



Seeps and Springs

OVERVIEW

Seeps and springs have a significant ecological impact and provide the majority of surface water to Bighorn Canyon National Recreation Area, though they account for less than 1% of the land. Human use has impacted seep and spring water sources for thousands of years through the introduction of livestock and non-native species. Aridland seeps and springs in Bighorn Canyon National Recreation Area (Bighorn Canyon) were identified as a vital sign for the Greater Yellowstone Inventory and Monitoring Network (GRYN). Protecting seep and spring resources requires in-depth understanding of their ecological character, controlling factors, and natural variability over space and time.

What is a Spring?

A spring is the flow of water from underground to the ground surface. Bighorn Canyon springs flow from an aquifer (underground reservoir) and the temperature as it leaves the ground is usually between 35 and 50°F. Usually, there is an aquifer whose water flows from a geologic contact or rock fracture. Water from springs may flow across the land surface for some distance. Seeps are areas of saturated soil or seasonal standing water whose flow is generally imperceptible to the casual observer. Springs generally have longer and greater presence of surface water than seeps. Using these as working definitions, Bighorn Canyon springs outnumber seeps. For this reason, the term springs will be used from this point forward.

A typical spring has four parts: orifice, runout, width, and recharge area. The orifice is the point where groundwater becomes surface water. In some springs the orifice is distinct, such as water flowing from a rock fracture. In others, the orifice may be diffusely spread over an area or along the face of a rock wall. In yet other cases, there may be several distinct orifices in close proximity. The runout is

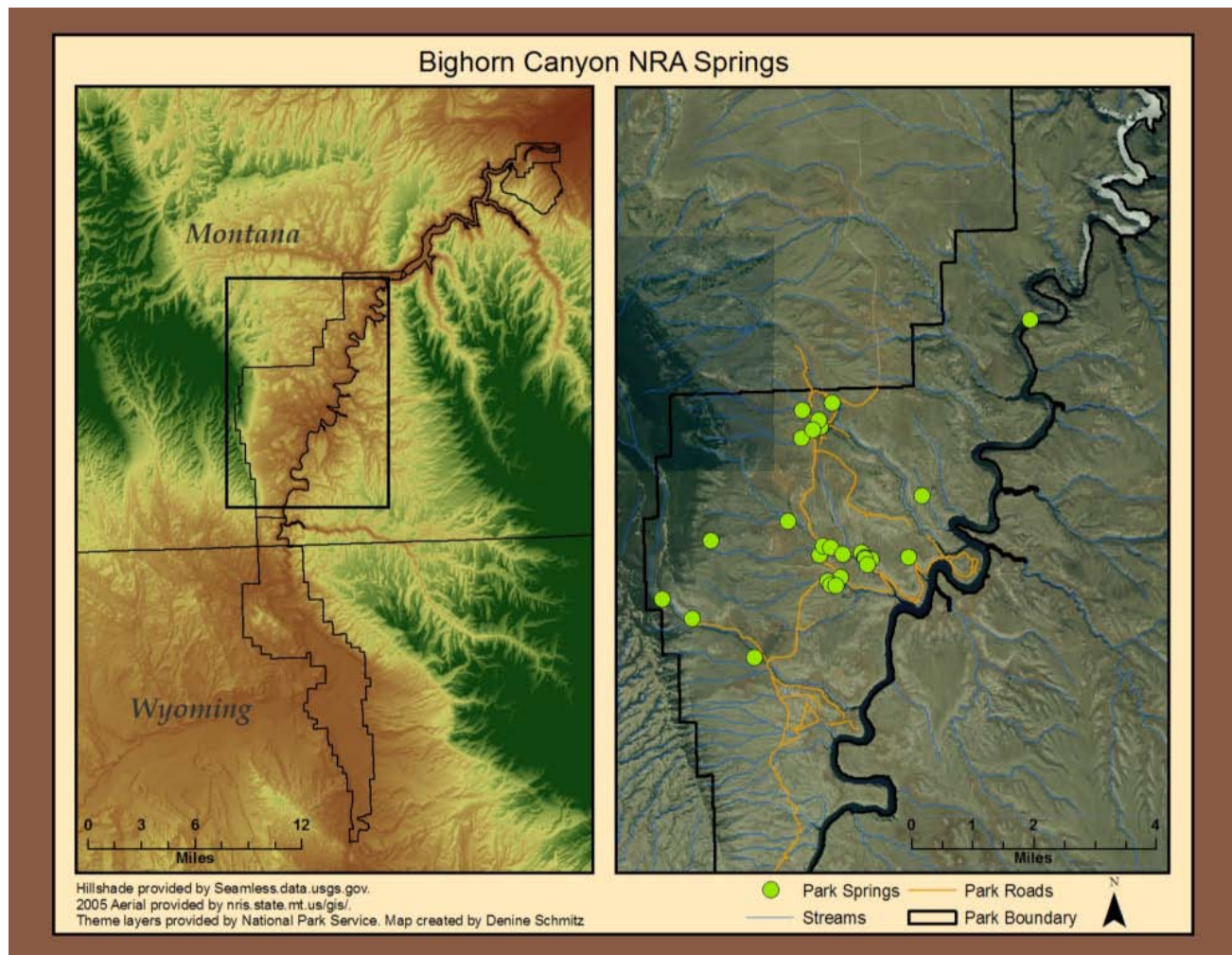
the distance spring water flows over the surface. This is a dynamic boundary that can change with season, depending on how tightly coupled a spring is to local climate. The width of a spring is the lateral distance across the runout at its widest point. A spring runout is most influenced by geomorphology, spring discharge, and, to a lesser extent, spring vegetation. The recharge area is the ground surface over which surface water penetrates soil and recharges the groundwater. Spring recharge areas vary greatly in size, from less than one square kilometer to greater than 100 square kilometers. Most springs collect water from a combination of small and large recharge areas. These four aspects of springs provide a framework for understanding the biology of springs and devising strategies for their preservation.

