U.S. Sheep Experiment Station Grazing and Associated Activities Project 2016

Final Soils Report

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Introduction

This report will discuss the effects on soils of continuing operations of the US Sheep Experiment Station (USSES) administered by the Agricultural Research Station (ARS) near Dubois, Idaho. The purpose of the Environmental Impact Statement (EIS), and specifically this report, is to ascertain whether continued operations would lead to degradation of soils resources beyond current conditions, and if the current conditions are in violation of relevant and applicable laws and regulations and Departmental policy and plans Fieldwork was performed during June and July 2008, and August 2009 to evaluate the existing conditions on the ground.

The project area is the collective properties of the ARS, USSES, totaling 48,330 acres. This includes old ranch lands recognized as Humphrey, Henninger, purchased in the early 1940s, and Headquarters (30,125 acres) and the summer grazing area in the Centennial Mountains (16,600 acres), which is approximately 25 miles due west of Yellowstone National Park.

USSES on average, grazes 3,300 mature sheep on their properties, but the number would drop to no more than 3,000 under the preferred alternative. Part of their mission is to monitor reproductive efficiency with the ultimate goal of increasing production in the context of environmental factors. Sheep numbers are kept below the carrying capacity of the USSES properties. Sheep are held at the headquarters facilities for most of the year, staged in the various pastures with supplemental feeding, and then grazed on the summer range for one to two months depending on weather conditions.

Methodology

Each of the ARS properties was transected during two separate field visits in 2008 (July 8 through July 12, and August 28 through September 2). Periodic observations of ground cover, surface condition, geology, and, where applicable, stream channel stability and trend were noted. Surface condition used soil indicators from the R4 soil quality monitoring protocol (USDA 2003). A supplemental overview assessment was performed in August 2009.

A classification of soil condition and cover with ratings 1 through 4 was devised to catalogue observations. These classifications were quantified to portray general conditions and spatial trends.

- Condition Class 1 represents soils that have had severe disturbance and are hydrologically impaired. Soil conditions follow USDA Forest Service (2003) criterion for long-term impairments to soil productivity with sparse ground cover, evidence of severe compaction (surface ponding), displacement, or erosion (rills, soil pedestals).
- Condition Class 2 represents soils showing evidence of disturbance with impaired hydrologic functionality, and little or no sign of recent sheet erosion. Soil ground cover and understory vegetation are adequate to resist erosion.
- Condition Class 3 indicates soil conditions reflecting a one-time impairment, but fully recovered hydrologic function.
- Condition Class 4 soils have a minimal sign of impairment, with full recovery of soil and hydrologic function.

Range surveys performed in 2009 by TEAMS range staff were also correlated with results from Keith Klements (1997) to gage soil conditions and long-term trend for soil productivity. Supplemental information was gathered through discussion with USSES staff in addition to Natural Resource Conservation Service (NRCS) soil scientist Bill Hiett (Idaho Falls, ID), and Justin Urroti and Ken Scalzone (Dillon, MT), and Bureau of Land Management (BLM) botanist, Wendy Velman (Billings, MT), along with historical assessments obtained from the USSES staff. Soils information is still being developed for the USSES though preliminary mapping concepts from the Clark county survey, and 1990s data collection (1991) was used. This information helped verify the appropriate range sites chosen from which to evaluate range condition. Ultimately, the professional knowledge of the USSES staff, NRCS staff, and BLM were invaluable for evaluating current conditions and trends.

Affected Environment

The ARS properties comprise low and highland areas along the northeastern edge of the Snake River Plain. The highlands serve as summer range and are located within the Centennial Mountains to the northeast of the USSES. The lowlands are lava-dominated sage plains where the sheep are grazed fall through spring.

The Centennials belong to the Rocky Mountain province and consist of folded and thrusted sedimentary rocks overlain with basalt and tertiary sediments. Vegetation ranges from mixed conifer to alpine meadow communities. The USSES has two summer ranges:

- West Summer - Includes “Odell”, which is west of O’dell Creek, and, to the east,
- East Summer– Toms Creek

The lowlands are gently sloping lava flow bench lands made up of Quaternary aged lava flows over rhyolite tuffs. These lava flows have inter-fingered alluvial deposits from the Centennial Mountains, in addition to fine-grained sediments from Aeolian (wind-blown loess) and lake (lacustrine) deposits (Stevenson, 1993 unpublished report, Link 2008). The USSES original Headquarters and the acquired old ranch Henninger are located on these lowlands with sage steppe as the dominant plant community. Another old ranch owned by ARS, Humphrey, borders these lowlands on the western foot slope of the Centennial Mountains, near Monida pass and is predominantly sagebrush.

This volcanic or lava plain, increases in elevation to the northeast and generates a strong moisture gradient from Headquarters to Henninger. Annual precipitation is in the range of 8-12 inches near the southwest corner of Headquarters and increases to 17-22 inches in the upper portion of Henninger, due to the orographic lift of the Centennial Mountains (Hiett, 2009, personal communication). The Centennials proper receive, on average, over 40 inches of precipitation annually primarily as snow (NRCS 1991; Prism Model, USDA Forest Service 2009).

Predominately, moisture and temperature gradients drive vegetation and soil development, although parent material along with other soil forming factors are also very important as well in soil genesis, development and morphology. On the lowlands, the cold temperatures and arid conditions make for slow soil development, in part due to the relatively recent lava flow-rock. The inherent parent material properties of the lava and interbedded alluvium are factors in the formation of both coarse-loamy and fine-loamy and loamy-skeletal soil textures. In this area, soil forming factors lead to predominantly well-drained conditions, which may be limiting plant available water during the growing season. In addition, cold climatic conditions also limit vegetative types to those more adaptive species, especially in areas over 6,200 feet elevation. This is an elevation above which soils are classified cryic; whereby mean annual temperatures are lower than 47 degrees F, thereby nominally shortening the length of the growing season and subsequent use and management of these soils. Headquarters and Henninger Ranch soils trend to cryic conditions. However, the summer pastures with gentle slopes and northern aspects in the Centennials and foothill Humphrey sites have these more extreme cold air influences (Hiett 2009, personal communication).

For the Headquarters and Henninger Ranches, the degree of soil development on the lava flows is a strong indicator of potential productivity. Lava ridges have very poor productivity potential compared to adjacent concave shaped swales that have accumulated sediment over time in response to water erosion/runoff from exposed bedrock. The basalt exposures, also known as pressure ridges, have lithic soils less than 20 inches deep to hard bedrock, with exposed bare mafic lava rock on the surface. Forage production varies from 250 to 800 pounds per acre on the pressure ridges (NRCS 1991). In contrast, soil development and productivity are accentuated by the micro-topography of the lava flows where swales continue to trap alluvial and Aeolian (wind-blown loess) sediment. Old alluvium and Aeolian deposition from nearby mountain glaciers and Pleistocene-aged Lake Terreton, once located at the foot of the Centennials, provides fine sediment for much of the soil profile (Stevenson 1993, Hiett 2009 personal communication). Production ranges from 1200 to 1600 pounds of forage per acre within these swales based on range site information (SCS 1981, NRCS 1991).

The productivity contrasts on the lava plain are highlighted by the vegetation. The lava pressure ridges support sparse sub-shrub communities compared to adjacent communities where grasses are dominant on deeper, more productive soils. More generally, vegetation includes: three-tip sage (*Artemesia tripartita*) as the dominant vegetation; with needle and thread (*Hesperostipa comata*), bluebunch wheatgrass (*Psuedoroegenaria spicata*), prairie junegrass (*Koeleria macrantha*), and sandberg poa (*Poa secunda*) typical grasses. Cheatgrass (*Bromus tectorum*) tends to occupy these less fertile areas in occasional small, less than half-acre clumps.

Soils deepen dramatically to greater than 60 inches in landforms characterized by concave shaped swale bottoms where thicker topsoil (the upper most layer(s) of the soil profile where concentration of organic matter and microorganisms are highest, providing abundant nutrients for plant growth) and subsurface clay accumulation provide increased water holding capacity and cation exchange capacity. Both positive and productive attributes support native and introduced pasture grasses. The swale indicator species are basin big sagebrush (*Artemesia tridentate spp. tridentata*) and basin wildrye (*Leymus cinereus*).

