Rapid Assessment Method for Springs Ecosystems in Southwestern New Mexico Manual

Version 1.0

2019

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Version 1.0 New Mexico Environment Department,

Surface Water Quality Bureau,

Santa Fe, New Mexico.

Acknowledgments: This manual was produced by the Museum of Northern Arizona Springs Stewardship Institute for the New Mexico Environment Department. The authors thank the SSI/SWQB Field Team for their careful and diligent data collection efforts and their thoughtful insights related to metric performance.

Funding: Funding for the development of the New Mexico Rapid Assessment Method for Springs in Southwestern New Mexico Manual and Field Guide was provided by the U.S. Environmental Protection Agency (EPA) Region 6 to the New Mexico Environment Department Surface Water Quality Bureau Wetlands Program through Wetlands Program Development Grant CD #00F736-01-0C. Additional funding was provided by Springs Stewardship Institute. The contents of this document do not necessarily reflect the views and policies of the EPA, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

Cover photo: Faywood Ciénega in City of Rocks State Park (photo: NMED)

Citation: Stevens, L.E.[1], J.D. Ledbetter[1], G. Hardwick[1] A.F. Hazelton[1], J. Jenness[1], A.E. Mendoza[1], M. McGraw[2], J. Moeny[2], E. Sawyer[2], E.R. Schenk[1], T. Schipper[1], S. Styer[2]. 2019. Rapid Assessment Method for Springs Ecosystems in Southwestern New Mexico Manual. New Mexico Environment Department, Santa Fe.

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1 Executive Summary

Introduction

Springs—ecosystems where groundwater reaches the Earth's surface—are among the most biologically, socioculturally, and economically important water resources, particularly in arid regions like New Mexico (Stevens and Meretsky 2008). Many endangered species, and numerous rare or endemic species of plants, invertebrates, amphibians, and fish are found only at springs, and many upland species require springs for water and habitat. Springs also have high cultural and socioeconomic value, often providing the only sources of water for livestock, farms, and ranches as well as some communities. Given the complex hydrological interactions between temperature, precipitation, infiltration, and aquifer dynamics, springs also are sensitive indicators of environmental change. While much attention and funding has been devoted to rivers, streams, playas, and wetlands, springs ecosystems have been largely overlooked in conservation, research, and management.

The purpose of this manual is to provide a framework for understanding current springs conditions, and to provide a standardized rapid assessment method for New Mexico springs ecosystems (Springs NMRAM). The manual was created for the New Mexico Environment Department (NMED) by the Springs Stewardship Institute (SSI). SSI is a global initiative of the not-for-profit Museum of Northern Arizona, with a mission to improve scientific understanding and stewardship of springs ecosystems. This manual presents the information, background, rationale, and discussion to inform those conducting inventory and assessment of springs in southwestern New Mexico. The field guide associated with this manual presents information and fieldsheets needed for technical staff who are conducting springs wetland inventory and assessment.

New Mexico Springs

Aquifer dynamics, groundwater flow paths, and groundwater status influence springs emergence and their vulnerability to water withdrawal, climate change/variability, and contamination. In this manual we present a conceptual model that relates physical and anthropogenic variables and processes to springs ecosystem integrity.

New Mexico contains portions of four physiographic provinces. The highest concentration of springs occur in the high elevation landscapes of the Rio Grande Rift (part of the Basin and Range province), Mogollon-Datil Volcanic Field (i.e., Gila Mountains) in the Basin and Range Province, and the Colorado Plateau and Southern Rocky Mountains Provinces. New Mexico is the fifth driest state in the U.S., making its aquatic resources not only rare, but also important for biodiversity protection and support of upland ecosystems. As of March 2019, 5,915 springs have been reported in New Mexico, according to Springs Online, a free online database of springs resources (https://springsdata.org/). Most of those springs locations were imported from the U.S. Geological Survey (USGS) National Hydrography Dataset (NHD), but lack information on flow, persistence (intermittent, ephemeral, perennial), springs type, or other characteristics. The majority of those springs are clustered among mountain ranges and along plateau rims, where faults, fractures, and geologic contacts force groundwater to the surface.

Understanding springs typology is important for recognizing biodiversity, and cultural, historic, and economic values. We present an overview of springs and springs microhabitat classification, building on historical and more recent concepts and terminology relevant to the State of New Mexico. The manual provides a review and description of 16 terrestrial springs types, using source geomorphology, among lentic (no to low velocity) or lotic (flowing) categories. Recognizing springs types requires experience, and we present an illustrated dichotomous key to springs types, along with a description of the common microhabitats associated with each springs type. However, the distribution of springs types in New Mexico is currently poorly known, due to the lack of springs surveys. Springs types in neighboring Arizona tend to group by physiographic province, with rheocrene and hillslope springs more common in the Basin and Range province, and hanging gardens and gushets more common on the Colorado Plateau. Helocrene springs (wet meadows springs) were once abundant throughout the Southwest, with low elevation ciénegas and higher elevation groundwater-dependent fens. However, due to extensive draining and management for livestock and agriculture, helocrenes are now among the most critically endangered ecosystem types in the Southwest.

Inventory Protocols

Inventory is a fundamental scientific element of ecosystem stewardship, and the Springs NMRAM process provides essential data on the distribution and status of resources, processes, values, and aquatic, wetland, riparian, and upland linkages. Systematic inventory precedes assessment, planning, action implementation, and monitoring, all of which contribute to development and implementation of a structured resource management strategy. Efficient, interdisciplinary inventory protocols also are essential for improving understanding of springs ecosystem ecology, distribution, status, and conservation. A review of inventory approaches is provided, along with guidance on program development, crew and volunteer coordination and safety, sampling time, permitting, a field equipment checklist, and other field work related topics. In addition, the manual describes the background information that should be compiled in the office prior to initiating field work.

The manual describes three levels of inventory. Level 1 involves compiling geographic information for sample design and logistics planning, typically during a brief field visit. Level 2 involves field site visits by a trained or professional team with expertise in geography, botany, zoology, and hydrogeology. Level 2 surveys are typically 1-2 hour detailed inventories of selected sites, recording data on field data sheets for subsequent data entry in the laboratory. Level 3 inventory work involves detailed research, including wetland delineation, and site mapping of sites of long-term monitoring or restoration significance. While some Level 3 protocols are briefly discussed, the focus of this manual is to provide instruction for Level 2 protocols to support the Springs NMRAM process.

The Level 2 inventory protocol focuses on 10 categories of information. Those categories include: georeferencing and site geography; site and microhabitat description; invertebrate and vertebrate faunal presence and density; vegetation composition, structure, and function; flow and water quality; site condition and risk in relation to anthropogenic use and impacts; and administrative context. Each field sheet is explained in detail. The manual also addresses post-field work activities, including data compilation and storage, as well as sterilization and maintenance of equipment and field clothing.

Information Management

The Springs NMRAM relies on sound, secure information that is well organized and archived, and used to qualify and justify assessment decisions about individual springs. SSI developed Springs Online—a secure, user-friendly, online database where users can easily enter, archive, and retrieve springs information (**http://springsdata.org)**. Springs Online is the result of nearly two decades of springs information management on nearly 100 different springs inventory and assessment projects around the West. This database is relational, providing the capability to contain many surveys related to each site and to analyze diverse variables and trends over time. It is broadly framed to accommodate a wide array of variables and information needs, and also supports data collected using several common protocols. It has been used and evaluated by many federal, state, and NGO agencies and organizations, and is actively being improved to ensure ever-greater facility and ease in data archiving and reporting.

The primary tables and the relationships between them are the foundation of a relational database that allow users to export meaningful data. It is important to provide a wide range of information products that are easy to export. Springs Online can provide commonly requested reports on flow, water quality, physical characteristics, soils, biota, and condition. It is also easy to export summary reports into Microsoft Word for individual surveys, or for a group of surveys that are collected into projects. The database manager can also design complex queries that export data for unanticipated information needs.

The information collected in each category is complex, and many of the data are interrelated. For example, water quality is linked to flow, geology, geomorphology, soils, flora, and fauna. To address this complexity, Springs Online provides a framework to compile this information and to analyze biological, physical, and cultural relationships, many of which are poorly understood.

The database facilitates archival of qualitative and quantitative information within these categories to document present conditions, establish a baseline for future reference, inform the assessment process, guide monitoring activities, evaluate stewardship efforts, track restoration actions, and monitor changes at individual springs, or for many springs across a landscape. The long-term value of such collaborative information management systems is the opportunity to share data with other springs ecosystem managers across political boundaries. The manual presents a step-by-step guide to data entry, editing, quality control, opportunities for relational analyses, and automated reporting.

The Springs Assessment Process

Springs often are ecologically impaired in New Mexico and throughout the world. The overuse of springs for domestic use, mining, and livestock, as well as contamination of groundwater supplies, has led to considerable impairment or destruction. Understanding the status of springs across a landscape begins with collecting high-quality comparative data on the current condition of springs, followed by a methodical evaluation of that information for management planning and actions.

The manual reviews assessment approaches, and provides guidance on in-office analyses to inform field observations and assessment.

Ecosystem assessment should be an efficient, data-driven process, based on actual conditions detected at the site during a field visit. The inventory and assessment team assesses the degree to which the site condition differs from that hypothesized to be the natural condition. To conduct a springs NMRAM, quantitative measurements are obtained by conducting a robust springs inventory, with the results used to answer a series of assessment questions. Responses to those questions are compiled to score a site condition. Basing the Springs NMRAM on quantitative measurements produces a result that is less biased, more precise, and more repeatable than a more qualitative evaluation procedure.

The purpose of this Springs NMRAM is to provide credible, repeatable, comparative evaluation of springs ecological integrity. This method is specifically designed to be scaled up to evaluate springs condition across landscapes and over time. Assessment of a springs ecosystem is based on four sources of information. These are 1) field inventory data, 2) a completed ecosystem stressors checklist, 3) a completed list of 19 springs assessment questions, and 4) the completed assessment summary sheet. The manual emphasizes completion of hard copy field sheets and forms for documentation of field observations.

Stressors Checklist

Various anthropogenic ecosystem stressors negatively affect the ecological function and integrity of springs. The manual identifies six categories of stressors in the checklist: 1) flow regulation and hydrological alteration, 2) soil and geomorphic alteration, 3) animal impacts, 4) recreation impacts, 5) structures or development impacts, and 6) land use impacts. Within each category, six to twelve stressors are listed, with space to identify other stressors.

The team manually or electronically ranks each stressor variable according to the degree to which the stressor is present at the springs ecosystem. Scores range from 1 (absent) to 4 (intense). In addition, each stressor category is weighted with "low", "medium", or "high", indicating which categories of stressors most strongly affect the ecosystem.

The Stressors Checklist is primarily informational, and is intended to clarify which stressors are most strongly influencing the site. While these results are not formally incorporated into the site assessment, they inform the assessment questions and also provide additional potential tools for NMED or other land managers to consider when forming management recommendations and prioritizing sites for restoration and monitoring.

Assessment Questions

While still in the field, after completing a springs ecosystem inventory and the Stressors Checklist, the assessment team should score the Springs NMRAM questions, using the Assessment Field and Site Summary Sheets.

The assessment questions address the site condition. There are 19 assessment questions, classified into five basic categories. The assessment categories are: 1) Aquifer Functionality, Water Quality, and Flow (Questions A-C); 2) Geomorphology (Questions D-G); 3) General Site Description (Questions H-J, informational only and not included in the final RAM score); 4) Habitat (Questions K-M); and 5) Biota (Questions N-S). Each category, its questions, and the scoring criteria are described in detail.

Assessment question scores range from 1.0 to 4.0 in half-integer increments (i.e., 1.5, 2.5 and 3.5). Ascending values indicate higher ecological integrity, with 1.0 representing an irrecoverably impaired condition, and 4.0 representing an ecologically pristine condition.

In some cases, the inventory and assessment team may not have sufficient information in the field to answer a question but may, with additional office research, answer the question in the office. In such cases, leaving a score blank among the Assessment Questions signifies that the team is committed to promptly scoring that question when they return to the office. Also, some of the questions may not be applicable to a given springs type.

Assessment Summary

The assessment scores are summarized by category and for the entire site using the Assessment Summary sheet. Individual subcategory scores are summed, divided by the total possible subcategory score, and then multiplied by 4.0. In cases where a subcategory question is not applicable (e.g., no outflowing springbrook is necessarily expected at helocrene wet meadow springs), the total possible score is reduced by 4.

The total site score is calculated in the same manner. All individual subcategory variable scores are summed, and that value is divided by the total possible site score (60 if there are no "non-applicable" subcategory scores). That fraction is then multiplied by 4.

Springs NMRAM Conclusions

The purpose of this Springs NMRAM is to provide the State of New Mexico with a comparative, information-based evaluation of the ecological integrity and condition of individual springs ecosystems. This Manual and the accompanying Field Guide were developed through inventory and assessment of more than 50 springs in southwestern New Mexico. Further inventory and assessment of springs in other New Mexico ecoregions is warranted to test and refine the assessment process described here. Springs assessment using the process described herein should provide managers with an understanding of the ecological integrity and stewardship opportunities and challenges in that springs ecosystem and among springs across the state, as well as the response of that springs ecosystem to management actions.

2 Introduction

New Mexico Rapid Assessment Method (Springs NMRAM)

Springs—ecosystems where groundwater reaches the Earth's surface—are among the most biologically, socioculturally, and economically important water resources, particularly in arid regions like New Mexico (Stevens and Meretsky 2008). Many endangered species, and numerous rare or endemic species of plants, invertebrates, amphibians, and fish are found only at springs, and many upland species require springs for water and habitat. Springs also have high cultural and socioeconomic value, often providing the only sources of water for livestock, farms, and ranches as well as some communities. Given the complex hydrological interactions between temperature, precipitation, infiltration, and aquifer dynamics, springs also are sensitive indicators of environmental change. While much attention and funding has been devoted to rivers, streams, playas, and wetlands, springs ecosystems have been largely overlooked in conservation, research, and management. Springs are abundant across most of New Mexico, with nearly 6,000 reported in the state (e.g., Fig. 2-1).

Despite their importance, springs ecosystems are poorly understood, incompletely mapped, and inadequately protected. The lack of information and attention has resulted in the loss of springs and springs-dependent natural, sociocultural, and economic resources through poorly informed management practices. Estimates of impairment or loss of springs in some southwestern landscapes exceed 90% (Grand Canyon Wildlands Council (GCWC) 2002). Until recently there has been little effort to systematically map, inventory, or assess the socioecological integrity of springs within or across administrative boundaries. Thus, existing information on New Mexico springs distribution and ecology is minimal, fragmented, and largely unavailable to land managers, tribes, conservation organizations, and researchers.

Fig. 2–1. Bead Spring, Gila National Forest. This spring and the surrounding area was heavily burned. Photo by John Moeny.

Springs are among the most biologically diverse, ecologically interactive, abundant, and socioculturally important terrestrial ecosystems, and exist in a wide array of types and settings in New Mexico. Although often small in area, springs serve as hotspots of aquatic, wetland and riparian diversity, and as keystone (ecologically highly interactive) ecosystems that play disproportionally important roles in relation to adjacent uplands. In addition, springs are intensively used by humans in New Mexico and throughout the world for water and other resources. Consequently springs often are ecologically impaired. Appropriate stewardship of springs in aridland states like New Mexico is hampered by a lack of knowledge of their condition.

The purpose of this manual is to provide a framework for understanding current springs conditions, and to provide a standardized rapid assessment method for New Mexico springs ecosystems (Springs NMRAM).

This manual has been created for the New Mexico Environment Department (NMED) by the Springs Stewardship Institute (SSI). SSI is a global initiative of the not-for-profit Museum of Northern Arizona, with a mission to improve scientific understanding and stewardship of springs ecosystems. Many sections this document have been adapted or revised from existing SSI protocols, manuals, and publications, as cited herein. All copied and revised sections have been approved by the relevant authors of the original publications.

This manual presents the information, background, rationale, and discussion to inform those conducting inventory and assessment of springs in southwestern New Mexico. The field guide associated with this manual presents information and fieldsheets needed for technical staff who are conducting springs wetland inventory and assessment.

This Springs NMRAM is presented in the following chapters and is intended to be comparable with similar ecosystem NMRAMs developed by NMED to ensure consistent and scientifically defensible assessment metrics for the major aquatic ecosystems of the state.

3 New Mexico Springs

Introduction

New Mexico is the 5th driest state in the U.S., making its aquatic resources not only rare but extremely important for biodiversity and supporting upland ecosystems. As of March 2019 there were 5,915 reported springs in New Mexico,

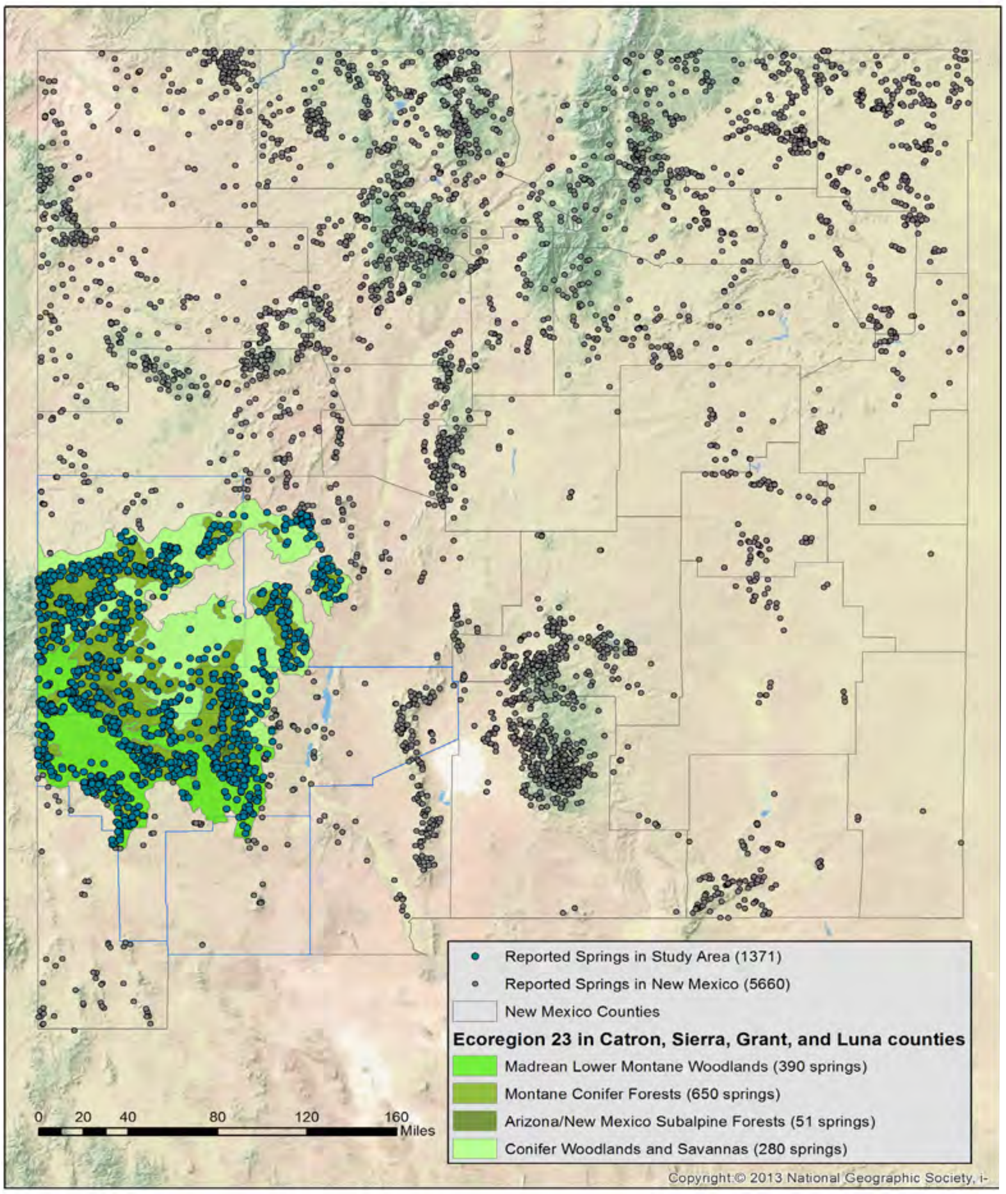


Fig. 3–1. Reported springs in New Mexico, with Ecoregion 23 highlighted. Springs locations from Springs Online (Springsdata.org, accessed March 2019). Springs in Ecoregion 23 are shown as blue points, and all other New Mexico springs are shown as olive points.

according to Springs Online, an online database of springs resources (https://springsdata.org/). Many of the documented springs were imported from the U.S. Geological Survey (USGS) National Hydrography Dataset (NHD) and lack information on flow, persistence (intermittent, ephemeral, perennial), springs type, or other characteristics. The majority of those springs are clustered along mountain ranges and plateau rims where faults, fractures, and geologic contacts are expressed at the surface (Fig. 3-1).

Physiographic Provinces

New Mexico contains portions of four physiographic provinces (Fig. 3-2). The highest concentration of springs occur in the high elevation landscapes of the Rio Grande Rift (part of the Basin and Range province), Mogollon-Datil Volcanic Field (i.e., Gila Mountains) in the Basin and Range Province, and the Colorado Plateau and Southern Rocky Mountains Provinces.

Fig. 3–3. Lower Vigil Spring, a rheocrene spring in the Gila National Forest.

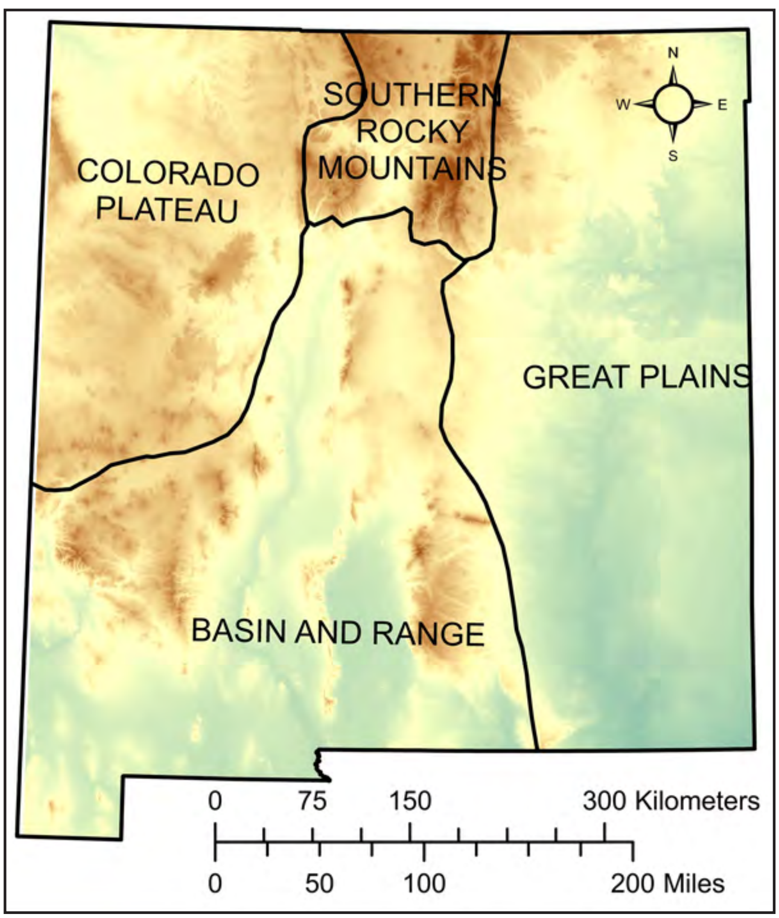


Fig. 3–2. Physiographic provinces of New Mexico, adapted by Andrea Hazelton from Fenneman and Johnson (1946).

Springs Ecosystem Conceptual Model

The terms "springs" and "springs ecosystems" are used interchangeably throughout this manual, but what constitutes a "springs ecosystem"? Ecosystems are groups of species co-occurring in and interacting with their physical habitat (Fig. 3-3). At a coarser scale, ecosystems in a region are grouped into biomes that support relatively discrete assemblages of plants and animals. The major biomes of New Mexico include: Chihuahuan Desert, Great Plains Grassland, Colorado Plateau Shrub-Steppe and the AZ-NM Mountains (Conifer Woodlands).

Springs ecosystems are unusually self-contained, making them ideal for the study of ecosystem ecology (Odum 1957, Blinn 2008). Springs are structured by physical interactions among geology, hydrology, and climate, and emerge as the result of geologic structure and aquifer mechanics. At their sources, springs ecosystems are strongly influenced by geomorphology and microclimate, as well as the disturbance regime and microsite productivity. All of those physical factors affect the development of microhabitats and soils. Springs are colonized through biogeographic processes, including active and passive dispersal of species, processes that generate the biological assemblage encountered during a site visit. This assemblage varies over time (e.g., daily, seasonal, inter-annual periods) naturally and because of human activities. Human exploitation of ecosystem goods and services affects the biological assemblage, microhabitats, and other ecosystem characteristics and processes. Stevens et al. (in review) identified and related these ecosystem elements and processes in a conceptual ecosystem model (Fig. 3-4).

Hydrogeology of New Mexico

Understanding the regional aquifers, groundwater flow paths, and groundwater status, is important for understanding the vulnerability of individual springs to water withdrawal, climate change/variability, and contamination. Conceptual and numerical groundwater models that synthesize geologic stratigraphy, structure, permeability of local basement rock, climate variability, and water withdrawal can be essential for understanding the role of springs on the landscape and the vulnerability of these resources to disturbance. While a statewide synthesis of groundwater information is beyond the scope of this manual, there are a number of resources that the inventory team can access to become familiar with the groundwater hydrology of the region in which they are working. The team can contact federal, state, and university hydrogeologists and water science centers for relevant hydrogeologic data for the springs in their geographic region. A few examples of available resources include:

- New Mexico Bureau of Geology and Mineral Resources, water resources, aquifer mapping program, and geologic mapping programs: https://geoinfo.nmt.edu/resources/water/
- U.S. Geological Survey New Mexico Water Science Center: https://nm.water.usgs.gov/infodata/groundwater.html

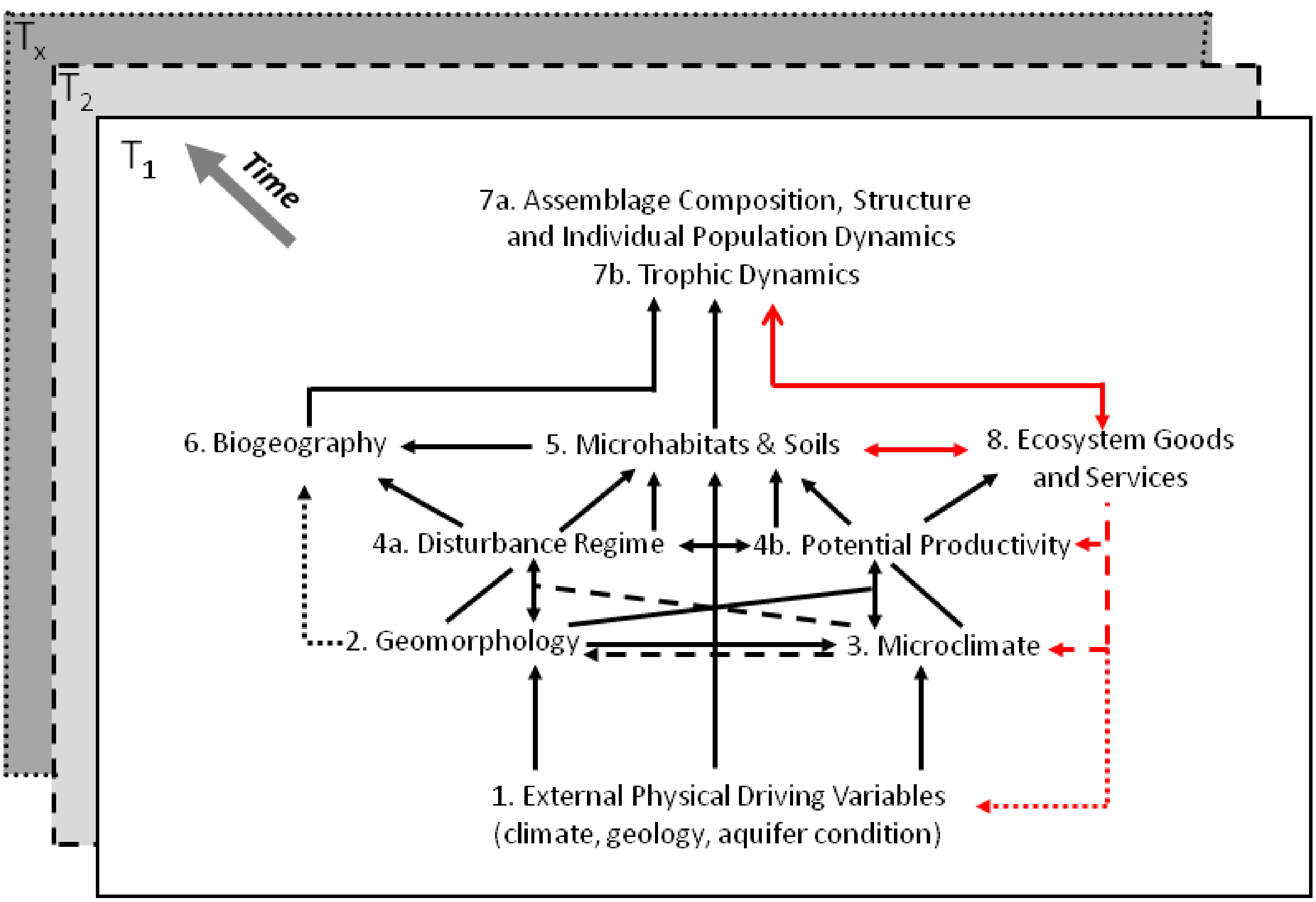


Fig. 3–4. Springs ecosystem conceptual model modified from Stevens and Springer (2004). Dashed arrows reflect indirect influences, while red arrows indicate human impacts.

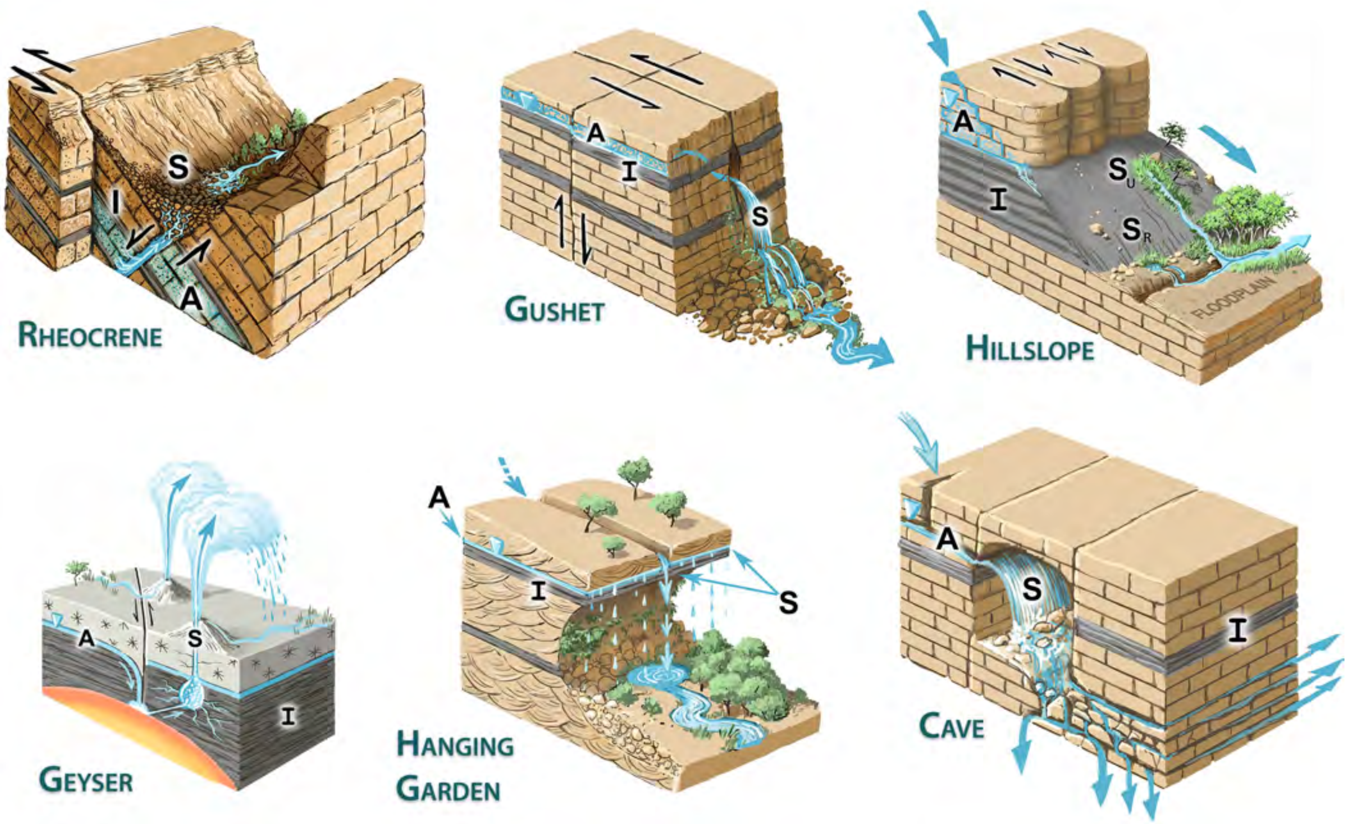


Fig. 3–5. Lotic springs types, with A=aquifer, S=source, and I=impermeable layer, illustrated by V. Leshyk for SSI © 2012).

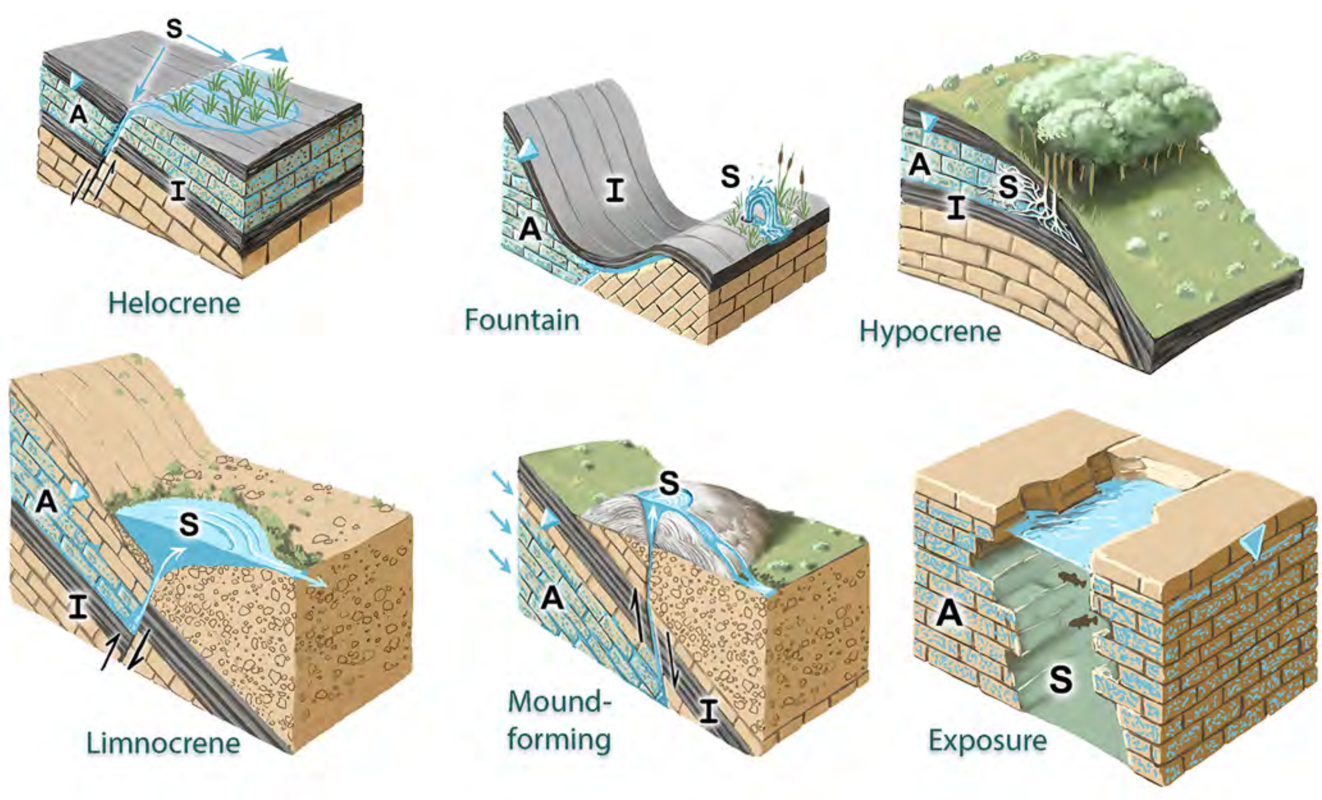


Fig. 3–6. Lentic springs types, with A=aquifer, S=source, and I=impermeable layer, illustrated by V. Leshyk for SSI © 2018).

- University of New Mexico, New Mexico State, and New Mexico Institute of Mining and Technology hydrology programs.
- Springs Stewardship Institute (SpringStewardshipInstitute.org)

Springs Types in New Mexico

Classifying springs using geomorphic and landscape attributes is essential for rapid assessments of springs ecological integrity (condition), status, and restoration potential. Stevens et al. (in review) describe 16 springs ecosystems subtypes among 12 active springs types based on geomorphology (Figs. 3-5, 3-6). Currently only a small percentage of the more than 5,900 documented New Mexico springs have been characterized according to springs type. The following summary has organized springs types into either lentic (low to no velocity; (Fig. 3-5)) or lotic (flowing; (Fig. 3-6)) categories. The accompanying information has been adapted from the Arizona Springs Restoration Handbook (Stevens et al. 2016).

Fig. 3–7. A fledgling Pygmy Nuthatch (*Sitta pygmaea*) at Adair Spring, Gila National Forest.

Biology and Ecology

Understanding the springs types and their general ecology and biodiversity are important to recognizing whether individual springs or springs types are likely to harbor endemic or rare species, statistically significant biodiversity, important cultural sites, and regionally important ecosystem services and economic values. Springs ecosystems in New Mexico interact with surrounding uplands and downstream surface water habitats, providing essential fresh water, food resources, and habitat complexity. In turn, springs are strongly influenced by their surrounding environment, ecosystem conditions, and human disturbance. Disturbances, such as fire, livestock grazing, recreation, impervious surface development, logging, and non-native species invasion can drastically alter springs ecological integrity and interactions. Therefore, a description of the types and conditions of surrounding ecosystems is needed to develop an understanding of interactions and ecological context of springs influence on the landscape.

Springflow-dominated sites may serve as paleorefugia, long-term stable sites in which evolutionary processes allow rare, relict, or adapted endemic species to evolve or persist (Nekola 1999). Springs also may serve as refugia, either seasonally or throughout the year, for state listed species of concern or federal threatened or endangered species. Seasonal and nocturnal monitoring of at least a representative subset of springs can help document whether and to what extent particular springs or springs types function as refugia or are essential for resident and migratory species (Fig. 3-7).

Cultural and Historical Aspects

Springs are among the most important cultural sites in the landscape, supporting paleontological and archaeological remains and containing evidence of prehistoric and historic use and harboring enormous contemporary cultural and economic values (e.g., Glennon 2002, Haynes 2008, Nabhan 2008, Rea 2008). An integrated, annotated history of human occupation and management of the springs and surrounding landscape helps identify springs that have significant sociocultural significance. Human use of springs in New Mexico extends back 13,000 years, since the earliest time of human presence in the Southwest, as revealed by the paleontological discoveries of J.R. Whiteman, E.B. Howard, and John L. Cotter at a paleo-springfed pond at "Clovis type" Locality #1 in Blackwater Draw in Curry County (Boldurian 2008). In historic times, human use of springs as ambush sites for big game gave way to occupation and agricultural uses.

Spanish exploration and route establishment across the Four Corners region (e.g., the Old Spanish Trail) often focused on springs as water sources, a practice that continued with American trapping and military expeditions, wagon road routing, rail line construction, and settlement. Springs are economically essential to rural New Mexico. For example, springs are commonly used as water sources for livestock grazing, and many ranches, some recreation sites (e.g., Gila Hot Springs), and some communities (e.g., Jemez) rely heavily on springs water for potable or utilitarian purposes. More recently, state, US Forest Service, Bureau of Land Management, and many other agencies have begun to focus more attention on improving springs management. Such efforts are gaining widespread public recognition and research. Springs are, and have long been, strongly human-dominated, but are among the most sustainable ecosystems. Improved springs stewardship requires planning that includes consideration of human impacts (West and McGuire 2002, Kodrick-Brown and Brown 2007, Kodrick-Brown et al. 2007).

Inventory teams need to be aware of cultural and landowner sensitivities before visiting a spring. Private and tribal land on the route to the spring, or including the spring, require consultation prior to field work. Stakeholders and landowners also can provide important information on land use history, site condition background, and access data not otherwise available. Consulting landowners and third-party stakeholders may reveal previous studies, information about aquifer conditions, and can help create on-the-ground grassroots stewardship that is more efficient and effective than centralized formal environmental stewardship. The project leaders should discuss the benefits of landowner involvement, citizen scientist contributions, taking note that crew field safety may involve consideration of potentially hostile reception to the concept of improving springs stewardship.

Springs Stressors

Many factors exert ecological stress on New Mexico springs, including both natural processes in this arid region, as well as direct and indirect human impacts (Fig. 3-8). Natural stressors include climate variability, natural changes in groundwater flow paths through seismic events, as well as wildfire, and wildlife grazing/overuse by native species (Fig. 3-9). Direct human impacts include: aquifer dewatering, either partially or completely for irrigation and consumptive purposes; flow diversion at the spring source; mining; livestock uses; point source groundwater contamination; and the use of springs as recreational sites. Indirect human impacts can include many of the above stressors, as well as non-native floral and faunal introduction, site and landscape influences, light and air pollution, changes in groundwater recharge due to upland land use change, and non-point source groundwater pollution. These factors and issues are included in the stressors list and assessment worksheets that the inventory and assessment team use to document conditions at a spring ecosystem during field site visits

Fig. 3–8. Developed Gold Gulch Spring, located in Gila National Forest.

Fig. 3–9. This previously unmapped and unnamed helocrene spring in the Gila Wilderness is severely burned and heavily trampled by stock and elk.

Some stressors exert localized impacts on an individual springs ecosystem or a springs complex. These stressors usually can be readily identified, while indirect stressors may be more regional in nature and more difficult to identify and mediate. Stressors also vary over time, with the impacts of some stressors varying seasonally, but others not detectable for many years after they have been initiated in the landscape. For example, groundwater contamination from a mine may not be detectable for decades or centuries, depending on groundwater residence time and flow path in the affected aquifer. Understanding the full suite of actual and potential stressors influencing a springs ecosystem will require background research into land use history, local and regional groundwater and aquifer hydrogeology, and consultation with landowners and stakeholders. A list of risk-related stressors and condition-based assessment questions is described in detail in the Springs NMRAM Assessment Chapter 7.

4 Springs as Subclasses of Wetlands

Introduction

Springs are wetland ecosystems in which groundwater is exposed at, and usually flows from the surface of the Earth (Fig. 4-1). Springs are widely recognized as abundant point sources of biodiversity and productivity, and often harbor substantial ecological, socio-cultural, and economic value (Perla and Stevens 2008; Gleick 2010; Hershler et al. 2014, 2017; Kreamer et al. 2015; Mueller et al. 2017). While of uncertain federal status as wetlands (US Army Corps of Engineers and Environmental Protection Agency 2015), springs are recognized as wetlands by the State of New Mexico. Many springs provide economically important water sources - most farms and ranches in New Mexico likely were founded (and many still rely) on springs, and some communities obtain some or all of their potable water supplies and recreational income from springs (e.g., Jemez Springs, NM). Despite their obvious ecological and socioeconomic importance, springs also are among the most globally threatened ecosystems due to anthropogenic groundwater depletion and pollution, and surface habitat modification (Stevens and Meretsky 2008; Knight 2015; Kreamer et al. 2015).

Improved stewardship of New Mexico springs requires a definitive classification system because springs ecohydrology, management, development, and restoration options all vary in relation to springs type (Kreamer et al. 2015, Stevens et al. 2016, Sinclair 2018). Identification of rare springs, systematic assessment of ecological integrity, variation in microhabitat distribution, and the distribution of rare, endemic or endangered springs-dependent species all are central natural resource management concerns that require knowledge of the springs type. Springs are highly individualistic ecosystems which vary widely in many features, and a definitive, widely accepted global springs classification system is essential to improve basic scientific understanding and ecosystem stewardship. However, after more than a century of springs, stream, and wetland classification efforts, the only definitive geomorphic classification system for springs is that of Springer and Stevens (2009).

Springs classification is a requirement for springs inventory protocols, of which the most widely used in the United States is now the Springs Stewardship Institute (SSI) Springs Inventory Protocol (Stevens et al. 2016). Other inventory protocols include those of the Nevada Desert

Fig. 4–1. Even Spring, is a previously unmapped spring in the Gila Wilderness. Many springs are missing from databases and topographic maps, leaving land managers with insufficient information to understand and protect these important resources.

Research Institute (Sada and Pohlmann 2006), the US Forest Service Level 2 Groundwater Dependent Ecosystems (2012; USFS GDE protocol), and the US Bureau of Land Management's Lentic and Lotic Proper Functioning Condition (PFC) assessments (Prichard et al. 2003; Dickard et al. 2015). Other springs inventory protocols have been proposed, but primarily have been developed by individual U.S. land agencies or research groups for local inventory purposes.

Understanding springs types is an essential component in development of a New Mexico Rapid Assessment Protocol, and much recent attention has been devoted to development of an efficient classification system for springs (Sada and Pohlmann 2006, Spitale 2007, US Forest Service 2012, Stevens et al. 2016). Springer et al. (2008), Springer and Stevens (2009), and the Museum of Northern Arizona Springs Stewardship Institute's website (SSI; 2016; springsstewardshipinstitute.org) provide typology classification guidance for springs and the microhabitats those springs support. This work has led to the recognition of a strong, positive relationship between microhabitat complexity and biological complexity within individual springs ecosystems (Sinclair 2018; Stevens et al. in review).

Here we present an overview of springs and springs microhabitat classification, building on historical and more recent concepts and terminology relevant to the State of New Mexico. Using Springer and Stevens (2009) classification and Stevens et al. (in review), we review identified springs types based upon geomorphology. Also, from that review, we provide Stevens et al.'s (in review) illustrated dichotomous key to springs types, and describe the physical characteristics and microhabitats most commonly associated with springs in New Mexico springs types. We discuss our findings in relation to the development of the Springs NMRAM.

Springs Classification

Historical Overview

The history of springs classification extends back more than a century, with attempts to classify springs by Fuller (1904), Thienemann (1907, 1922), Keilhack (1912), Waring (1915), Bryan (1919), Meinzer (1923), Clarke (1924), and Stiny (1933). Thienemann (1907) described several springs types in Scandinavia based on flow characteristics and geomorphology, including pool-forming limnocrene, stream channel rheocrene, and marshy helocrene springs. Meinzer (1923) described North American springs, including aquifer factors, flow variability, and water quality, as well as local geomorphology. Wallace and Alfaro (2001), Springer et al. (2008), and Glazier (2009) reviewed historical spring classification information. Springer and Stevens (2009) expanded earlier geomorphological characterization to include 12 discrete types of terrestrial springs, not including fossil paleosprings (i.e., springs that flowed in the non-recent geologic past, but no longer flow), but did not distinguish between floodplain and upland hillslope springs. Here we refine their system to provide a description of New Mexico springs types, and present illustrations of terrestrial types from the Springs Stewardship Institute's website to describe salient characteristics of those springs types (Table 4-1).

Meinzer (1923) identified 11 different suites of variables through which to classify springs, and various authors have proposed other useful classification schemes (see Glazier 2009 for a summary of 46 such schemes). These can be grouped into seven general conceptual approaches (Table 4-1), including those focused on characteristics of: 1) the aquifer, 2) springs discharge, 3) water quality (temperature, geochemistry), 4) landscape position, 5) local site geomorphology, 6) vegetation, and 7) combinations of those variables, and 8) vegetation (Springer and Stevens 2009).

Early classification approaches often were based on local or regional observations, geologic mapping, aquatic invertebrates, or relatively simple combinations of physical metrics. More recent efforts have focused on multivariate analyses of combined physical and biological characteristics.

Approaches

Aquifer-based Classification

Aquifer characteristics are defined by tectonics, parent bedrock, landscape position, geologic

Table 4–1. Springs classification approaches and references. References provided serve as examples, but there are numerous other studies, reports, and classifications that utilize these seven general approaches (see Glazier 2009).

General Approach	Variables Considered	Reference
1. Aquifer	"Deep-seated waters" (volcanic and fissure springs) vs. meteoric water (dimple, valley, channel, or border depression springs, vs. gravity, mesa, or hardpan contact springs). Other distinctions are based on aquitard dip angle and surface irregularity. Impervious rock tubular (solution/cavern, lava tubular, minor tubular) vs. quadrille, crosshatch, or inclined fracture.	Waring 1915; Bryan 1919; Meinzer 1923
	Aquifer lithology	Bryan 1919; Meinzer 1923
	Geologic horizon of the aquifer	Bryan 1919; Meinzer 1923
2. Springs Discharge	Flow quantity (1st order = highest flow; and strong vs. weak, or large vs. small)	Bryan 1919; Meinzer 1923
	Flow variability =100*((max-min)/mean)	Bryan 1919; Meinzer 1923
	Flow permanence (perennial vs. "intermittent") [1]	Bryan 1919; Meinzer 1923
3. Water Quality	Water temperature (cold or neutral, vs. geothermally warm or hot)	Waring 1915; Bryan 1919; Meinzer 1923
	Water chemistry	Waring 1915; Bryan 1919; Meinzer 1923
4. Landscape Position	Wetland designation as lacustrine, palustrine, etc.	Cowardin et al. 1979, Army Corps of Engineers and EPA 2015
5. Geomorphology	Character of openings of water issuance (seepage/filtration, fracture, tubular)	Bryan 1919; Meinzer 1923
	Sphere (subaerial vs. subaqueous)	Bryan 1919; Meinzer 1923
	Features produced by the springs (pool vs. precipitate or organic mound)	Bryan 1919; Meinzer 1923
	Mountain springbrook substratum composition (rocky, stony, pebbly, gravely, clay-sand springs, either rich or poor in vegetation cover)	Spitale 2007
	12 spheres of discharge	Springer and Stevens 2009
	Paleosprings	This report
6. Vegetation	Plant types (Halo-), meso-, and xero-phreatophytes	Meinzer 1923
	Wetland delineation vegetation methods	Cowardin et al. 1979, Army Corps of Engineers and EPA 2015
	Botanical classification of European Union freshwater ecosystems	European Commission EUR27 (2007)
7. Combined Metrics	Dip, siphon, unbedded gravity-forced artesian springs	Bryan 1919
	Parent rock structure and forcing mechanisms - gravity (depression, contact, fracture/tubular; and artesian) vs pressure (geothermal, CO2, other gases)	Cowardin et al. 1979, Army Corps of Engineers and EPA 2015

structure, climate, and anthropogenic impacts. Among the more notable distinctions in aquifer types is the difference between karst and non-karst aquifers. (e.g., Tobin et al. 2017). Depending on the geological setting, karstic aquifers are characterized by relatively rapid (days-decades), flashy flow paths through fractured carbonate strata, water closely reflecting the ambient temperature of the infiltration surface, and calcium carbonate-dominated groundwater geochemistry (Fig. 4-1). Springs sources geomorphology in karstic systems can include small to large gushets, hillslope, rheocrene, cave, exposure, and rarely fountain springs. Also, a wide array of non-karstic aquifers exists, of which the most common are non-carbonate sedimentary strata, basaltic and other igneous strata and, more rarely, metamorphic strata. Such systems can generate the full suite of springs types but generally have longer residence and response times except in the case of fracture dominated aquifers (Fetter 2001).

Discharge-based Classification

Overview: Springs can also be classified by flow rate, consistency, variability, persistence, and spring channel dynamics.

Flow Rate: Historically, Meinzer (1923) developed a series of discharge classes based on springs flow measurements at the time of survey. Meinzer's classes distinguished increased flow rates with a decreasing numeric scheme, with the largest streams described as "first order." This system is unfortunately both unintuitive and constraining. Instead we recommend a classification system in which springs flow is described on the basis of mean discharge in liters per second, expressed in base 10. This scale easily accommodates the wide range of spring discharges, from seeps with near-zero flow to large springs with a flow of greater than 50,000 liters per second. For example, a small ephemeral spring might have a mean discharge of $1*10^{-6}$ L/s; while the largest terrestrial springs on earth have mean flow rates of $3.63*10^{4}$ L/s (Ra-El-Ain Spring in Syria) to $5.03*10^{4}$ L/s (Dumanli Spring in Turkey; Alfaro and Wallace 1994; Karanjac and Günay 1980). That said, it is important to keep in mind that springs flow may vary widely among seasons from year to year, so it is important to

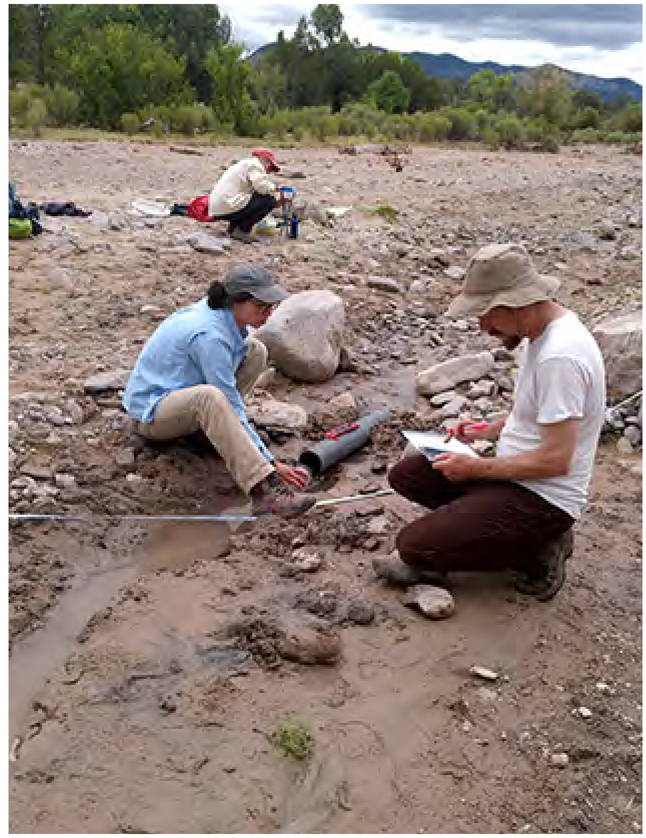


Fig. 4–2. Flow measurements at rheocrene springs can be strongly affected by runoff.

consider flow consistency and variability in discharge-based classification schemes.

Flow Consistency: Meinzer (1923) used spring perenniality to distinguish between spring classes. In this classification, springs can be considered perennial (if discharge is persistent) or intermittent (if discharge is interrupted or sporadic). Intermittent springs may occur seasonally (Fig. 4-2). However, human impacts on springs and aquifers alter the springs' natural state. Multiple records from a spring are needed to establish the flow consistency. The term "intermittent" has changed since 1923 to follow stream classifications. "Intermittent" is now defined as a stream, or spring, that flows for a short distance before sinking back into alluvium/colluvium to re-emerge downstream. Ephemeral springs, defined as sporadic or seasonal springs, are similar to Meinzer's description of intermittent springs (Stevens et al. 2016).

Flow Variability: Classification of springs by flow variability requires repeated discharge measurements over a long period of time. Short-term variability of the spring discharge may be due to loading effects, individual storms, and droughts. Longer-term variability maybe be due to long-term climate variations and hydrologic changes. Additionally, flow variability may affect the stability of spring microhabitats. Meinzer (1923) considered three classes of flow variability: constant, sub-variable, and variable. These classifications require numerous measurements to adequately characterize diurnal, seasonal, annual, inter-annual, and long-term variation. A discharge variability ratio (DVR) can be used to calculate the stream flow variability: DVR = Q10%/Q90%. By calculating the ratio of low and high flow, researchers can draw conclusions of spring variability: constant (DVR≈1) or highly variable (DVR≥10).

Persistence: Springs are known to act as refugia across ecological and evolutionary time scales. Springs that have recently developed are known as Holocene neorefugia while those that have existed since at least the Pleistocene are labeled paleorefugia (Nekola 1999). The older the spring, the more likely it contains high levels of endemism, unique species, and well-sorted assemblages of flora and fauna (Nekola 1999, Blinn 2008). A third type of spring, paleosprings, can be considered where a spring used to exist but can now only be identified using signs such as travertine deposits. Such paleosprings may contain important paleoclimate, paleontological, and archaeological remains (Haynes 2008).

Water Quality Classification

Temperature: Five classes of water temperature in springs are recognized in relation to the mean annual air temperature (modified from Alfaro and Wallace 1994): cold, normal, warm, hot, and superthermal springs. Cold-water springs discharge water that is at least 12.2° C cooler than the mean annual ambient temperature. Spring waters within 12.2° C of the mean ambient temperature are classified as "normal" and may, but do not necessarily, respond to ambient atmospheric temperature. Such conditions are likely to be found in springs sourcing from shallow aquifers, which may have temperatures that vary seasonally with air temperature. Springs are classified as "warm" if they discharge water that is at least 12.2° C above the mean ambient air temperature but cooler than 37.8° C. Hot springs, which have water temperatures above 37.8° C, are sourced either from large aquifers with long flow paths or from geothermal sources of heat. Superheated geothermal springs are derived from aquifers influenced by tectonics, and include geyser fields and profundal (deeper than the level of light penetration) marine settings. In settings such as those, life can exist at temperatures up to 121-130° C (extremophilic Archaea in Pacific Ocean seafloor vents). Variability in spring water temperature also may be important for water quality classification, but can be assessed only through repeated visits or by using recording thermistors.

Geochemistry: Water geochemistry has been variously classified through the surface-water pollution literature, but few studies attempt a comprehensive classification of spring-water geochemistry. Clarke (1924) classified the waters of mineral springs based on the dominance of seven ion groups---calcium, carbonate, chloride, magnesium, potassium, sodium, magnesium, sulfate, and combinations of these three constituents, as well as silica dioxide (SiO_2), borate (B_4O_7), nitrate, and phosphate, and pH. Futak and Langguth (1986) classified Greek springs as belonging to (1) normal earth alkaline (hydrogen-carbonatic) waters; (2) normal earth alkaline, hydrogen-carbonatic-sulfatic waters; or (3) enriched alkali earth alkaline (primarily hydrogen-carbonatic) waters. Dinius (1987) used an expert-based decision process to develop an index of surface-water quality to compare levels of pollution in bodies of fresh water, based on solute concentrations and specific conductance (µS/cm), pH, alkalinity, water color (platinum units), and [Cl], [O} and [NO_3], aqueous [O_2], rare earth elements, stable isotopes, biological oxygen demand, turbidity, and bacterial concentration; some of these variables may be relevant to springs water types. In addition, dissolved or gaseous methane, sulfides, and hydrogen are important indicators of subaqueous freshwater and seafloor vent springs.

Landscape Position Classification

Several springs classification systems focus on the position of the springs emergence in relation to landforms. Bryan (1919) described in detail the various ways that aquifer geology, bedrock stratigraphy, and slope angles result in springs emergence. More recently, Sada and Pohlmann (2006) characterized Great Basin springs as mountain slope, bajada, and valley floor types, a classification system reflected in that used by the Quivira Coalition et al. (2014) for New Mexico Springs. Such a classification system describes the overall landscape context of where springs emerge, but unfortunately does little to describe the actual source environment.

Geomorphology Classification

Source Geomorphology: Geomorphology is the most definitive way to classify springs ecosystem types. However, hydrologists have traditionally classified the physical geomorphology of springs at the point of emergence only (e.g., Bryan 1919; Meinzer 1923), and pay little attention to the post-emergence environment. Thienemann (1907, 1922) described several springs types on the basis of local geomorphology, including pool-forming limnocrenes, stream-channel rheocrenes, and marsh-forming helocrenes. Meinzer (1923) adopted this approach, describing the "sphere of discharge" of the springs source. Alfaro and Wallace (1994) and Wallace and Alfaro (2001) reviewed those historical spring classification schemes, and Springer et al. (2008) and Springer and Stevens (2009) expanded the early geomorphological characterization to include 12 discrete types of terrestrial springs, not including fossil paleosprings (i.e., springs that flowed in the non-recent geologic past, but no longer flow).

Spring Channel Dynamics: Springs that flow in, or into, channels can create distinct channel characteristics and morphology if the discharge is consistent and if surface run-off does not dominate the channel's flow regime. In general, surface water classifications systems do not adequately describe springbrook geomorphology. For example, the Rosgen (1996) stream classification system ignores differences between springflow-fed channels and those dominated by surface runoff. Springbrook channels in the Rosgen classification system may be Aa+, A, B, to G channel types, and most springs types are not clearly described. In part, this is because surface flow classification does not recognize the unique role of groundwater on channel geomorphology (Stevens et al. 2005). Griffiths et al. (2008) examined springbrook channels in the Southwestern USA, concluding that they were characterized by erratically linear channel segments with consistent flow at or near bank-full stage.

Springs at stream headwaters can create what is classified as a spring-dominated channel (Whiting and Stamm 1995). These channels are typically straighter than traditional surface water runoff channels and often are near or at bank-full stage (Whiting and Stamm 1995). If the channel contains significant surface runoff flow, then it is classified as a runoff-dominated channel (Whiting and Stamm 1995) and has all of the characteristics of a classic stream channel (e.g. Leopold et al. 1964; Rosgen 1996). These channels can be classified using the traditional stream classification systems. Some springs systems include a mix of spring and runoff dominated flow, and can best be described as spring-surface runoff channels (Stevens et al. 2016).

Vegetation-based Classification

Cowardin et al. (1979), the European Commission (2007), and others have used vegetation associations to classify springs and other freshwater habitats, producing in a large array of biologically-based floristic types that broadly overlap among geomorphic springs types. While of great interest botanically, these classifications generally do not match well with other classifications based on geology, aquifer characteristics, or microhabitat character. Vegetation-based classifications may also be of reduced use in areas that have sustained rapid climatic, land-use, or invasive species changes. Any classification based on variables that readily change through time is problematic.

Combined Metrics Classification

Meinzer (1923) subdivided the geomorphic spheres of discharge of springs in the United States on the basis of temperature and other water quality characteristics, flow, and flow consistency (Springer et al. 2008). However, as some of the metrics used in that scheme are nonintuitive, we do not recommend its use.

Springs often provide potable water supplies and karstic springs in particular have been the subject of extensive basic and applied research (e.g., Cantonati et al. 2016), including identification of aquifer rock types and water chemistry as a way to grossly classify springs. For example, analysis of groundwater quality among 588 undeveloped springs in the Trentino region of northern Italy in relation to four aquifer rock types (sedimentary, effusive, intrusive, and metamorphic strata). They reported a bimodal frequency peak in specific conductance (μS/cm), related primarily to Ca^{2+} and HCO^{3-} concentrations.

More recently, multivariate statistical analyses have sought to distinguish springs types on the basis of combined physical and biological characteristics. For example, Zollhöfer et al. (2000) conducted a multivariate habitat and aquatic invertebrate assemblage analysis of 16 variables from 34 Swiss Plateau and Jura Mountains springs. They reported discrimination of six springs types, including: karst, lime-sinter, unsintered, linear, and alluvial rheocrenes and anthropogenic limnocrenes, which contained characteristic fauna. However, regional landscapes like the Swiss Alps do not generate all possible springs types (neither helocrenes nor hanging gardens occur in their study) and thus cannot be compared. Sinclair (2018) used physical and floristic data from 352 southern Colorado Plateau springs, distinguishing discrete plant assemblages among hillslope, rheocrene, helocrene, and hanging garden springs, but was not able to obtain sufficient data to test for differences among other less-common springs types in that region (e.g., limnocrenes). Here we refined the Springer and Stevens (2009) terminology, share improved illustrations of terrestrial springs types from the Springs Stewardship Institute website, and more fully describe the salient characteristics of different springs types.

A Key to Springs Types

Overview

To our knowledge, the first dichotomous key for springs classification was that of Bryan (1919). He created a key to 26 springs types based on aquifer and water source hydrology, bedrock geology, and geologic structure. While influencing groundwater emergence, those characteristics, are not, in themselves, springs-specific and broadly overlap among geomorphologically-classified springs types. While Meinzer (1923), Alfaro and Wallace (1994), Springer et al. (2008), and Glazier (2009), described in detail the variation in aquifer geology, flow, water temperature and geochemistry, vegetation, and other factors, they did not attempt to assemble those data in such a fashion as to clearly distinguish types. The primary advantage of a springs classification system based on differentiation of emergence geomorphology is that springs type strongly influences ecosystem function and species assemblages. Thus, individual springs types are susceptible to different kinds of stressors and threats and require type-specific management actions. The geologic approach advanced by Springer and Stevens (2009) and Stevens et al. (in review) is recommended to facilitate integrated information management and assessment. In addition, a geomorphic approach readily lends itself to development of a dichotomous key, so that technicians can quickly document springs type.

Below we present a dichotomous key and illustrated description to the geomorphic terrestrial springs types identified by Springer and Stevens (2009) and refined by Stevens et al. (in review; Table 4-2). This classification also includes paleosprings, two types of hillslope springs (upland and floodplain), as well as three types of mound springs (carbonate, organic, and ice). Thus, some of Springer and Stevens (2009) springs types have been expanded to encompass commonly found divisions among previously identified springs types.

The springs types described in the key (Table 4-2) are based on revision of the Springer and Stevens (2009) classification system. The dichotomous key was developed by examination of more than 1,500 springs throughout the New World. While 13 primary springs types are described here, note that nearly all types of springs can be created through anthropogenic action, or have substantial anthropogenic attributes; springs in these situations would be labeled with the subtype “anthropogenic.” Common examples of anthropogenic springs range from livestock tanks, springs altered by diverting or piping flow from the original source, springboxes that have obliterated the natural source, and hot springs resorts. This key has been tested by colleagues and associates, both those familiar and unfamiliar with springs inventory classification.

Description of Springs Types

On the following pages we provide a description of each of the spring types identified in the dichotomous key (Table 4-2), along with common springs subtypes, alternate names, and examples.

Table 4–2. A dichotomous key to terrestrial springs types (Stevens et al. in review). Springs types are derived from Springer and Stevens (2009), but also include paleocrenes, floodplain vs. upland hillslope springs, and three mound-form springs subtypes added to their classification.

No.	Alternative	Springs Type
1	Groundwater expression of flow emerges or emerged within a cave (a water passage through basalt or other volcanic rock, or limestone), before flowing or emerging into the atmosphere	Cave
	Groundwater expression of flow emerges or emerged in a subaerial setting (direct contact with the atmosphere), including within a sandstone alcove, or subaqueously (beneath a body of water).	2
2	Groundwater is not expressed at the time of visit (the springs ecosystem is dry, though soil may be moist)	3
	Groundwater is expressed at the time of visit – seepage or flow is actively expressed (water or saturated soil is evident)	5
3	Evidence of prehistoric groundwater presence and/or flow exists (e.g., paleotravertine, paleosols, fossil springs-dependent species, etc.), but no evidence of contemporary flow or aquatic, wetland, or riparian vegetation	Paleospring
	Not as above	4
4	Soil may be moist but is not saturated by groundwater. The presence of groundwater is evidenced by wetland or obligate riparian vegetation	Hypocrene
	Groundwater is expressed through saturated soil, or as standing or flowing water	5
5	Groundwater is evident, but discharge is primarily lentic (standing or slow-moving), and flow downstream from the spring's ecosystem may be absent or very limited	6
	The majority of groundwater discharge flows actively within and/or from the site, and is primarily lotic (fast-moving)	10
6	Groundwater is expressed as a low gradient (<16°) patch of shallow standing water or saturated sediment or soil, typically strongly dominated by emergent wetland vegetation	Helocrene
	Subaqueous discharge creates an open body of water which lacks emergent wetland vegetation, and may or may not have outflow	7

No.	Alternative	Springs Type
7	The groundwater table surface is exposed as a pool, but without a focused inflow source, and with no outflow	Exposure
	Pool with one or more focused, subaqueous inflow sources, and generally with outflow, usually focused outflow	8
8	Springs source is an open pool of groundwater, not surrounded by a springs-created mound	Limnocrene
	Springs source is surrounded by, and has generated, a mound that may be chemical precipitate, ice, or organic matter	9
9	Springs source is surrounded by, or emerges from a mound composed of carbonate or other chemical precipitate	Mound-form (Carbonate)
	Springs source is surrounded by, and/or emerges from a mound composed of ice in a permafrost-dominated landscape (not reported in New Mexico)	Mound-form (ice)
	Springs source is surrounded by, and/or emerges from a mound composed of organic matter, such as decomposing vegetation	Mound-form (organic)
10	Springs flow emerges explosively and periodically, either by geothermal-derived or gas-derived pressure (not reported in New Mexico)	Geyser
	The springs flow emerges non-explosively, but by the action of gravity	11
11	Flow emerges from a focused point and rises well above ground level (10 cm or more)	Fountain
	Flow may emerge from a focused point, but without substantial rise above ground level	12
12	Flow emerges from a near-vertical or overhung, cliff-dominated bedrock surface, and not within an established surface flow channel (although a surface channel may exist above the source cliff)	13
	Not as above	14
13	Focused flow emerges from a nearly vertical bedrock cliff face (sometimes from a cave) and cascades, usually with some madicolous flow (a shallow sheet of white water)	Gushet
	Flow emerges across a horizontal geologic contact, typically dripping along a seepage front of sandstone over a shale or clay aquitard, and often creating a wet backwall. If a surface channel exists above the source area, a plunge pool and runout channel are likely to occur. This springs type may include unvegetated seepage patches on near-vertical or overhung bedrock walls.	Hanging garden
14	Flow emerges within a surface flow-dominated channel, which upstream may be a perennial stream or a dry channel	Rheocrene
	Flow emerges from a non-bedrock slope at a slope angle between 16° and 60°, and without an upslope channel. In some cases, these springs may emerge from the base of a cliff, but not from the cliff itself	15
15	Flow emerges within an active riparian channel margin or floodplain channel terrace and the source is subject to regular flood scour	Hillslope (Secondarily Rheocrene)
	Flow emerges in an uplands habitat, not associated with a channel that is subject to regular surface flow stream flood scouring	Hillslope (Uplands)

Springs Ecosystem Types and Descriptions

Cave

Definition: Groundwater emergence within a cave, from tubular, fissure, or joint geologic structure (Fig. 4-3; Meinzer 1923; Fetter 2001).

Common Attributes and Secondary Types: Can be perennial or ephemeral; anthropogenic subtype is possible (Fig. 4-4).

Alternate Names and Comments: Aquifer; karstic spring

Common Stressors: Groundwater extraction, pollution, and recreation.

