Sky Island Waters: Adapting the way spring ecosystems are monitored, managed, and restored

Final report for BOR WaterSMART Applied Science Grant #R18AC00023
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SKY ISLAND ALLIANCE

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Summary of Work Performed

Task 1—Develop a toolbox of enabling conditions for springs and streams

Springs Prioritization Tool

Between 2017-2019 we hosted five meetings with regional partners that had an interest in stewarding and/or studying spring ecosystems. Attending organizations included the Bureau of Land Management, Bureau of Reclamation, Coronado National Forest, Gila River Indian Community, Pima Association of Governments, Pima County, Saguaro National Park, Springs Stewardship Institute, The Tohono O'odham Nation, Tucson Water, Tucson Audubon, the University of Arizona Water Resources Research Center, U.S. Fish and Wildlife Service, Watershed Management Group, and Western Resource Advocates.

Topics covered included:

- Introduce the project and proposed approach for developing a tool
- Develop an understanding of partners information needs and potential uses of tool
    - Gather input from practitioners and springs managers to adapt approach
    - Develop an understanding of the most useful final products and format
    - Explore how best to include cultural values and climate change considerations in the toolbox
- Introduce draft tool and gather participant input on key variables of draft tool
    - Narrow attributes and ensure we're addressing them in a way that will be helpful for users
    - Discuss how much of this tool should be prepopulated versus flexible for users to select parameters themselves
    - Review attributes within variable categories

We conducted outreach during development of the tool at the Springs Ecosystem Science Symposium (June 2018), the Madrean Conference (May 2018), and multiple meetings of the Transboundary Madrean Landscape Conservation Design collaborative (2017-2019), and shared Version 1.0 through workshop at the Society for Ecological Restoration Southwest Chapter Conference (November 2019).

A Springs Prioritization Tool was developed to help land managers gain insight into the known biophysical attributes of 3,891 springs in Southern Arizona and evaluate the relative conservation value, current level of threat, and spatial isolation of these springs from other perennial water sources. The Spring Prioritization Tool was presented as a workshop for stakeholders at the Society of Ecological Restoration Annual Meeting in Tucson, AZ on November 8, 2019. During workshop, participants learned how to compare the condition and risk of springs across public and private lands with best available data to guide the prioritization of springs for protection and restoration actions on the ground. Participants received access to the spring attribute database (with both GIS-based and survey-based data) and training on how to use calculated scores to compare spring attributes and prioritize opportunities for conservation.

Synthesis of Policy Opportunities to Protect Water for Natural Areas

Since 2016 we've worked together with the University of Arizona Water Resources Research Center to promote dialogue, understanding, and innovation among water managers, natural resources managers, and community groups toward securing environmental flows for water-dependent natural areas. Two critical threats to healthy ecosystems are the lack of policy tools necessary to protect water at its source, and the lack of effective mechanisms for reinvesting water saved through conservation and efficiency back into natural areas. To develop these tools and mechanisms, we must effectively link regional discussions about water management with conservation and strategies to protect water dependent ecosystems and watersheds. We developed a policy guide that outlines available planning and management options for ensuring environmental flows by exploring the status of policies and regulations, highlighting successful examples of environmental flows projects, showcasing available tools for local decision making, and identifying future pathways available to include natural areas alongside human uses in water management.

Attachments:

[1.1] Policy Guide for Ensuring Environmental Flows

[1.2] Spring Prioritization Tool

- Map Viewer
- Spring Attribute Database (SpringTool_v1.0.xls)

Task 2—Synthesize currently used spring monitoring approaches and develop guidance on spring monitoring

Springs provide important water sources and create mesic habitats in otherwise arid ecosystems—sustaining a rich diversity of life in the southwestern United States and northern Mexico. To protect spring ecosystems from a range of environmental threats including aquifer depletion, spread of invasive species, and disturbance from livestock intrusion, spring physical and biological attributes need to be inventoried and monitored over time to detect change and inform adaptive conservation management. This summary of spring monitoring approaches describes a range of spring monitoring needs, methods, results, and how to interpret monitoring data into stewardship action. Specifically, this summary includes:

- **Stakeholder Input**—Summary of spring monitoring needs and vision from stakeholders convened as part of the 2018 Spring Ecosystem Symposium in Flagstaff, AZ.
- **Monitoring Methods**—Compares the purpose, costs, and benefits of example expert and amateur field methods to assess spring condition.
- **Monitoring Results**—Highlights lessons learned from spring monitoring sites in Arizona.

- **Stewardship Recommendations**—Recommends a process to convert monitoring data into a spring stewardship decision-making framework to inform further spring data collection and conservation action on the ground.

Attachments:

- Appendix A—Spring Monitoring Approaches
- Appendix B—Spring Inventory Protocol (SIP) Form
- Appendix C—Spring Ecosystem Assessment (SEAP) Form
- Appendix D—Adopt-a-Spring Survey Form and Macroinvertebrate Guide
- Appendix E—Spring Seeker Form

Task 3—Work with managers to utilize and revise the Arizona Springs Restoration Handbook

After publication of the Arizona Springs Restoration Handbook we received feedback through active restoration work with practitioners, that more guidance on how to think about plant palettes at spring sites was needed, as well as guidance on how to consider climate change adaptation needs in plant selection for spring restoration. We also found that in our own restoration work the was a topic in need of careful attention with many considerations in relation to pollinators and phenology. To address these needs, we developed an addendum to the Arizona Springs Restoration Handbook that is focused on the use of plants at spring sites to support wildlife, address restoration goals, and enhance resilience to long-term drought.

Spring Prioritization Tool

Sky Island Alliance created a Sky Island Springs Prioritization Tool to help land managers gain insight into the state of 3,891 springs in southern Arizona. The tool includes a spring attribute database, a spring conservation model, and an interactive map that allows users to compare the relative conservation value, level of threat, and spatial isolation of springs from other perennial water sources in the region. By using the map explorer (Figure 1), users can compare the condition and risk of springs across public and private lands with best available data to guide the prioritization of springs for protection and restoration actions on the ground.

The Spring Prioritization Tool was presented as a workshop for stakeholders at the Society of Ecological Restoration Annual Meeting in Tucson, AZ on November 8, 2019. During the workshop, participants learned how to compare the condition and risk of springs across public and private lands with best available data to guide the prioritization of springs for protection and restoration actions on the ground. Participants received access to the spring attribute database (with both GIS-based and survey-based data) and training on how to use calculated scores to compare spring attributes and prioritize opportunities for conservation. All Spring Prioritization Tool products are available online to the public: https://skyislandalliance.org/our-work/water-program/springs-prioritization-tool/

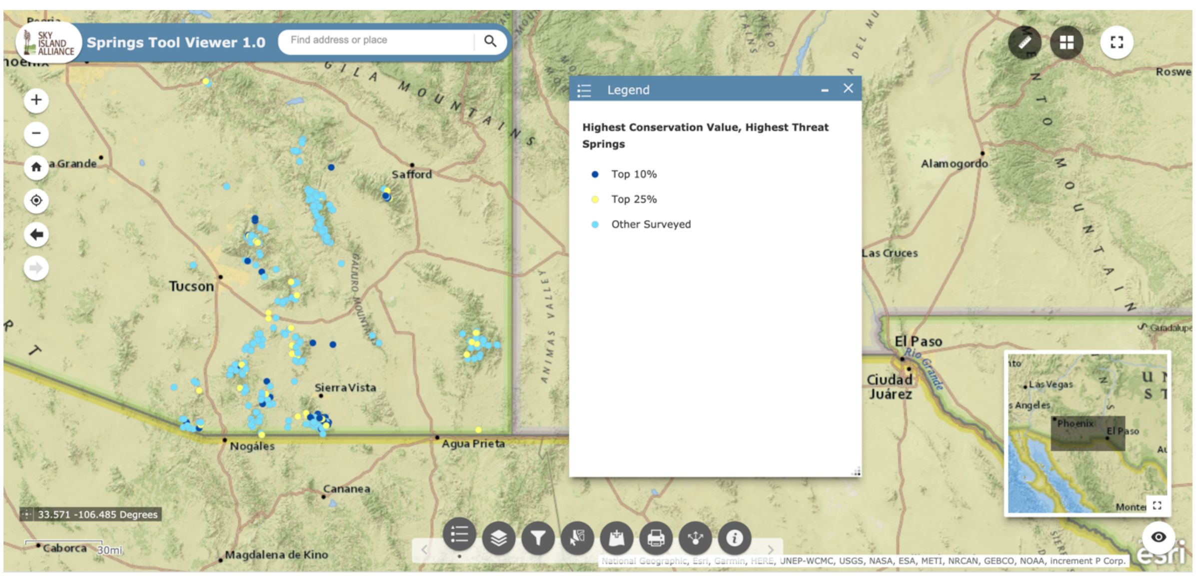


Figure 1—Springs across southeastern Arizona were categorized by their relative conservation value and threat based on best available data. The full interactive spring map is available here.

Tool Methodology

The Spring Prioritization Tool 1.0 contains an Excel database (*SpringTool_v1.0.xlsx*) of attributes for 3,891 total springs and calculated scores for comparing relative spring conservation value, threat, and isolation from other water sources. It was developed to help land managers and conservation practitioners in the northern Sky Island Region (Southern Arizona) better understand the physical, biological, and social context for springs in their region and to aid the prioritization of conservation activities. The database contains:

- **Metadata:** List of variable description, unit of measurement, scale of analysis, data source, date or version of data acquisition, hyperlink to data source, and notes on any data calculation conducted.
- **SpringsData:** Compiled original data compiled from many sources on variables for all springs included in the project.
- **ScoringMethod:** Description of how spring scores (conservation value, threat, and isolation) were calculated for all mapped springs and a subset of surveyed springs.
- **ScaledSpringsData:** Compiled springs data converted to a 0-10 scale which serve as inputs to spring score calculations.
- **Weighting:** Adjustable weighting to calculate spring scores from springs data.
- **SpringScores:** Calculated scores for spring conservation value, threat, and isolation and other key attributes included to aid spring prioritization for conservation activities.
- **KeyFindings:** Prioritization analyses for all springs included in the region.

All springs included in the database have GIS-derived attribute variables ("all springs") and a subset of springs (328) have additional variables derived from direct spring survey ("surveyed only"). All variables were scaled from 0-10 prior to inclusion in the spring conservation value, threat, and isolation score calculations (scaled spring data available on the "ScaledSpringsData" tab).

A Conservation Value score (Figure 2) was calculated for all springs where more critical habitat, greater winter precipitation, and less evapotranspiration likelihood constituted higher conservation value. An additional Conservation Value score was calculated for springs with available survey data and included the extra variables of water presence, flow, specific conductance, water temperature, habitat patch size, soil integrity, and habitat integrity. The Threat score was calculated for all springs based on road density, road proximity, well density, burn risk, urban proximity, and cropland density correlated with more threatened springs. For surveyed springs, an additional Threat score was calculated that includes observed grazing, nonnative plants, and nonnative animals at the spring site. A spring Isolation score was also calculated to determine which springs were further from other springs and perennial water as a metric from rarity on the landscape.

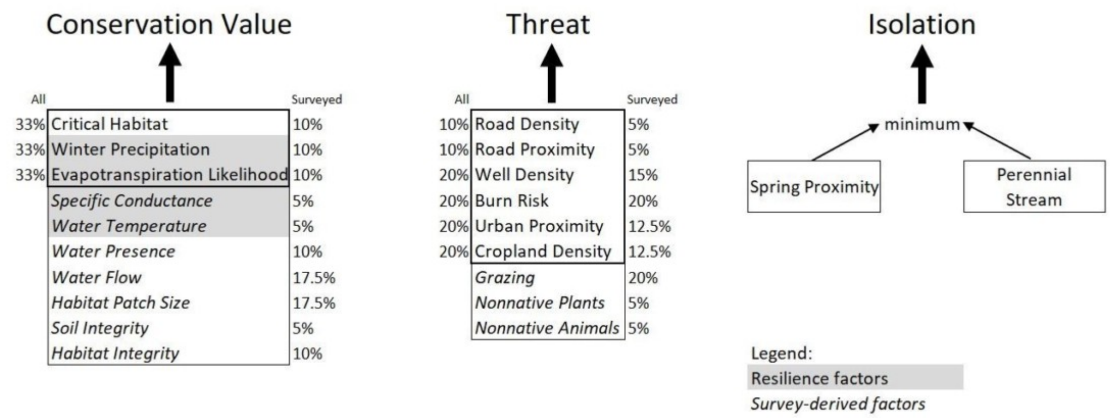


Figure 2— Variables used to calculate spring scores for conservation value, threat, and isolation. Scores for all mapped springs are in the bold outlined boxes and expanded scores for surveyed springs include the full list of variables. Percentages reflect relative weights of variables used in each score calculation.

Variable weighting for each spring score is adjustable on the “Weighting” tab separately. The relative weighting for each component of the calculated Conservation Value and Threat Scores can be changed separately. In the spreadsheet, the weighting will automatically adjust the final variable to ensure the total adds up to 100 (Figure 3).

Original Weighting:

	All	Surveyed Only
Conservation Value		
Critical Habitat	33.3	10
Evapotranspiration Likelihood	33.3	10
Winter Precip	33.4	10
Water Presence		10
Water Flow		17.5
Habitat Patch Size		17.5
Soil Integrity		5
Habitat Integrity		10
Specific Conductance		5
Water Temperature		5
Threat		
Road Density	10	5
Road Proximity	10	5
Well Density	20	15
Cropland Density	20	12.5
Urban Proximity	20	12.5
Burn Risk	20	20
Grazing		20
Non-native Plants		5
Non-native Animals		5

Example Weighting Change (yellow cells):

	All	Surveyed Only
Conservation Value		
Critical Habitat	50	20
Evapotranspiration Likelihood	25	10
Winter Precip	25	10
Water Presence		10
Water Flow		15
Habitat Patch Size		15
Soil Integrity		5
Habitat Integrity		5
Specific Conductance		5
Water Temperature		5
Threat		
Road Density	10	5
Road Proximity	10	5
Well Density	20	15
Cropland Density	20	12.5
Urban Proximity	20	12.5
Burn Risk	20	20
Grazing		20
Non-native Plants		5
Non-native Animals		5

Figure 3—A comparison of the original weighting (left) and example changed weighting (right) for conservation value and threat scores.

Tool Highlights

The "SpringsData" tab provides information on numerous spring attributes of interest to spring managers including:

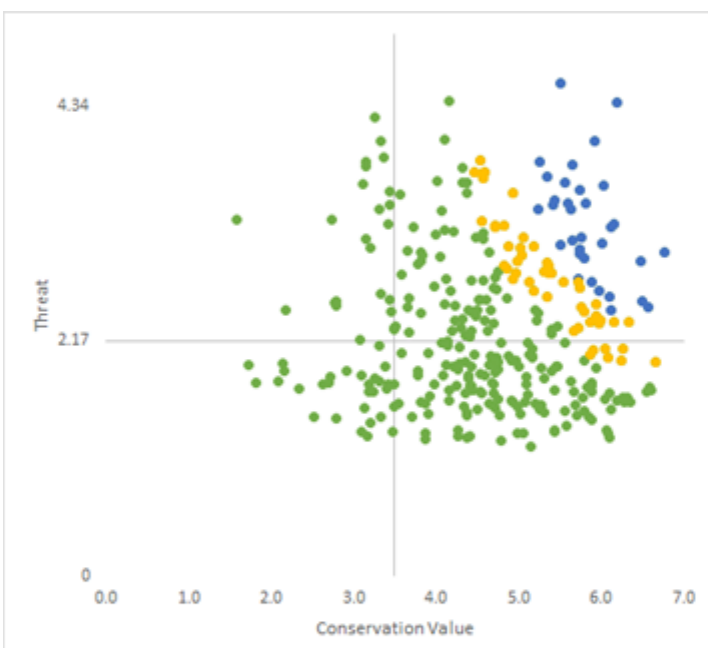
- **Water Presence (Water_Pres)**: The average percentage of spring survey visits when free water was visibly present, where higher values represents more consistent water availability and therefore higher conservation value. The accuracy of this parameter is affected by the number and seasonal timing of spring surveys, so values could inaccurately suggest perenniality if the surveys were only conducted in the wettest time of year.
- **Water Flow (MeasuredFl)**: The average flow measurements of the spring, when flow was measurable, where higher values represent greater water availability and therefore higher conservation value. The accuracy of this parameter is affected by the number and seasonal timing of spring surveys, so values could inaccurately suggest consistently high water availability if the surveys were only conducted once, or in the wettest time of year.
- **Accessibility (Dist_2_Rd)** The distance in kilometers to the closest known road or rail.

To understand which springs are most threatened, the calculated threat scores can be viewed in multiple ways:

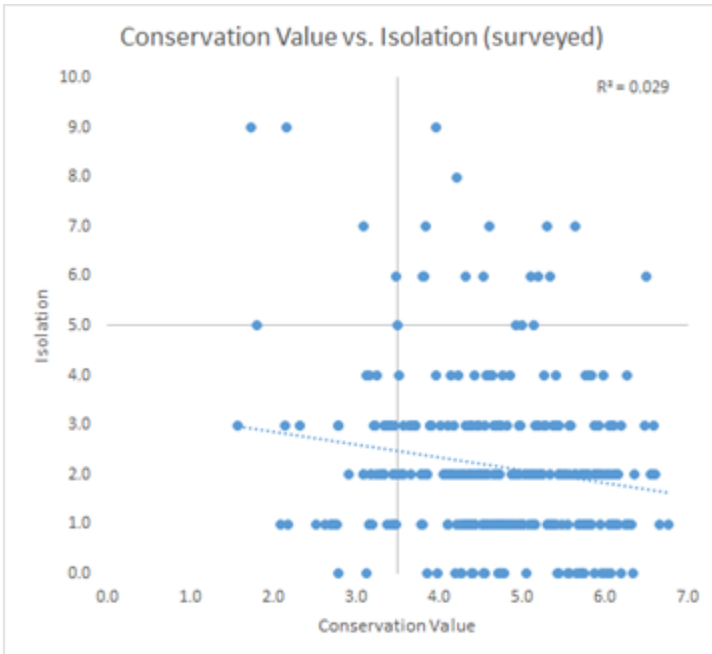
- Compare the calculated threat scores on the "SpringScores" tab in the SpringTool_v1.0.xlsx spreadsheet.
- View the relative threat scores on the Map Viewer for all springs by selecting the "Spring Scores - Threat All" data layer for 3,891 springs or the "Spring Scores - Threat Surveyed" data layer for the 328 surveyed springs.
- Look at the distribution of threat scores across springs on the "KeyFindings" tab of the SpringTool_v1.0.xlsx spreadsheet.

To understand which springs need protection most urgently, identify the springs that score highly for both conservation value and threat. These data can be viewed in multiple ways:

- View the high priority springs on the Map Viewer by selecting the "Highest Conservation Value, Highest Threat Springs" data layer for the 328 surveyed springs. If you also select the "Land Management" data layer, you can see the corresponding land management unit for high priority springs.
- On the "KeyFindings" tab of the SpringTool_v1.0.xlsx spreadsheet, springs in the lower left quadrant (low conservation value, low threat) may not be a priority for allocation of resources. Springs in the upper right quadrant (high conservation value, high threat) might be the highest priority springs, depending on the type of threat they face. The best investment may be springs of high conservation value and moderate to low threat (middle of right half). Conservation value and threat for surveyed springs does not seem to be correlated.



- Very isolated springs that score highly for conservation value could be another way to identify priority springs. Those are shown in the upper right quadrant of this graph, and have Conservation Value - Surveyed scores over 3.5 and Isolation scores of 5 or more.



Acknowledgements -This project was supported by the Bureau of Reclamation WaterSMART Applied Science Grant for the Desert and Southern Rockies Landscape Conservation Cooperatives and the Nina Mason Pulliam Charitable Trust. The creators of the Springs Prioritization Tool 1.0 acknowledge and appreciate the many contributions of technical experts and spring survey volunteers who made this project possible.

