Springs Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 1

Safety, Field Personnel, and Training

Version 1.00 (June 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP explains safety procedures and the qualifications needed for permanent and seasonal field personnel. Technicians must be prepared, both mentally and physically, for the extreme weather and difficult terrain of NCPN parks. Safe, accurate, consistent data collection begins with the hiring process.

Safety

The NCPN approach to crew safety requires that each crew 1) keep NCPN and park staff informed as to its activities, 2) evaluate risks and activities as they arise, and 3) be prepared to handle emergency situations. SEUG staff follows SEUG backcountry travel regulations when working on NCPN-supported springs monitoring in SEUG parks.

NCPN has a programmatic Field Safety Protocol that provides detailed safety procedures and is updated annually. Topics covered in the Field Safety Protocol include filing backcountry travel plans with Glen Canyon dispatch, checking in and out with safety contacts, how to use satellite phones and personal locator beacons, recommended first aid kit items, park contacts, and a general approach to responding to emergency and non-emergency incidents. Crew members also participate in developing the appropriate Job Hazard Analyses (JHA) for their position, which should be completed and signed before fieldwork begins. Example JHAs for springs monitoring activities are attached to this SOP in Appendix A and B.

At the beginning of the field season, each crew member should review the NCPN Field Safety Protocol. Prior to each field hitch, crew members should meet together to discuss potential safety hazards and review documentation from previous seasons recorded in each site's access information. When in the field, each NCPN crew carries a well-stocked first aid kit and a satellite phone and/or a SPOT beacon. Crew members should be trained in how to use items in the first aid kits and the satellite phone/SPOT and should know where these emergency materials are stored during fieldwork.

Monitoring crews spend considerable time in the backcountry under potentially hazardous conditions. The Field Safety SOP outlines the minimum procedures that the program must take to ensure crew safety. However, ultimately the responsibility lies with each crew member. Crew members must be prepared to ensure personal safety and survival for up to twenty-four hours in the backcountry. Crew members should use good judgment in the field to determine whether working conditions are acceptable. If a crew member feels that a situation is unsafe, s/he should take action to remove herself or himself from the situation. Safety should always be the first priority of every NCPN crew member.

Risks Inherent in Springs Monitoring

Risks inherent in springs monitoring in general, and specifically to monitoring the sites selected in NCPN parks, include the following:

Working alone

Field staff often will work alone when traveling to and from remote sites and when making measurements and collecting samples in the field. As a result, particular attention must be given to safety and safety check-ins.

Long road trips

Travel between parks will require long road trips at all times of the year and under varied weather and road conditions.

Backcountry travel

Accessing spring sample sites requires travel on secondary roads that are gravel or dirt, and some sites require hikes of up to three hours each way. The unsurfaced roads can become impassible during wet weather, and may remain muddy for several days after snowmelt. Hiking may be on or off trail through steep, rocky, sandy or muddy conditions. Hiking often occurs in washes that have flash flood potential. Accessing sample sites may require scrambling on sloping bedrock.

Varied weather conditions

The Colorado Plateau region is characterized by weather conditions that vary considerably through the seasons, day-to-day, and hour-by-hour. Snow, wind, and temperatures below 0°F occur in the winter, and summer temperatures are often well above 100°F. Lightning is common during the summer monsoon storms. Hypothermia and heat-related injury are possible, and occasional discomfort is certain. Successful field work requires preparation for this wide range of conditions.

Use of hazardous materials

Some of the water quality solutions and reagents used are hazardous and require proper storage, handling, and personal protection, including eye and skin protection.

Field Personnel

Staffing requirements

Springs monitoring requires hydrologic and vegetation expertise. A hydrologic technician (minimum GS-6/7) installs and maintains all hydrologic equipment and coordinates collection of hydrologic data. A biological science technician with previous vegetation monitoring experience (minimum GS-6/7) leads site characterization and vegetation sampling. The approach to vegetation monitoring in this protocol requires many decisions at each field site, and pilot sampling with multiple observers indicated that technicians with previous vegetation monitoring experience had more similar data than an experienced botanist without prior monitoring experience.

Qualifications and attributes

In addition to the technical skills, experience, and knowledge listed below, certain qualities are necessary for all NCPN field personnel. To maintain data quality, all staff should have the ability to successfully engage in repetitive, detail-oriented work with strict adherence to standard operating procedures. Technicians must be able to work independently and thrive in difficult field conditions. They should also be in good physical condition, able to hike up to 8 miles in a day, often with significant elevation change and off-trail conditions. Certification as a Wilderness First Responder (or Wilderness First Aid) and CPR is an asset. Employees should expect to travel to remote parks and work away from home for periods of up to 8 consecutive days and, in some instances, to camp in backcountry situations.

Technical Skills, Experience, and Knowledge

Lead Hydrologic Technician

- Experience taking flow measurements using a variety of methods, particularly volumetric methods.
- Experience calibrating and using multiparameter probes to take water quality measurements.

Biological Technician

- Previous experience with a rigorous vegetation monitoring program.
- Ability to identify common wetland genera and species.
- Ability to key plants to species using floras and technical keys.
- Competence in scrambling on bedrock to access hanging gardens.
- Willingness to be exposed to some poison ivy and heights.

Annual Training

Program overview – introduction to NCPN goals and projects

Administrative responsibilities and policies – timesheets, travel, work hours, leave policies, and equipment care

Safety – NCPN Field Safety SOP, Job Hazard Analysis, first aid kits, satellite phone use, personal locator beacon use, first aid kit contents, specific safety concerns

Government vehicles – proper use and care, vehicle inspection, tire changing, defensive driving

Park etiquette – biological soil crust, visitor interactions, low impact practices

GPS – navigation, logging points, data dictionaries

Photos – taking good reference photos, appropriate camera orientations for monitoring photos, checking time and date settings

Plant identification – making plant collections, using available plant references, review of common species with particular attention to difficult groups including grasses, sedges, rushes and willows

Vegetation measures – Using site maps and photo documentation to delineate surfaces in the field, endemic plant identification

Hydrologic measures – Calibrating water quality instrument, assuring stability prior to recording measurements (e.g., pool height stability, water quality instrument equilibration)

Data management – overview of data management, collecting high-quality data, annotating paper data sheets, entering and verifying field data in the database

Appendix A. Example JHA for springs monitoring field work

JOB HAZARD ANALYSIS **(CERTIFICATION OF HAZARD ASSESSMENT - 29 CFR 1910.133)** **U.S. National Park Service**	**JOB ACTIVITY: Monitoring Field Work** **DATE: 6/18/12** **PREPARED BY: Rebecca Weissinger** **CERTIFIED BY:**	
PERSONAL PROTECTIVE EQUIPMENT REQUIRED: Sun and rain protection, insect repellent, boots, water, communication equipment, shovel, and jack.		**QUALIFICATIONS, EXPERIENCE, OR TRAINING REQUIRED:** Basic backcountry competence
BASIC JOB STEPS	**HAZARDS**	**SAFE JOB PROCEDURE**
Break work down to basic elements (such as remove, lift, carry, stop, start, apply, return, squeeze, weld, saw, walk, hold, grind, place, etc.). Describe **what** is done, not how it is done.	For each job step, state what accident could occur and/or what hazard is present. To determine this, ask yourself if the person could fall; overexert; be exposed to burns, fumes, rays, gas, etc.; hit against, be struck by, come in contact with, be caught in, on, or between something?	State how each element of work should be performed to prevent the accident or avoid the hazard. What should the person do or not do? Be specific. What precautions should be taken? Ask yourself what you can do to eliminate, modify, guard, identify, or protect against the potential hazard or accident, including such things as how the worker stands, holds, uses, carries, dresses, etc.
1. Highway driving	a) Varied road conditions and road hazards such as animals and other obstructions b) Fatigue c) Behavior of other drivers d) Phone / mobile device use	Be well rested before road trips and constantly alert to obstructions and behavior of other drivers. Sleep if over tired on the way home after long days. Trade driving with passenger(s). Always wear seatbelt. Both hands on steering wheel at all times. It is against government policy to use your mobile device while driving.
2. Dirt road driving	a) Rough and rutted roads, high-clearance driving b) Muddy roads c) Narrow roads with short sight distances d) Animals and other obstructions e) Oncoming traffic	Be well-rested before road trips and constantly alert to obstructions and behavior of other drivers. If overtired, stop to sleep on the way home after long days. Trade driving with passenger(s). Always wear seatbelt. Both hands on steering wheel at all times. Be wary of washboards and blind corners. Maximum speed on unimproved roads is 30 mph, slower depending on conditions.
3. Inclement weather driving	a) Slippery roads and poor visibility	Drive slowly. Watch for snow, ice, ruts, washed-out roads, washboard surfaces, loose gravel, and flash floods. Be well-rested before road trips and constantly alert to obstructions and behavior of other drivers. If overtired, stop to sleep on the way home after long days. Trade driving with passenger(s).
4. Hiking	a) Steep, loose terrain b) Uneven footing c) Long distances	Wear sturdy shoes and don't rush on uneven terrain. Distribute weight low and close to back in backpack. Rest frequently and drink lots of water and hydrating liquids. Be wary of dangerous animals (domestic or wild).
5. Stream crossings	a) Swift currents, deep water b) Flood flows c) Cold water and ice d) Contaminated water	Approach streams cautiously. Don't enter stream if visual estimate of product of depth and velocity is >10 (depth in ft and velocity in ft/s). Be wary of slippery and loose stream beds and dangerous animals. Be prepared to self-rescue if you fall in.

6. Deal with environmental conditions	a) Temperature and sun exposure b) Adverse weather (rain, snow, lightning, and wind)	Wear sunscreen. Have appropriate extra clothing for weather changes. Keep to low areas during lightning. Watch for flash floods. Be prepared to spend the night out.
7. Animals	a) Insects: Scorpions and Spiders b) Snakes: Rattlesnakes c) Mammals: Mountain Lions and Bears	Avoid placing extremities in locations such as rock crevices and overhangs, behind shrubs, and over fallen logs without inspecting the locations first. Be aware of your surroundings. Walk carefully, listen for rattles, and be able to identify bear and mountain lion tracks. If tracks appear fresh, return to vehicle.

Appendix B. Example JHA for springs monitoring office work

JOB HAZARD ANALYSIS **(CERTIFICATION OF HAZARD ASSESSMENT - 29 CFR 1910.133)** **U.S. National Park Service**	**JOB ACTIVITY: Office activities** **DATE: 6/18/12** **PREPARED BY: Rebecca Weissinger** **CERTIFIED BY:**

PERSONAL PROTECTIVE EQUIPMENT REQUIRED:	**QUALIFICATIONS, EXPERIENCE, OR TRAINING REQUIRED:**

BASIC JOB STEPS	**HAZARDS**	**SAFE JOB PROCEDURE**
Break work down to basic elements (such as remove, lift, carry, stop, start, apply, return, squeeze, weld, saw, walk, hold, grind, place, etc.). Describe **what** is done, not how it is done.	For each job step, state what accident could occur and/or what hazard is present. To determine this, ask yourself if the person could fall; overexert; be exposed to burns, fumes, rays, gas, etc.; hit against, be struck by, come in contact with, be caught in, on, or between something?	State how each element of work should be performed to prevent the accident or avoid the hazard. What should the person do or not do? Be specific. What precautions should be taken? Ask yourself what you can do to eliminate, modify, guard, identify, or protect against the potential hazard or accident, including such things as how the worker stands, holds, uses, carries, dresses, etc.
1. Enter data	a) Repetitive motions b) Sitting in one place for long periods of time	Take frequent breaks and switch tasks with other crew members when possible.
2. Move field equipment	a) Back strain from lifting heavy objects	Lift with legs, not back. Ask for assistance when needed.
3. Calibrate multiparameter probe	a) Standing in one place for long periods of time b) Eye and skin irritation from Sodium Sulfite, pH and conductivity standards c) Inhalation of acid fumes	Wear eye protection, rubber gloves, apron, know clean up acid spills, work with exhaust fan running, take frequent breaks, comfortable shoes for standing, wash hands after processing. Do not allow sodium sulfite to become airborne.
4. Process bacterial samples	a) Danger of ingesting bacterial media b) Potential inoculation or ingestion of bacterial colonies after incubation	Wear rubber gloves, eye protection, and apron. Do not puncture bacteria containing plates after incubation, remove flammables from work area, do not let pressure cooker run dry, run exhaust fan during sterilization procedure. Keep bacteria plates in biohazard bags after counting colonies. Wash hands vigorously after handling bacteria plates.
5. Prepare and use decontamination solution	a) Eye and skin irritation from quaternary ammonium	Wear rubber gloves, eye protection, and apron. Have clean water available during preparation. Wash hands thoroughly after use.

Springs Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 2

Sampling Overview and Equipment Needed

Version 1.00 (June 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP describes which SOPs are used under various sampling scenarios and provides equipment lists for all activities.

Sampling Overview

The NCPN's springs monitoring program is designed to be completed by at least two individuals of differing expertise – a hydrologic technician and a biological technician specializing in vegetation – at differing intervals. Both should be present for site establishments, if possible. Hydrologic revisits occur monthly from March through November. Vegetation revisits occur once per growing season. Relevant SOPs for each field activity are documented in Table 1.

Table 1. SOPs needed for each type of field visit.

SOP	Site Establishment	Hydrologic Revisit	Vegetation Revisit
NCPN Field Safety or SEUG backcountry travel	X	X	X
3 – Site Characterization	X		
4 – Site Map and Vegetation Characterization	X		X
5 – Hydrology	X*	X	
6 – Site Condition	X		X
7 – Hanging Gardens	X**		X**
8 – Decontamination	X	X	

* at sites with flow or stage monitoring

** at hanging gardens

Equipment

Table 2. Safety and general equipment needed for all springs sampling.

Item	Number needed	Description	Notes
Safety Equipment			
First aid kit	1		content list in NCPN Field Safety Plan
Personal safety beacon	1		For use in field
Satellite phone	1		For use in camp
Satellite phone charger	1		
NCPN Field Safety Plan or SEUG backcountry travel plan	1		
NCPN Medical Information Form	1 per person		found in NCPN Field Safety Plan
Personal Safety Equipment - *provided by observers*			
Insect repellent			
Sunscreen			
Water bottles			
Sunhat or baseball hat			
Appropriate footwear and clothing			
General Equipment			
Digital camera	1	Small handheld	
Extra battery for digital camera	1		
Permit	2 per vehicle		one on vehicle dashboard, one with crew
Topographic Maps	1		access site
Sketch Map	1 per site		relocate monitoring locations on site
Printed photos	Variable		relocate and duplicate monitoring locations
Data sheets	variable		at least 25% on rite-in-the-rain paper
SOPs	Relevant set		
Clipboard	1	lightweight with interior storage	
Field notebook	1	small, Rite-in-the-Rain©	field notes
Pencils	3-5		

Table 3. Equipment needed for SOP #3 - site characterization.

Item	Number needed	Description	Notes
GPS	1	Trimble GeoXM or more accurate	
GPS car charger	1		

Item	Number needed	Description	Notes
Compass	1	with declination setting	set declination, take orifice bearing
Clinometer	1		measure slope
100-m reel tape	1	fiberglass reel tapes	measure spring outflow
Rangefinder	1	short-range	alternate for measuring spring outflow
Chaining pins	2	striped metal pins	secure reel tape
Solar pathfinder	1	Dome, tripod, and sunpath diagram	Use 37-43° latitude diagram

Table 4. Equipment needed for SOP #4 – site map and vegetation characterization

Item	Number needed	Description	Notes
Graph paper	1	4 squares per inch	draw map
Rangefinder	1	short-range	measure spring dimensions
Spring species list	1	species previously recorded at site	
Hand lens	1		
2-gallon resealable plastic bags	min. 2	2- gallon or larger	collect plants
Masking tape	1		label plant collections
Permanent marker	1		label plant collections
Trowel	1	small garden tool	extract specimen roots
Plant press	1	field press with card, blotter, and paper	store plant collections for identification
Relevant floras and park species lists		various by park	

Table 5. Equipment needed for SOP #5 – hydrology.

Item	Number needed	Description	Notes
Water quantity			
Flow instrument	0-1	Baski flume, weir plates, etc.	see NCPN site descriptions for specific needs
Hammer, duct tape, etc	0-1	As needed for weir plate setup	
Calibrated large plastic container	1-2	approximately 4000 ml	volumetric flow container, calibration fluid container in pack
Calibrated small plastic container	1-2	approximately 250-500 ml	volumetric flow container; capture water at shallow sites for water quality measurement
Bucket	0-1	variable	capture channelized flow

Item	Number needed	Description	Notes
Graduated plastic cylinder	0-1	1 L, marked in 10 ml increments	measure timed captures
Plastic bags	0-2	1-2 gallon-sized with no holes	capture channelized flow
Trowel or small shovel	0-1	small garden tool	build earthen dam for volumetric measurement; seal around flow instrument
Plumber's putty	0-1	orange-sized chunk, some sites.	funnel flow on bedrock for volumetric measurement
Retracting steel ruler	0-1	≥2 m long, marked in 0.1 cm increments	record pool stage
Folding ruler	0-1	any increments	verify that pool behind flow measurement structure is stable
Stopwatch	0-1	To 0.01 seconds	timed flow measurements
Voice recorder	0-1	small, with spare batteries	Increase accuracy of timed flow measurements on solo visits
Waders or sandals	0-1	appropriate for season	standing in water if required by site
Waterproof gloves	0-1 pair	seasonal need	protect hands from cold water
Poison ivy gear	variable	clothing, gloves, soap	prevent infection at relevant sites
Water quality			
Thermometer	1	Celsius, NIST traceable	water and air temperatures
Water quality meter	1	variable	at minimum pH and specific conductance
Calibration solutions	3	pH 7.01 and 10.01; conductivity 1413 mhos	in small field bottles
Small beakers or cups	2	About 50-mL	calibration of water quality meter
Batteries	variable	variable	for water quality meter
Small mesh bag	1		store calibration solutions
Fecal coliforms			
Coliform sample bottles	1 per sample	sterile 100-mL	enough for samples, duplicate, and field blank; check expiration date
Insulated water bottle coozy with ice	1	1- and 1.5-L size	carry bacteria samples to vehicle
Permanent marker	1		mark bottles and trays
Cooler with ice	1		store bacteria samples during transport
Gloves	1 pair		protect hands from reagent
Coliform reagent	1 per sample	IDEXX Colilert	check expiration date
Sterile DI water	1 bottle	in carry bottle in vehicle	for field blanks
IDEXX Quanti-tray 2000	1 per sample		check expiration date

Item	Number needed	Description	Notes
Sealer with rubber tray, including power cord	1	IDEXX Quantitray-2000 sealer	seal Quanti-trays
Incubator, including power cord	1	Thermotote scientific or other	capable of maintaining 34-36.5°C temperature
Colilert Quanti-tray 2000 comparator	1		Compare to yellow cells in processed bacteria samples
UV blacklight	1		fluoresce bacteria samples

Table 6. Equipment needed for SOP #7 – hanging gardens.

Item	Number needed	Description	Notes
Rare plant descriptions	1		target species
Spring species list	1	species previously recorded at site	

Table 7. Equipment needed for SOP #8 – decontamination

Item	Number needed	Description	Notes
Pump Sprayer	1	2- gallon herbicide pump sprayer	decontaminate equipment and personal items
Protective eyewear	1		use while mixing Quat solution
Quaternary ammonium	Pre-diluted	Quat128	decontaminate equipment and personal items
Quat-Chek test paper	1		test dilution of decontamination solution
Scouring brush	1		decontaminate equipment and personal items
Rubber gloves	6		protect hands during decontamination

Spring, Seep and Hanging Garden Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #3

Site Establishment and Characterization

Version 1.00 (June 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

The site characterization should be completed during the initial site visit. It details structural elements of the site that remain stable such as lithology, topographic setting, and spring type. Prior to site characterization, read Springer and Stevens (2009) to correctly classify springs.

Accepting a site for monitoring

Spring and hanging gardens locations are taken from previous studies and institutional knowledge but have not necessarily been evaluated for monitoring suitability. Accept a spring if the following criteria are met:

1. The site is correctly classified as a spring or hanging garden.
2. The site is safely accessible. No ropes, small hand holds, or prolonged exposure is required. A fall is unlikely to cause a life-threatening injury.
3. The site can be sampled without excessive resource damage, usually associated with displacement of saturated soils and roots on slopes or unusually dense and extensive woody vegetation.
4. For hydrologic monitoring, a stable flow monitoring location is also necessary. See SOP #5 for additional details.

Site Orientation and Setup

Upon arrival at each spring all observers should take time to walk around and thoroughly familiarize themselves with the site's characteristics. Spring ecosystems are fragile and delicate. Take care to avoid unnecessary trampling or disturbance of wetlands, land-surfaces, or vegetation in spring associated areas. If a location is not a spring, is inaccessible, or if sampling would cause too much impact to the site, reject the location for monitoring and indicate why the site was rejected.

Observations should refer to the spring orifice and to the first 50 meters of wetted stream channel downstream of the spring orifice. If the spring-fed channel meets a runoff-dominated channel at a distance of less than 50 meters, stop there. If this is a repeat visit use the same length and area as the previous visit, noting any changes. In some cases, such as a spring with associated wetland, survey the entire area including riparian/wetland vegetation. The total spring site encompasses the area dominated by riparian and wetland obligate vegetation, and includes unvegetated sub-areas such as those consisting of bare rock, gravel, or soil.

Guidelines for determining the extent of area to include (modified from USDA-FS 2012):

The study area should include the spring and a short distance of the run-out stream, or until it clearly becomes a stream, pool, or other ecosystem type. For this protocol, when appropriate we will use **50 meters** as a set run-out distance. This is the measured length of the spring-fed stream **downstream from the orifice**, up to a **maximum of 50 meters**, or to the point where the spring-fed **stream enters another stream or channel (wet or dry)**. Fifty meters is an arbitrary cut-off that has been established based on studies of numerous springs and because in most spring ecosystems at varying distances downstream the spring-fed stream changes from a spring-specific habitat to a lotic habitat due to cumulative changes in flow, temperature, and water quality.

Tips for recognizing the extent of the area to include in spring monitoring:
Hydrology: Water on the surface of the ground or saturated ground (not from recent precipitation)
Vegetation: The boundary (or edge) of the spring will generally be associated with a transition from vegetation dominated by obligate, facultative wet, and facultative species to more upland species, as distinguished by the Wetland Indicator Status of the US Fish and Wildlife Service (1996).
Landform: A change in slope (from steeper to flatter) can be associated with the edge of the spring.

A particular concern is to minimize investigator impacts such as trampling at the site. Trampling-intensive methods, such as using metric tapes to measure site dimensions and cover, are often not recommended as they often may damage sensitive habitats and plant populations. Instead, the investigators will use a laser rangefinder to describe the dimensions of the overall spring site and individual landform/geomorphic surfaces within the site.

Site Information

Accurate and consistent recording of site information is very important. The site name, date and times of site visit, and observer's names should always be recorded in the field. Other Site Information details can be completed in the office.

Site Name: The name of the site as it appears on a topographic map or official documents from the Park Service. If the site is unnamed use a local, named topographic feature such as a stream or drainage name. For example, an unnamed spring in Cottonwood Canyon could be called Cottonwood Spring. Use permanent features to distinguish each spring, e.g. Cottonwood Boulder Spring or Cottonwood Ledge Spring. If possible this name should be unique. ***The site name should be recorded in the provided field on <u>every side of every field form</u>.***

Date: Use mm/dd/yy format, e.g. 06/12/13 for June 12, 2013.

Park Code: Enter the appropriate acronym for the park unit (ARCH = Arches National Park, CANY = Canyonlands National Park, HOVE = Hovenweep National Monument, NABR = Natural Bridges National Monument).

Observers: Fill in the full name of all crew members.