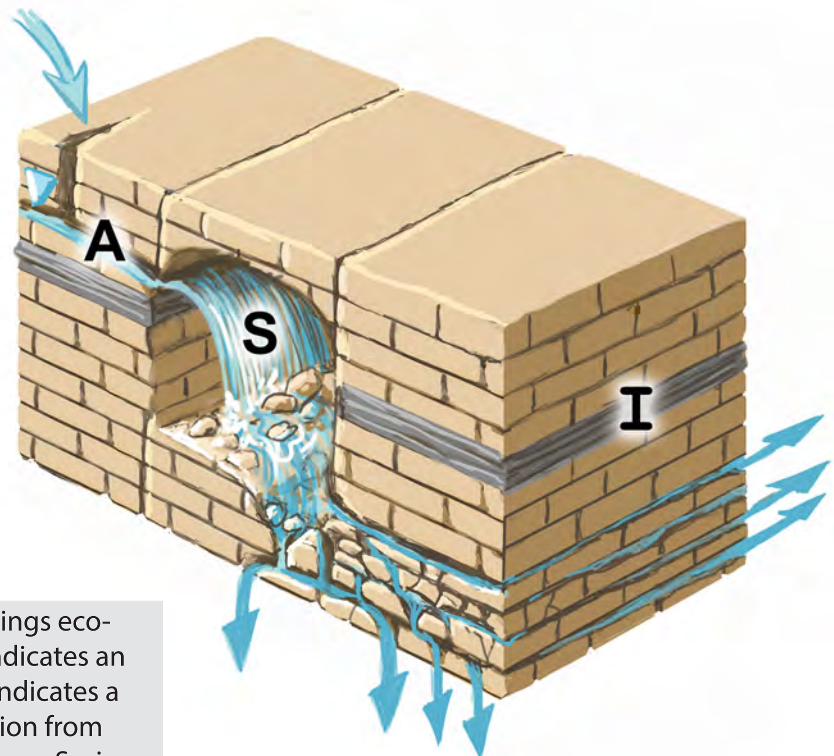


Fig. 4–3. In this illustration of a cave springs ecosystem, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist.

Fig. 4–4. Pivot Rock Springs, a cave emergence spring in Coconino National Forest, Arizona. This spring has been modified with a constructed dam that forms a pool.

Exposure

Definition: The groundwater is exposed to the atmosphere, but typically does not flow (Fig. 4-5). These gravity water bodies occur in fracture, contact, or depression structural contexts (Meinzer 1923; Fetter 2001).

Common Attributes and Secondary Types: This springs type is perennial by definition; anthropogenic subtype can be created by mines, livestock watering tanks, road cuts, etc.

Alternate Names and Comments: In-aquifer, cavern, or fissure springs; hydropetric; palustrine springs; surface expression of groundwater (Fig. 4-6).

Common Stressors: Groundwater extraction, pollution, recreation, filling/dredging, non-native species introduction, and climate change.

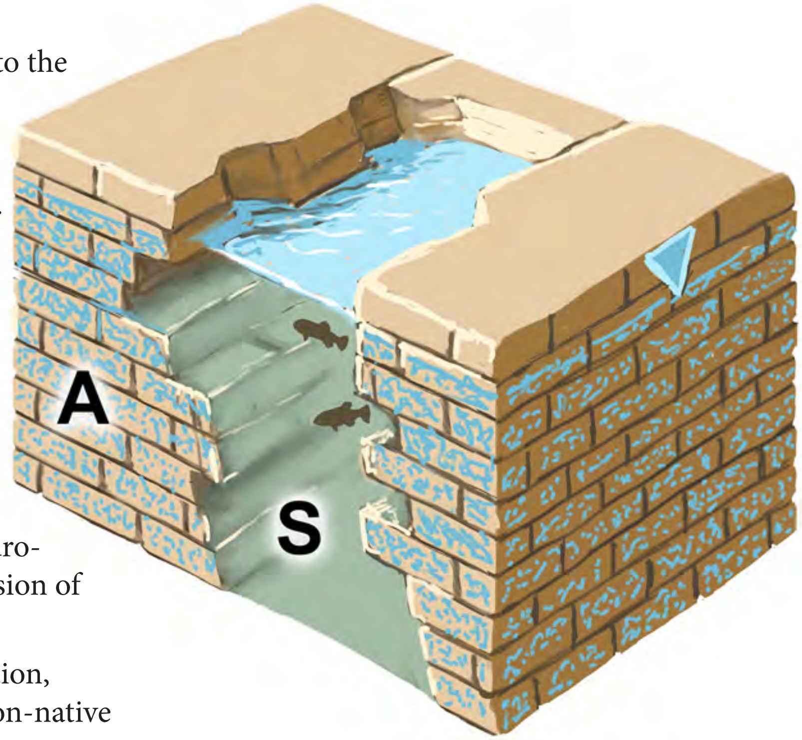


Fig. 4–5. In this illustration of an exposure springs ecosystem, "A" indicates aquifer input and "S" indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona, Springs Stewardship Institute and Victor Lesyk, artist. All rights are reserved.

Fig. 4–6. Devils Hole, an exposure spring located at Ash Meadows National Wildlife Refuge, Nevada. This warm spring is best known for serving as habitat for the only wild population of the endangered Devil's Hole Pupfish. Photo courtesy of U.S. Fish and Wildlife Service.

Fountain

Definition: An artesian upwelling of groundwater in a fracture or tubular geologic structural setting which forces flow to rise higher than the surrounding landscape (Fig. 4-7; Meinzer 1923).

Common Attributes and Secondary Types: This springs type can be ephemeral or perennial; an anthropogenic subtype can be created by drilling into an artesian aquifer (Fig. 4-8).

Alternate Names and Comments: Semi-terrestrial; palustrine or rarely, lacustrine.

Common Stressors: Groundwater extraction, pollution, livestock water supplies, recreation, non-native species introduction, and climate change.

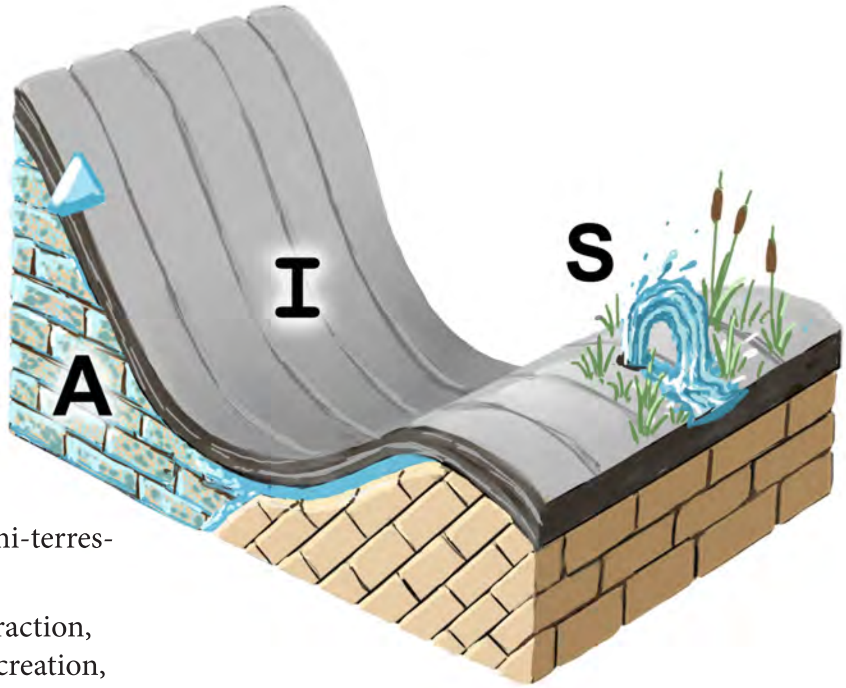


Fig. 4–7. In this illustration of a fountain springs ecosystem, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

Fig. 4–8. "Vulcans Bidet" is a fountain spring that emerges at Colorado River Mile 181 on the left in Grand Canyon National Park, Arizona. The spring is covered during high flows.

Geyser

Definition: Characterized by periodic discharge eruptions, groundwater is forcibly ejected by geothermal water (steam) or gas, often from a precipitate mound (Fig 4-9).

Common Attributes and Secondary Types: This springs type is by definition ephemeral, due to the periodicity of eruptions; an anthropogenic subtype can be created through well drilling into geothermal or CO_2-producing strata and aquifers (Fig. 4-10).

Alternate Names and Comments: Palustrine or riverine wetlands.

Common Stressors: Groundwater extraction, recreation, non-native species introduction, and climate change.

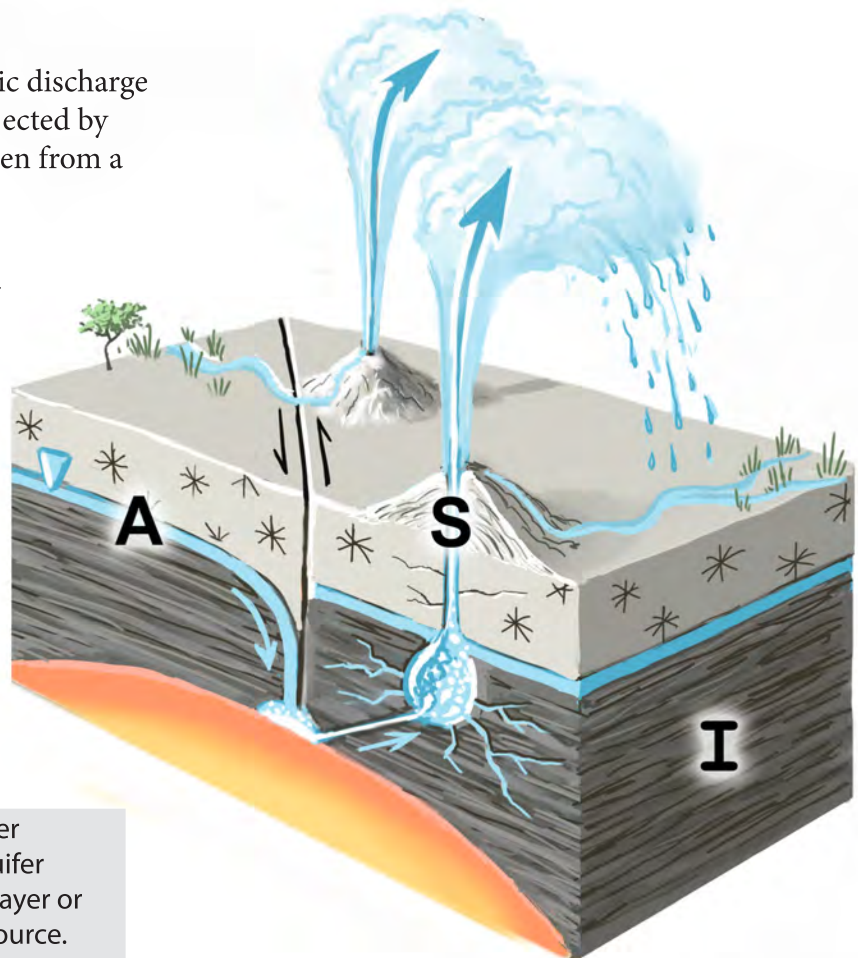


Fig. 4–9. In this illustration of a geyser springs ecosystem, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

Fig. 4–10. Crystal Geyser, near Green River, Utah. At this anthropogenic geyser, hydraulic eruptions are driven by carbon dioxide gas.

Gushet

Definition: Groundwater emerges and cascades in madicolous flow down a nearly vertical cliff (Figs. 4-11 and 4-12).

Common Attributes and Secondary Types: Common subtypes associated with this springs type are cave, hillslope, mound-form, rheocrene.

Alternate Names and Comments: Fracture, fissure, or joint springs; palustrine wetlands, cliff spring, hydropetric.

Common Stressors: Groundwater and surface water extraction, livestock water supplies, recreation, non-native species introduction, and climate change.

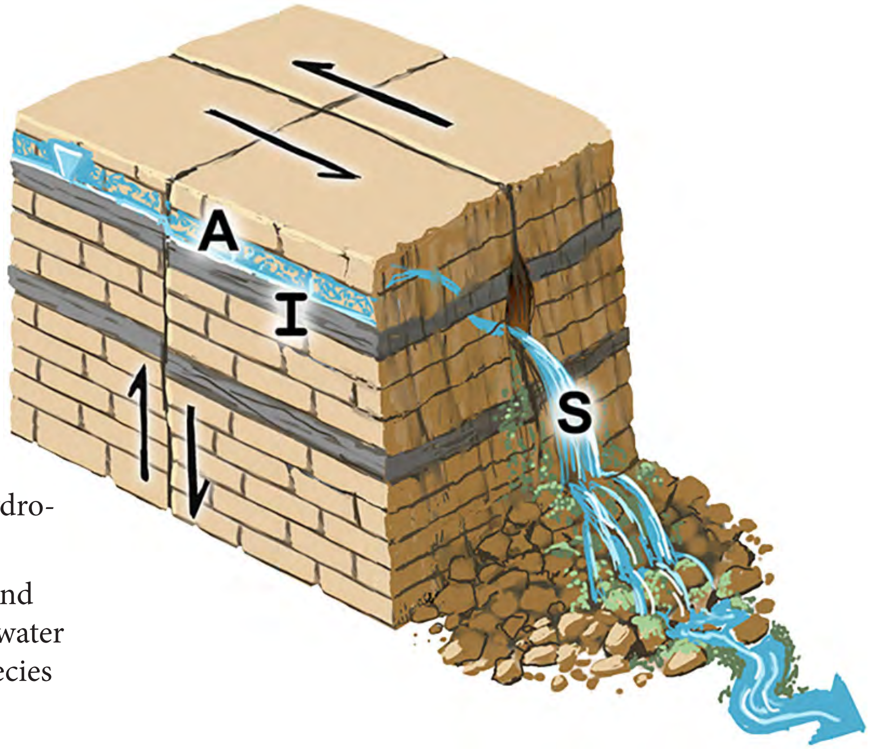


Fig. 4–11. In this illustration of a gushet springs ecosystem, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

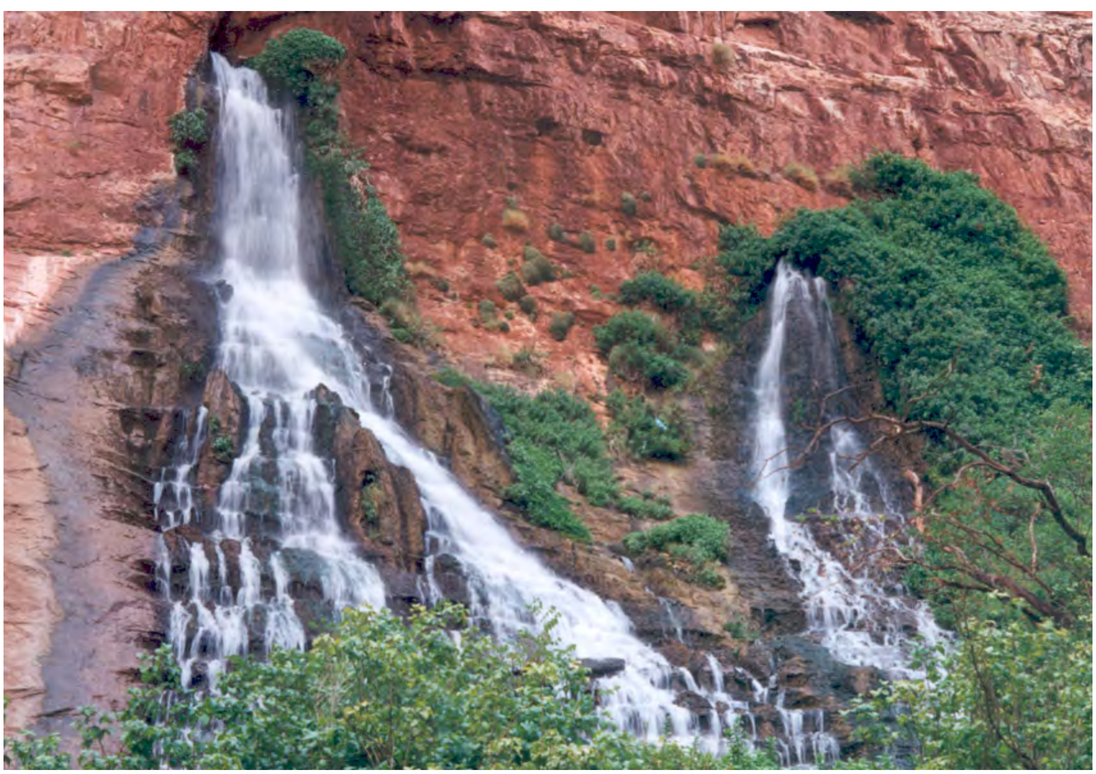


Fig. 4–12. Vaseys Paradise in Grand Canyon National Park, Arizona is a gushet.

Hanging garden

Definition: Contact emergence from a horizontally bedded aquifer (often sandstone or basalt) that overlies an aquitard (Figs. 4-13 and 4-14).

Common Attributes and Secondary Types: Can be perennial or ephemeral; common subtypes associated with this springs type are hillslope, moundform, and rheocrene; anthropogenic subtype is possible; for example, cliff seepage downstream from dams.

Alternate Names and Comments: Seepage area or contact springs (Bryan 1919, Meinzer 1923); Palustrine wetlands; contact and fracture or fracture zone system (Bryan 1919); cliff spring; a hydropetric spring.

Common Stressors: Groundwater and surface water extraction, livestock water supplies, recreation, non-native species introduction, and climate change.

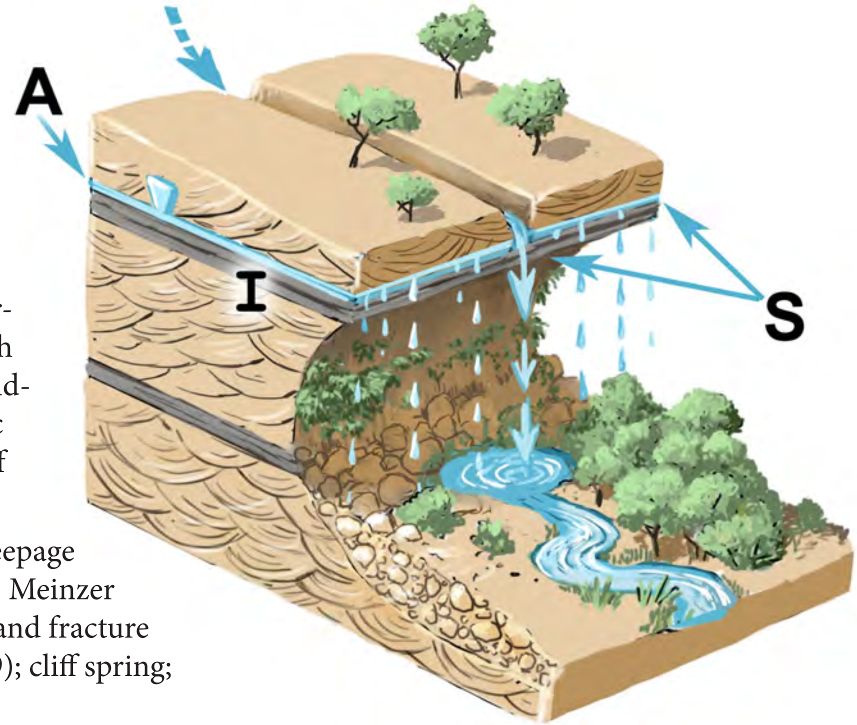


Fig. 4–13. In this illustration of a hanging garden springs ecosystem, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

Fig. 4–14. This classic hanging garden emerges above the Colorado River along a geologic contact in Glen Canyon National Recreation Area.

Helocrene

Definition: Low-gradient, marsh-forming, gravity-driven wet meadow springs ecosystem (Fig. 4-15). This springs type is characterized by non-focused seepage flow that arises from a contact or seepage geologic setting (Fig. 4-16).

Common Attributes and Secondary Types: This springs type can be ephemeral or perennial. Many helocrene springs are alkaline.

Alternate Names and Comments: fracture springs (Bryan 1919, Meinzer 1923); ciénegas (when below ca. 2000 m (Meinzer 1923); GDE fens; palustrine marshes; emergent and scrub-shrub wetlands; sinkholes; Pleistocene lakebed wetlands if groundwater expressed at surface; semi-terrestrial; GDE fen; wet slack (when ephemeral); ephemeral GDE marshes (Boulton 2005); moss-lichen and emergent and scrub-shrub wetlands; dispersed flow wetlands; permanent or non-permanent waters characterized as alkali, acid, salt pan, or gypsum (“lakes with large bacterial mats”); bryophyte-dominated travertine helocrenes; petrifying springs with tufa formations; Fennoscandian mineral-rich springs and springfens; mires (multiple subclasses); monsoon-driven or snowmelt-driven ephemeral slope wetlands; mineral-rich peatlands (noted for endemic species); iron-rich GDE fens; aufweis when permafrost- and ice-dominated high latitude settings.

Common Stressors: groundwater extraction, livestock water supplies (creation of open water), agricultural hay-mowing, urbanization, road construction (may dewater the downslope portion), peat mining, recreation, non-native species introduction, and climate change.

Ciénegas

New Mexico contains groundwater dependent ecosystems called ciénegas. These are helocrenic, and occasionally rheocrenic, low-gradient springs that support freshwater wet meadows. The centers of ciénegas are too wet to support trees and are composed of wetlands grasses, sedges, rushes, and forbs in a highly organic soil.

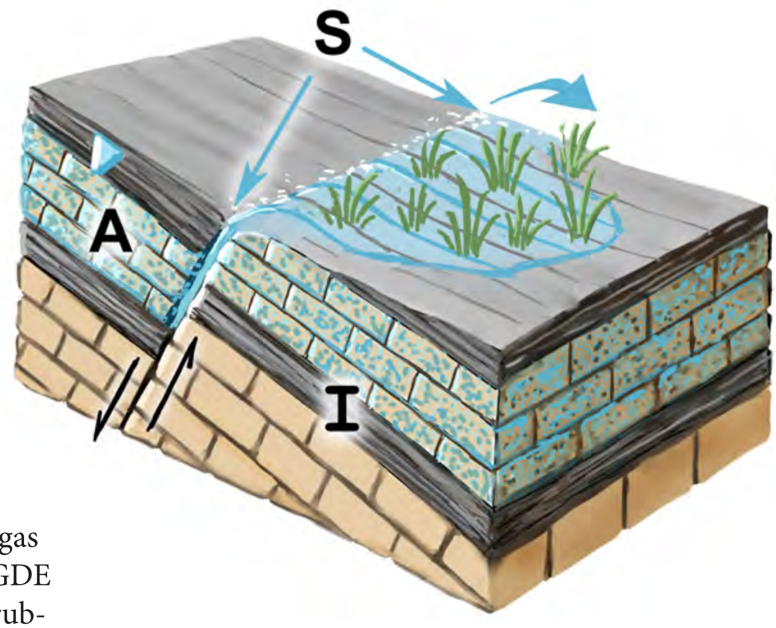


Fig. 4–15. In this illustration of a helocrene springs ecosystem, “A” indicates aquifer input, “I” indicates an impermeable layer or aquitard, and “S” indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

Ciénega margins often contain typical riparian trees including Gooding’s willows and cottonwoods. Nearly half of these unique wetland features in the contiguous U.S. are found in New Mexico, with most of the remainder found in neighboring Arizona and Sonora (Cole and Cole 2015).

Many ciénegas are highly impaired by channel incision, watering tank berms, roadways, and groundwater drawdown (Minckley and Brunelle 2007). Less than half are considered unimpaired or in a near natural state. Inventorying and assessing these ecosystems is especially important due to the number of ciénegas that are already impaired, destroyed, or at risk of impairment. The Springs NMRAM process is crucial for the long-term protection and restoration, of ciénegas, a unique ecosystem in New Mexico.

Fig. 4–16. Faywood Warm Ciénega, in Grant County, New Mexico. Ciénegas are unique subtypes of helocrene springs, found only in the American Southwest.

Hillslope

Definition: Groundwater emergence via gravity on relatively steep 16°-60° slopes, with diffuse or focused flow (Fig. 4-17). Flow is most often diffuse at the top of the springs and more focused at the bottom of the spring. Hillslope springs often support a wide array of wetland and riparian vegetation associations; when hillslope springs are travertine-forming, there is often an associated bryophytes (moss) community.

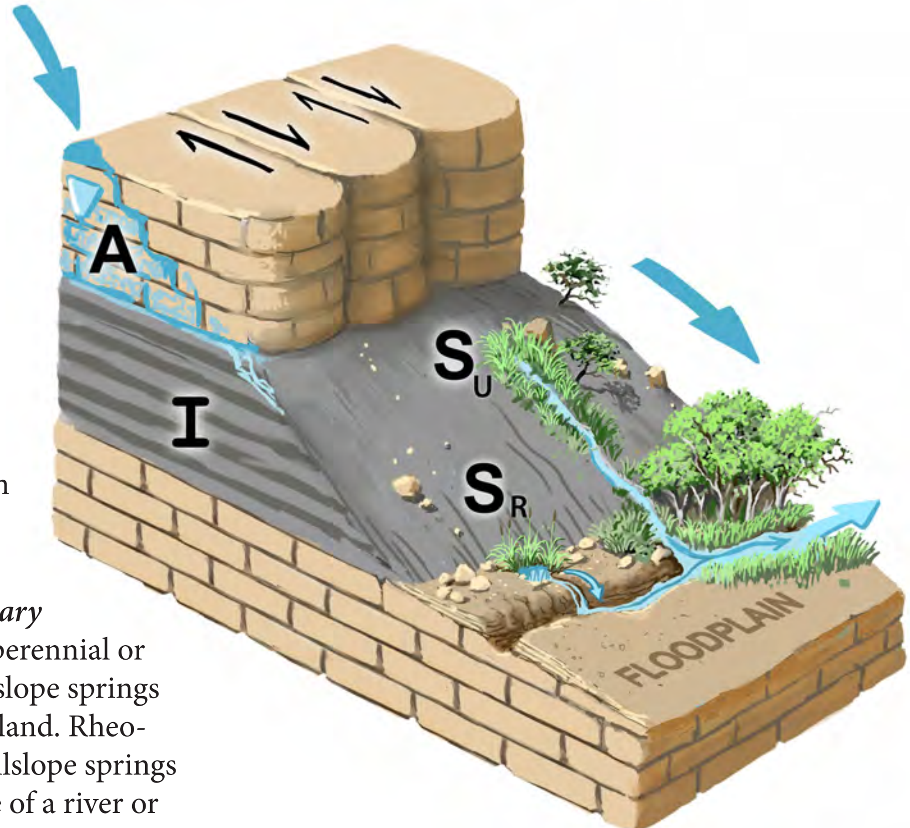


Fig. 4–17. This illustration of hillslope springs shows both an upland hillslope spring and a rheocrenic hillslope spring. "A" indicates aquifer input and "I" indicates an impermeable layer or aquitard. "S_U" marks the springs source of an upland hillslope spring, while "S_R" marks a rheocrenic hillslope springs source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

Common Attributes and Secondary Types: Hillslope springs can be perennial or ephemeral. Two subtypes of hillslope springs are common: rheocrenic and upland. Rheocrenic, or floodplain/riparian hillslope springs emerge from the bank or terrace of a river or stream (distinguished from a true rheocrene spring, which sources on the stream bed). Rheocrenic hillslope springs are subject to regular stream or river flooding, and usually contain wide-spread, flood-tolerant species. Upland hillslope springs are located outside of a riparian setting, are not subject to stream flooding, and commonly support rare species (Fig. 4-18). Anthropogenic subtypes of hillslope springs are also possible; these can be created by pipe or ditch leakage.

Alternate Names and Comments: Seepage area, fracture spring, fissure spring, joint spring, contact spring (Bryan 1919, Meinzer 1923); palustrine wetlands; spring-fed slope wetlands; headwater slope wetlands; semi-terrestrial or terrestrial cliff springs. Petrifying springs with tufa formations, when travertine-depositing; riverine wetlands; high-gradient ciénegas.

Common Stressors: Groundwater extraction, recreation, non-native species introduction, and climate change.

Fig. 4–18. Engineer Spring is an upland hillslope spring in Gila National Forest, near Luna NM.

Hypocrene

Definition: At this springs type, shallow groundwater is expressed through wetland vegetation but not as surface emergence or flow (Figs. 4-19, 4-20). Hypocrenes occur naturally, but also commonly develop from other springs types as groundwater tables decline through overdraft. Beyond the loss of surface water from a previously flowing spring, the plant community also shifts from being dominated by aquatic and wetland-obligate species, to dominance by riparian groundwater-dependent species, and ultimately to upland vegetation.

Common Attributes and Secondary Types: Mound-form and rheocrene springs are commonly hypocrene; anthropogenic hypocrene springs are common, due to groundwater depletion.

Alternate Names and Comments: Palustrine wetlands; Pleistocene lakebed wetlands where groundwater is not expressed at the surface; misinterpreted as terrestrial ecosystems that occasionally rely on groundwater; subsurface presence of groundwater (Eamus and Froend 2006).

Common Stressors: Groundwater depletion, urbanization, livestock grazing, non-native species introduction, and climate change.

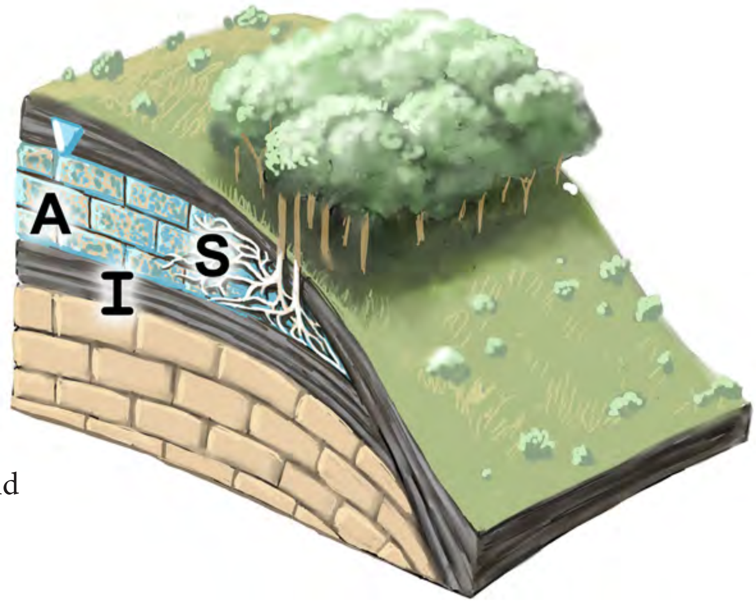


Fig. 4–19. In this illustration of an exposure springs ecosystem, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a springs source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

Fig. 4–20. This hypocrene spring is located at Colorado River mile 70 in Grand Canyon National Park, Arizona.

Limnocrene

Definition: : A pool-forming gravity springs ecosystem, forming from a fissure, depression, or contact geologic setting (Fig. 4-21; Meinzer 1923). Limnocrenes can contain acidic (e.g., some groundwater dependent bogs), or geothermal waters (e.g., Dianas Punchbowl in central NV and other Great Basin geothermal lakes). Prairie potholes are sourced, in part, from groundwater, and are examples of limnocrenes. Ephemeral limnocrenes are also recognized.

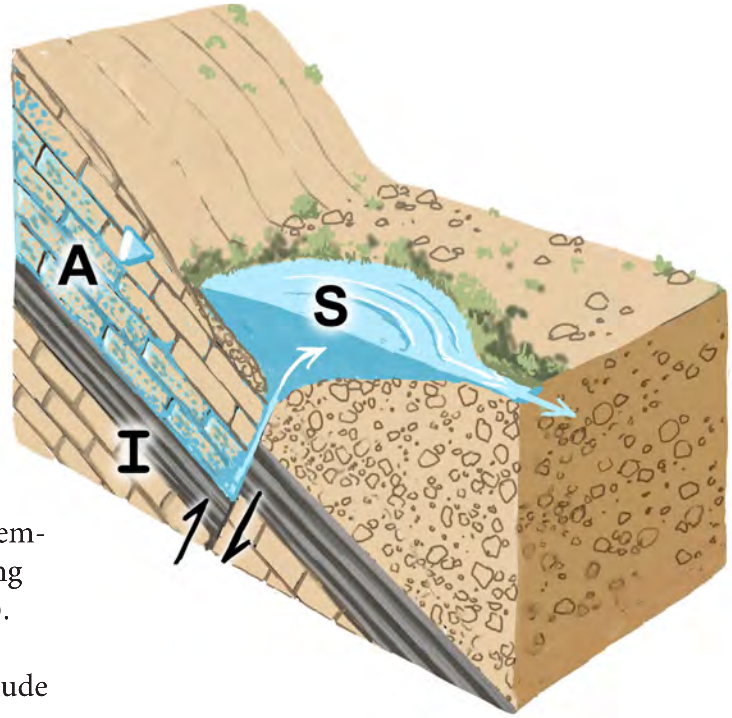


Fig. 4–21. In this illustration of a limnocrene spring, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a springs source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

Common Attributes and Secondary Types: Limnocrene springs can be perennial or ephemeral (for example, turloughs, the "disappearing lakes" found in limestone settings in Ireland). Limnocrene paleosprings can sometimes be recognized. Anthropogenic limnocrenes include GDE livestock watering tanks, mine pits, quarries, etc. (Fig. 4-22).

Alternate Names and Comments: Depressions, sinkholes (Bryan 1919, Meinzer 1923); lacustrine wetlands or aquatic bed wetlands; GDE ponds, pools, tanks, quarries (anthropogenic), or lakes; acid limnocrenes; prairie potholes (northern Great Plains in North America); perennial GDE pools and lakes. Vernal pools are not considered to be limnocrene springs, because they are sourced from surface water.

Common Stressors: Groundwater depletion, agricultural and mining pollution, urbanization, pond margin habitat alteration, livestock grazing, recreation, non-native species introduction, and climate change.

Fig. 4–22. Moreno Spring is located on private land in New Mexico. In 2018, surveyors classified it as a limnocrene spring because of the presence of several excavated pools of standing water. However, they believed it was originally a low gradient ciénega. The site has been manipulated over many years and used as an agricultural field and for livestock grazing. By 2019, it was changing into a floodplain hillslope springs ecosystem, as the excavated pools filled with sediment and became colonized by woody vegetation.

Rheocrene

Definition: Groundwater emergence within an established stream channel (i.e., a surface water channel, where the channel exists upstream of the springs source). Rheocrene springs generally occur because of geologic structural constraints on the groundwater flowpath (Fig. 4-23). This is often visible as the narrowing of a bedrock canyon, which forces groundwater out of floodplain alluvium and into the stream channel. Rheocrene springs are most visible when they emerge into otherwise dry channels, but they can also emerge into perennial streams (Fig. 4-24).

Common Attributes and Secondary Types: Rhythmic springs often are rheocrenes. Common secondary types for rheocrene springs are cave, geyser, gushet, hanging garden, helocrene, hillslope, limnocrene, mound-form; anthropogenic subtypes are possible as effluent releases and dam tailwater function as rheocrenes.

Alternate Names and Comments: channel or flowing springs, derived from fracture, fissure, contact, or seepage geologic structures (Bryan 1919; Meinzer 1923). Lotic springs as riverine wetlands, streambed wetlands (with no flowing water), unconsolidated shore wetlands perennial or ephemeral alkaline or acid rheocrene streams, hinge-felling wetlands that generate helocrenic conditions in dammed channels. Permanent (perennial) riverine aquatic, river base-flow springs, alluvial forest springs. Rhythmic (AKA beating heart, ebb and flow, periodic, pulsing, or siphon) springs may exist as rheocrenes (Huntoon and Coogan 1987).

Common Stressors: Groundwater extraction, livestock water supplies, agricultural hay-mowing, urbanization, road construction (may dewater or divert water from the downslope portion, or alter channel margins), recreation, non-native species introduction, and climate change.

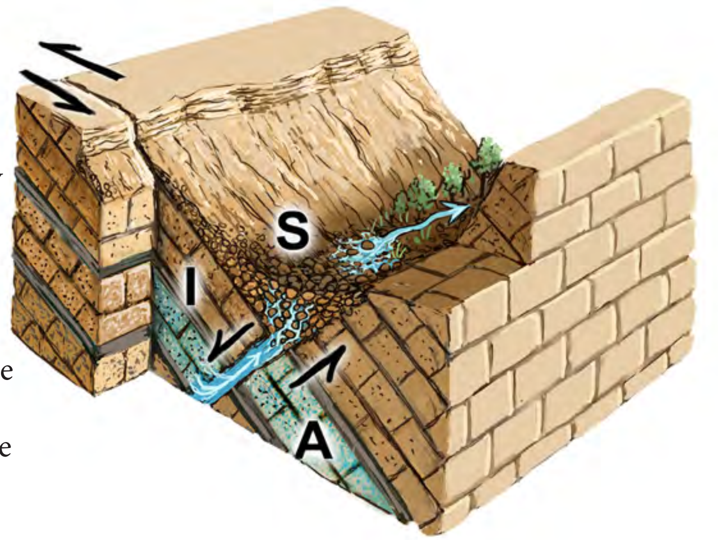


Fig. 4–23. In this illustration of a rheocrene spring, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist.

Fig. 4–24. Johnson Canyon Spring is a rheocrene spring that emerges into the streambed of Johnson Canyon, Gila National Forest, New Mexico.

Mound-form

Definition: : Precipitation of secondarily derived carbonates or organic (peat mound) matter creates a dome form, from which groundwater emerges and usually flows (Figs. 4-25 and 4-26). Ice-mound springs can occur in high elevation sites during winter months, but none have yet been reported in New Mexico.

Common Attributes and Secondary Types: Mound-form springs can be perennial or ephemeral. Subtypes include collapsed mound, organic mound, carbonate mound, and ice mound. Secondary springs types often associated with mound-form springs are geyser, fountain, helocrene, limnocrene, and paleosprings.

Alternate Names and Comments: precipitate mounds can form from depression, sinkhole, tubular, fissure, fracture, or joint geologic structures (Bryan 1919, Meinzer 1923); riverine or lacustrine wetlands, ponds or lakes. Pingos or hydrolaccoliths in ice-dominated environments.

Common Stressors: groundwater depletion; agricultural and mining pollution; urbanization, pond margin habitat alteration, livestock grazing/soil compaction, recreation, non-native species introduction, and climate change.

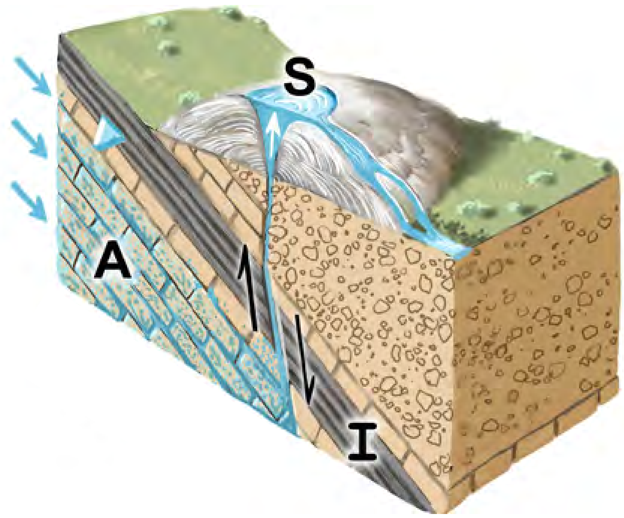


Fig. 4–25. In this illustration of a mound-form spring, "A" indicates aquifer input, "I" indicates an impermeable layer or aquitard, and "S" indicates a spring source. Image used with permission from Larry Stevens, Museum of Northern Arizona Springs Stewardship Institute, and Victor Lesyk, artist. All rights are reserved.

Fig. 4–26. Soda Dam is approximately 7,000 years old. This hot springs travertine mound formed along the Jemez River in northern New Mexico. Photo courtesy of James St. John (Geology, Ohio State University at Newark).

Other Springs Types

Not included in these illustrations are paleosprings that flowed in the recent geologic past (e.g., the Pleistocene or early Holocene), but no longer do so. Paleosprings usually occur as travertine mounds or exposures of fossilized peat.

Springs Distribution by Type

The distribution of springs types in New Mexico is currently unknown due to the lack of springs surveys. Springs types in neighboring Arizona tend to group by physiographic province, with rheocrene and hillslope springs more common in the Basin and Range province, and hanging gardens and gushets more common on the Colorado Plateau. Helocrene springs (wet meadows springs) were once abundant throughout the Southwest, with low elevation ciénegas and higher elevation groundwater-dependent fens. However, due to extensive draining and management for livestock and agriculture, helocrenes are now among the most critically endangered ecosystem types in the Southwest (Hendrickson and Minckley 1984).

Conclusions

The need for scientific agreement on basic classification of springs remains outstanding, and the absence of that agreement sows confusion among the public and managers who continue to use and manipulate these important and often irreplaceable ecosystems. Nearly all authors on all continents recognize springs biodiversity and socioeconomic importance, and the imperiled nature of springs ecosystems. However, the lack of consensus on springs classification has directly contributed to the lack of public, scientific, and governmental awareness of the importance of springs ecosystems, and the regional, national, and global demise of these important ecosystems (Cantonati et al. 2007; Stevens and Meretsky 2008; EC 2015; Kreamer et al. 2015; Knight 2015).

Springs ecosystem classification based on local geomorphology remains the most logical means of describing springs ecosystems. "Sphere of discharge" geomorphology provides spatially explicit physical description of the springs ecosystem. The other classification approaches are either insufficiently explicit to identify the sites as springs (aquifer, flow, and water quality approaches), insufficiently specific (landform position approaches), or vary over time (biotic, especially aquatic algae and invertebrates, and macrophytic vegetation approaches). A local geomorphological approach also readily lends itself to description of the extent of anthropogenic landscape alteration and provides for spatial quantification of those impacts, data which are useful in stewardship assessment, planning, implementation, and monitoring.

5 Springs Inventory Protocols

Springs Inventory Protocols Review

Introduction

Inventory is a fundamental element of ecosystem stewardship, providing essential data on the distribution and status of resources, processes, values, and aquatic, wetland, riparian, and upland linkages (e.g., Karr 1991, 1999; Busch and Trexler 2002; Richter et al. 2013). Systematic inventory precedes assessment, planning, action implementation, and monitoring in developmont of a structured resource management strategy. Efficient, interdisciplinary inventory protocols also are essential for improving understanding of springs ecosystem ecology, distribution, status, and conservation. Here we introduce and justify efficient, effective inventory protocols for springs ecosystems, and in subsequent chapters describe information management and assessment. These protocols will help improve springs stewardship across landscape management scales, from individual springs to springs distributed across large landscapes. This text has been adapted from Stevens et al. 2016 and is used with permission.

In New Mexico, springs inventory protocols need to be consistent with federal land and resource management legislation (e.g., the Antiquities Act of 1906, the U.S. National Park Service Organic Act of 1916; the multiple use mandates of the U.S. National Forest Service and the U.S. Bureau of Land Management, the Clean Water Act of 1973, the Endangered Species Act of 1973, as amended). Wetlands delineation and loss mitigation in the United States (U.S. Environmental Protection Agency and U.S. Department of the Army. 2015) have consumed much technical and regulatory attention. Those federal wetland delineation concepts and techniques often are not applicable to springs, particularly naturally ephemeral springs, hot springs, hanging gardens, and other springs in bedrock-dominated landscapes. In addition, those techniques are not suitable for rapid assessment of ecosystem condition. Development of local springs inventory protocols for specific regions, individual states, or individual agencies may not be broadly applicable across larger land areas. Therefore, such protocols may not contribute to the advancement of large-scale springs assessment, stewardship, or improved understanding of springs ecosystem ecology (e.g., Stevens et al. 2016). New Mexico-specific springs inventory and rapid assessment methods need to be robust yet operative for the state's Springs NMRAM protocol.

Inventory protocols should be efficient, interdisciplinary, and applicable to all types of springs found in New Mexico—subaerial or subaqueous, in any biome, and across watershed, state, and international boundaries. Such protocols will help advance understanding of springs ecosystem ecology and stewardship in the state, which are actively developing fields. Some, but by no means all, aquatic, wetland, and riparian inventory or monitoring approaches are appropriate or useful for springs inventory and monitoring. Inventory protocols for Mojave Desert springs administered by the U.S. National Park Service (Sada and Pohlmann 2006), and cold water New Zealand springs (Scarsbrook et al. 2007) have provided useful insights but are not necessarily applicable to hanging gardens or other New Mexico springs types. Protocols for stream-riparian hydrogeomorphic inventory are useful for surface flow-dominated streams and some rheocrene springs, but are generally inappropriate for groundwater flow-dominated springs. This is because of the fundamental differences in the roles and impacts of surface geomorphological processes. For example, channel meander and bank configuration are shaped by surface-flow flooding, whereas springflow dominated channels often tend to be linear or erratic (Griffiths et al. 2008). Also, beaver dams and large woody debris are widely regarded as essential to stream-riparian functioning, but often play little or

Fig. 5–1. Documentation of biota at springs is an important and common component of springs inventories. Non-native crayfish (Decapoda) threaten native species through predation and competition.

very different roles in springs ecosystems (Springer et al. 2015). Misapplication of stream-riparian and wetlands inventory techniques can distort interpretation of springs ecological integrity (Stevens et al. 2016).

Biological variables often are particularly important components of springs ecosystem management, and nearly all studies of springs to date have emphasized their biodiversity significance (Fig. 5/9). Despite the miniscule total area occupied by springs, more than 10 percent of the nation's endangered animal species are springs-dependent taxa (Stevens et al. 2016). High concentrations of rare species occur at some springs, in landscape contexts ranging from aridlands to mesic regions, and even submarine settings. Ecological risks to springs from groundwater pumping and source alteration are commonplace and abundant (Minckley and Deacon 1991, Stevens and Meretsky 2008). Regional, multi-springs inventories of biota include those for wetland plants (Patten et al. 2008, Spence 2008), Odonata (Stevens and Bailowitz 2009), aquatic Heteroptera (Stevens and Polhemus 2008), Coleoptera (Williams and Danks 1991), Trichoptera (e.g., Erman and Erman 1991, Erman 1992, Blinn and Ruiter 2009), and fish. Such data provide a background for the scope of biotic resources that should be considered in springs inventory and monitoring.

Fig. 5–2. Most springs inventory protocols include measurement of discharge.

The following is a short description of common North American springs inventory protocols. Many of these inventory protocols are designed to be paired with an ecological assessment method. A comparison of springs assessment methodology is presented in the next chapter of the Springs NMRAM manual.

U.S. Forest Service Groundwater Dependent Ecosystem (GDE) Protocol

The U.S. Forest Service completes springs surveys under the term "groundwater dependent ecosystems". GDE inventories are split into Levels 1, 2, and 3 surveys with free field guides for each type of survey available at: **https://www.fs.fed.us/science-technology/geology/groundwater/publications** (USFS 2012). The Level 1 survey is intended to be completed in two hours to verify the existence and general character of a GDE while the Level 2 survey is expected to take an entire day providing a robust dataset for the GDE site (USFS 2012). Level 3 surveys are conducted on a project basis and include continuous or high-resolution data to resolve a specific administrative project or activity (USFS 2012). GDE inventories include information about site access, basic geologic unit, current and recent weather, a site sketch map, vegetation quadrats, soil type and condition, hydrology, and floral and faunal lists.

BLM Lotic and Lentic Proper Functioning Condition (PFC)

The PFC framework was developed by the BLM, USFWS, and NRCS as a tool to rapidly determine the condition of riparian and wetland areas.

The PFC method was not specifically designed for springs ecosystems but can be used for many springs with some success. The method is split between lentic (standing water) and lotic (flowing water) environments, both of which evaluate the attributes and processes occurring at a site before determining the functional condition. A PFC is conducted by a small team and is largely qualitative, using a checklist to rapidly determine the relative function of a site's hydrology, vegetation, and soil attributes (BLM 1998).

The PFC approaches for springs assessment have been criticized because it is it a coarse resolution analysis that does not identify the type of springs resource, nor does it provide a fine resolution of related resources (e.g., flora, fauna).

U.S. Department of Defense – White Sands Protocol

The White Sands Protocol was developed to prioritize the protection of springs and riparian areas in southern New Mexico (Thompson et al. 2002). The protocol was developed using a panel of experts and was based on a classification of springs using the presence/absence of riparian area, surface water, flow consistency, human impacts, percent wetland plant species present, and the presence and abundance of non-native plant species (specifically tamarisk). While a creative and locally useful protocol, this approach does not emphasize quantification of inventory variables or differences among springs types, and did not provide a robust comparative quantitative method to compare springs within the landscape.

National Park Service Mojave and Chihuahuan Desert Protocol

The National Park Service springs inventory protocol was developed for two specific desert networks in the Southwest and has been modified several times over the past decade. The most recent standard operating procedure (SOP) was published in 2016. The inventory protocol includes field measurement of spring discharge, water quality (pH, temperature, dissolved oxygen, and specific conductance), and a site description. Laboratory analyses include benthic macroinvertebrates and some water quality parameters (alkalinity, nutrients, and some major cations and anions).

Desert Research Institute (DRI) Protocol

The DRI protocol was developed to inventory western springs using a Level 1 (basic characteristics) and Level 2 (long term monitoring) scheme (Sada and Pohlmann 2006). Level 1 data elements include spring location, drainage basin, site access, spring type, spring discharge, water quality (dissolved oxygen, temperature, pH, and conductivity), vegetation cover, substrate, and important floral and faunal taxa associated with the site. Level 2 surveys build on the Level 1 survey and can include long term monitoring of springs use, water quality and quantity, major cations, and a more in-depth floral and faunal survey (Sada and Pohlmann 2006).

Springs Stewardship Institute (SSI) Protocol

The SSI protocol was developed over the past two decades with the most recent revision presented here from Stevens et al. (2016). The SSI inventory directly informs the SSI springs ecosystem and assessment protocol and was designed in conjunction with the Springs Online relational database (springsdata.org). Field data sheets are specifically designed for rapid, efficient data entry into Springs Online, but data also can be entered into other worksheet or databasae formats.

Synthesis/Recommendations Regarding Inventory Approaches

The SSI protocol (Stevens et al. 2016) is the most comprehensive North American springs specific inventory method and incorporates components of all springs inventory methods used in the region. The protocol is based on lessons learned from the U.S. Forest Service, DRI, and the National Park Service protocols, and much discussion with agency staff and experts. As such, and with slight modification, it is the most appropriate method for rapid assessment of New Mexico springs ecosystems.

Springs NMRAM

Introduction

The protocol described here includes physical form and function of the springs ecosystem, as well as its biological integrity. The protocol was developed for a holistic inventory and assessment approach that can be easily implemented throughout the state. The results of both inventory and assessment can easily be entered (and retrieved) from the Springs Online relational database (springsdata.org), if so desired. Results from other methods have been imported into Springs Online with some success, but generally involve more back-end office work and QA/QC than using protocols that were specifically designed in conjunction with the database. For these reasons, we recommend that the Springs NMRAM use this inventory protocol, with an evaluation period to determine which sections are difficult to use and understand, and whether any specific refinements are needed for New Mexico springs and the Springs NMRAM process.

The inventory protocol is divided into three levels of complexity and detail. A Level 1 survey includes basic information about the springs location, and may include the springs type, geologic context, photographs, spring flow rate, and access. A Level 2 inventory includes a floral and faunal survey, a measure of potential productivity (available solar radiation), water chemistry (pH, conductivity, temperature, alkalinity, and dissolved oxygen), substrate, vegetative cover, slope, and aspect; additional water quality variables can also be measured using laboratory testing. Level 3 surveys involve project-specific, long-term research, management, or restoration monitoring of variables of interest (Stevens et al. 2016). Thus, at its simplest, a springs inventory can consist simply of a record consisting of a site name and georeferencing data, the date visited, the observer, and perhaps a photograph, whereas a full Level 2 inventory involves a site visit by an expert team who record data in 11 categories and may include laboratory geochemical and taxonomic analyses. The background, variables, and sampling methods for full Level 2 inventory are described below.

Field Work Planning

Site Selection

To be informative and useful to stewards, springs inventories in large landscapes must address stakeholder information needs. Most stewards have questions about specific, high priority springs while still wanting some general information about the dozens or hundreds of smaller springs within the management area. In order to effectively answer both the specific and general questions (especially within a limited budget) it is necessary to carefully consider the sampling strategy.

The inventory sampling strategy should be based on the steward's questions regarding the springs under their jurisdiction. For example, in order to answer any questions concerning the status of springs across the landscape (as opposed to a question about a specific spring) it is necessary to use a statistically rigorous sampling strategy-- this includes some level of randomness in the selection of springs to survey and an adequately large sample size. These goals can be accomplished in several ways.

If there are questions about the general distribution or status of springs across the landscape, or if the land manager wants to construct a groundwater model, a Level I inventory of springs across the entire landscape is a useful starting point. Level 1 distribution data can then be used to randomly select a suite of springs for Level 2 inventories; this provides a statistically rigorous way to answer specific question about the ecological integrity of the springs. A stratified-random sampling design can also be useful. The site selection can be stratified by location and/ or springs type, to help ensure full representation of springs across the land management unit with a slightly smaller sample size. Springs are often spatially clustered, and springs within clusters are likely to be similar. A statistical cluster analysis can be conducted to identify groups of springs based on latitude, longitude and elevation. Clusters of springs can be randomly selected, and one or several springs can be randomly selected within the selected clusters. It can also be advantageous to stratify the sampling design according to springs type to ensure sampling of rare springs types. Alternatively, a pure random study design can be used with a large enough sample size to be sure rare springs types are represented. Depending on the specific question posed by the land manager, power analysis can be used to estimate the appropriate sample size needed to answer the land manager's question with statistical rigor. Although the stewards may be interested in individual economically important springs, the rigor of the stratified random design should not be compromised by biased sampling.

Stakeholder Involvement

Prior to conducting field work, the survey team should contact private landowners or the Federal, Tribal, state, county, or local entities involved with the springs to communicate goals and objectives about the project, acquire additional information, and arrange access to springs included in the inventory. Because information collected on the sites is the intellectual property of the springs owner, the team needs to ensure the security and ownership of the inventory data with the steward.

Volunteer Coordination

Volunteers can provide an important work force for springs stewardship, but volunteer coordination and training is needed to ensure the credibility and proper entry of the data collected (Fig. 5-3). When working with state and federal agencies on land managed by these agencies, volunteer services agreement and release forms will need to be completed. A volunteer coordinator is often designated to perform the necessary recruitment, training, and logistical organization, and that individual should be intimately familiar with the project. Federal agencies typically have their own volunteer agreement forms.

When to Sample

In temperate regions with deciduous vegetation, springs base flow and water quality are most clearly interpretable during mid-winter, when transpiration losses are low. However, the middle of the temperate growing season is likely to be most revealing for biological variables. The timing of springs visits in areas with seasonally varying precipitation is subject to similar arguments. While a single site visit is highly informative, GCWC (2004) reported that three site visits in different seasons were needed to detect >95 percent of plant species at large springs, and up to six site visits (including nocturnal sampling) were needed to detect most of the aquatic and wetland invertebrate taxa at large sites. Inventories for fish and amphibian's likely require several visits, and detection of other wetland, riparian, and terrestrial vertebrates, such as avifauna and large mammals may require numerous visits through a long-term monitoring context. Assembling a reasonably complete vertebrate occurrence list at a given springs ecosystem is a long-term monitoring program element (Level 3 inventory).

Fig. 5–3. Volunteer coordination and training is essential to ensure credible scientific data and safety.

Permits

Prior to field data collection, state, federal, Tribal research permits, or permission from private landowners, may be required, and separate permits may be required for each land unit visited if a project extends across political jurisdictions. Permitting requires advance planning and may substantially delay inventory, assessment, and rehabilitation work. If specimens are collected during inventory, appropriate repositories should be used or established, and voucher specimens should be collected, prepared, and stored in professional collections for further research, monitoring, or potential litigation.

Crew Organization and Training

Level 2 inventory data are designed to be gathered during a 1-3 hour site visit by 4-6 trained specialists and assistants, with the duration of the site visit primarily determined by the size and complexity of the springs. Level 2 staff should include a geographer, a hydrogeologist, a biologist with an assistant, and a socio-cultural expert. One crew member serves as the crew leader and makes command-level decisions on logistics, safety, field equipment, and data management.

With proper planning and logistics coordination, Level 2 inventories should not exceed a 3 hour site visit or $2,000 per site visit in 2019 U.S. dollars, including logistics, sample analyses, and data entry. Costs often can be kept to half that rate or less, depending on site remoteness and complexity, as well as the level of detail desired for analyses. Additional time is needed for compilation of background information, logistics planning, laboratory analyses, specimen preparation and identification, completion of data management, and reporting for each site visited.

Coordination and training of the survey team should take place prior to the field season, including both laboratory and field activities. Workshops lead by staff involve a combination of class time in the morning, followed by afternoon field sessions. Staff and trainees travel to local springs and perform a full Level 2 inventory. Data entry and database training are available through the SSI website at springstewardshipinstitute.org. Quality assurance of the data within the database depends on well-organized and thorough data-entry.

Logistics Planning

Following site selection, it is important to develop a schedule and route plan for the inventory team to access springs. The plan should minimize travel distance and time, and also indicate natural barriers that may delay or prevent access (e.g., river crossings, escarpments, etc.). For larger projects, it may be helpful to complete a route analysis in GIS. Note that road layers for remote areas are frequently inaccurate.

Crew Safety and Risks

Safety is first in importance for the field team, and while all team members need to be mindful, safety is a primary responsibility for the crew leader. Vehicular safety, communications, first aid, instruction in the use and care of equipment, field data management, and final decisions over the safety of access are concerns for each member of the crew and its crew leader. In remote areas, the crew should always carry sufficient supplies of water, food, flashlights, shovels, extra spare tires, and first aid and other emergency supplies to deal with accidents and unexpected circumstances, such as rapid changes in weather. Hard hats and closed-toe boots are required in burned or construction areas. Georeferencing one's vehicle prior to beginning a remote field inventory will help ensure relocation of the vehicle, particularly at night, or if different return routes are taken.

Equipment List

The equipment useful for a Level 2 inventory is listed in Table 5-1. This is by no means an exhaustive list, and the crew should develop and refine their own list, including backup and maintenance tools, parts, and materials specific to their project. It is nearly axiomatic that the more expensive a piece of electronic field equipment is, and the farther the crew is away from the vehicles, the greater the likelihood of equipment failure. Therefore, it is important to have back-up systems or a strategy to cope with equipment failure. The crew should establish a maintenance program that includes vehicles, first aid kits, and equipment maintenance that follows manufacturer guidelines.

The Level 1 inventory should inform the Level 2 team about field equipment needs and environmental conditions (e.g., steep slope, rough terrain, high magnitude springs flows, etc.) to reduce unnecessary transport of cumbersome or heavy equipment, such as a cutthroat flume. This will help keep the equipment load to a reasonable size.

Contingency Planning

Unanticipated Conditions

Contingency planning is an important part of field work. Weather conditions can challenge project success. Other unanticipated factors can include: landscape instability; fire-related area closure; threats from large animals; border or drug-related criminal issues; encounters with irate individuals; vehicular accidents; or the springs under study might be submerged by a beaver dam impoundment.

Encountering New Springs

Survey crews may encounter unmapped springs during the course of searches for reported springs. Prior to field work, the crew should plan for such discoveries. The choices range from simple georeferencing and photographing in a Level 1 site verification, to conducting a full Level 2 inventory of the newly discovered springs. A provisional field name should be selected based on unique site characteristics, and not be a commonly used name, such as "Big", "Little", "Cold", "Warm", "Hot", or common plant names, such as "Cottonwood", "Willow", etc.

Inability to Locate Springs

Georeferencing coordinates commonly are inaccurate or blatantly incorrect (e.g., Fig. 5-4). The source of rheocrene springs can migrate up- or down-channel due to groundwater fluctuation. Such inaccuracies, particularly in rugged terrain or heavily forested areas may prevent the crew from finding the site. The crew should proceed to the designated point, establish a search radius, and designate a time limit for locating the springs (e.g. 250 meters from the reported location and 20 minute search time). Communications are a high priority in such situations: each crew member should maintain a line-of-site or radio contact. Ultimately the crew leader will determine the search intensity, while ensuring the safety of the crew. When several poorly mapped springs are clustered, distinguishing one from another may be difficult or impossible.

Field Sheets

Field data sheets are the most efficient and reliable method of information documentation for Level 1 and 2 springs inventories (Appendix A). Multistaff team information compilation and detection of data entry errors is impossible without hard-copy field sheets, and springs-related data have proven to be too complex for on-site electronic data entry systems. Therefore, we recommend field data entry on hard copy sheets, with data entry in the laboratory soon afterwards and QA/QC. The crew leader is responsible for keeping all field data from a site organized in a labeled folder or envelope and delivering it to the laboratory.

The field sheets described below are designed to facilitate field data entry and follow the organization of Springs Online database. Data fields are separated so that the crew leader can distribute pages to the appropriate team members (e.g., the botanist fills in the vegetation pages). Team members should sign their initials in the OBS field at the top of their pages to indicate who completed the field work.

At the end of the inventory, the crew leader should collect all field sheets and fill out the page numbers at the top of each page (e.g., Page 1 of 8) and assure that the spring name has been included on every page. The section labeled as "Entered

Fig. 5–4. Example of inaccuracies and uncertainty with different data sources in North Kaibab Ranger District, Kaibab National Forest in Northern Arizona. Mourning Dove Spring is spelled differently in three databases and is unnamed in two. Clustering of multiple sources in Mangum Canyon makes it difficult to identify individual springs.

by," "Checked by," and "Date" at the bottom of the field sheet are to be completed in the lab when all data on that page have been entered into the database and checked by a supervisor.

Level 1 Springs Inventory

A Level 1 inventory of the springs in a landscape is used to identify the distribution, access, and springs types, as well as flow sampling equipment needed for Level 2 inventories. The Level 1 field inventory sheet is found in Appendix A. Given the generally low-resolution understanding of springs distribution in North America and elsewhere (Stevens and Meretsky 2008, Ledbetter et al. 2014), we recommend that stewards of large landscapes (e.g., landscape parks, National Forest units, Tribal reservations), as well as regulatory agencies (e.g., NMED, the State Engineer's Office), conduct a systematic Level 1 inventory of springs in their landscape prior to conducting a more intensive Level 2 inventory. In large landscapes, a Level 1 survey should be initiated by first reviewing available mapping data, and by conducting interviews with knowledgeable individuals about springs distribution. Such efforts, conducted prior to Level 1 inventory field work, will greatly reduce field search time and inventory costs.

Level 1 inventory field site visit protocols are described by Sada and Pohlmann (2006) and Stevens et al. (2016). A Level 1 springs site visit is a brief (10-20 minute) site visit for the purposes of georeferencing, photography, recording springs type, and determination of flow measurement equipment needs (Table 5-1). Level 1 inventories are typically conducted by 1-2 trained individuals, such as technicians, scientists, or members of the educated lay public. This level of inventory is useful for identifying the distribution of springs in a landscape and determining the need and methods for the more rigorous Level 2 inventory. The information gathered in a Level 1 survey should include: georeferencing (with equipment type, datum, and position accuracy), directions and caveats about access to the site; observer(s) and date; a verbal description of the springs; photographs of the source and microhabitat array; spring type and approximate springs-influenced land area; the methods best suited to measure flow (e.g., capture, weir plate, flume, or wading rod); and notes on biota. A Level 1 inventory can be performed during programmatic searches for springs or on an ad libitum basis as springs are encountered during other activities.

Level 2 Springs Inventory

Introduction

A Level 2 springs inventory includes an array of measured, observed, or otherwise documented variables related to site and survey description, biota, flow, and the sociocultural-economic conditions of the springs at the time of the survey. To the greatest extent possible, measurements and estimates are to be made of actual, rather than potential, conditions—a practice needed to establish baseline conditions and for monitoring comparisons (e.g., Stevens et al. 2016). The protocols presented here were informed by discussion with many resource stewards and recommendations made by GCWC (2002, 2004), Sada and Pohlmann (2006), Springer et al. (2006), Stevens et al. (2006), Springer et al. (2008), Springer and Stevens (2009), and U.S. Forest Service (2012). These protocols are based on the springs ecosystem conceptual model of Stevens and Springer (2004) and Stevens (2008). The variables selected are the suite needed to improve basic understanding of springs ecosystem ecology, as well as the site's ecological integrity and anthropogenic influences, including regional or local ground and surface water extraction or pollution, livestock or wildlife grazing use, recreational visitation, and climate change.

With appropriate background information, a single Level 2 site visit is sufficient for assessment of ecosystem integrity. However, the Level 2 inventory protocols and information management protocols presented here also are suitable for basic monitoring and can provide baseline data for long-term Level 3 site management and restoration efforts. Level 2 springs inventories are rapid assessments of sites, and we regard activities such as wetland delineation, soil profile analyses, paleontological and historical use investigations, establishment of vegetation transects and plots, and other in-depth scientific and management activities as Level 3 research, management, and monitoring activities. Therefore, we do not recommend that such time-intensive efforts be included in the Level 2 rapid inventory protocol. Trend assessment also can be derived from Level 2

Table 5–1. Recommended equipment list for Level 2 springs surveys.

Category	Field Equipment Used in Springs Inventory and Assessment
All	Background information: site location, description, hydrogeology, and previous biotic surveys
All	Field data sheets, extra sheets, and 4 clipboards
All	Field computer (optional)
All	Pencils and permanent marker (Sharpie)
All	Personal safety gear; first aid kit, radios, flash lights
All	Protocols document
All	Screwdriver, pliers, and other tools to repair equipment
All	Spare batteries and parts for all equipment
All	Topographic maps and aerial photos of site at coarse- and fine-scale (1:24,000) resolution
All	Ziploc bags, Whirl-Pak bags (50 ea)
Biota-all	Field guides (plants, invertebrates, vertebrates, etc.)
Biota-all	Hand lens (10x)
Biota-aquatic	1% Clorox net sterilization in spray bottles, rinse water, and plastic sheet
Biota-aquatic	Inflatable boat, air pump, and paddles (deep water springs)
Biota-invertebrates	Dredge - Petite Ponar (deep water lentic sites only)
Biota-invertebrates	Ethyl acetate killing fluid (90%, 0.25L)
Biota-invertebrates	Ethyl alcohol (100%, 2 L)
Biota-invertebrates	Forceps (4 pr)
Biota-invertebrates	Glass vials 50
Biota-invertebrates	Hand lens 10X
Biota-invertebrates	Killing jar (3+)
Biota-invertebrates	Malaise Trap
Biota-invertebrates	Net - aerial sweepnet (2)
Biota-invertebrates	Net - hand (aquarium net (3)
Biota-invertebrates	Net – Kicknet
Biota-invertebrates	Net - Surber sampler
Biota-invertebrates	Paper or wax paper envelopes x 200
Biota-invertebrates	UV light trap
Biota-vertebrates	Binoculars 8x-10x
Flow	Baski portable cutthroat flume
Flow	Portable weirs - 45° and 90°
Flow	Velocity meter with wading rod and digital display unit, or FlowMaster
Flow	Volumetric containers, piping/tubing
Flow	Stopwatch with 0.01 sec timer
Geography	7.5’ Topographic map
Geography	Camera, batteries, digital cards (2)
Geography	Clinometer

Geography	Compass
Geography	Flagging
Geography	GPS unit (and spare as backup)
Geography	Graph paper for sketchmapping
Geography	Metric ruler (30 cm)
Geography	Munsell soil color chart
Geography	Pin flags
Geography	Solar Pathfinder
Geology	Hydrochloric acid (10% HCl) 100 mL bottle and dropper
Geology	Trowel, small or folding shovel
Geography and Vegetation	Cover density card
Geography and Vegetation	Measuring tapes - 30 m and 50 m
Geography and Vegetation	Plant press, blotter sheets, newspaper (several)
Geography and Vegetation	Range finder (metric)
Water quality	DI or distilled water- 1 L/site to calibrate and clean instruments
Water quality	Calibration log book for multi-parameter water-quality meter
Water quality	Calibration solutions for pH, dissolved oxygen, conductivity, etc.
Water quality	0.45 µm water filter and spare filters
Water quality	Labeling tape
Water quality	Latex gloves
Water quality	Multi-parameter field WQ meter; cables for temperature, pH, DO, SC, and optional (ORP, salinity, nitrate, ammonium, chloride, turbidity) probes; back-up meters; and WQ test strips
Water quality	Nalgene bottles - 1 per site + 12 additional (250 mL, acid washed and deionized water rinsed; project dependent)
Water quality	Nalgene bottles - 1 per site + 12 additional (10 mL, acid washed and deionized water rinsed; project dependent)
Water quality	Syringes for filtering (several/site)
Water quality	Thermometer (°C) for air and water

methods, but is considered a Level 3 activity because it is developed through monitoring.

In the following sections we describe the rationale behind selection of variables considered important for Level 2 springs inventory and the sampling methods. The text guides the reader through the field forms in Appendix A. The level 2 inventory is designed with sufficient flexibility to add notes, observations, references, images, data files, and information on unique or unusual features of individual springs, as they are encountered. Table 5-2 provides the sequence of activities for a Level 2 survey. Table 5-3 lists the inventory variables.

Fieldsheet Page 1

Overview

A clear, concise description of the site and its microhabitats is essential for mapping, monitoring, establishing the source elevation (i.e., useful for groundwater modeling), and relating other basic physical elements of the springs to its biota and human uses. The first page of the Level 2 inventory field form includes general geomorphic information about the site and the survey.

This first page should be filled out by the geographer, in consultation with the other staff

Table 5–2. Sequence of activities for Level 2 springs inventory surveys. Sequence step 1 is to be performed first, then step 2, etc.

Sequence	Field Sheet Page(s)	Activity
1	---	Pick up and check gear, lock and GPS vehicle
2	---	Proceed to site
3	1,3	Record start time; Biologist searches/observes wildlife sign
4	9	Team walks site, checks for upstream sources, considers assessment variables
5	1	Team agrees on extent of springs habitat, and distribution and naming of microhabitats
6	---	Team establishes a base site for operations
7	1	Geographer begins georeferencing and sketchmapping the site (sketchmap includes springs name, date, N arrow, scale bar, locations of measurements, photography).
8	1,7	Water quality and Solar Pathfinder measurements are made at source
9	1	Site and measurement point photography
10	5-6	Botanist develops a plant species list
11	4	Biologist observes/collects terrestrial invertebrates
12	5-6	Botanist visually estimates % cover of each species in each microhabitat, and collects specimens of unknowns
13	8	Replicated flow measurement at point of maximum surface expression; after measuring flow, dismantle the equipment and restore the measurement site
14	4	Conduct quantitative macroinvertebrate sampling
15	9	Team collectively conducts assessment of hydrogeology, geomorphology, habitat, biota, and human impacts
16	---	Make sure all data have been compiled; recollect all field gear; leave the site untrammeled
17	---	Return to vehicle and proceed to next activity

members, and should include the observer's initials (OBS). Most of the variables on the first page are self-explanatory, and a list of options for some more technical fields is provided on page 2. Here we provide justification and commentary on those variables. The variables to be recorded are listed along the left margin of the sheet, and include General, Georeferencing, SPF, Survey, Microhabitats, and Images tabs.

General Section

Spring Name: Many springs are unnamed, and often the name on topographic maps conflicts with that used by the land managing agency or the NHD database. Typically it is best to use the name assigned by the land manager. In cases where no springs name exists, it is helpful if the inventory team gives the springs complex a distinctive, colloquial name—a creative name that honors the site. As many springs have multiple sources, using the plural form, such as "Sledgehammer Springs" is appropriate. To reduce confusion, avoid naming a springs ecosystem "Big", "Warm", "Cold", or "Rock" Springs. Similarly, avoid naming it by the dominant vegetation type (e.g., "Cottonwood", "Sycamore", or "Willow" Springs). Such names are overused and may be impermanent, in the latter case because vegetation may change through time. It is customary in the United States to forgo the use of apostrophes in geographic names. Most springs are not named and the U.S. Geological Survey governs the naming of geologic features in the United States. Hence, a provisional name applied by the inventory team may eventually become the official name for that springs ecosystem. Therefore, it is important to assign a respectful name.

