Rapid Assessment Method for Springs Ecosystems in Southwestern New Mexico Field Guide

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 field guide 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 Field Guide. New Mexico Environment Department, Santa Fe.

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1 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. 1-1).

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. 1–1. 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 field guide is to provide guidance for a standardized rapid assessment method for New Mexico springs ecosystems (Springs NMRAM).

This field guide and accompanying manual have 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.

The manual presents the information, background, rationale, and discussion to inform those conducting inventory and assessment of springs in southwestern New Mexico. This field guide 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.

2 Springs Inventory Protocols

Fig. 2–1. 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.

Springs NMRAM

Introduction

The protocol described here includes physical form and function of the springs ecosystem, as well as its biological integrity (Fig. 2-1). 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. 2-2). 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.

Fig. 2–2. Volunteer coordination and training is essential to ensure credible scientific data and safety.

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).

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 2-1. 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. 2-3). 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.

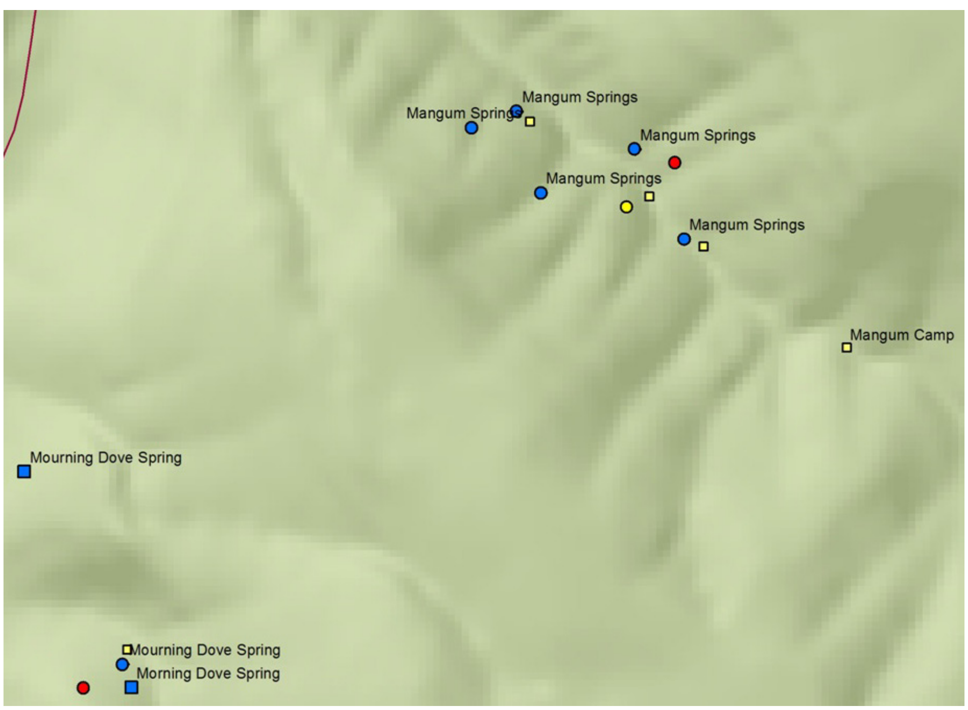


Fig. 2–3. Example of inaccuracies and uncertainty with different data sources in North Kaibab Ranger District, Kaibab National Forest in Northern Arizona. Mourning Dove Spring is spelled differently in three databases and is unnamed in two. Clustering of multiple sources in Mangum Canyon makes it difficult to identify individual springs.

Field Sheets

Field data sheets are the most efficient and reliable method of information documentation for Level 1 and 2 springs inventories (Appendix A). Multi-staff 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 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 2-1). 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.

Table 2–1. 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

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 activi-

Table 2–2. 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

ties. 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 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 2-2 provides the sequence of activities for a Level 2 survey. Table 2-3 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 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).

Table 2–3. 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 dDVSMOW), 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

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

Fig. 2–4. Solar Pathfinder is used to measure the photosynthetically active radiation at a springs ecosystem.

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. 2-4). 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 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 2-4). 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,

Table 2–4. 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

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 2-4). 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 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. 2-5). For very large sites, surveyors can use a rangefinder or GPS device to walk the perimeter.