Soils on the lava plain can also vary according to the type of lava flow; the rough surface "aa" lava breaks to coarse rock fragments that allows for deeper development and efficiently catches Aeolian sediments while the smooth "pahoehoe" lava formed a viscous and smooth surface that is prone to wind scour. Soils on both Henninger and Headquarters parcels are found on both pahoehoe and aa lava.

Across the lava plain, the shift in moisture to the northeast increases the potential vegetative productivity, with subsequent increase of fescue grasses (*Festuca spp.)* closer to the Centennial Mountains. Rainfall increases to 16-22 inches, creating an even-tempered growing environment with most of the carbonates in the soil profile, leached to a lower depth below the effective rooting area. The reduction of carbonates is marked by increases in mountain big sagebrush (*Artemesia tridentata ssp. vaseyana*) and Idaho fescue (*Festuca idahoensis*) (Ecosite B13-05, B13-39, NRCS (In development)). This increase in soil moisture is most evident in the Henninger pasture where the lava pressure ridges support aspen (*Populus tremuloides*) instead of sage. The plantings of crested wheatgrass in the southwest corner of Headquarters correlate to the low productive conditions from high carbonates and very low precipitation. These areas represent an altered plant community from the historic vegetation (Ecosite B11b-R011BY010ID, NRCS (In development).

Henninger ranch soils have greater depth than Headquarters soils because of alluvial deposits and underlying glacial outwash derived from the Centennial Mountains. This alluvium creates planar (flat horizontal, yet two-dimensional depositional) surfaces, with dry meadow conditions that support hay production. Silver sage (*Artemesia ludoviciana*) and mules-ears (*Wyenthia amplexicaulis*) are the prominent indicators of these semi-wet meadows along with associated vegetation species: death camas (*Zigadenus venenosus*), sedge (*Carex spp.*), and pasture grasses (Kentucky bluegrass (*Poa pratensis*) and timothy (*Phleum pratense*)). These soils have profound thick mollic epipedons (very dark brown to black surface horizon, high in organic matter; characteristically formed under grass) and clay subsoil's, with good productive capacity (R013XY039ID, NRCS (in development). Adjacent footslopes have moderately steep slopes and inceptic soils on weathered pitchstone obsidian residuum with low nutrient status on colluvial footslopes (R013XY005ID, NRCS (in development). Range production is upwards of 1,800 pounds forage per acre for hillocks and benchlands, compared to 1,400 pounds forage per acre on alluvial flats for average years.

Soils at Humphrey vary highly due to the minor slump (mass wasting) terrain. Ridge soils are lithic (shallow, less than 20 inches over hard bedrock) and skeletal (more than 35 percent rock (coarse) fragments ≥ 2mm by volume below 10 inches) with poor site quality. Back slope concavities are prone to form from the unconsolidated nature of the parent material; old alluvium gravels and cobbles from the Beaverhead formation. These "slips" form catchments that have deep soils below. Across a hill slope, soil depth varies from moderately deep too deep with dark topsoil's; 20" to 40" and ≤ 40" respectively. Productivity varies accordingly with the soils below catchment areas supporting robust grassland species. Mountain sage is the dominant component along with Idaho fescue and mountain brome.

The soils on the summer range have strong relationships with aspect and slope location or position on the landscape, which heavily influence productivity and vegetation. Moderately-deep loamy soils (20 to 40 inches deep) occur on ridgetops and hillslopes that support rich forb and short grass communities with forage production in the realm of 1,000-1,200 pounds per acre on windswept ridges, and 2,000-2,400 pounds per acre on deeper soils on protected gentle to rolling slopes. Topsoil contains a higher percentage of organic matter since forming from forb and grassland vegetation. Conifer thickets on side slopes and within protected aspects, shift forest floors to forest herb and conifer litter, with production of forages less than 200 pounds per acre.

Shifts in geology from igneous and metamorphic rocks to sedimentary limestone or shales can lead to shallow and less productive soils than soils deeper than 20 inches. Within soils forming in limestone and shale parent materials, steep armored gravel slopes support a sparse shrub layer and clumped conifers. Toms Creek is a good example of where a contact exists between sedimentary and volcanic rocks in the upper watershed. The western portion of the watershed has steep graveled slopes with sparse snowberry (*Symphorocarpos spp*.) and conifer clumps on shale's and limestone, compared to the forb- and grass-rich eastern portion of the watershed on mafic volcanic material.

Biological soil crusts, mostly unique to semi-arid and arid ecosystems are increasingly being recognized as potentially very important in evaluating range conditions and suitability for grazing. These complex communities are sometimes referred to as cryptogamic, microbiotic, cryptobiotic (soil cyanobacteria, algae, bryophytes, lichens, mosses, and fungi), and micophytic crusts. 'Biological crusts' though is an all-encompassing term that appropriately distinguishes itself from physical crusts, developed genetically/structurally within the soil or from anthropogenic impacts (i.e. cultural land treatments).

Figure 1. Biological micro-crusts, Boynton Canyon, AZ, in a transition zone between the Colorado

Biological crusts are recognized as having important attributes that increase surface soil stability, thus decreasing vulnerability to wind and water erosion, increased water infiltration, and improved soil fertility (e.g. carbon and nitrogen inputs). Yet these thin (normally < 4 mm or 5/32 in) crusts are fragile and susceptible to damage and even destruction from soil-surface disturbances, such as intensive overgrazing, off-road/off-highway/all-terrain vehicle use, and high-intensity fires. Full recovery, depending on the level or intensity of disturbance, may take less than 10 years, but could take 50 years or more; particularly so for mosses and lichens.

The extent and spatial distribution of crusts though is highly influenced by soil pH, the higher the pH the greater development (particularly when > than 9). In addition, crusts prefer to develop in exposed areas receiving abundant sunlight, spaced among low to a moderate density or basal area cover of bunchgrasses (e.g. Idaho Fescue, Bluebunch wheatgrass, Needlegrass), and not heavily influenced by rhizomatous vascular plants (e.g. Arrowleaf balsamroot, False lupine, Western yarrow). Some crust types may be basically absent or poorly developed in shady conditions, with plant litter on the soil surface, and where sandy soil textures, bedrock or a gravel erosional pavement exits. Crust formation is not as favorable on soils having clayey textures (i.e. exposed subsoils). Some crust species are known to be resistant to trampling (i.e. cyanobacterium), regardless of grazing pressure.

Mosses and lichens would likely be found in protected locations (e.g. under sagebrush, rocky slopes) where grazing pressure was absent or minimal. In addition, soils of the lava plain, where biological soil crusts would be more likely, are forming under a moisture regime bordering between xeric (Mediterranean like climate; cool moist winters, warm dry summers) and aridic (arid-like climate), therefore soil moisture is not as deficient with depth, generally between June and November verses the period between March and November respectively. Therefore, vegetation is somewhat more responsive, developed, vigorous and sustainable than on soils forming in a dryer aridic moisture regime, thus crusts are less likely to thrive and develop.

Little is currently known about occurrence of specific crust species on lands managed for grazing by the USSES. They haven't been described and classified to the species level, nor mapped to date. However, the presence of cyrotogamic crusts were recognized, documented, and evaluated during field inventory work to determine Ecological Rating (range condition) for the vegetation community by NRCS range conservationists on the Headquarters property in 1994. In addition, reconnaissance level observations on other sites in close proximity to the Steep Station ranges (Wendy Velman, 2011, personal communication), would suggest their extent and spatial distribution is limited as these lands are, with exception, well vegetated, often with significant vertical cover.

In absence of comprehensive information on soil biological crusts specific to lands managed for grazing on Sheep Station, assessments, inventory, analysis, and monitoring of this unique microbial soil crust community will have to be deferred for possible future research.

Summer Ranges

The vegetation and soil associations of the summer ranges are unique given the persistent tall forb communities and a high proportion of forbs within grasslands (ARS 2008a). Annual and perennial forbs are typically associated with degraded conditions where forb increases are accompanied by a lack of groundcover (Pyke et al. 2002). However, ongoing studies on the USSES suggest that the high presence of forbs here may be unique to these highlands. Past evaluations vary on the interpretation of conditions with initial estimates showing degraded conditions from the 1950s until the late 1970s, despite a steady grazing rate of 1,000 to 3,000 sheep (ARS 2008a). More recently, interpretations of range conditions shifted from good to excellent ratings and research focused on the prevalence and persistence of these vegetative conditions even within grazing exclosures (2008a).