Springs Type: Effective stewardship requires understanding the status of the groundwater supply, and the type and context of the springs (Scarsbrook et al. 2007). Springer and Stevens (2009) identified 12 types of springs that include lentic (standing water) and lotic (moving water) springs as described in the Springs as Subclasses of Wetlands chapter. Non-flowing paleosprings are not included in that list and are not discussed further here.

Location and Ownership: Country, state, and county, land unit (e.g., US Forest Service, NPS, Private), and land unit detail (e.g., Wilderness RD, Gila NF) are required fields in the database. The USGS quad and 8-digit HUC are optional, but are sometimes helpful. If left blank, these will be automatically updated in the database. Sites may be listed as sensitive by the steward due to their location (e.g., associated with archaeological resources), survey (e.g., hosting endangered species), both, or neither. Permissions in the Springs Online database restrict access to sensitive information, as the steward wishes.

Site Description: In this field, surveyors should describe the long-term context of the site. This includes the general geologic and geomorphic setting. Typically this description should apply to the permanent condition and features of the site. This is a free text field in the database, allowing room for describing the site, but not its ecological condition (see below).

Georeferencing Section

Georef Source and Device: The device used (GPS, map, etc) indicates the quality of the location information. Keep in mind that steep canyons may result in a high GPS error (noted in EPE, below).

Datum: Generally surveyors should use NAD-83 or WGS-84, although when using a USGS Quad sheet, NAD-27 may be unavoidable. It is critical to document the datum used, as it may result in positioning error of up to 400 m.

Geographic Coordinates: Surveyors may enter UTMs, decimal degrees, or both on the data sheet. However, the Springs Online database requires decimal degrees to add a new springs location. If using UTMs, be sure to include the zone. Declination is important for calculating true vs. magnetic north. Accurate elevation data are essential for groundwater modeling; however, accurate elevations are notoriously difficult to obtain using GPS. Therefore, using topographic maps or a digital elevation model may be more accurate than using GPS data for determining elevation. Generally, the geographer can have a higher confidence in the accuracy of GPS locations with a lower estimated position of error (EPE). Use the comment field for any concerns or notes about the coordinates (for example, if the source is under an overhang so the coordinates were taken 50 m away where a signal could be obtained).

Access Directions: Completing this section can save future surveyors an enormous amount of time

Table 5–3. List and description of variables measured or observed during a Level 2 springs ecosystem inventory, and information sources: F – field site visit, L – laboratory analyses, O – office. See key of abbreviations and options in Level 2 field forms.

Variable Category	Variable(s)	Description	Data Source
General	Spring name, country, state/province, county/municipality, USGS Quad, 8-digit HUC, unique Site ID	General information about location of the site. A numeric Site ID is automatically generated when a spring is added to the Springs Online database.	O
Land Ownership	Land unit and detail	Steward (e.g., NPS, USFS, private) and land management unit (e.g., Grand Canyon National Park)	O
Site Description		Describe the permanent geomorphic context, landscape setting, and springs type.	F
Access Directions	General location and access	Site access directions, being specific as possible, and noting any special precautions for returning teams.	F/O
Site Condition	Site condition	Describe site conditions as they present at the time of the inventory, including extent and forms of natural and human alteration of the site.	F
Georeference	Information source, datum, UTM zone, device, UTM easting, northing, latitude, longitude, elevation and accuracy (EPE, (m or ft), comments	Details of georeferencing. We recommend using the waypoint averaging function on your GPS unit. Note that SpringsOnline only accepts locations in decimal degrees.	F
SPF	Solar radiation budget	Mean monthly sunrise and sunset time, measured using a Solar Pathfinder to calculate total % seasonal and annual solar flux; sum mean winter, spring, summer, autumn and total annual direct SF and percent.	F
Survey	Date, start time, end time, surveyor's full names	Who performed the inventory, when and for how long?	F
Project	Project name	Allows a set of surveys to be grouped and analyzed together.	O
Microhabitats	Describe geomorphically distinct microhabitats influenced by the spring	Identify each geomorphic microhabitat and its surface type and subtype; slope variability (low, medium, high); aspect (note if compass declination is set to magnetic or true north); soil moisture, water depth and % cover; substrate composition by % surface particle size distribution and organic soil cover; % cover of precipitate, litter, and wood; average litter depth.	F

Images	Photographs	Describe photographs taken, indicate photo sites on the sketchmap, and include which camera was used. Make sure the photograph captures as much of the site as possible for rematching.	F
Sketch map	Site sketch map	Hand-drawn map, aerial photograph, or digitized map with scale, orientation, date, observers, landmarks, georeferencing points, photo points. Indicate the locations of flow measurement, photography, cardinal orientation, SPF and GPS measurements, and where the sketchmap is stored (attached, computer, etc).	F/O
Vegetation	Vegetation: Aquatic, wetland, and terrestrial plant species inventory	List all plant species detected, noting endemic and non-native taxa. Visually estimate the % cover in each microhabitat by stratum: aquatic cover (AQ), non-vascular cover (NV), basal cover (BC; % woody stem area emerging from ground), ground cover (GC, graminoid/herb/non-woody deciduous), shrub cover (SC, 0-4 m woody perennial), mid-canopy cover (MC, 4-10 m woody perennial), tall canopy cover (TC, >10 m woody perennial).	F/L
Invertebrates	Aquatic, wetland, and terrestrial invertebrate species inventory	List the species detected, noting endemic and non-native taxa; quantitative timed area-specified kicknet or Surber sampling type, species enumeration, substrate, depth, velocity notes by microhabitat.	F/L
Vertebrates	Aquatic, wetland, and terrestrial vertebrate species inventory	List of species detected, noting endemic and non-native taxa.	F/L
Geomorphology	Emergence environment	Cave, subaqueous, subaerial, other.	F
	Flow forcing mechanism	Gravity, thermal, or gas pressure.	F
	Hydrostratigraphic unit: geologic layer of aquifer, rock type	Describe parent rock and rock type.	O,F
	Channel dynamics	Surface vs. springflow dominance.	F
	Source geology and flow subtype	Springs emergence: contact, fracture, seepage, tubular.	F
	Springs type(s); 1° sphere of discharge, 2°, 3° spheres of discharge	Describe the springs type and subtype(s), *sensu* Springer and Stevens (2009; See Appendix C).	F
Flow	Flow consistency	Describe perenniality of flow from long-term records, history, geologic features, dendrochronology, or the presence of aquatic organisms.	F/O
	Flow measurement technique(s), location, mean rate	Replicated flow measurement using techniques described; note the measurement location and on sketchmap.	F

Water Quality	Field WQ parameters: time of day; air and water temperature at source; pH; specific conductance (µS/cm); concentrations of dissolved oxygen, total alkalinity ($CaCO_3$, HCO_3)	Instruments must be calibrated daily for accuracy. Maintain a calibration log. Correct the electrical conductivity for temperature to calculate specific conductance. Measure water chemistry as close to the source as possible.	F
	Laboratory WQ: Concentrations of base cations and anions, total dissolved solids, H and O stable isotopes (d^{18}OVSMOW and *d*DVSMOW), nutrients	Collect and filter water quality samples from as close to the source as possible in acid washed container. Refrigerate, and analyze as soon as possible. Samples for nutrient analyses should be rushed to the analytical laboratory.	F/L
Cultural Resources	Archaeological resources	Archaeological surveys, literature review.	O,F
	Contemporary cultural resources (TCP, ethnobiology, etc.)	Interviews with Tribal elders, botanical inventory, site visits with Tribes, literature review	O,F
	Historical resources	Historical surveys, literature review, interviews with elders	O,F
	Human impacts and uses	Signs of human uses and impacts	O,F
Bibliography	List of citations	List of reports and other citations about the site	O
QA/QC	Data collection and data entry quality assurance/control	QA/QC efforts and analytical and information management methods, including such elements as random sampling of raw data, archives of calibration logs, etc.	O

and limit danger. For example, if the site is only accessible from above, or it requires a difficult climb, this information is important to record. Further, if a site is only accessible with a long hike, or by crossing private land with large dogs, documenting these obstacles will expedite future inventory and monitoring efforts.

Solar Pathfinder (SPF) Section

The extent of photosynthetically active radiation (PAR) is important at springs in topographically complex terrains, determining the amount of light available for vegetation, the duration and frequency of freezing in winter, and evaporation and relative humidity in the summer months. A Solar Pathfinder (SPF; Solar Pathfinder Inc. 2012; http://www.solarpathfinder.com/) can be used to quickly determine the mean monthly duration of direct insolation (Fig. 5-5). The SPF device consists of a reflective, transparent dome mounted on a template of the sun path diagram specific to the latitude of the site. The template estimates the mean percent of direct sunlight each half hour between sunrise and sunset each month, as defined by the horizon. The percent total potential solar energy for an average day during any month is calculated. With a 1-2 minute measurement, the geographer can determine the site's potential PAR for the entire year. Note that atmospheric limitation of solar radiation is not measured, and that cloud cover, dust, and humidity reduce actual PAR. The instrument can be calibrated against actual sunrise and sunset times

Fig. 5–5. Solar Pathfinder is used to measure the photosynthetically active radiation at a springs ecosystem.

when such opportunities exist. In general, the SPF is accurate to within 0.5 hr and approximately 5 m of the measurement point. In some settings, double sunrises or sunsets may occur.

The Solar Pathfinder is by far the most efficient and least expensive approach to microsite collection of solar radiation data. Even 10 m digital terrain models cannot provide sufficiently precise information on microsite insolation. For Level 3 research, the SPF can be used to map solar energy budget around the perimeter of larger sites. Alternatively, a pyranometer and a weather station can be installed to monitor temperature, precipitation, and humidity in relation to solar radiation throughout the year.

Survey Section

Survey Date, Begin Time, and End Time: The survey date is a required field. The beginning and ending times are helpful for calculating the total time spent conducting the survey. The ending time is easily forgotten: all crew members should remind the crew leader to include this value at the end of the survey.

Surveyors: Enter full names of all of the surveyors. Although it is tempting to simply add initials, data reviewers will not necessarily recognize them.

Project: This is a required field in the Springs Online database. Projects are easy to add, and allow for easy data entry, QA/QC, and reporting.

Site Condition: This free text field should include specific circumstances at the springs at the time of the survey, including general ecological condition and conspicuous natural and anthropogenic features or impacts, such as recent flooding, grazing, recreational use, or fire. Such information is temporal, as opposed to the site description information (above).

Microhabitat Section

Based on their geomorphology and adding considerably to their biodiversity and socio-cultural functions, different springs types support unique suites of microhabitats. Habitat heterogeneity has long been recognized as an important contributor to species richness and diversity. Some springs types, particularly those of larger size, are characterized by high levels of geomorphic diversity due to the co-occurrence of several to as many as 14 discrete geomorphic microhabitats (Table 5-4). Geomorphic microhabitats are physical landform components of the springs ecosystem that develop from a variety of physical processes and are subject to distinct environmental forces. Pools, springbrook channels, hyporheic zones, wet or dry bedrock walls, madicolous zones (shallow sheets of racing white water), and other microhabitat types can occur in close proximity, but may support entirely different assemblages of organisms, which may or may not interact with each other, but contribute to the diversity of life at springs.

The microhabitat array at any springs ecosystem is determined by the geomorphology of the site, and in turn influences plant species occurrence, species richness, and many components of microclimate and site. Microhabitat diversity at springs has ecological consequences for springs ecosystems. After accounting for expected species-area effects, microsite diversity positively correlates with vascular plant richness and land gastropod diversity in western North America and elsewhere (Springer et al. 2015, Ledbetter et al. 2016, Sinclair 2018). Thus, the area of the springs-influenced habitat and the microhabitat heterogeneity of the ecosystem are important secondary variables to consider in springs inventory and management.

A simple and direct way to evaluate microhabitat heterogeneity at a springs ecosystem is to use the same diversity metrics that are commonly used to assess species diversity, such as the Shannon-Weiner Index; in lieu of the number and/ or relative abundance of species at the site, geomorphic diversity is calculated using the number and/or area of different microhabitats. It is also possible to achieve a similar goal using a more complex geometric edge-effect analyses.

Springs are complex ecosystems, in part because they can include a suite of geomorphically distinctive microhabitats, which are patches that form through various physical processes (Table 5-4). The list of common microhabitats includes: caves, backwalls, (wet or dry), channels, pools, terraces, colluvial slopes, and anthropogenic features, the occurrence and relative size of which vary by springs and springs type. The team should discuss and agree upon the array of geomorphic microhabitats existing at the site prior to mapping and vegetation description (below). Microhabitat definition

Table 5–4. Probability of occurrence (low, medium, or high) of different microhabitats among springs types. Hypocrenic conditions (*) often develop with distance from the source, and in response to declining groundwater table stage elevation from natural decreases in recharge or as a successional process due to anthropogenic groundwater depletion. Totals of likely (high probability), possible (medium probability), or unlikely (low probability) of the number of microhabitats present at a given springs type are presented on the right side of the table.

	Microhabitat Type												
Spring Type	**Backwall or sloping bedrock**	**Cave**	**Channel (wet)**	**Colluvial slope**	**Mound**	**Pool**	**Terrace**	**Pool margin**	**Low gradient ciénega**	**High gradient ciénega**	**Likely Occurrence (High)**	**Possible occurrence (Med)**	**Unlikely occurrence (Low)**
Cave	High	High	High	Low	Low	Med	Med	Med	Low	Low	3	3	4
Exposure	Med	Low	Low	Med	Low	High	Low	High	Low	Low	2	2	6
Fountain	Low	Low	Med	Med	Med	High	Med	Low	Med	Low	1	5	4
Gushet	High	Med	High	Med	Low	Med	High	Med	Low	Med	3	5	2
Geyser	High	Low	Med	Low	High	Med	Med	Low	Low	Low	2	3	5
Hanging garden	High	Low	High	High	Low	High	High	High	Low	Low	6	0	4
Helocrene	Low	Low	Med	Low	Med	Med	Med	Med	High	High	2	5	3
Hillsope-rheocrene	Med	Low	High	Med	Low	Med	High	Low	Med	Med	2	5	3
Hillsope-upland	Med	Low	High	Med	Low	Med	High	Low	Med	Med	2	5	3
Hypocrene *	Med	Low	Low	Med	Med	Low	Med	High	High	Med	2	5	3
Limnocrene	Med	Low	Med	Low	Med	High	Med	High	Med	Low	2	5	3
Mound-form	High	Low	Med	Med	High	Med	Med	High	Med	Med	3	6	1
Rheocrene	Med	Low	High	Med	Low	Med	High	Low	Med	Low	2	4	4

allows measurement of area and geomorphic diversity, plant species density, and other characteristics of the site. It is important to differentiate geomorphic microhabitats from vegetation, because vegetation cover may extend across portions of, or several entire microhabitats. Soil moisture, texture, and composition, as well as observations on soil quality and the extent of disturbance (e.g., trampling by livestock) are recorded for each microhabitat.

Microhabitat Description: Some sites will only contain one or two microhabitats, while large, complex sites may contain many. Microhabitats are listed from A-G (or more if necessary) on the field sheet. The survey crew should assign a unique letter name to each that all can easily remember. For example, there could be a wet channel (A), dry channel (B), west terrace (C), and east terrace (D).

Area: The crew member responsible for developing the sketchmap should calculate the area of each microhabitat in square meters. For smaller sites, surveyors should lay out a metric tape along the long axis of the springs ecosystem (Fig. 5-6). For very large sites, surveyors can use a rangefinder or GPS device to walk the perimeter.

Surface Type and Subtype: Microhabitat type values are listed in Table 5.4. Surface subtypes include: channel (CH) riffles, runs, margins, and Eph(emeral); wet or dry colluvial slope (CS) or sloping bedrock (SB) surfaces; channel terrace (TE) in the hydro- (H; flooded >annually), lower (L – flooded every 1-2 yr), middle (M; flooded every 2-10 yr) or upper (U; flooded >10 yr) riparian zone (RZ; e.g., "MRZURZ"). All surface types can have an anthropogenic subtype (All).

Slope Variability: This is judged as low, medium or high based on the consistency of the slope in a microhabitat. For example, a vertical wall would be given a low slope variability value if the entire surface is consistently 90°.

Aspect: Record the aspect of each microhabitat as a numeric value, as measured with a Brunton or a sighting compass. Note whether the compass has been adjusted for declination (i.e., whether the compass is reading magnetic versus true north), and if so, record at what declination the compass is set. Recall that $360^o = 0^o$. Note that declination also affects the setup of the Solar Pathfinder. If a declination of 0^o is used, the Springs Online database can convert magnetic to true north.

Slope Degrees: Measure the slope angle of each microhabitat patch in degrees using a clinometer.

Soil Moisture: Moisture is visually estimated as the springs-generated moisture in surface soils on a 0-10 scale, ranging from: dry (0 = no soil moisture, soil easily separates), moist (3 = little moisture), wet (6 = soil easily sticks together), saturated (8 = completely wet, added water does not soak up, but no standing water), and inundated (10 = water standing or flowing on the surface). These categories are also listed under #6 on Page 2 of the field sheets.

Fig. 5–6. The survey crew should stretch a metric tape along the long axis of the site, and perpendicularly. Photo credit Emile Sawyer.

Water Depth: Measure the maximum depth of water in centimeters in each microhabitat.

Water %: Percent water is visually estimated as the percent of the microhabitat surface that contains open water.

Substrate %: The visually estimated percent cover of substrate grain sizes is recorded on the data sheet under each numeric category. These soil texture categories follow a modified particle size scale: 1) clay, 2) silt, 3) sand (0.1-1 mm), 4) pea gravel (1-10 mm). 5) coarse gravel (1-10 cm), 6) small boulders (10-100 cm), 7) large boulders (>1 m), 8) bedrock, and 9) organic soil, including peat. Values for these nine substrate categories should sum to 100% for each microhabitat (see Schoeneberger et al. 2012).

Prec(ipitate) %: Percent cover of precipitate is visually estimated across the entire microhabitat. In some cases, precipitate may cover litter and wood and can therefore be as high as 100%.

Litter %: Percent litter cover on the mineral soil (Schoenberger et al. 2012) includes the percent of leaves, twigs, and small downed branches (<1 cm diameter) covering the ground, and should be visually estimated in each microhabitat.

Wood %: Percent cover of woody branches or logs >1 cm in diameter is visually estimated, with the provision that the sum of percent litter cover and percent wood cover cannot exceed 100%.

Litter (Depth; cm): Three or more measurements of litter depth should be averaged from different areas in the microhabitat to estimate litter depth across the entire microhabitat.

Site Photography

Overview: Surveyors should take site photographs that capture, to the extent possible, the context and condition of the springs ecosystem under study. Such photographs also can be used for long-term monitoring comparisons. However, heavy vegetation cover can obscure important site features, so selection of photo points should be carefully considered. Surveyors should take images of other features and biota (e.g., singly-occurring plant species that should not be collected). These can be uploaded into the plant, vertebrate, or invertebrate data forms in the database. Typically only 1-3 site photographs are uploaded into the database, and additional images should be labeled and stored for future reference.

Camera Used: In this field, surveyors should identify whose camera was used to take photographs of the site and where those site photographs are stored. Photographs are commonly misplaced or lost during and after inventory projects.

Photo # and Description: Surveyors should document photo numbers generated by the camera and describe the subject of the photograph, including the location it was taken and the direction (e.g., upslope toward the source). Cameras with GPS capability can help to identify the location of photographs, but this does not identify the subject matter.

Sketch Map Location: This refers to the location where the sketch map is stored (e.g., in a field book, in a folder, or electronically in a database).

Sketchmap

Once the microhabitats have been discussed and defined by the whole team, the geographer should field map them on an ortho-rectified site photograph, field tablet, or on graph paper, measuring the dimensions and cardinal orientation of the microhabitats (e.g., Figs. 5-7 and 5-8). The length and width of the site should be measured with a metric tape or rangefinder. Once the site is outlined, the sketchmap should include distinct features, such as: 1) site name, surveyors, date, a scale bar; 2) a sketch of the site to approximate scale, flow direction, springs source(s), the configuration of associated channels, pools, terraces, and other landforms indicated; 3) points at which georeferencing, photography, and Solar Pathfinder measurements were taken; 4) roads, trails, spring boxes, pipes, troughs, and other constructed features; and 5) unusual inventory finds. Be sure to collaborate with the entire team to assure that the sketchmap matches the microhabitat descriptions and the vegetation cover.

The sketchmap is scanned and uploaded into the survey and included along with site photographs in the archives.

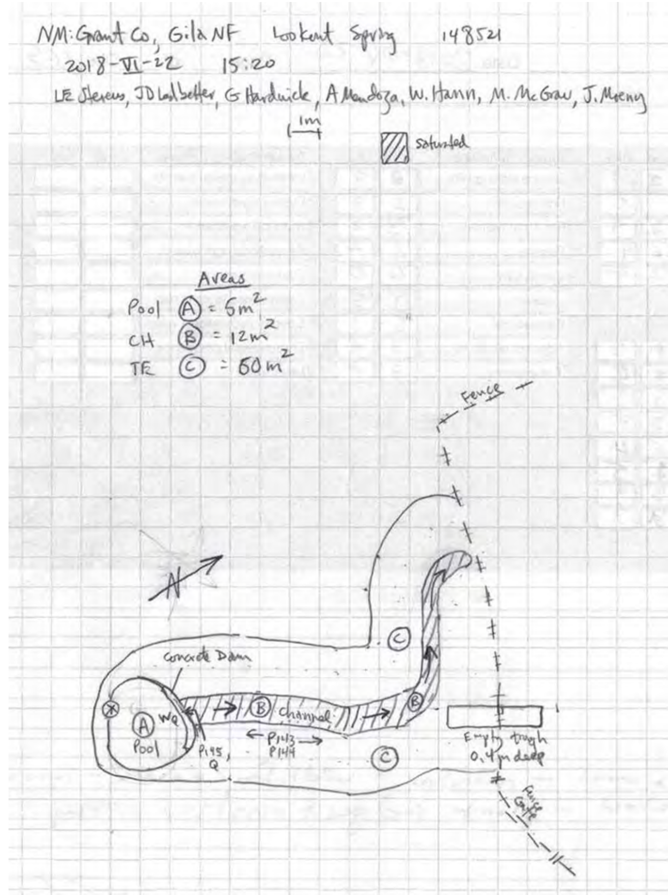


Fig. 5–7. Example of a field sketchmap. Lookout Spring on Gila National Forest.

Fieldsheet Page 2

This page contains lists of options for many of the variables found on the first page. For example, options for #1 Discharge Sphere (Spring Type) at the top of page 1 include: anthropogenic, cave, exposure, fountain, geyser, hanging garden, helocrene, hillslope, hypocrene, limnocrene, mound-form, and rheocrene springs types. This system uses less space than listing all of the options on each field form. As surveyors become more familiar with the options, they will need to refer to this list less often.

Fieldsheet Pages 3 and 4

Fauna Overview

All aquatic and terrestrial macrofauna detected at or within an approximate 100 m radius of the spring should be documented. Birds flying overhead should be recorded if they pass over this 100 m radius area, even though they may be much higher that 100 m above ground level. In addition to animals that are directly observed, the biologist should

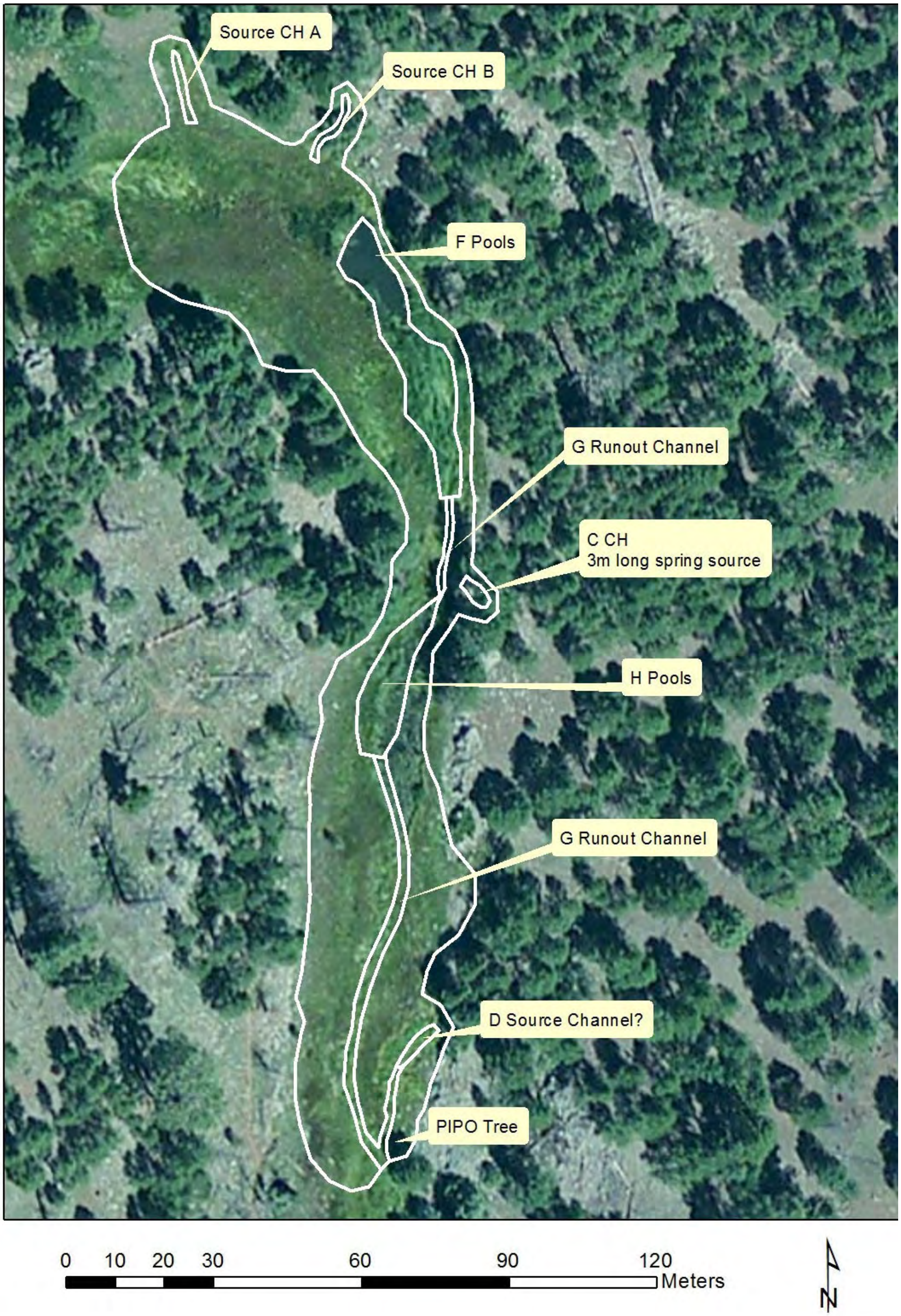


Fig. 5–8. Example of a sketchmap generated by walking the perimeters of microhabitats using a GPS, then bringing the data into ArcMap, refining the polygons, and adding labels. This method can be much more efficient and accurate for large, open , flat sites. It also is sometimes possible to draw polygons using aerial imagery. Either method is not feasible at small sites, or at those with dense vegetation or steep terrain. The site shown here is from LO Spring, Kaibab National Forest, Arizona. Aerial imagery courtesy of ESRI.

also record any animal sign observed in the 100 m radius area, such as tracks scat, burrows, antler rubs, etc. We recommend that the biologist spend at least five minutes at the site prior to the arrival or disturbance by the other team members to observe wildlife or sign that may subsequently disperse or be obliterated (Fig. 5-9). Aquatic and terrestrial macroinvertebrate detection methods differ considerably and are described separately below.

Aquatic and wetland life at springs commonly includes: Mollusca, Hexapoda, other invertebrates; fish; amphibians and reptile taxa; and birds and mammals. Species groups that are prone to endemism at aridland springs in the USA include: hydrobiid springsnails (Hershler et al. 2014); flatworms; physid aquatic snails; aquatic amphipods and isopods; various families of stoneflies; several families of Heteroptera waterbugs (especially Nepomorpha; e.g., Stevens and Polhemus 2008); dytiscid and dryopoid beetles; cyprinid minnows and cyprinodontid pupfish (Nelson 2008); other fish; and amphibians (e.g., **http://www.pwrc.usgs.gov/naamp/index.cfm**). In addition, rare but non-endemic taxa, as well as species potentially new to science may be detected during springs surveys (Sada and Pohlmann 2006, Stevens and Meretsky 2008, Stevens and Polhemus 2008, Stevens and Bailowitz 2009, Kreamer et al. 2015). Techniques for sampling vary by taxon, sometimes requiring specific equipment, preservation protocols, and considerable field and laboratory expertise.

Vertebrates

Documenting the use of the springs by terrestrial fauna is important for understanding the ecological role of the springs to the surrounding ecosystem. A wide array of terrestrial vertebrate taxa may occur at springs, including: fish, amphibians, reptiles, birds, and mammals. The biologist should record the species name of all vertebrates detected at or wihin a 100 m radius of the spring. If directly observed, the biologist should note how many individuals were observed, and write "obs." in the column labeled "Detection Type" (Fig. 5-9). If animal sign is observed, the species name should be recorded, the type of sign (scat, track, burrow, etc) should be recorded in the "Comments" column, and the No. Ind. (number of individuals) column should be left blank.

Fig. 5–9. Often surveyors will only find signs of vertebrate species, such as this coati skull. This can be noted on the vertebrates sheet under species name, with detection type as "sign" and "scat" under comments. These images can also be uploaded into the Springs Online database.

Wildlife use of springs can be surprisingly intensive. For example, GCWC (2002) reported 35 bird species, some in great abundance, watering at a small, remote spring on the North Rim of Grand Canyon during a Level 2 site visit. GCWC (2002, 2004) reported two- to five-fold higher avian (and butterfly) density and species richness at springs as compared to the surrounding uplands. Although many terrestrial vertebrate species may be detected during a single site visit, developing a relatively complete species list and quantifying use of a spring by those species requires many visits at different times of the year, a Level 3 research effort.

The presence of fish should be noted in Level 1 and Level 2 surveys, although quantitative sampling of the fish population is a Level 3 effort. During Level 2 surveys, identification and visual estimates of fish numbers are recorded. If permitted, specimens can be netted and, if necessary, preserved for identification. Observations made during a Level 1 or 2 inventory can inform recommendations for Level 3 monitoring, including the habitats to be sampled, specific questions to be answered, methods to be used for sampling, and equipment needed. Bonar et al. (2009) describe fish sampling techniques that can be used for Level 3 survey efforts, as well as specimen handling, data management, design, and analysis.

Fig. 5–10. Surveyors collected a predacious diving beetle larvae attempting to feast on a grasshopper. Both were documented and released at a spring in Apache-Sitgreaves National Forest, Arizona.

Herpetofaunal detection and monitoring should generally conform to the data standards and protocols of the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the National Forest Service multiple species inventory and monitoring protocols (http://www.fs.fed.us/psw/programs/snrc/featured_topics/msim/documents/msim_chapter_8_terrherps_fnl.pdf). If surveyors are able to take identifiable images of the species observed, they can be uploaded into the Springs Online database (e.g., Figs. 5-10 and 5-11).

Avian detection will vary hourly and seasonally. Observations of species or sign within 100 meters of the springs ecosystems should be associated with the site survey. Bird species observed greater than 100 m from springs ecosystems are more difficult to confidently associate with the site and should be noted as such on the data sheet, but not be included in the site list. Level 2 observations are opportunistic, while Level 3 methods can employ more formal protocols such as modified point counts or visual encounter surveys, with detection types including sight, sound, or sign (e.g., feathers, scat, tracks). Level 3 point count methods are described in the National Forest Service multiple species inventory and monitoring protocols (http://www.fs.fed.us/psw/programs/snrc/featured_topics/msim/documents/msim_chapter_3_landbirds_fnl.pdf).

Mammal detection will similarly be opportunistic during Level 2 inventories. Level 2 detection and monitoring uses visual encounter surveys. Such methods target diverse taxonomic groups and are less expensive than other live trapping or photographic methods. Observations of mammalian species and their sign within 100 m of the springs ecosystem can be associated with the site survey, and detection types include sight, sound, or sign (e.g., scat, tracks, kills, rubs and scent markings, etc.). Level 3 motion-activated photography, track plates, and hair snares may be used for more in-depth research.

Invertebrates

Aquatic and terrestrial macroinvertebrates are commonly of management interest at New Mexico springs, and can occur in great diversity. The biologist should be sufficiently familiar, not only with collection techniques and macroinvertebrate diversity in general, but also with species of management concern in the study area and quantitative sampling techniques (described below).

Aquatic Macroinvertebrates: Level 2 inventory of aquatic macroinvertebrates depends on the project study questions (e.g.., does the springs ecosystem support species of potential management interest?), as well as site conditions (e.g., Is there sufficient flow to sample quantitatively?). Many riparian and aquatic invertebrate taxa can be documented with the first Level 2 site visit. However, GCWC (2004) reported that several seasonal site visits in different seasons and years were needed to detect 90 percent of the macroinvertebrate taxa present. For the inventory of aquatic invertebrates, intensive spot sampling is sufficient to detect most species of potential management interest. Care should be taken to sample in various microhabitats,

Fig. 5–11. A black-tailed rattlesnake (*Crotalus molossus*) basking in the outflow from a warm spring along the Rio Grande river below Big Bend National Park, Texas.

including: riparian and aquatic vegetation; along shorelines; and in madicolous, pool surface, water column, benthic, and hyporheic zones.

If sufficient flow exists (flow >2 cm depth across a channel exceeding 10 cm width), timed quantitative benthic sampling also is appropriate to establish baseline density (number of individuals/m^2/min of sampling) and species density (number of species/sample or species/m^2). Quantitative benthic sampling techniques involve timed, replicated, and area-specific kicknet, Surber, Hess basket (mesh sizes of less than or equal to 1 mm), or petite Ponar dredge sampling, as described by Merritt et al. (2008) and the Environmental Protection Agency (**http://www.epa.gov/owow/monitoring**). At least three quantitative samples should be collected. Level 3 monitoring sampling should be repeated until variance in species richness and abundance stabilizes. Malaise, pitfall, colored pan, and ultra-violet light trapping, as well as drift and emergence trap sampling also are informative, but are Level 3 efforts.

Sampling for crayfish or other invasive invertebrates involves spot sampling, quantitative D-netting or seining, depending on project information needs and time available, with catch per unit effort (CPUE) or area as a standard metric. Great care must be exercised if protected species are present, and specific instructions about sampling for or around such species should be reviewed by the U.S. Fish and Wildlife Service and specified on the research permit. Stream invertebrate and vertebrate sampling is performed in an upstream direction, to limit error related to downstream drift into sampling nets.

Visually estimated percent cover (VE%C) of aquatic substrata and other aquatic habitat variables are recorded at each benthic sampling site. As with soils documentation, benthic grain size is visually estimated using the 1 to 8 plus organic particle size scale. Velocity, depth, algal or vascular plant species and cover, and water quality variables also should be recorded for each quantitative sampling site. Springs often support limited habitat and substrate; therefore, not all of the categories mentioned above may be present.

The appropriate quantitative method(s) to collect aquatic macroinvertebrates should be selected for each specific habitat type. The following sampling methods are commonly employed in aquatic invertebrate sampling.

Kick-Net: The kick-net sampling technique is a quantitative method that is used in flowing water in depths >2 cm. The kick-net is held on the stream floor perpendicular to the current, setting the pole ends firmly into the sediment to stabilize it. For shallow streams, a 0.09 m x 0.09 m frame can be placed on the stream floor and vigorously disturbed with a trowel or probe for one minute. Gravel and cobble substrates should be rotated and scraped on all sides while being disturbed to displace macroinvertebrates into the net.

For water depths greater than 0.5 meters, use a kick-net with an area of 1 m^2, and for water depths of 0.1 - 0.5 m use a D- or dip net and sample a smaller area (often 0.09 m^2). With all methods, be cautious to ensure that the flow successfully delivers specimens into the net.

Surber Sampler: A Surber sampler can be used to collect macroinvertebrates in spring channels with water depths of about 5 - 50 cm. Face the opening of the sampling device upstream into the current. Stabilize the net by placing one's foot on the corners. The sediment within the frame upstream of the net should be vigorously disturbed with a trowel or a probe for a specified amount of time (e.g., 1 min, making sure to rotate and scrape all sides of the sampling area. Dislodged macroinvertebrates will passively float downstream into the collecting device at the end of the net.

Aquatic Spot Sampling: Spot sampling is a qualitative method used for sampling shallow flows, vegetation, standing water and pools, and free-floating macroinvertebrates. A hand-net (aquarium net), D-frame net, or sieve can be used to sweep up benthic or free-floating macroinvertebrates (e.g., Figs. 5-10, 5-12, and 5-13).

Plankton Tow Netting: In large, moderate to fast-flowing streams, plankton tow nets can be deployed to capture drifting macroinvertebrates . depending on the concentration of suspended sediments, fine-mesh flow nets should be tested in situ to determine the appropriate duration of sampling. Several repeated samples of that duration are then collected, and the catch preserved for analysis in the laboratory.

Petite Ponar Sampling: Dredge sampling is used in lentic settings that are too deep to sample with other means, typically in deep-water limnocrene habitats. The dredge sample is hauled up, transferred to a bucket, and sieved at 0.5 to 1.0 mm mesh sieve. The area of a petite Ponar dredge is 0.023 m^2.

Terrestrial invertebrates: These invertebrate species occupy wetland, shoreline, and riparian vegetation niches around the periphery of springs. In general, springs terrestrial invertebrate fauna has been poorly studied, in part because few rapid assessment techniques exist for such habitats. Opportunistic "spot" sampling is most commonly used, but the biologist needs to be thoroughly familiar with the kinds of microhabitats and settings most likely to produce results. When possible, additional species are likely to be collected during night hours using spot, ultra-violet light traps, or pitfall traps; however, these techniques are usually beyond the scope of rapid inventory and assessment methods.

Collection: Documenting the use of the springs by terrestrial fauna also is important for understanding the ecological role of the springs ecosystem. A wide array of terrestrial macroinvertebrate taxa may be present, including: aerial adults of taxa with aquatic larvae (e.g., Ephemeroptera, Odonata, Plecoptera, Trichoptera, Lepidoptera, and many Diptera), and semiaquatic ochterid, gelastocorid, and saldid waterbugs.

Expert entomological taxonomy is required for the preparation and identification of various aquatic and wetland invertebrates. For example, the mandibles of cicindeline tiger beetles should be spread for ease of identification.

Prior to terrestrial macroinvertebrate collection, make sure the collecting nets are free from propagules from previously visited sites, and prepare a kill jar. Ethyl acetate (a commonly-used killing agent) can be added as needed in jars with plaster of Paris as an absorbing medium. Macroinvertebrates should be collected from all terrestrial habitat types within the spring vicinity, using the appropriate methods. Equipment used to collect macroinvertebrates will depend on the substrate type. Surveyors should collect at least three individuals or diagnostic portions of the macroinvertebrates encountered, and record any taxa observed but not collected on the data sheets. Some appropriate techniques for specimen collection and management are described below.

Fig. 5–12. Coarse substrate materials should be removed from samples in the field to prevent damage to the specimens.

Sweep Netting: Collection on vegetation, including small trees, shrubs, grass, and annual plants is conducted using the sweep net technique (Triplehorn and Johnson 2005). To collect macroinvertebrates, swiftly swing the net back and forth through vegetation for 1 min. Each vegetation type should be collected separately and recorded on the data sheet. Once macroinvertebrates are collected, shake them to the bottom of the net and transfer them to a kill jar.

Terrestrial Spot Collecting: Spot collecting is used for macroinvertebrates that can not be collected using the sweep net technique, including those found in tree trunks, under rocks, logs or fallen branches, in leaf litter, and in flight. Small or venomous macroinvertebrates can be collected with

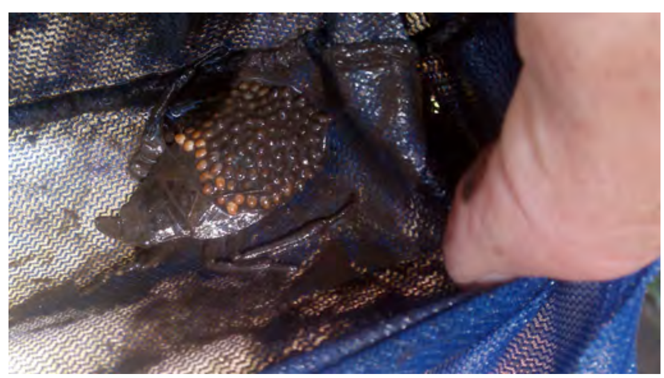


Fig. 5–13.   The male *Abedus herbredi* carries eggs on his back after the female abandons them. Several of these invertebrates were observed at Stacked Rocks Spring - a previously unmapped site in Gila National Forest.

Fig. 5–14. Mites are an example of cryptic, often-springs dependent species. Here, red mites have parisitized an *Argia* damselfly.

forceps. Flying macroinvertebrates (i.e. butterflies, dragonflies, and pollinators) can be captured with a sweep net, noting host plant species, if any. A small aerial net or an aspirator is useful for collecting small flies and other invertebrates in shoreline habitats.

Beating Sheet: This method is useful for collecting invertebrates that occur on vegetation and drop off the plant when disturbed (i.e., spiders, and adult stoneflies and caddisflies). Place a 1 mm or finer mesh insect net under a bush or tree, and tap the branches of the vegetation until the macroinvertebrates fall from the vegetation onto the net (Triplehorn and Johnson 2005).

Other Collection Methods: Nocturnal spot sampling, or the use of Malaise traps, ultraviolet light traps, colored pan traps, pitfall traps, and bait traps will reveal different terrestrial invertebrate assemblages not detected during the daylight hours. However, the use of these techniques is typically a Level 3 exercise.

Specimen Identification and Storage: Aquatic and soft-bodied specimens are transferred to a Whirlpack bag or a vial and usually are preserved in 70-100% ethanol. They are returned to the laboratory for sorting, enumeration, and identification. Be sure that the concentration of EtOH is sufficiently high because water from the sample may further dilute the sample. Samples collected by quantitative methods will include a mixture of substrate and macroinvertebrates, and coarse materials (Fig. 5-12) should be removed from the sample in the field to prevent damage to the specimens.

The bag or vial should be labeled with the site name, date, and substrate or habitat affiliation with a permanent marker, and an indelible ink label. The information also should be placed inside the bag or vial.

If quantitative benthic or tow-net samples are collected, they can be crudely sorted and enumerated in the field (a less precise but more cost-effective practice). At least three quantiative samples should be collected, and at least three individuals or diagnostic portions of aquatic macroinvertebrate morphospecies should be preserved for taxonomic verification. However, specimen collection should not take place if such actions threaten or harass local populations, or are not permitted. If genetics analyses are anticipated for some specimens, the entire sample should be preserved in 100% EtOH in sterile, inert containers and stored in a dark, refrigerated environment.

Because laboratory identification is time consuming and expensive, we recommend development of a voucher collection for the land management unit to expedite future Level 3 studies and monitoring. Specimens should be curated and preserved in accord with long-term museum conservation standards (Fig. 5-15).

Larval and pupal stages of macroinvertebrates are more difficult to identify than are adults. Therefore, it is sometimes useful to rear late-stage larvae or pupae to the adult stage for identification purposes. For example, mosquito larvae (Culicidae), caddisflies (Trichoptera) and other larval holometabolous forms (taxa that emerge from the pupal stage into the adult stage) can be collected alive, and placed in a labeled mason jar filled with stream water. Live specimens should be kept cool to minimize transport trauma. Specimens may be reared in the laboratory to the adult stage for identification. For detailed rearing instructions please consult Triplehorn and Johnson (2005) and Merritt et al. (2008).

Hydrobiidae springsnails, stoneflies, caddisflies, turbellarian flatworms, and other aquatic invertebrates are of interest as potential indicators of flow perenniality, and because species in those groups may be endemic to individual springs (e.g., Hershler et al. 2014). Collection and preservation techniques differ from those of other aquatic macroinvertebrates, and require consultation with a

Fig. 5–15. Common springs-dependent invertebrate taxa found throughout North America, displayed using appropriate preparation techniques.

taxonomist. Sada and Pohlmann (2006) describe collection and preservation of minute hydrobiid springsnails.

Nocturnal aquatic sampling may provide a different biological perspective of the springs invertebrate assemblage, as many taxa (e.g., leeches, Turbellaria, other Annelida, and many aquatic Hexapoda) are nocturnal and unlikely to be encountered during the daytime. Although more appropriate as Level 3 activities, the use of ultraviolet light traps and Malaise traps will result in the capture of many taxa not detected during the daylight hours, and UV light trapping in particular may be the only technique to detect some taxa, such as Trichoptera.

Terrestrial Specimen Preservation and Storage: Surveyors should place specimens of hard-bodied insects (e.g. butterflies, grasshoppers, beetles, wasps) into an acetate envelope, labeled with the location, date, collector, and habitat notes. Soft-bodied or very small specimens should be preserved in ethanol with a label placed inside.

Specimen Preparation: Consult Triplehorn and Johnson (2005) for detailed mounting and pinning instruction. Hard bodied macroinvertebrates are usually pinned, while small-bodied flies and other taxa are mounted on points. Pinned specimens should be placed in sealed invertebrate boxes or drawers, and protected from pests.

Fieldsheet Pages 5 and 6

Vegetation Overview

Springs vegetation typically is composed of a complex of aquatic, wetland, riparian, and upland species, and can occur in profuse, diverse, and unique combinations, often with rare as well as non-native species. Vegetation characterization is conducted in relation to stewardship goals and questions, and is often the most complex and time-consuming element of rapid field inventory and assessment. However, for many study sites, projects, and most springs types, it can be highly informative. The goal of the vegetation survey in the Level 2 protocol is to quickly and comprehensively describe vegetation composition, structure and function at springs. To achieve this end, we recommend visual estimation of percent cover (VE%C) of each species, with VE%C for woody species recorded separately for four specifically defined strata (see below).

VE%C methods used for floral rapid inventory are modified from Domin and Krajina (1933, as described in Bonham 2013), Daubenmire (1959), and Bailey and Poulton (1968). VE%C incorporates measures of vegetation composition and structure through semi-quantitative estimation of the cover of each plant species in each stratum in each microhabitat. This approach allows subtle differences in ranking to be documented. Typically, a single small individual is given a trace score of 0.01% cover, while a species with a few small individuals can be given scores of 0.1%, 0.2%, etc. Observer bias and error are still likely to occur, but the VE%C approach can provide ranked cover scores for each species, which is useful in non-parametric analyses.

VE%C requires detailed knowledge of local flora, as well as considerable practice in estimating foliar cover, data which are least reliable when conducted casually or by novices. Cover estimation error varies between observers but decreases with experience: it may exceed 25% when conducted by novices, so training with experts is important. Other quantitative techniques exist for measuring and monitoring vegetation, e.g., establishment of transects, plots, or marking individual plants (e.g., Barbour et al. 1987, Bonham 2013), but such methods are more time consuming and expensive than VE%C, may miss or misrepresent rare species, and are more difficult to interpret in among-site or among-springs-type comparisons. The inefficiency of quantitative techniques makes them inappropriate for Level 2 inventory and assessment, but such techniques may be appropriate for Level 3 research and monitoring efforts. Nonetheless, inventory staff collecting Level 2 VE%C should be continually aware of error related to observer bias, and should remain conservative in their practice of cover estimation. We generally find that VE%C is more accurately estimated through discussion among crew members, and with increasing experience.

Vegetation Data Collection

Once the extent of the sampling area has been determined, the team works together to agree on the number and type of microhabitats (polygons) present.

The botanist should create a list of plant species on the site on the field sheet. The botanist will then estimate VE%C for each species by cover code (stratum) in each microhabitat. Cover codes are the following:

- aquatic (AQ)—algae and emergent plants
- non-vascular (NV)—mosses, liverworts, and lichens
- basal cover (BC)—live or dead stems > 10 cm diameter emerging from the ground
- ground cover (GC)—herbaceous plants of any height, including graminoids
- shrub cover (SC)—woody plants 0-4 meters tall
- middle canopy (MC)—woody plants 4-10 meters tall
- tall canopy (TC)—woody plants >10 meters tall

In regions dominated by tall trees (e.g., rainforests), very tall canopy (VTC) also may be considered, but relation of VTC faunal habitat to the springs will be weak.

Note that a given plant species may occupy several strata. For example, cottonwood trees may be present as seedlings (ground cover), and mature trees may occupy shrub, mid- and tall-canopy space. While we use the terms cover code and stratum interchangeably, only woody species may occupy more than one stratum. Herbaceous species can only be recorded in the ground cover stratum, no matter how tall they are.

Note also that total %VE cover should not exceed 100% in each microhabitat.

Plant Specimen Collection

Plant species that cannot be determined on-site by the staff biologist should be collected, documented on the field sheet with a collection number, labeled with the site, date, and microhabitat, and returned to the laboratory for identification. If the unknown plant is a small annual, several individuals should be collected. For larger plants, be sure to collect enough material for identification. This generally includes leaves, flowers, and fruits at a minimum; if feasible and appropriate, roots or rhizomes and stems and/or bark should be collected. If only one individual of a species is detected on a site, it is best to photograph rather than collect it (Fig. 5-16). Plant specimens should be placed in a plant press and kept dry to prevent mold. In humid regions it is necessary to place specimens in a plant dryer after returning from the field in order to dry them for preservation and storage.

Algae, liverworts, mosses and other non-vascular plants can be collected if the steward is interested in taxonomic identification to species for these taxa. Algae are best preserved by placing the sample in filtered, buffered 3% glutaraldehyde, neutralized to pH 7 with NaOH.; or in Lugol's solution or other staining preservatives. Mosses can be hand collected and placed in an envelope for dry preservation. Aquatic plant species often are best pressed on wax paper to prevent the specimen from sticking to the pressing sheets. In the laboratory, the specimens should be air dried or oven dried at 60º C for 48 hr, before identification, preparation, or curation.

Fieldsheet Page 7

Flow Measurement Overview

Systematic hydrogeological measurements are needed for classifying, understanding, and monitoring spring ecosystems. Flow and geochemistry can add great insight into understanding aquifer mechanics and subterranean flow path duration. Modeling of flow variability improves with multidecadal monitoring, so measuring spring flow during each site visit is important. Springs flow

Fig. 5–16. Photograph, rather than collect, rare unknown species encountered at the site.

may be measured with one or more of the protocols listed below.

Meinzer (1923) developed a ranking scheme for springs discharge rate, a scale that is widely used but is both nonintuitive and incomplete: it inversely relates rank to discharge and does not capture the range of springs discharges. The scale presented in Springer et al. (2008), augmented slightly below, uses a logarithmic SI scale to rank springs discharge rates (Table 5-5).

Where and When to Measure Flow: Flow measurement requires planning, both for the logistics of sampling and the equipment to be used (Figs. 5-17 to 5-23). Springs flow should be measured at the point of maximum surface discharge, which is not likely to be the source but rather some distance downstream. The point of flow measurement should be recorded on the sketchmap. Understanding flow variability is important in many situations, and flow can be expected to vary seasonally at most shallow aquifer or low residence-time aquifers. The most conservative flow measurements are made when, or in settings where transpiration losses and precipitation contributions are minimal (e.g., winter, in bedrock emergence settings). However, it is equally important to understand the effects of riparian vegetation and groundwater withdrawal on springs discharge during the growing season, so mid-summer measurements are relevant as well. In short, there is no single time of year that is best for flow measurement.

Flow Measurement Techniques

General: Flow measurement techniques vary in relation to site and season, and the field sheet provides space for documenting the method(s) used to measure springs discharge. If available, Level I inventory data may help inform the team hydrogeologist as to what equipment is needed for flow measurement.

Most field methods of measuring spring discharge flow are somewhat imprecise, so it is a good practice to repeat a measurement several times at a single visit. With the methods described below, we recommend making at least six measurements and calculating the average value. If the discharge of the spring is low (first magnitude), the discharge measurement may take a long time and should be initiated early in the site visit. Second to fifth magnitude discharge is relatively faster and easier to measure. Measurement of sixth or higher magnitude discharges (large to non-wadeable channels) may take as long as or longer than unmeasurable to first magnitude measurements. The name, serial number (if available), and accuracy of the instrument(s) used to measure flow should be recorded, as well as observations of indications of recent high flows (e.g. high water marks or oriented vegetation or debris on or above the channel or floodplain).

Below we list several methods to measure springs flow, beginning with methods appropriate for estimating flow when it's too low to be measured, to methods to use when a stream is too deep to wade. If less than 100% of the discharge is captured by the device, the percent of flow captured should be estimated and recorded for each measurement.

Depression/sump: This method is typically used for unmeasurable to low flow springs with little to no surface expression of flow, and is used as a relative comparison value of discharge. First, excavate a depression within the seepage area. De-water

Table 5–5. Discharge magnitudes modified from Springer et al. (2008), ranges of discharge for class, and recommended instruments to measure discharge.

Discharge Magnitude	Discharge (English)	Discharge (metric)	Instrument(s)
Zero	No discernible discharge to measure	No discernable discharge to measure	Depression, float velocity, static head change
First	< 0.16 gpm	< 10 mL/s	Depression, Volumetric
Second	0.16 - 1.58 gpm	10 -100 mL/s	Weir, Volumetric
Third	1.58 -15.8 gpm	0.10 - 1.0 L/s	Volumetric, Weir, Flume
Fourth	15.8 – 158 gpm	1.0 - 10 L/s	Weir, Flume
Fifth	158-1,580 gpm; 0.35-3.53 cfs	10. - 100 L/s	Flume
Sixth	1,580 – 15,800 gpm; 3.53 – 35.3 cfs	0.10 - 1.0 m3/s	Current meter
Seventh	35.3 – 353 cfs	1.0 - 10 m3/s	Current meter
Eighth	353 – 3,531 cfs	10 - 100 m3/s	Current meter
Ninth	3,531 – 35,315 cfs	100 – 1,000 m3/s	Current meter
Tenth	>35,315 cfs	>1,000 m3/s	Current meter

the depression and record the time it takes for the depression to fill again (Fig. 5-17). Then measure the volume of the depression using a calibrated container or similar method. Repeat the measurement six times and calculate the average. This is an indirect, relative procedure, and must be interpreted with care because often a much larger area is seeping than the area where the depression was excavated.

Float velocity measurement: This flow measurement method is used for extremely low flows in circumstances when for some reason flow cannot be focused into a pipe, weir or flume. This method is substantially less accurate than the velocity measurement techniques listed below.

Begin by selecting a relatively unobstructed reach of straight channel that is long enough for a travel float time of at least 20 seconds. At the upstream and downstream ends of the reach, run a meter tape across the channel. At both locations, record the channel width, and measure the water depth at several regularly spaced points along the meter tape. It is important that the depth measurements are regularly spaced, because these measurements will be used to calculate the cross sectional area of channel. Also measure and record the length of the river reach, i.e. the distance between the two cross sections.

Now place a float (e.g., a wooden disk or other small object that will float) in the stream channel upstream of the first cross section tape so that it reaches stream velocity before passing across the upstream line. Record the amount of time it takes for the float to pass from the upstream cross section tape to the downstream tape. Also record the position of the float relative to the channel sides. Repeat this procedure six times, placing the float at a different location across the channel each time.

Stream discharge is calculated as the average velocity times the stream cross sectional area. To calculate average velocity, divide the length of the reach (in meters) by the average travel time (in seconds), and then multiply that number by 0.85 to adjust for the difference in stream velocity at the water's surface compared the locations deeper in the water column. The result of this calculation is average stream velocity in meters per second. Next calculate the area of each stream cross section by

Fig. 5–17. In this case, surveyors dug a hole and measured time to refill in order to measure flow.

multiplying the stream width (in meters) by the mean of the several depth measurements (also in meters). Calculate the mean of the two cross sectional area, producing an average channel cross sectional area in square meters.

Discharge (m^3/s) is calculated by multiplying the average stream velocity (m/s) by the average area of the section of the stream channel measured (m^2).

Timed volumetric (flow capture) measurement: Volumetric measurements are typically used in low magnitude discharge springs (Fig. 5-18), where flow can easily be focused into a volumetric container. This can be a highly accurate method of measuring flow, particularly if all the flow is successfully captured and the measurement is repeated several times. Accuracy depends on the calibration of the container used, and the observer's estimation of the percent capture of the springs discharge.

Start by constructing a temporary earthen or plumber's putty dam to divert water through a pipe of appropriate size for the amount of springs discharge. Allow the flow to stabilize before taking measurements. Then place a volumetric container under the pipe to catch the springs discharge. Record the time needed to fill the container, along with the volume of water in the container. Repeat the measurement six times and calculate the mean discharge in liters per second.

Several pipes and calibrated containers of various sizes appropriate for first to second magnitude discharge springs should be taken into the field to ensure the best measurement possible. Flow at

Fig. 5–18. Crews measure flow by creating a dam out of soil to direct the flow through a pipe.

Fig. 5–19. Surveyors occasionally must improvise in order to measure flow. In this case the crew used a tarp to collect dripping water at a hanging garden spring on the bank of the Colorado River in Grand Canyon, Arizona.

hanging gardens often is difficult to measure, but sometimes a tarp can be used to capture flow along a dripping geologic contact and measured using this method. (Fig. 5-19).

Portable weir plate: Weir plates are used to measure discharge in spring channels that have low to moderate magnitude values of discharge. The weir is pushed into a channel of loose material so that all the flow is diverted through the weir's V-shaped notch and the bottom of the notch is level with the stream bed (Fig. 5-20). The marks indicating stream stage should be on the upstream surface of the weir. Make sure the weir plate is plumb and level, and wait for the water level in the upstream stilling pool to stabilize. Measure the level of water on the upstream side of the weir (also called the static head) six times, and record all six measurements on the data sheet. Also be sure to record appropriate information on the geometry of the v-notch, which should be printed directly on the weir plate.

Using a weir plate in bedrock channels or channels with bed material coarser than fine gravel requires partially damming the channel with silt, clay, or plumber's putty while making sure not to obstruct the V notch. If all the springs flow cannot be diverted through the notch, be sure to write down the estimate of what percent of flow is captured through the weir. In all cases, it is important to photograph the weir setup (Fig. 5-20).

Portable weir plates are constructed with different V angles (e.g., 45, 60, 90 degrees), coefficients that affect calculation of flow (US Bureau of Reclamation 1997):

$$Q = 4.28C^{*}\tan(\theta/2)(H+k)^{5/2}$$

where Q = discharge (cubic ft/sec), C = discharge coefficient (below), θ = notch angle in degrees, H = head (ft), k = head correction factor (ft); and where C = 0.607165052 - 0.000874466963 θ + 6.10393334* 10-6 θ^2, and k (ft.) = 0.0144902648 - 0.00033955535 θ + 3.29819003x10-6 θ^2 - 1.06215442x10-8 θ^3.

Portable Cutthroat Flume: Typically, flumes are used in Springer et al.'s (2008) third to sixth magnitude discharge springs (Fig. 5-21). Flumes work best in low gradient channels with fine-grained bed material. The wing walls of the flume are pointed upstream in the channel in such a fashion as to focus as much flow as possible through the regular profile of the opening of the flume. The flume requires free fall of water from the downstream end of the flume.

Set the flume in a channel of loose material and use a bubble level on the floor of the upstream section to make sure it is leveled both longitudinally and transversely. Allow time for the flow to stabilize, and then measure and record the water level six times. The exact location in the flume where water depth should be measured varies according to the specific type of flume; workers should look this up before leaving for the field. Similarly, the equation used to convert stage to discharge varies by flume as well.

Fig. 5–20. Hydrologists use a V-notch weir plate to measure low volume flows in soft substrate.

Fig. 5–21. Cutthroat flumes are useful for more challenging settings. Although "portable", they are heavy and awkward for use in remote sites. This flume was used to measure flow at a helocrene in New Mexico.

Discharge is calculated according to the following equations, based on the width of the flume:

$Q = 0.494H^{2.15}$ 18"x1" long by wide, flume
$= 0.947H^{2.15}$ 18"x2" flume
$= 1.975H^{2.15}$ 18"x4" flume
$= 0.719H^{1.84}$ 36"x2" flume
$= 1.459H^{1.84}$ 36"x4" flume

where Q = discharge in cfs, and H = head (ft).

As with the other methods of measuring stream flow, it is important to photograph the measurement setup and record the estimate of percent of spring flow that was captured by the flume.

Current meter (Wilde 2008): Current meters are used for measuring flow in wadeable spring streams or in wide channels or high discharge channels where flow cannot be routed into a weir or a flume (Fig. 5-22). Select a measurement location in a straight reach where the streambed is free of large rocks, weeds, and protruding obstructions that create turbulence, and with a flat streambed profile to eliminate vertical components of velocity.

Stretch a tag line tightly across the channel perpendicular to flow, and anchored on each side. The cross section of the channel is divided into many evenly spaced partial sections, or into sections that capture equal amounts of flow. A section is a rectangle whose depth is equal to the measured depth at the location and whose width is equal to the sum of half the distances of the adjacent verticals. Surveyors wade across the stream with the current meter along the tag line, being sure to stand downstream of the velocity meter. Because of the safety involved in wading a channel, that individual should not wade too deeply into water and should not use hip waders in swift water without the use of a safety rope or other appropriate safety gear.

At each vertical, the following observations are recorded on the data sheet, (1) the distance to a reference point on the bank along the tag line, (2) the depth of flow, and (3) the velocity as indicated by the current meter. Velocity should be measured at 60% of the depth from the surface of water to the channel floor. The discharge of each partial section is calculated as the product of mean velocity times

Fig. 5–22. Current meters are best used in higher volume streams.

depth at each vertical, summed across the channel to provide total discharge.

New technology in the form of computer-integrated cross-sectional flow measurement is now available (e.g., Flowtracker, Sontek/YSI 2006), greatly improving the accuracy of streamflow measurement in open, wadeable channels. In larger, non-wadeable streams, a cableway and cable car or boat are needed to measure flow across a tag line.

Static head change: This method may be used for a relative comparison of the change in elevation of standing pools, and is useful for measuring flow in shallow wells or vertical culverts. A metric staff gage is placed in a standing pool and surface water elevation is recorded, and the geometry of the upper portion of the pool is measured (e.g., the diameter of a vertical culvert). The pool is rapidly bailed and the recovery rate is recorded. This measurement technique may be the only means of measuring flow in standing water, and accuracy depends on the quality of the pool geometry data.

Wetted area and water table depth measurement: Helocrenes, seeps, and other springs with highly diffuse discharge are sites at which surface flow cannot be focused and directly measured. Measurement and photography of the wetted area may be the only option for estimating the extent of springs flow. Piezometers (shallow wells) are commonly installed into helocrenes for Level 3 monitoring of depth of water table.

Visual flow estimation: Site conditions, such as dense vegetation cover, steep or flat slope, diffuse discharge into a marshy area, and dangerous access sometimes may not allow for direct measurement of discharge by the techniques listed above. Although visual estimation is highly imprecise, it may be the only method possible for some springs, but the method should be regarded as a last resort. Measurements and photographs should be taken to record the flow, and observations should be recorded on the data sheet, along with recommendation about future flow measurements.

Other flow measurement comments: All equipment should be calibrated and checked for consistency: equations listed are general and may not be accurate for individual weirs or flumes.

Subaqueous springs emerge from the floors of streams, lakes, or the ocean. Difference methods can be used to estimate flow of larger springs in stream channels. However, measurement in subaqueous lentic settings, such as lake floors or marine settings, may involve measurement of the area and velocity of discharging flow using SCUBA, large plastic bags, thermal modeling, or other techniques that cannot be accomplished during a rapid assessment.

Fig. 5–23. At Horse Camp Spring in the Gila Wilderness, subaqueous flow emerged into a flowing creekbed, making flow measurements difficult.

Geomorphology

Emergence Environment: The environment in which sources emerge include:

- Cave – Subterranean sources that may only be indirectly exposed to the atmosphere
- Subaerial, by geomorphic setting- Above-ground emergence - note the geomorphic setting (e.g., floodplain, prairie, piedmont, canyon floor or wall, mountainside, etc.)
- Subaqueous-lentic freshwater- Aquatic emergence into pond or lake – note substratum (organic ooze, silt, sand, rock)
- Subaqueous-lotic freshwater- Aquatic emergence into a stream or river –note substratum (organic ooze, silt, sand, rock)

Hydrostratigraphic Unit Description: The name and rock type of the source stratum/strata of the spring source should be described. Prior to visiting the site, the geologist should review the literature on local geology and structure. If a stratigraphic column or geologic map exists, it should be reviewed and taken into the field to confirm observations.

The rock type is defined as igneous, metamorphic, or sedimentary and the sub-type described. The size and shape of individual grains that comprise the rock can be described: if the grains are large enough, the size can be estimated with a mm ruler, but if the grains are small, a hand lens can be used to examine the size and shape of minerals comprising the rock for the description of the rock.

A drop of 10% HCl can be placed on a fresh, unweathered surface to discern if the minerals or the cement of the rock are comprised of carbonate (if so, the wetted surface will fizz). A rock color chart is consulted to describe the color of the rock. If it is uncertain what the type of rock is or the name of the stratigraphic unit, and if an appropriate permit is secured, a sample of the rock should be collected and analyzed in the laboratory. If a rock is collected, the date and site location should be recorded on the rock with a permanent marker. If the sample is poorly consolidated, it should be placed in a sample bag labeled with the site location information and date.

Flow Force Mechanisms: The forces that bring water to the surface may not be evident on a single visit, or without information on subsurface water from surrounding wells. If the forces that bring water to the surface are evident, they should be described. Typically, most springs are gravity fed. Artesian springs discharge water under pressure, or may issue from an aquifer that has an upper confining layer, subjecting the flow to fluid pressures in excess of the pressure due to gravity at the point of discharge. Thermal springs emerge when groundwater comes in contact with magma or geothermally warmed crust and is forced, sometimes explosively in geysers to the surface. Some springs do not flow and are not subject to pressurized discharge, while others have multiple forcing mechanisms. Anthropogenic factors, such as groundwater loading around large reservoirs, may create forces that anthropogenically affect springs emergence. One of the following mechanisms should be recorded along with additional notes. Note that additional data may be needed to determine the forcing mechanism.

- Gravity driven springs—Depression, contact, fracture, or tubular springs
- Artesian springs-—Increased pressure due to gravity-driven head pressure differential
- Geothermal springs—Springs associated with volcanism
- Springs emerge due to pressure produced by other forces—e.g., coke bottle springs are driven by constant gas build-up and release
- Springs due to pressure produced by anthropogenic forces—Anthropogenic artesian or geyser systems (e.g., hot springs associated with Hoover Dam, Arizona-Nevada)

Emergence: Groundwater may be exposed or flow from filtration settings (poorly consolidated, permeable materials), or from bedrock fracture joints, or solution passages. Also, springs may exist as groundwater exposed at the surface, but which does not flow above land surface. An additional emergence occurs as a stratigraphic contact environment in which springs, such as hanging gardens emerge along geologic stratigraphic boundaries. Following are typical source forms:

- Seepage or filtration spring--Groundwater exposed or discharged from numerous small openings in permeable material
- Fracture spring-- Groundwater exposed or discharged from joints or fractures
- Tubular spring-- Groundwater discharged from, or exposed in openings of channels, such as solution passages or tunnels
- Contact spring-- Flow discharged along a stratigraphic contact (e.g., a hanging garden)

Springs Runout Channels: The morphology of the channel is examined (if a channel exists) to determine if it is spring-dominated or surface-flow dominated. If a channel is springs-discharge dominated, the channel often is nearly bankfull at baseflow conditions. If the channel is surface-flow dominated, typically the channel is oversized for the baseflow of the spring. Typically there are two bankfull stages for surface-flow dominated channels; a small, incised channel for baseflow condition, and a larger, wider channel created by regular surface flooding (Rosgen 1996).

If a spring channel exists at the site, the slope, channel width, depth, sinuosity, substrate, and form can be measured and/or briefly described. The slope is measured with a clinometer over its distance. The width of the channel is measured from the top of the bank from one side to the other, perpendicular to the overall flow direction. A measuring tape is stretched across the channel and secured. Measure the depth of the channel from the stretched tape to the bottom of the stream to locate the deepest point (the thalweg). Width and depth should be measured at 3 to 5 locations within the springs-dominated channel or one meander of the channel. The distance between the two meanders should be measured with the measuring tape (or paced if the distance is greater distance than the tape). The size and shape of the clasts in the channel should be described using the substrate particle size scale. If the channel is directly on bedrock, the name of the rock unit should be recorded.

Field Sheet Page 8

Water Quality Overview

Field and laboratory water geochemistry methods are described by the U.S. Geological Survey (reviewed in Wilde 2008; Table 5-6) and endorsed by the Environmental Protection Agency. Air and water temperature, pH, specific conductance, electrical conductivity, total alkalinity, and dissolved oxygen concentration are commonly measured using daily-calibrated field instrumentation. Water quality samples and measurements are made at the springs source, rather than downstream to capture to the extent possible the characteristics of the supporting aquifer. Individual devices often are designed to measure multiple parameters (e.g., multimeters), but each probe needs to be calibrated against laboratory standards each day. Water quality kits can provide backup measurements when electronic units fail at remote sites.

Filtered 100 mL water quality samples can be collected in triple acid-washed bottles for laboratory analyses of major cations, anions, and nutrients, if such analyses are among the project objectives. One to two filtered water samples can be collected in 10 mL acid-washed bottles for stable isotope analyses. Water samples used to test for nitrogen and phosphate concentrations should be returned to the laboratory for analysis within 48 hr of sample collection. Water quality samples are stored on ice, but not frozen, following standard sample storage and time-to-analysis protocols. One note - in our experience, the more expensive the sampling device, the more likely it is to malfunction in remote field settings. Therefore, contingency planning is recommended, with several backup devices or strategies for obtaining water quality information, particularly for remote sites.

Field parameters: Field water quality measurement of specific conductance (uS/cm), pH, temperature (^{o}C), and dissolved oxygen (mg/L) should be conducted following U.S. Geological Survey and Environmental Protection Agency protocols (Wilde 2008). For example, an *InSitu*, Inc. Troll 9000 or YSI multi-parameter water quality meter with handheld Rugged Reader and quick calibration solutions can be used. These instruments are light-weight and portable and, with additional probes, can be used to measure oxidation reduction potential, salinity, depth, barometric pressure, nitrate, ammonium, chloride and turbidity if these field parameter data are needed. Alternatively, an electrical conductivity (EC), pH, and temperature meter, or equivalent can be employed for field measurements.

Calibration of the instrument should follow manufacturer recommendations. At a minimum, the instrument should be calibrated daily. A separate log book should be kept with the instrument with calibration information. The pages from the calibration log book should be copied and included with the field data form.

Field water-quality measurements from flowing water sites should be from discharge areas with uniform flow and stable bottom conditions (Wilde 2008). Field water-quality measurements from still water or pooled sites can be taken using spatially distributed vertical profiles; however, such standing waters at springs likely will be altered by atmospheric conditions and may not well reflect groundwater quality.

