herbaceous vegetation. The additional trampling on spring riparian areas devoid of vegetation results in topsoil loss during rainfall and snowmelt events. On soils with a high clay content, trampling can at times "seal" the spring, causing it to resurface in a different area or to not resurface at all. Impacts are generally greatest where the topography is steep in the immediate vicinity of a spring. At steep sites, ungulates spend more time at the spring and cause greater impacts than at springs surrounded by gentle topography.

Repeated heavy use by cattle gives a competitive advantage to those plants that exhibit an ability to grow, flower, and set seed in a very short time period or to those that have a very low growth form and are able to conduct photosynthesis in spite of being grazed at levels near the soil surface. This changes the plant community associated with the spring and the interrelationships between the biotic and abiotic components in the ecosystem.

Although exceptions exist, cattle generally have a greater impact on herbaceous vegetation than woody vegetation. The magnitude of impacts is determined by timing, duration, and frequency of grazing.

Wild horses and burros also utilize springs, which can have significant impacts. Unlike domestic livestock, wild horses and burros are not usually subject to grazing systems that would afford some protection or rest for springs. As a result, their activities frequently reduce or eliminate riparian vegetation, pollute aquatic habitats, and impact functioning condition. These impacts may be extreme because animals may concentrate near springs all year long if alternative watering sources are not available. These impacts are also magnified during drought periods. In addition, springs are areas of social interactions for wild horses and burros where the dominant males protect their bands of females. This territoriality tends to keep horses or burros using the same spring, increasing the negative impacts to these areas. As with other introduced species, it is frequently necessary to remove wild horses and burros to alleviate their impacts on spring ecosystems.

Domestic sheep are usually herded when grazed on public lands. As a result, their impact on springs is more a function of herding practices than the inherent behavior of the animal. When quickly moved through an area, the impact on springs is minimal. Severe damage to aquatic and riparian systems occurs when they are allowed to use an area for bedding or prolonged stays.

Native Species

Native species such as bison and elk can also impact springs. In areas where large populations exist, their impacts can be similar to those of livestock.

IV. Spring Resource Management Goals

Each spring may have a unique suite of biological, chemical, and physical characteristics. Springs may also differ in their sensitivity to a wide variety of uses, including ungulate grazing, recreation, mining, and water developments. Therefore, each spring may require an individual management prescription to maximize opportunities to maintain desired conditions and reduce use conflicts.

The overall goal of spring management is to maintain the ecological structure and function of the spring habitat by stabilizing discharge and spring brook morphology. Springs should not be subjected to impacts that change functional characteristics of aquatic and riparian biota (e.g., replacing a fauna that prefers flowing water with a fauna that occupies ponds and lakes, allowing nonnative invasive plants or animals to establish and possibly dominate aquatic and riparian communities or causing a decrease in biological diversity of aquatic and riparian systems). In situations where there is adequate biological information, habitats should be maintained in historical condition.

The overall goal can be broken down into the following individual goals:

Goal 1—Manage springs and their riparian areas as a unit. Guidelines that are currently used to manage wetland areas and riparian zones are useful for managing spring systems. Management direction to help determine appropriate uses and their intensity can be found in Leonard et al. (1997), Ehrhart and Hansen (1997), and Ehrhart and Hansen (1998).

Goal 2—Manage for proper functioning condition (PFC) of springs and associated riparian areas. Prichard et al. (1999) provide direction for assessing PFC. If current management is not achieving PFC, changes in management must be implemented. Specific management activities are discussed in Section V.

Goal 3—Manage springs to desired condition. Attaining PFC is an important aspect of spring management; however, it should not be the final goal. PFC is an assessment of the physical functioning of a riparian area through the consideration of vegetation, hydrology, and soil/landform attributes. PFC provides a state of resiliency that allows an area to sustain its ability to produce values related to both physical and biological attributes. PFC does not address all biological components of riparian systems, which are important elements for maintaining or restoring desired condition of spring ecosystems. Most of the time, reaching desired condition will result in the greatest biological diversity and the reestablishment of riparian and aquatic communities that characterize high-quality habitats with similar water temperature and chemistry, discharge, soils, and elevation.

Goal 4—Restore degraded springs and associated riparian areas. Restoration of biological diversity and PFC should be conducted in a manner consistent with the principles of spring restoration described in Section VI. Restoration is a high priority because many springs are in severely degraded condition.

Goal 5—Educate the public about the importance of springs through interpretive, watchable wildlife, and other environmental education programs. Historic and current interest in spring systems indicates that the public recognizes these resources as unique and valuable ecosystems. This interest provides an excellent opportunity for interpretive presentations to explain the historical and biological importance of springs. Interpretive programs should be developed to educate the public about the values and diversity of springs. These programs should also describe the potentially adverse effects of excessive resource utilization and introductions of nonnative species.

V. Spring Management Assessment and Priorities

The biotic and abiotic diversity of springs across the landscape often complicates the processes of identifying management concerns and prioritizing management programs. As in other aquatic systems, the effect of management on spring ecosystems can be assessed by evaluating habitat characteristics and aquatic and riparian communities. The section outlines a process for evaluating the effectiveness of existing management to accomplish the goals discussed in Section IV, identifying resource management deficiencies, determining management direction, and prioritizing management actions necessary to maintain the biological integrity of individual springs. Sites that this evaluation indicates are degraded should be restored. Restoration methods and priorities are discussed in Section VI.

Step 1—Survey and inventory springs within a management area to document current conditions and to accumulate biotic and abiotic information. This information should be used to prioritize management programs for individual springs. Inventories of springs and historical wetland areas should be conducted prior to restoration. Prichard et al. (1999) provide quantitative methods to determine physical, biological, and riparian measures. Plafkin et al. (1999) discuss how macroinvertebrate inventories can be conducted following rapid bioassessment protocols. Conducting adequate biotic surveys may be difficult for some groups of macroinvertebrates. Erman and Erman (1990) suggest that all members of the aquatic community can be determined only by using several different sampling methods during surveys that include different seasons. Although intensive surveys may be necessary to determine all members of the aquatic community, this amount of detail may not be necessary to assess biotic and abiotic conditions of a spring or to determine management direction that includes minimizing the impacts of detrimental activities.

Inventories should document existing conditions (when possible) and determine if any sensitive, endangered, or threatened species or their habitat are present. These surveys should also provide information to assess the biological potential of springs in the area and they may be important to document pretreatment conditions for restoration programs. Inventories should include locations of any habitat for species that may have been extirpated by previous disturbance, species that occur seasonally, or species that may be seasonally abundant (and easily captured by sampling). Some aquatic species and plant taxa are poorly known, yet they exhibit a surprising amount of endemism in many spring systems. Unknown species should be

AUTHORITIES FOR IDENTIFICATION OF TAXONOMIC GROUPS WITH KNOWN SPECIES ENDEMIC TO SPRINGS

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sent to recognized experts for identification.

Plafkin et al. (1999), Orth (1983), and Prichard et al. (1999) provide general guidance for assessing springs and riparian zones. If a spring provides habitat for species on the Federal list of threatened or endangered species, proper consultation procedures with the U.S. Fish and Wildlife Service (or within the State for State-listed species) must be followed.

