University of Nevada, Reno

Impact of Large Herbivore Use in Meadows on Lentic Function, Wetland Extent and Vegetation Hydric Status

A thesis submitted in partial fulfillment of the requirements of the degree of Master of Science in Natural Resources and Environmental Science

by

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Abstract

Livestock and wild horses disproportionately favor riparian areas over uplands when seasonal temperatures are high or upland vegetation becomes dry, especially in flatter, more accessible terrain. Long-term trampling by excess or prolonged stocking can cause damage to riparian roots, reducing the riparian extent. This study sought to assess how large herbivore use in meadows may impact riparian plants needed for or leading to lentic functions and related wetland extent (in relation to potential meadow size) and vegetation hydric status (wetness). We examined wild horse and livestock grazing variables of timing, duration, and intensity of livestock grazing, based on the focus provided by the Grazing Response Index (GRI) to consider opportunities for plant growth. Trail cameras were used to determine the relative amount of livestock and wild horse use at randomly chosen meadows likely to be high quality sage-grouse late-brood rearing habitat in each of nine allotments. Data collected using a modified draft lentic assessment, inventory, and monitoring protocol informed the interpretation of riparian proper functioning condition (PFC) assessments about management for PFC. Lentic PFC assessments indicate that none of the study lentic areas have maintained their size, now less than 60% of potential (PFC Item 3), all have altered flow patterns (Item 6), and all were functional at risk. Six of nine meadows were grazed by horses over periods long enough for individual preferred plants to be grazed by horses at least three times. At locations grazed by horses and cattle, the duration over which horse grazing occurred was always longer and the number of days grazed and animal minutes of grazing were greater for horses than cattle at all but one location. While many grazing management tools and strategies apply to livestock. Few are used for wild horses. There appears to be a need to expand tools and strategies for wild horse management for riparian areas, their functions, and values.

Keywords: Management tools, proper functioning condition, lentic methods, Grazing Response Index, trail cameras.

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Introduction

Management of livestock and wild horses in riparian areas is a perennial issue in the American West. Both disproportionately favor riparian areas over uplands when seasonal temperatures are high (Clary & Webster, 1989) or upland vegetation become dry in comparison to green riparian forage (Swanson, Wyman, & Evans, 2015). An increase in climate temperatures (NASA, 2013) underscores concern for conserving riparian resources.

Cattle and wild horses are sympatric grazers, favoring graminoids over other forage by 66 to 84% (Hansen & Clark, 1977; Hanley & Hanley, 1982; Krysl et al, 1984). Use overlap creates an opportunity for resource competition and increased stress in common areas. Sheep prefer grazing on upland sites, avoiding wet or marshy areas (Glimp & Swanson, 1994). Sheep are required to be managed under herded supervision on western public rangelands. There is a potential for sheep to damage meadows if undermanaged. Meadows are a reliable forage source through summer and offer a place to cool body temperatures for grazing animals in the arid West.

Grazing management in the recent past has emphasized management of livestock and wild horse stocking rates. Livestock managers during early western settlement in the 1900s recognized stocking reductions were needed. The Taylor Grazing Act of 1934 introduced livestock grazing management with locally adjusted stocking rates. For wild horses, it has been challenging to maintain stocking levels on the range through removal of excess animals, those "which must be removed from an area to preserve and maintain a thriving natural ecological balance and multiple-use relationship in that area" (Wild Free Roaming Horses and Burros Act of 1971 as modified by the Public Rangelands

Improvement Act of 1978). However, stocking may not be the only solution to management for healthy rangelands or riparian areas (Swanson et al., 2015; Nevada Sagebrush Ecosystem Program, 2014).

Few options are available for wild horse management. With no effective natural predators, herd gathers being discouraged by stakeholders, limited lifetime holding facilities and funds, populations remain largely unmanaged and excessive at this time.

Challenges of riparian management have been recognized in recent decades. Lotic systems were prioritized. Lentic systems, especially small-scattered ones, were often neglected in assessment, monitoring, and management strategies. Some lentic systems are quite large and became private ranches or have been managed by agencies as a priority because of their size (Swanson, Kozlowski, Hall, Heggem, & Lin, 2017). Where a spring or seep provides steady water year-round, lentic systems are desirable to livestock and wild horses especially in flatter and more accessible terrain. Lentic systems are less resilient than lotic systems (Prichard et al., 2003), as they are composed of finer soil fractions than lotic systems. Lentic systems require many years to develop a partially decomposed organic layer that works like a sponge to hold water (Mitsch & Gosselink, 2015) and many do not benefit from sediment accumulation as lotic systems do. Areas with groundwater discharge are susceptible to water flow path development, alteration, and functional degradation through erosion and organic matter oxidation. Trampling by excess or prolonged stocking causes damage to riparian roots by shearing and dehydration after incision (Prichard et al., 2003; Wyman, et al., 2006; Swanson, 2016). Lentic systems require time to develop or recover a partially decomposed organic layer and retain or accumulate fine soil fractions. Those with a gentle slope offer easy access for large ungulates, which can cause excess stress over time.

Jeffress and Roush (2010), and Beever and Brussard (2000) explain that horse damage is most pronounced around perennial riparian systems and is particularly harmful to sage grouse. Cole et al. (2004) linked packhorse utilization of mountain meadows to decreased productivity and vegetation cover. Olson-Rutz, Marlow, Hansen, Gagnon, and Rossi (1996) found a preference for grasses and an increase in the use of forbs as horses' time on meadows increased. Crane, Smith, and Reynolds (1997) found in Wyoming that bog/meadow habitats accounted for 1% of the study area, but 21% of the use by feral horses. Berger (1986) found 27 times more horse use per unit area in riparian areas than uplands in Nevada. Horse numbers in some areas are worrisome because wildlife has been observed to avoid watering sites when horses are present or are chased away by wild horses (Ostermann-Kelm, Atwill, Rubin, Jorgensen, & Boyce, 2008). In a five-year study, Boyd, Davies, and Collins (2016) found a bare ground increase at wild horse grazed sites. Yet, wild horse use did not affect sedge density.

Booth, Cox, and Likins (2015) observed that hummocks incurred by domestic grazing originate from the soil surface downward as a result of trampling and trailing, causing inter-hummock channeling and the dewatering of grazed wetlands. In lentic systems, large animal footprints augmented by cryogenic hummock formation combined with walking trails and loafing areas contribute to preferential water flow paths (Figure 1, 2, & 3). This results in increasing nick points or zones leading to incision, a channel with altered flow paths (Prichard et al., 2003) or a distinct thalweg channel within the meadow (Figures 4 & 5), rather than a wide area of dispersed sheet flow (Weixelman et al., 2011). Water flow paths and inter-hummock channeling allow water to exit meadows faster. As the water flow paths widen, they become convenient walking paths for large ungulates. Hoof traffic adds to soil compaction and erosion in interspaces (Davies, Collins, & Boyd, 2014), increasing the elevation difference and depth to water between hummock tops and bottoms. Dehydrated hummock tops shift from obligate or facultative wetland species to facultative and obligate upland species as the soil matrix water level drops in response to the difference in relative elevation between hummock top and interspace bottom (Prichard et al., 2003). The plant community shift also changes the vegetation stability rating as stabilizing wetland species are replaced with facultative to upland species with fewer roots.

Rhizomatous roots allow resource connections throughout the metapopulation. Excess hoof action can break rhizomatous connections, causing fragmentation of stabilizing riparian-wetland plant communities and preventing importation of photoassimilate (Marshall and Sagar, 1965) from parent tillers after defoliation. A break in the anatomical network disrupts resource allocation among the metapopulation (Briske, 1986). The plant community can shrink, reducing the riparian extent until recovery can occur. Boyd et al. (2016) found hydrophytic species did not increase at riparian sites rested from wild horse use in a five-year study.

Graminoid plant forms are adapted to grazing pressure within a range of defoliation specific to species physiological characteristics dependent on the avoidance or tolerance mechanisms (Briske, 1986). Long-term grazing pressure can shift a plant community from one that is more vertical with long tillers, characterized as having a higher degree of tolerance, to a community with shorter tillers expressing avoidance mechanisms. Species with avoidance characteristics increase, becoming dominant in the community. Successful management can benefit wildlife habitat by influencing vegetation structure. Grazing reduces decadence, stimulates meristem growth, and creates variation in the grazing lawn topography (Hobbs, 1996). According to Hobbs (1996), "Grazing lawns are patches within the landscape that contain plants maintained in a juvenile, rapidly growing state as a result of the effects of feeding by herbivores" (p. 702).

One defining characteristic of lentic systems is the presence of vegetation species that can survive in varying degrees of anaerobic soil conditions. Species have been assigned a rating, wetland indicator status, based on the probability each is expected to be in a wetland versus a nonwetland location (USDI Fish and Wildlife Service, 1993). The wetland indicator status was translated to a rating by Coles-Ritchie (2005) and applied to riparian monitoring in Burton et al., (2011):

- Obligate wetland (OBL), >99% likely to be found in wetlands. Hydric value 92-100,
- Facultative wetland (FACW), 67%-99% likely to be found in wetlands. Hydric value 67-83.
- Facultative (FAC), 34%-66% equally likely to occur in wetland or nonwetlands. Hydric value 42-58.
- Facultative upland (FACU), occurs in nonwetlands 67%-99% of the time but can be found in wetlands 1%-33% of the time. Hydric value 17-33.
- Obligate upland (UPL), may occur in wetlands in other regions but occurs >99% of the time in nonwetlands in the region specified. Hydric value 0-8.

Soil texture including a silt component may increase the potential for cryogenic hummock formation (Larson, Kiemnec, & Johnson, 2019; Smith et al., 2012). In excess, the result is continued erosion and incision with a reduction of wetland vegetation amount and spatial extent causing decreased functioning condition (Prichard et al., 2003; Wyman et al., 2006). Abnormal hummocks could be expected to take roughly 20-40 years to recover with rest from grazing (Booth et al., 2015; Cox, Booth, & Likins, 2016).