Laboratory Water Quality Analysis: Prior to field work, wash the appropriate and extra 100 mL and 4 mL polyethylene bottles in HCl acid three times and rinse with deionized water. After washing, allow the bottles to air dry and then cap them. Label each bottle with a distinctive color of labeling tape to distinguish treatments, if needed. Record the site, date, and treatment on the label during field data collection.

Latex gloves and safety glasses should be worn for water quality sampling. Filter, fill and rinse the sample container with water from the spring three times before collecting the sample. Do not contaminate the sampling container or the lid.

Samples should be stored on ice in the field but not frozen, and transferred to a refrigerator and stored at 4° C, then delivered to a certified analytical laboratory for processing. PO_4^{-3}, NO^{-3}, and NH_3 should be processed within 48 hours of collection, following USGS and EPA standards, while cation

Table 5–6. Chemical parameters, instrument type, detection limit, sample preparation and recommended sample handling times.

Chemical Parameter	Instrument	Detection Limit	Sample prep	Handling Time
18-Oxygen (^{18}O)			No filtering or preservation required	28 d
2-Hydrogen (^{2}H)			No filtering or preservation required	28 d
Nitrogen – Ammonia (NH_3)	Tehnicon Auto Analyzer, or comparable	0.01-2mg/l NH3-N	Filtered, 4	2 d
Phosphorus (PO_4^{-3})	Tehnicon Auto Analyzer, or comparable	0.001-1.0 mgP/l	Filtered, 4	2 d
Nitrate - Nitrite (NO_3^-)	Tehnicon Auto Analyzer, or comparable	0.05-10.0mg/L NO	Filtered, 4	2 d
Chloride (Cl^-)	Ion Chromatograph	0.5mg/L and higher	Filtered, no preservation required	28 d
Sulfate (SO_4^{-2})	Ion Chromatograph	0.5mg/L and higher	Filtered, no preservation required	28 d
Calcium (Ca^{+2})	Flame Atomic Absorption Spec.	0.2-7 mg/L	Filtered, HNO	28 d
Magnesium (Mg^{+2})	Flame Atomic Absorption Spec.	0.02-0.5 mg/L	Filtered, HNO	28 d
Sodium (Na^+)	Flame Atomic Absorption Spec.	0.03-1mg/L	Filtered, HNO	28 d

Fig. 5–24. Test kits are available to accurately measure field water quality characteristics, such as alkalinity. These require no calibration, are relatively inexpensive, and provide a useful backup system for electronic units.

and anion analyses should be undertaken within 28 days. Analyses are conducted using automated color imagery techniques or other appropriate analytical equipment (Table 5-6). Flame atomic absorption spectrophotometry should be used to analyze Mg^{+2}, Ca^{+2}, and Na^{+}. Ion chromatography is used to analyze PO_4^{-3}, NO^{-3}, and NH_3 (Table 5-6). Appropriate duplicate samples should be collected as controls (typically one in 10 samples are double-collected).

After Field Work

Specimen Data Management

Overview: Physical and biological specimens require preparation, identification, databasing, and curation, and should be archived in professional museum collections.

Invertebrates: Once separated from matrix materials in the laboratory, specimens are initially sorted into morpho-taxa and identified to order. Hard-bodied macroinvertebrates are pinned or transferred to separate envelopes, and aquatic macroinvertebrates should be transferred to individual vials with >70% ethyl alcohol distinguished by order. Subsequently, macroinvertebrates are identified to lower taxonomic levels, preferably to the genus or species level by an accredited taxonomist and using North American taxonomic keys (Thorp and Covich 1991, Triplehorn and Johnson 2005, Merritt et al. 2008). If quantitative samples were collected, macroinvertebrates should be enumerated and density (species/m2) should be calculated.

Each specimen should be accompanied with a label with the site name, date, substrate or habitat affiliation, taxonomic name of the macroinvertebrate, and the first name initial and full last name of the collector. Final collection labels for macroinvertebrates should be typed and printed on 3-5 pt. font on heavy-stock, white, high cotton-content paper no more than 6 x 15 mm in size (Triplehorn and Johnson 2005). Labels should be pinned below the macroinvertebrates for pinned or pointed specimens, or inside vials for alcohol-preserved specimens. Specimens should be identified to the lowest taxonomic level possible, databased, and properly curated into a secure, dark, cool environment.

Vegetation Data: Several features of the database aid in vegetation data entry, error checking, and reporting. Plant species taxonomy, nativity within biomes, and wetland status are archived in the database in a look-up table that automatically prevents taxonomic typographic errors during data entry. VE%C by microhabitat, stratum, nativity, and wetland status are summarized by species, by stratum, and by functional group in an automated report within the inventory database, saving a great deal of analytical and reporting time. SSI's Springs Online database distinguishes "stratum taxa" from total species richness in the automated vegetation reports.

Vegetation cover estimates are used to frame the assessment analysis of habitat extent, quality, and function (below). Along with the extent of non-native species cover and species richness, the database automatically reports many components of habitat structure and function based on vegetation characteristics of the site. When a large number of springs have been analyzed for vegetation, it will be possible to refine our understanding of the complex interactions among soils, aspect, elevation, climate, and biogeographic affinity on springs vegetation and habitat structure.

Plant specimens collected for identification or as voucher specimens should be dried in plant presses. Specimens retained as museum vouchers should be frozen in a deep freezer for at least five days to eliminate museum pests. A museum voucher specimen should be mounted and glued on a specimen sheet, identified to the species or varietal taxonomic level, and curated into a museum collection.

Equipment Maintenance

Tools, parts, and materials used while conducting field work for many dozens of springs over many weeks will undoubtedly require more corrective and preventive maintenance. Sensitive electronic equipment such as GPS units, field computers, satellite phones, radios, and water quality testers need to be properly stored in accordance with manufacturer instructions. This often entails replacing of water quality tester electrodes and storing in a special storage solution, software updates for GPS units and computers, and general battery maintenance of radios. All field equipment should also be washed and sterilized.

Vehicles also sustain damage and wear from transporting the survey team across sometimes vast landscapes during springs inventories. During the spring and summer seasons in the Southwest, weather is highly unpredictable with temperatures often exceeding 100° F. Thunderous monsoons can leave backcountry and forest roads washed-out or inundated with water and extremely muddy and difficult to navigate. Because of the varied and often harsh conditions survey to which vehicles are subjected, preventive and corrective maintenance should be a high priority. This entails regular oil and filter changes, checking of tire tread wear, thorough cleaning of undercarriage and engine compartment, and general cleanliness of the cab and truck bed.

6 Information Management

Data Management Introduction

Prior to beginning a springs inventory project, it is important to compile, organize, and archive available data, and to plan for management of the information to be collected. The springs information management system and its metadata should be easy to access, secure, and readily allow for new analyses. Few such information management systems presently exist for springs ecosystem data. Often, the limited available information is disorganized and largely unavailable to land managers, researchers, and stewards.

Springs Online Database

SSI developed Springs Online—a secure, user-friendly, online database where users can easily enter, archive, and retrieve springs information (http://springsdata.org/ Fig. 6-1). This database is relational, providing the ability to contain many surveys related to each site and to analyze diverse variables and trends over time. It is broadly

Fig. 6–1. Springs Online at http://springsdata.org/ is a secure database designed to enter, analyze, and report on springs data. Users must create an account, and a sophisticated permissions structure protects proprietary or sensitive information.

framed to accommodate a wide array of variables and information needs. It also supports data collected using several common protocols.

The primary tables and the relationships between them are the foundation of a relational database that allow users to export meaningful data. It is important to provide a wide range of information products that are easy to export. Springs Online can provide commonly requested reports on flow, water quality, physical characteristics, soils, biota, and condition. It is also easy to export summary reports into Microsoft Word for individual surveys, or for a group of surveys that are collected into a project. The database manager also can design complex queries that export data for unanticipated information needs.

The information collected in each category is complex, and many of the data are interrelated. For example, water quality is linked to flow, geology, geomorphology, soils, flora, and fauna. To address this complexity, Springs Online provides a framework to compile this information and to analyze biological, physical, and cultural relationships, many of which are poorly understood.

The database facilitates archival of qualitative and quantitative information within these categories to document present conditions, establish a baseline for future reference, inform the assessment process, guide monitoring, evaluate stewardship efforts, track restoration actions, and monitor changes influenced by aquifer depletion, climate change, and other factors for individual springs, or for many springs across a landscape. The long-term value of such collaborative information management systems is the opportunity to share data with other springs ecosystem managers across political boundaries.

A small team of experts with knowledge of geography, hydrology, biology, socioeconomics, and anthropology can gather field information, typically in about 1.5 to 3 hours, and record it on standardized field sheets. Springs Online pages and tabs match the format of the field sheets to allow an individual with limited training to enter the information quickly and easily. Although it is possible to enter some, if not all, of the data in the field (if internet access is available), this method lacks a paper trail that is of great value.

The Springs NMRAM inventory field sheet (Appendix A) includes seven pages for data entry, one key page that lists dropdown box options within the database, and a sheet of graph paper for the sketchmap. The system is populated with drop-down fields that facilitate data entry while minimizing error. Buttons and tabs allow the operator to easily move between forms.

Springs Online is designed based on the assumption that springs and wetlands stewards will want, use, and maintain a long-term information management program for their springs and springs management actions. In the case of large landscape management units (e.g., NMED), such an information management system needs to relate to the steward's goals as well as their geographic information system (GIS) program. Every night, all data are exported from Springs Online into a geodatabase that includes all related tables and metadata. Upon request from a land manager, SSI can export a geodatabase, clipped for their land unit, and provide updated geodatabases as new data are added. Thus, Springs Online provides a secure platform for data entry and reporting, and exports into a GIS to allow for geospatial analyses.

Information security is a high priority when archiving sensitive information gathered from Tribal lands, private property, and historical sites rich in artifacts in New Mexico. Springs Online offers secure archival of such information and can assign permissions specific to a steward and their staff. Project managers can create and administer their own project, and apply permissions for their staff or partners to access and edit data. This increases the autonomy of land management agencies to manage and protect their own information.

Springs Online User Accounts

This technology is freely available to all springs stewards who sign up for an account. Upon opening the ***Homepage*** (http://springsdata.org/index.php), users have the option of creating a new account or logging in.

Creating an Account

To set up a new account, click the ***Create Account*** button to open a ***Create New Profile*** form.

Fill in the information (those with red font are required). Under Land Units of Interest, Research Interest, and User Category, please provide sufficient information that will allow Springs Online administrators to apply appropriate permissions.

Create a user name and enter a password that you can remember. Then click ***Submit Profile***. You can always edit this information from the ***Homepage*** by clicking ***My Profile***.

Upon setting up an account, an email will be sent to the SSI Database Administrator. Permissions are not applied automatically, so users should also request access to data for specific land units and projects from administrators.

Please note that this database is a collaborative project, developed and administered by the Springs Stewardship Institute of the non-profit Museum of Northern Arizona. The database is intended for non-commercial research, conservation, and planning purposes only. For any commercial use, including consulting services, contact SSI to discuss the intended use and to arrange payment for the service. Please also note that the Springs Online citation is available from the ***Homepage*** and should be used to identify the data souce.

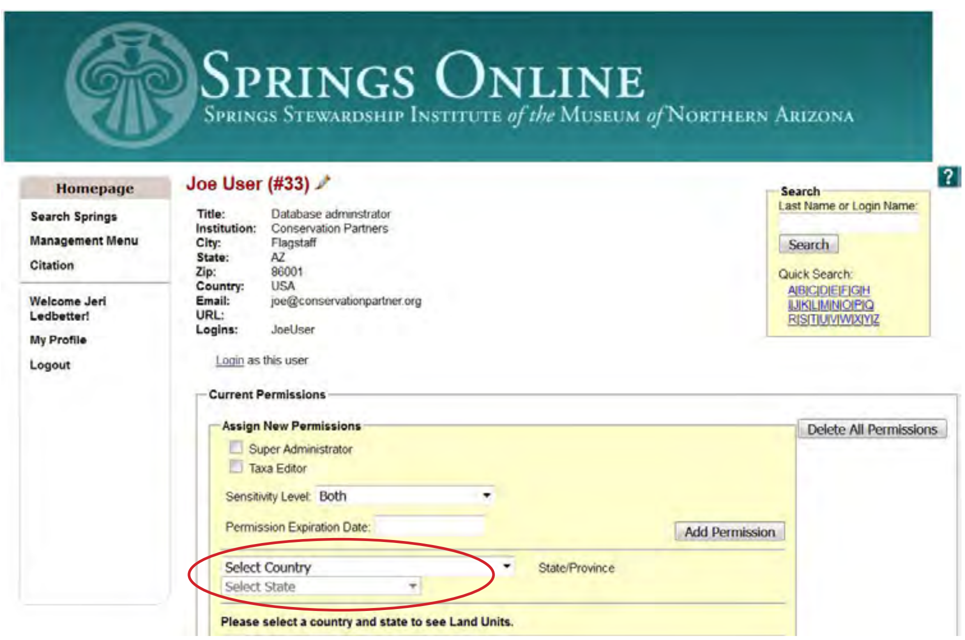


Fig. 6–2. Permissions form opened with a user selected. Select the Country and the State from the Dropdown lists (circled in red). The land units for which the Administrator has permissions will appear below.

User Permissions

The only springs location information that is available to users without specific permissions is that which has already been published (for example, included in USGS databases or depicted on maps), or cleared by the land manager or researcher for release. To access survey information, users must have permission for the ***Land Unit Detail*** as well as the ***Project***. ***Land Unit Details*** are individual units within a ***Land Unit*** category (e.g., US Forest Service is a land unit, and Kaibab NF, Williams RD is a ***Land Unit Detail***.) Each survey must be applied to a ***Project***. There are three primary levels of permissions - ***Reader***, ***Editor***, and ***Administrator***. These levels can be applied both to ***Land Unit Detail*** and to ***Projects***.

Reader permissions are useful for researchers and students, only allowing them to read and download, but not write data. ***Editor*** permissions are required in order to add or edit data. ***Administrator*** permissions allow the most capabilities, including adding or deleting sites or surveys, and renaming springs. ***Administrators*** can also apply permissions for other users for land units or projects, up to and including ***Administrator*** level.

Permissions may also be applied with an expiration date should they only be needed for a limited period of time. ***Sensitivity*** levels can be set for a site to ***none***, ***location data***, ***survey data***, or ***both***. Selecting both indicates that locations and survey data for all sensitive springs will be hidden from users unless they have that level of sensitivity permissions. Selecting none will indicate that no information is sensitive for the site, and any user with ***Land Unit Detail*** permissions will have unrestricted access to the data.

Administrators

We encourage land managers to take an active role in managing access to

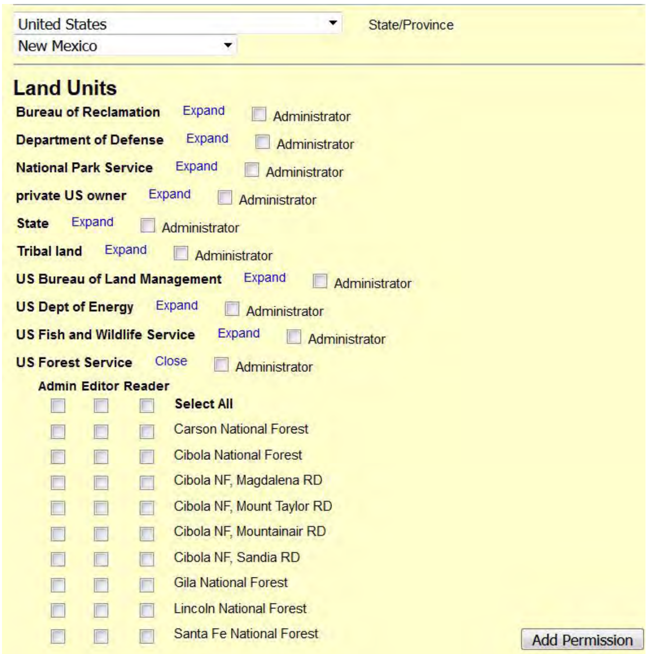


Fig. 6–3. Permissions form with Land Unit Details listed. Select one permission level - Admin, Editor, or Reader, and click Add Permission.

their data. Becoming an administrator for a Land Unit offers land managers the ability to grant or revoke permissions for other users, such as staff, volunteers, or contractors who are assisting with research and data entry. From the Home Screen, a land manger with Administrative permissions can select the ***Management Menu***, then click the ***User Permissions*** link. In the Search field, enter the last name or login name for a user, and click ***Search***. A list of names will appear under ***Users***. Clicking the desired name will open the ***Permissions*** form (Fig. 6-2).

From the ***Permissions*** form, set the ***Sensitivity*** level required to None, Location, Survey Data, or Both. Here you may also want to consider setting a ***Permission Expiration Date***, in the format yyyy-mm-dd.

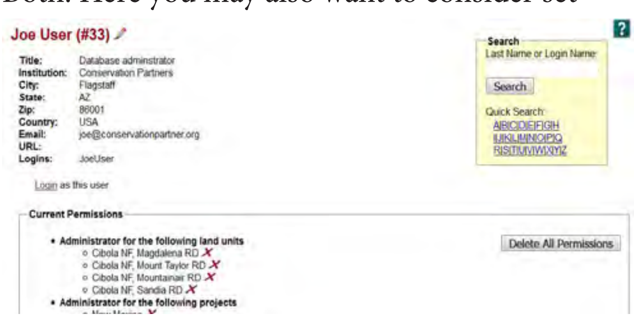


Fig. 6–4. Permissions form with permissions applied for New Mexico forests and the New Mexico project. To revoke individual permissions, click the red "X". To revoke all permissions, click the Delete All Permissions button.

The Administrator should apply permissions for the ***Land Unit Detail*** as well as the ***Project***. To access the list of Land Units, select the Country and the State. Click Expand to view the ***Land Unit Details*** (Fig. 6-3). Then check one permission level, and click ***Add Permissions***.

Next, under the Projects list, check ***Admin***, ***Editor***, or ***Reader*** permissions required, and then click ***Add Permissions***.

Permissions will then appear below the user information (Fig. 6-5). To revoke individual permissions, click the red X to the right. To revoke all permissions, click the ***Delete All Permissions*** button.

Taxonomic Editor

The database administrators wish to maintain relatively tight control over the taxonomy. Land Unit Administrators may make taxonomic edits to invertebrates, vertebrates, and flora. Please contact SSI to request this permission.

Training Site

This database is designed to let you easily add and update springs data, but we recognize that users might want to practice adding data or try out the interface in a safe way that will not affect the data in the live database.

SSI maintains a training site (Fig. 6-5) that mimics the database in all respects except that it

Fig. 6–5. Springs Online at http://springsdata.org/test is a practice site that allows users to experiment with entering and modifying data. Use of this site requires an account and permissions.

does not modify the live data. Users who would like to practice with the training site may access it at http://springsdata.org/test/. The information is refreshed regularly, but users will likely need to add a profile and obtain permissions for the test site as well.

Searching for Springs

Each spring is entered in the database with the georeferenced location, land ownership, and managing agency. The database automatically generates a unique ***Site ID number*** that is used in the relationship structure. This ***Site ID number*** also differentiates between springs with similar names (for example, there are currently nearly 400 "Willow Springs" in the database).

Although many remain unmapped, it is important to make sure a newly discovered spring is not already included before adding it. To avoid adding a duplicate record, conduct a thorough search for an existing record before you create a new one. To do this, click the ***Search Springs*** link from the ***Home Page*** to open the ***Search Form*** (Fig. 6-6). This interface allows users to enter a wide variety of search criteria.

Search by Coordinates

One of the best ways to find a spring is to search within a radius of the spring's coordinates. In the point radius search (circled in red in Fig. 6-6), enter the new spring's latitude and longitude in decimal degrees. Make sure to enter the longitude as a negative number if you are in the western hemisphere. Then enter a radius of 0.1 miles. Many springs are mis-mapped by this much or more. You have the option to change the units to kilometers. Then click the ***Search*** button.

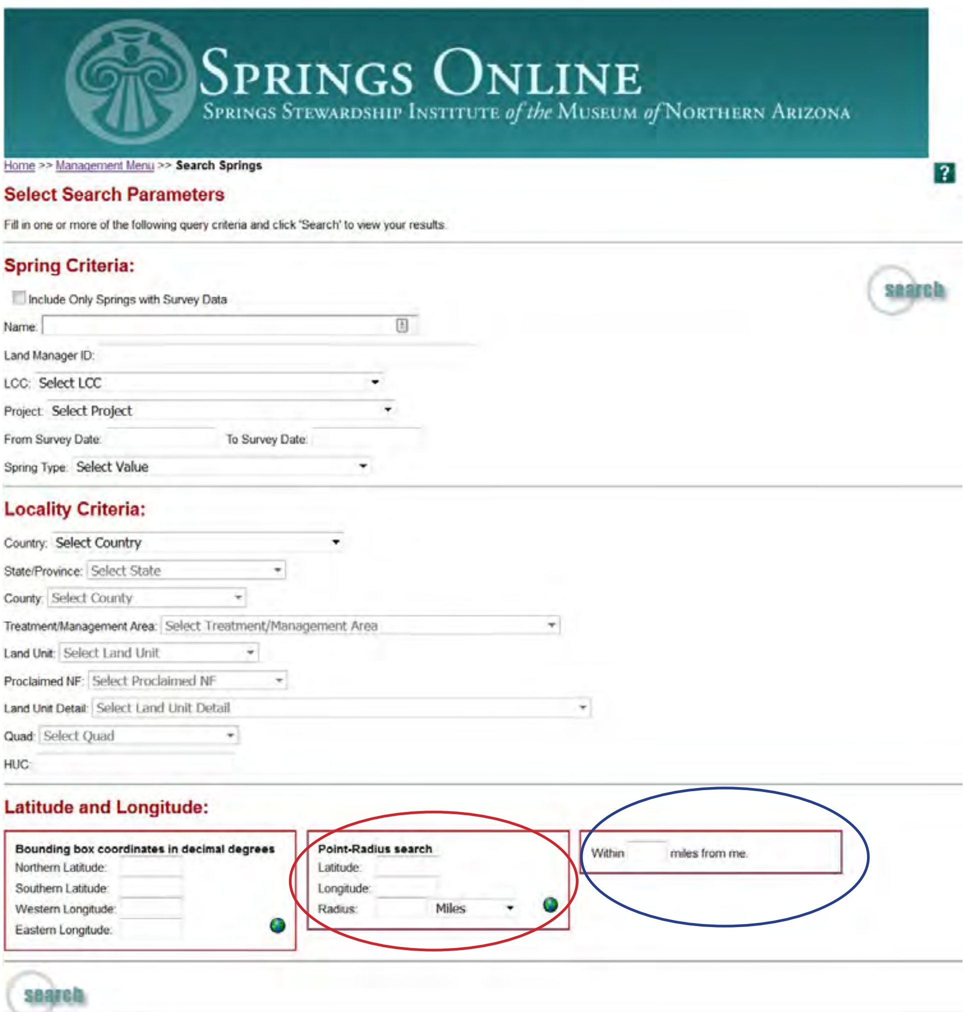


Fig. 6–6. Search Form with Search by Radius option (circled in red) or Search within a radius of your location, if location services are enabled on your device.

This will generate a list of springs within that search radius. If there are no results, try 0.2 miles, or 0.3 miles. If there are still no results, you may either have a new spring, or you may not have permissions to view springs data within that area.

If you are using a smartphone or tablet with location services enabled, you can try the option to search within a distance of your location (circled in blue in Fig. 6-6).

Other options include entering or drawing a bounding box or point radius search using a map by clicking the small globe to the right of either selection boxes. You can enter coordinates in these to narrow the search, then click the map symbol to open the map where you can move across the map using the Pan Tool (the

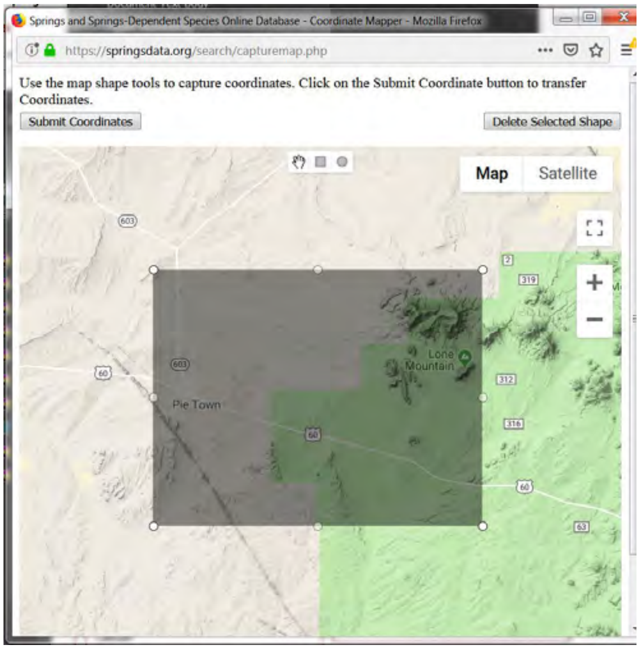


Fig. 6–7. Search Mapping Tool with a bounding box drawn. This tool is accessible from the Search Springs form.

hand), and draw in and refine the search boundary using the boundary tool (the box or the circle, Fig. 6-7). Note that you can also select ***Map*** or ***Satellite View***. Once you have set the boundary, click ***Submit Coordinates*** to copy the coordinates to the search criteria; then click ***Search*** to generate the Search Results (Fig. 6-8).

Search Parameters

Note the checkbox labeled, ***Include Only Springs with Survey Data***, to limit your search to locations with inventory data. Users can also locate springs by entering a variety of parameters in two categories - ***Spring Criteria*** and ***Locality Criteria***. One option under Spring Criteria is searching by name. However, as noted previously, searching by ***Spring Name*** is often not useful due to many springs having the same name. Also, many springs have more than one name, or they were imported from a data source that does not include the name (e.g., with NHD databases this is often the case). The other parameters are much more likely to yield the spring you seek. These include the Project, survey date range (entered in the format yyyy-mm-dd), and spring type.

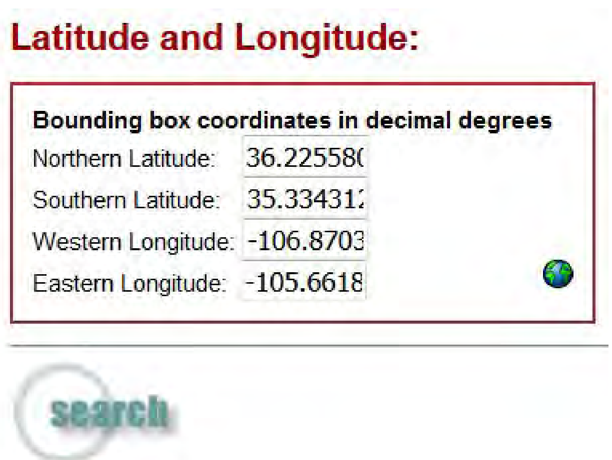


Fig. 6–8. Coordinates submitted from the bounding box drawn in Fig. 6-7.

The ***Locality Criteria*** includes cascading fields that filter based on higher level entries. For example, when you select United States as the ***Country***, the states appear as a list in the ***State/Province*** field. From here, entering the remaining fields is not necessarily required. For example, leave the ***County*** field blank to not limit the search to a particular county within the state. If you skip to the ***Land Unit*** and select US Forest Service, a list of ***Proclaimed National Forests*** will appear, as well as a list of forest ranger districts in the ***Land Unit Detail***. It is also possible to select by 8-digit Hydrologic Unit Code (***HUC***) or ***USGS Quad***.

Throughout the database, with few exceptions, no other values may be entered in the dropdown fields other than those listed. This eliminates the potential for misspellings and incorrect entries, and assures consistency of data for reporting and analysis. For example, requiring that species are always entered the same way makes it possible to view all occurrences of that species throughout the database.

Search Results

As an example, the bounding box created in Figs. 6-7 and 6-8 generated a ***Search Results*** list (Fig. 6-9). Click on the ***Basic Record Information*** link (circled in red in Fig. 6-9) to view general information about the selected spring (***Site ID***, ***Site Name***, ***Locality***, ***Land Unit***, ***USGS Quad***, 8-digit HUC, ***Coordinates***, and ***Data Source***, as well as an image if it is available. The ***Query*** symbol (circled in blue in Fig. 6-9) exports available data into a *.csv file that will open using Microsoft Excel. This includes the information above, along with much more detailed information. Click on the ***Maps*** tab to access map views, including Google Maps and Google Earth. Note that the

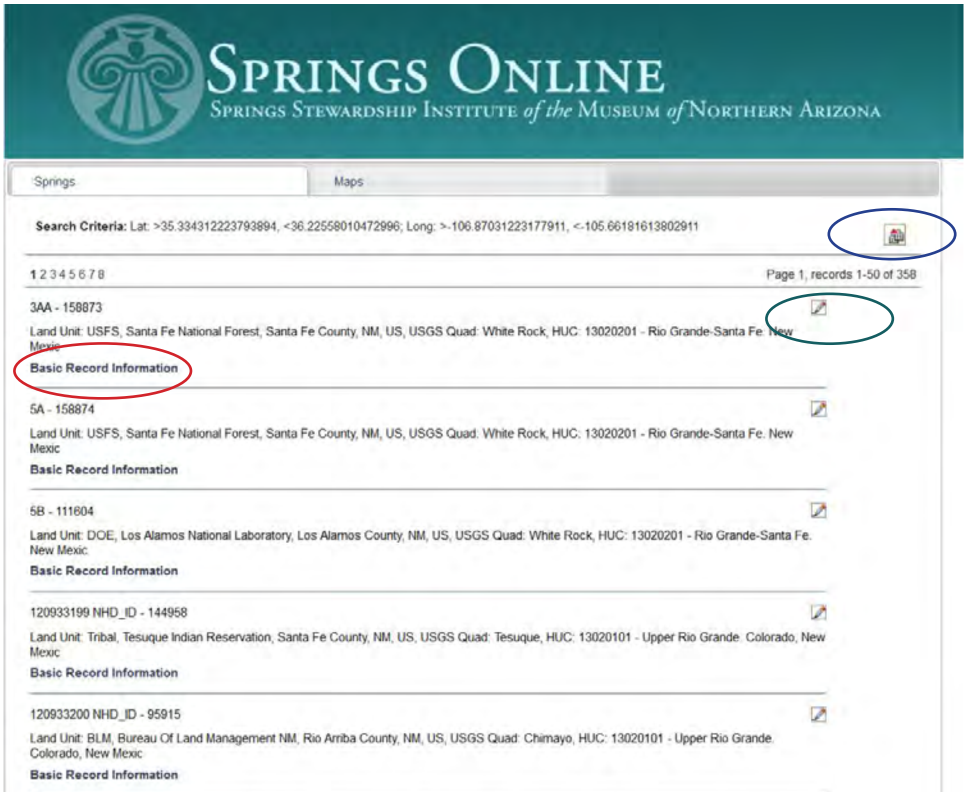


Fig. 6–9. First page of 358 search results from the bounding box created in Fig. 6-7. Click the Basic Record Information link (circled in red) to view general information about the site. Click the query symbol (circled in blue) to download a *.csv file with detailed information. Click the Edit symbol (circled in green) to open the Site Form. Select the Maps tab to view the selected springs in Google Earth or Google Maps.

only springs displayed will be those meeting your search criteria, and those that you have permission to access.

Click on ***Display Coordinates in Google Map*** to open the map view. This will display the results in a map where symbols are categorized by Spring Type. If it does not appear to open, it may be hidden behind your browser window, although it should be refreshed. You can zoom and pan in this map window, and select either ***Map*** or ***Satellite View*** (Fig. 6-10).

If you click on a symbol for a spring, a web page will open with ***Basic Record Information*** for the site. Please note that only one of these pages will open at a time, so if it does not appear to be working when you click on a spring, it may already be open in a browser window that is hidden from view; however, the information should be refreshed.

Click on the ***Springs*** tab to view the ***Search Results***. Click on the Edit button on the right of the spring name (circled in green in Fig. 6-9) to open the ***Site Information Form*** (described in the next section). This link will not be visible if you do not have the appropriate permissions. Please contact the land unit administrator or SSI at springsdata@musnaz.org if you need assistance.

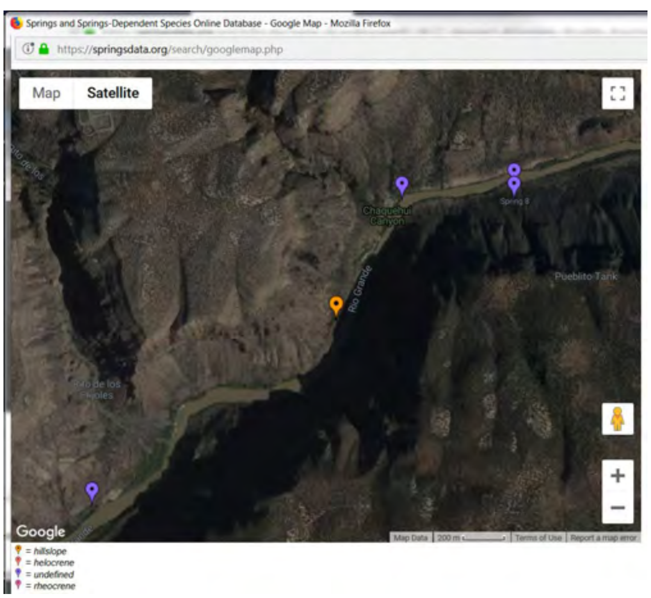


Fig. 6–10. From the Search Results, click the Map tab to view selected springs in Google Maps. This allows you to pan and zoom, and select Map or Satellite View. Symbols are based on the springs type, if known. Click on a spring symbol to view the basic record information.

Site Form

Each spring in the database has its own unique ***Site ID***. If you happen to know it (e.g., recording it during the process described above), this is the fastest and easiest way to open a site form for a spring. Rather than using ***Search Springs*** from the ***Homepage***, select ***Management Menu***, then

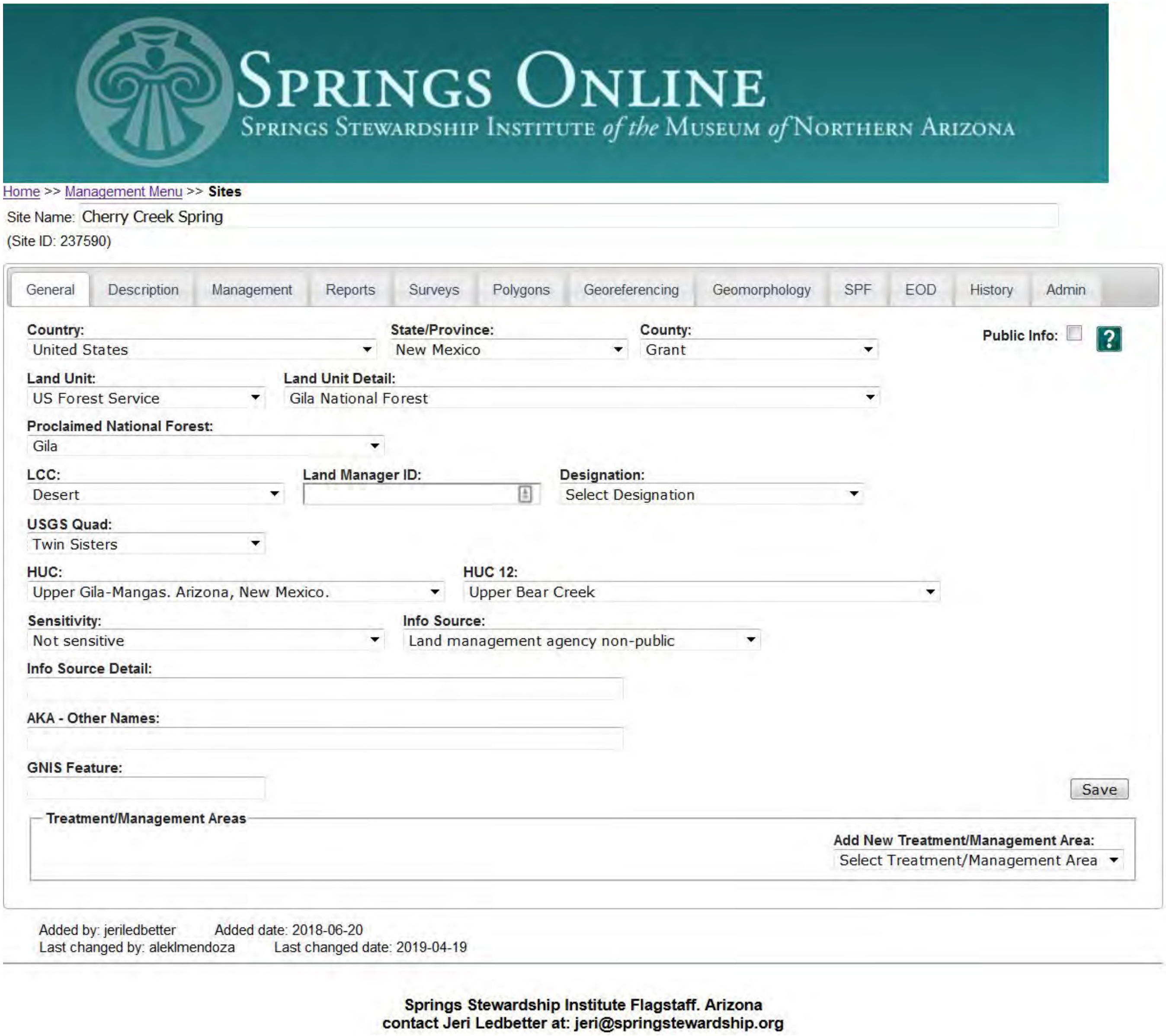


Fig. 6–11. Site Form with the General tab selected, displaying information about Cherry Creek Spring, Site ID 237590.

click ***Site/Survey Management***, and enter the Site ID. Here you can also enter the site name, which works if the name is unique (e.g., Susans Garden Spring). When you enter this information in the search field, a list of possible results will appear below; select the one that you are looking for to open the ***Site Form*** (Fig. 6-11).

Using the variety of ways to arrive at the ***Site Form***, here you will find eleven tabs that display information about the site that tend to not change over time, so they are all related to the ***Site Table*** in the database structure. These include fields such as ***County***, ***Land Ownership***, ***Coordinates***, ***Elevation***, ***Geomorphology***, ***Geology***, S***olar Radiation Budget***, ***Access Directions***, and an overall ***Description*** of the site and its history. The following screen shots and figure descriptions explain information in each of these tabs. Notice that when any data associated with a site are changed, the user name and date are recorded at the bottom of the form.

Site Form: General Tab

The ***General Tab*** includes locational information, such as ***Name***, ***Site ID***, ***State***, ***County***, ***Land Ownership***, and ***Land Unit Detail***. This tab also includes basic geographic information such as ***Landscape Conservation Cooperative*** (***LCC***), ***USGS Quad***, ***8-digit Hydrologic Unit***

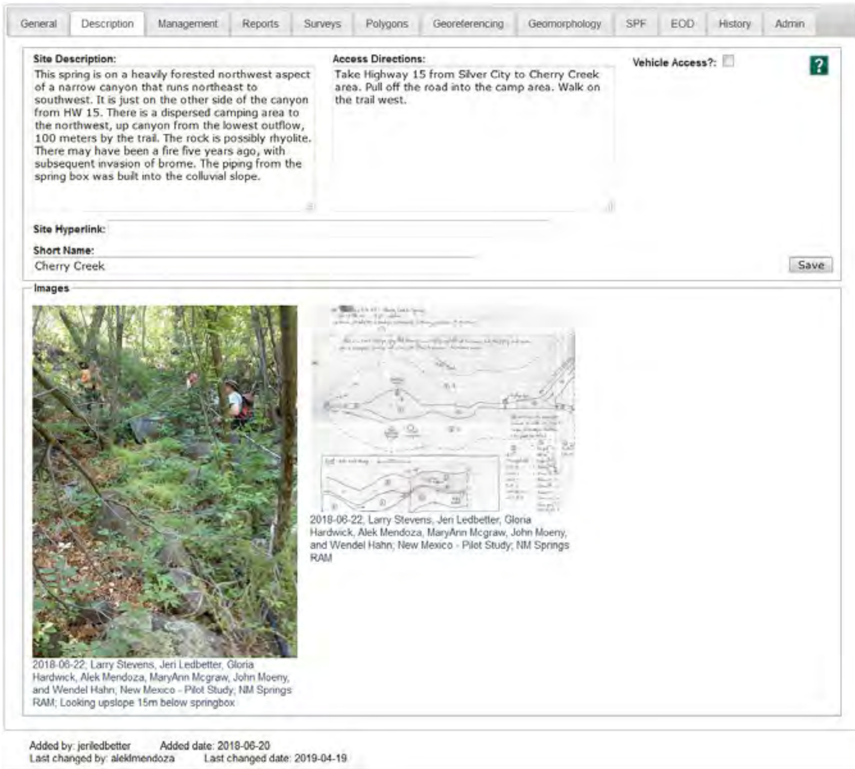


Fig. 6–12. Site Form with the General tab selected, displaying the Site Description, Access Directions, short name (used for mapping and data export), and the photograph and sketchmap from the most recent survey, if these are available.

Code (HUC), and ***12-digit HUC***. For springs with more than one name, enter additional names in the ***AKA*** field. If a land manager has a spring ID, that information can be entered into ***Land Manager ID***; this field is included in the search criteria on the ***Search Form***. There is an option to choose the ***Treatment/Management Area*** where the spring is located. In addition, the ***Sensitivity*** status of the site designates whether the Location or Survey information are sensitive, or neither or both. Some access Permissions are based on this field. The ***Public Info*** checkbox indicates whether or not data have been published (e.g., in the NHD database). After entering or updating data, click ***Save*** to avoid losing any of the information.

Site Form: Description Tab

The ***Description Tab*** includes the ***Site Description*** - general information about the site, its context, and history (Fig. 6-12). Use complete sentences and try to provide enough information that future surveyors will recognize the site. ***Access Directions***, also entered on this tab, should include any challenges to accessing it (e.g., crossing private land or climbing a cliff). Also it may include helpful details such as sensitive land constraints (Wilderness Areas, etc.). ***Images*** and ***Sketchmaps*** of the site from the most recent survey also are displayed on this tab. However, images can only be uploaded in a survey; they cannot be entered from this form. In the ***Site Hyperlink*** field you can enter a hyperlink to an internet location that may offer more information about a site. The ***Short Name*** eliminates the word "Spring" from the name is used for mapping and data exports. This field is populated when a new spring is added, but must be updated if the name is changed.

Site Form: Management Tab

The ***Management Tab*** provides fields to record Water Rights, Grazing Allotments, and Cultural Notes (Fig. 6-13). The management action module allows land managers to document actions such as restoration, rehabilitation, fencing, invasive species removal, etc. This module is currently available for beta testing; we welcome any comments or suggestions sent to springsdata@musnaz.org.

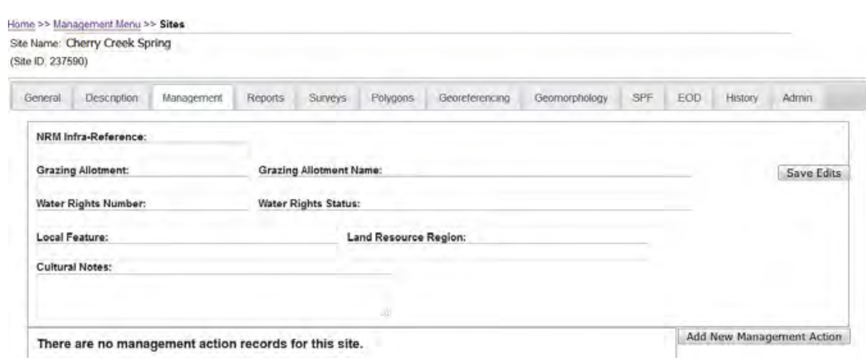


Fig. 6–13. Site Form with the Management tab selected, displaying Grazing Allotments, Water Rights, and Cultural Notes. The Management Action module, available for beta testing, is available here.

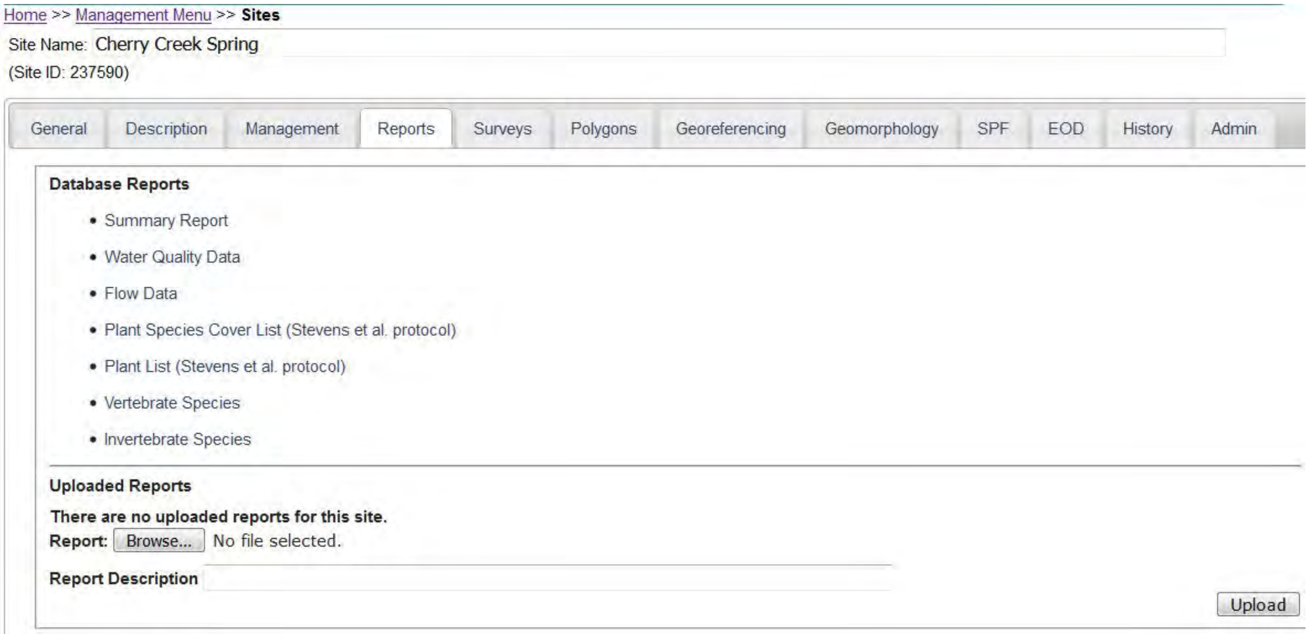


Fig. 6–14. Site Form with the Reports tab selected. The summary report exports all surveys into a Microsoft Word document that includes images, physical characteristics, and survey data. The other reports export data into *.csv files.

Site Form: Reports Tab

The ***Reports Tab*** is extremely useful once you have entered survey data (Fig. 6-14). Here, you can generate a site summary report in Microsoft Word that includes the physical characteristics, survey data, photographs, and the sketchmap. You can also generate reports that include all survey data for ***Water Quality***, ***Flow***, ***Plant Species Cover***, ***Plant Species***, ***Vertebrate Species***, and ***Invertebrate Specie***s. With one click, data are exported into a *.csv file. You can also upload any historic reports associated with the site in PDF format. This could include scans of field sheets, old reports, etc. Click the ***Browse*** button, enter a description of the report, and then ***Upload***. These reports will then be available for download.

Site Form: Surveys Tab

The ***Surveys Tab*** displays the level of inventory for a site, as well as a list of survey records (Fig. 6-15). The ***Inventory Level*** indicates if a site has not been verified, if it has been surveyed, or identifies a site as not being a spring. ***Survey Status*** indicates the ***Extent of Data*** (***EOD***) of the highest survey level, based on the number of categories of collected data (e.g., Site Surveyed, EOD (>7).

Survey records include the ***Survey Date***, in the format yyyy-mm-dd, the extent of data collected (***EOD***, a numeric value between 1 and 10 that represents a count of categories that contain data), the ***Project*** name and ***Surveyors***' names. There can be many surveys for each location. The list can be sorted by any field by clicking the

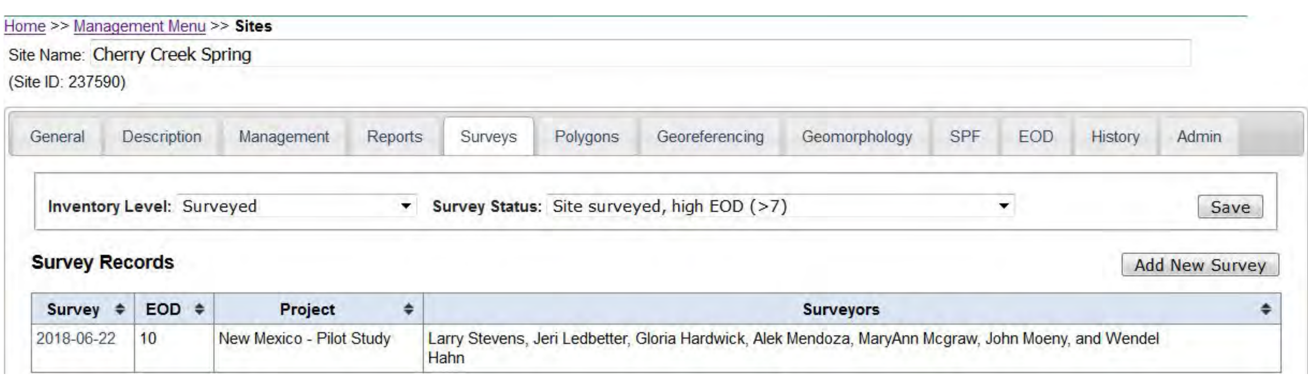


Fig. 6–15. Site Form with the Surveys tab selected. This tab indicates the level of inventory, and lists the surveys that have been entered. Click the date to open a survey.

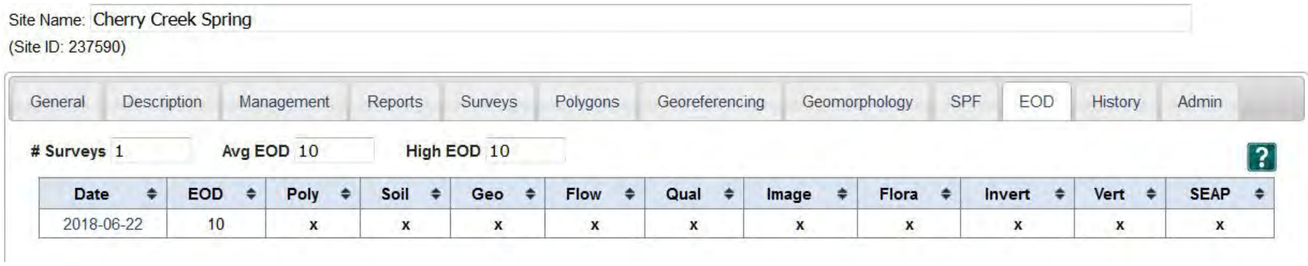


Fig. 6–16. Site Form with the EOD tab selected. Similar to the Surveys tab, this lists all of the surveys, but indicates which categories of data were collected. Click the date to open a survey.

arrow symbol in the column heading. The *Date* field is hyperlinked if a user has permission to access the data. Click the *Date* hyperlink to open a survey. Recall that a user must have permission for the Land Unit (in this case, Gila National Forest) as well as the Project (New Mexico - Pilot Study) to access a survey.

Site Form: Extent of Data (EOD) Tab

Similar to the Surveys tab, the EOD tab also lists the Survey Date, but displays "x" symbols that identify the categories that contain data (Fig. 6-16). Here the Date field is also hyperlinked if a user has permission to access survey data.

Site Form: Polygons (Site) Tab

The ***Polygons Tab*** displays the names and any comments associated with the Polygons (microhabitats) at the site (Fig. 6-17). Each polygon is assigned a ***Polygon Code***, (A, B, C...) as well as a ***Name***. The Name should be short, unique, and descriptive. Site Polygons may be applied to surveys, if appropriate. Should the geomorphology change, new microhabitats may be added. Detailed microhabitat characteristics (Soils, Vegetation, Moisture, Aspect, etc.) are not applied to the ***Site Polygon*** described here, but to the ***Survey Polygons*** described later. Click the ***Add Polygon*** button to add a new microhabitat. Should surveyors not identify microhabitats, the ***Entire Site*** is labeled ***Polygon X***. Please note that you must add and label ***Site Polygons*** here before they can be associated with a survey. ***Soils*** and ***Flora*** data can only be added to a ***Survey Polygon***. Once a microhabitat has been added, you can edit it by clicking the pencil symbol.

Site Form: Georeferencing Tab

This tab contains georeferencing information, as well as access to tools that will assist users with placing springs in the proper location (Fig. 6-18). ***Coordinates*** must be entered in NAD83 or WGS84. If coordinates are collected in NAD27, it is important to convert them correctly. Use http://www.ngs.noaa.gov/cgi-bin/nadcon.prl or another accurate conversion website.

Please note that if the ***Datum*** field is left blank, the point will not be considered accurate and will not be exported into a geodatabase. Users should enter coordinates in ***Decimal Degrees***. Periodically, SSI updates the ***UTMs*** and ***Degrees***, ***Minutes***, and ***Seconds*** based on this information, as well as the ***Township***, ***Range***, and ***Quarter Section***.

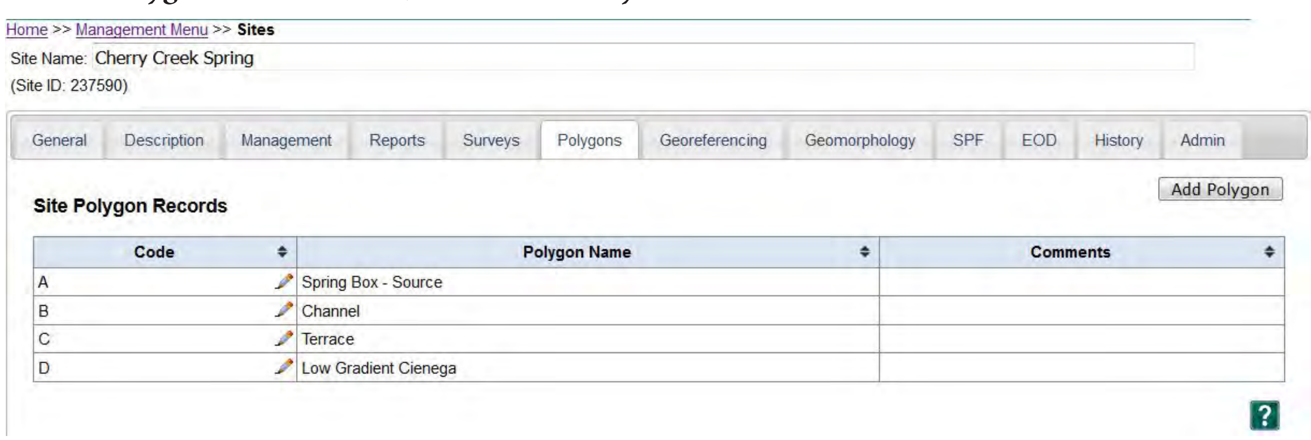
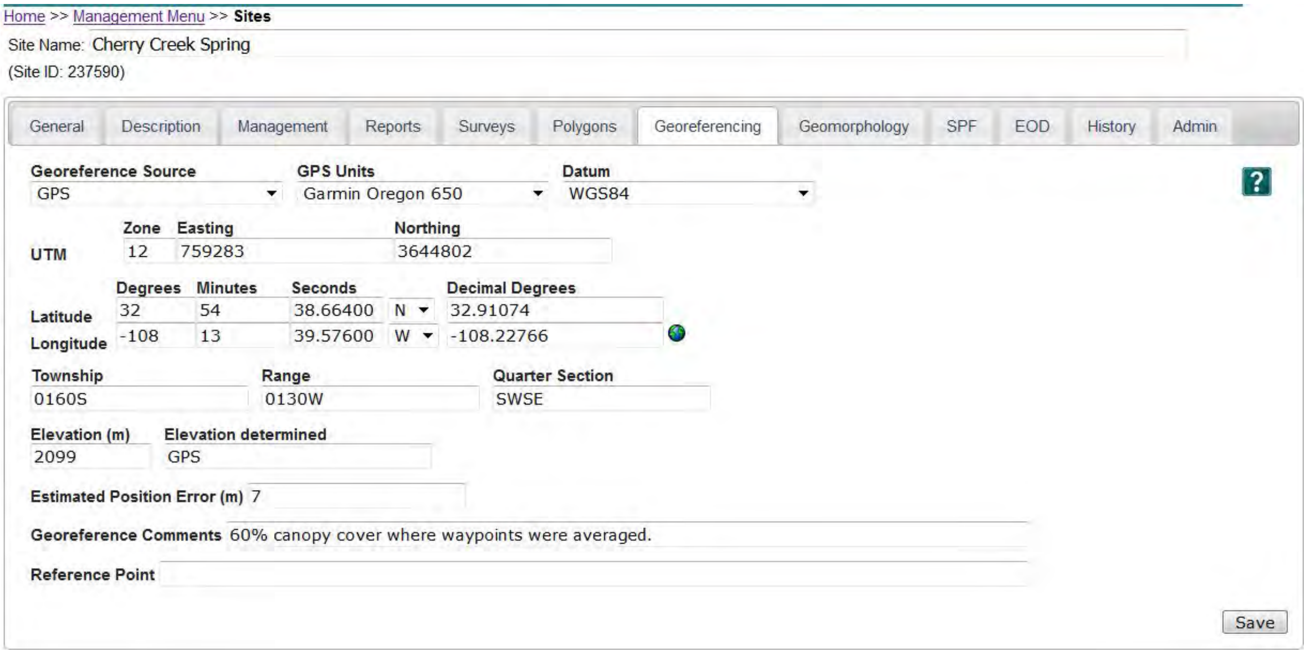


Fig. 6–17. Site Form with the Polygons tab selected. This lists the microhabitat polygons associated with the site.


Home >> Management Menu >> Sites

Site Name: Cherry Creek Spring

(Site ID: 237590)

General | Description | Management | Reports | Surveys | Polygons | Georeferencing | Geomorphology | SPF | EOD | History | Admin

Georeference Source: GPS
GPS Units: Garmin Oregon 650
Datum: WGS84

UTM — Zone: 12 — Easting: 759283 — Northing: 3644802

	Degrees	Minutes	Seconds		Decimal Degrees
Latitude	32	54	38.66400	N	32.91074
Longitude	-108	13	39.57600	W	-108.22766

Township: 0160S — Range: 0130W — Quarter Section: SWSE

Elevation (m): 2099 — Elevation determined: GPS

Estimated Position Error (m) 7

Georeference Comments 60% canopy cover where waypoints were averaged.

Reference Point

Save

Fig. 6–18. Site Form with the Georeference tab selected. Click the tiny globe to open Google Maps to view the site location (Fig. 6-19).

Elevation and *Estimated Position Error* should be entered in meters. If these were collected in feet, enter "ft" after the value (e.g. 4500ft), and the measurement will be converted to meters. As noted previously, many springs are inaccurately mapped. Should you feel compelled to change the coordinates to correct the location, please briefly explain in the Georeference Comments, and revise the *Georeference Source* and *GPS Unit* as appropriate.

The *Mapping Aid* (accessed via the small globe icon next to longitude) can be very useful, particularly if the estimated position error on your device is significant (Fig. 6-19). If you select the satellite layer and zoom in (Fig. 6-20), you can often clearly see (particularly in arid lands) the source of the spring, and the point may be mapped several meters off. If this is the case, you can drag and drop the point to the correct location. Please be careful with this feature. It can

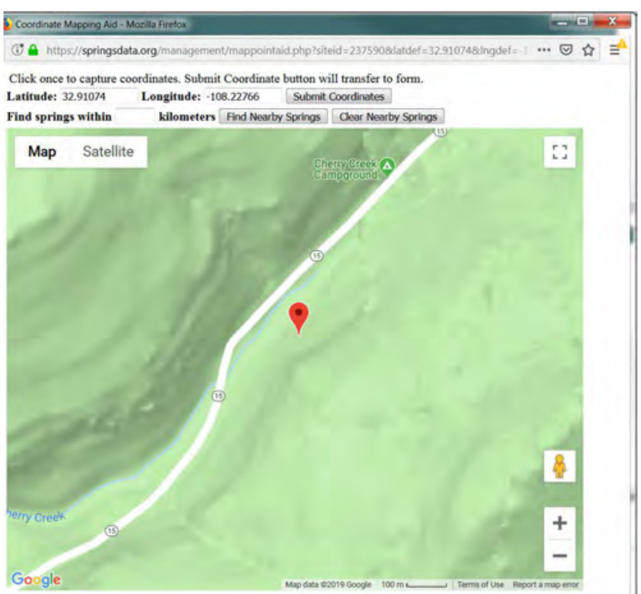


Fig. 6–19. Mapping tool opened to view the location of Cherry Creek Spring.

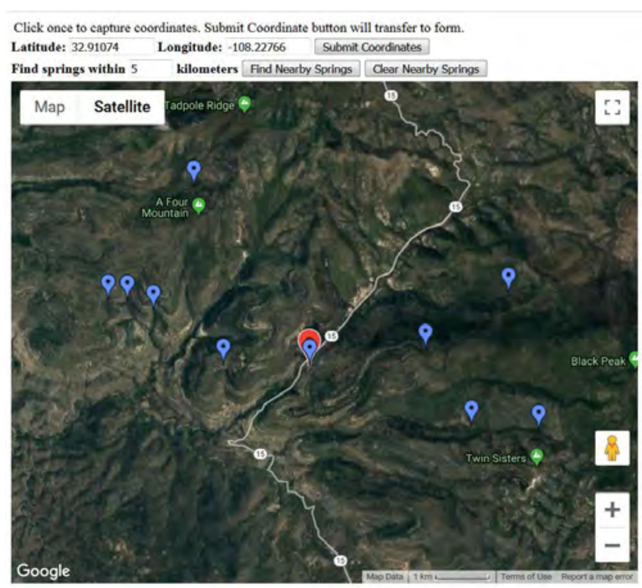


Fig. 6–20. Mapping tool with nearby springs mapped within a 5 kilometer radius.

be relatively easy to move the spring when you do not intend to. If this happens, simply close the mapping aid and the changes will not be saved. However, should you wish to save the new coordinates, click ***Submit Coordinates***, and the mapping window will close. The coordinates will be pasted into the fields on the ***Georeferencing Tab***, and the ***UTMs*** and ***Degrees***, ***Minutes***, and ***Seconds*** will be updated. Click ***Save*** to save the revised information.

You can also look for nearby springs from the mapping tool by entering a search radius and clicking "***Find Nearby Springs***". This is helpful with identifying duplicate springs entries. Hover the mouse over the various points to view the ***Spring Name*** and ***Site ID***.

Site Form: Geomorphology Tab

The Geomorphology information includes the ***Primary and Secondary Spring Type*** (Fig. 6-21). Also referred to as Sphere of Discharge, these include cave, exposure, fountain, geyser, gushet, hanging garden, helocrene, hypocrene, limnocrene, rheocrene, hillslope, mound-form, and anthropogenic. Generally, anthropogenic springs only emerge due to human manipulation (e.g., a mining excavation). Keys to these designations are displayed in the dropdown form. They are also fully described, with example photographs and diagrams, in the ***Subclass Chapter 4***. Although most springs have only one type of discharge sphere, some complex sites may have two or more.

Other fields on this tab include ***Emergence Environment***, ***Flow Force Mechanism***, ***Primary Lithology***, and ***Secondary Lithology***. When a Primary Lithology is entered, only appropriate Secondary Lithologies will be listed in the dropdown box for that field. For example, upon entering "Sedimentary" as the Primary Lithology, the Secondary Lithology will be limited to "sandstone, limestone, shale, etc." The name of the ***Geologic Layer*** and other geologic factors may be entered if known. The ***Soil Unit***, ***Ecological Unit***, and ***Map Sources*** are optional fields if this information is available.

The ***Distance to the Nearest Spring*** in meters will change as new springs are added. Periodi-

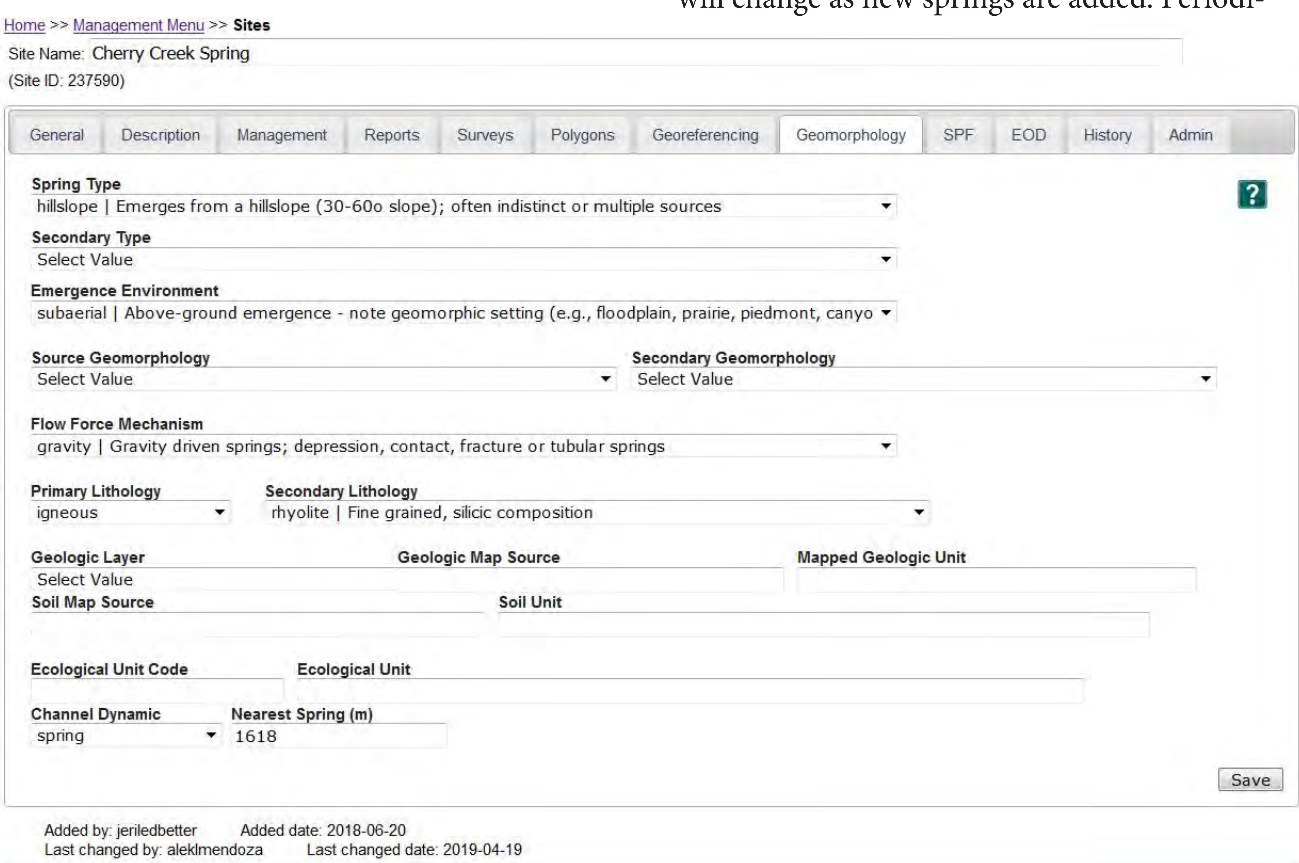
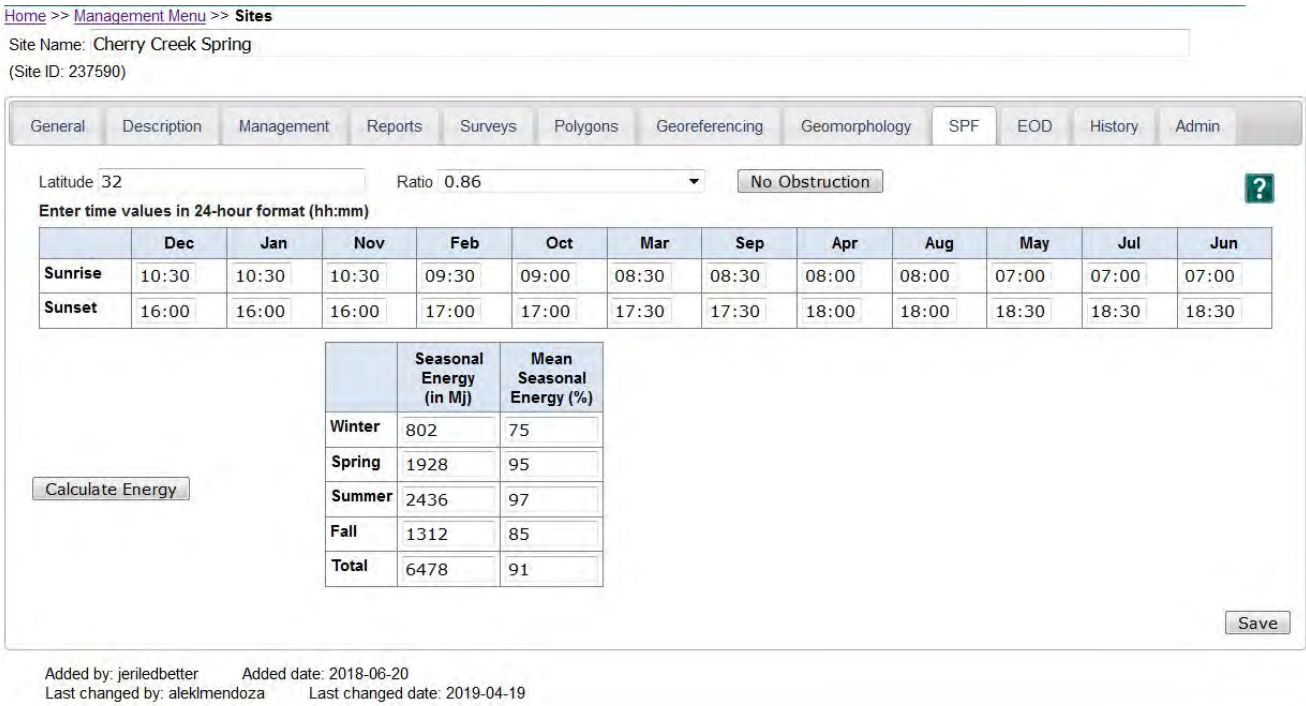


Fig. 6–21. Site Form with the Polygons tab selected. This lists the microhabitat polygons associated with the site.



Home >> Management Menu >> Sites

Site Name: Cherry Creek Spring

(Site ID: 237590)

General | Description | Management | Reports | Surveys | Polygons | Georeferencing | Geomorphology | SPF | EOD | History | Admin

Latitude 32 Ratio 0.86 No Obstruction

Enter time values in 24-hour format (hh:mm)

	Dec	Jan	Nov	Feb	Oct	Mar	Sep	Apr	Aug	May	Jul	Jun
Sunrise	10:30	10:30	10:30	09:30	09:00	08:30	08:30	08:00	08:00	07:00	07:00	07:00
Sunset	16:00	16:00	16:00	17:00	17:00	17:30	17:30	18:00	18:00	18:30	18:30	18:30

Calculate Energy

	Seasonal Energy (in Mj)	Mean Seasonal Energy (%)
Winter	802	75
Spring	1928	95
Summer	2436	97
Fall	1312	85
Total	6478	91

Save

Added by: jeriledbetter Added date: 2018-06-20

Last changed by: aleklmendoza Last changed date: 2019-04-19

Fig. 6–22. Site Form with the SPF (Solar Pathfinder) tab selected. Sunrise and sunset times are entered for each month of the year to calculate the seasonal energy that reaches the site.

cally, the database administrator updates these values.