Access Description: Provide detail on access, using prominent features for reference and including estimates of distance and travel time for each leg of the route. Use words that are unambiguous, e.g. "south" instead of "left", "downcanyon" instead of "below." The access description is very important for relocating the spring in the future, so please be thorough and accurate. Also record any hazard or safety information that may prompt alternate equipment or additional care, such as high cover of invasive weeds during the hike, water crossings, unstable slopes, mountain lion activity, etc.

Geographic Description

GPS coordinates: Using a handheld GPS unit, make sure the datum is set to NAD83, and make sure that the unit is set to the correct time zone. UTM x/y coordinates are a rectangular coordinate system with units in meters from the equator (the "y" or "Northing" value) and meters from a central meridian (the "x" or "Easting" value). Record a **waypoint** (UTM Easting and Northing) as near as possible to the spring orifice. Record the local UTM **zone**. If there is no GPS coverage at the orifice, find a nearby area with clear coverage, take a waypoint, and note the distance and bearing to the orifice. While in the field, mark the spring's location on a **topographic map** using a dot within a circle. If there is no GPS coverage at the site, UTMs can be estimated later using the position identified on the topographic map and GIS.

Aspect: Set the declination on the compass to true North (10º E for SEUG in 2016). With your back facing the orifice, determine the representative aspect of the spring in degrees.

Slope: Measure the representative slope of the dominant surface around the spring orifice in degrees using a clinometer or compass.

Slope Variability: Indicate the general variability of the slope on the site by choosing one of the following categories: high (3 or more abrupt changes in slope across site, e.g., a hanging garden with vertical backwall, steep colluvial slope, and low-gradient channel), medium (1-2 changes, e.g., a rheocrene spring with steep banks), low (0 changes, e.g., a wet meadow).

Potential Solar Radiation: In the dominant aspect of the spring near the middle of the site, place the Solar Pathfinder tripod and dome in a level area facing true south. Use the appropriate latitude template (37-43°), and level the dome using the level bubble. Locate the horizon in the reflection of the dome, and read the vertical (sunrise/sunset) and horizontal (month) white lines transecting the reflection of the horizon on the sunpath diagram. The vertical lines in contact with the east horizon will indicate the time of day the sunlight will be contacting the site and the vertical lines contacting the west horizon will indicate the time the sunlight will leave the site. On the datasheet, record the sunrise and sunset time for each month of the year, in the order they are presented on the solar pathfinder. In the office, calculate the sum of the unshaded numbers along a particular monthly sunpath, located on the sunpath diagram, to obtain the percent of the total available solar energy for an average day in that month. Average potential percent solar radiation (in relation to the unshaded potential budget) will be calculated for monthly, seasonal (spring, summer, fall, winter) and annual periods in the database.

Site Description

Spring Type

Identify spring types based on the descriptions below (from Springer and Stevens 2009). There may be more than one spring type represented at a spring. Note all present at site. Visual representations of the spring types are available in Appendix A. **Bolded** spring types are known to occur in SEUG parks.

Spring Type	Definition
Cave	Emergence in a cave in mature to extreme karst with sufficiently large conduits
Exposure	Cave, rock shelter fractures, or sinkholes where an unconfined aquifer is exposed near the land surface
Fountain	Artesian fountain with pressurized CO_2 in a confined aquifer
Geyser	Explosive flow of hot water from confined aquifer
Gushet	Discrete source flow gushes from a cliff wall of a perched, unconfined aquifer
Hanging garden	Dripping flow emerges usually horizontally along a geologic contact along a cliff wall of a perched, unconfined aquifer
Helocrene	Emerges from low gradient wetlands; often indistinct or multiple sources seeping from shallow, unconfined aquifers
Hillslope	Emerges from confined or unconfined aquifers on a hillslope (30-60° slope); often indistinct or multiple sources

Hypocrene	A buried spring where flow does not reach the surface, typically due to very low discharge and high evaporation or transpiration
Limnocrene	Emergence of confined or unconfined aquifers in pool(s)
Mound	Emerges from a mineralized mound, frequently at magmatic or fault systems
Rheocrene	Flowing spring, emerges into one or more stream channels

Describe Spring Orifice

Write a brief description of the spring orifice setting. Include information such as *emerges as diffuse flow from bottom of small pool*, or *orifice is located on hillslope and has been heavily trampled by livestock*.

Multiple Spring Orifices and Other Nearby Springs

Identify if there is more than one spring orifice. Spring orifices separated by more than 200 meters should be identified as separate springs. Note if there are other springs in the area that are further away than 200 meters, but closer than 0.5 miles (0.8 km).

Geology

Describe the geology at the source of the spring. Identify the primary lithology from rock types listed on the following table and the mapped rock unit using published geologic maps. Known SEUG springs predominately occur in sandstone or quaternary alluvial material. If unable to identify the rock unit on site, take photos and write a brief description, then after the trip consult with persons knowledgeable about local geology. Stratigraphic sections specific to SEUG are included in Appendix B and C.

Rock Type	
Sedimentary	
Shale	Fine grained, bedding planes present (fine grains smooth, not visible to eye)
Sandstone	Sand grains, visible to eye 0.06 to 2 mm
Limestone	Predominately calcite (fizzes easily)
Other	Describe in comments field
Evaporites	Salt, gypsum
Coal	Peat, lignite, subbituminous, bituminous
Conglomerate	Grains coarser than 2mm in a finer grain matrix
Mudstone	Fine grained, bedding planes absent (fine grains smooth, not visible to eye)
Siltstone	Fine grained, bedding planes present (fine grains gritty, not visible to eye)
Quaternary Alluvium	Alluvial deposits found in and adjacent to wash bottoms

Spring Channel Characterization

Spring, seep and hanging garden sites may or may not have an associated stream channel. Channel attributes including length, flow type, and channel type should refer to the most representative channel on the site within the first 50 m of the spring orifice or the first meander downstream of the spring orifice. This is the measured length of the spring-fed stream downstream from the orifice, up to a **maximum of 50 meters**, or to the point where the spring-fed **stream enters another stream channel (wet or dry)**.

Channel Presence

Indicate whether or not a stream channel is present. If a stream channel is present but is associated with a water or run-off source other than the spring, mark that the stream channel geomorphology is run-off dominated (see channel type below).

Number of Channels

Enter the number of channels present on site within the first 50 m of the spring orifice.

Channel Length

Record in meters (m) up to a maximum of 50m the length of the flowing channel (if it exists), along the channel thalweg, directly below the spring orifice.

Channel Type

The morphology of the channel should be examined (if a channel exists) to determine if it is spring-dominated or surface-flow dominated. If a channel is spring discharge dominated, the channel should be nearly bank full at base-flow conditions of the spring. If the channel is surface-flow dominated, typically the channel is oversized for the base-flow of the spring. Typically there are two bankfull stages for surface-flow dominated channels; a small, incised channel for base-flow condition, and a larger, wider channel for surface-flow dominated conditions.

Channel Type	
Spring discharge dominated	Only one terrace or bankfull channel and channel starts at or near the spring orifice.
Runoff dominated	High terrace or two bankfull channels, one terrace typically higher than a lower, smaller spring-discharge terrace. Channel features are evident upstream of spring flow affected area.
Mixed discharge	Both spring discharge and runoff, two terraces or bankfull channels. Channel features evident upstream of spring-flow affected area, but some channel features are different below orifice because of spring flow.

Channel Comments

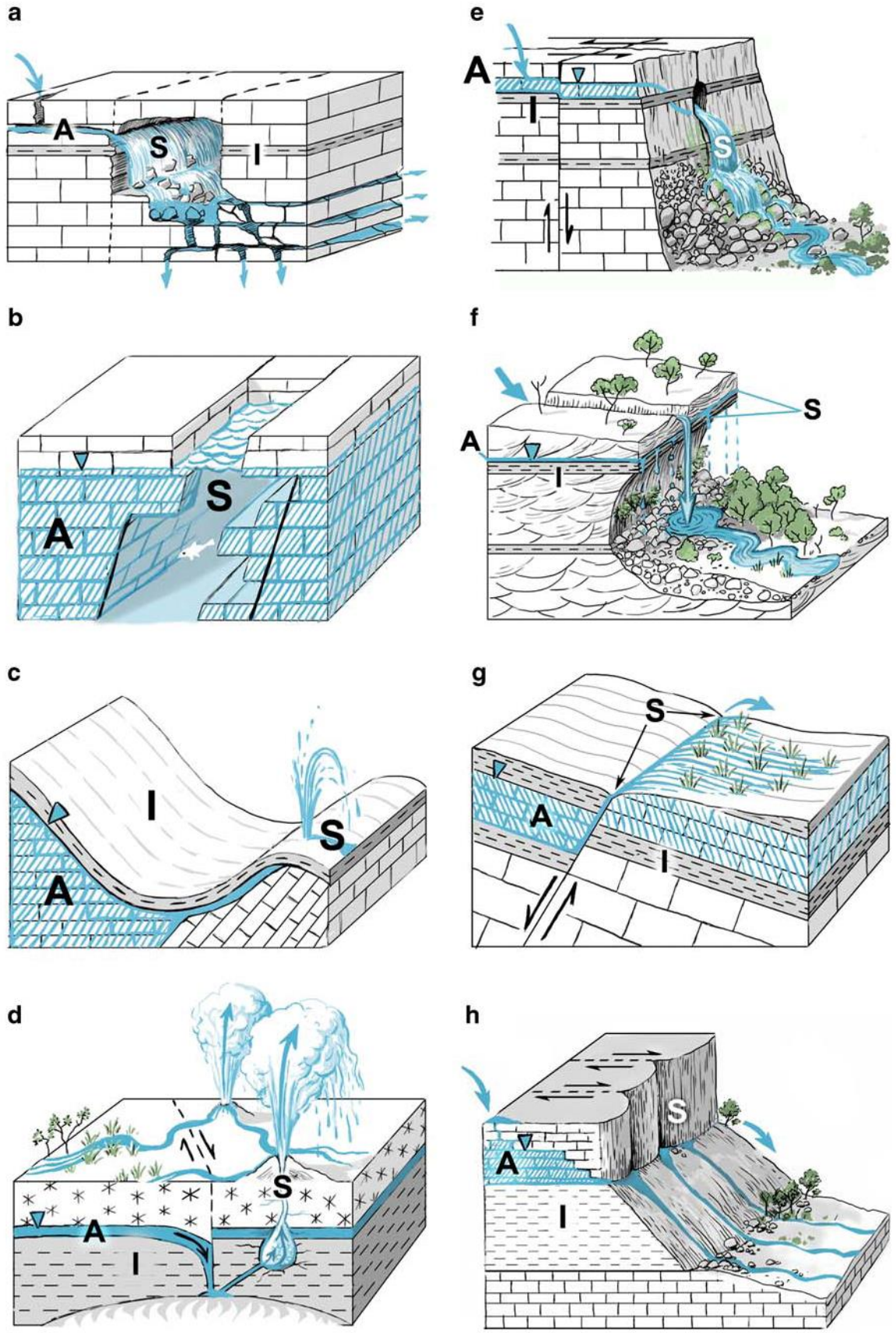
Provide additional explanatory comments, especially for mixed type.

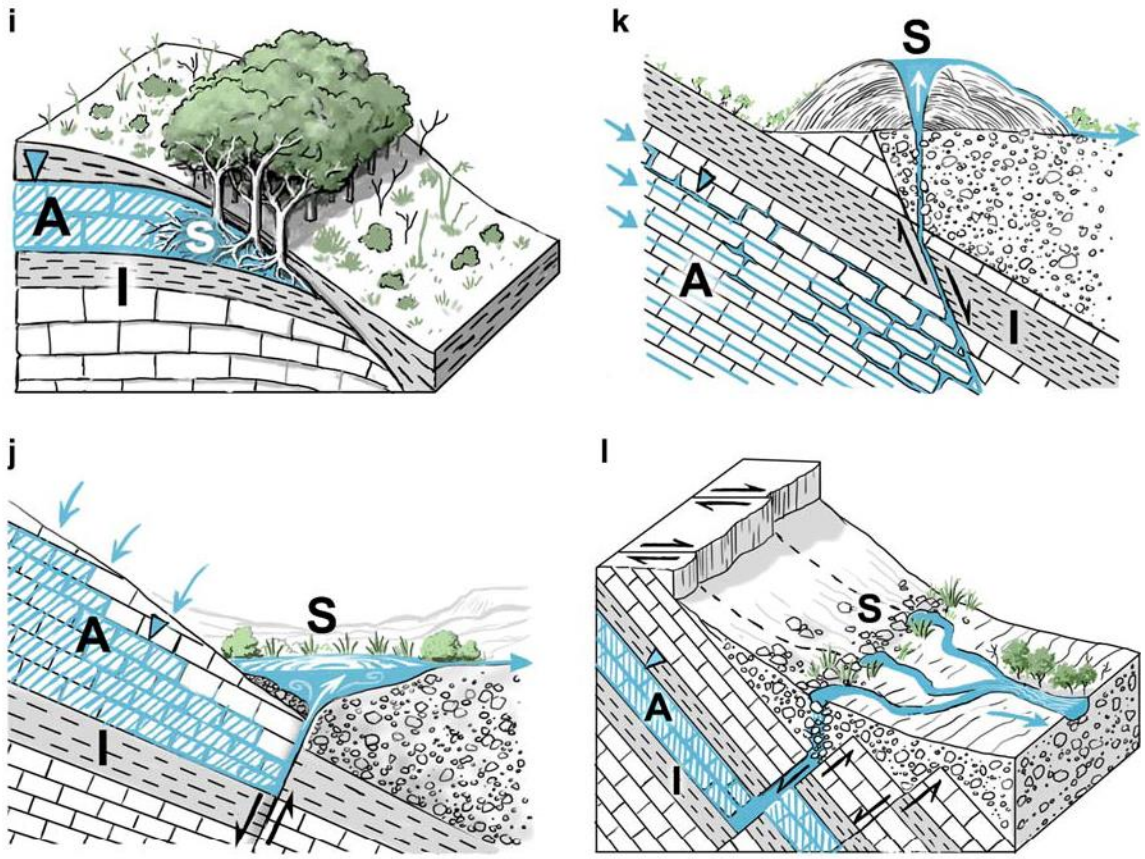
Literature Cited

Springer, A.E. and L.E. Stevens. 2009. Spheres of discharge of springs. Hydrogeology 17: 83-93.

United States Department of Agriculture – Forest Service (USDA-FS). 2012. Groundwater dependent ecosystems: Level II inventory field guide. General Technical Report WO-86b. USDA, Washington, D.C.

Appendix A. Spring types from Springer and Stevens (2009).

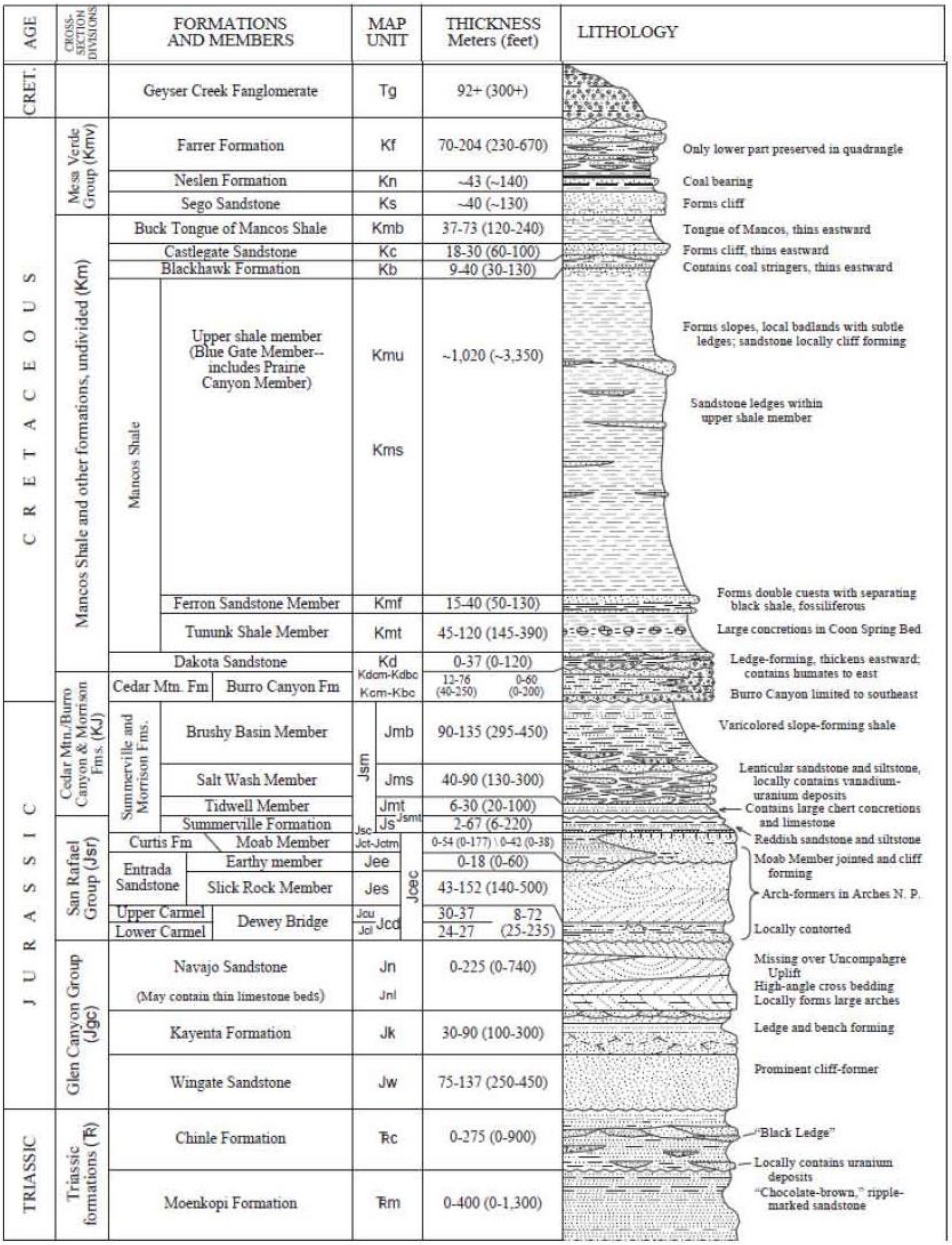




Sketches of springs spheres of discharge: **a** cave, **b** exposure, **c** fountain, **d** geyser, **e** gushet, **f** hanging garden, **g** helocrene, **h** hillslope, **i** hypocrene, **j** limnocrene, **k** mound form, l rheocrene. **A** aquifer, **I** impermeable stratum, **S** spring source. The inverted triangle represents the water table or piezometric surface. Fault lines are also shown, where appropriate.

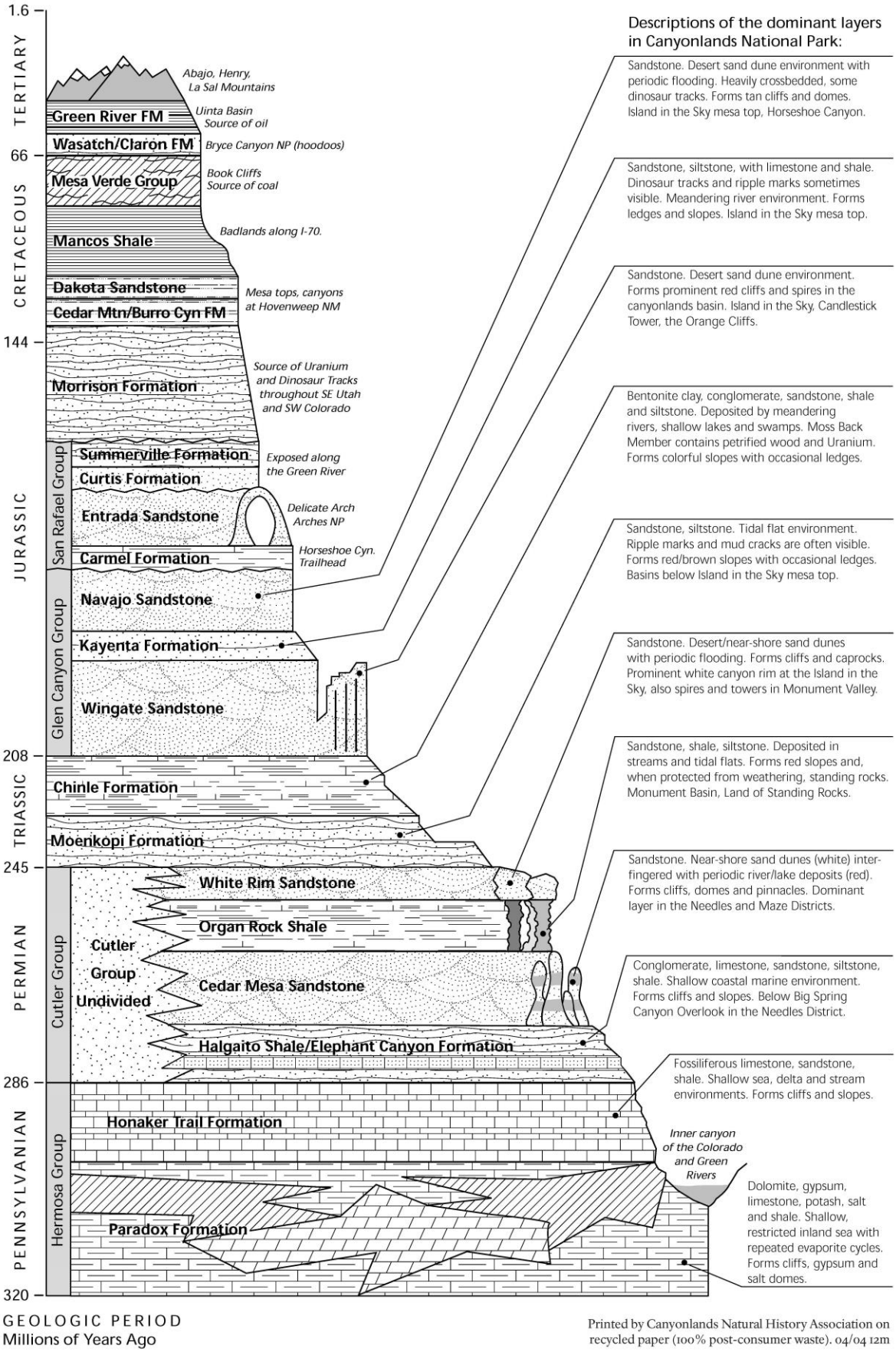
Reprinted with permission, Figure 1 in:
Springer, A.E. and L.E. Stevens. 2009. Spheres of discharge of springs. Hydrogeology 17: 83-93

Appendix B. Stratigraphic sections in portions of ARCH, CANY and HOVE.



GEOLOGIC MAP OF THE MOAB AND EASTERN PART OF THE SAN RAFAEL DESERT 30' X 60' QUADRANGLES, GRAND AND EMERY COUNTIES, UTAH, AND MESA COUNTY, COLORADO
by
Hellmut H. Doelling
Utah Geological Survey
2001

Appendix C. Stratigraphic sections in portions of CANY and NABR.



NCPN Springs Monitoring Site Characterization Datasheet - v. 1.00

Site Information

Site Name | Park Code | Date

Observers

Access Description

UTM - X | UTM - Y | Zone

Aspect (deg.) | Declination (deg.) | Slope (deg.) | Reject? Y N

Slope variability high medium low | If, Y, why?