Spring Monitoring Summary and Recommendations

Springs provide important water sources and create mesic habitats in otherwise arid ecosystems—sustaining a rich diversity of life in the southwestern United States and northern Mexico. To protect spring ecosystems from a range of environmental threats including aquifer depletion, spread of invasive species, and disturbance from livestock intrusion, spring physical and biological attributes need to be inventoried and monitored over time to detect change and inform adaptive conservation management. This summary of spring monitoring approaches addresses the following:

1. **Stakeholder Input**—Summary of spring monitoring needs and vision from stakeholders convened as part of the 2018 Spring Ecosystem Symposium in Flagstaff, AZ.
2. **Monitoring Methods**—Compares the purpose, costs, and benefits of example expert and amateur field methods to assess spring condition.
3. **Monitoring Results**—Highlights lessons learned from spring monitoring sites in Arizona.
4. **Stewardship Recommendations**—Recommends a process to convert monitoring data into a spring stewardship decision-making framework to inform further spring data collection and conservation action on the ground.

Stakeholder Input

On June 5, 2018, Sky Island Alliance and the Spring Stewardship Institute convened a stakeholder discussion on "The Current State of Springs Monitoring and Where We Go From Here" at the 2018 Springs Ecosystem Symposium in Flagstaff, AZ. This session catalyzed discussion and debate about the state of springs monitoring protocols and methodologic needs for future springs stewardship and restoration. On day one, participants were asked to respond to the following questions:

- What 3-5 monitoring needs do you think are top priority for spring ecosystems in the next 10 years?
- Is this happening anywhere now? Is it happening at the right time/spatial scale?
- What current monitoring programs or approaches are addressing these needs?

Responses were collated and used to inform the structure of the interactive session on day two where Stakeholders broke into small groups to discuss the following monitoring needs for springs in the Sky Island Region of the southwestern United States and northern Mexico:

- Flow; Groundwater (pumping); Coupling flow monitoring with climate monitoring, Water Quality/Chemistry
- Species (Diversity, Presence/Absence)
- Collecting long-term data/indicator springs
- Compile and analyze existing data

Each group answered the following questions for their monitoring need:

- How do we implement opportunities?
    - Are current approaches addressing this?
    - Do we need to do something different/new?
    - What is needed next?
    - How often and for how long?
    - Where? Particular location?
    - Who will do it?

Monitoring approaches already in place that were identified by the participants ranged from several citizen science monitoring approaches recently piloted in Arizona (Sky Island Alliance's Adopt-a- Spring program and development of a phone app by Wildlands Network and the Spring Stewardship Institute) to long-established, in-depth approaches such as those used by the National Park Service Monitoring Networks (Appendix A). Overall, managers desired to understand how springs are changing over time and between years, how intervention actions including restoration are achieving conservation and restoration goals, and how to know when tipping points have been reached that mark the permanent shift in spring ecosystems to another stable state. A list of important spring monitoring criteria were identified (Table 1) and specific recommendations from the stakeholder discussion included:

- Fill critical gaps in monitoring:
    - Conduct water quality monitoring because it is usually project-based and not widespread across monitoring efforts. This information can give insights into how water sources are changing and give insight into the seasonality of the source.
    - Collect and curate voucher specimens of plants and animals to ensure species occurrence data is scientifically rigorous.
    - Inventory invertebrate species as indicators of aquatic ecosystem health.
    - Conduct spring surveys 3 times per year to measure seasonal changes and increase accuracy of annual spring condition averages.

- Identify and monitor "sentinel springs" that will serve as reference sites to detect environmental changes across a diversity of spring discharge levels and ecoregions.
- Facilitate more collaborative monitoring between stakeholders, striving to share methods and increase data accessibility and compatibility.
- Champion longer-term funding sources for spring monitoring so this becomes a widespread component of spring management.

Table 1—Spring monitoring criteria were developed by stakeholders at the June 2018 workshop.

Spring Monitoring Category	Need
Flow	Continuous water level and discharge data
	Trends in spring output volume
	Correlation with groundwater pumping
	Water level during extreme events
	Seasonality of ephemeral springs
Water Quality	Stable water isotopes
	Major ion chemistry
	Trends in seasonally and over time
	Temperature
Biological Community	Diversity assessments (plants, invertebrates, vertebrates)
	Listed species
	Spring-dependent species
	Invasive species
	Trends in species abundance over time
Cultural Resources	Historical uses
Groundwater	Trends in groundwater extraction
	Trends in groundwater level
	Correlation with precipitation
	Water rights
Climate	Air temperature
	Ground temperature
	Trends in precipitation regimes
	Evapotranspiration from spring wetlands
Disturbance	Human development
	Livestock impacts
	Mining

Monitoring Methods

A wide variety of spring monitoring methods and protocols are developed and used by public land management agencies, academic researchers, and nongovernmental organizations seeking to understand spring ecosystems in their care. Such protocols generally seek to document trends in the status of the spring source itself, the biological community associated with the spring, cultural uses of the site, and threats to spring ecosystem function. However, the specific monitoring methods used in the field, the expertise of the field personnel, and the frequency of spring monitoring measurement is highly variable.

To highlight the range of spring survey approaches used for monitoring and their associated benefits and challenges, we compared the monitoring frameworks of three related, but distinct spring protocols from the Spring Stewardship Institute and Sky Island Alliance. These protocols all seek to understand the status of spring sources and ecosystems, yet they vary in the cost to implement and depth of data collected. Collectively, this set of protocols exemplify the practical tradeoff that exists between the desire to collect in-depth spring inventories at fewer springs/timepoints or less in-depth spring inventories at more springs/timepoints (Table 1).

The Spring Stewardship Institute sets a rigorous global standard for spring inventory, assessment, and monitoring through their Spring Inventory Protocol (SIP) (Appendix B) and Spring Ecosystem Assessment (SEAP) (Appendix C). This spring survey method is divided into three levels that range from quick, non-expert spring validations of ecosystem location (Level 1) to high-expertise and effort spring assessment of site condition and risk (Level 2) and longer-term monitoring (Level 3). To successfully implement this core spring inventory and assessment, it requires in-depth training on the protocol by Spring Stewardship Institute, a team of 3-4 experts with 2 assistants to conduct the field work, access to an extensive array of scientific equipment (Appendix B, Table 1), knowledge in geomorphology, spring ecology, taxonomy of plants, vertebrates, and invertebrates, cultural features of spring sites, and the spring's management context. When the protocol is implemented to its full potential, the quality of data is high and insight gained into the hydrological and biological condition of the spring site is adequate to inform management and protection efforts across multiple jurisdictions. However, it relies on a high investment of personnel with training and knowledge which can provide a practical barrier to implementation of the protocol across many springs and over time for monitoring purposes. Further, when the method is used by personnel or volunteers without sufficient expertise, the quality of data can be compromised and this can introduce observer bias into subsequent data analysis and spring management recommendations. Lastly, because the data collection occurs manually, there can be a delay in data entry and sharing to the Springs Online database which prevents the detailed insight gained through the protocol from being successfully applied to spring management.

Table 1. A comparison of three spring survey methods that range in purpose, expertise, equipment, and frequency.

Survey Attribute	Spring Inventory Protocol (SIP) & Spring Ecosystem Assessment (SEAP)[1]	Adopt-a-Spring (AAS)	Spring Seeker
Creator	Spring Stewardship Institute	Sky Island Alliance	Sky Island Alliance
Purpose	Assess spring site condition and risk level, collect data on aquifer and water quality, site geomorphology, habitat array, site biota, human uses and influences, and administrative context for spring management	Collect time trend information on flow, habitat area, water quality, plant and wildlife species present	Collect information on spring location, water, human impacts, with optional additional information on the habitat area, flora and fauna, site description, and cultural resources
Expertise Required	High	Low	None
Training Required	High	Low—Basic instruction provided to volunteers	Optional—Brief online training materials available to volunteers
Personnel needs	3-4 experts with 2 assistants	2 trained volunteers	1 non-expert volunteer
Survey Duration	1.5-3 hours minimum per survey	1+ hour per survey	<0.5 hours per survey
Survey Frequency	Once +	5 times per year	Once +
Special equipment	Yes	Yes	No
Data Entry	Manual data entry	Manual data entry	Direct upload to Survey123 from mobile device

[1] Stevens, L.E., A.E. Springer, and J.D. Ledbetter. 2016. Springs Ecosystem Inventory Protocols. Springs Stewardship Institute, Museum of Northern Arizona, Flagstaff, Arizona.

Sky Island Alliance adapted the SIP and SEAP into two separate monitoring protocols to increase the ease of implementation by non-expert volunteers and likelihood of repeated monitoring surveys over time through simplification. The first adaptation resulted in the Adopt-a-Spring (AAS) protocol (Appendix D) in 2014 that focused on collecting trend information 5 times a year on spring flow, area of wet habitat, water quality, and casual plant and wildlife observations. The AAS relied on simple water flow measurement equipment, basic observations by a team of minimally-trained volunteers, and photo records taken at the same location during each survey. Once the data was manually entered, the resulting data produced meaningful information on variation and trends in spring water flow and quality (see the Monitoring Results section for details), however the biological data was not consistently beneficial due to variability in volunteer plant and animal identification skills. Volunteer fatigue occurred over time and the monitoring effort proved challenging to sustain when relying on non-experts for the duration of the program.

The second Sky Island Alliance adaptation of the SIP and SEAP protocol was the creation of Spring Seeker in 2020 (Appendix E), a mobile survey designed for non-expert volunteers to use for the validation of spring locations and simple site condition assessments. While the Spring Seeker survey required no training or special equipment other than access to a mobile device in the field, open-access online training materials were made available to explain the survey attributes, and guidance was provided on where to find springs for assessment. The primary benefits of this method is its portability, requiring no manual data entry after the spring visits which increases data analysis efficiency and reduces errors. The simple data collected was shown to effectively serve as an early indication of highly at-risk springs. Additionally, this method did not require experts or the same field team to visit springs which facilitated the participation of more volunteers in the project. This downside of this method is that it did not require in-depth assessment of any spring so some surveys only consisted of the validation of spring location and confirmation of water presence. These surveys must be interpreted as the first phase of spring assessment, needing more in-depth spring inventory and assessment prior to forming management recommendations.

Significant tradeoffs exist between the acquisition of higher quality, in-depth assessments of spring condition conducted by experts and the number of springs that can be effectively assessed and monitored. It is recommended to use non-expert volunteer effort to collect simple location, water presence, and simple risk tracking on as many springs as possible, as often as possible. With rapid analysis of these crowd-source data and clear indications of when in-depth and expert assessments are warranted (see the Stewardship Recommendations section for more details), these simple monitoring approaches can provide valuable insight on where to focus the time and effort of spring experts on sites where significant management concerns or opportunities arise.

Monitoring Recommendations

When creating or adapting a spring monitoring protocol to meet the specific needs and interests of spring managers, we recommend considering the following factors:

- The expertise, skills, and interests of personnel not only writing the protocol, both those charged with implementing the protocol in the field, and managing the resulting data.
- The scientific question(s) of interest.
- The specific indicator variables that will provide desired information for spring stewardship and management.
- The desired and logistically feasible frequency of measurement.
- The availability of scientific measurement equipment and plan to calibrate.
- The resources available for training and quality control.
- The plan for data entry, interpretation, and sharing.
- A plan to manage and motivate spring monitoring volunteers (if needed).

Across all spring monitoring methods and approaches, there are some universal recommendations on monitoring methods to consider:

- Prior to any spring survey event, obtain landowner permission for access and any research/permits required by law.
- Develop a safety plan to encourage spring surveys are conducted with personnel health and safety prioritized.
- Especially for repeated monitoring spring surveys, minimize disturbance during spring visits to limit disruption to the spring ecosystem from vegetation loss, new social trail creation which could increase unplanned public access, erosion, and spread of invasive species, and aquatic pathogens.
- Consider the seasonality of sampling efforts to differentiate base from peak spring flow from peak.
- Acknowledge and seek to understand the multiple past, present, and future uses of springs that influence spring condition and its management.
- Protect natural and cultural features of springs by limiting public information about the location of sensitive springs.
- Consolidate spring data through Springs Online (Spring Stewardship Institute) with the appropriate, unique site identification number to facilitate data sharing across entities and the long-term study of springs globally.

Monitoring Results

Sky Island Alliance initiated its Adopt-a-Spring (AAS) monitoring protocol in 2014 to gather seasonal data on springs in southeast Arizona with volunteers. Fourteen spring sites in southeast Arizona were selected for a variety of purposes (Figure 1), including undeveloped springs in good condition to be monitored as reference sites for climate change impacts over time and disturbed springs affected by fire, cattle intrusion, or restoration to be monitored for recovery. Volunteers were trained and encouraged to monitor springs five times per year across the region. Monitoring surveys were regularly collected between 2014 and 2019 for many springs, however seasonal survey windows were more frequently missed in the dry summer and winter seasons, when more extreme temperatures affected volunteer availability and interest in field work. During one 2-year period of the program, a cohort of 51 volunteers were trained and contributed 736 hours over 48 spring surveys trips to monitor 6 springs. In total, 14 springs were monitored in the region with varying frequency and duration.

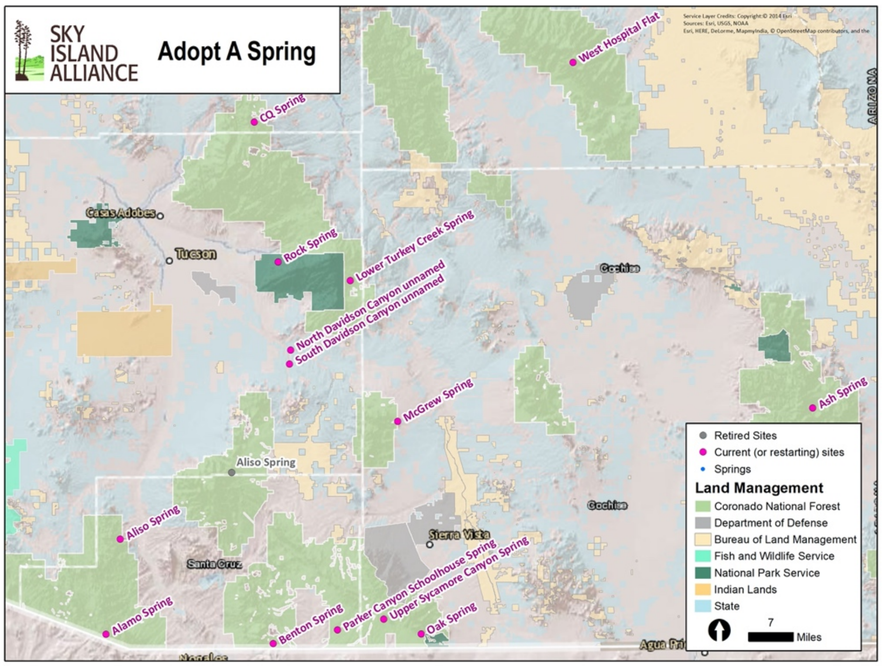


Figure 1. The distribution of fourteen Adopt-a-Spring spring sites in southeastern Arizona.

Across the AAS spring monitoring network, volunteers took photographs at designated photo locations and collected data following the AAS protocol on spring flow, wetted area of spring habitat, water quality, and opportunistic observations of plants, vertebrates, and invertebrates (Appendix C). The resulting monitoring data show that in general spring ecosystems are highly variable over time between seasons and years, so unrepeated spring surveys are unlikely to be representative of spring average and trending conditions. With longer monitoring, species richness at spring sites grows due to the increased sampling effort and the likelihood of detecting effects of climatological trends and disturbance events increases.

Hospital Flat Spring

Hospital Flat Spring was selected for AAS monitoring as a high elevation helocrene reference spring site situated in a large meadow in the Pinaleño Mountains of Graham County, Arizona. It is managed in the Pinaleño Ecological Management Area of Coronado National Forest by the USDA

Forest Service. Sky Island Alliance AAS volunteers monitored Hospital Flat Spring 29 times between August 4, 2013 and November 9, 2019, measuring changes in the wet habitat extent below the spring changing seasonally from a low of 2 to over 6 hectares. Photographs taken at standardized photo points show the seasonality of wetland meadow phenology, with peak plant greenness observed during the wet monsoon season (Figure 2). Water flow showed great variability between measurements without a long-term trend (Figure 3), however aspects of water quality did show trends across the whole monitoring period. Specifically, a fire burned in the area in 2017 and may have resulted in increasing water pH (Figure 4). Water and air temperature were variable and trended in opposite directions (Figure 5). While specific conductance increased, Adopt-a-Spring volunteers noted repeatedly that this may have been a result of drifting instrument calibration and this an issue to be addressed in monitoring that requires calibrated equipment (Figure 6).

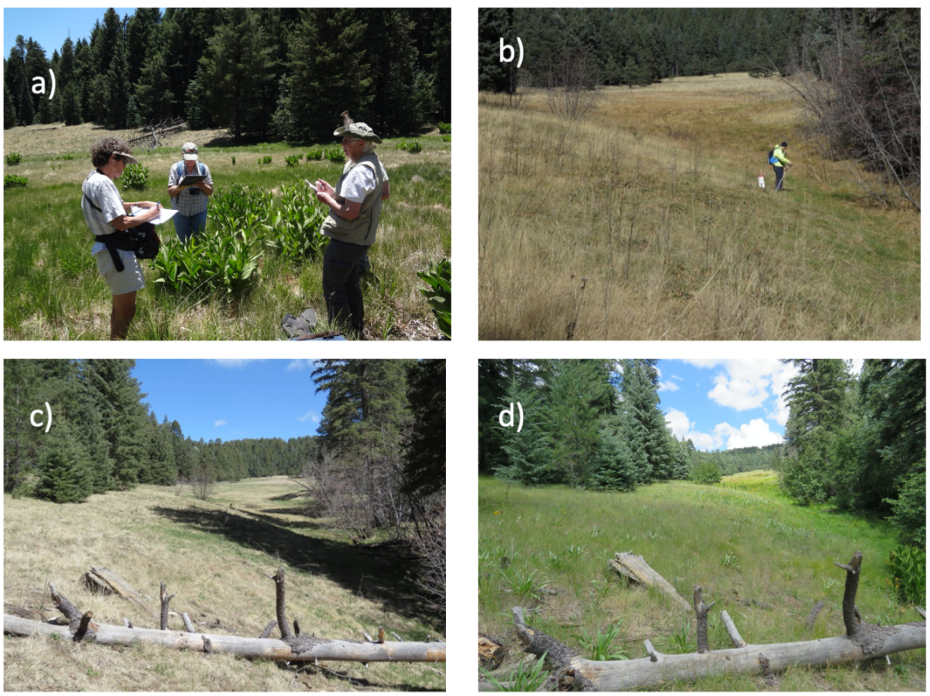


Figure 2. Photographs of a) volunteers collecting data at Hospital Flat Spring and seasonal changes in the wetland habitat north of the spring source in b) fall 2015, c) spring 2016, and d) wet summer 2016.