Figure 1. Cattle stepping in hummock interspaces while walking around the meadow.

Figure 2. Horses stepping in hummock interspaces while walking around the meadow.

Figure 3. Hummocks at Treasure Hill. Hummocks are dominated by Sandberg bluegrass (*Poa secunda* J. Presl) and common yarrow (*Achillea* yarrow. *millefolium* L.).

Figure 4. Nick point in thalweg at Treasure Hill.

Figure 5. Hoof shearing makes an opportunity for water to flow across the new nick point and further lower the water level.

Lentic systems are generally defined by Prichard et al. (2003) as “wetlands that provide enough available water to the root zone to establish and maintain riparian-wetland vegetation” (p. 1). Weixelman et al. (2011) defines meadow characteristics as having a shallow water table in the summer, fine-textured surface soil, and being dominated by herbaceous vegetation. The variability of hydrology, vegetation, and soil characteristics further classify the type and function of a meadow (Weixelman et al., 2011). A classification system helps establish a site's potential for assessment of its riparian functions (Prichard et al., 2003) to understand priorities for ways to increase or retain functioning attributes (Swanson, 2016). Knowing the potential gives managers a common vocabulary and expectation to understand management impacts, physical functions, and resource values.

Proper functioning condition (PFC) assessment (Prichard et al., 2003; Dickard et al., 2015) is used by the Bureau of Land Management to evaluate compliance with standards and guidelines. The term “PFC” refers to both a condition of a riparian-wetland area and a qualitative method for assessing that condition. A system rated PFC can be expected to respond with resilience to disturbance, and provide values such as forage, water, and wildlife habitat. Lentic systems rated functioning at risk may further deteriorate due to loss of functions or it may recover functions and values depending on management and weather events. Non-functioning riparian areas are not expected to provide abundant or reliable desired values.

Thirty-three percent of Nevada's lotic and 48% of Nevada’s lentic areas administered by the Bureau of Land Management (BLM) were reported to be in proper functioning condition (BLM, 2016). Forty-nine percent of lotic and 18% of lentic areas were functioning at risk (BLM, 2016). Meadows that are declining in condition decrease their saturated organic sponge, retain less water, and decrease the area of moisture retention for continued forb growth. Functioning at-risk areas may soon fail to retain water in the root zone required by sage-grouse forbs (Atamian et al., 2010).

Vegetation is a leading indicator of riparian degradation or recovery (Wyman et al., 2006). Plant physiological functions advance during periods of rest. Leaf structure converts sunlight and oxygen to carbohydrates stored in the roots. The root structure serves the plant by storing carbohydrates, water intake, and expanding the community. The plant community, in turn, stabilizes soil against erosion, and roots add to soil organic matter. While soil moisture enables both root growth and organic matter decomposition, soil saturation and anaerobic conditions enable growth of only some species, obligate wetland species, and it retards decomposition. Draining meadow soils leads to off-gassing of soil carbon (Reed et al., submitted). The loss of soil organic matter often leads to lowered infiltration and water storage. It also changes meadow topography, increasing drainage in a downward spiral. Vegetation and organic matter work to retain water in the system, especially in those locations where plants have the most water available for growth. The water retention facilitated by plant structures providing roughness that decreases flow velocity, and retention and capture of sediment and organic matter can be seen along the thalweg, especially if no or limited alteration occurs in the flow path.

An interagency effort is underway to standardize lentic-monitoring methods. The Draft-Lentic Assessment, Inventory, and Monitoring (Draft-Lentic AIM) (Dickard et al., 2015), was based on other protocols developed for upland and aquatic studies; BLM Assessment, Inventory, and Monitoring (Toevs et al., 2011), Multiple Indicator Monitoring (Burton et al., 2011), Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems. 2nd ed. Vol. 1 Core Methods (Herrick et al., 2015), and Groundwater-Dependent Ecosystems: Level II Inventory Field Guide (USFS, 2012). Lentic AIM may become an accepted quantitative data collection method that will support the lentic PFC assessment and management, just as Multiple Indicator Monitoring (Burton et al., 2011) has become the quantitative counterpart for Lotic areas. LAIM and its terrestrial counterpart were designed for long-term repeated measurements at study sites as needed to capture condition trend. Methods in this study use or adapted those found in the Draft-Lentic AIM protocol.

This study seeks to assess how large herbivore use in meadows may impact riparian plants needed for or leading to lentic functioning or resistance to erosion, riparian hydrology or alteration of flow pathways impacting water retention and reflected by wetland extent (reduction from potential meadow size) and vegetation hydric status (wetness). We examined wild horse and livestock grazing variables of timing (related to opportunity to grow or regrow during the growing season), duration (related to repeated defoliations), and intensity of use (related to leaf area for photosynthesis), based on the focus provided by the Grazing Response Index (Reed et al., 1999) to consider to what degree plant physiological needs are being met to allow riparian stabilizers to regain or maintain abundance and provide functions needed for wetland extent and vegetation hydric status relative to their potential.

Methods

Site Selection

Study site selection targeted core (now priority) greater sage-grouse habitat within wild horse and burro herd management areas (BLM) or wild horse territories (Forest Service) and thirty random grazing allotments (Appendix A). Using ArcGIS 10.2, overlapping GIS layers were clipped and evaluated using August, 2013 USDA's Farm Services Agency's National Agricultural Imagery Program (NAIP) imagery, U.S. Fish and Wildlife Service's 2013 National Wetland Inventory (NWI) mapping program, and Unites States Geological Survey (USGS) GIS imagery to identify 363 lentic meadows with late brood rearing habitat characteristics. Meadows were identified as redder areas in color infrared imagery and then further evaluated for vegetation detail, surrounding fence lines, dams above a meadow of interest or interfering roads. If vegetation appearance or texture indicated shrub patches, tree stands, or barren, salty, or dry areas, sites were rejected (75 meadows). Candidate sites (288) were ranked from 1 (best) to 3 on the following criteria; herbaceous vegetation in the meadow with surrounding sagebrush and no other influences received a 1 rating. Variables that decreased the rating include; proximity of pinyon-juniper (PJ) or other tall trees likely to provide raptor perches (eg. Populus sp.) (Casazza et al., 2011; Atamian et al., 2010; Commons, Baydack, & Braun, 1999; Connelly et al., 2004); association with lotic stream system; and steep slopes that would be unsafe for crew or undesirable for broods (Atamian et al., 2010). Sites were rejected if the area had burned within three years (2011-2013), as livestock grazing is typically suspended for three years to allow for recovery. One site, Becky Springs, burned in 2012; however, this came to light after the site was approved. Thus, it remained in the study. Rated meadows were randomly chosen by rank (rank 1 first, etc.) within each allotment for site visits to check suitability (Appendix A). Some sites were rejected as unsuitable upon visitation because they lacked two of four wetland indicators (TR Y-

87-1, 1987); were beyond reasonable vehicle and foot access as a result of road washouts; or had no visual evidence of wild horse use. Table 1 and Figure 6 show the sites selected for this study. A moist spring preceded a dry summer in 2016, the year this study occurred (Figure 7).

Table 1. Geography, herd management area or territory, allotment, and stocking rate.

Site	Latitude & Longitude	Elevation (m)	Herd Management Area or Horse Territory	Recent population count	Date	Allowable management level	Livestock AUMs	
							Current	Historic
WCC	40.215111, -114.989032	1,943	Maverick-Medicine	1,135	2016	166-276	2,674	2,674
WJ	38.851367, -116.394198	2,039	Little Fish Creek	349	2017	132	1,219	1,219
BS[+]	40.063245, -114.586239	1,910	Antelope	1,272	2017	150-324	3,842	3,842
CC	39.986546, 114.434109	2,356	Antelope	1,272	2017	150-324	10,149	10,149
TH	39.283699, -115.474158	2,316	Monte Cristo	85	2016	72-96	2,198	Unavailable
NS[+]	39.866889, -114.659086	2,465	Antelope	1,272	2017	150-324	700	700
LP[+]	39.855837, -114.662104	2,542	Antelope	1,272	2017	150-324	105	105
SM	38.861002, -116.583517	2,589	Butler Basin Dobin Summit	191 0	2014 2008	60-100 3	879**	Unavailable
SS	38.93457, -117.367651	2,538	Tierney	0	2012	Inactive	2,377	Unavailable

WCC=West Cherry Creek, WJ=Wagon Johnnie, BS=Becky Springs, CC=Chin Creek, TH=Treasure Hill, NS=North Steptoe, LP=Lovell Peak, SM=South Monitor, SS=South Shoshone.

Site selection criteria was initially based on an overlap of Geographic Information System (GIS) data: Core* Greater sage-grouse habitat (Coates et al., 2014, revised in 2015), United States Forest Service (USFS) or BLM livestock grazing allotments, and USFS Horse Territories (HT) or BLM Horse Management Areas (HMA). *The core habitat was revised since this initial selection process occurred. 2 of 10 sites in this thesis became priority, 2 became general habitat. The study area also excludes major land resource area (MLRA) 28A due to monsoonal rain events more common in the region (USDA NRCS, 2006).

[+]Becky Springs, North Steptoe, and Lovell Peak have been in non-use since 2013 due to drought.

**South Monitor has been closed to livestock grazing since 2002, according to the USFS. Livestock grazing was allowed the year of this study as a result of wild horse overpopulation on the permittee's authorized allotment.