Site Form: Solar Radiation (SPF) Tab

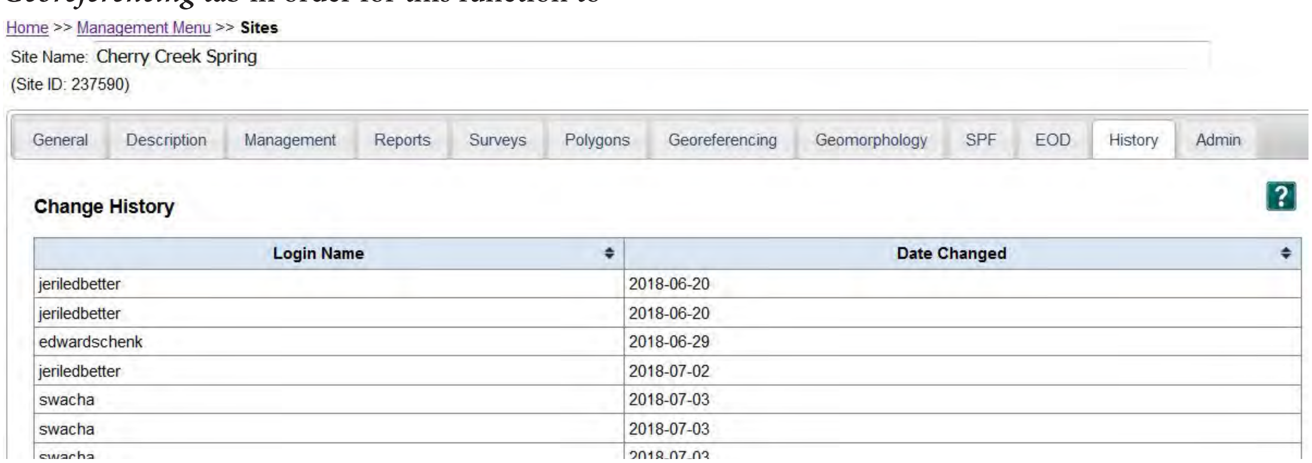
The solar radiation that reaches a site can be estimated using a Solar Pathfinder™ (Fig. 6-22). This relatively inexpensive device displays the sunrise and sunset at the source. The data should be entered in 24-hour time as hh:mm. Upon entering these, click the ***Calculate Energy*** and ***Save*** buttons to calculate the seasonal energy budget in Mj/m^2 and percent of potential energy for the site. The ***Latitude*** value must be entered on the ***Georeferencing*** tab in order for this function to work. Should there be no obstruction at the site, click the ***No Obstruction*** Button to automatically enter the values. This function also requires a ***Latitude*** value.

Site Form: History Tab

The ***History*** tab (Fig. 6-23) tracks the history of changes to a site record by login name and the date that the record was changed. This is useful for quality assurance and quality control.

Site Form: Admin Tab

The Admin tab (Fig. 6-24) enables users with Administrative permissions to change the site



Home >> Management Menu >> Sites

Site Name: Cherry Creek Spring

(Site ID: 237590)

General | Description | Management | Reports | Surveys | Polygons | Georeferencing | Geomorphology | SPF | EOD | History | Admin

Change History

Login Name	Date Changed
jeriledbetter	2018-06-20
jeriledbetter	2018-06-20
edwardschenk	2018-06-29
jeriledbetter	2018-07-02
swacha	2018-07-03
swacha	2018-07-03
swacha	2018-07-03

Fig. 6–23. Site Form with the History tab selected. The name and date is recorded when a user makes any changes to a site record.

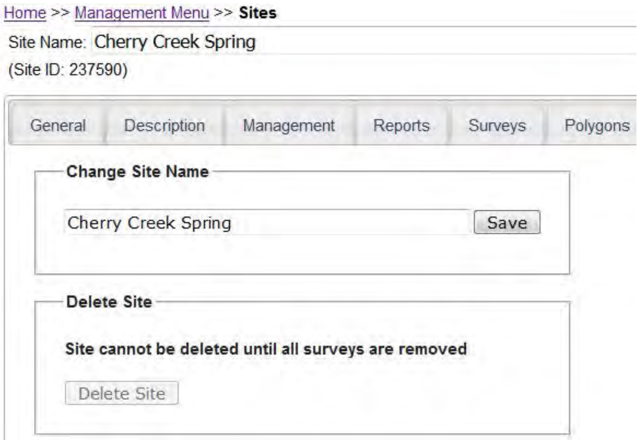


Fig. 6–24. Site Form with the Admin tab selected. This tab is only visible for users with Administrative permissions for the Land Unit.

name or to delete sites. A site may not be deleted if there are surveys associated with it. If you have such permission, be absolutely certain before you delete a site. If it should turn out to not be a spring, it is often best to change the inventory level to "Not a Spring" on the *Surveys* tab. In this case, write an explanation for the change in the *Site Description* field on the *Description* tab.

Survey Information

This section explains the process for accessing, adding, or editing survey data. To open a survey, select the *Surveys* tab and click on the *Survey Date*. This hyperlink will only be active if you have permissions to access the survey.

To add a new survey, locate the correct spring, select the *Surveys* tab, then click the *Add New Survey* button (Fig. 6-25). You will need to enter the *Survey Date* in the format yyyy-mm-dd. If known, enter the survey *Begin* and *End* times in 24-hour format (hh:mm). You must enter a *Project* from the dropdown list that you have permission to access. If you wish, you can add a new Project; you will automatically have *Administrative* permissions for your own project.

Select the *Survey Protocol*; the Springs NMRAM is listed under the dropdown. Enter the full names of the Surveyors (include an "and" before the final name), and click the *Create Survey* button.

There are ten tabs on the *Surveys* form – General, Reports, Flow, Water Quality, Invertebrates, Vertebrates, Images, SEAP, QAQC, and Admin. These tabs will be discussed in the screen shots and figures below.

Survey Form: General Tab

The *General* tab includes general information about the survey such as the *Survey Date*, *Beginning* and *Ending* times, and *Surveyors Names* (Fig. 6-26). As mentioned previously, each Survey

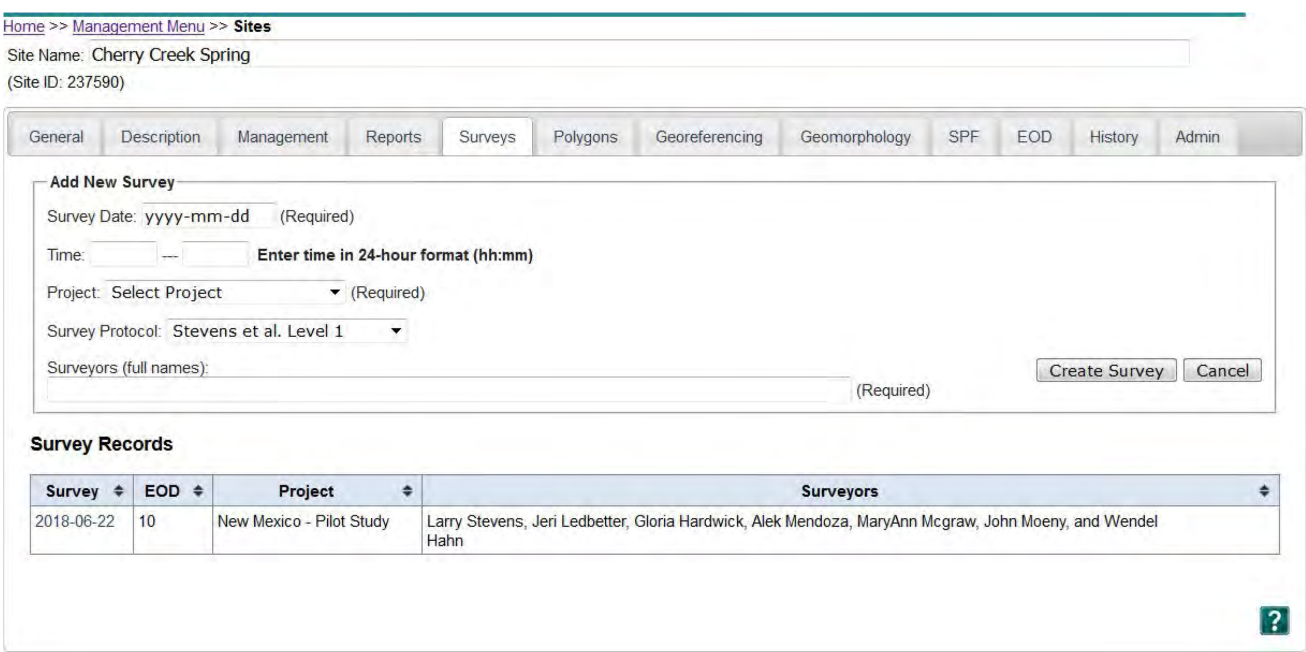


Fig. 6–25. Site Form with the Admin tab selected. This tab is only visible for users with Administrative permissions for the Land Unit.

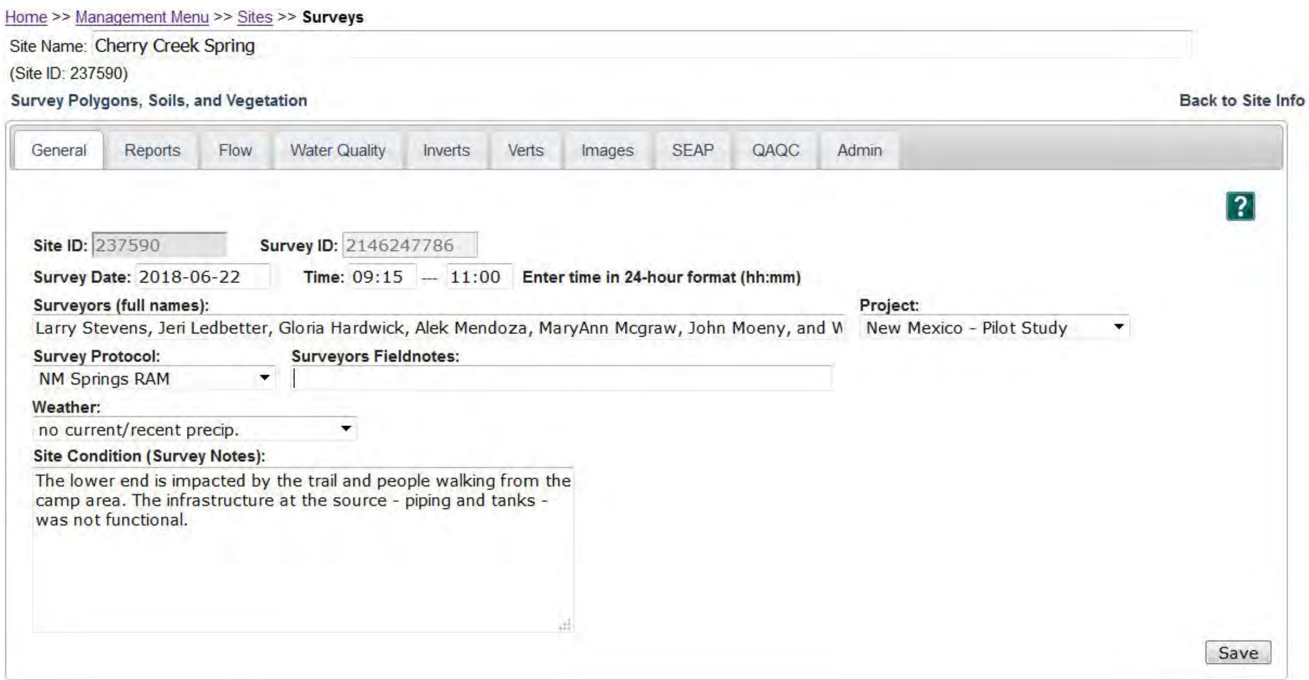


Fig. 6–26. Survey Form with the General tab selected. Note that each survey has a unique identifier. All survey data relate to this Survey ID.

must be associated with a ***Project***, and users must have permission to access the Project. Additional fields include the ***Survey Protocol*** and ***Weather*** at the time of the survey. To return to the ***Site Information*** form, click the ***Back to Site Info*** link.

Survey Notes refer to the condition of the site as it appears on the day of the survey. Please use complete sentences, but do not use separate paragraphs as these will not export properly. You could comment on heavy trampling by cattle or elk, ineffective fencing, recent fire or flooding, human over-use, etc. It can also include information that may not otherwise be reported in the standardized fields.

Survey Form: Reports Tab

From the ***Reports*** tab you can click the ***Summary Report*** hyperlink to generate a summary report in Microsoft Word that includes physical characteristics, survey data, images, and the sketchmap. See Appendix C for an example. You can also upload reports for the spring (e.g., water chemistry laboratory results).

Survey Form: Flow Tab

The ***Flow*** tab manages flow data for the survey (Fig. 6-27). ***Persistence*** will often be unknown. Similarly, ***Flow Variability*** requires multiple surveys over time to answer. ***Flow Consistency*** (e.g., perennial, ephemeral) can often be determined based on presence or absence of vegetation or aquatic invertebrate species. These are all drop-down fields.

In the ***Measurement Location*** field, briefly describe where surveyors took measurements, in addition to noting them on the Sketchmap. This should be entered as a complete sentence in active voice, (e.g., “Surveyors measured flow 10 meters below the first emergence.”)

If you have calculated the flow already, you can also enter the flow in the ***Measured Flow (L/s)*** field. Enter all flow measurements as liters per second (L/s) so they may be analyzed throughout the database.

The ***Flow Rate Scale*** (0-6) can be manually selected, but is automatically filled in when flow data are entered. At times, although there is water at the site it may be impossible to measure the flow. In this case, the Flow Rate Scale can be set to 9 to designate that it was unmeasurable, and the ***Unmeasurable*** field provides options to explain the circumstances.

Entering Raw Flow Data - This feature can save time and avoid errors if you have collected flow data in the field. To enter raw volumetric data, select ***Volume*** in the ***Measurement Technique*** dropdown list, and very briefly describe

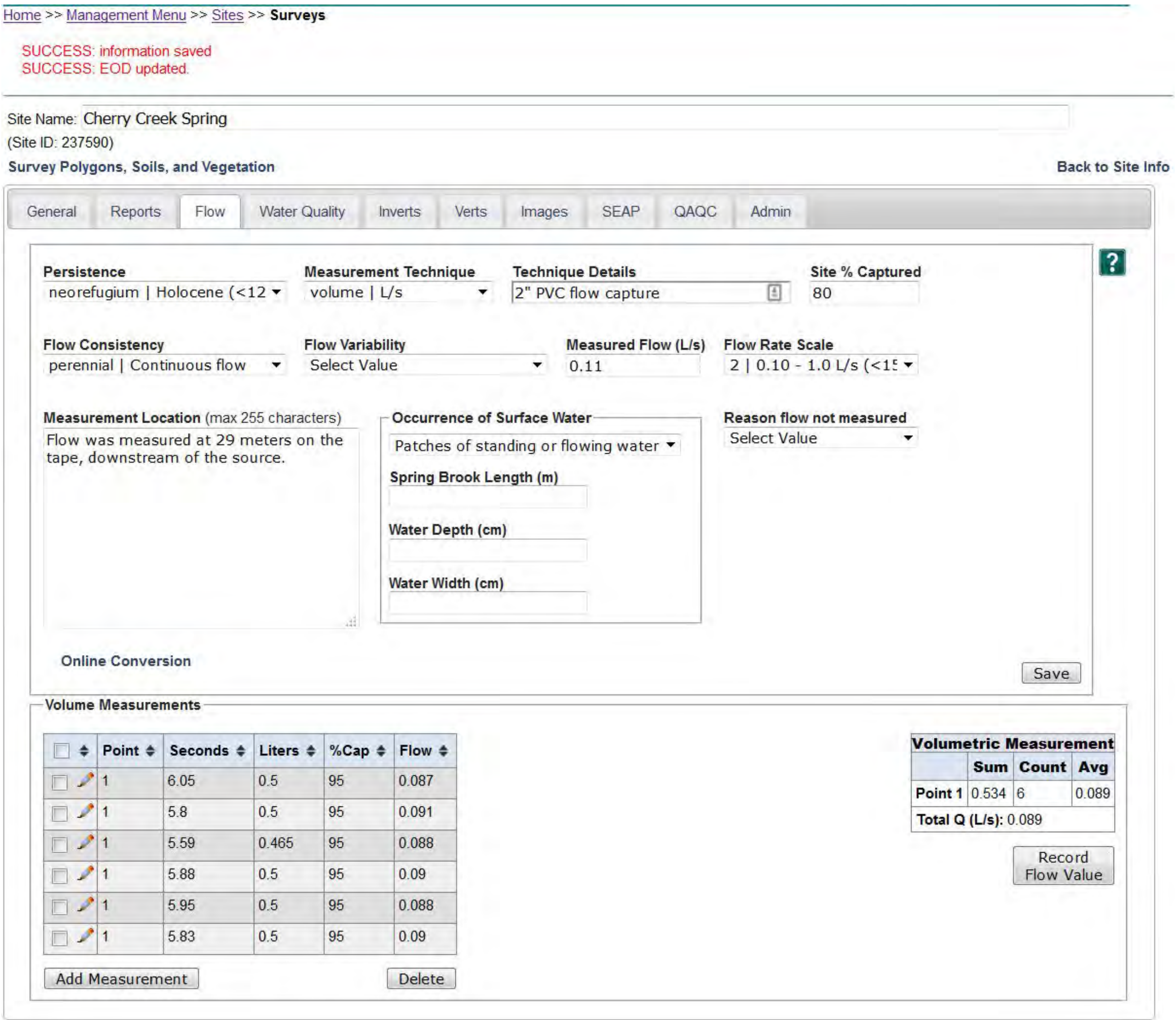


Fig. 6–27. Survey Form with the Flow tab selected. Six raw flow measurements were taken at one point.

the details about how the measurement was captured (e.g., 2” PVC pipe and calibrated cup). Also estimate the overall percent captured at the site in the ***Site % Captured*** field. Click the ***Add Measurement*** button; this will open a small form (Fig. 6-28). Enter the location point (1), the number of seconds, the volume captured in liters, and the estimated percent flow captured for each measurement. Click ***Add Measurement*** to record. Repeating this, you can record multiple measurements for each point where they were taken; these will be averaged.

Should you measure flow at an additional point - for example, in another channel - enter those as Point 2 and the combined calculated flow for each location point will be added together.

After entering all raw measurements, click the ***Record Flow Value*** button (Fig. 6-27). The estimated flow will be saved to the ***Measured Flow***

Fig. 6–28. Clicking the Add Measurement button will open a form to enter individual raw flow measurements. Point, Seconds, Liters, and % Captured are all required fields. Click Add Measurement to record it.

field, adjusted for the percent captured. If you do not complete this step, the flow will not be included in exported reports. Note that while the averaged measurements at Point 1 in Fig. 6-28 is 0.089 L/s, the ***Measured Flow*** is 0.11 L/s, adjusted for the estimated 80% captured.

Other flow measurement methods that can be chosen with the ***Measurement Technique*** drop-down list include current meter, flume, and weir.

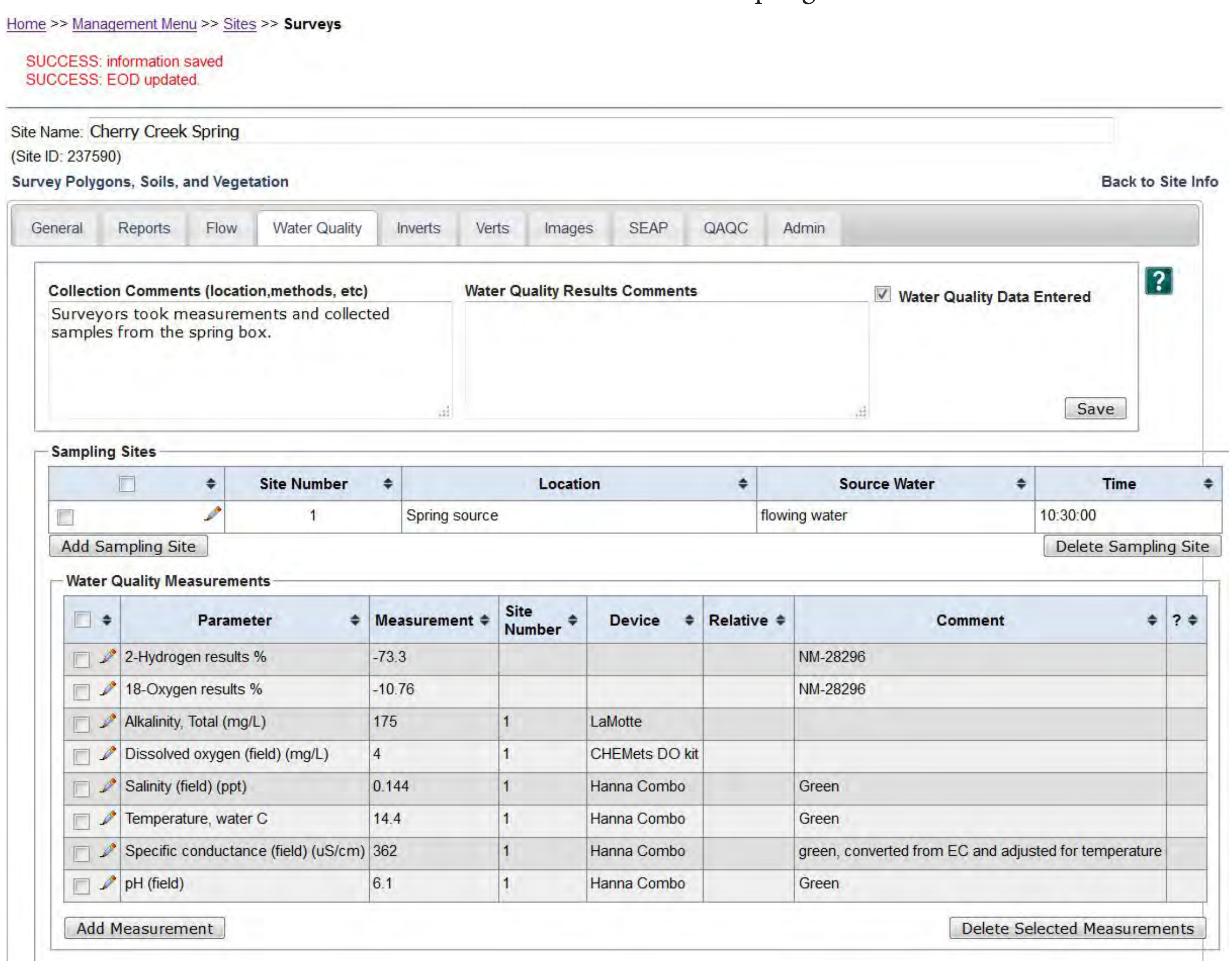
Additional Fields - Several other fields are based on other protocols, and are therefore optional for the Springs NMRAM. Select the entry for ***Occurrence of Surface Water*** from the list that best describes amount of water at the site. This is used in the US Forest Service GDE protocol. ***Spring Brook Length*** (m) and ***Water Depth*** (cm) are fields used in the Sada and Pohlman protocol.

Survey Form: Water Quality Tab

On the ***Water Quality*** tab, you will record water quality measurements taken in the field or results reported by a lab, along with the location of the measurements and comments related to the results (Fig. 6-29).

In the ***Collection Comments*** field, briefly describe (in complete sentences) the location and/or circumstances of the measurements. The location should also be noted on the Sketchmap. You could also include the date that the devices were last calibrated here. Any explanation about analysis of the water chemistry results should be entered in the ***Water Quality Results Comments*** field.

Before you add any measurements, you should add a sampling site to describe the location.



Home >> Management Menu >> Sites >> Surveys

SUCCESS: information saved
SUCCESS: EOD updated.

Site Name: Cherry Creek Spring
(Site ID: 237590)
Survey Polygons, Soils, and Vegetation

Back to Site Info

General | Reports | Flow | Water Quality | Inverts | Verts | Images | SEAP | QAQC | Admin

Collection Comments (location,methods, etc)
Surveyors took measurements and collected samples from the spring box.

Water Quality Results Comments

Water Quality Data Entered

Save

Sampling Sites

	Site Number	Location	Source Water	Time
	1	Spring source	flowing water	10:30:00

Add Sampling Site | Delete Sampling Site

Water Quality Measurements

	Parameter	Measurement	Site Number	Device	Relative	Comment	?
	2-Hydrogen results %	-73.3				NM-28296	
	18-Oxygen results %	-10.76				NM-28296	
	Alkalinity, Total (mg/L)	175	1	LaMotte			
	Dissolved oxygen (field) (mg/L)	4	1	CHEMets DO kit			
	Salinity (field) (ppt)	0.144	1	Hanna Combo		Green	
	Temperature, water C	14.4	1	Hanna Combo		Green	
	Specific conductance (field) (uS/cm)	362	1	Hanna Combo		green, converted from EC and adjusted for temperature	
	pH (field)	6.1	1	Hanna Combo		Green	

Add Measurement | Delete Selected Measurements

Fig. 6–29. Survey Form with the Water Quality tab selected. Add the measurement location(s) first, and then add measurements.

Fig. 6–30. Clicking the Add Sampling Site button will open a form to enter the location and source of water descriptions, identified as Site Numbers 1, 2, 3, etc.

Click the ***Add Sampling Site*** button to open a form (Fig. 6-30). Select a ***Site Number*** from the dropdown list (1, 2, 3, etc), then the ***Location*** and ***Source Water*** from the next two fields. Enter the ***Time*** of the measurements if it is known. Click the ***Save Location*** button to close the form and save the measurement location.

To add water chemistry measurements, click the ***Add Measurement*** button to open a form where you will record this information (Fig. 6-31). Then select the ***Parameter*** measured from the dropdown list. A wide variety of variables are listed; these comply with the EPA Storet list of water quality characteristics. Enter the ***Measurement***, which ***must*** be a number. Enter the Site ***Number*** (added above) from the dropdown list.

Next enter the ***Device*** used. If you wish to add a device that is not on the list, see the section on ***Editing Lookup Tables***. The ***Relative*** symbol is used to qualify the numeric value, such as "less than", "present", or "below minimum detectable levels." These are typically used for laboratory results. You can also add a ***Comment*** regarding individual field or lab results. If you have made any calculations or conversions (i.e. electrical conductivity to specific conductance), please make note of the original reading in this ***Comment*** field.

You can click the "?" box if the measurement is questionable. However, you might consider not entering it at all if the value is sufficiently dubious.

Once the measurement data are entered, click the ***Add Measurement*** button. The data entry form will close, and the measurement will appear in the list.

Should you wish to delete an entry, click the checkbox next to it, then click the ***Delete*** button. To edit an entry, click the ***Edit*** symbol (the pencil) within the measurements table.

Once all data have been entered, check the ***Water Quality Data Entered*** checkbox. If you are waiting for lab results, leave this box unchecked as a reminder that you anticipate additional data. If you have a large number of lab results, these can be imported. Contact SSI for assistance.

Survey Form: Invertebrates Tab

Use the ***Invertebrates*** tab to report invertebrate specimens collected or observed during the survey (Fig. 6-32). It is also possible to enter ***Benthic Sampling*** data.

Taxa are listed by the full scientific name. Springs Online includes over 10,000 taxa records. Some are only listed to order (e.g., Lepidoptera), while many taxa are listed to subspecies. Although some include ***Common Name***, most invertebrate species do not have a common name.

Click the ***Add Invert Record*** to open a blank set of fields (Fig. 6-33). In the ***Invertebrate Taxon*** field, begin typing any part of the scientific name

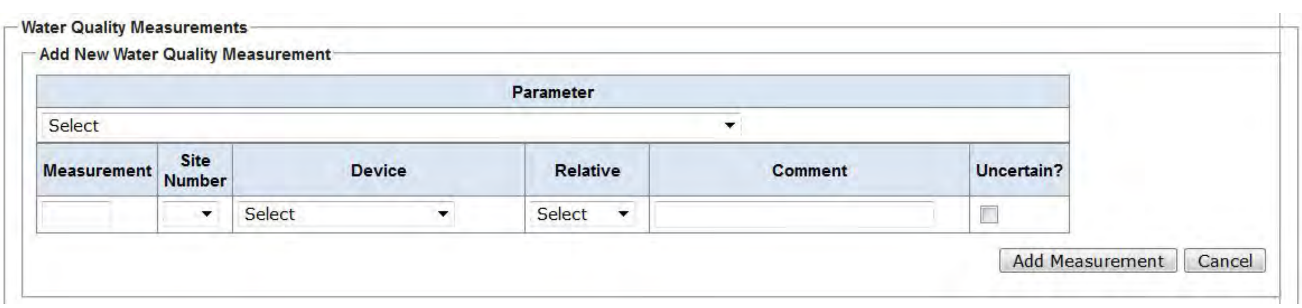
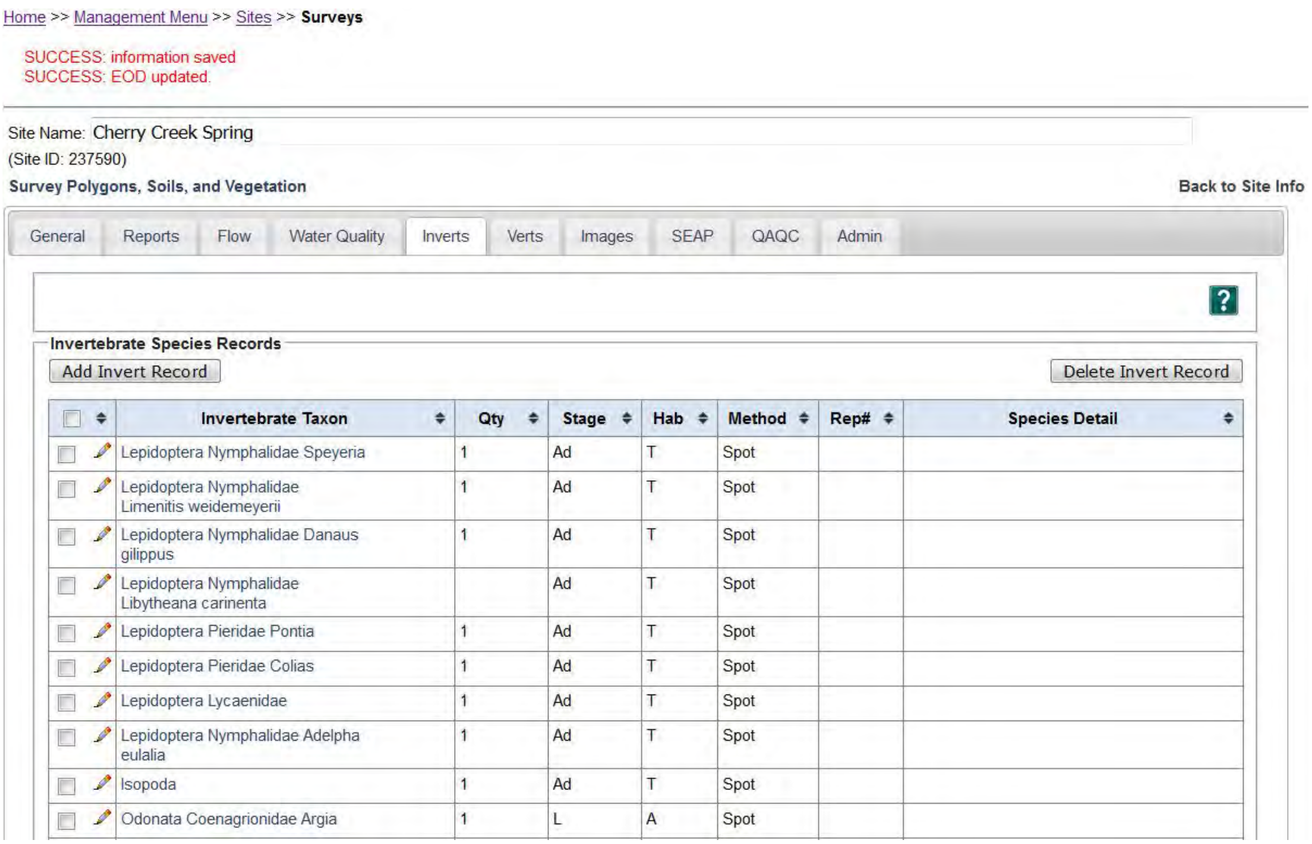


Fig. 6–31. Clicking the Add Measurement button will open a form to enter individual water quality measurements.



Home >> Management Menu >> Sites >> **Surveys**

SUCCESS: information saved
SUCCESS: EOD updated.

Site Name: Cherry Creek Spring
(Site ID: 237590)
Survey Polygons, Soils, and Vegetation **Back to Site Info**

General | Reports | Flow | Water Quality | Inverts | Verts | Images | SEAP | QAQC | Admin

Invertebrate Species Records

Add Invert Record | Delete Invert Record

	Invertebrate Taxon	Qty	Stage	Hab	Method	Rep#	Species Detail
	Lepidoptera Nymphalidae Speyeria	1	Ad	T	Spot		
	Lepidoptera Nymphalidae Limenitis weidemeyerii	1	Ad	T	Spot		
	Lepidoptera Nymphalidae Danaus gilippus	1	Ad	T	Spot		
	Lepidoptera Nymphalidae Libytheana carinenta		Ad	T	Spot		
	Lepidoptera Pieridae Pontia	1	Ad	T	Spot		
	Lepidoptera Pieridae Colias	1	Ad	T	Spot		
	Lepidoptera Lycaenidae	1	Ad	T	Spot		
	Lepidoptera Nymphalidae Adelpha eulalia	1	Ad	T	Spot		
	Isopoda	1	Ad	T	Spot		
	Odonata Coenagrionidae Argia	1	L	A	Spot		

Fig. 6–32. Survey Form with the Inverts tab selected. You can sort any of the columns by clicking the arrows at the top right of the field name.

to bring up a list of invertebrate species in the database. If the species has not been identified, it can be entered to any taxonomic level. For example, if all you know is that it is a dragonfly, enter "Odonata". If there are more than one, you can enter descriptions such as "sp 1", "sp 2", "blue", "large" in the ***Comments*** field. These will then be counted as separate species in the ***Species Count*** that is automatically calculated. Under ***Qty***, enter the number of specimens collected or observed; if this is unknown, or if there were too many to count, leave it blank and note the estimated number under ***Species Detail***. If known, enter the ***Lifestage*** (e.g. larva, adult, etc.), ***Habitat*** (Aquatic

Add Invertebrate Record to Survey

Add Image

Invertebrate Taxon						
Qty	**Stage**	**Hab**	**Method**	**Rep#**	**Species Detail**	**Identification Reference**
	Select	Select	Select			

Image (maximum size 1MB): Browse... No file selected.

Image Type
Other

Collection ID

Image Comment

Add Invert Record | Cancel

Fig. 6–33. Clicking the Add Invert Record button opens a form where you can enter the taxon, number, lifestage, habitat, sampling method, rep #, and any comments. You can also upload an image.

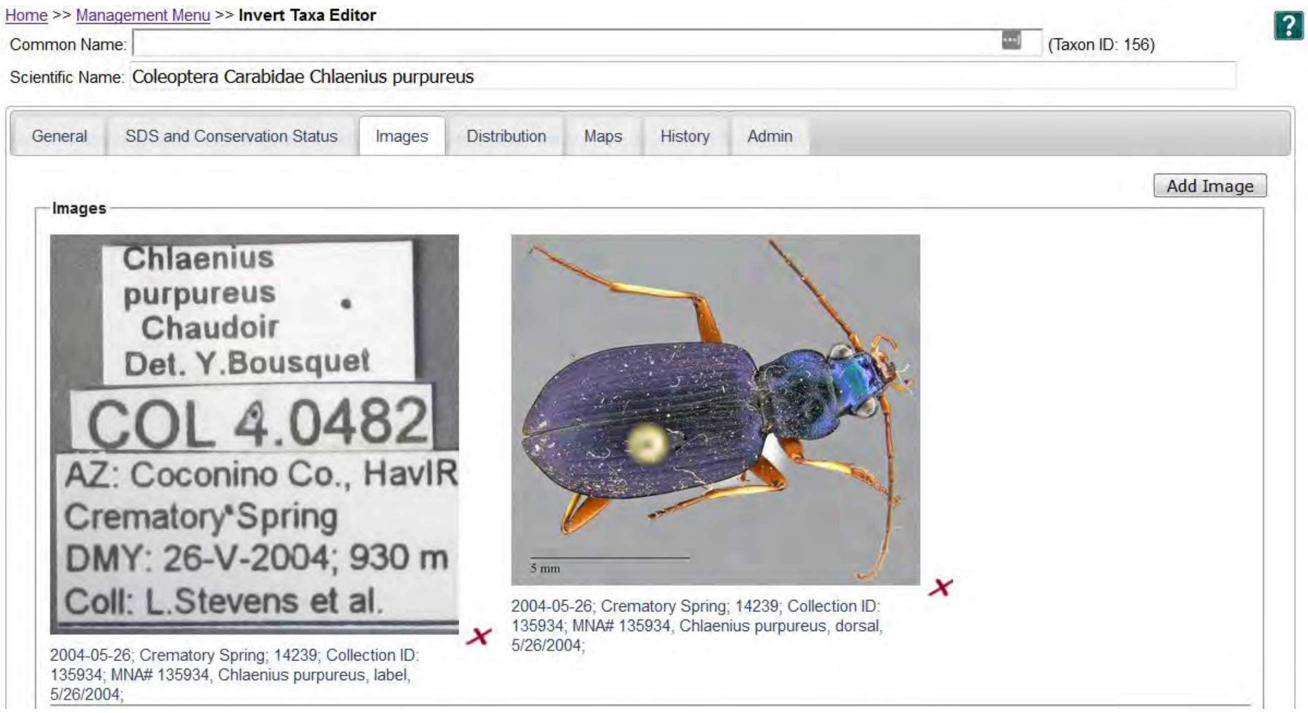


Fig. 6–34. Invertebrate Taxonomic Editor with an uploaded image of a specimen. When applied directly to a specimen in a survey, the image will be included in the Summary Report.

or Terrestrial), and sampling *Method* (spot or benthic). Enter the *Rep #* if it was collected in a benthic sample.

If you have an image of the specimen, click the *Add Image* hyperlink to open the necessary fields and the browsing button (Fig. 6-33). This image will be available in the *Taxonomic Editor* (Fig. 6-34), and will be included in the *Summary Report*. Browse to the image file and select it. The maximum file size is 1 MB. Then select the *Image Type* from the dropdown list. You can enter the *Specimen ID* if the collector has assigned one. Next, enter a caption for the image in the *Image Comment* field. If you wish to include a photo credit, enter the name. Once all data have been entered, click the *Add Invert Record* button.

If benthic (quantitative data) are entered, click the *Add Rep* button to describe the sampling site (Fig. 6-35). Add a *Rep #* from the dropdown list (1, 2, 3...). Include the *Velocity* in meters/second, *Depth* in centimeters, *Area* sampled in square meters, and the *Time* in seconds. Then describe the *Location*, *Substrate*, and any additional *Comments* in the appropriate fields. Click the *Add Rep* button to save the information. The *Rep #* will then be available in the dropdown list when you add new specimens.

If necessary, you can click one or more of the checkboxes left of the entries, then the *Delete Record* button to remove them. You can also click the *Edit* symbol (the pencil) to open the entry for editing.

Clicking the *Taxon Name* in a specimen record opens the *Invertebrate Taxonomic Editor* for that species, which displays the taxonomy as well as a list of all locations where that species has

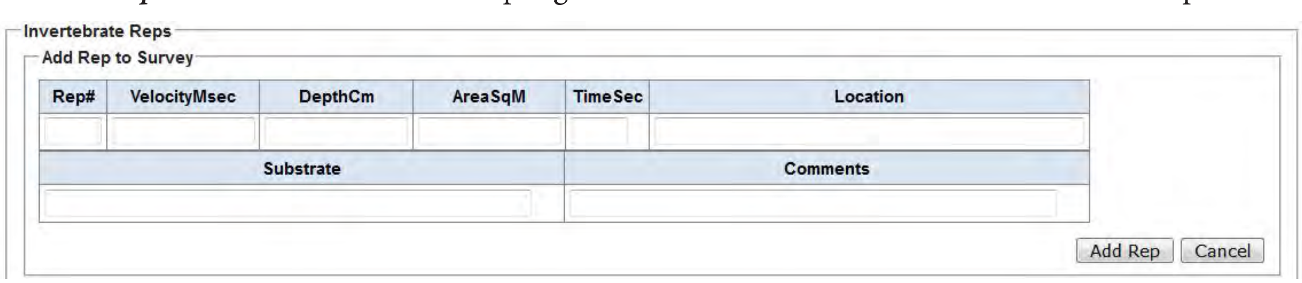


Fig. 6–35. If quantitative benthic data have been collected, click the Add Rep button to open a form where you can describe the location of the sampling.

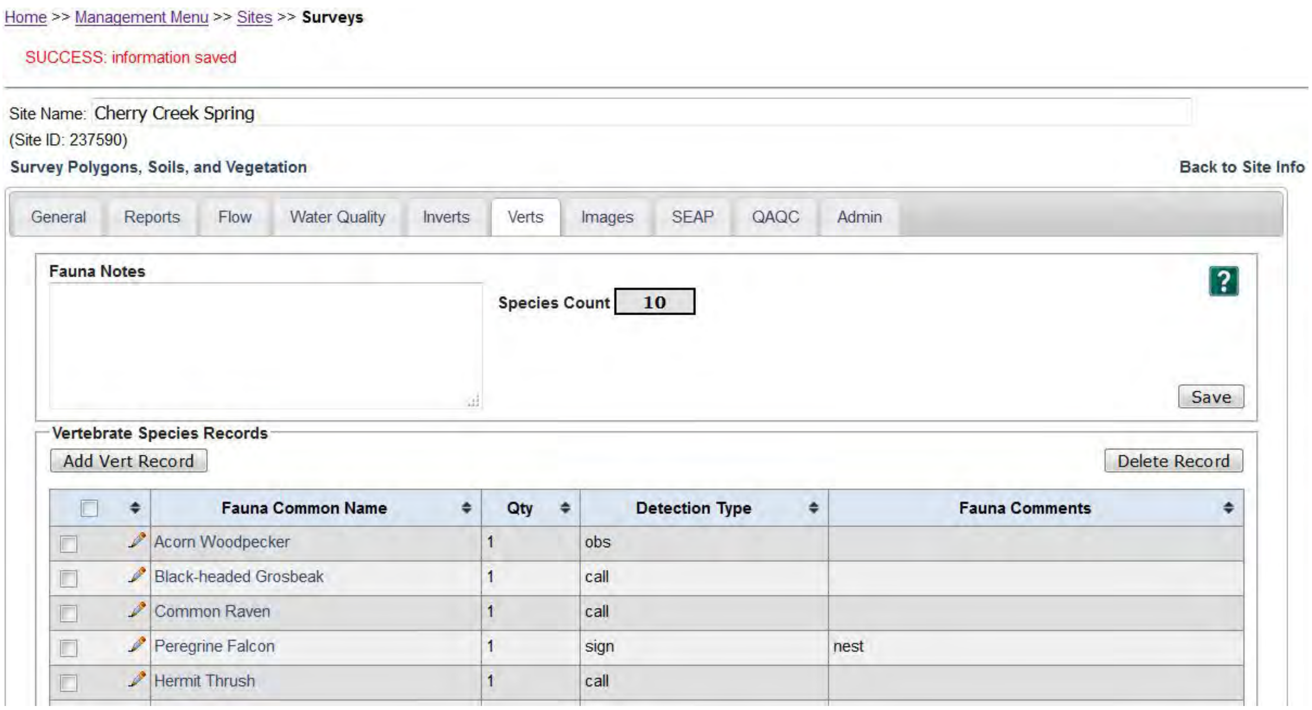


Fig. 6–36. Survey Form with the Vertebrate tab selected. Taxon are listed by common name, although the robust list of species in the database can be searched by scientific name as well.

been reported. This form opens as a new tab in most browsers. The *Taxonomic Editor* can also be accessed from the *Management Menu*. It includes an elevation range of reported species, as well as functionality to export the records or to display them on a map.

Survey Form: Vertebrates Tab

The *Vertebrates* tab design is similar to the *Invertebrates*, although vertebrate species are displayed by common name (Fig. 6-36). To add a record to the survey, click the *Add Vert Record* button. This will open a form (Fig. 6-37). Typing in the species or common name in the *Fauna Name* field will open a pull down list for selection. Enter the *Quantity*, if known. If the number is estimated, leave this field blank and describe it in the *Fauna Comments*. Enter the *Detection Type* (call, observation, sign, or reported). If you enter "sign" and describe it in the *Fauna Comments* field (scat, tracks, feathers, nest, etc.). The "reported" *Detection Type* is used when a knowledgeable source, such as a land owner, land manager, or researcher reports a species occurrence. In this case, enter the source of the information in the *Comments* field.

If you have an image of a species, you can upload it by clicking the *Add Image* hyperlink (Fig. 6-37). Then click the *Browse* button to select the image (maximum size of 1 MB). Enter the caption in the *Image Comment* field, including the photo credit if appropriate. This image will be included in the *Summary Report* as well as the

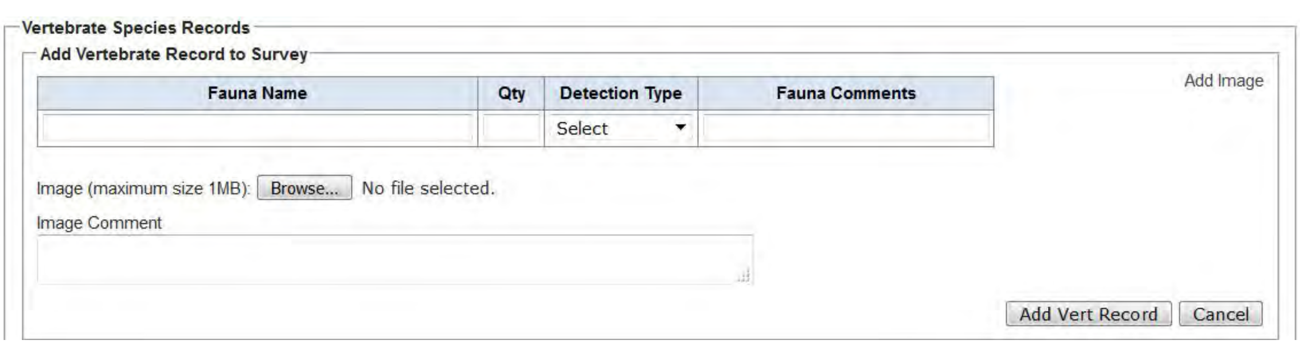


Fig. 6–37. Click the Add Vert Record button (Fig. 6-36) to open a form where you can add occurrence data for vertebrates that were observed, or for signs.

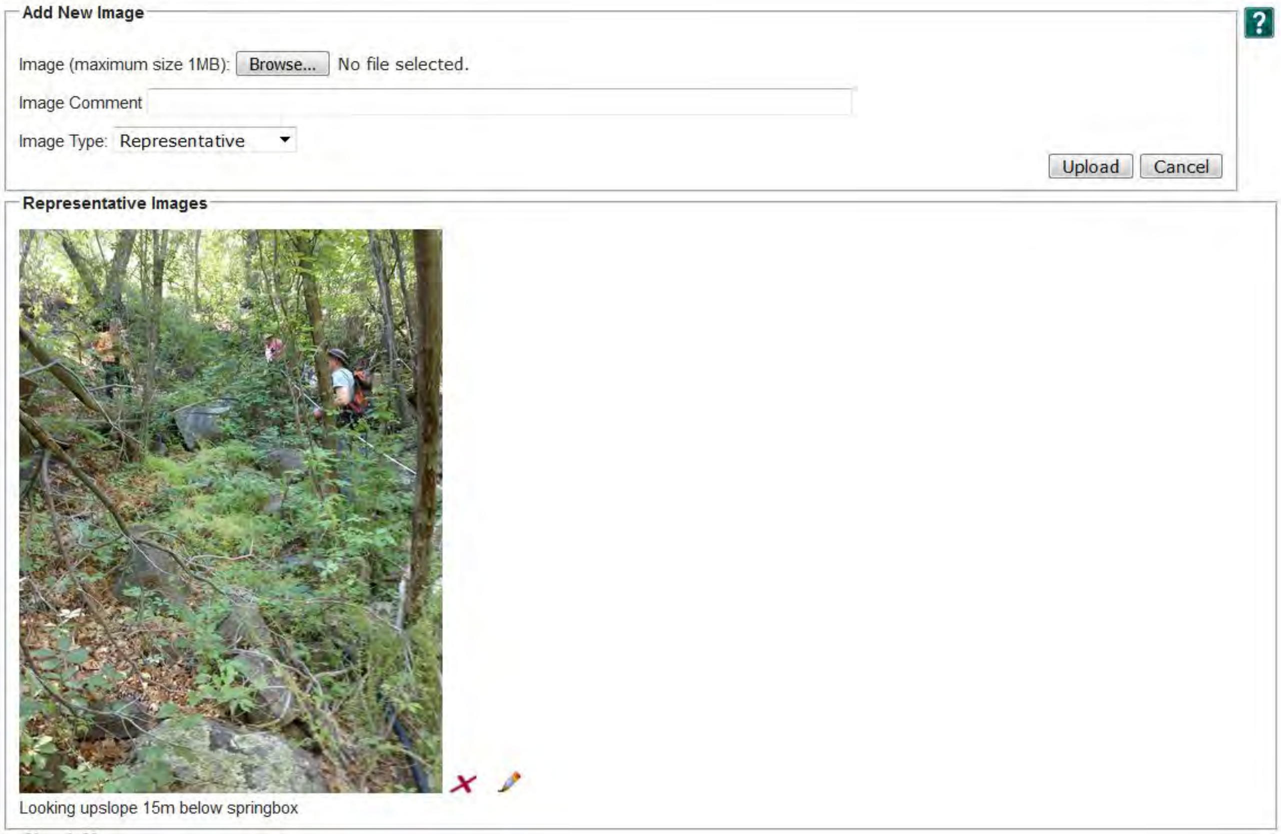


Fig. 6–38. From the survey form with Images tab selected, click the Add Image button to upload images, identify the image type, and enter captions.

Vertebrate Taxonomic Editor. Click the ***Add Vert Record*** to save it.

Use the ***Fauna Notes*** field to add any comments about all vertebrate and invertebrate records, such as the name of the biologist who identified the species. Note that the total ***Species Count*** is calculated.

Once ***Vertebrate*** data have been entered, you can click one or more of the checkboxes left of the entries, then the ***Delete Record*** button to remove them. You can also click the ***Edit Symbol*** (the pencil icon) to open the entry for editing. Clicking the species name for a record opens the ***Vertebrate Taxonomic Editor*** for that species and displays the taxonomy, a list of all locations where the species has been reported in the database.

Survey Form: Images Tab

This tab offers the ability to upload image files related to the survey, including the ***Sketchmap***, one ***Representative Photograph***, and ***Additional Images***, along with ***Image Notes*** (captions). These files should be chosen with care, however, as large and/or unnecessary image files will bog down the database, and increase the file size of exported summary reports to an unmanageable level. They should be resized to less than 1 MB, and saved as *.jpg files. Avoid uploading PDF files, as they will not be visible and will not appear in the summary report. To upload a photograph, click the ***Add Image*** button. A set of blank fields will appear (Figure 6-38).

Click the ***Browse*** button, then browse to the image. Make certain that there are no spaces in the file name, and that it is oriented properly and less than 1 MB in size. Select the image, and click ***Open***. Enter a brief description about the image's subject and orientation in the ***Image Notes*** field, such as "View downslope from the top of the site." or "View of the source from 5 meters below." These should be brief, complete sentences that describe the location and direction of the image with sufficient detail that subsequent surveyors could find the same location for a repeat photograph. Select the ***Image Type*** (Representative, Sketchmap, or Additional.) Only identify one image as Representative, and try to select one that most represents the site. Click the ***Upload*** button.

Once you have imported an image, should you wish to delete it, click the red "X" button. Click the edit symbol to edit the image information. Should you upload an image that appears upside-down or sideways, it was captured that way. Some imaging software will correct for this, as will a smart phone or tablet, so you will not realize that the orientation is incorrect until you upload it. If this happens, you will need to delete the image, correct the orientation, and re-upload it. Please do not upload any more than three or four photos per survey.

If you have a photo of a flora or fauna species, please attach it to the specific species record rather than to the Images tab. For example, when you enter a rattlesnake on the ***Vertebrates*** tab, please attach the photo directly to the record.

While on site, one team member should create a ***Sketchmap*** of the site using graph paper or a digital device. Sketchmaps should include the site name and date, scale, a north arrow, photo points, flow direction, GPS and SPF reading points, and water quality and flow measurement locations. Other helpful information includes location of trails, roads, fences, structures, or other modifications, as well as identifying a point of reference for future surveys.

Digital drawings are extremely helpful for particularly large, relatively flat sites. These may be drawn with digital tablets over topographic maps or aerial photographs, or surveyors can track the site perimeter with a GPS if reception is adequate and access is possible. However, these methods are not appropriate for very small sites, or for those with very steep slopes such as hanging gardens.

Scan sketchmaps as a *.jpg rather than a PDF, or they will not appear in this window after uploading. Also, usually a grayscale scan is sufficient.

Survey Form: QAQC Tab

The ***Quality Assurance/Quality Control*** (QAQC) tab displays data change history for the survey, and provides fields for quality control comments, the date that data were reviewed, and the login name of the reviewer.

Survey Form: Admin Tab

The ***Admin*** tab allows users with Administrator permissions for a project to delete a survey.

Polygons, Soils, and Vegetation

To add or edit survey polygons and to enter vegetation data, click the ***Survey Polygons, Soils, and Vegetation*** link on the ***Survey Form*** to open the Microhabitat Form (Fig. 6-39). Polygons are the geomorphic microhabitats influenced by the spring. The survey team should designate each microhabitat with a capital letter (A, B, C, etc.) as well as a short name that easily distinguishes it. It is helpful to include "source" in the name to designate which microhabitats contain the spring's sources. If the survey crew does not identify

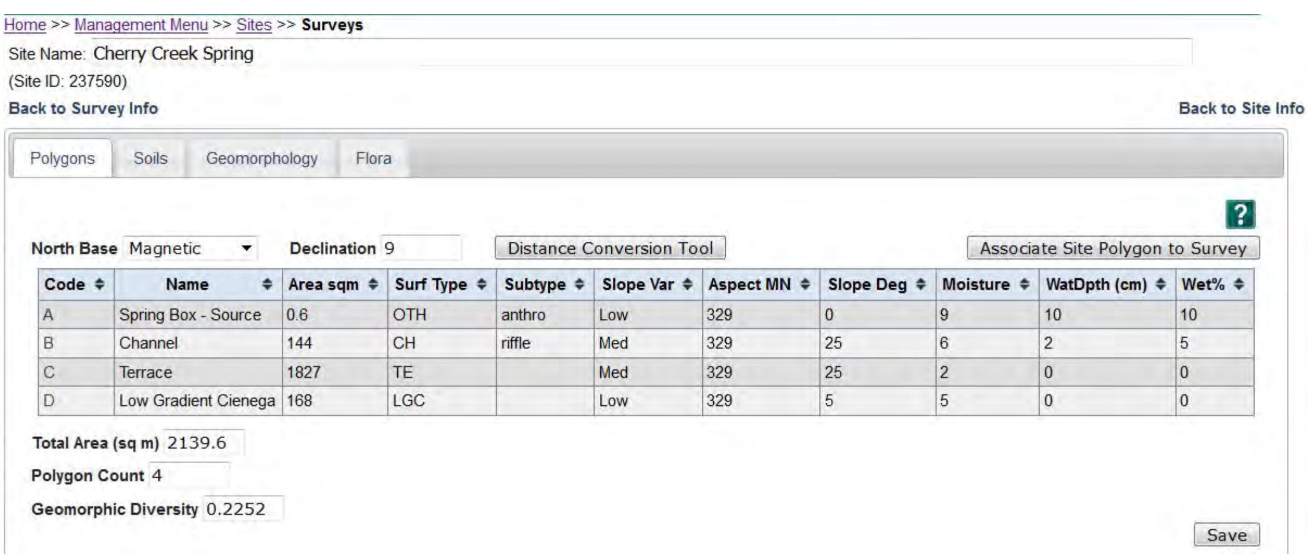


Fig. 6–39. Polygons, Soils, and Vegetation Form with the Polygons tab selected. Microhabitats, or polygons, must first be added to the Site Form, then associated with a survey.

Fig. 6–40. Clicking the Associate Site Polygon button opens this form, where you can select a Polygon Code from the dropdown list and complete the fields. Note that the Aspect column is hidden until you select a True or Magnetic aspect and click Save on the Polygons, Soils, and Vegetation Form (Fig. 6-39).

microhabitats, you will need to add at least one in order to enter vegetation data. Call this microhabitat "Entire Site" and label it as polygon X. Remember that polygons must first be entered on the *Site Polygons* tab on the *Site Form*, and may then be applied to the *Survey*.

On the *Microhabitat Form*, select the *North Base* as True or Magnetic to designate how *Aspect* was measured during the survey. If you enter Magnetic, you must also make sure there is a *Declination* value so the database can calculate *True North*. Make sure you click *Save* before associating a site polygon to the survey. Tip: The column for *Aspect* values (for example, the column "Aspect MN" in Fig. 6-39) will not be visible until you select your *North Base* option and then click *Save*.

To associate a *Site Polygon* with a survey, click the *Associate Site Polygon to Survey* button. This will open a blank *Add Site Polygon to Survey* form. Select the *Site Polygon* that you wish to add from the dropdown list in the *Code* field. If there are no polygons listed, return to the *Site Form* and add them. Enter the *Area* in square meters (this must be a numeric value.) For small sites, this is often calculated by counting squares on the sketchmap, or measuring the length and width. For larger sites, such as wet meadows, surveyors can walk the perimeter with a GPS or draw it using aerial imagery in GIS.

Select the *SurfType* from the dropdown list and the *Subtype* if there is one. Enter *Slope Variability*, the *Aspect*, the *Slope* in degrees, and select the *Moisture* value. The *Water Depth* should be measured in cm, and the *Wet%* as a percent value of the total polygon area that is covered by open water. If any of these values are unknown or are not indicated, leave them blank. Click the *Associate Polygon* to save this information.

Continue this process through each of the microhabitats that were identified in the survey. After all microhabitats have been entered, you *must* click the *Save* button to save the total area and calculate the geomorphic diversity.

To edit or remove an existing polygon, click on the *Code* letter to open the edit form. Here you can also click the "*Remove Polygon*" button to delete a polygon. However, you cannot delete a polygon that contains vegetation records.

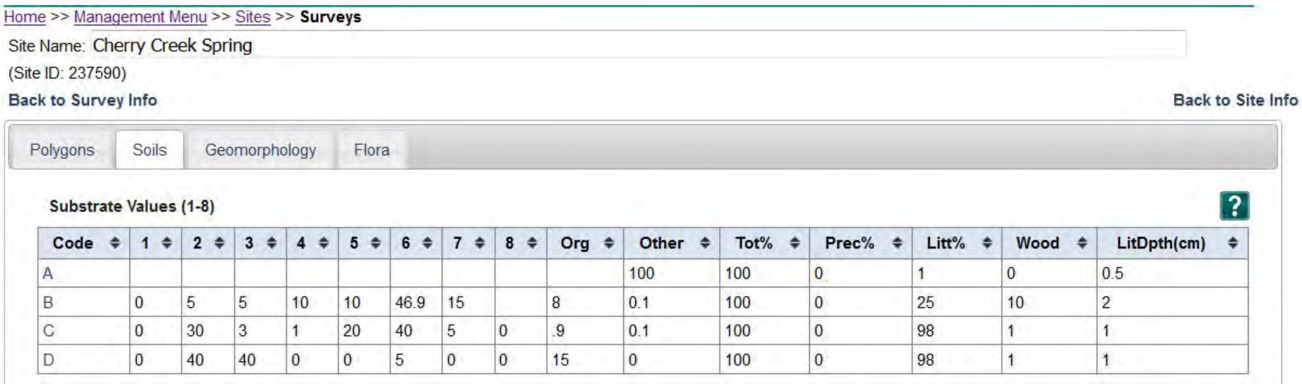
The *Total Area*, *Microhabitat Count*, and *Geomorphic Diversity* are calculated and displayed as you add new polygon data to the survey. However, these values are not saved until you click the *Save* button. If you edit the areas, you must click the *Save* button again to save the calculations.

Microhabitat Form: Soils

For each polygon the surveyors should estimate the percent of the polygon surface covered by each grain size represented, with the total equal to 100%, where:

1 = clay
2 = silt
3 = sand
4 = pea gravel
5 = coarse gravel
6 = cobble and small boulders (0.1 to 1 m in diameter)
7 = large boulders (more than 1 m)
8 = bedrock
Org = organic soil
Oth = other (anthropogenic features)

To enter this information, click the *Soils* tab (Fig. 6-41). The sum of the *Substrate* (1-8) plus


Home >> Management Menu >> Sites >> Surveys

Site Name: Cherry Creek Spring

(Site ID: 237590)

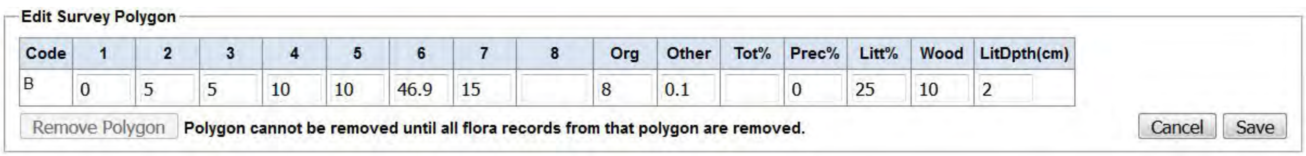
Back to Survey Info — Back to Site Info

Polygons | Soils | Geomorphology | Flora

Substrate Values (1-8)

Code	1	2	3	4	5	6	7	8	Org	Other	Tot%	Prec%	Litt%	Wood	LitDpth(cm)
A										100	100	0	1	0	0.5
B	0	5	5	10	10	46.9	15		8	0.1	100	0	25	10	2
C	0	30	3	1	20	40	5	0	.9	0.1	100	0	98	1	1
D	0	40	40	0	0	5	0	0	15	0	100	0	98	1	1

Fig. 6–41. Microhabitat Form (Polygons, Soils, and Vegetation) with the Soils tab selected. Click the Code for each polygon to open the edit form (Fig. 6-42).


Edit Survey Polygon

Code	1	2	3	4	5	6	7	8	Org	Other	Tot%	Prec%	Litt%	Wood	LitDpth(cm)
B	0	5	5	10	10	46.9	15		8	0.1		0	25	10	2

Remove Polygon — Polygon cannot be removed until all flora records from that polygon are removed. — Cancel — Save

Fig. 6–42. Soils Edit form opened to enter or edit substrate, precipitate, litter, wood, and litter depth values for Polygon B.

Organic and ***Other*** values is automatically calculated and should total 100%. Should this not be the case you will be admonished with a red total percent value. Please confer with your surveyors to correct this, but you will be able to continue entering data. This tab also contains fields for the estimated percent cover of ***Precipitate***, ***Litter*** and ***Litter Depth*** in centimeters, as well as percent cover of ***Wood*** (greater than an inch in diameter). To enter or edit these values, click the ***Code*** letter to open the ***Soils Edit*** form (Fig. 6-42).

Microhabitat Form: Geomorphology Tab

On the ***Geomorphology*** tab you can assign a ***Discharge Sphere*** and ***Secondary Sphere***, if applicable, to any ***Polygon***. These entries are limited to the microhabitats already applied to a survey. If there is no discharge from a microhabitat, leave it blank. Discharge spheres are limited to spring types as described by Stevens and Springer (2009). For simple sites this is generally not necessary, but for complex sites it may be helpful.

Microhabitat Form: Flora Tab

Typically, collection of vegetation data represents the lion's share of the field time, as well as the data entry time. SSI developed a streamlined method for efficient and accurate data entry. The ***Species***, ***Cover Type***, ***Percent Cover***, ***Native Status***, ***Wetland Status***, and ***Comments*** for each species in each strata are entered on the ***Flora*** tab (Fig. 6-43). Vegetation data may be entered in any order, but it is usually best to enter it in the order it appears on the field sheets. Although not required, the system is designed to accept the estimated percent cover of each species, within each strata, and within each microhabitat. At a minimum, required fields are the ***Polygon Code*** (Poly) and the ***Species***.

Vegetation Species

Springs Online includes all plants downloaded from the USDA Plants Database; this information is refreshed at least once per year. It also includes species that have been recently added by independent researchers, families, genus, and an array of unknown taxa options for plants that can not be identified.

Cover Codes

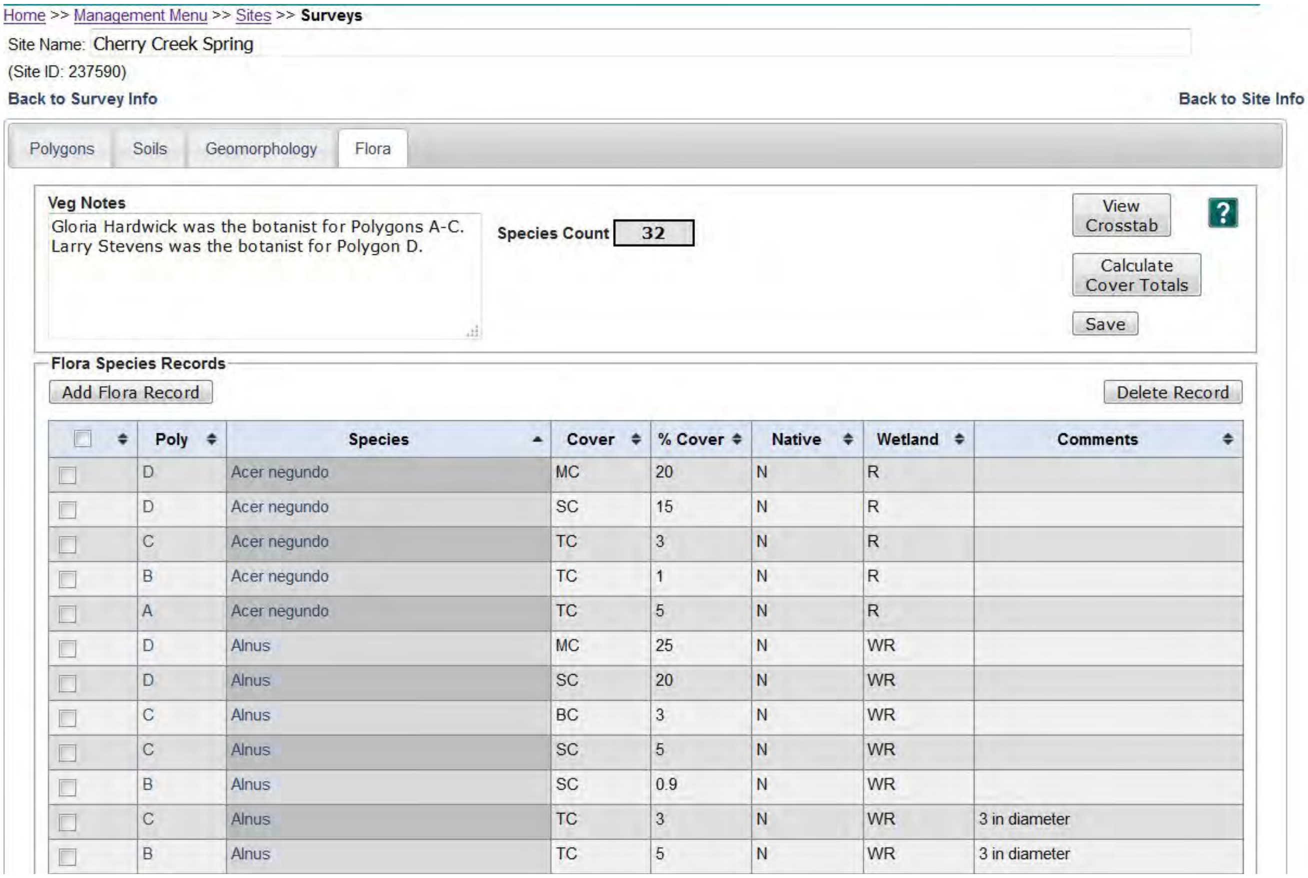
Cover Code (strata) options include:

GC = Ground Cover (non-woody annual; deciduous herbs; annual or perennial grasses, sedges, or rushes)

SC = Shrub Cover (woody perennial less than 4 m tall)

MC = Mid-canopy cover (woody perennial, between 4 and 10 m tall)

TC = Tall canopy cover (woody perennial, over 10 m tall)



Home >> Management Menu >> Sites >> Surveys

Site Name: Cherry Creek Spring

(Site ID: 237590)

Back to Survey Info | Back to Site Info

Polygons | Soils | Geomorphology | Flora

Veg Notes

Gloria Hardwick was the botanist for Polygons A-C.
Larry Stevens was the botanist for Polygon D.

Species Count 32

View Crosstab

Calculate Cover Totals

Save

Flora Species Records

Add Flora Record

Delete Record

	Poly	Species	Cover	% Cover	Native	Wetland	Comments
	D	Acer negundo	MC	20	N	R	
	D	Acer negundo	SC	15	N	R	
	C	Acer negundo	TC	3	N	R	
	B	Acer negundo	TC	1	N	R	
	A	Acer negundo	TC	5	N	R	
	D	Alnus	MC	25	N	WR	
	D	Alnus	SC	20	N	WR	
	C	Alnus	BC	3	N	WR	
	C	Alnus	SC	5	N	WR	
	B	Alnus	SC	0.9	N	WR	
	C	Alnus	TC	3	N	WR	3 in diameter
	B	Alnus	TC	5	N	WR	3 in diameter

Fig. 6–43. Microhabitat Form with the Flora tab selected. This is designed to record the percent cover for each plant species in each strata, in each polygon. The Species Count is automatically calculated, based on a concatenation of the Species and the Comments. In this example, the Alnus that was recorded in Polygon B and C must have the same comment; otherwise this would be recorded as two species.

AQ = Aquatic cover

BC = Basal cover (woody stems emerging from ground)

NV = Non-vascular (liverworts, mosses, lichens)

Percent Cover

The team botanist visually estimates the percent foliar cover for each ***Species*** in each ***Cover Code*** in each ***Polygon***. The total percent cover in any Polygon for any ***Cover Code*** should not exceed 100%.

Native Status

The available options for ***Native Status*** are based on the USDA Plants database. The ***Taxonomic Editor*** includes a ***Default Native Status*** that will automatically be copied into the ***Native Status*** field as a species is added. This saves a great deal of time. However, users can override this value if it is appropriate.

Wetland Status

Wetland Status ratings are based on definitions developed by L. E. Stevens (SSI) to distinguish wetland from riparian habitat affinity. Default values are also included for many taxa in the ***Taxonomic Editor***, and are copied into the ***Wetland Status*** field when a species is added. However, users can override this value as well. These wetland designations are:

A - Aquatic - rarely found away from standing or flowing water habitats. This is similar to Obligate (OBL) USDA wetland status described as "almost always a hydrophyte, rarely in uplands"

W - Wetland - almost always in wetland habitats, rarely in open water, riparian, or upland habitats. This is also similar to Obligate (OBL) USDA wetland status.