Solar Radiation:

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_____

Site Description

Spring Type

Type (circle one)	**Description**
Cave	Emergence in a cave in mature to extreme karst with sufficiently large conduits
Exposure	Cave, rock shelter fractures, or sinkholes where an unconfined aquifer is exposed near the land surface
Fountain	Artesian fountain with pressurized CO_2 in a confined aquifer
Geyser	Explosive flow of hot water from confined aquifer
Gushet	Discrete source flow gushes from a cliff wall of a perched, unconfined aquifer
Hanging garden	Dripping flow emerges usually horizontally along a geologic contact along a cliff wall of a perched, unconfined aquifer
Helocrene	Emerges from low gradient wetlands; often indistinct or multiple sources seeping from shallow, unconfined aquifers
Hillslope	Emerges from confined or unconfined aquifers on a hillslope (30-60° slope); often indistinct or multiple sources
Hypocrene	A buried spring where flow does not reach the surface, typically due to very low discharge and high evaporation or transpiration
Limnocrene	Emergence of confined or unconfined aquifers in pool(s)
Mound	Emerges from a mineralized mound, frequently at magmatic or fault systems
Rheocrene	Flowing spring, emerges into one or more stream channels

Geology

Aquifer Rock Type (circle one):	**Sedimentary**	
	Limestone	
	Sandstone	
	Shale	
	Other	
Geologic unit:		

Measured Size (m2):

Multiple Spring Orifices - closer than 200 m Yes No

Other Springs Nearby - greater than 200 m and less than 0.5 miles Yes No

Channel Present: Yes No

Number of channels:

Channel Length (m):

Channel type: spring discharge dominated | run-off dominated | mixed

Spring Orifice Description:

Channel Description:

NCPN Springs Monitoring Site Characterization Datasheet - v. 1.00

Site Information

Site Name CorCan3 Park Code ARCH Date 15 May 2014

Observers R. Weissinger

Access Description

From the pipeline access, follow the pipeline into Salt Wash. A social trail goes close to the northern wall at the end of the side canyon with the pipeline, or route find across to Cordova Canyon. Once in Cordova Canyon, walk along the north wall to an alcove at ground level on the north wall. Access includes clay roads and washes that are impassable when raining and may take a few days to dry. Hiking goes through lots of weeds including cheatgrass, tumbleweed + knapweed. Access in the seep is easy.

UTM-X UTM-Y Zone

Aspect (deg.) 191° Declination (deg.) 11° E Slope (deg.) 31°

Slope variability (high) medium low

Solar Radiation:

Sunrise: D 8:00 J 8:30 N 8:30 F 9:30 O 11:30 M NS ~~S~~ ~~A~~ ~~A~~ ~~M~~ ~~J~~ ~~J~~

Sunset: D 15:00 J 15:00 N 14:30 F 14:00 O 14:00 M NS ~~S~~ ~~A~~ ~~A~~ ~~M~~ ~~J~~ ~~J~~

Site Description

Spring Type

Type (circle one)	Description
Cave	Emerge entirely within a cave environment and not directly connected to surface flow
Limnocrene	Emerge as one or more lentic pools
Rheochrene	Emerge as flowing streams
Mound-form	Emerge from (usually carbonate) precipitate mounds
Heleocrene	Emerge usually in a diffuse fashion in cienega (marshy, wet meadow) settings.
Hillslope	Emerge from non-vertical hillslopes at 30-60° slope, and usually have indistinct or multiple sources
Gushette	Pour from cliff faces
(Hanging gardens)	Complex, multi-habitat springs emerge along geologic contacts and seep, drip, or pour onto underlying walls
Geysers	Geothermal springs that emerge explosively and usually erratically
Fountain	Cool-water artesian springs that are forced above the land surface by stratigraphic head-driven pressure
Exposure	Settings in which ground water is exposed at the surface but does not flow
Hypocrene	Springs in which ground water the water never reaches the surface

Geology

Aquifer Rock Type (circle one):	Sedimentary	
	Limestone	
	(Sandstone)	
	Shale	
	Other	

Geologic unit: Moab Member of Curtis Fm

Measured Size (m2): 716 m²

Multiple Spring Orifices - closer than 200 m (Yes) No

Other Springs Nearby - greater than 200 m and less than 0.5 miles (Yes) No

Channel Present: Yes (No)

Number of channels: N/A

Channel Length (m):

Channel type: spring discharge dominated / run-off dominated / mixed

Spring Orifice Description:

~70 m long seeping backwall with some drips, much of BW is ~3m high and is wet the whole width

Channel Description:

From Sand Dune Arch via pipeline - about 2 hrs.

Spring, Seep and Hanging Garden Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 4

Site Map and Vegetation Characterization

Version 1.01 (January 2018)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	1/2018	R. Weissinger	Record veg cover for total spring area	Improve analysis	1.01

A site sketch map and vegetation characterization should be completed at all sites during the initial site visit and following major trigger events such as fire, severe flooding, a 10% reduction in flow, or at management's request. The sketch map documents the site area, geomorphic surfaces, and repeat monitoring locations. Visual estimates of foliar cover for each vascular plant species are recorded for each geomorphic surface and for the total spring area.

Site Sketch Map

After familiarizing yourselves with the spring, sub-divide the site based on geomorphic surfaces and draw an initial sketch map showing these features (example in Fig. 1). Use a laser rangefinder to estimate distances. If an area can be traversed without displacing soil and plant roots, a meter tape may be used to measure dimensions. The sketch map provides the basis for subsequent monitoring efforts at the spring, so be careful and thorough.

A sketch map is completed for each site to document the overall structural make-up of the site and to provide a visual reference for data collected in various aspects of the spring ecosystem monitoring. The following items should be identified and documented on the sketch map for each site:

Sketch Map	
Site name	Channel structural controls (e.g. bedrock ledge or riffle)
Artist	Pool locations
Date	GPS reading location
Estimate map scale	Photo points
Locations/dimensions of each geomorphic/habitat surface, delineated as polygons	Location of water quality measurements
Spring orifice	Location of water quantity measurements
Channel location	Indication of north (true)
(→) Direction of flow	Human features (e.g., spring box, trail, etc.)

The purpose of the map is to provide a graphical representation of information recorded in other tabular data fields. An additional purpose of the sketch map is to document the location of specific study measurements such as photopoints, water quality and quantity measurement, etc.

Geomorphic Surface Polygon Delineation

Continuous landform/geomorphic surfaces will be drawn as polygons, as close to scale as possible on the map, so that the area covered by each geomorphic surface type can be estimated. Note that you may wish to create multiple polygons for a given geomorphic surface type, particularly if it is patchy or discontinuous across the spring site. Polygons will be labeled with a code (Table 1). These codes will be used to reference surface types shown on the map to geomorphic surfaces, the plant species list and other site characterization parameters.

Table 1. Definition of geomorphic surface types and codes.

Landform/Geomorphic Surface Types (modified from Springer et al. 2006)		
Surface Type	**Surface Type Code**	**Description**
Alcove Floor	ALC	Near-horizontal surface located inside an alcove
Backwall	BW	Vertical to sloping bedrock in alcove or cliff setting
Sloping Bedrock	SB	Sloping bedrock outside of an alcove or cliff setting
Colluvial (detritus) slopes	CS	Slopes of unconsolidated materials
Cave	C	A large natural hole in the side of a hill, cliff, or mountain
Channel	CH	A passage for water to flow along
High Gradient Cienega	HGC	Steeply sloping marshy area with diffuse flow
Low Gradient Cienega	LGC	Gently sloping to flat marshy area with unfocused flow
Spring Mound	SM	Buildup of materials surrounding a spring due to water quality properties, e.g. travertine
Pools	P	Pools of water resulting from springs or runoff in alcoves
Terrace	TE	Flat strip of land on the slope of a hill, associated with high water and floodplains
Total	TOT	Total spring area
Tunnel	TU	A passage extending back from an opening in the rock, e.g. a mine shaft
Upland	UPL	Describes upland surfaces surrounding the spring, use in conjunction with other codes, e.g., UPL CS
Other	OTH	Describe in comments section

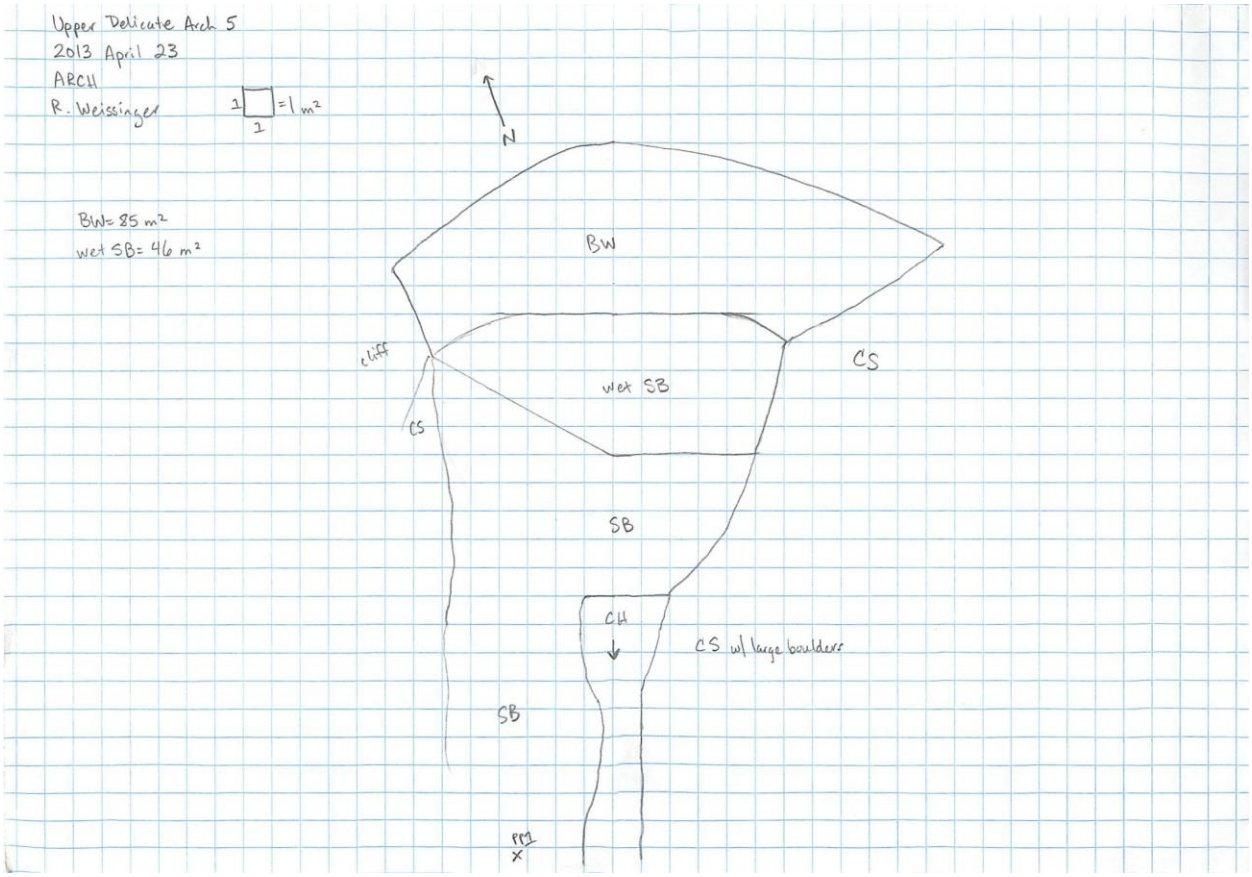


Figure 1. Example site sketch map showing geomorphic surfaces, photopoints, etc.

If possible, a panoramic photo should be taken of the site, and geomorphic surfaces can be drawn onto the photo in the office (Fig. 2). If a panoramic photo is not feasible, photos of the mapped edges of the spring with geomorphic surfaces drawn on can be helpful. See Appendix A for additional examples.

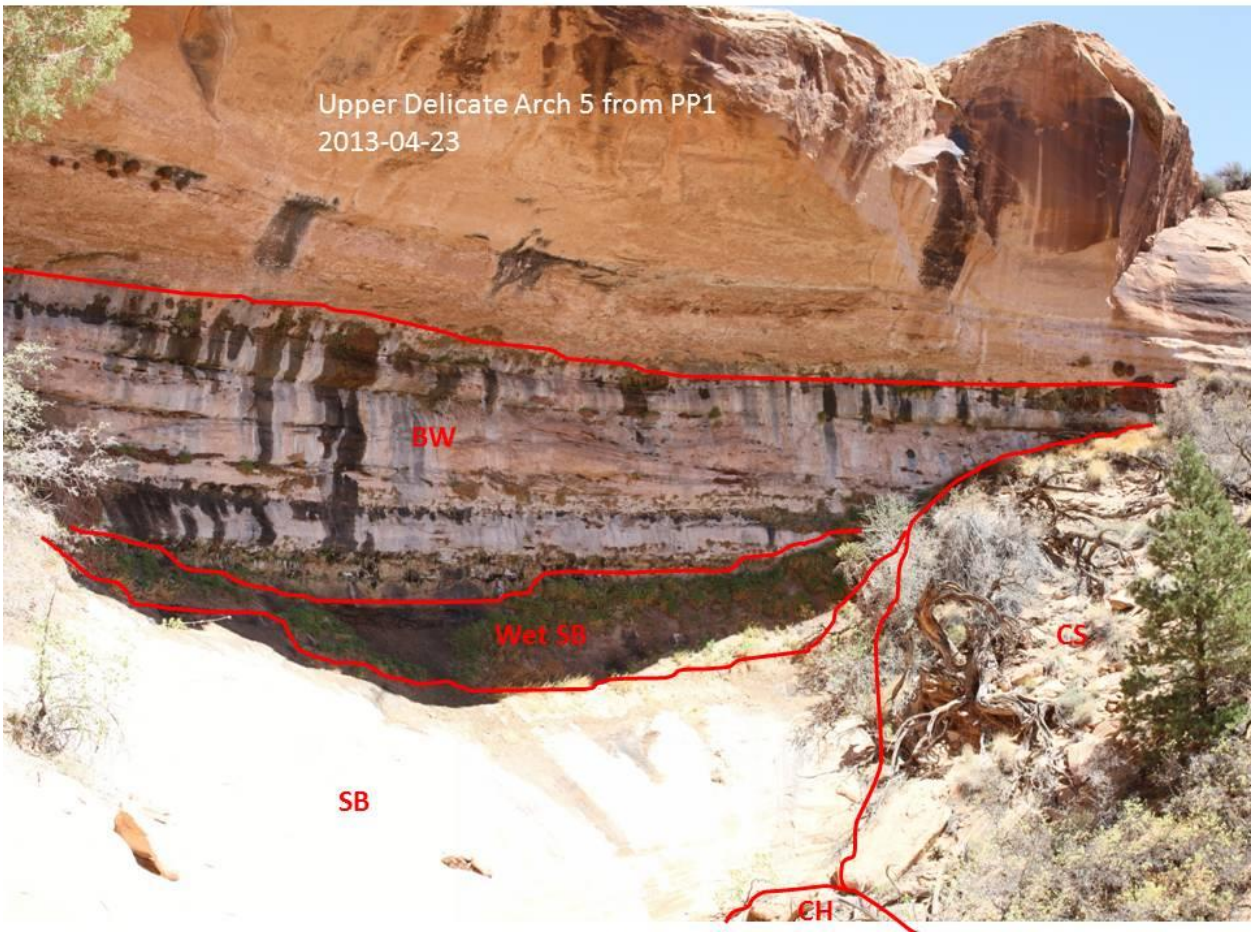


Figure 2. Example panoramic photo of site shown in Figure 1 sketch map, with geomorphic surfaces delineated.

Site Information

Geomorphic Surface Type

Record the geomorphic surface type code (listed above) for each polygon.

Polygon Area

Estimate or measure the **area of each polygon** (in square meters) and the **total spring area** represented by the map. Using the squares on the sketch map as a guide may be helpful.

Terrestrial and Aquatic Vegetation

Vegetation Characterization

Foliar cover of each vascular plant species will be estimated for the variety of terrestrial and aquatic landform/geomorphic surfaces at an individual spring site and for the total spring area. The cover of moss and algae should also be estimated for each geomorphic surface and the total area. Spend 1 minute per 5-m2 of vegetated area searching the site for additional species, for a maximum of two hours at larger sites. Do not include time spent keying plants in the allotted search time.

Vegetation Survey Start Time

Write in the 'local' time to the nearest minute upon beginning vegetation sampling, using an hour and minute format (**hhmm**). Use military time (add 12 to the hour beginning with 1pm through 11pm). Fill in all four digits. Examples are 0630 (6:30 am), 1402 (2:02 pm).

Vegetation Survey End Time
Write in the time to the nearest minute when vegetation sampling is completed, using an hour and minute format (**hhmm**). Use military time (add 12 to the hour beginning with 1pm through 11pm). Fill in all four digits. Examples are 0630 (6:30 am), 1402 (2:02 pm).

Plant Scientific Name
The first step in the vegetation survey is to compile a list of species on the site being evaluated. Full scientific names will be recorded on field sheets. The authority for botanical nomenclature for vascular plants is Welsh et al. 2003 (for UT, CO, and northern AZ). Dorn 2002 is the authority for Fossil Butte National Monument. When identity of a plant species is uncertain a collection may be made for later verification (see plant collection section below). Specimens collected for later verification should be assigned a unique identifier for later reconciliation with the determined scientific name.

Species Prominence (Canopy Cover) Class
Once the overall site has been surveyed and the species list compiled, identification specimens collected and uniquely labeled, the botanist visually estimates the percent cover for each species by landform/geomorphic surface type noted on the site sketch map.

The following prominence/cover class scale will be used to characterize individual species cover on each of the identified landform/geomorphic surfaces at a site. This prominence scale was developed by Spence (1993, 2004) and has been applied in studies of over 200 spring sites across Colorado Plateau parks.

Classes for Estimating Foliar Vegetation Cover

Class	Definition
1	<1% canopy cover
2	1 - <10% canopy cover
3	10 - < 25% canopy cover
4	25 - < 50% canopy cover
5	50 - < 95% canopy cover
6	95% or greater canopy cover

Unknown Plants
Sometimes it may be difficult or impossible to determine the specific identity of individual plants encountered during sampling. Crews may be unfamiliar with a plant or unable to distinguish one species from other similar species at the time of sampling.

When an unknown plant is encountered

A. Search the immediate area, looking for specimens of the unknown plant that are more readily identifiable (i.e., due to the presence of flowers or fruits from current or previous seasons).

B. If an identifiable specimen cannot be found, create a unique name using the following code: unk + 4 letter park code + S + date + your initials + collection number for the day (e.g., unkZION-S0409-ST1). Record this code in the appropriate column on your vegetation sampling datasheet instead of the species name.

C. Take a photograph of the unknown plant.

D. It is permissible to identify a plant only to the genus level if no identifiable parts are present for keying, or if hybridization makes species delineation difficult. Record the full Latin name of the genus followed by "sp." (e.g., *Opuntia* sp., *Tamarix* sp., etc.).

Collecting unknown plants

Once it has become apparent that no identifiable plants can be found or that a plant with identifiable features cannot be keyed out in the field, a collection of the plant should be made if more than 10 individuals occur at the site.

A. Attempt to collect as many identifiable parts as possible, including flowers, fruits, leaves, and roots. It is especially important to collect roots of forbs and grasses. You may need to collect from more than one plant to achieve this goal.

B. Wrap a piece of masking tape around the plant and use a fine-point Sharpie to label it with the unknown species code.

C. Carefully place the specimen inside a resealable plastic bag labeled with the reach number, unknown species code, date, and collector.

D. Place the sample in your backpack and in a shady spot until you get back to camp. Attempt to identify the plants when you return to camp.

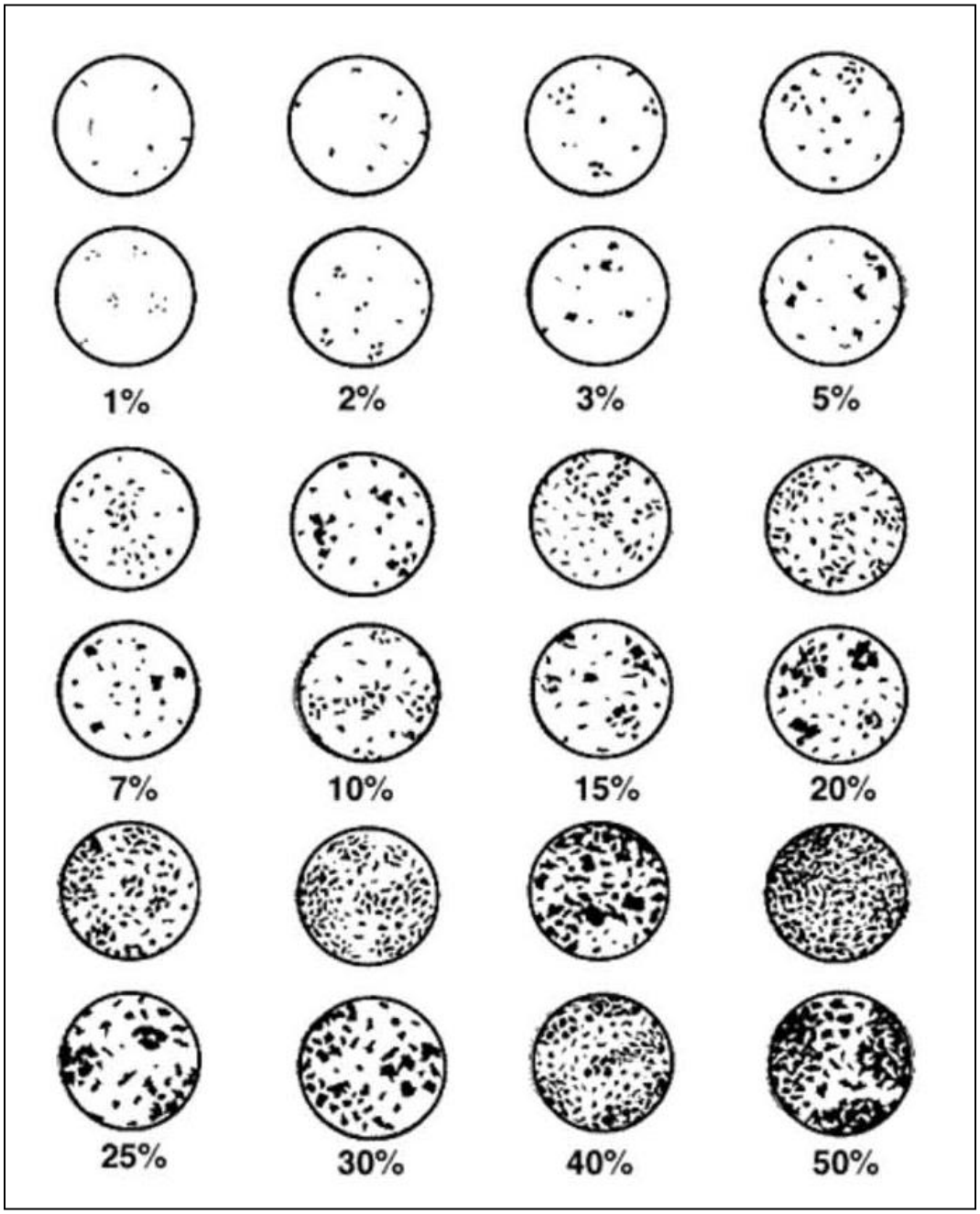
E. If the specimen cannot be identified right away, preserve the bag in a cooler as soon as possible. Make sure the specimen does not get wet. If a cooler is not available, press the plant between two sheets of newspaper.

Annotating datasheets

When updating data collection data sheets with identified plants, draw a line through the unknown code and write in the correct species code in the nearest available space. Initial and date the change on the datasheet.

Estimating Percent Cover

For this protocol cover estimates should be a percent of the total site or geomorphic surface polygon. Use the diagram below as an aid in estimating percent cover.



