PROTOCOL FOR DETERMINING AN ESTABLISHED VEGETATIVE CAP ON HAZARDOUS WASTE LAND TREATMENT UNITS

PREPARED FOR:

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1.0 INTRODUCTION AND PURPOSE

The purpose of this document is to provide guidance for the Montana Department of Environmental Quality (DEQ) in establishing methods for assessing physical, hydrologic and biotic conditions and for measuring vegetation on hazardous waste land treatment units (LTU). The ultimate purpose is to be able to quantify the vegetation cover, overall ground cover and assess ecological conditions so that individual LTUs may be or may not be certified as closed.

Proper closure of a land treatment area includes the establishment of a stable, self-sustaining, vegetative cap capable of growth at the site and able to protect the soil and watershed. Some period of post-seeding management may be necessary where soil amendments, supplemental irrigation, and herbicide applications would be beneficial. Beyond this period, the established perennial vegetative cap should be capable of maintaining growth and being self-sustaining. Goals for LTUs will need to be determined on an individual basis. Vegetation cover values will be determined and assessed based on the methods described in this document and use of reference sites.

The LTUs are located across the state of Montana. LTUs are sites where various types of hazardous waste were disposed of on the soil and tilled into the soil. The revegetation efforts take place on sites where the waste remains in place and is not covered by a soil cap which is then vegetated. Soil organisms break down a certain amount of the material but long chain hydrocarbons and heavy metals tend to remain. Wind and water are able to move hazardous constituents off LTU sites and this has potential to create human health problems in addition to being ecologically undesirable. Lack of desirable vegetation cover may also lead to colonization by noxious weeds and nearby agricultural producers and grazers can experience economic losses as a result of weed infestations.

Each LTU will be required to submit a variety of data and information to the DEQ during the process. The following list contains items for submission to DEQ that will be discussed in various sections below.

- Reference site location, description, and quantitative and qualitative data (Section 1.1)
- Soil and site stability data (Section 2.1)
- Hydrologic function data (Section 2.2)
- Biotic integrity data (Section 2.3)
- Hardcopies or electronic submission of supporting data forms and photographs for each of the above.

1.1 REFERENCE AREA

Vegetation caps are not a "one size fits all" assessment across large spatial areas with variable ecological conditions (see Spatial Variability below) and each LTU should be assessed relative to a comparable reference area or ecologic condition within the same general area rather than to a percentage, range, or number. The basis for all indicator assessments described in detail in TR 1734-6 is the comparison of each indicator to its "**degree of departure from the ecological site description and/or ecological reference area**" (Pellant et al. 2005). Without the use of a reference area, the DEQ guidance approach will violate the underlying basis of the TR 1734-6 process. The reference area does not need to be pristine, historically unused lands, or a climax plant community. The use of a reference area or site is a standard method for assessment reclamation or revegetation success, whether the assessment is qualitative or quantitative (Pellant et al. 2005).

Vegetation cover goals for individual LTUs may be higher than the measured values at a particular reference site. The goal for LTU closure is to have the vegetation act as a significant barrier to soil movement off site. As such, higher vegetation cover as compared to the reference site may be a necessary goal.

1.2 SPATIAL VARIABILITY

An understanding of the potential range of spatial variability both within and among ecological sites is necessary. For example, southfacing slopes are subject to higher evaporation rates and generally have shallower soils than north-facing slopes. Both higher evaporation rates and shallower soil depth result in lower soil moisture availability, increasing bare ground and the potential for rill formation, even on sites that are at or near their potential. Sites that are located lower on the landscape (downslope) may receive runoff water during intense storms or snowmelt. The effect of increased runoff can be positive when the additional water is retained onsite and becomes available for plant growth. Increased runoff can be negative if it results in greater erosion. Microsites that capture wind-driven snow generally have a higher production potential than sites that are typically free of snow, except where snow persists long enough that it significantly limits the length of the growing season. Sometimes these microsite differences are reflected in different ecological sites, but most ecological sites include a broad range of microsites with variable potential.

Across Montana, there is a high degree of spatial variability in ecological conditions including soil types, precipitation and vegetation types. This degree of ecological variability must be factored into a state wide LTU vegetation cap measuring and monitoring program. Each LTU will need to be assessed individually and a vegetation cover value goal will be determined based on those individual assessments and on comparisons to an appropriate reference site.

1.3 NOXIOUS WEEDS AND NON-NATIVE PLANTS

The state of Montana considers noxious and other weeds to be a significant problem for agricultural producers, grazers and ecological conditions. Montana aggressively treats weeds and has updated the state weed plan in 2008 (Montana Weed Control Association 2008; http://agr.mt.gov/weedpest/pdf/2008weedPlan.pdf). The state maintains updated weed lists and definitions of state and federal laws regarding weeds, maps of weed distribution across Montana and treatment options at http://mtwow.org/Weed-ID.html. See Appendix A for a Montana state list of weeds and definitions of the categories.

The LTUs across the state present an opportunity for noxious and other weeds to establish new and to expand existing populations. Many weedy species are well adapted to take advantage of the types of soil disturbance associated with the LTUs and once established may be difficult to eradicate or control. Species such as knapweeds (*Centaurea* spp.) or thistles (*Cirsium* spp.) have cost Montana agriculture millions of dollars each year in lost production and control implementation. While species such as cheatgrass (*Bromus tectorum*) is likely a permanent part of the range, control and eradication of noxious and other weeds should be a major focus of the LTU vegetation cover program.

All nonnative plants are not necessarily undesirable. For the DEQ vegetation cover goals it may become necessary to require LTUs be vegetated with grasses or forbs shown to rapidly colonize disturbed habitats (e.g., *Agropyron* spp.). These wheatgrasses are nonnative but do not have economically or ecologically unfavorable circumstances associated with their presence on the landscape.

2.0 ATTRIBUTES TO BE ASSESSED AND/OR MEASURED

General LTU location, weather, photographic information will be collected and included with all other data (Attachment I). Each of the below three attributes is summarized at the end of the Evaluation Sheet based upon a preponderance of evidence approach using the indicators selected by DEQ (Attachment II). This assessment is preliminary and may be modified with the interpretation of applicable quantitative vegetation monitoring (i.e., cover and density measures). Vegetation measurements are described in subsequent sections and data sheets are provided separate from the Evaluation Sheet. Plant data sheets are adapted from Forbis et al. (2007) and Elzinga et al. (1998).

The measures described in Sections 2.1, 2.2, and 2.3 were taken from Interpreting Indicators of Rangeland Health (Pellant et al., 2005). A variety of the citations included in the reference section of this document provide additional support.

2.1 SOIL/SITE STABILITY

The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

- Measures that address Soil/Site Stability:
  - Rills
  - Pedestals and/or terracettes
  - Bare ground
  - Gullies
  - Soil surface loss or degradation

2.2 HYDROLOGIC FUNCTION

The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

- Measures that address Hydrologic Function:
  - Rills
  - Pedestals and/or terracettes
  - Bare ground
  - Gullies
  - Soil surface loss or degradation
  - Litter amount

2.3 BIOTIC INTEGRITY

The capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants, animals, and microorganisms occurring both above and below ground.