Step 2—Identify factors that might limit management options. There are numerous factors that could impact the effectiveness of certain management actions. The following factors should be considered:

- Habitat quality
- Extent of wetland areas
- Occurrence of nonnative species and their source for invasion
- Ownership of spring and water rights
- State water laws
- Current and potential recreational use of the site
- Site potential
- Spring discharge

Additional factors may be determined through site evaluation and public input.

Because control of water is an essential component of land and resource management in the arid West, water rights are an important aspect of spring management. The BLM is entitled to hold water rights under State law and to claim Federal reserved rights. The latter arise where Congress has withdrawn and reserved public lands by statute for a specific Federal purpose, or where public lands have been administratively withdrawn for a specific Federal purpose. The withdrawal of lands from the public domain and reservation of land for a Federal purpose may, by implication, reserve water if water is necessary to accomplish the purpose of the reservation. If so, then an implied reservation of water exists. However, the reserved right created by the reservation is only for appurtenant and unappropriated waters as of the date of the reservation and only for the minimum amount necessary to fulfill the primary purposes of the reservation. BLM Manual Section 7250, *Water Rights* (USDI 1984), provides policies and guidance for use in acquiring, perfecting title to, and protecting water rights necessary for multiple-use management of the public lands.

One of the Federal reserved water rights of primary importance to the BLM and to management of springs is Public Water Reserve Number 107 (PWR 107). Through an Executive order signed on April 17, 1926, all land within one-quarter of a mile of all important springs and waterholes located on vacant and unappropriated or unreserved public lands was reserved for domestic human consumption and stock watering. Under this Executive order, certain water sources were reserved to prevent private monopolization of the public domain through control of important springs and waterholes. Not all springs on public lands are reserved under PWR 107 because the BLM, or in some cases, a court, may determine that certain springs do not qualify for such a reservation. In addition, no springs on acquired lands can be claimed under PWR 107.

PWR 107, and other Federal reserved rights, vest on the date of the reservation; in this case, the priority date is April 17, 1926. This means that an April 17, 1926, priority date is "senior" to all other water rights with later priority dates. In addition, Federal reserved rights are not subject to nonuse; however, to be preserved, existing Federal reserved water rights must be asserted and defended by the Federal Government in general stream adjudications properly initiated in State courts, pursuant to the McCarran Amendment (43 U.S.C. 666).

PWR 107 reserves only the minimum amount necessary to fulfill the purposes of the reservation; thus, not all of the flow from a spring may be reserved, and all water from a spring in excess of the minimum amount necessary for these limited public watering purposes is still available for appropriation under State water law. Therefore, to acquire rights in excess of this minimum amount, for stock watering or other purposes, BLM must apply for a water right under State law.

If livestock use of a spring is a management issue, it is important to determine what designated water uses are part of the water right for a spring. When the BLM asserts a reserved water right under PWR 107, it bases that claim on present and future use of the water by livestock and, if applicable, humans. Therefore, use by livestock is a specifically designated use of springs claimed under PWR 107, whether or not these springs are currently developed or undeveloped.

The BLM's 1995 range regulations (43 CFR 4120.3-9) state that for the purpose of livestock watering on the

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public lands, any right acquired on or after August 21, 1995, shall be acquired, perfected (as to title), maintained, and administered under the substantive and procedural laws as to the State within which such land is located. If the BLM wishes to designate additional uses (such as wildlife or recreation) for a spring developed as a stock water source, these uses must be applied for pursuant to State law. The BLM's 1995 range regulations also state that the BLM, to the extent allowed by State law, will acquire, perfect (as to title), maintain, and administer water rights (for livestock watering) in the name of the United States, as opposed to the livestock permittee. Where allowed by State law, and at BLM discretion, the BLM may agree to be a coholder with the permittee of a water right associated with a cooperative agreement in which the permittee has an investment. However, the BLM retains ownership of range improvements completed under cooperative agreements. Current State law allows private parties to cohold title to water rights in nearly all Western States except Arizona, Oregon, and Utah. In Nevada, this issue is under litigation in response to a bill passed by the State of Nevada prohibiting the BLM from holding stockwater rights on public lands. This issue is currently before the Nevada Supreme Court.

Prior to the 1995 range regulations, the BLM's policy on holdership of water rights was different and varied in its implementation. In the past, the BLM had allowed private parties to cohold or privately hold water rights for livestock water developments on public lands. In fact, in 1981 and 1984, the BLM issued policy allowing private water rights to be filed singly or jointly with BLM for the rights to water developed on the public lands (with certain restrictions). Therefore, there are springs on public lands with water rights held by the permittee. When a private party holds the water rights to waters on the public domain, this can complicate land management. For example, some owners of water rights on public lands have alleged a "taking" of property rights when wild horses or wildlife use the water or when changes are made to grazing management prescriptions for an allotment. Another example is when permittees who have lost their permit, for reasons such as repeated willful trespass, have used their water rights to block reallocation of forage to subsequent permittees. There is no one answer for how issues regarding management of springs should be resolved because water law varies from State to State and each situation is unique. The BLM must work cooperatively with the permittee and the State water resource agency to resolve conflicts if they arise.

Step 3—Develop goals to protect and restore the health of aquatic and riparian systems. Restoration should recover the health of the spring and associated wetland complex. Healthy springs function properly and sustain habitat and biological integrity through natural processes. More information on measuring PFC of the physical features of springs can be found in Prichard et al. (1999), and information on measuring the biological components can be found in Karr et al. (1986), Noss (1990) or Plafkin et al. (1999). Angermeier (1997) reviewed the importance of biological integrity and biological diversity in establishing restoration goals.

Step 4—Use an evaluation guide to determine management priority among multiple spring systems. Biotic and abiotic characteristics of a spring must be evaluated to determine management priorities and direction. Direction can be provided by examining habitat condition and determining if changes in use are necessary to reach PFC. Priority will be directed toward restoration to improve habitats that are functioning at risk, and protective measures may be required to maintain PFC. Biotic characteristics of a spring provide information to identify management priorities. High priority sites for restoration or protection have TES values and the greatest biological diversity. Lower priority sites will have less biological diversity and little TES value. Table 1 can be used to determine priority by evaluating: 1) spring permanence, 2) threatened/endangered/sensitive (TES) species values, 3) community composition, and 4) existing condition and regional scarcity. Each spring can be compared to the descriptions in the table to determine which features best describe the subject spring. Priority direction can be determined by analyzing the table and comparing results to: 1) identify sites to protect for TES and require management to prevent TES listings of either riparian or aquatic species, and 2) identify sites where changes in management are necessary to maintain PFC. Personal knowledge of additional site-specific characteristics is valuable in establishing final management priorities and should supplement information that is compiled to complete the table.

Step 5—Implement spring management strategies. Review and update existing plans to incorporate management strategies. In rare instances, a management plan may be required for an individual spring. If water developments are a part of the management plan, refer to USDI (1990) for specific water development tools, guidance, and policy. Full consideration should be given to maintaining fully functional aquatic and riparian systems when springs are developed.

Step 6—Design appropriate monitoring strategies to assess progress toward meeting management goals. Management effectiveness can be assessed and progress toward meeting goals can be documented through monitoring. Sites should be revisited periodically as part of the overall monitoring program.

Table 1. Evaluation guide to determine management priority for individual springs in a region. This is only a guide. It does not include every situation. There are many factors that can be considered and Field Offices may need to expand this table to fit their needs. See Appendix B for examples.