The persistence of the tall forb communities and high expression of forbs may also be an artifact of pre-settlement grazing disturbance from the late 1800s and early 1900s, and/or from turn of the century wildfire. The Great Burn proposed wilderness along the Montana and Idaho border has similar forb-dominated communities. In particular, there are very tall, mainly mono-cultural stands of coneflower (*Rudbeckia spp*.) with large expanses of bare soil. This community could be a relic from the 1910 wildfire. Sampled communities in the USSES summer pastures include an abundance of sticky purple geranium (*Geranium viscosissimum*), sunflower (*Heliomeris multiflora*), lambstongue groundsel (*Senecio integerrimus*), and cinquefoil (*Potentilla gracilis*).

The current vegetation could be considered an altered potential. The rich forb-land communities appear stable (see VanHorn-Ecret 1986, Klements 1997) and are not following traditional concepts for grassland regrowth with perhaps a strong interconnection to the soil biota community. Plants can affect soils nutrient status by forming a positive synergistic relationship (Hobbie 1992, Burke et al. 1998) as demonstrated in California Mediterranean grasslands and Colorado steppe (Vinton and Burke 1995). Moreover, the pertinent implication is the risk for ongoing erosion and sedimentation into creeks.

Current assessments found bare soil mainly along steep ridges and where thin soils occur, particularly in protected concavities. Bare soil is partially a function of the very active slips from the complex topography and protected snow patches. Extensive faulting and bedrock orientation have created unstable conditions that inhibit deep soil development. This is particularly evident in the upper Tom's Creek watershed where shaley slopes have shallow soils. Some limited bare soils are also evident on historical grazing sites, typically bedding areas. These erosion features do not connect to drainage bottoms.

Roads, including a four-wheeled drive jeep trail and the closed mine access road, account for most of the soil Condition Class 1 and 2 in Big Mountain, Odell, and East Summer pastures — about 30 percent of total measured sites, but only a minor fraction of the total summer pasture areas. Some water crossings have low ground cover (less than 50 percent) and minor rilling. Bedding areas have cover between 60 and 95 percent and a minor degree of compaction, though sites are often thin soil over bedrock as they are on ridge tops.

Tilling effects from rodents are pervasive, nearly 100 percent of slump slopes, particularly those with noted convex top surface and well drained. These sites are predominately broad leaf, forbs, and total live ground cover is about 60 percent, plus or minus a few percent.

The imprint of disturbance appears to vary in the summer pastures. Forbs and grasses respond quickly post disturbance as long as excessive soil erosion does not occur. In extreme areas where topsoil's are lost from historic grazing and fire disturbance, recolonization is slow and depends on the slope shape. Upper concave slopes are prone to soil erosion and limit soil redevelopment, while the lower catchments provide deposition zones. These conditions seem tied to geologic contacts with shale and alluvial deposits such as the Beaverhead formation.

Recovery trends are found in a 90-year tracking of range conditions in the subalpine ecosystem of the Wallowa Mountains in northeastern Oregon (Johnson 2003). Accelerated soil erosion rates diminished after the grazing pressure was reduced from historic highs in the 1950s. Recolonization in high meadows was strong as long as soils were somewhat intact. The exception was shallow soils in an erosive slope position. These areas hold a steady state where vegetation remained sparse and sheet erosion common.

Again, Toms Creek provided good context for soil potential. The area likely burned towards the early portion of the 1900s based on feedback from USSES staff. The current conditions show no erosion beyond dry ravel of the gravels and cobble. Slopes are well armored. These slopes support subshrub and sparse grass with occasional clumps of conifer. This slope shows possibly an altered potential from the fire and historical grazing use with lower water storage available than adjacent slopes with deeper soils

Headquarters Area

The flatland of Henninger, Humphrey and Headquarters are dominated by three-tip sagebrush. Headquarters is a primary wintering facility and has a more intensive use history than the other areas. In addition, these are historic ranch facilities, and thus have a long term grazing history. Grassland surrogates include rough fescue and Idaho fescue, more abundant in the upper basin allotments of Henninger and Humphrey. Invasive weeds are present, though targeted for control by select grazing and localized herbicide use.

Prescribed burning on the USSES has occurred on Headquarters since 1936, the purpose of which is to restore and improve the range. During the past 30 years, roughly 4,616 acres have burned by prescription, and 1,437 acres from wildfire (see range report). Prescribed burn occurs on approximately 200-acre units and averages 160 acres per year. Since 1990, prescribed burning efforts have used experimental designs to identify differences in impacts between fall and spring burning. The USSES is planning a 30-year fire-return interval, within the 25-40 year natural interval based on the ecological site references for historic range condition (NRCS (in review)).

The Henninger ranch was acquired from private owners in the 1940s. Flood irrigation does occur from midsummer to early fall each year. Farming does not occur, although, once in the past 30 years, a pasture has been cultivated and re-seeded (ARS 2008b).

Headquarters

The results of the summer 2008 survey found about 10 percent of 127 data points are soil condition class 1 or 2 showing substantial soil disturbance. Half of these points (and all with soil class condition rating of 1) are trails or roads. The remainder are small depressions that hold surface water or remain moist due to clayey deposits, and are trampled by livestock. Compaction and ponding of surface water are the most apparent disturbance.

Henninger Ranch

About one-half of the data points are soil condition class 1 or 2 due to compaction or soil loss. All of these points are on flat irrigated fields (points 2, 9 and 10) that have desert-like pavement, gravel surface, are highly compacted, and support little plant life other than arrowroot (*Maranta arundinacea*). Cover ranges between 70 and 95 percent in these areas. There is little slope to farmed fields, and therefore, it is plausible that soil loss is due primarily to wind erosion.

Humphrey Ranch

Disturbed areas are due to natural slumping in weakly cemented inter-bedded sandstone and siltstone. Sheep bedding areas are well vegetated, although they are compacted. The Beaver Creek floodplain/valley bottom has lush grass cover; as do all the smaller tributary valleys that support only ephemeral or disconnected flow in small incised, and loamy bank channels. The ephemeral drainage that connects with Beaver Creek ,which has abundant willow growth, showed bank trampling from sheep watering along a quarter mile of the stream. The sedge meadow drainages had no observed bank disturbance.

Environmental Consequences by Alternatives

Methodology

Field observations, professional judgment, insight from the NRCS, and referenced literature were used to evaluate the potential effects.

Spatial and Temporal Context for the Effects Analysis

The spatial boundaries for soils direct, indirect and cumulative effects are the ARS properties since soil processes occur largely in-place. The spatial boundary is the ARS lands Headquarters, Henninger, Humphrey and the summer pastures.

The BLM and FS grazing allotments established, under separate NEPA documentation, the numbers of sheep and grazing period that Sheep Station is authorized/permitted to use. Therefore, direct, indirect and cumulative effects were considered, evaluated for each property, and determination made that authorized uses as potential effects, were not deemed detrimental to soil productivity. Furthermore, since the BLM and FS grazing allotments are not adjacent, connected or otherwise contiguous to one another, nor ARS lands, there could be no additive effects, thus cumulative effects, between these various properties for inclusion in this EIS.

Effects occurring within ten years are considered short term. While long-term impacts are typically greater than 10 years. Short-term impacts are considered recoverable, with regrowth established and no displacement of topsoil. For long-term impacts, vegetation is slow to re-establish, and soil is partially removed by physical displacement and/or water and wind erosion processes, with slow to limited recovery of projected productive potential.