- Measures that address Biotic Integrity:
    - Soil surface loss or degradation
    - Litter amount
    - Plant mortality/decadence
    - Annual production
    - Invasive plants
    - Reproductive capacity of perennial plants
    - Cover of all plant species
    - Density of plant species

2.4 VEGETATION COVER AND DENSITY

Cover is a measure of the vegetation canopy's ability to intercept rainfall and disperse the energy from the rainfall and overland flow of water. Cover measures serve as good surrogates for biomass production at a particular site and will prove useful for effectiveness monitoring at LTUs. Density is the number of individuals of a species in a given unit of area and gives a measure of recruitment of new individuals into populations as well as loss of individuals.

3.0 ASSESSMENT PROCEDURE

3.1 REFERENCE SITE

The first step in the assessment should be locating an appropriate reference site for each LTU. Reference sites are sites across a particular landscape where characterizations of ecologically healthy conditions have been performed via data collection concerning soil, biotic and hydrologic conditions at the site. The collected data are compared to conditions thought to reflect the ecological conditions found at the site prior to the introduction of agriculture, mining or other human disturbance (Pellant et al. 2005 and references therein). For example, in Wyoming sagebrush vegetation a reference site would be one in which there might be a minimum amount of soil compaction, some acceptable range of cover values for native vegetation and hydrologic conditions where soil is not being removed by overland flow during rain events.

It is likely that there are data collected on currently established reference sites across much of Montana. The Natural Resource Conservation Service (NRCS) is a United States Department of Agriculture (USDA) branch that is responsible for the federal soil surveys and has mapped the majority of the United States soils. Many of these soil surveys identify reference sites in forests or on the range and give a span of ecological conditions thought to be within ecologically healthy conditions for the reference sites. The University of Montana's Cooperative Extension has agents throughout Montana and may have insight as to location of reference sites. Additional information can be found through local environmental consultants and university research labs.

Once the reference site is located for a particular LTU, an initial survey should be performed on the reference site, in which all the qualitative and quantitative measures described in Section 2 are employed to obtain information about each. This will provide a first set of data needed to create standards and acceptable values and ranges of values for the particular LTU. The data collected at the reference site may then be used for comparisons against data collected at the LTU. Each LTU in Montana will likely require different reference sites as soil conditions, precipitation and vegetation types vary across the state. Once the initial data are collected and standards and ranges of values are created, the DEQ will review the data and plan and either approve, deny or amend the procedures for each LTU.

3.2 VEGETATION SAMPLING

The second phase will be to establish vegetation sampling sites at each LTU. In addition to the qualitative measures employed to assess LTUs, two techniques to directly measure vegetation cover should be used at all LTUs (Section 4.0). Measuring plant density and cover will allow for trends to be directly observed and quantified.

The first step in understanding how best to allocate sampling effort will be to determine the number of transects necessary to adequately characterize the vegetation at the LTU. Vegetation data should be collected during the first sampling year and analyzed via species-transect curves. As the number of transects is increased within a given vegetation type, the number of new species encountered will rise until a limit is reached and no new species are being added with additional transects. It is likely that once that limit is reached, additional transects are providing no new information (species) and the sampling resources may be better allocated elsewhere. It is difficult to predict precisely how many transects will be needed at each LTU; the species-transect analysis will provide the appropriate number (Forbis et al. 2007). A reasonable first approximation is one transect per acre up to approximately 15 acres. A 25 acre LTU will likely not require 25 transects and a more reasonable number of transects for 25 acre site may be 15. This will depend on number of unique soil and vegetation types at the LTU. One caveat is that if sampling is being established on bare soils during the initial stages of revegetation and reclamation, one transect per acre should be the required effort. Once these LTU sites begin to produce sufficient vegetation the sampling effort may be refined. Once the initial species-transect number has been approximated at a particular LTU, the DEQ will review the data and approve, deny or amend that transect number.

The LTUs should be sampled in years 1, 2, 3, 5 and 7. Beyond that the sampling interval may be paired with other sampling routines such as water quality so that less time is needed to obtain data. If, at any time during the post-closure period, the vegetative cap is shown to be declining, annual evaluation will be required until the vegetative cap returns to acceptable levels. In general, vegetation restoration projects should be closely monitored during the first several years in an effort to detect early trends. Noxious weed infestations are more easily detected and treated if qualified personnel are monitoring annually.

3.3 QUALITATIVE SITE ASSESSMENT MEASURES

Each of the qualitative assessment should be made for each LTU. The original Pellant et al. (2005) has 17 individual measures and the DEQ selected a subset that is more focused on obtaining information relevant to LTU condition and closure. The subset includes: Rills, Pedestals and/or Terracettes, Bare Ground, Gullies, Soil Surface Loss or Degradation, Plant Mortality/Decadence, Litter Amount, Annual Production, Invasive Plants and Reproductive Capability of Perennial Plants.

This document and Pellant et al. (2005) provide extensive detail about each assessment and provide an Evaluation Matrix (EM) so the observer has criteria against which to compare each LTU and to determine the degree of departure from the reference condition. The EM is found in Attachment II.

3.4 TRAINING FOR SAMPLING PERSONNEL

Data collected at each LTU will only be as reliable as the data collectors' knowledge of the local flora and ecology. Contractors or employees collecting these data must know the flora of Montana and be able use a dichotomous key for unknown plant species. They should be familiar with soils, climate and general ecology of Montana and the area in which the LTU they are sampling is located. Additionally, collectors should be familiar with standard vegetation sampling techniques and be able to adapt to new techniques.

4.0 VEGETATION MEASUREMENTS

4.1 QUADRAT METHOD

4.1.1 General Description

Quadrats are rectangular sampling plots placed systematically along the line transects and are employed to measure density. Density is the number of individuals of a species in a given unit of area. For rhizomatous and other species for which the delineation of separate individual plants is difficult, density can also mean the number of stems, inflorescences, culm groups, or other plant parts per unit area. Since the DEQ's goal is to measure total ground cover, it is appropriate to count individual stems or culms from vegetatively reproducing grasses as individuals since each culm will account for some contribution to total ground cover.

This method will provide DEQ with a quantification of which species are increasing or decreasing in density at the LTUs. This information will prove useful in elucidation of species trends, early detection of non-native species encroachment and early detection of desirable species becoming less abundant.

Personnel collecting data will count the number of individuals from all species encountered within the 1 meter^2 area (quadrat). That number of individuals is used to calculate density (# of individuals per meter^2).

4.1.2 Areas of Use

This method has wide applicability and is suited for use with grasses, forbs, shrubs, and trees. This method should be suitable for all LTUs across Montana.