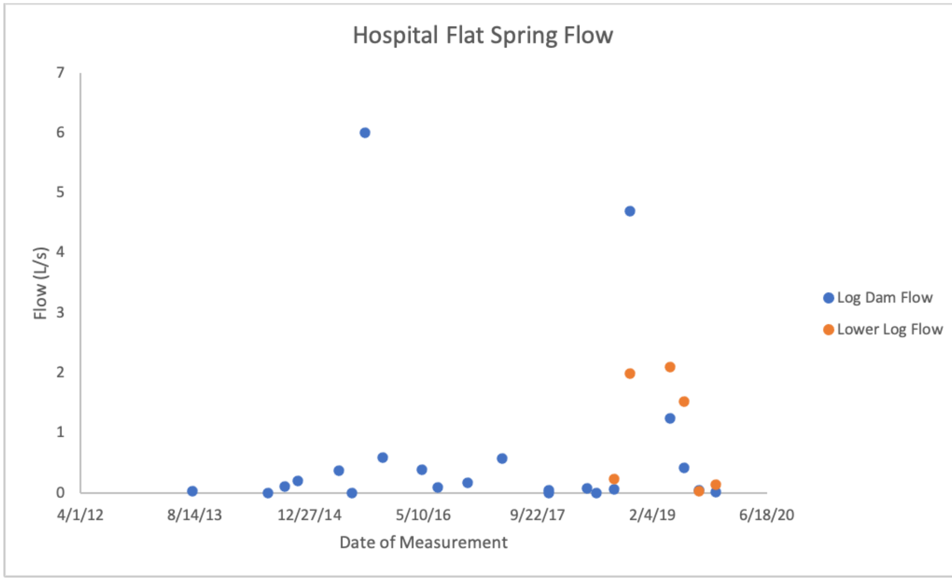


Figure 3. Spring flow was measured at Hospital Flat Spring 29 times between August 4, 2013 and November 9, 2019. Over this monitoring period, flow was consistently measured 75m downstream of the spring source at a fallen log functioning as a check dam at the confluence of the east and west channels. Peak flow was measured on August 27, 2015 shortly after a rain event and the flow reached 6.0 L/s. The spring was found to have no flowing water six times during the monitoring period. The final six measurement points included an additional flow measurement point near a lower log, revealing the variability in flow measurements between pools locations.

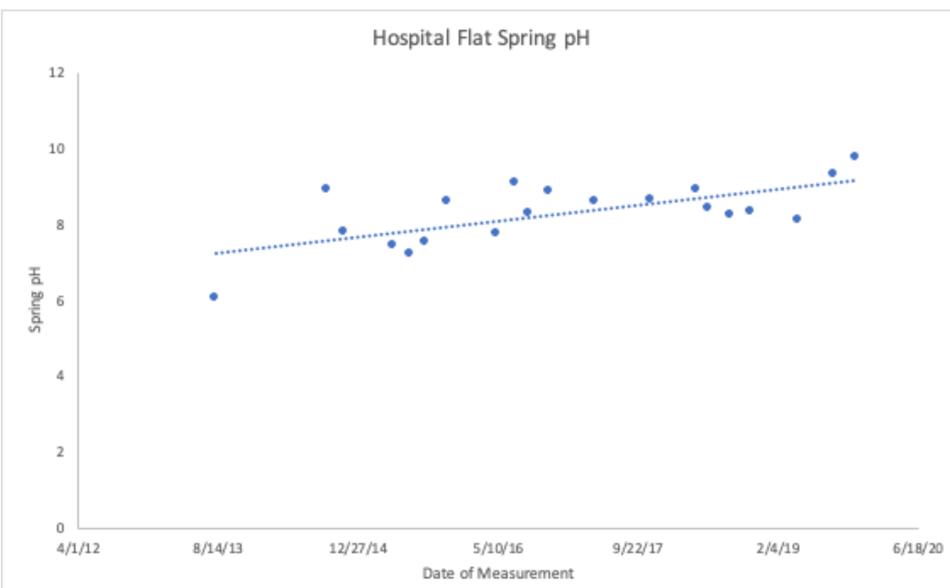


Figure 4. Hospital Flat Spring pH was measured over the monitoring period from 2013 to 2019 and increasing alkalinity of the spring water was observed with pH values increasing

3.69 points. This change in pH is possibly explained by a fire that burned in the area in 2017.

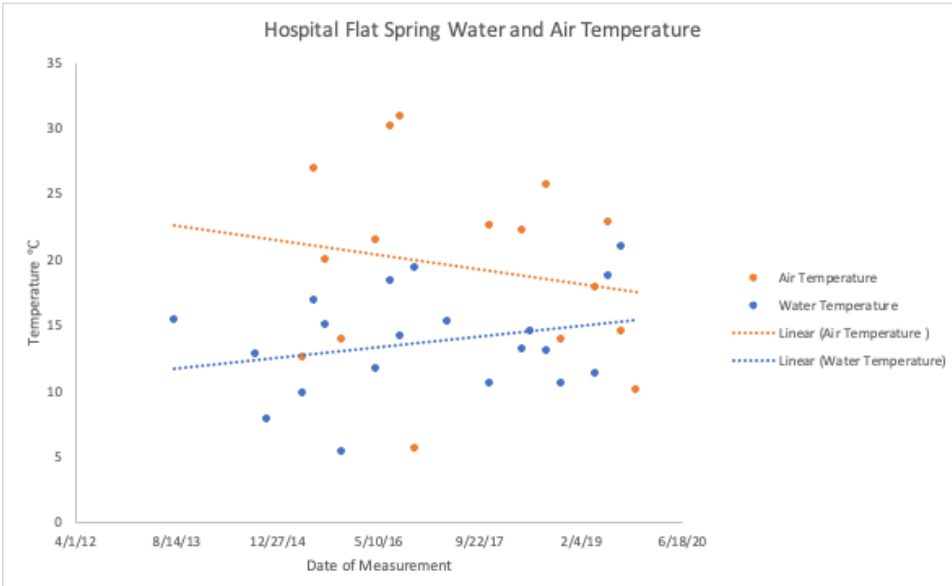


Figure 5. Hospital Flat Spring water temperature trended up by a few degrees during the monitoring period and air temperature did not trend upwards during the same monitoring period.

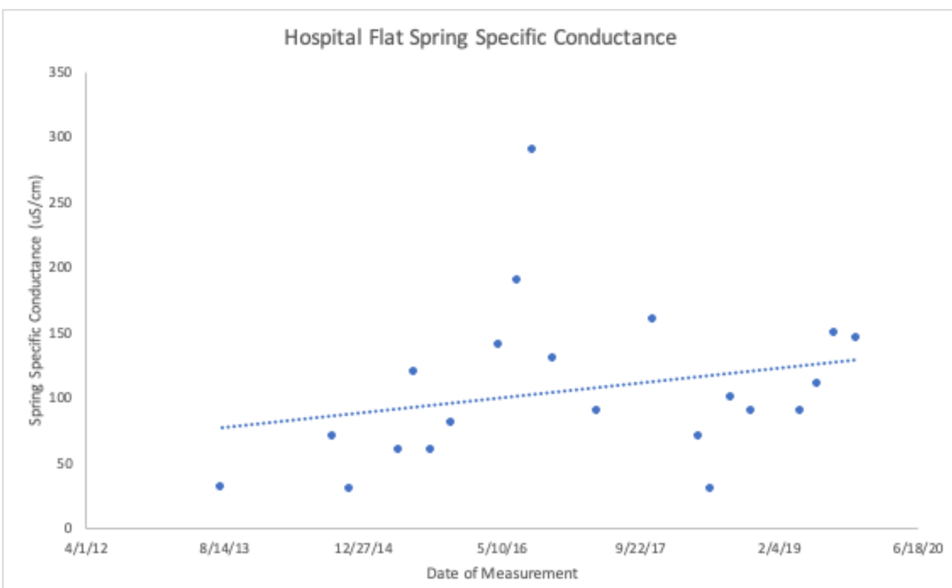


Figure 6. Hospital Flat Spring specific conductance was measured in the spring between August 4, 2013 and November 19, 2019. Monitors noted repeated concern during the

monitoring period about accuracy of the instrument's calibration and ability to function in very shallow water. The slight trend in increasing specific conductance may be due to equipment calibration issues and non-optimal condition for measurements during the monitoring period.

Rock Spring

Similarly to Hospital Flat Spring, Rock Spring was selected as reference site. It is located at a low elevation of 1023 m in the Rincon Mountains, Pima County, Arizona and is managed by the National Park Service at Saguaro National Park (Figure 7). Between 2014 and 2019, monitoring data showed wide variability in water flow, clear seasonal trends in water temperature that correlated with the hot seasons, and relative stability in pH (figure 8). The three major pools of Rock Spring exhibited seasonal variation in spring pool area over the seasons, with the greatest pool area occurring in winter (Figure 9). Rock Spring pool depth varied significantly more between pools and less between the seasons (Figure 9). With repeated surveys over time, the count of detected plant and vertebrate species increased as a result of sampling effort—something important to not interpret as an increase in species richness (Figure 10).

Figure 7. Rock Spring a) and b) upper pools and c) and d) lower reach of spring-fed habitat in the Rincon Mountains at Saguaro National Park.

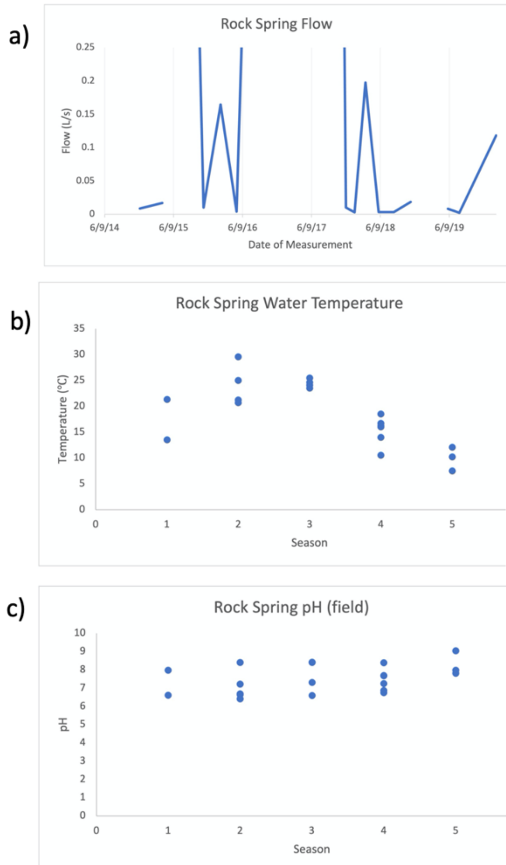


Figure 8. Rock Spring a) water flow, b) water temperature, and c) water pH.

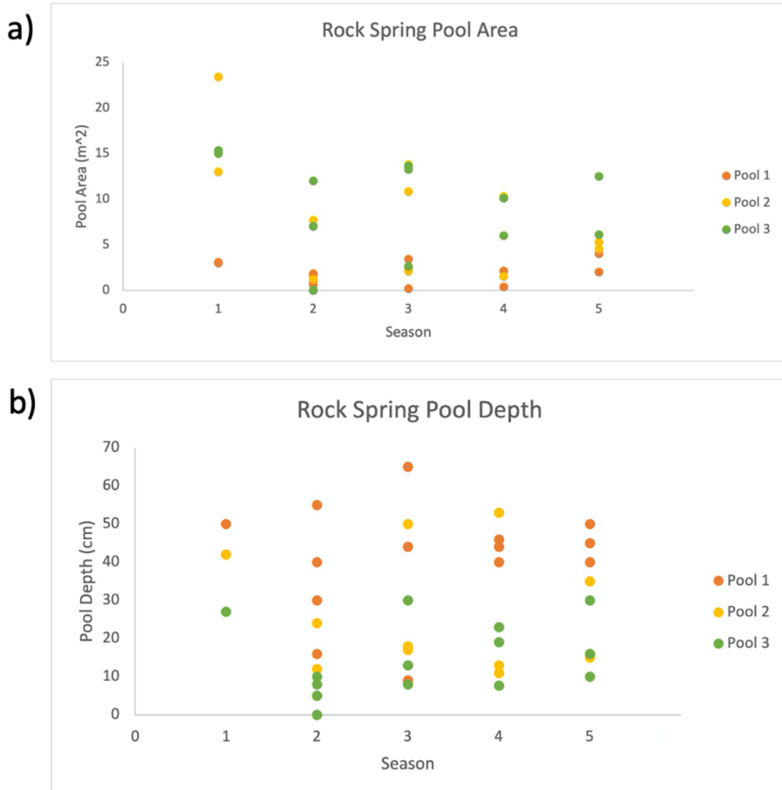
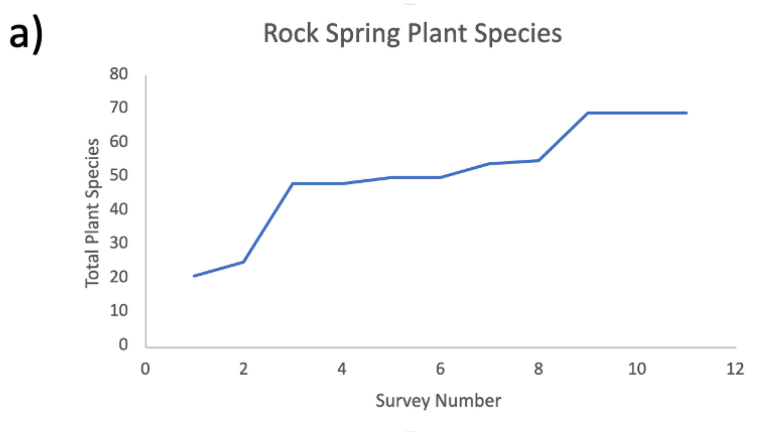


Figure 9. Variation across seasons (1=spring, 2=dry summer, 3=monsoon, 4=fall, and 5=winter) in Rock Spring pool a) area and b) depth.



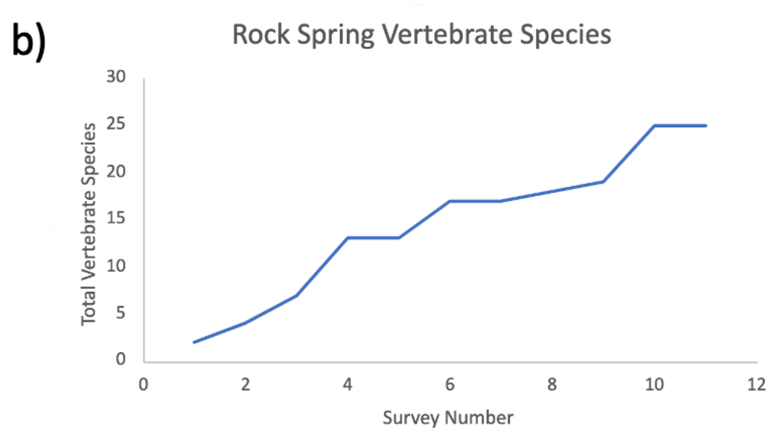


Figure 10. The cumulative increase in a) plant species and b) vertebrate species documented over successive Rock Spring surveys.

Aliso Spring

As with Rock Spring, monitoring over time has improved understanding of which floral and faunal species occur at Aliso Spring in the Tumacacori Mountains (Figure 11). Eighteen species of invertebrates, mammals, and birds were detected during the initial biological survey, but each survey added new species to the list resulting in 103 total species including 40 plants, 4 mammals, 22 birds, and 37 invertebrates (Figure 12). Notably in May 2016, birders discovered the Pine Flycatcher attempting to nest at Aliso Spring. The Pine Flycatcher occurs in northern Mexico and this was a first observation of an individual in this part of Arizona. This may be a species that will adapt to climate change by moving northwards into the U.S.

Figure 11. Aliso Spring a) middle pool in June 2017, b) middle pool in November 2018, and c) and spine-tipped dancers (*Argea extrania*) in the Tumacacori Mountains.

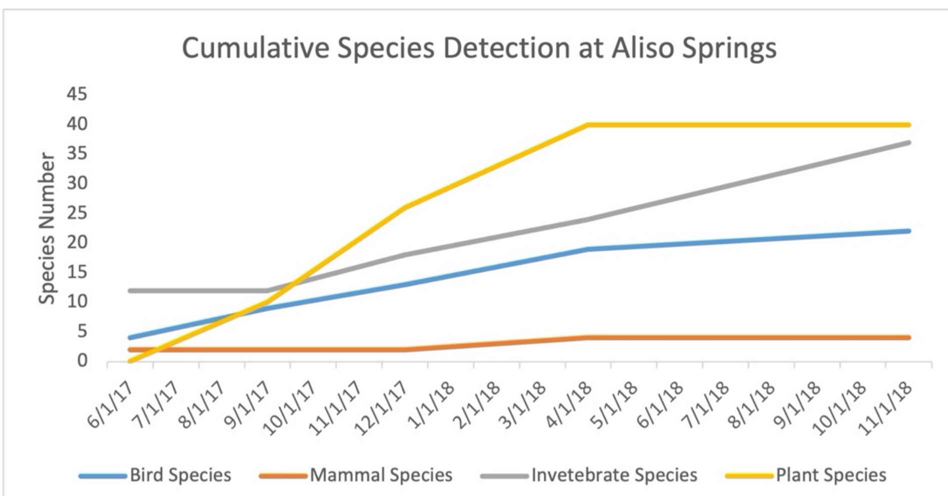


Figure 12. The cumulative increase in bird, mammal, invertebrate, and plant species documented over successive Rock Spring surveys as a result of increased survey effort.

Alamo Spring

Alamo Spring is rheocrene reference spring in southeastern Arizona, located in the Atascosa Mountains. This site experienced a low to moderate severity fire in summer 2016 (Figure 13), though the vegetation around the spring did not suffer as much damage as it did elsewhere in the drainage. The pools were noted to change predictably with the seasons, decreasing in depth and area in spring and dry summer, and increasing through monsoon, fall, and winter. The depth of upper pool (source) has remained essentially constant for multiple years through every season.

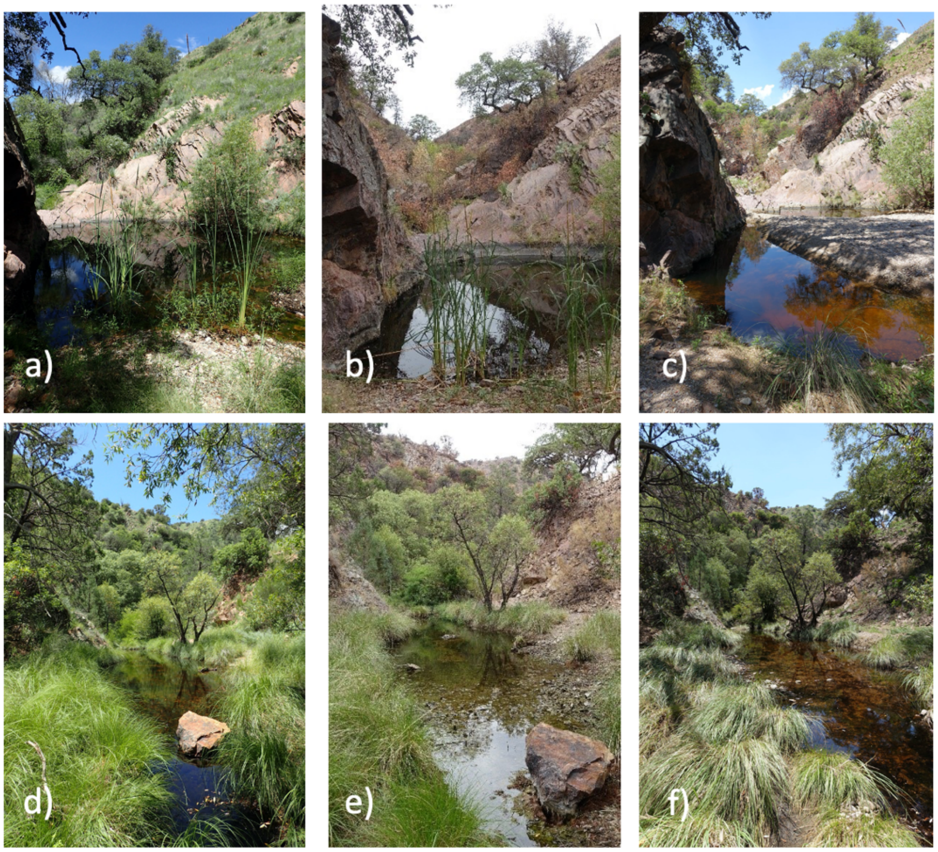


Figure 13. Seasonal photography at Alamo spring photo points reveals minimal vegetation changes around the upper spring pool over the course of year when a low-intensity fire burned in summer 2016; a) Point 1 monsoon 2015, b) Point 1 dry summer 2016 following fire, c) Point 1 monsoon 2016, d) Point 2 monsoon 2015, e) Point 2 dry summery 2016 following fire, and e) Point 2 monsoon 2016.