Fig. 2–5.   The survey crew should stretch a metric tape along the long axis of the site, and perpendicularly. Photo credit Emile Sawyer.

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° = 0°. Note that declination also affects the setup of the Solar Pathfinder. If a declination of 0° 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.

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.

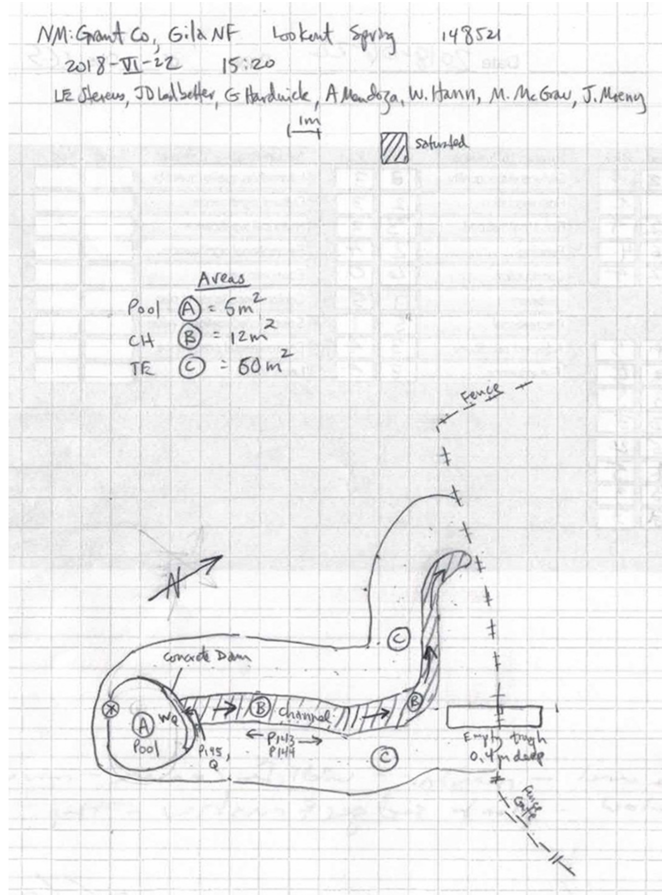


Fig. 2–6. Example of a field sketchmap. Lookout Spring on Gila National Forest.

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. 2-6 and 2-7). 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 direc-