4.1.3 Advantages and Limitations

- Generally, the density of mature perennial plants is not affected as much by annual variations in precipitation as are other vegetation attributes such as canopy cover or

herbage production
- Density is sensitive to changes in the adult population caused by long-term climatic conditions or resource uses
- Density provides useful information on seedling emergence, survival, and mortality and so is appropriate to understanding trends at a particular LTU
- Sampling is rapid, easily repeatable and reliable
- It can often be difficult to delineate an individual, especially when sampling sod forming plants (stoloniferous, or rhizomatous plants) and multi-stemmed grasses or closely spaced shrubs. Although in these cases a surrogate plant part (e.g., upright stems, inflorescences, culm groups) can be counted.

4.1.4 Equipment

The following equipment is needed:
- Study Location and Documentation Data form (Attachment I)
- Density form (Attachment III)
- Folding rulers (at least two and metric) or premade sampling frame
- Four rebar stakes approximately 18” for marking corners if necessary to leave permanently
- Tally counter (optional)
- Camera

4.1.5 Quadrat Location, Size and Shape

Quadrats should be placed at 15 meter intervals along the 100 meter tape used for the line transects. The quadrats will be placed at meters 15, 30, 45, 60, 75 and 90 for a total of 6 quadrats per 100 meter transect. The quadrats should be placed on the north side of the transect. If the transect is directly north-south then place the quadrats on the east side of the transect.

Quadrats should be 1 meter on each side and set in the shape of a square. One meter^2 is appropriate for sampling in grass, forb and small shrub dominated environments. If large trees are to be sampled then alterations to this method will be necessary. A premade metal, plastic or PVC frame may be used but is not necessary. Wooden folding meter stick rulers are easily configured, compact and portable.

4.1.6 Edge Effects

To eliminate measurement error due to edge effects, it is helpful to have rules for determining whether an individual plant that falls exactly on the edge of a quadrat is considered inside or outside the quadrat.

A good rule to follow is to count those individuals falling on the north and east edges of the quadrat as being inside the quadrat and those individuals falling on the south and west edges of the quadrat as being outside the quadrat.

4.1.7 Density per Quadrat

Calculate the estimated average density per quadrat for each species by dividing the total number of plants counted in the quadrat for each species. The average density may be estimated by transect (total number of plants by species divided by 6 (i.e., number of quadrats per transect)) or across an entire LTU. For example, a sample of 40 quadrats yields a total of 177 individual mature plants of a given species. The estimated average density of mature plants per quadrat is 177/40 = 4.4 plants/meter^2. Each measure will be useful for communicating the ecological condition of the LTU.

4.1.8 Photographs

Photographs should be taken at each quadrat sampled. The photograph should be taken focused on the 1 meter^2 area and from about 1 meter above the quadrat. The photos should be numbered consistent with the quadrats and transects. For example, the photo taken at the first quadrat of the transect with the identifier LTU13 would be LTU13-1.

4.1.9 Data Analysis and Interpretation

Confidence intervals should be constructed around each of the estimates of average density per quadrat and total quadrat density for each year. The averages of 2 years may be compared by using a *t* test (for independent samples). Averages of 3 or more years may be compared via analysis of variance (ANOVA). Density data collected at LTU may also be compared to any data collected at reference site.

4.2 LINE INTERCEPT METHOD

4.2.1 General Description

The line intercept method consists of horizontal, linear measurements of plant intercepts along the course of a line (tape). It is designed for measuring cover of grass or grass-like plants, forbs, shrubs, and trees. The following vegetation attributes are monitored with this method:

- Foliar and basal cover
- Species composition (by cover)

The line point intercept method is more complex than the density method above. Once the transect location is determined a permanent stake should be placed. Permanently marking transects will result in greater power to detect change. Then the 100 meter tape is extended and attached to a second permanent stake. The tape measure should be strung taught and kept above the vegetation.

Along each transect, 100 points will be sampled. Observers will generate a random number using a stopwatch so that within each meter segment of the transect, one point is randomly sampled. This removes the potential for sampling to be biased by the regular spatial patterning of shrubs and interspaces, a common problem in shrublands (Malkinson et al. 2003). At each point, a meter-long pin flag was lowered while the sampling personnel looks away to avoid observer bias. The overstory and understory species and the ground cover touched by the pin are recorded. All plants are recorded if the pin contacted any part of the plant. If there is a tall overstory (i.e. conifers), a densitometer (a mirrored, leveled device that can isolate an overhead sampling point) may be used. Vascular plants are identified to species while mosses and lichens were identified only as moss or lichen (Forbis et al. 2007).

4.2.2 Areas of Use

This method is ideally suited for semiarid bunchgrass-shrub vegetation types. This method should be suitable for all LTUs across Montana.

4.2.3 Advantages and Limitations

- Best suited where the boundaries of plant growth are relatively easy to determine
- Easily adapted to sampling varying densities and types of vegetation
- It is not well suited for estimating cover of:
    - single-stemmed species
    - dense grassland situations (e.g., tall and short grass prairie)
    - litter
    - gravel less than 1/2 inch in diameter.

4.2.4 Equipment

The following equipment is needed:

- Study Location and Documentation Data form (see Attachment I)
- Line Intercept form (see Attachment IV)
- Permanent yellow or orange spray paint
- Two stakes: 3/4 - or 1-inch angle iron not less than 32 inches long
- Hammer for stakes
- Measuring tapes: 100 meter, delineated in centimeters

4.2.5 Transect size, location and shape

Transects should be linear and 100 meters long. Transects should be located across each LTU such that there are approximately 1-100 meter transect per acre. The transects should not cross each other as this invalidates a variety of statistical tests. An individual transect should only sample one vegetation type at the LTU. Allowing transects to cross from one vegetation type to another creates several problems for analyzing data. First, the sample size of each vegetation type is reduced which may create problems based upon statistics required for analysis. Second, it becomes more difficult to group data from several transects intended to sample one vegetation type, if one or more of those transects cross vegetation types. Third, reference site data are generally collected within one vegetation type; comparing the LTU data to the reference site data becomes difficult.

4.2.6 Photographs

Photographs should be taken at each end of the 100 meter transects in each of the cardinal directions. These photographs should be taken so that the general condition of the vegetation along and near the transect is recorded. As described in the quadrat section, photographs should be taken at each quadrat site. If all photographs are taken as described, there will be 14 photos taken for each transect. This will aid the DEQ in understanding vegetation trends at each LTU.

4.2.7 Cover

Calculate the percent cover of each plant species by totaling the intercept measurements for all individuals of that species along the transect line and convert this total to a percent. Calculate the total cover measured on the transect by adding the cover percentages for all the species. This total could exceed 100% if the intercepts of overlapping canopies are recorded.

4.2.8 Composition

With this method, species composition is based on the percent cover of each species. Calculate percent composition by dividing the percent cover for each plant species by the total cover for all plant species.
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4.2.9 Data Analysis

Each transect is a single sampling unit. For trend analysis, permanent sampling transects are necessary. Since permanent transects are monitored, use either paired t-test or nonparametric Wilcoxon signed rank test when testing for change between years. When comparing 2 or more sampling periods, use repeated measures ANOVA.

