A RESTORATION GUIDE FOR NEVADA, GREAT BASIN AND MOJAVE/SONORAN DESERT SPRINGS: EXECUTIVE SUMMARY

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Prepared by:
The Nevada Springs Restoration Workshop Committee
Lawrence E. Stevens, Chair, Springs Stewardship Institute
Robert J. Andress, Gradient LLC
Stephanie Carman, Bureau of Land Management
Joseph Gurrieri, U.S. Forest Service
David Kreamer, University of Nevada Las Vegas
Donald R. Sada, Desert Research Institute
Cynthia Tait, U.S. Forest Service

Assisted by Abe Springer, Jeri Ledbetter, and Anya Fayfer,
Springs Stewardship Institute

INTRODUCTION

Springs are places where groundwater reaches the Earth's surface. Nevada, the nation's driest state, supports a great abundance of springs, which are among the most important productive and important ecosystems. Springs provide many Great Basin and Mojave Desert ranches and farms with domestic and livestock water, and support many of the region's unique plants and animals. In addition, springs are important paleontological, cultural, and historic sites. Springs often are intensively used for human purposes, but if the aquifers that support them are intact, springs can be remarkably resilient and can be readily managed for both human and natural functions. Concern for improving the sustainability of Nevada's springs, and experience with their rehabilitation, prompted us to develop this workbook on restoration. This book outlines our suggestions about improving the care of springs, and is intended for use by public and government springs stewards throughout the state. While the approach and methods proposed here apply directly to Nevada springs, they also may prove useful to springs stewardship in most arid states and regions (Fig. 1).

Nevada has long been a leader in the understanding of springs and the challenges of management, and our work follows the lead of *The Nevada Springs Conservation Plan* (Abele et al. 2011; http://www.fws.gov/nevada/partners/documents/springcons.pdf). That plan summarizes the current conditions, threats, and actions needed to conserve Nevada's springs. It was prepared to serve as a catalyst to advance conservation efforts for Nevada's spring systems. Here, we take the next step to improve Great Basin and Mojave Desert springs stewardship. We clearly recognize that springs and the ecological and economic amenities they provide are vital to those who own and manage them. Nonetheless, the use and ecological function of springs are not necessarily contrary purposes, as many land owners recognize. Springs can be sustainably used for water supplies or other services while still providing many natural ecological functions, and appropriate care of springs enhances both property value and the integrity of our natural heritage.

In this handbook, we suggest a rationale, methods and approaches for accomplishing both ends, clearly recognizing the primacy of stewardship rights and goals.

In general, we find that springs management is best achieved by following the following overall formula:

Define Desired Conditions and Goals→
Inventory→Assess→Plan→Implement→Monitor→
Evaluate Success and Modify as Needed

This approach improves understanding of how to achieve desired conditions for the springs, the trade-offs involved, as well as the costs and timing of stewardship actions. The approach can be used to address the following suite of issues: 1) Is there a problem? 2) What is the problem? 3) How bad is the problem? 4) How can the problem be solved? 5) Solve the problem and maintain and monitor the desired condition. The following document is framed around these questions into modules to help concerned citizen or government agencies consider options and move forward with solving springs stewardship challenges. If broadly adopted, such an approach will greatly help improve the ecological health and integrity of these highly valued resources, and our natural heritage in general.