McGrew Spring

McGrew Spring in the Whetstone Mountains was first surveyed by Arizona State Parks personnel in 2007 and subsequently monitored 20 times through November 2020 with support from Sky Island Alliance Adopt-a-Spring volunteers. It was observed over time that soil moisture in the pond and channel remains high (inundated) throughout the year, but decreases in the banks and wet meadow during drier times of year (Figure 14). Surveyors have recorded damage from cattle breaking through the fence and impacting the spring a number of times. Habitat disturbance by cattle trespass onto park land reached a high level in June 2019 that persisted through subsequent monitoring periods. Specifically, the monitoring documented the impact of cattle trampling and defecation that destroyed spring vegetation, cased soil erosion, and diminished water quality to the point that visual spring invertebrate surveys were no longer feasible to high turbidity (Figure 15). Similar disturbance was also detected at Parker Schoolhouse Spring in the Patagonia Mountains which surveyors noted repeated cattle trampling over the years (Figure 16.)

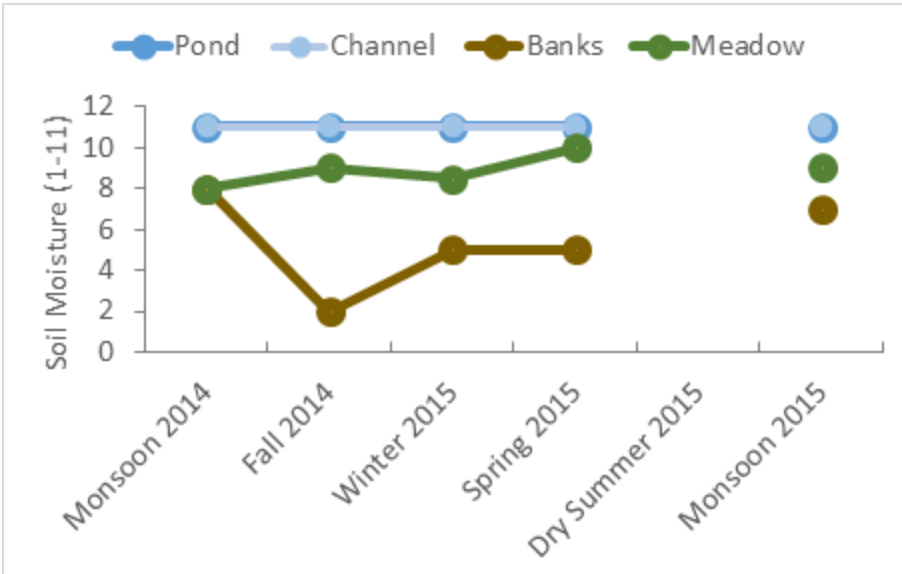


Figure 14. Trends in soil moisture at McGrew Spring from summer 2014 to summer 2015.

Figure 15. McGrew Spring with cattle trampling around the main pool edge.

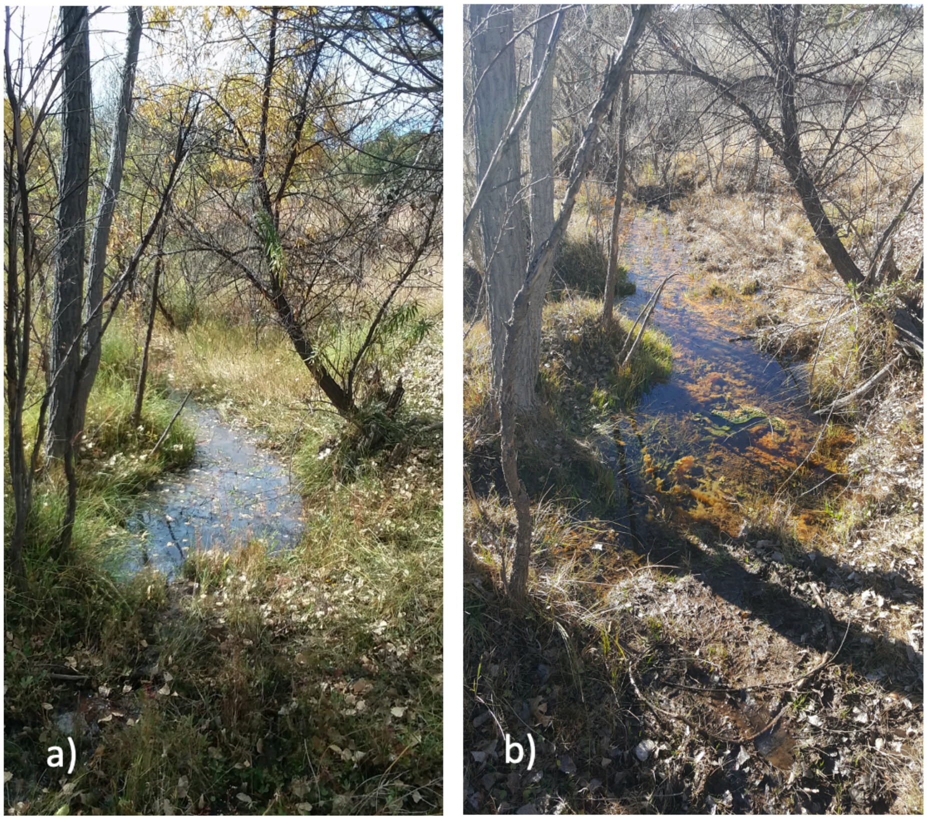


Figure 16. Parker Schoolhouse Spring photographed in 2019 a) before and b) after cattle trampling at the spring site.

Summary and Recommendations

In summary, the Adopt-a-Spring monitoring program exhibited effectiveness in detecting both seasonal and interannual trends in water flow and quality, building a species list of plants, vertebrates, and invertebrates over time, and documenting impacts of disturbance from events including fire and cattle intrusion. If seasonal data are needed to track hydrological trends, the five-season monitoring approach worked well for springs in southern Arizona that experience two wet seasons (winter and monsoon). Maintaining equipment calibration, building expertise to identify biological diversity, and sustaining long-term effort of volunteers to repeat surveys are three areas that were challenging for this spring monitoring effort.

A critical step in any spring monitoring program is to interpret the resulting data and identify opportunities for stewardship and restoration actions. Monitoring data can readily identify high conservation value springs that include important cultural and natural resources that deserve enhanced protection. Tracking trends at these springs over time can detect when these resources are directly threatened by human development, cattle, erosion, aquifer pumping, and invasive species. Monitoring data can also be used to measure the effectiveness of or determine the need for restoration treatments such as the improvement of wildlife access to surface water, cattle exclusion fencing, erosion control treatment above the spring, and the installation of native plants.

To effectively interpret spring monitoring data and identify stewardship and restoration actions, the first step is to define what sort of spring conditions trigger action under the appropriate land management goals, values, policies, and laws that affect stewardship activities locally. While spring management goals vary significantly across land management jurisdiction in the Sky Island region, all spring managers typically share interest in understanding and maintaining the presence and flow of spring water. For this reason, interpreting spring monitoring data action begins with understanding spring water availability because all other decisions stem from this basic spring condition.

SPRING SEEKER DECISION TREE

Following a spring survey or monitoring event, follow the decision tree outline below for recommended stewardship actions:

1. **Did you find the spring?**
    a. No – The source is not evident (go to 2)
    b. Yes – The source is evident but dry (go 3)
    c. Yes – The source is wet (go to 4)
2. **Missing Spring Actions:**
    a. Action: Verify original site coordinates.
    b. Action: Search for spring 250 m directly upstream and downstream. If still not found then search area along 100m transects spaced 20m apart:
        i. If the water source (wet or dry) is found (go to 1.)
        ii. If water source is not found then:
            1. Action: request a more experienced spring specialist search the area in the wettest season.
            2. Action: if confirmed missing by expert during the wet season, report the spring is gone on the Springs Online database.
            3. Action: watch for trend of multiple springs disappearing in a watershed and seek watershed policy solution to address spring loss.
3. **Dry Spring Actions**:
    a. Determine if the spring had known water present in the last 5 years:
        i. Yes – Revisit the spring seasonally to determine if the water source is still flowing intermittently.
        ii. No or Unknown – Are any wetland or riparian plants present and alive?
            1. Yes – Revisit spring seasonally to determine when water is available.
            2. No – go to 3.b.
    b. Are there any signs of habitat disturbance that might have buried the spring source or otherwise impeded water flow?

        i. Yes - If evidence of disturbance found, evaluate whether the spring source is recoverable through restoration action such as excavation, erosion control, or spring development repair.
            1. Action: Determine if rock material is available onsite for erosion control activities and list logistical considerations for doing restoration work at the site.
            2. Action: Notify land manager about restoration need.
        ii. No – go to 3.c.
    c. Are there signs of ground water pumping that could be limiting spring flow?
        i. Yes—Go to 4f.
        ii. No—Check spring again in the wettest season to check for water one more time.
            1. If water found in the future, go to 4.
            2. If no water found at the future survey time, go to 2bii.
4. **Wet Spring Actions:**
    a. Is the water flow and wetland habitat extent consistent and persistent over time?
        i. Yes or flow/wetland habitat increasing – HIGH CONSERVATION VALUE SPRING (go to 4d).
        ii. No or flow/wetland habitat decreasing – THREATENED SPRING (go to 4e).
    b. Are there historic cultural resources present? (e.g. Evidence of spring development and use of spring by native people):
        i. Yes – HIGH CONSERVATION VALUE SPRING:
            1. Action: Pause all stewardship plans until adequate cultural review is complete.
            2. Action: Alert appropriate agency and/or Tribe for follow up surveys.
            3. Action: Discuss potential conservation and stewardship activities with land manager that would be compatible with cultural resource protection.
            4. Action: Minimize future disturbance at the site by not broadly communicating the spring location or its cultural resources to the public.
        ii. No – go to 4c.
    c. Are there notable and/or listed vertebrate, invertebrate, or plant species present? (e.g. spring snails or fish)
            1. Action: Pause all stewardship plans until adequate natural resource review is complete.
            2. Action: Alert appropriate agency for follow-up surveys to confirm listed species (e.g. AZDGF for presence of spring snails).
            3. Action: Discuss potential conservation and stewardship activities with land manager that would be compatible with and beneficial to natural resource protection.
            4. Action: Minimize future disturbance at the site by not broadly communicating the spring location or its natural resources to the public.
        ii. No – go to 4d.
    d. HIGH CONSERVATION SPRING ACTIONS:

    i. Action: Submit spring survey data to the Spring Stewardship Institute's Springs Online database, noting the values worthy of protection.
    ii. Action: Monitor the spring annually to track spring condition.
    iii. Action: Determine spring risk and use to develop protection actions that will prevent or ameliorate spring degradation (go to 4e).

e. SPRING THREAT—Is there development at the site that is or may be restricting wildlife access to water (e.g. spring box, trough, tank, or pipes)? *Note: Some past human modification of springs may not be visible from a terrestrial survey and buried pipes and infrastructure may be affecting spring flow aboveground.*
    i. Yes—Determine if development can be removed or altered to improve safe access for wildlife (e.g. can small animals escape?) and increase surface water availability.
    ii. No—go to 4f.

f. SPRING THREAT—Are there signs of active pumping that may be removing spring water from the site (e.g. solar panels, piping, pumps)?
    i. Yes—Determine how much active pumping is occurring and the resulting impact on the spring site. If pumping is significant, speak with land managers and seek policy solution to limit pumping and ameliorate spring flow loss.
    ii. No—go to 4g.

g. SPRING THREAT—Is there evidence of livestock presence that is affecting spring water and habitat quality?
    i. Yes—Contact the land manager and seek solution to protect spring from livestock trampling and fouling of water with the installation of wildlife friendly cattle-exclusion fencing. Compromise that provides continued water supply to livestock is likely.
    ii. No—go to 4h.

h. SPRING THREAT—Is there evidence of mining impacts including mine shaft, tailings, equipment, or discolored water (red or orange)?
    i. Yes—Contact the land manager to encourage mine remediation.
    ii. No—go to 4i.

i. SPRING THREAT—Is there evidence of excessive human use of the spring (e.g. toilet paper/human waste, trash, erosion, close proximity of trails and roads)?
    i. Yes—Contact land manager about:
        1. Potentially restricting public access to protect sensitive habitats by removing social trails and installing signs or fencing about the impacts of trampling.
        2. Organizing a spring clean-up day to remove trash.
    ii. No—go to 4j.

j. SPRING THREAT—Are there invasive plant, invertebrate, or vertebrate species that threaten the biodiversity of the spring site?
    i. Yes—Contact land manager to develop invasive species removal strategy including:
        1. Secure permits to implement invasive species treatments.
        2. Organize invasive species removal.

3. If plants are removed, consider installation of native plants with local provenance to restore the flora.
4. Monitor the efficacy of invasive species treatment.

ii. No—Continue monitoring to detect new invaders early.

Before committing to any spring stewardship or restoration activity, it is important to evaluate the potential conservation values and threats for all the springs under consideration to ensure that priority for action is given to those springs with both high values and threats. The decision tree above simply outlines the type of resulting actions that may be warranted for a range of spring conditions but does not compare the relative spring values or threats of different springs. See the Springs Prioritization Tool for a methodology to compare multiple spring needs and opportunities.

Plant Restoration at Springs – An Addendum to the Arizona Springs Restoration Handbook

Which species of plants should be included in a project?

The first consideration for choosing a site appropriate species palette at any location is to have an accurate inventory of the plant species that occur on the site. Especially for potential restoration sites, onsite species diversity might be a depauperate representation of the full suite of appropriate species, and additional potential species for inclusion can be found through a variety of other methods. The flora of other nearby springs with similar characteristics (i.e., same watershed, similar elevation and geomorphology) can be used to diversify the palette. Vegetation surveys should always be conducted by people who have local knowledge of native plants, and/or in conjunction with regional botanical experts - Arizona has an amazingly diverse botanical heritage, with over 3,000 species of native plants!
Plant palette development should always include research from SEINet (http://swbiodiversity.org/), a database of plant specimens from dozens of herbaria. This database can be used to generate current and historic information about plants that have been collected at or near the restoration spring. SEINet is also an excellent resource to assist with identification of species.

Steps to developing a successful restoration plant palette

1. Conduct as complete a botanical inventory as possible during active growing season(s).
2. Add species from appropriate reference site(s).
3. Add species known to historically occur at the site if appropriate.
4. REMOVE invasive species from the list.
5. Sort the list by microhabitat and determine how many mature plants each microhabitat should have given the area available for planting.

6. Identify the preferred plant material type for each species (seed, container plant, size/age, cutting/pole planting, salvage/transplant). Important considerations include project budget, schedule, and investment to success ratio.
7. Determine species availability onsite, in the watershed, or with local nurseries. Ensure that project scheduling includes ample time to collect seed and grow plants to appropriate sizes prior to planned installation.

Species that are non-native invasives should never be considered as appropriate for restoration planting. Many of these species wreak havoc on site ecology; land managers and conservation organizations spend millions of dollars every year to remove invasive species from Arizona's wildlands. Many non-native invasive species may be present at springs, for example: Bermuda grass (*Cynodon dactylon*), giant reed (*Arundo donax*), fountain grass (*Pennisetum ciliare*), tamarisk (*Tamarix* sp.), sow thistle (*Sonchus* spp.), creeping bentgrass (*Agrostis stolonifera*), brome grasses (*Bromus* spp.) and periwinkle (*Vinca major*). If non-native invasive species are present at the restoration site, they should be removed as part of the site preparation and maintenance activities.

In some instances, particular native plant species may also be excluded from the plant palette, especially if they might become invasive. Examples include cattails (*Typha* spp.) or sawgrass (*Cladium* sp.) that can choke out natives and/or eliminate open water. Another filter for your restoration plant palette should include species availability. This could mean onsite or nearby collection of seed or cuttings for propagation, or direct salvage and translocation. In addition, some species may be available in the local nursery trade. Any collection of plant materials must be done with appropriate permissions and permits. If wild-collected, preference should be given to donor materials from within the same watershed if possible. The goal should always be to include as many different species as possible, as this will enhance wildlife and pollinator benefits at the site.

Scheduling Considerations

Arizona's bi-modal precipitation patterns mean that there may be a very different group of species present in winter, spring, and summer - multiple vegetation surveys over different growing seasons may be needed to get the most complete species inventory possible. In addition, a project schedule must include adequate time to gather plant materials in the correct season (seeds, cuttings, etc.) and, if applicable, time to grow the plants out to the desired size for installation.

This may seem daunting, but the good news is that plant material installation can occur in a phased manner - not all materials have to be installed at the same time. In fact, it can be beneficial to allow some natural plant recruitment to occur, as long as one or two species are not allowed to take over and crowd out other native species.

Desired Function

Native plant materials provide a wide variety of functions at springs, and depending on site conditions, you may want to consider this when choosing exactly which plants to use.

Erosion control and site protection - Plants that form mats of roots and stems (sometimes called rhizomatous or stoloniferous) can help to stabilize steep slopes or headcuts. Sedges, grasses, and rushes fit this bill.

Wildlife resources - If your project has species-specific conservation goals, there may be associated plant materials that will help to provide suitable habitat. Habitat considerations include vegetation structure to improve cover and provide breeding habitat for wildlife, as well as food in the form of associated insects, seeds, and fruits. Plant species can be chosen to provide the widest range of benefits possible - and generally this results in a diverse plant palette. Imagining what you want the site to look like in the future will help you to choose the right plant materials. Do you want large riparian trees for raptor habitat? Or do you need to maintain low vegetation so that bats have a flyway to access the site?

Case Study: Monarch butterfly conservation - Monarch butterflies (*Danaus plexippus*) are becoming increasingly imperiled throughout their range, and Arizona is an important state for large-scale monarch conservation. Monarchs in Arizona may join either the eastern or western migration routes, or, even more interesting, may overwinter in Arizona. A recent study has found that monarchs in Arizona are found at springs, seeps, wetlands, and riparian areas (Morris et al 2015). Healthy monarch populations require native milkweed (*Asclepias* spp.) populations to support larval monarchs and a variety of native nectar plants for adult monarchs. These species should be included in every spring restoration project in the state to contribute to the recovery and resilience of this iconic invertebrate species.

Which Plant Material Type is Appropriate?

Now that you know which species of plants you would like to include in your springs restoration project, you have to give some thought to which type of material is appropriate and available for use. The type of plant material you choose will affect project cost, scheduling, and success of species establishment. Below are the different options and considerations:

- **Passive establishment.** In many instances, native plants will naturally find their way to the restoration site and establish on their own. For instance, cattails and sedges will often become established this way if there are plants nearby. This is an easy and no-cost approach, however there is a risk of these species dominating the site and resulting in low plant diversity. Worse yet, many troublesome non-native invasives can also become established in this manner. One way to balance risks and benefits is to allow nature to do some of the planting, but to supplement with other native species that are not as likely to “blow in” – and, as always, to remove invasive species as soon as they are detected.
- **Seeds.** Seeds of desirable native species can be collected from nearby sites, or sometimes, are available commercially. Grasses and wildflowers are often readily established through seeding. Success will be highest when seed application is conducted in conjunction with natural precipitation patterns that match the germination season of

the species. As previously noted, Arizona's bi-modal precipitation patterns have resulted in distinctly different suites of seasonal species. Maximum success and species diversity can be achieved by seeding different seasonal seed mixes to take advantage of winter and summer rains.