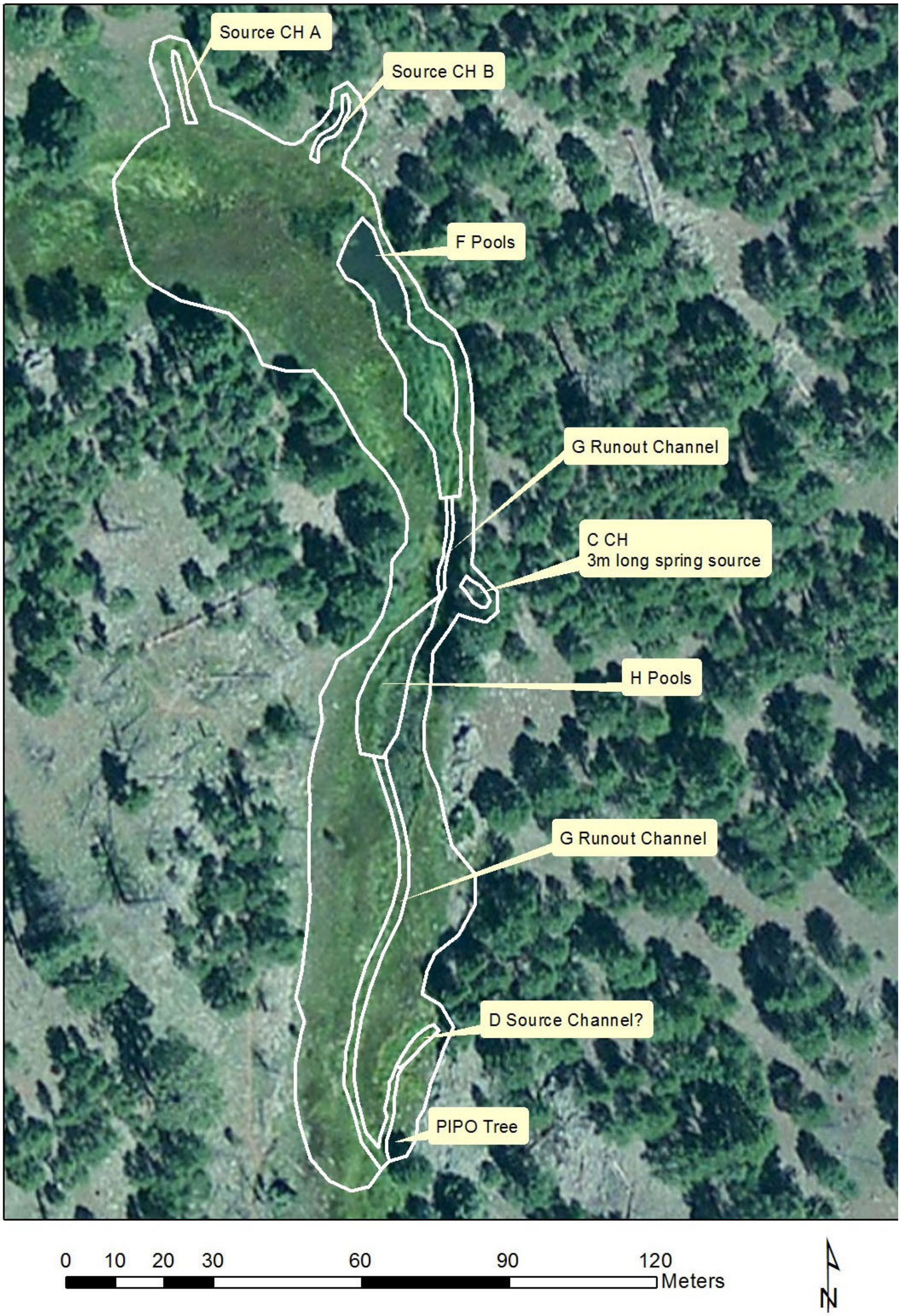


Fig. 2–7. Example of a sketchmap generated by walking the perimeters of microhabitats using a GPS, then bringing the data into ArcMap, refining the polygons, and adding labels. This method can be much more efficient and accurate for large, open , flat sites. It also is sometimes possible to draw polygons 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.

tion, 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.

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 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. 2-8). 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;

Fig. 2–8. 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.

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

Fig. 2–9. 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.

labeled "Detection Type" (Fig. 2-9). 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.

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.

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. 2-10 and 2-11).

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.

Fig. 2–10. 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.

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, 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. 2-9, 2-11, and 2-12).

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.

Fig. 2–11. Coarse substrate materials should be removed from samples in the field to prevent damage to the specimens.

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 mandi-

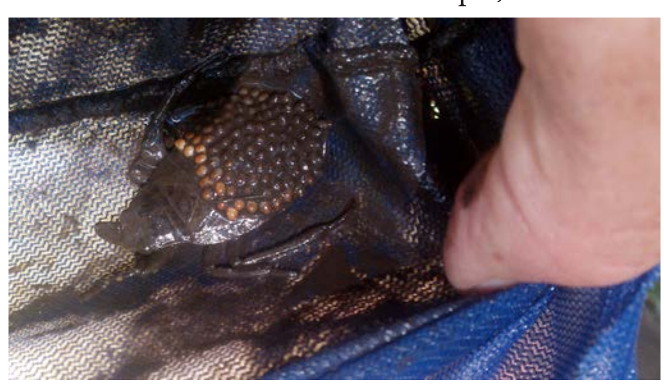


Fig. 2–12. The male *Abedus herbredi* carries eggs on his back after the female abandons them. Several of these invertebrates were observed at Stacked Rocks Spring - a previously unmapped site in Gila National Forest.

Fig. 2–13. Mites are an example of cryptic, often-springs dependent species. Here, red mites have parisitized an *Argia* damselfly.

bles 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.

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 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. 2-11) 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

Fig. 2–14. Common springs-dependent invertebrate taxa found throughout North America, displayed using appropriate preparation techniques.

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. 2-14).

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 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. 2-15). 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.

Fig. 2–15. Photograph, rather than collect, rare unknown species encountered at the site.

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 60° 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 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 2-5).

