United States Department of Agriculture

Rangeland Water Developments at Springs: Best Practices for Design, Rehabilitation, and Restoration

Joseph T. Gurrieri

Forest Service | Rocky Mountain Research Station | General Technical Report RMRS-GTR-405 | January 2020

Gurrieri, Joseph T. 2020. Rangeland water developments at springs: best practices for design, rehabilitation, and restoration. Gen. Tech. Rep. RMRS-GTR-405. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 21 p.

Abstract

Springs serve an ecologically important role as perennial water sources, essential habitat for native species, and support for stream flow. Spring developments on rangelands provide water to livestock and wildlife. Thoughtful design of sustainable developments will supply water to livestock and wildlife while maintaining the intrinsic ecological functions and values of springs. This guide addresses spring development project planning as well as long-term sustainable management of springs. The objectives of spring development design are (1) to retain hydrologic conditions in the developed spring habitat that are similar to undeveloped reference habitats and (2) to create a system that is easy to install and maintain. We present two gravity-flow development designs that incorporate flow-splitting devices to regulate environmental flows and levels and to work in a wide range of hydrologic conditions.

Keywords: springs, wetlands, fens, spring box, grazing, range management

Cover: Prince of the forest spring, Idaho. (Photo by USDA Forest Service.)

Author

Joseph Gurrieri is a Hydrogeologist with the USDA Forest Service, National Groundwater Technical Team in Lakewood, Colorado. He holds a M.S. degree in Geology from the University of Connecticut. He has been active in developing the groundwater program for the Forest Service and provides hydrogeologic services to Forest Service units nationwide.

Acknowledgments

This publication has been a collaborative effort among three staff areas within the USDA Forest Service: Minerals and Geology Management; Forest and Range Management and Vegetation Ecology; and Watershed, Fish, Wildlife, Air, and Rare Plants. I thank these Forest Service individuals for reviewing, and providing feedback on the manuscript: Steve Gibson, Warren Ririe, Linda Spencer, Cynthia Tait, Mary Manning, Nat Gillespie, and Joy Archuleta. Zach Freed and Allison Aldous (The Nature Conservancy) were willing partners in testing and evaluating spring box designs and environmental flow analysis techniques. Mark Gonzalez (National Riparian Service Team), Abe Springer (Northern Arizona University), and Sherm Swanson (University of Nevada, Reno) provided technical reviews and advice on the concepts and methods presented. I relied heavily on the springs ecology and restoration research efforts by Larry Stevens and Jeri Ledbetter of the Spring Stewardship Institute. Chris Carlson and Chris Frisbee (Forest Service Headquarters) provided support and helpful advice on navigating the approval, review, and publication process. Doug Wewer (Region 4 Engineering) and Tim Stroope assisted with the spring box designs. Additionally, I thank Kate Dwire, Frank McCormick, and Patricia Cohn (Rocky Mountain Research Station) for reviewing the manuscript and facilitating publication.

Table of Contents

1. Introduction

National Forests manage rangelands as sustainable, natural ecosystems for a variety of values and uses. Groundwater-dependent ecosystems are important components of rangelands that may be affected by management of surface resources. Among these groundwater-dependent ecosystems are springs and wetlands that provide valuable ecosystem services and clean water for rangeland management activities.

Protecting springs and wetlands from excessive livestock trampling and contamination is essential for long-term viability of water sources and is an important component of land stewardship. Range improvement projects that provide water for livestock and/or wildlife need to assess the effects of development on springs. Historically, the goal for a successful spring development was to maximize flows captured for stock water. Today, the overall ecological health of local aquatic, riparian, and terrestrial systems, together with livestock requirements, are factored into project design.

As competition for scarce water resources intensifies, the need for efficient and ecologically sustainable spring development will increase. This guide addresses spring development project planning as well as long-term sustainable management of springs. Increased awareness of alternatives for sustainable spring development expedites planning and informs defensible National Environmental Policy Act (NEPA) decisions.

Range conservationists, hydrologists, ecologists, and other specialists experienced in spring evaluation, monitoring, and development contributed to this guide. Information has also been drawn from *National Best Management Practices for Water Quality Management on National Forest System Lands, Volume 1* (USDA Forest Service 2012c) and work by the Nevada Springs Restoration Workshop Committee (2012). The Springs Stewardship Institute, The Nature Conservancy, and the Forest Service have collaborated since 2008 on mapping, describing, and protecting groundwater-dependent ecosystems in National Forests. These partnerships have resulted in better understanding of groundwater-dependent ecosystems and improved spring development designs that protect spring habitat while providing ample water for livestock and wildlife.

2. Purpose

The purpose of this guide is to share new and existing approaches and tools to design, rehabilitate, or restore spring developments that provide water for livestock or wildlife while protecting natural spring habitats. Forest Service rangeland managers and others responsible for aquatic or riparian resource management may benefit from this guide.

3. Background

On Western rangelands, groundwater-dependent ecosystems (springs and wetlands) serve an ecologically important role as perennial water sources, providing critical water for livestock, essential habitat for native species, and support for stream flow. In many watersheds, springs are the true headwaters providing clean, clear water for the benefit of downstream fish, fauna, flora, and communities who use the stream network. With their isolation and consistent water chemistry and flow rates, springs support many endemic, obligate, and rare aquatic species. Springs also supply water and forage for terrestrial wildlife and migratory birds. Springs were historically developed to capture flow for livestock watering or other uses without fully considering ecosystem services. Desiccation of spring habitats following diversion often eradicated aquatic communities and led to the extinction of species such as fish or snails.

Recent assessments in support of land management plan revisions have shown that many developed springs on rangelands are in poor ecological condition (fig. 1) (Dwire et al. 2018; Paffett et al. 2018; USDA Forest Service 2017b). Unsuitable water developments for livestock and wildlife have come under increasing scrutiny by concerned conservationists, managers, and members of the public.

Figure 1. Example of a poorly designed and maintained spring development. Lack of valves results in continuous flow and desiccation of the spring habitat. Trough is in the spring source area causing trampling of organic soils. Enclosure fence is nonfunctional. (Photo by USDA Forest Service.)