- **Cuttings.** Certain wetland species can be easily propagated by taking cuttings (aka pole plantings) at the appropriate time of year and either planting them directly onsite or raising them at a nursery facility. This is an easy way and inexpensive way to get vegetation established, but the method is only appropriate for species such as willows and cottonwoods.
- **Salvage and Translocation.** Donor plants can be translocated from nearby reference sites. Some species, such as *Eleocharis* spp., do very well with just a small transplantation effort and spread readily. If the project area has established native vegetation that will be disturbed during the restoration process, plans should be made to salvage them and translocate them.
- **Container plants.** The most costly plant materials are container plants that have been raised in a nursery, often from seeds collected onsite or at nearby reference sites. These plant materials allow for the inclusion of species that might not otherwise become established on the site (e.g., woody shrubs and trees, uncommon pollinator plants, rare species), and the opportunity to dramatically increase the site's botanical diversity. Practitioners should be sure to understand each species' ecological requirements to ensure that it is installed in the appropriate site microhabitat.

Approaches for Resistance and Resilience to Climate Change

Although more research is needed in this subject, a way to incorporate resistance and resilience to climate change (long-term drought in the case of Arizona) in your spring restoration project is to use assisted gene flow (AGF) approaches to "prestoration" (Aitken and Whitlock 2013). Under this approach, managers use species' genomes that are adapted not to the historical climate conditions of the species but to the projected climate conditions. While AGF is still controversial among some ecologists and conservations, the forestry industry has been using AGF approaches for quite a time now (Aitkin and Bemmels 2016), and there is growing acceptance of AGF among scientists as an important climate adaptation strategy (Browne et al 2019; McLaughlin et al. in review), especially if the source and recipient populations have not been isolated significantly for too long (Aitken and Whitlock 2013).

AGF can be seen as a space-for-time substitution approach to plant ecology and conservation, in which the researcher or manager collects seeds of any species of interest from the trailing edge of the species range – that is, at the hot-dry limit of its distribution – and plant them in more mesic environments. For example, if you are considering planting Arizona Alder (*Alnus oblongifolia* Torr.) at a spring located at 2,400 m of elevation in the Sant Catalina Mountains near Tucson, then perhaps you could find a spring at a lower elevation where alders currently find their lowest distribution in the area. Alders from this site have probably been chronically exposed to hotter and drier conditions compared to those from higher elevations and could disappear from those habitats in the future. By taking seeds from these low-elevation alders and planting them at higher elevations, you may be: a) using a better adapted genotype of alders to hotter and drier conditions in the future, and b) facilitating an upwards range shift of the entire alder population in the mountains, which might be especially desirable for species that are threatened locally or regionally.

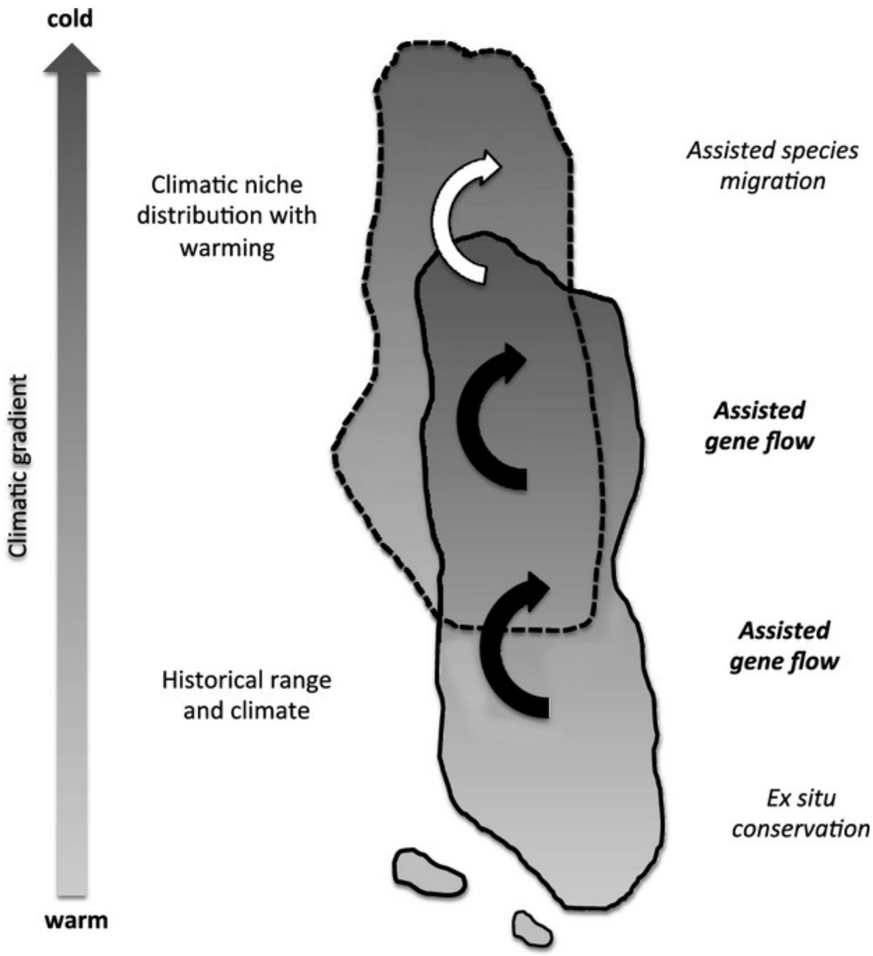


Figure 1. Schematic diagram from Aitken and Bemmels (2016) summarizing AGF and management options for reforestation and restoration. The climatic gradient can be latitude, elevation, or topographic variation (e.g., slope aspect).

Pollination-focused Restoration for Climate Adaptation

One of the major challenges that restoration ecologists and practitioners face with climate change is the change in the timing of life cycle events – also known as phenology. Phenology is mainly influenced by climate and thus, changes in precipitation and temperature that alter phenology have the potential to disrupt pollination and trophic dynamics (Campbell 2020). Examples of climate impacts on phenology include changes in the timing of flower blooming, plant leaf-out, insect emergence, and arrival and departure of migratory species (Campbell 2020). Such impacts can be particularly problematic in a region like Southern Arizona, where precipitation has a bimodal distribution (winter rains and summer monsoon), and species' phenology can be sensitive to one or both of those precipitation regimes.

Thus, pollination-focused approaches may have the ability to confer restoration projects with greater resistance and resilience to climate change, especially those projects that leverage species richness to support pollination dynamics. Enhancing species richness and focusing on temporal diversity of flowering after both rainy seasons increases redundancy and resource availability to pollinators (Campbell 2020). One way to plan and choose the most adequate species is to use a bloom calendar, which is a common tool in garden design to anticipate what species will bloom when. The following steps are critical to develop a successful pollinator-focused restoration project (Campbell 2020):

1. Inventory existing floral resources.
2. Develop baseline bloom calendar.
3. Select native plant species.
4. Monitor and adaptively manage.

Plant Palette Options by Microhabitat

The following tables were modified from the Technical Notes formulated by the Natural Resource Conservation Service of the U.S. Department of Agriculture. It includes a list of plant species that are suitable for spring restoration projects and provides basic information such as growth form, habitat, and relevant functional traits associated with restoration benefits.

Grass-like plants in habitats with frequent inundation				
Common Name	**Scientific Name**	**Growth Form**	**Elevation & Habitat**	**Relevant Traits**
Sedges	*Carex* species	Grass- like	Typically found above 5,000 feet but some species found down to 3,000 feet. Zones with saturated soils subject to periodic short-term inundation of 1 to 18 inches.	When mature, they provide important cover for small and medium-sized species. They typically show high survival rates, though recolonization may be slow if rootstocks have been eliminated from site. If rootstock is present, they are important species for fire recovery.[2]
Spikerush	*Eleocharis* species	Grass- like	Elevations from 150 to 9,000 ft. Wet areas, streams, ponds, lakes. Zones with occasional droughty soil conditions to saturated soils subject to periodic short- term inundation of 1 to 18 inches.	Its dense root mass makes this species an excellent choice for soil stabilization in riparian and wetland sites. The rhizomes also form a matrix for many beneficial bacteria making this plant an excellent choice for wastewater treatment. Their above ground biomass provides roughness that cause stream velocity to decrease and sedimentation to occur. Because of their fast growing and dense root systems, sedges and

2 https://www.fs.fed.us/rm/boise/AWAE/labs/awae_flagstaff/publications/steed_dewald_transplantingsedgessouthwest.pdf

				rushes are especially valuable for stream bank and shoreline stabilization.[3]
Bulrushes (Sedge family)	*Scirpus californicus,* *S. maritimus,* *S. pungens*	Grass- like	Elevations from near sea level to 9,000 ft. Meadows, ponds, and steams with standing water, up to 6 inches deep. Often in alkaline areas.	Same as above
Cattails (Narrowleaf & Common)	*Typha angustifolia & T. latifolia*	Grass- like	Elevations from 1,000 to 7,500. Marshes, streams, and ponds with standing water, up to 12 inches deep. Common cattail (*T. latifolia*) can be weedy.	Same as above
Rushes	*Juncus spp.*	Grass- like	Elevations from near sea level to 9,500 feet. Moist areas, meadows, streambanks, and shorelines with saturated soils and up to 2 inches of standing water.	Same as above
Shrubs and Grasses in Habitats of Periodic Inundation				
Common Name	**Scientific Name**	**Growth Form**	**Elevation & Habitat**	**Relevant Traits**
Seep Willow (Mule Fat, batamote, water-wally)	*Baccharis salicifolia (B. glutinosa)*	Shrub (thicket forming)	Up to 5,500 ft but usually lower. Mohave, Greenlee, Graham, Cochise, Santa Cruz, Pima, La Paz and Yuma counties.	Semi-deciduous; profile form willow-like; roots suckering and forming thickets; 1 or more stems; spreading out horizontally and then becoming erect (ascending). This makes the species a good candidate for soil stabilization. Because it can flower year-round it is also a good species for sustaining insect populations.[4]
Coyote Willow (Narrowleaf, Sandbar, Basket Willow)	*Salix exigua*	Creeping type shrub	Sea level to 7,000 ft. On moist sandy soils of streams in deserts, grasslands, pinyon-juniper & oak woodlands, lower Ponderosa pine forests.	Deciduous; clonal from root sprouting, often forming thickets. It is effective in shoreline protection and in stabilization and revegetation of eroded stream channels because of its early successional status, rapid growth, ability to root sprout, and quick development of fibrous and adventitious roots. Coyote willow is

[3] https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/idpmcpg11496.pdf

[4] http://southwestdesertflora.com/WebsiteFolders/All_Species/Asteraceae/Baccharis%20salicifolia,%20Seepwillow.html

				especially suited for planting on stream bottoms to prevent surface erosion.[5]
Alkali Muhly (Scratchgrass)	*Muhlenbergia asperfolia*	Grass (sod)	Moist, often alkaline, soils along streambanks. Apache, Navajo, Coconino, Yavapai, Maricopa, Pima, Cochise, and Mohave counties.	Grows in moist, often alkaline meadows, playa margins, and sandy washes, on grassy slopes, and around seeps and hot springs. scratchgrass reproduces through rhizomes, stolons and seed. These reproductive qualities allow it to be competitive with species that may be invasive in arid riparian zones. Has the potential to be especially useful in rehabilitation of areas following salt cedar (Tamarix ramossissima) removal.
Desert (Inland) Saltgrass	*Distichlis spicata*	Grass (sod)	Moist saline or alkaline soils along streams or springs. From sea level to 6,000 ft. Apache, Navajo, Coconino, Pinal, Yuma, La Paz, Cochise and Pima counties.	Saltgrass establishes after fire through seed and/or lateral spread by rhizomes. Livestock generally avoid saltgrass due to its coarse foliage. It can be an especially important late summer grass in arid environments after other forage grasses have deceased.
Shrubs, trees, and grasses in habitats with Occasional Inundation				
Common Name	**Scientific Name**	**Growth Form**	**Elevation & Habitat**	**Relevant Traits**
Seep Willow (Mule Fat, batamote, water-wally)	*Baccharis salicifolia (B. glutinosa)*	Shrub (thicket forming)	Up to 5,500 ft but usually lower. Mohave, Greenlee, Graham, Cochise, Santa Cruz, Pima, La Paz and Yuma counties.	Semi-deciduous; profile form willow-like; roots suckering and forming thickets; 1 or more stems; spreading out horizontally and then becoming erect (ascending). This makes the species a good candidate for soil stabilization. Because it can flower year-round it is also a good species for supporting insect diversity.
Arrow-weed	*Pluchea sericea*	Shrub	Throughout most of Arizona up to 3,000 ft. Along streams and in moist (sometimes saline) soils.	Beneficial to wildlife in general: rodents, insects, birds. Roots are shizomatous and often forms dense thickets making a good candidate for spring or shore protection.
Red Willow	*Salix laevigata*	Tree / Shrub	1,800 to 5,000 ft. Streams of oak, pinyon-juniper woodlands and deserts.	Similar to Coyote Willow

[5] https://www.fs.fed.us/database/feis/plants/shrub/salexi/all.html

Goodding or Black Willow	*Salix gooddingii*	Tree	150 to 5,000 ft. Steams of desert, desert grassland, and oak woodland.	Similar to Coyote Willow. This species has shown high survival rates (87%) in the Rio Grande region.
Arroyo Willow (White Willow)	*Salix lasiolepis*	Shrub / Tree	6,000 to 7,000 ft. Mountains streams of eastern AZ from Cochise and Pima Counties to Apache & Coconino Counties	Arroyo willow has good habitat value, high tolerance to flooding and sediment deposition, moderate drought tolerance, and low salt tolerance. It provides important habitat for a wide range of invertebrate and vertebrate species.[6]
Mexican (Blue) Elderberry	*Sambucus nigra (mexicana)*	Shrub / Tree	1,200 to 5,000 feet along streams and arroyos in desert and desert grasslands. Cochise, Santa Cruz, Pima, Gila, Yavapai and Mohave counties.	It is a useful ground cover for stabilizing streambanks and eroding sites. It provides food, cover, perching, and nesting sites for many species of birds and food and cover for various other wildlife, and it is important as browse for mule deer and elk. In the spring the leaves may be strongly scented and less palatable, but they sweeten and become more palatable by fall.[7]
Arizona Sycamore	*Platanus wrightii*	Tree	2,000 to 6,000 ft. Along streams & canyons in upper desert, desert grassland, & oak woodlands.	In streams or drainages, mid-size and large individuals are critical for flow and debris regulation. Asexual reproduction is important for post-fire recovery. Critical species for bird habitat. Provision of shade is also critical for micro-climate regulation. Similar to Ash trees, they are great trees for reclamation due to their tolerance of acidic soils.[8]
Fremont Cottonwood	*Populus fremontii*	Tree	150 to 6,000 ft. along streams in AZ.	Same as above
Narrowleaf Cottonwood	*Populus angustifolia*	Tree	5,000 to 7,000 ft. Along mountain streams in Ponderosa Pine and Pinyon-Juniper Woodlands	Same as above
Arizona (velvet) Ash	*Fraxinus velutinia*	Tree	2,500 to 7,000 ft. along streams, moist washes and canyons. Cochise, Apache, Santa Cruz, Pima, Coconino, and Yavapai counties.	Same as above. In addition, ash trees are known for their restoration potential after mining activities.

[6] https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/capmctn5782.pdf

[7] https://plants.usda.gov/plantguide/pdf/pg_sanic5.pdf

[8] Anonymous. 2000. Propagation protocol for vegetative production of container Platanus wrightii 'Wats.' plants; Los Lunas Plant Materials Center, Los Lunas, New Mexico. In: Native Plants Network. URL: http://nativeplants.for.uidaho.edu (accessed 3 October 2001). Moscow (ID): University of Idaho, College of Natural Resources, Forest Research Nursery.

Arizona Boxelder	*Acer negundo*	Tree	4,000 to 8,000 ft. Streams in oak woodlands & ponderosa pine forests	Same as above. In addition, this species has shown the ability to outcompete invasive Tamarix sp.
Arizona Black Walnut	*Juglans major*	Tree	3,500 to 7,000 ft. Along streams & canyons in the upper desert, desert grasslands, and oak woodlands.	Same as above. In addition, walnuts are a key part of many small and medium-size mammal species. Seeds might be able to better survive to fire events compared to other riparian tree species.
Netleaf Hackberry	*Celtis laevigata*	Tree	2,500 to 6,000 ft. Mountains and streams throughout most of Arizona.	Berries are important source of food for many mammals and birds. This species dies quickly with fire but it resprouts readily from the root collar.
Velvet Mesquite	*Prosopis velutinia*	Tree	Sea level to 5,500 ft. Widespread throughout Arizona and the major drainage systems.	Velvet mesquite annually provides an abundant and nutritious food source for numerous wildlife species when the pods ripen between June and late October. The beans and seeds form an important part of the diet of mice, kangaroo rats, woodrats, chipmunks, ground squirrels, rock squirrels, cottontail rabbits, skunks, quail, doves, ravens, jackrabbits, the raccoon, coyote, collared peccary, white-tailed, deer, mule deer, wild turkey, and mallard. Velvet mesquite plants contain numerous, dormant buds on an underground stem. Soil and rough bark sufficiently insulate the buds from the heat of most fires. Even 8-month-old seedlings have sufficiently developed underground stem buds to allow some plants to survive burning. Following top-killing fires, numerous sprouts arise from the underground buds.[9]
Western Honey Mesquite	*Prosopis glandulosa*	Tree	West portion of Arizona.	Similar as above
Screwbean Mesquite (tornillo)	*Prosopis pubescens*	Tree / Shrub	Sea level to 4,000 ft. Most commonly found in Yuma, La Paz and Mohave counties along floodplains and often on saline soils.	Similar as above
Desert Willow	*Chilopsis linearis*	Tree	1,500 to 5,000 ft. Washes and drainage ways. Found in all counties below the Mogollon Rim.	Important species for erosion control purposes such as buffer strips, windbreaks, reclamation projects, and for wildlife cover

[9] https://www.fs.fed.us/database/feis/plants/tree/provel/all.html

				and pollinators. It can also resprout after low to moderate intensity fires.[10]
Western Soapberry	*Sapindus saponaria*	Tree	2,400 to 6,000 ft. Cochise, Santa Cruz, Pima, Gila, Coconino, Yavapai, and Mohave counties.	Because of its low palatability to cattle, it can be used to deter cattle presence. Western soapberry provides hiding or resting cover for a variety of game species. It also furnishes nesting sites for doves and many songbirds.[11]
Big Sacaton	*Sporobolus wrightii*	Grass (bunch)	2,000 to 6,500 ft. Floodplains of Graham, Pinal, Navajo, Coconino, Cochise, Santa Cruz and Pima counties	Provide extensive cover to small and mid-sized species near water sources. It can also propagate vegetatively, and it is a good species for protecting soil moisture in springs and streams during the dry season.[12]
Alkali Sacaton	*Sporobolus airoides*	Grass (bunch)	2,500 to 6,500 ft. All counties except Mohave, Greenlee, Gila, Maricopa, and Yuma	Similar as above
Deergrass	*Muhlenbergia rigens*	Grass (bunch)	3,000 to 7,500 ft. All counties except Yuma, Maricopa, Mohave, Navajo, and Greenlee.	Deergrass is a valuable streambank stabilizer, as it has an extensive root system, and if grown in dense enough colonies, it can be an effective weed suppresser.[13]

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[10] https://www.fs.fed.us/database/feis/plants/shrub/chilin/all.html
[11] https://www.fs.fed.us/database/feis/plants/tree/sapsapd/all.html
[12] https://www.fs.fed.us/database/feis/plants/graminoid/spowri/all.html
[13] https://plants.usda.gov/factsheet/pdf/fs_muri2.pdf

Appendix A: Monitoring Approaches List

Spring Monitoring Programs and Approaches

List developed by stakeholders attending The Current State of Springs Monitoring and Where We Go From Here (June 5, 2018)