NCPN Springs Monitoring Site Map and Vegetation Datasheet - v. 1.01

Park: Site: Observer: Date:

Surface	Subdivision	Area
TOT		

Geomorphic Surfaces

ALC - Alcove floor
BW - Backwall
C - Cave
CH - Channel
CS - Colluvial slope
HGC - High gradient cienaga
LGC - Low gradient cienaga
OTH - Other
P - Pools
SB - Sloping bedrock
TE - Terrace
TOT - Total area
UPL - Upland

Plant Cover

1 - <1%
2 - 1-10%
3 - 10-25%
4 - 25-50%
5 - 50-95%
6 - >95%

Vegetation Cover Start: End:

Species Surface						**TOT**
Algae						
Moss						

entered 5/23/18

NCPN Springs Monitoring Site Map and Vegetation Datasheet - v. 1.00

Park: ARCH Site: Clover Canyon 3 Observer: R. Weissinger Date: 4 May 2018

Surface	Subdivision	Area (m2)
BW	BW	100
CS	CS	356

Geomorphic Surfaces	
ALC	Alcove Floor
BW	Backwall
C	Cave
CH	Channel
CS	Colluvial Slope
HGC	High Gradient Cienega
LGC	Low Gradient Cienega
SM	Spring Mound
P	Pools
TE	Terrace
TU	Tunnel
UPL	Upland
OTH	Other
SB	Sloping Bedrock

Plant Cover	
6	>95%
5	50-95%
4	25-50%
3	10-25%
2	1-10%
1	<1%

Vegetation Cover Start: 11:30 End: 12:00

Species	BW	CS								Total
Algae	x 4	x 1								3
Moss	x 2	x 1								2
Adiantum capillus-veneris	x 3	x 3								3
Aquilegia micrantha	x 1	x 2								2
Celtis reticulata		x 2								2
Cirsium calcareum		x 1								1
Elymus canadensis		x 1								1
Ephedra viridis		x 1								1
Epipactis gigantea	x 1	x 1								1
Habenaria zothecina		x 1								1
Mimulus eastwoodiae	x 3	x 1								2
Phragmites australis		x 2								2
Primula specuicola	x 1	–								1
Quercus gambelii		x 2								2
Rhus aromatica		x 2								2
Sambucus caerulea		x 2								2
Solidago velutina		x 1								1
Toxicodendron rydbergii		x 2								2

Spring, Seep and Hanging Garden Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 5

Hydrologic Monitoring

Version 1.01 (February 2021)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	2/8/2021	R. Weissinger	Update precision goal for flow; add sampling rule of thumb	Document current practices	1.01

Water quantity and core parameters of water quality (pH, water temperature, and specific conductance) are recorded at every spring with sufficient surface water during monthly site visits from March – November during the sampling year. The goal is to record spring conditions and avoid run-off. As a rule of thumb, sampling visits should be postponed if more than 0.2" of precipitation has fallen in the previous 48 hours.

Fecal coliform sampling is done only at selected sites of management interest (e.g., proximity to cattle grazing, substantial human use). The recommended water quantity measurement equipment and water quality and water quantity measurement locations are documented in each site's working file.

Weather

Recent precipitation
Indicate whether there has been precipitation during the previous week. Use direct observation if possible. Use weather station data if available to determine the date and amount.

Rain
Using the list below, indicate the level of intensity most representative of the site visit.

No rain
Mist or fog
Light drizzle
Light rain
Heavy rain
Snow

Air temperature
Record the air temperature (°C) in the shade at 1m above ground level.

Cloud cover
Record cloud cover to the nearest 10%.

Flow

Indicate whether flow is measurable or not. Unmeasurable flow does not mean "no flow" but rather that conditions may not permit either direct or indirect estimates (i.e. site in flood, channel conditions changed, etc.).

Flow Severity:

- Dry – No surface water present.
- No flow – Pooled surface water present, but no flow.
- Normal – Flowing spring water present.
- Flood – Flowing surface water present due to precipitation run-off. Flow measurement is not representative of spring flow.

Consult the site's access document for the specific equipment needed and measurement location for each site. During initial site visits, attempt to locate a flow measurement site downstream of all significant spring orifices where flow is or can be channelized. Use a geomorphically stable location such as a bedrock ramp or notch when possible. The same flow measurement site should be used at each visit unless geomorphic change at the site necessitates that a different site be selected. If multiple channels exist at a site, select the dominant channel (channel with the most flow) for the discharge measurement. If possible to measure flow in more than one channel, do this and sum the measurements. Clearly document the discharge measurement location(s) on the data sheet and on the site sketch. Estimate the percent of total flow not captured by the discharge measurement(s) and record this percent loss on the datasheet.

Most SEUG springs sampled in this monitoring program are sampled using the volumetric method. For this method, if necessary, capture the flow by constructing a small dam using local materials or plumber's putty, inserting a weir plate, or channelizing the flow through a flume. For the most minimal flows, it may be helpful to insert a length of plastic tubing in the dam, making sure to leave enough height below the downstream end of the tube for a plastic container. See Figures 1-2 for examples of common volumetric flow measurement set-ups. Wait several minutes to allow the pool behind the dam to stabilize. Record the pool height before and after sampling to determine that the pool is stable.

Place a plastic container (cup or Tupperware container of pre-determined volume or plastic bag) below the flow stream to capture all of the water. If there is not sufficient drop to fit a reasonably-sized container into the flow stream, the flow may be captured with a large, intact plastic bag. Volume can be determined by pouring captured water from the bag into volumetric containers.

Use a stopwatch to measure the total time required to fill the container. Record the volume of water (nearest 5 mL) and fill time (nearest 0.01 sec). The desired fill time is between 10 and 60 seconds; adjust the container size accordingly, if possible. Repeat this measurement a minimum of three times. The desired precision is that all measurements are within 2% of each other (e.g., if the fill time is 60 seconds, each sample should be within 1.2 seconds of each other). Up to 10% precision is acceptable. Sites that cannot be reliably measured in the desired 10-60 second interval may not meet these precision goals and should be evaluated individually. Calculate the average fill time when back in the office.

Figure 1. Example volumetric measurement using a temporary weir and bucket.

Figure 2. Example volumetric measurement using a pipe and bucket.

Stage

At limnocrene springs that under normal conditions have pooled water but no flow, measure the distance from a fixed reference marker such as an embedded object in a cliff wall or a permanent staff gage to the surface of the water. Currently stage is recorded at two springs in HOVE. See each site's access document for site-specific instructions. Record stage to the nearest tenth of a centimeter.

Piezometer

At Square Tower Spring at HOVE, measure the depth to water from the top of the piezometer casing. Remove the cap from the piezometer. Wait until de-pressurized water level has stabilized, usually 10-15 minutes. Rub chalk or silt on a steel measuring tape to the 1 m mark. Insert the measuring tape into the piezometer until the 1 m (100 cm) mark is level with the top of the piezometer casing. Remove the measuring tape and record the mark at which water has washed off the chalk or silt (nearest 0.1 cm).

Subtract the measurement from 100 to record the depth to water (nearest 0.1 cm). . Take two additional measurements in the same manner to ensure that the water level is stable (within 0.5 cm and not continuing to move in one direction). Measure from a small notch on the top of the casing to the ground surface (nearest 0.1 cm).

Water Quality

Water temperature (°C), pH, and specific conductance (µS/cm) are determined in the field using a Hanna Combo Waterproof Tester or more accurate field water quality meter (Table 1). Equipment manufacturer, model, and serial number should be documented on each datasheet. Complete instructions for this equipment can be obtained from the manufacturers' website and are available in electronic format on the NCPN server. The crew leader or person responsible for water quality measurements should be thoroughly familiar with all equipment and software prior to going into the field. Prior to each sampling trip, the crew leader must ensure that all equipment needed for water quality measurements is in working order.

Table 1. Minimum accuracy requirements for water quality instruments and acceptable calibration ranges for core parameters.

Measure	Instrument Accuracy	Acceptable Calibration Range
Temperature	± 0.5°C	± 1°C
pH	± 0.05	± 0.3
Specific conductance	± 2%	± 2%

All water quality instruments should be field calibrated at least once per day or if environmental conditions change extremely. Record the date and time of the most recent calibration on the datasheet. These basic steps for instrument calibration should be followed.

a. Cool standards to ambient water temperature by immersing in spring-water for 5-15 minutes.

b. Calibrate pH via 2-point method (7.01 and 10.01) as per instructions in the appropriate operator's manual. Instructions for the Hanna Combo Tester are below.
- Rinse the probe and a small beaker or cup two times with 7.01 pH calibration solution.
- Pour enough 7.01 calibration solution into a small beaker or cup to cover the instrument's sensors.
- Select the pH mode with Set/Hold button. Immerse the sensors in the calibration solution. Take an initial reading and record the reported pH and water temperature on the datasheet.
- Press and hold the Mode button until CAL is displayed. Wait until the instrument stabilizes and prompts you to switch calibration solutions.
- Rinse the probe and calibration beaker or cup two times with the 10.01 pH calibration solution.
- Pour enough 10.01 calibration solution into a small beaker or cup to cover the instrument's sensors. Immerse the sensors in the solution, and the instrument automically completes the calibration.
- When the instrument returns to Measurement mode, take a post-calibration reading and record the reported pH and water temperature on the datasheet. If the post-calibration reading is not within 0.3 pH of the calibration standard (9.71-10.31), re-calibrate the instrument.

c. Calibrate conductivity as per instructions in the appropriate operator's manual.
- Rinse the probe and a small beaker or cup two times with 1413 µS/cm calibration solution.
- Pour enough 1413 µS/cm calibration solution into a small beaker or cup to cover the instrument's sensors.
- Select the EC mode with Set/Hold button. Immerse the sensors in the calibration solution. Take an initial reading and record the reported specific conductance and water temperature on the datasheet.

- Press and hold the Mode button until CAL is displayed. The instrument automatically completes the calibration
- When the instrument returns to Measurement mode, take a post-calibration reading and record the reported specific conductance and water temperature on the datasheet. If the post-calibration reading is not within 28 µS/cm of the calibration standard (1385-1441), re-calibrate the instrument.

d. Dispose of used calibration solutions well away from the spring-water, preferably on bare ground. Rinse the probe twice with spring-water prior to immersing in the spring.

- Field water-quality measurements from flowing water spring sites should be taken as close to the orifice as possible. Consult the site's access document for the measurement location for each site. The same water quality measurement site should be used at each visit unless geomorphic change at the site necessitates that a different site be selected. Ideally the water quality measurement location will have uniform flow, stable bottom conditions, and water will be well mixed along the flow path. If the water is too shallow for a probe, a clean beaker may be rinsed three times with the spring water, then placed in the flow stream. Allow the beaker to fill and overflow, then place the water quality probe into the flowing water captured in the beaker. Measurement conditions should be noted in the *Water Quality Field Measurements: Comments and description* field. Water quality measurements should be taken upstream from the flow measurement site or prior to the flow measurement.

- Field water-quality measurements from still water or pooled sites are taken at the same measurement site at each visit. Consult each site's access document for the measurement location.

After the optimum sample location at a spring has been determined, the crewmember responsible for water quality sampling should place the instrument in the water, being careful to avoid direct contact of probes with bottom substrates. The water quality sample location should be described in detail on the datasheet and should be identified on the site sketch map.

a. Place the water quality instrument in water and allow it to equilibrate for several minutes (5 at a minimum).
b. After the instrument has equilibrated record at least three measurements. If using a Hanna Combo Tester, wait at least one minute between readings to ensure that readings have stabilized. If readings continue to change rapidly or in one direction, the instrument has not equilibrated. Wait an additional five minutes and try again.
c. Record measurement time and values, including temperature, on the hydrology datasheet.

The median reading for each parameter is entered into the water quality database. If no water quality measurements can be taken, describe why in the comments field (e.g., no surface water present, instrument malfunction, etc.).

Major disturbance

Indicate whether a major disturbance has occurred (fire, severe flooding, catastrophic rock fall, etc.), necessitating a new sketch map and vegetation characterization.

Fecal coliform sampling

Fecal coliform samples should be collected prior to or upstream of any other activity that disturbs the spring substrate. Record the time the sample is collected and immediately place on ice. The iced sample must be processed within 8 hours of collection. NCPN uses the IDEXX Colilert - Quantitray/2000 method:

At the field site

a. Collect a 100-mL sample of source water in the appropriate sterile sample bottle, being careful to avoid touching the rim or inside of the bottle or including sediment in the sample. Collect a duplicate sample, if scheduled.
b. Immediately place the sample(s) on ice in an insulated carrier.
c. Record the time the sample was collected on the datasheet.

At the field site or vehicle:

a. If a field blank is scheduled, label a sample bottle and pour distilled or deionized water into it, being careful to avoid touching the rim or inside of the bottle.
b. Immediately place the sample(s) on ice in an insulated carrier or cooler.
c. Record the time on the datasheet.

At the vehicle or office

a. As soon as possible after sample collection (maximum 8 hours), preheat the incubator to 35°C and turn on the Quantitray sealer. Remove the bacteria samples from ice and allow them to warm to air temperature.
b. Using gloved hands, carefully remove the lid from the sample bottle(s). Add one snap-pack of Colilert reagent per bottle, being careful not to touch the rim or inside of the bottle with your hands or the snap-pack. Gently shake the bottle until the reagent has dissolved.
c. Label a Quantitray for each sample with the sample name, date, and incubation start time. Record the sample bottle, reagent, and Quantitray expiration dates on the datasheet.
d. Pour the 100-mL sample into the Quantitray. Tap the small wells at the bottom of the tray several times to release trapped air bubbles.
e. Once the sealer is heated and the green light is on, place the unsealed Quantitray into the rubber tray and run it through the sealer. Immediately place the sealed Quantitray into the warmed incubator.
f. Allow samples to incubate at 34 – 36.5º C for 24 hours. If samples are pale yellow, put them back in the incubator for up to four hours prior to reading. Do not exceed the 4 hour limit, for a total of 28 hours of incubation.
g. Using an IDEXX comparator, separately count the number of large and small wells that are more yellow than the comparator. Record these numbers in the Total Coliform cells on the datasheet.
h. Using a blacklight in a darkened room, separately count the number of large and small wells that fluoresce under UV light. Record these numbers in the E. coli cells on the datasheet.
i. Use the look-up tables to determine the Most Probable Number (MPN) based on the count of large and small wells (Appendix A).

Quality Assurance/Quality Control for fecal coliform sampling

One duplicate and one field blank will be analyzed for 10% of samples or once per month, whichever is more frequent. A duplicate sample should be collected from source water at the same time and treated in the same way as a regular sample. A field blank uses distilled or deionized water treated in the same manner as a regular sample (kept on ice and processed with other samples). Field blank sample bottles may be filled at the sample site or at the vehicle.

Holding times (on ice) of samples may not exceed 8 hours prior to processing.

NCPN uses a portable incubator that does not maintain temperatures as well as a wall incubator. For this reason, an acceptable temperature range for our sampling is 34 – 36.5º C (IDEXX technical support 7/27/12). At temperatures below 34° the bacteria will not grow as expected, resulting in false negatives. At temperatures above 38° the cell walls of the bacteria begin to break down, also compromising results.

Samples must incubate for at least 24 hours (18 hours if using Colilert-18) prior to being read. If samples are pale yellow, put them back in the incubator for up to four hours prior to reading. Do not exceed the 4 hour limit.

If NCPN sampling is consistently above chronic or acute *E. coli* water quality standards, contact the Utah Department of Environmental Quality to develop a "hotspot" sampling approach. For compliance purposes, Utah QA procedures are more stringent than NCPN's screening procedures and include analyzing field blanks every day of sampling, taking triplicate samples, and maintaining an incubator temperature of 34.5 – 35.5°C.

Disposing of fecal coliform samples and materials
Used trays can be delivered to the Utah Department of Environmental Quality for batch sterilization.

Appendix A. IDEXX Most Probable Number (MPN) look-up table.

IDEXX Quanti-Tray®/2000 MPN Table *(per 100ml)*

# Large Wells Positive	# Small Wells Positive																								
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	<1	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.1	15.1	16.1	17.1	18.1	19.1	20.2	21.2	22.2	23.3	24.3
1	1.0	2.0	3.0	4.0	5.0	6.0	7.1	8.1	9.1	10.1	11.1	12.1	13.2	14.2	15.2	16.2	17.3	18.3	19.3	20.4	21.4	22.4	23.5	24.5	25.6
2	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.2	10.2	11.2	12.2	13.3	14.3	15.4	16.4	17.4	18.5	19.5	20.6	21.6	22.7	23.7	24.8	25.8	26.9
3	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.3	11.3	12.4	13.4	14.5	15.5	16.5	17.6	18.6	19.7	20.8	21.8	22.9	23.9	25.0	26.1	27.1	28.2
4	4.1	5.2	6.2	7.2	8.3	9.3	10.4	11.4	12.5	13.5	14.6	15.6	16.7	17.8	18.8	19.9	21.0	22.0	23.1	24.2	25.3	26.3	27.4	28.5	29.6
5	5.2	6.3	7.3	8.4	9.4	10.5	11.5	12.6	13.7	14.7	15.8	16.9	17.9	19.0	20.1	21.2	22.2	23.3	24.4	25.5	26.6	27.7	28.8	29.9	31.0
6	6.3	7.4	8.4	9.5	10.6	11.6	12.7	13.8	14.9	16.0	17.0	18.1	19.2	20.3	21.4	22.5	23.6	24.7	25.8	26.9	28.0	29.1	30.2	31.3	32.4
7	7.5	8.5	9.6	10.7	11.8	12.8	13.9	15.0	16.1	17.2	18.3	19.4	20.5	21.6	22.7	23.8	24.9	26.0	27.1	28.3	29.4	30.5	31.6	32.8	33.9
8	8.6	9.7	10.8	11.9	13.0	14.1	15.2	16.3	17.4	18.5	19.6	20.7	21.8	22.9	24.1	25.2	26.3	27.4	28.6	29.7	30.8	32.0	33.1	34.3	35.4
9	9.8	10.9	12.0	13.1	14.2	15.3	16.4	17.6	18.7	19.8	20.9	22.0	23.2	24.3	25.4	26.6	27.7	28.9	30.0	31.2	32.3	33.5	34.6	35.8	37.0
10	11.0	12.1	13.2	14.4	15.5	16.6	17.7	18.9	20.0	21.1	22.3	23.4	24.6	25.7	26.9	28.0	29.2	30.3	31.5	32.7	33.8	35.0	36.2	37.4	38.6
11	12.2	13.4	14.5	15.6	16.8	17.9	19.1	20.2	21.4	22.5	23.7	24.8	26.0	27.2	28.3	29.5	30.7	31.9	33.0	34.2	35.4	36.6	37.8	39.0	40.2
12	13.5	14.6	15.8	16.9	18.1	19.3	20.4	21.6	22.8	23.9	25.1	26.3	27.5	28.6	29.8	31.0	32.2	33.4	34.6	35.8	37.0	38.2	39.5	40.7	41.9
13	14.8	16.0	17.1	18.3	19.5	20.6	21.8	23.0	24.2	25.4	26.6	27.8	29.0	30.2	31.4	32.6	33.8	35.0	36.2	37.5	38.7	39.9	41.2	42.4	43.6
14	16.1	17.3	18.5	19.7	20.9	22.1	23.3	24.5	25.7	26.9	28.1	29.3	30.5	31.7	33.0	34.2	35.4	36.7	37.9	39.1	40.4	41.6	42.9	44.2	45.4
15	17.5	18.7	19.9	21.1	22.3	23.5	24.7	25.9	27.2	28.4	29.6	30.9	32.1	33.3	34.6	35.8	37.1	38.4	39.6	40.9	42.2	43.4	44.7	46.0	47.3
16	18.9	20.1	21.3	22.6	23.8	25.0	26.2	27.5	28.7	30.0	31.2	32.5	33.7	35.0	36.3	37.5	38.8	40.1	41.4	42.7	44.0	45.3	46.6	47.9	49.2
17	20.3	21.6	22.8	24.1	25.3	26.6	27.8	29.1	30.3	31.6	32.9	34.1	35.4	36.7	38.0	39.3	40.6	41.9	43.2	44.5	45.9	47.2	48.5	49.8	51.2
18	21.8	23.1	24.3	25.6	26.9	28.1	29.4	30.7	32.0	33.3	34.6	35.9	37.2	38.5	39.8	41.1	42.4	43.8	45.1	46.5	47.8	49.2	50.5	51.9	53.2
19	23.3	24.6	25.9	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6	39.0	40.3	41.6	43.0	44.3	45.7	47.1	48.4	49.8	51.2	52.6	54.0	55.4
20	24.9	26.2	27.5	28.8	30.1	31.5	32.8	34.1	35.4	36.8	38.1	39.5	40.8	42.2	43.6	44.9	46.3	47.7	49.1	50.5	51.9	53.3	54.7	56.1	57.6
21	26.5	27.9	29.2	30.5	31.8	33.2	34.5	35.9	37.3	38.6	40.0	41.4	42.8	44.1	45.5	46.9	48.4	49.8	51.2	52.6	54.1	55.5	56.9	58.4	59.9
22	28.2	29.5	30.9	32.3	33.6	35.0	36.4	37.7	39.1	40.5	41.9	43.3	44.8	46.2	47.6	49.0	50.5	51.9	53.4	54.8	56.3	57.8	59.3	60.8	62.3
23	29.9	31.3	32.7	34.1	35.5	36.8	38.3	39.7	41.1	42.5	43.9	45.4	46.8	48.3	49.7	51.2	52.7	54.2	55.6	57.1	58.6	60.2	61.7	63.2	64.7
24	31.7	33.1	34.5	35.9	37.3	38.8	40.2	41.7	43.1	44.6	46.0	47.5	49.0	50.5	52.0	53.5	55.0	56.5	58.0	59.5	61.1	62.6	64.2	65.8	67.3
25	33.6	35.0	36.4	37.9	39.3	40.8	42.2	43.7	45.2	46.7	48.2	49.7	51.2	52.7	54.3	55.8	57.3	58.9	60.5	62.0	63.6	65.2	66.8	68.4	70.0
26	35.5	36.9	38.4	39.9	41.4	42.8	44.3	45.9	47.4	48.9	50.4	52.0	53.5	55.1	56.7	58.2	59.8	61.4	63.0	64.7	66.3	67.9	69.6	71.2	72.9
27	37.4	38.9	40.4	42.0	43.5	45.0	46.5	48.1	49.6	51.2	52.8	54.4	56.0	57.6	59.2	60.8	62.4	64.1	65.7	67.4	69.1	70.8	72.5	74.2	75.9
28	39.5	41.0	42.6	44.1	45.7	47.3	48.8	50.4	52.0	53.6	55.2	56.9	58.5	60.2	61.8	63.5	65.2	66.9	68.6	70.3	72.0	73.7	75.5	77.3	79.0
29	41.7	43.2	44.8	46.4	48.0	49.6	51.2	52.8	54.5	56.1	57.8	59.5	61.2	62.9	64.6	66.3	68.0	69.8	71.5	73.3	75.1	76.9	78.7	80.5	82.4
30	43.9	45.5	47.1	48.7	50.4	52.0	53.7	55.4	57.1	58.8	60.5	62.2	64.0	65.7	67.5	69.3	71.0	72.9	74.7	76.5	78.3	80.2	82.1	84.0	85.9
31	46.2	47.9	49.5	51.2	52.9	54.6	56.3	58.1	59.8	61.6	63.3	65.1	66.9	68.7	70.5	72.4	74.2	76.1	78.0	79.9	81.8	83.7	85.7	87.6	89.6
32	48.7	50.4	52.1	53.8	55.6	57.3	59.1	60.9	62.7	64.5	66.3	68.2	70.0	71.9	73.8	75.7	77.6	79.5	81.5	83.5	85.4	87.5	89.5	91.5	93.6
33	51.2	53.0	54.8	56.5	58.3	60.2	62.0	63.8	65.7	67.6	69.5	71.4	73.3	75.2	77.2	79.2	81.2	83.2	85.2	87.3	89.3	91.4	93.6	95.7	97.8
34	53.9	55.7	57.6	59.4	61.3	63.1	65.0	67.0	68.9	70.8	72.8	74.8	76.8	78.8	80.8	82.9	85.0	87.1	89.2	91.4	93.5	95.7	97.9	100.2	102.4
35	56.8	58.6	60.5	62.4	64.4	66.3	68.3	70.3	72.3	74.3	76.3	78.4	80.5	82.6	84.7	86.9	89.1	91.3	93.5	95.7	98.0	100.3	102.6	105.0	107.3
36	59.8	61.7	63.7	65.7	67.7	69.7	71.7	73.8	75.9	78.0	80.1	82.3	84.5	86.7	88.9	91.2	93.5	95.8	98.1	100.5	102.9	105.3	107.7	110.2	112.7
37	62.9	65.0	67.0	69.1	71.2	73.3	75.4	77.6	79.8	82.0	84.2	86.5	88.8	91.1	93.4	95.8	98.2	100.6	103.1	105.6	108.1	110.7	113.3	115.9	118.6
38	66.3	68.4	70.6	72.7	74.9	77.1	79.4	81.6	83.9	86.2	88.6	91.0	93.4	95.8	98.3	100.8	103.4	105.9	108.6	111.2	113.9	116.6	119.4	122.2	125.0
39	70.0	72.2	74.4	76.7	78.9	81.3	83.6	86.0	88.4	90.9	93.4	95.9	98.4	101.0	103.6	106.3	109.0	111.8	114.6	117.4	120.3	123.2	126.1	129.2	132.2
40	73.8	76.2	78.5	80.9	83.3	85.7	88.2	90.8	93.3	95.9	98.5	101.2	103.9	106.7	109.5	112.4	115.3	118.2	121.2	124.3	127.4	130.5	133.7	137.0	140.3
41	78.0	80.5	83.0	85.5	88.0	90.6	93.3	95.9	98.7	101.4	104.3	107.1	110.0	113.0	116.0	119.1	122.2	125.4	128.7	132.0	135.4	138.8	142.3	145.9	149.5
42	82.6	85.2	87.8	90.5	93.2	96.0	98.8	101.7	104.6	107.6	110.6	113.7	116.9	120.1	123.4	126.7	130.1	133.6	137.2	140.8	144.5	148.3	152.2	156.1	160.2
43	87.6	90.4	93.2	96.0	99.0	101.9	105.0	108.1	111.2	114.5	117.8	121.1	124.6	128.1	131.7	135.4	139.1	143.0	147.0	151.0	155.2	159.4	163.8	168.2	172.8
44	93.1	96.1	99.1	102.2	105.4	108.6	111.9	115.3	118.7	122.3	125.9	129.6	133.4	137.4	141.4	145.5	149.7	154.1	158.5	163.1	167.9	172.7	177.7	182.9	188.2
45	99.3	102.5	105.8	109.2	112.6	116.2	119.8	123.6	127.4	131.4	135.4	139.6	143.9	148.3	152.9	157.6	162.4	167.4	172.6	178.0	183.5	189.2	195.1	201.2	207.5
46	106.3	109.8	113.4	117.2	121.0	125.0	129.1	133.3	137.6	142.1	146.7	151.5	156.5	161.6	167.0	172.5	178.2	184.2	190.4	196.8	203.5	210.5	217.8	225.4	233.3
47	114.3	118.3	122.4	126.6	130.9	135.4	140.1	145.0	150.0	155.3	160.7	166.4	172.3	178.5	185.0	191.8	198.9	206.4	214.2	222.4	231.0	240.0	249.5	259.5	270.0
48	123.9	128.4	133.1	137.9	143.0	148.3	153.9	159.7	165.8	172.2	178.9	186.0	193.5	201.4	209.8	218.7	228.2	238.2	248.9	260.3	272.3	285.1	298.7	313.0	328.2
49	135.5	140.8	146.4	152.3	158.5	165.0	172.0	179.3	187.2	195.6	204.6	214.3	224.7	235.9	248.1	261.3	275.5	290.9	307.6	325.5	344.8	365.4	387.3	410.6	435.2