Springs are frequently isolated from stream systems and are often developed in uplands to reduce grazing pressure in riparian areas along streams. Although upland developments may protect streams from livestock impacts, without appropriate livestock management (e.g., Swanson et al. 2015; U.S. Department of the Interior 2006) they transfer disturbance problems from streams to isolated upland springs and wetlands (U.S. Department of the Interior 2006). Springs are also selected for development to provide protection structures to reduce disturbance. However, depending on grazing management and maintenance, they may concentrate livestock resulting in more disturbance.

Livestock and wildlife affect springs through herbivory and physical impacts, such as hoof-action and wallowing. Inappropriate livestock grazing can compact or churn wet soils; increase sediment, nutrients and pathogens; break up the root mass; and reduce plant cover and the abundance of desired plant and animal species. In some places, grazing degrades spring ecology (Perla and Stevens 2008). In other places, grazing and animal activity is natural and can be rejuvenating (Kodrick-Brown and Brown 2007). Appropriate disturbance regimes for specific ecological settings should be determined and maintained.

4. Definitions

Where groundwater reaches the surface, an assemblage of plants and animals supported by groundwater may establish—hence the term **groundwater-dependent ecosystems**. Sometimes, groundwater emerges at a discrete point, usually called a **spring**. In many **wetlands** supported by groundwater, groundwater flow emerges in a more diffuse manner. Many permanent springs have associated wetlands of different types and extent. Likewise, many wetlands contain springs. Groundwater-dependent wetlands, such as **fens**, are in many cases springs covered by unconsolidated material (glacial deposits, pumice, or colluvium) that becomes saturated to the surface for prolonged periods, facilitating peat development. Groundwater emerging at or close to the ground surface and providing all or a significant portion of the available water is the common thread that links these features

KEY POINTS

- A properly designed and maintained water development benefits livestock and sustains the ecological values of a spring or wetland.
- Protection of springs and wetlands on rangelands, especially prevention of excess or prolonged trampling and contamination, is essential for the long-term viability of spring habitats and land stewardship.
- Innovative water developments can help minimize detrimental effects to spring and wetland ecosystem health.
- Focus on maintaining or enhancing ecological functions of the site.
- The critical issue in many discrete discharge springs is maintaining wetted area in pools and channels.
- The critical issue in diffuse discharge springs is maintaining a shallow water table and avoiding drainage, incision, and excess soil oxidation.
- Consider the water needs of plants and animals when planning water developments for rangelands.
- Implementing/enforcing an appropriate grazing system is often the most important component of spring habitat protection.
- Collect no more water than needed for the intended purpose of the spring development.

and their associated ecosystems. For the purpose of this guide, all of these isolated water features are referred to as springs with two sub-types: **discrete discharge springs** (fig. 2A) and **diffuse discharge springs** (fig. 2B).

The following definitions are from Coles-Ritchie (2014). **Restoration** is the process of assisting the recovery of an ecosystem that has been degraded. Ecological restoration focuses on re-establishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystem sustainability, resilience, and health under current and future conditions. **Rehabilitation** refers to a level of restoration defined by management objectives. Rehabilitation is not focused on restoring the site to predisturbance conditions, but rather improving the condition according to certain management objectives. **Maintenance** consists of those actions and management guidance that result in the maintenance of a spring site's existing ecological conditions and processes, particularly resiliency to disturbance.

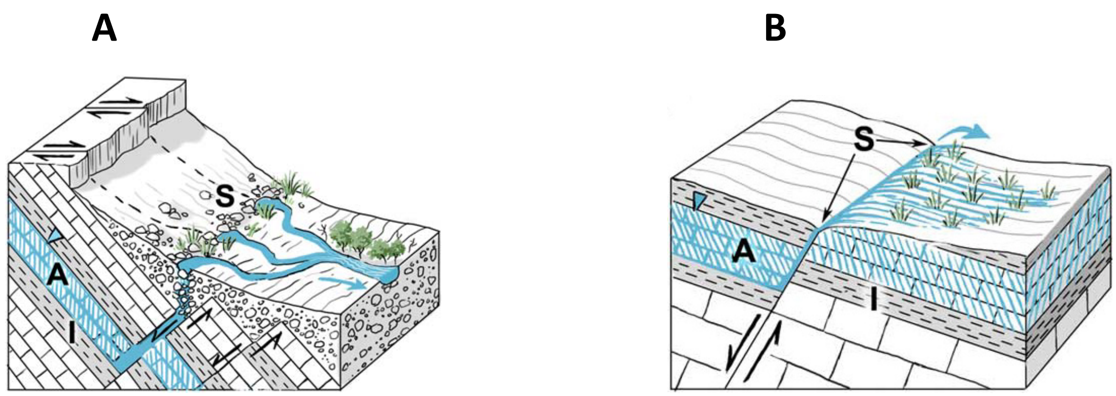

Figure 2. (A) Discrete discharge spring where groundwater emerges at a point with flowing water. (B) Diffuse discharge spring where groundwater emerges diffusely with little or no flowing water. With A = aquifer, S = source, and I = impermeable layer. (Images from Springer and Stevens, 2009.)

5. Desired Conditions for Springs

Although management direction in individual land management plans may vary, consensus over the past few years has settled on the following generic desired conditions for springs on rangelands:

- Groundwater systems function under normal patterns of recharge, flow, and discharge and are free of contamination. Groundwater-dependent ecosystems (e.g., wetlands, springs, and stream baseflows) have the water sources and hydrologic processes (e.g., water-table elevations) necessary to persist and to sustain associated plant and animal species and peat production where present.
- The ecological structure, diversity, and function of springs, wetlands and other aquatic ecosystems are maintained or restored.
- A diversity of types of springs across broad landscapes, especially spring types that are not very common, such as pool-forming springs, mound-forming springs, or fens are conserved.

- The aquifer supplying water to groundwater-dependent ecosystems is not being affected by groundwater withdrawal or loss of recharge.
- Soils of springs and wetlands are intact and functional; erosion and deposition are within the natural range.
- Springbrooks, if present, are functioning naturally and are not entrenched, eroded, dewatered, or substantially altered.
- Vegetation is composed of the anticipated cover of plant species associated with the site environment; hydric species are present and are not replaced by upland species.
- Livestock herbivory and trampling are not adversely affecting springs and wetlands.