Where and When to Measure Flow: Flow measurement requires planning, both for the logistics of sampling and the equipment to be used (Figs. 2-17 to 2-23). 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

Table 2–5. 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

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 the depression and record the time it takes for the depression to fill again (Fig. 2-16). 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.

Fig. 2–16. In this case, surveyors dug a hole and measured time to refill in order to measure flow.

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

Fig. 2–17. Crews measure flow by creating a dam out of soil to direct the flow through a pipe.

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 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. 2-17), 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

Fig. 2–18. 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.

discharge springs should be taken into the field to ensure the best measurement possible. Flow at 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. 2-18).

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. 2-19). 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

Fig. 2–19. Hydrologists use a V-notch weir plate to measure low volume flows in soft substrate.

to photograph the weir setup (Fig. 2-19).

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 $C = 0.607165052 - 0.000874466963\,\theta + 6.10393334 \times 10^{-6}\,\theta^2$, and $k\ (\text{ft.}) = 0.0144902648 - 0.00033955535\,\theta + 3.29819003 \times 10^{-6}\,\theta^2 - 1.06215442 \times 10^{-8}\,\theta^3$.

Fig. 2–20. 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.

Portable Cutthroat Flume: Typically, flumes are used in Springer et al.'s (2008) third to sixth magnitude discharge springs (Fig. 2-20). 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.

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).

Fig. 2–21. Current meters are best used in higher volume streams.

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. 2-21). 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 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.

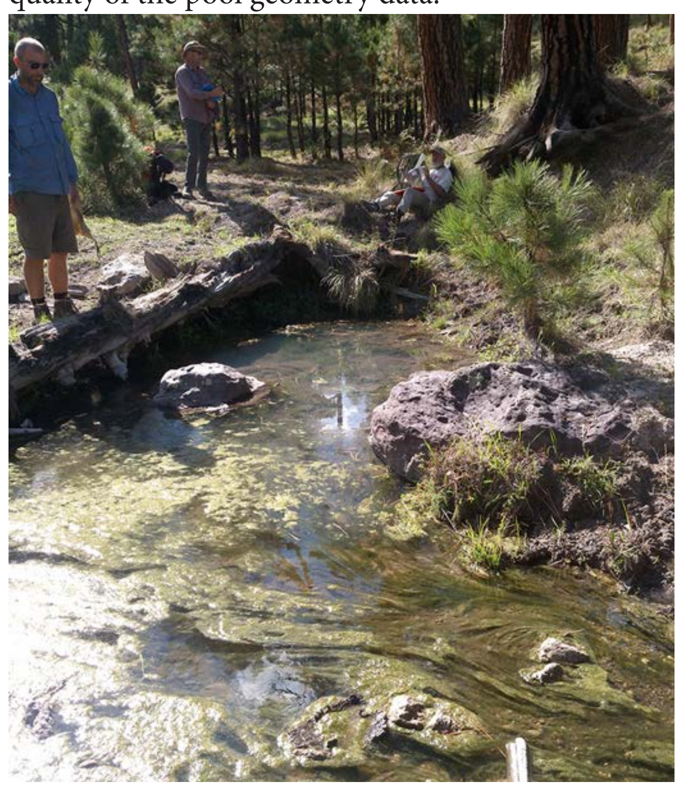


Fig. 2–22. At Horse Camp Spring in the Gila Wilderness, subaqueous flow emerged into a flowing creekbed, making flow measurements difficult.

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 (Fig. 22). 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.

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- Aboveground 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 2-6) 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 (Fig. 23).

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 hand-held 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.

Table 2–6. 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. 2–23. 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.

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 4º 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 and anion analyses should be undertaken within 28 days. Analyses are conducted using automated color imagery techniques or other appropriate analytical equipment (Table 2-6). 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 2-6). 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.

3 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 in the manual).

SiteName________________________________ID__________ Observer________________________

	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 in the manual.

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. 3–24. 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. 3–26. This long-dead cow lay on the terrace at Adair Spring.

Fig. 3–25. 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. 3–27. 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 in the manual.

Fig. 3–28. 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. 3–29. Soils have been heavily altered by livestock at Lookout Spring, located in the Gila National Forest.

Fig. 3–30. 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. 3–31. 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. 3–32. 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. 3–33. 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. 3–34. 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. 3–35. 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. 3–36. 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. 3–37. 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: What 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 in the manual.