4FRI spring restoration and monitoring (in 4FRI footprint with various stakeholders
Academic institutions)
AZGFD water quality specialists (flows and chemistry)
BLM "AIM" program Assessment Inventory Monitoring Program (national level; based on random sampling)

Chickasaw NRA OK (long-term data)
Del Rio Spring (continuous/long-term data)

Desert Research Institute

Devils Hole (long-term data)
Global Network of Isotopes in Precipitation (GNIP)
Global Network of Isotopes in Rivers (GNIR) (have some long-term records)

Havasupai Tribe
Kaloko-Honokohau NHP Hawaii (continuous data)

Montezuma Well (long-term monitoring)
Roaring Spring, National Park Service (long-term monitoring)
Northern Arizona University (Kaibab/Grand Canyon dye tracer study)
National Park Service Mojave Desert Network (long-term monitoring)

Sierra Club - Water Sentinels

Sky Island Alliance Adopt-a-Spring
Spring Stewardship Institute (including pre and post restoration)
SRP monitoring water output/inflows (at AZGFD hatcheries)
USFS Goundwater Dependent Ecosystem Level 1 + 2 (with field trainings)
USFS Prescott NF gathering flow data of current inventoried springs (minimum information for state water right adjudication within Verde River Watershed)

USGS surveys

Appendix B: SIP Field Sheets

Page ______ of _________ OBS____________

General

Spring Name____________________________________ [1]Spring Type _______________________

Country____ State_______ County_________________________ [2]Sensitivity _________

[3]Land Unit______________ Land Unit Detail___________________________________

Quad______________________ HUC____________________________

Georef

[4]Georef Source___________ Device_________________________ Datum_________

UTM Zone_______ UTM East__________________ UTM North_________________

Lat____________________Long___________________ Elev_________ ft or m

EPE______ ft or m Declination _____ Comment _____________________________

Site Description

Access Directions

SPF

Sunrise: D_______ J_______ N_______ F_______ O_______ M_______ S_______ A_______ A_______ M_______ J_______ J_______

Sunset: D_______ J_______ N_______ F_______ O_______ M_______ S_______ A_______ A_______ M_______ J_______ J_______

Survey

Date________________ Begin Time_____________ End Time______________

Surveyors____

____Project_________________

Site Condition

Microhabitats

Description	Area (m²)	[5]Surf Type	[6]Sub-Type	[7]Slope Var	Aspect T/M____	Slope Deg	[8]Soil moist	Water dpth(cm)	Water %	[9]Substrate %										Prec %	Litter %	Wood %	Litter (cm)
										1	2	3	4	5	6	7	8	Org	Oth				
A																							
B																							
C																							
D																							
E																							
F																							
G																							

Images

Camera Used____________________________________

Sketch Map Location______________________________

Photo #	Description

Entered by ________________________________ Date________ Checked by Date

1 Discharge Sphere (Spring Type)
Anthropogenic
Cave
Exposure
Fountain
Geyser
Gushet
Hanging Garden
Helocrene
Hillslope
Hypocrene
Limnocrene
Mound-form
Rheocrene

2 Sensitivity
None
Location
Survey
Both

3 Land Unit
BLM
DOE
NPS
Private
State
Tribal
USFS
Other

4 Georeference Source
GPS
Map
Other

5 Surface Type
BW Backwall
C Cave/Tunnel
CH Channel
CS Colluvial slope
HGC High Grad. Cienega
LGC Low Grad Cienega
Mad Madiculous Flow
P Pool
PM Pool Margin
SB Sloping Bedrock
SZ Spray Zone
SM Spring Mound
TE Terrace
Oth Other/anthropogenic

6 Surface Subtype
CH Riffle, Run, Margin, Eph
CS Wet, Dry
SB Wet, Dry
TE LRZ, MRZ, URZ, HRZ
UPL,LRZMRZ,LRZURZ,
MRZURZ, HRZMRZ
All Anthro (human influence)

7 Slope Variability
Low, Medium, High

8 Soil Moisture
0 - Dry
1 - Dry-Moist
2- Moist-Dry
3 - Wet-Dry
4- Moist
5 - Saturated-Dry
6 - Wet
7 - Saturated-Moist
8 - Wet-Saturated
9 - Saturated
10 - Inundated

9 Substrate
1 clay
2 silt
3 sand
4 fine gravel
5 coarse gravel
6 cobble
7 boulder
8 bedrock
Organic Soil
Other/anthropogenic

10 Lifestage
Adult
Egg
Exuviae
Immature
Larvae
Mixed
Other
Pupae
Shell

11 Habitat
AQ - Aquatic
T - Terrestrial

12 Method (Invertebrates)
Spot
Benthic

13 Detection Type (Vertebrates)
Call
Observed
Sign
Reported (by others)
Other

14 Cover Codes
GC Ground Cover
SC Shrub Cover
MC Midcanopy Cover
TC Tall Canopy Cover
AQ Aquatic Cover
NV Nonvascular (moss, etc)
BC Basal Cover

15 Emergence Environ/Detail
Cave
Subaerial
Subglacial
Subaqueous-lentic freshwater
Subaqueous-lotic freshwater
Subaqueous-estuarine
Subaqueous-marine

16 Source Geomorphology
Contact Spring
Fracture Spring
Seepage or filtration
Tubular Spring

17 Flow Force Mechanism
Anthropogenic
Artesian
Geothermal
Gravity
Other

18/19 Parent Rock Type/Subtype
Igneous
- andesite
- basalt
- dacite
- diorite
- gabbro
- grandodiorite
- granite
- peridotite
- rhyolite

Metamorphic
- gneiss
- marble
- quartzite
- slate
- schist

Sedimentary
- coal
- conglomerate
- dolomite
- evaporates
- limestone
- mudstone
- sandstone
- shale
- siltstone
- Unconsolidated

20 Channel Dynamics
Mixed runoff/spring dominated
Runoff dominated
Spring dominated
Subaqueous

21 Flow Consistency
Dry intermittent
Erratic intermittent
Perennial
Regular intermittent

22 Measurement Technique
Current meter
Weir
Flume
Other

Spring Name____________________________ Page ______ of _________ OBS____________

Invertebrates

Species Name	Qty	[10]Stage	[11]Habitat	[12]Method	Rep #	Comments

Benthic Rep

Rep #	Location	Velocity m/sec	Depth cm	Substrate	Area Sq M	Time Sec	Comments

Entered by ______________________ Date__________ Checked by _______________________ Date ___________

Vertebrates

Spring Name______________________ Page ______ of _________ OBS____________

Species Name	No. Ind	[13]Detection Type	Comments

Entered by ______________________ Date__________ Checked by _______________________ Date ___________

Spring Name__________________________ Page ______ of _________ OBS____________

Flora

Species Name	^{14}Str	A	B	C	D	E	F	G	H	Comments	No. Ind	Ver.

Entered by __________________________ Date___________ Checked by _________________________ Date ______________

Spring Name____________________________ Page ______ of _________ OBS____________

Flora

Species Name	14Str	A	B	C	D	E	F	G	H	Comments	No. Ind	Ver.

Entered by ____________________________ Date____________ Checked by _____________________________ Date _______________

Spring Name____________________________ Page ______ of _________ OBS_____________

Geomorphology

[15]Emerg Env__________________________ [17]Mechanism__________________________ Geologic Layer________________________

[15]Detail______________________________ [18]Rock Type____________________________ [20]Channel Dynamics____________________

[16]Source Geo__________________________ [19]Rock Subtype__________________________

Polygon	[1]Discharge Sphere	[1]Secondary Discharge	Comments

Water Quantity

[21]Flow Consistency____________________ [22]Measurement Technique_________________________ Flow Rate (Mean)_______________________________

Location of Measurements____Total Site % Captured______________________________

Discharge Comments____

Current Meter l/s m/s other_____

Cell	Distance	Width	Depth	Reading

Flume l/s m/s other_____

Point	Flume Size	Measurements					Avg Stage	% Flow

Volume

Container Size/Units____________

Point	Volume	Time to Fill	% Flow

Weir l/s m/s other_____

Point	Weir Size	Measurements				% Flow

Entered by ____________________________________ Date_____________ Checked by ____________________________ Date ________________

Spring Name__________________________ Page ______ of _________ OBS____________

Water Quality

Measurement Device 1 ____ Date Last Calibrated___________

Measurement Device 2 ____ Date Last Calibrated___________

Measurement Device 3 ____ Date Last Calibrated___________

Collection Location(s)____

Collection Comments ____

Weather

Air Temp ___________

Select one

___No current/recent precip.
___Rain during survey
___Recent rain
___Snow on ground
___Snow, hail, or sleet during survey

Field Measurements

Location	pH	EC	SC	Water Temp (°C)	Turbidity ntu	Dissolved O^2 %	Dissolved O^2 mg/L	Alkalinity mg/L	Salinity ppt	Other	Device

Collected for Analysis

Sample Type	Sample Taken?	DuplicateTaken?	Container	Filtered (Y/N)	Treatment	
Anions						
Cations						
Nutrients						
^{2}H and ^{18}O Isotopes						

Entered by _______________________________ Date___________ Checked by __________________________ Date ______________

SEAP

Spring Name ______________________ Date ______________ Page ____ of ____Obs_________

Information Source ____

Aquifer/WQ	Cond	Risk	Habitat	Cond	Risk	Human Influence	Cond	Risk	Administrative Context	Cond	Risk
Spring dewatered (Y/N)			Isolation			Surface water quality			Information quality/quantity		
Aquifer functionality			Habitat patch size			Flow regulation			Cultural significance		
Spring discharge			Microhabitat quality			Road/trail/railroad			Historical significance		
Flow naturalness			Native plant ecological role			Fencing			Recreational significance		
Flow persistance			Trophic dynamics			Construction			Economic value		
Water quality			**Score**			Herbivory			Conformance to mgmt plan		
Algal and periphyton cover			**Biotic Integrity**			Recreational			Scientific/educational value		
			Native plant richness/diversity			Adjacent conditions			Environmental compliance		
Geomorphology			Native faunal diversity			Fire influence			Legal status		
Site obliterated (Y/N)			Sensitive plant richness								
Geomorphic functionality			Sensitive faunal richness								
Runout channel Geometry			Nonnative plant rarity								
Soil integrity			Nonnative faunal rarity								
Geomorphic diversity			Native plant demography								
Natural physical disturbance			Native faunal demography								

Notes:

Recommendations:

Entered by ______________________ Date __________ Checked by ______________________ Date ____________

Appendix C: SEAP Data Sheet

Site____________________________________ Date____________Info Source_______________________

Springs Ecosystem Assessment Protocol Scoring Criteria

Aquifer and Water Quality

AFWQ0 Springs Dewatered (Y/N)

AFWQ1 Aquifer functionality

0 Aquifer depleted
1 Aquifer nearly depleted
2 Aquifer in significant decline
3 Aquifer declining slightly but detectably
4 Low to moderate aquifer withdrawal
5 Aquifer not or only very slightly pumped
6 Aquifer pristine; good potential reference site
9 Unable to assess aquifer functionality

AFWQ2 Springs discharge

0 No flow
1 Less than .1 liters per second
2 Between .1 and 1 liters per second
3 Between 1 and 10 liters per second
4 Between 10 and 100 liters per second
5 Between 100 and 1000 liters per second
6 Over 1000 liters per second
9 Unable to assess flow

AFWQ3 Flow naturalness

0 Springs dewatered
1 Springs mostly dewatered
2 Springs flow strongly reduced
3 Springs flow slightly, but distinctively, reduced
4 Springs flow only slightly reduced
5 Springs flow apparently natural
6 Springs pristine; good potential reference site
9 Unable to assess flow naturalness

AFWQ4Flow persistence

0 No springs flow
1 Flow ephemeral, less than 50% of time
2 Flow rarely ephemeral
3 Flow recently persistent
4 Flow apparent during Holocene
5 Flow continuous since late Pleistocene
6 Flow since mid-Pleistocene or earlier
9 Unable to assess flow persistence

AFWQ5Water quality

0 No water
1 Water quality less than 10% of natural condition
2 Water quality 10 to 30% of natural condition
3 Water quality 30 to 60% of natural condition
4 Water quality 60 to 90% of natural condition
5 Water quality 90 to 99% of natural condition
6 Water quality fully natural
9 Unable to assess water quality

AFWQ6 Algal and periphyton cover

0 Algal or periphyton cover wholly unnatural
1 Natural cover of algae or periphyton very poor
2 Natural cover of algae or periphyton poor
3 Natural cover of algae or periphyton moderate
4 Natural cover of algae or periphyton good
5 Natural cover of algae or periphyton very good
6 Cover of algae or periphyton wholly natural
9 Unable to assess algal and periphyton cover

Geomorphology

GEO1 Geomorphic functionality

0 Site obliterated unnaturally
1 <25% original natural microhabitat types remain
2 25-50% of natural microhabitat types remain
3 50-75% of natural microhabitat types remain
4 75-90% of natural microhabitat types remain
5 90-98% of natural microhabitat types remain
6 Natural microhabitat types pristine
9 Unable to geomorphic functionality

GEO2 Runout channel geometry

0 Original runout channel unnaturally obliterated
1 Channel virtually obliterated, trenched, or otherwise manipulated
2 Channel strongly altered, with only scant evidence of original course
3 Channel highly altered but with some functionality
4 Channel slightly altered, mostly functional
5 Channel functioning apparently naturally
6 Channel pristine
9 Unable to assess channel geometry

GEO3 Soil integrity

0 Natural soils eliminated
1 Virtually all natural soils eliminated
2 Soils thin or eliminated on most of site but a detectable amount remaining
3 Soils patchy and compromised, with degraded functionality
4 Soils large intact, and only slightly compromised
5 Soils apparently natural, with very minor reduction in functionality
6 Soils fully natural
9 Unable to assess soil integrity

GEO4 Geomorphic diversity

0 None; a completely unnatural condition
1 Very low geomorphic diversity
2 Low geomorphic diversity
3 Moderate geomorphic diversity
4 Good geomorphic diversity
5 Very good geomorphic diversity
6 Pristine; fully natural geomorphic diversity
9 Unable to assess geomorphic diversity

GEO5 Natural physical disturbance

0 Natural disturbance regime obliterated
1 Natural disturbance regime virtually eliminated
2 Highly altered natural disturbance regime
3 Moderately altered natural disturbance regime
4 Little altered natural disturbance regime
5 Nearly natural disturbance regime
6 Natural disturbance regime virtually pristine
9 Unable to assess natural disturbance regime

Site______________________________ Date_____________

Habitat

HAB1 Isolation

0 <10 m from the nearest springs ecosystem
1 10-50 m from the nearest springs ecosystem
2 50-100 m from the nearest springs ecosystem
3 100-500 m from the nearest springs ecosystem
4 500-1000 m from the nearest springs ecosystem
5 1-10 km from the nearest springs ecosystem
6 >10 km from the nearest springs ecosystem
9 Unknown distance to nearest springs ecosystem

HAB2 Habitat patch size

0 No springs habitat area
1 < 10 sq m habitat area
2 10 - 100 sq m habitat area
3 100-1000 sq m habitat area
4 .1 - 1 hectare habitat area
5 1 - 10 hectare habitat area
6 >10 hectare habitat area
9 Unable to assess habitat area

HAB3 Microhabitat quality

0 No microhabitats exist or remain
1 Very low microhabitat quality
2 Low microhabitat quality
3 Moderate microhabitat quality
4 Good microhabitat quality with some indication of impairment
5 Very good microhabitat quality, but past impairment suspected
6 Pristine microhabitat quality
9 Unable to assess microhabitat impairment

HAB4 Native plant ecological role

0 No native plant species present
1 Native species cover and biomass <25% of natural condition
2 Native species cover and biomass 25-50% of natural condition
3 Native species cover and biomass 50-75% of natural condition
4 Native species cover and biomass 75-90% of natural condition
5 Native species cover and biomass 90-98% of natural condition
6 Native species cover and biomass virtually pristine
9 Unable to assess native plant species ecological role

HAB5 Trophic dynamics

0 No trophic dynamics occurring
1 Trophic dynamics and ecological efficiency scarcely extant (<25%)
2 Trophic dynamics and ecological efficiency poor (25-50%)
3 Trophic dynamics and ecological efficiency moderate (50-75%)
4 Trophic dynamics and ecological efficiency fair (75-90%)
5 Trophic dynamics and ecological efficiency good (90-98%)
6 Trophic dynamics and ecological efficiency pristine (>98%)
9 Unable to assess trophic dynamics and ecological efficiency

Biolota

BIO1a Native plant richness and diversity

0 No native plant species remaining
1 <25% of expected species remaining
2 25-50% of expected species remaining
3 50-75% of expected species remaining
4 75-90% of expected species remaining
5 90-98% of expected species remaining
6 >98% of expected species remaining
9 Unable to assess native vascular plant richness and diversity

BIO1b Native faunal diversity

0 No expected species remaining
1 <25% of expected species remaining
2 25-50% of expected species remaining
3 50-75% of expected species remaining
4 75-90% of expected species remaining
5 90-98% of expected species remaining
6 >98% of expected species remaining
9 Unable to assess native faunal diversity

BIO2a Sensitive plant richness

0 No sensitive or listed plant species remain
1 <25% of expected species remaining
2 25-50% of expected species remaining
3 50-75% of expected species remaining
4 75-90% of expected species remaining
5 90-98% of expected species remaining
6 >98% of expected species remaining
9 Unable to assess native sensitive vascular plant species

BIO2b Sensitive faunal richness

0 No sensitive or listed faunal species remain
1 <25% of expected species remaining
2 25-50% of expected species remaining
3 50-75% of expected species remaining
4 75-90% of expected species remaining
5 90-98% of expected species remaining
6 >98 of expected species remaining
9 Unable to assess native sensitive faunal species

BIO3a Nonnative plant rarity

0 >75% of plant species are non-native
1 50-75% of plant species are non-native
2 25-50% of plant species are non-native
3 10-25% of plant species are non-native
4 5-10% of plant species are non-native
5 2-5% of plant species are non-native
6 <2% of plant species are non-native
9 Unable to assess nonnative plant species rarity

BIO3b Nonnative faunal rarity

0 >75% of faunal species are non-native
1 50-75% of faunal species are non-native
2 25-50% of faunal species are non-native
3 10-25% of faunal species are non-native
4 5-10% of faunal species are non-native
5 2-5% of the faunal species are non-native
6 <2% of faunal species are non-native
9 Unable to assess nonnative faunal species rarity

Site______________________________ Date_____________

BIO4a Native plant demography

0 No native plant populations remain
1 <25% of dominant native plant populations present and self-sustaining
2 25-50% of dominant native plant populations present and self-sustaining
3 50-75% of dominant native plant populations present and self-sustaining
4 75-90% of dominant native plant populations present and self-sustaining
5 90-98% of dominant native plant populations present and self-sustaining
6 Dominant native plant populations self-sustaining in a natural condition
9 Unable to assess native vascular plant population demography

BIO4b Native faunal demography

0 No natural faunal populations remain
1 <25% of native faunal populations present and self-sustaining
2 25-50% of native faunal populations present and self-sustaining
3 50-75% of native faunal populations present and self-sustaining
4 75-90% of native faunal populations present and self-sustaining
5 90-98% of native faunal populations present and self-sustaining
6 Native faunal populations self-sustaining in a natural condition
9 Unable to assess native faunal population demography

Freedom from Human Influences

FHI1 Surface water quality

0 No flow
1 Very poor surface water quality
2 Poor surface water quality
3 Moderate surface water quality
4 Good surface water quality
5 Very good surface water quality
6 Excellent surface water quality
9 Unable to assess desired surface water quality

FHI2 Flow regulation

0 Flow regulation influences have eliminated or destroyed the springs
1 Very extensive flow regulation influences
2 Extensive flow regulation influences
3 Moderate flow regulation influences
4 Limited flow regulation influences
5 Very limited flow regulation influences
6 No flow regulation effects
9 Unable to assess flow regulation influences