The boundary between a spring and the surrounding environment is not always distinct, but it is important to define an area of interest for management and research purposes. The spring “ecosystem” is considered to be the area that is most influenced by underground water, and it usually extends into the adjacent terrestrial community. The point at which the surface environment has a greater influence on water characteristics is considered the outer spring boundary.



Hillsboro Beaver Pond.

Figure 1. LEFT: The study area of the Bighorn Canyon Springs project centers on the middle section of the park accessed from the Lovell, WY entrance (indicate by the rectangle). RIGHT: A closeup map showing springs in the middle part of Bighorn Canyon National Recreation Area.



Where Are Bighorn Canyon Springs?

For a spring to occur, an aquifer must discharge water onto the ground surface. The most common setting for Bighorn Canyon springs is an area where geologic folding and faulting have exposed water-bearing rock layers. While springs are found throughout the park, the area of highest spring density is found in the middle section (Fig. 1) accessed from the Lovell, WY entrance, where there is a reverse fault that uplifts the Pryor Mountains. In addition, there are springs on the east side of the Pryor Mountains including Layout Spring, which feeds Layout Creek, and other springs such as Sorenson, Hillsboro, and Headgate.

Spring Ecology

The ecology of springs is controlled by five major environmental factors including climate, geology, groundwater dynamics, geomorphology, and biogeography. These five

factors combine to form linkages between underground water flow and the ecological processes in springs. Each of these factors is described in more detail below.

Climate

The areas of Bighorn Canyon where most springs are found receive less than 10 inches of precipitation per year. Yet, Bighorn Canyon springs maintain year-round water supply and support riparian and wetland ecosystems. This suggests that water from the springs actually recharges in a different environment from where it discharges. Isotope studies have determined that water from Bighorn Canyon springs actually arises from snowfall on the Pryor Mountains. The snow melts and recharges into the groundwater and emerges from springs in the region. The arid environment allows only those plants and animals with water conserving adaptations to survive. Yet, the water

provided by springs supports wetland and riparian flora and fauna.