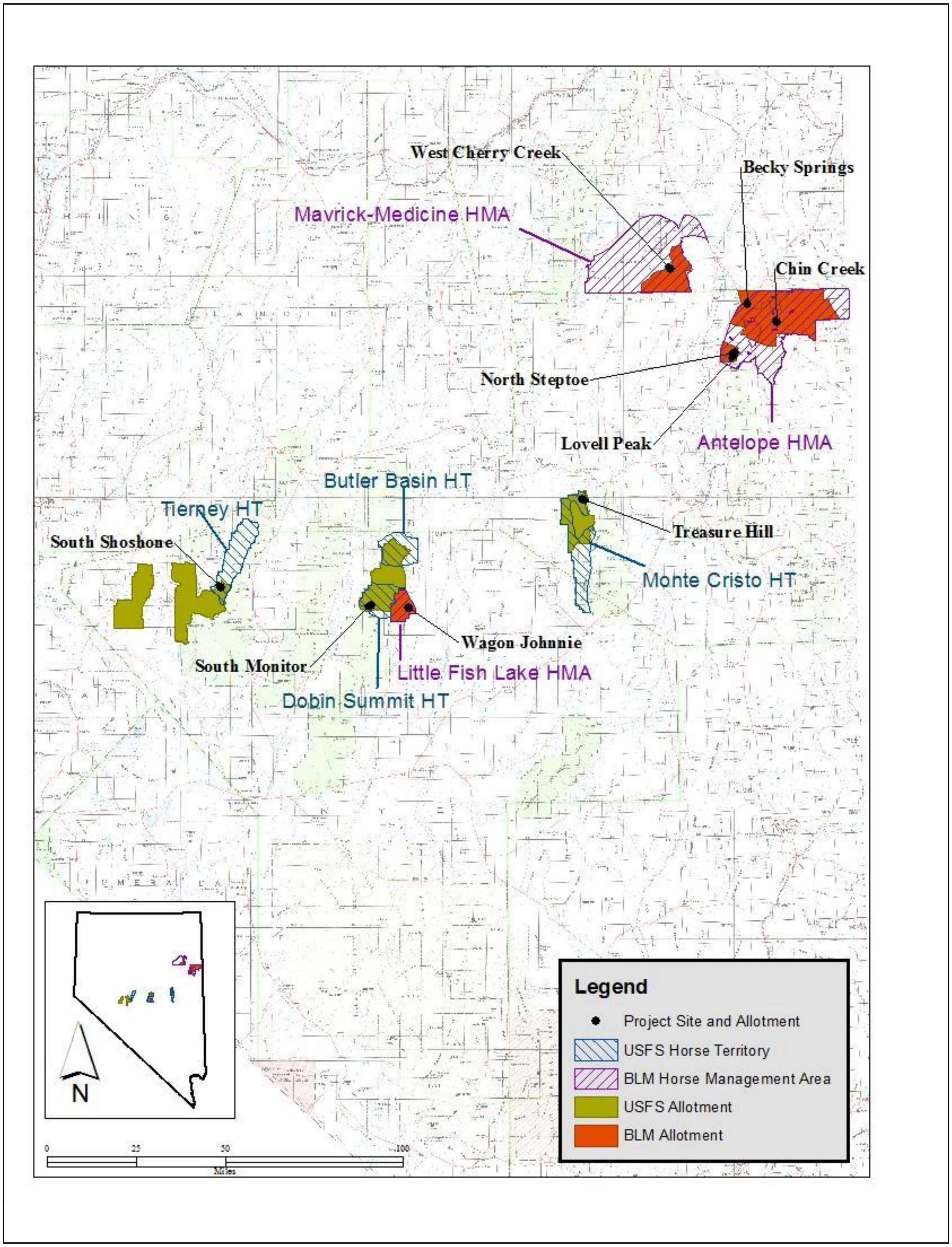


Figure 6. Map showing 9 sites located in Nevada. The sites are named after the allotment.

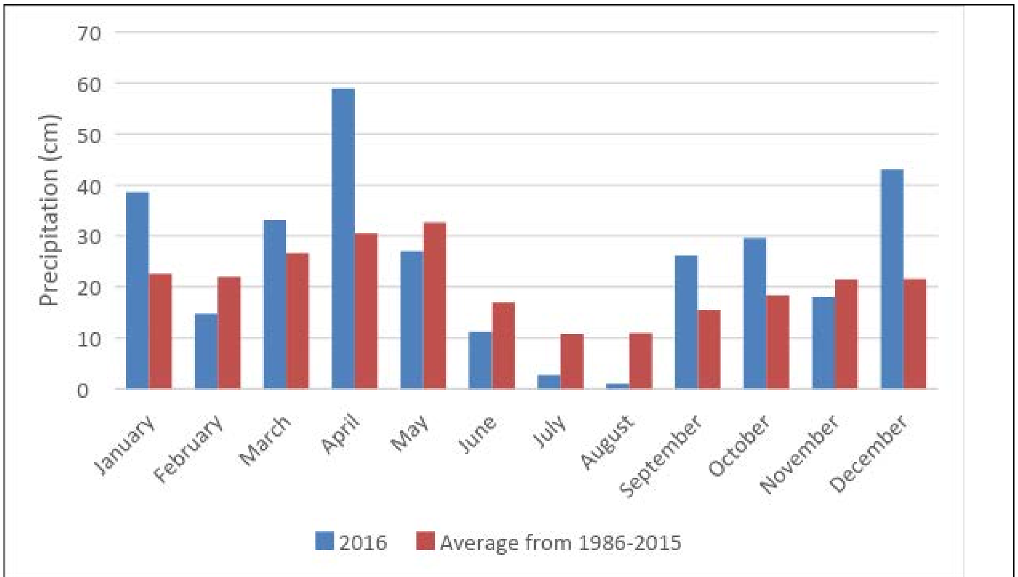


Figure 7. Average precipitation monthly from 1986-2015 and precipitation for 2016. Data for Eureka County, Nevada. PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 12 March 2019.

Proper Functioning Condition Assessment and meadow classification.

A lentic Proper Functioning Condition (PFC) assessment (Prichard et al., 2003) was performed in 2015. PFC hydrology, vegetation, and erosion/deposition (soil) attributes and processes (items) were assessed in relation to the system potential at each location. The research team (an interdisciplinary team) assigned a final categorical rating after considering the notes about the "yes's" and "no's" evaluating system attributes and conditions in the context of their functional roles and local potential.

Meadows were also classified according to the Hydro-Geomorphic Model (HGM) type using Weixelman et al. (2011) (Table 2).

Table 2. Meadow types with a brief description (Wiexelman et al., 2011).

Type	Meadows	Description
Depressional perennial	WCC, WJ	Depressional perennial meadows are characterized by the collection of runoff in a topographical depression, manmade or naturally occurring. Water flow is typically imperceptible. An example is a pond dug where the water table is high. The meadow center is often dominated by obligate to facultative wetland plant species, with strong vegetation zonation from the center outward as water or groundwater depth varies.
Discharge slope	BS, CC, TH, NS, LP, SM	Discharge slope meadows are characterized by groundwater discharge at the surface by way of springs or seeps in a gravity-driven sloping system with at least 20 cm of organic soil material in the top 40 cm of soil. Small areas of peat may be present. Obligate or facultative wetland species generally dominate the meadow where saturated soil conditions persist.
Dry meadow	SS	Dry meadows are characterized as runoff or precipitation being the main source of water. Groundwater was roughly deeper than 1 m for most or all of the growing season. They may resemble a depressional perennial system, without a depressional landform. Vegetation was typically dominated by grasses and dryland sedges or rushes.

WCC=West Cherry Creek, WJ=Wagon Johnnie, BS=Becky Springs, CC=Chin Creek, TH=Treasure Hill, NS=North Steptoe, LP=Lovell Peak, SM=South Monitor, SS=South Shoshone.

Field Measurements

The three components of lentic proper functioning condition assessment (Prichard et al., 2003), vegetation, hydrology, and geomorphology informed selection of quantitative methods. Methods in this study use or adapted those found in the Draft-Lentic AIM protocol (Dickard et al., 2015). A schedule of measurements included; (a) one time per field season - Proper Functioning Condition assessment (PFC), soil pit observations, meadow delineation, line point intercept on transects and thalweg; (b) two times per field season, July and August - percent cover of grasses, forbs, and bare ground; (c) three times per field season, roughly June, July, and August. - transect oblique photos and stubble height.

Meadow delineation. Wetland boundaries were delineated using the Army Corps of Engineers wetland delineation method (TR Y-87-1, 1987) considering hydrology, vegetation, and soil/landform.

Transect design. A long-axis traverses the greatest length of the wetland; on slopes, it occurred from the most upslope to the most downslope extent. The long-axis separated the wetland into two "halves," and in most cases, it was a single straight line. Where the site has a distinct bend, the long-axis did too.

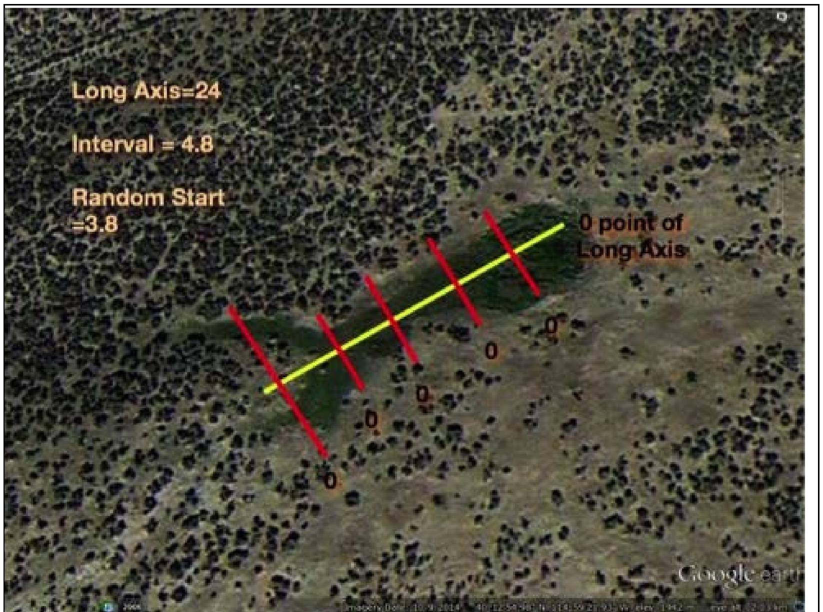


Figure 8. Standard layout of lateral transects in meadow region.