09-63235-01

IDEXX Quanti-Tray®/2000 MPN Table (*per 100ml*)

# Large Wells Positive	# Small Wells Positive																							
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
0	25.3	26.4	27.4	28.4	29.5	30.5	31.5	32.6	33.6	34.7	35.7	36.8	37.8	38.9	40.0	41.0	42.1	43.1	44.2	45.3	46.3	47.4	48.5	49.5
1	26.6	27.7	28.7	29.8	30.8	31.9	32.9	34.0	35.0	36.1	37.2	38.2	39.3	40.4	41.4	42.5	43.6	44.7	45.7	46.8	47.9	49.0	50.1	51.2
2	27.9	29.0	30.0	31.1	32.2	33.2	34.3	35.4	36.5	37.5	38.6	39.7	40.8	41.9	43.0	44.0	45.1	46.2	47.3	48.4	49.5	50.6	51.7	52.8
3	29.3	30.4	31.4	32.5	33.6	34.7	35.8	36.8	37.9	39.0	40.1	41.2	42.3	43.4	44.5	45.6	46.7	47.8	48.9	50.0	51.2	52.3	53.4	54.5
4	30.7	31.8	32.8	33.9	35.0	36.1	37.2	38.3	39.4	40.5	41.6	42.8	43.9	45.0	46.1	47.2	48.3	49.5	50.6	51.7	52.9	54.0	55.1	56.3
5	32.1	33.2	34.3	35.4	36.5	37.6	38.7	39.9	41.0	42.1	43.2	44.4	45.5	46.6	47.7	48.9	50.0	51.2	52.3	53.5	54.6	55.8	56.9	58.1
6	33.5	34.7	35.8	36.9	38.0	39.2	40.3	41.4	42.6	43.7	44.8	46.0	47.1	48.3	49.4	50.6	51.7	52.9	54.1	55.2	56.4	57.6	58.7	59.9
7	35.0	36.2	37.3	38.4	39.6	40.7	41.9	43.0	44.2	45.3	46.5	47.7	48.8	50.0	51.2	52.3	53.5	54.7	55.9	57.1	58.3	59.4	60.6	61.8
8	36.6	37.7	38.9	40.0	41.2	42.3	43.5	44.7	45.9	47.0	48.2	49.4	50.6	51.8	53.0	54.1	55.3	56.5	57.7	59.0	60.2	61.4	62.6	63.8
9	38.1	39.3	40.5	41.6	42.8	44.0	45.2	46.4	47.6	48.8	50.0	51.2	52.4	53.6	54.8	56.0	57.2	58.4	59.7	60.9	62.1	63.4	64.6	65.8
10	39.7	40.9	42.1	43.3	44.5	45.7	46.9	48.1	49.3	50.6	51.8	53.0	54.2	55.5	56.7	57.9	59.2	60.4	61.7	62.9	64.2	65.4	66.7	67.9
11	41.4	42.6	43.8	45.0	46.3	47.5	48.7	49.9	51.2	52.4	53.7	54.9	56.1	57.4	58.6	59.9	61.2	62.4	63.7	65.0	66.3	67.5	68.8	70.1
12	43.1	44.3	45.6	46.8	48.1	49.3	50.6	51.8	53.1	54.3	55.6	56.8	58.1	59.4	60.7	62.0	63.2	64.5	65.8	67.1	68.4	69.7	71.0	72.4
13	44.9	46.1	47.4	48.6	49.9	51.2	52.5	53.7	55.0	56.3	57.6	58.9	60.2	61.5	62.8	64.1	65.4	66.7	68.0	69.3	70.7	72.0	73.3	74.7
14	46.7	48.0	49.3	50.5	51.8	53.1	54.4	55.7	57.0	58.3	59.6	60.9	62.3	63.6	64.9	66.3	67.6	68.9	70.3	71.6	73.0	74.4	75.7	77.1
15	48.6	49.9	51.2	52.5	53.8	55.1	56.4	57.8	59.1	60.4	61.8	63.1	64.5	65.8	67.2	68.5	69.9	71.3	72.6	74.0	75.4	76.8	78.2	79.6
16	50.5	51.8	53.2	54.5	55.8	57.2	58.5	59.9	61.2	62.6	64.0	65.3	66.7	68.1	69.5	70.9	72.3	73.7	75.1	76.5	77.9	79.3	80.8	82.2
17	52.5	53.9	55.2	56.6	58.0	59.3	60.7	62.1	63.5	64.9	66.3	67.7	69.1	70.5	71.9	73.3	74.8	76.2	77.6	79.1	80.5	82.0	83.5	84.9
18	54.6	56.0	57.4	58.8	60.2	61.6	63.0	64.4	65.8	67.2	68.6	70.1	71.5	73.0	74.4	75.9	77.3	78.8	80.3	81.8	83.3	84.8	86.3	87.8
19	56.8	58.2	59.6	61.0	62.4	63.9	65.3	66.8	68.2	69.7	71.1	72.6	74.1	75.5	77.0	78.5	80.0	81.5	83.1	84.6	86.1	87.6	89.2	90.7
20	59.0	60.4	61.9	63.3	64.8	66.3	67.7	69.2	70.7	72.2	73.7	75.2	76.7	78.2	79.8	81.3	82.8	84.4	85.9	87.5	89.1	90.7	92.2	93.8
21	61.3	62.8	64.3	65.8	67.3	68.8	70.3	71.8	73.3	74.9	76.4	77.9	79.5	81.1	82.6	84.2	85.8	87.4	89.0	90.6	92.2	93.8	95.4	97.1
22	63.8	65.3	66.8	68.3	69.8	71.4	72.9	74.5	76.1	77.6	79.2	80.8	82.4	84.0	85.6	87.2	88.9	90.5	92.1	93.8	95.5	97.1	98.8	100.5
23	66.3	67.8	69.4	71.0	72.5	74.1	75.7	77.3	78.9	80.5	82.2	83.8	85.4	87.1	88.7	90.4	92.1	93.8	95.5	97.2	98.9	100.6	102.4	104.1
24	68.9	70.5	72.1	73.7	75.3	77.0	78.6	80.3	81.9	83.6	85.2	86.9	88.6	90.3	92.0	93.8	95.5	97.2	99.0	100.7	102.5	104.3	106.1	107.9
25	71.7	73.3	75.0	76.6	78.3	80.0	81.7	83.3	85.1	86.8	88.5	90.2	92.0	93.7	95.5	97.3	99.1	100.9	102.7	104.5	106.3	108.2	110.0	111.9
26	74.6	76.3	78.0	79.7	81.4	83.1	84.8	86.6	88.4	90.1	91.9	93.7	95.5	97.3	99.2	101.0	102.9	104.7	106.6	108.5	110.4	112.3	114.2	116.2
27	77.6	79.4	81.1	82.9	84.6	86.4	88.2	90.0	91.9	93.7	95.5	97.4	99.3	101.2	103.1	105.0	106.9	108.8	110.8	112.7	114.7	116.7	118.7	120.7
28	80.8	82.6	84.4	86.3	88.1	89.9	91.8	93.7	95.6	97.5	99.4	101.3	103.3	105.2	107.2	109.2	111.2	113.2	115.2	117.3	119.3	121.4	123.5	125.6
29	84.2	86.1	87.9	89.8	91.7	93.7	95.6	97.5	99.5	101.5	103.5	105.5	107.5	109.5	111.6	113.7	115.7	117.8	120.0	122.1	124.2	126.4	128.6	130.8
30	87.8	89.7	91.7	93.6	95.6	97.6	99.6	101.6	103.7	105.7	107.8	109.9	112.0	114.2	116.3	118.5	120.6	122.8	125.1	127.3	129.5	131.8	134.1	136.4
31	91.6	93.6	95.6	97.7	99.7	101.8	103.9	106.0	108.2	110.3	112.5	114.7	116.9	119.1	121.4	123.6	125.9	128.2	130.5	132.9	135.3	137.7	140.1	142.5
32	95.7	97.8	99.9	102.0	104.2	106.3	108.5	110.7	113.0	115.2	117.5	119.8	122.1	124.5	126.8	129.2	131.6	134.0	136.5	139.0	141.5	144.0	146.6	149.1
33	100.0	102.2	104.4	106.6	108.9	111.2	113.5	115.8	118.2	120.5	122.9	125.4	127.8	130.3	132.8	135.3	137.8	140.4	143.0	145.6	148.3	150.9	153.7	156.4
34	104.7	107.0	109.3	111.7	114.0	116.4	118.9	121.3	123.8	126.3	128.8	131.4	134.0	136.6	139.2	141.9	144.6	147.4	150.1	152.9	155.7	158.6	161.5	164.4
35	109.7	112.2	114.6	117.1	119.6	122.2	124.7	127.3	129.9	132.6	135.3	138.0	140.8	143.6	146.4	149.2	152.1	155.0	158.0	161.0	164.0	167.1	170.2	173.3
36	115.2	117.8	120.4	123.0	125.7	128.4	131.1	133.9	136.7	139.5	142.4	145.3	148.3	151.3	154.3	157.3	160.5	163.6	166.8	170.0	173.3	176.6	179.9	183.3
37	121.3	124.0	126.8	129.6	132.4	135.3	138.2	141.2	144.2	147.3	150.3	153.5	156.7	159.9	163.1	166.5	169.8	173.2	176.7	180.2	183.7	187.3	191.0	194.7
38	127.9	130.8	133.8	136.8	139.9	143.0	146.2	149.4	152.6	155.9	159.2	162.6	166.1	169.6	173.2	176.8	180.4	184.2	188.0	191.8	195.7	199.7	203.7	207.7
39	135.3	138.5	141.7	145.0	148.3	151.7	155.1	158.6	162.1	165.7	169.4	173.1	176.9	180.7	184.7	188.7	192.7	196.8	201.0	205.3	209.6	214.0	218.5	223.0
40	143.7	147.1	150.6	154.2	157.8	161.5	165.3	169.1	173.0	177.0	181.1	185.2	189.4	193.7	198.1	202.5	207.1	211.7	216.4	221.1	226.0	231.0	236.0	241.1
41	153.2	157.0	160.9	164.8	168.9	173.0	177.2	181.5	185.8	190.3	194.8	199.5	204.2	209.1	214.0	219.1	224.2	229.4	234.8	240.2	245.8	251.5	257.2	263.1
42	164.3	168.6	172.9	177.3	181.9	186.5	191.3	196.1	201.1	206.2	211.4	216.7	222.2	227.7	233.4	239.2	245.2	251.3	257.5	263.8	270.3	276.9	283.6	290.5
43	177.5	182.3	187.3	192.4	197.6	202.9	208.4	214.0	219.8	225.8	231.8	238.1	244.5	251.0	257.7	264.6	271.7	278.9	286.3	293.8	301.5	309.4	317.4	325.7
44	193.6	199.3	205.1	211.0	217.2	223.5	230.0	236.7	243.6	250.8	258.1	265.6	273.3	281.2	289.4	297.8	306.3	315.1	324.1	333.3	342.8	352.4	362.3	372.4
45	214.1	220.9	227.9	235.2	242.7	250.4	258.4	266.7	275.3	284.1	293.3	302.6	312.3	322.3	332.5	343.0	353.8	364.9	376.2	387.9	399.8	412.0	424.5	437.4
46	241.5	250.0	258.9	268.2	277.8	287.8	298.1	308.8	319.9	331.4	343.3	355.5	368.1	381.1	394.5	408.3	422.5	437.1	452.0	467.4	483.3	499.6	516.3	533.5
47	280.9	292.4	304.4	316.9	330.0	343.6	357.8	372.5	387.7	403.4	419.8	436.6	454.1	472.1	490.7	509.9	529.8	550.4	571.7	593.8	616.7	640.5	665.3	691.0
48	344.1	360.9	378.4	396.8	416.0	436.0	456.9	478.6	501.2	524.7	549.3	574.8	601.5	629.4	658.6	689.3	721.5	755.6	791.5	829.7	870.4	913.9	960.6	1011.2
49	461.1	488.4	517.2	547.5	579.4	613.1	648.8	686.7	727.0	770.1	816.4	866.4	920.8	980.4	1046.2	1119.9	1203.3	1299.7	1413.6	1553.1	1732.9	1986.3	2419.6	>2419.6

09-63235-01

NCPN Springs Monitoring Protocol SOP 5 Hydrology v. 1.00

Park Code: **Site Name:** **Date:**

Observer(s): **Air Temp (°C):**

Current Conditions: No rain Mist/fog Drizzle Light rain Heavy rain Snow

Cloud cover (%): **Water color:**

Precipitation dates and est. amounts in previous week:

Water Quantity Field Measurements

Measurable discharge: Y N **Severity:** Dry No flow Normal Flood

Volumetric

Documenting stable pool	**Time**	**Depth**
At tape placement:		
Before measurement:		
After measurement:		

Time	**vol(mL)**	**time (s)**	**estimated % loss**

Pool Surface Elevation

Time	**stage (m)**

Piezometer

Time piezometer uncapped: **Depth to ground surface (cm):**

Piezo # / Time	**Tape cut**	**Tape reading**	**Depth to water (ft)**	**Depth to water (cm)**

Water quantity comments and description of where measurement was taken:

Water Quality Instrument Calibration **Instrument:**

Calibration Date: **Calibration Time:** **Calibration Location:**

Parameter	**Standard**	**Initial Reading**	**Temp (°C)**	**Calibrated Reading**	**Temp (°C)**
pH 7.01					
pH 10.01					
spCond	1413				

Comments on calibration:

Water Quality Field Measurements **Taken?** Y N

Mixing: well moderately well poorly **Flow:** flowing still/pooled

Time	**Depth (cm)**	**pH**	**spCond (µS/cm)**	**Water Temp (°C)**	**DO (mg/L)**

Water quality comments and description of where measurements taken:

Fecal Coliform Sampling Incubation temp: Min (°C): Max (°C):

Sample collected? Y N **Held on ice?** Y N

	Date	**Time**		Big wells (positive)	Small wells (positive)	
Collection						**Reagent exp. date:**
Start incubation			Total coliforms			**Bottle exp. date:**
Read/analysis			E.coli			**Tray exp. date:**

2nd Sample collected? Y N **Held on ice?** Y N

Circle one: **Duplicate** **Field Blank**

	Date	**Time**		Big wells (positive)	Small wells (positive)	
Collection						**Reagent exp. date:**
Start incubation			Total coliforms			**Bottle exp. date:**
Read/analysis			E.coli			**Tray exp. date:**

Major Disturbance New sketch map and site characterization needed? Yes No

Describe:

Photos taken? Yes No

Photo notes

Park Code: ARCH **Site Name:** South Cordova Canyon **Date:** 3/19/2015

Observer(s): Mary Moran, Jared Chrisp **Air Temp:** 14.0 °C

Current conditions: No rain Mist or fog Light drizzle Light rain Heavy rain Snow **Cloud cover:** 0 %

Precipitation dates & est. amounts in previous week: None

Water Quantity Field Measurements

measurable discharge (y/n)	Water color	Visual est. of mixing
Y	clear	well

disch.method	serial #	flow value	units (C,G,M,blank)	meas type (M,E,blank)	avg veloc (ft/s, blank)	vtype (M,E,blank)
Volumetric			C	M		M

estimated discharge (cfs)	estimate type	stage (base, rising, peak or falling)	severity (dry, no flow, normal or flood)
		base	normal

Volumetric

Documenting stable pool	Time	Depth
At tape placement:		
Before measurement:		
After measurement:		

measurement	vol.(mL)	time (s)	(mL/s)	(gpm)	(cfs)	estimated % loss	adjusted flow (cfs)
1	6310	24.00	262.916			4%	
2	6300	23.28	270.619			4	
3	6548	26.50	247.094			4	
4							
5							
6							

stable flow? *average* = 0.0096 cfs

sum

Pool Surface Elevation

measurement	stage (m)	Relative pool elevation (1.5m – stage value)
1		

Flume

measurement	stage (ft)	Look up (gpm)			(cfs)	estimated % loss	adjusted flow (cfs)
1							
2							
3							
4							
5							

stable flow? *max*

Discharge comments and description of where measurement was taken:

Water Quality Instrument Calibration Instrument Make and Model: Hanna Combo Tester #4

Calibration Date: 3/19/15 Calibration Time: 12:35 Calibration Location: Cordova Springs

Parameter	Standard Value	Pre-Calibration Reading	Temperature	Post-Calibration Reading	Temperature
pH	7	7.07	13.2	----------	----------
pH	10	----------	----------	10.22	13.6
Conductivity	1413	1417	13.9	1412	13.3

Comments on calibration:

Water Quality Field Measurements

Measurements Taken? (Y/N): Y Water: (flowing) still/pooled

Time	Depth (cm)	Location	pH	Sp. Conductivity (µS/cm)*	Water Temperature (°C)	Baro. Pressure (mmHg)	Dissolved Oxygen (mg/L)
12:44	5	Typical	7.86	234	15.2		
12:51	5	Typical	7.85	234	15.2		
12:52	5	Typical	7.85	232	15.2		
		Average:					

Comments and description of where water quality measurements were taken:

Taken in over flowing cup.

Fecal Coliform Sampling Sample collected? (Y/N) Y Bacteria held at <10°C? (Y/N) Y

	Date	Time		Big wells (positive)	Small wells (positive)	
Collection	3/19/15	11:55	Total coliforms	3	0	
Start incubation	3/19/15	17:40	E. coli	0	0	
Duration held (days)				95L	MPN	95H
Read/analysis	3/20	19:05	Results			
Duration incubated (days)			Sample bottle expiration date	4/25/17		
Data credible? (Y/N)			Reagent expiration date	7/9/15		
			Quantitray expiration date	3/20/17		

2nd Sample collected? (Y/N) Y Bacteria held at <10°C? (Y/N) Y

Circle one: Duplicate (Field Blank)	Date	Time		Big wells (positive)	Small wells (positive)	
Collection	3/19	15:35	Total coliforms	0	0	
Start incubation	3/19	17:40	E. coli	0	0	
Duration held (days)				95L	MPN	95H
Read/analysis	3/20	19:05	Results			
Duration incubated (days)			Sample bottle expiration date	4/25/17		
Data credible? (Y/N)			Reagent expiration date	7/9/15		
			Quantitray expiration date	3/20/17		

Major Disturbance New sketch map and vegetation characterization needed? Yes No

If so, briefly describe disturbance:

Photos taken? Yes

Photo notes: matches

Springs Monitoring Protocol for Park Units in Aridland Networks

Standard Operating Procedure (SOP) #6

Site Condition and Repeat Photopoints

Version 1.01 (January 2020)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	1/2020	R. Weissinger	Record conditions for the total surface area	Standardize with vegetation methods change	1.01

Site condition is recorded and photo-points are taken during the initial site setup and once during the growing season in each subsequent sampling year. Site condition records the presence of target native and exotic plant and animal species, documents channel length, and estimates the percent of each geomorphic surface and the total spring area affected by different disturbances.

Site Condition

Target wildlife species

Conduct a timed search of 1 minute per 5-m^2 of surface water, up to 30 minutes total, looking for crayfish, amphibians, and fish. Record the species, if known, and life stages (i.e., egg, larvae, juvenile, adult) present. Also include descriptions of other wildlife species observed.

SEUG target wildlife species descriptions

Common Name	**Scientific Name**	**Descriptive Characteristics**
Bullfrog	*Rana catesbiana*	Smooth, wet-looking skin; very large frogs or tadpoles; eardrums larger than eyes
Leopard frog	*Rana pipiens*	Smooth, wet-looking skin; light-colored fold running from eye to hind leg; pale-bordered spots on back
Crayfish	*Orconectes* spp.	Mini lobsters

Bullfrog – Smooth, wet-looking skin; very large frogs or tadpoles; eardrums larger than eyes

Figure 1. Bullfrog, *Rana catesbiana*. Photo Wikipedia Creative Commons.

Northern leopard frog - Smooth, wet-looking skin; light-colored fold running from eye to hind leg; pale-bordered spots on back

Figure 2. Northern leopard frog, *Rana pipiens*. Photo Wikipedia Creative Commons.

Crayfish – Crustaceans that look like mini lobsters. All crayfish are exotic to SEUG.

Figure 3. Crayfish. Photo Wikipedia Creative Commons.

Target exotic plant species
Conduct a timed search of 1 minute per 5-m^2 of vegetated areas, up to 30 minutes total, looking for 1-10 target exotic species specified by park staff.

Channel Length
Record in meters (m) up to a maximum of 50m the length of the flowing channel (if it exists), along the channel thalweg, directly below the spring orifice.