Modified Alternative 1 - Proposed Action (Continue current management)

Modified Alternative 1 - Direct and Indirect Effects

The proposed action would continue sheep grazing and associated supporting management activities. The current soil conditions appear functional at all ARS ownerships. Bare soils are in the expected range for all areas sampled, and evidence of accelerated (outside natural range of variability) soil erosion is rare. Some compaction is evident on intensely used areas (e.g. around watering troughs, sheep driveways, bedding areas). However, soil properties/conditions (i.e. soil moisture, texture) for optimum compaction on lands normally grazed is minimized by dispersed use and rest rotation, limiting compaction that may be potentially detrimental to soil properties and qualities to those seasonal periods (e.g. late April to Mid-June) when soil water content/compressibility is highest. Some recovery of soil physical condition/function (e.g. unsaturated hydraulic conductivity and bulk density) can be measurable in the short-term with rotational grazing and natural processes, such as wetting and drying cycles, freeze and thaw cycles, plant root growth and decay, and soil fauna and flora activity. From a soil physical standpoint, all areas are functional and do not show overt signs of degradation.

Grazing effects

Using vegetation as an indicator of soil health, the current vegetation composition for Humphrey and the summer pastures appears stable, showing no signs of degrading range conditions. Reports on trend for the summer pastures by Klements (1997) and VanHorn-Ecret (1986) show the composition of vegetation within exclosures installed in the 1960s does not differ substantially from the composition outside exclosures. Humphrey has a strong presence of desirable native range species and approaches the expected sagebrush community type based on the NRCS range sites (SCS 1981). These conditions should persist given the long history of managed grazing by the USSES. The low utilization of six percent at Headquarters and 14 percent at Humphrey, along with the varied staging/gathering of sheep throughout the year; has resulted in the conditions observed. At Henninger, grazing use observations and higher utilization (24 percent) compared to the other properties, indicate a downward trend (see Range Report, 2009), possibly related to the altered hydrology regime from historic down-cutting of Dry Creek and irrigation diversion.

Localized areas of soil disturbance associated with sheep driveways and bedding would continue to occur, though the vegetation appears stable, healthy, and robust enough to recover seasonally, and no chronic erosion is occurring. Sheep on bedgrounds generate a substantial amount of nutrients from manure and urine. In addition, bedding reduces the amount of standing vegetation and can potentially increase the amount of bare-exposed soil from disturbance, and cause some compaction. However, infiltration rates will remain high and only from a rare storm occurrence (i.e. ≤ 100 year-24 hour rainfall) yielding a high intensity, long duration precipitation event, would runoff occur above background or historical occurrence, so as to potentially cause erosion damage and transport of suspended sediment, particulate matter (manure) and dissolved solids/nutrients off-site; whereby potential soil productivity and water quality would be adversely effected.

Headquarters

Soil function would continue at Headquarters with vegetation composition aligning with expected diversity and species representation (NRCS 1991, (in review)) on the shallow and moderately deep soils. Bottomlands have more divergent species mixes with a higher abundance of pasture grasses in addition to 10-15 percent of the property planted with crested wheatgrass (*Agropyron cristaetum*) to improve forage. The productive swales have an influx of exotic pasture grasses due to the richer soil fertility here. In these arid environments, higher productivity sites have a propensity for supporting exotic species (Lejuene and

Seastedt 2001, Bashkin et al. 2003). Vegetation composition would persist in the Headquarters areas, although crested wheatgrass could expand.

The presence of exotic grasses such as the planted paddocks of crested wheatgrass and pasture grasses impacts the soil biotic community (Wardle et al. 2004, Wolfe and Klironomos 2005), but does not lower productivity per se. Expansion of the perennial grasses would have less impact than expansion of cheatgrass (*Bromus tectorum*) (Norton et al. 2007). Predominance of cheatgrass changes the moisture regime in soil with finer root structure and different litter quality, ultimately shifting the fertility regime to favor itself, an unwelcome departure from conditions preferred or desired for adaptions by competing native species (Belnap and Phillips 2001, Thorpe and Callaway 2005, Norton et al. 2007). Currently, cheatgrass is relatively sparse across the range; ≤ 1 percent The presence of the exotic perennial grasses would most likely show changes in arbuscular mycorrhizal assemblages (Wardle et al. 2004) but not impact resources such as nutrients and water (Norton et al. 2007).

Henninger Ranch

Henninger shows degradation on the sage flats where conditions have departed from the expected community (see USSES Range Report. 2011; NRCS (in review)). Species composition is stable with pasture grasses and grazing increaser forb species, but lacks native grass species. The current condition shows a downward trend, although no obvious evidence of erosion was observed. Historical grazing at the site along with evidence of dewatering from entrenched drainages and irrigation diversion suggests a shift in the water table. There is irrigation both at the site and from adjacent land users. The upland sage community has likely expanded into bottomland areas though the extent is uncertain.

Henninger uplands show fair conditions with plant species diverging from the historic community. The exotic perennial grass smooth brome (*Bromus inermus*) is common indicating past seeding and thus may interfere with recolonization of native grass species. Observations found that upland rocky areas where conifers and aspen predominate are closer to the expected plant assemblage. That said, this area gets higher sheep use at 18 percent utilization than all other ownerships of ARS except Humphrey. The forested upland areas are stable; soil erosion is sparse at the site.

Humphrey Ranch

Continued sheep grazing at Humphrey would not substantially change soil resources from existing conditions. This area has moderate use at 18 percent (Table 1, page 11) and the vegetation is close to the expected range for this area. Overall, vegetation is robust, diverse and soil erosion not evident outside the bare slope zones from small landslip. These bare slope areas are considered a natural feature and continue to supply water deep soils in adjacent swales below. Soil development is a century to millennium process. The very dark accumulated organics in these swales compared to much shallower adjacent hill slope soils, suggest that these slips/shallow slope failures are a natural ongoing process.

Riparian soil impacts are mixed at Humphrey. Sedge meadow soils appear intact with minimal impacts for the north tributary of Beaver creek on Humphrey. Willow sedge soils along a quarter mile of southern Beaver Creek tributary will continue to experience seasonal impacts from sheep watering. Canada thistle and upland species along the banks here show historical grazing use at the site. Given the long history and steady grazing numbers, the conditions would likely stay the same with continued grazing.

Summer Range

Summer pastures show abundant productive capacity given the higher precipitation regime and vegetation state than on the lowland properties. Current vegetative assemblages suggest a stable vegetation community. Keith Klement found no outstanding differences for vegetation inside and outside exclosures during his 1990s sampling (1997). Sampling during summer 2009 showed vegetation within expected ranges for the sites compared to the soil surveys in the 1990s (see USSES Range Report. 2010; NRCS 1991). Given the similar management regime to the 1990s, the existing range and soil conditions would continue.

Some bare soils resulting from annual operations were observed, but they do not show evidence of chronic accelerated erosion. Soil disturbance from sheep drives is temporary and groundcover restored with regrowth. Past evidence of bare soils and degraded conditions is referenced (Klement 1997) and reported for Toms Creek in the middle 1980s (Montagne 1988). Bare soils are isolated and related to sheep bedding on ridges, past impacts from combination of old wildfire and/or historic grazing practices (Klement 1997), and natural bare slopes related to snow patches on protected aspects. Sheep bedding areas are typically scattered and less than one quarter acre each. The chronic erosion patch observed is one-quarter acre and continues to sheet wash. This area is not grazed. The snow slopes are steep, un-vegetated slopes and therefore experience only transient use by sheep.

Sheep impacts on the nutrient regime are most prevalent at bedding sites. A recent study by Leytem and Seefedt (2008) for sites on the USSES summer range highlights the changes. The bedding sites have reduced vegetation and this translates to lower organic carbon and long-term nitrogen (total N). The input of sheep feces offsets the lack of vegetation somewhat with spikes of ammonium (NH_4-N) and soluble phosphorus (P), although overall the bedding areas experience a net loss of nutrient potential (Leytem and Seefedt ,2008). The impact of these conditions can influence the vegetation at these bedding areas although specifics were not given in the study. More opportunistic vegetation is associated with these spikes (Vinton and Burke 1994) with exact characterizations dependent on grazing history and ecological context (Milchunas and Laurenroth 1993, Biondini et al. 1998).

Nutrient impacts from sheep grazing outside of the main congregation areas such as bedding areas are not expected. Areas outside of the bedding areas are well vegetated, thus shifts in nutrient cycling, due input from urine and manure would not occur. The dispersal of sheep and low utilization of available forages diminishes potential impacts.