Thalweg designated monitoring area (DMA). A thalweg transect was the line that best represented the lowest, and wettest part of the meadow where water flow was observed or would concentrate during runoff. It is the line most likely to experience erosion or channel incision. The thalweg transect overlaps any area of erosional concern. The thalweg transect tape threads through shrubs and around obstacles to waer flow like hummocks. Chain pins were often used to define the pathway, as the thalweg line was not straight.

Sampling.

Transect interval and rules. At wetlands on a slope, the 0-point of the long-axis was at the upslope end. The first perpendicular transect (transect # 1) was randomly placed relative to that point. Five perpendicular transects lie along the long axis. Transect to transect spacing was determined by dividing the length of the long-axis transect by 5. The location of the first transect intersection along the long-axis was randomized by picking a non-zero random number between 1 and the interval distance among transects. Transects perpendicular to the long-axis, extended across the wetland from one side to the other and were not allowed to cross or overlap.

Upland region determination. To ensure transects fully encompassed the wetland area and captured the zone of transition to uplands, transects were extended into adjacent uplands beyond the wetland boundary marked during site delineation by 10% of the wetland width (5% at each end). This total transect-spanned area, the delineated meadow, plus the 5% extension at each end, was referred to as the meadow region (Figure 8). Adjacent upland indicators that surround the meadow were captured by extending transects an additional 5 m on each side of the meadow region. This extension was referred to as the upland region.

Line-point intercept (LPI). LPI methods were applied to the perpendicular transects and the thalweg DMA transect. An extensive, detailed rule set for LPI with diagrams is available in Herrick (2015). Line point sample interval was determined by summing the length of all perpendicular transects in the meadow region and dividing by 200. To make sampling easier, the sample interval was sometimes shortened to a round number, making a minimum of 200 sample locations across the meadow region.

Residual vegetation (stubble height). At every tenth LPI interval, the stubble height of graminoid key species was measured to the nearest centimeter on each perpendicular and thalweg transect (Coulloudon et al., 1999). Meadow stubble height for visits one, two, and three is reported as an average.

Soil characteristics and determining wetland extent. A soil pit was dug (offset 1 meter from a perpendicular transect to avoid interference with vegetative sampling) at three zones: (1) adjacent to the thalweg to confirm site as a wetland; (2) at the mesic margin, in the middle of the extended 5m segment, to determine meadow expansion or contraction; (3) and in the upland region, at the outmost end of the 5 m upland segment. Soil characteristics were measured or observed to verify presence of wetland or upland soils, and to observe evidence of previous meadow contraction. B horizon characteristics included color of the organic and mineral layers using the Munsell color system chart (Munsell Color, 2009), texture of the mineral layer using a hand texture method (Schoeneberger, P. J. 2002), presence or absence of redoximorphic features (ie. mottles, redox depletions, ie., gleying or low chroma and high value) and the depth measurement of such features.

The soil characteristics, vegetation, and topography helped determine the potential (historic) wetland extent and the current wetland extent. The percent remaining was compared to the potential extent to determine the percent loss of lentic area.

Trail cameras.

This study used trail cameras to determine the relative amount of livestock and wild horse use, season of use, and time spent in the meadow. Auto-triggered/time-lapse field cameras were installed at a discrete location on the periphery of the meadow, no more than 30 meters away from areas of active use. Each camera was attached to a metal T-post in a protective box, secured with a padlock. Camera enclosures were fitted with anti-perching wires to prevent raptors from perching (Figure 9). Most cameras were mounted to face north to avoid morning and evening sun glare. Cameras were set to take one picture every 5 minutes and checked at each site visit to collect photos and change batteries. An Excel spreadsheet is used to enter the camera data.

Figure 9. Photo of trail camera at Treasure Hill. A security enclosure, pad lock and anti-perching wire are used to protect hardware and prevent predator birds from taking advantage of the perching opportunity.

Animal Use Minutes and Days.

Animal use derived from camera data recorded animal minutes of use by animal species and site during natural daylight. Images excluded lacked enough daylight to view the entire study area. The defined study area is the combination of the upland and meadow regions. The number of animals in each image was multiplied by 5 to determine the number of animal minutes for each 5-minute timeframe, and summed to tally animal minutes each day.

Grazing Response Index (GRI)

Animal use and stubble height data were used to estimate the grazing response index (GRI) (Reed et al., 1999). The GRI intensity score used stubble height (Hayder, 1972) to estimate intensity roughly measured as >7cm = +1, 7-1.8 cm = 0, and <1.8cm = -1. Opportunity refers or the amount of time in the riparian growing season when vegetation was not being grazed and was allowed to regrow or regrow ranged from +2 to -2, based on a scale ranging from full season of rest to no chance for recovery. Frequency was based on the duration of grazing periods with up to 12 days (one bite) as +1, duration of 13-25 days (time for one more bites after regrowth) = 0 and time for three bites >25 days as -1. The frequency, intensity, and opportunity scores were summed to determine the overall GRI score.

Field camera data were also used to establish the frequency. When livestock or wild horses were present for >7 days during the vigorous or active growing season (May-June) and >10 days in the slower growing season (July-August), that number of days was divided by 7 or 10 respectively to determine the appropriate frequency of grazing events on preferred plants (Reed et al., 1999). If the frequency was 1, the score was +1. If the frequency was 2, the score was 0. If the frequency was 3or more, the score was -1.

Results

The data collected in this study reflected wide variation among the nine sites. This variation kept simple regressions from revealing simple correlations. Lentic PFC assessments chosen to present variable conditions in relation to local site potential (Table

3) indicate that none of the study lentic areas have maintained their size (Item 3) and that all of them have had their flow patterns altered (Item 6). All were functional at risk. The percent of potential size among riparian areas was always less than 60% (Table 4).

The PFC assessment shows all nine sites have a diverse wetland and stabilizing vegetation community present (Items 9 & 11). Stabilizing riparian species [Nebraska sedge (Carex nebrascensis Dewey) and artic rush (Juncus articus Willd),], (Item 9) were present at all sites in varying combinations with other stabilizers, but most commonly near the wettest locations. The appropriate stabilizing community (Item 11) was also present at all sites. Items 9, and 11 as indicators suggest vegetation cover (Item 13) has the potential to increase if adequate opportunity for growth and regrowth is allowed. Most common "no" items causing at-risk conditions were in the vegetation categories; low age-class diversity (Item 8), low vigor (Item 12), low vegetative cover (Item 13), and abnormal hydrologic heaving (Item 14). Altered flow patterns on some sites were directly related to hummocks (Item 14). Low vegetation vigor (Item 12) at some sites seemed linked to low riparian vegetation cover, inadequate to dissipate energy and protect from overland flows (Item 13). Cover is adequate at five of nine sites (Table 3). Vegetation zonation from obligate wetland species in the meadow center to obligate upland species at or near the meadow margin reflects water depth and water retention as dehydration occurs from the outer zone inward as each hot season progresses. The category with next most common no’s was hydrology; shrinking riparian extent, altered water flow paths, and head cut development in a dam or stream channel. Often the failure of vegetation led to hydrologic issues. Other assessment items indicate additional individual variation.

Table 3. PFC Checklist summary including the items most commonly related to this study.

	WCC	WJ	BS	CC	TH	NS	LP	SM	SS
PFC Rating	FAR-D	FAR-D	FAR-D	FAR-D	FAR-D	FAR	FAR	FAR-U	FAR-D
Hydrology									
Item 1. Riparian-wetland area is saturated at or near the surface or inundated in “relatively frequent” events.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Item 3. Riparian-wetland area is enlarging or has achieved potential extent.	No	No	No	No	No	No	No	No	No
Item 6. Natural surface or subsurface flow patterns are not altered by disturbance.	No	No	No	No	No	No	No	No	No
Item 7. Structure promotes unsafe passage of water.	N/A	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vegetation	WCC	WJ	BS	CC	TH	NS	LP	SM	SS
Item 8. Diverse age-class distribution.	No	Yes	Yes	No	No	Yes	Yes	Yes	No
Item 9. There is diverse composition of riparian-wetland vegetation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Item 10. Species present indicate maintenance of riparian-wetland soil moisture characteristics.	No	No	No	No	No	No	No	No	No
Item 11. Vegetation is comprised of those plants or plant communities that have root masses capable of withstanding wind events, wave flow events, or overland flows.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 3. (Continued)									
Vegetation	WCC	WJ	BS	CC	TH	NS	LP	SM	SS
Item 12. Riparian-wetland species express high vigor	No	No	Yes	No	No	Yes	Yes	Yes	No
Item 13. Riparian-wetland vegetation cover is adequate to protect from high energy.	No	No	No	Yes	No	Yes	Yes	No	Yes
Item 14. Abnormal hydrologic upheaving is not present.	No	No	Yes	No	No	Yes	Yes	No	Yes
Soil	WCC	WJ	BS	CC	TH	NS	LP	SM	SS
Item 17. Saturation of soils is sufficient to compose and maintain hydric soils.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Item 19. Riparian-wetland is in balance with the water and sediment being supplied by the watershed.	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 4. Wetland size (m^2); potential, current and % reduction, and total hummocks observed on transects for each site.									
	WCC	WJ	BS	CC	TH	NS	LP	SM	SS
Potential	2,916	2,000	3,000	3,300	6,160	5,000	1,000	4,800	1,200
Current	781	744	860	1,800	1,868	1,800	500	1,653	480
% of potential	27%	37%	29%	55%	30%	36%	50%	34%	40%
Total hummocks on transects	6	27	0	5	57	0	0	24	0
WCC=West Cherry Creek, WJ=Wagon Johnnie, BS=Becky Springs, CC=Chin Creek, TH=Treasure Hill, NS=North Steptoe, LP=Lovell Peak, SM=South Monitor, SS=South Shoshone.									