Flow modification
If a flow modification is present, indicate which type, whether it is active or not, and estimate the percent of flow volume that is affected. Circle whether flow is slowed, stopped, or re-routed.

Soil erosion
Record the erosion categories present for each geomorphic surface (as determined by the site map) and record the percentage of the geomorphic surface affected by each type, using the classes defined below. Record the percentage of the total spring area affected by each type.

Erosion Category	Definition
Bank instability	Actively eroding, near vertical cut-banks along channels or pools
Rill/gully erosion	Removal of soil along drainage lines due to surface run-off
Pedestal development	Elevated surfaces within the spring perimeter that have lost connection to the groundwater level

Erosion Class	% Affected
1	>0 - 25%
2	25 - 50%
3	50 - 75%
4	75 - 100%

Other disturbances
While walking the spring perimeter and during sampling, observe signs of disturbance at the spring.

Record all disturbances present for each geomorphic surface and **within 50 meters** of the site. If the site is located in terrain where portions of the 50-m search area are inaccessible due to terrain (e.g., cliff walls), search the accessible portions only. Estimate the cover of each geomorphic surface and the total spring area affected by each disturbance using the cover classes below. Discrete disturbances can be plotted on the site map.

- If a significant disturbance not found on the list below is present, it should be recorded.
- If there is no disturbance to report, mark "none".

Common disturbances at springs.

Disturbance Type	Description
Beaver activity	Indicated by the presence of dams, slides, and characteristically chewed woody plant species.
Recent flooding	Indicated by flattened vegetation, turbidity, and debris lines. Only record flooding that appears to have occurred in the previous several days.
Recent fire	Recent fire indicated by blackened vegetation or ground surfaces. Do not include old fire scars.
Road or track	Paved, dirt, or two-track. Note whether it is presently open or closed.
Trail	Livestock or human trail. Note whether it is maintained or social.
Recreation use	Denoted by campfire rings, water source, trampling.
Livestock trampling/grazing	Indicated by the presence of livestock or livestock scat. Record species if possible.
Wildlife trampling/grazing	Significant impacts due to native or feral ungulates. Record species if possible.
Insect infestation	Tent caterpillars, grasshoppers, etc.
Exotic plant removal	Indicated by cut stumps, debris piles, dead plants, etc.

Disturbance Class	% Affected
1	< 1%
2	1-4%
3	5-9%
4	10-24%
5	25-49%
6	50- 74%
7	75-100%

Notes

Use this section to record any other notes or observations made while at the site. Record any other notes that may assist in interpreting results for the spring or describe interesting features of the spring, such as management activities noted, archeological sites, etc.

Photopoints

Photopoints are established at one or more locations at each spring. These points are revisited to document the change that occurs over time, so it is very important that their locations are described in detail so that they can be relocated in the future. It is recommended that if possible, at least one photo should be taken from above that overlooks the spring, perhaps from a nearby vantage point or accessible canyon rim. Once established, use the site map, descriptions, photos, and UTMs to accurately relocate photopoints. See Appendix A for an example packet of reference and monitoring photos.

Photopoint Establishment:

1. Write down the **Camera name, Model, and ID number**.
2. Note the name of the photographer.
3. Note the **weather conditions**, including cloud cover and wind, that could affect photo interpretation and matching.
4. Select a location to **Establish a photo point** that will be easy to find again (e.g. has permanent distinctive features and offers good views of spring features). When choosing points, think about whether vegetation is likely to grow that would obscure the view. You may establish several photopoint locations (numbered 1,2,3,etc.), from which one or more photos (views) can be taken. **Describe the location** (Location Description) in the space provided.
5. **Record the UTMs** of the photopoint using a GPS unit, if possible.
6. For the **Description** of photopoint, please be as detailed as possible, keeping in mind to include key site characteristics that are of a long-term nature (e.g. rocks, large trees). Be VERY detailed if you cannot get a GPS reading – note any major features that may help you mark the point location on the map.
7. Mark the name and location of each photopoint on the **sketch map,** if possible.
8. Use the potential solar radiation at a site and observations during the field visit to **recommend times** to take photos, preferably when the entire spring is in shade or in full sun.
9. Record the **Photo file number** (typically starts with 100-), and **Time** for each photo taken on the field form.
10. Take one or more photos with a person or an object at the photopoint to help **relocate** it. Try to include distinctive features such as the cliffline or large boulders. These are the reference photos. It is often helpful to take one or more contextual photos for the general location and a close-up photo to relocate the precise location.
11. From each photopoint, take photographs of the spring. Several views (i.e. bearings) may be taken from the same photopoint. These are repeat monitoring photos.
12. Set the appropriate declination on the compass according to the topographic map so that 0° on the compass points to true north. Facing the same direction as each photo is taken, determine and record the **bearing** of the photo in degrees. If the photo is angled up or down more than 5°, record the **angle** using a clinometer.

Repeating Photos:

1. Plan to take repeat photographs at the same time of year and, if possible, during the recommended time or at the same time of day as the original photographs.
2. Use the site map, descriptions, photos, and UTMs to accurately relocate photopoints.
3. Write down the **Camera name, Model, and ID number.**
4. Note the name of the photographer.
5. Record the **Start and End Times** bracketing when photos are taken.
6. Record the **Photo file number** (typically starts with 100-), and time for each photo taken on the field form.

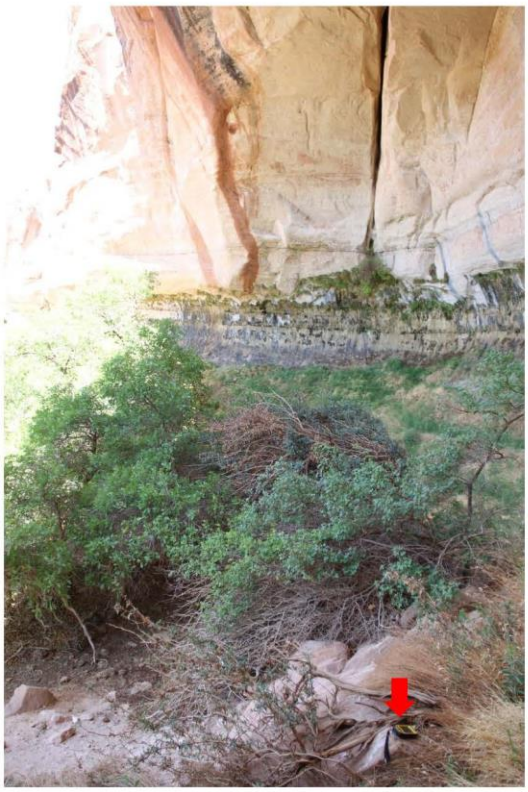
Tips for taking high quality photos:
Good default camera settings are Aperture Priority mode with an F-stop of 11, ISO 400, and automatic white balance. These settings should be sufficient for well-lit areas with bright or diffuse light. In contrasting light situations (bright sun and shade), review the photo to make sure that the spring area has the correct exposure, and adjust the exposure if needed. This may result in an over exposed sky area, but it is most important to capture the spring area well. In alcoves and deeply shaded areas, if the shutter speed is slower than $1/125^{th}$ of a second, the photo is likely to be blurry. You can increase the shutter speed by increasing the ISO. With the Canon EOS 7D, ISOs up to 3200 maintain acceptable photo quality. Alternately, a tripod can be used to obtain sharp photos with a slower shutter speed.

Appendix A. Example reference and repeat photo packet.

CorCan 3 PP1

On end of boulder/bedrock emerging from colluvial slope about 8m from eastern edge of seep near base of Mahonia fremontii

From eastern edge of colluvial slope looking west towards PP1 and cliff/backwall



PP1 - 258°, 14:20, before 11:00

PP1 - 281°, 14:20 , before 11:00

3

PP1 - 290°, 14:20 , before 11:00

PP1 - 308°, 14:20 , before 11:00

4

PP1 - 114°, 11:00 , before 11:00

6

NCPN Springs Monitoring Site Condition Datasheet - v. 1.00

Site Name: **Park** **Date** **Observer**

Wildlife and Exotic Plant Species	
Amphibians: Present Not Observed Species:	**Fish:** Present Not Observed Species:
Exotic Plants: Present Not Observed Species:	**Crayfish:** Present Not Observed

Channel and Flow Modifications
Flowing Channel Length (m) – up to 50m from orifice _____
Flow Modification *(circle all appropriate)*: none pipe diversion dam diversion open trough/tank pumping encasement excavation sealed cracks other
Is Modification **Active** (*circle*) Y N **% Flow Affected** _____ Slowed Stopped Re-routed

	Geomorphic Surface					
Erosion						
Bank instability						
Rill/gully						
Pedestal creation						
Disturbance						
Beaver activity						
Recent flooding						
Recent fire						
Road or track						
Trail						
Recreation use						
Livestock trampling/grazing						
Wildlife trampling/grazing						
Insect infestation						
Exotic plant removal						
Other						

Notes:

Erosion Classes	
1	>0 - 25%
2	25 - 50%
3	50 - 75%
4	75 - 100%

Disturbance Classes	
1	< 1%
2	1 - 4%
3	5 - 9%
4	10 - 24%
5	25 - 49%
6	50 - 74%
7	75 - 100%

Park **Site Name:** **Date:**

Site Condition and Disturbance - Within 50m of Spring *(place an X near all appropriate)*:

	Roads/OHV trails		Recent flooding
	Hiking trails		Recent Fire
	Recreation use (campfire rings, water source, trampling)		Livestock trampling/grazing (indicated by livestock or livestock fecal matter). Record species if possible.
	Contemporary human occupation/use (campsite, structure, …)		Wildlife trampling/grazing (indicated by wildlife or wildlife fecal matter). Record species if possible.
	Historic human occupation/use		Insect disturbance (Tent caterpillars, grasshoppers, etc.)
	Pre-historic occupation/use		Exotic plant removal (Indicated by cut stumps, debris piles, dead plants, …)
	None		Other (describe):

Notes:

NCPN Springs Monitoring Site Condition Datasheet - v. 1.00

Park ARCH **Site Name:** Clolamb **Date:** 7 May 2014

Wildlife and Exotic Plant Species	
Amphibians: Present Not Observed Species:	**Fish:** Present Not Observed Species:
Exotic Plants: Present Not Observed Species:	**Crayfish:** Present Not Observed

Channel and Flow Modifications

Flowing Channel Length (m) – up to 50m from orifice Ø

Flow Modification *(circle all appropriate)*: none pipe diversion dam diversion open trough/tank pumping encasement excavation sealed cracks other

Is Modification **Active** (*circle*) Y N **% Flow Affected** _____ Slowed Stopped Re-routed

	Geomorphic Surface					
Erosion	BW	ALC 1	CS	ALC 2		
Bank instability			1			
Rill/gully						
Pedestal creation			1			
Disturbance						
Beaver activity						
Recent flooding						
Recent fire						
Road or track						
Trail						
Recreation use						
Livestock trampling/grazing old		7	5	7		
Wildlife trampling/grazing						
Insect infestation						
Exotic plant removal						
Other						

Notes:
no new disturbances noted but extensive trampling from livestock through 1980s

Erosion Classes	
1	>0 - 25%
2	25 - 50%
3	50 - 75%
4	75 - 100%

Disturbance Classes	
1	<1%
2	1 - 4%
3	5 - 9%
4	10 - 24%
5	25 - 49%
6	50 - 74%
7	75 - 100%

Park ARCH **Site Name:** Clo Can 6 **Date:** 7 May 2014

Site Condition and Disturbance - Within 50m of Spring *(place an X near all appropriate)*:

	Roads/OHV trails		Recent flooding
	Hiking trails		Recent Fire
	Recreation use (campfire rings, water source, trampling)	X	Livestock trampling/grazing (indicated by livestock or livestock fecal matter). Record species if possible. dd.
	Contemporary human occupation/use (campsite, structure, …)		Wildlife trampling/grazing (indicated by wildlife or wildlife fecal matter). Record species if possible.
	Historic human occupation/use		Insect disturbance (Tent caterpillars, grasshoppers, etc.)
X	Pre-Historic occupation/use		Exotic plant removal (Indicated by cut stumps, debris piles, dead plants, …)
	None		Other (describe):

Notes:

lots of flakes in alcove

NCPN Springs Monitoring Photo Datasheet - v. 1.00

Park Code:	**Site Name:**	**Date:**

Camera Name, Model, and ID:	**Compass Setting** (*indicate by circling setting and writing degrees if appropriate*)	**Weather and Notes:**
Photographer:	_____ Degrees Declination Magnetic North	

PhotoPoint ID	UTM - Northing	UTM - Easting	Photopoint Description	Recommended Time

PhotoPoint ID	Time	File Number	Bearing (degrees)	Angle (degrees)	Photo Description

NCPN Springs Monitoring Photo Datasheet - v. 1.00

Park Code: ARCH **Site Name:** BH1 **Date:** 4 June 2015

Camera Name, Model, and ID:	Compass Setting (*indicate by circling setting and writing degrees if appropriate*)	Weather and Notes:
Canon EOS 7D w/ 20 mm lens	10°E Degrees Declination Magnetic North	warm, breezy, clear, 5% cloud cover
Photographer: R. Weissinger		

PhotoPoint ID	UTM - Northing	UTM - Easting	Photopoint Description	Recommended Time
PP1			on bedrock near Fra ano + step down to next ledge, 12-m from base of BW	early morning or late afternoon
PP2			on bedrock ledge downslope of ledge at base of BW, 15-m from base of BW	"

PhotoPoint ID	Time	File Number	Bearing (degrees)	Angle (degrees)	Photo Description
PP1		1872			looking N towards PP1 + end of seep, Fra ano
		1873			looking W towards PP1 + seep
		1874			close-up
PP1	9:25	1875	240°		pano W → E
↓		1876	261°		
		1877	299°		
		1878	329°		
		1879	350°		
↓		1880	14°		
PP2		1881			looking W to PP2
		1882			close-up
		1883			looking E + PP2
		1884			looking W to PP2, cliffline, edge of seep
PP2	9:30	1885	258°		pano W → E
↓		1886	278°		
		1887	320°		
		1888	349°		
↓	9:35	1889	20°		

Springs Monitoring Protocol for Park Units in Aridland Networks

Standard Operating Procedure (SOP) #7

Associated Measures at Hanging Gardens: Endemic Plant Counts

Version 1.01 (January 2018)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	1/2018	R. Weissinger	Record counts for total spring area	Improve analysis	1.01

This SOP includes instructions for monitoring endemic plant populations at hanging gardens. These measures should be taken during site establishment and during each revisit. When staff turnover results in a new observer, the new observer and another experienced vegetation monitoring observer should conduct independent counts at each site for one sample season to adjust discrepancies between long-time observer counts.

Endemic plant census

Using the site map and reference photographs, identify the backwall, alcove floor and spring-associated colluvial slope of the hanging garden, if present. Not all hanging gardens have all three features.

Search these three surfaces for 1 minute per 5-m2 of vegetated area, or a maximum of two hours total at larger sites, for the endemic plant species listed below. In accessible portions of the hanging garden, it is helpful to delineate portions of the search area using one or more folding rulers so that individuals are not counted more than once. Count up to 500 individuals for each species per geomorphic surface. For larger populations, estimate the **count** of each species in the *accessible portions only* of each surface using the following count classes (Table 1). After completing the geomorphic surfaces, estimate the count of each species for the **total spring area**.

Estimate the percent of each surface that is inaccessible. Delineate inaccessible portions on the site map and on the site overview photo. Inaccessible areas are primarily determined by steep colluvial slopes where traversing the slope would cause soil movement and root displacement.

Table 1. Count classes for endemic species at hanging gardens.

Count Code	Definition
N	Species not seen and presumed absent.
1-500	Number of individuals counted
A	501-100 0 individuals
B	1001-10,0000 individuals
C	> 10,000 individuals

The following target species list has been developed for Southeast Utah Group Parks:

Table 2. Endemic species and their presence in SEUG parks. P = Present in Park, U = Unconfirmed but suspected to occur in park, SJ = present in San Juan County.

Family	**Species**	**Counting Unit**	**Note**	**ARCH**	**CANY**	**NABR**
Asteraceae	*Cirsium rydbergii*	Rosette		P	P	P
Asteraceae	*Erigeron kachinensis*	Rosette	Rhizomatous		SJ	P
Liliaceae	*Zigadenus vaginatus*	Individual		P	P	P
Orchidaceae	*Habenaria zothecina*	Individual		P	P	P
Primulaceae	*Primula specuicola*	Rosette	Rhizomatous	P	P	U
Ranunculaceae	*Aquilegia micrantha*	Individual		P	P	P
Scrophulariaceae	*Mimulus eastwoodiae*	Stem	Stoloniferous	P	P	P

Species descriptions

Asteraceae – *Cirsium rydbergii* (Rydberg's thistle)

The large basal rosette, up to 100 cm across, and large leaves, up to 10 cm wide, distinguish this thistle at maturity from all other Utah thistles (Fig. 1). The leaves are green on both sides. Flowers are small and pink. Seedlings can be identified relatively early on (at about 3 cm across) by their light green color and shallowly lobed leaves. Do not count smaller seedlings that cannot be positively identified.

Figure 1. *Cirsium rydbergii* in flower.

Asteraceae – *Erigeron kachinensis* (Kachina daisy)

Sub-stoloniferous dwarf daisy with spatulate leaves, usually growing low to the ground or backwall (Fig. 2).

Figure 2. *Erigeron kachinensis* in flower.

Lilaceae – *Zigadenus vaginatus* (Alcove death camas)

Distinctive, narrow monocot leaf from 8-30 cm long. White flowers are borne in panicles on a single flowering stalk (Fig. 3). Individuals can be difficult to distinguish vegetatively from a distance. When in flower, flowering stalks can be counted.

Figure 3. *Zigadenus vaginatus* in flower.

Orchidaceae – *Habenaria zothecina* (Alcove bog-orchid)

Stem is leafy below, with rounded basal and cauline leaves. Flowers are green with a long spur (Fig. 4). This species can be confused with another orchid, *Epipactis gigantea*, when young and only two leaves are present. *Epipactis* leaves are pointed at the tip and strongly clasp the stem. *Epipactis* stems often have a purple tinge.

Figure 4. *Habenaria zothecina* in flower.

Primulaceae – *Primula specuicola* (Easter-flower)

Bi-colored rosettes are white mealy below and green above (Fig. 5). Flowers in early spring, but old flowering stalks often persist throughout the growing season.

Figure 5. *Primula specuicola* in flower.

Ranunculaceae – *Aquilegia micrantha* (Alcove columbine)

This species is the only columbine that grows in hanging gardens in southeast Utah. Small, typically white or pale flowers with a short sepal to spur length ratio are diagnostic (Fig. 6).

Figure 6. *Aquilegia micrantha* in bloom.

Scrophulariaceae – *Mimulus eastwoodiae* (Scarlet monkey-flower)

This species is the only monkey-flower common in hanging gardens of southeastern Utah. Generally a backwall specialist, the bright red flowers bloom in late summer and fall. Leafy stolons are easily recognizable when flowers are not present.

Figure 7. *Mimulus eastwoodiae* in flower.

NCPN Springs Monitoring Hanging Garden Datasheet - v. 1.20

Park Code: **Site Name**: **Observer:** **Date:**

Endemic Plant Species

	Backwall	**Alcove**	**Colluvial Slope**
% inaccessible			

Start Time:

End Time:

Count

Species	**Backwall**	**Alcove**	**Colluvial Slope**	**Total**
Cirryd				
Erikac				
Zigvag				
Habzot				
Prispe				
Aqumic				
Mimeas				

Count Code	**Definition**
N	Species not seen and presumed absent.
1-500	Count individuals
A	501-100 0 individuals
B	1001-10,0000 individuals
C	> 10,000 individuals

Family	**Species**	**Counting Unit**
Asteraceae	*Cirsium rydbergii*	Rosette
Asteraceae	*Erigeron kachinensis*	Rosette
Liliaceae	*Zigadenus vaginatus*	Individual
Orchidaceae	*Habenaria zothecina*	Individual
Primulaceae	*Primula specuicola*	Rosette
Ranunculaceae	*Aquilegia micrantha*	Individual
Scrophulariaceae	*Mimulus eastwoodiae*	Stem

NCPN Springs Monitoring Hanging Garden Datasheet - v. 1.10

Park Code: ARCtl **Site Name:** Uo Can 3 R. Weissinger **Date:** 4 May 2018

Endemic Plant Species

	Backwall	Alcove	Colluvial Slope
% inaccessible			

Start Time: 11:30
End Time: 11:50

Count

Species	Backwall	Alcove	Colluvial Slope	Total
Cirryd	N		N	N
Erikac	N		N	N
Zigvag	N		N	N
Habzot	N		⊠⊠ ⊠+50 ⊡ (86)	86
Prispe	⊠⊠⊡ (28)		N	28
Aqumic	(1)		⊠⊠ ⊠⊠⊡⊠ (55)	56
Mimeas	B		not counted	B

Count Code	Definition
N	Species not seen and presumed absent.
A	501-100 0 individuals
B	1001-10,0000 individuals
C	> 10,000 individuals

Family	Species	Counting Unit
Asteraceae	*Cirsium rydbergii*	Rosette
Asteraceae	*Erigeron kachinensis*	Rosette
Liliaceae	*Zigadenus vaginatus*	Individual
Orchidaceae	*Habenaria zothecina*	Individual
Primulaceae	*Primula specuicola*	Rosette
Ranunculaceae	*Aquilegia micrantha*	Individual
Scrophulariaceae	*Mimulus eastwoodiae*	Stem

entered 5/22/18

Springs Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 8

Decontamination Procedures

Version 1.00 (June 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP details proper decontamination of all sampling equipment and personal items to avoid the spread of invasive organisms. The removal of plant seeds from clothing and equipment is necessary prior to visiting each spring. Additional decontamination measures are used when clothing and equipment is submersed in water.

Prior to entering a spring, remove plant seeds from all equipment, personal items, and clothing. Check for seeds in backpacks, shoes, socks and pant cuffs and remove by hand picking or using a stiff brush.

In addition, at the end of a field day, the following procedures are to be used to prevent the spread of exotic invasive aquatic organisms for any items that have been submersed in water.

- Remove all mud and debris using a scrub brush.
- Spray with 5% Quat solution (instructions below) and allow to rest 10 minutes.
- Rinse with water.
- When feasible, allow to dry completely before entering another body of water.

Decontamination Procedure

- Set up a portable disinfection tank using a 5% cleaning solution of quaternary ammonium compound – common cleaning agents used in homes, swimming pools, and hospitals that are safe for gear and equipment when used at the recommended concentration. Two brands are readily available from GSA or local suppliers: *Quat128*® (by Waxie) or *Sparquat 256*® (by Spartan). Costs and effectiveness are comparable; use either.

  Recipe for 5% cleaning solution using either *Quat128*® ***or*** *Sparquat 256*®

Volume of tap water	**Volume of *Quat128*®**	**Volume of *Sparquat 256*®**
100 mL water	4.63 mL	3.00 mL
1 gallon water	6.35 liquid oz.	4.12 liquid oz.
1 gallon water	12.7 tbsp	8.2 tbsp
1 gallon water	0.79 cups	0.51 cups
100 gallons water	4.96 gallons	3.22 gallons
1000 gallons water	49.6 gallons	32.2 gallons

- Put the 5% cleaning solution in backpack spray pumps to clean portable equipment. The solution must be in contact with the surface being sanitized for at least 10 minutes and then rinsed with water.
- Test cleaning solution before each use according to the directions below. The cleaning solution can be used repeatedly for up to a week unless heavily muddied or diluted. If the concentration is too weak, dispose of the used solution properly and make a new solution.

Safety

- Use protective, unlined rubber gloves and splash goggles or face shield when handling the cleaning solution and take extra precautions when handling undiluted chemicals. Have eye wash and clean water available on-site to treat accidental exposure.
- Consult the product label and Material Safety Data Sheet for additional information.