Since springs in Bighorn Canyon are supplied by water from the surrounding area, regional climate is an important influence on spring flow parameters. Temperature and precipitation control spring size and seasonal longevity as well as which plants can grow nearby. At regional scales, climatic cycles that produce long cool-wet or warm-dry periods influence groundwater recharge and soil development. At the local scale, microclimate affects the potential evaporation rates of aquatic and riparian ecosystems.

Geology

While climate has the greatest impact on spring flow, geology is the main driver of water chemistry in springs. The chemical make up of spring water is the product of everything that comes in contact with it – geology, atmosphere, biota, upland inputs, and soil. In general, those parts of the environment that contact spring water for the longest periods will have the greatest influence. Thus, the longer water is underground within an aquifer, the more the water chemistry will have a “signature” from the surrounding rocks. Bighorn Canyon has a substantial amount of limestone, dolomite, and gypsum-rich bedrock, all of which are high in calcium and magnesium. Springs discharging from calcium/magnesium-rich aquifers usually have higher buffering capacities than those from sandstone or shale layers. Gypsum layers impart high levels of sulfate in spring waters.

Groundwater Dynamics

Aquifers that are surrounded by different types of rocks may be connected by faults and fissures and their waters may mix to varying degrees. This means that the chemical composition of spring water may be influenced by the rocks surrounding more than one aquifer. Similarly, the flow rate and other characteristics of a spring may be influenced by water that recharges from several different areas.

Geomorphology

The landforms associated with springs are highly variable, and this variation can produce springs of different types. For example, hanging gardens drip water down rock faces and have little ability to form water-holding soil (Fig. 2). In contrast, rheocrenes, which are springs that discharge their waters into confined channels on the ground’s surface, have the ability to support riparian ecosystems (Fig. 3). Finally, helocrenes are springs that emerge from low gradient wetlands with multiple sources (Fig. 4). Sometimes springs may have characteristics of more than



Figure 2. Pickett’s Wall Seep is an example of a hanging garden with little soil development and plant species adapted for life on rocky surfaces.

one type, and as a result the flora and fauna associated with each spring can be very different. Therefore, the geomorphology of springs greatly contributes to spring biodiversity and productivity. The suite of geomorphic surfaces associated with each of these spring types affects aquatic and riparian community composition through their varying abilities to retain water and influence flow velocity, water chemistry, and temperature (Stevens and Springer 2004).

Biogeography

Biogeography, or the degrees to which springs are isolated from each other, influences the dispersal and colonization of aquatic and riparian species found in springs. Also, springs tend to express a narrow range of environmental conditions (eg. stable flow and water chemistry), and this can lead to a high degree of endemism. Some Bighorn Canyon springs, for example, provide habitat for Hapeman’s Coolwort (*Sullivantia hapemanii* var. *hapemanii*), which is a rare species known only to rocky, calcareous wetlands in north-central Wyoming, south-central Montana, and central Idaho (Heidel 2004). Further, narrow, stable environments such as those found in springs tend to favor specialist species over generalist species (Sada et al. 2005).



Figure 3. Hillsboro Spring is an example of a rheocrene where a spring emerges and forms a stream channel.

Biological Characteristics

The mosaic of microhabitats supported at a spring produces a great deal of biodiversity and endemism. Plant community assemblages within each microhabitat are a product of geology, geomorphic surface type, and hydrology. Likewise, macroinvertebrate assemblages organize based on geomorphic surface type and changing conditions with distance from the spring orifice (Erman 1998; Sada and Vinyard 2002).