Some or all of these statements can guide a spring development project and be modified to reflect site-specific conditions. They are offered here as examples of what a site with an ecologically sustainable spring development might look like.

6. Amount of Water to Divert

Groundwater discharging from aquifers supports springs. Any activity that lowers or raises the water table or groundwater discharge rate, or alters the groundwater chemistry, can affect the integrity of springs habitat. Extraction of groundwater from wells and springs may partially or completely dewater individual or entire complexes of springs, resulting in desiccation and fragmentation of springs habitat. Diversions that remove only a small proportion of flow, or slightly lower the water table, may minimally affect biota, as long as structure and function of the habitat are preserved. Diversions that occur infrequently or intermittently may also minimally affect biota. In general, as diversion volume increases, the spring's water depths, temperatures, and velocities change, and species such as springsnails and wetland plants, which have very specific habitat requirements, are easily extirpated (Morrison et al. 2013; Sada 2008).

For springs developed to provide water for livestock, the assessment of flow volume required is critical, especially if anticipated demand is a substantial portion of supply. Water requirements for beef cattle can range between roughly 6 and 18 gallons per animal per day (Lardy et al. 2008). A watering system designed with excessive flow rates wastes a valuable resource and may desiccate spring habitat. A watering system designed with inadequate flow rates deprives livestock of water and can cause unacceptable disturbance as animals linger at the site trying to drink.

When a spring or wetland is to be developed or rehabilitated, a hydrologic analysis can determine the proper diversion rate necessary to sustain the spring ecosystem. Determining hydrologic criteria, such as the water table depth necessary to provide sufficient soil moisture to plant roots, defines the acceptable level of change that can occur in flows before ecological impacts ensue (Aldous and Bach 2014). If water extraction shifts the hydrologic conditions below that defined by the criteria, ecological harm may occur, including impairment of wetland soils or loss of desired plant and animal communities. Figure 3 illustrates typical changes in wetland plants and soils associated with a dropping water table.

Figure 3. Likely ecosystem changes associated with a dropping water table due to groundwater extraction. (Image courtesy of Aldous et al. 2014.)

Land managers seek to understand how much groundwater can be diverted from springs or wetlands without altering the overall ecological function, which includes persistence of native species. A key driver for diffuse discharge springs is the maximum depth to water table that the species in question can tolerate. So, it is important to know the groundwater depth requirements of local vascular herbaceous and bryophyte plant species. To estimate the environmental flows and levels needed to support the ecosystem, information should be gathered to quantify hydrological attributes, such as water table fluctuations, seasonal variation in discharge, and ecological attributes including species and their optimal soil water requirements.

Available references for analyzing a water development regime that can maintain a healthy wetland plant community in a diffuse discharge setting include: USDA Forest Service 2017a, available from the National Groundwater Program staff, and Cooper and Merritt (2012). These references show how to develop hydrologic criteria for diffuse discharge springs by determining flow levels required to sustain or restore the spring. As an example, on the Fremont-Winema National Forest, an environmental flow and level analysis was used to design a spring development in a fen (Aldous et al. 2014). Analyses indicated that continuous diversion of over 1–2 gallons per minute throughout the grazing season would lower the water table and affect wetland plants in the area surrounding the spring box (fig. 4). However, with a float valve at the trough to stop overflow, intermittent diversion at higher rates was possible.

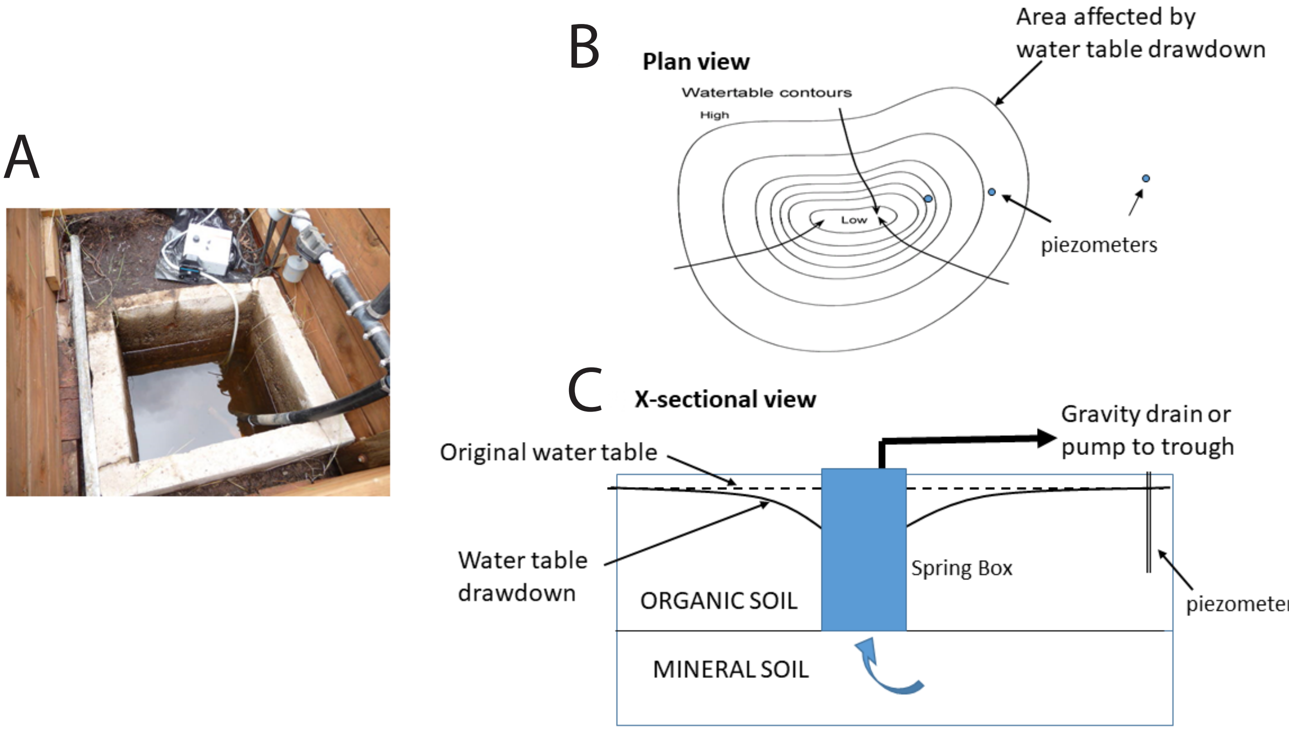

Figure 4. (A) Example of a spring development in a diffuse discharge spring (fen), Fremont-Winema National Forest. (B) Schematic plan view showing a cone of depression (also referred to as the area of influence), resulting from extraction of water from a collection box. (C) Schematic cross-sectional view showing the drawdown cone around the collection box.

