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Vegetation Community Classification and Mapping of the Idaho National Laboratory Site 2019

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Executive Summary

The Idaho National Laboratory (INL) Site is located in southeast Idaho and occupies 2,300 km^2 (890 mi^2) of sagebrush steppe. The INL Site is managed by the U.S. Department of Energy (DOE) and serves as a science-based, applied engineering national laboratory that supports the DOE missions in nuclear and energy research, science, and national defense.

The most recent vegetation mapping effort at the INL Site was completed in 2011, and in terms of resolution, accuracy, and statistical rigor, this vegetation classification and map represented a substantial improvement over previous mapping efforts. The vegetation class descriptions and the map have been used extensively to support inventory and monitoring of ecological resources on the INL Site. However, it is important to update the classification and map periodically to ensure that both the vegetation classes identified on the INL Site and the mapped boundaries of those classes remain accurate.

Three main factors justify updating the vegetation classification and map. First, four large wildland fires burned approximately 23% of the INL Site leaving the map outdated in those regions. Second, there were numerous map polygons assigned to two-class complexes which can overestimate the area of some individual classes and can make it more difficult to directly target sampling or monitoring in one specific vegetation class. Finally, field observations, especially within recently burned areas, showed that vegetation communities have begun to shift in composition, and in some regions non-native annual grass and forb abundance has increased considerably.

The goal of this project was to develop an updated vegetation classification and map of the current distribution of plant communities on the INL Site. Our specific objectives included: 1) characterize the vegetation community types present on the INL Site; 2) define the spatial distribution of those community types; and 3) conduct a quantitative accuracy assessment of the resulting map.

Objective 1 – Plant Community Classification

An update to the vegetation classification was the first step in the process of updating the vegetation map for the INL Site. The primary objective of the plant community classification was to sample a representative range of plant communities across the INL Site and organize them into meaningful vegetation classes. Our approach for the previous classification effort relied heavily on quantitative methodologies. Overall, the technique worked well; each class was readily defined by a few dominant or co-dominant species and similarity scores between vegetation class pairwise comparisons were typically below 50%. Because the prior classification approach yielded vegetation classes that were meaningful with respect to local plant community dynamics and were useful from a mapping standpoint, we used the same approach for the classification update. However, we made changes to increase plot sampling efficiency. The new plot sampling methodology better addressed plot-to-polygon scale issues, and improved characterization of underrepresented classes.

During the summer of 2017, we collected vegetation data on 333 plots to support the updated vegetation classification. Plots were selected according to a stratified random design using Geographic Information System (GIS) data layers including the previous vegetation map updated

with current wildland fire boundaries. Cover data were collected using point interception frames located along a 50 m transect within a conceptualized linear plot. We completed a quantitative classification using cover by species data from each plot. For the classification update, we compared eight classification methods using seven evaluators. The seven evaluators used to determine the most appropriate classification method were also used as criteria to assess the optimal number of clusters, or vegetation classes for that classification method. For both the model selection and evaluation of the optimal number of classes, we considered twenty-nine possible classification solutions.

We determined that beta-flexible ($\beta = -0.25$) was the best classification method and the optimal solution contained 16 clusters. The update to the classification resulted in 10 fewer classes than the prior classification. The reduction in the number of vegetation classes from the classification update is a consequence of some of the localized, patchy classes from the initial classification being enveloped into fewer, more comprehensive classes that are more interpretable at the targeted mapping scale. Therefore, the linear plot design did appear to yield a better overall classification, resulting in vegetation classes that were more reasonable for their intended use.

As with the results from the previous classification effort, we organized and interpreted the updated vegetation class list within the context of the National Vegetation Classification (NVC). The NVC is a hierarchical framework under which standardized vegetation classes, or species associations, are organized. Of the 16 vegetation classes identified in the INL Site classification update, 12 are natural vegetation classes and four are ruderal classes, or classes dominated by non-native species. Within the native classes, there was one woodland class, six shrubland classes, two shrub grasslands, and three grasslands. Within the ruderal classes, there was one shrubland, two grasslands, and a class characterized by mixed weedy forbs that tend to dominate areas with a specific hydrologic regime, namely playas. All the vegetation classes identified for the INL Site in the classification update were classified at hierarchical levels comparable to an Association in the NVC.

Objective 2 – Vegetation Class Delineations and Mapping

We used the 2017 Idaho National Agricultural Imaging Program (NAIP) color-infrared multispectral imagery as the primary base map layer for map delineations. The 2015 Idaho NAIP imagery was also utilized in regions where standing water was present in the 2017 imagery and obscured the ground. To assist with the vegetation class delineations, we calculated two vegetation indices (i.e. the Normalized Difference Vegetation Index and the Soil-adjusted Vegetation Index), as well as a statistical texture layer (i.e. 3x3 Range) from the baseman imagery. We also used ancillary GIS data layers (e.g. digital elevation model) during the image delineation process to help identify patterns on the landscape.

Based on previous mapping experience, we understood the limitations of applying automated image classification methods in a semi-arid sagebrush steppe environment and relied on manual photointerpretation of digital imagery directly within a GIS. The map delineations were produced through manual interpretation and digitizing at a 1:6,000 mapping scale using a suite of GIS editing tools.

After reviewing the vegetation class list resulting from statistical clustering, it was apparent that several vegetation classes were unlikely to be recognizable in multispectral imagery.

Consequently, there were two sets of the original 16 vegetation classes that were combined into a single map class resulting in a total of 14 map classes. To capture the fine-scale details of five non-vegetation classes (e.g. paved roads and borrow sources) and one agricultural class, we digitized at approximately a 1:2,000 mapping scale.

Once the map delineations were completed, we implemented spatial topology to perform the final Quality Assurance/Quality Control of the map polygons. Topology rules test whether polygons erroneously overlap one another or have small gaps between adjacent polygons that should share a common edge. We manually edited all vector errors and topology validation was rerun to verify all geometric errors were fixed.

The updated INL Site vegetation map contains 7,637 polygons, of which 7,265 (95.1%) represent vegetation classes. The remaining 372 (4.9%) polygons were assigned to non-vegetation special classes that accounted for only 30.3 km^2 (7,478.8 acres) of the total mapped area. The Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland class contained the largest amount of total area mapped with 851.2 km^2 (210,330.9 acres). The second largest class mapped was the Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland class with 570.8 km^2 (141,035 acres). The three largest map classes cover 73.2% of the vegetated area on the INL Site, suggesting the majority of vegetation communities are dominated by big sagebrush (*Artemisia tridentata*) or species most commonly associated with post-fire communities where big sagebrush was previously present.

The Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland class also had the greatest number of map polygons with 2,388 and an average polygon area of 0.36 km^2 (88.1 acres). The class containing the second largest number of polygons was the Cheatgrass Ruderal Grassland class with 1,435 polygons. However, the mean area of Cheatgrass Ruderal Grassland class was much smaller at 0.06 km^2 (15.9 acres) and many of the polygons mapped were isolated individual patches rather than larger contiguous areas.

Objective 3 – Vegetation Map Accuracy Assessment

During the summer of 2018, a total of 453 independent validation plots were collected and used to support the accuracy assessment of the final vegetation map. We used a standard error matrix to calculate map accuracy metrics including user's/producer's accuracy, overall accuracy and the Kappa statistic.

Initially, we maintained the two big sagebrush classes [i.e. Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland] as distinct classes that were each allocated the appropriate number of random field validation plots. However, upon reviewing two instances where independent field crews sampled the same plot location at different times, we found that field crews confused big sagebrush classes (i.e. Class 6 and Class 8) in both cases. Consequently, whenever either class was recorded in the field or assigned to map polygons, they were combined prior to the accuracy assessment calculations. Combining these two vegetation classes resulted in 13 total map classes considered for the accuracy assessment.

The accuracy assessment results showed an overall map accuracy of 77.3% and a Kappa value of 0.75. The map accuracy result values were higher than three of the four methods used to validate the previous vegetation map. The Kappa value is close to the 0.8 threshold which can be interpreted as strong agreement and is also higher than three of the four error matrix results from the previous vegetation map accuracy assessment.

The Juniper Woodland had the highest user's and producer's accuracy at 100% with no documented mapping errors. The map class with the next highest user's accuracy was the combined Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland class at 93.9%. There were five other classes that all had a user's accuracy above 80%. The second highest producer's accuracy was the Black Sagebrush Shrubland class at 94.7%. The Shadscale Saltbush – Winterfat Shrubland class was also very high with a producer's accuracy of 93.3%. There were four additional classes that had producer's accuracy above 80%.

List of Acronyms

AGL	Above Ground Level
APFO	Aerial Photography Field Office
ASW	Average Silhouette Width
BRDF	Bidirectional Reflectance Distribution Function
BLR	Big Lost River
CCA	Candidate Conservation Agreement
CFA	Central Facilities Area
CRMO	Craters of the Moon National Monument and Preserve
DEM	Digital Elevation Model
DOE	Department of Energy
ESER	Environmental Surveillance, Education, and Research Program
ESRI	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System
GPS	Global Positioning System
ISA	Indicator Species Analysis
INL Site	Idaho National Laboratory Site
LiDAR	Light Detection and Ranging
MCR	McClain Rao Index
NAIP	National Agricultural Imaging Program
NDVI	Normalized Difference Vegetation Index
NED	National Elevation Dataset
NPS	National Park Service
NRCS	Natural Resource Conservation Service

NVC	National Vegetation Classification
NVCS	United States National Vegetation Classification Standard
PARTANA	Partition Analysis Ratio
PAM	Partitioning Around Medoids
PBC	Point Biserial Correlation
SAVI	Soil-adjusted Vegetation Index
TNC	The Nature Conservancy
QA/QC	Quality Assurance/Quality Control
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

1.0 Introduction

1.1 INL Site Description and Background

The Idaho National Laboratory (INL) Site is located in southeast Idaho and occupies 2,300 km^2 (890 mi^2) including portions of five counties: Bingham, Bonneville, Butte, Clark and Jefferson (Figure 1-1). The INL Site is managed by the Department of Energy (DOE) and the original purpose for the facility was the design and testing of nuclear reactors. The INL Site now serves as a science-based, applied engineering national laboratory that supports the DOE missions in nuclear and energy research, science, and national defense.

The INL Site is positioned at the northern extent of the Great Basin and is characterized by cold desert sagebrush steppe vegetation. Over the past sixty years, plant communities on the INL Site have been classified into between eight and twenty-six distinct vegetation types (McBride et al. 1978, Anderson et al. 1996, Shive et al. 2011). Mean elevation of the INL Site is 1500 m (4921.3 ft). Surficial geology is strongly influenced by volcanic activity and soils include wind-blown sand or loess over basalt and a few alluvial deposits. Because soil movement patterns are influenced by abundant basalt outcrops and frequent windy conditions, transitions between soils types and textures may be quite abrupt.

Annual precipitation at the INL Site averages 207 mm (8.14 in), with May and June typically being the wettest months. Snow cover may persist from a few weeks to several months in the winter. Mean annual temperature for the INL Site (recorded at Central Facilities Area) is 5.7 °C (42°F); however, high diurnal and seasonal temperature fluctuations are normal (Clawson et al. 2018). Wind direction is predominately from the southwest, but changes to the northeast for a few early morning hours daily (Anderson and Inouye 2001; Clawson et al. 2018).

See Shive et al. (2011) for a more thorough and detailed discussion of the background of INL Site (Section 1.1), hydrography (Section 1.2), geomorphology (Section 1.3), soils (Section 1.4), climate (Section 1.5), principal lineament and fire history (Section 1.6), wildlife (Section 1.7), and vegetation (Section 1.8).

1.2 Rationale for Updating the Vegetation Map

The most recent vegetation map for the INL Site was based on vegetation classification data and imagery from 2008 (Shive et al. 2011). In terms of resolution, accuracy, and statistical rigor, this vegetation classification and map represented a substantial improvement over previous efforts to classify and map vegetation at the INL Site. Since its completion, the vegetation class descriptions and the map have been used extensively to support inventory and monitoring of ecological resources on the INL Site. Several of the monitoring and adaptive management tasks outlined in the Candidate Conservation Agreement (CCA) for Greater Sage-grouse (DOE and USFWS 2014), including assessment of the status of the habitat distribution trigger, require an accurate vegetation map. The vegetation map is also instrumental for identifying and prioritizing potential habitat for sensitive species, identifying restoration and/or weed control opportunities, and characterizing affected environments for National Environmental Policy Act analyses. Over the past decade, the vegetation class descriptions and map have become one of Environmental

Surveillance, Education, and Research (ESER) Program's most important datasets and they are used to support nearly every ecologically based task.

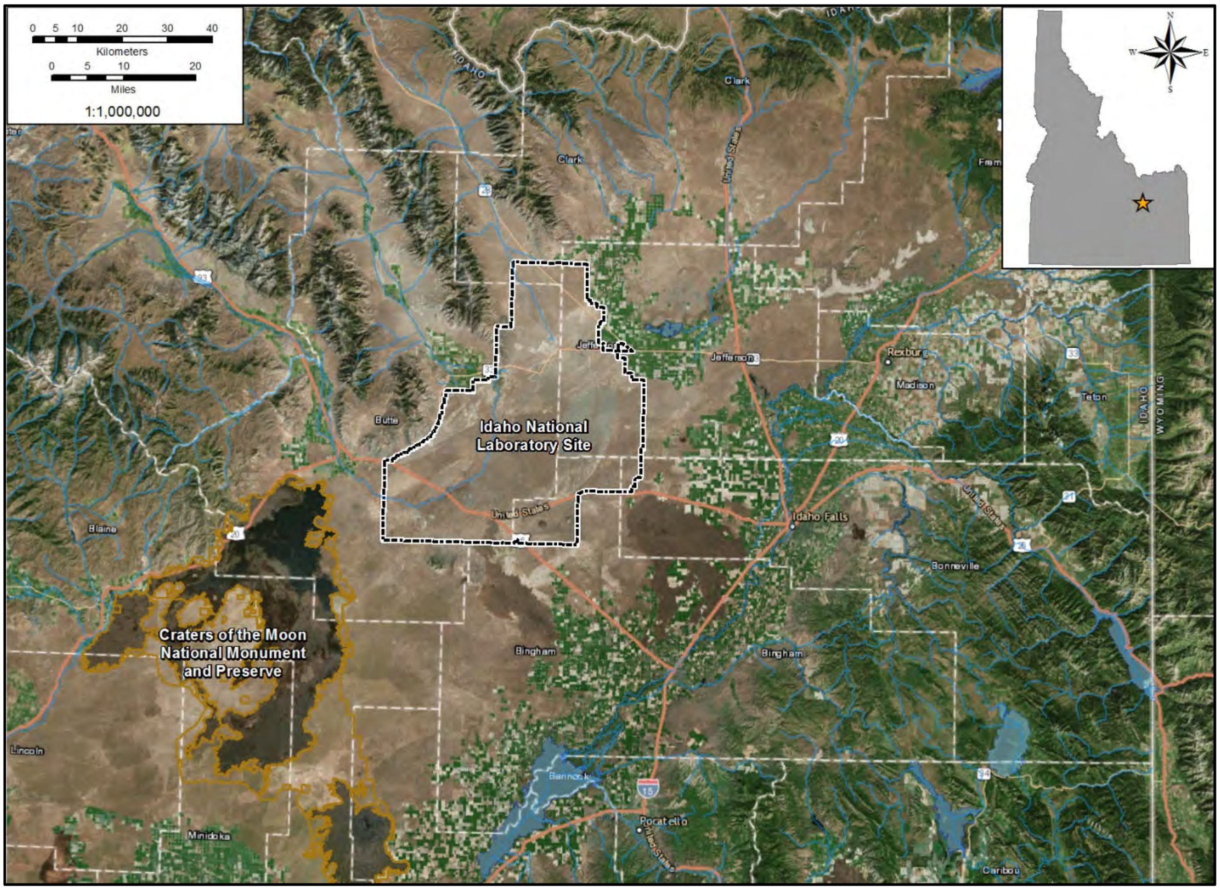

Figure 1-1. Map of southeast Idaho showing location of the Idaho National Laboratory Site, county boundaries, major roads and waterways, and the nearby Craters of the Moon National Monument and Preserve.

There were three factors that formed the basis for making updates to the existing vegetation map. First, there were four large wildland fires that burned from 2010-2012 and the previous vegetation map quickly became outdated in these regions. Second, there were numerous map polygons assigned to two-class complexes which listed the two main vegetation classes present within the polygon boundary. While this provided additional information for the map user, it also overestimated the area of some individual classes, and made it more difficult to directly target sampling or monitoring in one specific vegetation class. Finally, field observations across the INL Site, especially within recently burned areas, showed that vegetation communities have begun to shift in composition, and in some regions non-native annual grass and forb abundance has increased considerably.

These changes affect the way vegetation classes are defined and mapped across the INL Site and are an important consideration for all ESER tasks that utilize the vegetation class descriptions and the map. Because the vegetation class descriptions and map are so integral to the ESER

Program, it is important to update the classification and map periodically to ensure that both the vegetation classes identified on the INL Site and the mapped boundaries of those classes remain accurate.

1.2.1 Update Areas Burned from Wildland Fire

The most spatially discrete changes across the INL Site landscape since the completion of the last map were caused by four, relatively large wildland fires totaling 52,820 ha (130,521 acres). These fires altered vegetation communities on approximately 23% of the INL Site (Figure 1-2). The ESER Program conducted post-fire mapping within all four burned areas to delineate patches of unburned sagebrush and update the area and distribution estimate for the habitat baseline described in the CCA annual monitoring reports (Shurtliff et al. 2015, Shurtliff et al. 2016). However, new non-sagebrush vegetation class boundaries within the burned areas were unknown, requiring a new mapping effort to fully understand current vegetation patterns.

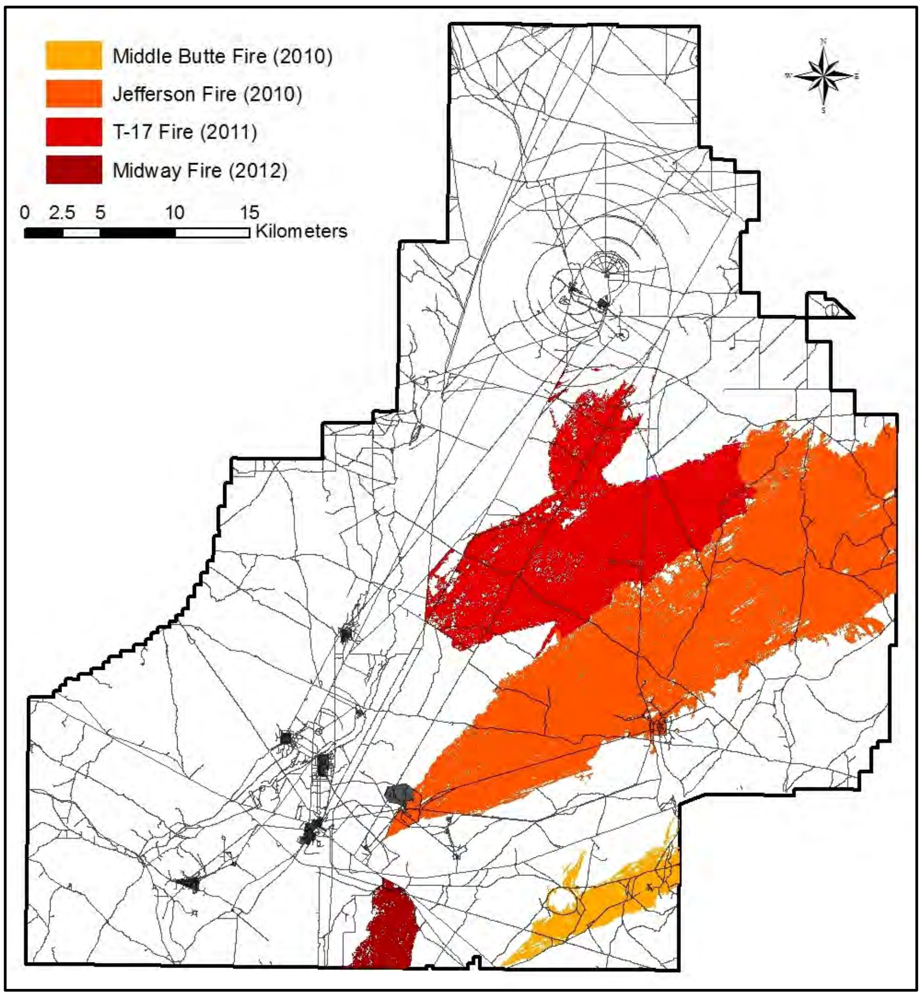

Figure 1-2. Major wildland fires that burned on the Idaho National Laboratory Site from 2010-2012.

1.2.2 Divide Two-Class Complexes

The Shive et al. (2011) vegetation map included map polygons assigned two class codes which were referred to as two-class complexes. For the map user, two-class complexes indicate that either of the two classes could be found as an isolated patch within a patchwork mosaic across the polygon or they were more evenly distributed across the polygon and the two classes gradually transition between one another. While the additional information of assigning two-class complexes can be valuable for some applications, there are times when one particular map class is identified for conservation planning or a project siting study. The ambiguity of not knowing which vegetation class may be present at a location of interest can add uncertainty which may not be acceptable for other applications. Vegetation classes of conservation value (e.g. sagebrush habitat) can also be estimated more accurately when polygons are assigned as single classes and previous two-class complexes are divided into their individual components.

1.2.3 Characterize Changes to Vegetation Communities

Field observations within recently burned areas showed highly variable results. Immediately after fire, native grassland and shrubland classes established, but an increased abundance of non-native annual grasses and forbs was also noted (Shurtliff et al. 2016, Shurtliff et al. 2017). On plots in burned and recovering habitat, non-native annuals, primarily cheatgrass, have increased markedly over the past six years (Shurtliff et al. 2019). There are also localized areas where Russian thistle (*Salsola kali*) increased in abundance and dominated areas such as low-lying playa basins after favorable precipitation events (Shurtliff et al. 2016).

Over the last ten years, the INL Site has experienced anomalous precipitation patterns where late summer and fall accumulations accounted for the majority of annual rainfall in most years (Shurtliff et al. 2019). Short-term precipitation patterns, which deviate from historical patterns of seasonality, favor some plant species and functional groups over others. Due to changes documented in ESER's annual vegetation monitoring data, a new vegetation classification is needed to update the vegetation classes defined on the INL Site and encompass any transitions occurring to the plant communities driven by both natural ecological processes and abiotic factors. In particular, the increasing abundance of non-natives warrants an updated classification that better defines classes dominated by annual grasses and forbs.

1.3 INL Site Vegetation Classification and Mapping Project Overview

The goal of updating the vegetation community classification and map is to develop a map reflective of current ground conditions and more spatially accurate distribution of plant communities on the INL Site. Our specific objectives are to:

- Characterize the vegetation community types present on the INL Site (see Chapter 2)
- Define the spatial distribution of those community types (see Chapter 3), and
- Conduct a quantitative accuracy assessment of the resulting map (see Chapter 4).

As with the previous classification and mapping effort, we followed the general process developed by the National Park Service (NPS) Vegetation Inventory Program (formerly known as U.S. Geological Survey-NPS Vegetation Mapping Program) for use in land management planning (U.S. Department of Interior, NPS 2009). This approach can be divided into two major project components: the plant community classification and the image delineation and mapping. Plant community classification entails multivariate analysis of applicable vegetation data sets, resulting in a statistically definable list of vegetation classes which can be interpreted within the context of the National Vegetation Classification Standard Association-level vegetation classes (FGDC 2008). The image delineation and mapping process consists of digitizing polygon boundaries using current digital color-infrared aerial imagery, several ancillary data layers, and image processing techniques to define areas of vegetation similarity. Products from each component are then reconciled by assigning vegetation community class names to each of the delineated polygons resulting in a comprehensive vegetation map. Once the vegetation map is completed, an independent accuracy assessment is conducted to evaluate the quality of the resulting map.

Our classification and mapping methods deviated slightly from our most recent previous effort and from the NPS Vegetation Inventory protocols, although the overall process was similar and the resulting data products are comparable with the vegetation classification and map recently completed at the neighboring Craters of the Moon National Monument and Preserve (Bell et al. 2009). Many of the primary processing steps do not differ from the NPS Vegetation Inventory Program approach, however; the specific analysis methods we followed for some tasks were modified. Because we were not constrained to defined protocols, we were able to explore novel statistical methods and improve upon the standard mapping approaches. The following chapters report on the methods and results from our classification analysis, mapping methods, and quantitative map accuracy assessment.

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2.0 Plant Community Classification

2.1 Introduction

An update to the vegetation classification is the first step in the process of updating the vegetation map for the Idaho National Laboratory (INL) Site. The primary objective of the plant community classification is to sample a representative range of plant communities across the INL Site and organize them into meaningful vegetation classes. Generally, vegetation classification is a process used to identify plant communities and/or vegetation classes by either designating communities in the field based on subjective interpretation of vegetation physiognomy and species composition, or by sorting field-sampled vegetation plots into groups based on compositional similarities. There are both non-quantitative and quantitative approaches to sorting and grouping vegetation plot data. Non-quantitative techniques, which include methods like relevé table-sorting (Braun-Blanquet, 1964), are not unlike field-based interpretations in that they are inherently subjective, and results can be difficult to reproduce. Quantitative categorization (i.e. cluster analysis) encompasses a large number of mathematical methods which allow for a more objective classification of vegetation data. Quantitative methods aren't entirely objective as the process is iterative and clustering results reflect the models, assumptions, and importance values chosen by the investigators. Quantitative approaches are, however, generally more objective, defensible, and repeatable than non-quantitative techniques.

The vegetation classification approach used for the 2008 classification effort relied heavily on quantitative methodologies (Shive et al 2011). A multivariate statistical approach that is consistent with, but more rigorous than the general approach recommended in the current National Park Service (NPS) guidance (Lea 2011) was used. Several classification methods were compared using multiple classification evaluators. Once the best classification method was identified, the classification evaluators were used as criteria to assess the optimal number of clusters for that classification method. Clusters with high beta diversity scores were further refined, or divided, using the same classification method and evaluator criteria. Good separation between vegetation classes can be difficult in areas like the INL Site where communities occur as a "continuously varying phenomenon, a consequence of the distribution and proportional abundances of individual species, rather than a mosaic of discrete 'types" (Anderson 1991). Given the inherent challenges of characterizing INL Site communities, the classification methodology worked very well; each class was readily defined by a few dominant or co-dominant species and similarity scores between vegetation class pairwise comparisons were typically below 50% (Shive et al. 2011).

Because the prior classification approach yielded vegetation classes that were meaningful with respect to local plant community dynamics and were useful from a mapping standpoint, we chose to use the same approach for the classification update. However, we used lessons learned from the previous effort to improve the process. Specifically, we improved plot-sampling efficiency, better addressed plot-to-polygon scale issues, and better characterized underrepresented classes.

As with the previous classification results, we organized and interpreted the updated vegetation class list within the context of the National Vegetation Classification (NVC). The NVC is a hierarchical framework under which standardized vegetation classes, or species associations, are organized. The upper levels of the hierarchy are defined by the general physiognomy and growth form of the dominant plant species, while the lower levels are defined by species compositions (Table 2-1). Ecological units which comprise several levels of the NVC hierarchy are cataloged and electronically available through the NatureServe (2017) database.

Table 2-1. Hierarchical levels of the National Vegetation Classification (reproduced from FGDC 2008).

Hierarchy Level	Criteria
Upper: Physiognomy plays a predominant role.	
L1 – Formation Class	Broad combinations of general dominant growth forms that are adapted to basic temperature (energy budget), moisture, and/or substrate or aquatic conditions.
L2 - Formation Subclass	Combinations of general dominant and diagnostic growth forms that reflect global macroclimatic factors driven primarily by latitude and continental position, or that reflect overriding substrate or aquatic conditions.
L3 – Formation	Combinations of dominant and diagnostic growth forms that reflect global macroclimatic factors as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions.
Middle: Both floristics and physiognomy play a significant role.	
L4 – Division	Combinations of dominant and diagnostic growth forms and a broad set of diagnostic plant taxa that reflect biogeographic differences in composition and continental differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.
L5 – Macrogroup	Combinations of moderate sets of diagnostic plant species and diagnostic growth forms that reflect biogeographic differences in composition and subcontinental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.
L6 – Group	Combinations of relatively narrow sets of diagnostic plant species (including dominants and co-dominants), broadly similar composition, and diagnostic growth forms that reflect biogeographic differences in composition and sub-continental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.
Lower: Floristics plays a predominant role.	
L7 – Alliance	Diagnostic species, including some from the dominant growth form or layer, and moderately similar composition that reflect regional to subregional climate substrates, hydrology, moisture/nutrient factors, and disturbance regimes.
L8 – Association	Diagnostic species, usually from multiple growth forms or layers, and more narrowly similar composition that reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes.

The NVC was developed by the Federal Geographic Data Committee (FGDC) to address the National Vegetation Classification Standard (NVCS; FGDC 1997, 2008), which represents an effort to improve coordination among federal agencies on programs and/or projects involving vegetation classifications and resulting vegetation type descriptions. It provides guidance for classification methodologies to be applied at a local scale and facilitates the successive refinement of the NVC. Cross walking the vegetation class list from the INL Site to the NVC, and following the same class naming conventions, allows for some consistency between the INL Site vegetation map and maps developed for other agencies. It also facilitates the interpretation of the vegetation classes described for the INL Site within the overall hierarchical framework of the NVC.

2.2 Methods

2.2.1 Study Design

Sample scale and plot size were a key concern for the study design of the classification update. Our intended mapping scale had been established at 1:6,000, but sampling plant communities at scales that were directly compatible with the mapping scale would be logistically impossible and potentially unreasonable in terms of the scale at which plant communities occur or are customarily defined. Also, of concern was the necessity of collecting statistically independent data which were sampled objectively, from as many plots as possible, while maintaining the ability to adequately characterize species composition and cover at each plot.

During the previous classification effort, we chose to use 20 m (65.6 ft) x 20 m (65.6 ft) plots as the fundamental sample unit. This plot size was within the range of sampling scales that had been used to characterize vegetation at the INL Site for several previous monitoring and research efforts and is not unreasonable for sampling plant communities in more general applications (Stohlgren 2007). The scale is also similar to that used by the NPS at other Southern Idaho Parks (e.g. Bell et al. 2009) and is at the upper end of plots sizes recommended for sampling shrub and shrub-steppe communities specifically for classifications to support mapping efforts (Environmental Systems Research Institute et al. 1994).

For the update to the classification, we considered using slightly larger plots to better define vegetation classes at the scale at which they occur across the landscape. During the previous classification effort, resulting plant communities were easy to recognize at the scale they were sampled but multiple classes often occurred as fine-scale patchwork mosaics within mapped polygons. This pattern of occurrence led us to assign vegetation classes to map polygons using a system of two-class complexes. To address this issue and to classify communities at a larger scale we changed the plot design to a rectangular plot. Rectangular plots are often favored over circular or square plots for general monitoring applications because they better capture the heterogeneity of the community being sampled (Elzinga et al. 1998). We further analyzed data collected to support the previous classification using circularity indices and concluded that using rectangular plots would overcome some of the fine-scale patchiness inherent to our earlier effort and allow us to classify plant communities at a larger scale that would be more meaningful for the updated map.

We ultimately decided to use a single, 50 m (164 ft) x 1 m (3.28 ft) transect line as a plot. Because there is some area associated with the transect, it is technically a plot and we refer to it as a linear plot, or simply plot, hereafter. This sample design captured as much heterogeneity of each plant community as possible, while maintaining a reasonable sampling effort at each linear plot. Although one of our goals was to increase the scale at which vegetation classes were defined, we also recognize the importance of reducing the ambiguity in the classification results. In order to reduce variability within vegetation classes and increase differentiation among vegetation classes, we chose to allow field crews to shift linear plot locations to areas that did not cross obvious gradients and were as representative of the surrounding plant community as possible. We acknowledged that vegetation classes resulting from this sampling approach would likely be somewhat idealized, but less so than the prior classification results. However, we argue this strategy resulted in more discrete cluster analysis, and, in turn, more easily distinguishable map classes and vegetation communities.

2.2.2 Sampling Methodology

We sampled each linear plot for absolute cover by species, photo plots and transect-scale photographs, Global Positioning System (GPS) position data, and categorical variables including class physiognomy, most abundant species in each growth form, and notes about the context of the plot within the landscape. A diagram of the layout and general sample design for the 50 m (164 ft) linear plot is shown in Figure 2-1 and the detailed sampling protocol, including all sampling directions used during the field sampling effort are included in Appendix A.

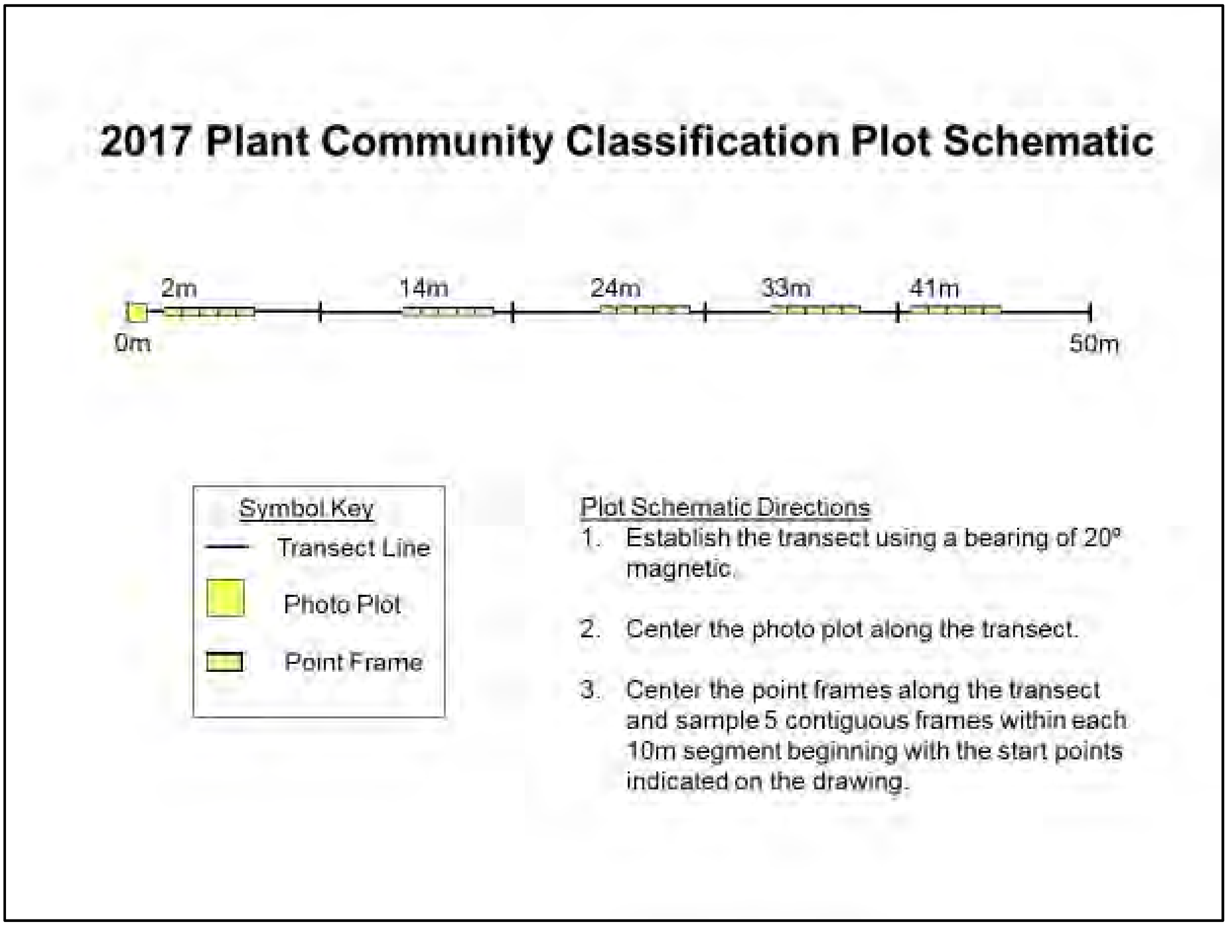

Figure 2-1. Diagram (not to scale) of the 50 m linear plot layout used to collect data during the 2017 field season to support a classification of plant communities on the Idaho National Laboratory Site.

Collection of cover data was the most important component of the entire sample design, as those data would be used as the input variables for the multivariate classification models. We chose a point-intercept sampling method described by Floyd and Anderson (1982), in which points are sighted using a 0.5 m (1.6 ft) x 1.0 m (3.3 ft) frame (henceforth referred to as "point sighting frame"). Thirty-six points are arranged on 10 cm centers and are sighted through two sets of crosshairs. Point sighting frames have been used on multiple vegetation monitoring and research projects over the past 25 years (e.g. Anderson and Forman 2002, Blew and Forman 2010, Forman et al. 2010, Forman and Hafla 2010) and are generally considered to be the most precise and cost-efficient quantitative sampling method commonly used at the INL Site (Blew and Forman 2010). Previous investigations on sampling effort and cover estimate precision using point sighting frames indicated that 20 to 30 frames were sufficient for characterizing all but the rarest species in a plot (Blew and Forman 2010). Because the objective guiding our data collection effort was to classify plant communities, which are most often defined by their dominant species, we determined that 25 point sighting frames per plot would be adequate, but we were aware that rare species may have been missed entirely.

Point sighting frames were located within each linear plot using a stratified random configuration. Each 50 m (164 ft) transect was divided into five 10 m (32.8 ft) segments and five-point sighting frames were located beginning at a random point within each 10 m (32.8 ft) segment. We used the same random start locations for all plots sampled. Point sighting frames were placed contiguously to address spatial autocorrelation issues. Halvorson et al. (1994) described a spatial pattern of about 2 m (6.6 ft) for sagebrush and associated resource islands in sagebrush steppe rangelands. Thus, individuals located within the range of spatial pattern of the community are likely to be sampled using a single point sighting frame. This potential autocorrelation issue is also of concern and has been addressed in line intercept sampling by ensuring the line is "long enough to include all phases of any mosaic pattern that may be present" (Greig-Smith 1983). Therefore, point sighting frames placed contiguously over 5 m (16.4 ft) should sufficiently overcome the spatial pattern described for sagebrush steppe.

Foliar cover rules were used for determining the number of "hits" by each species under the point sighting frame. There were two rationales for selecting foliar, rather that basal or aerial cover. First, we wanted our plot cover estimate to approximate the amount of "cover" detected by the sensor in the images used for polygon delineations. This would facilitate the use of the plot cover data as map "training data" to assist with the assignment of vegetation classes to delineated polygons. Second, while more stable and less sensitive to weather fluctuations, basal cover tends to underestimate the relative importance, or biomass, of grasses in a plant community (Bonham 1989). Our ability to characterize and describe the differences between grassland plant communities and shrubland plant communities was an essential component of our classification objective, which made accurately assessing the relative importance of grass and shrub species a critical factor for understanding the classification results.

We referred to the PLANTS National Database (USDA, NRCS 2017) as the taxonomic standard for species nomenclature during the data collection and classification process. Occasional departures from this standard reflect naming conventions from long-term vegetation research efforts at the INL Site. Site-specific identification and nomenclature conventions are described in Forman and Hafla (2005) and Forman et al. (2010).

2.2.3 Plot Site Selection

The plant community classification linear plot site selection process consisted of two primary steps. First, we calculated a landscape filter using a Geographic Information System (GIS) to identify potential sampling area across the INL Site. The purpose of the landscape filter is to remove all non-vegetated areas (e.g. facilities, landfills, etc.) and exclude areas adjacent to roads where plant communities may be affected by road proximity. After the total area of the INL Site was filtered to just regions where we could potentially sample vegetation plots, the second step was to select statistically valid plot locations within the potential sampling area.

Limiting the distance from roads to access sampling plots is a logistical consideration where we wanted to maximize sampling efficiency. This maximum distance from roads increased the number of plots we could sample per unit time and limited navigation time to remote plot locations. Given the known presence and approximate distribution of plant communities from the previous mapping effort (Shive et al. 2011), this sampling approach seemed reasonable and we were confident that unique plant communities would be missed solely due to chance, as opposed to systematic spatial bias. The landscape filter was produced using ArcGIS Geoprocessing tools. The *Multiple Ring Buffer* analysis tool in ArcGIS was applied to the most recently updated INL Site roads data layer. We selected a 100 m (328 ft) buffer to remove any road effects that may influence native vegetation, and an 1100 m (3,609 ft) buffer that defined the outer extent of the potential sampling area resulting in 1 km (0.62 mi) swaths adjacent to each access road. Lastly, the buffered polygons were clipped to the INL Site boundary to remove excess area outside of the INL Site.

Next, we removed all non-vegetation areas, which included borrow sources (e.g. gravel pits) and facility footprints, from the potential sampling area using the *Clip* geoprocessing tool (Figure 2-2). We used the official borrow source boundary rather than the excavated area visible in imagery because in most cases the area approved for excavation commonly extends beyond the current excavated area and those visual boundaries change frequently. We used the general facility footprint GIS data layer to remove potential area for sampling within facility boundaries.

Figure 2-2. The Idaho National Laboratory Site landscape filter used to identify potential sampling area for vegetation classification plots. All roads (paved and dirt two-tracks) were buffered by 100 m and 1100 m, and the area outside of the 1 km swath was removed. Borrow source pit boundaries as well as and general facility footprints representing non-vegetated areas were also removed.

Once the final potential sampling area layer was created, in was combined with the previous INL Site vegetation map using the *Spatial Join* function in ArcGIS. This step added the previously mapped vegetation class boundaries within the potential sampling area in preparation for site selection of plot locations.

Within the potential sample area, we used a guided approach, based on results from the previous classification and map, to determine how many plots will be required and how they should be distributed across the INL Site. There have been four large wildland fires that burned since the most recent INL Site vegetation map was completed and published (Shive et al. 2011). All the burned areas represent regions of the INL Site vegetation map that are no longer representative of the existing vegetation classes present on the ground. Consequently, we could not consider previous mapped vegetation class boundaries to assist with the site selection process within the burned areas. All wildland fire boundaries from 2010-2012 (i.e. all fires that burned since the vegetation map was published) were combined using the *Dissolve* geoprocessing tool. The combined wildland fire boundaries were then removed from the potential sampling area using the *Intersect* geoprocessing tool (Figure 2-3).

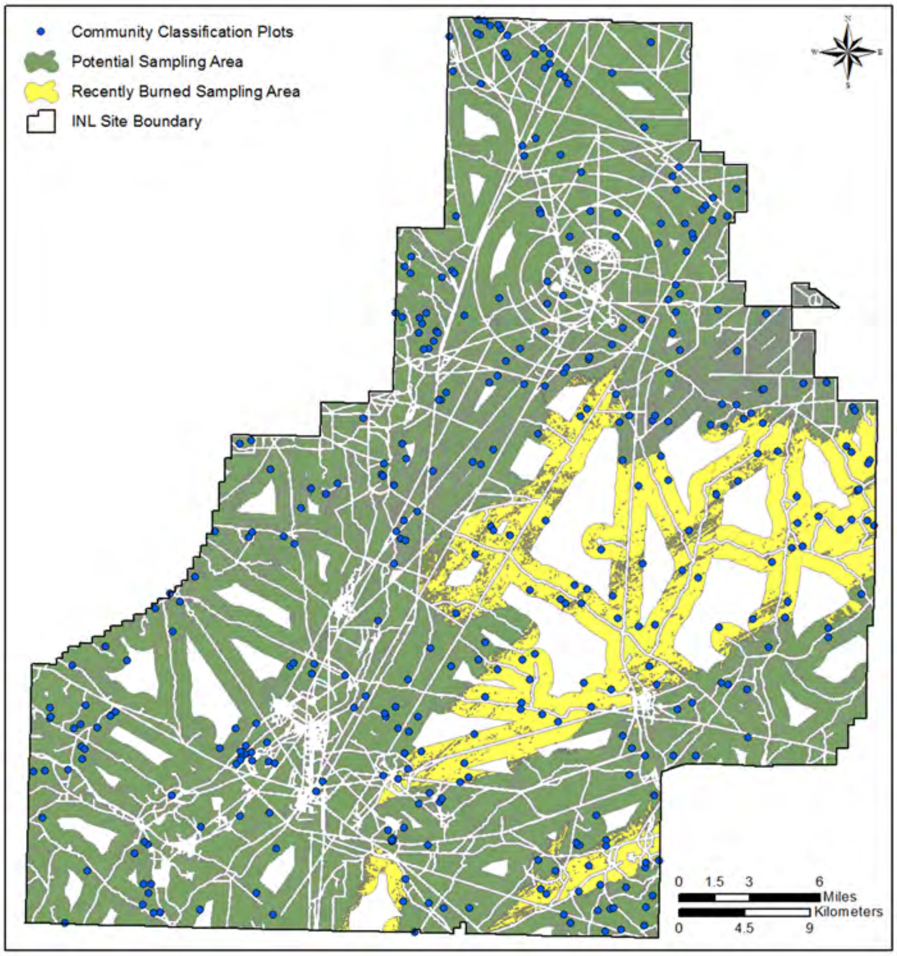

Figure 2-3. The distribution of 363 vegetation classification plot locations selected on the Idaho National Laboratory Site. Sampling plot locations were randomly selected within the recently burned sampling area and randomly stratified among existing mapped vegetation classes across the potential sampling area.

We allocated 75 plots within the recently burned sampling area to represent post-fire recovering communities (Figure 2-3). Because the current vegetation class boundaries are unknown within the recently burned area, we randomly selected the locations of all 75 plots. Previous fires in the region of the Site have shown native grasses and green rabbitbrush (*Chrysothamnus viscidiflorus*) dominating the plant communities after fire, and we considered this when selecting the appropriate number of plots within those vegetation classes outside the burned area (Table 2-2).

Within the unburned potential sampling area, we used a stratified random sampling scheme to select plot locations. Each of the previously defined vegetation classes (Shive et al. 2011) was reviewed to determine how well the community was characterized. We used species accumulation curves to determine which of the vegetation classes resulting from in the 2008 classification (Shive et al. 2011) were oversampled and which classes could be characterized better by increasing sample sizes. For all vegetation classes with adequate sample sizes, the species accumulation curve generally stabilized between eight and 15 plots. Therefore, we limited the number of plots to a maximum of 20 for all widespread vegetation classes that had adequate sample sizes during the previous classification effort. Sample sizes of spatially limited vegetation classes that we determined to be under sampled during the previous classification were increased by 50%. See Table 2-2 for the number of plots of each vegetation class targeted for sampling to support the classification update.

Table 2-2. Summary of the number of vegetation classification plots selected for each existing vegetation map class to support an updated vegetation classification for the Idaho National Laboratory Site.