Fig. 3–38. 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. 3–39. Tiger Salamanders (Ambystoma spp) often are top predators in lentic habitats in New Mexico.

Fig. 3–40. 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 in the manual.

Fig. 3–41. The number of non-native plant species relative to that of native species can indicate the level of human disturbance of a site.

Fig. 3–42. 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 in the manual.

Fig. 3–43. 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 in the manual.

Fig. 3–44. Encroachment into wet meadows by woody vegetation often indicates a declining water table and changing plant demographics.

Fig. 3–45. 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. 3–46. 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 in the manual.

Fig. 3–47. 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. 3–48. 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. 3–49. 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 in the manual), 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 in the manual.

Table 3–1. 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

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__________

New Mexico Surface Water Quality Bureau and SSI rev March 2019

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]Habitat	[12]Method	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 __________

Vertebrates

Spring Name__________________________ Page ______ of _________ OBS____________

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 notes

Flora

Species Name	14Str	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 ____________

Appendix B - Assessment Field Sheets

SiteName________________________________ID__________ Observer______________________

Impact	Stressor Checklist	1 Absent	2 Minor	3 Moder-ate	4 Intense
	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______________________

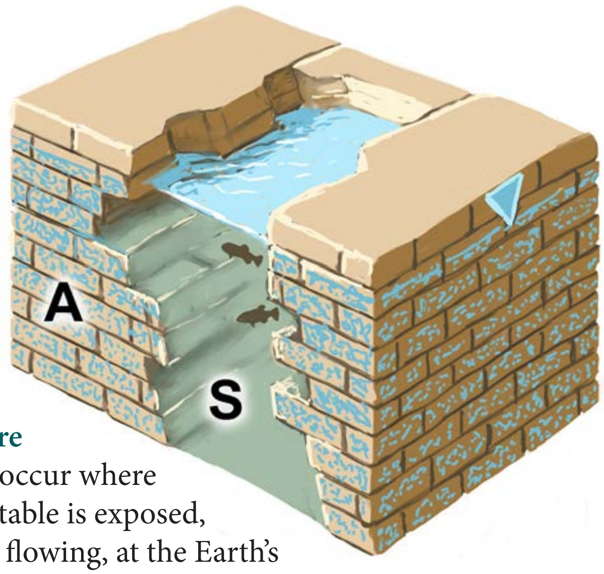
Spring Type Dichotomous Key

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

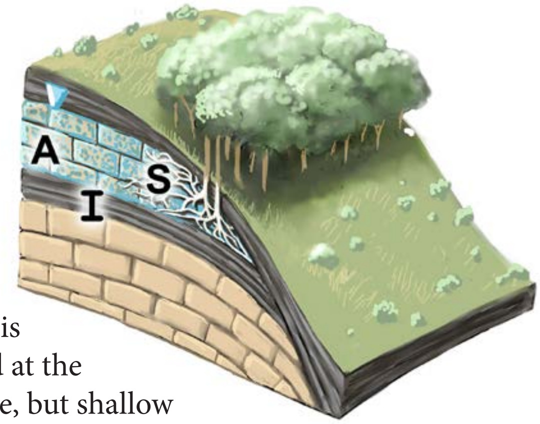
SiteName______________________________________ID___________ Observer_________________________

Spring Type Dichotomous Key Page 2

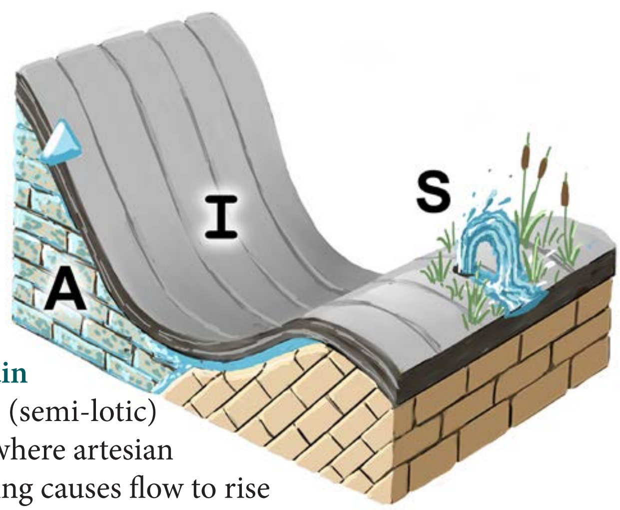
No.	Alternative	Springs Type
9	Springs source is surrounded by, or emerges from a mound composed of carbonate or other chemical precipitate	Mound-form (Carbonate)
	Springs source is surrounded by, and/or emerges from a mound composed of ice in a permafrost-dominated landscape (not reported in New Mexico)	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)