In the case of discrete discharge springs, habitat values center on the source and the springbrook. To estimate the environmental flows and levels needed to support the ecosystem, information should be gathered to quantify hydrological attributes such as wetted area, depth, flow volume and flow velocity. Substantial decreases in springbrook physical habitat (e.g., wetted area, depth, and velocity) occur with relatively small (10 percent to 20 percent) discharge reductions (Morrison et al. 2013).

In most cases, only a small percentage of water can be diverted without significant ecological impacts. However, small diversions are usually adequate to supply water to livestock. With small flows and large needs for livestock water at key times, storage may be required.

Three groundwater-ecology relationships are evident:

1. For diffuse discharge springs, plant species distributions respond closely to the position of the water table. The majority of wetland plants grow well where the depth to the water table is approximately 20 cm or less (fig. 3). However, some species can tolerate water tables up to 70 cm below the land surface (e.g., *Carex aquatilis*) (Aldous and Bach 2014).

2. For peatlands (generally associated with diffuse discharge springs), the process of peat accretion depends on a high and stable water table provided by groundwater discharge (fig. 3). Lowering the water table below 20 cm results in desiccation of organic soils (Aldous and Bach 2014).
3. For discrete discharge springs, substantial decreases in springbrook physical habitat quality can occur with relatively small (10 percent to 20 percent) discharge reductions (Morrison et al. 2013).

In a few States, water rights laws may limit decision space on leaving water in the system for ecological purposes. A water rights specialist should be consulted to determine a viable, site-specific course of action. In some States, NRCS has stipulated that no more than ¼ of the total flow of a spring should be diverted (total flow rate determined during the driest part of the year) (USDA NRCS 2017). While no scientific support for this criteria could be found, it can be used as a general rule of thumb for planning a spring development where no critical species or other mitigating issues exist.

6.1 Flow Splitting

To avoid extracting the entire flow from a spring, flow splitting ensures some flow remains in the source area while still providing water for livestock. Flow splitting generally involves fitting the spring box with piping and an adjustable flow splitter to regulate how much water continues to emerge at the source and how much is diverted for use. If the piping directs flow into a trough or tank, a shut-off valve keeps water from being diverted in the nongrazing season (or plant recovery period). Float valves keep the trough full but stop excess flow away from the spring. Float valves require frequent maintenance during the grazing season.

7. Spring Development Designs

Published guidance for planning and installing spring developments provides important engineering specifications, but do not focus on low impact alternatives or address aspects of ecological sustainability (for example, Sanderson et al. 1990; USDA Forest Service 1989; USDA NRCS 2006, 2010, 2011). However, they can and should be used in conjunction with this document. More recently, *Ecological Considerations in Spring Development* (USDA NRCS 2016) acknowledges the ecological importance of springs and encourages careful evaluation of functions and values before development is undertaken. An inventory/evaluation using standard assessment methods (USDA Forest Service 2012a; 2012b; U.S. Department of Interior, 2020) can determine beforehand which functions and values to protect or enhance during development.

The objectives of spring development design are to retain hydrologic conditions in the spring habitat that are similar to undeveloped reference habitats, and to create a system that is simple, cheap, and easy to install and maintain. We present two gravity-flow designs that incorporate flow-splitting devices to regulate environmental flows and levels, work in a wide range of hydrologic conditions, and are easy to construct. If development of undisturbed springs cannot be avoided, then eco-friendly design principles should be incorporated. These designs (discussed below) are intended to protect the hydrology of the spring in three ways:

1. Outside of the grazing season a shut-off valve in the spring box stops flow to the trough;
2. During the grazing season, water only flows to the trough when the float valve is triggered; and
3. Even when the float valve is triggered, the water table will not drop below a preset threshold in diffuse discharge springs, and a wetted channel area is maintained in discrete discharge springs.

7.1 Design for Diffuse Discharge Systems (Fens, Wetlands)

For springs with diffuse natural flow that seeps from large saturated areas without a single point of discharge, the objective is to maintain a shallow water table. If the water table drops below certain ecological thresholds, water is no longer available for wetland vegetation. Figures 5 and 6 show spring box designs for diffuse discharge situations.

A traditional spring box sends all the water through a pipe—diverting it away from the natural spring and draining the water table down to the level of the pipe, sometimes a full meter below the surface, which is too deep to support wetland flora and fauna. In contrast, this diffuse discharge spring box design makes one simple adjustment—an elbow, or standpipe, that can be pivoted to the desired height and keeps the water table high enough to sustain the groundwater level needed by plants and animals. The adjustable elbow inserts into the inflow pipe within the spring box (figs. 5, 6) and allows the user to set the desired water table depth. The inflow pipe within the spring box can be shut-off to stop flow to the trough when livestock are not grazing.

Figure 5. View of the interior of the spring box at a diffuse discharge spring. The elbow joint is adjustable and is set to maintain the threshold water table depth determined for the spring and the season. (Photo courtesy of The Nature Conservancy.)