Testing Solution

- To determine if the solution is below the 5% strength use "Quat Chek 1000" Test Papers (purchase these from the supplier of the cleaning compound). The used cleaning solution needs to be diluted to about 600 ppm of ammonium compounds before it can be tested with these papers.
  - Take **one** cup of 5% *Sparquat 256*® cleaning solution, pour into a bucket. Add **5** cups of water. Mix. <u>OR</u>
  - Take **one** cup of 5% *Quat128*® cleaning solution, pour into a bucket. Add **4** cups of water. Mix.
- Test the diluted solution with "Quat Chek" Test Paper. Match up the color of the paper with the ppm's on the color chart. For optimal disinfection, the diluted solution should have a concentration between 600 and 800 ppm. If it is too dilute, dispose of properly and make a new cleaning solution. Do not use diluted solution for decontamination.

Disposal

- Do not dump cleaning solution into any stream or lake, or on areas where it can migrate into any stormdrain, waterbody, or sensitive habitat.

Storage

Sparquat 256® and *Quat128*® can be stored up to two years in an unopened container without losing its effectiveness. Both should be stored in a cool, dry place, out of direct sunlight. Temperatures can range from 32° to 110° F.

Springs Monitoring Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 9

Data Management

Version 1.00 (June 2016)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This Standard Operating Procedure (SOP) describes data management procedures for all data derived from springs monitoring in Northern Colorado Plateau Network (NCPN) park units. The procedures for data management given in this SOP follow guidelines and standards that are described in the NCPN Data Management Plan (Beer et al 2005).

1 Definitions and Acronyms

NPS	National Park Service
NCPN	Northern Colorado Plateau Network
I&M	Inventory & Monitoring Program of the National Park Service
IRMA	Integrated Resource Management Applications
SOP	Standard Operating Procedure
GIS	Geographic Information Systems
GPS	Global Positioning System
PDF	Portable Document Format
TIFF	Tagged Image File Format
JPG	Joint Photographic Experts Group File Format
FGDC	Federal Geographic Data Committee. The interagency committee that promotes the coordinated development, use, sharing, and dissemination of geographic data.
Tabular dataset	A dataset organized in a table or group of tables where each column and row has a specific interpretation; often produced by Microsoft (MS) Excel, MS Access, database, or statistical software, and managed as text, spreadsheet, or relational databases.
Spatial dataset	A dataset that is natively read by mapping software; often produced by mapping software, such as ESRI ArcMap and ArcInfo; also includes georeferenced imagery, geodatabases, as well as hardcopy aerial photographs, satellite imagery and maps.

Primary dataset	The dataset that is the most comprehensive and representative of the data associated with a project. This dataset can normally be used independently of other project datasets and is often distributed to external users. The primary dataset can be tabular or spatial. For most NCPN monitoring projects, the primary dataset will be either an MS Access database or a geodatabase.
Raw data	Data that have not been subjected to either quality control or documentation procedures; includes data recorded by hand on hard-copy forms, digital files from handheld devices, GPS receivers, telemetry data loggers, etc.
Certified data	Finalized project data, i.e., data that have undergone thorough quality assurance and screening as well as complete documentation.
Working database	A project-specific database for entering and processing data for the current season (or other logical period of time). This might be the only database for short-term projects where there is no need to distinguish working data for the current season from the full set of validated project data.
Master database	Project-specific database for storing the full project data set, used for viewing, summarizing, and analysis. Only used to store certified data.
Data products	Information that is derived from certified project data.
Project level metadata	A metadata record associated with the primary project dataset that contains cross references to all project data products and is uploaded to the IRMA Data Store.
Quality assurance (QA) procedures	Procedures used to maintain a defined level of quality throughout all stages of data development.
Quality control (QC) procedures	Procedures used to monitor or evaluate the quality of data products.

2 Overview of Springs Data Management

Springs monitoring data are acquired as specified in the protocol SOPs using two different methods: 1) digitally recorded by a GPS (spatial data) or datalogger (water quality) and, 2) manually recorded on paper data sheets (hydrology, vegetation and site characterization). Springs data are stored in a Microsoft Access database designed to accommodate all data on the various field forms (see Section 3). This database is populated via a combination of data import and data entry. Digital data recorded using GPS units are imported, while data recorded on paper data sheets are manually entered into the database (see Section 4). Once all data have been entered and imported, the data are verified and validated (see section 5). Data are subsequently documented (see Section 8) and archived (see Section 7). Hydrologic data stored in the NCPN database are exported to the NPStoret format so that they can be shared with the NPS Water Resources Division.

3 Database Design

The primary dataset associated with the NCPN springs monitoring project is a tabular dataset stored in a Microsoft (MS) Access database, referred to subsequently as the springs database. This database is in Access 2007/2010 format, and has a frontend/backend file structure:

- *Springs.mdb*: This frontend file contains all queries, forms, reports, and associated Visual Basic (VB) application code.
- *Springs_be.mdb*: This backend file contains the database tables.

The frontend/backend file structure allows multiple users to enter data in a network environment, and allows for easy backup and transfer of the data tables. Users typically launch the frontend file, and a utility will prompt them to establish a link to the backend file.

The springs database conforms to Natural Resource Database Template standards established by the national Inventory and Monitoring program. The design includes standardized core tables for elements, such as Locations and Events, that are common to most monitoring datasets, as well as field data tables that can be customized to meet project data requirements. Field data tables are organized largely by SOP and are linked in time and space to enable integrated data analysis. Species, contacts, and attribute look-up tables provide standardized values for many data fields, and metadata tables track database revisions and data edits.

Since the springs database is currently under development, an overview of the database design is provided here. Each springs monitoring site has a location record, which stores basic location information as well as other site characteristics that are recorded during site establishment. Each spring can have many site visits. During each site visit, several different types of observations are recorded. The main types of monitoring observations recorded are described briefly below:

- Flow is recorded at most sentinel sites at Arches National Park (ARCH), Canyonlands National Park (CANY), and Hovenweep National Monument (HOVE).
- Relative pool height is recorded at two sentinel sites at HOVE.
- Depth to water is recorded in two shallow piezometers at one sentinel site in HOVE.
- Core water quality measurements (pH, specific conductance, and water temperature,) are recorded at all sentinel monitoring sites. Optional water quality measurements (dissolved oxygen, total coliform, Escherichia coli) may also be recorded at sentinel monitoring sites.
- Weather conditions (e.g., air temperature, cloud cover) are recorded at all sentinel monitoring sites.
- Endemic plant counts are recorded at all hanging garden sites.
- Repeat photos are taken at all sites.
- Soil erosion is estimated for each geomorphic surface at all sites.
- Disturbance impacts are estimated for each geomorphic surface at all sites.

- Qualitative descriptions of site disturbances are recorded at all sites.
- Exotic species observed during timed plant and animal walks are recorded at all sites.

4 Populating the Springs Database

Prior to each field season, the working database for the springs monitoring protocol is prepared for the upcoming field season's data entry. The working database is initially an "empty" database, i.e., it contains no observation data, just populated lookup tables and certain "static" site information (e.g., location information). The working database is used for data entry, verification, and validation for a given field season. After the dataset in the working database is certified, it is merged into the master springs database.

For the remainder of this document, the term "springs database" refers to the working database. The springs database is populated via a combination of data import and data entry.

4.1 Data Import

Records for springs monitoring sites can be established in the database either manually or by importing site location data collected via GPS units. It is expected that most site records will be created manually during data entry. In such cases, the site record will subsequently be updated with the corrected GPS data. Table 1 lists the fields either imported or derived from GPS data. Elevation will not be imported directly from the GPS data, but rather will be derived from digital elevation models.

Table 1. Fields Imported/Derived from GPS Data into tbl_Locations

Elevation	UTM_Zone
E_Coord N_Coord	Rcvr_Type
Coord_Units	Max_PDOP
Coord_System	Max_HDOP
Datum	GPS_File_Name

Site location data are expected to be relatively static over time. Thus, GPS data will normally only be imported when a site is initially established. When imported, spring location data will be imported from corrected GPS files into *tbl_Locations*.

4.2 Data Entry

The majority of data in the springs database will be populated via data entry. Data entry should occur as soon as possible after data collection is completed, before the next observation occurs, and by the person who collected the data or someone who is familiar with the project and data. The primary goal of data entry is *to record data in digital form with 100% accuracy.*

Detailed data entry instructions are provided in the Springs Database User's Guide - Draft (NCPN-NPS 2013a). The user's guide is available as a standalone document in the same folder location as the working copy of the springs database:

X:\Active_Monitoring_Projects\Springs\Data\Database\Current

The project manager makes certain that persons performing data entry are familiar with the user's guide and understand how to enter data and follow the protocols. Data entry technicians are responsible for becoming familiar with the field data forms, database software, database structure, and any standard codes for data entry. The data manager, in conjunction with the project manager, will ensure that the user's guide is kept current as new features are implemented in the database and/or as data entry procedures change.

QA/QC measures for data entry are built into the database forms to automatically validate data where possible. Data entry forms maximize the use of auto-filled fields, range limits, pick lists, and spelling checks. Error messages alert the operator to correct mistakes. Any errors or omissions that become apparent during data entry should be resolved as soon as possible. In such cases, the data entry technician should contact the person who collected the data for clarification. The appropriate modifications should then be made to the field sheets or documented in a log according to the instructions provided in Section 5.

5 Data Verification and Validation

To ensure that springs monitoring data are of the highest possible quality, verification and validation of springs monitoring data will be performed according to the procedures described in the NCPN Quality Assurance and Quality Control Guidance Document (NCPN-NPS 2008a). *Data verification* checks that data entered into a secondary (i.e., electronic) format match the source data, while *data validation* checks that the data make sense.

5.1 Data Verification

Data verification immediately follows data entry and involves checking the accuracy and completeness of the computerized records against the hard copy field records and identifying and correcting any errors. The following verification methods will be used to verify springs data:

1. **Visual review at data entry**. The person doing data entry verifies each and every record after input and immediately corrects any errors.
2. **Visual review after data entry**. All records are compared to the original data source. Each data field on the corresponding electronic data entry form is compared with the original values from the hard copy, preferably by a second person who did not perform the data entry. Any errors that are discovered are corrected in the database as soon after data entry as possible.
3. **Summary queries and tallies**. Queries are run that detect broad errors such as duplicate or omitted records. Examples of such queries are given below:

a. Listing and count of the monitoring springs established by park by year.
b. Listing and count of the monitoring springs visited by park by year.
c. For each year/park/spring combination, a count of the number of photo points recorded.

4. **Visual review of spatial data**. Using GIS, springs monitoring location data are visually inspected for accuracy. This review will take place at the end of the field season.

Detailed verification procedures are provided in Springs Database Quality Assurance (QA)/Quality Control (QC) Procedures – Draft (NCPN-NPS 2013b).

5.2 Data Validation

While many errors are prevented by including validation routines that function during data entry, additional review of the data by the project manager is needed to detect generic and specific errors that fall outside the scope of automated validation.

Invalid data commonly consist of slightly misspelled names, the wrong date, or out-of-range errors in parameters with well-defined limits (e.g., elevation). Other errors consist of unreasonable metrics or associations. For example, suppose a species was dominant at a spring during the current year's visit, but there was no observation recorded during the previous year's visit. Such data seem questionable and might indicate a species identification error. These types of logic errors (or potential errors) can be challenging to resolve, and in some cases it may not be possible to resolve them during the current year. Such questionable data will be flagged for future resolution.

Validation queries are of two types: one type presents tabular data in ways that allow records to be reviewed for content and context; the other type performs specific calculations or routines to detect logic or range errors. Corrections to errors detected during validation require notations in the *original paper field records* about how and why the data were changed. Modifications to the field records, whether made during data collection or subsequently, should be clear and concise while preserving the original data entries or notes. The original data entries should be crossed out with a single line and initialed - they should ***not*** be erased. Validation efforts should also include a check for the completeness of a data set since field sheets or other sources of data could easily be overlooked.

Detailed validation procedures are provided in Springs Database Quality Assurance (QA)/Quality Control (QC) Procedures – Draft (NCPN-NPS 2013b).

5.3 Data Quality Review and Communication

The project manager and any personnel involved in data collection or entry will meet several times during the field season to discuss data quality problems and issues. Procedures may need revision if verification and validation processes reveal an unacceptable level of data quality. Quality checks may also reveal the need to modify field or computer forms if data transcription or entry errors are frequent.

Once validation has been completed, metadata will be created for the springs datasets (refer to Section 8 for details on metadata). An important part of this metadata is data quality documentation, which consists of the verification and validation results. This data quality documentation, along with the project data certification form, will be used to notify end users and other project personnel of project data quality. For example, any questionable data that have been flagged will be identified. The project data certification form will be completed by the project manager to indicate that the data are complete, they have passed quality assurance checks, and they are documented and ready for archiving, posting, and distribution. The data certification form can be found in the NCPN Project Data Life Cycle Guidance Document (NCPN-NPS 2007a). The data quality documentation and data certification form will be stored in the springs project archive folder.

6 Version Control

Version control is the process of managing copies of changing files over the course of a project. Change includes any alteration to the structure or content of the files, which should not be made without the ability to fully recover a dataset as it existed before changes were made. NCPN uses several techniques to help ensure proper version control: data archiving (refer to Section 7 for data archiving details), directory structure conventions, backup procedures (refer to the user's guide [NCPN-NPS 2013a]), and database versioning.

6.1 Directory Structure Conventions

NCPN has adopted directory structure conventions for I&M project folders (NCPN-NPS 2007b). Based on these conventions, each project has an active folder for storing all current or working project files and an archive folder for storing archived project files. In general, the active project folder stores only the most recent project files (e.g., data and reports from current year, current protocol version). All active project folders are stored on the NCPN shared drive (X:). The active springs project folder is in the following location:

X:\Active_Monitoring_Projects\Springs

The structure of the active project folder is as follows (all folders are not shown):

- **Data**:
  - **Database** (Springs database):
    - **Backups**: Contains one or more backup copies of database files made during data entry (not retained permanently).
    - **Current**: Contains the working database (current year data) and user's guide.
    - **Master**: Contains a copy of the master database (complete data record) to be used for analysis and reporting (the master database is stored in the springs archive folder).
  - **Field_Forms**: Contains scanned field forms for current year.
  - **GPS_Downloads**: Contains corrected data downloaded from GPS units.

  - **Spatial**: Contains GIS files related to site selection.
- **Field_Crews**: Contains files used by field crews, such as plant lists and trip reports.
- **NCPN_Working_Files**: Contains miscellaneous files used internally, such as database requirements documentation.
- **Project_Life_Cycle**: Contains files related to project data life cycle tracking for current year, e.g., data certification form, data quality documentation (refer to Section 8 for more details on the project data life cycle).
- **Protocol**:
  - **PDF**: Contains PDF of current version of protocol.
  - **Native_Format**: Contains source files for current version of protocol.
- **Reports**:
  - **PDF**: Contains PDF version of current annual project reports and any other reports produced during current year.
  - **Native_Format**: Contains source files used to create current year reports.

For additional details on NCPN directory structure conventions, refer to the NCPN Directory Structure Guidance Document (NCPN-NPS 2007b).

6.2 Database Versioning

Database versioning refers to the process of tracking modifications to the database structure or application code, which can occur independently of modifications to the data. NCPN uses a version numbering scheme to track database modifications, in which modifications are grouped into software releases. Major releases are those involving significant changes to the database and are designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). For releases with only minor database changes (e.g., bug fixes), version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02, etc). Database version information is maintained within the database, and can be viewed by choosing the **About** tab on the springs main menu page, and then choosing **View release history**. Whenever a database version change occurs, copies of the database files are placed in the appropriate archive location (refer to Section 7).

7 Data Archiving

Archiving is a critical step in ensuring the long-term preservation of data. Springs data will be archived on an annual basis, after the current year data have been certified and annual report completed. Archiving of certain data may occur more frequently, e.g., if a protocol version change occurs. Archiving will be done for both digital and hard copy data.

7.1 Digital Data Archiving

All digital springs data will be archived on the NCPN read-only shared drive (R:) in the springs archive folder (R:\Archive\Monitoring_Archive\Springs\). Table 2 lists the springs monitoring digital data files that require archiving, along with their respective archive folder locations. The digital files listed in Table 2 will also be burned onto an archival-standard CD or DVD and sent to the Western Archeological and Conservation Center (WACC) according to the procedures outlined in the NCPN Archiving Guidance

Document (NCPN-NPS 2010). WACC is the official archival repository for all NCPN data. This facility provides temperature and humidity-controlled storage conditions and a professional archives staff, and it meets all NPS museum standards.

Table 2. Springs Digital Data Archiving Summary

Data Product(s)/ File(s)	Archive Location[1]	Comments
Database	Data\<*year*[2]>\Database\	• Contains certified springs database files for a given year, master database files, and metadata
Field forms	Data\<*year*>\Field_Forms\	• Contains digital field forms (PDF) for a given year
GPS data	Data\<*year*>\GIS_Data\ GPS_Data\	• Contains both uncorrected and corrected GPS data files for a given year
Project data life cycle files	Project_Life_Cycle\<*year*>\	• Contains archived files related to project data life cycle tracking for a given year
Protocol	Protocol\<*version*[3]>\	• Contains archived protocol files (PDF and source files) for a given version
Protocol review	Protocol_Review\<*year*>\	• Contains archived protocol review documents for a given year
Reports	Reports\<*year*>\	• Contains archived report files (PDF and source files) for a given year
Sampling design files	Sampling_Design\<*year*>\	• Contains archived files related to sampling design for a given year
Photos	R:\Archive\ NCPN_Photos_Archive\ NCPN Photos\ Springs	• Archive location is an absolute path • Renamed photo files archived as part of NCPN photo database processing - refer to NCPN Photo Management Guidance Document (NCPN-NPS 2008b) for details
Original photos	R:\Archive\ NCPN_Photos_Archive\ Raw_Photo_Data_Archive\ Monitoring\Springs\<*year*>	• Archive location is an absolute path • Contains original, unedited (e.g., not rotated) photo files • Archived as part of photo database processing

7.2 Hard Copy Data Archiving

All hard copy springs data will be archived at WACC according to the procedures outlined in the NCPN Archiving Guidance Document (NCPN-NPS 2010). Table 3 lists the springs monitoring hard copy data files that require archiving, along with a summary of archiving procedures. Digital copies of applicable items in Table 3 are also provided to parks for their working files.

Table 3. Springs Hard Copy Data Archiving Summary

[1] Archive location is relative to R:\Archive\Monitoring_Archive\Springs\ unless stated otherwise.
[2] <*year*> indicates year in yyyy format.
[3] <*version*> indicates protocol version key number, e.g., Version_Key_1

Data Product(s)/File(s)	Comments
Field forms	• Original field forms stored in NCPN archives at WACC. • Digital copies retained in NCPN office.
Reports	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office and provided to parks included in springs monitoring project.
Protocol	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office. • Digital copies provided to parks included in springs monitoring project.
Protocol review	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office.
Photos	• Slides or selected prints stored in NCPN archives at WACC. • Digital copies retained in NCPN office.
Data/metadata Printouts	• Archival copies of project-level metadata stored in NCPN archives at WACC. • Hard copies retained in NCPN office. • Digital copies of relevant printouts provided to parks included in springs monitoring project. • Above applies to any other data/metadata printouts deemed critical to long-term springs monitoring
Project data life cycle files	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office.

8 Metadata

Metadata, which is defined as structured information about the content, quality, condition, and other characteristics of data, is a critical step toward ensuring that data sets are usable for their intended purposes well into the future. Metadata can take many different forms, including formal FGDC-compliant metadata, IRMA Data Store records, and protocol version information.

To comply with NPS metadata requirements, metadata for springs datasets will be created following NCPN metadata procedures (NCPN-NPS 2007c):

- An IRMA Data Store metadata record will be created for the springs database (since it is considered the *primary dataset* for the springs monitoring project). The Data Store metadata record, also referred to as the project level metadata, will be updated annually.
- All other springs datasets and data products (see **Dataset/Data Product** column in Table 4) will be documented as cross-reference citations in the project level metadata record.

Another type of metadata specific to NCPN is the Project Data Life Cycle (PDLC) checklist, which helps to ensure that all data management activities (e.g., data verification/validation, metadata, archiving) are completed each year for monitoring projects. In accordance with this requirement, a PDLC checklist will be completed each

year for springs monitoring data. For further details related to the PDLC checklist, refer to the NCPN Project Data Life Cycle Guidance Document (NCPN-NPS 2007a).

Table 4 summarizes the metadata tasks required for springs monitoring datasets and data products, and Table 5 describes the tasks and provides references where more detailed procedures are described.

Table 4. Summary of Metadata Tasks for Springs Monitoring Data

Dataset/ Data Product	IRMA Data Store	X-Ref Citation	PDLC Check-list	MVT	Photo DB	DB Doc
Database	X		X			X
GIS Data		X	X			
Report(s)	X	X	X			
Protocol	X	X	X	X		
Photos		X	X		X	
Field Forms		X	X			

Table 5. Metadata Task Descriptions

Metadata Task	Metadata Task Description	Reference(s)
IRMA Data Store	An IRMA Data Store record is created for the project metadata and then updated annually. Data Store records are also created for each report. A Data Store record is also created for the protocol and updated as needed.	Metadata Guidance Document (NCPN-NPS 2007c), IRMA Data Store Documentation and Help Manual (NRSS-NPS 2012)
X-Ref Citation	A cross reference citation is added to the project level metadata record.	Metadata Guidance Document (NCPN-NPS 2007c)
PDLC Checklist	The PDLC checklist is completed, which includes adding product records to the NCPN Project Tracking Database.	Project Data Life Cycle Guidance Document (NCPN-NPS 2007a), Project Tracking Guidance Document (NCPN-NPS 2008c, in development)
MVT	The Master Version Table is updated as needed.	Protocol Versioning Guidance Document (NCPN-NPS 2009)
Photo DB	Photo records are added to the NCPN Photo Database.	Photo Management Guidance Document (NCPN-NPS 2008b)
DB Doc	Database table and field documentation is updated as needed.	To be developed upon completion of the database

A metadata questionnaire has been developed to assist in gathering the information needed for metadata creation (see the NCPN Metadata Guidance Document (NCPN-NPS 2007c)).

The complete protocol for this project (Protocol Narrative and all SOPs) is an integral component of the project metadata. All narrative and SOP version changes are noted in a Master Version Table (MVT), which is maintained in SOP #11. Any time the narrative or an SOP version change occurs, a new Version Key number (VK#) must be created and recorded in the MVT, along with the date of the change and the versions of the narrative and SOPs in effect. The Version Key number is essential for project information to be

properly interpreted and analyzed. *The protocol narrative, SOPs, and data should not be distributed independently of this table.* Refer to the NCPN Protocol Versioning Guidance Document (NCPN-NPS 2009) for detailed protocol versioning procedures.

9 Photo Management

Photos taken as part of springs monitoring are managed following NCPN photo management procedures, which are described in detail in the NCPN Photo Management Guidance Document (NCPN-NPS 2008b). This section will focus on digital photo management, since springs monitoring photos are taken with digital cameras.

Photos are initially uploaded to a temporary folder on the NCPN shared drive (X:). This drive is backed up regularly, with a backup rotation scheme that includes off-site storage of backups. Refer to the NCPN Disaster Recovery Guidance Document (NCPN-NPS 2007d) for detailed backup procedures. The photos are then documented (NCPN-NPS 2008b) and quality checked (NCPN-NPS 2013b). Any issues discovered are resolved. For example, duplicate photos or photos of very poor quality are usually discarded.

Photos are then uploaded to the NCPN Photo Database. As part of this process, the image files are moved to the NCPN read-only shared drive (R:). This drive is also backed up regularly, with off-site storage of backups. The read-only drive serves as the primary long-term storage location for the photos. In addition, copies of the photos are burned onto archival-standard DVDs and sent to WACC, the official archival repository for NCPN data. This is in accordance with NPS Director's Order 11D: Records and Electronic Information Management (NPS 2012), which requires that all NPS natural resource records be retained permanently and receive archival care as soon as practical.