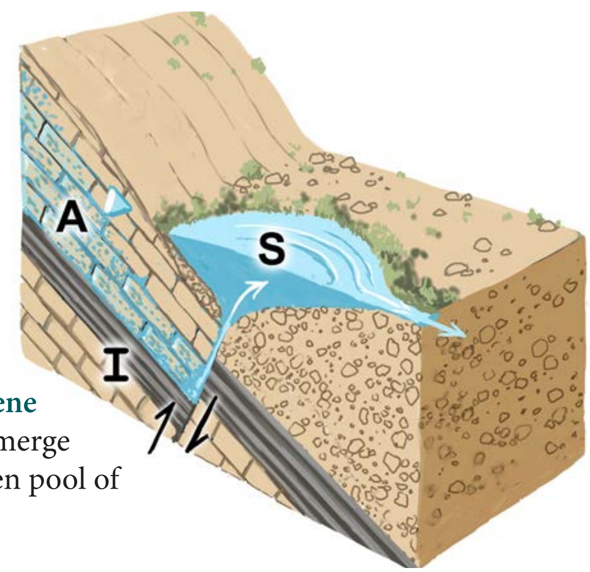
Exposure
springs occur where a water table is exposed, without flowing, at the Earth's surface.



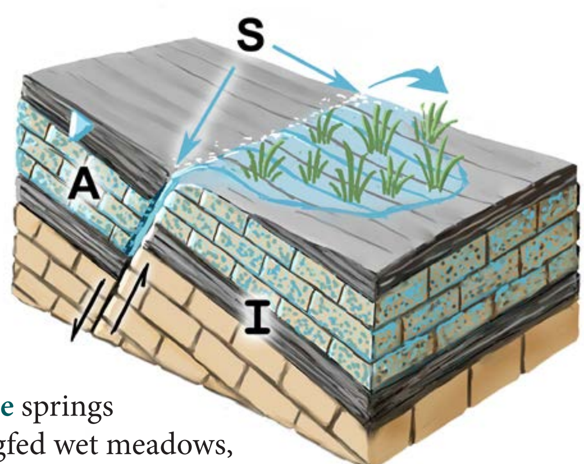
Hypocrene
springs occur where groundwater is not expressed at the Earth's surface, but shallow groundwater is discharged by transpiration through wetland vegetation.



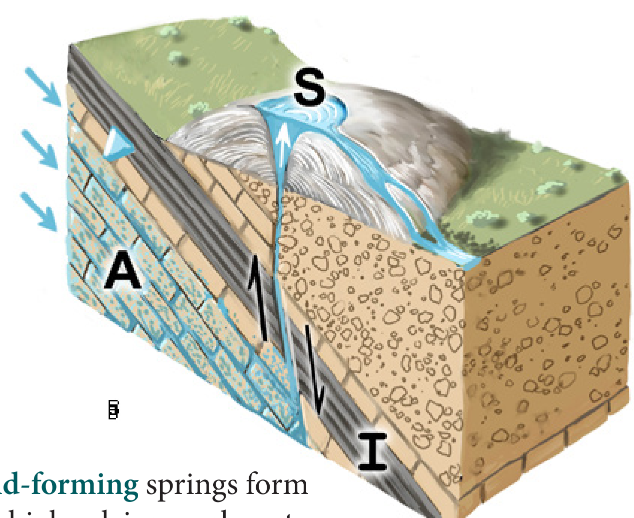
Fountain
springs (semi-lotic) occur where artesian upwelling causes flow to rise higher than the surrounding landscape.



Limnocrene
springs emerge into a open pool of water.