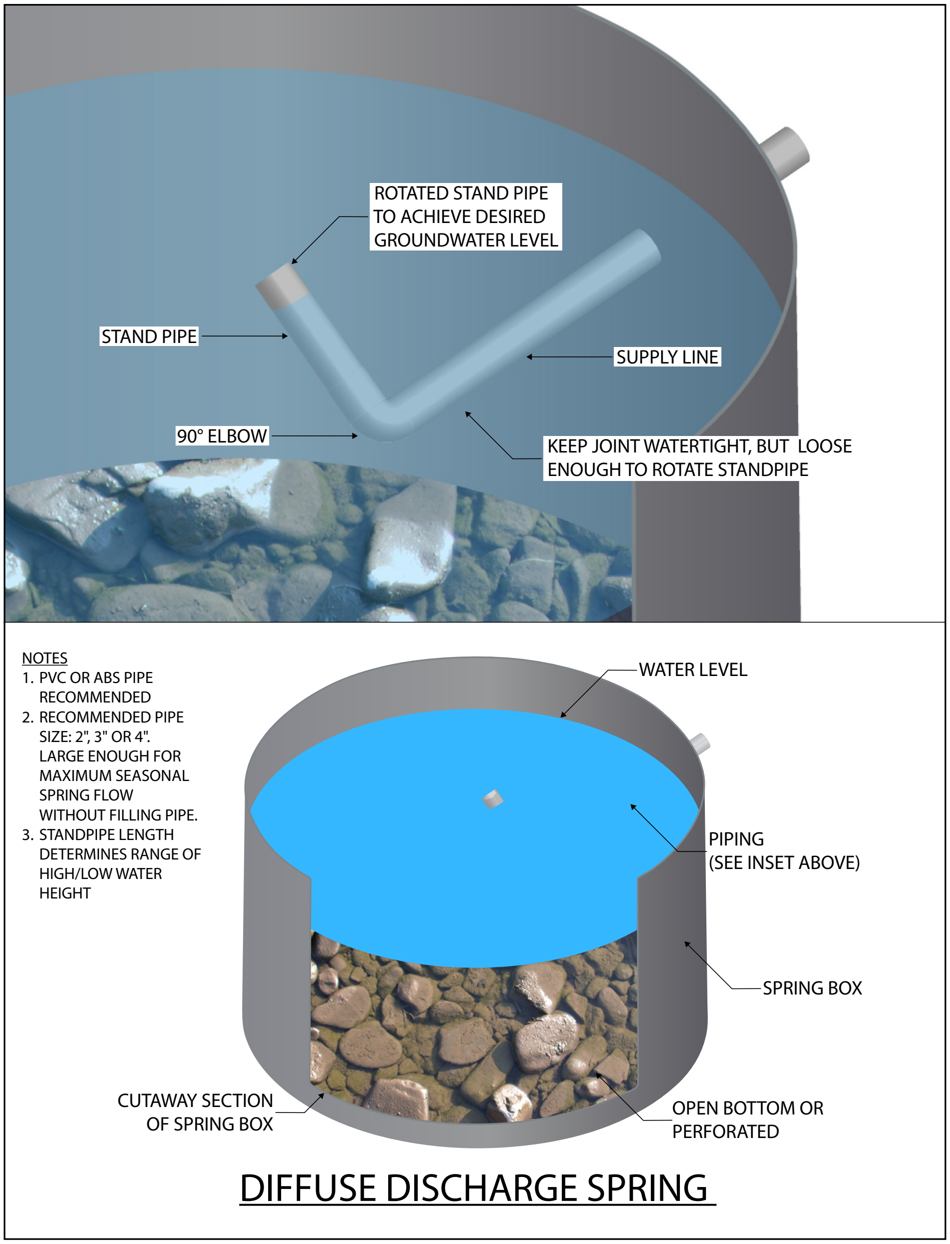

Figure 6. Gravity flow spring box design that incorporates features for regulating the amount of water extracted from a diffuse discharge (non-flowing) spring. The standpipe is rotated to achieve the desired groundwater level.

7.2. Design for Discrete Discharge Systems (Springbrooks)

For springs with a discrete natural flow in which water emerges from one or more specific orifices, the objective is to maintain continuous flow throughout the spring channel or pool downstream. Interruption of flow and reduction in wetted areas in the spring channel or pool could impact obligate aquatic plants and animals.

Alteration to discrete discharge springs can involve diversion from the preemergence area (upgradient) or postemergence (downgradient). Preemergence diversion involves excavating the spring's groundwater source, installing a slotted pipe catchment system, back filling the excavation, and piping the water. Remember that constructing spring boxes directly into a spring emergence typically obliterates the source area—the most biologically important habitat of a springs ecosystem. Postemergence diversion may preserve some ecological function at the spring's source but can affect downstream springbrook and wetland functions.

For discrete discharge springs, a good design splits the spring box's inflow pipe to direct water both to the spring ecosystem and to the trough (figs. 7, 8). Shortly after the split, adjustable valves on each pipe allow a user to control flow to spring and trough—cattle can have more water when they need it or the trough pipe can be completely shut off so all water goes to the spring ecosystem when no cattle are present. The adjustable valve on the spring box-to-trough pipe also acts as a seasonal shut-off valve. An overflow pipe returns excess water straight to the spring channel so that it is never dry.

Another, less intrusive water collection system for discrete discharge springs is a simple pipeline collection tray (fig. 9). It can be placed in a spring channel with minimal disturbance and little time and effort. Plugging by debris and algae growth can be a problem, aggravated by warm temperatures and sunlight. So, a tray design works best in shaded, cold-water spring channels.

Figure 7. Valves control the flow of water at this spring box. There is always some water routed to the spring to keep the ecosystem functioning. The trough is fitted with a float valve so water is diverted from the spring only when a demand is present. (Photo courtesy of The Nature Conservancy.)

Figure 8. Gravity flow spring box design that incorporates features for regulating the amount of water extracted from a discrete discharge (flowing) spring with valves for regulating the amount of water apportioned between the trough and the ecosystem.