Spring Permanence	TES Species Values	Community Composition	Existing Condition & Regional Scarcity	Management Priority
Perennial	TES species present	*Natives > exotics (plant cover) *Riparian zone dominated by wetland plant species *Macroinvertebrate community with high proportion of pollution intolerant forms *Endemic or rare native macroinvertebrate species present *Used by more than one species of riparian obligate migratory birds	*Proper functioning condition or functioning at risk with an upward trend (no spring box; no impoundments) *Springs regionally scarce	High
Perennial	TES species present, or historic or refuge habitat for TES species	*Natives > exotics (plant cover) *Riparian zone with approx. equal numbers of upland and wetland plant species *Macroinvertebrate community represented by pollution tolerant and intolerant forms *No endemic or rare macroinvertebrate species present, but former habitat for such species present *Used by single species of riparian obligate migratory birds	*Proper functioning condition or functioning at risk with an upward trend *Springs not regionally scarce	Moderate
Intermittent	No TES species	*Exotics > natives (plant cover) *Riparian zone dominated by upland plant species *Macroinvertebrates dominated by pollution tolerant forms (e.g.,chironomids oligocheates) *No endemic or rare native macroinvertebrate species present *Not used by riparian obligate migratory birds	*Proper functioning condition or functioning at risk with an upward trend *Springs not regionally scarce	Low

VI. Spring Restoration

The purpose of this section is to provide general guidance for restoration of aquatic and riparian components of spring wetland ecosystems. General principles for the preferred approach to ecological restoration are presented in Table 2 and contrasted to those of less desirable rehabilitation projects. Restoration is defined as the reestablishment of the structure and function of an ecosystem, including its natural biological diversity (Cairns 1988; Williams et al. 1997), and therefore differs from reclamation, rehabilitation, and habitat creation. Fortunately, most spring systems will begin to recover once the primary causes of disturbance are removed or modified. For this reason, the following guidance encourages natural recovery processes and disfavors artificial treatments. Small, incremental steps will achieve recovery with a minimum of risk to TES species.

Successful restoration will often require changes in management to alleviate or minimize factors degrading habitat quality and compromising the biological integrity of aquatic and riparian systems. Once these factors have been identified, an evaluation guide (Table 3) may be used to identify restoration priorities for individual springs in a resource area or region. Elements of this guide are similar to those considered to determine management priority. The highest priority springs for restoration are those that are functioning at risk, have high biological diversity, or are either occupied by or were historical habitat for TES species. Low priority sites are nonfunctioning, functioning at risk with a downward or no apparent trend, or have low biological diversity and intermittent aquatic habitat.

"Due to our limited intellectual and technological capability, successful restoration usually has less to do with skillful manipulation of ecosystems than it does with staying out of nature's way. Most ecosystems are resilient and natural restoration will occur if we allow it. To the extent possible, restoration should promote and complement natural recovery rather than attempt to repair undesired conditions."

P.L. ANGERMEIER (1997)

TABLE 2. Comparing principles of ecological restoration to rehabilitation efforts.

Ecological Restoration	Rehabilitation
Focus on spring ecosystems	Focus only on water
Correct primary causes of degradation	Treat symptoms of degradation
Restore native species diversity	Retain populations of introduced species
Encourage natural recovery processes	Install structural treatments
Use adaptive approach: implement, monitor, and adjust	Implement actions without monitoring effects

Table 3. Evaluation guide to determine restoration priorities for individual springs in a region. This is only a guide. It does not include every situation. There are many factors that can be considered and Field Offices may need to expand this table to fit their needs. See Appendix B for examples.

Spring Permanence	TES Species Values	Potential Community Composition	Existing Condition & Regional Scarcity	Restoration Priority
Perennial	TES species present	*Potential for natives > exotics (plant cover) *Potential for riparian community dominated by wetland plant species *Potential for macroinvertebrate community with high proportion of pollution intolerant forms *Potential for endemic or rare native macroinvertebrate species present *Potential for use by more than one species of riparian obligate migratory birds	*Functioning at risk with a downward or no apparent trend *Springs not regionally scarce	High
Perennial	TES species present, or historic or refuge habitat for TES species	*Potential for natives > exotics (plant cover) *Riparian community with approximately equal numbers of upland and wetland plant species *Macroinvertebrate community represented by pollution tolerant and intolerant forms *Potential for endemic or rare macroinvertebrate species *Potential for use by riparian obligate migratory birds	*Functioning at risk with downward or no apparent trend *Springs not regionally scarce	Moderate
Intermittent	No TES species	*Exotics > natives (plant cover) *Riparian community dominated by upland plant species *Macroinvertebrate community dominated by pollution tolerant forms (e.g., chironomids oligocheates) *No potential for endemic or rare native macroinvertebrate species *Not used by riparian obligate migratory birds	*Proper functioning condition or functioning at risk *Springs not regionally scarce	Low

Step 1—Identify historical condition, desired condition, and restoration priority. It is important that all parties and interests understand the potential and desired condition of a spring and associated habitats. Desired condition should be based on maximizing habitat potential and biological integrity. In situations when historical habitat conditions are known, management direction can be assessed by identifying historical uses and modifying management to: 1) maintain the historical quantity of spring flows; 2) maintain the historical extent, abundance, and diversity of riparian vegetation; and 3) maintain historical structure of aquatic communities. Sources of information regarding historical abiotic and biotic condition of spring systems include early biological surveys, university archives, historical photographs, county museum records, diaries of amateur and professional naturalists, agency file reports, and scientific journals (Wissmar 1997). In some cases, if information on historical condition is lacking, it may be infeasible or impractical to restore the historical condition. In these cases, site potential and restoration goals may be determined by identifying characteristics of good quality habitats and biotic communities at nearby springs that have been little affected by degrading uses and that are similar in size, elevation, and water chemistry.

Much of the information that is used to determine management priorities (Table 1) can also be used to help prioritize restoration needs. Table 3 summarizes important elements of the restoration evaluation.

Step 2—Identify factors affecting site potential. Initial biotic and abiotic surveys should summarize habitat characteristics and attempt to identify factors that influence habitat quality. Influencing factors may be natural (e.g., periodic drying, occasionally scoured by floods or avalanches, or burned by fire) or unnatural (e.g., aquatic systems degraded by recreation, diversion, excessive ground-water removal, impoundment, improper ungulate grazing, or nonnative species).

Step 3—Eliminate or otherwise modify land use practices that inhibit natural spring and wetland recovery. Achieving this step may help in achieving many others. Once the water supply is established and the land is protected from disturbance, many other physical and biological aspects may follow. It is critical that restoration activities correct the primary cause of habitat degradation rather than simply treating the symptoms (Frissell 1997). If spring brook channels are unstable and severely eroding, it is important to correct the primary cause of the erosion (e.g., inappropriate livestock use or a road located along the stream channel) rather than treat the inchannel symptom (e.g., install bank protection). If instream structures are used, they should be one component of a more holistic effort at restoration that includes elimination of poor land use practices.