FHI3 Road, Trail, and Railroad effects

0 Road, trail, or railroad influences have eliminated the springs
1 Very extensive road, trail, or railroad influences
2 Extensive road, trail, or railroad influences
3 Moderate road, trail, or railroad influences
4 Limited road, trail, or railroad influences
5 Very limited road, trail, or railroad influences
6 No road, trail, or railroad influences
9 Unable to assess road, trail, or railroad influences

FHI4 Fencing effects

0 Negative influences of fencing have eliminated the springs
1 Very extensive negative influences of fencing
2 Extensive negative influences of fencing
3 Moderate negative influences of fencing
4 Limited negative influences of fencing
5 Very limited negative influences of fencing
6 No negative influences of fencing
9 Unable to assess influences of fencing

FHI5 Construction effects

0 Construction influences eliminated the springs
1 Very extensive negative construction influences
2 Extensive negative construction influences
3 Moderate negative construction influences
4 Limited negative construction influences
5 Very limited negative construction influences
6 No negative construction influences
9 Unable to assess construction influences

FHI6 Herbivore effects

0 Herbivory influences have eliminated the springs
1 Very extensive negative herbivory influences
2 Extensive negative herbivory influences
3 Moderate negative herbivory influences
4 Limited negative herbivory influences
5 Very limited negative herbivory influences
6 No negative herbivory influences
9 Unable to assess herbivory influences

FHI7 Recreational effects

0 Recreation influences have eliminated the springs
1 Very extensive negative recreational influences
2 Extensive negative recreational influences
3 Moderate negative recreational influences
4 Limited negative recreational influences
5 Very limited negative recreational influences
6 No negative recreational influences
9 Unable to assess recreational influences

FHI8 Adjacent lands condition

0 Ecological condition of adjacent landscape has eliminated the springs
1 Very extensive negative influences of adjacent landscape
2 Extensive negative influences of adjacent landscape
3 Moderate negative influences of adjacent landscape
4 Limited negative influences of adjacent landscape
5 Very limited negative influences of adjacent landscape
6 No negative influences of adjacent landscape
9 Unable to assess influences of adjacent landscape

Site______________________________ Date____________

Administrative Context

AC1 Information quality/quantity
- 0 No information or map exists
- 1 Very limited mapping or other information
- 2 Limited mapping or other information exists
- 3 A modest amount of credible mapping and other information exists
- 4 Credible mapping and other scientific information exists
- 5 A great deal of high quality mapping and other information has been gathered and compiled
- 6 The springs is used as a research site, with much high quality information available
- 9 Unable to assess information quantity and quality

AC2 Indigenous significance
- 0 No significance as an indigenous cultural site
- 1 Virtually no evidence of indigenous cultural features or resources
- 2 One culturally significant feature or resource
- 3 Two or more culturally significant features or resources
- 4 Several culturally significant features or resources
- 5 Numerous indigenous culturally significant features or resources
- 6 Cultural significance essential for the well-being of one or more indigenous cultures
- 9 Unable to assess indigenous cultural significance

AC3 Historical significance
- 0 No historical significance
- 1 Very little evidence of historically significant elements
- 2 One historically significant element
- 3 Two or more historically significant elements
- 4 Several historically significant elements
- 5 Numerous historically significant elements
- 6 Historical significance essential for the well-being of the culture
- 9 Unable to assess historical significance

AC4 Recreational significance
- 0 Desired effects of recreational use not achieved
- 1 Very extensive deviation from desired effects of recreational use
- 2 Extensive deviation from desired effects of recreational use
- 3 Moderate deviation from desired effects of recreational use
- 4 Limited deviation from desired effects of recreational use
- 5 Very limited deviation from desired effects of recreational use
- 6 No deviation from desired effects of recreational use
- 9 Unable to assess deviation from desired effects of recreational use

AC5 Economic value
- 0 The springs has no economic value
- 1 Very limited economic value
- 2 Limited economic value
- 3 Modest economic value
- 4 Considerable economic value
- 5 High economic value
- 6 Very high economic value
- 9 Unable to assess economic value

AC6 Conformance to mgmt plan
- 0 No management plan
- 1 Minimal management planning
- 2 Very preliminary management plan
- 3 Management plan exists, but receives little management attention
- 4 Management plan given moderate attention
- 5 Management plan given substantial management & legal consideration
- 6 Management plan fully implemented and followed
- 9 Unable to assess conformance to management plan

AC7 Scientific/educational value
- 0 No features of scientific or educational interest
- 1 One scientifically or educationally important feature
- 2 Two features of scientific or educational interest
- 3 Several features of scientific or educational interest
- 4 4-9 features of scientific or educational interest
- 5 At least 10 features of scientific or educational interest
- 6 Numerous features of scientific or educational interest
- 9 Unable to assess scientific or educational significance

AC8 Environmental compliance
- 0 No socioenvironmental compliance conducted or considered
- 1 Very little socioenvironmental compliance conducted or considered
- 2 Little socioenvironmental compliance conducted or considered
- 3 Preliminary socioenvironmental compliance conducted
- 4 Socioenvironmental compliance undertaken, not yet completed
- 5 Socioenvironmental compliance completed, not enacted
- 6 Environmental compliance, and designation of critical habitat, is complete
- 9 Unable to assess environmental compliance

AC9 Legal status
- 0 No land, water, or ecosystem legal rights exist or are recognized
- 1 Rights may exist but have not been adjudicated or enforced
- 2 Rights exist but application for those rights/uses are pending; no enforcement
- 3 Rights exist and applications have been made; limited enforcement
- 4 Rights applications have been completed; moderately robust enforcement
- 5 Rights have been established; robust enforcement

6 Rights established and defended; legislative protection; robust enforcement
9 Unable to assess legal status

Risk

0 No risk to site
1 Negligible risk to site
2 Low risk to site
3 Moderate risk to site
4 Serious risk to site
5 Very great risk to site
6 Extreme risk to site
9 Unable to assess risk to site

Site______________________________ Date______________________________

Information Source______________________________ Cultural Radius (meters)______________

Cultural Values

Archaeological Value

0 No archaeological evidence present at or near spring
1 Almost no evidence of archeological remains near the spring
2 Minor evidence of archaeological artifacts near the spring (i.e., ceramics)
3 Moderate evidence of archaeological remains near the springs; hunting camp remains, potentially including hearth(s) but no dwellings evident
4 Artifacts, petroglyphs, minor ruins, and/or irrigation works are present, demonstrating fairly extensive prehistoric use of the site
5 Artifacts, petroglyphs, ruins, and/or water works, and dwelling sites are present, demonstrating extensive prehistoric use
6 Artifacts, petroglyphs, remains, and extensive ruins nearby, protected by the tribe due to great archaeological significance
9 Unable to assess archaeological value

Petroglyphs
Shrines
Walls
Jewelry
Ceramics
Flakes
Hearths
Ruins
Irrigation
Middens
Agriculture
Human Remains
Historical Archaeology
Other archaeology

Education/Knowledge Value

0 No knowledge of the site recorded in tribal history or academic records, and no information reasonably expected to exist
1 Knowledge of site expected to exist, but not available, no longer taught
2 Knowledge of site is documented but is minimal and not used in education or research
3 Moderate knowledge of site exists; is used to a moderate extent in education and/or as a research site
4 Fairly significant education and/or research significance
5 Very good educational and/or research significance, providing trans-generational knowledge
6 Outstanding educational and/or research significance; trans-generation knowledge; great concern about protecting site for educational purposes
9 Unable to assess educational or research significance

Youth education
Elder knowledge
Trans-generational
Culturally-specific
Academic research
Academic education
Non-academic education
Other knowledge

Ethnoecology

0 No record or presence of plant and/or animal species used for food, utilitarian, food, medicinal, ceremonial, or other purposes

1Former presence of ethnobiological resources, but no longer present, or very few ethnobiological resources
2 Only 1 ethnobiologically important species present, or only a few species that can readily be obtained elsewhere
3 Several ethnobiologically important species present, although they can be found elsewhere
4 Several ethnobiologically important species present, of which at least one is difficult to acquire elsewhere
5 Numerous ethnobiologically important species present, with one or more being unique to the site
6 Many ethnobiologically important species present, including many that cannot be found elsewhere
9 Unable to assess ethnobiologically important species

Plants

Used for food
Firewood, constr, etc.
Medicinal purposes
Ceremonial purposes
Extirpated species
Endangered species
Restoration potential
Multiple use/other

Animals

Used for food
Utility animals
Medicinal purposes
Ceremonial purposes
Extirpated species
Endangered species
Restoration potential
Multiple use/other

Ethnoecological processes

Ethnogeological processes

Dyes
Paints
Ceramics

Tribal/Band Historical Significance

0 History of the site has been lost and is not taught in neither academic nor non-academic settings

Site______________________________ Date______________

1 History of the site is very limited and poorly available
2 History of the site is limited, primarily available in unpublished reports (i.e., water resources, cultural preservation office, etc.)
3 History of the site is moderately available and not well known
4 Site history information availability is good and relatively widely known
5 Site history information availability is very good and quite widely known in both academic and non-academic settings
6 Site history information is excellent, and is taught by the elders to other tribal members in both academic and non-academic settings
9 Unable to assess tribal history of the site

Spring on Historic Route

Site Sacredness

0 No record of historical or contemporary site sacredness; no possibility of the site being sacred
1 Site sacredness is very minor; sacredness possible but not specifically recognized
2 Site sacredness is recognized, but has no specific sacred role or function
3 Site sacredness is moderate, related to one specific role or function
4 Site sacredness is fairly high, related to two specific roles or functions
5 Site is highly sacred, related to several specific roles or functions
6 Site is very highly sacred, related to many specific roles or functions
9 Unable to assess sacredness of site

Sacredness of water
Sacredness of traditional foods
Sacredness of materials
Sacredness of medicines
Sacredness of ceremonial substances
Sacredness of archaeological remains
Sacredness of stories
Spirits or divine beings
Passage point to/from other worlds
Significance in afterlife
Site is sacred
Site is sacred for its pristine character
Site important as route or waypoint

National Registry of Historic Places
NRHP Condition

0 Site has no potential for listing with the Tribe(s) or non-tribal agencies
1 Site has not been recognized by Tribe(s) as having potential for NRHP status, or has been recognized as having very little potential
2 Site has been recognized by the Tribe(s) and/or non-Tribal agencies as having low potential for NRHP status
3 Site has been recognized by the Tribe(s) and/or non-Tribal agencies as having moderate potential for NRHP status, but not formally proposed
4 Site is recognized and listed with the Tribe(s), and NRHP status has been proposed
5 Site is recognized and listed with the Tribe(s), and NRHP status is anticipated and pending
6 NRHP status has been fully completed with both the Tribe(s) and the federal government
9 Unable to assess NRHP potential

Application Status

0 No culturally significant properties exist
1 NRHP status application completed
2 NRHP application submitted
3 NRHP status pending acceptance of application
4 NRHP status approved, but process not complete
5 NRHP status approved
6 NRHP status established
9 Unable to assess NRHP process

Recognized by Tribe as worthy of listing
Recognized by agencies as worthy of listing
Application submitted and refused

Economic Value

0 No economic use or sale of springs resources
1 Very little economic value OR formerly of very limited economic value, but no longer used for agriculture, recreation, or ethnobiological economics
2 Low economic value; use or sale of springs resources depends on erratic availability of resources, weather conditions, etc
3 Moderate economic use(s) or value of springs resources, primarily for single family subsistence; limited financial benefits to larger community
4 Good economic uses and sale of springs agricultural, recreation, and/or ethnobiological resources to the Tribe and/or external communities
5 Very good economic uses and sale of springs' agricultural, recreation, and/or ethnobiological resources to the Tribe and/or external communities
6 Tribe receives excellent financial benefits from the use(s) and sale of springs agricultural, recreation, non-use, and/or ethnobiological resources
9 Unable to assess economic value to the Tribe and/or external communities

Single family use/sales
Communal use/sales
Tribal use/sales
Livestock support
Potable water
Irrigation water

Site______________________________ Date______________

Mineral extraction
Mining permits
Electrical power
Recreational visitation
Non-agricultural plants
Non-agricultural animals
Aquatic agric. plants
Wetland agric. plants
Nonhunted ethnofaunal
Native fish
Farmed fish
Fishing permits
Wildlife
Hunting licenses
Real estate
Non-use values
Other economic values

Tribal Legal Significance

0 No legal interest or consideration of the site's resources
1 Little to no legal status; very little outside interest
2 Very low legal status; little outside interest
3 Moderate legal significance – some outside interest
4 Legal status is fairly well established, and the site is fairly well protected
5 Site legal status is clearly established, and may apply to more than one Tribe
6 Site legal status very clearly established; legal standing is an important precedent
9 Unable to assess legal status

Tribal—individual
Tribal-clan
Tribal
Tribal—multicultural
State
Federal
Agency
Other

Tribal Contemporary Use

o Tribal use or non-use value
1 No direct use but may have potential or non-use value
2 One minor use and may have potential non-use value
3 Slight use—2 uses plus some non-use value
4 Moderate use—3-5 uses plus some non-use value
5 Much use—5-7 uses plus some non-use value
6 Extensive use—8 or more uses and non-use value
9 Unable to assess tribal use or non-use value

Tribal water use
External water use
Irrigation use
Agricultural use
Ceremonial use
Fishing use
Hunting use
Gathering use
Educational use
Mineral extraction
Fuel use
Energy use
Aesthetic use
Recreational use
Guiding visitation use
Route in use

Appendix D

Sky Island Alliance Adopt-A-Spring Program Datasheet

General

Spring Name ______ Country **USA** State **AZ** County ______

Land Mgmt. ______ LU Detail ______ Quad ______ HUC ______

Georef

Georef Source **GPS** Device ______ UTM Zone ______ Datum ______

UTM E ______ UTM N ______ Elevation ______

Survey

Date ______ Begin Time ______ End Time ______ Survey Leader ______

Access Directions

Microhabitats

	Description	Wetted Area (m^2)	Soil Moisture[1]	H_2O depth (cm)	Other Notes
A					
B					
C					
D					
E					

[1]Soil Moisture Key

1 - DRY	**7 - WET**
2 - Dry-Moist	*8 - Saturated-Moist*
3 - Moist-Dry	*9 - Wet-Saturated*
4 - Wet-Dry	**10 - SATURATED**
5 - MOIST	
6 - Saturated-Dry	

TIP - *First consider whether the the moisture content is (1) DRY, (5) MOIST, (7) WET, or (10) INUNDATED. If it's something other than one of these 4 classes consider which of the others best describes it on the 1-10 scale.*

PPs

Photo Points Taken? *If yes, check box. If no, explain in Notes on page 3.* | **1** ☐ | **2** ☐ | **3** ☐ | **4** ☐ | **Others** ☐ | **Photographer(s) Initials**

Surveyor Information

Name	Volunteer?	Round-trip Miles Driven (personal vehicle)	Hours Volunteered (including travel time)	Notes or Considerations
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

Office Use Only

Checked by ______ Date ______

SSI Entered by ______ Date ______

Vol. Entered by ______ Date ______

SKY ISLAND ALLIANCE

Scientific Name	Common Name	# Observed	Method (obs, call, scat, track)	Comments

Sky Island Alliance Adopt-A-Spring Program Datasheet

Fauna

Flora

Use this section to describe unique species or floral observations that have not/may not have been accounted for in the botanical inventory for the site.

Water Flow

Volume				Location of Water Flow Measurements
Reading	**Volume**	**Time to Fill**	**% Flow**	
1				
2				
3				
4				
5				

Flow Rate (avg. mL/sec)	Total Site % Captured

Comments on Water Flow

Water Quality

Location of Water Quality Measurements

Calibration & Calibration Testing (Hanna HI-98130)

pH Calibrated?	pH Tested?	EC Calibrated?	EC Tested?
☐	☐	☐	☐

Water Quality Readings (Hanna HI-98130)

pH	Conductivity (mS)	Water Temp (°C)	Air Temp (°C)

5				
6				
7				

Comments on Water Quality and/or Calibration Procedure

Notes - Please add any descriptive information that you think is unique to your visit to the site during the visit. **See the "Datasheet Instructions" document for further guidance.**

Wet/Dry Transect

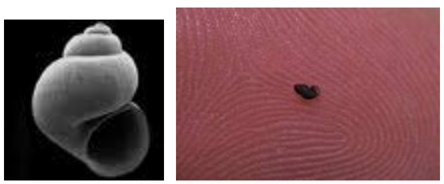
Start Distance	End Distance	Subtotal Distance	Soil Moisture	Type (pool, run, dry, etc.)	Comment

3						
	Pool Length					
	Run Length					
	Dry Length					
	Other Length					
	Total Length					

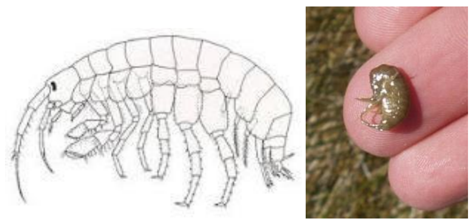
Species likely to indicate perennial water:

Giant water bug (*Abedus herberti*): 1-2 in long, oval, males w/eggs on back, flightless, requires perennial water

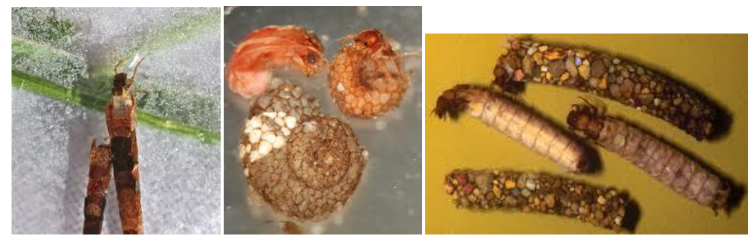
Caddisfly (*Phylloicus*): 0.5-2 in long, case of glued leaf segments, often long-lived (1 year) and thus requires perennial water



Springsnails: like tiny black sand, 0.05 in long, dense near springheads, see picture on finger above for size



Amphipods (*Gammarus*): small crustaceans, often abundant in springs



Other caddisflies: a number of caddisfly species are found in perennial springs with a number of case styles

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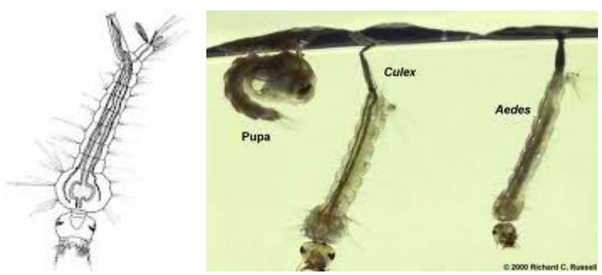
Species often found in temporary water:

Midges (Chironomidae):
0.1-0.75 in long, white or red, often moving slowly in silt or open water



Mosquitos (Culicidae):
0.1-0.6 in long, white larvae & dark pupae, both active swimmers & responsive to shadows

Physidae snails:
Much larger than springsnails, 0.15-0.75 in long, slowly move along substrate often in high densities

Appendix E: Spring Seeker App Fields

SPRING SEEKER
SKY ISLAND ALLIANCE

Get Started

Download Survey123 to a mobile device – Visit the app store for your smartphone or tablet and download the free Survey123 app.