5.0 QUALITATIVE SITE CONDITION ASSESSMENT CATEGORIES

The information and photographs contained in Section 5.1 through 5.10 is taken from Interpreting Indicators of Rangeland Health (Pellant et al. 2005). This information is included to provide details and images for the biotic, soil and hydrologic measures DEQ will require at the LTUs. The matrix (see Attachment II) provides specific criteria from Pellant et al. (2005) the DEQ will require for judging the relative deviation away from ecologically healthy conditions found at each LTU. Assuming that an appropriate reference area can be established for all hazardous waste land treatment unit comparisons, the minimum overall assessment category for an established vegetative cap should be the "Slight to Moderate" degree of departure from the ecological site description and/or ecological reference area. This "Slight to Moderate" degree of departure category provides a range that will allow an experienced and knowledgeable environmental scientist or ecologist to determine with some certainty that the vegetative cap is established. Once an initial site assessment has been documented at a particular LTU, the DEQ will review the data and approve, deny or amend the assessment process.

5.1 RILLS

Rills (small erosional rivulets) are generally linear and do not necessarily follow the microtopography that flow patterns do (Figures 1 and 2). They are formed through complex interactions between raindrops, overland flow, and the characteristics of the soil surface (Bryan 1987). The potential for rills increases as the degree of disturbance (loss of cover) and slope increases. Some soils have a greater potential for rill formation than others (Bryan 1987, Quansah 1985). Therefore, it is important to establish the degree of natural versus accelerated rill formation by interpretations made from the soil survey, rangeland ecological site description, and the ecological reference area. Generally, concentrated flow erosional processes are accelerated when the distance between rills decreases.

FIGURE 1. RILLS ARE A NATURAL COMPONENT OF THIS SITE DUE TO ERODIBLE SOILS.

FIGURE 2. SHORT LINEAR RILL CAUSED BY ACCELERATED WATER FLOW.

5.2 PEDESTALS AND/OR TERRACETTES

Pedestals and terracettes are important indicators of the movement of soil by water and/or by wind (Anderson 1974, Morgan 1986, Satterlund and Adams 1992, Hudson 1993). Pedestals are rocks or plants that appear elevated as a result of soil loss by wind or water erosion (Figure3). Pedestals can also be caused by non-erosional processes, such as frost heaving or through soil or litter deposition on and around plants (Hudson 1993). Thus, it is important to distinguish and not include this type of pedestalling as an indication of erosional processes.

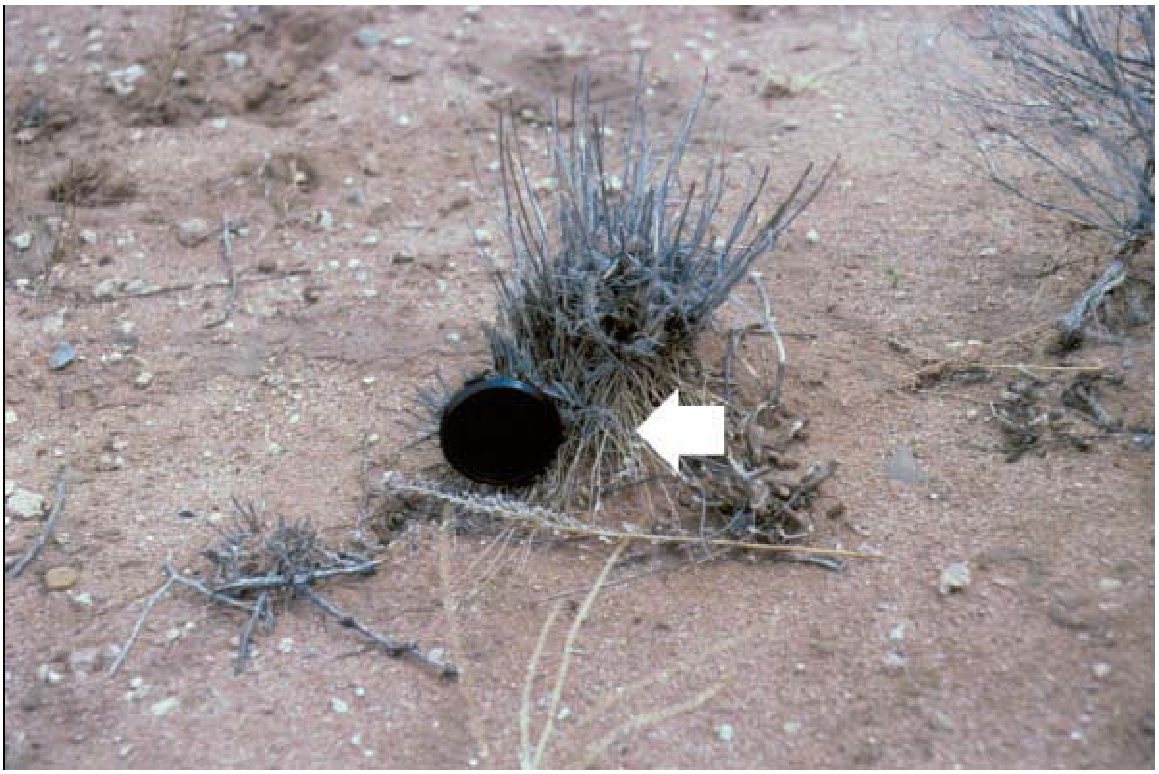

FIGURE 3. PLANT PEDESTAL CAUSED BY WIND EROSION. NOTE THE EXPOSED ROOTS (ARROW).

Terracettes are benches of soil deposition behind obstacles caused by water movement (Figure 4). As the degree of soil movement by water increases, terracettes become higher and more numerous and the area of soil deposition becomes larger. Terracettes caused by livestock or wildlife movements on hillsides are not considered erosional terracettes, thus they are not assessed in this protocol. However, these terracettes can affect erosion by concentrating water flow and/or changing infiltration. These effects are recorded with the appropriate indicators (e.g., water flow patterns, compaction layer, and soil surface loss and degradation).

FIGURE 4. TERRACETTE (ARROW) CAUSED BY LITTER OBSTRUCTION IN WATER FLOW PATTERN.

5.3 BARE GROUND

Bare ground is exposed mineral or organic soil that is susceptible to raindrop splash erosion, the initial form of most water-related erosion (Morgan 1986) (Figures 5 and 6). It is the remaining ground cover after accounting for ground surface covered by vegetation (basal and canopy (foliar) cover), litter, standing dead vegetation, gravel/rock, and visible biological crust (e.g., lichen, mosses, algae) (Weltz, et al. 1998).