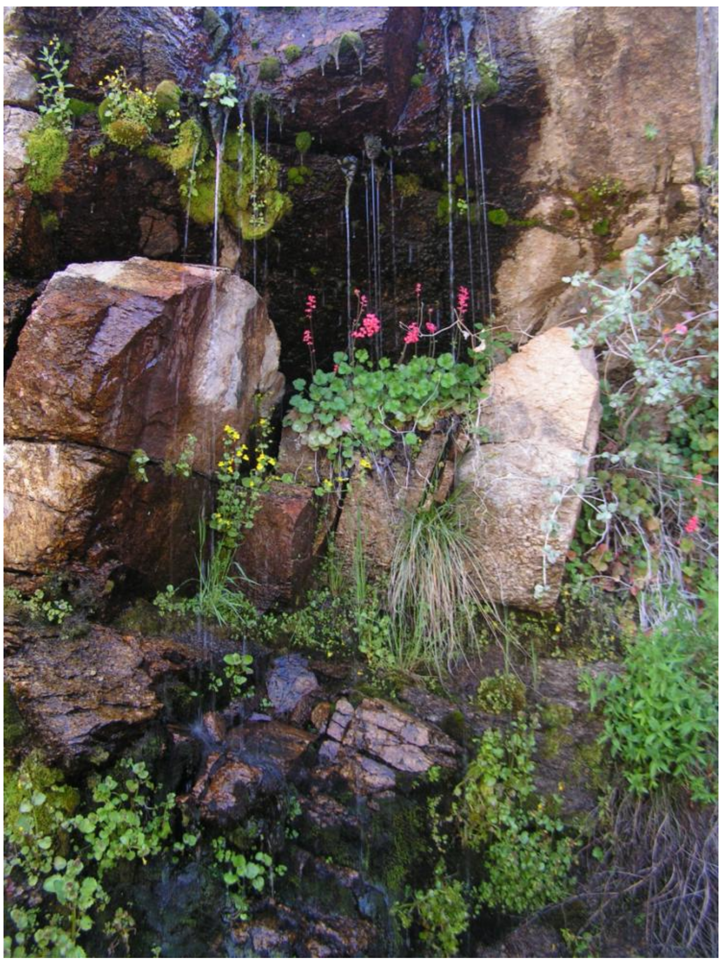

Fig. 1: Bug Spring, Pima County, Arizona, May 2012.

VISIT SITE: RECOGNIZING PROBLEMS

Many springs are intensively used and altered for various purposes, and many springs ecosystems are highly impaired. However, springs can be used and managed sustainably to provide human services, such as water delivery, as well as natural ecological functions. Recognizing the goals for management of a spring, ecological stressors, and stewardship solutions generally requires careful consideration, particularly if those solutions require substantial effort and cost. Here we provide a table to quickly recognize stewardship problems with springs (Table 1) and a decision flow chart as to how to solve stewardship problems (Fig. 2). Potential solutions for these problems vary by springs types, because of inherent differences in aquifer function, geomorphology, microhabitat arrays, and species occurrence. Descriptions of springs types, with examples and sketches, are available at SpringStewardship.org.

Table 1: A quick check-list of ecological functions and stressors for quickly identifying stewardship challenges at springs ecosystems.

Springs Type:	Hillslope, Limnocrene, Helocrene, Rheocrene, Hanging Gardens, Other:	
Function	**Common Stressors (Circle Any That Apply)**	**Status (Poor, Fair, Good)**
Aquifer/flow	Groundwater pumping, climate change (drought)	
Groundwater quality	Groundwater pollution	
Surface water quality	Surface point source pollutants	
Geomorphology	Alteration of the source or outflow	
Flow regulation	Spring box, diversion, piping	
Aquatic habitat	Dewatering; geomorphic, siltation or herbivore impacts	
Wetland habitat	Dewatering; geomorphic, erosional or herbivore impacts	
Riparian habitat	Dewatering; geomorphic, erosional or herbivore impacts	
Adjacent uplands	Erosion; fire; geomorphic or herbivore impacts	
Native aquatic.wetland species	Loss or decline of desired native species	
Native riparian species	Loss or decline of desired native species	
Native upland speces	Loss or decline of desired native species	
Nonnative aquatic/wetland species	Occurrence or dominance of undesired nonnative species	
Nonnative riparian species	Occurrence or dominance of undesired nonnative species	
Nonnative upland species	Occurrence or dominance of undesired nonnative species	
Economics	Domestic, agricultural, or mining water supplies; water bottling; wood supplies; wildlife; other	
Other		