Table 1. Percent annual AUM utilization per property, compared with the proposed action (Alt 1)

Properties	AUM Available	Existing Alt1	Percent of Available AUMs used by Alternative			
			Alt2	Alt3	Alt4	Alt5
Agricultural Research Service properties	48,667	8	NA	6	8	5
Headquarters	28,353	6	NA	5	7	4
Humphrey	4,476	18	NA	27	20	11
Henninger	1,914	18	NA	16	21	11
East Summer Range (Toms Cr.)	4,043	6	NA	NA	NA	3
West Summer Range (Odell Cr./Big Mt.)	9,881	5	NA	NA	5	3
Forest Service Allotments	23,269	3	NA	13	4	≤1
Snakey-Kelly	1,756	25	NA	13	25	NA
East Beaver	17,887	1	NA	NA	2	<1
Meyers Creek	3,076	1	NA	NA	NA	<1
Mud Lake	560	160	28.2	28.2	28.6	29.6

Overall the summer pastures have likely improved from the 1980s with rest rotation instituted, elimination of one band of sheep (1,000 animals), and continued emphasis on herding for light, even use by sheep. Adaptive management principles emphasize even usage by the sheepherders and avoidance of low productivity sites. The poor conditions cited by Montagne (1988) at Toms Creek were initially monitored for grazing effects, and later closed to grazing altogether due to low availability of forage, and snow displacing the monitoring exclosure fencing (Jacobson, 2009, personal communication).

Infrastructure

Other effects considered are the impacts of grazing-related actions such as fence building and road-grading. On the Headquarters area, there are 2 miles of paved road, 21 miles of gravel-surfaced roads, and approximately 120 miles of dirt-surfaced roads, most on flat terrain and many having a gravelly surface with some vegetation on the roadway. These roads are subject to wind-blown fugitive dust, and localized sheet and rill erosion in response to intense, longer duration rainfall events. Although these potential effects are viewed as minimal, in that fugitive dust is essentially limited due normal formation of a physical crust; dust generated by limited vehicular traffic and annual maintenance is provided on about 20 miles by motor grader; including cross drain construction or surface drain installation, and spot surfacing where needed, Erosional sediment will most always be trapped in roadside vegetative cover, or where undulating surfaces and/or litter, etc. is present to trap sediment; soil productivity will be maintained.

In addition, about 14,000 linear feet (2.65 miles) of permanent firebreak about 30 feet wide, is maintained/rough graded by motor grader annually around the headquarters office and housing area. About 10 acres of bare mineral soil is potentially subject to erosion from overland water flow from intense, longer duration rainfall events, and wind, as are unsurfaced roads. Likewise, about 15 acres of bare soil could be created by dozer and motor grader each year in support of the Station’s prescribed annual burning program.

Invasive plants

The control of invasive plants enhances soil productivity by limiting the spread of weeds capable of adversely influencing soil function/properties and qualities. The containment and eradication strategies pose risk for adverse effects from select grazing and herbicide use. Select grazing can result in overgrazing of non-target species if grazers are mismanaged. The most common herbicides used, Curtail (2,4 D), Krovar (Bromacil and Diuron), and Roundup (Glyphosate) have minimal adverse effects on soil biota, but do vary in leaching and runoff potential. Krovar has particularly high risk for offsite transport to groundwater and runoff.

Herbicides are used to control the spread of invasive plants, and manage vegetation for both fuel reduction and wildlife habitat purposes. The main species targeted are leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea stroebe*), and cheatgrass (*Bromus tectorum*). Minor infestations are noted for hoary cress (*Cardaria draba*), lambsquarters (*Chenopodium album*), kochia (*Bassia scoparia*) and thistle (*Cirsium spp.*). Occasional herbicide control is conducted for rare sightings of henbane (*Hyoscyamus niger*), greater burdock (A*rctium lapps L*.), woad or dyers woad (I*satis tinctoria L*.), and houndstongue hawkweed (Hie*racium cynoglossoides* Arv.-Touv). Handspraying targets roadsides, feedlots and corrals, and near buildings. Broadcast spraying is done with a four-wheeler or tractor-mounted boom-sprayer in small pastures and large feedlots. Although rare, about 60 acres are sprayed annually (**Error! Reference source not found.**, page **Error! Bookmark not defined.**). Approximately 90% of the application is along roadsides.

The ecological, and thus soil related, implication is notable for leafy spurge, spotted knapweed, and cheatgrass. These plants are pervasive in arid rangelands. The success of these species may be due in part to positive feedbacks they create in the soils as self-sustenance, in addition to lack of predators such as soil pathogens (Thorpe and Callaway 2005, Wolf and Klironomos 2005). Cheatgrass changes soil structure and can influence nutrient content and timing (Hawkes et al. 2006, Norton et al. 2007). Spotted knapweed may “mine” phosphorus unavailable to other species (Thorpe et al. 2006) in addition to altering nutrient cycles with its root exudates (Thorpe and Callaway 2005).

Selective grazing by sheep is documented as effective for control and eradication of leafy spurge and spotted knapweed (Olson and Lacey 1994, Tu et al. 2003). Selective grazing for leafy spurge has reportedly resulted in up to 90 percent eradication (Olson and Lacey 1994), while spotted knapweed control is mixed, probably due to the bittering agent in leaves cnicin (Whitney and Olson 2006). It would make sense that select grazing would benefit soils by moving plant community structure further toward native composition.

Herbicide application indirectly benefits soil function by containing the spread of noxious weeds, particularly those that alter soil nutrient regimes. Most of the spraying focuses on weed containment and eradication along travelways and high-disturbance areas such as the feedlots. Adverse impacts on soil organisms overall is not expected given the low toxicity listed by Tu et al. (2003) and using application rates within label restrictions. Decomposition of all listed herbicides is primarily by soil microbe metabolism.

However, certain suites of microbes are sensitive to Picloram, Imazapyr and Triclopyr. Picloram has some toxicity to certain fungi at high application rates and is known to affect the nitrification portion of the N mineralization cycle (SERA 2003a). Triclopyr is toxic to some soil bacteria at low and high doses (2004). Arsenal has slight effect on soil microbes at high doses (SERA 2004).

Table 2. Herbicides typically used, types and location.

Herbicide/Herbicide combinations	Treatment Areas	Frequency	Notes
2,4 D amine and Clorpyralid	Roadside, fence line, and pasture invasive species treatment	Annual	Leaches, esp. sandy soils and shallow water tables
2,4 D amine and Trilsopropanol	Roadside, fence line, and pasture invasive species treatment	One time	Leaches, esp. sandy soils and shallow water tables.
2,4 D amine	Roadside, fence line, and pasture invasive species treatment	One time/annual	Weak adsorption to soil particles
Aminopyralid	Roadside, fence line, and pasture invasive species treatment	One time/annual	Relatively mobile in soil, but most retained in the upper 12 inches of the soil profile (fine-loamy or finer textures); moderate leaching risk
Bromacil and Diuron	Feedlot surfaces	Annual	Weak sorption in soil; leaches readily
Non-aquatic glyphosate	Roadside, fence line, and pasture invasive species treatment	One time	Strong adsorption to soil
Tebuthiuron	Selective shrub management in pastures	One time	Highly water soluble, low adsorption to soil particles, high leaching potential
Picioram	Pasture invasive species management	One time	Weak adsorption to soil; moderate leaching risk

Herbicides are typically used on disturbed areas such as roadsides and feedlots. These areas are characteristically compacted and barren, and may increase herbicide residence time. Soil chemical and biological processes are key to the breakdown of herbicides, so impaired conditions can lead to longer residency. Krovar and Tordon have relatively long residence times in soils, with soil half lives in the order of a year or more (Extronet 1993, SERA 2003a); while Roundup and Garlon have short residency times in soil, at 47 days (SERA 2003b) and 30 days (SERA 2004) respectively. It should be noted that these half-lives are averages and vary depending on the amount of moisture available, organic matter and warmth for soil processing (Bollag and Liu 1990).