Altered flow paths that led to drainage and dehydration (Item 10) of these lentic areas can be observed in the pattern of hydric species across the meadow areas on line point intercept transects of varying length (Table 5), by the average meadow hydric values, and by the difference between the thalweg hydric values and the rest of the meadow areas hydric values (Table 6). At eight sites, the average wetland indicator values (Table 6) showed the thalweg supported more hydric status species. If there had been no thalweg channel, water would have been retained in the soil matrix at an elevation above the water in the observed thalwegs providing hydric conditions for higher wetland status species (OBLW and FACW) away from the thalweg or across a broader low elevation surface of the meadow.

Table 5. Average hydric value of species on line point intercept transects, at the first, last and every 10^{th} hit. S=site, T=transect, LS=left side, RS=right side, W=water, X=No vegetation. 0=upland, 25=Facultative upland, 50=Facultative, 75=Facultative wet, 100=Wetland obligate (after Coles-Ritchie 2012).

S	T	LS	Every 10^{th} line point intercept hit on transect												RS
W	1	38	25	25	100										75
C	2	100	88	100	100	88	75	83	100	63					42
C	3	50	100	100	W	100									38
	4	W	17	50											50
	5	50	50												50
WJ	1	X	25	100	25										50
	2	50	S	64	S	25									X
	3	50	50	S	75	X	X	X	W	W	X	X	X	50	50
	4	X	X	X	X	X									X
	5	0	X	25	25										X
BS	1	25	38	88	100										100
	2	0	W	W	W										X
	3	X	50	100											50
	4	X	W	63											X
	5	X	100	100	75										25
CC	1	19	25	100	33										33
	2	25	17	X	67	67	63	100	75	100	75	33			33
	3	31	25	75	67	63									25
	4	38	67	25	75	50									33
	5	25	50	42	42										50
TH	1	38	42	38	33										25
	2	25	25	38	13	0									0
	3	38	50	44	38	33	63	100	25	75	75				19
	4	38	25	100	W										13
	5	25	63	W	25										X

Table 5. (Continued)															
NS	1	42	75	50											38
	2	33	58	58	75										50
	3	25	50	W	75	67	58								42
	4	33	75	75	75	W	50	58	58	38	50	38	38		50
	5	50	50	42	50	38									38
LP	1	38	50	58	33										25
	2	50	38	W	58										38
	3	25	75	W	88	67									38
	4	38	38	100	100	92	50	75	38	38	63	58	50		50
	5	38	69	50	38	100									42
	1	42	38	75											56
SM	2	0	50	75											83
	3	50	56	63	88	58	63	75	75	88	100	88			38
	4	50	75	88	88	88	75								67
	5	75	88	100	100	88	88								38
SS	1	42	0	0	X										X
	2	25	42	25	50										50
	3	25	25	13	X	X									0
	4	25	50	50	50	25									13
	5	0	38	50	38										25
WCC=West Cherry Creek, WJ=Wagon Johnnie, BS=Becky Springs, CC=Chin Creek, TH=Treasure Hill, NS=North Steptoe, LP=Lovell Peak, SM=South Monitor, SS=South Shoshone.															
The resulting value shows that meadows have upland leaning values throughout the meadow, and especially on the fringes.															

Table 6. Wetland indicator status and hydric value of each site by meadow region and thalweg.

	Meadow		Thalweg	
Site	Hydric value	Wetland indicator status	Hydric value	Wetland indicator status
WCC	33	FACU	65	FACW
WJ	34	FACU	88	OBL
BS	37	FACU	83	FACW
CC	40	FAC	64	FACW
TH	33	FACU	41	FAC
NS	39	FAC	82	FACW
LP	39	FACU	100	OBL
SM	62	FAC	53	FAC
SS	15	FACU	38	FAC

WCC=West Cherry Creek, WJ=Wagon Johnnie, BS=Becky Springs, CC=Chin Creek, TH=Treasure Hill, NS=North Steptoe, LP=Lovell Peak, SM=South Monitor, SS=South Shoshone.

Vegetation conditions indicated by the amount of bare ground (Tables 3 and 7) were probably related to intensity of utilization or stubble height (Table 7) and other grazing management factors in the grazing response index (Table 9). Sites with a neutral or positive GRI score were not grazed by horses, South Monitor, or grazed only briefly, South Shoshone; or in a rested from cattle burned area, Becky Springs, or an area not visited by cattle, South Shoshone. Vegetation condition would also be related to cumulative effects on meadow hydrology (Tables 3, 4, 5, and 6).

May and June are identified as the most vigorous growing season months. Plant growth slows during July and August. Figure 10 shows the days and months ungulates are captured on camera. West Cherry Creek, Wagon Johnnie, Becky Springs, Chin Creek, Treasure Hill, North Steptoe, and Lovell Peak are used by wild horses consistently from the beginning of camera data in the spring until the end of camera data, usually in September. The GRI score for horse frequency is a -1 at West Cherry Creek, Wagon Johnnie, Becky Springs, Chin Creek, Treasure Hill, and Lovell Peak; frequency at North Steptoe is a zero (Table 9), as the plants do not have more than 7-10 days to recover after grazing. Where cattle are present, Wagon Johnnie, Chin Creek, Treasure Hill, and Lovell Peak, cattle grazing activity occurs over a shorter part of the growing season. Sheep grazing periods at Chin creek were even shorter, short enough for +1 frequency and opportunity scores.

Table 7. Meadow region bare ground (% BG M) at the last site visit, average meadow stubble height (MSH)(cm) at visits 1, 2 and 3, and average thalweg stubble height (TSH)(cm).

	WCC	WJ	BS	CC	TH	NS	LP	SM	SS
% BG M	65%	88%	40%	35%	65%	29%	62%	58%	57%
MSH 1	9	7	14	14	12	21	8	25	29
MSH 2	13	4	22	12	7	16	5	7	35
MSH 3	9	4	17	7	4	16	7	6	31
TSH	10	10	14	23	13	16	6	9	23

Table 8. Soil texture and color in the top 40 cm at each site. The color hue was 10YR, value, and chroma are written as “value/chroma”.

Site	Wet		Margin		Upland	
	Texture	Color	Texture	Color	Texture	Color
WCC	Silt/clay	13/2	Clay/loam	5/2	Clay/loam	6/2
WJ	Clay	3/1	Silt/clay	4/2	Silt/clay/loam	5/2
BS	Silt/loam	3/2	Sandy/clay	5/2	Sand	6/2
CC	Silty/sand/loam	2/1	Sandy/clay/loam	2/1	Sandy/loam	3/2
TH	Silty/clay	3/1	Silty/sand	2/1	Clay/loam	5/2
NS	Sandy/clay	4/2	Sandy/clay	3/1	Sandy/loam	3/2
LP	Sandy/clay	2/1	Sandy/clay	2/1	Sandy/clay/loam	5/2
SM	Peat	2/1	Sandy/silt	2/1	Sandy clay	4/2
SS	Sandy loam	4/1	Fine silt	2/1	Sandy/loam	3/2

Bare ground percentages (Table 7) were higher than expected for systems expected to be densely vegetated. Bare ground often leads to erosion of hydric soil and compaction. Bare ground indicates the root crown is not present to expand the stabilizing species, nor protect the soil. Table 9 indicates the frequency of defoliation by horses and cattle could have been excessive with long grazing periods for plants in need of recovery to be stressed by repeated defoliation. Horse grazing across much or most of the growing season provided little opportunity for plants to grow or regrow. Cattle management offered more chance for growth and regrowth with mixed results (-1, 0, & +1) across meadows. Both herbivores combined allowed little or no opportunity for regrowth during the growing season.

Table 9. Grazing Response Index for Intensity, frequency, and opportunity by horses, cattle, sheep, and combined.

Site	Season end Stubble Height (cm)	Horse and cattle Intensity	Horse Fre-quency	Horse Oppor-tunity	Cattle Fre-quency	Cattle Oppor-tunity	Sheep Frequ ency	Sheep Oppor-tunity	GRI Score	Horse, Cattle, & Sheep Total
WCC	9	-1	-1	0	NA	NA	NA	NA	-2	-2
WJ	4	0	-1	-2	-1	-1	NA	NA	-3	-5
BS	17	+1	-1	0	NA	NA	NA	NA	0	0
CC	7	+1	-1	-1	-1	-1	+1	+1	-1	-1
TH	4	0	-1	-2	-1	+1	NA	NA	-3	-3
NS	7	+1	0	0	NA	NA	NA	NA	1	1
LP	7	+1	-1	-1	0	+1	NA	NA	-1	0
SM	6	0	NA	NA	-1	0	NA	NA	-1	-1
SS	31	+1	+1	+2	NA	NA	NA	NA	4	4

WCC=West Cherry Creek, WJ=Wagon Johnnie, BS=Becky Springs, CC=Chin Creek, TH=Treasure Hill, NS=North Steptoe, LP=Lovell Peak, SM=South Monitor, SS=South Shoshone. SH=stubble height, SE=season end, I=Intensity, F=frequency, O=opportunity.

Table 10. Total animal use days, minutes, and intensity[1].