Microhabitats found in Bighorn Canyon springs are various. For example, Headgate Seep supports a cienega, or low slope wet meadow (Fig. 4). Pickett's Wall Seep supports a wet wall of clinging mosses and cliff-dwelling plants such as Hapeman's coolwort. The spray zone of Layout Spring supports a host of macroinvertebrate species indicative of pristine waters (Fig. 5).



Figure 4. Headgate Seep is an example of a helocrene where a spring emerges in several places and forms a wetland.

Efforts to characterize spring biota are underway in Bighorn Canyon. Macroinvertebrates were assessed at 20 springs in May 2007. The findings will be summarized in a report and made available in 2008. Spring flora will be characterized at a later date.

Species in adjacent habitats depend on springs for food, water, and shelter. During a bat survey in the Pryor Mountains, captures of Pallid, Spotted, and Townsend's Big-eared bats occurred at sites within 5 miles of Bighorn Canyon (Hendricks and Currier 2004). Most captures occurred in association with ponds and springs. Springs provide habitat for many amphibian species in the Great Basin (Bradford 2002). Nesting, foraging, breeding, and migratory habitat for birds is commonly found in aridland springs (Williams et al. 1984). Sada and Vinyard (2002) documented four endemic vole subspecies in Great Basin springs. Most land animals in aridland environments are dependent on surface water, and the springs in Bighorn Canyon provide most of the perennial surface water on the plateaus above the Bighorn Lake.

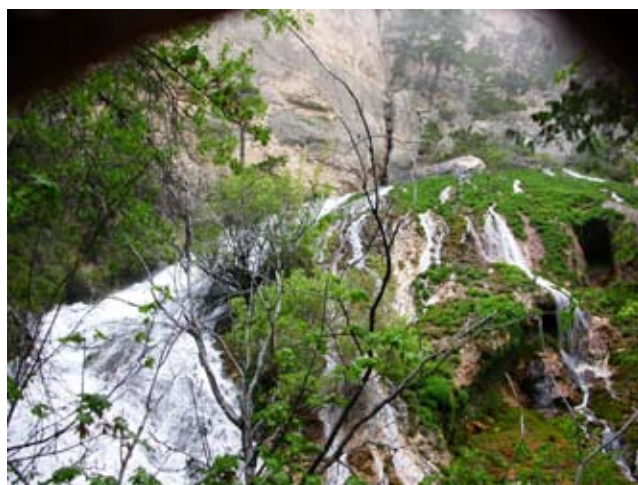


Figure 5. Layout Spring has a host of microhabitats that include spray zones, hanging gardens, riparian zones, and streams.

Threats and Concerns

Aridland seeps and springs (hereafter termed springs) have three unique features – water, biologically diverse biota (some endemic), and their stability over time. For these reasons they are often historic and prehistoric culturally significant sites, as well as ecological hotspots. It is the combination of these features that synergistically creates aridland spring ecosystems to which surrounding life is drawn. Threats to the water quantity and quality and biodiversity arise from natural and anthropogenic sources. This section describes potential threats to Bighorn Canyon seeps and springs based on environmental impact assessments, research, inventories, and monitoring programs related to desert springs of the Great Basin area of the United States.

Water Quantity

Changes in distributions of spring wetlands and riparian areas within spring areas are caused by changes to water flow, whether natural or anthropogenic. Lowered water tables, decreased flows, and shorter flow duration result in smaller spring areas. Changes in groundwater levels also may produce shifts in plant community composition. Numerous studies in arid regions have documented wetland and spring ecosystem shrinkage and losses due to groundwater pumping from shallow aquifers across the West. For example, in Colorado's San Luis Valley, a long-term average water table drop of 0.66 m resulted in a shift in wetland species composition (Cooper 1994).