Herbicide combinations using 2,4 D, Clorpyralid, Trilsopropanol, Aminopyralid, Bromacil, Tebuthiuron, Triclopyr amine, and Picloram have moderate to high leaching potential and can contaminate groundwater if used near shallow aquifers (Extronet 1993, Dow 2008, Dupont 2008). Herbicide buffers are recommended to ensure adequate protection (see Protocols, Appendix A: Integrated Pest Management). Glyphosate has a very strong affinity to soils, and thus has the least potential for affecting groundwater. Once absorbed by soils the herbicide is degraded by soil microbes, and is unavailable to plants.

Shrub removal using herbicides In addition to the above herbicide treatments for control of invasive/noxious weeds, three experimental applications of herbicide are planned over the next five years, totaling 800 acres (see Map 5 in DEIS). The objective is to determine the effectiveness of the herbicides selected to reduce P. tridentate (antelope bitterbrush) presence in old sagebrush stands, where sagebrush is decreasing in stand/cover density, and P. tridentate increasing. Plans, including recommended BMP's, will be prepared for these experimental applications. The herbicides selected will be 'registered by USEPA' as those shown above, and their use will be according to label directions, and other available technical guides that reflect soil *properties/*suitability, site conditions; hydrology; herbicide mobility and persistence; weather; timing, and method of application; and protocols for personal safety, storage, handling/mixing, transportation, spills, disposal of unused herbicide and containers. Prescribed Burning

Actual burned area (prescribed burn and wildfire) over the past 30 years was about 6,054 acres. Prescribed burns over the last 30 years have covered about 4,616 acres of the Headquarters property. In the next five years, the Sheep Station plans to experimentally burn 400 acres. However, since the natural burning cycle yields a return cycle of once every 30 years, these acres should fully recover their vegetation cover within two to three growing seasons. Erosion and sedimentation therefore, is of low risk to soil productivity and water quality.

Indirect activities considered are range stewardship activities such as prescribed burning and treatment of noxious invasive weeds. The latter is done through a combination of targeted grazing by sheep and use of herbicides (Appendix C of the EIS).

Prior to implementing a prescribed burn, a burning plan will be prepared by trained professional range scientists and technicians, that reflect range conditions (soil and vegetation) and weather to achieve burn objectives, while protecting future soil productivity. Short-term adverse impacts to soils from severe burning are not expected from either fall or spring burning as fuel loads are light, resulting in fires of shorter duration and intensity (less soil heating). Nor is erosion rates predicted to increase given the low seasonal rainfall. Prescribed burning is expected to increase mineral forms of N and P in the short term (1-2 years), with long-term effects uncertain. Soil biota and productivity would be adversely affected with expansion of cheatgrass.

Prescribed fire generally increases mineralization cycles in the short-term (Fisher and Binkley 2000, Erickson and White 2008) with long-term consequences depending on the vegetation and soil biotic conditions (Hart et al. 2005). Plant available nitrogen and phosphorus increases for the first (one) year, while increases in sagebrush systems of up to four years for nitrate are reported (Rau et al. 2007). Mackenzie et al. (2006) have found elevated nitrate in nearby forested systems for up to 60 years. The effects are highly dependent on biological substrate and precipitation since mineralization is a soil biotic process (Hart et al. 2005, Rau 2007).

Cheatgrass is of particular concern with regards to changes to the soil nutrient regime and the risk of more frequent flashy fires (D'Antonio and Vitousek 1992, Norton et al. 2007). These sagebrush regimes appear sensitive to the increased fire frequency associated with cheatgrass expansion (NRCS (in review), Zouhar et al. 2008). Cheatgrass invasion is thought to occur during high moisture years and may actually decline in drought (Zouhar 2008). ARS personnel have not observed cheatgrass expansion in the mountain big sagebrush vegetation types where they are burning.

Modified Alternative 1 – Cumulative Effects

ARS Properties

Grazing and associated supporting management activities, as proposed under this Alternative, would have little if any additional cumulative effects on soils

Non ARS –Lands

Of the grazing allotments utilized by Sheep Station, Meyers Creek and East Beaver Creek (FS Lands) are grazed in summer to early fall when soil conditions are capable of supporting managed grazing with slight risks of adverse impacts to soil properties and qualities, particularly so with sheep numbers very low,with a very light forage utilization;1 percent respectively. On the Snakey-Kelly (FS) allotment, used for winter grazing, a period when soil conditions are most favorable for protecting soil productivity (e.g. low soil moisture, thus potential compaction, and likely frozen soil in the upper soil horizons) sheep will utilize less than 30 percent of available forages.

Since FS allotments, and DOE Lands used for a winter feedlot (Mud Lake), aren't contiguous to one another, nor ARS properties, there isn't any additive effects, thus cumulative effects, between these various properties.

Presuming an upgrade of the existing transmission line occurs in the future, and in doing so existing roads are used, and no new towers are constructed, effects to soil productivity would be comparable to normal power line maintenance operations. Effects would be short term in that they would be appropriately mitigated by installation of various best management practices (e.g. cultivation/ripping, fertilization, and. revegetation).

Thus cumulative effects would not occur, so as to be easily discernable, if at all, including non-ARS lands as well.

Modified Alternatives 2-5

Modified Alternatives 2-5 Direct and Indirect Effects

Where grazing is to be discontinued, this would allow for more leaf litter to become available for organic accumulation and recovery of soil function in compacted areas in the long term. Alternative 2, the no grazing alternative, would not produce detectible/measurable changes in the short-term for soils on Headquarters, Humphrey, Henninger Ranch, or East and West Summer pastures; since the current utilization is only slight to light use (Table 1). Soil conditions should improve at Henninger for Alternative 2, since use would be discontinued compared to the current 18 percent forage utilization, but recovery would not likely be discernible in the short-term. Alternative 3 and 4 would extend grazing through summer months on Headquarters, and boost AUMs used, but the effect is uncertain as no discernible changes are anticipated since utilization of available forages continues at less than 5 percent, and sheep grazed/acre over this large acreage would be insignificant.

Conceptually, where grazing is discontinued on lowlands, plant and soil associations would persist since the arid conditions lend to slow recovery potential. Long-term studies on sheep grazing during the mid-20th century show varied potential for recovery based on current soil potential and vegetation composition (Michunas and Laurenroth 1993, Johnson 2003). State and transition models developed for rangeland integrate these ideas and use indicator species and surface soil conditions to judge not only current condition, but also recovery or trajectory of the plant community (NRCS (in review)). Compacted staging areas for animals would stay compacted for the long term given arid conditions and the relatively infertile environment. In contrast, uplands with species compositions closer to the historic climax communities and with hydrologic regimes intact would have greater regrowth potential. For the USSES properties on the lava plains, Henninger has the highest potential for regrowth with no grazing given the favorable climatic conditions.

The absence of sheep grazing would improve litter accumulation and retention of biomass. This cover would add mulch and further protection to soils. Plant composition changes would be difficult to detect after resting given the resilience of the current communities and the closeness to the expected natural habitat for the northern reaches of Headquarters, and especially Humphrey, using the NRCS ecological site logic. Again, the differences may be subtle given the current low uses on these lands.

Cessation of grazing would improve footslope and dry meadow sites at Henninger for Alternative 2. Henninger serves as a staging area and has utilization of 18 percent (Table 1). Henninger has higher moisture, deep soils, and lacks the calcareous upper soil layer that can limit plant production. Improvement would be most notable on the footslope sage sites. The predominant species mix of pasture grasses in the lowlands would persist and therefore a higher-level plant community state is not expected, though production could improve. In addition, the altered hydrology from irrigation and deeper entrenchment of Dry Creek has less potential to support historic dry meadow plant species.

Humphrey pasture has strong semblance to the expected native vegetative community, and, therefore, may show minute improvements except in the willow riparian area. Floodplain soils along this tributary of Beaver Creek would show improvement over the current condition if grazing were terminated, since soils have good functional attributes, albeit with some Canada thistle and upland shrubs. Compaction is rare and the current vegetation suggests good soil through-flow. Given these conditions, recovery potential is high. The collapsed banks would stabilize allowing improved movement of soil moisture outward. In addition, mesic vegetation species adjacent to the stream could establish without sheep grazing facilitating vegetation and soils recovery.

No differences would be detected in the short term for alternatives 2-5.