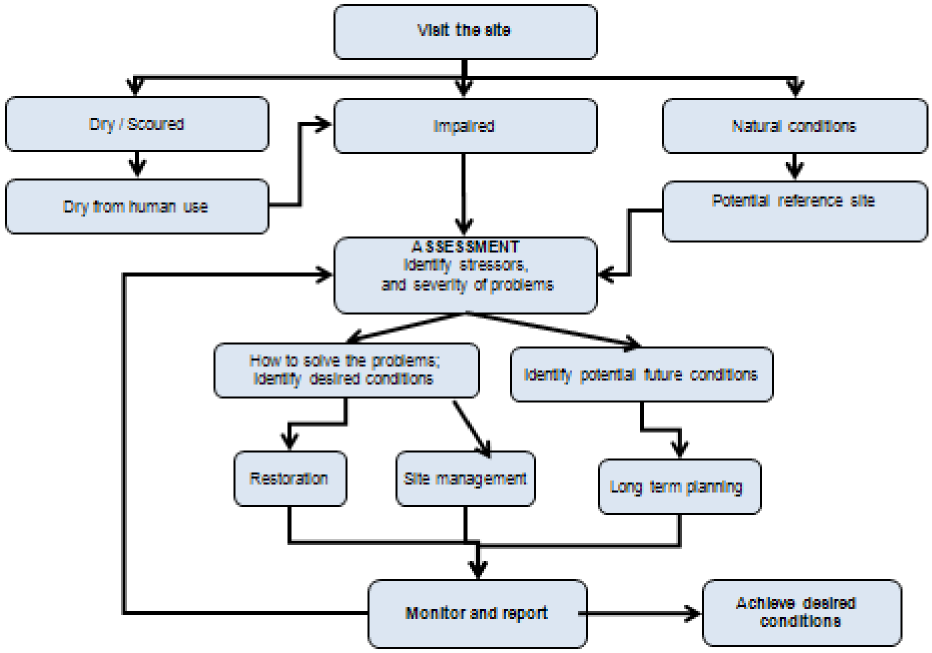

Fig. 2: A flow chart of problem recognition and resolution for improving springs stewardship.

Individuals and agencies managing springs often express concerns about the sustainability of their springs. In our work as stewardship advisors we often hear the comment, "My springs are drying up." Are these concerns real, and if so, what are the causes? Is the loss of springs simply a matter of leaking pipes, or encroaching vegetation that transpires groundwater; or is the problem related to channel incision, groundwater pumping or long-term drought? Another common concern involves decreasing water quality. The array of possible causes here may involve stagnation from failing or poorly designed infrastructure, local or regional groundwater pollution, changes in dissolved minerals related to reduced flows or unwanted plant growth, or self-protection from potential law suits.

If a spring is in natural condition and is valued for its natural qualities, it may not require any additional stewardship action; however, it may be important as a reference site, to use in evaluating the health of other nearby springs. If so, sharing information about the site may benefit other land stewards and managing agencies, and state and federal programs exist that support wetland conservation and management.

Several other comments are worth mentioning in relation to Figure 1. For example, if the springs are naturally dry or scoured, it may not be worthwhile or possible to manage them for an alternative ecological condition. Other common stressors include invasion of invasive weeds or nonnative animals, trampling by herbivores, or erosion from human uses at the spring or in the surrounding landscape. Springs stewardship can be improved by talking with experts, who may help identify problems arising from multiple causes, or regional groundwater issues. The federal allotment managing agencies, the Natural Resources Conservation Service, and the Nevada Department of Wildlife all provide information about springs stewardship to interested citizens.

Fig. 2 provides a convenient flow chart showing how to proceed with recognizing and assessing the management options to improve and ensure the sustainability of springs.

WHAT IS THE GOAL, WHAT IS THE PROBLEM, AND HOW BAD IS IT?

Many springs have been altered by a number of human activities that impair ecological integrity. The desired condition is often to maintain a spring's functional characteristics that are similar to their historic condition, which represents ecological integrity. These conditions may be different for each spring, and discussion with a group of knowledgeable people will inform the most appropriate pathway to reach desired conditions.