Vegetation Class	# of Plots
Streambank Wheatgrass Herbaceous Vegetation/Western Wheatgrass Herbaceous Vegetation	20
Big Sagebrush Shrubland	20
Needle and Thread Herbaceous Vegetation	10
Green Rabbitbrush Shrubland	15
Green Rabbitbrush/Bluebunch Wheatgrass Shrub Herbaceous Vegetation	20
Green Rabbitbrush – Winterfat Shrubland	20
Basin Big Sagebrush Shrubland	20
Wyoming Big Sagebrush Shrubland	20
Crested Wheatgrass Semi-natural Herbaceous Vegetation	20
Bluebunch Wheatgrass – Sandberg Bluegrass Herbaceous Vegetation	18
Utah Juniper Wooded Shrub and Herbaceous Vegetation	12
Indian Ricegrass Herbaceous Vegetation	10
Cheatgrass Semi-natural Herbaceous Vegetation	16
Basin Wildrye Herbaceous Vegetation	7
Sickle Saltbush Dwarf Shrubland	7
Sandberg Bluegrass Herbaceous Vegetation	6
Black Sagebrush/Sandberg Bluegrass Dwarf-shrub Herbaceous Vegetation	12
Tall Tumblemustard – Cheatgrass Semi-natural Herbaceous Vegetation	10
Three-tip Sagebrush Shrubland	5
Low Sagebrush Dwarf Shrubland	10
Spiny Hopsage Shrubland	5
Shadscale Dwarf Shrubland	5
Unknown Burned Area	75

2.2.4 Analytical Approach

The analytical approach to classifying the vegetation cover data collected in 2017 is best described as a multi-step process. First, we identified the best classification model for describing the structure and pattern of species abundance and composition using the plot cover data. Next, we determined the optimal number of clusters, or vegetation classes, within the dataset. We calculated summary statistical descriptions for the classifications with the most optimal number of clusters and we described those clusters in terms of mean species cover and constancy. The classification solution was evaluated with regard to vegetation classes described in the previous classification and the Association-level vegetation types described in the NVC. We also evaluated several clusters within the classification to determine whether they should be further split. The process will be summarized here; however, a detailed description of the classification process is included in Appendix B.

In order to identify the best possible classification method given the general cluster structure of the INL Site data, we compared eight classification methods: **(1)** average linkage (Sokal and Michener 1958), **(2)** centroid linkage (Sokal and Michener 1958), **(3)** complete linkage (McQuitty 1960), **(4)** beta-flexible clustering (Lance and Williams 1967), **(5)** k-means analysis (MacQueen 1967), **(6)** partitioning around medoids, (i.e. PAM; Kauffman and Rousseeuw 1990), **(7)** single linkage (Sneath 1957), and **(8)** variance minimization linkage, (i.e. Ward's method; Ward 1963). PAM and k-means analysis are non-hierarchical methods while the other six are hierarchical agglomerative methods. We compared the eight methods using seven classification evaluators, five of which are geometric, and two of which are indicator species-based analyses. The classification evaluators we used for our analyses were: **(1)** indicator species analysis (ISA) number of significant indicators (Dufrêne and Legendre 1997; McCune and Grace 2002), **(2)** ISA average p-value (Dufrêne and Legendre 1997; McCune and Grace 2002), **(3)** C-index (Hubert and Levin 1976), **(4)** average silhouette width, (i.e. ASW; Rousseeuw 1987), **(5)** point biserial correlation, (i.e. PBC; Brogden 1949), **(6)** partition analysis ratio; (i.e. PARTANA; Roberts 2005, Aho et al. 2008), and **(7)** McClain Rao index (i.e. MCR; McClain and Rao 1975). We compared the eight classification methods with respect to their 29 simplest clustering solutions (i.e. 2 to 30 clusters) and made comparisons of methods for each evaluator.

The seven evaluators used to determine the most appropriate classification method were also used as criteria to assess the optimal number of clusters for that classification method. The geometric evaluators (ASW, C-index, PARTANA, PBC, and MCR) index classification effectiveness based on cluster compactness and distinctness in multivariate space (cf. Dale 1991). The non-geometric evaluators (ISA number of significant indicators, and ISA average p-value) measure classification effectiveness with respect to indicator species. For instance, a clustering solution in which a species occurs predominantly in one cluster while being absent from others indicates a "real" cluster structure from the perspective of that species (Aho et al. 2008). As with the initial model selection, we considered twenty-nine possible classification solutions.

We selected the "best" solution with respect to the optimal number of clusters and generated classification descriptions. Descriptions consist of relevé tables and conventional statistical summaries. Relevé tables were generated using the mean cover and constancy of each species within each cluster. Columns were sorted according to total big sagebrush (*Artemisia tridentata*) cover and rows were sorted according to species' fidelity (Aho 2006). Conventional statistical summaries included the following metrics for each component cluster; total number of transects, total cluster richness, mean transect richness, mean transect cover, mean Simpson's diversity (Simpson 1949), mean Shannon-Weiner diversity (MacArthur and MacArthur 1961), and beta diversity (Whittaker 1960).

Upon finalizing the classification, we generated a vegetation class list. We named plant communities according to the conventions outlined by the FGDC (2008), using constancy and mean cover as criteria to determine nominal taxa for each cluster or class. Generally, the species with the highest constancy and mean cover values were coincident within each cluster and only species having 100% constancy and cover within the top three or four mean values were used in the class name. A few of classes contained species having high mean cover values, but less than 100% constancy. When mean cover values of these species indicated they were likely co-dominants in the plant community, meaning cover values of these species approached or exceeded cover values of the next most dominant species having 100% constancy, we included these species in the class name.

In order to better describe the amount of similarity between the vegetation classes, we calculated the complement of the Bray-Cutis measure of dissimilarity (Bray and Curtis 1957) for each pairwise set of vegetation classes. The Bray-Curtis metric calculates similarity by comparing absolute cover values on a species by species basis for comparisons between each pair of vegetation classes (based on mean cover by species) and returns a proportional value between 0 and 1. A value of 0 indicates that the two vegetation classes have no species in common and a value of 1 indicates that the two vegetation classes are identical, containing the same species at the same mean absolute cover values for each species.

We developed a dichotomous key to INL Site vegetation classes, as they were defined by the final classification, using constancy and mean cover values for each class. Because specific ranges of cover values are difficult to estimate rapidly in the field, dichotomies in the key are driven by relative abundance concepts like; "dominant," "co-dominant," "abundant," "common," and "rare." While these concepts facilitate efficient data collection, they necessarily oversimplify the range of variability present in most plant communities. These generalizations result in plant communities defined by plots which are typical of the center of a cluster, and plots near the cluster periphery may "key" differently than they clustered in the classification analysis, especially for clusters with substantial overlap. We used the dichotomous key to assign plant communities observed in the field to previously delineated polygons (see Chapter 3) and to assign vegetation classes to plots sampled during independent map validation data collection (see Chapter 4).

We also used the classification results to generate fact sheets describing each vegetation class (Appendix D). Facts sheets include summary statistics detailing species composition and abundance within the class, as well as summary statistics on the abundance and distribution of the class across the INL Site. They also contain narrative descriptions of each class with additional information about the general physiognomy of the class and abiotic conditions associated with class occurrence.

2.3 Results and Discussion

2.3.1 Classification Results

From June through August 2017, we sampled 333 linear plots across the INL Site. About six weeks into the data collection, we began reviewing the number of plots sampled in each vegetation type using the qualitative data fields indicating the physiognomic class and most abundant species within each growth form at each plot sampled. Once we exceeded the number of linear plots, we had estimated to be optimal for characterization of a particular vegetation class, we discontinued sampling plots selected to target communities representing that class. Ultimately, we sampled fewer than the 363 plots originally selected, primarily because plots in the recently burned areas included classes that were already represented elsewhere. We also ensured the spatial plot distribution of each class type was adequate before discontinuing sampling of that vegetation class. We used cover values from all 333 plots the classification analyses.

In general, evaluators favored classification methods generating spherical clusters (i.e. average linkage, beta-flexible clustering (β = -0.25), complete linkage, PAM, and Ward) were favored by the evaluators. As a result, spherical cluster interpretation of the INL Site data (as opposed to a linear cluster interpretation) was deemed the most valid one. Beta-flexible clustering (β = -0.25) created the strongest classifications as it had the highest composite evaluator scores when considering all seven evaluators (Appendix B). This result is very similar to that of the classification completed in 2008, where beta-flexible clustering was also determined to be the best classification method. Because the dominant species and the general structure of the plant communities at the INL Site was unlikely to change drastically over the past decade, this result is not unexpected. We proceeded with classifying INL Site plant communities using the beta-flexible clustering.

The optimal clustering solution using beta-flexible clustering described 16 distinct clusters. Once we selected a final classification solution, we analyzed clusters to determine whether they could be further split, focusing on clusters with high beta diversity scores. Beta diversity scores were lower in the 2017 classification than they were in the 2008 classification and the range of beta diversity scores across the clusters was much narrower in 2017 (0.3 to 0.6) than in it was in 2008 (0.7 to 5.8). This result indicates that clusters from the 2017 classification represented a comparable range of variability when compare to one another and the clusters tended to be more consistently defined when compared to the 2008 classification. Overall the 2017 data yielded a better classification result that was less likely to benefit from additional splitting. Furthermore, the clusters from the 2017 classification with the highest beta diversity scores were also the clusters with some of the lowest plot numbers, which would preclude splitting of those classes.

A review of the relevé table (Appendix B) confirmed that all the vegetation classes represented by clusters in the 16-cluster solution were unique, and that few of the communities we had anticipated detecting were absent. The Bray-Curtis comparisons confirmed that there was reasonable separation between vegetation classes (Table 2-3); only one pairwise set of classes had an index value above 0.5. Given that most species are generalists and occur in most plant communities across the INL Site and only differ in the relative cover of each species across the landscape, this result was better than we had anticipated.

Table 2-3. Bray-Curtis similarity scores for all pairwise comparisons of 16 vegetation classes defined using classification analyses on cover data collected in 2017 across the Idaho National Laboratory Site.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	*	0.42	0.27	0.43	0.32	0.52	0.16	0.30	0.30	0.28	0.27	0.19	0.15	0.13	0.21	0.18
2	0.42	*	0.33	0.48	0.40	0.39	0.15	0.29	0.34	0.33	0.32	0.22	0.12	0.10	0.15	0.22
3	0.27	0.33	*	0.41	0.48	0.45	0.15	0.35	0.34	0.32	0.26	0.26	0.11	0.11	0.18	0.37
4	0.43	0.48	0.41	*	0.41	0.40	0.12	0.22	0.31	0.43	0.28	0.20	0.09	0.06	0.15	0.20
5	0.32	0.40	0.48	0.41	*	0.44	0.17	0.38	0.32	0.34	0.31	0.24	0.10	0.11	0.16	0.23
6	0.52	0.39	0.45	0.40	0.44	*	0.25	0.49	0.38	0.38	0.28	0.19	0.14	0.17	0.20	0.27
7	0.16	0.15	0.15	0.12	0.17	0.25	*	0.24	0.16	0.20	0.10	0.09	0.07	0.07	0.09	0.13
8	0.30	0.29	0.35	0.22	0.38	0.49	0.24	*	0.32	0.36	0.26	0.19	0.18	0.23	0.17	0.25
9	0.30	0.34	0.34	0.31	0.32	0.38	0.16	0.32	*	0.36	0.23	0.19	0.14	0.15	0.18	0.25
10	0.28	0.33	0.32	0.43	0.34	0.38	0.20	0.36	0.36	*	0.20	0.14	0.15	0.12	0.16	0.21
11	0.27	0.32	0.26	0.28	0.31	0.28	0.10	0.26	0.23	0.20	*	0.21	0.08	0.09	0.18	0.18
12	0.19	0.22	0.26	0.20	0.24	0.19	0.09	0.19	0.19	0.14	0.21	*	0.10	0.20	0.11	0.23
13	0.15	0.12	0.11	0.09	0.10	0.14	0.07	0.18	0.14	0.15	0.08	0.10	*	0.32	0.15	0.19
14	0.13	0.10	0.11	0.06	0.11	0.17	0.07	0.23	0.15	0.12	0.09	0.20	0.32	*	0.11	0.14
15	0.21	0.15	0.18	0.15	0.16	0.20	0.09	0.17	0.18	0.16	0.18	0.11	0.15	0.11	*	0.27
16	0.18	0.22	0.37	0.20	0.23	0.27	0.13	0.25	0.25	0.21	0.18	0.23	0.19	0.14	0.27	*

The 2008 classification initially resulted in 22 vegetation classes and some of those classes were further split, which led to a final list of 26 classes. The 2017 update to the classification resulted in 10 fewer classes (16 total). The reduced number of classes does not indicate a loss of vegetation types on the INL Site but reflects the change in sample design. The goal of changing our sample design was to minimize the likelihood of defining vegetation classes at a small, patchy scale that would not be useful for the mapping effort. Thus, the reduction in the number of vegetation classes from the classification update is a consequence of some of the localized, patchy classes from the initial classification being enveloped into fewer, more comprehensive classes that are more interpretable at our mapping scale. The linear plot design did appear to be effective at capturing more of the heterogeneity present within each vegetation class at a scale more reasonable for the intended use of the updated classification results. The change in sample design also yielded a better overall classification as evidenced by the beta diversity and Bray-Curtis scores. When compared to the 2008 classification, the results from the 2017 classification translated into a simpler and more straightforward dichotomous key as well (Appendix C).

2.3.2 Vegetation Class Descriptions

The updated classification resulted in 16 vegetation classes for the INL Site. The class list, with class names assigned according to NVCS (FGDC 2008) conventions, is presented in Table 2-4. Of the 16 vegetation classes identified in the INL Site classification update, 12 are natural vegetation classes and four are ruderal classes, or classes dominated by non-native species. Within the native classes, there was one woodland class, six shrubland classes, two shrub grasslands, and three grasslands. Within the ruderal classes, there was one shrubland, two grasslands, and a class characterized by mixed weedy forbs that tend to dominate areas with a specific hydrologic regime, namely playas. All the vegetation classes identified for the INL Site in the classification update were classified at hierarchical levels comparable to an Association in the NVC (NatureServe 2017).

Table 2-4. Sixteen vegetation classes identified for the Idaho National Laboratory Site using cluster analyses. Classes are based on cover data from 333 plots sampled in 2017. Class naming conventions follow those outlined by the Federal Geographic Data Committee (2008).

Cluster #	Scientific Class Name	Colloquial Class Name	# of Plots
1	*Chrysothamnus viscidiflorus* / *Poa secunda* - *Pseudoroegneria spicata* Shrub Grassland	Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland	38
2	*Bromus tectorum* Ruderal Grassland	Cheatgrass Ruderal Grassland	50
3	*Chrysothamnus viscidiflorus* / *Elymus lanceolatus* Shrub Grassland	Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland	36
4	*Chrysothamnus viscidiflorus* / *Alyssum desertorum* (*Bromus tectorum*) Ruderal Shrubland	Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland	37
5	*Hesperostipa comata* Grassland	Needle and Thread Grassland	22
6	*Artemisia tridentata* - *Chrysothamnus viscidiflorus* (*Artemisia tripartita*) Shrubland	Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland	21
7	*Agropyron cristatum* Ruderal Grassland	Crested Wheatgrass Ruderal Grassland	25
8	*Artemisia tridentata* Shrubland	Big Sagebrush Shrubland	28
9	*Pascopyrum smithii* Grassland	Western Wheatgrass Grassland	17
10	(*Leymus cinereus*) - Mixed Mustards Infrequently Inundated Playa/Streambed	(Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed	12
11	*Juniperus osteosperma* Woodland	Juniper Woodland	11
12	*Achnatherum hymenoides* Grassland	Indian Ricegrass Grassland	4
13	*Atriplex confertifolia* - *Krascheninnikovia lanata* Shrubland	Shadscale Saltbush – Winterfat Shrubland	7
14	*Atriplex gardneri* (*Krascheninnikovia lanata*) Shrubland	Gardner's Saltbush (Winterfat) Shrubland	8
15	*Artemisia nova* Shrubland	Black Sagebrush Shrubland	8
16	*Artemisia arbuscula* Shrubland	Low Sagebrush Shrubland	9

Utah juniper (*Juniperus osteosperma*) was the dominant tree species in the woodland class. Many of the shrubland and shrub grassland classes were dominated by big sagebrush and/or green rabbitbrush. Black sagebrush (*Artemisia nova*) and low sagebrush (*Artemisia arbuscula*) each dominated a shrubland class, but the sample sizes of plots representing those classes were relatively small for each of the clusters, likely because they are somewhat restricted in their size and spatial extent. Shadscale saltbush (*Atriplex confertifolia*) and Gardner's saltbush (*Atriplex gardneri*) each co-dominated a class with winterfat (*Krascheninnikovia lanata*); these classes were also limited in distribution and had low sample sizes. Dominant species characterizing the herbaceous plant communities included; needle and thread (*Hesperostipa comata*), western wheatgrass (*Pascopyrum smithii*), and Indian ricegrass (*Achnatherum hymenoides*). Crested wheatgrass (*Agropyron cristatum*), cheatgrass (*Bromus tectorum*), and introduced mustard species (*Sisymbrium altissimum*, *Descurainia* spp., *Alyssum desertorum*) dominated the four ruderal vegetation types. Great Basin wildrye (*Leymus cinereus*) historically dominated playas and streambeds on the INL Site, but these communities have shifted to dominance by introduced mustards, so this class was also characterized as a ruderal class. Narrative descriptions and summary statistics for each vegetation class can be found in the individual class fact sheets (Appendix D).

Compared to the previous classification, we were able to crosswalk our updated vegetation classes to NVC Association-level classes much more directly. This was largely due to substantial improvements in the NVC (NatureServe 2017) over the past decade. Many NVC Associations were refined over the past several years and many additional Associations have been added, especially the less common natural classes and the ruderal classes. The NVC ruderal classes were generally only defined at the Alliance level in 2008 and are now characterized at the Association level. These improvements were useful for the updated classification because a greater proportion of the plots clustered into to ruderal classes in 2017 than in 2008.

Changes in the vegetation class structure from 2008 to 2017 represents a shift to fewer, more generally characterized classes. Two Utah juniper dominated classes for the 2008 classification are now represented by one class with a wider range of Utah juniper cover. Three big sagebrush classes that differentiated between big sagebrush subspecies were resolved in two classes in the 2017 classification. Several narrowly defined natural herbaceous classes are now included in green rabbitbrush shrub grasslands and a few very localized communities with an abundance of spiny hopsage (*Grayia spinosa*) and dwarf goldenbush (*Ericameria nana*) were enveloped into big sagebrush or green rabbitbrush vegetation classes, depending on the co-dominant shrub. The only previously identified class that was not directly subsumed by another class in the classification update was one dominated by winterfat. Communities with an abundance of winterfat are now split among several vegetation classes depending on which shrub species co-dominates the community.

In total, 63% of the plots classified to one of the 12 native vegetation classes. Of the natural shrublands, the two classes dominated or co-dominated by big sagebrush had the greatest number of plots (15%). The natural shrub grasslands comprised about 22% of the sample and were generally dominated by green rabbitbrush with an abundance of understory grasses. The natural grassland with greatest sample size was (5) Needle and Thread Grassland; the three natural grassland classes combined represented about 13% of the plots sampled. The (11) Juniper Woodland class, saltbush classes and dwarf sagebrush classes were each characterized by fewer plots than many classes, but that was to be expected because those classes occur in a more limited distribution across the INL Site.

The class from the updated classification with the greatest number of plots was the (2) Cheatgrass Ruderal Grassland. In fact, 124 of the 333 plots sampled (37%) classified to one of the four ruderal vegetation classes. When compare to the prior classification, the relatively large number of plots that clustered to ruderal classes, green rabbitbrush shrub grasslands, and grasslands, reflects fire activity and a related increase in dominance by non-natives over the past decade. In additional to wildland fire, shifts in precipitation may also play a role in the increasing dominance by non-natives on the INL Site (Forman and Hafla 2018).

3.0 Vegetation Class Mapping

3.1 Introduction

Remote sensing technology has played an integral role in mapping the environment, specifically land cover, across various spatial and temporal scales for decades (Townshend 1992). Results from early vegetation mapping studies were visually attractive and generally assumed to be correct because the maps depicted reasonable patterns and distribution of land cover classes (Dicks and Lo 1990). Even though map classification accuracy was only qualitatively evaluated; the ability to map large extents without the logistical constraints of sending field crews to collect large quantities of field data in remote areas was quickly embraced by many scientists and land managers.

As mapping accuracy assessments shifted from qualitative assessments to quantitative methods it became apparent that most land cover maps did not achieve the mapping accuracies expected, and in many cases were below acceptable levels for management applications (Foody 2002). Even as technology continued to improve and sensors began collecting more spectral bands (i.e. hyperspectral imagery), it was recognized that certain vegetation types or land cover classes can be difficult to map accurately because the spectral similarities in imagery (Okin et al. 2001). Image classification of vegetation classes can be challenging in many environments, but arid and semi-arid regions are particularly difficult and known to pose additional mapping problems (Huete 1988, Vanselow and Samimi 2014).

Automated classification and mapping have become the standard for most image analysis projects and this approach has numerous advantages over traditional photointerpretation techniques. Automated classifications are unbiased and not significantly influenced by the experience of the image analyst, repeatable given similar types of image datasets, and can also be applied to very large images over broad regions. One of the underlying assumptions behind automated classification algorithms is each intended map class is spectrally determinate, meaning each vegetation class has a unique reflectance pattern that does not match or substantially overlap other vegetation classes. This assumption is generally not realistic for most environments and particularly sagebrush steppe semi-arid landscapes where different vegetation communities can appear spectrally similar (Okin et al. 2001).

Vegetation communities in arid environments tend to have low absolute vegetative cover values, commonly less than 50% (Okin et al. 2015). Because the area of exposed bare ground can exceed the total vegetative cover within any given extent, the sensor records more spectral information from the ground rather than the plants growing on the surface. In these environments, the image data more likely depict patterns of surface characteristics and soil types rather than vegetation communities. Thus, low vegetative cover values diminish the suitability of automated classification algorithms to accurately map vegetation communities distributed across similar soil types (Bayless-Edwards 2019).

The potential shortcomings of automated pixel-based classification algorithms in a sagebrush steppe environment suggest an alternative approach is needed to produce accurate vegetation class boundaries. Long before digital image datasets were available and automated classification algorithms were developed, image analysts relied on traditional aerial photograph interpretation to map the environment. An image analyst intuitively considers variables other than pixel value including; location, size, shape, shadow, tone/color, texture, and pattern (Jensen 2000). More recent advances in automated classification algorithms are now focused on object-oriented classifications that intend to utilize these spatial and contextual variables in an automated strategy. Nonetheless, computer software cannot currently reproduce complex human reasoning and the intuitive interpretation process an analyst utilizes when delineating features in an image.

Manual delineations have several advantages over automated methods and may serve conservation and management needs better, particularly on the INL Site. Commonly, a GIS Analyst can see a physical boundary in remote sensing imagery, but it becomes difficult to attempt to "train" an algorithm to detect the same edge. The image analyst can rely on contextual cues such as proximity to other resources or vegetation types, shape, size, or a broad scale pattern that becomes lost at the individual pixel level. Manual delineations generate a vector-based map of sinuous polygons even though the base map is comprised of square pixels. Traditional pixel-based image classification results in a per pixel designation that can appear in a salt-and-pepper distribution where pixels of multiple vegetation classes can be present within a very small area. One of the primary uses of the vegetation map is to document the current distribution of sagebrush habitat to support the Candidate Conservation Agreement (CCA; DOE and USFWS 2014). Polygons representing sagebrush habitat can easily be combined into a single GIS layer used for conservation planning and management, whereas a scattering of pixels that are not always adjacent to one another creates a more difficult challenge for managing a patchwork mosaic of habitat.

There are also some drawbacks to manual delineations making this traditional approach less attractive for more modern applications. First, depending on the size of the study area manual delineations can take significantly more time to complete compared to automated approaches. Secondly, a manual mapping approach relies on the mapping experience, familiarity with vegetation types in imagery, and bias of the individual performing the delineations. This method can also be criticized for the lack of repeatability compared to an automated method.

We understood the possible limitations of automated classification methods and decided to employ manual photointerpretation of the digital imagery directly within a GIS framework. This approach provides other advantages over traditional methods, such as the capability to overlay additional image datasets and ancillary GIS data layers to help identify vegetation class boundaries. Map delineations are also automatically georeferenced to a coordinate system while digitizing boundaries. A GIS provides a suite of vector editing tools that allow for quick spatial adjustments to delineations, and we can also implement polygon topology rule sets to perform Quality Assurance/Quality Control (QA/QC) of the delineations to ensure spatial accuracy.

3.2 Methods

3.2.1 Digital Imagery

The U.S. Department of Agriculture operated the National Agricultural Imaging Program (NAIP) that collects high spatial resolution digital imagery across each state on a 2-5-year return interval. These image datasets are made publicly available and can be downloaded for free as compressed county mosaics or as uncompressed 3.75' x 3.75' quarter quadrangles. Imagery is scheduled for collection to coincide with agricultural peak growing season which occurs in middle to late summer in Idaho.

The 2017 Idaho NAIP digital imagery was collected at a nominal ground sample distance of 40cm using nine Cessna 441, one Reims F406, one Piper, and one Merlin aircraft flying at an average flight height of 8400 m above ground level (AGL) for the SH120 acquisition and 4400 m AGL for SH100 acquisition. Aircraft flew with Leica Geosystem's ADS100/SH100 digital sensors with firmware 4.57 or ADS100/SH120 digital sensors with firmware 4.57 (USDA-FSA-APFO 2018).

The NAIP image dataset is multispectral with four spectral bands including three covering the visible region of the electromagnetic spectrum, and an additional band in the near-infrared region. The ADS100 spectral ranges are; Red 619-651 nm, Green 525-585 nm, Blue 435-495 nm and Near-infrared at 808-882 nm. The raw image data are orthorectified using 10 m USGS National Elevation Dataset (NED) Digital Elevation Model (DEM). The Xpro orthorectification software was used to apply an atmospheric-BRDF radiometric correction to the imagery. This correction compensates for atmospheric absorption, solar illumination angle and bi-directional reflectance (USDA-FSA-APFO Aerial Photography Field Office 2018). The spatial resolution of the 2017 Idaho NAIP dataset is 1 m and the pixel values are delivered with an 8-bit (e.g. 0-255) radiometric resolution. The image data are georeferenced to the North American Datum 1983 and Universal Transverse Mercator Zone 12N projection.

The 2017 Idaho NAIP was the primary base map imagery used to update the vegetation map delineations, however the 2015 Idaho NAIP was also used to help interpret vegetation class distributions that can vary annually and to reconcile boundaries in regions covered by water in the 2017 imagery (e.g. Big Lost River [BLR] Sinks; Figure 3-1).

3.2.2 Image-Derived Data Layers

There have been a variety of vegetation indices developed specifically for identifying vegetation distributions from remotely sensed data (Jensen 2000). We calculated two common vegetation indices to help highlight and assist with the interpretation of vegetation class boundaries. The most common vegetation index used today is the Normalized Difference Vegetation Index (NDVI; Rouse et al. 1974). A second commonly used vegetation index is the Soil-adjusted Vegetation Index (SAVI; Huete 1988). The SAVI is designed to improve NDVI results in regions with large proportions of exposed bare ground and attempts to remove soil-plant interactions by including a soil calibration factor. Both vegetation indices were calculated using Environmental Systems Research Institute (ESRI) ArcGIS® Image Analysis tools.

The previous vegetation mapping project incorporated spatial texture data layers to assist with the delineation process (Shive et al. 2011). The texture layers were calculated using block statistics from square moving window that progressively moves across each image pixel in the dataset. Initially we evaluated a variety of different statistical measures and window sizes and found the 3x3 window size and range statistics to be most useful to help accentuate edges and general vegetation patterns across the landscape that are less evident in the raw imagery. We calculated this spatial texture layer for the 2017 imagery and incorporated the data layer into the delineation process.

3.2.3 Ancillary GIS Data Layers

Vegetation distribution patterns across a landscape tend to follow appropriate soils types. While a GIS soils data layer for the INL Site exists (Olson et al. 1995), those data were not specifically produced for the INL based on field studies and have been almost entirely interpolated from adjacent Idaho counties occasionally creating abrupt soil type transitions. Consequently, these data layers were of little use helping define vegetation class boundaries.

Topography can also influence patterns of vegetation distribution because aspect affects the amount of incoming solar radiation a community receives and can serve as a surrogate for soil moisture. We used a 10 m resolution USGS NED DEM mosaic and calculated raster layers for Slope, Aspect, and Hillshade (i.e. artificial topographic shading) using topographic modeling tools from the ArcGIS Spatial Analyst® extension. There were some instances where broad topographic relief corresponded to vegetation class boundaries, and where possible we considered topographic contours to help identify vegetation map class boundaries.

The most recent INL Site vegetation map data layer (Shive et. al 2011) provided a good starting point for making map updates. Although the current vegetation map classes are slightly different than the classes defined previously, many map classes in the existing vegetation map cross walked directly with the statistical classification results described in Chapter 2 and Appendix C. Aside from changes on the landscape caused by wildland fire, we have observed some vegetation community's composition starting to transition to a state where non-native species are becoming more prevalent, and in particular, recovering post-fire vegetation communities are beginning to show signs of increased cheatgrass (*Bromus tectorum*) presence and abundance. The previous vegetation map has been periodically updated following wildland fire to support the CCA's goal of monitoring sagebrush habitat (DOE and USFWS 2014, Shurtliff et al. 2015, Shurtliff et al. 2016), but the recovering vegetation class boundaries have not been updated. We have conducted post-fire vegetation surveys in areas recently burned, and those field data were also considered when we updated map class boundaries.

3.2.4 Image Delineations

The previous vegetation map was manually digitized at a 1:12,000 scale which was chosen to maintain consistency with regional mapping efforts at the nearby Craters of the Moon National Monument and Preserve under the National Park Service (NPS) Vegetation Inventory Program. Before we initiated mapping updates, we decided to increase the mapping scale to 1:6,000 to more adequately delineate fine-scale features and changes occurring on the INL Site. We have recently mapped unburned sagebrush patches following wildland fire at a scale around 1:2,000 (Shurtliff et al. 2015, Shurtliff et al. 2016), and increasing the mapping scale for the vegetation map update will enable the more accurate documentation of sagebrush habitat distribution on the INL Site for CCA conservation considerations.

The manual interpretation process resembles traditional photointerpretation mapping methods, but we digitized polygon boundaries directly within a GIS. Working in a GIS allows vector polygons to be managed within a georeferenced and topological environment. The manual delineation process consisted of toggling between NAIP image datasets, and image-derived data layers, to identify vegetation class boundaries. We initially developed visual associations between known vegetation classes on the ground and their corresponding spectral signatures in the imagery. In some areas the distinct vegetation class boundary was not obvious, and we manually adjusted the image display stretch in local regions to accentuate edges or contrast.

Once a boundary was visually identified by an analyst, we manually digitized polygons using tools from the ArcGIS and ArcPro Editor Toolbar. We manually digitized vegetation patch boundaries using the *Sketch Tool* to create new features. When two features shared an adjacent edge, we used the *Trace Tool* with snapping enabled to maintain topology between polygons.

In 2017 and 2018, there was an uncharacteristically large amount of water flowing onto the Site that filled the BLR Sinks and most of Spreading Areas A and B. The 2017 NAIP imagery captured the extent of standing water when the imagery was collected which made it impossible to see the vegetation growing in these areas. We relied on the 2015 NAIP imagery to understand the vegetation class patterns obscured by water in the 2017 NAIP imagery. Fortunately, the majority of area where water was pooled was assigned to a single map class in the BLR Sinks and a single map class in the Spreading Areas (i.e. in addition to the gravel pit/borrow source boundaries). Ultimately, the presence of water in the 2017 NAIP imagery did not impact the mapping process or cause any delineation issues.

There were five non-vegetation classes and one agricultural class we digitized at a finer 1:2,000 scale to capture the details of those features. Anthropogenic features (e.g. paved roads and facilities) and regions of surface disturbance characterized by little vegetative cover (e.g. gravel and borrow pits) are widespread throughout the INL Site, although these features encompass a small total area. The vegetation map data has supported a number of ongoing and potential future monitoring and research projects on the INL Site, and we wanted to make sure anthropogenic features are excluded from the actual vegetation polygons where they could negatively impact other studies (e.g. site selection) or obstruct field crews from navigating in the field (e.g. BLR channel). Below is a summary of the special feature classes which were pre-defined and mapped but not identified as part of the vegetation classification effort or evaluated for mapping accuracy.

Facilities - This map class represents all the major active Site facilities that contain large buildings, warehouses, cooling towers, etc. Examples are the Materials and Fuels Complex and the Central Facilities Area (CFA). This map class also includes decommissioned facilities as well as minor infrastructure or new project footprints where anthropogenic structures are present. Examples of minor infrastructure include the National Security Test Range and CFA main gun range.

Agriculture - The INL Site is bordered by agricultural fields along the northeast edge of the Site and also along the west-central boundary. Along the agricultural interface, there are areas where agricultural field have expanded and now overlap the INL Site boundary slightly. Even though the Agriculture map class is actually vegetation, it does not represent a natural community present on the INL Site and is denoted with a special feature class code.

Big Lost River Channel - The BLR enters the INL Site from the southwest and flows north past CFA and Idaho Nuclear Technology & Engineering Center ending at an ephemeral wetland known as the BLR Sinks. The BLR channel is small in width (approximately 10-20 m [32.8-65.6 ft] wide) and proved difficult to accurately delineate at a 1:6,000 scale. The BLR channel is a unique feature on the INL Site, and although it doesn't contain water annually, it makes sense to remove it from vegetation polygons.

Borrow Sources/Disturbed - This map class represents the INL Site active and inactive borrow sources and gravel pits. We identified these locations from the most recent GIS data layer and used the approved pit boundary rather than the currently excavated area. The last vegetation map digitized only the excavated area which required periodic updates when further excavations occurred. Knowing that ultimately the entire pit boundary will likely be excavated, we wanted to completely remove that area from mapped vegetation classes. There are numerous small road-side borrow sources along the State and Federal Highways also included in this special map class, in addition to areas where recent surface disturbance has removed vegetation (e.g., water trough installation within grazing allotments).

Exposed Rock/Cinder - This map class consists of areas where exposed rock and cinder are present, and vegetation is absent or has extremely low cover. The class is primarily located on Middle Butte and also includes some smaller spots where previous pits or borrow sources were capped with basalt rocks.

Paved Roads - This map class includes paved roads within the secure area of the INL Site as well as State and Federal Highway systems that bisect the INL Site. This map layer does not include any gravel or two-track T-roads present throughout the INL Site.

3.2.5 Assigning Mapped Polygons to Vegetation Classes

Once the vegetation class delineations were completed, the next step was to assign each map polygon to a vegetation class. Typically ground data are used to help train automated algorithms or assist with assigning vegetation classes to mapped polygons. The field data collected to support the plant community classification were limited because the goal was to collect fine scale quantitative cover data and not to provide widespread training data to assist with the mapping portion of the project. We relied on the previous vegetation map as general guide to vegetation class presence and distribution. We also incorporated field data collected across areas that have burned since 2010 to better understand how vegetation communities have changed and established in the years following fire (Shurtliff et al. 2016).

After reviewing the vegetation class list resulting from statistical clustering (Table 2-4), it was apparent that several classes were unlikely to be partitioned in multispectral imagery. Previous vegetation mapping experience on the INL Site has shown that many native grass communities appear spectrally similar in the four-band multispectral imagery (Shive et al. 2011). Even in shrubland communities where the understory is comprised of different assemblages of native communities, many times the spectral response in these areas are indistinguishable even when the dominant grass species changes. Consequently, there were two sets of the original 16 vegetation classes that were combined into a single map class resulting in a total of 14 map classes. The first set of vegetation classes combined into a single map class were the (3) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and the (5) Needle and Thread Grassland classes. This map class combination generally represents communities that establish following wildland fire. There was a lot of overlap between the cover and species composition in these two vegetation classes and needle and thread grass tends to be very common throughout most post-fire vegetation communities. The second set of vegetation classes combined were the (12) Indian

Ricegrass Grassland and (14) Gardner's Saltbush (Winterfat) Shrubland classes. Indian ricegrass is a species commonly found within (14) Gardner's Saltbush (Winterfat) Shrubland communities and is difficult to differentiate in imagery. Because these two classes tend to co-occur spatially and have similar species composition and relative cover, it made sense to combine them into a single map class (see Table 2-3).

We used a special class designation in the previous vegetation map to denote when specific vegetation class polygons were severely degraded and did not represent the typical class composition or description. Using the dichotomous key in these areas will be difficult and vegetation class selection would have to be forced as there will be nodes in the key where neither option is suitable. We maintained the 'Degraded' designation in only two map polygons for the updated map and they are identified in the GIS data layer with an asterisk inserted after the map class code.

3.2.6 Final Map Polygon Quality Control

Once we completed the final edits and revisions to the map polygons, we implemented two quality control measures to help eliminate any errors in the dataset. First, we queried the map class code in the geodatabase and reviewed the general distribution of each class to visually verify vegetation classes didn't plot in obviously wrong locations (e.g. juniper woodland plotting in the center of the INL Site). Class codes were sorted in the geodatabase and we checked to make sure there were no entries with extra digits or transposed numbers.

We also created and implemented a geodatabase topology to perform the final QA/QC of the map polygons. GIS topology refers to a set of integrity rules that define the spatial relationships among and between point, line, and polygon geometry. The ESRI File Geodatabase offers a suite of topology rules that can be selected to validate the spatial accuracy of GIS data. We selected two topology rules, *Must Not Have Gaps* and *Must Not Overlap*, and ran topology validation on the final map polygons. These topology rules test whether polygons erroneously overlap one another or have small gaps between adjacent polygons that should share a common edge. The validation report is summarized in a database table that allows each individual error to be viewed and corrected. We manually edited all vector errors using the ArcGIS Editor Toolbar, and topology validation was rerun to verify all geometric errors were fixed.

3.3 Results and Discussion

The new INL Site vegetation map contains 7,637 polygons, of which 7,265 (95.1%) represent vegetation classes (Figure 3-1). The remaining 372 (4.9%) polygons were assigned to non-vegetation special classes that accounted for only 30.3 km^2 (7,478.8 acres) of the total mapped area. The largest single polygon mapped was 449.87 km^2 (111,165.4 acres) representing the (3/5) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland class spanning the central region of the INL Site including much of the area where the Jefferson Fire and T-17 Fire burned in 2010 and 2011, respectively (Figure 3-1). The next largest single polygon mapped was 165.4 km^2 (40,868.6 acres) representing the (6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland class located in the southwest corner of the INL Site.

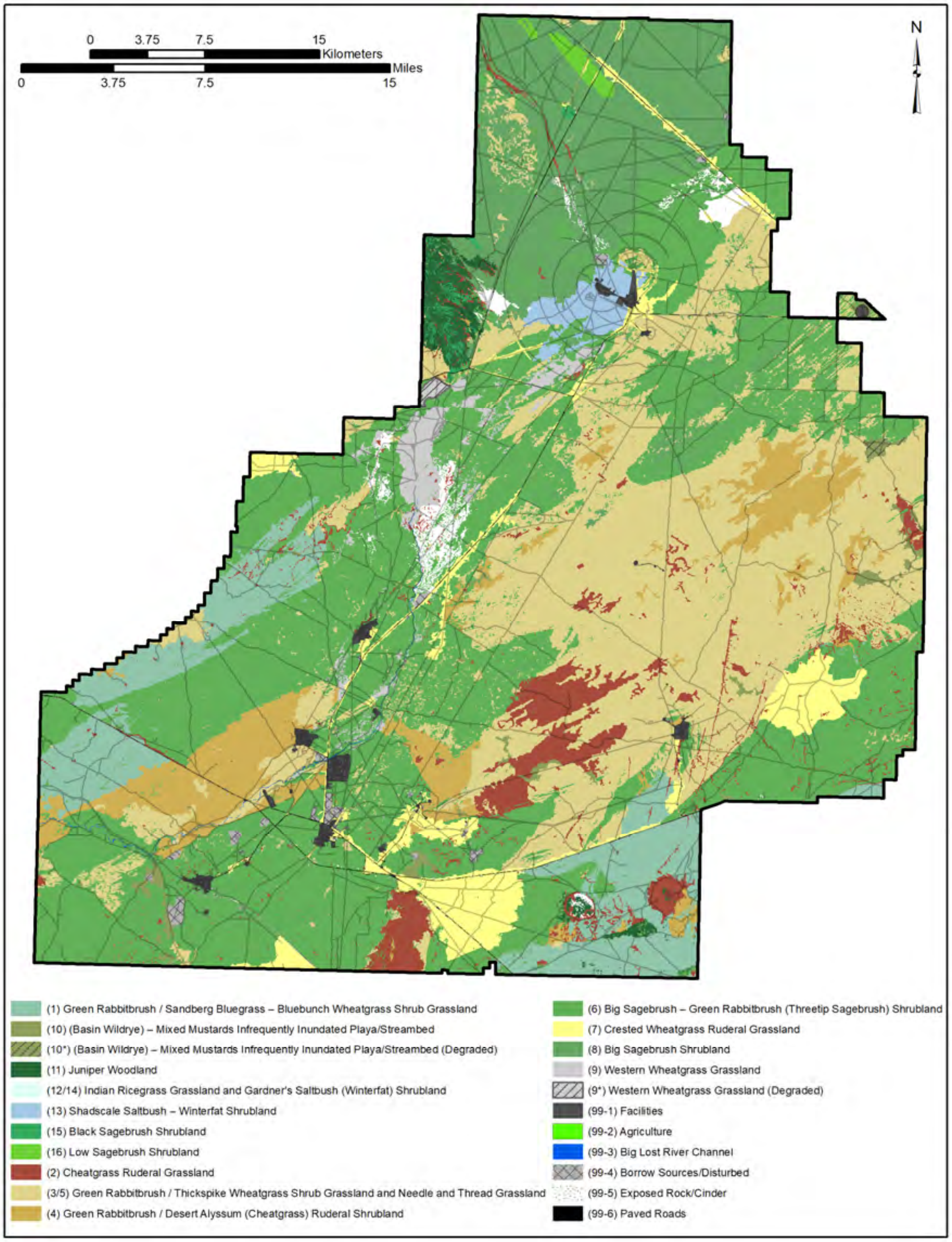

Figure 3-1. The updated Idaho National Laboratory Site vegetation map. Vegetation classes marked with an asterisk and symbolized with diagonal hatching represent degraded vegetation communities most commonly dominated by non-native species.

Table 3-1. Vegetation map class summary for the Idaho National Laboratory Site. The two map classes denoted with an asterisk represent degraded vegetation communities that were assigned the most closely related map class, but generally contain an abundance of non-native species not well-represented in the dichotomous key.

Map Class Name	Total Area (acres)	Total Area (km^2)	# of Polygons	Mean Area (acres)
(1) Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland	39388.16	159.40	51	772.32
(2) Cheatgrass Ruderal Grassland	22832.95	92.40	1436	15.90
(3/5) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland	141034.94	570.75	1058	133.30
(4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland	33021.23	133.63	115	287.14
(6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland	210330.09	851.18	2387	88.11
(7) Crested Wheatgrass Ruderal Grassland	23924.96	96.82	102	234.56
(8) Big Sagebrush Shrubland	59529.83	240.91	891	66.81
(9) Western Wheatgrass Grassland	7742.69	31.33	377	20.54
(9*) Western Wheatgrass Grassland (Degraded)	454.96	1.84	1	454.96
(10) (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed	3337.61	13.51	49	68.11
(10*) (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed (Degraded)	513.79	2.08	1	513.79
(11) Juniper Woodland	5832.08	23.60	385	15.15
(12/14) Indian Ricegrass Grassland and Gardner's Saltbush (Winterfat) Shrubland	6021.63	24.37	250	24.09
(13) Shadscale Saltbush – Winterfat Shrubland	4824.05	19.52	14	344.58
(15) Black Sagebrush Shrubland	1209.83	4.90	145	8.34
(16) Low Sagebrush Shrubland	1517.94	6.14	3	505.98

The smallest mapped polygon was 151.4 m^2 (0.04 acre) representing the (3/5) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland class on the western boundary of the INL Site. When we initially began map draft delineations, we were using an older copy of the INL Site GIS boundary layer. During the development of the new map, a more accurate INL Boundary layer was created that shifted the edge by over 100 m in some regions (Mahnami, unpublished data). When we clipped the mapped polygons with new boundary layer, it resulted in some very small polygons near the border. We also incorporated very small polygons of unburned sagebrush patches and juniper stands from post-fire mapping at a finer scale to support the CCA (Shurtliff et al. 2015, Shurtliff et al. 2016).

The (6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland class contained the largest amount of total area mapped with 851.2 km^2 (210,330.9 acres) (Table 3-1). The second largest class mapped was the (3/5) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland class with 570.8 km^2 (141,035 acres) (Table 3-1). The next largest mapped class, (8) Big Sagebrush Shrubland, drops substantially in area with 240.9 km^2 (59,529.8 acres; Table 3-1). The (8) Big Sagebrush Shrubland class overlaps considerably with the (6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland class and these two classes are regularly observed intermixing across much of the mapped area on the ground. The three largest map classes cover 73.2% of the vegetated area on the INL Site, suggesting the majority of vegetation communities are dominated by big sagebrush or species most commonly associated with post-fire communities where big sagebrush was previously present.

The (6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland class also had the greatest number of map polygons with 2,387 and an average polygon area of 0.36 km^2 (88.1 acres; Table 3-1). The class containing the second largest number of polygons was the (2) Cheatgrass Ruderal Grassland class with 1,436. However, the mean area of (2) Cheatgrass Ruderal Grassland class was much smaller at 0.06 km^2 (15.9 acres; Table 3-1) suggesting that many of the polygons mapped were isolated individual patches rather than larger contiguous areas (Figure 3-1). Although many of the polygons assigned to the (2) Cheatgrass Ruderal Grassland class were small in terms of area, this class has expanded greatly in distribution since the last vegetation map and can be found mixed within most vegetation classes, especially in areas recovering from recent wildland fire.

There were only two polygons designated as degraded in the map (Table 3-1). One polygon was a large playa on the eastside of the INL Site that is generally dominated by spotted knapweed (*Centaurea maculosa)* and other non-native weedy species. The second degraded polygon was located at the BLR Sinks ephemeral wetland that contains a variety of non-native weedy species. In some years it can be difficult to observe enough native species to use the dichotomous key and confidently select a vegetation class at either of these locations.