Springs and a portion of their spring brooks should always be protected from activities that decrease biological diversity and cause functional changes in aquatic and riparian communities. The intensity of use at each spring should be limited to levels that maintain or restore biological diversity. Many rare aquatic species occur at spring sources and upper reaches of spring brooks, indicating that spring sources should be maintained in a natural condition. If flow diversion is necessary, surveys should be conducted to determine biological consequences of reduced spring discharge. Information from these surveys may also assist in determining where diversions may be placed in order to minimize decreases in biological diversity. Using spring boxes for diversion is discouraged because it impacts spring source habitats that are often occupied by TES species. Physical and biological integrity of spring sources can often be protected by diverting water from a dry well placed below the source in the spring brook bed. Future development of springs should be minimal and diversions should be limited to only the amount of water needed for the intended use. Surveys should be conducted to determine biological diversity and quantities of water that should remain in the spring brook. Diversions should also be limited to periods when water is needed at a specified destination and they should not continue throughout the year when diversion is unnecessary. All water should remain in a spring brook when not being used for other purposes.

Other uses (e.g., recreation and ungulate use) should not detrimentally impact the natural character of a spring source or its spring brook. Greater lengths of the spring brook should be protected when biological information indicates that protecting a source does not provide sufficient management to maintain biological diversity. The length of the spring brook needing protection should be identified from field surveys.

Step 4—Protect rare, sensitive, threatened, or endangered species and their habitats. The first principle of successful restoration is to protect any remaining sensitive or high-quality resources (Doppelt et al. 1993; Frissell 1997). Temporary fencing, flags, or other markings may be necessary to ensure that sensitive habitats are not disturbed. It also may be necessary to closely monitor any remaining rare species to ensure that habitats are not inadvertently degraded during restoration work.

Step 5—Protect remaining high-quality habitat areas. In addition to protecting TES species and their habitat, any remaining high-quality habitat areas should be protected in the restoration process. These may include headsprings that have not been disturbed or patches of native woody vegetation.

Step 6—Control nonnative animal and plant species. Often nonnative plant and animal species need to be controlled in order to facilitate restoration. It is critical that control efforts be targeted specifically to nonnative species. These efforts should be prioritized so that species harming threatened or endangered species or species changing the functional characteristics of riparian vegetation are eradicated as soon as they are located. Extreme caution should be exercised when eradicating nonnative species because many treatments may adversely affect a spring's biological diversity. Extensive planning may be required to minimize impacts of these treatments and prevent them from causing long-term changes in community structure and biological diversity. Methods to minimize impacts include manual removal of target species, targeting only a small portion of habitat during a single treatment, or establishing refuges for species where they are protected from treatment effects.

Nonnative species that are a high priority for removal may include mosquito fish (*Gambusia affinis*) goldfish (*Carassius auratus*), cichlid fishes (*Cichlasoma* and *Tilapia*), bullfrogs (*Rana catesbeiana*), saltcedar (*Tamarix ramosissima*) and giant reed (*Arundo donax*). If species-specific control efforts are unavailable and more generic treatments must be substituted (e.g., rotenone to eliminate nonnative fish or broad-spectrum herbicide to eliminate exotic weeds), nontarget species should be protected. This might include temporarily holding nontarget species in aquaria or other facilities, treating only during certain times of the year, or treating only under certain weather conditions. If nonnative woody plants, such as saltcedar or Russian olive (*Elaeagnus angustifolia*), are controlled, it may be necessary to reintroduce desirable native species such as willows, cottonwoods, or alders if they do not naturally reappear.

Nonnative plant inventories (including surveys for noxious weeds) should be an integral part of initial spring condition assessments. Basic assessments of invasion rates and condition of native vegetation should be documented.

Treatment of noxious weeds requires a three-tier process: assessment, environmental documentation (NEPA compliance), and implementation. Depending on the species, treatments will vary and will include manual removal (cultural control), herbicide application, and potentially, biocontrol methods, or a combination of these methods. The most effective methods for reducing noxious weed invasions are to avoid manipulating unaltered spring systems at or near the spring source by installing water developments and to minimize herbivory and trampling impacts. Once site hydrology is altered by changing flow patterns and soil deposition, noxious weeds are quickly able to invade the altered area. A number of treatments exist to control noxious weeds in wetlands. Contact State and local experts to select appropriate methods.

Monitoring of noxious weed invasions should consist of gathering pretreatment baseline information on invasion size and condition of existing native vegetation to determine which method(s) will provide the greatest success. At a minimum, pre- and post-treatment photo monitoring plots should be established. Followup monitoring is essential to check for reestablishment of noxious weeds and the recovery of native vegetation. Reliable monitoring methods include establishing photo plots and determining the percent of understory plant cover using line, point-intercept, or cover board measurements and the percent of overstory cover using a densiometer.

Step 7—Reintroduce native species as necessary. If native species have been extirpated from the spring but occur in remaining parts of their range, reintroduction may be warranted. Guidelines for reintroductions of aquatic species are available from the American Fisheries Society (Williams et al. 1998) or may be included in recovery plans. Such guidelines should be consulted prior to any reintroduction attempts. Concerns about reintroductions include habitat issues (e.g., adequacy of habitat to fulfill all life history requirements of reintroduced species, impacts to other rare species from the reintroduced species) and species issues (e.g., obtaining reintroduced stock from the most appropriate source, introducing undesirable pathogens or parasites with the reintroduced species).

Often native plant species do not need to be planted because of latent seed sources. In situations where revegetation is necessary to restore spring brook banks and riparian zones, restoration programs may include the following provisions:

- Use site-specific plant material by growing plugs of native vegetation (e.g., grass, graminoid, or shrub genera) including, but not limited to, *Poa, Leymus, Juncus, Carex, Salix* spp., or taking divisions or cuttings (willow poles) from existing vegetation. If native plant material is unavailable at the site due to severe impacts, use vegetation from the nearest ecologically similar site based on spring type, soils, elevation, and site potential.

- Use weed-free mulches to minimize water loss and plant stress and install plant protectors to reduce herbivory.

- Install biodegradable erosion netting or other erosion prevention material along banks or in denuded areas.

Step 8—Monitor the effectiveness of actions on desired conditions. Effectiveness monitoring is conducted in order to determine if goals and objectives are being achieved. In other words, this type of monitoring answers the question, "Did our planned actions achieve the desired results?" Monitoring should be designed to determine whether restoration actions resulted in changes toward desired condition. Parameters monitored must be measurable and relate back to the established goals of the restoration plan. The collection of pretreatment data on vegetation density, cover, and species composition may be needed to determine such changes. Establish photo points at several locations to track changes in vegetation and condition. Additional suggestions on how to design monitoring to detect desired changes are provided by Kershner (1997).

Step 9—Analyze monitoring data and recommend changes in management as necessary. Implementation and effectiveness monitoring data should be analyzed to determine what restoration treatments worked, to what extent the desired results were achieved, and what treatments did not work (Walters 1986). Comparison of treatment information with data from an undisturbed reference site or pretreatment data from the spring being restored can easily demonstrate changes to habitat condition. Such information may lead to recommended changes in management strategies. If so, it is important to document and communicate the rationale for such changes.

Step 10—Communicate the results to interested parties. Monitoring reports can build support for restoration efforts by demonstrating positive change in spring, riparian, and wetland conditions. Partners and other interested parties should be kept informed of progress so that interest in and support for the project are maintained. Even if desired results were not achieved, it is important to document these findings in writing and communicate the results so that we can learn from our efforts and modify future management to achieve desired condition. With existing variability in weather patterns and environmental disturbances, unanticipated results may be likely. For these reasons, adaptive management and incremental implementation of restoration actions are sound strategies.