The first step in improving physical and biological condition of a spring is to develop a vision and desired outcome. Ensuring sustainable flow and water quality is often a primary goal, but in other situations the protection, preservation or recovery of individual or groups of species, or the overall ecological integrity of the site, may be important goals. Changes in management and restoration programs may not be needed for springs that are minimally affected by human actions, or for springs with persistent flow that are unaffected by natural factors such as drying or scouring floods. The description of specific objectives often enables us to clearly recognize milestones and endpoints in the recovery or improvement of spring conditions.

Identifying problems affecting desired condition of a spring involves understanding activities that are stressing the system. In arid regions, stressors are generally related to excessive native and non-native grazing and trampling, surface water diversions, presence of invasive species, and excessive groundwater use. The influence of these on ecological integrity of a spring is relative to the amount of influence of riparian and aquatic systems. Small disturbances have little influence on integrity, but degradation of a system increases with the magnitude, frequency, and duration of activity. Desired conditions may occur where there is little evidence of livestock use, minimal surface and ground water diversion, and where invasive species are uncommon members of either the riparian or aquatic communities.

Desired conditions cannot occur when stressors have a large influence on riparian vegetation and aquatic life, or when the abundance or distribution of rare species is decreased. High levels of stress are evidenced by:

- Spring morphology is altered (e.g., a flowing spring brook is ponded, a spring brook is channelized or dredged).
- Surface discharge in upper reaches of a spring brook is decreased by more than a critical amount of its natural discharge.
- Grazing, trampling, and other factors can alter the species composition of riparian communities as compared to conditions documented in nearby healthy riparian systems. Deleterious alterations may include diminished presence of woody, obligatory, or facultative wetland vegetation, increasing presence of upland species in the riparian system.
- Invasive species that are established and dominate either the riparian or aquatic communities, including bullfrogs, crayfish, non-native mollusks, salt cedar, cattails. Nonnative species such as crayfish prey on and reduce native species (Fig. 3).

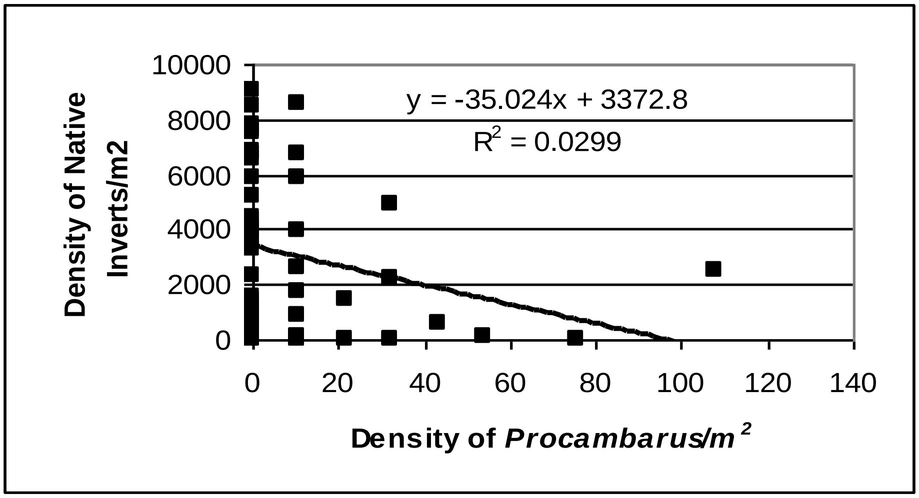

Fig. 3: Density of non-native *Procambarus* red crayfish reduces the density of native macroinvertebrates in Ash Meadows springs in southern Nevada.

WHAT CAN BE DONE?

Springs management and restoration methods are determined by spring type and stressors. Common spring types in Nevada include stream-channel (rheocrene), pool-forming (limnocrene), and marsh or wet meadow (helocrene) springs. Desired conditions are most easily achieved when matched with the spring type and characteristics of the pre-disturbance spring. Site assessment should determine the overall feasibility of achieving the pre-disturbance spring condition based on degree of physical alteration and impact at any given site (Fig. 4).