10 References

- Beer, M., E. Nance, A. Wight, M. Powell, and R. DenBleyker. 2005. Northern Colorado Plateau Network, data management plan. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT. 86 pp plus appendices.
- NCPN-NPS 2007a. Project Data Life Cycle Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2007b. Directory Structure Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2007c. Metadata Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2007d. Disaster Recovery Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.

- NCPN-NPS 2008a. Quality Assurance and Quality Control Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2008b. Photo Management Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2008c. Project Tracking Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2010. Archiving Guidance Document, Version 2.00. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2013a. Springs Database User's Guide - Draft. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2013b. Springs Database Quality Assurance (QA)/Quality Control (QC) Procedures - Draft. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NPS 2012. National Park Service. 2012. NPS Director's Order 11D: Records and Electronic Information Management. (http://www.nps.gov/policy/DOrders/DO-11D.pdf)
- NRSS-NPS 2012. The IRMA Data Store Help Manual. National Park Service, Natural Resource Stewardship and Science, Fort Collins, CO.

Springs Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 10

Data summary, analysis and reporting

Version 1.00 (June 2016)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP provides an overview of data summary, analysis and reporting procedures. Raw data are compared to previously collected data to catch misidentified species and values that represent unlikely amounts of change between years. Once data quality issues are resolved, analyses can be conducted. Two general types of analyses are performed: 1) summary reporting of the most recent monitoring observations (summary reports and annual briefs), and 2) comprehensive assessments of the long term data set (power to detect trend of the overall sampling design, evaluation of trends, and inclusion of other parameters that may explain variation or trends over time).

1.0 Data Summaries

Data should be summarized for the following variables:

Vital Sign	Reporting Variables (reporting unit)	Test for Long-Term Trends
Water Quantity	Flow (nearest 0.01 L/min) Stage (nearest 0.01 m)	Seasonal Kendall tau
Water Quality	pH (nearest 0.1) specific conductance (nearest 10 µs/cm) water temperature (nearest 1° C)	Seasonal Kendall tau
Vegetation Species Composition	Endemic plant counts (hanging gardens only) Native species % cover and richness Exotic species % cover and richness Wetland species % cover and richness Wetland: Upland cover ratio	General Additive Model

Water Quantity and Water Quality

Summarize flow, stage, pH, water temperature, and specific conductance annually (March-November) and seasonally (March-May, June-August, September-November) for each sentinel spring. Present the number of samples, median, range, and standard deviation of measurements. Document missing samples and indicate the reason. Graphical representations such as values over time and boxplots by month are also helpful ways of presenting data for each site.

Vegetation Data

Endemic plant counts

Summarize by species for each hanging garden and each hanging garden's geomorphic surfaces. For data summaries, count code data may be presented. For data analysis and graphing, numeric substitutions are necessary.

Count Code	Definition	Substitution
N	Species not seen and presumed absent.	0
1-500	Count data	none
A	501-1000 individuals	750
B	1001-10,0000 individuals	5000
C	> 10,000 individuals	10000

Species richness

Species richness is the number of unique species encountered. For each spring, calculate richness of all species, nonnative species, species by life form (e.g., tree, shrub, etc.), and species by wetland status group (obligate, facultative wet, facultative upland, upland). Species richness data should be included in site summaries but still need to be evaluated for their power to detect trends.

Vegetation cover

Percent cover is calculated for each species, native and exotic, and wetland status group for each geomorphic surface by summing the mid-points of the cover class recorded for each species. A wetland to upland cover ratio is calculated by summing obligate and facultative wet cover and dividing by the sum of upland and facultative upland cover. Vegetation cover data should be included in site summaries but still need to be evaluated for their power to detect trends.

Cover Class	Definition	Mid-Point
1	<1% canopy cover	0.05
2	1 - <10% canopy cover	5
3	10 - < 25% canopy cover	12.5
4	25 - < 50% canopy cover	37.5
5	50 - < 95% canopy cover	72.5
6	95% or greater canopy cover	97.5

2.0 Data Quality Assessment

Before data analysis and reporting, data should be additionally evaluated for reasonable levels of change based on historical conditions at each spring. For instance, a measure may appear to be valid based on the database domain, but represent an unreasonable (and unlikely) change in conditions since the last field visit.

Summarized attributes should be compared between years, and all suspect values (large increases or decreases) should be flagged and resolved before the data are analyzed. In addition, data should be evaluated for the omission of historically dominant species or the appearance of dominant species not detected in previous years. New occurrences of a species should be compared with the park-level species list and species-range limits.

Suspect measures or species should be evaluated by field crew members and by field verification if possible. Any corrections made to the database should be recorded in the QAQC log. Suspect data that are not resolved should also be flagged in the QAQC log so that it can excluded from analyses, if appropriate. Suspect data that cannot be resolved in the office should be brought to the attention of the field crew at the next monitoring visit so that they may eventually be resolved.

3.0 Common issues with time series data

Representativeness
The target population for hydrologic data is base spring-flow at each site. If data are sampled during a flood event, they may be used for data summaries but should be excluded from the dataset prior to trend analyses.

Outliers
Data that are more than 2 standard deviations from the mean are considered outliers. Check each outlier for data transcription or human errors and for comments on the site visit that may explain unusual conditions. Unless the data are found to be erroneous, retain the data in the dataset and use analysis methods that are robust to outliers (e.g., ranking, non-parametric, etc.).

Missing data
Missing samples should be avoided as much as possible but are inevitable in a monitoring program. Missed samples become less important over time, and data should not be estimated. For data above or below detection limits (e.g., if flow is unmeasurable, but present), do not use substitutions. Use analysis methods that are robust to uncertain data, e.g., Kendall tau, etc., see Helsel and Hirsch (2002).

Serial correlation
Repeated measures over time can often be serially correlated, introducing bias into analyses. Model residuals should be tested for autocorrelation. If autocorrelation is present, it can be specifically accounted for in mixed models by including a temporal

correlation structure within the model (see, for example, Zuur et al. 2009). A seasonal Kendall test that accounts for serial dependence is also available, although it is only robust with large sample sizes (Hirsch and Slack 1984).

3.0 Summary Reports and Annual Briefs

Summary Reports
The primary objectives of the summary, or "status", report are to 1) document monitoring activities for the period of record, 2) summarize data and describe the current condition of resources, and 3) provide information to park managers in a timely manner that increases data utility and communication. In addition to tabular and/or graphical summaries of monitoring data, the report should include important assessment points of management interest.

Assessment Points

- Presence of target exotic plants or animals
- Novel disturbance – e.g., trespass cattle, increased social trailing, etc.
- Shift in pH or conductivity indicating possible aquifer contamination
- Repeated presence of *E. coli* indicating possible fecal contamination

Annual Briefs
Each year, information from summary reports and other analyses is further summarized in 1-2 page briefs that provide resource managers with a concise summary of issues of concern. NCPN produces two types of briefs: vital signs briefs and park briefs. The springs and seeps vital sign brief summarizes findings from springs and seeps monitoring in all NCPN parks. Park briefs are produced for each NCPN park unit and contain a section on springs and seeps monitoring. Existing vital sign briefs and park briefs should be consulted for formatting.

4.0 Comprehensive Assessments

Comprehensive analyses and reports are completed periodically on the long term data set. Comprehensive reports should be structured like typical scientific manuscripts (introduction, methods, results, discussion, and literature cited sections) and may include any of the analyses described in this section.

Sampling-Design Power to Detect Trends
The current sampling design was developed using legacy and pilot data that may not accurately reflect the monitoring data over time. The sampling design should be checked periodically to ensure that the assumptions are being met and to explore improvements that may better meet the original monitoring and sampling objectives. Sampling designs

are evaluated by calculating variance and power to detect trends of varying magnitudes. For the springs monitoring program, the desired power is a better than 80% likelihood of not obtaining a false negative, i.e., not detecting a trend when in fact, a trend exists.

Variance estimates are derived from all years of relevant monitoring data, not just observations from the current field season. Changes in methods that would affect variance (e.g., more precise methods, new instruments, etc.) may necessitate a new analysis period. To achieve the desired power, alternative survey designs can be evaluated to determine appropriate enhancements, such as an increase in sample size or more frequent visits to established springs, to achieve the original sampling objective. Power-to-detect-trend is evaluated with alternative numbers of panels, sample sizes, and re-visit schemes. A trend may be reported as a yearly rate or a rate over a set number of years. This conversion is outlined for increasing (eq. 1, Table 2) and decreasing (eq. 2, Table 2) rates of trend. Results are then used to determine which survey designs best meet the original sampling objectives.

Table 2. Formula for converting a yearly rate of trend to a rate of trend over a set number of years.

Conversion for rate of trend

$$I = e^{rt} \quad (1)$$

$$D = 1 - e^{rt} \quad (2)$$

where;

I = % increase over t years
D =% decrease over t years
r = the yearly rate of increase or decrease
t = the total time period of increase or decrease

Site-based water quantity and water quality data

The current monitoring design for water quantity data is estimated to detect a 5% annual change in 6 years of sampling (Weissinger and Moran 2013). Irvine et al. (2012) developed a power analysis for water quality data based on repeated iterations of the seasonal Kendall tau test using pilot data representative of future sampling conditions. Data are deseasonalized by creating residuals from the monthly median, then the residuals are randomized within months and across years. Multiple permutations of the tests are compared to develop an estimate of the power to detect trend with varying sampling scenarios and time periods. This approach is appropriate for future power analyses of monthly water quality and water quantity data from this program.

Population-based vegetation data

A preliminary analysis of power to detect trends in endemic species used simulated data for *Aquilegia micrantha* taken from a double observer pilot study. Variability documented within the pilot study was used to simulate a dataset with the proposed sampling design's revisit design. For a sample size of 10 springs per year, it was

estimated that a 10% change in Aquilegia micrantha could be detected over 20 years using a Poisson regression model (Tipton 2013).

The current sampling design must be tested for each species and vegetation metric after adequate data have been collected; we recommend this analysis occur after 6 years of data collection. If methods for power analysis using General Additive Models (GAMs; see trend assessment section below) have been developed, that would be the appropriate assessment for these types of data. In the absence of this type of analysis, the Poisson regression model used by Tipton (2013) can be used.

Trend Assessments

Long-term trend analyses are performed after at least 6 years of monitoring data are collected. Data are analyzed for the period of record, and for any period where 1) a change is expected to have occurred due to a known impact at or up-gradient of the spring or 2) a change is apparent after a graphical inspection of the data record. To more conservatively inform managers of potential changes in springs ecosystems, data will be evaluated at a statistical significance of $p \leq 0.10$.

When significant trends are detected, reasons for these trends should be evaluated by literature reviews, comparison with similar data sets, and additional assessments using ancillary information. When unidirectional trends are not detected, correlations may help us understand system drivers. Local climate records and remotely-sensed vegetation data can provide valuable context for springs data.

Frequentist Methods

Site-based analyses

For site-specific analyses, such as water quantity and water quality data from sentinel sites, Helsel and Hirsch (2002) cover various data analysis scenarios based on the distribution of the data (parametric, nonparametric, or mixed). Monotonic trend tests look for gradual, uni-directional changes over time, while step trends evaluate before and after a change at a specific point in time. The monotonic trend hypothesis is more commonly used for general monitoring unless there is a reason to test for a step trend.

Monthly water quantity and water quality data in this monitoring program have been designed to be tested for long-term trends using the seasonal Kendall tau, a non-parametric test for monotonic trends in data that have a strong seasonal pattern, such as spring-flow. The test accounts for seasonal variations by comparing ranks of data from the same recurring time intervals; for example, in a monthly sampling scenario, March values are compared only to other March values, July values to July values, and so forth. Deseasonalizing is done by subtracting seasonal medians from each of the values to be regressed. A Mann-Kendall test for trend is done for each season, with the Seasonal Kendall test statistic being the sum of the several Mann-Kendall test statistics.

The data can also be fitted with a non-parametric equivalent of a regression line called a Sen slope, which is calculated as the median annual slope of all possible pairs for a season. This slope corresponds to the estimated median annual change in the parameter,

and the percent annual change can be calculated as (median annual Sen slope/median annual value) × 100.

For step trends, in which a sudden jump in the data is expected or observed to have occurred, the non-parametric Seasonal Rank Sum test is likely to be an appropriate test for springs water quantity and water quality data. The Rank Sum test (also known as the Mann-Whitney "U" test or Wilcoxen Rank Sum test) tests the assumption that two populations (before and after a change) have the same distribution. The Seasonal Rank Sum test computes the rank-sum statistic separately for each season, sums the test statistics, and then evaluates the overall summed test statistic.

Population-based analyses

Hanging garden vegetation data from this monitoring program are designed to be tested for long-term trends in populations using mixed-effects models (Larsen et al. 1995). There are four populations in the initial sampling design: 1) Courthouse Wash, 2) Upper Salt Wash, 3) the Delicate Arch and Freshwater Canyon areas at Arches National Park, and 4) all of Natural Bridges National Monument. These populations are based on geographic proximity but may not reflect actual population boundaries. As the initial datasets are evaluated, the project manager should consider whether these populations should be kept separate or whether all springs at Arches NP can be evaluated together.

General Additive Models (GAMs) are a non-parametric extension of Generalized Linear Models that have no a priori assumptions about the shape of the response (i.e., linear, quadratic, etc.; Wood 2006). Given the still preliminary nature of the vegetation data being collected by this program, GAM analysis is an appropriate first step for determining whether simpler linear models can be used for each population. Because smoothed functions do not have simple interpretable parameters to report, when the comparison of GAMs indicates that linear responses are adequate, estimate parameters and the confidence intervals of those estimates via conventional linear models.

Given differences among springs in spring size, aspect, and habitat availability, spring identity is treated as a categorical (factor) fixed effect. We have no a priori reason to expect linear trends or linear responses to predictors. Therefore, each model should be fitted with and without smoothing via penalized smoothing using the gam function. For example, to test for temporal trends in vegetation data for each spring, accounting for an interaction between time and the individual spring, fit both linear (Equation 1) and smoothed (Equation 2) models of the forms:

Equation 1: *Vegetation ~ Spring + Date + Spring:Date*

Equation 2: *Vegetation ~ Spring + s(Date,by=Spring)*

The degree of smoothing in the second model is selected using generalized crossvalidation. Models can be compared using the Akaike Information Criterion (AIC). Generally the smallest AIC is considered the best fit model, but models with ΔAIC <4 are roughly equivalent (Burnham and Anderson 2002).

The output from this model is a measure of the intercept and slope, the significance of the slope and intercept being different from zero, and measures of the variance and covariance of the regression parameters. A significant slope indicates a significant trend at the alpha level used to assess significance or below.

Bayesian Methods

Bayesian methods for trend assessment identify the probability of different slope-parameter values (Gelman et al. 2000, Wade 2000) given the observed data. This differs from frequentist methods which calculate the probability of observing data given a specific value for a parameter, such as the null hypothesis. Assessing the probability of different slope values is potentially important for various reasons. First, sampling designs are largely based on a few key features. The minimum detectable trend at a reasonable power level for many of the other responses will likely be much higher. Estimating the probability of slope values may be the best way to provide insight into trends for these attributes. Second, even for the key features around which sampling designs were based, Bayesian methods may reveal the potential of declining trends before rejecting the null hypothesis that the regression slope equals 0 with conventional statistics.

Bayesian methods use a likelihood distribution generated from the sample data that provides the probability of observing the data for every possible parameter value. Combining this with a prior distribution produces a posterior distribution which is used to make inference about parameters. The prior distribution reflects previous knowledge about the distribution of parameters which can be developed as the monitoring program progresses (Efron 2013). Once an informed prior is in place, the probability of various increasing and decreasing slopes should be evaluated based on the posterior distribution and the consequences of not alerting management of a potential trend. The result of this assessment is the derivation of the probability of different levels of decline/increase. Even when conventional statistics do not reveal a significant trend, relatively high probabilities (e.g., $\geq$0.70) of trends with an informed Bayesian model may warrant special attention.

Including Explanatory Variables

Model-based methods

Model-selection procedures consider a range of potential factors influencing directional change in resource conditions. Even if a significant trend occurs as a function of time, the relationship between other explanatory variables and spring measures should be evaluated to determine potential 'causal' factors of trends. These other explanatory variables can include biophysical features of the springs (e.g., aspect, potential solar radiation, etc.) as well as other measures (e.g., climatic conditions).

Model selection methods (Burnham and Anderson 2002) evaluate the explanatory power of different models of trends in spring measures. Multiple models are considered, each with different combinations of independent variables and interaction terms. All models should be based on hypothesized, ecologically meaningful relationships. Adjusted AIC (Akaike's Information Criterion) or Bayesian Information Criterion (BIC) generated with a mixed-effects model are used to determine the best predictive model as well as the

importance of independent variables; the latter penalizes additional parameters more than AIC does.

The primary model in this model-selection procedure is the response of interest vs. time (see frequentist methods above). Alternative models can be based on measures of climate, land use, and land condition, as well as other measures that may be considered important. When evaluating other variables, they are either included in an interaction with time or time is replaced with the variable.

The result of the model-selection procedure is the selection of the model (i.e., set of independent variables) which best predicts the trend of the response variable. This, in turn, aids in explaining reasons for the observed trend. For instance, if alternative models with one or more driver attributes (e.g., drought days) accounted for more variance than just using time, trends may be attributed to these attributes in a correlational relationship, but not necessarily a causal relationship. If alternatives to time account for less variance, other avenues of investigation should be considered to explain reasons for observed trends.

Correlations
There will be instances where a monitored attribute fails to exhibit a trend (i.e., a direction change), but instead may have periods of decline followed by recovery. In other words, natural variation may be more evident than a precipitous decline or increase, and it may mirror the variation in a key driver attribute. Discerning this variation and reasons for it can involve many complex procedures. As a first step, however, correlational methods can provide useful insight and are relatively simple.

For attributes that fluctuate between declines and increases, correlations with climate, land cover/use, land condition, and other potential drivers should be considered. Strong correlations between a response and driver may be sufficient to understand reasons for the observed variation over time (e.g., strong correlation between flow and winter precipitation).

Another type of correlation assessment is path analysis (Lindquist 2000). This method accounts for the inter-correlated structure among factors by decomposing correlations to direct and indirect effects. For instance, changes in flow in an alluvial spring may be influenced by precipitation alone or by vegetation cover alone or by the influence of precipitation on vegetation cover. A path analysis would decompose the effects of climate and of vegetation cover on flow, while considering the combined influence of climate and vegetation. The result of a path analysis is the indication of the strength of direct and indirect factors on a response, thus providing insight into reasons for the observed changes in a response. Path analysis is based on correlation values and the simultaneous solution of structural equations. Simple examples of the construction and use of path analysis are provided in Lindquist (2000) and Van Bruggen and Arneson (1986); details of path analysis are provided in Pugesek et al. (2003).

5.0 References

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: A practical Information Theoretic approach. Second edition. Springer, New York, NY, USA.

Efron, B. 2013. Bayes' theorem in the 21st century. Science 340: 1177-1178.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2000. Bayesian Data Analysis. Chapman & Hall/CRC, New York.

Helsel, D.R. and R.M. Hirsch. 2002. Statistical methods in water resources. Ch. A3 in Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4, Hydrologic Analysis and Interpretation. http://water.usgs.gov/pubs/twri/twri4a3/

Hirsch, R.M. and J.R. Slack. 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research 20: 727-732.

Irvine, K. M., K. Manlove, and C. Hollimon. 2012. Power analysis and trend detection for water quality monitoring data: An application for the Greater Yellowstone Inventory and Monitoring Network. Natural Resource Report NPS/GRYN/NRR—2012/556. National Park Service, Fort Collins, Colorado.

Larsen, D. P., N. S. Urquhart, and D. L. Kugler. 1995. Regional scale trend monitoring of indicators of trophic condition of lakes. Water Resources Bulletin, 31:117-140.

Lindquist, J. E. 2000. A method of estimating direct and indirect effects of Armillaria root disease and other small-scale forest disturbances on canopy gap size. Forest Science, 46:356-362.

Pugesek, B. H., A. Tomer, and A. von Eye. 2003. Structural equation modeling. Cambridge University Press, Cambridge, UK.

Tipton, J. 2013. Rare plant power analysis for the National Park Service at Arches, Canyonlands, and Natural Bridges. Internal report to NPS, Moab, UT.

Van Bruggen, A. H. C. and P. A. Arneson. 1986. Path coefficient analysis of effects of *Rhizoctonia solani* on growth and development of dry beans. Phytopathology, 76:874-878.

Wade, P. R. 2000. Bayesian methods in conservation biology. Conservation Biology, 14:1308-1316.

Weissinger, R., and M. Moran. 2013. Proposed sampling design for springs, seeps, and hanging gardens monitoring in the Northern Colorado Plateau Network. Natural Resource Report NPS/NCPN/NRR—2013/618. National Park Service, Fort Collins, Colorado.

Wood, S. N. 2006. Generalized additive models: an introduction with R, volume 66. CRC Press, Boca Raton, Florida, USA.

Zuur, A.F., E.N. Ieno, N.J. Walker, A.A. Saveliev, and G.M. Smith. 2009. Mixed effects models and extensions in ecology with R. Springer, New York, NY.

Springs Monitoring Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 11

Revising the Protocol Narrative and SOPs

Version 1.01 (January 2018)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	1-1-2018	R. Weissinger	Update VK	Record metrics for total site area	1.01

This SOP explains how to make and track changes to the protocol narrative and related SOPs. Following these guidelines ensures that data collection and processing procedures are documented and retained for use and interpretation of historical data sets. Project staff should refer to this SOP when any changes to an approved protocol document are necessary. The procedures in this SOP are based on the NCPN Protocol Versioning Guidance Document (NCPN-NPS 2009).

Procedures

1. Modifications must be reviewed for clarity and technical soundness. Small changes or additions to existing methods will be reviewed in-house by NCPN Inventory and Monitoring staff. An outside review is required for substantive changes in methods. Regional and national staff of the National Park Service and experts outside of the Park Service with familiarity in hydrology and vegetation monitoring and data analysis will be used to review major changes.

2. Record all changes to a protocol document (protocol narrative or SOP) in the document's revision history log, even minor edits like fixing typos or formatting changes. It is not necessary to record the specific edits made, rather just the fact that typos were fixed or formatting changes were made. For minor edits, record the same document version number in the revision history log. For actual protocol changes (e.g., changes in methods, equipment), assign a new version number in the revision history log. Depending on the significance of the changes, it may be okay to combine multiple changes in the same entry in the revision history log. Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02, etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). Record the previous version number, date of revision,

author of the revision, and the reason for the changes along with the new version number (if applicable).

3. Narrative and SOP updates may occur independently. That is, a change in one SOP will not necessarily invoke changes in other SOPs; a narrative update may not require SOP modifications. The NCPN tracks the narrative and SOP version numbers in a Master Version Table (MVT), which is maintained in this document (SOP #11). Any time a narrative or an SOP version change occurs, a new Version Key number (VK#) must be created and recorded in the MVT, along with the date of the change and the versions of the narrative and SOPs in effect. The VK number increments by whole integers (e.g., 1, 2, 3, 4, 5). Updates to the MVT also must be provided to the NCPN Data Manager for inclusion in the master version table database. *The protocol narrative, SOPs, and data should not be distributed independently of this table*.

4. New versions of the protocol narrative and SOPs must be posted on the NCPN web page. Older versions of the Protocol Narrative and SOPs must be archived in the NCPN Springs Protocol Library: (R:\Monitoring_Archive\Springs\Protocol).

Springs Monitoring, Northern Colorado Plateau Network
Master Version Table

Version Key #	Effective Date	Narrative	SOP 1	SOP 2	SOP 3	SOP 4	SOP 5	SOP 6	SOP 7	SOP 8	SOP 9	SOP 10	SOP 11
VK1	8-1-2013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VK2	1-1-2018	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.01

References

NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.