Invasive Plants

Eliminating grazing and active management in Alternatives 2-5 would have uncertain impacts for invasive weeds, and thus soil productivity. Eliminating selective sheep grazing and loss of active management could further expand distribution of existing invasives. On the other hand, reduced sheep numbers and associated inputs of fecal matter and disturbance, along with less travel use of road ways decreases opportunities for invasive plants and, thus, impacts to soil productivity.

Herbicide use would decline with elimination of the Humphrey range in Alternative 2, (Table 2, page 14). Although, 800 acres are planned for herbicide treatment within the next 5 years to evaluate effectiveness of different herbicides on control of P. tridentate in old sagebrush stands on Headquarters Range. No changes in soil productivity are anticipated with this reduction in use since the sprayed areas are primarily disturbed sites. The tradeoffs are similar to those for the elimination of selective grazing.

Prescribed Burning

Alternatives 3-5 would have similar impacts from prescribed burning to Alternative 1, since these alternatives retain Headquarters, Humphrey, and Henninger as primary range. The assumption is the elimination of sheep grazing at Headquarters would eliminate the burning program.

Modified Alternatives 2-5 – Cumulative Effects

Alternative 2. With elimination of grazing, there wouldn't be any further or additional cumulative effects.

Modified Alternative 3. Cumulative effects, even a slight decrease in forage utilization on ARS Properties, coupled with light forage utilization, effects would be minimal, and of slight risk to soil function and values for soils under this Alternative - not easily measured or documented.

Modified Alternative 4. With equivalent forage utilization on the Henninger Ranch property as in alternative 1, and dropping grazing on the East Summer Range , cumulative effects would be minimal and not easily measured or documented. Soils would remain stable for all properties, except for a slight downward trend for the Henninger property under Alternatives 3 and 4.

Modified Alternative 5. With reduced grazing, >50 percent, a decrease in potential cumulative effects would occur.

Non ARS –Lands

Effects from continued grazing and related activities on Non-ARS Lands, supporting the mission of Sheep Station, including past, present, and foreseeable future grazing and related actions is not foreseen as detrimental to soil productivity, and/or other functions and values provided by the soil resources in the long-term.

Because utilization of available forages under Alternatives 2-5 would be either eliminated, reduced, or increased somewhat in different allotments, adverse soil effects to productive potential would be slight, and likely not measurable; retaining fair-good suitability for long-term grazing use as planned. No cumulative effects are anticipated.

Summary of Cumulative Effects

Adverse cumulative effects are not expected for any of the alternatives. Effects from the mine at Odell, wildfire and prescribed burning are not degrading soil productivity.

The additive effects of past grazing are considered more in detail within the context of the current plant community and soil condition (see Affected Environment and Direct Effects sections). Over the last 86 years, grazing management appears relatively consistent with possibly upward trends in the last twenty years from reduced grazing and rest rotation in the uplands along with evolving grazing practices.

Rehabilitation has occurred on the Forest Service section of road to Blair Lake and to the Odell mine, stabilizing soils and returning hydrologic function. Soil impairments from soil removal would continue on the road crossing ARS property, and at the mine site (see USSES Hydrology Report, 2015). Observations in summer 2009 found some sign of continued off road vehicle use. The forb-dominated vegetation was responding well due to the presence of mollic soils (soils possessing a dark colored, high-organic matter, nutrient-enriched, surface layer/horizon). Ruts were still visible in some areas with continued erosion between water bars. Reclamation at this area will depend on successfully blocking motorized travel. Adverse effects are limited to the road area and thus isolated.

Historic wildfire could continue to affect soil productivity on USSES lands on the summer range. Wildfire effects from the early 1900s remain visible in the East Summer range, with old erosion gullies still observed on the north side of Toms Creek divide. This is indicative of the low productive soils forming from interbedded dolomitic limestone and shale on steep slopes. Elsewhere, evidence of old wildfires aren't visible, and soils stable and vegetation robust. Recent fire on the Meyers Creek allotment shows quick recovery.

Modified Alternatives 1-5 Summary of Effects

Table 3. Summary of soil effects: A comparison of direct/indirect and cumulative effects by alternative.

Soil Effects	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Grazing					
Agricultural Research Service Properties					
Headquarters	Stable	Slight improvement with added leaf litter	Stable		
Henninger	Downward trend from decreased plant vigor, litter production	Improvement on lowland and footslopes with higher litter, less disturbance	Downward trend	Downward trend	Slight improvement with less grazing use
Humphrey	Stable	Improvement in Beaver Creek riparian soils	Stable	Stable	Stable
Summer Range	Stable	Slight improvement with added leaf litter	Slight improvement with added leaf litter	Risk for downward trend in summer west from no rest-rotation	Slight improvement with added leaf litter
Forest Service Allotments					
Snakey-Kelly	Stable	Improvement	Stable		Improvement
East Beaver	Stable	Improvement	Improvement	Stable	
Meyers Creek	Stable	Improvement	Improvement	Stable	
Mud Lake	Stable	Stable	Stable	Stable	
Other Activities					
Invasive Plants	Decreases risk of invasion, potential offsite leaching of krovar at feedlots	Uncertain: eliminates grazing weed dispersal, decreases active control	Decreases risk of invasive plants, possible offsite leaching of krovar at feedlots		
Prescribed burning	Mimics fire cycle, increases cheatgrass spread risk	Tradeoff: Lowers cheat grass risk and active burning program	Mimics natural fire cycle, increases cheatgrass spread risk		

Irreversible and Irretrievable Commitment of Soil Resources

No irreversible commitments of soil resources, on USESS properties, under all alternatives considered, are recognized. Although, there are areas where productive potentials are considered irretrievable, as soils have, and will be committed to in the future, or restricted for other uses (e.g. Permanent/annually maintained firebreaks, roads, sheep driveways). This represents a management decision to restrict use and management of those lands for purposes other than grazing, but those decisions/actions are not irreversible. They represent a commitment of soil resources necessary to support the overall research mission established by executive order and public law for Sheep Station, through use and management as proposed in each alternative. Potential impacts to soil productivity have been recognized, but those impacts aren't irreversible; adversely impacted soils can be managed and/or restored to achieve full benefits, functions and values.

References

ARS. 2008a. Excerpt from History of Summer Range. Memo from Dubois ARS staff. August 19, 2008.

ARS. 2008b. Grazing Associated Activities. Memo from Dubois ARS staff. June 20, 2008b

Bashkin, M., T.J. Stohlgren, Y. Otsuki, M. Lee, P. Evangelista, and J. Belnap. 2003. Soil characteristics and plant exotic species invasion in the Grand Staircase-Escalante national Monument, Utah, USA. Applied soil Ecology. 22(1) 67-77

Bollag, J.M., S.Y. Liu. 1990. Biological Transformation processes of Pesticides. In Pesticides in the Soil Environment. H.H. Cheng. (ed.) Soil Science Society of America book series, no. 2. Madison, Wis., USA: Soil Science Society of America. p. 169-211

Belnap, J. and S.L. Phillips. 2001. Soil biota in an ungrazed grassland: response to annual grass (*Bromus tectorum*) invasion. Ecological Applications. 11(5): 1261-1275

Biondini, M.E., B.D. Patton, and P.E. Nyren. 1998. Grazing intensity and ecosystem processes in a northern mixed-grass prairie, USA. Ecological Applications. 8(2): 469-479

Burke, I.C., W.K. Lauenroth, M.A. Vinton, P.B. Hook, R.H. Kelly, H.E Epstein, M.R. Aguiar, M.D. Robles, M.O. Aguilera, K.L. Murphy, and R.A. Gill. 1998. Plant-Soil Interactions in temperate grasslands. Biogeochemistry. 42: 121-143

D'Antonio, C.M. and P.M. Vitousek 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annu. Rev. Ecol. Syst. 23: 63-87

Dow AgroSciences. 2008. Specimen Label – Curtail Specialty Herbicide (2,4 dichlorophenoxyacetic acid, salt). Revised 09-24-08. Dow AgroSciences LLC, Indianapolis, IN. 9 p.

DuPont. 2008. DuPont Krovar I DF (bromacil and diuron). E.I. du Pont de Nemours and Company. Wilmington, Delaware. 9 p.