	WCC	WJ	BS	CC	TH	NS	LP	SM	SS
Horse days	49	85	44	47	76	13	37	None	1
Horse minutes	1,005	16,070	2,995	17,365	22,290	4,140	4,870	None	25
Horse intensity	.3	4.32	.58	27.73	4.83	1.11	4.6	0	.01
Cattle days	None	35	None	58	23	None	3	23	None
Cattle minutes	None	14,226	None	32,665	15,300	None	1,900	9,965	None
Cattle intensity	None	1	None	23.62	1.84	None	2.58	2.95	None
Sheep days	None	None	None	8	None	None	None	None	None
Sheep minutes	None	None	None	21,090	None	None	None	None	None
Sheep intensity	None	None	None	14.67	None	None	None	None	None
Total ungulate days	49	120	44	113	99	13	40	23	1
Total ungulate minutes	1,005	30,296	2,995	71,120	37,590	4,140	6,770	9,965	25
Total ungulate intensity	.3	5.32	.58	66.02	6.67	1.11	7.17	2.95	.01
Total days captured on camera	176	155	176	176	105	70	69	25	81
Total days recovery [2]	26	0	7	28	0	16	15	0	71
Horse recovery	26	6	7	31	0	16	15	NA	71

Table 10. (Continued)

Cattle recovery	NA	89	NA	77	44	NA	50	0	NA
Sheep recovery	NA	NA	NA	147	NA	NA	NA	NA	NA
Total days captured on camera	176	155	176	176	105	70	69	25	81

[1]Intensity is calculated by taking the minutes each species was captured on the field camera, divided by the total minutes captured, divided by the defined meadow region area (m^2), multiplied by 10,000 m^2/(ha.), to calculate the minutes per minutes per Ha.

[2]Recovery defined in the methods section. None=species was not present, NA=not applicable.

WCC=West Cherry Creek, WJ=Wagon Johnnie, BS=Becky Springs, CC=Chin Creek, TH=Treasure Hill, NS=North Steptoe, LP=Lovell Peak, SM=South Monitor, SS=South Shoshone.

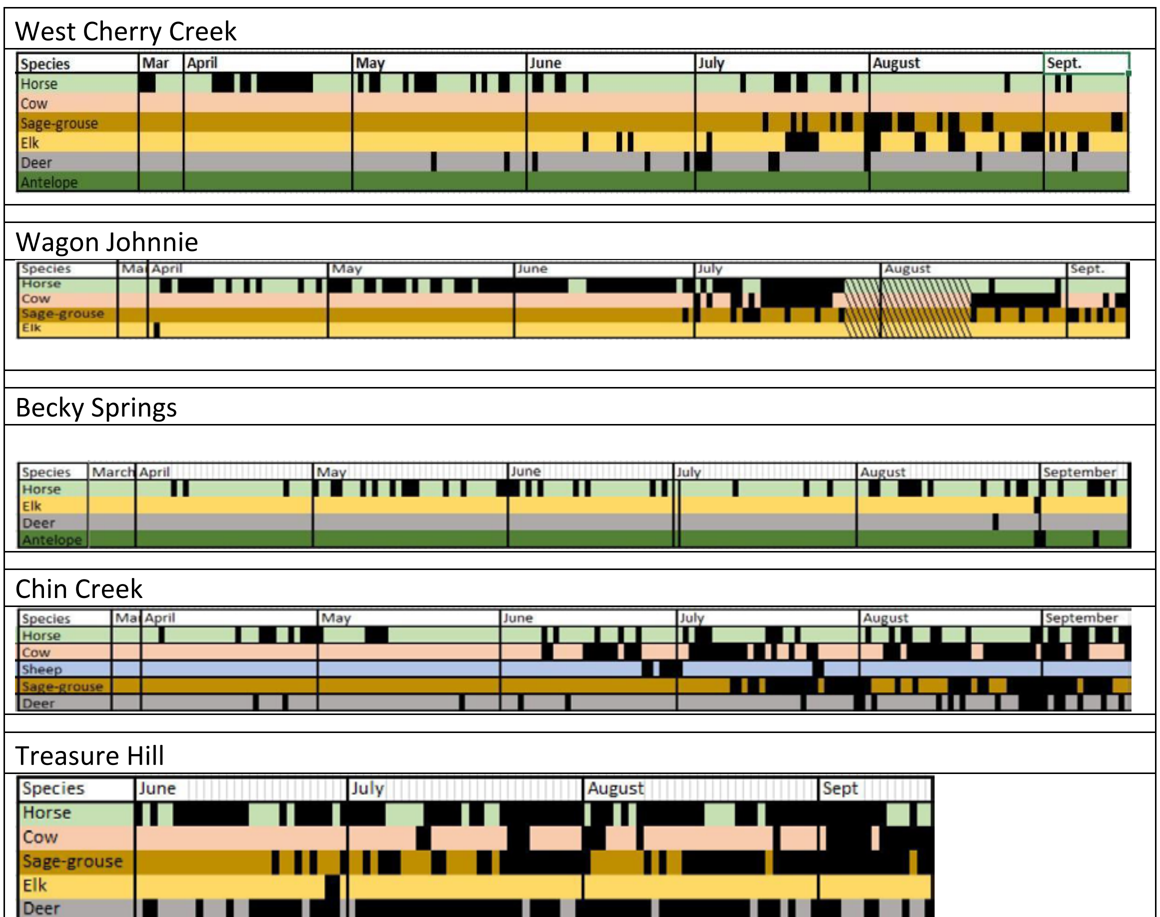
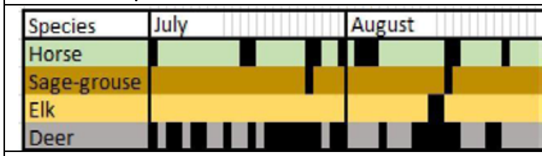
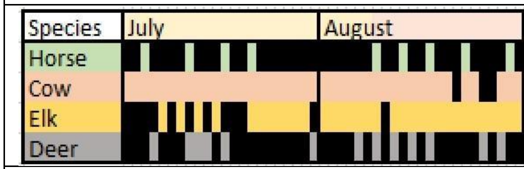


Figure 10. Summary of season of use captured on trail cameras. Solid black are days when use occurred by species, cross hatched periods represent no data due to camera failure (no battery etc.).

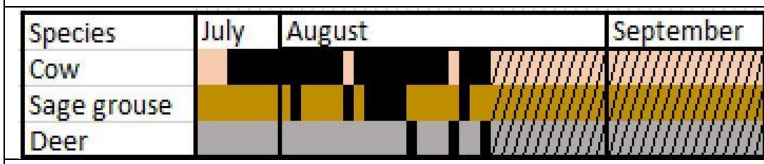
North Steptoe



Lovell Peak



South Monitor



South Shoshone

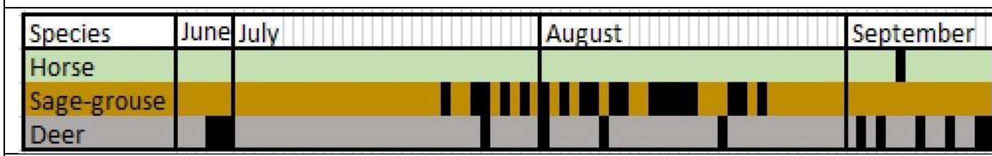


Figure 10. (Continued)

Discussion

In the early decades of public rangeland management the emphasis was on fixing the overgrazing problem by allocating specific areas, allotments, to ranches and getting the stocking rate right for the carrying capacity. This study began with recognition that when the emphasis was to spread animals widely and leave them to graze season-long in the same many areas, riparian areas were falling apart (Wyman et al., 2006). When sacrificing areas around waters was still accepted by many, fish and wildlife biologists drew attention to the diminishing biodiversity of riparian areas (Behnke and Raleigh, 1978). To showcase their potential, exclosures were built to showcase their importance and to contrast recovery from continued grazing impacts (Sarr, 2002). Some biologists recognized that widespread exclosures were not a sustainable solution while others recognized that grazing could be useful for promoting wildlife habitat (e.g. Beck and Mitchell, 2000).

In recent decades the search has been on for grazing systems (Platts, 1991) or standards (Clary and Leininger, 2000; Bengeyfield, 2006) that could be applied at scale. Where riparian grazing problems have been perceived as overgrazing and the management has been to reduce stocking rates, we have learned that stocking rate reductions had to be severe. The attraction of green riparian areas is too great during seasons when upland vegetation has become rank, dormant, brown, and deficient in protein. Fortunately there are many additional riparian management strategies for livestock (Wyman et al., 2006; Swanson et al., 2015).

Unfortunately, the only tool available for wild and free-roaming horse and burro population management has been stocking rate and exclosure fencing. Appropriate management levels (AMLs) were set in most herd management areas by the early 2000s. For a time, gathers were used to strive for herd sizes within AML. For some years gathers stopped when the capacity for adoptions and warehousing became limited by economics and politics. Gathers resumed after 2018. However the national public lands wild horse population has not been within AML since the passage of the Wild and Free Roaming Wild Horse and Burro Act in 1971. Furthermore, it was not until the National Wild Horse and Burro Management Handbook of 2010 (BLM, 2010) that riparian area functionality was prescribed for herd management.

As the greater sage-grouse conservation effort re-emphasized late brood rearing habitat and riparian functions (Stiver et al., 2015), this study came to focus on the overlap among core (now priority) sage-grouse habitat (Coates et al., 2014; 2015) in lentic meadows, herd management areas and livestock allotments. While many tools can work for livestock grazing management, the most useful ones involve limiting periods of use, especially in the spring and summer, to enable riparian recovery (Swanson et al., 2015). This study evaluated grazing season, duration, and intensity. Since horses also seek water and palatable nutritious forage, this study evaluated also their use season, duration, and intensity in riparian areas. We also evaluated the impacts of their combined use on riparian plants and functions.

Lentic riparian habitats differ widely in their potential (Prichard et al., 2003; Weixelman et al., 2011; Coles-Ritchie & Gurrieri, 2012). This study sought to emphasize those that would be most useful to greater sage-grouse (Atamian et al., 2010) where the summers are dry and moist riparian meadows provide green forbs in late summer. These habitats are important for late-brood rearing without nearby raptor perches in tall shrubs or trees. While this focus narrowed diversity among sites, it also may have eliminated some sites that had already lost riparian functions due to problematic historic livestock or horse grazing. Future studies of similar subjects could benefit from using more narrowly defined sites with similar meadow classification (e.g. Weixelman et al., 2011) and possibly by allocating study effort to use of controls.