WR - Wetland Riparian - occurs approximately equally in wetland and riparian habitats, but rarely in aquatic or upland habitats, and rarely in

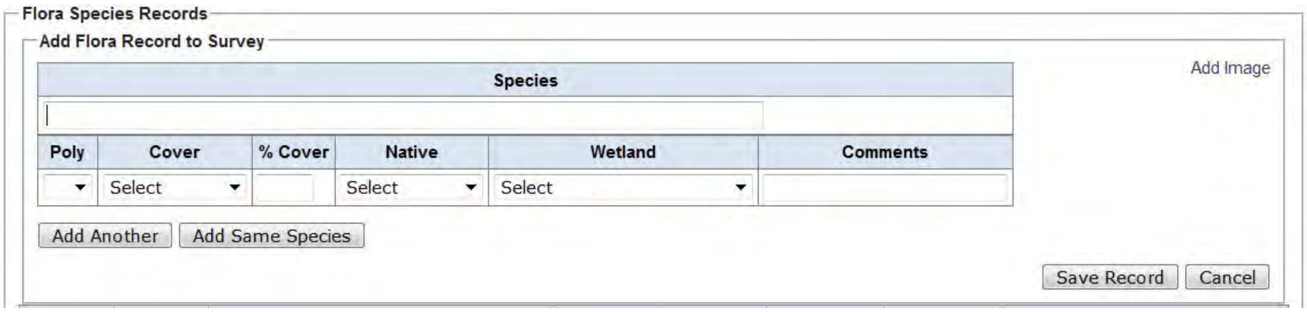


Fig. 6–44. Click the Add Flora Record to open the Add Flora Record to Survey form. Using the tab key to move between the fields will save an enormous amount of time for a large site with many species.

aquatic habitats. Similar to Facultative Wetland (FACW) USDA wetland status.

R - Riparian - phreatophyte, sometimes occurring in wetlands but rarely in uplands and never in aquatic habitats. Similar to Facultative Wetland (FACW) USDA wetland status.

F - Facultative - Usually occurs in uplands, but occasionally occurs in or peripheral to riparian habitats, but never in wetland or aquatic habitats. Similar to Facultative (FAC) and Facultative Upland (FACU) USDA wetland status.

U - Upland - Rarely and only incidentally occurs in dry riparian habitats, but occurs almost always in uplands, and never in wetland or aquatic habitats. Similar to Upland (UPL) USDA wetland status.

Adding Plant Species Occurrence Data

To add a new plant occurrence, click the ***Add Flora Record*** button. This will open a form with the appropriate fields (Fig. 6-44) along with handy buttons to enter many records in succession.

In the ***Species*** field, begin typing the common name or any part of the scientific name to bring up a select list. Click the appropriate taxon from the list to add it to the ***Species*** field. Enter the ***Polygon Code***, ***Cover Code***, and ***% Cover***. The ***Native Status*** will be automatically populated by the default status in the taxa list, but you may override this, or fill it in if missing. Similarly, the ***Wetland Status*** may be automatically populated by the default status for that species. Next, enter any ***Comments*** about the species. Click the ***Add Another*** to save the information and open the blank form for the next entry. If the same species occurs in another polygon or strata, clicking the ***Add Same Species*** button will populate the fields with the same information.

Tip: Using the Tab key rather than the mouse to move between the fields will save an enormous amount of time. From the ***Comments*** field, hitting the tab key will move the cursor to the ***Add Another*** button, and clicking it again will move it to the Add Same Species button. Hitting return will save the record and open a new form.

List unidentified plant species to the highest taxonomic level possible in the species field, with notations such as “sp.1” or “yellow flower” in the ***Comments*** field. It is important to note, however, that the database calculates species counts by concatenating the ***Species*** and the ***Comments*** fields. Therefore, Carex listed in one polygon with “sp 1” in the ***Comments*** field and Carex in a different polygon without that comment will be considered two species. While this is particularly helpful in certain situations (unknown grass with “sp.1” in the details and unknown grass with “sp.2” will be appropriately reflected as two species), it is important to maintain consistency in the comments when making multiple entries for the same species.

If you wish to upload a photograph, click the ***Add Image*** hyperlink, browse to the image (making sure the orientation is correct and the size is less than 1 MB), and enter a caption. This image will be included in the ***Summary Report*** as well as the ***Taxonomic Editor.***

Once data have been entered, you may edit the entries by clicking the ***Polygon Code***. You may also delete entries by clicking the checkbox next to them and then the ***Delete Record*** button. Any column can be sorted in ascending or descending order. In the ***Veg Notes*** field, please note the name of the botanist, or any other general information about the vegetation (e.g., recently burned, dying back, etc.), and click ***Save***.

It is good practice to click the ***View Crosstab Query*** button to open an alphabetized list of all plant species entered at the site, including native status, cover code, and percent cover in each polygon. Reviewing this query will highlight missing cover codes or comments for the same species that are not entered the same way. This should open as a new tab in most browsers.

Back on the ***Microhabitat*** form, clicking the ***Species*** field will open the ***Flora Taxanomic Editor*** form that lists the scientific name, common name, USDA symbol, wetland status, and default codes. It also lists each site in the database where that species has been reported and allows users to download data and view occurrence data on a map.

Management Menu

Site and Survey Management

This hyperlink opens a form where you can search for a spring by entering the ***Site Name*** or the ***Site ID*** number. Searching by a spring name is only useful for springs with uncommon names. With 150,000 records, and many springs with the same name—"Willow," "Cold," or "Warm" for example—you are unlikely to find the spring you seek. Searching by the unique Site ID, however, works well if you happen to know it.

Adding a New Spring

If you have completed a thorough search and are convinced that you have a new spring to add, click the ***Add New Site*** button. Required fields in this form are a ***Name*** (even one that you or the surveyors assign), ***Country***, ***State***, ***County***, ***Land Unit***, ***Land Unit Detail***, ***Latitude*** and ***Longitude*** in decimal degrees, and the ***Information Source***.

To obtain the coordinates, you can click on the globe symbol to open Google Maps, and navigate to the location. Here you can also search for nearby springs to make sure you are not introducing a duplicate site (Fig. 6-45). Even if you have the coordinates, it is a good idea to use this mapping tool to make sure you are placing it in the correct location (e.g., in the proper hemisphere).

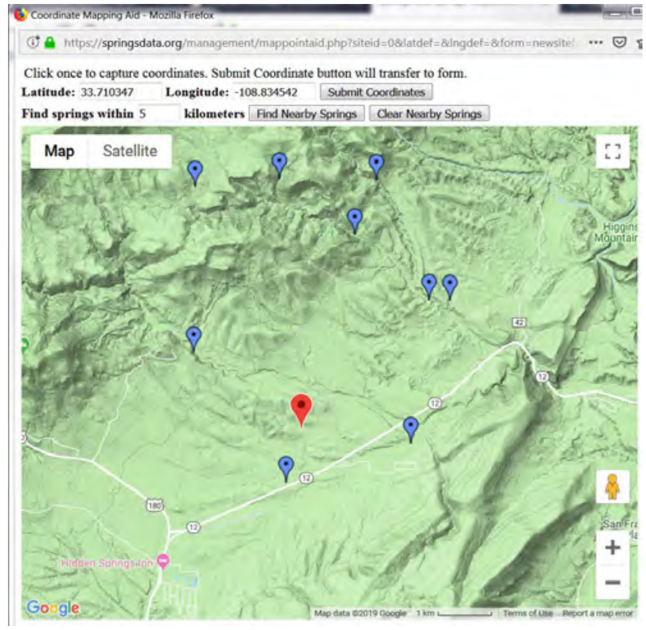


Fig. 6–45. When adding a new spring, use the mapping tool to make sure the site is correctly placed, and the Find Springs tool to make certain you aren't introducing a duplicate record.

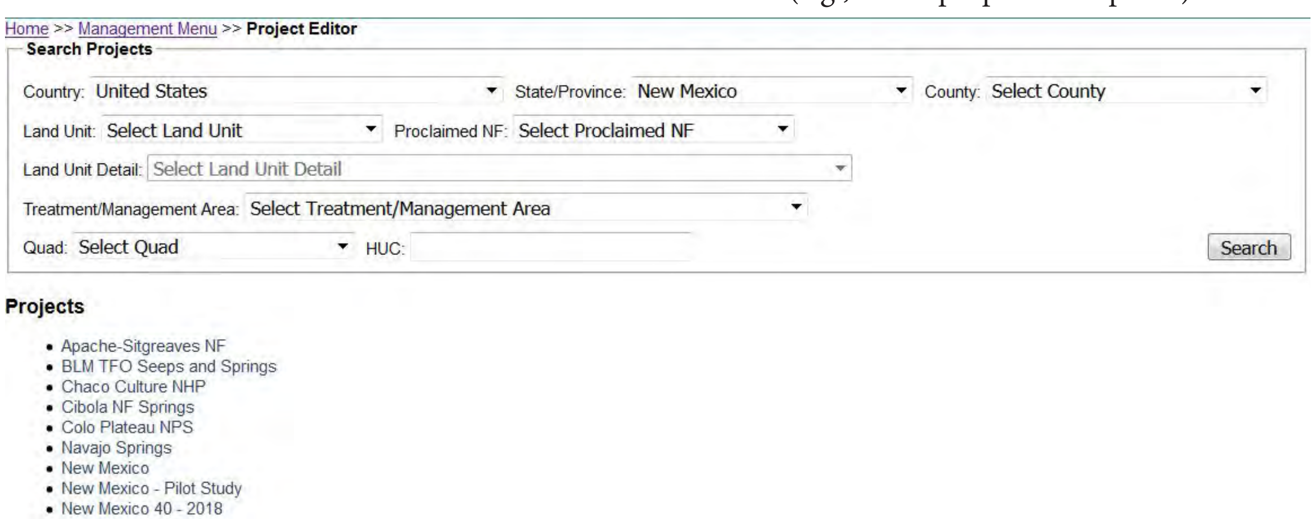


Fig. 6–46. From the Project Manager, enter search parameters to locate projects conducted within a specific land area.

When naming a new spring, please choose one that is unique, respectful, and reflects the character of the site. Please include "Springs" in the name as well.

The ***Public Info*** box is extremely important to note. If the new spring is on Tribal lands, private land, within a national park, or if the information is sensitive for any other reason, please uncheck this box. Click the ***Create Site*** to add the spring. This will open the ***Site Form*** for further editing.

Project Management

From the ***Management Menu***, the ***Project Management*** hyperlink opens the Project Form. Here you may add your own project. Click the ***Add New Project*** button to open a form. Enter a short, descriptive, ***Project Name*** that distinguishes it from other projects (e.g., do not name it Springs Inventory). Also you can enter an associated ***Hyperlink*** if appropriate, and a more detailed description of the project under ***Comments***. You will automatically be granted Administrator permissions to the project that you add, but others will not be able to access the information unless you grant permission.

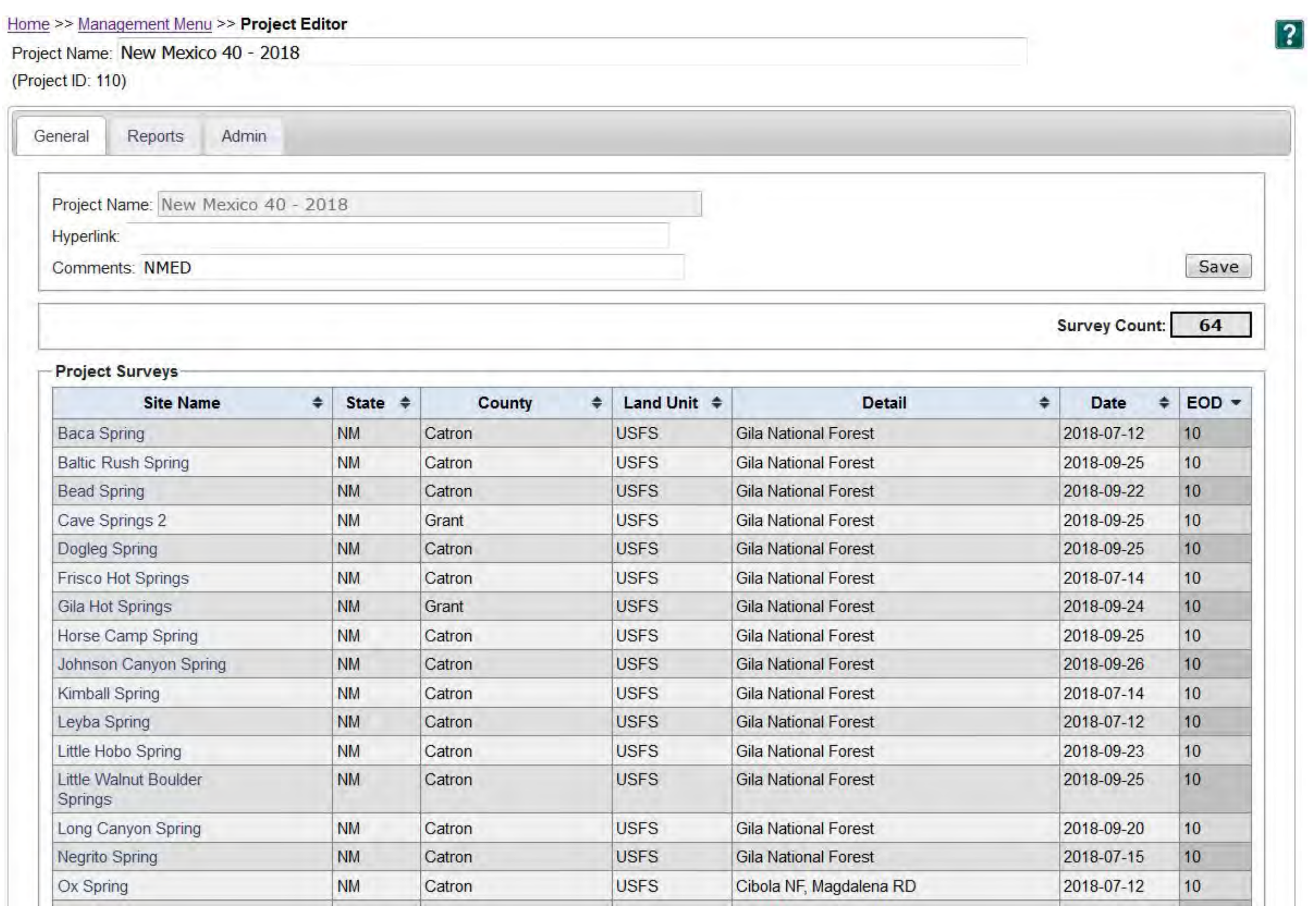
To open a current project, if you know the ***Project Name,*** begin typing it in the ***Project*** search field, and a list of options will appear below. Click the one that you want to open.

If you do not know the project name, you can enter search parameters (Fig. 6-46). Click the ***Search*** button to view a list of projects that fall within the parameters. If you have permissions to access the information, the projects listed will be hyperlinked.

However you access a project, the ***General*** tab lists locations that have been surveyed under that project (Fig. 6-47). You can sort the list by any of the columns by clicking the arrow at the right of the field name. Click the ***Site Name*** hyperlink from the list to open a survey in a new browser tab.

Project Reports

Click the ***Reports*** tab to view available project reports. The first one, ***User List***, creates and


Home >> Management Menu >> Project Editor
Project Name: New Mexico 40 - 2018
(Project ID: 110)
General Reports Admin
Project Name: New Mexico 40 - 2018
Hyperlink:
Comments: NMED
Save
Survey Count: 64
Project Surveys

Site Name	State	County	Land Unit	Detail	Date	EOD
Baca Spring	NM	Catron	USFS	Gila National Forest	2018-07-12	10
Baltic Rush Spring	NM	Catron	USFS	Gila National Forest	2018-09-25	10
Bead Spring	NM	Catron	USFS	Gila National Forest	2018-09-22	10
Cave Springs 2	NM	Grant	USFS	Gila National Forest	2018-09-25	10
Dogleg Spring	NM	Catron	USFS	Gila National Forest	2018-09-25	10
Frisco Hot Springs	NM	Catron	USFS	Gila National Forest	2018-07-14	10
Gila Hot Springs	NM	Grant	USFS	Gila National Forest	2018-09-24	10
Horse Camp Spring	NM	Catron	USFS	Gila National Forest	2018-09-25	10
Johnson Canyon Spring	NM	Catron	USFS	Gila National Forest	2018-09-26	10
Kimball Spring	NM	Catron	USFS	Gila National Forest	2018-07-14	10
Leyba Spring	NM	Catron	USFS	Gila National Forest	2018-07-12	10
Little Hobo Spring	NM	Catron	USFS	Gila National Forest	2018-09-23	10
Little Walnut Boulder Springs	NM	Catron	USFS	Gila National Forest	2018-09-25	10
Long Canyon Spring	NM	Catron	USFS	Gila National Forest	2018-09-20	10
Negrito Spring	NM	Catron	USFS	Gila National Forest	2018-07-15	10
Ox Spring	NM	Catron	USFS	Cibola NF, Magdalena RD	2018-07-12	10

Fig. 6–47. Project Form with the New Mexico 40 - 2018 project selected, and the list of surveys conducted under the project.

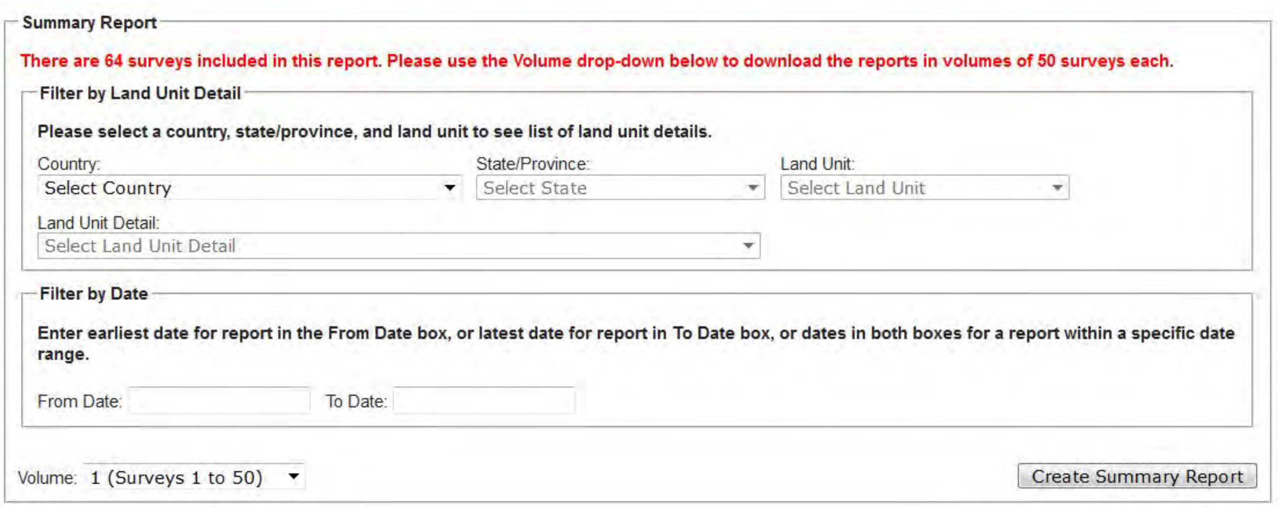


Fig. 6–48. Reports tab on the Project Form, where one can export a site or project summary report. These may be filtered by location or by date. Larger reports must be exported in volumes of no more than 50 surveys.

opens a Microsoft Word document that lists all users who have access, and their permission level. The second report, ***All Surveys***, exports as a *.csv file that will open in Microsoft Excel. It contains general information about each survey, with the fields typically included in Table 1 of a report. The remainder of the reports in the upper section of the ***Reports*** tab include a variety of survey data exports as *.csv files that can be opened in Microsoft Excel.

The ***Summary Report*** section exports survey reports into an editable Microsoft Word document. These are similar to the ***Survey Reports*** described previously with an example in Appendix C. However, they are combined into one indexed document. You can filter the reports by entering parameters for ***State***, ***Land Unit***, ***Land Unit Detail***, or by survey ***Date*** (Fig. 6-48). If a project exceeds 50 surveys, they must be exported in volumes. Once exported, these reports usually require some editing, such as resizing images.

Reference Management

Accessed from the ***Management Menu***, this form allows users to search for, edit, and add ***References*** to the database. You can also associate species to these references. Begin typing in the ***Title*** or the ***Author*** search fields, and select the record from the list that appears below. Click the ***Add Reference*** button to add a new reference, first making sure that it isn't already in the database.

Lookup Table Management

From the ***Management Menu***, click the ***Lookup Table Manager*** link to add GPS units, Geologic Layers, Land Units, USGS Quads, Countries, and Provinces that are not already included in the database. For example, from the dropdown list, select Water Chemistry Device. Here users may add specific devices that they use during their surveys by clicking the ***Add Value*** button. Similarly, users may wish to add a GPS unit to the list here.

Land Unit Management

From the ***Management Menu***, click the ***Land Unit Management*** hyperlink to open this interface. Type in the land unit (e.g., US Forest Service) and click the results to open the ***Land Unit Editor*** form. Click the ***Details*** tab to generate a list of all ***Land Unit Detail*** records that are hyperlinked. Click the record to open the ***Land Unit Detail*** form. If surveys have been entered in this unit, they will be listed below. If a user has appropriate permission for both the land unit and the survey, the ***Site Name*** will be hyperlinked to the survey. This form includes a ***Reports*** tab that is similar to the Projects reports.

Taxonomic Editors

The taxonomic editors allow users to look up flora, invertebrates, and vertebrates by location and distribution, as well as access to the conservation and springs-dependent status.

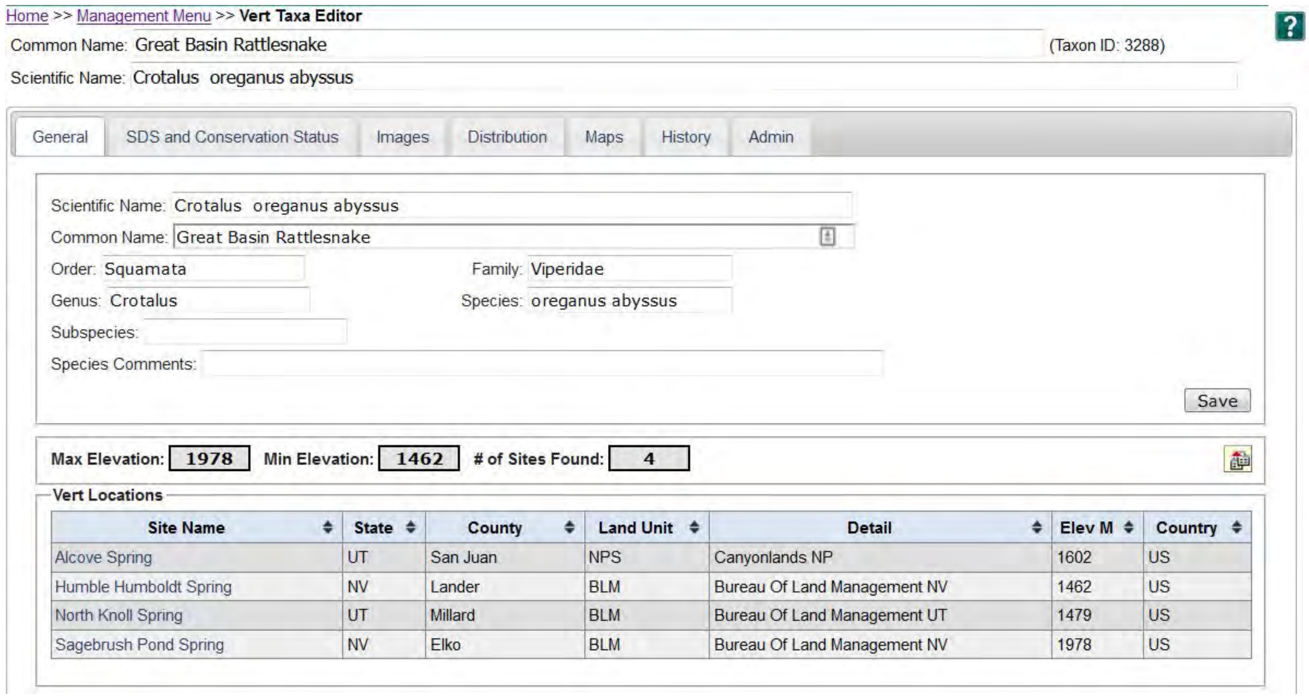


Fig. 6–49. Vertebrate Taxonomic Editor with the Great Basin Rattlesnake (*Crotalus oreganus lutosus*) selected. The General tab for all taxonomic editors includes basic information and a list of locations where the species has been reported. The number of these sites is automatically calculated, along with the maximum and minimum elevations. The taxonomic lists are robust, but are by no means complete, particularly for invertebrate species. The plant taxon list includes all species downloaded from the USDA Plants database, and is refreshed regularly.

Taxonomic Editors for plants, invertebrates, and vertebrates are available from the ***Management Menu***. These were initially described in the Survey section. Upon opening the taxonomic editor, you can look up species by their Taxon ID, if you know it, the scientific name, or the common name. Type the name or ID into the search field, and select the desired species from the list that appears below to open the form. You can also search by conservation status and springs-dependent status fields, although not all taxa have been updated with this information.

Editing taxonomic data requires special permissions. SSI welcomes collaboration from partners interested in reviewing taxonomy and updating the conservation status, distribution, and Springs-Dependent Species (SDS) information. We are also developing a more robust reference list that is cross-referenced to species.

Taxonomic Editor: General Tab

Although some of the fields of the three ***Taxonomic Editors*** vary, the structure and capabilities are similar. The ***General*** tab includes basic taxonomic information, and lists sites within the database where the selected species have been reported (Fig. 6-49). The ***Maximum*** and ***Minimum Elevations***, as well as the number of sites where the species has been reported is automatically updated when a user selects a species is selected. Click the query symbol to export the data to a *.csv file.

Taxon Editor: SDS and Conservation Status

This tab includes information about the conservation status of the species, including ***ESA***, ***IUCN***, and ***NatureServe*** designations. However, these fields have not been populated for all taxa, and recent changes may not be reflected. Other fields will accept other designations for ***National*** and ***Subnational*** conservation status (a free text field). The ***Status Comments*** is also a free text field used to enter additional information or comments about the conservation status. Other fields include ***Endemism Level***, ***Species Life History***, and ***Aquatic Status*** with dropdown choices. These also have not been populated for the entire

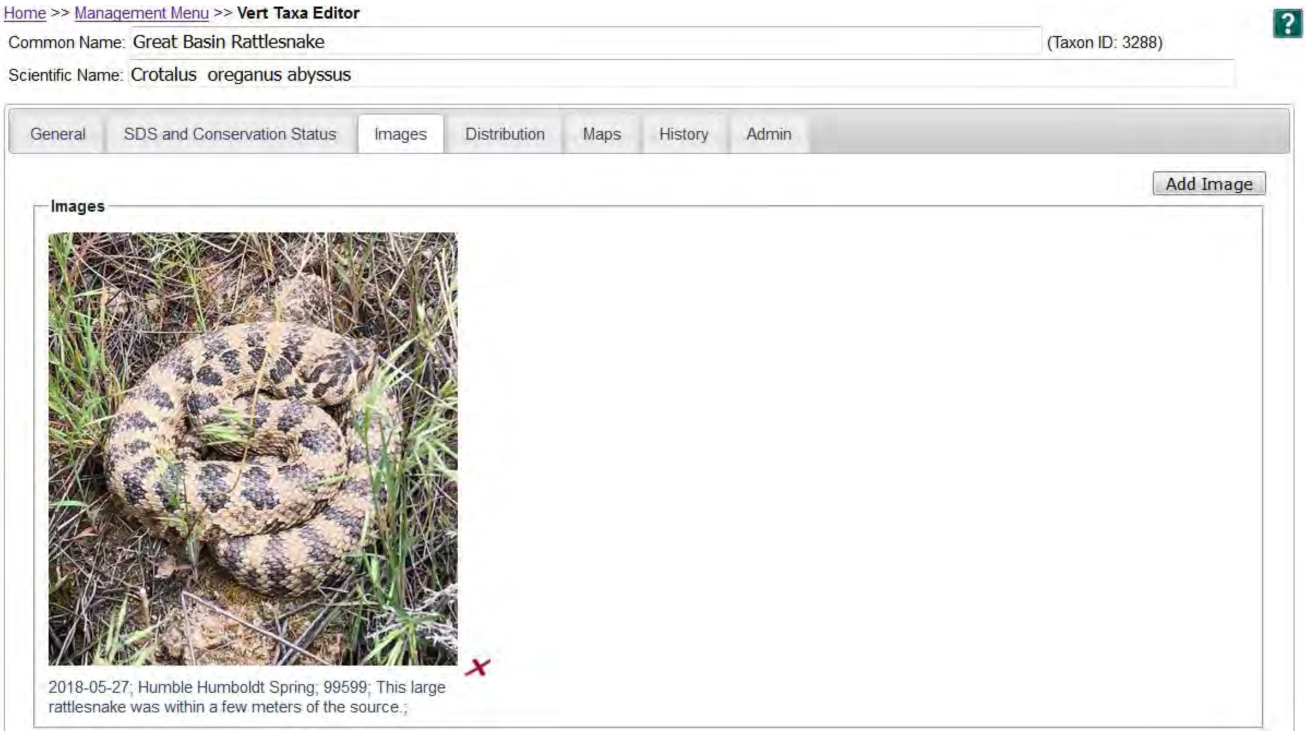


Fig. 6–50. Vertebrate Taxonomic Editor with the Great Basin Rattlesnake and the Images tab selected. Images may be uploded directly into the taxonomic editor, or to surveys. If the latter, the caption will be hyperlinked to the survey.

taxonomic list. You can also link to references that have been added through the ***Reference Editor*** using the ***Link Reference*** button.

Taxon Editor: Images

Any images that have been uploaded directly to the ***Taxonomic Editor***, or from within a survey will appear on this tab (Fig. 6-50). If the image was uploaded through a survey, the date and location will be included in the caption, and hyperlinked to open the survey. Click on an image to open it in a separate browser tab.

Users are welcome to upload species images, but are advised to make sure they have permission to do so. Also, images should be of a reasonable size, and preferably *.jpg files.

Taxon Editor: Distribution

Users can upload *.jpg images of rangemaps here, or enter locality descriptions.

Taxon Editor: Occurrence Maps

From the ***Maps*** tab, click the hyperlinks to display coordinates in Google Maps or Google Earth.

Taxon Editor: History

If a user adds or makes any changes to a taxon record, their user name and the date will be recorded in the list on the ***History*** tab. This is similar to the History list on both the Site and Survey form.

Taxon Editor: Admin

Users with T***axonomic Editor*** permissions may delete species here. However, this option is grayed out if there are associated occurrence records.

Geodatabase Exports

Each night, all data from Springs Online, along with lookup tables and metadata, are exported into a geodatabase on our secure server. We can clip this geodatabase by any number of boundaries, and distribute it upon request. This system provides a user-friendly way to enter data through Springs Online, combined with access to the data through a powerful tool for spatial analysis.

Information Management

All data, photographs, the sketchmap, and other collected data should be entered into the database as soon as possible while the survey crews still remember the sites. All hard copy documents should be safely archived (scanned or hard copy), and should remain available for future reference.

Quality Assurance/Quality Control:

Quality control analyses of data entered into such a system should be conducted using standard methods (Ledbetter et al. 2014, described at: http://springstewardshipinstitute.org/ and the Springs NMRAM QA/QC standard methods).

Data quality control for data accuracy and entry is the responsibility of the crew supervisor. All data entry should be overseen and checked by the project supervisor or the information manager. Data entry errors and data checking should be documented and corrected.

Survey Summary Reports

The survey Summary Report can be generated from Springs Online after the survey data have been entered. These can be exported for a specific survey from the ***Survey*** form, or for an entire project in the ***Projects Management*** form.

A standard springs survey report was designed to summarize all data collected using the Stevens et al. (2016) Level 2 inventory protocol. However, other published springs inventory protocols may be selected, and thus the report structure can vary depending on which protocol was used to conduct the survey. Currently, the Sada and Pohlman (2006) and the US Forest Service GDE Level I survey protocols (2012) are supported. However, the report is generally compatible with other protocols, including the Springs NMRAM. Complete reports contain 11 sections, along with representative and additional photographs and a scan of the site sketchmap.

1. General location and survey information: The first section includes the county, watershed and 8-digit hydrologic unit code (HUC), land manager and land unit name, and the name of the USGS topographic quarter-quad map name. The latitude and longitude in decimal degrees and elevation in meters are also reported here.

This section also includes the details of the survey, including the names of the surveyors, the date, starting time and duration of the survey, the protocol used, the project name, and the survey completion level (e.g. data were collected in 10 of 10 categories). Below this section is the representative photograph, and a caption.

2. Physical Description: The Physical Description section begins with the spring type, geological setting, and the site description as reported by the surveyors. This should include an overview of the spring's physical setting, context, history, and the general vegetation type and land use in the surrounding area. It also should describe any springs development present, such as spring boxes or pipes.

Next this section describes the microhabitats associated with the spring, the number of microhabitats recorded, their basic descriptions (channel, terrace, etc.), and the aerial extent of each. It also reports the geomorphic diversity, which is calculated based on the number and extent of the microhabitats, using the Shannon-Weiner diversity.

Following this paragraph is a table that reports characteristics of each microhabitat, such as slope, aspect, water depth, etc. (See example summary report).

3. Geomorphology: This section includes a description of the emergence environment, including geologic setting, flow force mechanism, and how isolated the spring is from other springs. Solar radiation, as measured using the Solar Pathfinder, is also reported here.

4. Access Directions: This section contains driving and/or walking directions for reaching the site. Particularly, if access is difficult (e.g., requiring a strenuous hike or a difficult climb), this should be noted to assist future surveyors.

5. Survey Notes: This section includes the surveyors' comments about the condition of the site on the day of the survey. This should include anthropogenic impacts, condition of infrastructure, trampling, and other information that does not fit into other categories.

6. Flow: The summary includes the estimated springs flow rate, including method that surveyors used to measure it, the location where flow was measured, the estimated percent captured, and any caveats about how the measurement was accomplished. If surveyors were unable to measure flow, the reason is stated here (e.g., no outflow).

7. Water Quality: This section reports the location(s) and time that water samples were collected, and any comments about field measurements or samples collected. This is followed by a table with the results, including the characteristic, measurement, location ID, instrument used, and comments.

8. Flora: This section begins with a summary of the floristic survey, including the botanists who conducted the survey, the species richness and density, and the number of native and non-native species documented. Following this are two tables; the first table reports the total number of plant species and the number of wetland plant species recorded in each vegetation stratum, and the second table is a species list with associated cover values within each microhabitat and stratum.

9. Fauna: This section includes any comments reported by the surveyors about vertebrates and invertebrate species observed at the site, , including the number of vertebrate and invertebrate taxa that were documented. Two tables follow the summary; the first table is an invertebrate taxa list and the second is a vertebrate species list. Both tables include data on number of observations and method of detection.

10. Assessment: This section is related to the Stevens et al. (2012) assessment method.

11. Management Recommendations: This section includes any management recommendations reported by the surveyors, based on the condition assessment.

The report concludes with the scanned sketch-map of the site, as well as additional photos and captions, if available.

The summary report is a powerful tool that can assist land managers in understanding the context and condition of the springs ecosystem, as well as its structure, biotic assemblages, and physical attributes. This information will allow NMED to understand the distribution and status of the various springs types in New Mexico, and consider management recommendations. An example of a completed Summary Report is included in Appendix C.

7 Springs Ecosystem Rapid Assessment

Introduction

Springs are groundwater dependent ecosystems that are highly threatened by human activities, and often are ecologically impaired in New Mexico and throughout the world. The overuse of springs for domestic use, mining, and livestock, as well as contamination of groundwater supplies, has led to impairment or destruction of many of these ecosystems (Stevens and Meretsky 2008; Kreamer et al. 2015). Understanding the status of springs across a landscape begins with collecting quality data on the current condition of springs, followed by a methodical evaluation of that information for management planning and actions.

The purpose of this Springs New Mexico Rapid Assessment Method (Springs NMRAM) is to provide credible, repeatable evaluation of springs ecological integrity. This method is specifically designed to be scaled up to evaluate springs condition across a landscape and over time.

This assessment approach will be improved as it is more thoroughly tested. It will help inform and guide decision-making based on the status, importance, and potential for restoration of individual springs considered in a regional context. Such an ecosystem health assessment is fundamental to improving springs ecology and stewardship.

Developing the Springs NMRAM

Overview

Several springs ecological integrity assessments have been developed over the last two decades (Paffett et al. 2018). The most prominent assessment protocols for the American Southwest have been the Department of Defense method for the White Sands Proving Grounds (Thompson et al. 2002), the National Park Service protocols developed for the Mojave and Chihuahuan Deserts (Sada and Pohlmann 2006), the Bureau of Land Management's Proper Functioning Condition (PFC) tool for lentic and lotic systems (Prichard 1998, 2003, respectively), the U.S. Forest Service groundwater dependent ecosystem model (USFS 2012), and the Springs Stewardship Institute's Springs Ecological Assessment Protocol (SEAP; Stevens et al. 2012). Nearly all of these protocols focus on common elements (e.g., flow, water quality, habitat area, human impacts, sensitive species, etc.), and no single approach has been widely accepted. The number of factors, amount of qualitative versus quantitative decision-making, and the resolution of individual valuations, varies considerably between these methods.

The Springs NMRAM integrates elements of the aforementioned springs-specific protocols. In developing the Springs NMRAM we also reviewed several riparian assessment protocols (Stromberg et al. 2004; Stevens et al. 2005) and dozens of Rapid Assessment Methods that have been developed for other ecosystem types (Fennessy et al. 2004; Dorney et al. 2018). We incorporated the collective field experience of many experts, including the SSI staff and the NMED staff who have developed wetland, riparian, playa NMRAMs across New Mexico over the past decade. Based on this review and consultation, we distilled a number of principles. We have clarified the Springs NMRAM around these principles.

Background Considerations

Assessments need to begin with actual measurements (or quantified estimates)

Ecosystem assessment should be an efficient, data-driven process. There are intrinsic trade-offs between efficiency and information content; however, actual quantitative measurements are less biased, more precise, and more repeatable than qualitative evaluation procedures. We recommend the measurement of a rather wide array of ecological and anthropogenic impact variables, including flow, water chemistry, native and non native species distribution, and other variables of management interest. We recommend using the Springs Inventory Protocol (Chapter 5) to fulfill this requirement.

Assess the site deviation from the natural condition

In these rapid ecosystem assessments, the inventory team assesses the degree to which the site condition differs from that hypothesized to be the natural condition.

Begin with the geomorphic context

The comparison between current site condition and “natural” condition should begin with evaluation of the geomorphic context. There are several reasons for this. First, springs are best classified based on their geomorphology. This is because the geomorphology of the spring is a strong indicator of how it functions and interacts with the surrounding landscape (see chapter 3). Also, springs geomorphology does not readily change without direct and dramatic human intervention (e.g. a helocrene spring can be excavated to form a limnocrene spring, and groundwater overdraft can create a hypocrene spring out of any other type). In contrast, the hydrology and biota of a spring are moving targets, often varying dramatically among seasons and years, with or without human intervention.

Assessment should be based on existing conditions, not potential conditions

Future conditions at springs are not predictable, and therefore the assessment team should evaluate existing conditions and threats, not potential ecosystem responses to future conditions.

Use reference sites to understand and recognize natural springs condition

Reference sites are useful to achieve a variety of goals. They can be used to examine and understand the range of natural variation in ecosystem variables, to scale Springs NMRAM scoring, and to train assessment team members. Analyses of reference site data are likely to reveal information gaps and biases about causal relationships and human impacts (Brinson and Rheinhardt 1996). Unfortunately, at this time there are no designated springs reference sites in New Mexico. To remedy this problem, a panel of independent authorities may be convened to recommend sites and characteristics that are geomorphically and ecologically functional and consonant with expected natural conditions.

Reference sites are best located in parks, wilderness areas, and other protected landscapes, and should be georeferenced, described in detail, assessed according to this Springs NMRAM protocol, and used to scale the scoring of similar types of springs. The array of reference types should include different springs types, be distributed across elevation, slope, and aspect, and be relatively free from conspicuous anthropogenic impacts, especially livestock grazing, water diversion, pollution, roads, and ground water extraction.

Assessment should be repeatable by different inventory teams

Without repeatability, the results are relative and of little use for comparisons, long-term planning, or stewardship. There are two aspects to achieving this metric. First, the assessment should be designed with well-defined, clearly worded rating criteria for evaluating springs ecological condition. Clearly defined criteria reduce human error, miscommunication, and drift in evaluation technique. Second, and just as importantly, the assessment team should be properly trained to conduct the assessments.

Individual ecosystem characteristics should be rated separately, and those ratings should build to a rating for the entire springs ecosystem

A single composite site score is useful for judging site health and developing regional restoration priorities. However, it is important to recognize that a single summary score should not constitute the final interpretation of ecosystem condition. For example, a springs ecosystem may be functioning well physically, but be biologically degraded. Alternately, a springs’ hydrology and geomorphology may be highly altered, but the ecosystem may still support a high diversity of native species. To fully understand a site's ecological condition and make management recommendations, it is crucial to examine category scores as well as the overall site score.

Springs management goals should be considered when interpreting site condition scores

While the basis of the Springs NMRAM is comparing the site condition to an unaltered, "natural" condition, it is important to remember that springs are frequently managed for specific purposes. In many cases, successful implementation of management goals will create conditions that are farther from "natural," leading to lower assessment scores. In these cases we recommend using the Springs NMRAM results as guidance for seeking a balance between anthropogenic management goals and ecological function.

Springs NMRAM Refinement

This Springs NMRAM is a pilot effort, one that undoubtedly will be refined through additional data analyses and review. Testing and review is needed and welcomed to guarantee its continued scientific relevance, cost-effectiveness ,and flexibility. Such revisions will help improve land, wildlife, cultural, and socioeconomic resource management (Rapport et al. 2003).

Conducting a Springs NMRAM

Springs NMRAM Overview

The assessment process should begin in the office by compiling background information on the springs in the landscape of interest (see Pre-Field Activities, below). This information is used to understand the landscape context of the springs and to prioritize sites for inventory and assessment.

Once sites are selected, they should be visited and inventoried using the Springs Inventory Protocol (Chapter 5). This data is used to produce site summary reports and also directly informs the Rapid Assessment.

Surveyors should complete the Springs NMRAM scoring after completing the Springs Inventory Protocol. Scoring should be completed on-site in the field, or immediately afterwards, while memory of the site is fresh.

The entire Springs NMRAM process uses four suites of information. These are: 1) the results of the Springs Inventory Protocol (SIP); 2) the stressors checklist; 3) scoring of 19 assessment questions, as well as scoring three geography questions that do not contribute to the assessment score; and 4) a workbook to guide the team on scoring each assessment question.

Each step and component in the Springs NMRAM scoring process is described below.

Assessment Team Composition

The Springs NMRAM inventory and assessment protocols are designed to be conducted by a team of experts or highly trained technicians, and scoring is based on the expectation that the team will make informed and unbiased scientific judgments about the site (Stevens et al., 2016). The team should include expertise in hydrogeomorphology, aquatic biology, riparian ecology, and sociocultural issues. Team members should be thoroughly trained in: springs inventory, classification, and assessment techniques; interpretation of geomorphic consistency; and detecting subtle site historical impacts. The team should be informed as to regional background data (below). A team leader should be designated who is responsible for oversight, team safety, and data wrangling.

Pre-Field Activities

Overview

Dedicated office time is required prior to the field visit to compile background information on the springs in the landscape of interest. This will aid in site selection and also will provide a valuable regional context for the interpretation of site conditions when in the field.

In order to effectively evaluate springs ecological functionality, it is necessary to understand the regional cultural, hydrogeolgical, biological, and cultural context in which the springs exist at landscape and regional scales.

Springs Distribution

Springs distribution should be compiled and integrated through a Geographic Information Systems (GIS) analysis. This step is crucial for planning field logistics. If possible, georeference springs source elevations to 3 meter accuracy.

Such accuracy is necessary for groundwater modeling.

Cultural Context

Incorporation of cultural expertise will contribute to the inventory and lay the groundwork for the compliance activities often needed for restoration. Traditional indigenous on-reservation and off-reservation land use history and practices should be compiled, as well as applicable archaeological and traditional cultural property information in the study area.

Historical Land Use

The historic role of natural and anthropogenic land uses and disturbance plays a strong role in existing ecosystem traits and functions. However, the impacts of previous land uses are often difficult to interpret in the field. Therefore, we recommend compiling all information available on local and regional land use history, including: descriptions of prehistoric, historic, and traditional cultural uses and values; verbal histories of elders; matching of historical photographs; administrative history; contemporary land management, including well-drilling, springs piping, and road construction history; land and water rights ownership, state and federal groundwater management policy, and other legal issues; economic resources distribution; and current demography and economic trends.

Aquifer Hydrogeology

To better understand aquifer hydrology in the landscape of interest, it is valuable to summarize all available information on these topics: regional climate; regional and springs-specific geology; groundwater supplies and dynamics; springs distribution; groundwater and springs geochemistry; hydrography and trends in springs discharge; the extent of groundwater use, well distribution, ground- and surface water pollution, and spring discharge regulation; major surface flow event history; surface stream sedimentological history; seasonal trends in flow and water quality; basin soils; and any other relevant physical factors.

Numerical groundwater flow models, such as the U.S. Geological Survey's three-dimensional, finite-difference MODFLOW program (Harbaugh and McDonald 1996), use a series of equations for flow and water budgets to describe water movement through aquifers (Anderson and Woessner 1992). Modeling predictions for springs should be developed for varying climate conditions and groundwater extraction rates.

Biological Context

Springs management is often focused on sensitive, threatened, endangered, endemic, and non-native taxa. Prior to field visits, it is useful to research and compile a list of species expected at the site. Separate lists of expected sensitive, threatened, endangered, and noxious or exotic species are also useful.

Springs NMRAM Inventory and Information Management

Upon arriving at a study spring, the first step in the Springs NMRAM process is to complete a springs inventory. A carefully executed springs inventory provides the data necessary to assess the site condition and verify the assessment. The assessment includes the completed Stressors Checklist, the completed Assessment Questions, the calculated Site Assessment report.

Stressors Checklist

Following the field inventory, the next step in the Springs NMRAM process is for the team to fill out the Stressors Checklist while still in the field. Six basic categories of stressors are addressed in this checklist: 1) flow regulation and hydrological alteration, 2) soil and geomorphic alteration, 3) animal impacts, 4) recreation impacts, 5) structures or development impacts, and 6) land use impacts. Each stressor category is subdivided into six to twelve subcategory variables, and each includes the opportunity to identify "other" stressors.

The team manually or electronically checks the level of impact risk of each stressor variable on the springs ecosystem, with impacts ranging from 1 (absent, no impact) to 4 (intense impact). The Stressors Checklist is informational and is intended to clarify which stressors are influencing the site. The results of the Stressor Checklist are not formally incorporated into the overall site condition score; rather, they are used to inform the assessment questions and also provide an additional tool for NMED to consider management recommendations. An example of a completed Stressors Checklist is included in Appendix C.

Springs Assessment

Approach

Specific questions that focus on site conditions have been shown to be the most effective assessment tools (Dorney et al. 2018). While still in the field, after completing a springs ecosystem inventory and the Stressors Checklist, the assessment team should score all 19 of the Springs NMRAM questions listed below, using the Assessment Field and Site Summary Sheets.

Assessment Questions

The assessment questions address the site condition in five basic categories: 1) Aquifer Functionality, Water Quality and Flow (Questions A-C); 2) Geomorphology (Questions D-G); 3) General Site Description (Questions H-J, informational only and not included in the final RAM score); 4) Habitat (Questions K-M); and 5) Biota (Questions N-S). Each category and its questions are described in detail in Chapter 8: Assessment Field Guide. Scores range from 1.0 to 4.0 in half-integer increments (i.e., 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0). Ascending values indicate higher ecological integrity, with 1.0 representing an irrecoverably impaired condition, and 4.0 representing an ecologically pristine condition.

In some cases, the inventory and assessment team may not have sufficient information in the field to answer a question but may, with additional office research, answer the question in the office. In such cases, leaving a score blank among the Assessment Questions signifies that the team is committed to promptly scoring that question when they return to the office. Also, some of the questions may not be applicable to a given springs type. For example, a springbrook may naturally not be a feature of a helocrene ciénega. In such cases, those should be scored as "n/a".

Assessment Scoring

Category scores are calculated using the scored responses to the individual assessment questions. First, individual subcategory scores are summed. That number is divided by the total possible subcategory score (often 12, 16, or 20, depending on the number of subcategory variables and whether there are any "non-applicable" subcategory scores). That fraction is then multiplied by 4.0. Values less than 1.0 are increased to 1.0 (the minimum possible score). In cases where a subcategory question is not applicable (e.g., no outflowing springbrook is necessarily expected at helocrene wet meadow springs), the total possible score is reduced by 4 and that adjusted subcategory value is then divided by the sum of subcategory values, with scores less than 1.0 increased to 1.0. The resulting category scores will vary between 1.0 and 4.0. For example, if the three AFWQF question scores summed to 5, and the total category score for three questions was 3 x 4 =12, the AFWQF category score would be (5/12)*4= 1.7, rounding to 1.5.(a slightly better than poor score) These category scores serve in rapid intra-site assessment of conditions among categories.

The total site score is calculated in the same manner. All individual subcategory variable scores are summed, and that value is divided by the total possible site score (60 if there are no "non-applicable" or unanswered subcategory scores). That fraction is then multiplied by 4. Scores less than 1.0 are increased to 1.0. Again, for each subcategory that is not applicable, the total possible score is reduced by 4. The resulting overall site score will vary between 1.0 and 4.0, in accord with prior NMRAM protocols. For example, if the total subcategories score is 51 and the possible site score is 60, the total site score would be (51/60)*4 = 3.4, rounding up to 3.5 (a near pristine score).

The purpose of the Springs NMRAM is to provide the State of New Mexico with a comparative information-based evaluation of the ecological integrity and condition of individual springs. Therefore, any spring that has been assessed using this process will provide the managers with a clear understanding of the ecological integrity and stewardship opportunities and challenges within that springs ecosystem, among assessed springs across the state, and the responses of that springs ecosystem to management actions.

Periodic Program Review

The Springs NMRAM inventory and assessment protocols are based on the protocols described in Chapter 5. Conceptual and technological advances in the fields of springs ecology and ecological assessment are occurring on a regular basis. Therefore, the inventory and Springs NMRAM protocols should be re-evaluated periodically (e.g., every five years or so) to ensure that the data being collected meet the managers and NMED needs, and to determine if and how the protocols require revision. We strongly recommend that any protocol adjustments be calibrated with past data before being adopted, to ensure that legacy data can continue to be useful in determining long-term trends. In addition, the associated information management system should be rigorously maintained and periodically reviewed and upgraded to ensure long-term archival and relational integration of springs information for the State of New Mexico.

8 Assessment Field Guide

Introduction

Rapid assessment of the ecological integrity (condition) of a springs ecosystem is accomplished by first conducting a site visit. Two major tasks should be completed during the site visit; first, conduct a springs inventory (see Chapter 5 for the protocol), and next, fill out the Stressors Checklist (described below, in this chapter). The data collected from these two activities is then used to answer 19 assessment questions.

It is best to answer the assessment questions in the field or as soon as possible after leaving the field site. However, there are a few assessment questions that may be more accurately answered with additional research or calculations that are not easily done in the field. Those questions can be left blank in the field and addressed as soon as possible upon returning to the office.

We recommend entering the springs inventory data into the Springs Online database soon after arriving back in the office. Once the data are entered, there are several summary statistics that Springs Online automatically calculates. Some of these summary statistics (for example total cover of exotic plants) are helpful in answering or refining the answers to the assessment questions.

After the all assessment questions are answered, the responses are used to calculate condition scores for each category, followed by an assessment score for the whole site. This chapter serves as a guide to complete the Stressors Checklist, answer Assessment Questions, and derive Category and Whole-site Assessment scores.

Stressors Checklist

The Stressors Checklist is an important secondary source of information about the factors influencing the study site. It should be completed after the springs inventory protocol, and provides additional insight into the condition of the spring and what factors are influencing its condition. The Stressors Checklist should be completed during the springs site visit, preferably through a collaborative discussion within the inventory team. The team should focus on the ecosystem directly influenced by the spring.

Six basic categories of stressors are addressed in the checklist: 1) flow regulation and hydrological alteration, 2) soil and geomorphic alteration, 3) animal impacts, 4) recreation impacts, 5) structures or development impacts, and 6) land use impacts. These categories were chosen based on extensive field and literature review of the anthropogenic factors influencing springs ecosystem integrity in North America. Within each category, six to twelve stressors are listed, and there is also space to identify "other" stressors.

The list is designed to be filled out with check marks that indicate the degree to which each stressor is present at the site. Scores range from 1 (absent) to 4 (intense). In addition to assigning a numeric rating to each individual stressor, the survey team should also evaluate the overall impact of each stressor category on the site's condition. Impact rating for each category should be recorded in the left-most column of the data sheet, as "low", "medium" or high."

The electronic form will automatically calculate a score for each stressor category, based on responses in the checkboxes. However, it is important to remember that the Stressor Checklist is simply a tool to aid in understanding which external factors are influencing site condition. The secondary impact rating for each category (the "low," "medium," "high" rating) is not formally incorporated into the category scores; rather that rating too should be considered a tool for understanding site condition. An example of a completed Stressors Checklist is included for Cherry Creek Spring (Appendix C).

SiteName________________________________ID__________ Observer______________________

Impact	Stressor Checklist	1 Absent	2 Minor	3 Moder-ate	4 Intense
Impact	**Flow regulation or hydrological alteration**				
	Surface water diverted away (ditch, pipe, etc)				
	Springbox, springhouse, or cap (enclosed in concrete, metal, rock, etc)				
	Upgradient pre-emergence groundwater flow capture (e.g. pipe)				
	Downgradient capture of surface flow (into tank, trough, etc)				
	Flow regulated by impoundment or dam (e.g., berm, concrete structure)				
	Source excavated to create open water (e.g., tank)				
	Non-point source surface water pollution (e.g., road, agricultural, mining)				
	Point source surface water pollution (e.g., sewage leakage, ungulate feces)				
	Groundwater contamination (evidenced by dead animals, vegetation, odor)				
	Nearby wells (groundwater extraction - consider size and proximity)				
	Prolonged drought (Palmer's index, moderate=2, severe=3, extreme=4)				
	Other hydrologic disturbance ______________________				
	Flow regulation, hydrologic alteration (max=48)				
	Soil or geomorphic alteration				
	Erosion - overall landscape, general, human influenced				
	Erosion - on-site human influenced (e.g., channel, gully, cutbank)				
	Excavation (e.g., pond creation, springbox and installation)				
	Soil compaction (e.g., livestock trampling, vehicle use)				
	Deposition, debris flow, spoil pile, or land fill				
	Pedestals or hummocks due to livestock or wildlife				
	Ruts (from vehicles)				
	Soil removal (e.g., gravel or other mining, road construction)				
	Soil contamination (e.g., oil, salt licks, refuse)				
	Trails (human or animals)				
	Other soil disturbance ______________________				
	Soil or geomorphic alteration (max=44)				
	Animal impacts				
	Habitat alteration by aquatic species (e.g., beaver, muskrat, nutria)				
	Habitat alteration by terrestrial species (e.g., gopher, squirrel burrows)				
	Wildlife grazing, browsing, defecating, or trampling (e.g., elk, deer)				
	Livestock grazing, browsing, defecating, or trampling				
	Non-native predators (e.g., crayfish, introduced fish, domestic animals)				
	Other animal effects______________________				
	Animal impacts (max=24)				

SiteName________________________________ID____________Observer______________________

	Stressor Checklist	1 Absent	2 Minor	3 Moder-ate	4 Intense
Impact	**Recreation impacts**				
	Camp sites (e.g., fire rings, refuse, site leveling, compaction)				
	Tracks or trails by recreational motorized vehicles (dirt bikes, ATV, UTV)				
	Tracks or trails from hiking, mountain biking				
	Tracks or trails from pack animals				
	Hunting/fishing (e.g., game cameras, salt licks, carcasses, lures/line)				
	Target practice (e.g., shotgun shells, gunshot damage)				
	Urban park lands, sports fields, swimming pools				
	Passive recreation (e.g., birdwatching, photography, hot spring)				
	Refuse or other waste disposal (e.g., toilet paper, cans, bottles)				
	Excessive human visitation				
	Human modification (e.g., hot springs dams, structures, climb/cave gear)				
	Other recreation disturbance ______________________________				
	Recreation impacts (max=48)				
	Structures or development impacts				
	Abandoned infrastructure (non-functioning piping, springboxes, or tanks)				
	Utility corridors or power lines				
	Residential development				
	Industrial or commercial development, mining structures				
	Light or noise pollution				
	Erosion control structure (e.g., gabeons, grade controls)				
	Wildlife entrapment risk (e.g., missing springbox lid, open tank no escapement)				
	Fence - geomorphically inappropriate and/or nonfunctioning				
	Oil or gas well				
	Pipeline external to site (e.g., oil, gas, water)				
	Other structural disturbance ______________________________				
	Structures or development impacts (max=44)				
	Land use impacts				
	Fire regime				
	Crop production (current or past)				
	Ranch use (current or past)				
	Road, incl. construction or maint. (paving type, use intensity, and proximity)				
	Restoration, rehabilitation, or remediation actions				
	Sensitive species protection efforts (e.g., fish translocation)				
	Biological resource extraction (e.g., aquaculture, fisheries, plant collecting)				
	Physical resource extraction (e.g., mining, quarrying)				
	Forest management (e.g., thinning, timber harvest, planting)				
	Scientific activities, including sentinel site monitoring				
	Education activities (e.g., environmental education, tourism, youth camp)				
	Other land use effects____________________________________				
	Land use impacts (max=48)				

Condition Assessment Questions

These 19 assessment questions are designed to aid the inventory team in documenting the site condition according to consistent, repeatable criteria. Questions are classified into five basic categories. Higher scores equate to better condition of that factor or resource. An example of a completed assessment question form is provided in Appendix C for Cherry Creek Spring.

Aquifer Function, Water Quality

The following factor condition questions (A-C) are related to the apparent condition of the aquifer and water table, short-term climatic conditions, quality of groundwater at the source(s), and anthropogenic alteration of surface flow.

A. Water table

Question: Is there evidence that the water table is dropping, and the aquifer is failing to produce natural quantities of water for the springs ecosystem? For example, is woody vegetation (e.g., cottonwood, tree willow, other woody phreatophytes) showing evidence of mortality or declining health? Is woody upland vegetation encroaching? Or is an area now dry that was apparently previously groundwater supported? Is there an abandoned well or windmill? Any of these can indicate a declining water table.

Background: Springs are groundwater-dependent ecosystems, thus their ecological integrity is virtually entirely dependent on the supporting aquifer. The more obvious signs of water table decline are listed below, but additional information from groundwater modeling or data from nearby wells can add certainty to the field observations. Note that the absence of surface flow is not necessarily evidence of water table decline; see the description of hypocrene springs in chapter 3.

Confidence Value: Medium, and best verified with modeling or well log data.

Rationale: Incontrovertible detection of water table change requires analysis of well log data, and also may be indicated through groundwater modeling; however, depletion of shallow aquifers is often detected by surface vegetation and abandoned water extraction equipment and conveyance, such as pipes or irrigation ditches. For a rapid assessment, evidence of these elements is sufficient to indicate water table depletion.

Seasonality: In shallow aquifers, water table elevation is likely highest following winter snowmelt. Deeper aquifers are less sensitive to seasonality.

Assessment Protocol: Based on field observations, and office research on groundwater modeling and well log data, if available.

Scoring:

1. The aquifer is depleted or in significant decline, as evidenced by: total loss of springs fauna (requires knowledge of springs fauna formerly occupying the site); total loss of wetland vegetation cover (observed as dead wetland plants), and/or substantial encroachment of upland vegetation.
2. The aquifer is moderately depleted, with evidence of decreasing or dying springs-dependent fauna or wetland vegetation cover, and/or encroachment of upland vegetation.
3. Aquifer is slightly but detectably depleted, with minor evidence of decreasing or dying wetland vegetation cover and/or limited encroachment of upland vegetation.
4. The aquifer appears to be in pristine or near-pristine condition, with no evidence of reduced flow, loss of wetland vegetation, or encroachment of upland vegetation.

-- Surveyors are unable to assess the water table condition in the field, but will conduct follow-up research (e.g., interview the land manager) and assign a score.

Scaling Procedure and Rationale: Use half-decimal values from 1.0 (highly degraded) to 4.0 (pristine). Scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

Fig. 8–1. Upland vegetation has encroached in the channel downstream of Honey Bee Dam Spring, located in the Gila National Forest.

B. Surface water quality

Question: What is the quality of water after it emerges onto the surface? Is there visual, olfactory, or other evidence of contamination (e.g., feces, strong odor, unusual color)?

Background: Groundwater and post-emergence surface water quality is a critically important characteristic that influences all aspects of a springs ecosystem's ecological and socio-cultural function and integrity. Common sources of springs flow contamination in New Mexico include livestock feces

Confidence Value: Low to medium.

Rationale: Water quality is widely assessed using EPA standards for conductivity and contaminants, but this standard is not necessarily appropriate for evaluating the ecological condition of New Mexico springs. Natural springs waters in the Southwest often exceed EPA standards for safe drinking water, in many cases supporting highly adapted organisms. Therefore we have selected indicator variables that are regionally appropriate and readily detected during a field site visit.

Seasonality: Seasonality does not play a consistent role in anthropogenic influences on springs water quality, although odors may be more apparent during warmer weather.

Assessment Protocol: The protocol for this question does not require intensive water quality testing, which would need to be performed at a State-certified laboratory using high quality sample collecting techniques. However, this approach may not detect contamination that does not result in obvious odors or discoloration, and therefore has relatively low reliability. If obvious signs of ground- or surface-water contamination are reported, more intensive investigation of water quality may be warranted.

Scoring:

1. The surface water quality is extremely poor with strong visual, olfactory, or other indications.
2. Moderately low surface water quality, with some visual, olfactory, or other indications.
3. Moderately high surface water quality, with little visual, olfactory, or other indication of impairment.
4. High surface water quality, with no visual, olfactory, or other indication of impairment.

-- Surveyors were unable to assess surface water quality in the field, but will conduct follow-up research (e.g., locate existing water quality data) and assign a score.

Scaling Procedure and Rationale: Higher scores equate to better condition of that factor or resource. Use half-decimal values from 1.0 (highly degraded) to 4.0 (pristine). Scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

Fig. 8–3. This long-dead cow lay on the terrace at Adair Spring.

Fig. 8–2. The water in this heavily trampled spring in the Gila Wilderness had a strong odor from ungulate urine and feces.

C. Springs flow

Question: Is there evidence that the springs flow has been altered through human actions, such as wells, diversions, or capping?

Background: Springs flow can be extracted prior to emergence or after emergence. Extraction and diversion may not always be apparent, as pipes often are deeply buried, and there may be no surface evidence of the extraction or diversion.

Confidence Value: Medium to high.

Rationale: This question is critical to understanding the extent to which flow, a critical characteristic of springs ecosystems, has been altered. Springs flow measurement is a standard practice during inventory; however, credibly answering the question may require flow monitoring information that is only rarely available.

Seasonality: Springs discharge often varies over the course of the year. Shallow aquifer springs may respond strongly to climate, particularly to melting snow-pack, and therefore can be highly variable or even ephemeral. Most hydrologists prefer to measure flow during mid-winter, when evapotranspiring riparian vegetation is not reducing springs discharge. Deeper aquifer springs are less sensitive to climate, and may show limited or lagged responses to climate variability.

Assessment Protocol: Based on field measurements and observations. Additional office research on streamflow gauge data can help evaluate local to regional changes in groundwater discharge, particularly during dry seasons.

Scoring:

1. The springs ecosystem that previously flowed is dry, with no flow evident at the source(s), or has been completely diverted or capped.
2. Springs flow from the source(s) has been greatly reduced due to wells, diversions, or capping.
3. Springs flow from the source(s) appears to have been slightly reduced due to wells, diversions, or capping.
4. Springs flow from the source(s) appears to be natural or near natural, with no wells, diversions, or capping.

-- Surveyors are unable to assess springs flow in the field, but will conduct follow-up research (e.g., locating historical information about use) and assign a score.

Scaling Procedure and Rationale: Higher scores equate to better condition of that factor or resource. Use half-decimal values from 1.0 (highly degraded) to 4.0 (pristine). Scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0. Space for comments about aquifer functionality and water quality are provided on the worksheet.

Fig. 8–4. All water is captured in tanks and springboxes at Harris Canyon Spring in the Gila National Forest.

Geomorphology

The following questions are related to the natural geomorphic integrity of the springs ecosystem. Scores will vary from 1.0 (highly altered) to 4.0 (pristine), using half decimals. For question E, if an estimated percent cover is within 5% of a boundary score, a half-decimal should be applied. Scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

D. Natural geomorphic diversity

Question: Are the expected microhabitats for this springs ecosystem type present, and/or are additional natural microhabitats or anthropogenic microhabitats present? Are geomorphic processes negatively influenced by human activities at the springs?

Background: Different springs types support different geomorphic microhabitats and microhabitat diversity influences springs biodiversity; however, anthropogenic microhabitats can diminish springs biodiversity and ecological function. Therefore, this question addresses the number of natural and anthropogenic microhabitats

Confidence Value: Medium to high, if the inventory and assessment team is trained to identify geomorphic microhabitats.

Rationale: The array of microhabitat array at a springs ecosystem influences its functionality, which species can exist there, as well as overall ecosystem biodiversity. For example, plant species richness is positively related to the number of microhabitats present (Springer et al. 2014; Sinclair 2018), and such patterns also are expected for both invertebrates and vertebrates.

Seasonality: The microhabitat array is not influenced by seasonality.

Assessment Protocol: This question is answered by calculating the difference between observed and expected microhabitat presence, and requires understanding which microhabitats are most likely to occur at which springs types. See Worksheet D for clarification of the microhabitat types expected to occur at different springs types. An expected microhabitat at a given springs type scores as "3", moderately probable microhabitats that occur at a given springs type score as "2", and other natural microhabitats score as "1". Each anthropogenic microhabitat reduces the final score by 1.0, so the sum of microhabitats for the site is discounted for anthropogenic microhabitats.

Scoring:

Use Worksheet D to calculate this assessment score. The score calculated using Worksheet D may be interpreted using these descriptions:

1. The microhabitats that are expected or may occur in this springs ecosystem type are missing.
2. Few of the microhabitats that are expected or may occur in this springs type are present.
3. Most, but not all of the microhabitats that are expected or may occur in this springs ecosystem type are present.
4. All of the microhabitats that are expected, as well as others that may occur in this springs ecosystem type are present.

Scaling Procedure and Rationale: Use worksheet D to calculate a geomorphic diversity score. An example of a completed worksheet D for Cherry Creek Spring is provided in Appendix C.

Fig. 8–5. Heavily manipulated sites such as Dripping Gold Spring often have fewer natural microhabitats than are expected, resulting in a lower geomorphic diversity.

E. Soil integrity

Question: To what extent are the soils, if present, altered due to anthropogenic influences? Natural soils can be affected by trampling, paving, trailing, vehicle tracks, fire pits, and other factors. What percent of the natural soils have been affected by these impacts?

Background: Natural soils are characterized by organic matter overlying mineralized subsurface materials. Soils develop in response to geologic processes, parent rock geology, vegetation, and climate over time.

Confidence Value: Medium.

Rationale: Soil integrates climate, geology, vegetation, land use, and time, and therefore is an excellent indicator of site alteration.

Seasonality: The only way seasonality affects soil assessment is whether if the soil is obscured from view by snow or dense vegetation.

Assessment Protocol: This protocol involves visual estimation of the percent of alteration of natural surface soil, including peat in its various forms.

Scoring:

1. Between 75 to 100% of the surface area of natural soils, including peat, have been eliminated.
2. Between 50 to 75% of the surface area of natural soils, including peat, are altered and highly compromised.
3. Between 25 to 50% of the surface area of natural soils and/or peat deposits are altered, and soils are somewhat compromised.
4. Between 0 to 25% of the surface area of natural soils and/or peat deposits are altered, or natural soils are not expected to occur at that springs ecosystem type (e.g., bedrock-dominated gushet or hanging gardens springs).

Scaling Procedure and Rationale: Higher scores equate to higher cover of natural soils. Anthropogenic alteration of soils reduces the total percent cover. A caveat here is that naturally bedrock-dominated springs types (e.g., gushets, hanging gardens, some upland hillslope springs) may have little natural soil, but be in good geomorphic condition. Therefore, it is important to recognize that scoring this variable should include consideration of the geomorphic consistency of the site.

Fig. 8–6. Soils have been heavily altered by livestock at Lookout Spring, located in the Gila National Forest.

Fig. 8–7. McFate Spring in the Gila National Forest has been excavated and bermed to form a pond for watering livestock. Soils are heavily trampled.

F. Natural physical disturbance

Question: Is the site subject to its natural geomorphic disturbance regime, including flooding, rockfall, mammalian herbivore influences, or other natural disturbances? Fire disturbance is considered in the next question.

Background: Upstream impoundments and channel alterations influence natural flooding, or inundate rheocrene springs downstream. Stabilization measures reduce natural disturbances such as rockfall or sprawling. Intensive mammalian herbivore use can alter the site geomorphology. Exclosures, while well-intended, can eliminate wildlife use, resulting in proliferation of wetland vegetation and loss of surface water and habitat. The four characteristics of ecological disturbance are timing, magnitude, duration, and frequency, all of which can be altered by upstream or upslope influences, climate change, and other processes.

Confidence Value: Low to medium

Rationale: Each springs type is subject to natural disturbances, which influence geomorphology, biodiversity, and goods and service. ***Seasonality:*** Natural disturbance regimes, such as flooding, are highly seasonal, whereas rockfall, slope failure, and other forms of natural disturbance may be less clearly seasonally influenced.

Assessment Protocol: This question is scored based on the expert opinion of the inventory and assessment team at the time of the site visit. Examine signs of recent disturbance, such as flood sediments, organic debris strand-lines, signs of recent rockfall, or storms. In-office information often can be compiled to improve the confidence in this score.

Scoring:

1. The natural disturbance regime is nearly or entirely altered, and is largely unrecoverable. All four characteristics have been altered.

2. The natural disturbance regime is moderately to highly altered, and is not likely to recover. Two or more disturbance characteristics have been altered.

3. The natural disturbance regime is slightly altered, but could recover. One disturbance characteristic has been altered.

4. The disturbance regime is nearly or entirely natural, and none of the disturbance characteristics have been altered.

---Surveyors could not evaluate the disturbance regime, but will conduct follow-up research (e.g., review hydrology) and assign a score.