VII. Summary

Springs and seeps are distinctive habitats that often support unique plant, invertebrate, and vertebrate communities. Most springs are comparatively constant environments that are minimally affected by temperature variation, scouring, and droughts that structure aquatic and riparian communities in streams and rivers. Biological diversity of persistent springs in good condition is greater than it is in either seeps, ephemeral springs, or springs degraded by diversions, impoundment, excessive livestock grazing, or nonnative species. The currently degraded condition of many springs and the recent extinction and extirpation of populations found only in these habitats indicate that changes are necessary to maintain the biological integrity of these aquatic macroinvertebrate and riparian systems.

Springs are usually small and management often requires targeting uses within a limited area. Springs and a portion of their spring brooks should always be protected from activities that reduce biological diversity or cause functional changes in aquatic and riparian communities. Many TES species that rely on springs are most abundant near spring sources and the upper portions of spring brooks, indicating that these areas are most sensitive to uses that degrade habitat quality. If a spring must be used, the impacted area should be limited to lower reaches of spring brooks where resource values are lowest. Management deficiencies that allow habitat degradation can often be identified using techniques to assess the PFC of lotic systems as described in Prichard et al. (1999), but additional insight may be necessary to assess requirements to protect or restore TES species. Biological conditions of springs may also be assessed by examining macroinvertebrate communities using rapid bioassessment techniques.

The large number of springs in some areas, the wide variety of uses that degrade habitat quality, and incomplete biological surveys often make it difficult to prioritize management and restoration programs. Highest priority management springs are perennial, regionally scarce sites that are used by more than one species of migratory bird. High priority sites also have TES species, riparian systems that are dominated by native wetland species, and aquatic macroinvertebrate communities dominated by pollution intolerant forms. These springs should also be in PFC or functioning at risk with an upward trend. Aquatic macroinvertebrate communities in moderate priority sites may consist of both pollution tolerant and intolerant forms. These springs may be used by a single obligate riparian bird species and they occur in areas where springs are not regionally scarce. Their riparian systems are dominated by native wetland species and they may be either occupied or known historical habitat for TES species. Low priority management sites include intermittent springs that are in PFC or functioning at risk with an upward trend, and they occur in areas where springs are not regionally scarce. Their aquatic macroinvertebrate community is dominated by pollution tolerant forms and the riparian system is dominated by nonnative wetland species.

Restoration programs may be required to return aquatic and riparian systems to their historical biological diversity and community structure and function. Restoration programs must begin by managing uses that degrade habitat quality; such degradation is most commonly a result of impacts from nonnative species, reductions in discharge caused by diversion or excessive ground-water use, pollution, and excessive ungulate or recreational use. Restoration programs may also be prioritized by considering habitat condition, spring persistence, the regional abundance of springs, TES species values, use of the habitat by migratory birds, and the potential for reestablishing historical riparian and aquatic macroinvertebrate communities. Restoration programs should discourage use of artificial treatments and allow natural processes to facilitate recovery.

The effectiveness of management and restoration programs must be determined by monitoring whether goals and objectives are being achieved. Monitoring programs should include photo points and biological data that describe pre- and post-treatment condition of species composition, vegetative cover, or other metrics that can document changes which can be attributed to management and use.

Implementing programs that maintain the biological integrity of springs and seeps will reduce extinctions and the extirpation of unique populations while protecting habitats with high biodiversity, unique plant and animal communities, and TES species.

Appendix A. Spring Ecosystem Ecology

A number of studies have examined the aquatic ecology of springs (e.g., Williams and Smith 1990; Glazier 1991; Williams and Danks 1991; Ferrington 1995; Botosaneanu 1998). Work from other regions and systems also provides basic information about Western U.S. springs; however, knowledge of crenobiology lags behind lentic and lotic ecology. Additional information is necessary to fully understand the interacting aspects of spring biotic and abiotic characteristics, but it is widely accepted that chemical composition, morphology, water temperature, and environmental variation usually combine to create a unique habitat in each spring (Hynes 1970; Pritchard 1991; Erman and Erman 1995; van der Kamp 1995).

Most spring-fed systems include aquatic species that are close relatives to common species in other North American wetlands. Many are also habitat for endemic fish, mollusks, and aquatic insects. Environmental characteristics affect plant and animal assemblages at springs. Most spring environments are less variable than other aquatic habitats (e.g., streams, rivers, and lakes), which causes variability in spring populations and assemblage structure to be comparatively low (Minckley 1963; van der Kamp 1995). Variation is typically lowest near the source (where environments are comparatively stable) and greatest downstream (where environmental variability is higher) (Deacon and Minckley 1974). Species composition of source and downstream communities are usually different. Species in source habitats often do not occur downstream where temperature variation is greatest, and many source species prefer habitats that are unique to spring sources (Hayford et al. 1995; Hershler 1998; O'Brien and Blinn 1999).

There are also seasonal differences in abundance and changes in aquatic species richness and abundance along the continuum. 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 density was highest near the source and during the period January through September. Abundance also differs throughout the year in response to food availability, temperature, reproduction, and migration (Minckley 1964; Glazier and Gooch 1987; Varza and Covich 1995; Hayford and Herrmann 1998).

Smaller springs are generally autotrophic aquatic systems that depend little on allochthonous carbon sources, which is similar to energy budgets of low order streams (Minshall 1978; Cushing and Wolf 1984). In larger springs, energy may also enter during periodic floods that flush carbon from the surrounding landscape. Plant and animal assemblages in springs are also similar to aquatic and riparian assemblages associated with streams and ponds. However, they exhibit diverse compositional and structural characteristics that are unique. Springs with harsh environments (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 within and surrounding harsh environments may be limited to animals and plants that can tolerate conditions where osmoregulation and respiration are difficult (Brock 1994; Kristijansson and Hreggvidsson 1995). In montane Sierra Nevada springs, Erman and Erman (1995) found species diversity was correlated with spring permanence, calcium concentration, specific conductance, pH, magnesium, and alkalinity. Flies (Diptera) are the most common animals in harsh environments and blue-green algae frequently dominates the vegetation community of hot springs. In cooler habitats where harshness is moderate, stoneflies (Plecoptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera) are common components of the aquatic fauna. Sada and Nachlinger (1996, 1998) also found that spring size and habitat conditions influence the biological diversity of southern Nevada springs. Aquatic and riparian communities at larger springs and springs that had been minimally altered had greater biological diversity than communities at small and highly disturbed springs.

The ecology of hot springs differs from that of thermal and cold springs. Hot springs are scattered throughout the western U.S., but animal communities in these systems may be comparatively depauperate due to the extremes of temperature and acidity. Hot springs are rarely occupied by vertebrates and most macroinvertebrates cannot live in these extreme environments. Consequently, communities in thermal systems are dominated by two types of aquatic microorganisms (microbial flora): 1) thermophiles, which are organisms tolerant of extremely high water temperatures (>100 °C), and 2) thermoacidophiles, which are organisms tolerant of highly acidic water (pH of 3 or less). Additionally, thermal springs are sometimes covered by dense vegetative mats comprised of cynobacteria and *Chloroflexus* sp. (a photosynthetic bacterium). As the mat grows, the cells underneath become shaded and die, and they are replaced by other bacteria capable of surviving dimmer light conditions. Color variation in this layer is a function of the ratio of chlorophyll to plant carotenoids.