The wetland extent was reduced from its potential at all sites (Table 4). The reduction can is seen with the soil pit texture and color results (Table 8). The color of the soil reveals the wetland characteristics had previously extended into the area dominated by upland vegetation, as indicated by a Munsell chroma value of 2 or less in a majority of upland region soil samples. Also, the meadow regions appeared to be drying as indicated by the line-point intercept species values (Table 5). South Shoshone may be close to its vegetative potential; however, the others were expected to be dominated by facultative and obligate species, according to Wiexelman et al. (2011).

Vegetation type and amount is a leading indicator and mechanism for understanding either unraveling or restoring riparian functions and conditions (Wyman et al., 2006; Hall et al., 2014; Swanson et al., 2015). However, physical impacts that create channels where none had existed may have begun the process of dehydration long before this study. This could have led to altered species composition drier plant communities as shown in table 3 (Item 10) and tables 6 and 7. Even though hydrologic items are usually a lagging indicator, following vegetation trend (Swanson et al., 2015; Hall et al., 2014; Wyman et al., 2006) there was apparently an association between hydrologic conditions (Items 6) and wetland indicator rating (Item 10), and (Tables 5 and 6). A thalweg, the lowest elevation line or area where water flows deepest downslope, had an altered flow path (Item 6), a channel, at all sites. A rill, gully, or channel water flow path is not characteristic of these meadow types (Wiexelman et al., 2011). Vegetation will likely be a leading indicator of recovery because riparian cover of stabilizer plants (Item 13) are needed to provide roughness and stability within altered flow paths (Table 3 Item 6) to halt and reverse the degradation process (Prichard et al., 2003; Wyman et al., 2006).

PFC items 8 (age class diversity), 12 (vigor), & 13 (abnormal hydrologic heaving) are related to plant health. Fragmentation of the rhizomatous plant community (bare ground in Table 7) reduces the ability to share resources through the rhizome network (Marshall & Sagar, 1965). A diverse age-class would be expressed with seed development and new shoots from expanding rhizomes. Vigor is expressed with fully developed leaf blades and deep saturated color versus stress from grazing or weather. Vegetation cover would be expressed with rhizomes and new leaf shoots filling bare interspaces or expanding outward from the center. With little to no stress, these three indicators may increase during the growing season (Boyd et al., 2016; Reed et al., 1999).

Abnormal hydrologic upheaving (Item 14), or hummocks, were present at five locations (Table 3 & 4). Hummocking occurred at Wagon Johnnie and Treasure Hill in nearly 100% of the meadow region. The soil texture in the meadow region at these sites contained a silt/clay component. Soil texture including a silt component may increase the potential for cryogenic hummock formation (Larson et al., 2018; Smith et al., 2012; Prichard et al., 2003). Three sites with a smaller presence of hummocking contained little to no silt; South Monitor (sandy/silt/clay), Chin Creek (sandy/clay) and West Cherry Creek (clay/loam). The five sites with hummocks, West Cherry Creek, Wagon Johnnie, Chin Creek, Treasure Hill, and South Monitor, received the most ungulate use among all sites. More research into how silt content interacts with livestock use may be useful to land managers.

Data collected using the draft lentic AIM protocol or a modification of it informed the PFC assessment as to what components could be modified by management to work toward PFC, according to meadow potential. The amount of bare ground and the vegetation wetland indicator status reflect modified management and condition. For example, while North Steptoe, Lovell Peak, and South Monitor had “yes’s” to all vegetation items except item 10, the wetland indicator status of the meadow averaged drier than facultative wet (Table 6) whereas obligate to facultative wetland plant species were expected to dominate these sites (Table 2). Wetland indicators dominated only along the thalweg.

Plant health plays a role in riparian functioning at each site where large ungulate grazing occurs. Maintaining a robust rhizome network supporting and supported by vigorous leaf blades will promote recovery after defoliation. Briske, (1986) found resource allocation among structural units may increase survival and competitive ability in response to stress. Also common to each example, is an indication of the need to modify grazing management to focus on plant health. Livestock and wild horse diets overlap, competing for nutrient rich green graminoids (Hansen & Clark, 1977; Hanley & Hanley, 1982; Krysl et al, 1984). GRI offers a planning tool for understanding actual use and intensity with grazing principles for the benefit of plant health. Using GRI as a planning tool, livestock in the aforementioned sites could be scheduled for rest or seasonal shift in the next year. While wild horses cannot currently be scheduled strategically a pasture fence could enable this if allowed by law and policy.

GRI intensity scores range between -1 and +1 among sites. The intensity score can be adjusted for livestock by reducing the duration of grazing in the area. Adjusting wild horse stocking may also improve the GRI score. However, reduced stocking rate is often not successful for cattle and may not be successful for horses in large pastures with small riparian areas because remaining animals continue to focus their grazing in riparian areas.

The GRI cattle opportunity score ranges from -2 to +2. Cattle opportunity at Wagon Johnnie and Chin Creek score -1. Wild horse opportunity at Wagon Johnnie, Chin Creek, and Lovell Peak are negative and indicate that an opportunity for plant growth is needed by changing management of wild horses.

Table 4 shows the percent reduction of potential riparian area. Given PFC items 8, 12, & 13 combined with the GRI opportunity and frequency scores, the link between grazing management and plant health are apparent. The riparian extent will continue to shrink if the desired riparian plant community is over stressed and cannot expand.

West Cherry Creek, Wagon Johnnie, Becky Springs, Chin Creek, Treasure Hill, and North Steptoe appear to be crossing a functional threshold. The at-risk rating and condition of associated attributes indicate the grazing management on these systems has been tilting the meadow's resilience balance past its natural range (Elmore & Kauffmen, 1994; Pellant et al., 2018; Prichard et al., 2003; Swanson et al., 2015).

Plant physiological functions advance during periods of recovery without grazing. Leaf structure converts sunlight and oxygen to carbohydrates stored in the roots. The root structure serves the plant by storing carbohydrates, water intake, and expanding the community. The plant community, in turn, stabilizes soil against erosion, and roots add to soil organic matter. While soil moisture enables both root growth and organic matter decomposition, soil saturation and anaerobic conditions enable growth of only obligate wetland species, and it retards decomposition.

Draining meadow soils leads to off-gassing of soil carbon (Reed et al., submitted). The loss of soil organic matter often leads to lowered infiltration and water storage. It also changes meadow topography, increasing drainage in a downward spiral. Vegetation and organic matter work to retain water in the system through the growing season, especially in those locations where plants have the most water available for growth. Water retention can be seen along the thalweg and especially if no alteration to the flow path has occurred.

Management Implications

Nevada's lentic systems are a limited resource susceptible to long-term grazing disturbance. These resources provide values for grazing, downstream water users and wildlife. While many grazing management tools and strategies apply to livestock, there appears to be a need to expand tools and strategies for wild horse management for riparian areas and functions. For example, the Nevada Sage-grouse conservation plan (Nevada Sagebrush Ecosystem Program, 2014) calls for riparian pastures to protect late brood rearing habitat such as meadows in herd management areas or territories. Additional management tools should be considered or developed for wild horses in the interest of conserving lentic resources under the pressure of climate change and for the benefit of livestock and wildlife. Management tools for wild horses and burros at this time include reducing herd size by gathering to meet AML. Ironically, since our nation has not been successful in meeting AML, the carrying capacity of riparian areas has diminished in many locations and AML will often need to be reduced to meet standards for rangeland, riparian, wild horse, and wildlife habitat recovery and management (BLM, 2010) unless additional management tools and strategies for horses are developed.

In spite of limited forage and water in horse management areas and horse territories, herd gathers have not been prioritized to reach AML. A majority of wild horses and burros maintain an acceptable body mass index long after rangeland and riparian conditions deteriorated. Awareness of stresses to plants through consideration of GRI factors, intensity as well as frequency and opportunity, may better inform managers about when herd gathers are needed. The GRI score addresses grazing management as a function of both livestock (the grazer) and plant physiology (the grazed). Plant physiology and health are inherently responsive to the number of defoliations, amount of leaf material remaining, and the opportunity for rest and recovery during the growing season (Reed et al., 1999). Any one of these GRI components can be mitigated by the others, especially if varied among years. If the current year's grazing intensity exceeds vegetation management strategies, opportunity or frequency can be adjusted the following year in order to adjust for those objectives. The overall score can inform management on the need to adjust management next year, depending on objectives. Plant health would have a chance to improve if opportunity for growth or regrowth during the growing season is allowed. By manipulating the GRI components by timing, duration, and season of use, the riparian plant species should expand their community to increase the functioning condition.

Also, riparian conditions assessed with PFC allows land managers to compare a site's assessment to what is expected, given the meadow classification or description of its potential. By knowing what sites could be and what they need to regain or maintain riparian functions, managers can make informed decisions for improving plant health and functionality. Methods from lentic AIM could be used to monitor within the context of integrated riparian management to determine long term (3-5 year) vegetation shifts towards objectives. Monitoring and adaptive management of tools and strategies in response to those indicators that lead to PFC will make these efforts successful (Swanson et al., 2016; 2018).

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Appendix A

Table 1. Allotment selection/rejection list. 21 allotments were selected for a larger study. Those marked with an "*" were used in this study.