Because climate is a primary driver of spring flow, and therefore of spring ecosystems, it is also a potential vector of change in spring ecosystem quality and extent. The last 10,000 years has seen variation in climate. An investigation

in the northern Bighorn Basin indicated the early Holocene (10,000 yr B.P.) was cooler and wetter than the present climate and during the middle Holocene a warming trend occurred (Lyford et al. 2002). Further, Lyford and others (2002) described wetter conditions between 4400 and 2700 yr B.P., and the last 2700 yr has been increasingly arid. It is likely that spring discharge has varied with the climatic shifts.

Use of spring sites by humans for water use continues to be common practice. In Bighorn Canyon, every large spring site (e.g. Hillsboro, Sorenson, Lockhart) has been altered for household or agricultural uses, many at spring sources. According to archeologists, historic and prehistoric communities used Bighorn Canyon spring sites for water, food, and shelter material sources.

Alterations occur in many forms and include:

1. Capping the orifice and piping water to target areas (Fig. 6)
2. Eliminating spring vegetation around the orifice and building spring houses (Fig. 7)
3. Damming surface flow at the orifice (Fig. 8)
4. Diverting surface flow downstream of the orifice (Fig. 9)
5. Diverting surface flow upstream of the orifice (Fig. 10)
6. Groundwater pumping
7. Water rights policies and disputes.



Figure 6. Sorenson spring was capped in the early 1900s and the water piped for agricultural and household use.



Figure 7. Lockhart ranch features a springhouse used to keep food cold.



Figure 8. Stockponds were a common development at spring sites.

Water Quality

Impacts to water quality may occur through groundwater pollution (e.g. sewage, fertilizers, or toxic chemicals), surface runoff from contaminated uplands into spring sites, or decreases in discharge. Bighorn Canyon springs are fairly resilient to changes in acidity due to the high buffering capacity of calcium and magnesium ions. However, spring biota may be dependent on a narrow range of conditions and might decline or be lost altogether should water chemistry change.

Pollution in groundwater and surface runoff may affect Bighorn Canyon springs. Run-off may transport herbicide



Figure 9. A diversion downstream of Tyler's Torrent is used to irrigate a restored historic orchard at the Hillsboro Ranch site.

residues from weed control operations and petrochemicals from road maintenance to near by springs. Large storm events may move large amounts of sediment into spring sites, burying plant and macroinvertebrate species as well as habitat.

Changes in spring flow may result in altered water quality. During high flow, for example, the surface environment exerts its influence at a greater distance than at a low flow site. Before surfacing, spring water chemistry is indicative of the aquifer through which it flows, but



Figure 10. Due to diversion upstream of the Mason-Lovell spring, discharge has decreased and contributed to the loss of riparian vegetation.

processes such as evaporation, atmospheric deposition of chemicals, and biological activities can alter water chemistry once it reaches the surface. Thus, changes in flow rate that result in expansion or constriction of the wetted area can alter salt concentrations, temperature, and pH of water on the surface.

Threats to Diverse Spring Biota

Habitat and species losses, particularly the loss of endemic species, are major concerns. While the status of Bighorn Canyon spring vegetation and macroinvertebrate ecology have yet to be determined, lessons learned in Great Basin springs have served as a guide. Sada and Vinyard (2002) identified human water use, physical changes to the springs, and biological invasions as the major threats to aquatic and invertebrate species in Great Basin springs. In Bighorn Canyon, trampling (humans, cattle, and wild horses), road improvements, and natural disturbances are also potential threats.

Human trampling has the highest potential to impact spring wetlands because development tends to occur around springs. Virtually all cultural sites (Lockhart, Hillsboro, Ewing-Snell, and Mason-Lovell) occur near springs. These historic sites also are sites of prehistoric human activities (Finley, personal communication). People may damage sensitive vegetation, disturb substrate surfaces vital for invertebrates, and introduce sediment, non-native species, and contaminants to spring areas. Further impacts due to increases in water developments and introduced species are mounting. Their cumulative impact may cause a permanent loss of species and ecosystem processes.