Scaling Procedure and Rationale: Higher scores equate to higher naturalness of disturbance, as opposed to disturbance facilitated by humans. Anthropogenic alteration of the disturbance regime reduces ecological functionality and frequently reduces the presence and health of native plant and animal populations. A caveat here is that naturally highly disturbed rheocrene and hillslope springs types may become more productive if upslope disturbance intensity decreases. Therefore, it is important to recognize that scoring this variable should include consideration of the ways in which anthropogenic alteration of disturbance influences springs ecosystems.

Fig. 8–8. Honey Bee Dam Spring in the Gila National Forest has been dammed, resulting in reduced natural physical disturbance. Also, the dam reservoir filled with sediment, eliminating its utility in flow regulation or impoundment.

G. Natural Fire Regime

Question: Is the springs ecosystem subject to its natural fire disturbance regime? Has a past fire negatively affected the springs ecosystem? Has fire suppression created unnaturally dense vegetation, threatening the springs with a catastrophic burn?

Background: Like other forms of disturbance, the four characteristics of a fire regime are timing, magnitude, duration, and frequency. Those factors may not be apparent from a field site visit. However, that information might be available through an office analysis of a Burned Area Emergency Response (BAER) report. As with other forms of disturbance, fire can be a regular, natural, but intense form of disturbance on a springs ecosystem.

Confidence Value: Low to medium.

Rationale: Some springs types, such as gushets, may be somewhat buffered from wildfire impacts, but most can be strongly affected. Fire can influence bedrock geomorphology, allochthonous soil, water, and nutrient delivery (especially in rheocrene springs), habitat, biota, and goods and service. Like other forms of disturbance, the impacts of fire can vary in intensity, and can vary in relation to timing, magnitude (intensity), duration, and frequency, all of which can be altered by upstream or upslope conditions, climate change, livestock grazing intensity, and other processes. Upper elevation springs may be sustain the same fire frequency as the surrounding upland forests. In contrast, fire may preferentially burn low elevation springs, which support enough plant life to result in extensive litter fall.

Seasonality: Fire is usually highly seasonal in its occurrence and intensity. Typically in New Mexico, late springtime and summer are the primary seasons for natural fire.

Assessment Protocol: This question is scored based on the expert opinions of the inventory and assessment team. Examine signs of recent fire. In-office information often can be compiled to improve the confidence in this score.

Scoring:

1. The natural fire disturbance regime is nearly or entirely altered, and is largely unrecoverable. All four fire disturbance characteristics have been altered.

2. The natural fire disturbance regime is moderately to highly altered, and is not likely to recover. Two or more fire disturbance characteristics have been altered.

3. The natural fire disturbance regime is slightly altered, but could recover. One fire disturbance characteristic has been altered.

4. The fire disturbance regime is nearly or entirely natural, and none of the fire disturbance characteristics have been altered.

---Surveyors could not evaluate the disturbance regime, but will conduct follow-up research (e.g., review fire boundary and intensity maps) and assign a score.

Scaling Procedure and Rationale: Higher scores equate to higher naturalness of fire disturbance, as opposed to disturbance generated by human activity. Anthropogenic alteration of the fire regime reduces ecological functionality, nutrient dynamics, and the distribution of native and non-native biota.

Space is provided on the worksheet for comments about geomorphology, soils, and natural disturbance.

Fig. 8–9. Signal Peak Road Spring and the surrounding area was burned in an intense fire.

Geographic Context

The following questions relate to the level of isolation and size of the springs ecosystem. These intrinsic site characteristics reflect the ecological importance of the springs ecosystem and are likely to influence stewardship prioritization, but they do not reflect the condition and are therefore not counted in the assessment scoring. If an estimated distance or area is within 10% of a boundary score, a half-decimal should be applied. Therefore, scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

H. Isolation from other springs.

Question: How isolated is this springs ecosystem from other reported springs?

Background: The importance of a springs ecosystem as a water source often increases with isolation. However, springs isolation (or lack thereof) should not reduce the potential administrative importance of a springs ecosystem. Therefore, the answer to this question is quantitative and informational, and is not counted in the overall site assessment score.

Confidence Value: High

Rationale: The distance to the nearest springs ecosystem influences many ecological dynamics, including how important a springs ecosystem is within the adjacent landscape, as well as whether or not the springs can serve as a genetic stepping stone, versus a sink for biological diversity.

Seasonality: Associated fauna are likely to be strongly influenced in their use of the springs by seasonality, and seasonality often influences flow, sometimes geochemistry, and access to the site. The ecological significance of a springs ecosystem is likely to intensify under warmer conditions, when water is both more often needed and less available.

Assessment Protocol: This assessment protocol is conducted in-office as a geographic systems analysis of springs distribution in the region, in Springs Online. In that analysis the distance to the nearest springs ecosystem is calculated and recorded. Field documentation of nearby springs sometimes refines the score (below).

Scoring:

1. The nearest reported springs ecosystem is less than 100 m away.
2. The nearest reported springs ecosystem is between 100 and 1,000 m away.
3. The nearest reported springs ecosystem is between 1 and 10 km away.
4. The nearest reported springs ecosystem is more than 10 km away.

---Surveyors were unable to determine springs isolation, but will conduct follow-up research (i.e., GIS analysis of isolation) and assign a score.

Scaling Procedure and Rationale: Higher scores equate to greater distances between springs. Anthropogenic reduction of springs density reduces the ecological functionality of remaining springs, and the distribution of native and non-native biota. Note that this variable is descriptive only, and is not included in the overall assessment score.

Fig. 8–10. Highly isolated springs are of greater importance as wildlife water supplies, particularly in arid regions.

I. Isolation from perennial sources

Question: How isolated is this springs ecosystem from the nearest perennial water body, such as a stream or lake?

Background: The importance of a springs ecosystem increases with isolation from other water bodies besides springs, such as streams, rivers, ponds, and lakes.

Confidence Value: Moderate to high

Rationale: Flora and fauna populations occupying springs that are connected to, or in the vicinity of other perennial bodies of water may have enhanced gene flow and lower likelihood of supporting endemic species. Springs near other bodies of water may sustain higher rates of invasion by non-native crayfish, predatory game fish, bullfrogs, and other non-native species, and therefore such springs may be at greater risk due to high levels of habitat connectivity.

Seasonality: Several non-native animals, including crayfish and bullfrogs travel overland during rainy periods, such as the southwestern monsoon season.

Assessment Protocol: This assessment protocol is conducted in-office as a geographic systems analysis of springs in relation to other mapped perennial water bodies in the region. Unfortunately, mapping of perennial waters is imprecise throughout the nation, and field observations or measurements may greatly enhance the accuracy of this analysis. The metric used is distance from the springs ecosystem to the nearest perennial water body.

Scoring:

1. The nearest reported perennial water body is less than 100 m away.

2. The nearest reported perennial water body is between 100 and 1,000 m away.

3. The nearest reported perennial water body is between 1 and 10 km away.

4. The nearest reported perennial water body is more than 10 km away.

---Surveyors were unable to determine the distance to the nearest perennial water body, but will conduct follow-up research (i.e., through GIS analysis of isolation) and assign a score.

Scaling Procedure and Rationale: Higher scores equate to greater isolation from other perennial water bodies. Anthropogenic reduction of springs density increases the isolation in relation to other water bodies, with likely impacts on the ecological functionality and the extent of native and non-native species occurrence at springs. Note that this variable is descriptive only, and is not included in the overall assessment score.

Fig. 8–11. Proximity to perennial water sources influences the composition and nativity of species occurring at a spring.

J. Habitat size

Question: How large is this springs ecosystem?

Background: The importance of a springs ecosystem increases with its functioning size—the surface area that is directly influenced by the spring.

Confidence Value: High

Rationale: Aridland springs function as islands of wetland habitat surrounded by arid uplands. The well-known species-area relationship in insular biogeography effectively describes the conceptual relationship between habitat area and species richness for sessile species. Strong positive relationships between springs size and springs plant species have been documented by Springer et al. et al. (2014), Ledbetter et al. (2016), and Sinclair (2018).

Seasonality: Many species that occupy springs in New Mexico have seasonally specific behavior, such as migratory birds and bats, and winter-dormant invertebrates and herpetofauna. Therefore, species-area relationships at springs are likely to vary seasonally, based on detection potential and species life history constraints.

Assessment Protocol: This protocol is based on measurement of the springs-influenced habitat area during the site visit, and recorded on the site sketchmap.

Scoring:

1. The springs ecosystem size is less than 100 m^2.

2. The springs ecosystem size is between 100 - 1,000 m^2.

3. The springs ecosystem size is between 1,000 and 10,000 m^2.

4. The springs ecosystem size is greater than 10,000 m^2.

---Surveyors were unable to determine the size of the springs ecosystem, but will conduct follow-up research . For example, if the ecosystem is too large to measure, aerial imagery may be used to assign a score

Scaling Procedure and Rationale: Higher scores equate to greater habitat area. Anthropogenic reduction of springs habitat area decreases biodiversity, and may affect different taxa in different ways, negatively affecting the ecological functionality and distribution of both native and non-native species at springs. Note that like springs isolation, this variable is descriptive only, and is not included in the overall assessment score.

Space is provided on the worksheet for comments about the general site description, isolation, and habitat area of the springs ecosystem being inventoried and assessed.

Fig. 8–12. The springs habitat area influences the number and composition of species occurring there. A small spring generally supports fewer species, lower species density, and less ecological interchange with the surrounding uplands.

Fig. 8–13. Large springs such as Faywood Ciénega tend to support more species and have larger ecological influences in the surrounding uplands.

Habitat

The following questions relate to the capacity of the springs and its associated microhabitats to support native species and natural ecosystem processes. Habitat area, quality, productivity, and diversity strongly influence springs ecosystem ecology and biota, and anthropogenic degradation of springs habitat reduces the extent and importance of those ecological variables.

Scoring of habitat questions Please use half-decimal values from 1.0 (highly degraded) to 4.0 (pristine). Scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

K. Microhabitat quality

Question: What is the condition of the microhabitats associated with the site? Consider the overall habitat quality in each of the microhabitats and the intensity of all apparent anthropogenic impacts.

Background: Springs ecosystems can support multiple microhabitats, and each of those microhabitats can support its own suite of species that may or may not interact with those in other microhabitats. Anthropogenic activities may affect one or more or all microhabitats.

Confidence Value: Moderate to high

Rationale: Human activities can influence some or all microhabitats at a springs ecosystem. For example, intensive livestock use may cause pedestal formation, feces deposition, erosion, or other impacts on wetland microhabitat surfaces. Construction of roads, springboxes, or berms, as well as pollution can degrade microhabitat quality.

Seasonality: In temperate regions, microhabitat quality varies seasonally, with the highest productivity and biodiversity typically occurring in the summer and early autumn.

Assessment Protocol: This assessment protocol is based on visual assessment of the condition of the microhabitats occurring at the springs ecosystem being inventoried and assessed.

Scoring:

1. No natural microhabitats remain, or the remaining natural microhabitats are in very poor condition.

2. At least one natural microhabitat is in poor condition, with significant impairment evident, and anthropogenic habitats may be present.

3. All natural microhabitats are ecologically moderately intact, but some impairment is evident. If anthropogenic habitats are present, they are historic and have recovered ecologically.

4. All natural microhabitats are nearly or fully ecologically intact, with little or no impairment. No anthropogenic microhabitats are present.

Scaling Procedure and Rationale: Higher scores equate to higher levels of microhabitat quality. Anthropogenic reduction of microhabitat quality reduces ecological functionality and species richness. One caveat here is that anthropogenic alterations of springs can sometimes increase species richness. For example, artificial ponds in helocrenes may attract additional bat species to the area.

Fig. 8–14. Although somewhat degraded by many years of heavy livestock use, Adair Spring in Gila National Forest includes three microhabitats that supports a high diversity of native plant species and aquatic invertebrates.

L. Native plant cover

Question: *W*hat is the proportion of native to non-native plant cover?

Background: Native vegetation cover is generally supportive of native animal species, while non-native plant cover may exclude native fauna, increase wildfire frequency and intensity, and attract or support undesirable species through changes in ecological structure and processes.

Confidence Value: High

Rationale: Documentation of plant cover by species in seven strata (aquatic, non-vascular, ground cover, shrub cover, mid-canopy, tall canopy, and basal cover) will be accomplished during the inventory and assessment and will reveal not only the extent of non-native plant cover by stratum, but also the wetland status and the ecological structure of the springs ecosystem, with relevance to wildlife habitat availability.

Seasonality: Assessment of native plant foliar cover at New Mexico springs is preferably done during the summer months, but at least during the growing season, between mid-April and mid-October.

Assessment Protocol: This assessment question is informed by the Springs Inventory Protocol. Particularly for sites with high plant diversity, entering data into Springs Online can better support more accurate scoring for this variable.

Scoring:

Scores will vary from 1.0 (highly altered) to 4.0 (pristine). If an estimated percent cover is within 5% of a boundary score, a half-decimal should be applied. Therefore, scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

1. No native plant species are present, or less than 40% of the plant cover is native.

2. Between 40 and 80% of the plant cover is native.

3. Between 80 and 95% of the plant cover is native.

4. More than 95% of the plant cover is native.

-- Surveyors were unable to evaluate the native plant species ecological role. For example, surveyors could collect plant specimens or photographs to be subsequently verified.

Scaling Procedure and Rationale: Higher scores indicate greater cover by native species. Anthropogenic impacts can reduce native plant species cover, considerably altering habitat quality, ecological functionality, and species richness. One caveat here is that springs occurring in alkaline or bedrock-dominated settings may naturally be virtually devoid of vegetation. An example of plant cover calculations is provided in Appendix C for Cherry Creek Springs.

Fig. 8–15. Blue-eyed grass (*Sisyrinchium*) is a common wet meadow species in the iris family that is easily overlooked unless it is in bloom.

M. Native food web dynamics

Question: What is the condition of the natural food web at this springs ecosystem?

Background: Ecologically intact springs ecosystems support diverse food web interactions, with robust vegetation (where geomorphically appropriate) supporting diverse populations of invertebrate and vertebrate herbivores and predators. This can range from mountain lions to dragonflies. Trophic cascades exist within some springs (e.g., Montezuma Well, Blinn 2008), and springs provide ambush habitat for predators.

Confidence Value: Medium to high

Rationale: Trophic structure, as indicated by the presence of vegetation, primary consumers, and secondary or top consumers (predators), indicates that ecosystem functionality at a site is high.

Seasonality: Most animal species occurring at or using New Mexico springs are influenced by seasonality. Also, the intensity of the ambush function, whereby predators use springs to ambush prey, also is likely to vary seasonally.

Assessment Protocol: This assessment protocol is based on observation or sign of wildlife of varying trophic levels.

Scoring:

1. No natural food web dynamics are evident, with no observation or evidence of predators.
2. There is some evidence of natural food web dynamics, indicated by the observation or evidence of at least one predator.
3. There is moderate evidence of natural food web dynamics, indicated by the observation or evidence of several predators from a range of trophic levels.
4. The food web dynamics appear to be natural or nearly natural, indicated by the observation or evidence of several predators from a range of trophic levels.

Scaling Procedure and Rationale: Higher scores indicate higher levels of trophic interaction. Anthropogenic impacts on trophic structure can influence native plant species cover and wildlife presence, in turn altering habitat quality, ecological functionality, and species richness. Please use half-decimal values from 1.0 (highly degraded) to 4.0 (pristine). Scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

The worksheet provides space for comments about habitat size, quality, isolation, and food web.

Fig. 8–16. Tiger Salamanders (Ambystoma spp) often are top predators in lentic habitats in New Mexico.

Fig. 8–17. Blacktail rattlesnakes are important predators of small, warm-blooded animals.

Biota

Floral and faunal species biodiversity is an important topic in stewardship discussions about springs.

N. Native vs. non-native plant species:

Question: What is the proportion of native plant species?

Background: Anthropogenic impacts at springs commonly include introduction of non-native plant species, potentially with negative impacts on native flora. Non-native species can degrade habitat quality, ecological functionality, and native plant species richness. Non-native plant species can overwhelm native plant communities at springs, thus the proportional representation of native and non-native plant species is an important assessment variable.

Confidence Value: Moderate to high

Rationale: Springs function as biodiversity hotspots, supporting many rare, endemic, and some endangered species, as well as a host of non-springs-dependent and upland species. Thus, springs have inordinately high levels of species packing and biodiversity.

Seasonality: Virtually all species occurring at springs in New Mexico are influenced by seasonality.

Assessment Protocol: This assessment question is informed by the Springs Inventory Protocol, which calls for identification of every plant species in the springs-influenced habitat.

Scoring:

1. Between 0 and 40% of the plant species are native.
2. Between 40 and 80% of the plant species are native.
3. Between 80 and 95% of the plant species are native.
4. More than 95% of the plant species are native.

-- Surveyors were unable to evaluate the proportion of native plant species, but will conduct follow-up research (e.g., collect a plant specimen for later identification) and assign a score.

Scaling Procedure and Rationale: Higher scores indicate higher proportions of native plant species. If an estimated percent cover is within 5% of a boundary score, a half-decimal should be applied. Therefore, scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

An example of plant cover calculations is provided in Appendix C for Cherry Creek Springs.

Fig. 8–18. The number of non-native plant species relative to that of native species can indicate the level of human disturbance of a site.

Fig. 8–19. In June 2018, surveyors identified 39 plant taxa at Moreno Springs, 28 of which were native.

O. Presence of noxious weed species

Question: How many plant species from the New Mexico's Noxious Plant Species list are present?

Background: New Mexico recognizes a number of plant species as severe threats to the state's ecosystems, and the presence of these plants at a springs ecosystem may warrant management attention.

Confidence Value: High

Rationale: New Mexico noxious plant species are widely recognized for exerting deleterious impacts on many aspects of the state's ecosystems and economics.

Seasonality: New Mexico's designated noxious plant species are most easily identified during the growing season, and not during winter.

Assessment Protocol: The protocol involves counting the number of New Mexico designated noxious weed species, and using that number to score the questions. *Troublesome Weeds of New Mexico* is an excellent illustrated resource, available at https://aces.nmsu.edu/pubs/weeds/welcome.html. The New Mexico Noxious Weed List is included in worksheet O.

Scoring:

1. Three or more NM noxious weed species are present.
2. Two NM noxious weed species are present.
3. One NM noxious weed species is present.
4. No NM noxious weed species are present.

--- Surveyors were unable to evaluate the presence of noxious species, but will conduct follow-up research (e.g. collect samples for identification) and assign a score.

Scaling Procedure and Rationale: Higher scores indicate lower numbers of NM noxious weed species present at the site. Anthropogenic introduction of noxious non-native plant species exerts negative impacts on native species and ecosystem integrity, degrading habitat quality, ecological functionality, and native species richness. Please use full decimal values from 1.0 (highly degraded) to 4.0 (pristine).

An example of noxious weed presence is provided in Appendix C for Cherry Creek Springs.

Fig. 8–20. Cheatgrass (*Bromus tectorum*) is a highly invasive grass species that is included in the New Mexico noxious plants list. It is an indicator of disturbed soil conditions and can increase fire frequency, changing native plant composition. Image courtesy of USDA-NRCS PLANTS Database / Hitchcock, A.S. (rev. A. Chase). 1950. Manual of the grasses of the United States. USDA Miscellaneous Publication No. 200. Washington, DC.

P. Natural plant demography

Question: Is the population structure (demography) of woody vegetation appropriate to the site? For example, is the springs ecosystem becoming unnaturally dominated by woody plant species (e.g., conifer, Russian olive, Siberian elm, tamarisk) or invasive wetland species (e.g., *Typha* or *Phragmites*), as evidenced by the presence of multiple life stages (e.g., seedling, sapling, mature plants)? Upland woody shrubs or trees encroaching onto the site can reveal an unnatural transition due to human activity or disturbance.

Background: The invasion of upland woody shrubs or trees, or the loss of wetland species indicates water table subsidence, and transition of the springs habitat into upland dry land habitat.

Confidence Value: High

Rationale: Observation of encroachment of woody species, die-back of wetland plant species, or demographic skewing indicates that a springs ecosystem is under stress from water table subsidence.

Seasonality: Patterns of woody encroachment or wetland die-back likely will be visible throughout the year.

Assessment Protocol: This assessment question is informed by completion of worksheet P.

Scoring:

1. The site is almost entirely dominated by woody plant species or invasive wetland species.
2. The site is largely, but not entirely dominated by woody plant species or invasive wetland species.
3. The site contains some encroachment by woody plant species or invasive wetland species.
4. The vegetation at the springs ecosystem appears appropriate.

Scaling Procedure and Rationale: Higher scores indicate lower extent of woody encroachment, wetland vegetation die back, or other indications of springs disappearance. Use half-decimal values from 1.0 (highly degraded) to 4.0 (pristine). Scores should be recorded as: 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0. An example of plant demography assessment is provided in Appendix C.

Fig. 8–21. Encroachment into wet meadows by woody vegetation often indicates a declining water table and changing plant demographics.

Fig. 8–22. Encroachment of woody vegetation into wet meadows increases the risk of catastrophic fire.

Q. Sensitive species presence

Question: Did surveyors identify any sensitive plant or animal species?

Background: Rare, endemic, sensitive, threatened and/or endangered species often present policy-related or legal management issues to springs stewards.

Confidence Value: High

Rationale: Identification of rare, endemic, sensitive, threatened and/or endangered species at springs may trigger management responsibilities and actions.

Seasonality: Many sensitive species have seasonally-varying life cycles, but most are most active during the growing season months.

Assessment Protocol: The inventory and assessment team should identify any rare, endemic, sensitive, threatened and/or endangered species in the vicinity of the site. In-office research on the potential occurrence of sensitive species is recommended prior to conducting field work.

Scoring:

4. One or more sensitive or listed plant or animal species were identified, or the site is designated critical habitat for a species.

--- Surveyors were unable to evaluate the presence of such species, or due to spring type or naturally non-supportive habitat there is no reason to expect any of these species at the site.

The assessment field sheet provides a comment box for recording which sensitive species were detected at the springs ecosystem, as well as the abundance.

Scaling Procedure and Rationale: A score of "4" indicates that a sensitive species of plant or animal was detected at the site. Also, if the site is known as part of designated critical habitat, the site should score as "4". For example, no sensitive species were detected at Cherry Creek Springs, so no score was entered for this question. However, the site assessment score is not reduced as a result of the site not supporting sensitive species.

Fig. 8–23. Ladies'-tresses (*Spiranthes*) are wet meadow orchids that occur at middle and upper elevations in New Mexico.

R. Proportion of native animal species

Question: What is the proportion of native invertebrate and vertebrate species?

Background: Non-native animal species can exert negative impacts on native species and ecological processes, degrading the springs ecosystem.

Confidence Value: Moderate to high

Rationale: Detection of non-native animal species is needed to evaluate the risks they pose to the site.

Seasonality: Detection of non-native animal species may be more difficult during the winter months.

Assessment Protocol: All animal species detected during the field site visit are recorded. Please see the list of nonnative fauna in Worksheet S in the assessment fieldsheets.

Scoring:

1. Between 0 and 40% of the animal species present are native.
2. Between 40 and 80% of the animal species present are native.
3. Between 80 and 95% of the animal species present are native.
4. More than 95% of the animal species are native.

---Surveyors were unable to evaluate the proportion of native animal species, but will conduct follow-up research and assign a score.

Scaling Procedure and Rationale: Higher scores indicate a higher percentage of native faunal species. Anthropogenic introduction of non-native animal exerts negative impacts on native species and ecosystem integrity, degrading habitat quality, ecological functionality, and native species richness. Please use half-decimal values from 1.0 (highly degraded) to 4.0 (pristine). If an estimated percent cover is within 5% of a boundary score, a half-decimal should be applied. Therefore, scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0.

A list of common non-native animal species is provided in Appendix B Worksheet S, and an example of non-native animal percent occurrence is provided for Cherry Creek Springs in Appendix C.

Fig. 8–24. Non-native red swamp crayfish (*Procambarus clarkii*) are voracious predators of aquatic life in New Mexico springs, consuming invertebrates, frogs, fish, and even snakes.

Fig. 8–25. Native canyon treefrogs (*Hyla arenicolor*) are susceptible to non-native predators, such as crayfish, sports fish, and bullfrogs.

S. Number of non-native animal species

Question: How many non-native aquatic and terrestrial animal species are present? For example, to what extent are nonnative mollusks, crayfish, bullfrogs, and game or aquarium fish species present?

Background: Non-native animal species can exert negative impacts on native species and ecological processes, degrading the springs ecosystem. One caveat: not all animal species occupying a springs ecosystem are likely to be detected during a single site visit. Therefore, this score is expected to be refined with multiple visits.

Confidence Value: Low to Moderate

Rationale: Detection of non-native faunal species is needed to evaluate the risks they pose to the site.

Seasonality: Detection of non-native animal species may be more difficult during the winter months.

Assessment Protocol: This assessment question is based on recording of all animal species detected during the field site visit. Please complete Worksheet S in the assessment fieldsheets.

Scoring:

1. Three or more nonnative animal species were detected.
2. Two nonnative animal species were detected.
3. One nonnative animal species was detected.
4. No nonnative animal species were detected.

---Surveyors were unable to evaluate the presence of non-native species, but will conduct follow-up research (e.g. collect samples for identification) and assign a score.

Scaling Procedure and Rationale: Higher scores indicate a lower number of non-native animal species. Please use half-decimal values from 1.0 (highly degraded) to 4.0 (pristine). Scores should be recorded as 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0. A list of common non-native faunal species is provided in the Appendix, and an example of non-native animal percent occurrence is provided for Cherry Creek Springs.

Fig. 8–26. American bullfrogs (*Lithobates catesbeianus*) are widespread, voracious, non-native predators in wetland habitats throughout New Mexico. https://www.invasivespeciesinfo.gov/profile/bullfrog.

Assessment Summary Scoring

Total Category Scores

The Assessment Summary worksheet (Table 8-1) is used to compile scores for each assessment question. Within each category, those scores are summed to calculate a category score, the magnitude of which varies in relation to the number of questions. The calculated category score is divided by the maximum possible category score, and then multiplied by 4 to produce a final category score, which will vary from 1 to 4.

For example, using Cherry Creek Spring (Appendix C), if assessment questions A-C in the Aquifer Functionality category are scored 3.5, 4.0, and 2.0, the sum would be 9.5. Dividing by the total possible score (3 questions, a maximum score of 4 each = 12), gives a score of 9.5/12 = 0.792. When multiplied by 4, the final category score is 3.17 (rounded to 3.2). Thus, the category score indicates slightly better than good (3.0) aquifer condition at the site.

Total Site Score

The total site score is calculated by 1) summing all category scores, 2) dividing that sum by the maximum possible score, 3) multiplying by 4, and 4) rounding to one decimal place. Recall that Geographic Context questions H through J are not included in this calculation.

In the case of the Cherry Creek Spring assessment, the total score was 48.5 out of a maximum possible score of 60. Therefore, 48.5/60 = 0.808, and multiplying by 4 results in a total site score of 3.23, which rounds to 3.2. This indicates that the Cherry Creek Spring ecosystem is in slightly better than good condition, with the primary impairment related to dysfunctional piping and water storage structures.

Final Site Report

The final site report for a Springs NMRAM should include: 1) a survey summary report, 2) a completed stressor checklist, 3) completed assessment fieldsheets with associated worksheets, and 4) a completed Springs NMRAM Summary Worksheet. An example of a final site report for Cherry Creek Spring is provided in Appendix C.

Table 8–1. New Mexico Springs Rapid Assessment Method summary worksheet, used for generating category and total site scores.

Assessment Question	Assessment Question Score	Sum of Question Scores	Category Score
Aquifer Functionality & Water Quality: A. Water table alteration			
Aquifer Functionality & Water Quality: B. Surface water quality impairment			
Aquifer Functionality & Water Quality: C. Springs flow rate			
Aquifer Functionality & Water Quality: Category Total Possible Score =12		Sum of AFWQ Assessment question scores	AFWQ Score = (Sum/12)*4
Geomorphology: D. Natural geomorphic diversity			
Geomorphology: E. Soil Integrity			
Geomorphology: F. Natural physical disturbance			
Geomorphology: G. Natural fire regime			
Geomorphology Category: Total Possible Score =16		Sum of Geomorphology Assessment question scores	Geo Score = (Sum/16)*4
Geographic Context: H: Isolation from other springs			
Geographic Context: I. Isolation from nearest perennial water source			
Geographic Context: J. Springs habitat area (size)			
Geographic Context Category: (not counted in total score)		Sum of Geographic Context	Not used in Assessment calculations
Habitat: K. Microhabitat quality			
Habitat: L. Native plant cover			
Habitat: M. Native food-web dynamics			
Habitat Category: Total Possible Score =12		Sum of Habitat questions scores	Habitat Score = (Sum/12)*4

Assessment Question	Assessment Question Score	Sum of Question Scores	Category Score
Biota: N. Native vs. non-native plant species richness			
Biota: O. Presence of noxious weed species			
Biota: P. Plant demography			
Biota: Q. Sensitive flora and fauna richness			
Biota: R. Native and non-native faunal species percent			
Biota: S. Non-native faunal species richness			
Biota Category: **Total Possible Score =20 (excluding Q)**		Sum of Biota questions scores	Biota Score = (Sum/20)*4
Total Site Condition Score: (Total possible = 64) 1=irrecoverable 2=poor 3=good 4=pristine		Sum of Category Scores not including Geography	Total Site Score = (Sum/64)*4

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Appendix A - Inventory Field Sheets

General

Spring Name____________________________________ Springs Online ID#_____________ [1]Spring Type _______________________

Country US State NM County_________________________ [2]Sensitivity _________

[3]Land Unit____________ Land Unit Detail__________________________________

Quad_____________________ HUC___________________________

Site Description

Georef

[4]Georef Source__________ Device_________________________ Datum_________

UTM Zone______ UTM East_________________ UTM North_________________

Lat___________________Long__________________ Elev_________ ft or m

EPE______ ft or m Declination _____ Comment _____________________________

Access Directions

SPF

Sunrise: D_______ J_______ N_______ F_______ O_______ M_______ S_______ A_______ A_______ M_______ J_______ J_______

Sunset: D_______ J_______ N_______ F_______ O_______ M_______ S_______ A_______ A_______ M_______ J_______ J_______

Latitude checked?

Survey

Date________________ Begin Time_____________ End Time______________

Surveyors____

______________________________________Project New Mexico

Site Condition

Microhabitats

	Description	Area (m^2)	[5]Surf Type	[6]Sub-Type	[7]Slope Var	Aspect T/M____	Slope Deg	[8]Soil moist	Water dpth(cm)	Water %	[9]Substrate % 1	2	3	4	5	6	7	8	Org	Oth	Prec %	Litter %	Wood %	Litter (cm)
A																								
B																								
C																								
D																								
E																								
F																								
G																								

Images

Whose Camera Used_________________________________

Sketch Map Location________________________________

Photo #	Description (caption)

Entered in database by _______________________ Date________ Checked by _______________________ Date________

1 Discharge Sphere (Spring Type)
- Anthropogenic
- Cave
- Exposure
- Fountain
- Geyser
- Gushet
- Hanging Garden
- Helocrene
- Hillslope
- Hypocrene
- Limnocrene
- Mound-form
- Rheocrene

2 Sensitivity
- None
- Location
- Survey
- Both

3 Land Unit
- BLM
- DOE
- NPS
- Private
- State
- Tribal
- USFS
- Other

4 Georeference Source
- GPS
- Map
- Other

5 Surface Type
- BW Backwall
- C Cave/Tunnel
- CH Channel
- CS Colluvial slope
- HGC High Grad. Cienega
- LGC Low Grad Cienega
- Mad Madiculous Flow
- P Pool
- PM Pool Margin
- SB Sloping Bedrock
- SZ Spray Zone
- SM Spring Mound
- TE Terrace
- Oth Other/anthropogenic

6 Surface Subtype
- CH Riffle, Run, Margin, Eph
- CS Wet, Dry
- SB Wet, Dry
- TE LRZ, MRZ, URZ, HRZ UPL,LRZMRZ,LRZURZ, MRZURZ, HRZMRZ
- All Anthro (human influence)

7 Slope Variability
- Low, Medium, High

8 Soil Moisture
- 0 - Dry
- 1 - Dry-Moist
- 2- Moist-Dry
- 3 - Wet-Dry
- 4- Moist
- 5 - Saturated-Dry
- 6 - Wet
- 7 - Saturated-Moist
- 8 - Wet-Saturated
- 9 - Saturated
- 10 - Inundated

9 Substrate
- 1 clay
- 2 silt
- 3 sand (0.1-1mm)
- 4 fine (pea) gravel (1-10 mm)
- 5 coarse gravel (1-10 cm)
- 6 cobble /small boulders(10-100 cm)
- 7 large boulders (>1 m)
- 8 bedrock
- Organic Soil, including peat
- Other (usually anthropogenic)

10 Lifestage
- Adult
- Egg
- Exuviae
- Immature
- Larvae
- Mixed
- Other
- Pupae
- Shell

11 Habitat
- AQ - Aquatic
- T - Terrestrial

12 Method (Invertebrates)
- Spot
- Benthic

13 Detection Type (Vertebrates)
- Call
- Observed
- Sign
- Reported (by others)
- Other

14 Cover Codes
- GC Ground Cover
- SC Shrub Cover
- MC Midcanopy Cover
- TC Tall Canopy Cover
- AQ Aquatic Cover
- NV Nonvascular (moss, etc)
- BC Basal Cover

15 Emergence Environ/Detail
- Cave
- Subaerial
- Subglacial
- Subaqueous-lentic freshwater
- Subaqueous-lotic freshwater
- Subaqueous-estuarine
- Subaqueous-marine

16 Source Geomorphology
- Contact Spring
- Fracture Spring
- Seepage or filtration
- Tubular Spring

17 Flow Force Mechanism
- Anthropogenic
- Artesian
- Geothermal
- Gravity
- Other

18/19 Parent Rock Type/Subtype
- Igneous
  - andesite
  - basalt
  - dacite
  - diorite
  - gabbro
  - grandodiorite
  - granite
  - peridotite
  - rhyolite
- Metamorphic
  - gneiss
  - marble
  - quartzite
  - slate
  - schist
- Sedimentary
  - coal
  - conglomerate
  - dolomite
  - evaporates
  - limestone
  - mudstone
  - sandstone
  - shale
  - siltstone
  - Unconsolidated

20 Channel Dynamics
- Mixed runoff/spring dominated
- Runoff dominated
- Spring dominated
- Subaqueous

21 Flow Consistency
- Dry intermittent
- Erratic intermittent
- Perennial
- Regular intermittent

22 Measurement Technique
- Current meter
- Weir
- Flume
- Other

Spring Name__________________________ Page ______ of _________ OBS____________

Invertebrates

Species Name	Qty	[10]Stage	[11]Hab-itat	[12]Meth-od	Rep #	Comments

Benthic Rep

Rep #	Location	Velocity m/sec	Depth cm	Substrate	Area Sq M	Time Sec	Comments

Entered in database by __________________ Date___________ Checked by __________________ Date ___________

New Mexico Surface Water Quality Bureau and SSI rev March 2019

Spring Name__________________________ Page ______ of _________ OBS____________

Vertebrates

Species Name	No. Ind	[13]Detection Type	Comments

Entered in database by ________________ Date__________ Checked by _________________ Date __________

Spring Name__________________________ Page ______ of _________ OBS____________

Flora

Flora notes

Species Name	[14]Str	A	B	C	D	E	F	G	H	Comments	Verified?

Entered in database by ____________________________ Date___________ Checked by _______________________________ Date ________________

Spring Name__________________________ Page ______ of _________ OBS____________

Flora

Flora notes

Species Name	[14]Str	A	B	C	D	E	F	G	H	Comments	Verified?

Entered in database by ____________________________ Date___________ Checked by _______________________________ Date ________________

Spring Name____________ Page ____ of ____ OBS________

Geomorphology

[15]Emerg Env____________ [17]Mechanism____________ Geologic Layer____________

[15]Detail____________ [18]Rock Type____________ [20]Channel Dynamics____________

[16]Source Geomorphology____________ [19]Rock Subtype____________

Polygon	[1]Discharge Sphere	[1]Secondary Discharge	Comments

Flow

[21]Flow Consistency____________ [22]Measurement Technique____________ Flow Rate (Mean)____________

Location of Measurements____________ Total Site % Captured____________

Discharge Comments____________

Reason if flow not measured (circle) diffuse outflow little outflow no outflow hazard spring is dry hazard other ____________

Current Meter l/s m/s other_____

Cell	Distance	Width	Depth	Reading

Flume l/s m/s other_____

Point	Flume Size	Measurements					Avg Stage	% Flow

Volume

Container Size/Units____________

Point	Seconds	Liters	% Flow

Weir l/s m/s other_____

Point	Weir Size	Measurements				% Flow

Entered in database by ____________ Date________ Checked by ____________ Date ________

Water Quality

Spring Name____________________________ Page ______ of _________ OBS_____________

Device 1 ____ Date Last Calibrated____________

Device 2 ____ Date Last Calibrated____________

Device 3 ____ Date Last Calibrated____________

Weather

Air Temp _____C or F

Select one

___No current/recent precipitation
___Rain during survey
___Recent rain
___Snow on ground
___Snow, hail, or sleet during survey

Sampling Locations (circle) (circle)

1	source down-gradient stream exiting wetland pool hole well other ___________	standing water flowing water
	comments	
2	source down-gradient stream exiting wetland pool hole well other ___________	standing water flowing water
	comments	
3	source down-gradient stream exiting wetland pool hole well other ___________	standing water flowing water
	comments	

Field Measurements

Location #	pH	EC	SC	Water Temp (°C)	Turbidity ntu	Dissolved O^2 %	mg/L	Alkalinity mg/L	Salinity ppt	Other	Device

Collected for Analysis

Sample Type	Sample Taken?	DuplicateTaken?	Container	Filtered (Y/N)	Treatment	
Anions						
Cations						
Nutrients						
^{2}H and ^{18}O Isotopes						

Entered in database by _________________________________ Date______________ Checked by _______________________________ Date _________________

Spring Name____________________________ Page _______ of __________ OBS_____________

Scale - 1 square = _____ meters Date ____________

B Appendix - Assessment Field Sheets

SiteName____________________ID__________ Observer____________________

Impact	Stressor Checklist	1 Absent	2 Minor	3 Moder-ate	4 Intense
Impact	**Flow regulation or hydrological alteration**				
	Surface water diverted away (ditch, pipe, etc)				
	Springbox, springhouse, or cap (enclosed in concrete, metal, rock, etc)				
	Upgradient pre-emergence groundwater flow capture (e.g. pipe)				
	Downgradient capture of surface flow (into tank, trough, etc)				
	Flow regulated by impoundment or dam (e.g., berm, concrete structure)				
	Source excavated to create open water (e.g., tank)				
	Non-point source surface water pollution (e.g., road, agricultural, mining)				
	Point source surface water pollution (e.g., sewage leakage, ungulate feces)				
	Groundwater contamination (evidenced by dead animals, vegetation, odor)				
	Nearby wells (groundwater extraction - consider size and proximity)				
	Prolonged drought (Palmer's index, moderate=2, severe=3, extreme=4)				
	Other hydrologic disturbance ____________________				
	Flow regulation, hydrologic alteration (max=48)				
	Soil or geomorphic alteration				
	Erosion - overall landscape, general, human influenced				
	Erosion - on-site human influenced (e.g., channel, gully, cutbank)				
	Excavation (e.g., pond creation, springbox and installation)				
	Soil compaction (e.g., livestock trampling, vehicle use)				
	Deposition, debris flow, spoil pile, or land fill				
	Pedestals or hummocks due to livestock or wildlife				
	Ruts (from vehicles)				
	Soil removal (e.g., gravel or other mining, road construction)				
	Soil contamination (e.g., oil, salt licks, refuse)				
	Trails (human or animals)				
	Other soil disturbance ____________________				
	Soil or geomorphic alteration (max=44)				
	Animal impacts				
	Habitat alteration by aquatic species (e.g., beaver, muskrat, nutria)				
	Habitat alteration by terrestrial species (e.g., gopher, squirrel burrows)				
	Wildlife grazing, browsing, defecating, or trampling (e.g., elk, deer)				
	Livestock grazing, browsing, defecating, or trampling				
	Non-native predators (e.g., crayfish, introduced fish, domestic animals)				
	Other animal effects____________________				
	Animal impacts (max=24)				

SiteName________________________________ID______________Observer______________________

	Stressor Checklist	1 Absent	2 Minor	3 Moder-ate	4 Intense
Impact	**Recreation impacts**				
	Camp sites (e.g., fire rings, refuse, site leveling, compaction)				
	Tracks or trails by recreational motorized vehicles (dirt bikes, ATV, UTV)				
	Tracks or trails from hiking, mountain biking				
	Tracks or trails from pack animals				
	Hunting/fishing (e.g., game cameras, salt licks, carcasses, lures/line)				
	Target practice (e.g., shotgun shells, gunshot damage)				
	Urban parklands, sports fields, swimming pools				
	Passive recreation (e.g., birdwatching, photography, hot spring)				
	Refuse or other waste disposal (e.g., toilet paper, cans, bottles)				
	Excessive human visitation				
	Human modification (e.g., hot springs dams, structures, climb/cave gear)				
	Other recreation disturbance ______________________				
	Recreation impacts (max=48)				
	Structures or development impacts				
	Abandoned infrastructure (non-functioning piping, springboxes, or tanks)				
	Utility corridors or power lines				
	Residential development				
	Industrial or commercial development, mining structures				
	Light or noise pollution				
	Erosion control structure (e.g., gabeons, grade controls)				
	Wildlife entrapment risk (e.g., missing springbox lid, open tank no escapement)				
	Fence - geomorphically inappropriate and/or nonfunctioning				
	Oil or gas well				
	Pipeline external to site (e.g., oil, gas, water)				
	Other structural disturbance ______________________				
	Structures or development impacts (max=44)				
	Land use impacts				
	Fire regime				
	Crop production (current or past)				
	Ranch use (current or past)				
	Road, incl. construction or maint. (paving type, use intensity, and proximity)				
	Restoration, rehabilitation, or remediation actions				
	Sensitive species protection efforts (e.g., fish translocation)				
	Biological resource extraction (e.g., aquaculture, fisheries, plant collecting)				
	Physical resource extraction (e.g., mining, quarrying)				
	Forest management (e.g., thinning, timber harvest, planting)				
	Scientific activities, including sentinel site monitoring				
	Education activities (e.g., environmental education, tourism, youth camp)				
	Other land use effects______________________				
	Land use impacts (max=48)				

SiteName____ID___________ Observer__________________________

Spring Type Dichotomous Key

No.	Alternative	Springs Type
1	Groundwater expression of flow emerges or emerged within a cave (a water passage through basalt or other volcanic rock, or limestone), before flowing or emerging into the atmosphere	Cave
	Groundwater expression of flow emerges or emerged in a subaerial setting (direct contact with the atmosphere), including within a sandstone alcove, or subaqueously (beneath a body of water).	2
2	Groundwater is not expressed at the time of visit (the springs ecosystem is dry, though soil may be moist)	3
	Groundwater is expressed at the time of visit – seepage or flow is actively expressed (water or saturated soil is evident)	5
3	Evidence of prehistoric groundwater presence and/or flow exists (e.g., paleotravertine, paleosols, fossil springs-dependent species, etc.), but no evidence of contemporary flow or aquatic, wetland, or riparian vegetation	Paleospring
	Not as above	4
4	Soil may be moist but is not saturated by groundwater. The presence of groundwater is evidenced by wetland or obligate riparian vegetation	Hypocrene
	Groundwater is expressed through saturated soil, or as standing or flowing water	5
5	Groundwater is evident, but discharge is primarily lentic (standing or slow-moving), and flow downstream from the spring's ecosystem may be absent or very limited	6
	The majority of groundwater discharge flows actively within and/or from the site, and is primarily lotic (fast-moving)	10
6	Groundwater is expressed as a low gradient (<16°) patch of shallow standing water or saturated sediment or soil, typically strongly dominated by emergent wetland vegetation	Helocrene
	Subaqueous discharge creates an open body of water which lacks emergent wetland vegetation, and may or may not have outflow	7
7	The groundwater table surface is exposed as a pool, but without a focused inflow source, and with no outflow	Exposure
	Pool with one or more focused, subaqueous inflow sources, and generally with outflow, usually focused outflow	8
8	Springs source is an open pool of groundwater, not surrounded by a springs-created mound	Limnocrene
	Springs source is surrounded by, and has generated, a mound that may be chemical precipitate, ice, or organic matter	9

SiteName______________________________________ID___________ Observer_________________________

Spring Type Dichotomous Key Page 2

No.	Alternative	Springs Type
9	Springs source is surrounded by, or emerges from a mound composed of carbonate or other chemical precipitate	Mound-form (Carbonate)
	Springs source is surrounded by, and/or emerges from a mound composed of ice in a permafrost-dominated landscape (not reported in New Mexico)	Mound-form (ice)
	Springs source is surrounded by, and/or emerges from a mound composed of organic matter, such as decomposing vegetation	Mound-form (organic)
10	Springs flow emerges explosively and periodically, either by geothermal-derived or gas-derived pressure (not reported in New Mexico)	Geyser
	The springs flow emerges non-explosively, but by the action of gravity	11
11	Flow emerges from a focused point and rises well above ground level (10 cm or more)	Fountain
	Flow may emerge from a focused point, but without substantial rise above ground level	12
12	Flow emerges from a near-vertical or overhung, cliff-dominated bedrock surface, and not within an established surface flow channel (although a surface channel may exist above the source cliff)	13
	Not as above	14
13	Focused flow emerges from a nearly vertical bedrock cliff face (sometimes from a cave) and cascades, usually with some madicolous flow (a shallow sheet of white water)	Gushet
	Flow emerges across a horizontal geologic contact, typically dripping along a seepage front of sandstone over a shale or clay aquitard, and often creating a wet backwall. If a surface channel exists above the source area, a plunge pool and runout channel are likely to occur. This springs type may include unvegetated seepage patches on near-vertical or overhung bedrock walls.	Hanging garden
14	Flow emerges within a surface flow-dominated channel, which upstream may be a perennial stream or a dry channel	Rheocrene
	Flow emerges from a non-bedrock slope at a slope angle between 16° and 60°, and without an upslope channel. In some cases, these springs may emerge from the base of a cliff, but not from the cliff itself	15
15	Flow emerges within an active riparian channel margin or floodplain channel terrace and the source is subject to regular flood scour	Hillslope (Secondarily Rheocrene)
	Flow emerges in an uplands habitat, not associated with a channel that is subject to regular surface flow stream flood scouring	Hillslope (Uplands)

SiteName________________________ID__________Observer______________

Primary Type [ ] Secondary Type [ ]

Condition Assessment Questions Page 1

Aquifer Functionality and Water Quality

The following questions are related to the apparent condition of the aquifer and water table, short-term climatic conditions, and the quality of groundwater at the source(s), as well as anthropogenic alteration of surface flow. Score with half decimals from 1.0 to 4.0.

A. Water table: Is there evidence that the water table is dropping and the aquifer is failing to produce natural quantities of water for the springs ecosystem? For example, is woody vegetation (e.g., cottonwood, tree willow, other woody phreatophytes) showing evidence of mortality or declining health? Is woody upland vegetation encroaching? Or is an area now dry that was apparently previously groundwater supported? Is there an abandoned well or windmill? Any of these can indicate a declining water table.

1. The aquifer is depleted or in significant decline, as evidenced by: total loss of springs fauna (requires knowledge of springs fauna formerly occupying the site); total loss of wetland vegetation cover (observed as dead wetland plants), and/or substantial encroachment of upland vegetation.
2. The aquifer is moderately depleted, with evidence of decreasing or dying springs-dependent fauna or wetland vegetation cover, and/or encroachment of upland vegetation.
3. Aquifer is slightly but detectably depleted, with minor evidence of decreasing or dying wetland vegetation cover and/or limited encroachment of upland vegetation.
4. The aquifer appears to be in pristine or near-pristine condition, with no evidence of reduced flow, loss of wetland vegetation, or encroachment of upland vegetation.

-- Surveyors are unable to assess the water table condition in the field, but will conduct follow-up research (e.g., interview the land manager) and assign a score.

B. Surface water quality: What is the quality of water after it emerges onto the surface? Is there visual, olfactory, or other evidence of contamination (e.g., feces, strong odor, unusual color)?

1. The surface water quality is extremely poor with strong visual, olfactory, or other indications.
2. Moderately low surface water quality, with some visual, olfactory, or other indications.
3. Moderately high surface water quality, with little visual, olfactory, or other indication of impairment.
4. High surface water quality, with no visual, olfactory, or other indication of impairment.

-- Surveyors were unable to assess surface water quality in the field, but will conduct follow-up research (e.g., locate existing water quality data) and assign a score.

C. Springs flow: Is there evidence that the springs flow has been altered through human actions, such as wells, diversions, or capping?

1. The springs ecosystem that previously flowed is dry, with no flow evident at the source(s), or has been completely diverted or capped.
2. Springsflow from the source(s) has been greatly reduced due to wells, diversions, or capping.
3. Springsflow from the source(s) appears to have been slightly reduced due to wells, diversions, or capping.
4. Springsflow from the source(s) appears to be natural or near natural, with no wells, diversions, or capping.

-- Surveyors are unable to assess springsflow in the field, but will conduct follow-up research (e.g., locating historical information about use) and assign a score.

Comments about aquifer functionality and water quality.

Geomorphology

The following questions are related to the natural geomorphic integrity of the springs ecosystem. Score with half decimals from 1.0 to 4.0.

D. Natural geomorphic diversity: Are the expected microhabitats for this springs ecosystem type present, and/or are additional natural microhabitats or anthropogenic microhabitats present? Are geomorphic processes negatively influenced by human activities at the springs? Use Worksheet D to calculate this assessment score. The score calculated using Worksheet D may be interpreted using these descriptions:

1. The microhabitats that are expected or may occur in this springs ecosystem type are missing.
2. Few of the microhabitats that are expected or may occur in this springs ecosystem type are present.
3. Most, but not all of the microhabitats that are expected or may occur in this springs ecosystem type are present.
4. All of the microhabitats that are expected, as well as others that may occur in this springs ecosystem type are present.

SiteName________________________________ID____________Observer____________________

Condition Assessment Questions Page 2

E. Soil integrity: To what extent are the soils, if present, altered due to anthropogenic influences? Natural soils can be affected by trampling, paving, trailing, vehicle tracks, fire pits, and other factors. What percent of the natural soils have been affected by these impacts? If an estimated percent cover is within 5% of a boundary score, a half-decimal should be applied.

1. 1. Between 75 to 100% of the surface area of natural soils, including peat, have been eliminated.
2. Between 50 to 75% of the surface area of natural soils, including peat, are altered and highly compromised.
3. Between 25 to 50% of the surface area of natural soils and/or peat deposits are altered, and soils are somewhat compromised.
4. Between 0 to 25% of the surface area of natural soils and/or peat deposits are altered, or natural soils are not expected to occur at that springs ecosystem type (e.g., bedrock-dominated gushet or hanging gardens springs).

F. Natural physical disturbance: Is the site subject to its natural geomorphic disturbance regime, including flooding, rockfall, mammalian herbivore influences, or other natural disturbances? Fire disturbance is considered in the next question. Upstream impoundments and channel alterations influence natural flooding, or inundate rheocrene springs downstream. Stabilization measures reduce natural disturbances such as rockfall or sprawling. Intensive mammalian herbivore use can alter the site geomorphology. Exclosures, while well-intended, can eliminate wildlife use, resulting in proliferation of wetland vegetation and loss of surface water and habitat. The four characteristics of ecological disturbance are timing, magnitude, duration, and frequency.

1. The natural disturbance regime is nearly or entirely altered, and is largely unrecoverable. All four characteristics have been altered.
2. The natural disturbance regime is moderately to highly altered, and is not likely to recover. Two or more disturbance characteristics have been altered.
3. The natural disturbance regime is slightly altered, but could recover. One disturbance characteristic has been altered.
4. The disturbance regime is nearly or entirely natural, and none of the disturbance characteristics have been altered.

---Surveyors could not evaluate the disturbance regime, but will conduct follow-up research (e.g., review hydrology) and assign a score.

G. Natural Fire Regime: Is the springs ecosystem subject to its natural fire disturbance regime? Has a past fire negatively affected the springs ecosystem? Has fire suppression created unnaturally dense vegetation, threatening the springs with a catastrophic burn?

1. The natural fire disturbance regime is nearly or entirely altered, and is largely unrecoverable. All four fire disturbance characteristics have been altered.
2. The natural fire disturbance regime is moderately to highly altered, and is not likely to recover. Two or more fire disturbance characteristics have been altered.
3. The natural fire disturbance regime is slightly altered, but could recover. One fire disturbance characteristic has been altered.
4. The fire disturbance regime is nearly or entirely natural, and none of the fire disturbance characteristics have been altered.

-- Surveyors could not evaluate the disturbance regime, but will conduct follow-up research (e.g., review fire boundary and intensity maps) and assign a score.

Comments about geomorphology, soils, and disturbance.

Geographic Context

The following questions relate to the level of isolation and size of the springs ecosystem. These intrinsic site characteristics reflect the ecological importance of the springs ecosystem and are likely to influence stewardship prioritization, but they do not reflect the condition and are therefore not counted in the assessment scoring. If an estimated distance or area is within 10% of a boundary score, a half-decimal should be applied.

H. Isolation from other springs ecosystems: How isolated is this springs ecosystem from other reported springs? The importance of a springs ecosystem increases with isolation.

1. The nearest reported springs ecosystem is less than 100 m away.
2. The nearest reported springs ecosystem is between 100 and 1,000 m away.
3. The nearest reported springs ecosystem is between 1 and 10 km away.
4. The nearest reported springs ecosystem is more than 10 km away.

-- Surveyors were unable to determine springs isolation, but will conduct follow-up research (e.g., GIS analysis of isolation) and assign a score.

SiteName______________________________ID____________Observer____________________

Condition Assessment Questions Page 3

I. Isolation from perennial sources: How isolated is this springs ecosystem from the nearest perennial water body, such as a stream or lake? The importance of a springs ecosystem increases with isolation from other water bodies.

1. The nearest reported perennial water body is less than 100 m away.
2. The nearest reported perennial water body is between 100 and 1,000 m away.
3. The nearest reported perennial water body is between 1 and 10 km away.
4. The nearest reported perennial water body is more than 10 km away.

-- Surveyors were unable to determine the distance to the nearest perennial water body, but will conduct follow-up research (i.e., GIS analysis of isolation) and assign a score.

J. Habitat size: How large is this springs ecosystem? The importance of a springs ecosystem increases with its functioning size—the surface area that is directly influenced by the spring.

1. The springs ecosystem size is less than 100 m^2.
2. The springs ecosystem size is between 100 - 1,000 m^2.
3. The springs ecosystem size is between 1,000 and 10,000 m^2.
4. The springs ecosystem size is greater than 10,000 m^2.

---Surveyors were unable to determine the size of the springs ecosystem, but will conduct follow-up research. For example, if the ecosystem is too large to measure, aerial imagery may be used to assign a score.

Comments about the geographic context and importance of the springs ecosystem.

Habitat

The following questions relate to the capacity of the springs and its associated microhabitats to support native species and natural ecosystem processes. Habitat area, quality, productivity, and diversity strongly influence springs ecosystem ecology and biota, and anthropogenic degradation of springs habitat reduces the extent and importance of those ecological variables. Score with half decimals from 1.0 to 4.0.

K. Microhabitat quality: What is the condition of the microhabitats associated with the site? Consider the overall habitat quality in each of the microhabitats and the intensity of all apparent anthropogenic impacts. Springs ecosystems can support multiple microhabitats, and each of those microhabitats can support its own suite of species that may or may not interact with those in other microhabitats. Anthropogenic activities may affect one or more or all microhabitats. Human activities can influence some or all microhabitats at a springs ecosystem. For example, intensive livestock use may cause pedestal formation, feces deposition, erosion, or other impacts on wetland microhabitat surfaces. Construction of roads, springboxes, or berms, as well as pollution can degrade microhabitat quality.

1. No natural microhabitats remain, or the remaining natural microhabitats are in very poor condition.
2. At least one natural microhabitat is in poor condition, with significant impairment evident, and anthropogenic habitats may be present.
3. All natural microhabitats are ecologically moderately intact, but some impairment is evident. If anthropogenic habitats are present, they are historic and have recovered ecologically.
4. All natural microhabitats are nearly or fully ecologically intact, with little or no impairment. No anthropogenic microhabitats are present.

L. Native plant cover: What is the proportion of native to non-native plant cover? Native vegetation cover is generally supportive of native animal species, while non-native plant cover may exclude native fauna, increase wildfire frequency and intensity, and attract or support undesireable species through changes in ecological structure and processes. If an estimated percent cover is within 5% of a boundary score, a half-decimal should be applied.

1. No native plant species are present, or less than 40% of the plant cover is native.
2. Between 40 and 80% of the plant cover is native.
3. Between 80 and 95% of the plant cover is native.
4. More than 95% of the plant cover is native.

-- Surveyors were unable to evaluate the native plant species ecological role. For example, surveyors could collect plant specimens or photographs to be subsequently verified.

SiteName________________________________ID_____________Observer_____________________

Condition Assessment Questions Page 4

M. Native food web dynamics: What is the condition of the natural food web at this springs ecosystem? Ecologically intact springs ecosystems support diverse food web interactions, with robust vegetation (where geomorphically appropriate) supporting diverse populations of invertebrate and vertebrate herbivores and predators. This can range from mountain lions to dragonflies. Trophic structure, as indicated by the presence of vegetation, primary consumers, and secondary or top consumers (predators), indicates that ecosystem functionality at a site is high.

1. No natural food web dynamics are evident, with no observation or evidence of predators.
2. There is some evidence of natural food web dynamics, indicated by the observation or evidence of at least one predator.
3. There is moderate evidence of natural food web dynamics, indicated by the observation or evidence of several predators from a range of trophic levels.
4. The food web dynamics appear to be natural or nearly natural, indicated by the observation or evidence of several predators from a range of trophic levels.

Comments about habitat quality, plant cover, and food web dynamics.

Biota

The following questions pertain to flora and faunal species detected during the survey. Floral and faunal species biodiversity is an important topic in stewardship discussions about springs. Score with half decimals from 1.0 to 4.0.

N. Native vs. non-native plant species: What is the proportion of native plant species? Non-native plant species can overwhelm native plant communities at springs, thus the proportional representation of native and non-native plant species is an important assessment variable. If an estimated percent cover is within 5% of a boundary score, a half-decimal should be applied.

1. Between 0 and 40% of the plant species are native.
2. Between 40 and 80% of the plant species are native.
3. Between 80 and 95% of the plant species are native.
4. More than 95% of the plant species are native.

-- Surveyors were unable to evaluate the proportion of native plant species, but will conduct follow-up research (e.g., collect plant specimens for identification) and assign a score.

O. Presence of noxious weed species: How many plant species from the noxious list are present? Please see New Mexico Noxious Weed List, and complete Worksheet O.

1. Three or more NM noxious weed species are present.
2. Two NM noxious weed species are present.
3. One NM noxious weed species is present.
4. No NM noxious weed species are present.

-- Surveyors were unable to evaluate the presence of noxious species, but will conduct follow-up research (e.g. collect samples for identification) and assign a score.

P. Plant demography: Is the population structure (demography) of woody vegetation appropriate to the site? For example, is the springs ecosystem becoming unnaturally dominated by woody plant species (e.g., conifer, Russian olive, Siberian elm, tamarisk) or invasive wetland species (e.g., *Typha* or *Phragmites*), as evidenced by the presence of multiple life stages (e.g., seedling, sapling, mature plants)? Upland woody shrubs or trees encroaching onto the site can reveal an unnatural transition due to human activity or disturbance.

1. The site is almost entirely dominated by woody plant species or invasive wetland species.
2. The site is largely, but not entirely dominated by woody plant species or invasive wetland species.
3. The site contains some encroachment by woody plant species or invasive wetland species.
4. The vegetation at the springs ecosystem appears appropriate.

Q. Sensitive flora and fauna richness: Did surveyors identify any sensitive plant or animal species? Rare, endemic, sensitive, threatened and/or endangered species often present policy-related or legal management issues to springs stewards.

4. One or more sensitive or listed plant or animal species were identified, or the site is designated critical habitat for a species.

--- Surveyors were unable to evaluate the presence of such species, or due to spring type or naturally non-supportive habitat there is no reason to expect any of these species at the site.

Sensitive species present or reported at the site. Indicate whether, rare, common, or abundant.

SiteName_______________________ID_____________Observer_______________________

Condition Assessment Questions Page 5

R. Proportion of native animal species: What is the proportion of native invertebrate and vertebrate species? Non-native animal species can exert negative impacts on native species and ecological processes, degrading the springs ecosystem. If an estimated percent cover is within 5% of a boundary score, a half-decimal should be applied.

1. Between 0 and 40% of the animal species present are native.
2. Between 40 and 80% of the animal species present are native.
3. Between 80 and 95% of the animal species present are native.
4. More than 95% of the animal species are native.

---Surveyors were unable to evaluate the proportion of native animal species, but will conduct follow-up research and assign a score.

S. Number of non-native animal species: How many non-native aquatic and terrestrial animal species are present? For example, to what extent are nonnative mollusks, crayfish, bullfrogs, and game or aquarium fish species present? Non-native animal species can exert negative impacts on native species and ecological processes, degrading the springs ecosystem. One caveat: not all animal species occupying a springs ecosystem are likely to be detected during a single site visit. Therefore, this score is expected to be refined with multiple visits. Please complete Worksheet S.

1. Three or more nonnative animal species were detected.
2. Two nonnative animal species were detected.
3. One nonnative animal species was detected.
4. No nonnative animal species were detected.

---Surveyors were unable to evaluate the presence of non-native species, but will conduct follow-up research (e.g. collect samples for identification) and assign a score.

Comments about Biota.

SiteName________________________ID__________Observer________________

Primary Type [ ] Secondary Type [ ]

Worksheet D

Table 2. Probability of microhabitats occurring at each springs type.

	Microhabitat Type												
Spring Type	**Backwall or sloped bedrock**	**Cave**	**Channel**	**Colluvial slope**	**Mound**	**Pool**	**Terrace**	**Pool margin**	**Low gradient cienega**	**High gradient cienega**	**No. Likely**	**No. Possible**	**No. Unlikely**
Cave	High	High	High	Low	Low	Med	Med	Med	Low	Low	3	3	4
Exposure	Med	Low	Low	Med	Low	High	Low	High	Low	Low	2	2	6
Fountain	Low	Low	Med	Med	Med	High	Med	Low	Med	Low	1	5	4
Gushet	High	Med	High	Med	Low	Med	High	Med	Low	Med	3	5	2
Geyser	High	Low	Med	Low	High	Med	Med	Low	Low	Low	2	3	5
Hanging garden	High	Low	High	High	Low	High	High	High	Low	Low	6	0	4
Helocrene	Low	Low	Med	Low	Med	Med	Med	Med	High	High	2	5	3
Hillsope-rheocrene	Med	Low	High	Med	Low	Med	High	Low	Med	Med	2	5	3
Hillsope-upland	Med	Low	High	Med	Low	Med	High	Low	Med	Med	2	5	3
Hypocrene *	Med	Low	Low	Med	Med	Low	Med	High	High	Med	2	5	3
Limnocrene	Med	Low	Med	Low	Med	High	Med	High	Med	Low	2	5	3
Mound-form	High	Low	Med	Med	High	Med	Med	High	Med	Med	3	6	1
Rheocrene	Med	Low	High	Med	Low	Med	High	Low	Med	Low	2	4	4

Table 3. Scoring worksheet with the count of each microhabitat and anthropogenic influence for each.

Microhabitat Type	Likelihood	Liklihood Score	Count	Score	Anthro Count
Backwall or Sloping Bedrock					
Cave					
Channel					
Colluvial Slope					
Spring mound					
Pool					
Terrace					
Pool margin					
Low gradient cienega					
High gradient cienega					
			Totals:		

SiteName________________________ID__________Observer________________

Primary Type [ ] Secondary Type [ ]

Worksheet D (cont.)

Scoring Question D requires the following steps:

1) Table 2 is a reference list showing the probability of occurrence of each natural microhabitat at a given springs type. Use Table 2 to look up the probability of occurrence of each natural microhabitat for the springs type being surveyed. In the Likelihood column of Table 3, copy these probabilities for the springs type you are surveying.
2) The Likelihood Score column in Table 3 will autofill based on the values entered into the Likelihood column (low probability = 1, medium probability = 2, and high probability = 3).
3) In the Count column in Table 3, record how many of each microhabitat were observed at the spring (e.g. there may have been 1 channel and 2 terraces). These data should also have been recorded on page 1 of the inventory field sheets.
4) Multiply values in the Likelihood Score column by values in the Count column to generate values for the Prelim. Score column.
5) Sum the Prelim Score column to generate a Preliminary Site Sore.
6) Table 4 is a cross-walk reference list to convert the Preliminary Site Score to a Preliminary Question D Assessment Score. For example, if you are surveying a hanging garden and use Table 3 to calculate a Preliminary Site Score of 10, your Preliminary Question D Assessment Score will be 2.5 (from the right column of Table 4).
7) Now return to Table 3 and record the number of significant anthropogenic microhabitats present (e.g., berms, concrete slabs, metal tanks, etc.).
8) Subtract the number of significant anthropogenic microhabitats from the preliminary Question D Assessment Score to generate a final Question D score. Record this final score in the box for Assessment Question D on the assessment field sheet.

Table 4. Assessment Score chart for condition assessment question D.

Cave	Exposure	Fountain	Gushet	Geyser	Hanging Garden	Helocrene	Hillslope-rheocrene	Hillslope (upland)	Hypocrene	Limnocrene	Mound-Form	Rheocrene	Anthropogenic	Assessment Score
≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	All	1
1	1		1	1	1-4	1	1	1	1	1	1	1		1.5
2-3	2		2-3	2	5-7	2	2	2	2	2	2-3	2		2
4-5	3		4-5	3	8-10	3	3	3	3	3	4-5	3		2.5
6-7	4	1-2	6-7	4	11-13	4	4	4	4	4	6-7	4		3
8	5		8	5	14-17	5	5	5	5	5	8	5		3.5
≥ 9	≥ 6	≥ 3	≥ 9	≥ 6	≥ 18	≥ 6	≥ 6	≥ 6	≥ 6	≥ 6	≥ 9	≥ 6		4

SiteName____________________ID__________Observer________________

Worksheet O

New Mexico Noxious Weed List
Updated September 2016

If a species is absent, check the absent box; if present, enter 1. Count the total at the bottom of page 2, and respond to question O.

Class C Species: Class C species are wide-spread in the state. Management decisions for these species should be determined at the local level, based on feasibility of control and level of infestation.	**Absent**	**Present**
Cheatgrass, *Bromus tectorum*		
Curlyleaf pondweed, *Potamogeton crispus*		
Eurasian watermilfoil, *Myriophyllum spicatum*		
Giant cane, *Arundo donax*		
Hydrilla, *Hydrilla verticllata*		
Jointed goatgrass, *Aegilops cylindrica*		
Musk thistle, *Carduus nutan*		
Parrotfeather, *Myriophyllum aquaticum*		
Russian olive, *Elaeagnus angustifolia*		
Saltcedar, *Tamarix spp.*		
Siberian elm, *Ulmus pumila*		
Tree of heaven, *Ailanthus altissima*		
Class B Species: Class B Species are limited to portions of the state. In areas with severe infestations, management should be designed to contain the infestation and stop any further spread.	**Absent**	**Present**
African rue, *Peganum harmala*		
Bull thistle, *Cirsium vulgare*		
Chicory, *Cichorium intybus*		
Halogeton, *Halogeton glomeratus*		
Malta starthistle, *Centaurea melitensis*		
Perennial pepperweed, *Lepidium latifolium*		
Poison hemlock, *Conium maculatum*		
Quackgrass, *Elytrigia repens*		
Russian knapweed *Acroptilon repens*		
Spiny cocklebur, *Xanthium spinosum*		
Teasel, *Dipsacus fullonum*		

Worksheet O (Cont.)

SiteName_______________________________________

Watch List Species: Watch List species are species of concern in the state. These species have the potential to become problematic. More data is needed to determine if these species should be listed. When these species are encountered please document their location and contact appropriate authorities.	**Absent**	**Present**
Crimson fountaingrass, *Pennisetum setaceum*		
Meadow knapweed, *Centaurea pratensis*		
Myrtle spurge, *Euphorbia myrsinites*		
Pampas grass, *Cortaderia sellonana*		
Sahara mustard, *Brassica tournefortii*		
Syrian beancaper, *Zygophyllum fabago L.*		
Wall rocket, *Diplotaxis tenuifolia*		
Class A Species: Class A species are currently not present in New Mexico, or have limited distribution. Preventing new infestations of these species and eradicating existing infestations is the highest priority	**Absent**	**Present**
Alfombrilla, *Drymaria arenariodes*		
Black henbane, *Hyoscyamus niger*		
Brazillian egeria, *Egeria densa*		
Camelthorn, *Alhagi psuedalhagi*		
Canada thistle, *Cirsium arvense*		
Dalmation toadflax, *Linaria dalmatica*		
Diffuse knapweed, *Centaurea diffusa*		
Dyer's woad, *Isatis tinctoria*		
Giant salvinia, *Salvinia molesta*		
Hoary cress, *Cardaria spp.*		
Leafy spurge, *Euphorbia esula*		
Oxeye daisy, *Leucanthemum vulgare*		
Purple loosestrife, *Lythrum salicaria*		
Purple starthistle, *Centaurea calcitrapa*		
Ravenna grass, *Saccharum ravennae*		
Scentless chamomile, *Matricaria perforata*		
Scotch thistle, *Onopordum acanthium*		
Spotted knapweed, *Centaurea biebersteinii*		
Yellow toadflax, *Linaria vulgaris*		
Yellow starthistle, *Centaurea solstitialis*		
Total Noxious Weed Species Present:		

Worksheet P

SiteName________________________________

This table lists vegetation elements that are considered unnatural for each springs type. For the springs type you are surveying, circle all elements present. In the right column, record the total number of unnatural vegetation elements for the springs type you are surveying.

Springs Type	Ground Cover	Woody Cover	Tree Cover	# Unnatural Elements
Cave	Excessive algal cover	n/a	n/a	
Exposure	Excessive algal, Typha or Phragmites cover	Dead shrub cover (all life stages)	Dead tree cover (all stages)	
Fountain	Dead wetland vegetation (all life stages)	Excessive phreatophyte or upland shrub seedling or sapling cover	Excessive phreatophyte or conifer seedlings or saplings	
Geyser	Excessive algal cover	Excessive phreatophyte or upland seedling or sapling shrub cover	Excessive phreatophyte or conifer seedlings or saplings	
Gushet	Dead wetland vegetation, or excessive non-wetland plant species	Dead shrubs, or excessive upland shrub seedling or sapling cover	Dead trees, or excessive conifer or upland plant seedlings or sapling presence	
Hanging Garden	Dead wetland vegetation, or excessive non-wetland plant species	Dead shrubs, or excessive upland shrub seedling or sapling cover	Dead trees, or excessive conifer or upland plant seedlings or sapling presence	
Helocrene	Dead wetland vegetation or excessive unvegetated ground (alkaline springs may not support no or little wetland vegetation)	Dead shrubs, or excessive phreatophyte or upland shrub seedling or sapling cover	Dead, or unnaturally excessive phreatophyte or upland tree seedling or sapling cover	
Hillslope	Dead wetland vegetation, or excessive non-wetland plant species	Dead shrubs, or excessive phreatophyte or upland shrub seedling or sapling cover	Dead, or unnaturally excessive phreatophyte or upland tree seedling or sapling cover	
Hypocrene	Dead wetland vegetation	Dead shrubs	Dead tree seedlings, saplings, mature individuals	
Limnocrene	Excessive unnatural algal, Typha or Phragmites cover	Dead shrubs, or excessive upland shrub seedling or sapling cover	Dead trees, or excessive upland tree seedling or sapling cover	
Mound-form	Excessive unnatural algal, Typha or Phragmites cover	Dead shrubs, or excessive upland shrub seedling or sapling cover	Dead trees, or excessive upland tree seedling or sapling cover	
Rheocrene	Excessive unnatural algal, Typha or Phragmites cover	Dead shrubs, or excessive upland shrub seedling or sapling cover in riparian zone	Dead trees or excessive upland tree seedling or sapling cover in riparian zone	
Total Count				

Worksheet S

If species is present, place a checkmark in the right-most column of the table. Count the total at the bottom of the last page, and respond to question S.