3.3.1 INL Site Vegetation Map Comparisons

The new vegetation map dataset is the most detailed map ever produced for the INL Site. The most recent vegetation map prior to this update (Shive et al. 2011) represented a significant improvement over earlier mapping because the vegetation classes were statistically defined, and a thorough quantitative accuracy assessment of the map was conducted. Because this map is essentially an update to the Shive et al. (2011) map that followed the same general methods, we anticipate the function and utility of the new map to seamlessly support conservation monitoring and land management considerations on the INL Site.

The most obvious difference between the maps was the number of map polygons added. The Shive et al. (2011) map contained a total of 2,038 polygon with 1,964 representing vegetation classes. The updated map now contains 7,637 polygons, of which 7,265 represent vegetation classes. The added map detail improves the spatial accuracy of vegetation class boundaries on the ground and allows larger polygons to be split into smaller polygons where separate classes could be delineated (Figure 3-2). Mapping at a finer scale also enabled us to delineate patches of non-native species of concern (e.g. cheatgrass) that tend to establish and then encroach into adjacent areas.

The other notable difference is the reduced number of vegetation map classes in the new map. The previous vegetation classification identified 26 vegetation classes on the INL Site, one of which was excluded from the map due to the small spatial scale of the class distribution (Shive et al. 2011). In addition to a greater number of classes in the previous map, polygons were commonly assigned to two-class complexes that resulted in a total of 127 pairwise combinations. The new map only contains 14 unique vegetation classes, which simplifies the complexity for the map user to understand what vegetation communities to expect on the ground within a polygon assigned to a two-class complex.

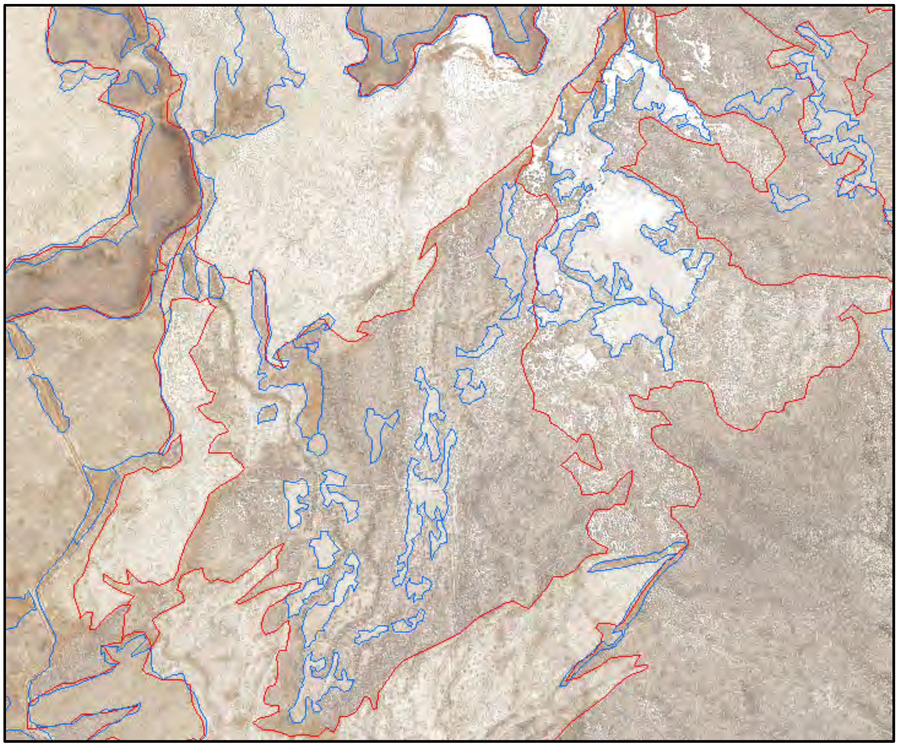

Figure 3-2. An example subset of the new Idaho National Laboratory Site vegetation map plotted on 2017 National Agricultural Imaging Program true-color imagery. The red polygons are results from the Shive et al. (2011) map delineated at a 1:12,000 scale. The blue polygons are from the current updated vegetation map delineated at a 1:6,000 scale. In this example, the finer scale delineation of classes can be seen within larger encompassing polygons from the previous map.

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4.0 Vegetation Map Accuracy Assessment

4.1 Introduction

Early remote sensing applications produced visually attractive map products, but quantitative accuracy assessment of the mapping results was typically an afterthought (Jensen 1996). Classifying or mapping imagery can be challenging; however, the collection of quality ground validation data and the corresponding accuracy assessment may be the most difficult step in the image classification process (Congalton and Green 1999). The goal of any accuracy assessment is to provide the map user with the information needed to interpret map errors and assess what implication those errors may have on intended applications. It is important that the appropriate measures of accuracy are selected, as some metrics may have insignificant bearing on project goals (Stehman 1997). We provide a brief discussion of accuracy assessment topics below, including a general overview of the error matrix and conceptual examples of accuracy metrics and statistical considerations for designing accuracy assessment surveys.

4.1.1 Error Matrix

One of the fundamental elements of a mapping project is an independent accuracy assessment which adds validity to the project and provides a basis for evaluating the utility of the map for potential applications. There have been a number of proposed statistical methods for validating image classification accuracy, but the error matrix remains the most commonly used method to calculate map accuracies and serves as the basis for most descriptive and analytical statistics (Congalton 1991, Congalton and Green 1999). The error matrix, also known as a confusion matrix or contingency table, is a square array organized in rows and columns where predicted data is compared to measured data through cross-tabulation. The columns in an error matrix represent the reference data collected on the ground, and the rows in an error matrix represent the classified (or map) data.

The error matrix supports the calculation of numerous measures of map and class accuracy. The most commonly reported measures of classification accuracy are the user's accuracy, producer's accuracy, and overall accuracy. User's accuracy represents the probability that a classified image pixel or map polygon is actually that category on the ground (Story and Congalton 1986). The complement of user's accuracy represents a measure of the commission error rate. For example, if the user's accuracy for the of a map class is 80%, the commission error rate for this class is 20%. Producer's accuracy represents the probability that a true positive location on the ground is correctly classified (Congalton and Green 1999). The complement of producer's accuracy can be interpreted as an omission error rate. Overall accuracy provides a measure of the agreement among all map classes and reference data and serves as a single metric that collectively represents the entire classified map (Congalton and Green 1999).

Conceptually, we can consider a scenario where the Big Sagebrush Shrubland map class has a calculated user's accuracy of 60% and a producer's accuracy of 85%. This means a person using the map would only find the Big Sagebrush Shrubland class to be present 60% of the time map polygons are visited in the field. From the map producer's perspective, 85% of the time Big Sagebrush Shrubland is present, it is mapped correctly. In other words, 85% of the time the Big Sagebrush Shrubland class is observed on the ground it has been correctly mapped as Big

Sagebrush Shrubland, but only 60% of polygons mapped as Big Sagebrush Shrubland are actually Big Sagebrush Shrubland on the ground.

One critique of the overall accuracy metric is that it does not account for agreement between map and reference data that can occur by chance alone. Cohen (1960) introduced a discrete multivariate technique called the Kappa coefficient as a novel method to evaluate overall map accuracy which allows for compensation due to chance agreement. Calculation of the Kappa coefficient represents a measure of the agreement between predicted and reference data with values ranging from -1 to +1. Kappa values are generally expected to be positive since a positive correlation between the map and reference data is assumed. Landis and Koch (1977) described three general ranges for Kappa: a value greater than 0.80 indicates strong agreement; a value between 0.40 and 0.80 indicates moderate agreement; and a value below 0.40 represents poor agreement. The Kappa coefficient can also be used to test for statistical significance and comparisons between different classifications and corresponding matrices (Rosenfield and Fitzpatrick-Lins 1986).

4.1.2 Accuracy Assessment Field Data Collection

The use of an error matrix requires the consideration of underlying statistical assumptions when designing an accuracy assessment study. Specific considerations include: selecting the appropriate sampling scheme, collecting adequate sample size, maintaining sample independence, and accounting for spatial autocorrelation issues (Congalton 1991, Stehman and Czaplewski 1998, Foody 2002).

There are various options for the sampling scheme such as simple random sampling, stratified random sampling, and systematic sampling. Each sampling method has inherent advantages and disadvantages and many times the selection of a sampling scheme is driven by project funding and the logistics of accessing remote locations and/or sampling across the range of variability. Random sampling is an attractive method because it conforms to underlying statistical assumptions. More commonly, stratified random sampling is undertaken where some practical limits are placed upon the truly random site selection (e.g. proportionally allocated sample sizes among predicted classes).

Collecting adequate sample sizes of reference data is important and requires thoughtful consideration so the resulting accuracy assessment is meaningful and representative of the entire map area from which the sample was drawn (Hay 1979). The goal is similar to traditional field surveys where the intent is to collect cost-effective, representative, and statistically rigorous data across the entire study area; however, in practice compromises may be needed. General sample size guidelines have been proposed which suggest a minimum of 50 samples per land cover class, and if the study area is large (i.e. more than a million acres) the minimum number of samples should be increased to 75-100 samples per class (Congalton 1991). This guideline is a theoretical construct based on early mapping studies. However, these guidelines can be considered quite ambitious when the logistical and financial considerations of collecting large amount of reference data are factored into a study design. This strict standardized sample size requirement may not be realistic when there may be rare or unique classes limited in distribution within a study area and forcing more samples into these map classes begins to compromise the sampling independence of reference data.

Sample independence is a concern when all field data for both image classification and validation are collected at the same time. It is important that any field data used during the classification mapping effort is kept separate from the data used to validate the final map. A related sampling independence principle is that of spatial autocorrelation among reference data points. Spatial autocorrelation is a statistical concept which describes the relationship of a variable according to the spatial arrangement of data values where the strength of correlation depends on the distance and direction separating the locations. The underlying premise is that data values near one another are more likely to be similar. If two plots are sampled in close proximity, they may violate the sample independence consideration because they effectively represent the same location.

Validation or reference data are commonly referred to as ground-truth data and any disagreement between the map and ground data is assumed to be a map error. However, the ground data are also subject to errors and in some cases, the reference data may contain more errors than the map, especially where qualitative visual estimates are made by an observer, (Congalton and Green 1999, Lunetta et al. 2001). Reference data errors may arise from a number of scenarios including assigning the wrong thematic class labels in the field or misregistration of field plots and classified data. These problems and others have been recognized by researchers and the use of the term ground “truth” to describe validation data is now discouraged (Khorram 1999).

4.2 Methods

4.2.1 Field Validation Site Selection

The original National Park Service (NPS) Vegetation Inventory Program guidelines recommended estimating sample sizes through proportional allocation based on map class abundance and frequency (Environmental Systems Research Institute [ESRI] et al. 1994). They suggested 30 samples (for abundant and fragmented classes), 20 samples (for abundant, but less fragmented, or less abundant, but more fragmented classes), and five samples or fewer (for rare or very rare classes) per class (ESRI et al. 1994). More recently updated NPS Vegetation Inventory Program guidelines were revised to address the concern that meaningful accuracy estimates were difficult to make for rare map classes (Lea and Curtis 2010). The new guidelines suggest 30 samples for classes that are abundant (more than 50 ha), 0.6 samples/ha (for classes that cover at least 8.33 ha but no more than 50 ha), and five samples (for rare classes that cover less than 8.33 ha; Lea and Curtis 2010).

During the development of the previous vegetation map for the Idaho National Laboratory (INL) Site (Shive et al. 2011), we decided to follow the general methods used by the NPS Vegetation Inventory Program, but we deviated slightly from their standard protocols where our knowledge on the INL Site vegetation communities and monitoring datasets could be incorporated to help improve the process. While designing the accuracy assessment site selection methods for the updated map, we compromise between the original and updated NPS Vegetation Inventory guidelines (ESRI et al. 1994, Lea and Curtis 2010). We used the updated draft vegetation map polygons to stratify the sampling effort across each map class. We assigned 30 validation plots to each common vegetation class that contained an abundant amount of area on the INL Site. Less common vegetation classes that were more limited in distribution were assigned no fewer than 20 validation plots. Lea and Curtis (2010) present an equation to determine the minimum distance from polygon boundaries that should be buffered to avoid validation plots located too close to polygon edges:

$$\text{Buffer Size} = \sqrt{R^2 + F^2 + M^2}$$

where R = radius of plot (observation area); F = maximum horizontal error (Global Positioning System); M = imagery spatial error

We selected a plot radius of 28 m (91.9 ft; see Section 4.2.2), estimated the maximum horizontal error from Global Positioning System (GPS) in the field to be 10 m (32.8 ft), and assumed 6 m (19.7 ft) of potential spatial error in the NAIP imagery (USDA-FSA Aerial Photography Field Office, unpublished data). This equation resulted in a polygon buffer of 30 m (98.4 ft). We also maintained at least 30 m (98.4 ft) between validation plots to maintain sample independence.

4.2.2 Plot Data Collection

Initially, we selected 400 random plot locations stratified across each draft map class. Some of the randomly selected points were dropped during field data collection for a variety of reasons, such as access issues from impassable roads. Around the midpoint of the field season we considered current sample sizes and decided to generate additional random points for rare classes to help achieve minimum sample size requirements, and to expand the distribution and number of plots located within recently burned areas.

Field crews were provided GPS receivers with plot point locations uploaded as waypoint files. Each plot waypoint was assigned a nondescript plot identification number and information about the identity of the polygon class was excluded to avoid influencing crews about the class they were sampling. Because the validation plot locations were randomly selected, some ended up in a transition zone between vegetation classes or in a locally unique spot that was not representative of the surrounding landscape. Field crews were instructed to visually scan the landscape within the local vicinity to determine whether the plot was located within a fairly homogenous region. Homogenous did not necessarily mean all the same species present, but rather all the same general vegetation class within the anticipated plot extent. Whenever appropriate, the field crew shifted the plot center point into an area more representative of the surrounding landscape, but they were limited to a 40 m (131.2 ft) total distance the plot could be relocated. This restriction was placed to avoid violating sample independence from other potentially close random plot locations.

Once the plot center point was located either by navigating to a GPS waypoint or after a shifting the plot into a more representative area, a stake was inserted into the ground. Then the plot perimeter was established and marked by extending a thin rope attached to the center stake and placing reference poles in the ground in the four cardinal directions (Appendix F). We considered the suggested plot sizes for semi-arid shrublands and herbaceous vegetation and chose a plot size that accounted for the range of variability across most vegetation classes on the INL Site (Lea and Curtis 2010). The standard plot area sampled for nearly all vegetation classes was 0.25 ha (28 m radius [91.9 ft]; Figure 4-1). The only exception was the juniper woodland class where plot size was increased to accommodate interspace distances between tree canopies that require a larger plot size to encompass the natural spacing in this vegetation class. All juniper woodland accuracy assessment plots were denoted with a unique plot identification number and plot area was increased to 0.5 ha (40 m radius [131.2 ft]; Figure 4-1).

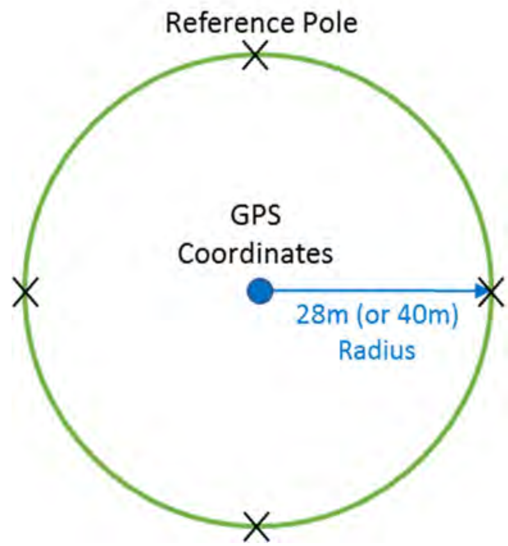

Figure 4-1. Idaho National Laboratory Site vegetation map accuracy assessment plot schematic. Plot size was 0.25 ha (28 m radius) for all semi-arid shrubland and herbaceous vegetation classes, or 0.5 ha (40 m radius) for all woodlands. The 'X' marks the locations of four reference poles that were visual aids for plot boundaries. Global Positioning System (GPS) coordinates were collected at the plot center, and representative plot photos were taken from the center aimed towards each reference pole.

Once the general plot boundary was established, each field crew member walked around the plot noting the dominant and co-dominant species present. After each field crew member finished their visual assessment, they both worked through a dichotomous field key (Appendix C) to assign the most appropriate vegetation class to the plot. The field crew recorded the location of the plot center and other plot data using a Trimble GeoXH receiver with a project specific data dictionary. The field crews were given the opportunity to mark 'Yes under a field called Key Agreement if the plot was accurately characterized by the dichotomous key, or 'No' to denote when the plot was difficult to fit into a class using the dichotomous key. The key was developed based on the classification sampling results and statistical analysis from 2017. Because the purpose of classification is to organize plant communities into generalized vegetation classes, the key may not have performed well for identifying all the rare or unique vegetation classes on the INL Site. Areas where the Key Agreement field was marked 'No' typically contained non-native weedy species or were dominated by shrubs or grasses that were not diagnostic species in the key dichotomies. There was also an optional field to record a second vegetation class if the key did not work well. The crew could assign a reasonable second vegetation class call that may be more appropriate for the plot. There was a second optional data field for comments to provide context of the issues encountered at the plot or anything else that may help data interpretation. Once the plot data were recorded, reference photos were taken looking in the four cardinal directions from the plot center (Figure 4-1; Appendix F).

After all the field data were collected and GPS coordinates were post-processed, a GIS Analyst reviewed the validation plot locations and database table for errors introduced during the data entry. There were 52 plots initially flagged for further review where vegetation classes were recorded in regions of the INL Site where that class was not expected (i.e. locations where particular vegetation classes plotted outside known ranges) or when 'No' was recorded for the Key Agreement field.

ESER staff, including plant ecologists and a natural resource specialist, reviewed all the flagged plots to determine whether those data should be discarded from the dataset. As a group, we considered the photographs collected at each plot to help evaluate the vegetation class present within questionable plots. If there was an obvious error recorded in the field data that contradicted the class visually identifiable in the plot photographs, we changed the class designation for the plot. When the photographs were difficult to interpret, the class designation was left unchanged. Plots were removed from the dataset when there was no clear vegetation class identifiable in the photographs. These areas tended to have an abundance of non-native species that were not well represented in the vegetation classification, and consequently did not work well using the dichotomous key.

4.2.3 Accuracy Assessment Calculations

Once the error matrix was fully populated, we calculated the most common map accuracy metrics. Specifically, we calculated the user's and producer's accuracy, overall accuracy, and the Kappa coefficient. Following the equations for the accuracy metrics, we provide a sample error matrix showing example calculations from hypothetical data (Figure 4-2).

User's accuracy is calculated as:

$$\frac{n_{ii}}{n_{i+}}$$

where i is the vegetation class, n_{ii} is the number of matches between the map and reference data (major diagonal), and n_{i+} is the total number of samples of i in the map data (row total). User's accuracy is calculated by dividing the number of true positive (correct) samples by the total samples in the error matrix row.

Producer's accuracy is calculated as:

$$\frac{n_{ii}}{n_{+i}}$$

where n_{+i} is the total number of samples of i in the reference data (column total). Producer's accuracy is calculated by dividing the number of true positive (correct) samples by the total samples in the error matrix column.

Overall accuracy is calculated as:

$$\frac{\sum_{i=1}^{k} n_{ii}}{n}$$

where k is the number of vegetation classes and n is the total number of validation plots. Conceptually this metric is calculated by dividing the sum of all class true positives (correct) by the total samples in the error matrix.

Estimates of map accuracy are produced though sampling inference drawn from map sites, and it has been suggested that map accuracy estimates should be accompanied by confidence intervals (Thomas and Allcock 1984). We calculated the 90% confidence interval for each map class as:

$$\hat{p}\left\{z_{\alpha}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}+\frac{1}{2n}\right\}$$

where $\hat{p}$ is the sample (class) accuracy probability, z_{α} is the z-score (1.645) for the two-tailed significance level (Zar 1996), and n is the number of sites sampled. We chose the 90% confidence interval to match the NPS Vegetation Inventory Program and make our results comparable.

The **Kappa coefficient** is calculated as:

$$\widehat{K} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}\left(x_{i+} \bullet x_{+i}\right)}{N^{2} - \sum_{i=1}^{r}\left(x_{i+} \bullet x_{+i}\right)}$$

where N is the total number of validation plots (samples in the error matrix), r is the number of rows in the error matrix, x_{ii} is the number of correct observations of row i and column i (major diagonal), x_{i+} is the total observations in row i, and x_{+i} is the total number of observations in column i.

		Reference (Validation) Data				
		Class 1	Class 2	Class 3	Class 4	Row ∑
Classified (Map) Data	Class 1	**16**	1	3	1	*21*
	Class 2	0	**18**	0	1	*19*
	Class 3	1	1	**19**	0	*21*
	Class 4	0	1	2	**21**	*24*
	Column ∑	*17*	*21*	*24*	*23*	*85*

	Producer's Accuracy	User's Accuracy
Class 1	16/17 = 94.1%	16/21 = 76.2%
Class 2	18/21 = 85.7%	18/19 = 94.7%
Class 3	19/24 = 79.2%	19/21 = 90.5%
Class 4	21/23 = 91.3%	21/24 = 87.5%

Overall Accuracy = (16+18+19+21)/85 = **87.1%**

Figure 4-2. A sample error matrix depicting four generic map classes and the corresponding accuracy metric calculations. The yellow diagonal cells represent true positive class agreement, while all off-diagonal errors inform the map user about class-to-class mapping errors.

4.3 Results and Discussion

4.3.1 Validation Plot Data

During the summer of 2018, a total of 453 validation plots were collected and used to support the accuracy assessment of the final vegetation map. We used the *Spatial Join* function in ArcGIS to add the vegetation class code assigned to the polygon that contained the plot location to the database table. The field (reference) data and map data were exported into two columns, and we used a Pivot Table in Microsoft Excel to populate the error matrix. Once the error matrix tabulation was competed, we calculated both user's and producer's accuracy for each map including 90% confidence intervals. We also calculated overall map accuracy and Kappa as representative measures of map accuracy.

Initially, we maintained the two big sagebrush classes [i.e. (6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and (8) Big Sagebrush Shrubland] as separate, distinct classes that were each allocated the appropriate number of random field validation plots. But as field sampling progressed throughout the summer, there were two instances where independent field crews sampled the same plot location at different times. In both cases, the field crews chose different big sagebrush classes. There was considerable statistical classification overlap between these two vegetation classes and it was anticipated that these two could likely be difficult to distinguish in the field and can be distributed as patchwork mosaic across the landscape making the determination subjective. Consequently, whenever either class (6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland or class (8) Big Sagebrush Shrubland was recorded in the field or assigned to map polygons, they were combined prior to the accuracy assessment calculations. Combining these two vegetation classes resulted in 13 total map classes for the INL Site.

4.3.2 Map Accuracy Assessment

The accuracy assessment results showed an overall accuracy of 77.3% and a Kappa value of 0.75 (Table 4-1). Considering there were 13 map classes distributed across the large extent of the INL

Site, the results suggest the final vegetation map is a good representation of vegetation classes found on the ground. The map accuracy result values were higher than three of the four methods used to validate the previous vegetation map (Shive et al. 2011). The Kappa value is close to the 0.8 threshold which can be interpreted as strong agreement (Landis and Koch 1977) and is also higher than three of the four error matrix results from the previous vegetation map accuracy assessment (Shive et al. 2011).

The (11) Juniper Woodland had the highest user's and producer's accuracy at 100% with no documented mapping errors (Table 4-1). This map class is an exception compared to most of the others because it is unmistakable in the imagery and does not overlap with other vegetation classes spectrally. Utah Juniper (*Juniperus osteosperma*) is the only tree species commonly found on site, although there are some individual, cottonwood (*Populus sp.*) trees along the Big Lost River (BLR) and historic Birch Creek drainages.

The map class with the next highest user's accuracy was the combined (6/8) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland class at 93.9% (Table 4-1). There were five other classes that all had a user's accuracy above 80% (Table 4-1). The lowest user's accuracy was the (4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland class at 37.1%.

The second highest producer's accuracy was the (15) Black Sagebrush Shrubland class at 94.7% (Table 4-1). The (13) Shadscale Saltbush – Winterfat Shrubland class was also very high with a producer's accuracy of 93.3% (Table 4-1). There were four additional classes that had producer's accuracy above 80% (Table 4-1). The lowest producer's accuracy was also in the (4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland class at 44.8%.

4.3.3 Map Class Summary

Class 1 - Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland
This map class had the fourth largest total mapped area and the largest mean area per polygon (Table 3-1). When this class was mapped, it was primarily larger contiguous polygons distributed in the southern and western portion of the INL Site. This map class represents post-fire vegetation communities that establish following wildland fire in areas previously dominated by big sagebrush (*Artemisia tridentata*) and are at a relatively higher elevation than sagebrush dominated communities in the center of the INL Site.

This class had a user's accuracy of 81.3% and a producer's accuracy of 61.9% (Table 4-1). There were ten plots where this class was incorrectly mapped as two other map classes: Class (3/5) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland (n=5) and Class (4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland (n=5). These mapping errors are likely due to difficulty identifying grass understories amongst green rabbitbrush (*Chrysothamnous viscidiflorous*). Green rabbitbrush shrublands were generally more recognizable in the imagery, although the understory species were not.

Class 2 - Cheatgrass Ruderal Grassland
This class exhibited a patchy distribution, and isolated polygons of cheatgrass (*Bromus tectorum*) can be observed across most of the INL Site within nearly every other map class. Class 2 had the

third smallest mean area/polygon (Table 3-1), although some larger polygons were mapped in the central region of the INL Site, and across the extent of the Midway Fire from 2012.

This map class showed good agreement with field data and had a user's accuracy of 77.8% and a producer's accuracy of 82.4% (Table 4-1). This class was most commonly confused with Class (4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland which is characterized as a green rabbitbrush shrubland with a degraded understory that can include cheatgrass. Cheatgrass has become more prevalent across the INL Site, especially within areas that have burned in the last decade (Shurtliff et al. 2019), and the total area of this map class has increased substantially since to the previous mapping effort (Shive et al. 2011). Some of mapping errors may have been due to cheatgrass being present in the degraded understory, but not becoming dense enough to warrant assigning the plot to Class 2 in the field. In the imagery cheatgrass has a characteristic red color once it has senesced, and Class 4 also shows the same red hues. During the mapping process it became a subjective decision for the GIS Analyst to decide when the red colors became prominent enough to assign the map polygon to Class 2 and when to assign it to Class 4.

Class 3/5 - Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland

This map class is widespread throughout much of the INL Site that had previously burned and is in good ecological condition. In the years following the Jefferson and T-17 fires in the central region of the INL Site, we conducted some post-fire surveys to monitor which vegetation classes were reestablishing (Shurtliff et al. 2016). We found a lot of variability in the vegetation classes present in recently burned areas, and it was common to observe vegetation classes dominated by green rabbitbrush, native bunchgrasses, or cheatgrass all within a small spatial extent.

This map class showed moderate agreement with ground validation data and had a user's accuracy of 68.4% and a producer's accuracy of 65.0% (Table 4-1). This class was most commonly mapped incorrectly and confused with the Class (4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland which contains many of the same characteristic overstory species. Class 4 can be considered a transition class between good condition Class 3/5 and the more heavily degraded Class (2) Cheatgrass Ruderal Grassland that are both commonly found throughout recently burned regions on the INL Site. The next most common mapping error occurred between Class (1) Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland which species composition overlaps considerably with Class 3/5 (Table 2-3) and can be difficult to distinguish in multispectral imagery because all green rabbitbrush dominated communities appear similar.

Class 4 - Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland

Class 4 showed generally poor agreement between the map and ground validation data and had a user's accuracy of 37.1% and a producer's accuracy of 44.8% (Table 4-1). This class had the most mapping errors of any other map class. As described above, the most frequent mapping errors occurred between (3/5) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland class which is likely due to the overlap in species composition and cover. In the imagery, this class had a reddish-pink hue that suggests the presence of senesced cheatgrass. For the GIS Analyst, it was a subjective decision when this class had enough native species present to assign it to Class 3/5, or when cheatgrass density appears to be great enough to warrant the (2) Cheatgrass Ruderal Grassland designation. It was also noted above that due to the similarity between classes that have the same dominant shrub species, there were mapping errors with the (1) Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland class.

The Bray-Curtis metric calculates similarity between communities by comparing relative cover values on a species by species basis and returns a proportional value between 0 and 1. The Bray-Curtis community similarity matrix (Table 2-3) shows that the classes most commonly confused with Class 4 were all above a value of 0.4. This supports the notion that these classes are more similar to one another compared to other map classes, and mapping errors between them should be expected. Shive et al. (2011) used a Bray-Curtis threshold of 0.35 to combine classes for fuzzy membership, and the errors presented above would have been considered acceptable due to class similarities.

Class 6/8 - Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland

This map class had the largest total area mapped (Table 3-1) and is widespread across the entire INL Site. Mean area per polygon was lower for Class 6/8 than some other classes because although there were numerous large, contiguous polygons, there were also many small polygons mapped as unburned patches within the burned area. Big sagebrush is one of the most important vegetation communities on the INL Site and is recognized as a major component of sagebrush habitat for great sage-grouse (*Centrocercus urophasianus*) described in the Candidate Conservation Agreement (DOE and USFWS 2014).

There was good agreement between this map class and ground validation data with user’s accuracy of 93.9% and a producer’s accuracy of 79.3% (Table 4-1). The difference between user’s and producer’s accuracy suggests that nearly all the places where Class 6/8 was mapped, it was accurate on the ground. However, there were additional locations where this class was identified in the field but was mapped incorrectly as a different class. Surprisingly, the two classes most commonly confused with Class 6/8 were Class (13) Shadscale Saltbush – Winterfat Shrubland and Class (9) Western Wheatgrass Grassland. Mapping errors were observed most often within historical floodplains where fluvial deposits provide the appropriate soil types for Class 9 and Class 13. The observed mapping errors generally occurred near the edge of two adjacent polygons and the delineated edge could have been adjusted slightly near the transition, but it was difficult to accurately determine in the imagery. The majority of errors were localized and there were not widespread, blatant mapping problems in areas where dense sagebrush stands have been documented. Additional mapping errors that followed the general pattern described above were found near polygon boundaries in the gradual transition zone between adjacent vegetation classes.

Table 4-1. Idaho National Laboratory Site vegetation map accuracy assessment error matrix and associated metrics including user's and producer's accuracy, overall accuracy, Kappa coefficient values, and 90% confidence intervals for individual classes. The columns in the error matrix represent field validation data, and the rows represents map data. Vegetation class codes: (1) Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland, (2) Cheatgrass Ruderal Grassland, (3/5) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland, (4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland, (6/8) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland, (7) Crested Wheatgrass Ruderal Grassland, (9) Western Wheatgrass Grassland, (10) (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed, (11) Juniper Woodland, (12/14) Indian Ricegrass Grassland and Gardner's Saltbush (Winterfat) Shrubland, (13) Shadscale Saltbush – Winterfat Shrubland, (15) Black Sagebrush Shrubland, (16) Low Sagebrush Shrubland.

Class Code	1	2	3/5	4	6/8	7	9	10	11	12/14	13	15	16		User's Accuracy	90% Confidence -	Interval +
1	**26**	1		4		1								32	**81.3%**	68.3%	94.2%
2		**28**		4		1		2		1				36	**77.8%**	65.0%	90.6%
3/5	5	1	**26**	4	2									38	**68.4%**	54.7%	82.1%
4	5	3	9	**13**	1	4								35	**37.1%**	22.3%	52.0%
6/8		1	1	1	**92**		1						2	98	**93.9%**	89.4%	98.4%
7	1				2	**26**								29	**89.7%**	78.6%	100.0%
9	1		3	1	6		**13**	1		2				27	**48.1%**	30.5%	65.8%
10	3		1	2		3		**22**		2				33	**66.7%**	51.7%	81.7%
11									**30**					30	**100.0%**	98.3%	100.0%
12/14	1				3			1		**25**				30	**83.3%**	70.5%	96.2%
13					7		1			2	**14**			24	**58.3%**	39.7%	77.0%
15					2						1	**18**		21	**85.7%**	70.8%	100.0%
16					1	1						1	**17**	20	**85.0%**	69.4%	100.0%
	42	34	40	29	116	36	15	26	30	32	15	19	19	**453**			
Producer's Accuracy	**61.9%**	**82.4%**	**65.0%**	**44.8%**	**79.3%**	**72.2%**	**86.7%**	**84.6%**	**100.0%**	**78.1%**	**93.3%**	**94.7%**	**89.5%**		**Overall Accuracy = 77.3%**		
90% Confidence -	48.4%	70.1%	51.3%	27.9%	72.7%	58.6%	68.9%	71.1%	98.3%	64.5%	79.4%	83.7%	75.3%		**Kappa = 0.75**		
Interval +	75.4%	94.6%	78.7%	61.7%	85.9%	85.9%	100.0%	98.2%	100.0%	91.7%	100.0%	100.0%	100.0%				

Class 7 - Crested Wheatgrass Ruderal Grassland

This class was most commonly mapped in distinct areas of large homogenous patches where crested wheatgrass (*Agropyron cristatum*) had historically been planted, and also along infrastructure corridors (e.g., paved roads and power lines) where seed has likely been spread. Field observations suggest this class is slowly encroaching into adjacent native stands of vegetation, but it is unclear how long it takes to convert a patch of native vegetation into an area dominated by crested wheatgrass. Class 7 varies spectrally, and it is difficult to accurately detect the edge where the vegetation composition changes, so estimates of the rate of expansion can be difficult to determine. Based on years of observation it is safe to assume that the edge of Class 7 map polygons will likely expand through time, and any area in close proximity to Class 7 may eventually be converted to this class.

This map class had a user's accuracy of 89.7% and a producer's accuracy of 72.2% (Table 4-1). This class was most commonly confused with Class (4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland and Class (10) (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed. Both classes contain non-native, weedy species in the understory and, when using the dichotomous key could have resulted in assigning the plot to one of the classes listed above.

Class 9 - Western Wheatgrass Grassland

This map class is most often associated with hydrologic systems and is mapped throughout the floodplain of the BLR and the historical Lake Terreton playa. However, there are localized patches of Class 9 recorded within a matrix of different vegetation classes that are not necessarily associated with hydrologic systems. The soils where Class 9 is found tend to appear bright in the imagery, and vegetative cover is typically low making it difficult to accurately delineate class boundaries using aerial imagery.

This class had the second lowest user's accuracy of 48.1% and a producer's accuracy of 86.7% (Table 4-1). The large discrepancy between the accuracy metrics means that Class 9 was over-estimated in the map (i.e. errors of commission), but most places it was mapped, it was found to correctly correspond to field data. Class (6/8) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland was the most common mapping error documented for this class, and those errors occurred throughout the BLR floodplain where patches of sagebrush were distributed among patches of rhizomatous grasses.

Class 10 - (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed

This map class had a limited amount of mapped area and exhibited a patchy distribution across the landscape most commonly driven by topographic low-lying areas that are seasonally inundated. Field observations following large fires have found playas to be highly dynamic where the density of non-native weedy species fluctuates significantly from year-to-year. Shurtliff et al. (2016) reported observations of dense stands of Russian thistle (*Salsola kali*) in playas within the Jefferson Fire burned area, but during the vegetation classification field data collection, Russian thistle was largely absent or present in much lower densities within these locations. Nonetheless, mustards and other weedy species are now generally more common than basin wild rye (*Leymus cinerus*) which probably historically dominated these playas on the INL Site.

This class showed moderate agreement with field data and had a user's accuracy of 66.7% and a producer's accuracy of 84.6% (Table 4-1). Mapping errors were prevalent across multiple map classes and were generally indicative of the map class surrounding the playa where Class 10 was mapped.

Class 11 - Juniper Woodland

This map class represents the areas dominated by the only abundant native tree species found on the INL Site. The distribution of Class 11 is concentrated along the toe of the Lemhi mountain range in the northwest corner of the INL Site and some smaller stands remaining near Middle Butte following multiple fires in the area.

This class had a user's and producer's accuracy of 100% with no recorded mapping errors (Table 4-1). This map class is an exception compared to other map classes because it is spectrally unique and one of the easiest classes to delineate. The greatest difficulty for the GIS Analyst is deciding when to delineate small stands containing only a few individuals. There will be many instances where individual juniper trees can be found within other map classes, especially moving downslope from the Lemhi range, where the density of trees is too low to warrant the Class 11 designation.

Class 12/14 Indian Ricegrass Grassland and Gardner's Saltbush (Winterfat) Shrubland

This map class contained very little area and the distribution was primarily along the BLR floodplain or in areas locally dominated by the presence of Gardner's saltbush (*Atriplex gardneri*) in the northern region of the INL Site. Winterfat (*Krascheninnikovia lanata*) ranges from absent to co-dominant in stands of this class it is a species that can be observed in numerous other map classes but was not sampled in densities great enough to classify a unique vegetation class during our classification analysis.

This map class had a user's accuracy of 83.3% and a producer's accuracy of 78.1% (Table 4-1). The class most commonly mistaken for Class 12/14 was Class (6/8) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland. The mapping errors with Class 6/8 occurred when stands of winterfat were dispersed within a larger matrix of big sagebrush communities.

Class 13 Shadscale Saltbush – Winterfat Shrubland

This map class had one of the most limited distributions with the second lowest number of polygons mapped (i.e. except for polygons denoted as degraded; Table 3-1). Class 13 was only mapped in the playa near the Specific Manufacturing Capability/Loss of Fluid Test Facility in the northern region of the INL Site.

This map class showed mixed agreement with ground observation and had a user's accuracy of 58.3% and a producer's accuracy of 93.3% (Table 4-1). The lower user's accuracy means this class was mapped in more places than it was observed during ground validation surveys. But higher producer's accuracy confirms that whenever Class 13 was observed in the field it was correctly mapped. The most common mapping error occurred between Class (6/8) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland and is discussed in the Class 6/8 summary.

Class 15 Black Sagebrush Shrubland

This map class had the lowest total mapped area and lowest mean area per polygon of any map class (Table 3-1). Class 15 was most commonly mapped within the interspace between stands of juniper trees in the Lemhi mountain range, especially where there are steeper slopes. Class 15 can also occur in isolated patches across shrublands in the northern region of the INL Site.

This map class showed very good agreement with ground validation data and had a user's accuracy of 85.7% and a producer's accuracy of 94.7% (Table 4-1). There were a few mapping errors recorded in the northern region of the Site where this class was mixed with Class (6/8) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland and Big Sagebrush Shrubland and Class (16) Low Sagebrush Shrubland.

Class 16 Low Sagebrush Shrubland

This map class had the second lowest area mapped, and although it only contained three polygons, Class 16 had the second largest mean area per polygon (i.e. excluding one polygon denoted as degraded; Table 3-1). Class 16 has a very limited distribution within the INL Site and consists of one large swath in the northern region of the INL Site east of Richard's Butte bisected as it crosses Highway 22 to the south.

This map class had a user's accuracy of 85.0% and a producer's accuracy of 89.5% (Table 4-1). The mapping errors were mostly observed where Class 16 mixes with Class 6/8 and Class 15 as described above.

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5.0 Map Applications and Other Considerations

5.1 Using the INL Site Vegetation Map

There are limitations to all classifications and mapping products that should be considered by end users. We encourage all potential users of the map to understand how the classification and map were derived and to consider the strengths and limitations of the products as they may influence various applications.

Each plant community will encompass a range of variability in both vegetative cover and species composition and overlap among classes is a standard result of multivariate classification analyses. Interpreting plant communities into meaningful and mappable units requires designations that result in vegetation classes which are inherently variable. The ambiguity associated with classification results often stems from species distributions which tend to vary continuously across the landscape rather than abrupt transitions at distinct edges (Anderson 1991). The same is true of the vegetation classes defined for the Idaho National Laboratory (INL) Site; therefore, users of the INL Site vegetation map are encouraged to consider the range of community variability which is represented by each vegetation class and relationships between vegetation classes when using the class descriptions (Appendix D), dichotomous key (Appendix C), and the Geographic Information System (GIS) map dataset (Appendix E).

There are a variety of accuracy metrics that can be produced from an error matrix, and although we report multiple measures of map and class accuracy, there are other metrics (e.g., misclassification rate, false positive rate, etc.) that may be better suited for a particular application or research projects. For example, depending on the goals of individual research projects, certain errors may be considered more costly than others and associated error weights could be assigned to improve modeling and predictive abilities. We have included the raw error matrix table in Chapter 4 to enable map users to calculate whatever other accuracy metrics are most pertinent for their intended application.

The vegetation classes were mapped at a 1:6,000 scale and may provide too much detail for some projects that are only concerned with major cover type distributions (e.g. shrublands, grasslands, etc.). Map polygons can always be hierarchically collapsed into more general map classes to facilitate comparisons to other data products or simplify the dataset for models that only require vegetation cover types rather than detailed Association-level classes. For example, if a project was seeking to predict habitat for sagebrush obligate species, all the classes designated as a sagebrush-dominated community could be selected and exported using a GIS to create a new combined sagebrush class. This is the approach that was taken to estimate the amount and distribution of sage-grouse habitat on the INL Site to support the Candidate Conservation Agreement (DOE and USFWS 2014).

5.2 Comparison of Classification and Mapping Results from other Projects

Some agencies are working towards completing inventories and maps of natural resources, including vegetation and changes in vegetation over time. Each program has defined different goals and objectives based on their specific needs. Consequently, there are a variety of products available, and while many datasets can be reasonably compared, there are notable differences between any two classification and mapping efforts. Here, we discuss some of the similarities and differences between this map product and others.

Community classification methodologies can range from observational and qualitative in nature to quantitative and statistically rigorous. Our approach to classifying plant communities required the use of some informed decision making but was primarily quantitative in terms of the data collected and the analytical approach applied. By selecting the multivariate model and appropriate number of vegetation classes using optimality criteria, we arrived at a solution that was less arbitrary and more standardized than methods that had been previously applied to INL Site vegetation data except for Shive et al. (2011).

Association-level crosswalks between the classes identified by the most recent local classification effort and the National Vegetation Classification (NVC; NatureServe 2017) were much more straightforward than they were with the previous effort. During the previous classification effort, there were several discrepancies between INL Site and NVC classes, but updates and revisions to the NVC have resulted in many more Association-level classes that directly relate to the vegetation classes resulting from the INL classification update. The NVC remains a valuable resource for interpreting INL Site vegetation classes and it provides an important bridge between INL Site vegetation classes and those identified for resource management applications by neighboring agencies.

We recognized the possible limitation of automated image classifications (e.g. unsupervised or supervised) in a semi-arid environment where total vegetative cover is low and the spectral signature of vegetation classes overlap considerably in the imagery. There were numerous classes that were difficult to discriminate relying on image interpretation alone, and only through field observations and previous mapping experience on the INL Site were we able to identify some class distributions. The manual mapping approach worked well for this project, and even though it may be more time consuming, it is likely the most accurate mapping method available given the image datasets we used for this project.

It is difficult to make direct comparisons between the new vegetation map and maps produced prior to 2011, because there had never been a quantitative assessment of previous vegetation map products on the INL Site until Shive et al. (2011) published their map. The updated vegetation map contains greater spatial detail reflective of current ground conditions following three years (2010-2012) of large wildland fires that burned since the completion of the previous INL Site vegetation map (Shive et al. 2011). Map class accuracies in the new map generally remain high for the most abundant classes present across the INL Site, although the areas recovering from recent wildland fires showed a high level of variability and corresponding mapping errors. Within the local region, Craters of the Moon National Monument and Preserve (CRMO) completed a vegetation map in 2009 using the same imagery and similar processing methods (Bell et al. 2009). The map products are comparable, in terms of the number of classes defined and the corresponding map class accuracies, however the vegetation class types vary considerably at CRMO.

An important factor to consider is the influence of scale on the mapping project, and this issue was recognized early in the National Park Service Vegetation Inventory Program (TNC and ESRI 1994). The sampling scale used to collect vegetation field data to support the community classification was much finer than the mapping scale used during image delineations. Sampling at a fine scale captures the ecological pattern present in that specific locality; however, ecological patterns of plant communities can change as the sampling scale is increased to the large extent of the INL Site.

The 1:6,000 mapping scale used during this project is finer than those used for the NPS Vegetation Inventory Program and most regional vegetation or habitat datasets, such as Idaho Gap Analysis Program (Scott 1993) and U.S. Geological Survey SAGEMAP (Knick and Schueck 2002) which are both intended to be used at a 1:100,000 scale. The INL Site vegetation map classes can be collapsed to more general classes to facilitate the crosswalk with other regional datasets. The INL Site vegetation map can be utilized in broad-scale models intended for use at the 1:100,000 scale; however, the user needs to be cautious when incorporating coarser regional datasets into analyses conducted at scales larger than the intended use.

5.3 Recommendations for Vegetation Classification and Mapping Updates

Quantitatively sampling and classifying vegetation data at the intended mapping scale would be logistically difficult and resource intensive. However, reconciling the classification and mapping scale is an important consideration when using this mapping approach. Although we made substantial improvements to addressing scale issues with the current iteration of the classification and map, we recommend continuing to explore novel quantitative sampling and experimental designs to address overcoming scale limitations inherent to the community classification data.

The vegetation map could potentially benefit from additional remotely sensed datasets to update or refine the vegetation map if they become available site-wide. There have been a number of small research projects across the INL Site that have had more advanced sensors acquire imagery, but the data do not cover the entire INL Site. Hyperspectral imagery encompasses many spectral bands (i.e. tens to hundreds) which may improve the capability to discriminate between vegetation classes that appear the same in four-band color-infrared imagery used to create this vegetation map. Light Detection and Ranging (LiDAR) sensors collect high resolution topographic data models of the landscape. Using processing algorithms, LiDAR data can be analyzed to calculate surface feature heights. If we had information about vegetation heights, it may be possible to further refine polygons where shrubland and herbaceous classes are both included.

The vegetation map should be considered a dynamic dataset that is continually updated through time, especially following disturbances that can alter vegetation classes across the landscape. Following large wildland fires, we suggest waiting until after the first growing season post-fire before conducting new delineations and assigning new polygons to a vegetation class. If digital imagery is collected to map the fire, the same image dataset can be used to modify or delineate new class boundaries.

Aside from changes caused by large disturbance, the vegetation map should be reviewed and updated periodically to prevent it from becoming outdated. The new vegetation map provides a base map template from which future revisions and modifications can be made directly to the map. The National Agricultural Imaging Program (NAIP) collects high spatial resolution digital imagery on a two-five year return interval across the entire State of Idaho. The NAIP image datasets are free to the public, have the same or similar specifications to the image datasets used during this mapping project, and are collected on an interval that would be appropriate to update the INL Site vegetation map.