Many early studies determined that springs in the Western U.S. support unique animals (e.g., Gilbert 1893; Brues 1932; Hubbs and Miller 1948b; Taylor 1966). These early studies are complemented by recent work documenting approximately 200 endemic vertebrate and invertebrate taxa that occupy only these habitats (see Sada and Vinyard in press). Spring endemism is most widespread in the intermountain region and in habitats below 2200 meters elevation where historical use of water by humans may have been greatest (e.g., Cole and Watkins 1977; Hershler 1985; Hershler and Sada 1987; Hershler and Landye 1988; Shepard 1990; Skinner 1994; Erman 1996; Hershler

1998). Sada and Vinyard (in press) found that 158 of 199 endemic Great Basin aquatic animals primarily occur in mid- and lower elevation springs. Surveys in the Western U.S. are incomplete for most habitats and for many animal groups, indicating that future work will discover additional taxa (Hubbs et al. 1974; Deacon and Williams 1984; Sada et al. 1995; Hamlin 1996). Recent descriptions of mollusks and insects from a number of western springs (e.g., Hershler and Sada 1987; Shepard 1990; Erman 1996, 1997; Hershler 1998) also indicate that there may be additional undiscovered species.

Many habitats are occupied by a single or several endemic species. Communities with the highest endemic species diversity are concentrated in thermal springs of southern Nevada (e.g., Ash Meadows, Pahranagat Valley) and eastern California (Death and Owens Valleys) where there are endemic plants, fishes, mollusks, and aquatic insects (Hershler and Sada 1987; U.S. Fish and Wildlife Service 1990, 1998; Polhemus and Polhemus 1994; Hershler 1998; Schmude 1999). The importance of springs to regional biological diversity was also recognized by Anderson and Anderson (1995) who observed that insects in springs significantly contribute to the diversity of aquatic fauna in arid regions.

The complex influences of the physical and chemical environment on plant and animal physiology cause most springs to be biologically distinct. Additionally, habitat characteristics (e.g., water velocity, temperature, substrate composition, and environmental variation) also influence the distribution of aquatic and riparian species along the continuum of habitat from the spring source to where the spring dries or enters a larger aquatic habitat. For instance, stoneflies, caddisflies, and amphipods occur mostly in gravel habitats with strong current. Flies (Diptera), nematodes, and many dragonflies (Odonata) occur where environmental variation (e.g., variation in temperature, discharge, dissolved oxygen concentration, etc.) is greater and where current velocity is low and there is silty substrate. Although additional information is needed to identify habitats preferred by endemic macroinvertebrates, it appears that these species prefer specific habitat types. 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 and Sada 1987; Hershler 1998; Sada and Herbst 1999). Endemic beetles (e.g., *Stenelmis* sp. and *Microcylleopus* sp.) and bugs (e.g., *Ambrysus* sp. and *Limnocoris* sp.) are most common where gravel substrate occurs with high current velocities (Sada and Herbst 1999). Populations of these endemic taxa represent relict populations that became established during ancient pluvial periods over the past several million years (Taylor 1985; Hershler and Pratt 1990). These taxa occur only in springs that have not been severely altered and that have provided continuous aquatic habitat ever since ancestral forms first established. These springs have not dried and they are reliable water sources that can be used for conservation and public use when development programs are properly designed.

The aquatic flora of freshwater spring systems exhibits diverse compositional and structural characteristics unique to these community types and critical to associated aquatic biota. The emergent vegetation that occurs on the water surface of springs is comprised of several dominant species depending upon the gradient of a particular spring site. In low- to moderate-gradient springs, plants in the pondweed (*Potamogeton*), duckweed (*Lemna*), ditch-grass (*Ruppia*), horned-pondweed (*Zannichellia*), and watercress (*Rorippa*) genera are dominant. These species often provide an important food source for migratory waterfowl and *Rorippa* spp., in particular, is a critical component for rare mollusks (Sada and Nachlinger 1996).

Along spring banks the vegetation gradient shifts to monocot-dominant species in the sedge (*Carex*), spike-rush (*Eleocharis*), and bulrush (*Scirpus*) genera, which provide important structural characteristics necessary for water temperature regulation and hiding and nesting cover for wildlife. Depending on the spring type, overstory vegetation may or may not be present. When overstory occurs, it is most likely to consist of genera such as *Rosa* (rose) *Rhamnus* (coffeeberry), *Betula* (water birch), *Rhus* (skunkbush or lemonadeberry), *Ribes* (currant), *Cercis* (redbud), *Salix* (willow), and *Populus* (aspen).

Because of the relative isolation and often relictual nature of many spring systems, plant diversity and endemism is high compared to adjacent 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 (126–150 species) was also recorded at springs along the southwestern edge of the Great Basin in Owens Valley, California (DeDecker 1980; Ferren and Davis 1991).

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 species in the genus *Astragalus* (milk vetch) (Ferren and Davis 1991). In Nevada, 17 wetland plants are on Sensitive or Watch Lists (Nevada Natural Heritage Program Database 1998), and in the Great Basin region of eastern California (Mono and Inyo Counties), 35 wetland plants are considered rare (Skinner 1994).

Riparian vegetation ecology at thermal springs may differ from fresh, cool water systems. At thermal springs, vegetation often responds to unique combinations of temperature, moisture, and salinity gradients (Brotherson and Rushforth 1987; Kristjansson and Hreggvidsson 1995). In a study of a Great Basin spring system in Benton Valley, California, Brotherson and Rushforth (1987) found that springs with higher temperatures consisted of two major terrestrial zones plus an algal mat at the edge of the open water; a more complex pattern of vegetation with four distinct zones was found at cooler springs. Zonation at cooler springs followed a pattern where total cover, moisture, and number of sedges decreased from the bank toward upland vegetation. Soil temperature, number of species per quadrat, grass and shrub cover, and diversity increased from the bank toward upland vegetation. A total of 25 vascular plant species were associated with these springs, all of which were restricted to one or more vegetation zones.

Little information has been compiled to demonstrate the value of spring-fed riparian habitats to western U.S. birds, reptiles, amphibians, and mammals. However, extensive work in lotic riparian habitats indicates their importance to these animals (e.g., Warner and Hendrix 1984; Johnson et al. 1985; Naiman and Rogers 1997). Good riparian habitat has high structural diversity created by dense undergrowth of tangled vegetation and debris, more open vegetation at midlevel, and a comparatively open canopy provided by large trees. In many of the western U.S.'s riparian zones, this structure is a dense undergrowth of shrub willow and debris, willows at midlevel, and a willow and cottonwood tree canopy. Mesquite (*Prosopis* spp.) woodlands are also common in lower elevation and latitude regions (Hendrickson and Minckley 1984). Riparian habitat has been reduced at many springs by diversion, burning, vegetation control, and excessive ungulate grazing. As a result, suitable riparian habitat has been eliminated or degraded so that species such as brown-headed cowbirds (*Molothrus ater*) can more easily invade nesting areas.