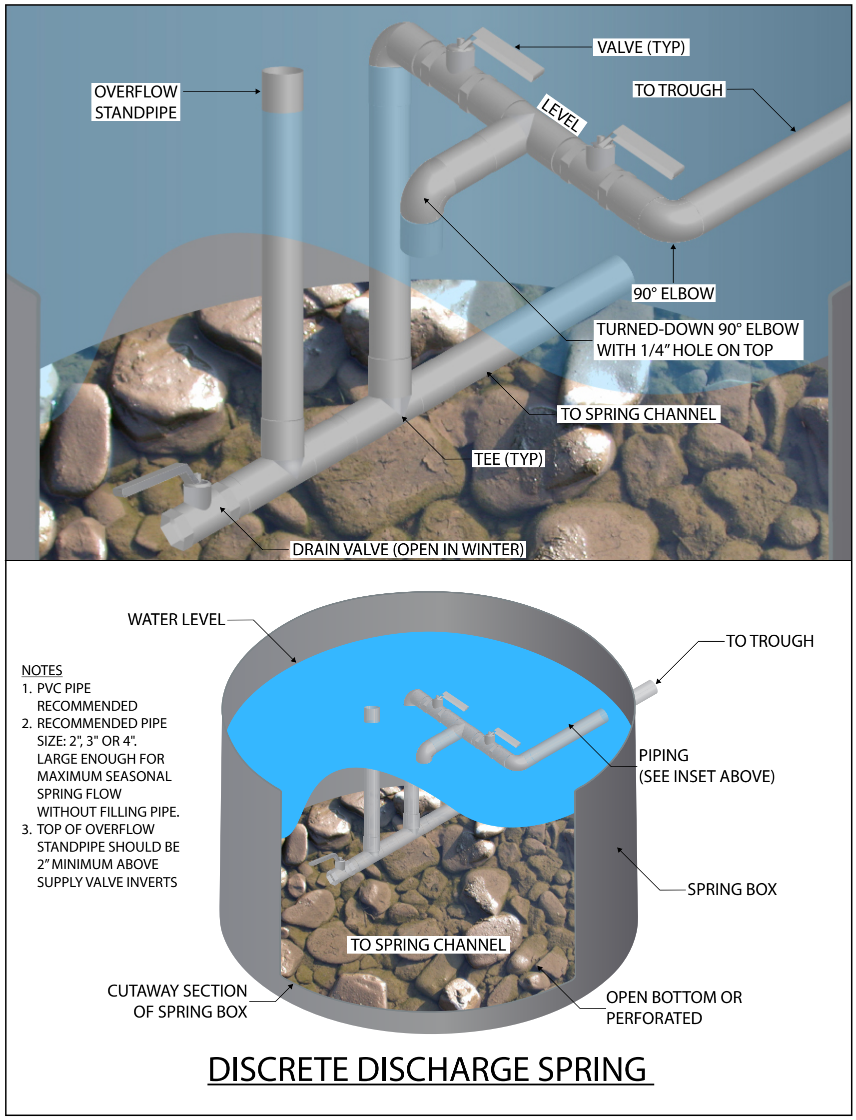

Figure 9. Pipeline collection tray in a spring channel. (Photo by USDA Forest Service.)

7.3. Trough Design

Water flows from the spring box to the trough in designs for both diffuse and discrete spring developments. Troughs should be equipped with float valves that shut off inflow to the trough when it is full. This prevents overflow and wasted water (fig. 10). A “weep hole” drilled upstream of the float valve ensures that the trough has a small amount of water circulating through it to improve water quality. If a float valve is not feasible, excess flow should be piped from the trough outflow back into the spring habitat as close to the source as possible, and pipes should be buried to keep the water cool. Float valves require protection from damage by livestock or wildlife. They can be protected with fencing, expanded metal covers, or homemade log or plank shields (fig. 10).

Figure 10a. Tractor tire trough at a spring. A large float valve like this resists damage from cattle. (Photo courtesy of The Nature Conservancy.)

Figure 10b. Cheap and easy float valve protection using logs. (Photo by USDA Forest Service.)

Figure 10c. Trough with a float valve protected by an internal fence (effective, but not a bat friendly design). (Photo courtesy of the Bureau of Land Management.)

A variety of wildlife use water troughs installed for livestock, but troughs can be deadly for animals that get in but cannot get out. Obstructions such as bracing, fencing, posts or vegetation over or adjacent to the trough can drastically reduce access for bats and birds that drink in flight. Many wildlife species, including sage grouse, accidentally drown in stock tanks that do not have adequate escape ramps. All troughs must have ramps. Wildlife escape structures are easy to build, are inexpensive, and can virtually eliminate wildlife mortality in water troughs. Properly designed and installed, these structures also improve livestock health by maintaining clean water that is uncontaminated by drowned animals. See Taylor and Tuttle (2012) and USDA NRCS (2012) for wildlife mitigation strategies at water developments.

8. Rehabilitation/Restoration of Spring Developments

Many water developments on rangelands are poorly designed or have fallen into disrepair through lack of maintenance or nonuse (fig. 11). Lack of ongoing maintenance can threaten springs and surface water quality and may pose a safety risk to the public, domestic animals, and wildlife. Appropriate design elements are relatively easy to incorporate into spring developments. Obsolete spring developments can be rehabilitated or decommissioned when opportunities arise (such as allotment management plan revision, NEPA sufficiency review, BMP review, or by encouraging a willing permittee).

Figure 11. A development needing rehabilitation. Overflow from the trough does not return to the spring ecosystem, wasting a valuable resource in a dry landscape and depriving aquatic fauna (spring snails) of habitat. (Photo courtesy of The Nature Conservancy.)

To restore flow at the source and functionality of downstream springbrooks or wetlands, it may be necessary to modify flow regulation structures. Most spring developments can be improved by simple fixes such as installing a float valve on the trough, installing a flow splitter, moving the trough to a less damaging location farther from the source, shifting the point of diversion downstream from the source, removing a dam, modifying a spring box and pipes, piping excess water back to the spring where soils support wetland vegetation, or reerecting/expanding an exclosure or riparian pasture fence (fig. 12).

Figure 12. A well designed but poorly maintained spring development. A gravel-hardened surface next to the trough prevents erosion and sediment and the low elevation trough allows access for wildlife. Note: Enclosure fence around important wetland area is in disrepair. (Photo by USDA Forest Service.)

Restoration of springs ecosystems is easily accomplished if the source aquifer is relatively intact. Restoration efforts are often successful (Stacey et al. 2011), with benefits such as conservation of important water sources, enhanced availability and integrity of spring habitats, and the preservation of sensitive species (Stevens et al. 2016). Water developments can be decommissioned or reclaimed when the need for them ceases or when recurrent impacts indicate they cannot be properly managed with available resources.