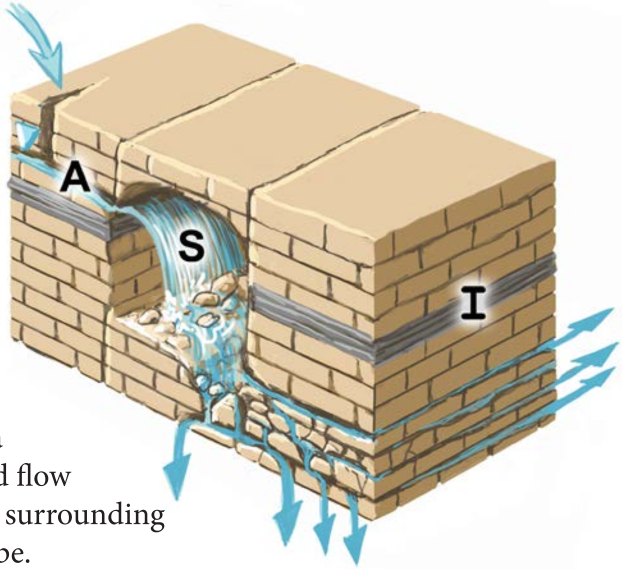


Helocrene springs
are springfed wet meadows, called ciénegas at elevations up to about 2,135 m (7,000 ft), or groundwater-dependent fens at higher elevations.

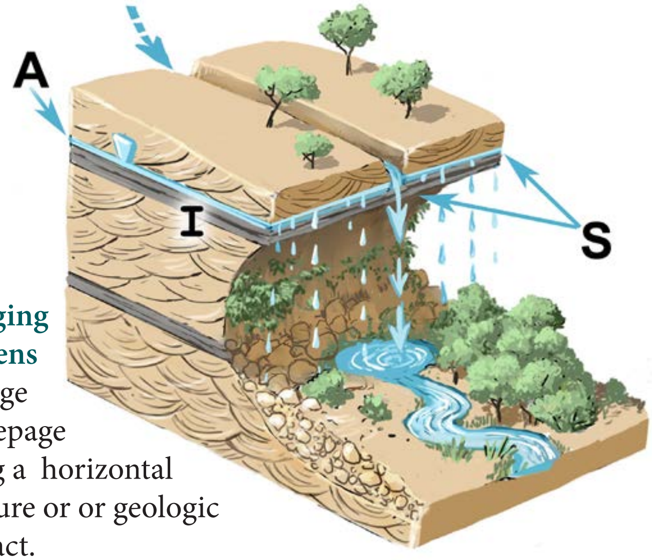


Mound-forming springs form where high calcium carbonate concentrations create travertine. This type also forms in the arctic where ice builds up, forming pingo ice hills or aufeis ice sheets.

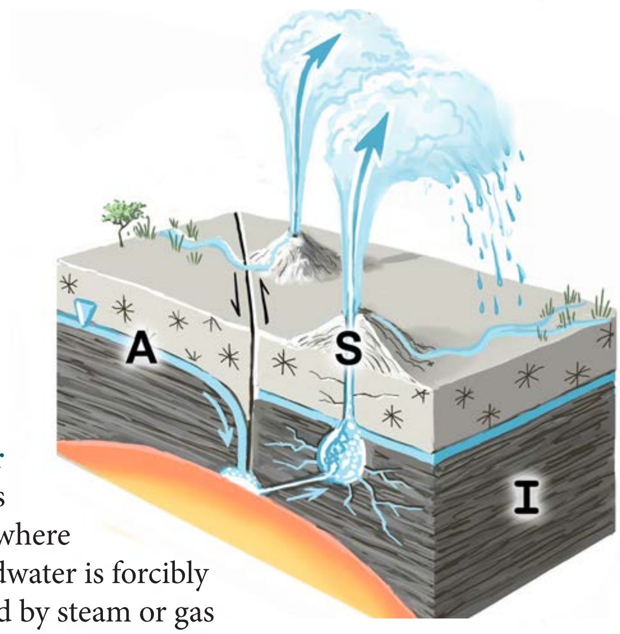
Fig. 50. Lentic and semi-lotic springs types, redrawn for SSI by V. Leshyk, modified from Springer and Stevens (2009).