Spring-fed riparian habitats can provide structurally diverse cover for resting, nesting, and feeding. The extent to which birds depend on water for drinking appears related to their dietary habits. Granivorous birds drink more than carnivorous or insectivorous birds (Fisher et al. 1972). Williams and Koenig (1980) related the significantly higher water dependency they observed in summer resident birds (when compared with permanent residents) to the greater frequency of granivory in non-migrant permanent residents. Various species may respond differently to the presence of surface water. Williams and Koenig (1980) suggested that western tanagers (*Piranga ludoviciana*) may be dependent on springs during migration in central California, while Gubanich and Panik (1986) rarely recorded this species drinking from springs in western Nevada. Gubanich and Panik (ibid) did observe insectivorous species such as the American robin (*Turdus migratorius*), Townsends solitare (*Myadestes townsendi*), mountain bluebird (*Sailia currocoides*), northern flicker (*Colaptes cafer*), and horned lark (*Eremophila alpestris*), and five species of warbler drinking from springs. Both of these studies suggested that the stresses of migration may make insectivorous and frugivorous species 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 use was greatest at the site with greater tree and shrub cover. Species such as the rufous-sided tohee (*Pipilo erythrophthalmus*), red-breasted nuthatch (*Sitta canadensis*), mountain chickadee (*Parus gambeli*), shrub jay (*Aphelocoma coerulescens*), and stellers jay (*Cyanocitta stelleri*) were never observed drinking away from cover. Many instances of birds seeking cover in trees and shrubs near springs when avian predators appeared were also observed.

Spring-fed riparian habitats are also used by other vertebrates, some of which 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.

Appendix B. Examples

These following examples, which are taken from work conducted by Sada and Nachlinger (1996) in the Spring Mountains, Clark County, Nevada, illustrate using a table to prioritize spring ecosystem management. Included with the examples are some suggested management alternatives.

Management Priority and High Restoration Priority

Willow Spring is a small perennial spring lying in the center of a heavily used picnic area. Its spring brook has been impounded and channelized. The presence of concrete, trails, and picnic sites have eliminated riparian vegetation. While some native species still exist, two springsnail species that are endemic to the Spring Mountains area have been extirpated. The site is functioning at risk. Even with this disturbance, native vegetation dominates the riparian community and biological diversity is near average for springs in the Spring Mountains. These factors suggest that the recovery potential is high. According to the guidelines in Tables 1 and 3, this site has a moderate management priority and a high restoration priority. Implementing proper management to improve existing conditions should cause biological diversity to increase. See Figures B1 and B2.

Management Priority Evaluation

Spring Permanence	TES Species Values	Community Composition	Existing Condition and Regional Scarcity	Management Priority
X			X	High
	X	X		Moderate
				Low

Restoration Priority Evaluation

Spring Permanence	TES Species Values	Potential Community Composition	Existing Condition and Regional Scarcity	Management Priority
X			X	High
	X	X		Moderate
				Low

Suggested Management Direction

- Move the picnic facilities to a location at least 165 feet (50 m) downstream from the spring source and direct management toward recovering riparian vegetation and spring brook integrity.
- Initiate a restoration program to achieve PFC by reestablishing riparian vegetation and returning water to the historical spring brook.
- Reintroduce springsnails from nearby springs.
- Implement an education program to inform the public about reasons for management/use changes.
- Monitor the recovery process.

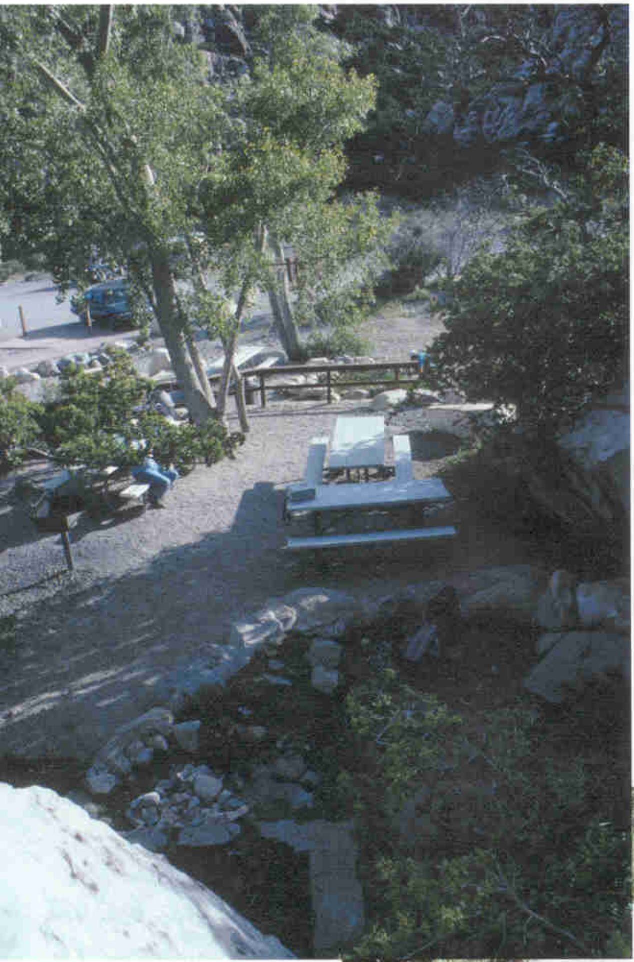

Figure B1

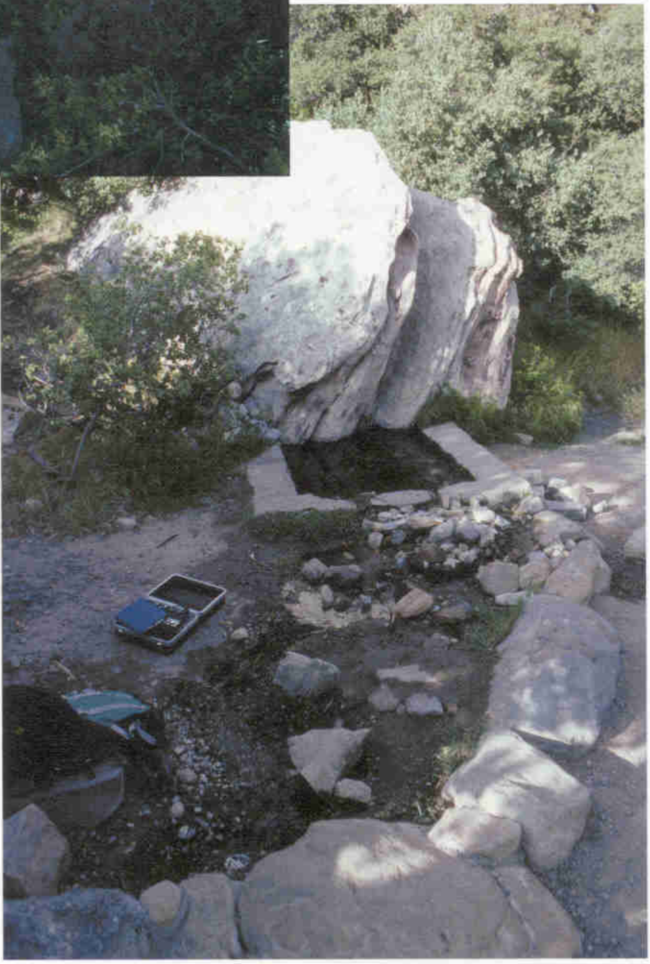

Figure B2

High Management Priority and Low Restoration Priority

Kiup Spring is a moderate sized perennial spring (> 5 liter/minute) that is fenced and slightly disturbed by ungulates. It is in PFC, supports a springsnail population, and has moderate biological diversity. Ungulates use may be causing the erosion that is occurring east of the meadow According to the guidelines in Tables 1 and 3, this site has high management priority because it provides habitat for TES species. It has low restoration priority because current management is maintaining biological integrity. See Figure B3.