Erickson, H.E., and R. White. 2008. Soils under fire: soils research and the Joint Fire Science Program. General Technical Report PNW-GTR-759: USDA Forest Service, pacific Northwest Research Station, Portland, OR. 17p.

Extronet. 1993. Pesticide information profile for Bromacil. Extention Toxicology Network. Cornell University. Ithaca, NY. 8p.

Fisher, R.F. and D. Binkley. 2000. Ecology and Management of Forest Soils. 3rd Edition. John Wiley & Sons, New York

Hart, S.C., T.H. DeLuca, G.S. Newman, M.D. MacKenzie, and S.I. Boyle. 2005. Post-fire vegetative dynamics as drivers of microbial community structure and function in forest soils. Forest Ecology and Management. 220: 166-184

Hawkes, C.V., J. Belnap, C. D'Antonio, and M.K.Firestone. 2006. Arbuscular mycorrhizal assemblages in native plant roots change in the presence of invasive exotic grasses. Plant and Soil. 281: 369*-380

Hiett, B. 2009. [Personal Communication]. Sept 14, 2009/May 9, 2011. Discussion about the USSES-ES soils characteristics and distribution, and the States Ecosite Project. Party leader, Soil Scientist for Clark County Survey, Natural Resources Conservation Service. Idaho Falls, ID.

Hobbie, S. 1992. Effects of plant species on nutrient cycling. TREE 7(10): 336-339

Jacobson,Q. 2009. [Personal communication]. Agriculture Research Station Range Conservationist. Discussion on ditch history and background management information for USSES lands. Dubois, ID. 6p.

Johnson, C.G., Jr. 2003. Green fescue rangelands: changes over time in the Wallowa Mountains. General Technical Report PNW-GTR-569. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 41p.

Klements, K. 1997. Condition and trend analysis on subalpine rangeland grazed by sheep in the Centennial Mountains, Montana. M.S. Dept. Rangeland Ecology and Watershed Management. University of Wyoming. Laramie, WY. 82p.

LeJeune, K.D., Seastedt, T.R. 2001. Centaurea species: the forb that won the west. Conserv Biol. 15:1568-1574

Leytem ,A.B., and S.S. Seefedt. 2008. Impact of sheep bedding on soil nutrient dynamics in the Centennial Mountains of Montana and Idaho. Soil Science. 173(8): 503-510

Link, P. 2008. Map of Neogene Snake River Plain—Yellowstone Volcanic Province. Digital Atlas of Idaho. University of Idaho. Moscow Idaho. Available [ONLINE] @ http://geology.isu.edu/Digital_Geology_Idaho/Module11/mod11.htm

MacKenzie, M.D., T.H. DeLuca, and A. Sala. 2006. Fire exclusion and nitrogen mineralization in low elevation forests of western Montana. Soil Biology & Biochemistry. 38: 952-961

Milchunas, D.G. and W.K. Laurenroth. 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. Ecological Monographs. 63(4): 327-366

Montagne, C. 1988. Field Examination of Tom Creek Headwaters. Centennial Mountains, Southwest, MT. Unpublished Report to Red Rock Lakes National Wildlife Refuge. Lakeview, MT. 3p.

Natural Resource Conservation Service. 1991. United States Sheep Experiment Station summer range soil survey, Beaverhead County, Mont.

Natural Resource Conservation Service. In review. Compilation of ecological site descriptions and range sites applicable to Agriculture Research Station ownerships. Includes Range sites: R011BY002ID, R011BY027ID, R013XY005ID, R013XY039ID. Contact Bill Hiett, Natural Resource Conservation Service, Idaho Falls, ID.

Norton, J., T.A. Monaco, and U. Norton. 2007. Mediterranean annual grasses in western North America: kids in a candy store. Plant Soil. 298: 1-5

Olson, B.E., and J.R. Lacey. 1994. Sheep: A method for controlling rangeland weeds. Sheep Research Journal. Special Issue: 105-112

Pyke, D.A., J.E.Herrick, P. Shaver, and M. Pellant. 2002. Rangeland health attributes and indicators for qualitative assessment. J. Range Manage. 55: 584-597

Rau, B.M., R.R. Blank, J.C. Chambers, and D.W. Johnson. 2007. Prescribed fire in a Great Basin sagebrush ecosystem: Dynamics of soil extractable nitrogen and phosphorus. Journal of Arid Environments. 71: 362-375

Scalzone, K. 2011. [Personal Communication]. Discussion about previous soil mapping detail on the summer pastures used by Sheep Station in the Centennial Mountains. Soil Scientist, Natural Resouces Conservation Service, Dillon, MT.

SERA (Syracuse Environmental Research Associates, Inc.). 2003a. Picloram - Revised Human Health and Ecological Risk Assessment Final Report. SERA TR 03-43-26-01b. June 30, 2003.

SERA (Syracuse Environmental Research Associates Inc.). 2003b. Glyphosate- Human Health and Ecological Risk Assessment Final Report. SERA TR 02-43-09-04a. March 1, 2003.

SERA (Syracuse Environmental Research Associates, Inc.). 2004. Imazapyr - Human Health and Ecological Risk Assessment - Final Report. SERA TR 04-43-17-05b. December 18, 2004.

Soil Conservation Service. 1981. Range sites for Beaverhead County. Dillon, MT.

Stevenson, T.K. 1993. Letter on Geology of Clark County Soil Survey Area. State Geologist. Soil Conservation Service. Boise, ID. 6p.

Taylor, Bret. 2008. Personal Communications with Bret Taylor, Rangeland Scientist, ARS, USSES Dubois, Idaho, Personal Communication October 2008

Thorpe, A.S., V. Archer, and T.H. DeLuca. 2006. The invasive forb, Centaurea maculosa, increases phosphorus availability in Montana grasslands. Applied Soil Ecology. 32: 118-122

Thorpe, A.S. and R.M. Callaway. 2005. Interactions between invasive plants and soil ecosystems: positive feedbacks and their potential to persist. *In* M.W. Cadotte, S.M. McMahon and T. Fukami (eds.) Conceptual ecology and invasions biology. Springer. Great Britain. 331-351pp.

Tu, M., C. Hurd, and J. M. Randall. 2003. Weed Control Methods Handbook: Tools &Techniques for Natural Areas. The Nature Conservancy, version June 2003.

Urroti, J. 2009. [Personal Communication]. Discussed soil properties on Humphrey pasture. Soil Scientist for Beaverhead County Soil Survey. Natural Resource Conservation Service. Dillon, MT.

USDA Forest Service. 2003. Soil Quality Monitoring Supplement R4_2509.18-2002-1. Forest Service Handbook. USDA Forest Service, Intermountain Region, Ogden, UT. 15p.

USDA Forest Service. 2009. Prism Climate Model, Water Erosion Prediction Project (WEPP). Available [ONLINE] @ *http://fsweb.moscow.rmrs.fs.fed.us/fswepp/* [Sept 16, 2009].

VanHorn-Ecret, R. L. 1986. An ecological analysis of the tall forb community of the Centennial Mountains, Montana. M.S. Thesis, Univ. of Idaho. Moscow, Ida.

Velman, W. 2011. {Personal Communication]. Discussed biologic soil microcrusts, and possible occurrence on Sheep Station. Botanist, Bureau of Land Management, Billings, MT.

Vinton, MA and IC Burke. 1995. Interactions between individual plant species and soil nutrient status in short grass steppe. Ecology 76(4): 1116-1133

Wardle, D.A., R.D. Bardgett, J.N. Klironomos, H. Setala, W.H. van der Putten, and D.H. Wall. 2004. Ecological linkages between aboveground and belowground biota. Science. 304: 1629-1633

Whitney,T.R. and B.E. Olson. 2006. Conditioning ewes and lambs to increase consumption of spotted knapweed. Applied Animal Behavior Science. 100: 196-203

Wolfe, B.E., and J.N. Klironomos. 2005. Breaking new ground: Soil communities and exotic plant invasion. BioScience. 55(6): 477-487

Zouhar, K, J.K. Smith, S. Sutherland, and M.L. Brooks. 2008. Wildland fire in ecosystems: fire and nonnative invasive plants. Gen. Tech. Rep. RMRS-GTR-42. Vol. 6. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. pp.152-159