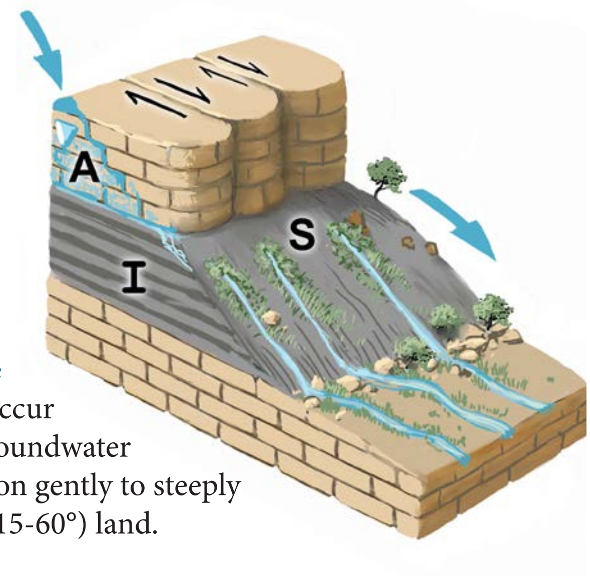
Cave springs emerge within a cave and flow into the surrounding landscape.



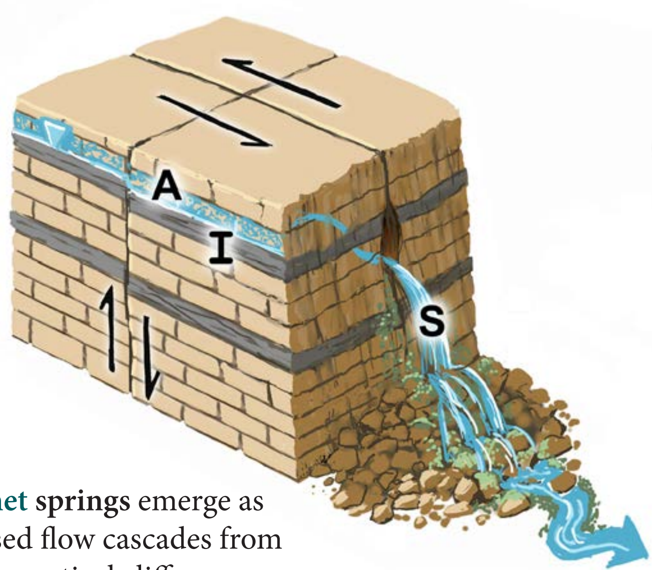
Hanging gardens emerge as seepage along a horizontal fracture or or geologic contact.



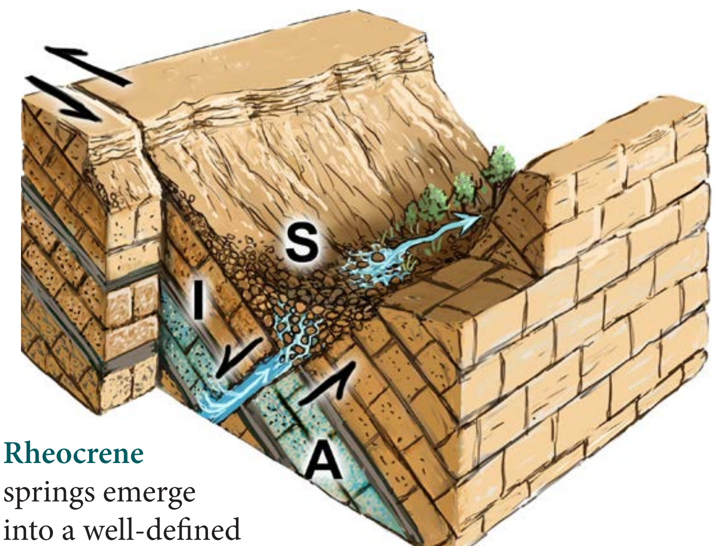
Geyser springs occur where groundwater is forcibly erupted by steam or gas pressure.



Hillslope springs occur where groundwater emerges on gently to steeply sloping (15-60°) land.



Gushet springs emerge as focused flow cascades from nearly vertical cliffs.



Rheocrene springs emerge into a well-defined wet or dry channel. They are commonly subject to regular surface-flow flooding.

Fig. 51. Lotic springs types, redrawn for SSI by V. Leshyk, modified from Springer and Stevens (2009).

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, 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	
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 Cut-throat 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 mexi- canus*	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			