Coles-Ritchie et al. (2014) and Stevens et al. (2016) provide useful guidance for spring restoration including background information on the nature of springs ecosystems, inventory and assessment protocols, and tools necessary for effective restoration and monitoring.

9. Things to Consider Before Implementing a Spring Development Project

There are many concepts that practitioners, representing different disciplines and perspectives, have integrated into livestock water developments to make them more sustainable. Here are some concepts to consider when planning or designing a spring development.

9.1. Planning Spring Developments

- Should the intrinsic ecological values of the spring have priority over market-based grazing values? To decide, consider the spring's accessibility, suitability as a backcountry water source, suitability as habitat for special status species, aesthetics, and significance to Tribal Nations (Mueller et al. 2017).
- What types of springs are present, and are some types more valuable than others? Springs may be more significant to the landscape if they have the following characteristics:
  - Large flow rate (biodiversity tends to increase with flow rate)
  - Large areal extent
  - No invasive species
  - An undisturbed condition (undisturbed springs are rare)
  - Presence of sensitive, unique, or obligate species
  - Rare spring type, such as mound-forming or fens
  - Cultural importance
- What is the existing condition of the spring versus the desired condition?
- Are native and/or sensitive species present? Sites with sensitive species (threatened, endangered, species of interest, species of concern) will require more specialized and thorough assessment of site conditions, and impact prevention, management, or mitigation measures.
- What threats does the development pose for the spring habitat and how can we address them?
- Are alternative methods and solutions available (e.g., changes in the grazing system) that will (1) eliminate the need to modify the spring and associated habitat, or (2) allow development of the spring while protecting native species and habitat?
- Is there a need to limit trampling of important springs habitat? If so, periodic recovery periods, riparian pasture fencing, or exclosure fencing might be an option, but resources and capacity for management and fence maintenance should be in place for the long term.
- At desert springs, well-intended practices like fencing to exclude livestock may backfire as vigorous wetland vegetation growth can consume surface water habitat needed by aquatic biota (Kodrick-Brown and Brown 2007). In these situations, consider protective riparian pasture fencing that allows controlled grazing to provide optimal levels of disturbance and open water for fish and bats.

9.2. Designing Spring Developments

- Formulate design objectives: ecological sustainability, delivery of water to livestock, and cost of construction and maintenance.
- Inventory and assess spring ecosystem functions and values before starting a new spring development.
- Implement a grazing system with livestock numbers, timing, duration and frequency that mitigates livestock impacts to springs (Swanson et al. 2015; U.S. Department of the Interior 2006).
- Conduct a hydrologic analysis to determine the flow rate of the spring and the amount of water needed by livestock.
- Use a flow-splitting device to leave as much flow in the spring ecosystem as possible, diverting the calculated livestock need into the trough. In many cases, a small flow rate to the trough will meet livestock needs. Discrete discharge spring ecosystems may be impacted if greater than 10 percent to 20 percent of flow is diverted.
- Use float valves and shut-off valves to stop outflow when there is no use.
- Constructing spring boxes directly into a spring emergence zone typically obliterates the source area, which is the most biologically important habitat of a springs ecosystem.
- Avoid destructive trenching, excavation, or installation of grout walls or perforated pipe systems into spring sources. When needed, place them in a downstream location or a less unique habitat.
- If spring discharge is small, provide storage for flow collection during low-use periods so that water is available during high-use periods.
- Place the water trough, tank, or pond well outside spring habitat to avoid or minimize impacts to spring and wetland vegetation from livestock trampling or vehicle access.
- Route trough overflow back to the spring ecosystem, as close to the spring source as possible. Bury pipelines to and from troughs to limit temperature increases of water returning to spring habitat.
- Install wildlife escape ramps in all tanks and troughs.
- Harden the ground next to the trough or tank to avoid soil erosion and compaction.
- Plan and budget for regular and ongoing maintenance. If maintenance is in doubt, design the system so it will need less maintenance.
- Perform implementation and effectiveness monitoring to evaluate success in meeting design objectives and minimizing undesirable impacts to the spring ecology. (See USDA Forest Service, in press).

References

Aldous, A.R.; Bach, L.B. 2014. Hydro-ecology of groundwater-dependent ecosystems: applying basic science to groundwater management. Hydrological Sciences Journal. 59(3–4): 1–15.

Aldous, A.R.; Gurrieri, J.T.; Bach, L.B.; [et al.]. 2014. A groundwater balancing act: environmental flows and levels for groundwater-dependent fens of the antelope grazing allotment, Fremont-Winema National Forest, Oregon. Unpublished report on file with: U.S Department of Agriculture, Forest Service, National Groundwater Program Lakewood, CO, and The Nature Conservancy, Portland, OR. 34 p.

Coles-Ritchie, M.; Solem, S.J.; Springer, A.E.; [et al.]. 2014. Framework for Springs Stewardship Program and proposed action development: Spring Mountains National Recreation Area, Humboldt-Toiyabe National Forest. Gen. Tech. Rep. RMRS-GTR-330. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 63 p.

Cooper, D.J.; Merritt, D.M. 2012. Assessing the water needs of riparian and wetland vegetation in the Western United States. Gen. Tech. Rep. RMRS-GTR-282. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 125 p.

Dwire, K.; Mellmann-Brown, S.; Gurrieri, J. 2018. Potential effects of climate change on riparian areas, wetlands, and groundwater-dependent ecosystems in the Blue Mountains, Oregon, USA. Climate Services. 10:44–52.

Kodric-Brown, A.; Brown, J.H. 2007. Native fishes, exotic mammals, and the conservation of desert springs. Frontiers in Ecology and the Environment. 5: 549–553.

Lardy, G.; Stoltenow, C.; Johnson, R. 2008. Livestock water. AS-954, NRCS. Fargo, ND: North Dakota State University. 8 p.

Morrison, R.R.; Stone, M.C.; Sada, D.W. 2013. Environmental response of a desert springbrook to incremental discharge reductions: Death Valley National Park, California, USA. Journal of Arid Environments. 99: 5–13.

Mueller, J. M.; Lima, R.E.; Springer, A. E. 2017. Can environmental attributes influence protected area designation? A case study valuing preferences for springs in Grand Canyon National Park. Land Use Policy. 63: 196–205.