The amount and distribution of bare ground is one of the most important contributors to site stability relative to the site potential; therefore, it is a direct indication of site susceptibility to accelerated wind or water erosion (Smith and Wischmeier 1962, Morgan 1986, Benkobi, et al. 1993, Blackburn and Pierson 1994, Pierson et al. 1994, Gutierrez and Hernandez 1996, Cerda 1999). In general, a site with bare soil present in a few large patches will be less stable than a site with the same ground cover percentage in which the bare soil is distributed in many small patches, especially if these patches are unconnected (Gould 1982, Spaeth et al. 1994, Puigdefabregas and Sanchez 1996).

The amount of bare ground can vary seasonally, depending on impacts on vegetation canopy (foliar) cover (e.g., herbivore utilization), and litter amount (e.g., trampling loss), and can vary annually relative to weather (e.g., drought, above average precipitation) (Gutierrez and Hernandez 1996, Anderson 1974). Current and past climate must be considered in determining the adequacy of current cover in protecting the site against the potential for accelerated erosion.

FIGURE 5. AMOUNT OF BARE GROUND IS SLIGHT RELATIVE TO SITE POTENTIAL AND RECENT WEATHER.

FIGURE 6. AMOUNT OF BARE GROUND IS EXCESSIVE RELATIVE TO SITE POTENTIAL AND RECENT WEATHER.

5.4 GULLIES

A gully is a channel that has been cut into the soil by moving water (Figures 7 and 8). Gullies generally follow natural drainages and are caused by accelerated water flow the resulting downcutting of soil. Gullies are a natural feature of some landscapes and ecological sites, while on others management actions (e.g., excessive grazing, recreation vehicles, or road drainages) may cause gullies to form or expand (Morgan 1986). In gullies, water flow is concentrated but intermittent.

Gullies may be assessed by observing the numbers of gullies in an area and assessing the severity of erosion on individual gullies. General signs of active erosion, (e.g., incised sides along a gully) are indicative of a current erosional problem, while a healing gully is characterized by rounded banks, vegetation growing bottom and on the sides (Anderson 1974), and a reduction in gully depth (Martin and Morton 1993). Active headcuts may be a sign of accelerated erosion in even if the rest of the gully is showing signs of healing (Morgan 1986).

FIGURE 7. GULLY THAT SHOWS SIGNS OF ACTIVE EROSION (NICKPOINTS - SEE ARROWS) AND DOWNCUTTING.

FIGURE 8. RELATIVELY STABLE GULLY WITH FEW SIGNS OF ACTIVE EROSION WITH GOOD VEGETATION RECOVERY OCCURRING.

5.5 SOIL SURFACE LOSS OR DEGRADATION

The loss or degradation of part or all of the soil surface layer or horizon is an indication of a loss in site potential (Dormaar and Willms 1998, Davenport et al. 1998) (Figure 9). In most sites, the soil at and near the surface has the highest organic matter and nutrient content. This generally controls the maximum rate of water infiltration into the soil and is essential for successful seedling establishment (Wood et al. 1997). As erosion increases, the potential for loss of soil surface organic matter increases, resulting in further degradation of soil structure. Historic soil erosion may result in complete loss of this layer (Satterlund and Adams 1992, O'Hara et al. 1993).

In areas with limited slope, where wind erosion does not occur, the soil may remain in place, but all characteristics that distinguish the surface from the subsurface layers are lost. Except in soils with a clearly defined horizon immediately below the surface (e.g., argillic), it is often difficult to distinguish between the loss and degradation of the soil surface. For the purposes of this indicator, this distinction is unnecessary—the objective is to determine to what extent the functional characteristics of the surface layer have been degraded. Note also that visible soil erosion is covered in discussions of Pedestals and/or Terracettes.

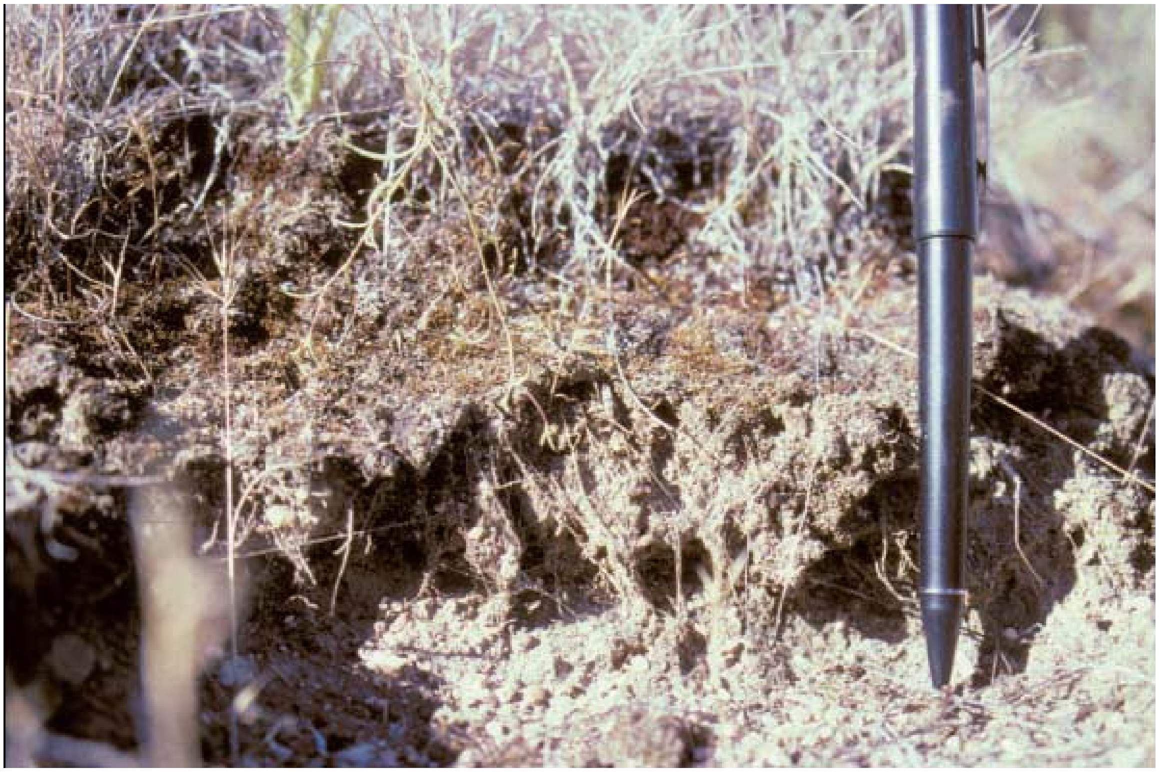

FIGURE 9. EVIDENCE OF SOIL SURFACE LOSS (FOREGROUND) IS EVIDENT WHEN COMPARED TO THE COVER OF THE PLANT AND BIOLOGICAL CRUST IN THE BACKGROUND.

The two primary indicators used to make this evaluation are the organic matter content (Dormaar and Willms 1998) and the structure (Karlen and Stott 1994) of the surface layer or horizon. Soil organic matter content is frequently reflected in a darker color of the soil, although high amounts of oxidized iron (common in humid climates) can obscure the organic matter. In arid soils, where organic matter contents are low, this accumulation can be quite faint. The use of a mister to wet the soil profile can help make these layers more visible.