Management Priority Evaluation

Spring Permanence	TES Species Values	Community Composition	Existing Condition and Regional Scarcity	Management Priority
X	X		X	High
		X		Moderate
				Low

Restoration Priority Evaluation

Spring Permanence	TES Species Values	Potential Community Composition	Existing Condition and Regional Scarcity	Management Priority
X	X			High
		X		Moderate
			X	Low

Suggested Management Direction

- Determine if ungulate grazing is becoming excessive.
- Maintain the exclosure fence.
- Monitor soil erosion along the east side of the spring and install control structures if necessary.

FIGURE B3

High Management Priority and Low Restoration Priority

LaMadre Spring supports riparian and aquatic habitats that are in PFC. The spring is comparatively large, perennial, dominated by native riparian vegetation, and supports comparatively high biological diversity for springs in the Spring Mountains. This site provides habitat for TES species. It is minimally disturbed by current uses; however, the area is actively used by hikers. Trails through riparian vegetation have been developed by hiker use rather than by management design. Increased use of existing trails will cause erosion and degrade habitat quality. According to the guidelines in Tables 1 and 3, this site has high management priority because it provides habitat for TES species. It has low restoration priority because current management is maintaining biological integrity. See Figure B4 and B5.

Management Priority Evaluation

Spring Permanence	TES Species Values	Community Composition	Existing Condition and Regional Scarcity	Management Priority
X	X	X	X	High
				Moderate
				Low

Restoration Priority Evaluation

Spring Permanence	TES Species Values	Potential Community Composition	Existing Condition and Regional Scarcity	Management Priority
X	X	X		High
				Moderate
			X	Low

Suggested Management Direction

- Design and redirect trails to prevent erosion from increased recreational use.
- Monitor the impacts of existing use and change management if habitat condition deteriorates.

Figure B4

Figure B5

Moderate Management and Restoration Priority

Stanley B Spring is a comparatively large perennial spring that supports riparian and aquatic habitats in PFC. This type of spring is common within the region that it occurs. The site is not disturbed under current management; however, the area is actively used by hikers. Existing trails have been developed by historical use rather than by management design. Increased use of existing trails may cause erosion and degrade habitat quality. The site has no known rare species but has comparatively high biological diversity. See Figure B6.

Management Priority Evaluation

Spring Permanence	TES Species Values	Community Composition	Existing Condition and Regional Scarcity	Management Priority
X		X		High
			X	Moderate
	X			Low

Restoration Priority Evaluation

Spring Permanence	TES Species Values	Potential Community Composition	Existing Condition and Regional Scarcity	Management Priority
X		X		High
				Moderate
	X		X	Low

Suggested Management Direction

- Manage recreational use to protect aquatic and riparian habitats.
- Monitor riparian and aquatic habitats to ensure existing conditions are maintained.

FIGURE B6

Low Management and Restoration Priority

Younts Spring is an intermittent spring that lies within a dry impoundment on the floor of a wash. The impoundment fills only during runoff from rain or melting snow at higher elevations. The spring is too small to measurably add water to the impoundment and it may dry during drought. The impoundment supports a dense saltcedar stand.

Riparian and aquatic biological diversity are low and almost one-half of riparian diversity is nonnative plants. Obligate wetland plants are less than 10 percent of the riparian community and 25 percent of the riparian community is upland plants. There are no TES species present, but the area is in PFC. Because this is an intermittent system, it has a low management priority, and since it is in PFC, it has a low restoration priority. See Figure B7.

Management Priority Evaluation

Spring Permanence	TES Species Values	Community Composition	Existing Condition and Regional Scarcity	Management Priority
				High
		X		Moderate
X	X		X	Low

Restoration Priority Evaluation

Spring Permanence	TES Species Values	Potential Community Composition	Existing Condition and Regional Scarcity	Management Priority
				High
		X		Moderate
X	X		X	Low

Suggested Management Direction

- Control the saltcedar.
- Eliminate the impoundment.
- Monitor to determine if management changes are effective.

FIGURE B7

Glossary

ABIOTIC: Nonliving, lifeless.

ALLOCHTHONOUS: Ecosystems in which energy is derived from outside the habitat; e.g., aquatic systems where energy is provided by riparian vegetation that falls into the water and decays. Compare to autochthonous.

ARTESIAN: Water under confined pressure. See also potentiometric level.

AUTOCHTHONOUS: Ecosystems in which energy is produced within the habitat; e.g., aquatic systems where energy is provided by sunlight that in turn produces plant growth. Compare to allochthonous.

AUTOTROPHIC: Organisms capable of synthesizing complex organic substances from simple inorganic substrates.

BIOLOGICAL DIVERSITY: Biotic characteristics of a landscape unit that are described by species, community, and genetic diversity.

BIOTIC: Living.

CAROTENOIDS: Plants containing a class of accessory photosynthetic pigments that include the carotenes (yellows, oranges, and reds) and xanthophylls (yellow).

CRENOBIOLOGY: The study of the biology of springs.

CYANOBACTERIA: Blue-green algae.

EDAPHIC: Factors occurring because of the nature of soil.

ELECTRICAL CONDUCTANCE: Ability of a substance to transmit electricity.

FRUGIVOROUS: An animal that eats fruit.

GRANIVOROUS: An animal that eats grain.

HELOCRENE: A spring source that is shallow and marshy.

LIMNOCRENE: A spring source that is a deep pool.

MONOCOT: A type of flowering plant with a single leaflike structure to its embryo. This group includes grasses.

POTENTIOMETRIC LEVEL: The level at which water rises in a well drilled into a confined aquifer. Water only flows from a spring if the potentiometric level is above the ground surface.

RELICT: Populations which are persistent remnants of an ancient lineage of plants or animals that were formerly widespread and that currently occur in isolated habitats.

RHEOCRENE: A flowing spring.

Spring potential: The future biotic and abiotic condition of a restored habitat following implementation of improved management treatments.

Spring brook: A channel that carries water flowing from a spring.

Spring province: A group of springs in close geographical proximity.

Temporal fluctuation: Fluctuations that occur over time.

Thermoacidophiles: Plants and animals that only occupy thermal or hot, acid habitats.

Thermophiles: Plants and animals that only occupy thermal or hot habitats.

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13. ABSTRACT *(Maximum 200 words)*

In the Western United States, springs have commonly been developed to provide water for livestock, mining operations, and the human population. They also provide important habitat for numerous species of plants and wildlife, some of which are unique to springs. Development of springs can result in functional changes to spring ecosystems. Each spring has a unique combination of physical, chemical, and biological characteristics and may differ in its sensitivity to disturbance. Therefore, management of springs may require individual prescriptions to achieve the overall goal of maintaining the ecological structure and function of the spring habitat. Management priorities can be determined by evaluating habitat characteristics and aquatic and riparian communities. This evaluation will indicate when sites are degraded and require restoration. Much of the same information used to determine management priorities can be used to determine restoration priorities. Successful restoration will often require alleviating or minimizing factors that degrade habitat quality or compromise the biological integrity of aquatic and riparian systems. Natural recovery processes are desirable because they minimize the risk to threatened, endangered, or sensitive species.

14. SUBJECT TERMS

- Springs
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