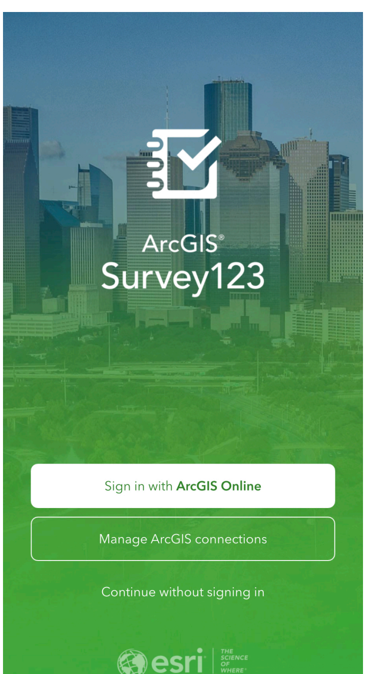
- Apple
- Android

Download the Spring Seeker survey – Download and open the survey on your smartphone or tablet in the Survey123 app before you go to the field

- https://arcg.is/18aCjm. Choose "open in Survey123"

Read about land access and safety in the field: Spring Seeker Safety

Spring Seeker Waters Map – Use this map to plan your explorations of springs in the Sky Islands. Zoom in and identify the name of the spring and the Site ID to include in your Spring Seeker survey.



Version 0.1
Created July 6, 2020
Modified October 12, 2020

Required Survey Components:

Sky Island Spring Seeker

Survey questions are listed in approximately their order of importance. A few at the top are required, so we can gather the most basic information about the site. The farther you can get, the more helpful it will be!

Site ID

Check [this map] for the Site ID of known water sources.

Surveyor(s) *

Email *

Date of Visit *

Tuesday, February 23, 2021

Where is the site? *

Photo *

Place your backpack by the water (this helps give us an idea of its size). Take one photo that represents the site well. Make sure you can see the water, vegetation, and immediate surroundings.

Sky Island Spring Seeker

What is the name of the water source? (if known)

Is the water source wet today? *

- Yes - there is standing or flowing water of any quantity
- Moist ground only - wet or damp soil (no standing or flowing water)
- No, but there are plants here that need extra water.
- No, it is totally dry

If you know how reliable this water source is, tell us about it.

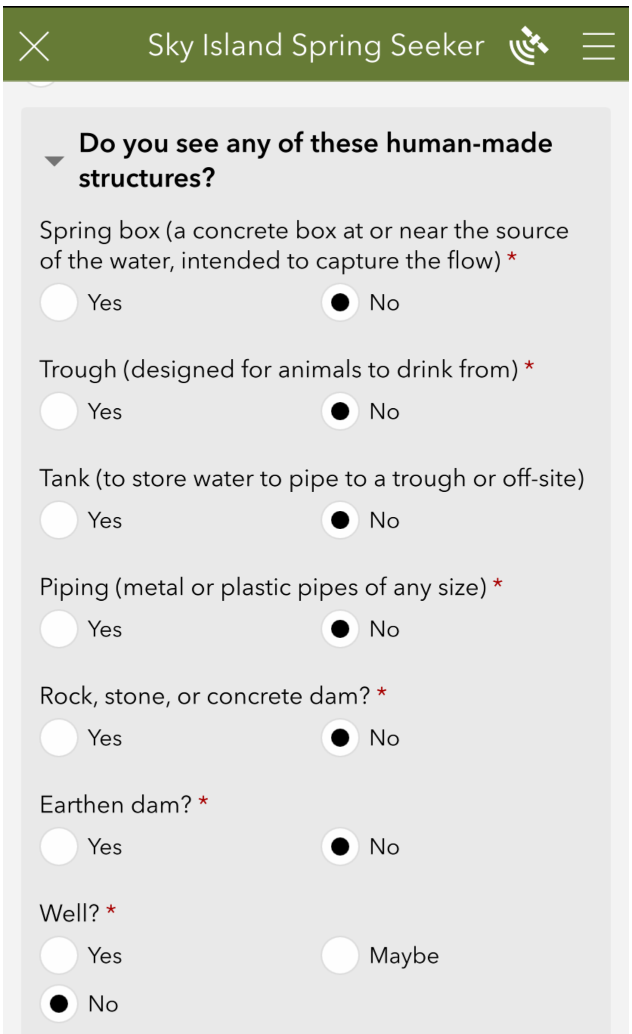
- Always has standing or flowing water
- Usually has water, but may occasionally dry up
- Reliably has water, but can dry up seasonally
- Has water after it rains
- Other

Do you see any of these human-made structures?

Human Impacts

If you can spend another 10 minutes or more at the water, we can learn a lot more about this water source!

Required Survey Components:



Sky Island Spring Seeker

Do you see any of these human-made structures?

Spring box (a concrete box at or near the source of the water, intended to capture the flow) *

○ Yes ● No

Trough (designed for animals to drink from) *

○ Yes ● No

Tank (to store water to pipe to a trough or off-site)

○ Yes ● No

Piping (metal or plastic pipes of any size) *

○ Yes ● No

Rock, stone, or concrete dam? *

○ Yes ● No

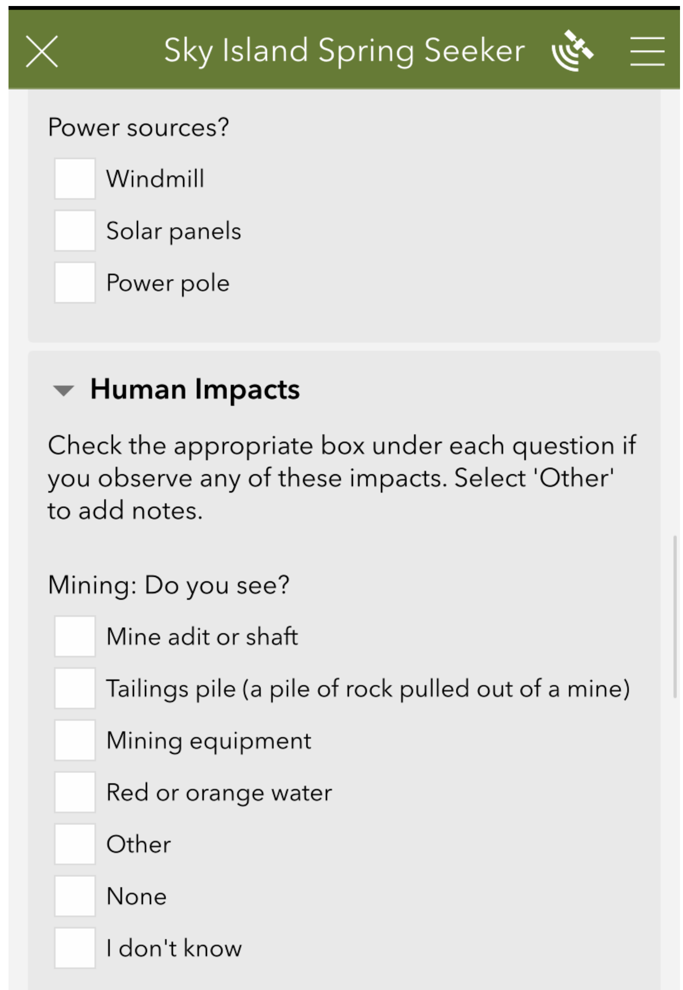
Earthen dam? *

○ Yes ● No

Well? *

○ Yes ○ Maybe

● No



Sky Island Spring Seeker

Power sources?

- [ ] Windmill
- [ ] Solar panels
- [ ] Power pole

Human Impacts

Check the appropriate box under each question if you observe any of these impacts. Select 'Other' to add notes.

Mining: Do you see?

- [ ] Mine adit or shaft
- [ ] Tailings pile (a pile of rock pulled out of a mine)
- [ ] Mining equipment
- [ ] Red or orange water
- [ ] Other
- [ ] None
- [ ] I don't know

SPRING SEEKER
SKY ISLAND ALLIANCE

Required Survey Components:

Sky Island Spring Seeker

Human Impacts

Check the appropriate box under each question if you observe any of these impacts. Select 'Other' to add notes.

Mining: Do you see?

- Mine adit or shaft
- Tailings pile (a pile of rock pulled out of a mine)
- Mining equipment
- Red or orange water
- Other
- None
- I don't know

Livestock: Do you see?

- Plants eaten down
- Cow, horse, or sheep hoofprints
- Cow, horse, or sheep poop
- Large patches of bare soil, like a bedding area
- Trails
- Other
- None
- I don't know

Sky Island Spring Seeker

People: Do you see?

- Toilet Paper/Human Waste
- Trash
- Road
- Trail
- Unnatural patches of bare soil
- Campsite by the water
- Other
- None
- I don't know

SPRING SEEKER
SKY ISLAND ALLIANCE

Required Survey Components:

Sky Island Spring Seeker

Invasives: Do you see?

- [ ] Brome grass
- [ ] Fountain grass
- [ ] Giant reed (Arundo)
- [ ] Horehound
- [ ] Johnsongrass
- [ ] Tamarisk
- [ ] Tree of Heaven
- [ ] Vinca (Periwinkle)
- [ ] Other plants
- [ ] Bullfrog
- [ ] Crayfish
- [ ] Mosquitofish
- [ ] Sunfish
- [ ] Other animals
- [ ] None
- [ ] I don't know

Sky Island Spring Seeker

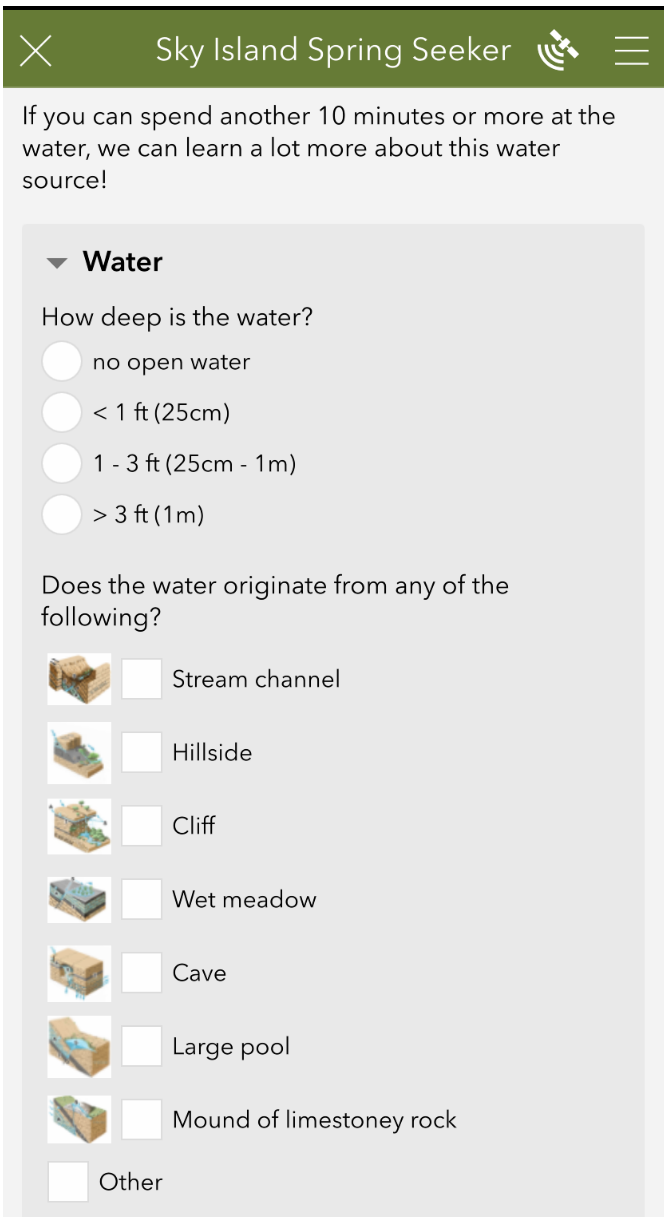
Soil health: Do you see?

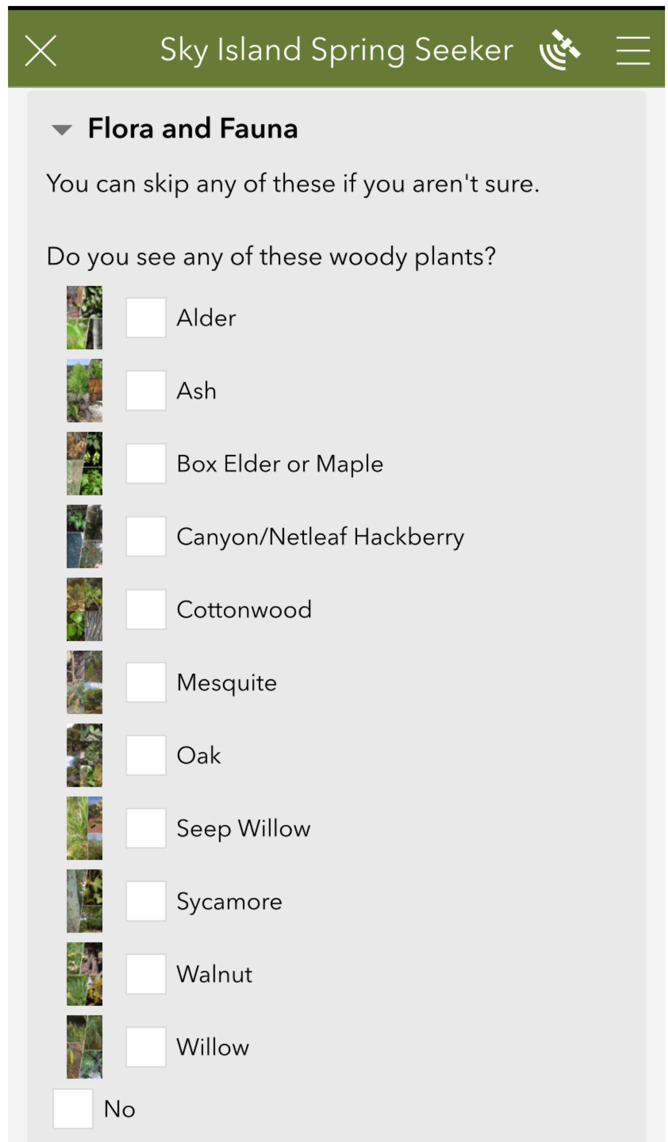
- [ ] Large bare areas
- [ ] Trampling
- [ ] Headcuts
- [ ] Soil sloughing off slopes or banks
- [ ] Incised channels (unusually deep and steep-sided)
- [ ] Other
- [ ] None
- [ ] I don't know

Fire: Do you see?

- [ ] Burn marks on trees
- [ ] Many standing or fallen heavily burned trees
- [ ] Signs of heavy flooding (sediment deposits, flood debris, or erosion issues mentioned in the previous question)
- [ ] Other
- [ ] None
- [ ] I don't know

Optional Survey Components:



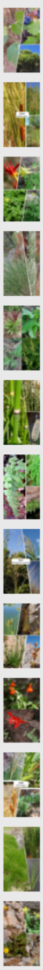


SPRING SEEKER
SKY ISLAND ALLIANCE

Optional Survey Components:

Sky Island Spring Seeker

Do you see any of these wetland plants?



- [ ] Canyon grape
- [ ] Cattail
- [ ] Columbine
- [ ] Deer grass
- [ ] Dock
- [ ] Horsetail (Equisetum)
- [ ] Maidenhair fern
- [ ] Reed/Cane (Phragmites)
- [ ] Rush
- [ ] Scarlet monkeyflower
- [ ] Sedge
- [ ] Spikerush (Eleocharis)
- [ ] Yellow/Seep monkeyflower
- [ ] No

Sky Island Spring Seeker

Do you see any fish?

- ○ No
- ○ Yes

Do you see any snails?

- [ ] No
- [ ] Large ones (about the size of a dime)
- [ ] Tiny ones (smaller than your pinkie nail)

Do you see any of these amphibians?

- [ ] Frogs and/or toads (not sure what kind)
- [ ] Bullfrogs
- [ ] Leopard frogs
- [ ] Toads
- [ ] Any kind of tadpole
- [ ] Salamanders

SPRING SEEKER
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Optional Survey Components:

Sky Island Spring Seeker

Do you see any of these aquatic insects?

- ☐ Caddisflies
- ☐ Diving beetles
- ☐ Dragon or damselflies
- ☐ Giant water bugs
- ☐ Mayflies
- ☐ Stoneflies
- ☐ Water boatmen/backswimmers
- ☐ Water striders
- ☐ Other

Flora & Fauna notes

Sky Island Spring Seeker

Site Description

How large is the area that is changed by the water's presence?

Think big here and look at the part of the landscape that has different vegetation because the water is nearby. This could include riparian trees, or even a mesquite bosque surrounding it.

- ○ Smaller than a small living room (< 10ft x10ft)
- ○ Smaller than half a tennis court (between 10ft x 10ft and 10ft x 100ft)
- ○ Smaller than 2 basketball courts (between 10ft x 100ft and 100ft x 100ft)
- ○ Smaller than 2 football fields (between 100ft x 100ft and 100ft x 1000ft)
- ○ larger than 2 football fields

Which way does the site face?

You can select up to two directions (e.g. checking both N and E indicates the site faces NE).

- ☐ N
- ☐ S
- ☐ E
- ☐ W
- ☐ The site is flat

Site description.

Tell us a little bit about the setting and layout of the water source.

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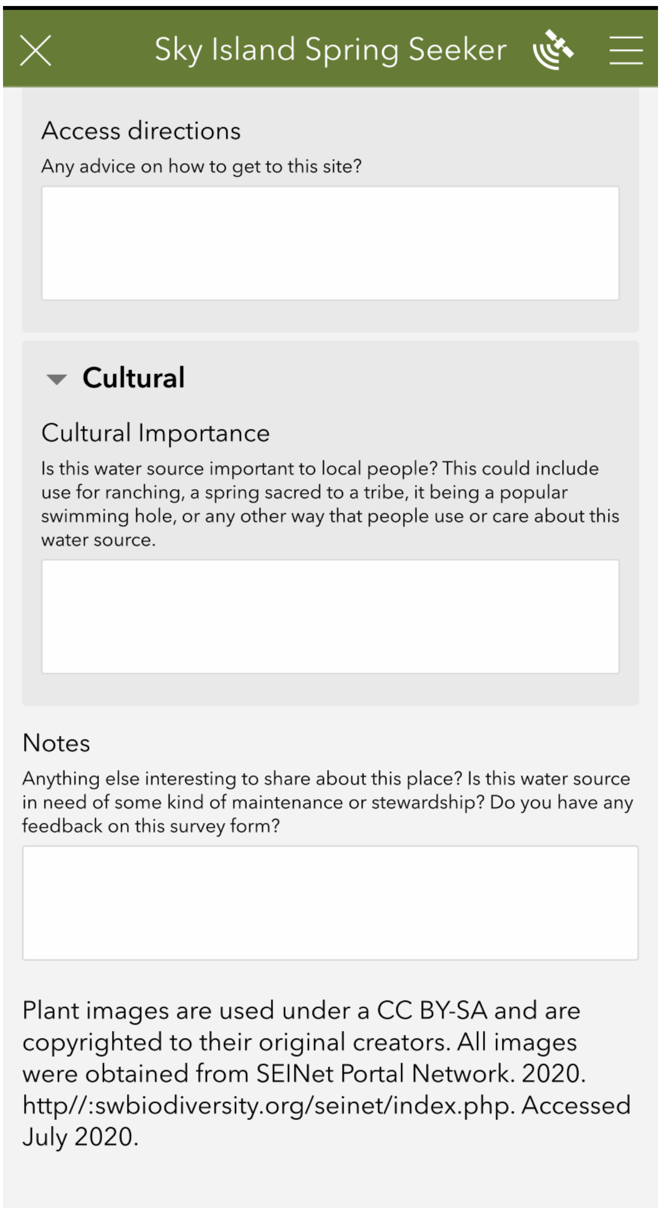
Optional Survey Components:


Sky Island Spring Seeker

Access directions

Any advice on how to get to this site?

Cultural

Cultural Importance

Is this water source important to local people? This could include use for ranching, a spring sacred to a tribe, it being a popular swimming hole, or any other way that people use or care about this water source.

Notes

Anything else interesting to share about this place? Is this water source in need of some kind of maintenance or stewardship? Do you have any feedback on this survey form?

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