Soil structural degradation is reflected by the loss of clearly defined structural units or aggregates at one or more scales from <1/8 inch to 3 to 4 inches. In soils with good structure, pores of various sizes are visible within the aggregates. Structural degradation is reflected in a more massive, homogeneous surface horizon and is associated with a reduction in infiltration rates (Warren et al. 1986). In heavier soils, degradation may also be reflected by more angular structural units. Comparisons to intact soil profiles at reference sites can also be used, although in cases of severe degradation, the removal of part or all of the A horizon, or of one or more textural components (e.g., Hennessey et al. 1986) may make identification of appropriate reference areas difficult.

5.6 PLANT MORTALITY/DECADENCE

The proportion of dead or decadent (e.g., moribund, dying) to young or mature plants in the community, relative to that expected for the site under normal disturbance regimes, is an indicator of the population dynamics of the stand (Figures 10 and 11). If recruitment is not occurring and existing plants are either dying or dead, the integrity of the stand would be expected to decline and undesirable plants (e.g., weeds or invasives) may increase (Pyke 1995). A healthy range has a mixture of many age classes of plants relative to site potential and climatic conditions (Stoddard et al. 1975).

Only plants native to the site (or seeded plants if in a seeding) are assessed for plant mortality. Plant mortality may vary considerably depending on natural disturbance events (e.g., fire, drought, insect infestation, disease).

FIGURE 10. DEAD AND DECADENT SAGEBRUSH (ARTEMISIA SPP.) PLANTS.

FIGURE 11. DECADENT SHRUB WITH DEAD BRANCHES.

5.7 LITTER AMOUNT

Litter is any dead plant material (from both native and exotic plants) that is detached from the base of the plant (Figures 12, 13 and 14). The portion of litter that is in contact with the soil surface (as opposed to standing dead vegetation) provides a source of soil organic material and raw materials for on-site nutrient cycling (Whitford 1988, 1996). All litter helps to moderate the soil microclimate and provides food for microorganisms (Hester et al. 1997). Also, the amount of litter present can play a role in enhancing the ability of the site to resist erosion. Litter helps to dissipate the energy of raindrops and overland flow, thereby reducing the potential detachment and transport of soil (Hester et al. 1997). Litter biomass represents a significant obstruction to runoff (Thurow et al. 1988a or b).

The amount of litter (herbaceous and woody) present is compared to the amount that would be expected for the same type of growing conditions in the reference state per the Reference Sheet. Litter is directly related to weather and the degree of biomass utilization each year. Therefore, climatic influences (e.g., drought, wet years) must be carefully considered in determining the rating for the amount of litter. Be careful not to confuse standing-dead plants (plant material that is not detached from the plant and is still standing) with litter during this evaluation.

Some plant communities have increased litter quantities relative to the site potential and current weather conditions. An example is the increased accumulation of litter in exotic grass communities (e.g., cheatgrass) compared to native shrub steppe plant communities. In this case, the litter in excess of the expected amount results in a downgraded rating for the site. Note in the Comments section on the Evaluation Sheet for this indicator if the litter is undergoing decomposition (darker color) or oxidation (whitish color which may also be an indication of fungal growth). In addition to amount, litter size may be important because larger litter tends to decompose more slowly and is more resistant to runoff. If litter size is considered as part of this indicator, it should be addressed in the Reference Sheet.

FIGURE 12. AMOUNT OF LITTER IS IN BALANCE WITH SITE POTENTIAL AND RECENT WEATHER.

FIGURE 13. LITTER IS UNCOMMON COMPARED TO WHAT IS EXPECTED GIVEN THE SITE POTENTIAL AND RECENT WEATHER.

FIGURE 14. AMOUNT OF LITTER AND STANDING DEAD VEGETATION IS WELL ABOVE WHAT IS EXPECTED DUE TO THE PRESENCE OF AN EXOTIC ANNUAL GRASS.

5.8 ANNUAL PRODUCTION

Primary production is the conversion of solar energy to chemical energy through the process of photosynthesis (Figures 15 and 16). Annual production, as used in this document, is the net quantity of above-ground vascular plant material produced within a year. It is an indicator of the energy captured by plants and its availability for secondary consumers in an ecosystem given current weather conditions. Production potential will change with communities or ecological sites (Whittaker 1975), biological diversity (Tilman and Downing 1994), and latitude (Cooper 1975). Annual production of the evaluation area is compared to the site potential (total annual production) as described in the Reference Sheet.

Comparisons to the Reference Sheet are based on peak above ground standing crop, no matter when the site is assessed. If utilization of vegetation has occurred or plants are in early stages of growth, the evaluator(s) is required to estimate the annual production removed or expected and include this amount when making the total site production estimate. Do not include standing dead vegetation (produced in previous years) or live tissue (woody stems) not produced in the current year as annual production.

All species (e.g., native, seeded, and weeds) alive (annual production only) in the year of the evaluation, are included in the determination of total aboveground production. Therefore, type of vegetation (e.g., native or introduced) is not an issue. For example, Rickard and Rogers (1988) found that conversion of a sagebrush steppe plant community to an exotic annual grassland greatly affected vegetation structure and function, but not above-ground biomass production.

As with the other indicators, it is important to consider all possible local and landscape level explanations for differences in production (e.g., runoff/run-on due to landscape position, weather, regional location, or different soils within an ecological site) before attributing production differences to differences in other site characteristics.

FIGURE 15. PRODUCTION OF CURRENT YEAR'S ABOVEGROUND BIOMASS IS CONSISTENT WITH SITE POTENTIAL AND RECENT WEATHER.

FIGURE 16. PRODUCTION OF CURRENT YEAR'S ABOVEGROUND BIOMASS IS WELL BELOW SITE POTENTIAL RELATIVE TO RECENT WEATHER.

5.9 INVASIVE PLANTS

Invasive plants are plants that are not part of (if exotic), or are a minor component of (if native), the original plant community or communities that have the potential to become a dominant or co-dominant species on the site if their future establishment and growth is not actively controlled by management interventions (Figures 17 and 18). Species that become dominant for only one to several years (e.g. short-term response to drought or wildfire) are not invasive plants. This indicator deals with plants that are invasive to the evaluation area. These plants may or may not be noxious and may or may not be exotic. In Montana many invasive plant species have large economic impacts to agriculture and livestock production.

Invasives can include noxious plants (i.e., plants that are listed by a State because of their unfavorable economic or ecological impacts), nonnative, and native plants. Native invasive plants (e.g., pinyon pine or juniper into sagebrush steppe) must be assessed by comparing current status with potential status described in the Reference Sheet. Historical accounts, ecological reference areas, and photographs also provide information on the historical distribution of invasive native plants.