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Appendix A

Vegetation Classification Sampling Protocol

Establish Transect

1. Navigate to the SW end, or start point, of the selected transect.

2. Visualize the transect extending about 50m to the NE. Shift the start point, if necessary, to ensure the transect doesn't cross any abrupt vegetation and/or soil boundaries. The start point may also be shifted to ensure the vegetation under the transect is representative of the surrounding area.

    a. Stretch a tape 50m toward the NE using a compass bearing of 20º magnetic.

    b. Ensure the tape is straight and pin both ends so that it remains tight.

    c. Record the Plot ID, Date, and Observers on the Plot Checklist.

Photographs

1. Ensure the camera mode is set to "Auto," the flash is turned off, and the lens is zoomed out so that the maximum area possible is visible in the frame.

2. Two photos will be taken at each plot, a close-up photo and a photo of the transect and surrounding landscape.

    a. The close-up photo will be taken by composing the image so that upper and lower edges of the frame are located at 0m and 1m and the transect is centered vertically through the frame so that the image is split into left to right halves by the transect (see plot schematic).

        i. The photographer should stand 12-18" behind the SW end of the transect and in line with the transect. The camera should be held between 1m and 1.5m above the ground and so that it is "landscape" (not "portrait") oriented.

        ii. Depress the shutter-release button about half way to auto focus. A green square will appear on the screen when the lens is focused.

        iii. Depress the shutter-release button the rest of the way to release the shutter and take the photo.

        iv. Review the photo and retake if necessary.

    b. The landscape transect photo will be taken with the photographer standing in the same location as was used for the photo frame.

i. Rotate the camera lens upward and compose the photo such that the transect runs vertically through the center of the frame and at least some of the sky is visible at the top of the frame.

ii. Depress the shutter-release button about half way to auto focus. A green square will appear on the screen when the lens is focused.

iii. Depress the shutter-release button the rest of the way to release the shutter and take the photo.

iv. Review the photo and retake if necessary.

3. Record the photo file names on the Plot Checklist.

Electronic Datasheet File Setup

1. Launch the spreadsheet application on the tablet and locate the PCC Datasheet Template.
2. Select “make a copy” from the document menu and rename the template according to the following convention:
    a. Acronym of project
        i. “pcc” for this project
    b. Date with 6 numbers and no symbols
        i. mmddyy
    c. Plot number preceded by the letter “p”
    d. Initials of recorder
    e. Letter or number indicating which tablet is used.

For example:

pcc062817p1005afx

indicates that the data file is from the Plant Community Classification Project on June 28, 2017. Plot 1005 was collected by Amy Forman using tablet “x.”

Plant Cover by Species – Point Frame

1. Position the point frame according to the plot diagram and such that the long axis is parallel to and centered along the tape marking the transect line.

2. Make sure that the point frame is level.

3. Read the point frame and record vegetation "hits" at the species level using foliar cover rules, explained below:

    a. All vegetative structures (non-reproductive) intercepted by shrubs, grasses, and forbs are considered "hits." Record non-vegetation entities (bare ground, litter, rock, etc.) only if a vegetative layer is not present at a given point. Record more than one "hit" for a point if more than one species is present under a point (i.e. multiple vegetation layers).

    b. On plots where junipers are present, determine juniper "hits" using a laser pointer aimed upward into the canopy. To orient upward, use the double crosshairs at each point on the point-frame to position each sample point for the laser pointer. Record a "hit" in the "opt tree" column of the electronic datasheet when the laser beam intercepts the juniper canopy.

4. Record data in the electronic data form using standardized INL species codes.

5. Repeat the procedure at all point frame sampling locations within the plot.

6. Once competed, record the file name of the electronic datasheet on the Plot Checklist.

GPS Location and Data Dictionary

1. The GPS units will be set up following ESER Program standards. If you think any setting may have been inadvertently changed, please contact the ESER GIS Lab.

2. Two GPS positions will be collected at each plot, one at the SW start point and one at the NE end point.

    a. At the SW start point, open a new Rover File at each transect.

        i. Accept the default Location and File Name.

        ii. Select the appropriate Dictionary Name (Vegetation Map 2017) from the drop-down menu if not already selected.

        iii. Click on the "Create" button.

            1. Stand so that the GPS unit is directly over the SW start point and open the SW Point Feature.

2. Click OK and accept default Antenna Height options.

3. The SW start point Point Feature requires a minimum of 120 positions (2 minutes of static data collection).

4. The data dictionary will be populated while collecting the Point Feature at the SW start point and will include:

   a. Enter the Plot ID.

   b. Enter the names of the observers.

   c. Select the most appropriate physiognomic class (shrubland, grassland, shrub herbaceous, woodland, weedy annuals, other).

   d. For each growth form (shrub, graminoid, forb), enter the INL species code for the most abundant species. If there are two equally abundant species of the same growth form, enter the INL species code for the second species in the co-dominant species field. Otherwise, enter "na" for the co-dominant species.

   e. Make any additional notes that may be pertinent about the location, context, or substrate along the transect.

5. Once the data dictionary has been populated and at least 120 positions have been logged at the SW start point, close the SW Point Feature.

iv. Move to the NE end point of the transect; the NE end point Point Feature requires a minimum of 120 positions (2 minutes of static data collection).

1. Stand so that the GPS unit is directly over the NE end point and open the NE Point Feature.

2. Once at least 120 positions have been logged, close the NE Point Feature.

b. Once both point features have been collected, close the Rover File and record the file name on the Plot Checklist.

Unknown Species Log

1. Any individual which cannot be readily identified to the species level during the plot sampling process should be collected for identification in the laboratory using the INL Site Reference Herbarium collection and/or appropriate flora keys.

2. Use a unique unknown code to identify the unknown individual in the electronic datasheet. Codes that make reference to identifying characteristics of an individual are particularly helpful. For example "UNKFYelFlow" could be used to denote an unknown forb with a yellow flower.

3. Every attempt should be made to collect a specimen outside the plot boundary. If an individual cannot be located adjacent to the plot, then photos should be taken of the unknown individual. Photos should capture as many details of leaf shape, flower anatomy, etc. as possible to facilitate the identification process.

4. Once a specimen has been located outside the plot boundary, as much of the individual as possible should be collected, including; roots, stems, leaves, flowers, and/or fruit. The specimen should be placed in either a plastic bag or plant press. A plastic bag may be used if the specimen will be identified within a day or two of collection. A plant press should be used if more than a few days will pass between collection and identification.

5. Label the plastic bag or the corner of the blotter paper in the plant press with the plot number and the unknown code used in the electronic datasheet.

6. Complete the unknown species log on the plot checklist indicating where the individual was located within the plot, a brief description of the individual, and the unknown code used to designate the individual in the electronic data form. The "Final ID" section of log will be completed once a positive identification has been made in the laboratory.

Appendix B

Classification Report

Community Classification Results

Aurora Bayless-Edwards and Ken Aho

SUMMARY

This document contains community classification results generated from the 2017 vegetation cover data. There were sixteen optimal vegetation clusters defined by a Flexible-β (β = -0.25) clustering solution. We found this optimal solution using a suite of cluster analysis methods evaluated by geometric and non-geometric evaluators. The spatial locations of each 2017 surveyed transect are color coded to represent cluster occupancy and identified graphically in the document. Relevé tables, conventional statistical summaries by cluster, and evaluated classifications are included. The sixteen clusters identified in this classification define sixteen distinct vegetation communities across the INL site as surveyed in 2017. However, the practical applicability of this clustering solution for management required refinement through field studies conducted in 2018.

Overview

This classification identified sixteen optimal vegetation clusters. These clusters can be used, in turn, to define sixteen distinct vegetation communities across the site. The spatial locations of each transect identified to cluster are shown in Figure 2. The Relevé tables, conventional statistical summaries by cluster, and evaluated classifications are attached below in the figures and tables sections.

Classification Methods

To identify the best possible classification method given the general cluster structure of the INL Site data, we considered classification solutions from eight classification methods following Shive et al. (2011). The methods used were: (1) average linkage (Sokal 1958), (2) centroid linkage (Sokal 1958), (3) complete linkage (McQuitty 1960), (4) Flexible-β (β = -0.25; Lance & Williams 1967), (5) k-means analysis (MacQueen 1967), (6) partitioning around medoids, (i.e., PAM; (Kaufman & Rousseeuw 2009), (7) single linkage (Sneath & Sokal 1973), and (8) variance minimization linkage (i.e., Ward's method; Ward Jr 1963). PAM and k-means analysis are non-hierarchical methods whereas the other six are hierarchical agglomerative methods. Hierarchical classification solutions describe hierarchical relationships, which are more important in the context of closely related or explicitly nested communities (Aho et al. 2008; Baselga 2010). On the other hand, non-hierarchical solutions delineate clusters without requiring hierarchical community structures. Non-hierarchical solutions are often appropriate when communities are geographically unique. In this case, communities would have a high degree of turnover in space, and communities must share few species, particularly across geographic gradients (Belbin 1987; Belbin & McDonald 1993).

We compared these eight classification methods with respect to their twenty-nine simplest clustering solutions (i.e., two to thirty clusters). This range of cluster numbers in solutions was informed by the previous mapping effort in which twenty-two optimal clusters were assigned (Shive et al. 2011).

Selection of Classification Method and Cluster Number

We compared the eight classification methods using seven classification evaluators, with five geometric and two indicator-species (non-geometric) criteria (Table 1). These were: (1) indicator species analysis (ISA) number of significant indicators (Dufrêne & Legendre 1997; McCune et al. 2002) (2) ISA average p-value (Dufrêne & Legendre 1997; McCune et al. 2002), (3) C-index (Hubert & Levin 1976), (4) average silhouette width, (i.e., ASW; Kaufman & Rousseeuw 2009), (5) point biserial correlation, (i.e., PBC; Brogden 1949), (6) partition analysis ratio; (i.e., PARTANA; Aho et al. 2008), and (7) McClain Rao index (i.e., MCR; McClain & Rao 1975).

These seven evaluators were used to determine the best classification method and assess the optimal number of clusters. Geometric evaluators (ASW, C-index, PARTANA, PBC and McClain Rao index) index classification effectiveness based on cluster compactness and distinctness in multivariate space (Dale 1991). The non-geometric evaluators (ISA number of significant indicators, and ISA average p-value) measure classification efficacy based on the constancy and fidelity of indicator species to defined clusters (Dufrêne & Legendre 1997, Aho et al. 2008). We selected the 'best' classification method by ranking the methods (ranks 1-8). We considered the rank of each method's maximum performance across solutions and across evaluators. To break ties we also ranked methods using the mean cluster solution within each method across evaluators (ranks 1-8; Table 1). After finding the optimal method, we selected the cluster number by finding the single solution that ranked the best within that method (1-29; Table 1). This identified a Flexible-β (β = -0.25) sixteen-cluster solution as the optimum solution.

Classification Efficacy

To ensure these clusters could be translated to useful vegetation communities for management, we considered hierarchical relationships between clusters (Figure 1), species-space distributions of clusters (Figure 3), relevé tables (Table 2), community indicator species (specified in ISA evaluators), conventional statistical summaries (Table 3), and geographic patterns in species abundances across the site (Figure 2).

We ensured that clusters described vegetation communities useful for management by matching clusters with measured species abundances and constancies across the geographic extent of the site (Table 2, Figure 2). We assumed these abundances and constancies could be easily assessed in the field. For holistic consideration of cluster structure in species space, we considered the hierarchical dendrogram (Figure 1) and non-metric multidimensional scaling plots (Figure 3). Finding cluster distinctness and compactness adequate, we moved forward with the classification. We considered conventional statistical summaries (Table 3). These included total cluster richness, mean transect richness, mean transect cover, mean Simpson’s diversity (Simpson 1949), mean Shannon-Weiner diversity (MacArthur & MacArthur 1961), and β-diversity (Whittaker 1960). These summaries indicated the spatial and geometric species-space trends fit well with conventional methods of conceptualizing vegetation community structure.

Recommendations

We found the sixteen-cluster Flexible-β solution adequately represented distinct vegetation communities present on the INL in 2017, and could be carried forward into community descriptions and mapping. However, the long-term efficacy of theses clusters requires further refinement. The practical applicability of these clusters, particularly for land managers, cannot be comprehensively assessed until after further field studies in 2018.

Figures

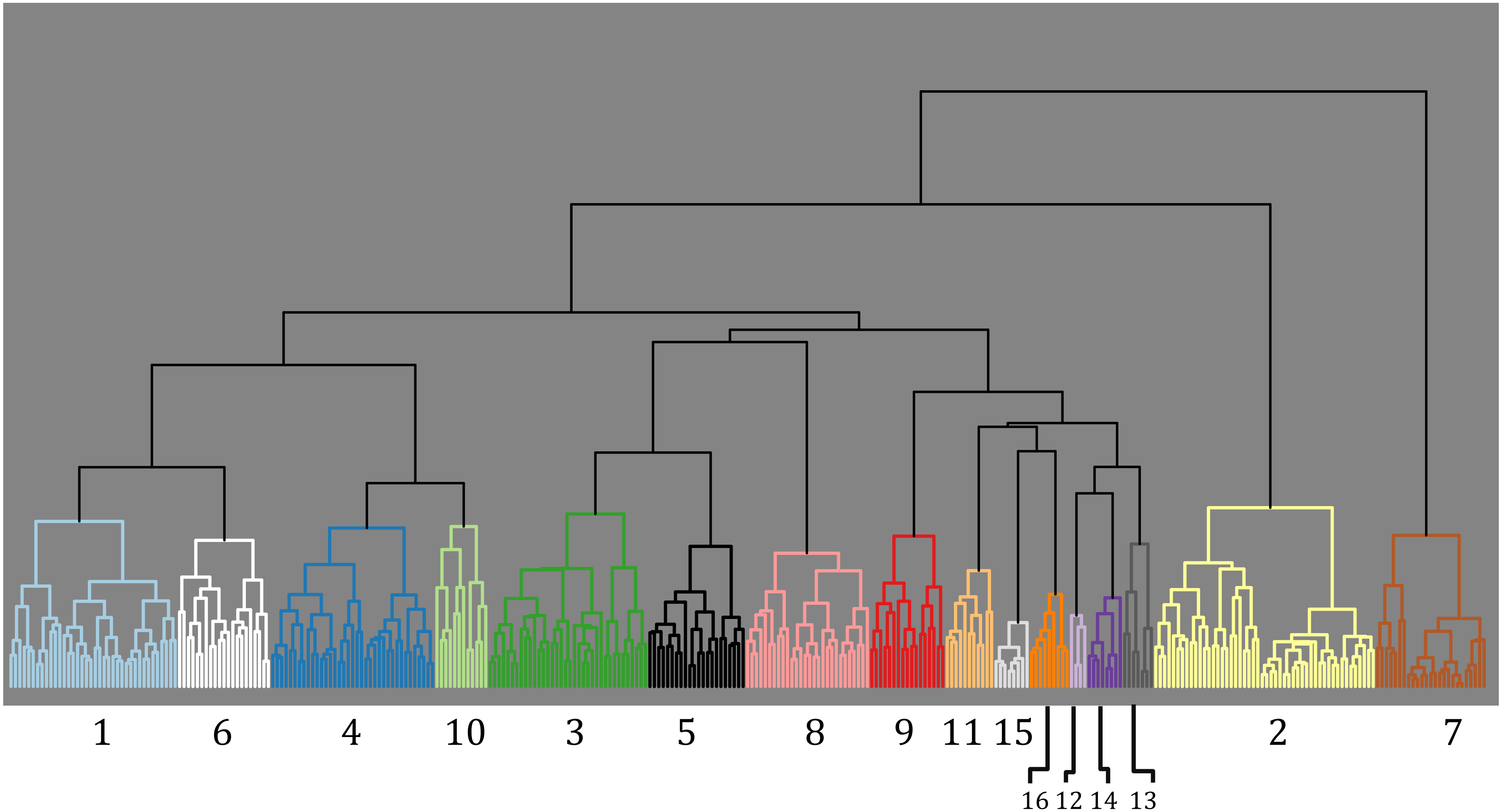

Figure 1. Dendrogram shows Flexible β = -0.25 16-cluster solution. Hierarchical relationships between clusters are shown as dendrogram nodes. Each leaf of the dendrogram represents one transect represented across species space. Colors denote cluster occupancy (clusters 1-16).

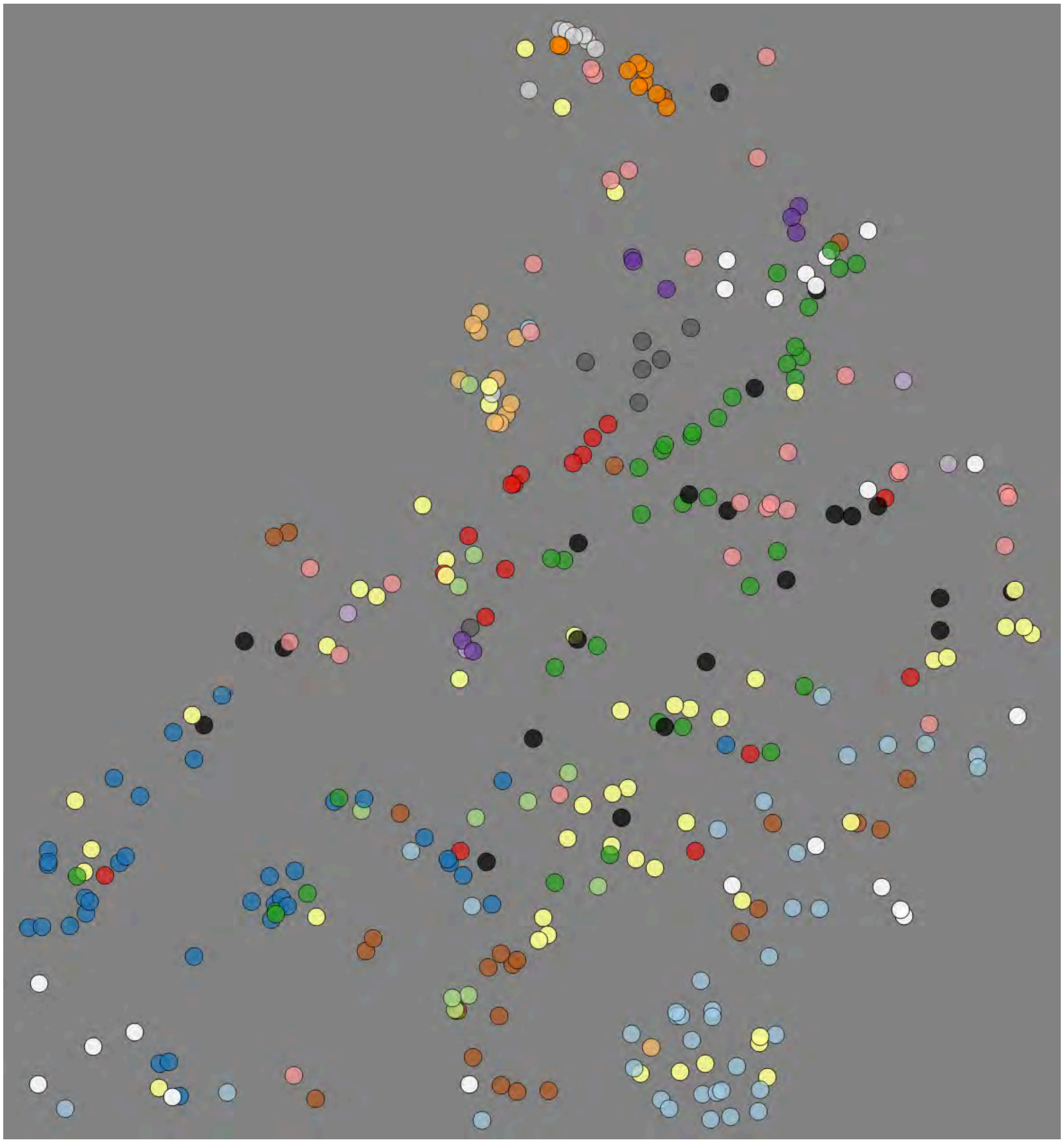

Figure 2. Map shows spatial distribution of clusters. Colors denote cluster occupancy: cluster 1 = light blue; cluster 2 = yellow; cluster 3 = dark green; cluster 4 = dark blue; cluster 5 = black; cluster 6 = white; cluster 7 = brown; cluster 8 = pink; cluster 9 = red; cluster 10 = light green; cluster 11 = light orange; cluster 12 = light purple; cluster 13 = dark gray; cluster 14 = dark purple; cluster 15 = light gray; cluster 16 = dark orange.

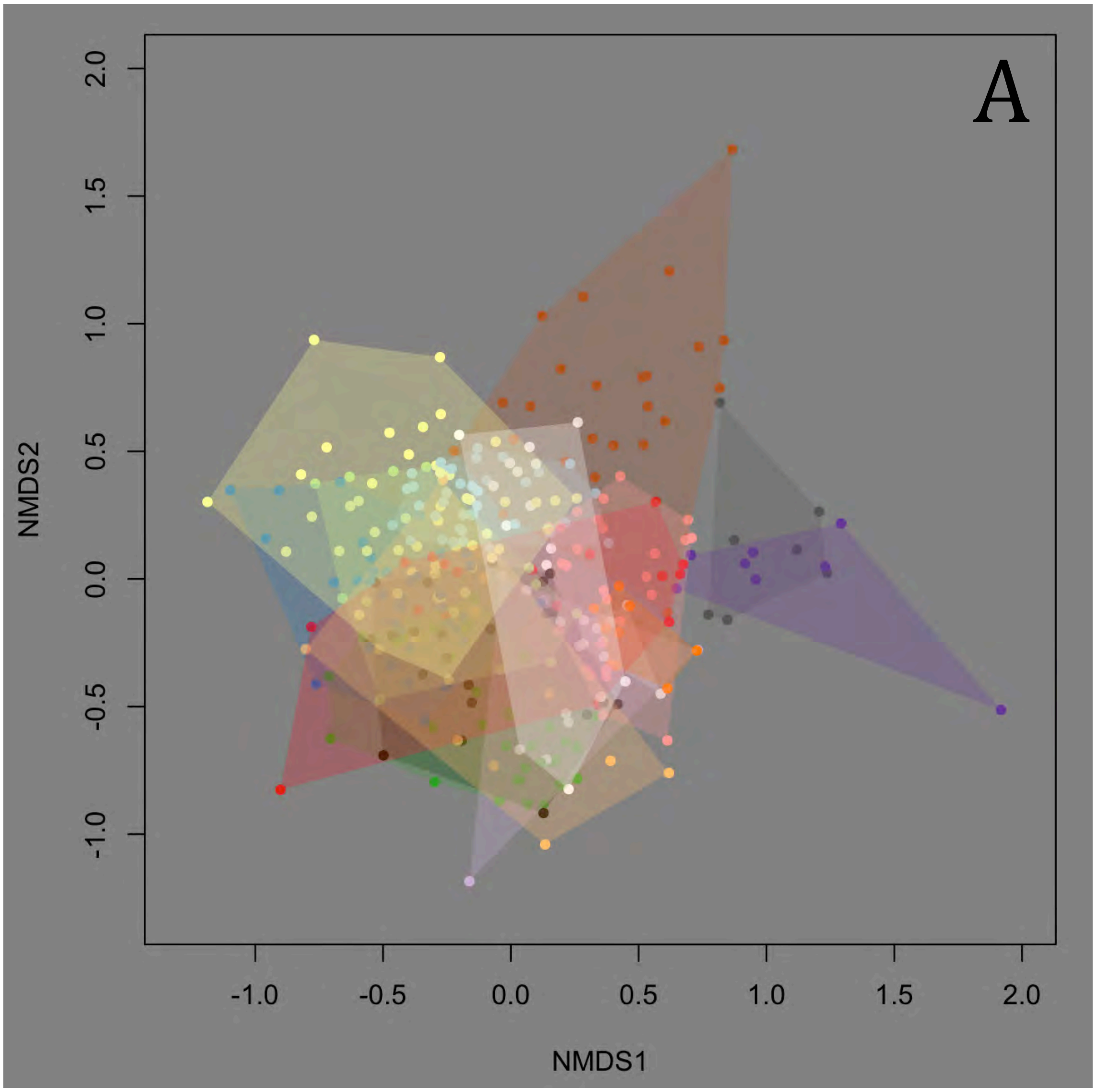

Figure 3. Non-Metric Multidimensional Scaling (k = 3 (A: 1&2, B: 2&3), stress = 0.19797) plot of transects in species-space. Points indicate transects. Hulls indicate clusters. Color indicates cluster occupancy: cluster 1 = light blue; cluster 2 = yellow; cluster 3 = dark green; cluster 4 = dark blue; cluster 5 = black; cluster 6 = white; cluster 7 = brown; cluster 8 = pink; cluster 9 = red; cluster 10 = light green; cluster 11 = light orange; cluster 12 = light purple; cluster 13 = dark gray; cluster 14 = dark purple; cluster 15 = light gray; cluster 16 = dark orange.

Continued

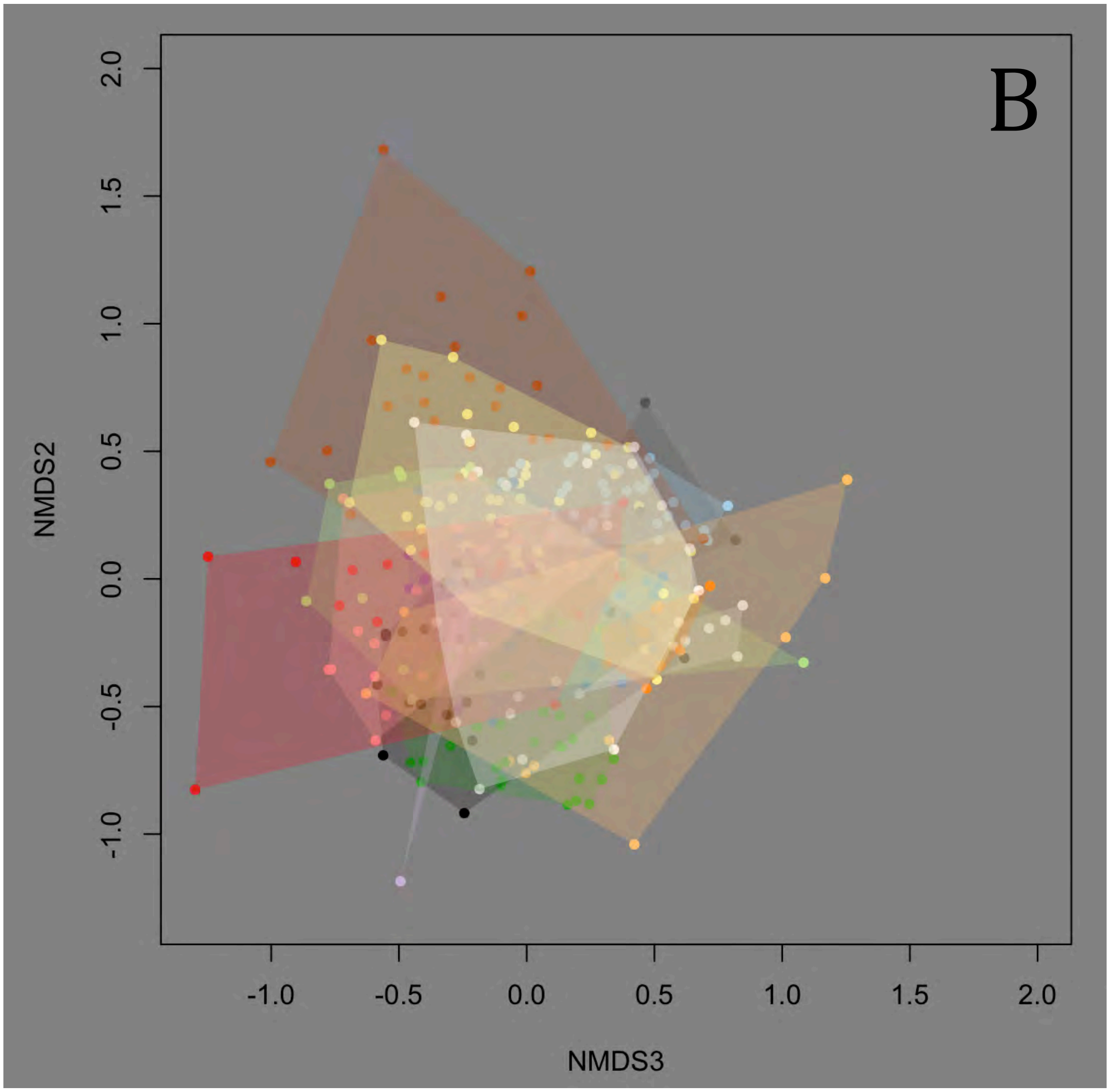

Figure 3. *Continued*

Tables

Table 1. Classification solutions were evaluated across geometric and non-geometric evaluators. Flexible-β = -0.25 preformed the best in terms for maximum classification solutions, and experienced the least chaining.

		Evaluator			
		ASW	C-index	PARTANA	MCR
Maximum Value by Classification Method	Single	0.016024309	0.858276362	2.296470906	0.90393475
	Complete	0.223353057	0.88818257	3.312192633	0.870372127
	Average	0.245538681	0.906626886	3.304786175	0.835047055
	Centroid	0.044947893	0.918269052	3.339212235	0.927798727
	Ward	0.240005908	0.897468141	3.366062006	0.840696092
	Flexible β = -0.25	0.238769752	0.903557651	3.420070952	0.804538532
	Kmeans	0.174819128	0.846055392	3.125085887	0.782296367
	PAM	0.22215613	0.875086514	3.30445509	0.807470056
Mean Value by Classification Method	Single	-0.098644025	0.81140087	1.974752276	0.889890847
	Complete	0.200233953	0.842392633	2.92962943	0.64775006
	Average	0.206595128	0.861403653	2.949640906	0.688296447
	Centroid	-0.187093243	0.818539447	1.998014271	0.900564875
	Ward	0.214723642	0.850134251	3.026843882	0.617409806
	Flexible β = -0.25	0.211742269	0.850677788	3.032790613	0.61579832
	Kmeans	0.142739027	0.78923743	2.800783127	0.647645286
	PAM	0.201053994	0.829469829	2.958937823	0.622803344

		Evaluator		
		PBC	ISA *p*-value	ISA #
Maximum Value by Classification Method	Single	0.363580668	0.494744828	21
	Complete	0.573976886	0.721682759	52
	Average	0.595095916	0.658117241	35
	Centroid	0.156570717	0.422951724	21
	Ward	0.582400553	0.42442069	22
	Flexible β = -0.25	0.578074899	0.746517241	58
	Kmeans	0.525080815	0.75717931	64
	PAM	0.530142885	0.754158621	57
Mean Value by Classification Method	Single	0.21300788	0.389598939	16.61538462
	Complete	0.521058334	0.662284881	35.11538462
	Average	0.558254142	0.610845093	27
	Centroid	0.149417167	0.377629708	12.42307692
	Ward	0.526924811	0.377815915	12.61538462
	Flexible β = -0.25	0.525257631	0.688598939	47.11538462
	Kmeans	0.45194653	0.713179841	50.23076923
	PAM	0.494479662	0.701872679	47.34615385

Table 2. Releve table shows species cover and constancy by cluster clusters. Colors denote cluster occupancy: cluster 1 = light blue; cluster 2 = yellow; cluster 3 = dark green; cluster 4 = dark blue; cluster 5 = black; cluster 6 = white; cluster 7 = brown; cluster 8 = pink; cluster 9 = red; cluster 10 = light green; cluster 11 = light orange; cluster 12 = light purple; cluster 13 = dark gray; cluster 14 = dark purple; cluster 15 = light gray; cluster 16 = dark orange. Constancy classes are 0% = '.', 0-10% = +, 12-20% = 1, 20-30% = 2, 30-40% = 3, 40-50% = 4, 50-60%=5, 60-70% = 6, 70-80%=7, 80-90%= 8, 90-100% = 9. Cover classes are show as 0% = '.', 0-0.01%='+', 0.01-1% = A, 1-2% = B, 2-5% = C, 5-25% = D, >25% = E.

Scientific Name	Cluster 13	Cluster 16	Cluster 11	Cluster 3
Juniperus osteosperma	..	..	9E	..
Artemisia arbuscula	..	9D	..	..
Cercocarpus ledifolius	..	..	..	..
Artemisia nova	..	1A	'+'B	1A
Artemisia tridentata	..	1A	'+'A	'+'A
Artemisia tripartita	..	..	..	..
Atriplex confertifolia	7D	6B	'+'A	..
Atriplex falcata	4B	..	..	..
Grayia spinosa	..	..	1A	..
Krascheninnikovia lanata	5D	7B	2A	3B
Ericameria nauseosa	..	..	..	'+'A
Chrysothamnus viscidiflorus	..	8C	6B	9D
Eriogonum microthecum	..	9B	3A	3A
Gutierrezia sarothrae	..	..	2A	1A
Ericameria nana	..	..	..	..
Tetradymia spinosa	2A	..	..	..
Linanthus pungens	..	7B	'+'A	1A
Purshia tridentata	..	..	..	..
Sarcobatus vermiculatus	1A	..	..	..
Symphoricarpos oreophilus	..	..	'+'A	..
Tetradymia canescens	..	..	..	2A
Agropyron cristatum	..	3A	..	'+'A
Elymus lanceolatus	..	..	..	9D
Pascopyrum smithii	4A	..	1A	1A
Pseudoroegneria spicata	..	..	4C	'+'A
Carex douglasii	..	..	..	1A
Leymus salinus	..	..	2A	..
Leymus cinereus	..	..	'+'A	'+'A
Elymus trachycaulus	..	..	..	..
Hordeum jubatum	..	..	..	..
Koeleria macrantha	..	..	..	..
Leymus flavescens	..	..	..	'+'A
Achnatherum hymenoides	5A	9D	9C	9D
Poa secunda	4C	8C	6B	2C
Elymus elymoides	9C	9C	4A	4A
Hesperostipa comata	..	3A	7C	9D
Achnatherum thurberianum	..	..	..	'+'A

Scientific Name	Cluster 13	Cluster 16	Cluster 11	Cluster 3
Allium acuminatum	..	..	'+'A	..
Allium textile	..	1A	..	1A
Arabis holboellii	..	..	..	..
Arabis cobrensis	..	1A	..	..
Arabis lignifera	..	..	1A	..
Arenaria franklinii	..	1A	2A	'+'A
Astragalus ceramicus	..	..	..	1A
Astragalus agrestis	..	..	..	..
Astragalus calycosus	1A	..	..	2A
Astragalus convallarius	..	..	'+'A	..
Astragalus curvicarpus	..	..	..	..
Astragalus filipes	..	..	..	'+'A
Astragalus gilviflorus	..	..	..	'+''+'
Astragalus geyeri	..	..	..	'+'A
Astragalus lentiginosus	..	..	..	3A
Astragalus purshii	..	..	..	'+'A
Carduus nutans	..	..	..	..
Balsamorhiza sagittata	..	..	..	..
Castilleja pallescens	..	..	..	..
Calochortus bruneaunis	..	..	1A	..
Cirsium arvense	..	..	..	..
Castilleja angustifolia	..	..	..	..
Comandra umbellata	..	..	..	'+'A
Corallorhiza maculata	..	..	..	'+'A
Crepis acuminata	..	..	1A	1A
Cryptantha interrupta	..	..	'+'A	'+'A
Pteryxia terebinthina	..	..	..	..
Erigeron filifolius	..	..	..	'+''+'
Erigeron pumilus	..	1A	1A	1A
Erigeron compositus	..	..	..	..
Eriogonum caespitosum	..	..	'+'A	..
Eriogonum ovalifolium	..	1A	3A	3A
Ipomopsis congesta	..	..	1A	1A
Stenotus acaulis	..	..	..	..
Iva axillaris	..	..	..	3A
Grindelia squarrosa	..	..	..	..
Lomatium dissectum	..	..	..	'+'A

Scientific Name	Cluster 13	Cluster 16	Cluster 11	Cluster 3
Lomatium foeniculaceum	2A	..	2A	..
Hedysarum boreale	..	..	..	1A
Lupinus argenteus	..	..	..	..
Ionactis alpina	..	..	'+'A	..
Lupinus sericeus	..	..	'+'A	..
Lygodesmia grandiflora	..	..	2A	'+'A
Pleiacanthus spinosus	..	..	..	1A
Oenothera caespitosa	..	..	'+'A	'+'A
Oenothera pallida	..	..	'+'A	'+''+'
Lithospermum ruderale	..	..	..	..
Orobanche fasciculata	..	..	..	..
Phacelia hastata	..	..	..	..
Phlox hoodii	1A	7A	1A	4A
Lupinus holosericeus	..	..	..	..
Phlox longifolia	1A	1A	'+'A	'+'A
Psoralidium lanceolatum	..	..	'+'A	'+'A
Schoenocrambe linifolia	5B	5A	1A	1A
Sphaeralcea munroana	..	1A	1A	2A
Stanleya viridiflora	..	..	'+'A	..
Townsendia florifer	..	2A	'+'A	'+''+'
Penstemon humilis	..	..	'+'A	..
Penstemon radicosus	..	..	..	..
Zigadenus venenosus	..	..	..	..
Phlox aculeata	..	..	..	'+'A
Rumex venosus	..	..	..	'+'A
Verbena bracteata	..	..	..	..
Opuntia polyacantha	5A	9A	2A	5A
Escobaria missouriensis	..	..	..	..
Alyssum desertorum	..	2C	..	5C
Amaranthus blitoides	..	..	..	..
Ambrosia acanthicarpa	..	..	..	..
Bromus arvensis	..	..	..	..
Bromus tectorum	1A	2A	8D	5B
Chenopodium album	..	..	'+'A	..
Chenopodium leptophyllum	..	1A	'+'A	1A
Tiquilia nuttallii	..	..	..	..
Camissonia andina	..	..	..	..

Scientific Name	Cluster 13	Cluster 16	Cluster 11	Cluster 3
Camissonia minor	..	..	..	..
Cordylanthus ramosus	..	2A	..	..
Camelina microcarpa	..	..	..	..
Cryptantha scoparia	1A	2A	5A	1A
Descurainia pinnata	1A	2A	8A	9C
Descurainia sophia	1A	2A	..	'+'A
Chorispora tenella	..	..	..	..
Eriastrum wilcoxii	1A	6A	1A	2A
Eriogonum cernuum	..	..	6B	4A
Gayophytum diffusum	..	..	'+'A	'+'A
Aliciella leptomeria	..	..	..	..
Ipomopsis minutiflora	..	..	..	..
Gilia sinuata	..	..	7B	'+'A
Halogeton glomeratus	5A	..	2B	'+''+'
Lactuca serriola	..	..	'+'A	..
Erodium cicutarium	..	..	..	..
Lappula occidentalis	..	2A	7A	5A
Eriogonum maculatum	..	..	..	..
Lepidium perfoliatum	..	..	..	..
Leptosiphon septentrionalis	..	..	..	..
Mentzelia albicaulis	1A	..	3A	3A
Juncus bufonius	..	..	..	..
Ceratocephala testiculata	..	..	..	..
Lupinus pusillus	..	..	'+'A	..
Salsola kali	..	..	5A	4A
Sisymbrium altissimum	..	1A	'+'A	3A
Phacelia glandulifera	..	..	5A	2A
Thlaspi arvense	..	..	..	..
Chamaesyce maculata	..	..	..	..
Chaenactis douglasii	..	..	'+'A	2A
Machaeranthera canescens	..	..	..	2A
Thelypodium laciniatum	..	..	..	..
Tragopogon dubius	..	..	'+'A	'+'A
Woodsia oregana	..	..	'+'A	..

Scientific Name	Cluster 12	Cluster 15	Cluster 4	Cluster 14
Juniperus osteosperma	..	..	..	..
Artemisia arbuscula	..	2A	..	..
Cercocarpus ledifolius	..	..	..	..
Artemisia nova	..	9E	..	..
Artemisia tridentata	4A	3A	1A	4B
Artemisia tripartita	..	..	..	..
Atriplex confertifolia	..	3A	..	..
Atriplex falcata	2D	..	..	9E
Grayia spinosa	..	..	..	..
Krascheninnikovia lanata	..	1A	..	4D
Ericameria nauseosa	..	..	1B	..
Chrysothamnus viscidiflorus	4C	6A	9D	1A
Eriogonum microthecum	..	8A	1A	..
Gutierrezia sarothrae	..	1A	..	..
Ericameria nana	..	..	..	..
Tetradymia spinosa	..	..	..	..
Linanthus pungens	..	8B	1A	..
Purshia tridentata	..	..	..	..
Sarcobatus vermiculatus	..	..	..	..
Symphoricarpos oreophilus	..	..	..	..
Tetradymia canescens	..	1A	2A	..
Agropyron cristatum	..	..	..	..
Elymus lanceolatus	4A	1A	4C	..
Pascopyrum smithii	..	..	3C	..
Pseudoroegneria spicata	..	1A	4C	..
Carex douglasii	..	..	1B	..
Leymus salinus	..	..	..	..
Leymus cinereus	2A	..	'+'A	..
Elymus trachycaulus	..	..	..	..
Hordeum jubatum	..	..	'+'A	..
Koeleria macrantha	..	..	..	..
Leymus flavescens	..	..	..	..
Achnatherum hymenoides	9E	9C	8D	7C
Poa secunda	..	9D	8C	..
Elymus elymoides	7C	9B	7B	8C
Hesperostipa comata	7B	3A	6D	..
Achnatherum thurberianum	..	..	..	..

Scientific Name	Cluster 12	Cluster 15	Cluster 4	Cluster 14
Allium acuminatum	..	..	'+''+'	..
Allium textile	..	2A	'+'A	..
Arabis holboellii	..	..	..	..
Arabis cobrensis	..	..	..	..
Arabis lignifera	..	..	..	..
Arenaria franklinii	..	1A	2A	..
Astragalus ceramicus	..	..	..	..
Astragalus agrestis	..	..	'+'A	..
Astragalus calycosus	..	..	..	..
Astragalus convallarius	..	..	..	..
Astragalus curvicarpus	..	..	1A	..
Astragalus filipes	..	..	4A	..
Astragalus gilviflorus	..	..	..	..
Astragalus geyeri	..	..	..	..
Astragalus lentiginosus	..	..	2A	..
Astragalus purshii	..	..	1A	..
Carduus nutans	..	..	..	..
Balsamorhiza sagittata	..	..	..	..
Castilleja pallescens	..	..	..	..
Calochortus bruneaunis	..	1A	'+''+'	..
Cirsium arvense	..	..	'+'A	..
Castilleja angustifolia	..	..	..	..
Comandra umbellata	..	..	..	..
Corallorhiza maculata	..	..	..	..
Crepis acuminata	..	..	2A	..
Cryptantha interrupta	..	1A	'+'A	..
Pteryxia terebinthina	..	..	..	..
Erigeron filifolius	..	..	..	..
Erigeron pumilus	..	..	2A	..
Erigeron compositus	..	..	..	..
Eriogonum caespitosum	..	1A	..	..
Eriogonum ovalifolium	..	3A	1A	..
Ipomopsis congesta	..	..	2A	..
Stenotus acaulis	..	..	..	..
Iva axillaris	..	..	'+'A	..
Grindelia squarrosa	..	..	'+''+'	..
Lomatium dissectum	..	..	1A	..

Scientific Name	Cluster 12	Cluster 15	Cluster 4	Cluster 14
Lomatium foeniculaceum	..	..	1A	..
Hedysarum boreale	..	..	..	..
Lupinus argenteus	..	..	1A	..
Ionactis alpina	..	..	..	..
Lupinus sericeus	..	..	..	..
Lygodesmia grandiflora	..	..	..	..
Pleiacanthus spinosus	..	..	'+'A	..
Oenothera caespitosa	..	1A	..	..
Oenothera pallida	..	..	..	..
Lithospermum ruderale	..	..	..	..
Orobanche fasciculata	..	..	..	..
Phacelia hastata	..	..	..	..
Phlox hoodii	2A	9B	5B	..
Lupinus holosericeus	..	..	'+'A	..
Phlox longifolia	..	6A	2A	..
Psoralidium lanceolatum	..	..	..	..
Schoenocrambe linifolia	2A	1A	2A	3A
Sphaeralcea munroana	4C	1A	3A	..
Stanleya viridiflora	..	..	..	..
Townsendia florifer	..	..	'+'A	..
Penstemon humilis	..	..	..	..
Penstemon radicosus	..	..	..	..
Zigadenus venenosus	..	..	'+'A	..
Phlox aculeata	..	..	'+'A	..
Rumex venosus	..	..	..	..
Verbena bracteata	..	..	..	..
Opuntia polyacantha	4A	9A	2A	1A
Escobaria missouriensis	..	1A	..	..
Alyssum desertorum	2A	..	9E	..
Amaranthus blitoides	..	..	..	..
Ambrosia acanthicarpa	..	..	..	..
Bromus arvensis	..	..	'+''+'	..
Bromus tectorum	4D	2A	9D	..
Chenopodium album	..	..	..	..
Chenopodium leptophyllum	..	3A	'+''+'	..
Tiquilia nuttallii	..	..	..	..
Camissonia andina	..	..	..	..

Scientific Name	Cluster 12	Cluster 15	Cluster 4	Cluster 14
Camissonia minor	..	..	..	..
Cordylanthus ramosus	..	7A	1A	..
Camelina microcarpa	..	..	..	..
Cryptantha scoparia	..	1A	'+'A	2A
Descurainia pinnata	7A	1A	3A	..
Descurainia sophia	2A	..	'+'B	1A
Chorispora tenella	..	..	..	..
Eriastrum wilcoxii	4A	4A	3A	3A
Eriogonum cernuum	..	..	..	..
Gayophytum diffusum	..	1A	'+'A	..
Aliciella leptomeria	..	..	..	..
Ipomopsis minutiflora	..	..	..	..
Gilia sinuata	..	1A	..	..
Halogeton glomeratus	..	..	'+''+'	3A
Lactuca serriola	..	..	..	..
Erodium cicutarium	..	..	..	..
Lappula occidentalis	7A	1A	4A	4B
Eriogonum maculatum	..	..	'+''+'	..
Lepidium perfoliatum	..	..	..	..
Leptosiphon septentrionalis	..	..	..	..
Mentzelia albicaulis	2B	1A	'+''+'	3A
Juncus bufonius	..	..	..	..
Ceratocephala testiculata	..	..	..	..
Lupinus pusillus	..	..	..	..
Salsola kali	..	..	'+'A	..
Sisymbrium altissimum	4A	..	2A	..
Phacelia glandulifera	..	..	..	..
Thlaspi arvense	..	..	..	..
Chamaesyce maculata	..	..	..	..
Chaenactis douglasii	..	..	1A	..
Machaeranthera canescens	..	..	4A	..
Thelypodium laciniatum	..	..	..	..
Tragopogon dubius	2A	..	1A	..
Woodsia oregana	..	..	..	..