Cattle and wild horses can damage spring areas. Cattle-trailing is a long-standing operation in Bighorn Canyon with potential to impact springs along the park road. Damage to vegetation, breakdown of banks, introduction of pollutants and non-native seed through fecal deposition are common impacts by cattle.

As park staff improve cultural and environmental resources, increases in infrastructure are inevitable. Road improvements, additional buildings, restrooms, restoration of historical sites, range and wildlife habitat restoration, and weed management are examples. Because many of the developed resources (and potential future developments) are near spring sites or include use of springs as water sources, springs continue to be endangered by human activity.

Natural disturbance can remove plants, animals, and microbes from spring ecosystems and facilitate the colonization of others. Upland disturbances such as fire, rockfall, and overland erosion may impact spring productivity, geomorphology, soil development, and microhabitat composition. The direct effects of wildfire on ecosystems surrounding spring orifices are relatively unexplored. Rockfall produced from freeze-thaw actions

may alter spring orifice geomorphology, soil development, microhabitat distribution, and can re-route surface and subsurface flow. Upland erosion into spring areas may be increased due to upland fire, ungulate grazing, or insect-induced land cover changes. Surface runoff due to upland disturbance, if routed through spring areas, may wash away plant communities rooted on rocks and thin soils as well as aquatic and terrestrial invertebrate communities. The frequency, severity, and timing of such disturbances potentially influence spring ecosystems, which can be highly evolved to a specific set of environmental conditions.

Non-native Species

Non-native species can decrease or eliminate native spring plant and animal populations through predation, competition, and hybridization. Non-native introductions could have occurred early in Bighorn Canyon's human history from hunter-gatherer populations inadvertently or intentionally transferring individuals between sites. Human activities have accelerated the rate of non-native species expansion in aridland springs of the Great Basin during the last 200 years (Hershler and Sada 2002). In Bighorn Canyon, *Rorippa nasturtium* var. *curvipes* (watercress) is an obvious example. Other non-native species potentially impacting Bighorn Canyon springs include *Euphorbia esula* var. *uralensis* (leafy spurge), *Tamarix chinensis* (salt cedar), *Eleagnus angustifolia* (Russian olive), *Agrostis stolonifera* (creeping bentgrass), *Poa pratensis* (Kentucky bluegrass), *Bromus tectorum* (cheat grass), *Bromus inermis* (smooth brome grass), and *Potamopyrgus antipodarum* (New Zealand mudsnails).

The magnitude of anthropogenic threats to spring biota will become clearer as park staff acquire more information on Bighorn Canyon springs. Great Basin springs have high levels of endemism. Springs in this region have

lost substantial biotic resources due to anthropogenic disturbance, development, and increased human population. Bighorn Canyon springs may suffer a similar fate. However, the population pressure in Bighorn Canyon and surrounding areas is low. Thus, the greatest pressure originates from NPS management of Bighorn Canyon (particularly future developments around spring areas) and land use within private in-holdings. These impacts threaten springs near the park road and developed areas the most.

Management

Natural and anthropogenic impacts to springs have occurred historically and will likely continue to occur in the future. Bighorn Canyon is managed as a multi-use natural resource. Water developments associated with interpretive sites and resource improvements (e.g. cultural site restoration, cattle trailing operations, wild horse range expansion) are ongoing. Impacts to spring ecosystems can be minimized by withdrawing water (surface or groundwater) from locations more than 100 meters downstream from spring sources and fencing out cattle. Outside of spring areas, water diversions or developments will have little effect on spring ecosystems, although they will heavily impact downstream riparian and wetland habitat.

Park staff are monitoring spring water quality and discharge to identify responses to the impacts discussed above. Macroinvertebrate surveys were performed in May 2007. The results of those surveys will provide insight into the status of spring biota, expand the list species known to the park, and potentially identify indicators of specific impacts. While spring vegetation has yet to be characterized, park staff are in the early stages of developing a monitoring plan.



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