Key to table	Established (green)	Rejected (red)	Waiting conformation (yellow)	Not considered (white)

Allotment	**Agency**	**Random Number**	**Accept or reject**
Spanish Ranch	BLM	1.330607013	Accepted & established July 15, 2015
Austin	BLM	2.837649	Accepted & established June 11, 2015
*Treasure Hill	USFS	3.524887844	Accepted & established June 30, 2015
Meadow Canyon	USFS	3.950621052	Tentatively accepted. June 29, 2015. Horse use to be confirmed with aerial. Move or reject in 2016.
Tuledad	BLM	3.950621052	Accepted & established August 4, 2015
Buffalo HIlls	BLM	5.485702078	Accepted & established August 4, 2015
Bare	BLM	5.807672353	Accepted & established June 2, 2015
*South Monitor	USFS	5.807672353	Accepted & established June 30, 2015
Wagon Johnnie	USFS	6.714072085	Accepted, later rejected after site visit, meadows are fenced. July 1, 2015.
Grass Valley	BLM	6.714072085	Rejected-No suitable riparian-wetland signal on NAIP. July 2015
*South Shoshone	USFS	8.299508652	Accepted & established July 28, 2015
Simpson Park	BLM	9.094515824	Accepted. Horse sign confirmed March 21, 2016.
Moores Creek C&H	USFS	9.2568991	Accepted & established July 28, 2015
Cloverdale-Reese River	USFS	10.03753777	Rejected-Inactive allotment, no grazing February 14,2015
Marysville	USFS	10.1474044	Accepted-Later rejected after site visit due to no horse use, July 2015
Flanigan	BLM	10.55330058	Reject- Current site fenced, no horse use. Other sites do not appear to have viable riparian.
Washington	USFS	10.92257454	Accepted-Later rejected after site visit due to no horse use September 2015
Ruby Hill	BLM	11.49327067	Accepted-Later rejected. Fenced, no horse access December 2015
Tierney Creek	USFS	12.12500381	Rejected- No suitable riparian-wetland signal on NAIP
Kelly Creek/North Moinrtor	USFS	12.55684072	Accepted, later rejected after site visit, no horse use. Riparian area invaded by PJ, currently dry. October 2015
JD	BLM	13.1183813	Rejected. No horse use.
North Moores	USFS	14.27198096	Rejected-No No suitable riparian-wetland signal on NAIP

Creek (winter)			
Little Fishlake	USFS	15.2272103	Rejected-No No suitable riparian-wetland signal on NAIP
*West Cherry Creek	BLM	16.98049867	Accepted & established August 12, 2015
Squaw Valley	BLM	17.889749	Accepted & established July 16, 2015
Elkhorn	USFS	18.74446852	Rejected. No suitable riparian-wetland signal on NAIP
Gold Park	USFS	19.3243202	Rejected. No suitable riparian-wetland signal on NAIP
Illipah	USFS	21.06387524	Rejected. No suitable riparian-wetland signal on NAIP
Black Point	BLM	22.90719321	Rejected. No suitable riparian-wetland signal on NAIP
Shannon Station	BLM	23.72508927	Rejected. No suitable riparian-wetland signal on NAIP
Pine Forest	BLM	25.09231849	Rejected-HMA redefined. No longer fit study criteria.
North Shoshone	USFS	25.33646657	Rejected. No suitable riparian-wetland signal on NAIP
Stoneburger	USFS	26.5602588	Rejected. No suitable riparian-wetland signal on NAIP
Bitner	BLM	30.15228736	Accepted. Later rejected. Meadow fenced/private. July 1, 2015
Soldier Meadows	BLM	30.23163549	Tentatively accepted-Will reject spring 2016
Bullhead	BLM	31.66600543	Rejected-Inaccessible in the Expedition.
Paiute Meadows	BLM	33.27127903	Rejected-Inaccessible in the Expedition. Try in spring or summer
*Wagon Johnnie	BLM	33.28726527	Accepted & established July 1, 2015
Monitor Winter	USFS	35.16953032	Accepted & established March 23, 2016
Porter Canyon	BLM	35.84704123	Accepted-Horse use confirmed March 21, 2016
South Smith Creek	BLM	35.96911527	Accepted, later rejected, inaccessible.
*Lovell Peak	BLM	36.37195959	Accepted & established August 12, 2015
Monitor Valley (East and West)	USFS	40.4095584	Rejected. No suitable riparian-wetland signal on NAIP
Monitor Complex	USFS	40.98788415	Rejected. No suitable riparian-wetland signal on NAIP
*Becky Springs	BLM	43.2861892	Accepted & established August 11, 2015
*North Steptoe	BLM	44.92934965	Accepted & established August 12, 2015
Tippett	BLM	48.20093387	Rejected. No suitable riparian-wetland signal on NAIP

*Chin Creek	BLM	48.3169042	Accepted & established August 12, 2015
Tom Plain	USFS	49.81383709	Rejected. No suitable riparian-wetland signal on NAIP
Sampson Creek	BLM	49.89165929	Accepted & established August 12, 2015
Willow Race Track	BLM	51.75939207	Rejected. No suitable riparian-wetland signal on NAIP. 2/14/2015
Cottonwood	BLM	52.59559923	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Tippet Pass	BLM	53.67595447	Rejected-No suitable riparian-wetland signal on NAIP
Six Mile	BLM	56.937654	Rejected-No suitable riparian-wetland signal on NAIP
Badlands	BLM	57.43583483	Rejected-No suitable riparian-wetland signal on NAIP
Odgers	BLM	58.2903531	Rejected. Grazing suspended.
Willow Ranch	BLM	59.01669362	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Nut Mountain	BLM	64.21616849	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Antelope Valley	BLM	65.54765465	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
North Butte Valley	BLM	65.80401013	Viable. Consider if needed. Some options marked in arcmap.
Winter Range NV	BLM	66.82943205	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Pumpernickel	BLM	67.69615772	Viable. Consider if needed. Some options marked in arcmap.
Warm Springs	BLM	68.611713	Maybe 2/14/2015
Spanish Gulch	BLM	68.75820185	Deleted 2/14/2015
Evans	BLM	70.18646809	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Romano	BLM	74.58113346	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP. Mining?
South Butte	BLM	76.79677725	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Carico Lake	BLM	80.64210944	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
South Buffalo	BLM	81.83233131	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Medicine Butte	BLM	82.36335337	Consider if needed. Some options marked in arcmap.
Twin Peaks	BLM	82.98378992	Accepted 2/14/15
Dry Mountain	BLM	83.97366	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Moorman Ranch	BLM	86.46504105	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Valley Mountain	BLM	87.12424085	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Sand Creek	BLM	87.82726191	Rejected 2/14/2015. No suitable riparian-

			wetland signal on NAIP
Gilbert Creek	BLM	89.78545488	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Arambel	BLM	89.96856594	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Goldbanks	BLM	91.24423963	Maybe viable. Consider if needed. Some options marked in arcmap.
Massacre Mountain	BLM	92.2836289	Rejected. Fenced and severely altered. Summer 2015.
Duckwater	BLM	92.33680227	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Big Canyon	BLM	93.45988342	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Currie	BLM	99.09360027	Maybe viable. Consider if needed. Some options marked in arcmap. Best parts maybe fenced.
North Steptoe Trail	BLM	100.5035554	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Wall Canyon East	BLM	101.92837	Maybe 2/14/15
Sunnyside	BLM	106.1677908	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Massacre Lakes	BLM	107.6693014	Maybe viable. Consider if needed. Some options marked in arcmap.
Maverick/Ruby #9	BLM	112.1677297	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Blue Wing/Seven Troughs	BLM	114.4810327	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Sweeney Wash	BLM	115.622425	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Railroad Pass	BLM	122.788171	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Becky Creek	BLM	122.8064821	Maybe viable. Consider if needed. Some options marked in arcmap.
Cold Creek	BLM	123.1177709	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Dixie Valley	BLM	123.8196966	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Roberts Mountain	BLM	132.9752495	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Maverick Springs	BLM	133.0301828	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Lucky C	BLM	134.8063601	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Newark	BLM	135.2763451	Maybe viable. Consider if needed. Some options marked in arcmap.
Gold Canyon	BLM	138.2366405	Maybe viable. Consider if needed. Some options marked in arcmap.
Edwards Creek	BLM	138.8592181	Viable. Consider if needed. Some options marked in arcmap.
Three Bars	BLM	139.5611438	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Red Rock	BLM	143.4614093	Rejected 2/14/2015. No suitable riparian-

			wetland signal on NAIP
Monte Cristo	BLM	146.5254677	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Spruce	BLM	158.0248421	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
South Pancake	BLM	158.3910642	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Little Owyhee	BLM	165.5690176	Consider if needed. Some options marked in arcmap. Lotic.
Warm Springs Trail	BLM	165.8497879	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Jakes Unit Trail	BLM	166.4845729	Not considered. Max study sites reached. Look on NAIP, if needed.
Home Station Gap	BLM	167.3940245	Not considered. Max study sites reached. Look on NAIP, if needed.
Ruby Valley	BLM	170.0308237	Not considered. Max study sites reached. Look on NAIP, if needed.
Fox Mountain	BLM	170.3909421	Not considered. Max study sites reached. Look on NAIP, if needed.
Piaute	BLM	171.1355937	Not considered. Max study sites reached. Look on NAIP, if needed.
Leadville	BLM	172.5333415	Not considered. Max study sites reached. Look on NAIP, if needed.
Manhattan Mountain	BLM	174.6269112	Not considered. Max study sites reached. Look on NAIP, if needed.
Winnemucca Ranch	BLM	175.5851924	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Clan Alpine	BLM	176.4213996	Not considered. Max study sites reached. Look on NAIP, if needed.
Browne	BLM	179.7112949	Not considered. Max study sites reached. Look on NAIP, if needed.
Stone Cabin	BLM	180.1629688	Rejected 2/14/2015. No suitable riparian-wetland signal on NAIP
Alder Creek	BLM	181.9391461	Rejected 14Feb2015-No suitable riparian-wetland signal on NAIP
Fish Creek Ranch	BLM	186.0591449	Not considered. Max study sites reached. Look on NAIP, if needed.
Thirty Mile Spring	BLM	189.8251289	Not considered. Max study sites reached. Look on NAIP, if needed.
Little Humboldt	BLM	190.4843287	Not considered. Max study sites reached. Look on NAIP, if needed.
Owyhee	BLM	191.8637654	Not considered. Max study sites reached. Look on NAIP, if needed.
Seven Mile	BLM	196.4110233	Not considered. Max study sites reached. Look on NAIP, if needed.
Pleasant Valley	BLM	196.642964	Not considered. Max study sites reached. Look on NAIP, if needed.
Cherry Creek	BLM	196.7833491	Viable. Consider if needed. Some options marked in arcmap.