Scientific Name	Cluster 2	Cluster 9	Cluster 10	Cluster 5
Juniperus osteosperma	..	..	'+'A	..
Artemisia arbuscula	..	..	..	..
Cercocarpus ledifolius	..	..	'+'A	..
Artemisia nova	'+'A	..	'+'A	..
Artemisia tridentata	2C	4C	3C	3C
Artemisia tripartita	..	..	..	..
Atriplex confertifolia	'+'A	..	'+'A	..
Atriplex falcata	'+'A	1A	'+'A	..
Grayia spinosa	'+'A	1B	..	'+'A
Krascheninnikovia lanata	'+'A	3A	2B	1A
Ericameria nauseosa	'+'A	1A	1A	'+'A
Chrysothamnus viscidiflorus	7D	6D	4C	8C
Eriogonum microthecum	'+'A	'+'A	1A	'+'A
Gutierrezia sarothrae	1A	..	..	..
Ericameria nana	'+'A	..	..	'+'A
Tetradymia spinosa	..	'+''+'	..	..
Linanthus pungens	'+'A	..	'+'A	1A
Purshia tridentata	'+''+'	..	..	..
Sarcobatus vermiculatus	..	'+'A	..	..
Symphoricarpos oreophilus	'+'A	..	..	..
Tetradymia canescens	'+'A	1A	..	'+'A
Agropyron cristatum	1A	..	3B	'+'A
Elymus lanceolatus	1B	'+'A	2B	4C
Pascopyrum smithii	1B	9E	1A	1A
Pseudoroegneria spicata	2C	..	'+'A	1B
Carex douglasii	'+'A	2C	1C	..
Leymus salinus	'+'A	..	'+'A	..
Leymus cinereus	'+'A	..	4D	'+'A
Elymus trachycaulus	..	..	..	..
Hordeum jubatum	'+'A	..	..	..
Koeleria macrantha	..	..	..	..
Leymus flavescens	..	..	..	..
Achnatherum hymenoides	7C	7C	4A	8D
Poa secunda	6C	2C	4C	2C
Elymus elymoides	7C	5B	6C	7B
Hesperostipa comata	5C	4C	3C	9E
Achnatherum thurberianum	..	..	..	'+'A

Scientific Name	Cluster 2	Cluster 9	Cluster 10	Cluster 5
Allium acuminatum	..	..	..	..
Allium textile	..	'+''+'	..	'+'A
Arabis holboellii	..	..	..	..
Arabis cobrensis	..	..	..	..
Arabis lignifera	'+'A	..	..	..
Arenaria franklinii	'+'A	'+'A	1A	'+'A
Astragalus ceramicus	..	..	..	'+'A
Astragalus agrestis	'+'A	..	'+'A	..
Astragalus calycosus	..	1A	..	..
Astragalus convallarius	..	..	..	..
Astragalus curvicarpus	'+'A	..	..	..
Astragalus filipes	'+'A	2A	'+'A	..
Astragalus gilviflorus	..	..	..	..
Astragalus geyeri	..	..	..	'+''+'
Astragalus lentiginosus	1A	3A	'+'A	1A
Astragalus purshii	'+''+'	..	'+'A	'+''+'
Carduus nutans	'+'A	..	..	..
Balsamorhiza sagittata	'+'A	..	..	..
Castilleja pallescens	..	..	..	..
Calochortus bruneaunis	'+''+'	..	..	..
Cirsium arvense	'+''+'	..	..	..
Castilleja angustifolia	'+'A	..	..	..
Comandra umbellata	..	..	..	..
Corallorhiza maculata	..	..	..	'+'A
Crepis acuminata	1A	'+'A	1A	'+'A
Cryptantha interrupta	'+''+'	..	'+'A	..
Pteryxia terebinthina	'+'A	..	..	..
Erigeron filifolius	..	..	..	'+'A
Erigeron pumilus	1A	..	..	'+'A
Erigeron compositus	..	..	..	'+''+'
Eriogonum caespitosum	'+''+'	..	'+'A	..
Eriogonum ovalifolium	..	..	1A	3A
Ipomopsis congesta	'+'A	..	..	..
Stenotus acaulis	..	..	'+'A	..
Iva axillaris	'+'A	1A	2A	1A
Grindelia squarrosa	..	..	..	..
Lomatium dissectum	'+'A	..	'+'A	'+'A

Scientific Name	Cluster 2	Cluster 9	Cluster 10	Cluster 5
Lomatium foeniculaceum	'+'A	..	'+'A	'+''+'
Hedysarum boreale	..	..	..	..
Lupinus argenteus	'+'A	..	..	..
Ionactis alpina	..	..	..	..
Lupinus sericeus	..	..	..	..
Lygodesmia grandiflora	..	..	'+'A	'+'A
Pleiacanthus spinosus	'+'A	'+'A	..	1A
Oenothera caespitosa	..	..	..	'+'A
Oenothera pallida	..	'+'A	..	'+''+'
Lithospermum ruderale	'+'A	..	..	..
Orobanche fasciculata	..	..	..	..
Phacelia hastata	'+'A	..	..	'+'A
Phlox hoodii	2A	3A	4A	1A
Lupinus holosericeus	..	..	..	..
Phlox longifolia	'+'A	1A	1A	'+'A
Psoralidium lanceolatum	..	'+'A	..	'+'A
Schoenocrambe linifolia	2A	5C	4A	3A
Sphaeralcea munroana	4A	4A	1A	3A
Stanleya viridiflora	..	..	..	..
Townsendia florifer	'+'A	'+''+'	'+''+'	..
Penstemon humilis	..	..	..	..
Penstemon radicosus	..	'+'A	..	..
Zigadenus venenosus	..	..	..	..
Phlox aculeata	'+'A	..	..	..
Rumex venosus	..	'+'A	..	'+'A
Verbena bracteata	..	'+'B	..	..
Opuntia polyacantha	1A	2A	4A	3A
Escobaria missouriensis	..	..	'+''+'	..
Alyssum desertorum	6C	4C	9D	4B
Amaranthus blitoides	..	'+'A	..	..
Ambrosia acanthicarpa	..	..	..	..
Bromus arvensis	'+''+'	..	..	..
Bromus tectorum	9E	5C	8C	8D
Chenopodium album	..	..	..	..
Chenopodium leptophyllum	'+'A	1A	1A	4A
Tiquilia nuttallii	..	..	..	'+''+'
Camissonia andina	..	..	..	..

Scientific Name	Cluster 2	Cluster 9	Cluster 10	Cluster 5
Camissonia minor	..	..	..	..
Cordylanthus ramosus	'+'A	..	..	'+'A
Camelina microcarpa	..	..	'+'A	..
Cryptantha scoparia	'+'A	'+'A	3A	3A
Descurainia pinnata	6B	5B	6D	9C
Descurainia sophia	2B	1A	6D	2A
Chorispora tenella	'+''+'	..	..	..
Eriastrum wilcoxii	2A	3A	'+''+'	3A
Eriogonum cernuum	'+''+'	..	..	2A
Gayophytum diffusum	1A	'+'A	1A	'+'A
Aliciella leptomeria	..	..	..	..
Ipomopsis minutiflora	..	..	..	..
Gilia sinuata	'+''+'	..	1A	'+'A
Halogeton glomeratus	1A	3B	..	..
Lactuca serriola	'+'A	..	'+''+'	..
Erodium cicutarium	'+''+'	..	..	..
Lappula occidentalis	7B	7C	9C	8B
Eriogonum maculatum	..	..	..	..
Lepidium perfoliatum	..	..	..	..
Leptosiphon septentrionalis	..	..	..	'+'A
Mentzelia albicaulis	'+'A	2A	2A	2A
Juncus bufonius	..	'+'A	..	..
Ceratocephala testiculata	'+''+'	..	..	..
Lupinus pusillus	..	..	..	..
Salsola kali	2A	1A	3B	1A
Sisymbrium altissimum	6B	2A	3B	4C
Phacelia glandulifera	..	..	..	1A
Thlaspi arvense	'+''+'	..	..	..
Chamaesyce maculata	'+''+'	..	..	..
Chaenactis douglasii	'+'A	'+'A	'+''+'	'+''+'
Machaeranthera canescens	2A	1A	1A	'+''+'
Thelypodium laciniatum	..	..	..	'+'A
Tragopogon dubius	1A	1A	'+''+'	1A
Woodsia oregana	..	..	..	..

Scientific Name	Cluster 7	Cluster 1	Cluster 6	Cluster 8
Juniperus osteosperma	..	..	..	..
Artemisia arbuscula	'+'A	..	..	'+'A
Cercocarpus ledifolius	..	..	..	..
Artemisia nova	..	..	'+'A	'+'A
Artemisia tridentata	5C	3C	8D	9E
Artemisia tripartita	'+'A	1B	3D	..
Atriplex confertifolia	'+'A	..	..	1A
Atriplex falcata	'+'A	..	..	..
Grayia spinosa	'+'A	..	..	'+'A
Krascheninnikovia lanata	1A	'+'A	2C	2C
Ericameria nauseosa	'+'A	'+'A	1A	'+'A
Chrysothamnus viscidiflorus	7C	9D	9D	8C
Eriogonum microthecum	1A	2A	3A	1A
Gutierrezia sarothrae	..	..	..	'+'A
Ericameria nana	..	..	..	'+'A
Tetradymia spinosa	..	..	..	..
Linanthus pungens	'+'A	2A	3A	1A
Purshia tridentata	..	..	..	..
Sarcobatus vermiculatus	..	..	..	..
Symphoricarpos oreophilus	..	..	..	..
Tetradymia canescens	..	'+'A	5B	..
Agropyron cristatum	9E	1A	1A	1A
Elymus lanceolatus	1A	1A	6C	4B
Pascopyrum smithii	'+'A	1B	1A	'+''+'
Pseudoroegneria spicata	'+'A	7D	3B	'+'A
Carex douglasii	'+'A	'+'A	..	..
Leymus salinus	..	..	..	..
Leymus cinereus	1A	'+'A	2B	..
Elymus trachycaulus	'+'A	..	..	..
Hordeum jubatum	..	..	..	..
Koeleria macrantha	..	'+'A	..	..
Leymus flavescens	..	..	..	..
Achnatherum hymenoides	2A	5A	7C	8C
Poa secunda	2A	9D	4B	4A
Elymus elymoides	3A	9C	8B	8C
Hesperostipa comata	1A	2A	3B	5C
Achnatherum thurberianum	..	'+'A	..	..

Scientific Name	Cluster '+'A	..	..	'+'A
Allium acuminatum	..	1A	'+'A	..
Allium textile	..	'+''+'	..	..
Arabis holboellii	..	..	..	'+'A
Arabis cobrensis	..	..	..	..
Arabis lignifera	..	'+''+'	'+'A	'+'A
Arenaria franklinii	'+'A	2A	1A	..
Astragalus ceramicus	..	..	..	..
Astragalus agrestis	..	..	..	..
Astragalus calycosus	..	..	1A	..
Astragalus convallarius	..	..	..	..
Astragalus curvicarpus	..	'+'A	..	..
Astragalus filipes	..	1A	'+'A	'+'A
Astragalus gilviflorus	..	..	..	..
Astragalus geyeri	..	..	..	..
Astragalus lentiginosus	'+''+'	1A	2A	'+''+'
Astragalus purshii	'+''+'	1A	'+'A	'+'A
Carduus nutans	..	..	..	..
Balsamorhiza sagittata	..	'+'A	..	..
Castilleja pallescens	..	..	..	'+'A
Calochortus bruneaunis	..	'+''+'	..	..
Cirsium arvense	..	..	..	..
Castilleja angustifolia	..	'+'A	'+'A	..
Comandra umbellata	..	..	..	..
Corallorhiza maculata	..	..	..	'+''+'
Crepis acuminata	'+'A	5A	2A	..
Cryptantha interrupta	..	'+'A	'+'A	'+''+'
Pteryxia terebinthina	..	..	..	..
Erigeron filifolius	..	..	..	..
Erigeron pumilus	..	6A	1A	1A
Erigeron compositus	..	..	..	..
Eriogonum caespitosum	..	..	'+'A	..
Eriogonum ovalifolium	'+'A	'+''+'	2A	..
Ipomopsis congesta	..	2A	'+'A	'+''+'
Stenotus acaulis	..	'+'A	..	..
Iva axillaris	'+'A	..	3A	1A
Grindelia squarrosa	..	..	..	..
Lomatium dissectum	..	'+''+'	1A	'+''+'

Scientific Name	Cluster 7	Cluster 1	Cluster 6	Cluster 8
Lomatium foeniculaceum	..	1A	'+'A	'+''+'
Hedysarum boreale	..	..	..	..
Lupinus argenteus	..	..	'+''+'	..
Ionactis alpina	..	..	'+''+'	..
Lupinus sericeus	..	..	..	..
Lygodesmia grandiflora	..	..	'+'A	..
Pleiacanthus spinosus	..	..	'+'A	1A
Oenothera caespitosa	..	'+''+'	1A	..
Oenothera pallida	..	..	'+'A	..
Lithospermum ruderale	..	'+'A	..	..
Orobanche fasciculata	..	..	..	'+''+'
Phacelia hastata	..	..	..	..
Phlox hoodii	3A	6A	4A	3A
Lupinus holosericeus	..	..	..	..
Phlox longifolia	'+'A	4A	'+'A	..
Psoralidium lanceolatum	..	..	'+'A	'+'A
Schoenocrambe linifolia	'+'A	3A	2A	2A
Sphaeralcea munroana	'+'A	2A	'+'A	2A
Stanleya viridiflora	..	'+'A	..	'+'A
Townsendia florifer	..	1A	'+'A	'+''+'
Penstemon humilis	..	..	..	..
Penstemon radicosus	..	..	..	..
Zigadenus venenosus	..	'+'A	..	..
Phlox aculeata	..	2A	'+'A	..
Rumex venosus	..	..	..	..
Verbena bracteata	..	..	..	..
Opuntia polyacantha	1A	1A	3A	5A
Escobaria missouriensis	..	..	..	..
Alyssum desertorum	1A	4C	3B	2A
Amaranthus blitoides	..	..	..	..
Ambrosia acanthicarpa	..	..	..	'+''+'
Bromus arvensis	..	'+''+'	..	..
Bromus tectorum	3A	9D	5C	6C
Chenopodium album	..	..	..	..
Chenopodium leptophyllum	'+''+'	'+''+'	2A	4A
Tiquilia nuttallii	..	..	'+'A	'+'A
Camissonia andina	..	..	..	1A

Scientific Name	Cluster 7	Cluster 1	Cluster 6	Cluster 8
Camissonia minor	..	..	..	1A
Cordylanthus ramosus	'+'A	1A	2A	1A
Camelina microcarpa	'+'A	..	..	..
Cryptantha scoparia	'+'A	'+'A	1A	6A
Descurainia pinnata	3A	9B	9C	6C
Descurainia sophia	1A	1A	2A	1A
Chorispora tenella	..	..	..	..
Eriastrum wilcoxii	'+'A	1A	2A	3A
Eriogonum cernuum	'+''+'	..	3A	1A
Gayophytum diffusum	'+'A	'+''+'	'+'A	'+'A
Aliciella leptomeria	..	..	'+''+'	'+'A
Ipomopsis minutiflora	..	'+'A	..	..
Gilia sinuata	..	'+''+'	'+'A	3B
Halogeton glomeratus	2A	2A	1A	2A
Lactuca serriola	..	'+'A	'+''+'	'+''+'
Erodium cicutarium	..	..	'+''+'	..
Lappula occidentalis	2A	8B	7B	7B
Eriogonum maculatum	..	..	..	..
Lepidium perfoliatum	'+'A	..	..	..
Leptosiphon septentrionalis	..	..	..	..
Mentzelia albicaulis	..	..	1A	3A
Juncus bufonius	..	..	..	..
Ceratocephala testiculata	..	'+''+'	..	..
Lupinus pusillus	..	..	..	..
Salsola kali	..	2A	3A	1A
Sisymbrium altissimum	1A	4A	1A	'+'A
Phacelia glandulifera	..	..	1A	2A
Thlaspi arvense	..	..	..	..
Chamaesyce maculata	..	..	..	..
Chaenactis douglasii	..	2A	2A	..
Machaeranthera canescens	'+'A	2A	1A	..
Thelypodium laciniatum	..	..	'+'A	..
Tragopogon dubius	'+''+'	1A	'+''+'	..
Woodsia oregana	..	..	..	..

Table 3. Conventional statistical summaries table shows the metrics for each component cluster. The metrics shown by cluster are: Total number of transects per cluster; total cluster richness; mean plot richness; mean plot cover; mean Simpson's diversity (Simpson 1949); mean Shannon-Weiner diversity (MacArthur and MacArthur 1961); and mean beta diversity (Whittaker 1960). Colors denote cluster occupancy. Cluster 1 = light blue; cluster 2 = yellow; cluster 3 = dark green; cluster 4 = dark blue; cluster 5 = black; cluster 6 = white; cluster 7 = brown; cluster 8 = pink; cluster 9 = red; cluster 10 = light green; cluster 11 = light orange; cluster 12 = light purple; cluster 13 = dark gray; cluster 14 = dark purple; cluster 15 = light gray; cluster 16 = dark orange. Gray cells show metric maximum values.

Metric	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Number of transects	38	50	36	37
Total Species Richness	71	85	73	65
Mean Species Richness	0.490	0.586	0.503	0.448
Mean Shannon Diversity	2.393	2.065	2.603	2.313
Mean Simpson Diversity	0.852	0.683	0.868	0.812
Mean plant cover	0.881	0.999	0.745	1.185
Mean Beta Diversity (Whittaker)	0.356	0.368	0.341	0.351

Metric	Cluster 5	Cluster 6	Cluster 7	Cluster 8
Number of transects	22	21	25	28
Total Species Richness	68	74	50	65
Mean Species Richness	0.469	0.510	0.345	0.448
Mean Shannon Diversity	2.354	2.904	1.319	2.449
Mean Simpson Diversity	0.789	0.896	0.456	0.795
Mean plant cover	0.879	0.671	0.679	0.586
Mean Beta Diversity (Whittaker)	0.355	0.329	0.345	0.378

Metric	Cluster 9	Cluster 10	Cluster 11	Cluster 12
Number of transects	17	12	11	4
Total Species Richness	54	61	65	21
Mean Species Richness	0.372	0.421	0.448	0.145
Mean Shannon Diversity	2.580	2.780	2.303	1.420
Mean Simpson Diversity	0.825	0.899	0.772	0.561
Mean plant cover	0.754	0.915	0.712	0.821
Mean Beta Diversity (Whittaker)	0.368	0.331	0.396	0.487

Metric	Cluster 13	Cluster 14	Cluster 15	Cluster 16
Number of transects	7	8	8	9
Total Species Richness	22	14	39	34
Mean Species Richness	0.152	0.097	0.269	0.234
Mean Shannon Diversity	1.793	1.426	1.706	2.135
Mean Simpson Diversity	0.760	0.614	0.635	0.789
Mean plant cover	0.452	0.505	0.529	0.505
Mean Beta Diversity (Whittaker)	0.534	0.583	0.400	0.400

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Appendix C

Dichotomous Key to INL Site Plant Communities

Dichotomous Key Information

This key was designed for use in collecting accuracy assessment data to support the final vegetation map. Because specific ranges of cover values are difficult to estimate rapidly in the field, dichotomies in the key are driven by relative abundance concepts like; “dominant,” “co-dominant,” “abundant,” “common,” and “rare.” While these concepts facilitate efficient data collection, they necessarily oversimplify the range of variability present in most plant communities. In some cases, neither choice in a dichotomy describes a specific assemblage encountered in the field very well. Under those circumstances, the user was encouraged to choose the better of the two options. On rare occasions, plant communities were dominated by species not represented in the key. This occurred most often in assemblages dominated by non-native species which are not characteristic of a ruderal vegetation class. When this situation occurred, the user was directed to make choices based on the most abundant species which are represented in the key.

2018 INL Site Plant Community Key

1a Trees are present.

Woodland Classes (pg. 2)

1b Trees are very sparse or absent.

2a Shrubs clearly dominate the plant community; herbaceous species may be common, but don't contribute substantial relative vegetation cover.

Shrubland Classes (pg. 2)

2b Herbaceous species are abundant, providing substantial relative vegetative cover.

3a Herbaceous species are primarily native.

4a Shrub species are abundant to co-dominant.

Shrub Grassland Classes (pg. 4)

4b Herbaceous species clearly dominate the plant community.

Grassland Classes (pg. 8)

3b Herbaceous species are primarily introduced.

Ruderal Classes (pg. 9)

Woodland Classes

1a *Juniperus osteosperma* is the most abundant tree species.

Class 11 – Juniper Woodland

1b *Juniperus osteosperma* is **NOT** the most abundant tree species.

Key as if trees are not present

Shrubland Classes

1a *Artemisia* species range from abundant (contributing substantial cover) to dominant in the shrub stratum of the plant community.

2a *Artemisia tridentata* and/or *Artemisia tripartita* are the most abundant sagebrush species.

3a *Artemisia tridentata* strongly dominates the shrub stratum; other shrub species may be present, but don't contribute substantial cover.

Class 8 – Big Sagebrush Shrubland

3b *Artemisia tridentata* ranges from abundant to co-dominant in the shrub stratum; other shrub species are also abundant to co-dominant, particularly *Chrysothamnus viscidiflorus* and/or *Artemisia tripartita*.

Class 6 – Big Sagebrush – Green Rabbitbrush (Three-tip Sagebrush) Shrubland

2b *Artemisia arbuscula* and/or *Artemisia nova* are the most abundant sagebrush species.

4a *Artemisia arbuscula* is the most abundant sagebrush species in the shrub stratum and the plant community generally occurs on flat topography with fine soils.

Class 16 – Low Sagebrush Shrubland

4b *Artemisia nova* is the most abundant sagebrush species in the shrub stratum and the plant community generally occurs in hilly or rolling topography with coarser soils.

Class 15 – Black Sagebrush Shrubland

1b The shrub stratum of the plant community is clearly dominated by non-*Artemisia* species.

5a *Chrysothamnus viscidiflorus* is the most abundant shrub species.

6a *Chrysothamnus viscidiflorus* clearly dominates the shrub stratum.

7a Herbaceous understory species are primarily native grasses.

8a *Elymus lanceolatus*, *Achnatherum hymenoides*, and/or *Hesperostipa comata* are the most abundant grasses.

Class 3 – Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland

8b *Poa secunda*, *Pseudoroegneria spicata*, and/or *Elymus elymoides* are the most abundant grasses.

Class 1 – Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland

7b Herbaceous understory species are primarily introduced grasses and/or forbs.

Class 4 – Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland

6b Other shrub species range from abundant to co-dominant.

9a *Artemisia tridentata* and/or *Artemisia tripartita* are abundant.

Class 6 – Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland

9b *Atriplex* species and/or *Krascheninnikovia lanata* are abundant to co-dominant.

10a *Atriplex* species are more abundant.

11a *Atriplex confertifolia* is the most abundant salt desert shrub species.

Class 13 – Shadscale Saltbush – Winterfat Shrubland

11b *Atriplex gardneri* is the most abundant salt desert shrub species.

Class 14 – Gardner's Saltbush (Winterfat) Shrubland

10b *Krascheninnikovia lanata* is more abundant.

12a *Artemisia tridentata* and/or *Artemisia tripartita* are common.

Class 6 – Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland

12b *Atriplex* species are common.

13a *Atriplex confertifolia* is the most abundant salt desert shrub species.

Class 13 – Shadscale Saltbush – Winterfat Shrubland

13b *Atriplex gardneri* is the most abundant salt desert shrub species.

Class 14 – Gardner's Saltbush (Winterfat) Shrubland

5b The shrub stratum is clearly dominated by species other than *Chrysothamnus viscidiflorus.*

14a *Atriplex* species dominate the shrub stratum.

15a *Atriplex confertifolia* is the most abundant salt desert shrub species.

Class 13 – Shadscale Saltbush – Winterfat Shrubland

15b *Atriplex gardneri* is the most abundant salt desert shrub species.

Class 14 – Gardner's Saltbush (Winterfat) Shrubland

14b *Krascheninnikovia lanata* dominates the shrub stratum.

16a *Artemisia tridentata, Chrysothamnus viscidiflorus* and/or *Artemisia tripartita* are common.

Class 6 – Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland

16b *Atriplex* species are common.

17a *Atriplex confertifolia* is the most abundant salt desert shrub species.

Class 13 – Shadscale Saltbush – Winterfat Shrubland

17b *Atriplex gardneri* is the most abundant salt desert shrub species.

Class 14 – Gardner's Saltbush (Winterfat) Shrubland

Shrub Grassland Classes

1a *Artemisia tridentata* is abundant in the shrub stratum.

2a *Artemisia tridentata* is clearly the most abundant species the shrub stratum; other shrub species may be present, but don't contribute substantial cover.

Class 8 – Big Sagebrush Shrubland

2b *Artemisia tridentata* ranges from abundant to co-dominant in the shrub stratum; other shrub species are also abundant to co-dominant, particularly *Chrysothamnus viscidiflorus* and/or *Artemisia tripartita*.

Class 6 – Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland

1b *Artemisia tridentata* ranges from absent to common, but doesn't contribute substantial cover to the shrub stratum.

3a *Chrysothamnus viscidiflorus* is the most abundant species in the shrub stratum.

4a Herbaceous understory species are primarily native; half or more of herbaceous cover is from natives.

5a Bunchgrasses dominate the understory.

6a *Leymus cinereus* is common to abundant.

Class 10 – (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed

6b *Leymus cinereus* is sparse to absent.

7a *Achnatherum hymenoides*, and/or *Hesperostipa comata* are the most abundant grasses.

8a *Achnatherum hymenoides* is clearly the most abundant grass species; *Hesperostipa comata* is absent or nearly so.

Class 12 – Indian Ricegrass Grassland

8b *Hesperostipa comata* is present.

9a *Hesperostipa comata* clearly dominates the understory.

Class 5 – Needle and Thread Grassland

9b *Hesperostipa comata* is abundant and *Achnatherum hymenoides*/*Elymus lanceolatus* also range from present to abundant.

Class 3 – Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland

7b *Poa secunda*, *Pseudoroegneria spicata*, and/or *Elymus elymoides* are the most abundant grasses.

Class 1 – Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland

5b Rhizomatous grasses dominate the understory.

10a *Pascopyrum smithii* clearly dominates the understory.

Class 9 – Western Wheatgrass Grassland

10b *Elymus lanceolatus* ranges from abundant to dominant and a mix of other grass species are abundant to co-dominant.

Class 3 – Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland

4b Herbaceous understory species are primarily introduced; more than half of herbaceous cover is from non-natives.

11a *Agropyron cristatum* is the most abundant herbaceous species.

Class 7 – Crested Wheatgrass Ruderal Grassland

11b The most abundant understory species are annuals.

12a *Bromus tectorum* is the most abundant herbaceous species.

Class 4 – Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland

12b The most abundant herbaceous species are forbs.

13a *Alyssum desertorum* is generally the most abundant herbaceous species, though a mix of introduced weeds may be common, and the location is generally upland.

Class 4 – Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland

13b *Descurainia* ssp., *Sisymbrium* ssp., and/or other taller-statured mustards are generally the most abundant herbaceous species, though additional introduced species may be common, and the location is proximate to a low-lying playa or streambed.

Class 10 – (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed

3b The shrub stratum is clearly dominated by species other than *Chrysothamnus viscidiflorus.*

14a *Artemisia arbuscula* and/or *Artemisia nova* are the most abundant shrub species.

15a *Artemisia arbuscula* is the most abundant sagebrush species in the shrub stratum and the plant community generally occurs on flat topography with fine soils.

Class 16 – Low Sagebrush Shrubland

15b *Artemisia nova* is the most abundant sagebrush species in the shrub stratum and the plant community generally occurs in hilly or rolling topography with coarser soils.

Class 15 – Black Sagebrush Shrubland

14b *Atriplex* species and/or *Krascheninnikovia lanata* are the most abundant shrub species.

16a *Atriplex* species dominate the shrub stratum.

17a Atriplex confertifolia is the most abundant salt desert shrub species.

Class 13 - Shadscale Saltbush – Winterfat Shrubland

17b *Atriplex gardneri* is the most abundant salt desert shrub species.

18a *Achnatherum hymenoides* co-dominates the plant community; it provides at least as much cover as *Atriplex gardneri.*

Class 12 – Indian Ricegrass Grassland

18b *Achnatherum hymenoides* ranges from sparse to abundant, but does **NOT** co-dominate the plant community.

Class 14 – Gardner's Saltbush (Winterfat) Shrubland

16b *Krascheninnikovia lanata* dominates the shrub stratum.

19a *Artemisia tridentata, Chrysothamnus viscidiflorus* and/or *Artemisia tripartita* are common.

Class 6 – Big Sagebrush – Green Rabbitbrush (Three-tip Sagebrush) Shrubland

19b *Atriplex* species are common.

20a *Atriplex confertifolia* is the most abundant salt desert shrub species.

Class 13 - Shadscale Saltbush – Winterfat Shrubland

20b *Atriplex gardneri* is the most abundant salt desert shrub species.

Class 14 – Gardner's Saltbush (Winterfat) Shrubland

Grassland Classes

1a Bunchgrasses dominate the plant community.

2a *Leymus cinereus* is common to abundant.

Class 10 – (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed

2**b** *Leymus cinereus* is sparse to absent.

3a *Achnatherum hymenoides*, and/or *Hesperostipa comata* are the most abundant grasses.

4a *Achnatherum hymenoides* strongly dominates the plant community; *Hesperostipa comata* is absent, or nearly so. Other species may be present, but don't contribute substantial cover.

Class 12 – Indian Ricegrass Grassland

4b *Hesperostipa comata* ranges from present to dominant.

5a *Hesperostipa comata* clearly dominates the plant community.

Class 5 – Needle and Thread Grassland

5b *Hesperostipa comata* is present and other species may range from common to abundant as well.

6a *Achnatherum hymenoides* and/or *Elymus lanceolatus* range from present to abundant.

Class 3 – Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland

6b *Poa secunda, Pseudoroegneria spicata,* and/or *Elymus elymoides* also range from present to abundant.

Class 1 – Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland

3b *Poa secunda, Pseudoroegneria spicata,* and/or *Elymus elymoides* are the most abundant grasses.

Class 1 – Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland

1b Rhizomatous grasses dominate the plant community.

7a *Pascopyrum smithii* clearly dominates the plant community.

Class 9 – Western Wheatgrass Grassland

7b *Elymus lanceolatus* ranges from abundant to dominant and a mix of other grass species are abundant to co-dominant.

Class 3 – Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland

Ruderal Classes

1a *Agropyron cristatum* is the most abundant herbaceous species.

Class 7 – Crested Wheatgrass Ruderal Grassland

1b The most abundant herbaceous species are annuals/biennials.

2a *Bromus tectorum* is the most abundant herbaceous species; *Chrysothamnus viscidiflorus* may be present, but cover is low and other introduced herbaceous species are sparse.

3a *Bromus tectorum* strongly dominates the plant community.

Class 2 – Cheatgrass Ruderal Grassland

3b *Chrysothamnus viscidiflorus* ranges from common to abundant and/or other introduced herbaceous species range from abundant to co-dominant.

Class 4 – Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland

2b The most abundant herbaceous species are forbs.

4a *Alyssum desertorum* is generally the most abundant herbaceous species, though a mix of introduced weeds may be common, and the location is generally upland.

Class 4 – Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland

4b *Descurainia* ssp., *Sisymbrium* ssp., and/or other taller-statured mustards are generally the most abundant herbaceous species, though additional introduced species may be common, and the location is proximate to a low-lying playa or streambed.

Class 10 – (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed

Appendix D.

Fact Sheet Descriptions

The vegetation class factsheets describe each class identified during the plant community classification process. The fact sheets include summary statistics and narrative text useful for understanding the defining characteristics of community types represented by each vegetation class. Information about the relationship of these vegetation classes to the National Vegetation Classification (NVC) and the range and distribution of these classes on the INL Site is also included.

Class Name, Color Block, Numeric Code, and Number of Plots

Both colloquial and scientific class names have been included in the title of each fact sheet. Vegetation class names follow National Vegetation Classification Standard (NVCS) conventions (see Chapter 2). The color block preceding the colloquial name corresponds to the color used to represent the class in the map book (see Appendix E). The numerical code was derived from the classification and represents the cluster number assigned to the class during the analytical process (see Appendix B). Numerical codes and corresponding class names are included in Table D-1. Number of plots indicates the total number (and percentage) of the 333 classification plots that classified or clustered into each vegetation class.

Table D-1. Sixteen vegetation classes identified for the Idaho National Laboratory Site using cluster analyses. Classes are based on vegetation cover data from 333 plots sampled in 2017.

Cluster #	Scientific Class Name	Colloquial Class Name	# of Plots
1	*Chrysothamnus viscidiflorus* / *Poa secunda* - *Pseudoroegneria spicata* Shrub Grassland	Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland	38
2	*Bromus tectorum* Ruderal Grassland	Cheatgrass Ruderal Grassland	50
3	*Chrysothamnus viscidiflorus* / *Elymus lanceolatus* Shrub Grassland	Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland	36
4	*Chrysothamnus viscidiflorus* / *Alyssum desertorum* (*Bromus tectorum*) Ruderal Shrubland	Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland	37
5	*Hesperostipa comata* Grassland	Needle and Thread Grassland	22
6	*Artemisia tridentata* - *Chrysothamnus viscidiflorus* (*Artemisia tripartita*) Shrubland	Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland	21
7	*Agropyron cristatum* Ruderal Grassland	Crested Wheatgrass Ruderal Grassland	25
8	*Artemisia tridentata* Shrubland	Big Sagebrush Shrubland	28
9	*Pascopyrum smithii* Grassland	Western Wheatgrass Grassland	17
10	(*Leymus cinereus*) - Mixed Mustards Infrequently Inundated Playa/Streambed	(Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed	12
11	*Juniperus osteosperma* Woodland	Juniper Woodland	11
12	*Achnatherum hymenoides* Grassland	Indian Ricegrass Grassland	4
13	*Atriplex confertifolia* - *Krascheninnikovia lanata* Shrubland	Shadscale Saltbush – Winterfat Shrubland	7
14	*Atriplex gardneri* (*Krascheninnikovia lanata*) Shrubland	Gardner's Saltbush (Winterfat) Shrubland	8
15	*Artemisia nova* Shrubland	Black Sagebrush Shrubland	8
16	*Artemisia arbuscula* Shrubland	Low Sagebrush Shrubland	9

Representative Class Photo

This photograph is as representative of mean cover and species composition of the vegetation class as possible. All vegetation classes encompass a range of plant communities, some of which may differ slightly in physiognomic appearance from that depicted in the class photograph.

Summary Bray-Curtis Scores

This table summarizes the amount of similarity between a given vegetation class and all other vegetation classes defined during the classification effort. We used the complement of the Bray-Cutis measure of dissimilarity as our similarity metric (see Chapters 2 and 4). The Bray-Curtis metric calculates similarity by comparing absolute cover values on a species by species basis for comparisons between each pair of vegetation classes (based on mean cover by species) and returns a proportional value between 0 and 1. A value of 0 indicates that the two vegetation classes have no species in common and a value of 1 indicates that the two vegetation classes are identical, containing the same species at the same mean absolute cover values for each species. The table is sorted in descending order, so the most closely related class is listed first.

Characteristic Species

Characteristic species are listed for each vegetation class and are based on constancy and mean cover values derived from the classification analyses (see Chapter 2). Mean cover, the standard deviation of cover, and constancy are provided for every species with at least 50% constancy and greater than 3% cover for any species with less than 50% constancy. Within each functional group (i.e. shrubs, grass, and forbs) species are sorted in descending order with respect to mean cover values. Cover and constancy values represent an average for each species calculated from all plots that clustered to each vegetation class (see “number of plots” at the top of the page).

It is important to note that in many classes there are very few forbs listed in the characteristic table. This should not be interpreted to indicate that a vegetation class is depauperate in forbs. Many classes have high species richness in the forb functional group, but the identity of the forb species and the cover values of those species are so variable from one plot to another that when averaged across all plots, no single species has a high enough constancy/minimum cover value to include in the characteristic table. The same is true of many sub-dominant shrub species as well.

Primary Class Description

The first paragraph of the primary class description contains the floristic description of the vegetation class. It includes some discussion of the species that are characteristic of the class as well as species that may occur commonly and are locally abundant but are not necessarily constant enough to be included in the characteristic species table. The abundance of both individual species and functional groups (e.g. shrubs, annual forbs, etc.) is addressed in very general terms. Shrubs and trees are often described in terms of canopy cover; ranging from open to nearly closed (or dense), and all species are described in terms of relative cover. Frequently used cover terms in order of increasing abundance are; sporadic, sparse, low, common, moderate, abundant, sub-dominant, co-dominant, and dominant. The second paragraph of the primary class description discusses the topographical, edaphic, and other environmental conditions commonly associated with the vegetation class as it occurs on the INL Site.

National Vegetation Classification Crosswalk

This table contains information crosswalking the vegetation classes identified during the INL Site vegetation classification process (see Chapter 2) to similar Associations described in the NVC. NVC data were summarized using NatureServe (2019). The vegetation classes identified for the INL Site generally contain more variability, especially in the herbaceous component, than is represented in NVC Association-level classes. Therefore, several NVC Associations could be related to any single INL Site vegetation class. The crosswalk includes all potentially related NVC Associations, and they are sorted in descending order according to which Associations occur most frequently within each vegetation class on the INL Site. Additionally, there are potentially some Associations that have not yet been described and which could have been included in the table had they been described at the time of publication.

The first table column includes the colloquial names of NVC Associations similar to the vegetation class identified at the INL Site, and the second column contains the NatureServe Database Code for each Association. A code indicating the conservation status rankings of the NVC Associations is found in the third column of the table. The conservation ranks are described in Table D-2. Because the INL Site Vegetation classes don't crosswalk directly to NVC Associations in a one-to-one relationship, the conservation status of the NVC Associations cannot be directly applied to the INL Site vegetation classes. The combined conservation status ranks should be interpreted cautiously, but they can be viewed as the best indication of the status of the vegetation class given the limited information available on NatureServe and the variability inherent in the crosswalk.

Table D-2. Association conservation rank descriptions form NatureServe (2010).

Conservation Rank	Conservation Rank Description
G1	Critically Imperiled
G2	Imperiled
G3	Vulnerable
G4	Apparently Secure
G5	Secure
GNR	Not Yet Ranked

Range

This section provides a narrative description of the range and distribution of each vegetation class on the INL Site as well as information on the range and distribution of similar vegetation types range-wide. The INL Site range description is based on the results of this mapping effort and on historical reports of the occurrence of various assemblages across the INL Site. The global range description is based on the Association ranges provided by NatureServe (2019) and by the distribution information provided for the dominant species provided by PLANTS National Database (USDA, PLANTS 2019).

Background and Ecology

A brief description of the history and dynamics of the vegetation class, as it has been documented on the INL Site, is included in this section. Much of the information provided here can be traced back to previous plant community research from the INL Site. This section may also contain some discussion about the range-wide dynamics of the vegetation type as it is summarized in the NVC.

Range of Variation

Many vegetation classes contain a substantial range of variation in terms of species composition and distribution. This section contains a brief narrative and two photos depicting some of the plant communities that represent some of the more extreme ends of the potential range of species composition and physiognomy that could occur within each vegetation class.

Map Unit Description

The range and distribution map depict the distribution of the polygons representing each vegetation class across the INL Site. In most cases vegetation classes directly corresponded to map classes. In a few cases, two vegetation classes were combined into one map class (see Chapter 3). Under those circumstances, the same distribution map is shown in the fact sheet for each individual vegetation class. This section also contains map class summary statistics, including total area, total number of polygons and mean polygon size.

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1	

Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland

Chrysothamnus viscidiflorus / Poa secunda - Pseudoroegneria spicata Shrub Grassland 38 plots (11%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
6	0.52	**8**	0.30	**12**	0.19
4	0.43	**10**	0.28	**16**	0.18
2	0.42	**11**	0.27	**7**	0.16
5	0.32	**3**	0.27	**13**	0.15
9	0.30	**15**	0.21	**14**	0.13

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Chrysothamnus viscidiflorus	green rabbitbrush	16.6	9.5	100
Artemisia tridentata	big sagebrush	4.9	9.5	32
Graminoid				
Poa secunda	Sandberg bluegrass	23.6	11.2	100
Bromus tectorum	cheatgrass	12.1	12.4	100
Pseudoroegneria spicata	bluebunch wheatgrass	10.4	11.1	71
Elymus elymoides	bottlebrush squirreltail	4.6	4.0	95
Achnatherum hymenoides	Indian ricegrass	0.8	1.2	58
Forb				
Lappula occidentalis	flatspine stickseed	1.5	2.2	82
Descurainia pinnata	western tansymustard	1.1	1.8	92
Erigeron pumilus	shaggy fleabane	0.6	1.1	66
Crepis acuminata	tapertip hawksbeard	0.5	0.9	55
Phlox hoodii	Hood's phlox	0.3	0.4	61
Sisymbrium altissimum	tall tumblemustard	0.3	0.5	50

CLASS DESCRIPTION

The (1) Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland class generally exhibits a shrub canopy that ranges from moderately open to nearly closed with an abundant medium-tall herbaceous layer. Green rabbitbrush (*Chrysothamnus viscidiflorus*) clearly dominates the shrub stratum and other shrubs like big sagebrush (*Artemisia tridentata*) and gray horsebrush (*Tetradymia canescens*) occur sporadically. Sandberg bluegrass (*Poa secunda*) dominates and Bluebunch wheatgrass (*Pseudoroegneria spicata*) is typically abundant and often co-dominates the herbaceous stratum. Bottlebrush squirreltail (*Elymus elymoides*) may be locally abundant in some stands of this vegetation class; Indian ricegrass (*Achnatherum hymenoides*) and thickspike wheatgrass (*Elymus lanceolatus*) are often present, but these species generally contribute little total cover. Forbs are diverse and highly variable in stands of this vegetation type. Shaggy fleabane (*Erigeron pumilus*), tapertip hawksbeard (*Crepis acuminata*), and Hood's phlox (*Phlox hoodii*) are the perennial forbs that occur with the greatest cover and constancy. Cheatgrass (*Bromus tectorum*) is present in nearly all communities of this vegetation type, though cover can range from very low to quite abundant.

Stands of this vegetation type are generally supported by loamy soils with a moderate depth to bedrock. Neither very coarse nor very fine soils are conducive to the dominance or co-dominance of bluebunch wheatgrass in the plant community. This community tends to occur on the rolling upland topography found at the higher elevations around the periphery, especially to the south and west. It is not found in the slightly lower elevation areas near the center of the INL Site. The slightly higher elevations around the periphery of the INL Site likely experience more precipitation and have higher soil moisture holding capacity as bluebunch wheatgrass is rare where soils are very coarse. This class is often associated with post-fire burn scars.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Yellow Rabbitbrush / Bluebunch Wheatgrass Shrubland	CEGL005594	GNR
Bluebunch Wheatgrass - Sandberg Bluegrass Grassland	CEGL001677	G4
Bluebunch Wheatgrass Grassland	CEGL001660	G2
Sandberg Bluegrass Moist Meadow	CEGL001657	G4?
Bluebunch Wheatgrass - Arrowleaf Balsamroot - Sandberg Bluegrass Grassland	CEGL001662	G2
Bluebunch Wheatgrass - Indian Ricegrass Grassland	CEGL001674	G3G4
Bluebunch Wheatgrass - Western Wheatgrass Grassland	CEGL001675	G4
Yellow Rabbitbrush Shrub Grassland	CEGL002530	GNR
Bluebunch Wheatgrass - Tapertip Hawk's-beard Grassland	CEGL005609	GNR
Yellow Rabbitbrush Talus Shrubland	CEGL002347	GNR
Bluebunch Wheatgrass - Needle-and-Thread Grassland	CEGL001679	G4

RANGE

Idaho National Laboratory Site

(1) Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland tends to occur on the rolling upland topography found at the higher elevations around the periphery of the INL Site, especially to the south and west. This class is often associated with wildland fire scars. It may also occur in areas that have experienced non-fire related declines in big sagebrush cover.

Global

This herbaceous shrubland contains species that occur over a wide range of landscapes within the intermountain northwest regions of the western U.S. These species range from Nevada to Canada’s southern boarders, and their ranges extend east from the Great Plains to California and Oregon in the west. Although the individual dominant species in this class are widely distributed, the combination of species that define the class likely occurs in limited distribution. Its distribution is restricted to sites with elevation and precipitation levels adequate to support bluebunch wheatgrass. It tends to occur in wildland fire burn scar areas and is limited to sites which have experienced little anthropogenic disturbance.

BACKGROUND AND ECOLOGY

The plant community dynamics resulting in this vegetation type on the INL Site are a combination of recent wildland fire and little to no grazing pressure from domestic livestock. Because green rabbitbrush can readily resprout, plant communities dominated by green rabbitbrush are often the result of a recent wildland fire. While bluebunch wheatgrass can also resprout subsequent to fire, communities characterized by a bluebunch wheatgrass-dominated herbaceous layer generally don't persist under moderate or greater grazing pressure during the growing season.

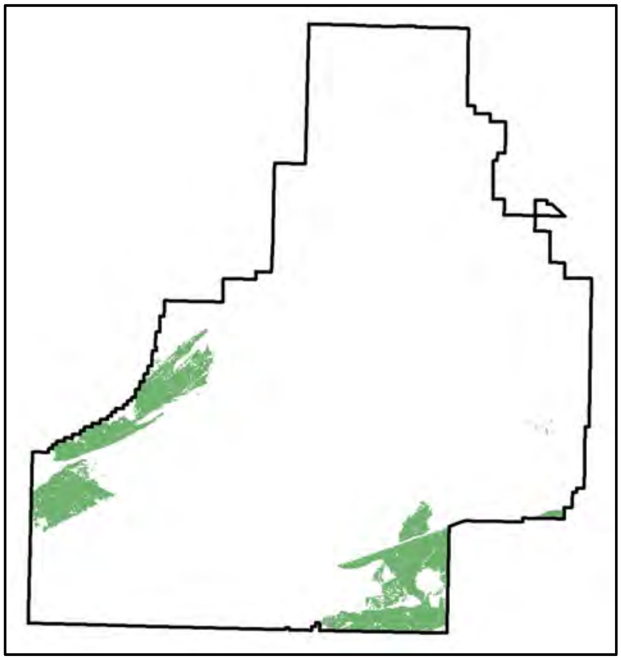
This community historically occurred in areas relatively unaffected by persistent disturbance, like overgrazing by livestock, and stands were rarely weedy. Stands of this vegetation type appear to be shifting from the herbaceous layer being dominated by bluebunch wheatgrass to an increasing dominance by Sandberg's bluegrass. Native and non-native annual forbs also tend to occur more frequently and with greater abundance than they have in the past. These trends suggest that communities within this vegetation class may be becoming less resilient.

RANGE OF VARIATION

Left: Relatively high green rabbitbrush and Sandberg bluegrass cover with moderate cheatgrass cover.