Nevada Springs Restoration Workshop Committee. 2012. Nevada Springs restoration workbook: A restoration guide for Nevada, Great Basin and Mojave/Sonoran desert springs: executive summary. Unpublished report on file with: U.S Department of Agriculture, Forest Service, National Groundwater Program, Lakewood, CO. 11 p.

Paffett, K.; Stevens, L.E.; Springer, A.E. 2018. Ecological assessment and rehabilitation prioritization for improving springs ecosystem stewardship. In: Dorney, J.; [et al.], eds. Wetland and stream rapid assessments: development, validation, and application. Amsterdam: Elsevier: Chapter 4.5.3: 475–487.

Perla B.S.; Stevens, L.E. 2008. Biodiversity and productivity at an undisturbed spring in comparison with adjacent grazed riparian and upland habitats. In: Stevens, L.E., Meretsky, V.J., eds. Aridland springs in North America: Ecology and conservation. Tucson, AZ: University of Arizona Press: 230-243.

Sada, D. 2008. Synecology of a springsnail (Caenogastropoda: Hydrobiidae) assemblage in a Western U.S. thermal spring province. The Veliger. 50(2): 59–71.

Sanderson, H.R.; Quigley, T.M.; Swan, E.E.; [et al.]. 1990. Specifications for structural range improvements. Gen. Tech. Rep. PNW-GTR-250. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 120 p.

Springer, A. E.; Stevens, L. E. 2009. Spheres of discharge of springs. Hydrogeology Journal. 17(1): 83-93.

Stacey, C.J.; Springer, A.E.; Stevens, L.E. 2011. Have arid land springs restoration projects been effective in restoring hydrology, geomorphology, and invertebrate and plant species composition comparable to natural springs with minimal anthropogenic disturbance? CEE review 10-002 (SR87). Collaboration for Environmental Evidence:

Stevens, L.E.; Ledbetter, J.D.; Springer, A.E.; [et al.]. 2016. Arizona springs restoration handbook. Spring Stewardship Institute, Museum of Northern Arizona, Flagstaff, AZ; and Sky Island Alliance, Tucson, AZ. 126 p.

Swanson, S. 2016. Integrated lentic riparian grazing management. In: Iwaasa, A.; Lardner, H.A.; Schellenberg, M.; [et al.], eds. Proceedings 10th International Rangelands Congress; 2016 July 18–22; Saskatoon, SK, Canada. 10(2.3-5): 454–456.

Swanson, S.; Wyman, S.; Evans, C. 2015. Practical grazing management to maintain or restore riparian functions and values. Journal of Rangeland Applications. 2: 1–28. ISSN: 2331-5512.

Taylor, D.A.R.; Tuttle, M.D. 2012. Water for wildlife—A handbook for ranchers and range managers. Austin, TX: Bat Conservation International. 20 p.

USDA Forest Service. 1989. Facilities for watering livestock and wildlife, 89-1. Missoula, MT: Missoula Technology & Development Center. 71 p.

USDA Forest Service. 2012a. Groundwater-dependent ecosystems: Level I inventory field guide: Inventory methods for assessment and planning. Gen. Tech. Rep. WO-86a. Washington, DC: U.S. Department of Agriculture, Forest Service. 201 p. https://www.fs.fed.us/science-technology/geology/groundwater/publications.

USDA Forest Service. 2012b. Groundwater-dependent ecosystems: Level II inventory field guide: Inventory methods for project design and analysis. Gen. Tech. Rep. WO-86b. Washington, DC: U.S. Department of Agriculture, Forest Service. 131 p. https://www.fs.fed.us/science-technology/geology/groundwater/publications.

USDA Forest Service. 2012c. National best management practices for water quality management on National Forest System lands, volume 1: National core BMP technical guide. FS-990a. Washington, DC: U.S. Department of Agriculture, Forest Service. 165 p.

USDA Forest Service. [In press]. National best management practices for water quality management on National Forest System lands, volume 2: National core BMP monitoring technical guide. FS-990b. Washington, DC: U.S. Department of Agriculture, Forest Service.

USDA Forest Service. 2017a. Determining environmental flows and levels for groundwater dependent ecosystems. Unpublished report on file with: U.S Department of Agriculture, Forest Service, National Groundwater Program, Lakewood, CO. 7 p.

USDA Forest Service. 2017b. Manti-La Sal National Forest plan revision assessment report. On file with: Manti-La Sal National Forest, Price, Utah. 280 p.

USDA Natural Resources Conservation Service [USDA NRCS]. 2006. Conservation practice standard: Spring development code 574. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service. 4 p.

USDA Natural Resources Conservation Service [USDA NRCS]. 2010. Chapter 32: Well design and spring development. In: Engineering Field Handbook, Part 631. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service. 63 p.

USDA Natural Resources Conservation Service [USDA NRCS]. 2011. Chapter 12: Springs and wells. In: Engineering Field Handbook, Part 650. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service. 51 p.

USDA Natural Resources Conservation Service [USDA NRCS]. 2012. Wildlife escape ramps for livestock watering troughs. Portland, Oregon. 2 p.

USDA Natural Resources Conservation Service [USDA NRCS]. 2016. Ecological considerations in spring development. Technical Note No. WNTSC TN 190-EQ-1. Portland, Oregon, West National Technology Support Center, Environmental Quality. 14 p.

USDA Natural Resources Conservation Service [USDA NRCS]. 2017. Letter providing guidance on planning, designing, and installing spring developments in accordance with Virginia Conservation Practice Standard, Spring Development (code 574). Richmond, Virginia, January 10, 2017.

U.S. Department of the Interior. 2006. Riparian area management: grazing management processes and strategies for riparian-wetland areas. Technical Reference 1737-20. BLM/ST/ST-06/002+1737. Denver, CO: Bureau of Land Management, National Science and Technology Center. 105 p.

U.S. Department of Interior. 2020. Riparian area management: Proper functioning condition assessment for lentic areas. Technical Reference 1737-16. U.S. Department of Interior, Bureau of Land Management, National Operations Center, Denver, Colorado.

To learn more about RMRS publications or search our online titles:
RMRS web site at: https://www.fs.fed.us/rmrs/rmrs-publishing-services