Fig. 4: Moapa Warm Springs channel rehabilitation, achieved through a partnership between the U.S. Fish and Wildlife Service and Otis Bay, Inc. (http://www.otisbay.com/projects/nevada/moapa/pederson/moapapederson.html)

Can the site be rehabilitated through management action(s) or are restoration activities required? There are two approaches to achieving desired conditions; 1) changes in the management of the site or individual resources; and 2) physical, on-the-ground restoration. Changes in management do not require physical site manipulation, but may involve reduction or removal of stressors such as water diversion, removal of invasive species, and/or livestock grazing, but may involve monitoring. If it is determined that a change in management is sufficient to achieve desired conditions, a management strategy can be developed. Remedies for impaired springs may include site specific actions depending on the amount and characteristics of site stressors. While many unimpaired or natural sites might require little action or management, impaired springs with rare or sensitive species can benefit from habitat improvement and monitoring. Remedies also may include site rehabilitation and restoration, which are site reconstruction activities that require construction equipment or hand tools to achieve desired conditions.

Three types of management actions can be considered: 1) protection of natural sites, 2) eliminating identified stressors to reduce impairment, or 3) management actions to prevent or alleviate potential, future threats. Stressors to a site can include groundwater extraction, impacts to groundwater quality, livestock grazing, surface water diversion, invasive species, or recreation impacts. The magnitude of the stressor or impairment will typically inform the project approach. In certain situations a change in management may be sufficient to alleviate stressors while in other situations physical, on the ground actions may be necessary.

MANAGEMENT STRATEGIES TO ALLEVIATE STRESSORS

Groundwater extraction: Methods to eliminate stressors related to groundwater extraction can include determination of the impacts by nearby wells to flow at the site of concern. A management strategy could be to vary the pumping schedule or location to reduce impacts to spring source discharge.

Impacts to water quality: Impacts to groundwater quality could be due to nearby industrial or agricultural activities. Management strategies may include monitoring downstream changes in water quality, and removal or control of the sources of pollution. Stagnation or eutrophication may result in diminished water quality. Management strategies to prevent stagnation can include minimizing nutrient input and maintaining unobstructed discharge. Water quality may also be affected by livestock.

Livestock grazing: Inappropriate or excessive livestock grazing affects springs by compressing wet soils, breaking down banks, increasing sediment and nutrients, and reducing plant cover and the presence of desired riparian species. However, these adverse impacts can often be mitigated by simply changing how livestock are managed. Changes to fencing, season of use, duration of use, livestock numbers, livestock type (e.g. cow/calf pairs, yearlings, sheep), or off-site watering facilities can all contribute to improved management of impaired spring sites.

Surface water diversion: Decreasing a springs' discharge reduces the amount and productivity of aquatic and riparian habitats, in turn decreasing the number of plants and animals of the site. Management options include changing the location, frequency, or quantity of diversion, allowing an increased amount of flow to discharge to the spring outflow habitat.

Invasive species: Invasive species often threaten the integrity of springs and adjacent landscapes. Non-native species management for springs restoration may involve preventing introduction, mechanical removal of invasive plants or animals, fencing, biological control, or the application of pesticides.

Recreation impacts: Recreational activities at springs include swimming, camping, picnicking, horse-camping, hunting, OHV use, fishing, and other activities, which compact or disturb soils, remove vegetation, introduce contaminants or non-native species, and disturbing wildlife. Reducing these impacts may range from building trails and boardwalks, restricting vehicular access, to elimination of camping or site closure.

SPRINGS RESTORATION

Overview: Restoration or rehabilitation involve actions that improve springs stewardship, including physical reworking of the physical characteristics, processes, and species at a site. Springs emerging from unimpaired aquifers often are remarkably resilient and can respond positively to such actions. Restoration actions may range from relatively minor activities, such as planting native species or removal of small manmade structures like spring boxes, tanks and piping, to larger- scale physical manipulation and reconstruction of site geomorphology. Where natural drainage and geomorphology are intact and physical conditions allow the desired conditions to be achieved, it may only be necessary to remove or modify infrastructure in a way that alleviates impacts and stressors. Complete physical reconstruction is typically required at sites where pre-disturbance topography and natural drainage has been highly altered or obliterated.