Right: Relatively low green rabbitbrush cover and relatively high bluebunch wheatgrass cover.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 1 includes 51 map polygons covering 159.4 km^2 (39,388.2 acres) of area. This class has the largest mean polygon area of 3.13 km^2 (772.3 acres) suggesting it was primarily mapped as larger contiguous polygons.

2 Cheatgrass Ruderal Grassland

Bromus tectorum Ruderal Grassland — 50 plots (15%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
4	0.48	**3**	0.33	**16**	0.22
1	0.42	**10**	0.33	**7**	0.15
5	0.40	**11**	0.32	**15**	0.15
6	0.39	**8**	0.29	**13**	0.12
9	0.34	**12**	0.22	**14**	0.10

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Chrysothamnus viscidiflorus	green rabbitbrush	6.9	7.3	80
Graminoid				
Bromus tectorum	cheatgrass	55.0	22.5	100
Pseudoroegneria spicata	bluebunch wheatgrass	3.9	9.2	30
Poa secunda	Sandberg bluegrass	3.6	5.5	66
Hesperostipa comata	needle and thread	3.4	6.2	52
Achnatherum hymenoides	Indian ricegrass	3.4	4.8	72
Elymus elymoides	bottlebrush squirreltail	2.1	3.3	72
Forb				
Alyssum desertorum	desert alyssum	3.8	5.8	66
Sisymbrium altissimum	tall tumblemustard	1.9	2.8	66
Lappula occidentalis	flatspine stickseed	1.3	2.0	76
Descurainia pinnata	western tansymustard	1.1	1.5	70

CLASS DESCRIPTION

Cheatgrass (*Bromus tectorum*), an introduced invasive, annual grass species dominates this vegetation class. Total vegetation cover is highly variable from one stand to another. Native species persist in some stands; however, cover and diversity are typically low, and component native species composition can be quite variable depending on the plant community that was present prior to the conversion to an introduced herbaceous species. Native shrubs may occur sporadically with low cover values. Green rabbitbrush (*Chrysothamnus viscidiflorus*), big sagebrush (*Artemisia tridentata*) and gray rabbitbrush (*Ericameria nauseosa*) are shrubs that occur most frequently in this class. Bluebunch wheatgrass (*Pseudoroegneria spicata*), Sandberg bluegrass (*Poa secunda*), needle and thread (*Hesperostipa comata*), Indian ricegrass (*Achnatherum hymenoides*), and bottlebrush squirreltail (*Elymus elymoides*) are the most frequently occurring native grasses in this community type, although they tend to occur sporadically with sparse cover relative to cheatgrass. Several native perennial and annual forb species may also occur infrequently in stands of this type. Introduced annual forbs such as tall tumblemustard (*Sisymbrium altissimum*) desert alyssum (*Alyssum desertorum*) often occur in patches with substantial abundance within communities of this vegetation class.

This vegetation class can occur across a wide range of environmental conditions and is not tightly constrained by slope, aspect, soil texture, or soil depth. It is often associated with sites which have been anthropogenically disturbed. Communities that are dominated by cheatgrass also frequently occupy basalt outcroppings, stabilized dunes, and low-lying playas and drainages. This vegetation class is becoming increasingly common in post-fire communities on the INL Site.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Cheatgrass Ruderal Grassland	CEGL003019	GNA
Sandberg Bluegrass - Cheatgrass Ruderal Grassland	CEGL005604	GNA
Crested Wheatgrass - Cheatgrass Ruderal Grassland	CEGL005471	GNR
Russian-thistle species Ruderal Grassland	CEGL004004	GNR
Tall Tumblemustard - Cheatgrass Ruderal Grassland	CEGL005614	GNA
Rubber Rabbitbrush / Cheatgrass Ruderal Shrubland	CEGL002937	GNA

RANGE

Idaho National Laboratory Site

Cheatgrass in common in anthropogenically disturbed areas including roadsides, infrastructure associated with grazing allotments (e.g. water troughs, fences, salt blocks, etc.), wildland fire containment lines, and other activities that result in soil disturbance. It appears to be becoming more common in post-burn communities that have not experienced soil disturbance as well. Most large cheatgrass-dominated patches are located across the central and southern portions of the INL Site. Outside of recent burn scars, patch size of this vegetation class tends to be small and it often occurs within a matrix of native vegetation classes.

Global

The distribution of this vegetation class coincides with the range of the *Bromus tectorum* Semi-natural Herbaceous Alliance, which occurs throughout much of western North America from the western Great Plains to the intermountain and southwestern U.S. Cheatgrass is a widespread ruderal species that occurs within sagebrush steppe habitat boundaries coinciding with the interior of the western U.S.

BACKGROUND AND ECOLOGY

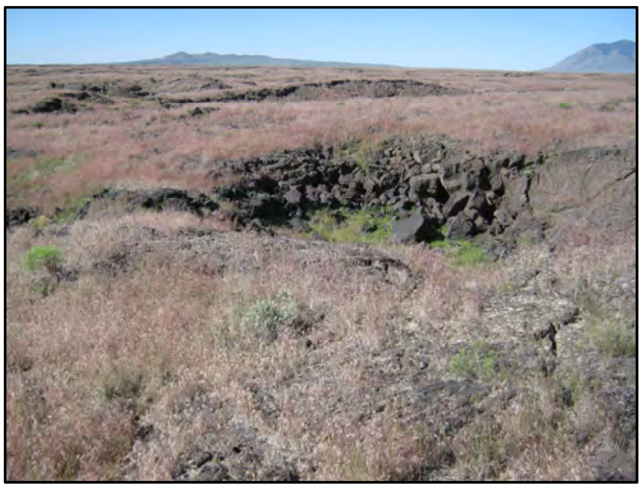
The unique life history characteristics of cheatgrass and the altered ecological process associated with this species have promoted the spread of it and other exotic annual bromes at the expense of sagebrush shrublands and related assemblages in large parts of the western U.S. This species tends to dominate or co-dominate primarily on sites that have been severely impacted by multiple and/or ongoing disturbance events. Cheatgrass response to stressors appears to be quite variable across the range of the species.

At the INL Site, cheatgrass historically occurred with high frequency and low abundance. It was found nearly everywhere, but densities were generally very low. Since data collection began on permanent plots in 1950, the distribution of cheatgrass increased across the INL Site, but mean densities had not increased significantly until recently. Historical resistance of post-fire communities to increases in cheatgrass may have been due, in part, to dynamic native plant communities which were in good ecological condition prior to the fire. More recent data have suggested that cheatgrass dominance has increased on the INL Site, especially in communities five to ten years post-burn.

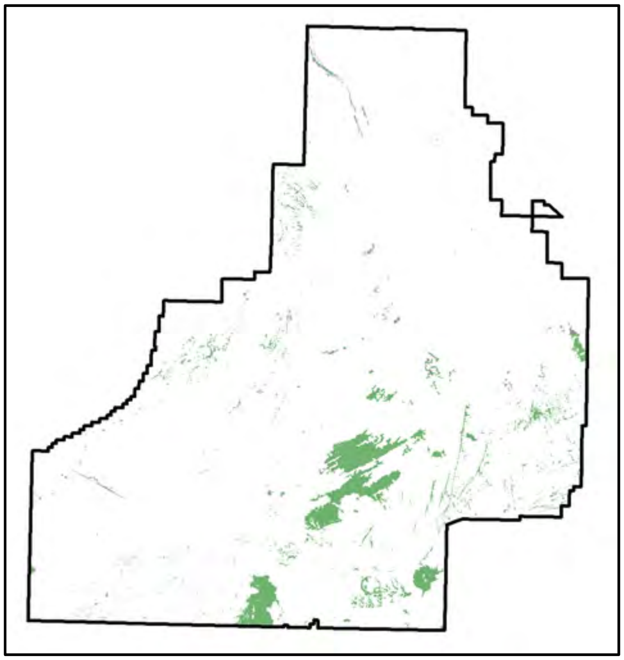
RANGE OF VARIATION

Left: Large expanse of high cheatgrass cover associated with exposed basalt; native shrubs occur sporadically.

Right: Cheatgrass dominated patch within a matrix of native communities; other non-native annuals are abundant.



MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 2 has a widespread distribution with isolated patches mapped within in nearly every other map class. This class has the second largest number of mapped polygons with 1,436 contributing to 92.4 km^2 (39,388.2 acres) of total mapped area. Class 2 has the third smallest mean polygon area with 0.06 km^2 (15.9 acres), although some larger polygons were mapped in the central region of the INL Site, and across the extent of the Midway Fire from 2012.

	3

Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland

Chrysothamnus viscidiflorus / Elymus lanceolatus Shrub Grassland 36 plots (11%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
5	0.48	**9**	0.34	**11**	0.26
6	0.45	**2**	0.33	**15**	0.18
4	0.41	**10**	0.32	**7**	0.15
16	0.37	**1**	0.27	**14**	0.11
8	0.35	**12**	0.26	**13**	0.11

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Chrysothamnus viscidiflorus	green rabbitbrush	8.1	8.0	94
Opuntia polyacantha	plains pricklypear	0.6	0.9	58
Graminoid				
Elymus lanceolatus	thickspike wheatgrass	18.7	14.0	100
Achnatherum hymenoides	Indian ricegrass	12.2	9.1	92
Hesperostipa comata	needle and thread	11.6	9.2	92
Bromus tectorum	cheatgrass	1.2	2.1	56
Forb				
Alyssum desertorum	desert alyssum	2.9	7.1	58
Descurainia pinnata	western tansymustard	2.7	2.8	94
Lappula occidentalis	flatspine stickseed	0.8	1.8	53
Phlox hoodii	Hood's phlox	0.4	0.7	50
Eriogonum cernuum	nodding buckwheat	0.4	0.8	50

CLASS DESCRIPTION

The plant communities represented by this vegetation class are characterized by an abundance of native, perennial rhizomatous grasses. The dominant species in the herbaceous stratum is thickspike wheatgrass (*Elymus lanceolatus*). Several native bunchgrasses are generally also present; Indian ricegrass (*Achnatherum hymenoides*) and needle and thread (*Hesperostipa comata*) are the most abundant. Green rabbitbrush (*Chrysothamnus viscidiflorus*) occurs with high constancy and low to moderate cover. Additional shrubs, such as big sagebrush (*Artemisia tridentata*), spiny hopsage (*Grayia spinosa*), and winterfat (*Krascheninnikovia lanata*) may also occur sporadically and with minimal cover. A variety of forb species may be present in communities of this class with low to moderate cover. Some of the more consistently occurring species include western tansymustard (*Descurainia pinnata*), flatspine stickseed (*Lappula occidentalis*), and Hood's phlox (*Phlox hoodii*). Cover from non-native herbaceous species may range from absent to moderate. In stands where they occur, the most abundant non-native species include cheatgrass (*Bromus tectorum*), and desert alyssum (*Alyssum desertorum*).

This shrub herbaceous community type occurs across a variety of terrain throughout the INL Site. It is generally associated with rolling upland sites and aspect is of little importance with respect to stand distribution. Soils supporting this rhizomatous plant community are moderate to relatively deep and trend towards to coarse-textured loams. This class is very common in post-fire recovering plant communities.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Yellow Rabbitbrush Shrub Grassland	CEGL002530	GNR
Thick-spike Wheatgrass Grassland	CEGL002588	GNR
Yellow Rabbitbrush / Needle-and-Thread Shrubland	CEGL002799	GNR
Thick-spike Wheatgrass - Needle-and-Thread Grassland	CEGL001746	G1
Thick-spike Wheatgrass - Silverleaf Phacelia Grassland	CEGL001745	G2
Thick-spike Wheatgrass - Silvery Lupine Grassland	CEGL005595	GNR

RANGE

Idaho National Laboratory Site

The (3) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland class is widely distributed across the INL Site and occurs with relatively high frequency. This community tends to be ubiquitous in lower elevation areas coincident with the center of the INL Site and occurs somewhat less frequently as elevation increases slightly near the southern and northern extents of the INL Site. It is often associated with burn scars from wildland fires, but it occurs in many other disturbed and non-disturbed areas as well. Because green rabbitbrush is one of the most abundant species on the INL Site and it is relatively resilient to disturbance, this vegetation class may occur anywhere sagebrush cover is low.

Global

The dominant species in this vegetation class occur throughout the Rocky Mountain States and much of the western U.S. This particular herbaceous shrubland has been documented in disturbed areas from California, Nevada, Colorado, Utah, Idaho, And Montana.

BACKGROUND AND ECOLOGY

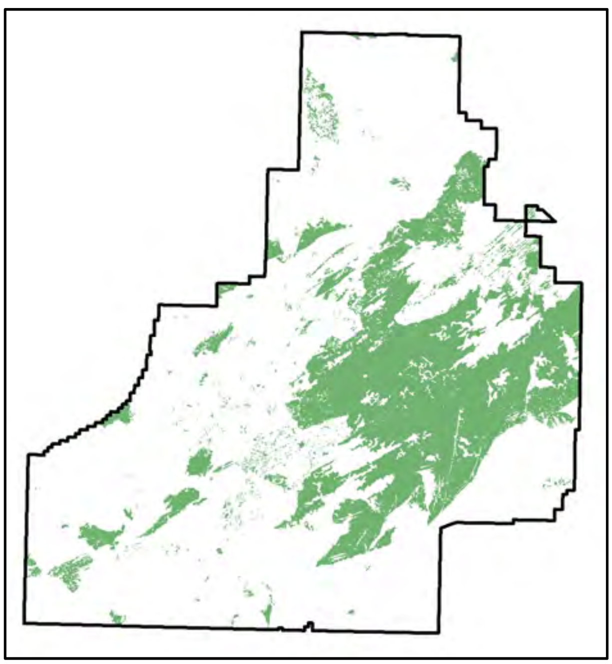
Dominance by green rabbitbrush was once thought to result from either chronic or catastrophic disturbance in plant communities common to sagebrush steppe ecosystems. It is often the dominant species in areas disturbed by processes such as active colluvial slopes, active sand dunes, severely or frequently burned areas, and by overgrazing. However, the species is common and widely distributed in various plant communities across the INL Site, and although dramatic increases in cover often result from disturbance, green rabbitbrush cover has also been trending upward in undisturbed plant communities. Thickspike wheatgrass communities have likely increased in their distribution because they commonly occur in post-fire burn scars and approximately 38% of the INL Site area has burned in the previous 25 years.

RANGE OF VARIATION

Left: Lower green rabbitbrush cover and thickspike wheatgrass mixed with other native grasses and cheatgrass.

Right: Higher green rabbitbrush cover with patches of thickspike wheatgrass interspersed throughout.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 3 is mapped as a combined class with Class (5) Needle and Thread Grassland because they are difficult to distinguish in the imagery and tend to co-occur spatially across the landscape and widespread throughout areas that have burned recently. Class 3/5 has the third largest number of polygons with 1,058 polygons mapped across 570.8 km^2 (141,034.9 acres). Mean polygon area is 0.54 km^2 (133.3 acres).

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4	Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland

Chrysothamnus viscidiflorus / Alyssum desertorum (Bromus tectorum) Ruderal Shrubland 37 plots (11%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
2	0.48	**6**	0.40	**12**	0.20
10	0.43	**9**	0.31	**15**	0.15
1	0.43	**11**	0.28	**7**	0.12
5	0.41	**8**	0.22	**13**	0.09
3	0.41	**16**	0.20	**14**	0.06

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Chrysothamnus viscidiflorus	green rabbitbrush	13.1	8.7	92
Graminoid				
Bromus tectorum	cheatgrass	16.4	17.8	92
Hesperostipa comata	needle and thread	9.9	18.2	68
Achnatherum hymenoides	Indian ricegrass	5.1	6.5	86
Pseudoroegneria spicata	bluebunch wheatgrass	4.5	6.9	46
Poa secunda	Sandberg bluegrass	4.0	5.5	81
Elymus elymoides	bottlebrush squirreltail	1.4	2.3	76
Forb				
Alyssum desertorum	desert alyssum	44.9	20.0	100
Phlox hoodii	Hood's phlox	1.7	2.8	57

CLASS DESCRIPTION

This vegetation class represents plant communities where the shrub stratum is dominated by green rabbitbrush (*Chrysothamnus viscidiflorus*), but the herbaceous understory is dominated by non-native annuals. The canopy of the shrub layer ranges from open to moderately dense. Few other shrub species are common in this plant community, but big sagebrush (*Artemisia tridentata*) individuals may occur sporadically. The herbaceous layer is generally very diverse and substantial in terms of species composition and relative cover. Desert alyssum (*Alyssum desertorum*) is usually the dominant herbaceous species; however, several non-native annual species may be abundant or even dominate localized stands. Additional non-native species may include: cheatgrass (*Bromus tectorum*), saltlover (*Halogeton glomeratus*), Russian thistle (*Salsola kali*), tall tumblemustard (*Sisymbrium altissimum*), and herb sophia (*Descurainia sophia*). Native herbaceous species are common in this vegetation type but when combined they contribute *less* than half of the total herbaceous cover. Native bunchgrasses such as needle and thread (*Hesperostipa comata*), Indian ricegrass (*Achnatherum hymenoides*), bottlebrush squirreltail

(*Elymus elymoides*), and Sandberg bluegrass (*Poa secunda*) are almost always present but never highly abundant. Associated native forbs generally contribute very little cover, but the most frequently occurring species is Hood's phlox (*Phlox hoodii*).

The distribution of this vegetation type is not tightly constrained by soil texture or depth. It often occurs in areas with rolling topography and gentle slopes like old basalt flows with some soil accumulation. This class generally occurs in areas that have experienced relatively recent wildland fire and occasionally appears to be associated with locations that have experienced greater than average livestock use.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Yellow Rabbitbrush / Cheatgrass Ruderal Shrubland	CEGL005591	GNA
Yellow Rabbitbrush / Sandberg Bluegrass - Cheatgrass Ruderal Shrubland	CEGL005593	GNA
Yellow Rabbitbrush Talus Shrubland	CEGL002347	GNR

RANGE

Idaho National Laboratory Site

The distribution of this vegetation class is restricted to wildland fire scars on the INL Site, although it is not ubiquitous across all fire scars. The (4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland class occurs in scars of wildland fires that have burned in the past 25 years, but which have had enough recovery time for green rabbitbrush to become abundant.

Global

Documentation of this ruderal shrubland community has improved and it reportedly occurs throughout the Colorado Plateau, southeastern Utah, and Idaho. It is characteristically found in disturbed or recently burned areas that once supported sagebrush shrublands.

BACKGROUND AND ECOLOGY

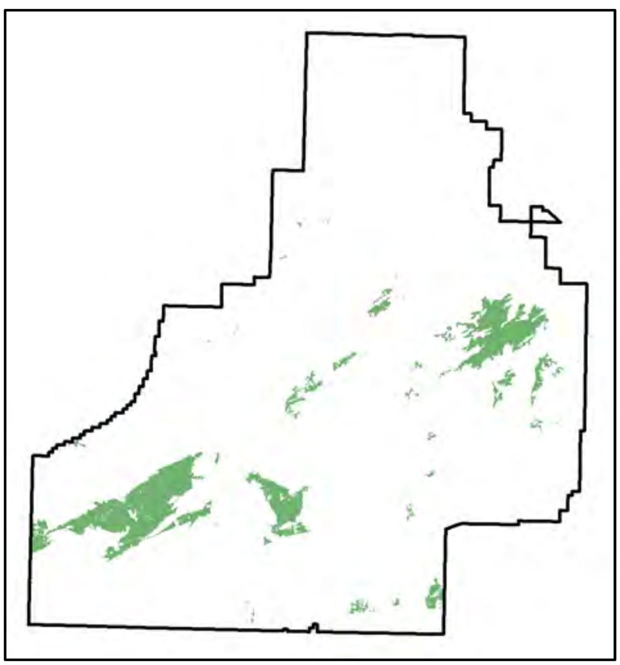
While green rabbitbrush communities are well documented to occur in sagebrush shrublands that have experienced wildland fire, very little information is currently available on desert alyssum. It has not historically been considered an invasive species and it is found throughout the United States and Canada. On the INL Site, it appears to function as an ephemeral where its abundance can vary greatly from one year to another.

RANGE OF VARIATION

Left: Lower green rabbitbrush cover and some native herbaceous cover.

Right: Lower green rabbitbrush cover and high cheatgrass cover.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 4 is most commonly mapped in areas that have burned and now have a degraded understory. This class includes 115 polygons distributed across 133.63 km^2 (33,021.2 acres). Mean polygon area is 1.16 km^2 (287.1 acres).

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5 Needle and Thread Grassland

Hesperostipa comata Grassland — 22 plots (7%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
3	0.48	**10**	0.34	**16**	0.23
6	0.44	**1**	0.32	**7**	0.17
4	0.41	**9**	0.32	**15**	0.16
2	0.40	**11**	0.31	**14**	0.11
8	0.38	**12**	0.24	**13**	0.10

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Chrysothamnus viscidiflorus	green rabbitbrush	4.6	4.4	86
Artemisia tridentata	big sagebrush	4.6	7.2	32
Graminoid				
Hesperostipa comata	needle and thread	37.9	13.3	100
Bromus tectorum	cheatgrass	7.9	9.7	82
Achnatherum hymenoides	Indian ricegrass	5.4	5.4	86
Elymus lanceolatus	thickspike wheatgrass	3.5	6.5	50
Elymus elymoides	bottlebrush squirreltail	1.3	1.8	73
Forb				
Descurainia pinnata	western tansymustard	4.2	5.5	91
Sisymbrium altissimum	tall tumblemustard	3.2	8.3	50
Lappula occidentalis	flatspine stickseed	1.2	2.0	86

CLASS DESCRIPTION

The grassland community represented by this vegetation class occurs in small to medium-sized patches, often in scars of recent wildland fires. Needle and thread (*Hesperostipa comata*) forms a moderate to dense herbaceous layer. Thickspike wheatgrass (*Elymus lanceolatus*) and Indian ricegrass (*Achnatherum hymenoides*) tend to have high constancy but contribute moderate to low relative cover in this vegetation type. Additional native grass species which may be common, but not necessarily constant include Western wheatgrass (*Pascopyrum smithii*) and bottlebrush squirreltail (*Elymus elymoides*). Scattered shrubs may be present and include green rabbitbrush (*Chrysothamnus viscidiflorus*), big sagebrush (*Artemisia tridentata*), plains pricklypear (*Opuntia polyacantha*), and winterfat (*Krascheninnikovia lanata*), but they often occur with very low cover. Native forbs tend to have low to moderate cover and high diversity and species composition is highly variable among sites. Some of the more common species include western tansymustard (*Descurainia pinnata*), flatspine stickseed (*Lappula occidentalis*), and whitestem blazingstar (*Mentzelia albicaulis*). Non-native species cover ranges from absent to nearly co-dominant in patches of this community type. When present, the most abundant non-native species are cheatgrass (*Bromus tectorum*), tall tumble mustard (*Sisymbrium altissimum*), and desert alyssum (*Alyssum desertorum*).

Needle and thread may occur in a variety of substrates, ranging in texture from loams to very sandy soils. It tends to dominate where soils are moderately deep and well-drained. Consequently, this vegetation class on the INL Site is often found on rolling upland topography such as basalt flows with substantial accumulation of coarse-textured soils, including stabilized dunes. The patch size of this community type is directly influenced by the scale and abruptness at which soil depth and texture changes.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Needle-and-Thread Great Basin Grassland	CEGL001705	G2G4
Needle-and-Thread - Indian Ricegrass Grassland	CEGL001703	G2
Thick-spike Wheatgrass - Needle-and-Thread Grassland	CEGL001746	G1
Needle-and-Thread - Sandberg Bluegrass Grassland	CEGL001704	G1
Yellow Rabbitbrush / Needle-and-Thread Shrubland	CEGL002799	GNR

RANGE

Idaho National Laboratory Site

The (5) Needle and Thread Grassland class is strongly associated with post-fire native vegetation recovery. Although a few occurrences of this vegetation class are in areas which have not recently burned, it is most often located in fire scars which have burned in the past few decades, especially in the lower elevation areas near the eastern central portion of the INL Site where wind deposits sand and loess after fire.

Global

The needle and thread grassland vegetation class is abundant and widespread throughout the western U.S. Needle and thread dominated grasslands are found within the Colorado Plateau, Great Basin, and Colorado Rocky Mountains. The distribution is described as a limited patchwork pattern within a broad spatial extent where environmental conditions have disturbed sandy soils that once supported sagebrush shrublands.

BACKGROUND AND ECOLOGY

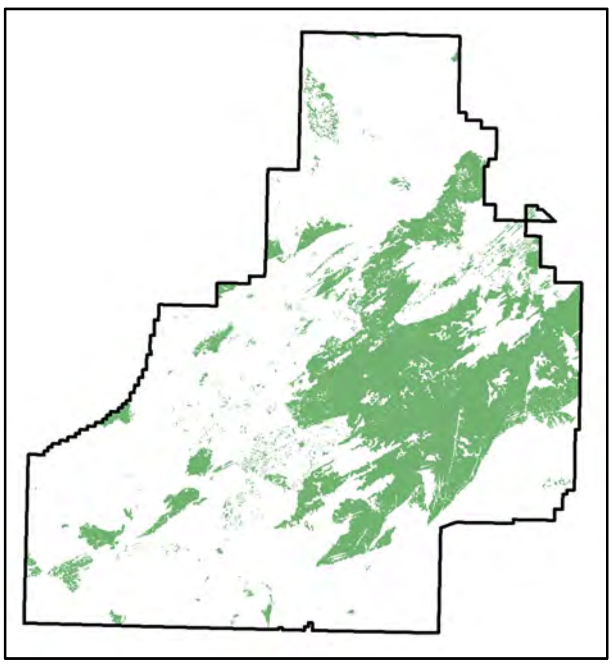
Needle and thread grass is a common understory species within big sagebrush shrublands. In sagebrush stands where it was abundant pre-fire, it becomes a dominant species in the post-fire community. It appears to continue to dominate for long periods of time in areas where soils are extremely sandy such as stabilized dunes. Global conservation rankings for this vegetation type tend to be low because they are limited in distribution and are sensitive to disturbance, so many occurrences of this class tend to be weedy.

RANGE OF VARIATION

Left: Patchy distribution of (5) Needle and Thread Grassland within a recovering wildland fire scar.

Right: (5) Needle and Thread Grassland occupying a stabilized dune.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 5 is mapped as a combined class with Class (3) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland because they are difficult to distinguish in the imagery and tend to co-occur spatially across the landscape and widespread throughout areas that have burned recently. Class 3/5 has the third largest number of polygons with 1,058 polygons mapped across 570.8 km^2 (141,034.9 acres). Mean polygon area is 0.54 km^2 (133.3 acres).

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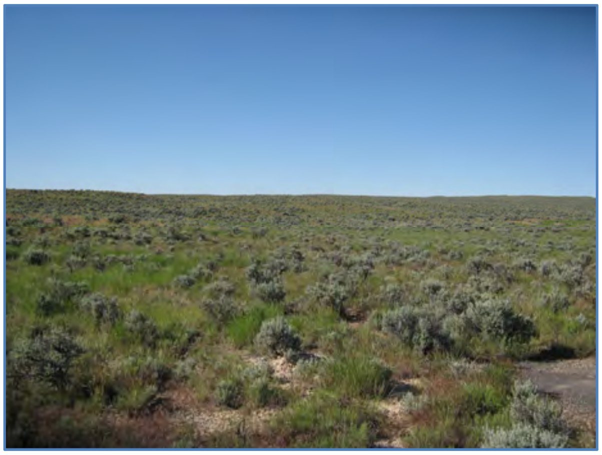
6	**Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland**

Artemisia tridentata - Chrysothamnus viscidiflorus (Artemisia tripartita) Shrubland 21 plots (6%)



Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
1	0.52	**2**	0.39	**7**	0.25
8	0.49	**9**	0.38	**15**	0.20
3	0.45	**10**	0.38	**12**	0.19
5	0.44	**11**	0.28	**14**	0.17
4	0.40	**16**	0.27	**13**	0.14

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Chrysothamnus viscidiflorus	green rabbitbrush	17.1	10.2	100
Artemisia tridentata	big sagebrush	8.8	8.6	81
Artemisia tripartita	threetip sagebrush	6.0	11.4	33
Tetradymia canescens	spineless horsebrush	1.4	1.9	52
Graminoid				
Bromus tectorum	cheatgrass	3.9	5.9	57
Elymus lanceolatus	thickspike wheatgrass	2.4	3.0	62
Achnatherum hymenoides	Indian ricegrass	2.2	3.6	76
Elymus elymoides	bottlebrush squirreltail	1.6	1.5	81
Forb				
Descurainia pinnata	western tansymustard	2.2	3.9	90
Lappula occidentalis	flatspine stickseed	1.3	1.8	76

CLASS DESCRIPTION

This broadly defined big sagebrush class is characterized by an open to moderately dense shrub layer. Big sagebrush (*Artemisia tridentata)* is always abundant, but other shrubs also range from abundant to co-dominant. Green rabbitbrush (*Chrysothamnus viscidiflorus*) is always abundant across this community type and it can be dominant in some stands. This vegetation class also encompasses threetip sagebrush stands (*Artemisia tripartita*); it is not present in all communities of this vegetation type, but where it does occur it ranges from abundant to co-dominant. Other shrubs occur sporadically within stands of this shrubland: spineless horsebrush (*Tetradymia canescens*), winterfat (*Krascheninnikovia lanata*), and spiny hopsage (*Grayia spinosa*) are a few of the more commonly occurring species. The herbaceous stratum of this plant community ranges from sparse to moderate in terms of cover. Species composition of native grasses may be quite variable from one stand to another; however, bottlebrush squirreltail (*Elymus elymoides*), Sandberg bluegrass (*Poa secunda*), thickspike wheatgrass (*Elymus lanceolatus*), Bluebunch wheatgrass (*Pseudoroegneria spicata*), and Indian ricegrass (*Achnatherum hymenoides*) are among the most abundant grass species. Forbs present on more diverse sites may include: Hood's phlox (*Phlox hoodii*), *Chenopodium* spp., *Eriogonum* spp., western tansymustard (*Descurainia pinnata*), and flatspine stickseed (*Lappula occidentalis*). Cover from exotic species ranges from absent to moderate, the most abundant of which are cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum*), and desert alyssum (*Alyssum desertorum*).

A wide range of plant communities are represented by this class and they can occupy a wide range of environmental conditions. Heterogenous communities characterized by a mix of shrub species in the overstory often occur in areas with moderately complex topography where soil textures and depths change abruptly and at fine spatial scales, such as on rolling hills created by soil accumulation over basalt flows. This community type is also often associated with linear sand dunes and is distributed amongst dry braided stream channels. Substrates are highly variable and range from very fine to coarse-textured and may have low salinity and high sand content, gravel and/or rocks.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Big Sagebrush / Yellow Rabbitbrush / (Sandberg Bluegrass) Shrubland	CEGL000999	G5
Threetip Sagebrush / Bluebunch Wheatgrass Shrub Grassland	CEGL001538	G2G3
Big Sagebrush / Indian Ricegrass Shrubland	CEGL001006	G3G5
Wyoming Big Sagebrush / Bluebunch Wheatgrass Shrub Grassland	CEGL001535	G4
Wyoming Big Sagebrush / Bluebunch Wheatgrass Shrubland	CEGL001009	G5?
Basin Big Sagebrush / Western Wheatgrass - (Thick-spike Wheatgrass) Shrubland	CEGL001017	G3?
Wyoming Big Sagebrush / (Crested Wheatgrass, Russian Wildrye) Seeded Grasses Ruderal Shrubland	CEGL002185	GNA
Threetip Sagebrush / Sandberg Bluegrass Shrubland	CEGL005483	GNR
Wyoming Big Sagebrush / Cheatgrass Ruderal Shrubland	CEGL005477	GNA
Threetip Sagebrush / Thurber's Needlegrass Shrubland	CEGL005479	GNR
Threetip Sagebrush / Western Wheatgrass Shrubland	CEGL005482	GNR
Wyoming Big Sagebrush - Antelope Bitterbrush / Bluebunch Wheatgrass Shrubland	CEGL001050	G3Q
Big Sagebrush - (Rubber Rabbitbrush) / Cheatgrass Ruderal Shrubland	CEGL002699	GNA
Antelope Bitterbrush - Big Sagebrush / Indian Ricegrass Shrubland	CEGL003478	GNR
Big Sagebrush / Rubber Rabbitbrush Shrubland	CEGL000998	G5
Big Sagebrush / Basin Wildrye Shrub Grassland	CEGL001458	G2G4
Basin Big Sagebrush / Needle-and-Thread Shrubland	CEGL002966	G4?
Bud Sagebrush / Squirreltail Shrubland	CEGL002992	GNR

RANGE

Idaho National Laboratory Site

Sagebrush steppe communities are represented across the majority of the INL Site, and the (6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland vegetation class is the largest and most inclusive of the big sagebrush vegetation types. The distribution of this vegetation class is only restricted by major disturbances like fire, which removes sagebrush, and by soil texture and chemistry conditions which are too extreme to support big sagebrush. Occurrences of three-tip sagebrush-dominated plant communities within this vegetation class may also be found as small patches with other vegetation classes near the southern and western boundaries. These small patches are often so limited in total area that they were not classified as an independent vegetation class.

Global

This vegetation class is expansive throughout the semi-arid Great Basin and Columbia Plateau of the Western U.S. Its occurrences become more limited as it extends into surrounding environments of the southern deserts, north of the U.S. border into British Columbia, east into the Great Plains, and west towards the Cascade Mountains.

BACKGROUND AND ECOLOGY

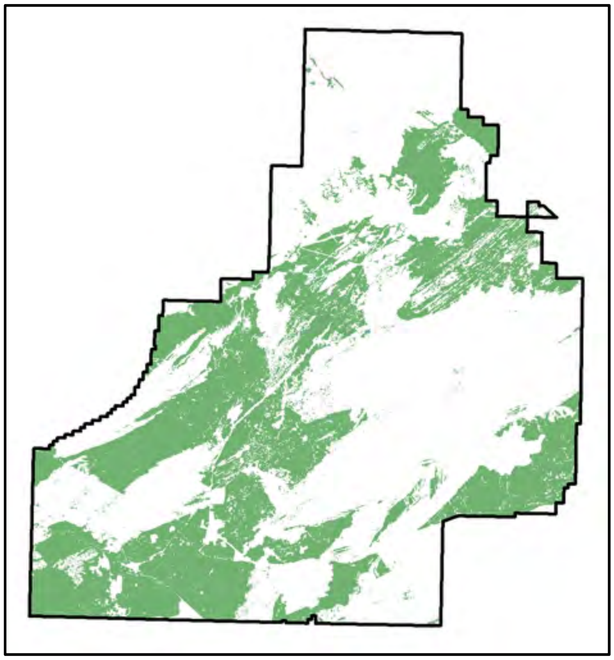
Communities dominated by big sagebrush are important across the western United States as they provide important ecosystem services and wildlife habitat. Many big sagebrush communities are declining in both extent and condition. Declines often result from a combination of stressors including wildland fire, non-native species invasion, drought, and overuse. Big sagebrush does not resprout following fire, so once it has been removed from a plant community, several decades or more may be required for it to become fully re-established.

RANGE OF VARIATION

Left: Sagebrush/green rabbitbrush canopy is open with abundant herbaceous understory.

Right: Shrub canopy is denser and herbaceous species are less abundant.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 6 is widespread throughout the INL Site and can commonly be observed intermixing locally with Class (8) Big Sagebrush Shrubland in areas where big sagebrush density is high and green rabbitbrush becomes less abundant. This class includes the largest number of mapped polygons with 2,387 distributed across the largest amount of mapped area of any map class with 851.2 km^2 (210,330.1 acres). Mean polygon area is 0.36 km^2 (88.1 acres).

7	**Crested Wheatgrass Ruderal Grassland**

Agropyron cristatum Ruderal Grassland 25 plots (8%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
6	0.25	**1**	0.16	**11**	0.10
8	0.24	**2**	0.15	**15**	0.09
10	0.20	**3**	0.15	**12**	0.09
5	0.17	**16**	0.13	**13**	0.07
9	0.16	**4**	0.12	**14**	0.07

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Artemisia tridentata	big sagebrush	4.6	6.9	52
Chrysothamnus viscidiflorus	green rabbitbrush	3.6	4.7	80
Graminoid				
Agropyron cristatum	crested wheatgrass	49.7	15.2	100

CLASS DESCRIPTION

This vegetation class is characterized by a moderate to dense herbaceous layer which is strongly dominated by crested wheatgrass (*Agropyron cristatum*). Crested wheatgrass is a perennial bunchgrass from the plains of Siberia, and it is often considered to be a naturalized species. On the INL Site it forms nearly monotypic stands with very little species diversity. Other non-native herbaceous species may occur in this community as well, especially in areas with soil disturbance, but they generally contribute very little total cover. Native species, which may be present sporadically with very low cover values, include shrubs, particularly green rabbitbrush (*Chrysothamnus viscidiflorus*) and big sagebrush (*Artemesia tridentata*), and grasses such as Indian ricegrass (*Achnatherum hymenoides*), Sandberg bluegrass (*Poa secunda*), and bottlebrush squirreltail (*Elymus elymoides*).

This introduced grassland generally occurs because it has been planted into rangelands and pastures to improve forage production and it is well suited to the cold, semi-arid conditions of higher elevation rangelands. Consequently, stands can occur in a wide variety of anthropogenically-disturbed habitats, including highway rights-of-way, revegetation projects, fire scars, etc. and its distribution does not appear to be tightly constrained by soil texture/depth, topography, or moisture availability.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Wyoming Big Sagebrush / (Crested Wheatgrass, Russian Wildrye) Seeded Grasses Ruderal Shrubland	CEGL002185	GNA
Crested Wheatgrass - (Western Wheatgrass, Needle-and-Thread) Ruderal Grassland	CEGL005266	GNA
Crested Wheatgrass - Cheatgrass Ruderal Grassland	CEGL005471	GNR
Yellow Rabbitbrush / Crested Wheatgrass Shrubland	CEGL005590	GNR

RANGE

Idaho National Laboratory Site

Crested wheatgrass-dominated communities occur along roadsides and in and around areas where it was historically planted in response to wildland fire and non-native annual species invasions, such as Tractor Flats and east of the Highway 20/26 junction. The most extensive stands often occur in close proximity to major roadways, power lines, and facility areas.

Global

Crested wheatgrass is widespread and abundant as it was once planted extensively. It occurs in the northern extent of the Great Plains and across the western states of the U.S. reaching into Canada. Crested wheatgrass is widespread and abundant in semi-arid ecosystems.

BACKGROUND AND ECOLOGY

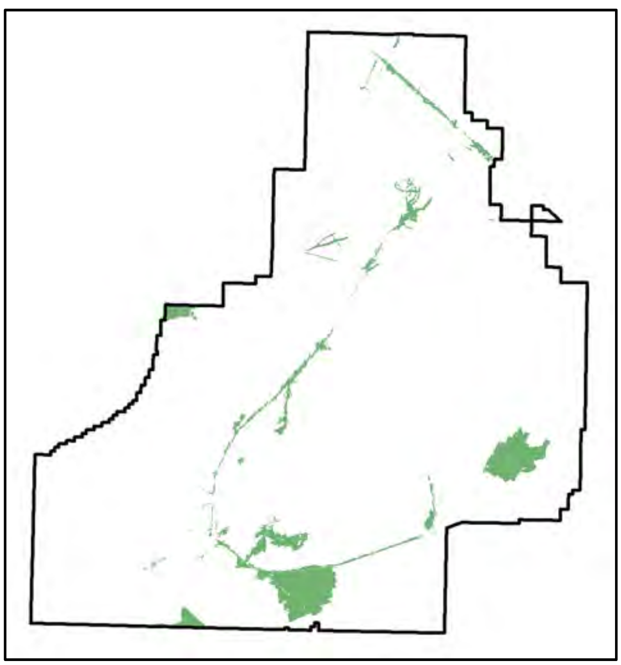
Crested wheatgrass is invading otherwise native vegetation communities across the INL Site. Major roadways, powerlines, and well-used two-tracks appear to provide major vectors of spread. However, crested wheatgrass is also invading the understory of sagebrush stands with very little apparent influence from anthropogenic vectors. As crested wheatgrass becomes abundant in the herbaceous understory, native species, including sagebrush, decline in importance, eventually resulting in monotypic crested wheatgrass stands. The persistence and competitive advantage of crested wheatgrass over native species appears to be a function of very high propagule pressure. Although crested wheatgrass is often identified as *Agropyron cristatum* at the INL Site, *Agropyron desertorum* has been planted and is common as well. The species are taxonomically very similar and are often difficult to distinguish from one another in the field.

RANGE OF VARIATION

Left: A monoculture of crested wheatgrass with relatively high total cover.

Right: Crested wheatgrass interspersed with sagebrush. This is an example of crested wheatgrass expanding in a native community and outcompeting and replacing the native understory species.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 7 is most commonly mapped in areas of large homogenous patches where crested wheatgrass had historically been planted, and also along infrastructure corridors (e.g. paved roads and power lines) where seed has likely been spread. This class includes 102 polygons covering 96.8 km^2 (23,925 acres). Mean polygon area is 0.95 km^2 (234.6 acres).

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	8	Big Sagebrush Shrubland

Artemisia tridentata Shrubland — 28 plots (8%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
6	0.49	**1**	0.30	**14**	0.23
5	0.38	**2**	0.29	**4**	0.22
10	0.36	**11**	0.26	**12**	0.19
3	0.35	**16**	0.25	**13**	0.18
9	0.32	**7**	0.24	**15**	0.17

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Artemisia tridentata	big sagebrush	25.0	8.2	100
Chrysothamnus viscidiflorus	green rabbitbrush	3.5	3.7	82
Opuntia polyacantha	plains pricklypear	0.6	1.2	57
Graminoid				
Hesperostipa comata	needle and thread	4.6	6.1	54
Elymus elymoides	bottlebrush squirreltail	3.9	5.3	89
Bromus tectorum	cheatgrass	2.0	4.0	64
Achnatherum hymenoides	Indian ricegrass	2.0	2.5	86
Forb				
Descurainia pinnata	western tansymustard	2.5	4.1	64
Lappula occidentalis	flatspine stickseed	1.0	1.3	71
Cryptantha scoparia	Pinyon Desert cryptantha	0.9	1.6	61

CLASS DESCRIPTION

This big sagebrush class is characterized by a moderate to dense shrub layer. Green rabbitbrush (*Chrysothamnus viscidiflorus*) is generally present across this community type, although cover is relatively low. Other shrubs occur sporadically, generally with low frequency and sparse cover. Plains pricklypear (*Opuntia polyacantha*) and shadscale saltbush (*Atriplex confertifolia*) are a few of the more commonly occurring species. The herbaceous stratum of this plant community ranges from sparse to moderate in terms of cover. Species composition of native grasses may be quite variable from one stand to another; however, needle and thread (*Hesperostipa comata*), bottlebrush squirreltail (*Elymus elymoides*), and Indian ricegrass (*Achnatherum hymenoides*) are among the most abundant grass species. Forbs present on more diverse sites may include: western tansymustard (*Descurainia pinnata*), flatspine stickseed (*Lappula occidentalis*), Hood's phlox (*Phlox hoodii*), *Chenopodium* spp., and *Eriogonum* spp. Cover from exotic species ranges from absent to moderate, the most abundant non-natives are cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum*), and desert alyssum (*Alyssum desertorum*).

Stands of this shrubland community are found on flat to gently rolling topography and soils are generally shallow. Soils are fine-textured and may have a loam or clay loam composition but may also include very rocky soils associated with basalt outcrops. As a consequence of shallow and/or fine-textured soils, water infiltration and availability are often limited where extensive stands of this type occur on the INL Site. The unvegetated surfaces of this plant community are characterized by bare soil and they generally have low to moderate litter cover.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Big Sagebrush Shrubland	CEGL000991	G5
Big Sagebrush / Squirreltail Shrubland	CEGL001001	G5?
Wyoming Big Sagebrush / Sparse Understory Shrubland	CEGL002768	GNR
Wyoming Big Sagebrush / Squirreltail Shrubland	CEGL001043	G4G5
Wyoming Big Sagebrush / Sandberg Bluegrass Shrubland	CEGL001049	G4
Big Sagebrush / Indian Ricegrass Shrubland	CEGL001006	G3G5
Wyoming Big Sagebrush / Bluebunch Wheatgrass Shrubland	CEGL001009	G5?
Wyoming Big Sagebrush / Indian Ricegrass Shrubland	CEGL001046	G5
Wyoming Big Sagebrush / Western Wheatgrass Shrub Grassland	CEGL001047	G4
Wyoming Big Sagebrush / Needle-and-Thread Shrubland	CEGL001051	G2
Wyoming Big Sagebrush / Mixed Grasses Shrub Grassland	CEGL001534	G5
Big Sagebrush / Yellow Rabbitbrush / (Sandberg Bluegrass) Shrubland	CEGL000999	G5
Wyoming Big Sagebrush - Shadscale Saltbush Shrubland	CEGL001040	G3G5

RANGE

Idaho National Laboratory Site

The INL Site supports extensive stands of big sagebrush and this vegetation class is widely distributed. It is particularly well represented in the northern portion of the INL Site where soils tend be fine in texture and shallow in depth. The distribution of this vegetation class is restricted by major disturbances like fire, which removes sagebrush, and by soil texture and chemistry conditions which are too extreme to support big sagebrush.

Global

This vegetation class is broadly distributed and commonly found in the plateaus, basins, and plains within semi-arid environments dominated by big sagebrush throughout the Intermountain West of the U.S. It occurs in limited distribution across the desert southwest and is more widely distributed in the semi-arid Great Basin and Columbia Plateau.

BACKGROUND AND ECOLOGY

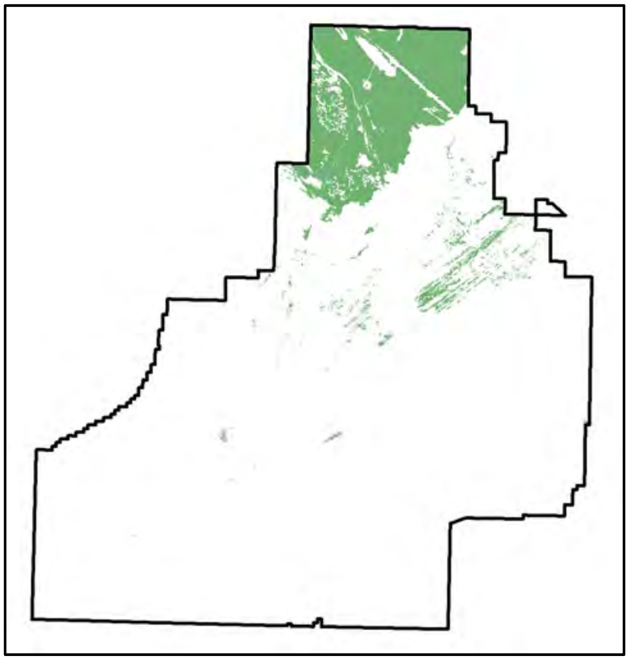
Communities dominated by big sagebrush are important across the western United States as they provide important ecosystem services and wildlife habitat. Many big sagebrush communities are declining in both extent and condition. Declines often result from a combination of stressors including wildland fire, non-native species invasion, drought, and overuse. Big sagebrush does not resprout following fire, so once it has been removed from a plant community, several decades or more may be required for it to become fully re-established.