New Mexico Exotic Animal List

Edited from the USGS Nonidigenous Aquatic Species (https://nas.er.usgs.gov/queries/SpeciesList.aspx?Group=&Sortby=1&state=NM) and the Biota Information System of New Mexico (BISON; http://bison-m.org/)

Group	Common Name	Family	Scientific Name	Nativity in NM	Present
Amphibians-Frogs	American Bullfrog	Ranidae	*Lithobates catesbeianus*	Exotic	
Amphibians-Frogs	Green Frog	Ranidae	*Lithobates clamitans*	Exotic	
Amphibians-Frogs	Barred Tiger Salamander	Ambystomatidae	*Ambystoma mavortium*	Exotic	
Birds	Chukar	Phasianidae	*Alektoris chukar*	Exotic	
Birds	Eurasian Collard Dove	Columbidae	*Streptopelia decaocto*	Exotic	
Birds	European House Sparrow	Passeridae	*Passer domesticus*	Exotic	
Birds	Pheasant	Phasianidae	*Phasianus colchicus*	Exotic	
Birds	Rock Dove (Common Pigeon)	Columbidae	*Columba livia*	Exotic	
Birds	Starling	Sternidae	*Sternus vulgaris*	Exotic	
Coelenterates-Hydrozoans	freshwater jellyfish	Olindiidae	*Craspedacusta sowerbyi*	Exotic	
Crustaceans-Cladocerans	a waterflea	Daphnidae	*Daphnia lumholtzi*	Exotic	
Crustaceans-Copepods	a calanoid copepod	Temoridae	*Eurytemora affinis*	Exotic	
Crustaceans-Copepods	anchor worm	Lernaeidae	*Lernaea cyprinacea*	Exotic	
Crustaceans-Crayfish	Red Swamp Crayfish	Cambaridae	*Procambarus clarkii*	Exotic	
Crustaceans-Crayfish	Rusty Crayfish	Cambaridae	*Faxonius rusticus*	Exotic	
Crustaceans-Crayfish	Virile Crayfish	Cambaridae	*Orconectes virilis*	Exotic	
Crustaceans-Crayfish	Western plains crayfish	Cambaridae	*Faxonius causeyi*	Native (part)	
Fishes	Arctic Grayling	Salmonidae	*Thymallus arcticus*	Exotic	
Fishes	Bairdiella	Sciaenidae	*Bairdiella icistia*	Exotic	
Fishes	Black Bullhead	Ictaluridae	*Ameiurus melas*	Native (part)	

Group	Common Name	Family	Scientific Name	Nativity in NM	Present
Fishes	Black Crappie	Centrarchidae	*Pomoxis nigromaculatus*	Exotic	
Fishes	Black Drum	Sciaenidae	*Pogonias cromis*	Exotic	
Fishes	Blue Catfish	Ictaluridae	*Ictalurus furcatus*	Native (part)	
Fishes	Bluegill	Centrarchidae	*Lepomis macrochirus*	Native (part)	
Fishes	Brook Stickleback	Gasterosteidae	*Culaea inconstans*	Exotic	
Fishes	Brook Trout	Salmonidae	*Salvelinus fontinalis*	Exotic	
Fishes	Brown Bullhead	Ictaluridae	*Ameiurus nebulosus*	Exotic	
Fishes	Brown Trout	Salmonidae	*Salmo trutta*	Exotic	
Fishes	Bullhead Minnow	Cyprinidae	*Pimephales vigilax*	Exotic	
Fishes	Channel Catfish	Ictaluridae	*Ictalurus punctatus*	Native (part)	
Fishes	Coho Salmon	Salmonidae	*Oncorhynchus kisutch*	Exotic	
Fishes	Common Carp	Cyprinidae	*Cyprinus carpio*	Exotic	
Fishes	Cutbow trout	Salmonidae	*Oncorhynchus clarkii x mykiss*	Native Hybrid	
Fishes	Cutthroat Trout	Salmonidae	*Oncorhynchus clarkii*	Exotic	
Fishes	Dolly Varden	Salmonidae	*Salvelinus malma*	Exotic	
Fishes	Fathead Minnow	Cyprinidae	*Pimephales promelas*	Native (part)	
Fishes	Flathead Catfish	Ictaluridae	*Pylodictis olivaris*	Native (part)	
Fishes	Gila Topminnow	Poeciliidae	*Poeciliopsis occidentalis occidentalis*	Native	
Fishes	Gizzard Shad	Clupeidae	*Dorosoma cepedianum*	Exotic	
Fishes	Golden Shiner	Cyprinidae	*Notemigonus crysoleucas*	Exotic	
Fishes	Golden Trout	Salmonidae	*Oncorhynchus aguabonita*	Exotic	
Fishes	Goldfish	Cyprinidae	*Carassius auratus*	Exotic	
Fishes	Grass Carp	Cyprinidae	*Ctenopharyngodon idella*	Exotic	
Fishes	Green Sunfish	Centrarchidae	*Lepomis cyanellus*	Native (part)	
Fishes	Gulf Killifish	Fundulidae	*Fundulus grandis*	Exotic	
Fishes	Guppy	Poeciliidae	*Poecilia reticulata*	Exotic	
Fishes	Inland Silverside	Atherinopsidae	*Menidia beryllina*	Exotic	
Fishes	Iowa Darter	Percidae	*Etheostoma exile*	Exotic	
Fishes	Kokanee Salmon	Salmonidae	*Oncorhynchus nerka*	Exotic	

Group	Common Name	Family	Scientific Name	Nativity in NM	Present
Fishes	Lake Trout	Salmonidae	*Salvelinus namaycush*	Exotic	
Fishes	Largemouth Bass	Centrarchidae	*Micropterus salmoides*	Native (part)	
Fishes	Largespring Gambusia	Poeciliidae	*Gambusia geiseri*	Native	
Fishes	Longear Sunfish	Centrarchidae	*Lepomis megalotis*	Exotic	
Fishes	Mexican Golden Trout	Salmonidae	*Oncorhynchus chrysogaster*	Exotic	
Fishes	Northern Pike	Esocidae	*Esox lucius*	Exotic	
Fishes	Orangemouth Corvina	Sciaenidae	*Cynoscion xanthulus*	Exotic	
Fishes	Pirate Perch	Aphredoderidae	*Aphredoderus sayanus*	Exotic	
Fishes	Plains Killifish	Fundulidae	*Fundulus zebrinus*	Native (part)	
Fishes	Rainbow Trout	Salmonidae	*Oncorhynchus mykiss*	Exotic	
Fishes	Redear Sunfish	Centrarchidae	*Lepomis microlophus*	Exotic	
Fishes	Red Drum	Sciaenidae	*Sciaenops ocellatus*	Exotic	
Fishes	Rio Grande cutthroat trout	Salmonidae	*Oncorhynchus clarkii virginalis*	Native	
Fishes	Rock Bass	Centrarchidae	*Ambloplites rupestris*	Exotic	
Fishes	Sacramento Perch	Centrarchidae	*Archoplites interruptus*	Exotic	
Fishes	Sailfin Molly	Poeciliidae	*Poecilia latipinna*	Native	
Fishes	Sargo	Haemulidae	*Anisotremus davidsonii*	Exotic	
Fishes	Sheepshead Minnow	Cyprinodontidae	*Cyprinodon variegatus*	Largely exotic	
Fishes	Smallmouth Bass	Centrarchidae	*Micropterus dolomieu*	Exotic	
Fishes	Snake River Finespotted Cutthroat Trout	Salmonidae	*Oncorhynchus clarkii behnkei*	Exotic	
Fishes	Spotted Bass	Centrarchidae	*Micropterus punctulatus*	Exotic	
Fishes	Spooted Sea Trout	Salmonidae	*Cynoscion nebulosus*	Exotic	
Fishes	Striped Bass	Moronidae	*Morone saxatilis*	Exotic	
Fishes	Tench	Cyprinidae	*Tinca tinca*	Exotic	
Fishes	Threadfin Shad	Clupeidae	*Dorosoma petenense*	Exotic	
Fishes	Tilapia	Cichlidae	*Tilapia sp.*	Exotic	
Fishes	Walleye	Percidae	*Sander vitreus*	Exotic	
Fishes	Warmouth	Centrarchidae	*Lepomis gulosus*	Exotic	
Fishes	White Bass	Moronidae	*Morone chrysops*	Exotic	

Group	Common Name	Family	Scientific Name	Nativity in NM	Present
Fishes	White Crappie	Centrarchidae	*Pomoxis annularis*	Exotic	
Fishes	Wiper	Moronidae	*Morone chrysops x M. saxatilis*	Exotic	
Fishes	Yellow Bullhead	Ictaluridae	*Ameiurus natalis*	Exotic	
Fishes	Yellow Perch	Percidae	*Perca flavescens*	Exotic	
Fishes	Yellowstone cutthroat trout	Salmonidae	*Oncorhynchus clarkii bouvieri*	Exotic	
Fishes	Zebra danio	Cyprinidae	*Danio rerio*	Exotic	
Insect- Hymenoptera	Honey Bee	Apideae	*Apis melifera*	Exotic	
Insect- Lepidoptera	Small white	Pieridae	*Pieris rapae*	Exotic	
Mammals	Barbary Sheep (Aoudad)	Bovidae	*Ammotragus lervia*	Exotic	
Mammals	Black Rat	Muridae	*Rattus rattus*	Exotic	
Mammals	Domestic cat	Felidae	*Felis catus*	Exotic	
Mammals	Domestic Cow	Bovidae	*Bos taurus*	Exotic	
Mammals	Domestic dog	Canidae	*Canis lupus familiaris*	Exotic	
Mammals	Eastern Fox Squirrel	Sciuridae	*Sciurus niger*	Exotic	
Mammals	Feral Burro	Equidae	*Equus asinus*	Exotic	
Mammals	Feral Horse	Equidae	*Equus ferus caballus*	Exotic	
Mammals	Feral Pig	Suidae	*Sus scrofa*	Exotic	
Mammals	Himalayan Tahr	Bovidae	*Hemitragus jemlahicus*	Exotic	
Mammals	House Mouse	Muridae	Mus musculus	Exotic	
Mammals	Nine-banded Armadillo	Dasypodidae	*Dasypus novemcinctus mexicanus*	Exotic	
Mammals	Norway Rat	Muridae	*Rattus norvegicus*	Exotic	
Mammals	Nutria	Myocastoridae	*Myocastor coypus*	Exotic	
Mammals	Oryx	Bovidae	*Oryx gazella*	Exotic	
Mammals	Persian Ibex	Bovidae	*Capra aegagrus hircus*	Exotic	
Mammals	Siberian Ibex	Bovidae	*Capra siberica siberica*	Exotic	
Mollusks-Bivalves	Asian clam	Cyrenidae	*Corbicula fluminea*	Exotic	

Group	Common Name	Family	Scientific Name	Nativity in NM	Present
Mollusks-Gastropods	European ear snail	Lymnaeidae	*Radix auricularia*	Exotic	
Mollusks-Gastropods	European physa	Physidae	*Physella acuta*	Exotic?	
Platyhelminthes	Asian tapeworm	Bothriocephalidae	*Schyzocotyle acheilognathi*	Exotic	
Reptiles-Turtles	Malayan Snail-eating Turtle	Emydidae	*Malayemys subtrijuga*	Exotic	
Reptiles-Turtles	Midland Painted Turtle	Emydidae	*Chrysemys picta marginata*	Exotic	
Reptiles-Turtles	Red-Eared Slider	Emydidae	*Trachemys scripta elegans*	Native (part)	
Reptiles-Turtles	Snapping Turtle	Chelydridae	*Chelydra serpentina*	Native (part)	
Reptiles-Turtles	Yellow-bellied Slider	Emydidae	*Trachemys scripta scripta*	Exotic	
Reptiles- Squamates	Mediterranean Gecko	Gekkonidae	*Hemidactylus turcicus*	Exotic	
			Total Exotic Species Present:		

Table 5. New Mexico Springs Rapid Assessment Method summary worksheet

Assessment Question	Assessment Question Score	Sum of Question Scores	Category Score
Aquifer Functionality & Water Quality: A. Water table alteration			
Aquifer Functionality & Water Quality: B. Surface water quality impairment			
Aquifer Functionality & Water Quality: C. Springs flow rate			
Aquifer Functionality & Water Quality: Category Total Possible Score =12			
Geomorhology: D. Natural geomorphic diversity			
Geomorhology: E. Soil Integrity			
Geomorhology: F. Natural physical disturbance			
Geomorhology: G. Natural fire regime			
Geomorphology Category: Total Possible Score =16			
Geographic Context: H: Isolation from other springs			
Geographic Context: I. Isolation from nearest perennial water source			
Geographic Context: J. Springs habitat area (size)			
Geographic Context Category: (not counted in total score)			
Habitat: K. Microhabitat quality			
Habitat: L. Native plant cover			
Habitat: M. Native food-web dynamics			
Habitat Category: Total Possible Score =12			

Assessment Question	Assessment Question Score	Sum of Question Scores	Category Score
Biota: N. Native vs. non-native plant species richness			
Biota: O. Presence of noxious weed species			
Biota: P. Plant demography			
Biota: Q. Sensitive flora and fauna richness			
Biota: R. Native and non-native faunal species percent			
Biota: S. Non-native faunal species richness			
Biota Category: Total Possible Score =20 (excluding Q)			
Total Site Condition Score: (Total possible = 64) 1=irrecoverable 2=poor 3=good 4=pristine			

C Appendix - Sample Summary Report

Cherry Creek Spring
Survey Summary Report, Site ID 237590

Submitted April 13, 2019 by Springs Stewardship Institute

Location: The Cherry Creek Spring ecosystem is located in Grant County in the Upper Gila-Mangas Arizona, New Mexico 15040002 HUC, managed by the US Forest Service. The spring is located in the Gila National Forest, in the Twin Sisters USGS Quad, at 32.91074, -108.22766 measured using a GPS (WGS84, estimated position error 7 meters). The elevation is approximately 2099 meters. Larry Stevens, Jeri Ledbetter, Gloria Hardwick, Alek Mendoza, MaryAnn Mcgraw, John Moeny, and Wendel Hahn surveyed the site on 6/22/18 for 01:45 hours, beginning at 9:15, and collected data in 10 of 10 categories. This survey was conducted under the New Mexico - Pilot Study project using the NM Springs RAM protocol.

Fig 1.1 Cherry Creek Spring: Looking upslope 15m below springbox

Physical Description: Cherry Creek Spring is a hillslope spring. This spring is on a heavily forested northwest aspect of a narrow canyon that runs northeast to southwest. It is just on the other side of the canyon from HW 15. There is a dispersed camping area to the northwest, up canyon from the lowest outflow, 100 meters by the trail. The rock is possibly rhyolite. There may have been a fire five years ago, with subsequent invasion of brome. The piping from the spring box was built into the colluvial slope. The microhabitats associated with the spring cover 2139.6 sqm. The site has 4 microhabitats, including A -- a 1 sqm other, B -- a 144 sqm channel, C -- a 1827 sqm terrace, D -- a 168 sqm low gradient cienega. The geomorphic diversity is 0.23, based on the Shannon-Weiner diversity index.

Table 1.1 Cherry Creek Spring Microhabitat characteristics.

Code	A	B	C	D
Name	Spring Box - Source	Channel	Terrace	Low Gradient Cienega
Area sqm	0.6	144	1827	168
Surface type	OTH	CH	TE	LGC
Surface subtype	anthro	riffle		
Slope variability	Low	Med	Med	Low
Aspect TN	319	319	319	319
Slope degrees	0	25	25	5
Moisture (scale 1-10)	9	6	2	5
Water depth cm	10	2	0	0
Area % open water	10	5	0	0
Substrate				
1 - Clay %	0	0	0	0
2 - Silt %	0	5	30	40
3 - Sand %	0	5	3	40
4 - Fine gravel %	0	10	1	0
5 - Coarse gravel %	0	10	20	0
6 - Cobble %	0	46.9	40	5
7 - Boulder %	0	15	5	0
8 - Bedrock %	0	0	0	0
Organic %	0	8	.9	15
Other % (anthropogenic)	100	0.1	0.1	0
Precipitate %	0	0	0	0
Litter %	1	25	98	98
Wood %	0	10	1	1
Litter Depth (cm)	0.5	2	1	1

Geomorphology: Cherry Creek Spring emerges from a igneous, rhyolite rock layer in an unknown unit. The emergence environment is subaerial, with a gravity flow force mechanism. The site receives approximately 91% of available solar radiation, with 6478 Mj annually.

Access Directions: Take Highway 15 from Silver City to Cherry Creek area. Pull off the road into the camp area. Walk on the trail west.

Survey Notes: The lower end is impacted by the trail and people walking from the camp area. The infrastructure at the source - piping and tanks - was not functional.

Flow: Surveyors measured a flow of 0.11 liters/second, using a timed flow volume capture method. Flow was adjusted for an estimate of 80% of site flow capture. Flow was measured at 29 meters on the tape, downstream of the source.

Water Quality: Measurements were taken in the spring box. Location 1: at the spring source in flowing water at 10:30:00.

Table 1.2 Cherry Creek Spring Water Quality with multiple readings averaged.

Characteristic Measured	Average Value	Site Number	Device	Comments
18-Oxygen results %	-10.76			NM-28296
2-Hydrogen results %	-73.3			NM-28296
Alkalinity, Total (mg/L)	175	1	LaMotte	
Dissolved oxygen (field) (mg/L)	4	1	CHEMets DO kit	
pH (field)	6.1	1	Hanna Combo	Green
Salinity (field) (ppt)	0.144	1	Hanna Combo	Green
Specific conductance (field) (uS/cm)	362	1	Hanna Combo	green, converted from EC and adjusted for temperature
Temperature, water C	14.4	1	Hanna Combo	Green

Flora: Gloria Hardwick was the botanist for Polygons A-C. Larry Stevens was the botanist for Polygon D. Surveyors identified 32 plant species at the site, with 0.015 species/sqm. These included 24 native and 8 nonnative species.

Table 1.3 Cherry Creek Spring Cover Type.

Cover Type	Species Count	Wetland Species Count
Ground	16	4
Shrub	12	4
Mid-canopy	5	2
Tall canopy	4	4
Basal	5	3
Aquatic	1	1
Non-vascular	2	0

Table 1.4 Cherry Creek Spring Vegetation % Cover in Microhabitats.

Species	Cover Code	Native Status	Wetland Status	Comments	A	B	C	D
Acer negundo	MC	N	R		0	0	0	20
Acer negundo	SC	N	R		0	0	0	15
Acer negundo	TC	N	R		5	1	3	0
Alnus	BC	N	WR		0	0	3	0
Alnus	MC	N	WR		0	0	0	25

Species	Cover Code	Native Status	Wetland Status	Comments	A	B	C	D
Alnus	SC	N	WR		0	0.9	5	20
Alnus	TC	N	WR	3 in diameter	0	5	3	0
Bromus	GC	I	F		0	0	0	80
Carex	GC	N	W	praegracilis?	0	0	0	1
Conopholis	GC			orobanche? dead	0	0	0.01	0
Equisetum arvense	GC	N	WR		0	0.08	1	0
Fraxinus velutina	BC	N	R		0	0	2	0
Fraxinus velutina	SC	N	R		0	10	15	0
Fraxinus velutina	TC	N	R		70	3	5	0
Galium	GC	I	F		0	0	0	3
Galium aparine	GC	N	WR		0	20	0	0
Glyceria	GC	NI	W	grandis? striata?	0	30	0.3	0
Juglans	MC				0	0	0	5
Juglans	SC				0	0	0	5
Juglans major	BC	N	R		0	0	0.1	0
Juglans major	TC	N	R		1	0.4	2.1	0
Parthenocissus vitacea	SC	N			0	0.2	0.3	0
Penstemon barbatus	GC	N	U		0	0	0.01	0
Pinus ponderosa	SC	N	F		0	0	0.02	0
Poa pratensis	GC	NI	F		0	0	0	10
Prunus	GC		F	Choke cherry?	0	0.3	0.1	0
Prunus	SC		F	Choke cherry?	0	0	0	10
Pteridium aquilinum	GC	N	U		0	0.1	0.1	0
Quercus gambelii	BC	N	F		0	0	0.5	0
Quercus gambelii	MC	N	F		0	0.2	0.5	0
Quercus gambelii	SC	N	F		0	0.1	0.5	0
Robinia	SC		F		0	0	0	5
Robinia neomexicana	BC	N	F		0	0	0.5	0
Robinia neomexicana	MC	N	F		0	0.1	0.2	0
Robinia neomexicana	SC	N	F		0	0.3	0.5	0
Rumex	GC	NI	F		0	0	0	1
Smilacina racemosa	GC	N	U	Similicura? (Macunther?)?	0	0	0.1	0
Thalictrum fendleri	GC	N	F		0	0	0.02	0
Toxicodendron rydbergii	SC	N	F		0	0.5	5.02	0
unknown grass	GC			no bloom	0	0	0.01	0
unknown Lichen	NV	N			30	15	5	0.1
unknown moss	NV	N			40	5	0	0
Verbascum	GC	I	F		0	0	0	0.1
Veronica	AQ	N	A		0	0.01	0	0
Vitis arizonica	SC	N	R		0	0.4	0.5	5

Fauna: Surveyors collected or observed 13 aquatic and 10 terrestrial invertebrates and 10 vertebrate specimens.

Table 1.5 Cherry Creek Spring Invertebrates.

Species	Lifestage	Habitat	Method	Rep#	Count	Species Detail
Araneae Gnaphosidae	Ad	T	Spot		1	
Basommatophora Physidae	I	A	Spot		1	
Coleoptera Elmidae	Ad	A	Spot		2	
Coleoptera Hydrophilidae	Ad	A	Spot		2	
Diptera Chironomidae	L	A	Spot		2	
Diptera Nematocera	L	A	Spot		1	
Diptera Simuliidae	L	A	Spot		1	
Haplotaxida Lumbricidae	Ad	A	Spot		2	
Hemiptera Macroveliidae Macrovelia hornii	Ad	A	Spot		1	Verified
Hirudinida	Ad	A	Spot		1	
Isopoda	Ad	T	Spot		1	
Lepidoptera Lycaenidae	Ad	T	Spot		1	
Lepidoptera Nymphalidae Adelpha eulalia	Ad	T	Spot		1	
Lepidoptera Nymphalidae Danaus gilippus	Ad	T	Spot		1	
Lepidoptera Nymphalidae Libytheana carinenta	Ad	T	Spot			
Lepidoptera Nymphalidae Limenitis weidemeyerii	Ad	T	Spot		1	
Lepidoptera Nymphalidae Speyeria	Ad	T	Spot		1	
Lepidoptera Pieridae Colias	Ad	T	Spot		1	
Lepidoptera Pieridae Pontia	Ad	T	Spot		1	
Odonata Coenagrionidae Argia	L	A	Spot		1	
Trichoptera	L	A	Spot		1	Sp. 1
Trichoptera	L	A	Spot		6	Sp. 2
Veneroida Sphaeriidae Pisidium	L	A	Spot		1	

Table 1.6 Cherry Creek Spring Vertebrates.

Vertebrate Species Common Name	Count	Detection	Comments
Acorn Woodpecker	1	obs	
Black-headed Grosbeak	1	call	
Common Raven	1	call	
Peregrine Falcon	1	rep	nest
Hermit Thrush	1	call	
Sapsucker	1	sign	heavy damage, holes in velvet ash
Steller's Jay	1	call	
Gopher	1	sign	
Mourning Dove	1	obs	
Pocket Gopher	1	sign	burrows

Assessment: Assessment scores were compiled in 5 categories and 33 subcategories, with 9 null condition scores, and 9 null risk scores. Aquifer functionality and water quality are moderate with some restoration potential and there is negligible risk. Geomorphology condition is good with significant restoration potential and there is low risk. Habitat condition is good with significant restoration potential and there is low risk. Biotic integrity is very good with excellent restoration potential and there is low risk. Human influence of site is very good with excellent restoration potential and there is negligible risk. Administrative context status is undetermined due to null scores and there is undetermined risk due to null scores. Overall, the site condition is good with significant restoration potential and there is negligible risk.

Table 1.7 Cherry Creek Spring Assessment Scores.

Category	Condition	Risk
Aquifer Functionality & Water Quality	3.8	1.2
Geomorphology	4	2
Habitat	4.2	2.4
Biota	4.9	1.9
Human Influence	5.1	1.7
Administrative Context	0	0
Overall Ecological Score	4.5	1.8

Management Recommendations: If this site is to receive rehabilitation attention, a stepping stone trail would help to reduce erosion.

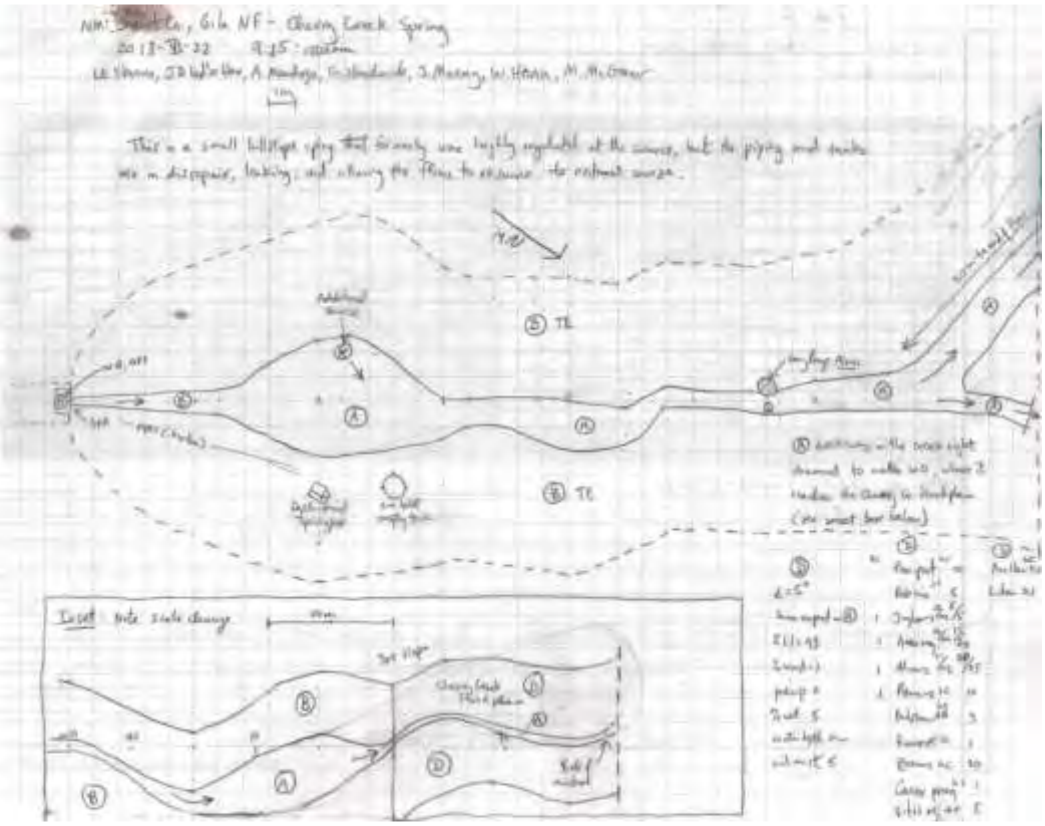

Fig 1.2 Cherry Creek Spring Sketchmap.

SiteName Cherry Creek Spring ID 237590 Observer L. Stevens and J Ledbetter

	Stressor Category and Subcategory Variables		1 Absent	2 Minor	3 Moder-ate	4 Intense
Impact	**Flow regulation or hydrological alteration**					
	Surface water diverted away (ditch, pipe, etc)				✔	
	Springbox, springhouse, or cap (enclosed in concrete, metal, rock, etc)				✔	
	Upgradient pre-emergence groundwater flow capture (e.g. pipe)		✔			
	Downgradient capture of surface flow (into tank, trough, etc)			✔		
	Flow regulated by impoundment or dam (e.g., berm, concrete structure)			✔		
	Source excavated to create open water (e.g., tank)				✔	
	Non-point source surface water pollution (e.g., road, agricultural, mining)		✔			
	Point source surface water pollution (e.g., sewage leakage, ungulate feces)		✔			
	Groundwater contamination (evidenced by dead animals, vegetation, odor)		✔			
	Nearby wells (groundwater extraction - consider size and proximity)		✔			
	Prolonged drought (Palmer's index, moderate=2, severe=3, extreme=4)			✔		
	Other hydrologic disturbance ______					
high	***Flow regulation, hydrologic alteration (max=48)***	20	5	6	9	0
	Soil or geomorphic alteration					
	Erosion - overall landscape, general, human influenced		✔			
	Erosion - on-site human influenced (e.g., channel, gully, cutbank)			✔		
	Excavation (e.g., pond creation, springbox and installation)				✔	
	Soil compaction (e.g., livestock trampling, vehicle use)		✔			
	Deposition, debris flow, spoil pile, or land fill			✔		
	Pedestals or hummocks due to livestock or wildlife		✔			
	Ruts (from vehicles)		✔			
	Soil removal (e.g., gravel or other mining, road construction)		✔			
	Soil contamination (e.g., oil, salt licks, refuse)		✔			
	Trails (human or animals)		✔			
	Other soil disturbance ______					
med	***Soil or geomorphic alteration (max=44)***	14	7	4	3	0
	Animal impacts					
	Habitat alteration by aquatic species (e.g., beaver, muskrat, nutria)		✔			
	Habitat alteration by terrestrial species (e.g., gopher, squirrel burrows)		✔			
	Wildlife grazing, browsing, defecating, or trampling (e.g., elk, deer)		✔			
	Livestock grazing, browsing, defecating, or trampling		✔			
	Non-native predators (e.g., crayfish, introduced fish, domestic animals)		✔			
	Other animal effects______					
low	***Animal impacts (max=24)***	5	5	0	0	0

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	Stressor Category and Subcategory Variables	1 Absent	2 Minor	3 Moder-ate	4 Intense
Impact	**Recreation impacts**				
	Camp sites (e.g., fire rings, refuse, site leveling, compaction)	✓			
	Tracks or trails by recreational motorized vehicles (dirt bikes, ATV, UTV)	✓			
	Tracks or trails from hiking, mountain biking	✓			
	Tracks or trails from pack animals	✓			
	Hunting/fishing (e.g., game cameras, salt licks, carcasses, lures/line)	✓			
	Target practice (e.g., shotgun shells, gunshot damage)	✓			
	Urban parklands, sports fields, swimming pools	✓			
	Passive recreation (e.g., birdwatching, photography, hot spring)	✓			
	Refuse or other waste disposal (e.g., toilet paper, cans, bottles)	✓			
	Excessive human visitation	✓			
	Human modification (e.g., hot springs dams, structures, climb/cave gear)	✓			
	Other recreation disturbance ______________________				
low	***Recreation impacts (max=48)*** 11	11	0	0	0
	Structures or development impacts				
	Abandoned infrastructure (non-functioning piping, springboxes, or tanks)			✓	
	Utility corridors or power lines	✓			
	Residential development	✓			
	Industrial or commercial development, mining structures	✓			
	Light or noise pollution	✓			
	Erosion control structure (e.g., gabeons, grade controls)	✓			
	Wildlife entrapment risk (e.g., missing springbox lid, open tank no escapement)	✓			
	Fence - geomorphically inappropriate and/or nonfunctioning	✓			
	Oil or gas well	✓			
	Pipeline external to site (e.g., oil, gas, water)	✓			
	Other structural disturbance ______________________				
low	***Structures or development impacts (max=44)*** 12	9	0	3	0
	Land use impacts				
	Fire regime		✓		
	Crop production (current or past)	✓			
	Ranch use (current or past)	✓			
	Road, incl. construction or maint. (paving type, use intensity, and proximity)	✓			
	Restoration, rehabilitation, or remediation actions	✓			
	Sensitive species protection efforts (e.g., fish translocation)	✓			
	Biological resource extraction (e.g., aquaculture, fisheries, plant collecting)	✓			
	Physical resource extraction (e.g., mining, quarrying)	✓			
	Forest management (e.g., thinning, timber harvest, planting)	✓			
	Scientific activities, including sentinel site monitoring	✓			
	Education activities (e.g., environmental education, tourism, youth camp)	✓			
	Other land use effects______________________				
low	***Land use impacts (max=48)*** 12	10	2	0	0

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Primary Type Hillslope Secondary Type

Condition Assessment Questions Page 1

Aquifer Functionality and Water Quality

The following questions are related to the apparent condition of the aquifer (water table), short-term climatic conditions, and the quality of groundwater at the source(s), as well as surface flow impacts. Score with half decimals from 1.0 to 4.0.

A. Water table: Is there evidence that the water table is dropping and the aquifer is failing to produce natural quantities of water for the springs ecosystem? For example, is woody vegetation (e.g., cottonwood, tree willow, other woody phreatophytes) showing evidence of mortality or declining health? Is woody upland vegetation encroaching? Or is an area now dry that was apparently previously groundwater supported? Is there an abandoned well or windmill? Any of these can indicate a declining water table.

Score: 3.5

1. The aquifer is depleted or in significant decline, as evidenced by: total loss of springs fauna (requires knowledge of springs fauna formerly occupying the site); total loss of wetland vegetation cover (observed as dead wetland plants), and/or substantial encroachment of upland vegetation.
2. The aquifer is moderately depleted, with evidence of decreasing or dying springs-dependent fauna or wetland vegetation cover, and/or encroachment of upland vegetation.
3. Aquifer is slightly but detectably depleted, with minor evidence of decreasing or dying wetland vegetation cover and/or limited encroachment of upland vegetation.
4. The aquifer appears to be in pristine or near-pristine condition, with no evidence of reduced flow, loss of wetland vegetation, or encroachment of upland vegetation.

-- Surveyors are unable to assess the water table condition in the field, but will conduct follow-up research (e.g., interview the land manager) and assign a score.

B. Surface water quality: What is the quality of water after it emerges onto the surface? Is there visual, olfactory, or other evidence of contamination (e.g., feces, strong odor, unusual color)?

Score: 4

1. The surface water quality is extremely poor with strong visual, olfactory, or other indications.
2. Moderately low surface water quality, with some visual, olfactory, or other indications.
3. Moderately high surface water quality, with little visual, olfactory, or other indication of impairment.
4. High surface water quality, with no visual, olfactory, or other indication of impairment.

-- Surveyors were unable to assess surface water quality in the field, but will conduct follow-up research (e.g., locate existing water quality data) and assign a score.

C. Springs flow: Is there evidence that the springs flow has been altered through human actions, such as wells, diversions, or capping?

Score: 2

1. The springs ecosystem that previously flowed is dry, with no flow evident at the source(s), or has been completely diverted or capped.
2. Springsflow from the source(s) has been greatly reduced due to wells, diversions, or capping.
3. Springsflow from the source(s) appears to have been slightly reduced due to wells, diversions, or capping.
4. Springsflow from the source(s) appears to be natural or near natural, with no wells, diversions, or capping.

-- Surveyors are unable to assess springsflow in the field, but will conduct follow-up research (e.g., locating historical information about use) and assign a score.

Comments about aquifer functionality and water quality

The site has been heavily modified for flow regulation, but the structures are old and no longer functioning.

Geomorphology

The following questions are related to the natural geomorphic integrity of the springs ecosystem. Score with half decimals from 1.0 to 4.0.

D. Natural geomorphic diversity: Are the expected microhabitats for this springs ecosystem type present, and/or are additional natural microhabitats or anthropogenic microhabitats present? Are geomorphic processes negatively influenced by human activities at the springs? Use Worksheet D to calculate this assessment score.

Score: 3

1. The microhabitats that are expected or may occur in this springs ecosystem type are missing.
2. Few of the microhabitats that are expected or may occur in this springs ecosystem type are present.
3. Most, but not all of the microhabitats that are expected or may occur in this springs ecosystem type are present.
4. All of the microhabitats that are expected, as well as others that may occur in this springs ecosystem type are present.

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Condition Assessment Questions Page 2

E. Soil integrity: To what extent are the soils, if present, altered due to anthropogenic influences? Natural soils can be affected by trampling, paving, trailing, vehicle tracks, fire pits, and other factors. What percent of the natural soils have been affected by these impacts?

3

1. 1. Between 75 to 100% of the surface area of natural soils, including peat, has been eliminated.
2. Between 50 to 75% of the surface area of natural soils, including peat, is patchy and highly compromised.
3. Between 25 to 50% of the surface area of natural soils and/or peat depositshas been altered, but soils are somewhat compromised.
4. Between 0 to 25% of the surface area of natural soils and/or peat deposits has been altered, or natural soils are not expected to occur at that springs ecosystem type (e.g., bedrock-dominated gushet or hanging gardens springs).

F. Natural physical disturbance: Is the site subject to its natural geomorphic disturbance regime, including flooding, rockfall, mammalian herbivore influences, or other natural disturbances? (Fire is considered in the next question.) For example, upstream dams reduce natural flooding, or inundate rheocrene springs downstream. Stabilization measures can reduce natural disturbances such as rockfall or spawling. Intensive mammalian herbivore use can alter the site geomorphology. Exclosures, while well-intended, can eliminate wildlife use, resulting in proliferation of wetland vegetation and loss of surface water and habitat. The four characteristics of ecological disturbance are timing, magnitude, duration, and frequency.

3.5

1. The natural disturbance regime is nearly or entirely altered, and is largely unrecoverable. All four characteristics have been altered.
2. The natural disturbance regime is moderately to highly altered, and is not likely to recover. Two or more disturbance characteristics have been altered.
3. The natural disturbance regime is slightly altered, but could recover. One disturbance characteristic has been altered.
4. The disturbance regime is nearly or entirely natural, and none of the disturbance characteristics have been altered.

---Surveyors could not evaluate the disturbance regime, but will conduct follow-up research (e.g., review hydrology) and assign a score.

G. Natural Fire Regime: Is the springs ecosystem subject to its natural fire disturbance regime, displaying natural fire frequency and intensity unaltered by fire suppression? For example, has fire suppression resulted in unnaturally dense vegetation, or has fire suppression resulted in overly dense vegetation that burned catastrophically? The four characteristics of ecological disturbance are timing, magnitude, duration, and frequency.

3

1. The natural fire disturbance regime is nearly or entirely altered, and is largely unrecoverable. All four fire disturbance characteristics have been altered.
2. The natural fire disturbance regime is moderately to highly altered, and is not likely to recover. Two or more fire disturbance characteristics have been altered.
3. The fire natural disturbance regime is slightly altered, but could recover. One fire disturbance characteristic has been altered.
4. The fire disturbance regime is nearly or entirely natural, and none of the fire disturbance characteristics have been altered.

-- Surveyors could not evaluate the disturbance regime (e.g., review fire boundary and intensity maps), but will conduct follow-up research and assign a score.

Comments about geomorphology, soils, and natural disturbance.

The anthropogenically-altered source and channel terrace do not substantially reduce the ecological integrity of the site.

Geographic Context

The following questions relate to the level of isolation and size of the springs ecosystem. These intrinsic site characteristics reflect the ecological importance of the springs ecosystem and are likely to influence stewardship prioritization, but they do not reflect the condition and are therefore not counted in the assessment scoring.

H. Isolation from other springs ecosystems: The importance of a springs ecosystem increases with isolation. How isolated is this springs ecosystem from other reported springs? (This is not counted in the condition score.)

3

1. The nearest reported springs ecosystem is less than 100 meters away.
2. The nearest reported springs ecosystem is between 100 and 1,000 meters away.
3. The nearest reported springs ecosystem is between 1 and 10 kilometers away.
4. The nearest reported springs ecosystem is more than 10 kilometers away.

-- Surveyors were unable to determine springs isolation, but will conduct follow-up research and assign a score.

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Condition Assessment Questions Page 3

I. Isolation from perennial sources: The importance of a springs ecosystem also increases with isolation from other water bodies. How isolated is this springs ecosystem from the nearest perennial water body, such as a stream or lake?

3

1. The nearest reported perennial water body is less than 100 meters away.
2. The nearest reported perennial water body is between 100 and 1,000 meters away.
3. The nearest reported perennial water body is between 1 and 10 kilometers away.
4. The nearest reported perennial water body is more than 10 kilometers away.

-- Surveyors were unable to determine the distance to the nearest perennial water body, but will conduct follow-up research (i.e., GIS analysis of isolation) and assign a score.

J. Habitat size: How large is this springs ecosystem? The importance of a springs ecosystem increases with its functioning size—the surface area that is directly influenced by the spring.

3

1. The springs ecosystem size is less than 100 square meters.
2. The springs ecosystem size is between 100 - 1,000 square meters.
3. The springs ecosystem size is between 1,000 and 10,000 square meters.
4. The springs ecosystem size is greater than 10,000 square meters.

---Surveyors were unable to determine the size of the springs ecosystem, but will conduct follow-up research . For example, if the ecosystem is too large to measure, aerial imagery may need to be used to assign a score.

Comments about the geographic context and importance of the springs ecosystem.

This springs ecosystem is relatively isolated, and therefore potentially of significance as a wildlife water source.

Habitat

The following questions relate to the capacity of the springs and its associated microhabitats support native species and natural ecosystem processes. Habitat area, quality, productivity, and diversity strongly influence springs ecosystem ecology and biota, and anthropogenic degradation of springs habitat reduces the extent and importance of those ecological variables. Score with half decimals from 1.0 to 4.0.

K. Microhabitat quality: What is the condition of the microhabitats associated with the site? Consider the overall habitat quality in each of the microhabitats and the intensity of all apparent anthropogenic impacts. Springs ecosystems can support multiple microhabitats, and each of those microhabitats can support its own suite of species that may or may not interact with those in other microhabitats. Anthropogenic activities may affect one or more or all microhabitats. Human activities can influence some or all microhabitata at a springs ecosystem.For example, intensive livestock use may cause pedestal formation, feces deposition, erosion, or other impacts on wetland microhabitat surfaces. Construction of roads, springboxes, or berms, as well as pollution can degrade microhabitat quality.

3

1. No natural microhabitats remain, or the remaining natural microhabitats are in very poor condition.
2. At least one natural microhabitat is in poor condition, with significant impairment evident, and anthropogenic habitats may be present.
3. All natural microhabitats are ecologically moderately intact, but some impairment is evident. If anthropogenic habitats are present, they are historic and have recovered ecologically.
4. All natural microhabitats are nearly or fully ecologically intact, with little or no impairment. No anthropogenic microhabitats are present.

L. Native plant cover: What is the proportion of native to non-native plant cover? Native vegetation cover is generally supportive of native animal species, while non-native plant cover may exclude native fauna, increase wildfire frequency and intensity, and attract or support undesireable species through changes in ecological structure and processes.

3.5

1. No native plant species are present, or less than 40% of the plant cover is native.
2. Between 40 and 80% of the plant cover is native.
3. Between 80 and 95% of the plant cover is native.
4. More than 95% of the plant cover is native.

-- Surveyors were unable to evaluate the native plant species ecological role. For example, surveyors could collect plant specimens or photographs to be subsequently verified.

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Condition Assessment Questions Page 4

M. Native food web dynamics: What is the condition of the natural food web at this springs ecosystem? Ecologically intact springs ecosystems support diverse food web interactions, with robust vegetation (where geomorphically appropriate) supporting diverse populations of invertebrate and vertebrate herbivores and predators. This can range from mountain lions to dragonflies. Trophic structure, as indicated by the presence of vegetation, primary consumers, and secondary or top consumers (predators) indicate that ecosystem functionality at a site is high.

3

1. No natural food web dynamics are evident, with no observation or evidence of predators.
2. There is some evidence of natural food web dynamics, indicated by the observation or evidence of at least one predator.
3. There is moderate evidence of natural food web dynamics, indicated by the observation or evidence of several predators from a range of trophic levels.
4. The food web dynamics appear to be natural or nearly natural, indicated by the observation or evidence of several predators from a range of trophic levels.

Comments about habitat quality, plant cover, and food web dynamics.

The site supports a relatively high diversity of trophic linkages, including primary producers and consumers as well as Peregrine Falcon and other top predators.

Biota

The following questions pertain to flora and faunal species detected during the survey. Floral and faunal species biodiversity is an important topic in stewardship discussions about springs. Score with half decimals from 1.0 to 4.0.

N. Native vs. non-native plant species: What is the proportion of native plant species? Non-native plant species can overwhelm native plant communities at springs, thus the proportional representation of native and non-native plant species is an important assessment variable.

2.5

1. Between 0 and 40% of the plant species are native.
2. Between 40 and 80% of the plant species are native.
3. Between 80 and 95% of the plant species are native.
4. More than 95% of the plant species are native.

-- Surveyors were unable to evaluate the proportion of plant species, but will conduct folow-up research (e.g., collect a plant specimen for later identification) and assign a score.

O. Presence of noxious weed species: How many plant species from the noxious list are present? Please see New Mexico Noxious Weed List, and complete worksheet O.

3

1. Three or more NM noxious weeds are present.
2. Two NM noxious weeds are present.
3. One NM noxious weed species is present.
4. No NM noxious weeds are present.

-- Surveyors were unable to evaluate the presence of noxious species, but will conduct follow-up research (e.g. collect samples for identification) and assign a score.

P. Plant demography: Is the population structure (demography) of woody vegetation appropriate to the site? For example, is the springs ecosystem becoming unnaturally dominated by woody plant species (e.g., conifer, Russian olive, Siberian elm, tamarisk) or invasive wetland species (e.g., *Typha* or *Phragmites*), as evidenced by the presence of multiple life stages (e.g., seedling, sapling, mature plants)? Upland woody shrubs or trees encroaching onto the site can reveal an unnatural transition due to human activity or disturbance.

4

1. The site is nearly or entirely unnaturally dominated by woody plant species or invasive wetland species.
2. The site is largely dominated by woody plant species or invasive wetland species.
3. The site contains some encroachment by woody plant species or invasive wetland species.
4. The vegetation at the springs ecosystem appears appropriate.

Q. Sensitive flora and fauna richness: Rare, endemic, sensitive, threatened and/or endangered species often present policy-related or legal management issues to springs stewards. Did surveyors identify any sensitive plant or animal species?

4. One or more sensitive or listed flora or fauna species were identified.

-- Surveyors did not detect any sensitive species.

Sensitive flora and fauna species present or reported, indicating whether they are rare, common, or abundant

No sensitive floral or faunal species were detected.

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Condition Assessment Questions Page 5

R. Proportion of native faunal species: What is the proportion of native invertebrate and vertebrate species? Non-native animal species can exert negative impacts on native species and ecological processes, degrading the springs ecosystem.

4

1. Between 0 and 40% of the faunal species present are native.
2. Between 40 and 80% of the faunal species present are native.
3. Between 80 and 95% of the faunal species present are native.
4. More than 95% of the faunal species are native.

---Surveyors were unable to evaluate the proportion of native faunal species, but will conduct folow-up research and assign a score.

S. Number of non-native faunal species: How many non-native aquatic and terrestrial faunal species are present? For example, to what extent are nonnative mollusks, crayfish, bullfrogs, and game or aquarium fish present? Non-native animal species can exert negative impacts on native species and ecological processes, degrading the springs ecosystem. One caveat: not all animal species occupying a springs ecosystem are likely to be detected during a single site visit. Therefore, this score is expected to be refined with multiple visits. Please complete Worksheet S.

3

1. Three or more nonnative faunal species were detected.
2. Two or more nonnative faunal species were detected.
3. One or more nonnative faunal species were detected.
4. No or more nonnative faunal species were detected.

---Surveyors were unable to evaluate the presence of non-native species, but will conduct follow-up research (e.g. collect samples for identification) and assign a score.

Comments about Biota

Lumbricidae earthworm, an invasive species, was detected. Of 32 plant species detected, 8 were non-native. This included Bromus, which covered 80% of the low gradient cienega.

SiteName Cherry Creek Spring ID 237590 Observer

Primary Type Hillslope Secondary Type

Worksheet D

Table 2. Metric of spring types with likelihood of microhabitat subtypes.

	Microhabitat Type												
Spring Type	**Backwall or sloped bedrock**	**Cave**	**Channel (wet)**	**Colluvial slope**	**Mound**	**Pool**	**Terrace**	**Pool margin**	**Low gradient cienega**	**High gradient cienega**	**Likely occurrence**	**Possible occurrence**	**Unlikely occurrence**
Cave	High	High	High	Low	Low	Med	Med	Med	Low	Low	3	3	4
Exposure	Med	Low	Low	Med	Low	High	Low	High	Low	Low	2	2	6
Fountain	Low	Low	Med	Med	Med	High	Med	Low	Med	Low	1	5	4
Gushet	High	Med	High	Med	Low	Med	High	Med	Low	Med	3	5	2
Geyser	High	Low	Med	Low	High	Med	Med	Low	Low	Low	2	3	5
Hanging garden	High	Low	High	High	Low	High	High	High	Low	Low	6	0	4
Helocrene	Low	Low	Med	Low	Med	Med	Med	Med	High	High	2	5	3
Hillsope-rheocrene	Med	Low	High	Med	Low	Med	High	Low	Med	Med	2	5	3
Hillsope-upland	Med	Low	High	Med	Low	Med	High	Low	Med	Med	2	5	3
Hypocrene *	Med	Low	Low	Med	Med	Low	Med	High	High	Med	2	5	3
Limnocrene	Med	Low	Med	Low	Med	High	Med	High	Med	Low	2	5	3
Mound-form	High	Low	Med	Med	High	Med	Med	High	Med	Med	3	6	1
Rheocrene	Med	Low	High	Med	Low	Med	High	Low	Med	Low	2	4	4

Table 3. Scoring worksheet with the count of each microhabitat and anthropogenic influence for each.

Microhabitat Type	Likelihood	Liklihood Score	Count	Prelim. Score	Anthro	Final Score
Backwall or Sloping Bedrock						
Cave						
Channel	High - 3	3	1	3	0	3
Colluvial Slope						
Spring mound						
Pool						
Terrace	High - 3	3	1	3	0	3
Pool margin						
Low gradient cienega	Med - 2	2	1	2	0	2
High gradient cienega						
Anthropogenic			1			
Total Score		**Likely**			**Total**	8

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Primary Type Hillslope Secondary Type

Worksheet D (cont.)

Scoring Question D requres the following steps:

1) Table 2 is a reference list of the probability of occurrence of a natural microhabitat at a given springs type (low probability = 1, medium probability = 2, high probability = 3). Use Table 2 to look up to record the probability of occurrence and number of natural microhabitat types occurring at the springs ecosystem being surveyed.
2) Record probability of occurrence of each natural microhabitat for that springs typein the Likelihood column of Table 3. The Likelihood Score column will autofill based on the value entered into the likelihood column.
3) Record the number of each microhabitat type in the Count column in Table 3. These data should have been recorded on page 1 of the inventory field sheets.
4) Multiply the Likelihood Score by theCount to generate a value for the Prelim. Score column.
5) Sum the Prelim Score column to generate a Preliminary Site Sore.
6) Table 4 is a cross-walk reference list in which the Preliminary Site Score is compared with the number of expected natural microhabitats for that springs type to produce a preliminary Question D Assessment Score (right column of Table 4).
7) Record the number of significant anthropogenic microhabitats present (e.g., berms, concrete slabs, metal tanks, etc.), in Table 3,
8) Subtract the number of significant anthropogenic microhabitats from the preliminary Question D Assessment Score to generate a final Question D score. Record this final score in the box for Assessment Question D on the assessment field sheet.

Table 4. Assessment Score chart for condition assessment question D.

Cave	Exposure	Fountain	Gushet	Geyser	Hanging Garden	Helocrene	Hillslope-rheocrenic	Hillslope (upland)	Hypocrene *	Limnocrene	Mound-Form	Rheocrene	Anthropogenic	Assessment Score
<=0	<=0	<=0	<=0	<=0	<=0	<=0	<=0	<=0	<=0	<=0	<=0	<=0	All	1
0-2	0-1		0-2	0-1	0-4	0-1	0-1	0-1	0-1	0-1	0-2	0-1		1.5
2-3	1-2		2-3	1-2	4-7	1-2	1-2	1-2	1-2	1-2	2-3	1-2		2
3-5	2-3		3-5	2-3	7-10	2-3	2-3	2-3	2-3	2-3	3-5	2-3		2.5
5-7	3-4	1-2	5-7	3-4	10-14	3-4	3-4	3-4	3-4	3-4	5-7	3-4		3
7-8	4-5		7-8	4-5	14-17	4-5	4-5	4-5	4-5	4-5	7-8	4-5		3.5
>=9	>=6	>=3	>=9	>=6	>=18	>=6	>=6	>=6	>=6	>=6	>=9	>=6		4

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Worksheet O

New Mexico Noxious Weed List
Updated September 2016

If a species is absent, check the absent box; if present, enter 1. Count the total at the bottom of page 2, and respond to question O.

Class C Species: Class C species are wide-spread in the state. Management decisions for these species should be determined at the local level, based on feasibility of control and level of infestation.	**Absent**	**Present**
Cheatgrass, *Bromus tectorum*	✓	
Curlyleaf pondweed, *Potamogeton crispus*	✓	
Eurasian watermilfoil, *Myriophyllum spicatum*	✓	
Giant cane, *Arundo donax*	✓	
Hydrilla, *Hydrilla verticllata*	✓	
Jointed goatgrass, *Aegilops cylindrica*		
Musk thistle, *Carduus nutan*	✓	
Parrotfeather, *Myriophyllum aquaticum*	✓	
Russian olive, *Elaeagnus angustifolia*	✓	
Saltcedar, *Tamarix spp.*		
Siberian elm, *Ulmus pumila*		
Tree of heaven, *Ailanthus altissima*	✓	
Class B Species: Class B Species are limited to portions of the state. In areas with severe infestations, management should be designed to contain the infestation and stop any further spread.	**Absent**	**Present**
African rue, *Peganum harmala*	✓	
Bull thistle, *Cirsium vulgare*	✓	
Chicory, *Cichorium intybus*	✓	
Halogeton, *Halogeton glomeratus*	✓	
Malta starthistle, *Centaurea melitensis*	✓	
Perennial pepperweed, *Lepidium latifolium*	✓	
Poison hemlock, *Conium maculatum*	✓	
Quackgrass, *Elytrigia repens*	✓	
Russian knapweed *Acroptilon repens*	✓	
Spiny cocklebur, *Xanthium spinosum*	✓	
Teasel, *Dipsacus fullonum*	✓	

Worksheet O (Cont.)

SiteName Cherry Creek Spring

Watch List Species: Watch List species are species of concern in the state. These species have the potential to become problematic. More data is needed to determine if these species should be listed. When these species are encountered please document their location and contact appropriate authorities.	**Absent**	**Present**
Crimson fountaingrass, *Pennisetum setaceum*	✓	
Meadow knapweed, *Centaurea pratensis*	✓	
Myrtle spurge, *Euphorbia myrsinites*	✓	
Pampas grass, *Cortaderia sellonana*	✓	
Sahara mustard, *Brassica tournefortii*	✓	
Syrian beancaper, *Zygophyllum fabago L.*	✓	
Wall rocket, *Diplotaxis tenuifolia*	✓	
Class A Species: Class A species are currently not present in New Mexico, or have limited distribution. Preventing new infestations of these species and eradicating existing infestations is the highest priority	**Absent**	**Present**
Alfombrilla, *Drymaria arenariodes*	✓	
Black henbane, *Hyoscyamus niger*	✓	
Brazillian egeria, *Egeria densa*	✓	
Camelthorn, *Alhagi psuedalhagi*	✓	
Canada thistle, *Cirsium arvense*	✓	
Dalmation toadflax, *Linaria dalmatica*	✓	
Diffuse knapweed, *Centaurea diffusa*	✓	
Dyer's woad, *Isatis tinctoria*	✓	
Giant salvinia, *Salvinia molesta*	✓	
Hoary cress, *Cardaria spp.*	✓	
Leafy spurge, *Euphorbia esula*	✓	
Oxeye daisy, *Leucanthemum vulgare*	✓	
Purple loosestrife, *Lythrum salicaria*	✓	
Purple starthistle, *Centaurea calcitrapa*	✓	
Ravenna grass, *Saccharum ravennae*	✓	
Scentless chamomile, *Matricaria perforata*	✓	
Scotch thistle, *Onopordum acanthium*	✓	
Spotted knapweed, *Centaurea biebersteinii*	✓	
Yellow toadflax, *Linaria vulgaris*	✓	
Yellow starthistle, Centaurea solstitialis	✓	
Total Noxious Weed Species Present:		0

Worksheet P

Record the number of unnatural vegetation elements.

Springs Type	Ground Cover	Woody Cover	Tree Cover	# Unnatural Elements
Cave	Excessive algal cover	n/a	n/a	
Exposure	Excessive algal, Typha or Phragmites cover	Dead shrub cover (all life stages)	Dead tree cover (all stages)	
Fountain	Dead wetland vegetation (all life stages)	Excessive phreatophyte or upland shrub seedling or sapling cover	Excessive phreatophyte or conifer seedlings or saplings	
Geyser	Excessive algal cover	Excessive phreatophyte or upland seedling or sapling shrub cover	Excessive phreatophyte or conifer seedlings or saplings	
Gushet	Dead wetland vegetation, or excessive non-wetland plant species	Dead shrubs, or excessive upland shrub seedling or sapling cover	Dead trees, or excessive conifer or upland plant seedlings or sapling presence	
Hanging Garden	Dead wetland vegetation, or excessive non-wetland plant species	Dead shrubs, or excessive upland shrub seedling or sapling cover	Dead trees, or excessive conifer or upland plant seedlings or sapling presence	
Helocrene	Dead wetland vegetation or excessive unvegetated ground (alkaline springs may not support no or little wetland vegetation)	Dead shrubs, or excessive phreatophyte or upland shrub seedling or sapling cover	Dead, or unnaturally excessive phreatophyte or upland tree seedling or sapling cover	
Hillslope	Dead wetland vegetation, or excessive non-wetland plant species	Dead shrubs, or excessive phreatophyte or upland shrub seedling or sapling cover	Dead, or unnaturally excessive phreatophyte or upland tree seedling or sapling cover	
Hypocrene	Dead wetland vegetation	Dead shrubs	Dead tree seedlings, sap-lings, mature individuals	
Limnocrene	Excessive unnatural algal, Typha or Phragmites cover	Dead shrubs, or excessive upland shrub seedling or sapling cover	Dead trees, or excessive upland tree seedling or sapling cover	
Mound-form	Excessive unnatural algal, Typha or Phragmites cover	Dead shrubs, or excessive upland shrub seedling or sapling cover	Dead trees, or excessive upland tree seedling or sapling cover	
Rheocrene	Excessive unnatural algal, Typha or Phragmites cover	Dead shrubs, or excessive upland shrub seedling or sapling cover in riparian zone	Dead trees or excessive upland tree seedling or sapling cover in riparian zone	

Worksheet S

If species is present, check the present box; if present, enter 1. Count the total at the bottom of the last page, and respond to question P.

New Mexico Exotic Faunal List

Edited from the USGS Nonidigenous Aquatic Species: https://nas.er.usgs.gov/queries/SpeciesList.aspx?Group=&Sortby=1&state=NM

Group	Common Name	Family	Scientific Name	Nativity in New Mexico	Present
Amphibians-Frogs	American Bullfrog	Ranidae	*Lithobates catesbeianus*	Exotic	
Birds	Chukar	Phasianidae	*Alektoris chukar*	Exotic	
Birds	Eurasian Collard Dove	Columbidae	*Streptopelia decaocto*	Exotic	
Birds	Eurppean House Sparrow	Passeridae	*Passer domesticus*	Exotic	
Birds	Pheasant	Phasianidae	*Phasianus colchicus*	Exotic	
Birds	Rock Dove (Common Pigeon)	Columbidae	*Columba livia*	Exotic	
Birds	Starling	Sternidae	*Sternus vulgaris*	Exotic	
Coelenterates-Hydrozoans	freshwater jellyfish	Olindiidae	*Craspedacusta sowerbyi*	Exotic	
Crustaceans-Cladocerans	a waterflea	Daphnidae	*Daphnia lumholtzi*	Exotic	
Crustaceans-Copepods	a calanoid copepod	Temoridae	*Eurytemora affinis*	Exotic	
Crustaceans-Copepods	anchor worm	Lernaeidae	*Lernaea cyprinacea*	Exotic	
Crustaceans-Crayfish	Conchas Crayfish	Cambaridae	*Orconectes deanae*	Exotic	
Crustaceans-Crayfish	Red Swamp Crayfish	Cambaridae	*Procambarus clarkii*	Exotic	
Crustaceans-Crayfish	Rusty Crayfish	Cambaridae	*Faxonius rusticus*	Exotic	
Crustaceans-Crayfish	Virile Crayfish	Cambaridae	*Orconectes virilis*	Exotic	
Crustaceans-Crayfish	Western plains crayfish (Canadian R)	Cambaridae	*Faxonius causeyi*	Native (part)	
Fishes	Arctic Grayling	Salmonidae	*Thymallus arcticus*	Exotic	
Fishes	Bigscale Logperch	Percidae	*Percina macrolepida*	Native	

Group	Common Name	Family	Scientific Name	Nativity in New Mexico	Present
Fishes	Black Bullhead	Ictaluridae	*Ameiurus melas*	Exotic	
Fishes	Black Crappie	Centrarchidae	*Pomoxis nigromaculatus*	Exotic	
Fishes	Blue Catfish	Ictaluridae	*Ictalurus furcatus*	Exotic	
Fishes	Bluegill	Centrarchidae	*Lepomis macrochirus*	Exotic	
Fishes	Brook Stickleback	Gasterosteidae	*Culaea inconstans*	Exotic	
Fishes	Brook Trout	Salmonidae	*Salvelinus fontinalis*	Exotic	
Fishes	Brown Bullhead	Ictaluridae	*Ameiurus nebulosus*	Exotic	
Fishes	Brown Trout	Salmonidae	*Salmo trutta*	Exotic	
Fishes	Channel Catfish	Ictaluridae	*Ictalurus punctatus*	Exotic	
Fishes	Coho Salmon	Salmonidae	*Oncorhynchus kisutch*	Exotic	
Fishes	Common Carp	Cyprinidae	*Cyprinus carpio*	Exotic	
Fishes	Cutbow trout	Salmonidae	*Oncorhynchus clarkii x mykiss*	Native Hybrid	
Fishes	Cutthroat Trout	Salmonidae	*Oncorhynchus clarkii*	Exotic	
Fishes	Dolly Varden	Salmonidae	*Salvelinus malma*	Exotic	
Fishes	Fathead Minnow	Cyprinidae	*Pimephales promelas*	Exotic	
Fishes	Flathead Catfish	Ictaluridae	*Pylodictis olivaris*	Exotic	
Fishes	Gila Topminnow	Poeciliidae	*Poeciliopsis occidentalis occidentalis*	Native	
Fishes	Gizzard Shad	Clupeidae	*Dorosoma cepedianum*	Exotic	
Fishes	Golden Shiner	Cyprinidae	*Notemigonus crysoleucas*	Exotic	
Fishes	Golden Trout	Salmonidae	*Oncorhynchus aguabonita*	Exotic	
Fishes	Goldfish	Cyprinidae	*Carassius auratus*	Exotic	
Fishes	Grass Carp	Cyprinidae	*Ctenopharyngodon idella*	Exotic	
Fishes	Green Sunfish	Centrarchidae	*Lepomis cyanellus*	Exotic	
Fishes	Gulf Killifish	Fundulidae	*Fundulus grandis*	Exotic	
Fishes	Guppy	Poeciliidae	*Poecilia reticulata*	Exotic	
Fishes	Inland Silverside	Atherinopsidae	*Menidia beryllina*	Exotic	
Fishes	Iowa Darter	Percidae	*Etheostoma exile*	Exotic	
Fishes	Lake Trout	Salmonidae	*Salvelinus namaycush*	Exotic	

Group	Common Name	Family	Scientific Name	Nativity in New Mexico	Present
Fishes	Largemouth Bass	Centrarchidae	*Micropterus salmoides*	Exotic	
Fishes	Largespring Gambusia	Poeciliidae	*Gambusia geiseri*	Native	
Fishes	Longear Sunfish	Centrarchidae	*Lepomis megalotis*	Exotic	
Fishes	Mexican Tetra	Characidae	*Astyanax mexicanus*	Exotic	
Fishes	Northern Pike	Esocidae	*Esox lucius*	Exotic	
Fishes	Pirate Perch	Aphredoderi-dae	*Aphredoderus sayanus*	Exotic	
Fishes	Plains Killifish	Fundulidae	*Fundulus zebrinus*	Often exotic	
Fishes	Rainbow Trout	Salmonidae	*Oncorhynchus mykiss*	Exotic	
Fishes	Red Shiner	Cyprinidae	*Cyprinella lutrensis*	Native	
Fishes	Redear Sunfish	Centrarchidae	*Lepomis microlophus*	Exotic	
Fishes	Rio Grande cutthroat trout	Salmonidae	*Oncorhynchus clarkii virginalis*	Native	
Fishes	Rock Bass	Centrarchidae	*Ambloplites rupestris*	Exotic	
Fishes	Sacramento Perch	Centrarchidae	*Archoplites interruptus*	Exotic	
Fishes	Sailfin Molly	Poeciliidae	*Poecilia latipinna*	Native	
Fishes	Sheepshead Minnow	Cyprinodonti-dae	*Cyprinodon variegatus*	Largely exotic	
Fishes	Smallmouth Bass	Centrarchidae	*Micropterus dolomieu*	Exotic	
Fishes	Snake River Finespotted Cutthroat Trout	Salmonidae	*Oncorhynchus clarkii behnkei*	Exotic	
Fishes	Spotted Bass	Centrarchidae	*Micropterus punctulatus*	Exotic	
Fishes	Striped Bass	Moronidae	*Morone saxatilis*	Exotic	
Fishes	Tench	Cyprinidae	*Tinca tinca*	Exotic	
Fishes	Threadfin Shad	Clupeidae	*Dorosoma petenense*	Exotic	
Fishes	Tilapia sp.	Cichlidae	*Oreochromis*	Exotic	
Fishes	Walleye	Percidae	*Sander vitreus*	Exotic	
Fishes	Warmouth	Centrarchidae	*Lepomis gulosus*	Exotic	
Fishes	Western Mosquitofish	Poeciliidae	*Gambusia affinis*	Exotic	
Fishes	White Bass	Moronidae	*Morone chrysops*	Exotic	

Group	Common Name	Family	Scientific Name	Nativity in New Mexico	Present
Fishes	White Crappie	Centrarchidae	*Pomoxis annularis*	Exotic	
Fishes	Wiper	Moronidae	*Morone chrysops x M. saxatilis*	Exotic	
Fishes	Yellow Bullhead	Ictaluridae	*Ameiurus natalis*	Exotic	
Fishes	Yellow Perch	Percidae	*Perca flavescens*	Exotic	
Fishes	Yellowstone cutthroat trout	Salmonidae	*Oncorhynchus clarkii bouvieri*	Exotic	
Fishes	zebra danio	Cyprinidae	*Danio rerio*	Exotic	
Mammals	Barbary Sheep (Aoudad)	Bovidae	*Ammotragus lervia*	Exotic	
Mammals	Domestic cat	Felidae	*Felis catus*	Exotic	
Mammals	Domestic Cow	Bovidae	*Bos taurus*	Exotic	
Mammals	Domestic dog	Canidae	*Canis lupus familiaris*	Exotic	
Mammals	Feral Burro	Equidae	*Equus asinus*	Exotic	
Mammals	Feral Horse	Equidae	*Equus ferus caballus*	Exotic	
Mammals	Goat	Bovidae	*Capra aegagrus hircus*	Exotic	
Mammals	Nutria	Myocastoridae	*Myocastor coypus*	Exotic	
Mollusks-Bivalves	Asian clam	Cyrenidae	*Corbicula fluminea*	Exotic	
Mollusks-Gastropods	European ear snail	Lymnaeidae	*Radix auricularia*	Exotic	
Mollusks-Gastropods	European physa	Physidae	*Physella acuta*	Exotic?	
Platyhelminthes	Asian tapeworm	Bothriocephalidae	*Schyzocotyle acheilognathi*	Exotic	
Reptiles-Turtles	Malayan Snail-eating Turtle	Emydidae	*Malayemys subtrijuga*	Exotic	
Reptiles-Turtles	Midland Painted Turtle	Emydidae	*Chrysemys picta marginata*	Exotic	
Reptiles-Turtles	Pond Slider	Emydidae	*Trachemys scripta*	Native	
Reptiles-Turtles	Red-eared Slider	Emydidae	*Trachemys scripta elegans*	Native to SE NM	

Group	Common Name	Family	Scientific Name	Nativity in New Mexico	Present
Reptiles-Turtles	Snapping Turtle	Chelydridae	*Chelydra serpentina*	Native to E NM	
Reptiles-Turtles	Yellow-bellied Slider	Emydidae	*Trachemys scripta scripta*	Exotic	
				Total Exotic Species Present:	

Table 5. New Mexico Springs Rapid Assessment Method summary worksheet

Assessment Question	Subcategory Score	Sum of Subcategory Scores	Category Score
Aquifer Functionality & Water Quality: A. Water table alteration	3.5		
Aquifer Functionality & Water Quality: B. Surface water quality impairment	4		
Aquifer Functionality & Water Quality: C. Springs flow rate	2		
Aquifer Functionality & Water Quality: Category Total Possible Score =12		9.5	3.2
Geomorhology: D. Natural geomorphic diversity	3		
Geomorhology: E. Soil Integrity	3		
Geomorhology: F. Natural physical disturbance	3.5		
Geomorhology: G. Natural fire regime	3		
Geomorphology Category: Total Possible Score =16		12.5	3.1
Geographic Context: H: Isolation from other springs	3		
Geographic Context: I. Isolation from nearest perennial water source	3		
Geographic Context: J. Springs habitat area (size)	3		
Geographic Context Category: (not counted in total score)		9	3
Habitat: K. Microhabitat quality	3		
Habitat: L. Native plant cover	3.5		
Habitat: M. Native food-web dynamics	3		
Habitat Category: Total Possible Score =12		9.5	3.2

Assessment Question	Subcategory Score	Sum of Subcategory Scores	Category Score
Biota: N. Native vs. non-native plant species richness	2.5		
Biota: O. Presence of noxious weed species	3		
Biota: P. Plant demography	4		
Biota: Q. Sensitive flora and fauna richness	--		
Biota: R. Native and non-native faunal species percent	3		
Biota: S. Non-native faunal species richness	4		
Biota Category: **Total Possible Score =20 (excluding Q)**		17	3.4
Total Site Condition Score: (Total possible = 64) 1=irrecoverable 2=poor 3=good 4=pristine		**48.5**	**3.2**

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