Invasive plants may impact an ecosystem's type and abundance of species, their interrelationships, and the processes by which energy and nutrients move through the ecosystem. These impacts can influence both biological organisms and physical properties of the site (Olson 1999). These impacts may range from slight to catastrophic depending on the species involved and their degree of dominance. Invasive species may adversely affect a site by increased water usage (e.g., salt cedar (tamarisk) in riparian areas) or rapid nutrient depletion (e.g., high nitrogen use by cheatgrass).

Some invasive plants (e.g., knapweeds) are capable of invading undisturbed, climax bunchgrass communities (Lacey et al. 1990), further emphasizing their use as an indicator of new ecosystem stress. Even highly diverse, species rich plant communities are susceptible to exotic species invasion (Stohlgren et al. 1999).

FIGURE 17. CHEATGRASS (BROMUS TECTORUM) IS AN EXOTIC INVASIVE ANNUAL GRASS THAT CAN DOMINATE THE UNDERSTORY IN DISTURBED SHRUBLANDS.

FIGURE 18. STATE-LISTED NOXIOUS WEEDS, SUCH AS THIS KNAPWEED IN IDAHO, ARE ANOTHER CATEGORY OF INVASIVE PLANTS.

5.10 REPRODUCTIVE CAPABILITY OF PERENNIAL PLANTS

Adequate seed production is essential to maintain populations of plants when sexual reproduction is the primary mechanism of individual plant replacement at a site (Figures 19 and 20). However, annual seed production of perennial plants is highly variable (Harper 1977). Since reproductive growth occurs in a modular fashion similar to the remainder of the plant (White 1979), inflorescence production (e.g., seedstalks) becomes a basic measure of reproductive potential for sexually reproducing plants, and clonal production (e.g., tillers) for vegetatively reproducing plants. Since reproductive capability of perennial plants is greatly influenced by weather, it is important to determine departure from the expected value in the Reference Sheet by evaluating management effects on this indicator. Ecological reference areas provide a good benchmark to separate weather versus management influences on this indicator.

Seed production can be assessed by comparing the number of seedstalks and/or number of seeds per seedstalk of native or seeded plants (not including invasives) in the evaluation area with what is expected as documented on the Reference Sheet. Mueggler (1975) recommended comparison of seedstalk numbers or culm length on grazed and ungrazed bluebunch wheatgrass plants as a measure of plant recruitment potential. Seed production is related to plant vigor since healthy plants are better able to produce adequate quantities of viable seed than are plants that are stressed or decadent (Hanson and Stoddart 1940).

For plants that reproduce vegetatively, the number and distribution of tillers or rhizomes is assessed relative to the expected production of these reproductive structures as documented in the Reference Sheet.
Recruitment is not assessed as a part of this indicator since plant recruitment from seed is an episodic event in many rangeland ecological sites. Therefore, evidence of recruitment (seedlings or vegetative spread) of perennial, native, or seeded plants is recorded in the comment section on the Evaluation Sheet, but is not considered in rating the reproductive capabilities of perennial plants.

This indicator considers only perennial plants. With the exception of hyperarid ecosystems (e.g., Arabian peninsula and northern Atacama desert), nearly all rangelands have the potential to support perennial plants (Whitford 2002). A plant community that lacks perennial plants is rarely, if ever, included in the reference state. Evaluation areas that have no perennial plants would be rated “Extreme to Total” for this indicator because they no longer have the capacity to (re)produce perennial plants.

FIGURE 19. PERENNIAL FORBS AND GRASSES SHOW GOOD POTENTIAL FOR REPRODUCTION AS EVIDENCED BY FLOWERS AND SEEDSTALK PRODUCTION.

FIGURE 20. REPRODUCTION POTENTIAL OF THIS SHRUB IS LOW DUE TO LACK OF SEED PRODUCTION.

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APPENDIX A

MONTANA NOXIOUS WEED LIST

This list of weed species is taken from the Montana Weed Control Association's 2008 Montana weed management plan. Authored by Montana noxious weed summit advisory council weed management task force. The document may be found at http://agr.mt.gov/weedpest/pdf/2008weedPlan.pdf

Lists is effective March 27, 2008

Category 1

Category 1 noxious weeds are weeds that are currently established and generally widespread in many counties of the state. Management criteria include awareness and education, containment and suppression of existing infestations and prevention of new infestations. These weeds are capable of rapid spread and render land unfit or greatly limit beneficial uses.

- Canada thistle (*Cirsium arvense*)
- Field bindweed (*Convolvulus arvensis*)
- Whitetop or Hoary cress (*Cardaria draba*)
- Leafy spurge (*Euphorbia esula*)
- Russian knapweed (*Centaurea repens*)
- Spotted knapweed (*Centaurea maculosa*)
- Diffuse knapweed (*Centaurea diffusa*)
- Dalmatian toadflax (*Linaria dalmatica*)
- St. Johnswort (*Hypericum perforatum*)
- Sulfur (Erect) cinquefoil (*Potentilla recta*)
- Common tansy (*Tanacetum vulgare*)
- Oxeye-daisy (*Chrysanthemum leucanthemum* L.)
- Houndstongue (*Cynoglossum officinale* L.)
- Yellow toadflax (*Linaria vulgaris*)
- Hoary alyssum (*Berteroa incana)*

Category2

Category 2 noxious weeds have recently been introduced into the state or are rapidly spreading from their current infestation sites. These weeds are capable of rapid spread and invasion of lands, rendering lands unfit for beneficial uses. Management criteria include awareness and education, monitoring and containment of known infestations and eradication where possible.

- Purple loosestrife or lythrum (*Lythrum salicaria*, *L. virgatum*, and any hybrid crosses thereof).
- Tansy ragwort (*Senecio jacobea* L.)
- Meadow hawkweed complex (*Hieracium pratense*, *H. floribundum*, *H. piloselloides*)
- Orange hawkweed (*Hieracium aurantiacum* L.)
- Tall buttercup (*Ranunculus acris* L.)
- Tamarisk [Saltcedar] (*Tamarix* spp.)
- Perennial pepperweed (*Lepidium latifolium*)
- Rush skeletonweed (*Chondrilla juncea*)

- Yellowflag iris (*Iris pseudacorus*)
- Blueweed (*Echium vulgare)*

Category 3

Category 3 noxious weeds have not been detected in the state or may be found only in small, scattered, localized infestations. Management criteria include awareness and education, early detection and immediate action to eradicate infestations. These weeds are known pests in nearby states and are capable of rapid spread and render land unfit for beneficial uses.

- Yellow starthistle (*Centaurea solstitialis*)
- Common crupina (*Crupina vulgaris*)
- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Dyer's woad (*Isatis tinctoria*)
- Flowering rush (*Butomus umbellatus)*
- Japanese knotweed complex (*Polygonum cuspidatum*, *sachalinense & polystachyum)*

Category 4

Category 4 noxious weeds are invasive plants and may cause significant economic or environmental impacts if allowed to become established in Montana. Management criteria include prohibition from sale by the nursery trade. Research and monitoring may result in the plant being listed in a different category.