A site restoration plan is needed to identify and relate the goals to the desired outcomes. This plan should clarify the overall project approach, methods, budget, and schedule. The desired conditions and project design will be equally influenced by project goals and objectives. Strategies selected to alleviate stressors and restore any given spring will be informed by life history data and habitat characteristic requirements for target species. A monitoring strategy should be included to identify monitoring variables, to provide information and adjust post-restoration management practices, and to evaluate project success.

Restoration involves remediating the impacts of habitat alteration through physical, on-site actions and reduction of non-native species impacts, but should be undertaken after management practices have been rectified. After the stressors have been removed, the most important restoration activities for springs include those listed below.

Livestock grazing: Restoring a site from livestock grazing impacts may involve improving bank stability, decompacting soils, controlling invasive species, and revegetation, and vary in relation to springs type and elevation.

Restoration of the spring source: Spring sources and uppermost reaches of spring brooks are often important for springs-specialist plants and animals. Modification of flow regulation structures (e.g., dams, diversions, spring boxes) may be necessary to restore the flow at the source and restoring the functionality of downstream spring brooks or wetlands. For example, installing a flow splitter, shifting the point of diversion downstream from the source, removing a dam, or modifying a spring box and pipes may help ensure flow at the springs source, with the amount of diverted flow to be evaluated based on goals for the site.

Restoration of the spring brook and channel: If the spring brook channel is functioning naturally and is geomorphically appropriate, no action may be necessary. If not, the array of active options for restoring spring brooks range from reintroduction of flow to the historic channel, restoration of an existing channel, or constructing a new, geomorphically appropriate channel. Depending on the spring type and size of the spring, these activities may involve minor to substantial construction activities.

Restoration of wetland, wet meadows, cienegas or fen habitats: Marsh-forming (helocrene) are characterized by diffuse flow across shallow-gradient landscapes. Restoration of such habitats often involves filling in ditches, preventing erosional head-cutting with grade control structures, eliminating erosional channels, removing drainage tiles or subgrade water diversion structures to decrease groundwater depth, and by replanting native wetland plant species. The goal of fen restoration is often to regenerate peat formation by recreating conditions that characterized the undisturbed marsh.

Restoration of pool-forming springs: Pool-forming (limnocrene) springs are influenced by groundwater pumping, and may be subjected to stagnation, eutrophication, and deoxygenation, changes that reduce habitat quality and functionality. Restoration challenges for limnocrenes may involve recreating natural water quality and desired pool area.

Invasive species: Restoring habitat often requires elimination of non-native species. Large earth-moving equipment may be needed to remove undesired trees, such as tamarisk, palms, Russian olive, and elms. Construction of fish barriers, weirs, or other structures also may be constructed to to exclude non-native fish. Construction of exclosures may be used to prevent grazing and browsing impacts of undesired mammal species.

Recreation impacts: Restoration of springs from recreational activities is generally similar to those for grazing impacts. Decompaction of soils, replanting vegetation, introduce contaminants or non-native species, and disturbing wildlife. Reducing these impacts may range from building trails and boardwalks, restricting vehicular access, to elimination of camping or site closure.

CONCLUSIONS

Collectively, the above management and restoration approaches and actions have been demonstrated to be highly effective in helping to ensure the sustainability of springs, both for human uses and for natural amenities. But while this handbook provides guidance to springs stewards interested in employing best management practices, more work needs to be done. The methods discussed here are still evolving, and we look forward to updating the book with new approaches as they are tried and demonstrated. We hope this book contributes to improving the sustainability of the springs of Nevada and the Great Basin and Mojave Deserts, and we welcome comments and suggestions for improving these techniques.

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