RANGE OF VARIATION

Left: Moderate shrub canopy with low herbaceous cover and notable shrub interspaces.

Right: Higher herbaceous cover and a more heterogenous community distribution.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 8 is widespread and abundant throughout the northern portion of the INL Site but can also be found in small patches extending down towards the center of the Site. This class includes 891 polygons across 240.9 km^2 (59,529.8 acres). Mean polygon size is 0.27 km^2 (66.8 acres).

9 Western Wheatgrass Grassland

Pascopyrum smithii Grassland 17 plots (5%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
6	0.38	**5**	0.32	**12**	0.19
10	0.36	**4**	0.31	**15**	0.18
3	0.34	**1**	0.30	**7**	0.16
2	0.34	**16**	0.25	**14**	0.15
8	0.32	**11**	0.23	**13**	0.14

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Chrysothamnus viscidiflorus	green rabbitbrush	5.1	5.9	65
Graminoid				
Pascopyrum smithii	western wheatgrass	29.6	15.1	100
Achnatherum hymenoides	Indian ricegrass	3.6	4.0	76
Carex douglasii	Douglas' sedge	3.0	8.6	24
Bromus tectorum	cheatgrass	2.3	4.0	59
Elymus elymoides	bottlebrush squirreltail	1.7	2.5	53
Forb				
Schoenocrambe linifolia	flaxleaf plainsmustard	3.7	5.4	53
Lappula occidentalis	flatspine stickseed	3.3	7.8	76
Descurainia pinnata	western tansymustard	1.2	2.3	59

CLASS DESCRIPTION

The plant community represented by this vegetation class is characterized by an abundance of native, perennial rhizomatous grasses. The dominant species is western wheatgrass (*Pascopyrum smithii*). In addition to the rhizomatous grasses, several native bunchgrasses are generally present, often with much lower cover, and may include Indian ricegrass (*Achnatherum hymenoides*) and bottlebrush squirreltail (*Elymus elymoides*). Green rabbitbrush (*Chrysothamnus viscidiflorus*) occurs with moderate constancy, and low to moderate cover. Additional shrubs, such as big sagebrush (*Artemisia tridentata*), spiny hopsage (*Grayia spinosa*), and winterfat (*Krascheninnikovia lanata*) may also occur sporadically and with minimal cover. A variety of forb species may be present with low to moderate cover. Some of the more consistently occurring perennial species include flaxleaf plainsmustard (*Schoenocrambe linifolia*) and povertyweed (*Iva axillaris*), while annuals are highly variable from one year to another. Cover from non-native herbaceous species may range from absent to moderate. In stands where they occur, the most abundant non-native species is usually cheatgrass (*Bromus tectorum*); desert alyssum (*Alyssum desertorum*), tall tumblemustard (*Sisymbrium altissimum*), and saltlover (*Halogeton glomeratus*) may also occur occasionally.

Western wheatgrass-dominated areas are often found in proximity to ephemeral stream channels, playas, or other localized features that may have greater water accumulation and availability on a seasonal basis. Stands typically occur as a patchwork mosaic. Soils supporting this rhizomatous plant community are relatively deep and may range from fine-textured silt or clay loams to fairly coarse-textured loams. The unvegetated interspace surface has moderate to high exposure of bare soil, is relatively free of rock, and has only low to moderate cover of litter.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Western Wheatgrass Central Rocky Mountain Grassland	CEGL005653	GNR
Bluebunch Wheatgrass - Western Wheatgrass Grassland	CEGL001675	G4
Western Wheatgrass - Foxtail Barley Saline Prairie	CEGL001582	G4

RANGE

Idaho National Laboratory Site

The Western Wheatgrass Grassland class is widely distributed across the INL Site with relatively low frequency. This community tends to occur ubiquitously in lower elevation areas coincident with the west - center of the Site and occurs somewhat less frequently as elevation increases slightly near the southern and northern extents of the Site.

Global

Patches of native wheatgrass species which characterize this vegetation class have been documented across the north western/central states, including Idaho, Montana, Wyoming and Colorado and likely spread north into Canada as well. This wheatgrass prairie type occurs in semi-arid environments throughout the central Rocky Mountains, the north end of the Great Plains from the U.S. and extending further north into Canada.

BACKGROUND AND ECOLOGY

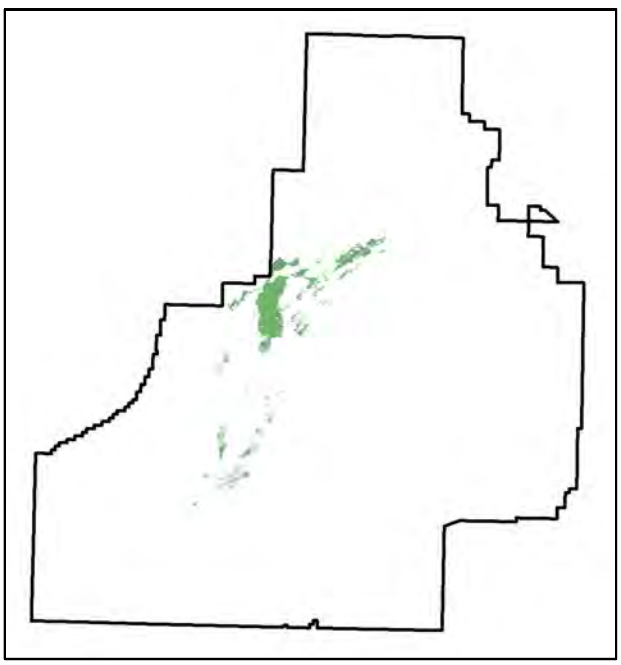
Western wheatgrass tends to occur in areas that were traditionally in close proximity to surficial water features. Western wheatgrass has a tendency to occur along the banks of the Big Lost River, near low playa areas, within some distance of runoff corridors, and around other areas where water accumulates. Because these areas of greater water availability have a more restricted distribution than in the past, due to changes in precipitation patterns and upstream flow diversion structures, this community type has likely experienced a decrease in distribution.

RANGE OF VARIATION

Left: A very weedy area with low relative cover of western wheatgrass and a large amount of bare ground.

Right: A mixed grass meadow consisting of a number of both rhizomatous grass as well as bunch grasses and an occasional shrub. High cover in general but lower cover of western wheatgrass than is typical.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 9 is most often associated with hydrologic systems and is mapped primarily throughout the floodplain of the Big Lost River (BLR). This class includes 377 polygons covering 31.3 km^2 (7,742.7 acres). There is one additional polygon mapped at the BLR Sinks area that is marked as 'Degraded.' The degraded polygon encompasses 1.84 km^2 (455 acres). Mean polygon area, excluding the degraded polygon, is 0.08 km^2 (20.5 acres).

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10 (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed

Leymus cinereus - Mixed Mustards Infrequently Inundated Playa/Streambed 38 plots (4%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
4	0.43	**2**	0.33	**7**	0.20
6	0.38	**3**	0.32	**15**	0.16
9	0.36	**1**	0.28	**13**	0.15
8	0.36	**16**	0.21	**12**	0.14
5	0.34	**11**	0.20	**14**	0.12

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Artemisia tridentata	big sagebrush	3.7	6.6	33
Chrysothamnus viscidiflorus	green rabbitbrush	3.3	6.9	50
Opuntia polyacantha	plains pricklypear	0.2	0.3	50
Graminoid				
Leymus cinereus	basin wildrye	13.6	19.2	42
Carex douglasii	Douglas' sedge	4.6	15.8	17
Poa secunda	Sandberg bluegrass	4.3	7.3	42
Hesperostipa comata	needle and thread	3.4	6.4	33
Bromus tectorum	cheatgrass	2.5	2.9	83
Elymus elymoides	bottlebrush squirreltail	2.2	4.3	67
Achnatherum hymenoides	Indian ricegrass	0.8	1.5	50
Forb				
Alyssum desertorum	desert alyssum	20.5	17.0	92
Descurainia pinnata	western tansymustard	9.1	19.4	67
Descurainia sophia	herb sophia	7.5	19.5	67
Lappula occidentalis	flatspine stickseed	2.5	2.8	92
Schoenocrambe linifolia	flaxleaf plainsmustard	0.7	1.2	50

CLASS DESCRIPTION

The (10) (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed plant community may be dominated by basin wildrye (*Leymus cinereus*), a mix of mustard species, or any combination thereof. Various abundant mustard species include desert alyssum (*Alyssum desertorum*), herb sophia

(*Descurainia sophia*), western tansymustard (*Descurainia pinnata*), and flaxleaf plainsmustard (*Schoenocrambe linifolia*), and tall tumblemustard (*Sisymbrium altissimum*). Cheatgrass (*Bromus tectorum*), a non-native annual grass, is generally present, but mean cover is low. Total vegetation cover ranges from 10% to 70%, and less than half is generally from native species. In additional to basin wildrye, other native species may occur in many stands of this vegetation type; however, cover and diversity are typically low, and component native species can be quite variable depending on the plant community that was present prior to the conversion to introduced species. Native shrubs, specifically green rabbitbrush (*Chrysothamnus viscidiflorus*), may occur sporadically with low abundance values. Bottlebrush squirreltail (*Elymus elymoides*) is the most constantly occurring native grass, although needle and thread (*Hesperostipa comata*) and Sandberg bluegrass (*Poa secunda*) may be locally more abundant where they occur. Native forb species may also occur with sparse cover values and variable species composition across stands of this vegetation type.

Historically, the physiognomy of this vegetation class is that of a tall, moderately dense grassland that is dominated by basin wildrye. Most basin wildrye is found along lower elevation riparian (or remnant riparian) corridors and in association with playas where seasonal flooding may occur. Generally, weedy variations of this vegetation type tend to occur as patches on mesic sites with more soil moisture than is available to the surrounding vegetation. Soils are often fine in texture with substantial clay content. Depths range from moderate to relatively deep and are often poorly drained, though some locations with moderate drainage also support stands of this vegetation class.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Basin Wildrye Bottomland Wet Meadow	CEGL001480	G1
Tall Tumblemustard - Cheatgrass Ruderal Grassland	CEGL005614	GNA
Basin Wildrye Alkaline Wet Meadow	CEGL001479	G2G3Q

RANGE

Idaho National Laboratory Site

Although this vegetation class is distributed widely across the INL Site, it typically occurs as small patches and the total amount of area represented by this class alone is quite limited. At the INL Site, good condition stands of basin wildrye occur in just a few, extremely limited areas associated with playas in the central portion of the Site. Most of the locations that contain an elevated abundance of mixed mustards are found along degraded remnant riparian corridors as well as in larger playas that have experienced some disturbance. This vegetation class tends to occur in areas with enough depth to bedrock to make them useful as borrow sources for backfill and topsoil material. Therefore, many of the larger expanses of this vegetation type have already been altered for extracting construction materials, and once the community has been disturbed by the removal of soil, it does not recover readily to its pre-disturbed state.

Global

This vegetation class is found in small patches of alkali playas, streambeds, or meadows which experience seasonal flooding within the Great Basin and Intermountain Region between 1400 m and 3000m. This vegetation type is found mainly in the Great Basin and the Intermountain Region and extends just into the western part of the Northern Great Plains. Although it occupies a small amount of total area in any western state, it has a fairly widespread range.

BACKGROUND AND ECOLOGY

This vegetation type has a widespread distribution, but is badly degraded over much of its range and has declined markedly in average ecological condition throughout the western U.S. This vegetation type was formerly very abundant in interior valleys, but now usually occurs as limited patches. Declines in the condition of basin wildrye-dominated communities both at the INL Site and range-wide are likely related to altered hydrological regimes and other stressor such as drought, overgrazing by domestic livestock, and pressure from non-native species.

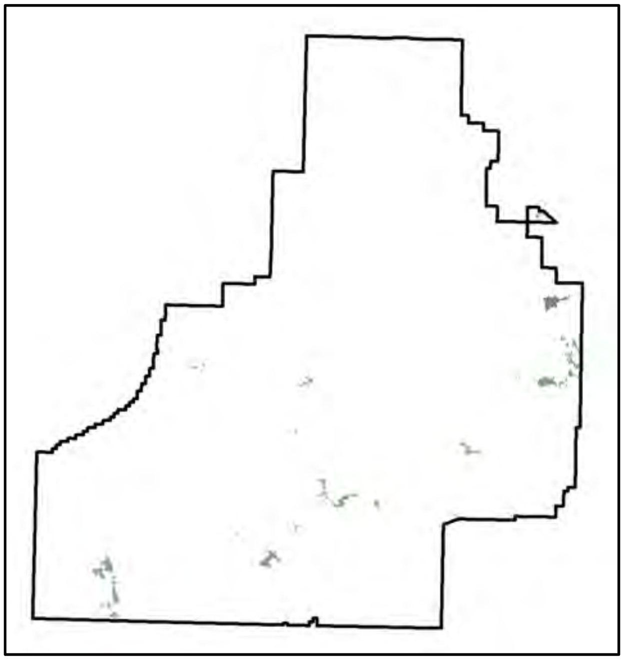
On the INL Site, this vegetation class likely occupies areas with greater than average soil moisture availability due to water accumulation and deep, fine-textured soils. These sites were once dominated by basin wildrye and/or native, rhizomatous grasses. A combination of persistent and ongoing disturbances such as altered hydrologic regime, wildland fire, livestock overgrazing, and soil disturbance related to borrow material extraction contributed to the conversion of these areas to mustards and non-native annuals. Unfortunately, there are very few locations that fit the condition of good on the INL Site.

RANGE OF VARIATION

Left: A playa dominated by cheatgrass and mustards. Although not visible, there is also likely an abundance of desert alyssum as well. Low to non-existent relative cover of basin wildrye found at this heavily degraded location.

Right: High relative cover of basin wildrye located in a good condition playa.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 10 has a limited amount of mapped area and exhibits a patchy distribution across the landscape most commonly driven by topographic low-lying areas that are seasonally inundated (i.e. playas). This class includes 409 polygons covering 13.5 km^2 (3,337.6 acres). There is one additional polygon on the east side of the INL Site that is marked 'Degraded' due to the presence of non-native species. The degraded polygon encompasses an area of 2.1 km^2 (513.8 acres). Mean polygon area, excluding the degraded polygon, is 0.28 km^2 (68.1 acres).

11 Juniper Woodland

Juniperus osteosperma Woodland — 11 plots (3%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
2	0.32	**8**	0.26	**16**	0.18
5	0.31	**3**	0.26	**15**	0.18
4	0.28	**9**	0.23	**7**	0.10
6	0.28	**12**	0.21	**14**	0.09
1	0.27	**10**	0.20	**13**	0.08

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Tree				
Juniperus osteosperma	Utah juniper	31.9	17.5	100
Shrub				
Chrysothamnus viscidiflorus	green rabbitbrush	1.6	2.2	64
Graminoid				
Bromus tectorum	cheatgrass	8.4	14.8	82
Pseudoroegneria spicata	bluebunch wheatgrass	4.4	6.1	45
Hesperostipa comata	needle and thread	3.8	4.1	73
Achnatherum hymenoides	Indian ricegrass	3.7	4.5	91
Poa secunda	Sandberg bluegrass	1.5	2.4	64
Forb				
Eriogonum cernuum	nodding buckwheat	1.5	1.9	64
Gilia sinuata	rosy gilia	1.4	1.9	73
Salsola kali	Russian thistle	0.9	1.7	55
Descurainia pinnata	western tansymustard	0.8	0.7	82
Phacelia glandulifera	sticky phacelia	0.8	1.1	55
Lappula occidentalis	flatspine stickseed	0.4	0.4	73
Cryptantha scoparia	Pinyon Desert cryptantha	0.2	0.3	55

CLASS DESCRIPTION

The structure of this vegetation class ranges from savanna-like, with an open tree canopy of Utah juniper (*Juniperus osteosperma*) and a highly variable understory composition to a woodland with a relatively closed canopy of Utah juniper. A discernable shrub stratum may or may not be present in any given stand.

When present, the shrub stratum is typically open and is dominated by sagebrush species (*Artemisia* spp.), green rabbitbrush (*Chrysothamnus viscidiflorus*), or some combination thereof. The herbaceous layer may be dominated by one or co-dominated by several native, perennial bunchgrasses including: bluebunch wheatgrass (*Pseudoroegneria spicata*), Indian ricegrass (*Achnatherum hymenoides*), needle and thread (*Hesperostipa comata*), Sandberg bluegrass (*Poa secunda*). Cheatgrass (*Bromus tectorum*) cover is highly variable but may approach 20% in some degraded areas. Plains pricklypear (*Opuntia polyacantha*) may be locally abundant in some stands. Native forbs are common and diverse, but cover is generally low. The most common forbs are native and may include: Western tansymustard (*Descurainia pinnata*), Pinyon Desert cryptantha (*Cryptantha scoparia*), nodding buckwheat (*Eriogonum cernuum*), and sticky phacelia (*Phacelia gladulifera*). Narrowleaf goosefoot (*Chenopodium leptophyllum*), whitestem blazingstar (*Mentzelia albicaulis*) and tapertip hawksbeard (*Crepis acuminata*) occur with some regularity as well.

This vegetation class occurs on higher elevation sites with slopes ranging from gentle to steep. Aspect does not appear to restrict the distribution of this community type at upper elevations, but it limits the distribution to north- and/or east-facing slopes at lower elevational extents. Soils are often poorly developed, shallow, and rocky. A range of soil textures may support this vegetation class; however, they often tend to be coarse and sandy for juniper stands at the INL Site.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Utah Juniper Woodland	CEGL000727	G5
Utah Juniper / Black Sagebrush Woodland	CEGL000728	G5?
Utah Juniper / Black Sagebrush / Rock Woodland	CEGL000729	G5
Utah Juniper / Big Sagebrush / Indian Ricegrass Woodland	CEGL000731	G4G5
Utah Juniper / Sparse Understory Woodland	CEGL000732	GNRQ
Utah Juniper / Bluebunch Wheatgrass Open Woodland	CEGL000738	G4
Utah Juniper / Needle-and-Thread Wooded Grassland	CEGL001489	G1Q
Utah Juniper / Mixed Shrubs Talus Woodland	CEGL002266	GNRQ
Utah Juniper / Wyoming Big Sagebrush Woodland	CEGL005617	GNR
Utah Juniper / Needle-and-Thread Open Woodland	CEGL002815	GNR
Utah Juniper / Cheatgrass Ruderal Woodland	CEGL002817	GNA
(Rocky Mountain Juniper, Utah Juniper) / Dwarf Goldenbush Wooded Grassland	CEGL005599	GNR
Utah Juniper / Wyoming Big Sagebrush / Needle-and-Thread Wooded Shrubland	CEGL005600	GNR
Utah Juniper / Little Sagebrush Woodland	CEGL002757	G5

RANGE

Idaho National Laboratory Site

The distribution of Utah juniper-dominated vegetation classes on the INL Site is restricted to the foothills around the Lemhi Mountains and in proximity to the large buttes near the southern boundary. Individual trees may occur sporadically or in small clusters elsewhere on the INL Site, particularly on basalt outcroppings, but these areas are generally so limited in extent that they don't represent true juniper communities.

Global

The range of Utah juniper includes states located throughout the intermountain west and desert southwest. This plant community occurs extensively in foothills and montane transition zones throughout that range.

BACKGROUND AND ECOLOGY

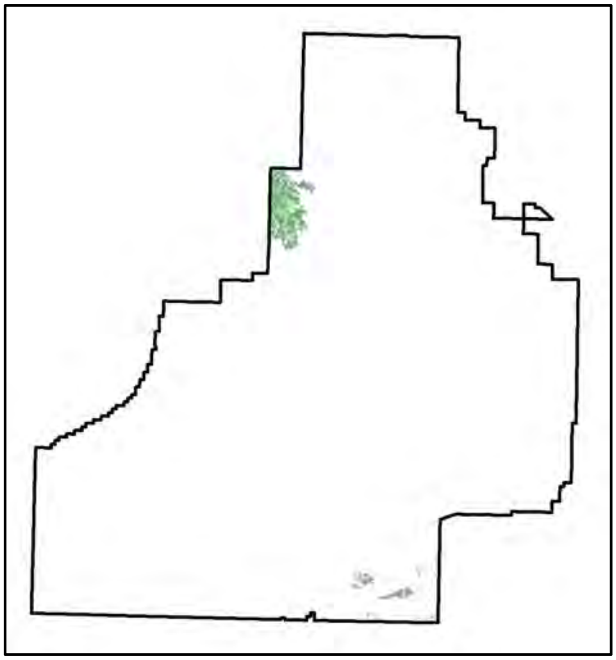
Juniper encroachment is currently considered to be a threat to sagebrush steppe communities in the intermountain west. Review of aerial photos dating back to 1949 suggests that not only are junipers not encroaching into sagebrush steppe communities on the INL Site, but that few if any individuals have established outside of historical juniper community boundaries. Very little is currently known about the population structure of juniper stands occurring on the INL Site.

RANGE OF VARIATION

Left: This mid-elevation site has high relative cover for a Utah juniper community. The trees are smaller in stature allowing more light and therefore more lower stratum species to thrive. It is also likely this site is ungrazed, further contributing to increased undergrowth.

Right: A large mature stand of Utah juniper forms a more closed canopy woodland; there is relatively little cover in the shrub and herbaceous strata.

MAP UNIT DESCRIPTION



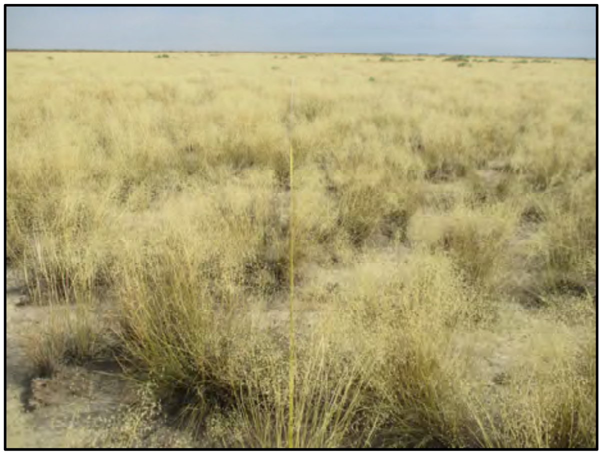
Range and Distribution

Map Unit Summary Statistics

Class 11 distribution is concentrated along the toe of the Lemhi mountain range in the northwest corner of the INL Site and in some smaller stands remaining near Middle Butte following multiple fires in the area. This class includes 385 polygons across 23.6 km^2 (5,832.1 acres). Mean polygon area is 0.06 km^2 (15.2 acres).

12 Indian Ricegrass Grassland

Achnatherum hymenoides Grassland 4 plots (1%)



Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
3	0.26	**14**	0.20	**9**	0.19
5	0.24	**4**	0.20	**10**	0.14
16	0.23	**8**	0.19	**15**	0.11
2	0.22	**6**	0.19	**13**	0.10
11	0.21	**1**	0.19	**7**	0.09

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Atriplex gardneri	Gardner's saltbush	5.1	10.2	25
Chrysothamnus viscidiflorus	green rabbitbrush	2.2	2.7	50
Opuntia polyacantha	plains pricklypear	0.2	0.3	50
Graminoid				
Achnatherum hymenoides	Indian ricegrass	53.3	14.3	100
Bromus tectorum	cheatgrass	7.1	14.2	50
Elymus elymoides	bottlebrush squirreltail	3.8	4.1	75
Hesperostipa comata	needle and thread	1.4	1.2	75
Elymus lanceolatus	thickspike wheatgrass	0.2	0.3	50
Forb				
Sphaeralcea munroana	whitestem globemallow	4.5	8.9	50
Lappula occidentalis	flatspine stickseed	0.7	0.6	75
Sisymbrium altissimum	tall tumblemustard	0.6	0.7	50
Descurainia pinnata	western tansymustard	0.2	0.3	75
Eriastrum wilcoxii	Wilcox's woollystar	0.1	0.2	50

CLASS DESCRIPTION

This grassland vegetation class occurs in small to medium-sized patches, often associated with dwarf shrub communities. It may also occur in burned sagebrush shrublands that were in good condition prior to the wildland fire. Indian ricegrass (*Achnatherum hymenoides*) strongly dominates this grassland vegetation class. Needle and thread (*Hesperostipa comata*), thickspike wheatgrass (*Elymus lanceolatus*), and bottlebrush squirreltail (*Elymus elymoides*) are also common graminoids, but the occur with much lower abundance. More degraded sites can have a noticeable amount of cheatgrass (*Bromus tectorum*) but it is highly variable from site to site. Scattered shrubs may be present. Green rabbitbrush (*Chrysothamnus viscidiflorus*) has moderate constancy and is sometimes abundant. Gardner's saltbush (*Atriplex gardneri*) and plains pricklypear (*Opuntia polyacantha*) are also common, while big sagebrush (*Artemisia tridentata*), winterfat (*Krascheninnikovia lanata*), and gray horsebrush (*Tetradymia canescens*) may also occur sporadically. Forbs have high diversity but species composition is inconsistent among sites and total cover is generally sparse. Seasonal precipitation plays a greater role in forb composition at these sites than other factors.

This vegetation type can occur across a range of geomorphic features and is not tightly constrained by soil texture and/or depth. Although Indian ricegrass can occupy a range of sites as a co-dominant, it appears to thrive and occur as a community dominant under abiotic conditions that restrict the distribution of other species at the INL Site. These conditions may include fine, shallow, sandy, and/or rocky soils and soils with high alkalinity and/or salinity.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Indian Ricegrass Shrub Grassland	CEGL003300	GNR
Indian Ricegrass Shale Barren Grassland	CEGL001651	G2
Indian Ricegrass - Lemon Scurfpea Grassland	CEGL001650	G3Q

RANGE

Idaho National Laboratory Site

This vegetation class is often distributed within lower elevation areas near the west-central and northeastern portions of the INL Site. Communities of this type are common in fine soils associated with large playas and the Big Lost River near its terminus. They are also associated with burn scars from relatively recent wildland fires, especially in sandy areas prone to dune formations.

Global

This grassland vegetation class occurs as discrete patches throughout the Intermountain West of the U.S. from the southern end of the Colorado Plateau extending north into Canada. As a community dominant, Indian ricegrass likely occurs as small patches distributed widely throughout the greater range of the species.

BACKGROUND AND ECOLOGY

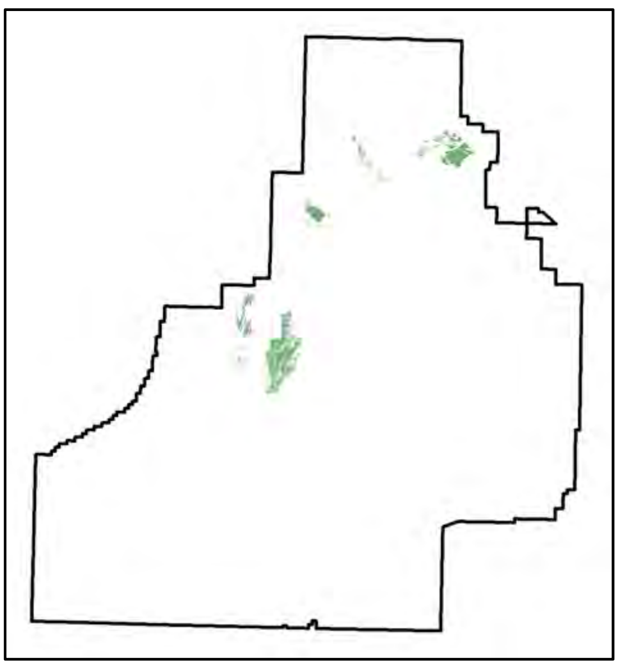
Indian ricegrass communities have been documented as occurring range-wide under two very disparate sets of environmental conditions; stabilized sand dunes and shale barrens. It is also documented to occur with substantial abundance in areas which have experienced soil disturbance such as blowouts and small mammal mounds. Indian ricegrass occurs with relatively low cover values and high constancy in most other vegetation classes on the INL Site.

RANGE OF VARIATION

Left: An Indian ricegrass community associated with salt desert shrub species such as winterfat and shadscale saltbush.

Right: A post fire Indian ricegrass community typical of a sandier location. This particular community is abundant with green rabbitbrush and also has moderate cheatgrass cover.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 12 is mapped as a combined class with Class (14) Gardner's Saltbush (Winterfat) Shrubland and has very little mapped area which is distributed primarily along the Big Lost River floodplain or in areas locally dominated by the presence of Gardner’s saltbush in the northern region of the INL Site. This class includes 250 polygons across 24.4 km^2 (6,021.6 acres). Mean polygon area was 0.1 km^2 (24.1 acres).

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13 Shadscale Saltbush – Winterfat Shrubland

Atriplex confertifolia - Krascheninnikovia lanata Shrubland — 7 plots (2%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
14	0.32	**10**	0.15	**12**	0.10
16	0.19	**6**	0.14	**5**	0.10
8	0.18	**9**	0.14	**4**	0.09
1	0.15	**2**	0.12	**11**	0.08
15	0.15	**3**	0.11	**7**	0.07

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Atriplex confertifolia	shadscale saltbush	15.6	12.0	71
Krascheninnikovia lanata	winterfat	14.3	15.2	57
Opuntia polyacantha	plains pricklypear	0.2	0.2	57
Graminoid				
Elymus elymoides	bottlebrush squirreltail	4.7	4.2	100
Poa secunda	Sandberg bluegrass	3.6	9.5	43
Achnatherum hymenoides	Indian ricegrass	0.7	1.1	57
Forb				
Schoenocrambe linifolia	flaxleaf plainsmustard	1.4	1.9	57
Halogeton glomeratus	saltlover	0.1	0.1	57

CLASS DESCRIPTION

Low-growing shadscale saltbush (*Atriplex confertifolia*) is the dominant shrub in this vegetation class. In some stands, the shrub stratum is nearly monotypic and in others it can be quite diverse. Other shrubs and dwarf shrubs, when present, typically include winterfat (*Krascheninnikovia lanata*) and plains pricklypear (*Opuntia polyacantha*), however bud sage (*Picrothamnus desertorum*), Wyoming big sagebrush (*Artemisia tridentata*), spiny hopsage (*Grayia spinosa*), and greasewood (*Sarcobatus vermiculatus*) may also occur on occasion. The herbaceous stratum is generally very sparse and communities in this vegetation class often have large expanses of exposed, bare soil. Bottlebrush squirreltail (*Elymus elymoides*) occurs with high constancy. Indian ricegrass (*Achnatherum hymenoides*) and Sandberg bluegrass (*Poa secunda*) are also often present but sparse. Forbs vary greatly across the range of this vegetation class and rarely contribute significant cover. Degraded stands may contain non-native annuals like saltlover (*Halogeton glomeratus*) in the understory.

Communities dominated by shadscale saltbush generally occur on low-lying, flat playas and similar topographic features that are periodically flooded. Soils tend to be fine and poorly drained, often with a hardpan layer. They may also be slightly alkaline and/or saline in nature.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Shadscale Saltbush Great Basin Shrubland	CEGL001294	G5
Shadscale Saltbush - Winterfat Shrubland	CEGL001301	G3G5
Winterfat Dwarf-shrubland	CEGL001320	G5?
Shadscale Saltbush Sparse Shrubland	CEGL003830	GNR
Shadscale Saltbush / Squirreltail Shrubland	CEGL001302	G3G5
Shadscale Saltbush / Indian Ricegrass Shrubland	CEGL001311	G3
Winterfat / Indian Ricegrass Dwarf-shrubland	CEGL001323	G4
Winterfat / Sandberg Bluegrass Dwarf-shrubland	CEGL001326	G3
Shadscale Saltbush - Bud Sagebrush / Winterfat Shrubland	CEGL001296	G5
Shadscale Saltbush / Bud Sagebrush Shrubland	CEGL001295	G5

RANGE

Idaho National Laboratory Site

The distribution of shadscale saltbush is widespread across the INL Site and it occasionally occurs as a sub-dominant shrub in big sagebrush vegetation classes. As a community dominant, shadscale saltbush’s distribution is restricted to the north central portions of the INL Site, where it occurs in a few, relatively large sands. Specifically, it is located within the historical drainages, floodplains, and playas of Birch Creek, the Big Lost River, and Lake Terreton.

Global

Though widely distributed across the western U.S., including the Colorado Plateau, the Great Basin, the Wyoming Basin, and the Columbia Plateau, the range of this vegetation type is discontinuous and patchy.

BACKGROUND AND ECOLOGY

Throughout shadscale saltbush’s range, large stands of this vegetation type are uncommon. Elsewhere, high-quality stands are rare due to anthropogenic influences; however, shadscale saltbush communities at the INL Site are in relatively good condition. Shadscale abundance on the INL Site is thought to fluctuate over periods of thousands of years, increasing in response to drier conditions over prolonged time periods.

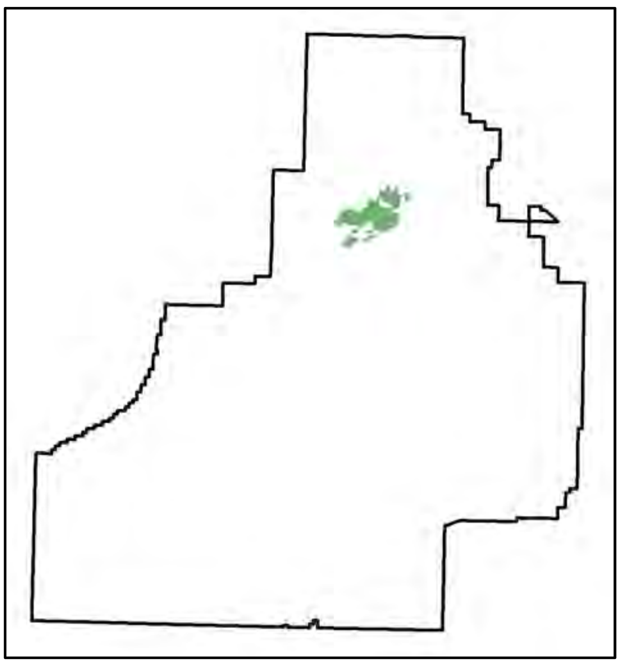
Winterfat is an important forage species for native and non-native grazers alike. It is highly palatable in the winter and is tolerant of heavy browsing. Winterfat shrublands often occur as "islands" surrounded by shadscale, spiny hopsage, Wyoming big sagebrush, or other vegetation types. Winterfat is often found in the gradient between sagebrush/green rabbitbrush communities and salt desert shrub communities.

RANGE OF VARIATION

Left: Sparse cover of shadscale saltbush with few other species present.

Right: High general cover with a multitude of other shrub and grass species.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 13 has one of the most limited distributions with the second lowest number of polygons mapped of any map class. This class only contains 14 polygons across 19.5 km^2 (4,824.1 acres). Mean polygon area is 1.4 km^2 (344.6 acres).

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14 Gardner's Saltbush (Winterfat) Shrubland

Atriplex gardneri (*Krascheninnikovia lanata*) Shrubland 8 plots (2%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
13	0.32	**16**	0.14	**15**	0.11
8	0.23	**1**	0.13	**2**	0.10
12	0.20	**10**	0.12	**11**	0.09
6	0.17	**3**	0.11	**7**	0.07
9	0.15	**5**	0.11	**4**	0.06

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Atriplex gardneri	Gardner's saltbush	29.8	8.4	100
Krascheninnikovia lanata	winterfat	8.3	11.7	50
Graminoid				
Elymus elymoides	bottlebrush squirreltail	4.1	3.4	88
Achnatherum hymenoides	Indian ricegrass	2.4	3.3	75
Forb				
Lappula occidentalis	flatspine stickseed	1.1	1.7	50

CLASS DESCRIPTION

Gardner's saltbush (*Atriplex gardneri*) is the dominant species in this sparsely vegetated shrubland community. Stands of this vegetation type are generally very simple in terms of structure and species composition. Winterfat (*Krascheninnikovia lanata*) may co-dominate this plant community when it occurs. Otherwise, the shrub canopy rarely contains additional shrubs; green rabbitbrush (*Chrysothamnus viscidiflorus*) may occur sporadically. Bottlebrush squirreltail (*Elymus elymoides*) and Indian ricegrass (*Achnatherum hymenoides*) occur with high constancy in the sparse herbaceous stratum. Herbaceous diversity is typically low and forb cover is sparse. Forbs in this community are often non-native and annual.

Communities of this type are often associated with topographic features which are intermittently flooded on the INL Site. These features often include historically slow-moving, braided stream channels and vegetated playa systems. Gardner's saltbush is abundant on medium to fine textured soils, often with substantial clay content. Soils also tend to be poorly drained and are often alkaline.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Gardner's Saltbush Dwarf-shrubland	CEGL001438	G3G5
Gardner's Saltbush / Indian Ricegrass Dwarf-shrubland	CEGL001444	G3
Gardner's Saltbush / Western Wheatgrass Dwarf-shrubland	CEGL001445	G3
Winterfat / Sandberg Bluegrass Dwarf-shrubland	CEGL001326	G3

RANGE

Idaho National Laboratory Site

Gardner’s saltbush occurs with a very limited distribution on the INL Site. It is most often intermixed with other vegetation classes and occurs in medium and fine-textured alkaline soils in the center and on the north end of the INL Site. It is generally associated with extensive playa systems, especially in proximity to the Big Lost River Sinks and the historical terminus of the Birch Creek drainage.

Global

This dwarf shrubland occurs within the Rocky Mountain System and can be scattered throughout the Interior Western U.S. commonly associated with shale substrate. Gardner’s saltbush (*Atriplex gardneri*) is currently the accepted nomenclature; it was previously identified as sickle saltbush (*Atriplex falcata*).

BACKGROUND AND ECOLOGY

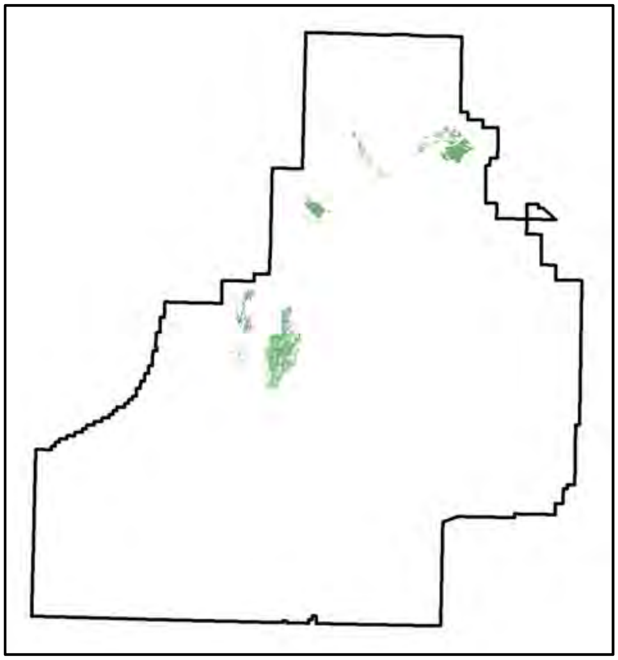
Communities dominated by Gardner’s saltbush and other species identified as sickle saltbush are prevalent in alkaline soils with limited plant-available moisture and are often considered a component of the salt desert shrub ecosystems of the Great Basin and Desert Southwest.

RANGE OF VARIATION

Left: High relative cover of Gardner’s saltbush with almost no other species present.

Right: Moderate cover of Gardner’s saltbush with higher cover of both winterfat and Indian ricegrass.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 14 is mapped as a combined class with Class (12) Indian Ricegrass Grassland and has very little mapped area, which is distributed primarily along the Big Lost River floodplain or in areas locally dominated by the presence of Gardner's saltbush in the northern region of the INL Site. This class includes 250 polygons across 24.4 km^2 (6,021.6 acres). Mean polygon area is 0.1 km^2 (24.1 acres).

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15 Black Sagebrush Shrubland

Artemisia nova Shrubland 8 plots (2%)

Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
16	0.27	**9**	0.18	**2**	0.15
1	0.21	**8**	0.17	**13**	0.15
6	0.20	**10**	0.16	**14**	0.11
11	0.18	**5**	0.16	**12**	0.11
3	0.18	**4**	0.15	**7**	0.09

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Artemisia nova	black sagebrush	30.6	2.9	100
Linanthus pungens	granite prickly phlox	1.2	1.5	88
Eriogonum microthecum	shrubby buckwheat	0.9	0.8	88
Chrysothamnus viscidiflorus	green rabbitbrush	0.9	1.5	63
Opuntia polyacantha	plains pricklypear	0.5	0.3	100
Graminoid				
Poa secunda	Sandberg bluegrass	7.9	4.1	100
Achnatherum hymenoides	Indian ricegrass	2.9	2.6	100
Elymus elymoides	bottlebrush squirreltail	1.6	1.5	100
Forb				
Phlox hoodii	Hood's phlox	1.3	0.9	100
Cordylanthus ramosus	bushy bird's beak	0.7	0.7	75
Phlox longifolia	longleaf phlox	0.4	0.4	63
Eriastrum wilcoxii	Wilcox's woollystar	0.1	0.2	50

CLASS DESCRIPTION

Black sagebrush (*Artemisia nova*) dominates the open shrub stratum of communities in this shrubland vegetation class. Sandberg bluegrass (*Poa secunda*) dominates an herbaceous stratum, which is characterized by low to moderate cover. Diversity may be quite high in communities of this vegetation type. Other shrubs and dwarf shrubs common in this class include: shrubby buckwheat (*Eriogonum microthecum*), granite prickly phlox (*Linanthus pungens*), green rabbitbrush (*Chrysothamnus viscidiflorus*), and plains prickly pear (*Opuntia polyacantha*). Indian ricegrass (*Achnatherum hymenoides*) and bottlebrush squirreltail (*Elymus elymoides*) occur with high constancy in the herbaceous layer, but other species may be locally abundant as well. Native forbs are conspicuous and diverse, but species composition may vary from one stand to another. Phlox species (*Phlox hoodii*, *Phlox longifolia*) and bushy bird's beak (*Cordylanthus ramosus*) occur with the most regularity.

This vegetation class occurs on topography ranging from gently rolling to moderately steep slopes and topographic positions ranging from lower toe-slopes to open, exposed ridges. The distribution of this vegetation type does not appear to be tightly constrained by aspect. Stands occur on shallow, calcareous soils which are generally poorly developed, but well-drained. Soils often contain abundant unconsolidated rock and gravel.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Black Sagebrush Shrubland	CEGL001417	G3G5
Black Sagebrush / Squirreltail Shrubland	CEGL001418	G4G5
Black Sagebrush / Indian Ricegrass Shrubland	CEGL001422	G4G5
Black Sagebrush / Sandberg Bluegrass Shrubland	CEGL001423	G3

RANGE

Idaho National Laboratory Site

This vegetation class is common in the northwest portion of the INL Site where it is associated with the foothills at the base of the Lemhi and Beaverhead Mountain Ranges. It also occurs on and around large and small buttes across the INL Site. Small patches of this community type can be found within other vegetation classes but not at a mappable scale.

Global

This vegetation class occurs throughout the western U.S. within the Wyoming Basin through the Colorado Plateau and into the Great Basin. Black sagebrush-dominated communities are discontinuously distributed creating isolated stands. Black sagebrush-dominated communities are widely, but discontinuously distributed throughout the western United States. The co-dominance of Sandberg bluegrass in the dwarf-shrubland community is uncommon, however it has been documented to occur occasionally in the Columbia Basin, Great Basin, and Snake River Plain.

BACKGROUND AND ECOLOGY

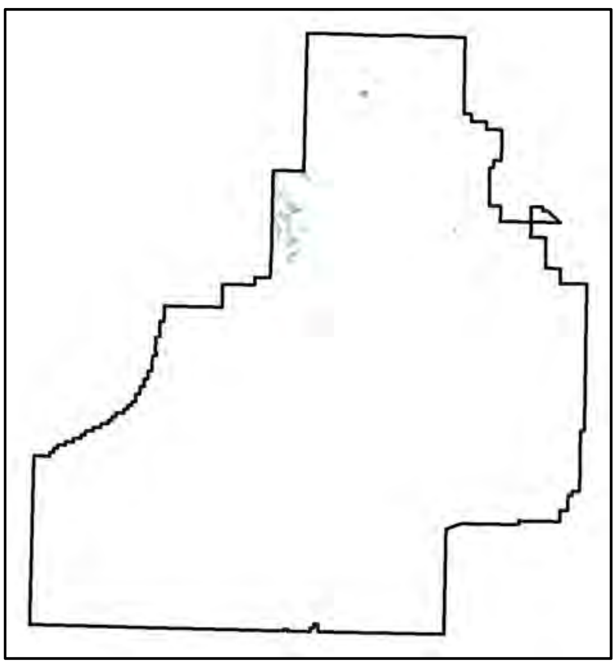
This vegetation type is likely restricted to shallow, rocky soil sites which are unable to support more robust native grasses like bluebunch wheatgrass (*Pseudoroegneria spicata*). Numerous stands throughout its global range are currently protected, though some low-elevation sites are at risk for cheatgrass (*Bromus tectorum*) invasion and subsequent wildland fire.

RANGE OF VARIATION

Left: A lower elevation site with higher general cover and species variation.

Right: A lower elevation site with high relative cover of Sandberg bluegrass, a combination that is somewhat unique to this community globally but is more common at the INL Site.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 15 has the lowest total mapped area and the lowest mean area per polygon of any map class. Class 15 distribution is most commonly mapped within the interspace between stands of juniper trees in the Lemhi mountain range. This class contains 145 polygons across 4.9 km^2 (1,209.8 acres). Mean polygon area is 0.03 km^2 (8.3 acres).