- Scotch broom (*Cytisus scoparius)*

ATTACHMENT I

EXAMPLE

STUDY LOCATION AND DOCUMENTATION DATA FORM

EXAMPLE

MONTANA DEQ LTU STUDY LOCATION AND DATA FORM

Date: ______________________________

LTU name, location, and general description including Township, Range, and Section and USGS 7.5 minute quad map

____

____

____

____

Surrounding vegetation ((agriculture, sagebrush, coniferous)

____

____

____

Observers

____

____

Weather (windy, calm, raining etc)

____

____

Climate (weather for the season of data collection, i.e. dry year, rainy year)

____

____

Plot Number or Identifier (Paradise LTU-1)

____

____

Plot location (both ends of transects)

UTM Easting: ______________________________ Northing: ______________________________

(or) Longitude: ______________________________ Latitude: ______________________________

Transect Compass Bearing (degrees): ______________________________

Plot Photographs (Transects (taken at each end)

North: ______________________________ South: ______________________________

East: ______________________________ West: ______________________________

North: ______________________________ South: ______________________________

East: ______________________________ West: ______________________________

EXAMPLE

MONTANA DEQ LTU STUDY LOCATION AND DATA FORM
-2-

Density plots (six per transect)

1 _______________

2 _______________

3 _______________

4. ______________

5. ______________

6._______________

Topographic position and Aspect (top of hillock, toe of slope)

____

____

____

____

Additional Notes:

ATTACHMENT II

EVALUATION MATRIX

The matrix below should be used at each LTU as described in Section 5.0 Qualitative Site Condition Assessment Categories. Further details may be found in Pellant et al. (2005).

EVALUATION MATRIX

Indicator	Extreme	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Rills	Rill formation is severe and well defined throughout most of the site.	Rill formation is moderately active and well defined throughout the site.	Active rill formation is slight at infrequent intervals; mostly in exposed areas	No recent formation or rills; old rills have blunted or muted features.	Current or past formation of rills as expected for the site.
Pedestals and/or Terracettes	Abundant active pedastaling and numerous teracettes. Many rocks and plants are pedestaled; exposed plant roots are common.	Moderate active pedestalling; terracettes common. Some rocks and plants are pedestaled with occasional exposed roots.	Slight active pedestalling; most pedestals are in flow paths and interspaces and/or on exposed slopes. Occasional terracettes present.	Active pedestalling or terracette formation is rare; some evidence of past pedestal formation, especially in water flow patterns on exposed slopes.	Current or past evidence of pedestaled plants or rocks as expected for the site. Terracettes are absent or uncommon.
Bare Ground	Much higher than expected for the site. Bare areas are large and generally connected.	Moderate to much higher than expected for the site. Bare areas are large and occasionally connected.	Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected.	Slightly to moderately higher than expected for the site. Bare areas are small and rarely conncected.	Amount and size of bare areas match that expected for the site.
Gullies	Common with indications fo active erosion and downcutting; vegetation is infrequent on slopes and/or bed. Nickpoints and headcuts are numerous and active.	Moderate in number to common with indications of active erosion; vegetation is intermittent on slopes and/or bed. Headcuts are active; downcutting is not apparent.	Moderate in number with indications of active erosion; vegetation is intermittent on slopes and/or bed. Occasional headcuts may be present.	Uncommon, vegetation is stabilizing the bed and slopes; no signs of active headcuts, nickpoints or bed erosion.	Match what is expected for the site; drainages are represented as natural stable channels; vegetation common and no signs of erosion.

Indicator	Extreme	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Soil Surface Loss or Degradation	Soil surface horizon absent. Soil structure near surface similar to, or more degraded, than that in subsurface horizons. No distinguishable difference in surbsurface organic matter content.	Soil loss of degradation severe throughout site. Minimal differences in soil organic matter content and structure of surface and subsurface layers.	Moderate soil loss or degradation in plant interspaces with some degradation beneath plant canopies. Soil structure is degraded and soil organic matter content is significantly reduced.	Some soil loss has occurred and /or soil structure shows signs of degradation, especially in plant interspaces.	Soil surface horizon intact. Soil structure and organic matter content match that expected for site.
Plant Mortality/ Decadence	Dead and/or decadent plants are common	Dead and/or decadent plants are somewhat common	Some dead and/or decadent plants are present	Slight plant mortality and/or decadence	Plant mortality and decadence is barely present
Litter amount	Largely absent or dominant relative to site potential and weather.	Greatly reduced or increased relative to site potential and weather.	Moderate more or less relative to site potential and weather.	Slightly more or less relative to site potential and weather.	Amount is what is expected for the site potential and weather.
Annual Production	Less than 20% of potential production	20-40% of potential production	40-60% of potential production	60-80% of potential production	Exceeds 80% of potential production
Invasive Plants	Dominate the site	Common throughout the site	Scattered throughout the site	Present primarily on disturbed sites	Rarely present on the site
Reproductive Capability of Perennial Plants	Capability to produce seed or vegetative tillers is severely reduced relative to recent climatic conditions	Capability to produce seed or vegetative tillers is greatly reduced relative to recent climatic conditions	Capability to produce seed or vegetative tillers is somewhat limited relative to recent climatic conditions	Capability to produce seed or vegetative tillers is only slightly limited relative to recent climatic conditions	Capability to produce seed or vegetative tillers is not limited relative to recent climatic conditions

ATTACHMENT III

DENSITY METHOD DATA SHEETS

Page ____ of ____

Density

Study Number	Date	Examiner	Allotment Name & Number	Pasture	Plot Size

Study Location

Plot	1		2		3		4		5		6		7		8		9		10		Total	
Coordinates																						
Plant Species	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling

100

Illustration 21

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Density

Study Number	Date	Examiner	Allotment Name & Number	Pasture	Plot Size
Empire #4	9/6/96	Cindy Cone	Empire - 21206	South	16 m^2

Study Location: Study is 2 mi. south of Antelope fence on the EAST side of the road.

Plot	1		2		3		4		5		6		7		8		9		10		Total	
Coordinates	0	3	0	4	16	7	16	48	32	21	32	27	32	38	48	8	48	27	64	34		
Plant Species	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling
HIBE	6		5	2	6	3			6	6	11	6			7					6	41	23
BOHI	4				3								10		4						21	
BOER 4	1								3				1								5	
HATE	3						3										4	1			10	1
LYPH	10		4				2	6					4								20	6
AAFF	3				1															8	4	8
Lupine															4		2			5	6	5
BOCU															1						1	
BOGR																	13				13	

Illustration 21

ATTACHMENT IV

LINE INTERCEPT DATA SHEET

Line Intercept

Page____of____

Study Number	Date	Examiner	Allotment Name & Number	Pasture
Line Length	Transect Location			

NOTES (Use other side or another page, if necessary)	Grass Species							Forb Species						Shrub Species					NOTES
																			Totals
Totals																			
% Cover																			
% Comp																			100%

Illustration 12