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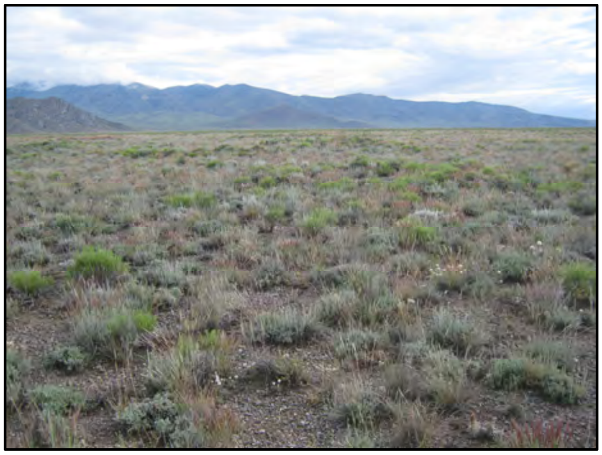
16 Low Sagebrush Shrubland

Artemisia arbuscula Shrubland — 9 plots (3%)



Representative Class Photo

Summary Bray-Curtis Scores

Class #	BC Score	Class #	BC Score	Class #	BC Score
3	0.37	**5**	0.23	**13**	0.19
15	0.27	**12**	0.23	**11**	0.18
6	0.27	**2**	0.22	**1**	0.18
9	0.25	**10**	0.21	**14**	0.14
8	0.25	**4**	0.20	**7**	0.13

CHARACTERISTIC SPECIES

Scientific Name	Common Name	Mean Cover (%)	SD (+/-)	Constancy (%)
Shrub				
Artemisia arbuscula	low sagebrush	20.3	6.9	100
Chrysothamnus viscidiflorus	green rabbitbrush	2.8	2.8	89
Atriplex confertifolia	shadscale saltbush	1.8	1.9	67
Linanthus pungens	granite prickly phlox	1.7	1.8	78
Krascheninnikovia lanata	winterfat	1.6	1.5	78
Eriogonum microthecum	shrubby buckwheat	1.1	0.8	100
Opuntia polyacantha	plains pricklypear	0.8	0.7	100
Graminoid				
Achnatherum hymenoides	Indian ricegrass	9.4	5.9	100
Poa secunda	Sandberg bluegrass	2.3	2.9	89
Elymus elymoides	bottlebrush squirreltail	2.1	2.2	100
Forb				
Eriastrum wilcoxii	Wilcox's woollystar	0.5	0.7	67
Phlox hoodii	Hood's phlox	0.5	0.5	78
Schoenocrambe linifolia	flaxleaf plainsmustard	0.2	0.3	56

CLASS DESCRIPTION

This vegetation class is characterized by a short-statured, open dwarf-shrub canopy that is dominated by low sagebrush (*Artemisia arbuscula*). Other shrubs and dwarf shrubs may be common in the canopy and additional species often include: green rabbitbrush (*Chrysothamnus viscidiflorus*), shadscale saltbush (*Atriplex confertifolia*), granite prickly phlox (*Linanthus pungens*), plains pricklypear (*Opuntia polyacantha*), shrubby buckwheat (*Eriogonum microthecum*), and winterfat (*Krascheninnikovia lanata*).

The herbaceous stratum is generally sparse and is dominated by native bunchgrasses. Bottlebrush squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), and Sandberg bluegrass (*Poa secunda*) all occur with very high constancy. Forb cover is low and species composition is variable; although Hood's phlox (*Phlox hoodii*) and Wilcox's woollystar (*Eriastrum wilcoxii*) are present with moderate frequency.

Occurrences of this vegetation class are restricted to relatively flat, low-lying topographic features. Soils are fine to very fine in texture and may contain some rock and/or gravel, especially noticeable on the surface. Soil depth often appears to be limited and a hard pan layer may be present, restricting drainage. Salinity and/or alkalinity may also affect productivity at sites where this vegetation class occurs.

NATIONAL VEGETATION CLASSIFICATION CROSSWALK

Related NVC Associations	Database Code	Conservation Rank
Little Sagebrush / Sandberg Bluegrass Shrub Grassland	CEGL001411	G5
Little Sagebrush / Granite Prickly-phlox Shrubland	CEGL003482	G4
Little Sagebrush / Slender Buckwheat Shrubland	CEGL003483	G2G3

RANGE

Idaho National Laboratory Site

Mapped polygons of this class are primarily located in the northern portion of the INL Site. Smaller stands of this vegetation class are also located in the central and western portions of the INL Site on or around playas. These small occurrences are below the mapping scale and did not contribute enough total area to justify mapping them separately.

Global

This vegetation class occurs in the Columbia Plateau, Snake River Plain, and the Great Basin along with specific locations in Yosemite National Park described from high elevation shrubland ecosystems. It often occurs as small discontinuous patches with other sagebrush steppe vegetation types.

BACKGROUND AND ECOLOGY

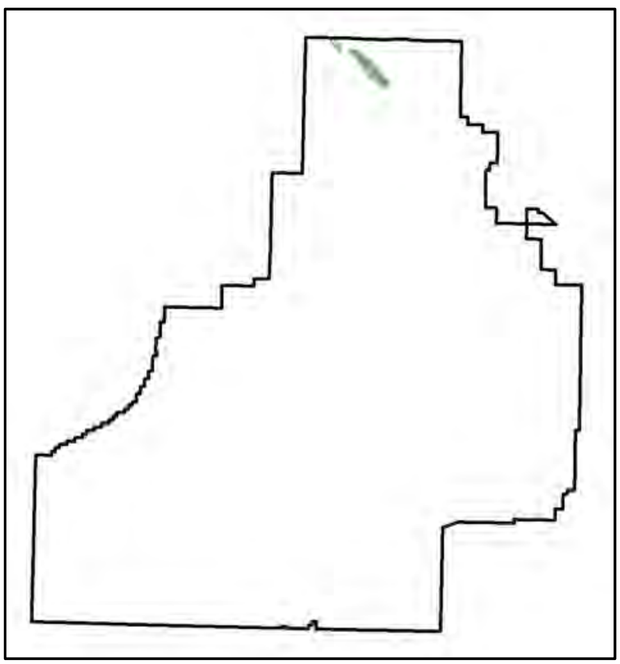
Both low sagebrush and black sagebrush (*Artemisia nova*) were once considered to be variations within the same species. Since vegetation research and monitoring began at the INL Site in 1950, the taxonomy of the species changed, splitting the previously recognized subspecies into separate species. Early vegetation maps of the INL Site depict extensive polygons containing low sagebrush, but many of low sagebrush-dominated stands in that map would be identified as black sagebrush communities according to current taxonomic standards. Currently, both low sage and black sage communities are considered separate and distinct and are mapped individually.

RANGE OF VARIATION

Left: Average low sagebrush cover with relatively high Sandberg bluegrass (*Poa secunda*) cover.

Right: Relatively high cover of low sagebrush with very low cover of all other species.

MAP UNIT DESCRIPTION



Range and Distribution

Map Unit Summary Statistics

Class 16 has a very limited distribution and consists of one large swath in the northern region of the INL Site. Class 16 has the second smallest amount of area mapped, but it has the second largest mean area per polygon. This class includes only three polygons across 6.1 km^2 (1,517.9 acres). Mean polygon area is 2.05 km^2 (506 acres).

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Appendix E

INL Site Vegetation Map Book

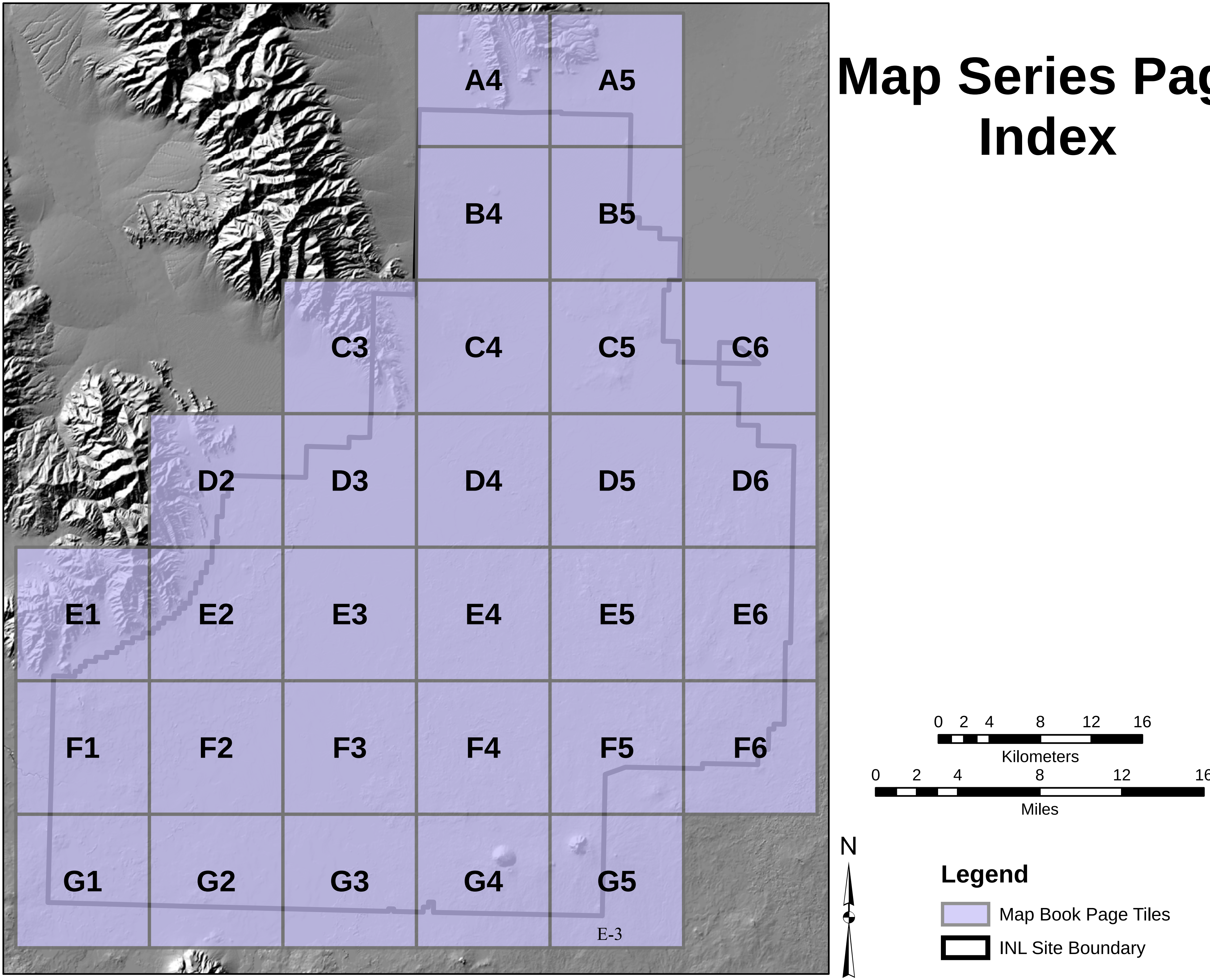
Map Book Information

The INL Site vegetation map is presented here in a hard-copy map book series. There are too many small polygons for a standard size printed map to convey the necessary detail. We selected a 1:60,000 scale to present the map because it shows fine scale map details while minimizing the number of map pages required to display the entire INL Site.

We have added some additional Geographic Information System data layers to the vegetation map layout to provide more information to the map user. We included the INL Site roads data layer for reference on each map book page. We also used a 10 m Digital Elevation Model (DEM) hillshade (i.e. artificial topographic shading) to include some topographic information with the polygons. The vegetation map layer is displayed with a partial transparency so the shadows and contours of the DEM are evident and can provide information to help interpret the map. We have also added a background image that borders the INL Site to provide context for the surrounding lands. The background imagery is the 2017 Idaho National Agricultural Imaging Program (NAIP) 1 m resolution true-color imagery.

There are a two map polygons that have a special cross-hatching fill and are labeled as 'Degraded' in parentheses. This label is intended to inform the map user that these areas contain vast expanses of weedy species not common to the assigned map class. We had to assign each polygon to a vegetation class, and in some areas the polygons were so weedy it was difficult to key the area to an existing class. The (Degraded) label will inform the map user that even though a vegetation class is assigned to that polygon, on the ground an observer would expect to find vegetation species and composition that does not match other areas assigned to the same vegetation class.

Map Series Page Index



(1) Green Rabbitbrush / Sandberg Bluegrass – Bluebunch Wheatgrass Shrub Grassland

(2) Cheatgrass Ruderal Grassland

(3/5) Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland

(4) Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland

(6) Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland

(7) Crested Wheatgrass Ruderal Grassland

(8) Big Sagebrush Shrubland

(9) Western Wheatgrass Grassland

(9*) Western Wheatgrass Grassland (Degraded)

(10) (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed

(10*) (Basin Wildrye) – Mixed Mustards Infrequently Inundated Playa/Streambed (Degraded)

(11) Juniper Woodland

(12/14) Indian Ricegrass Grassland and Gardner's Saltbush (Winterfat) Shrubland

(13) Shadscale Saltbush – Winterfat Shrubland

(15) Black Sagebrush Shrubland

(16) Low Sagebrush Shrubland

(99-1) Facilities

(99-2) Agriculture

(99-3) Big Lost River Channel

(99-4) Borrow Sources/Disturbed

(99-5) Exposed Rock/Cinder

(99-6) Paved Roads

See Page: N/A

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See Page: A5

See Page: B4

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3/5	8	99-6

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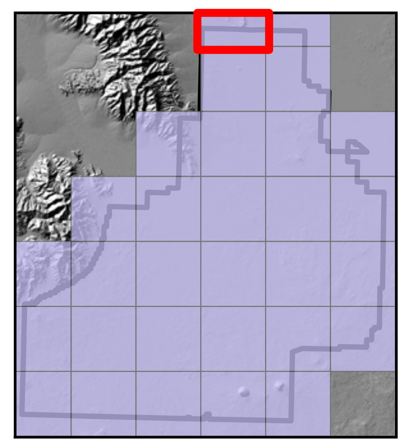

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A4

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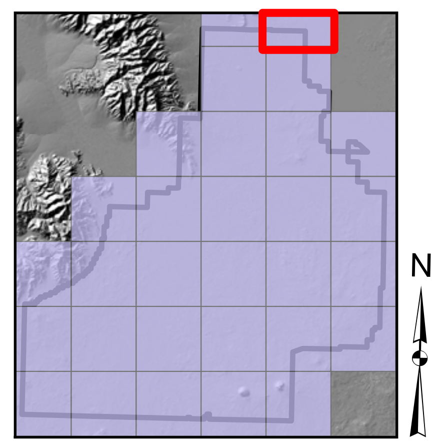

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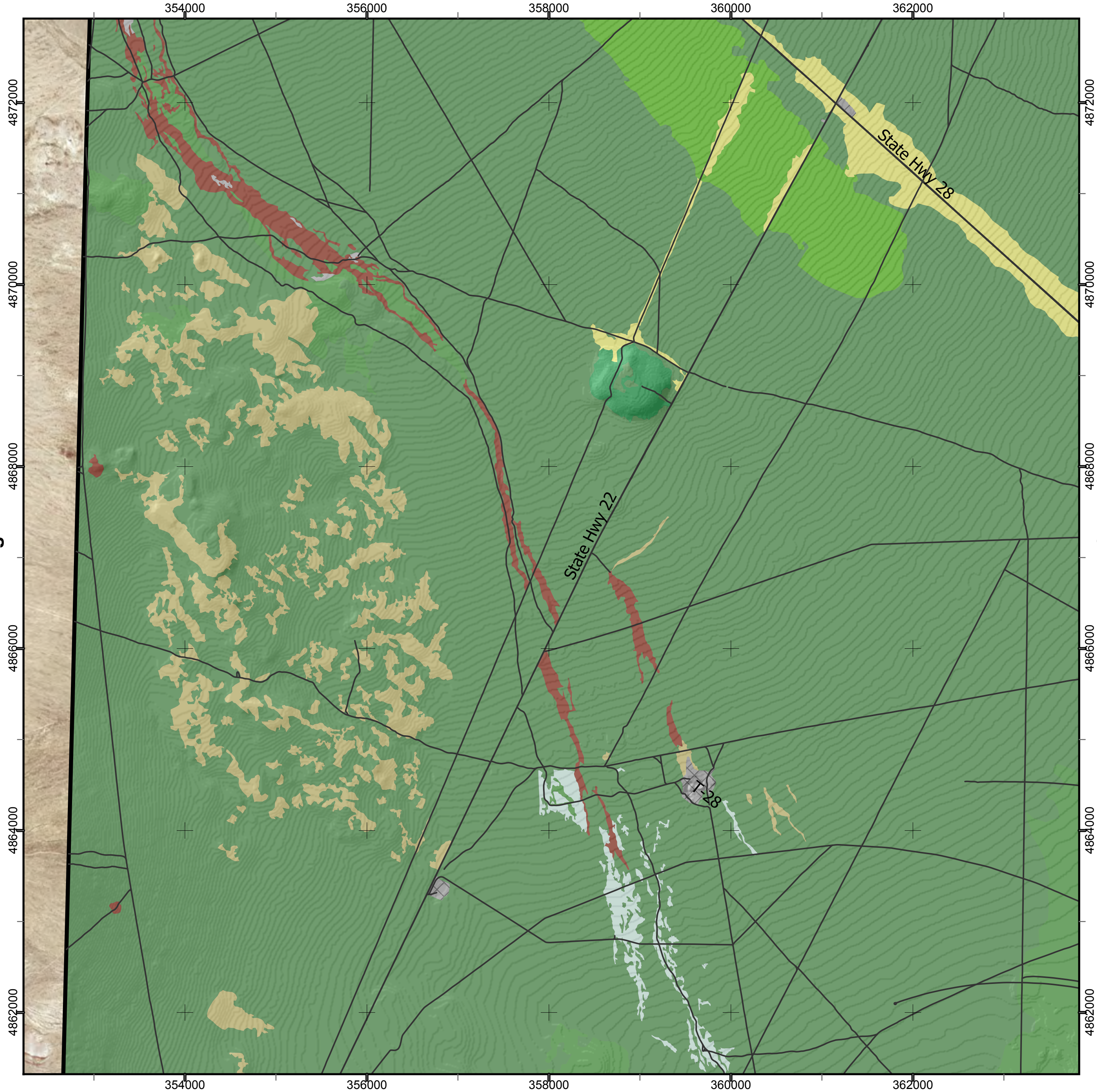

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Kilometers

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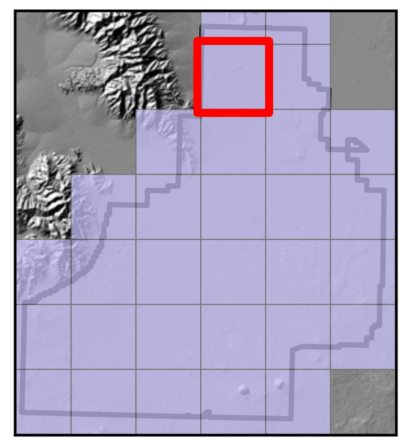

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Environmental Surveillance, Education, and Research Program

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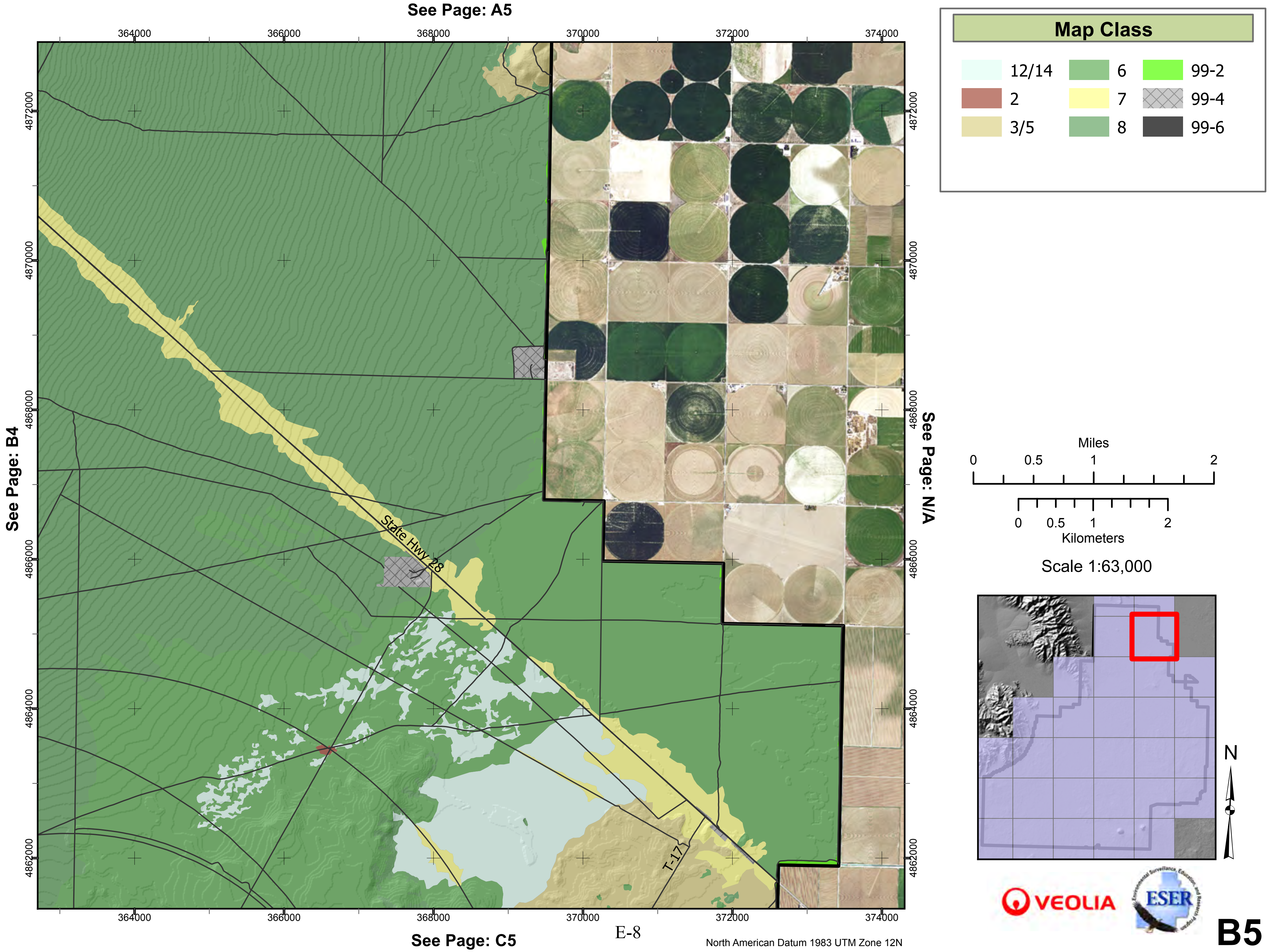
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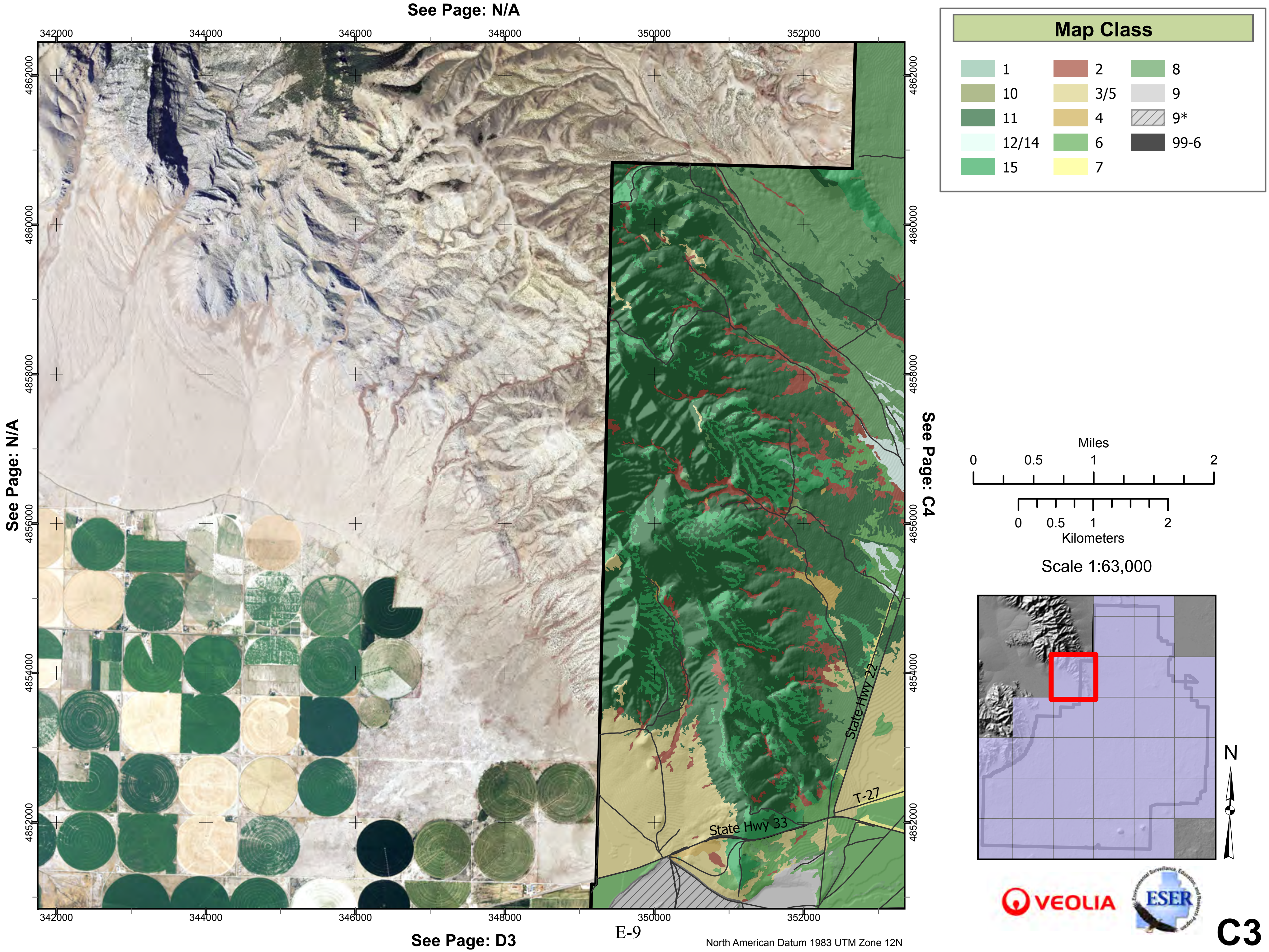

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C3

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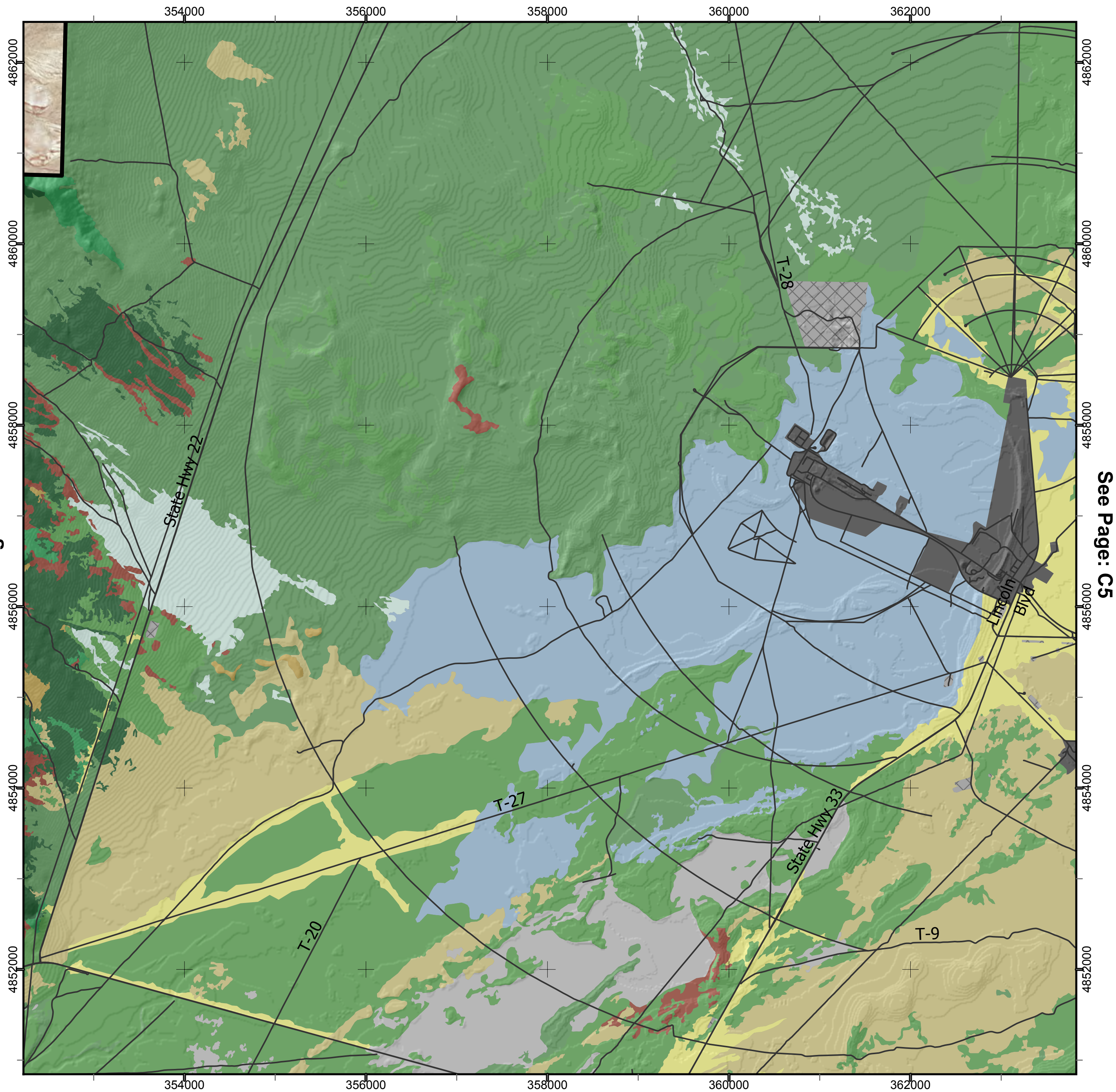

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See Page: C5

See Page: D4

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Kilometers

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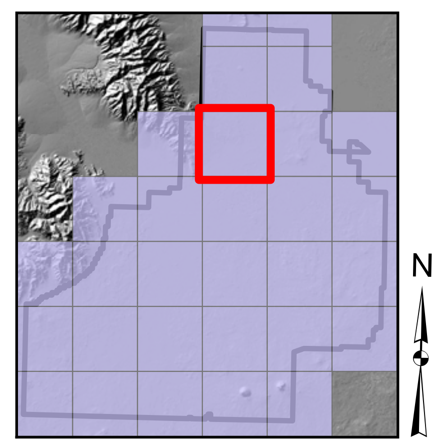

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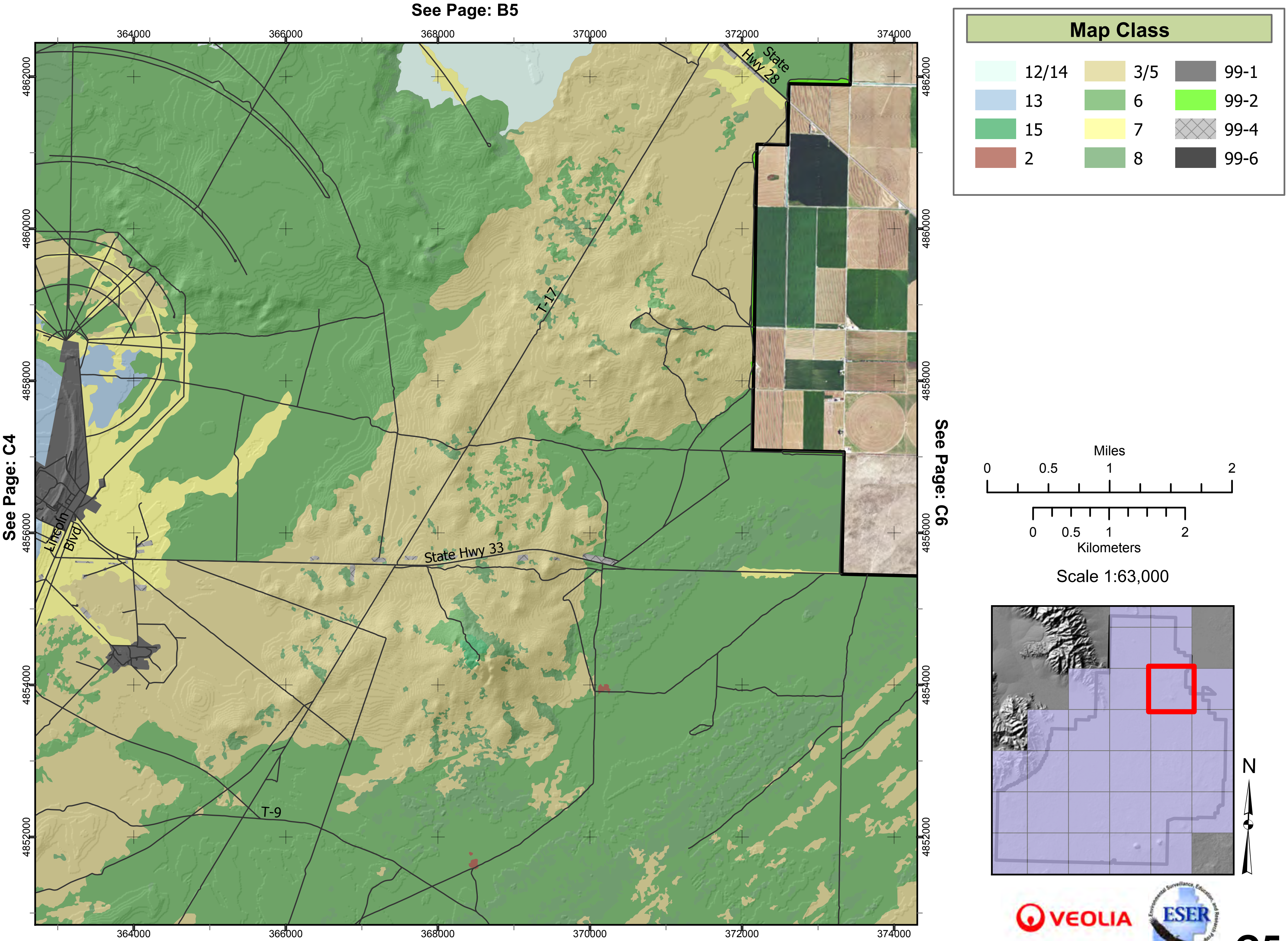

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Map Class

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Kilometers

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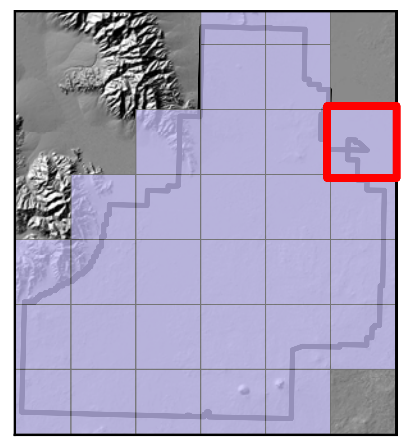

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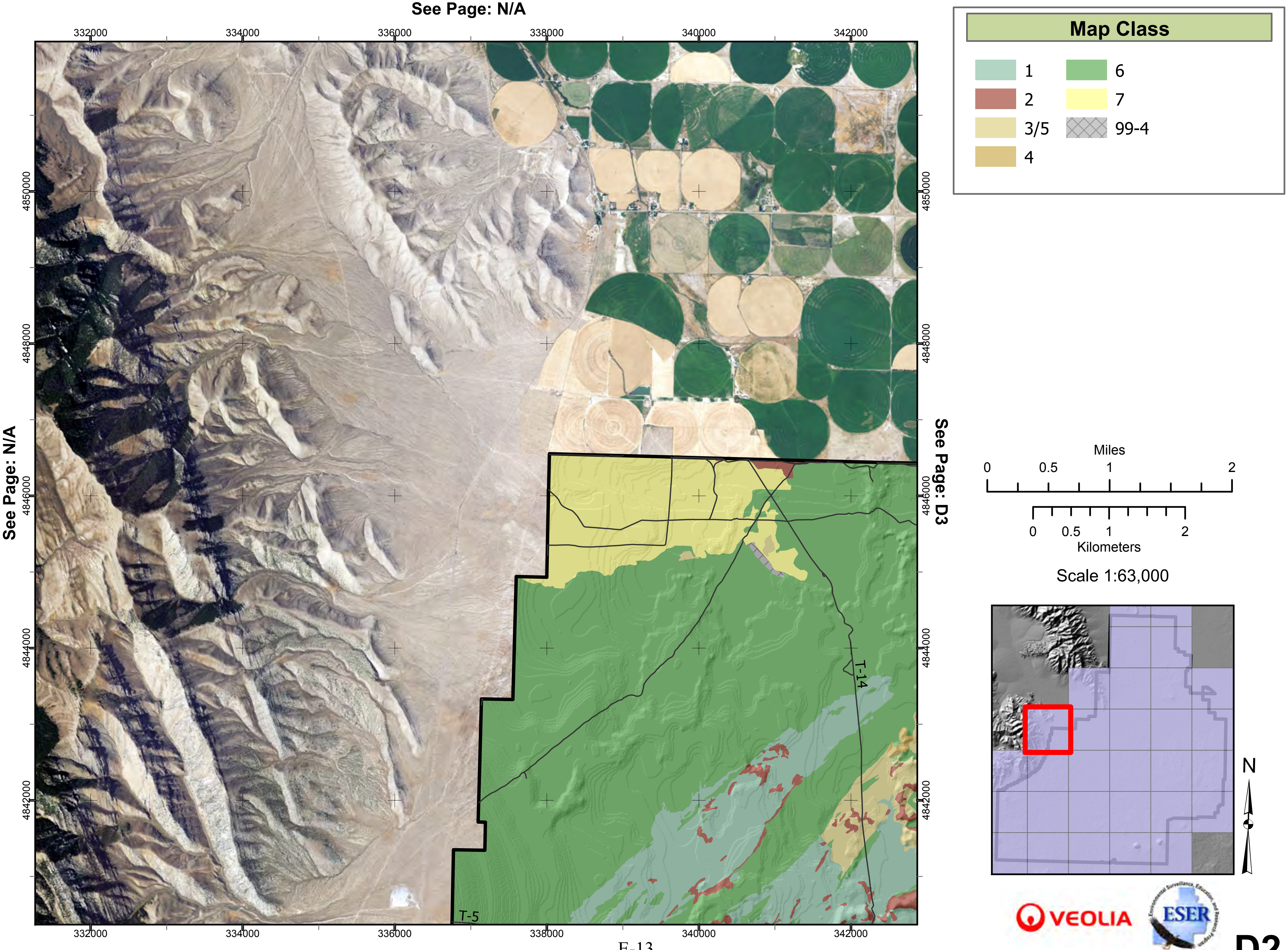

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North American Datum 1983 UTM Zone 12N

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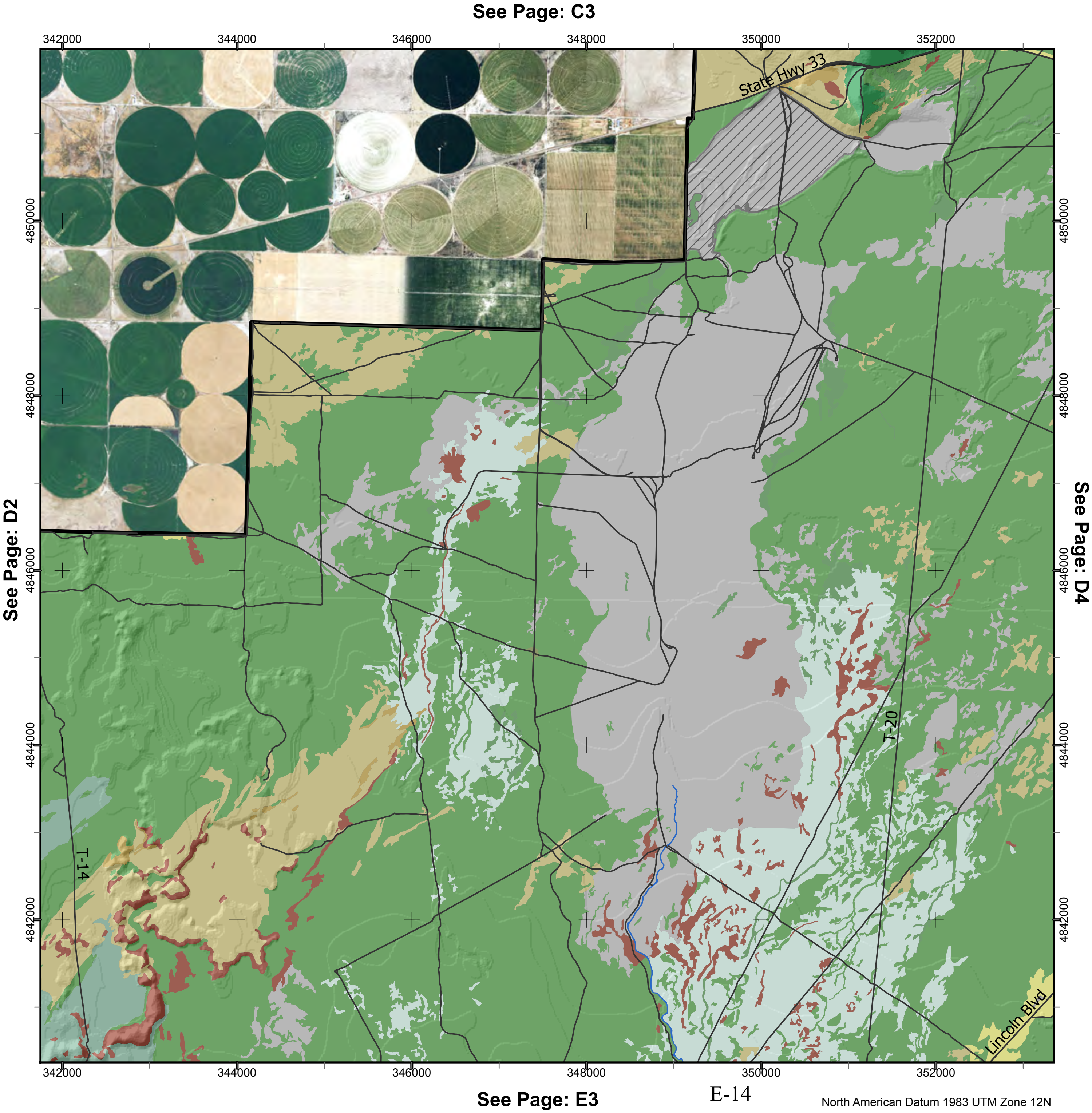

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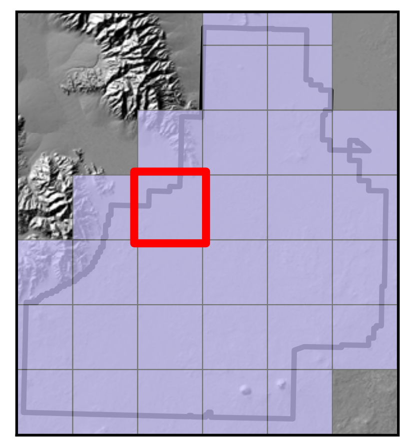

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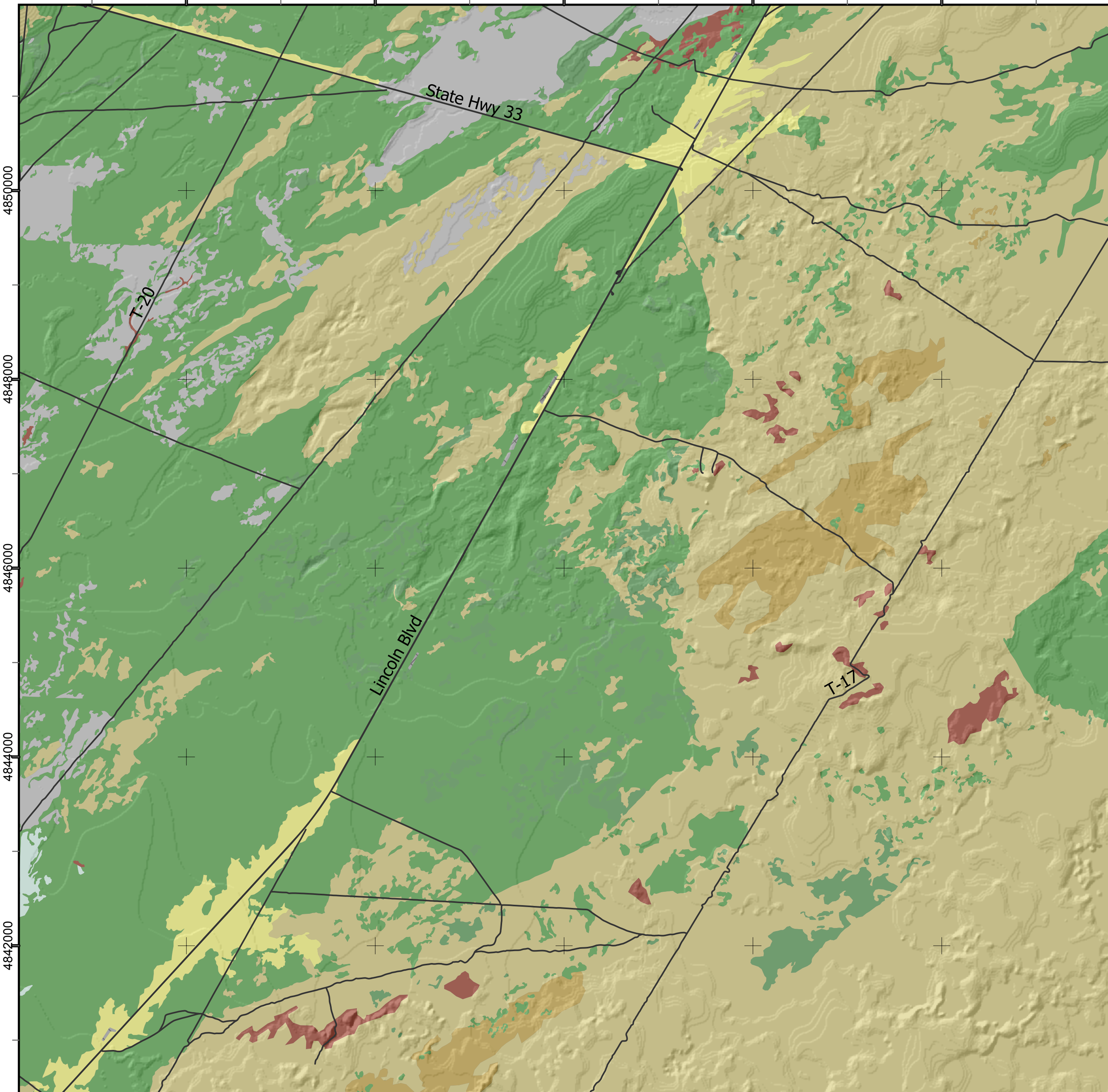

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Kilometers

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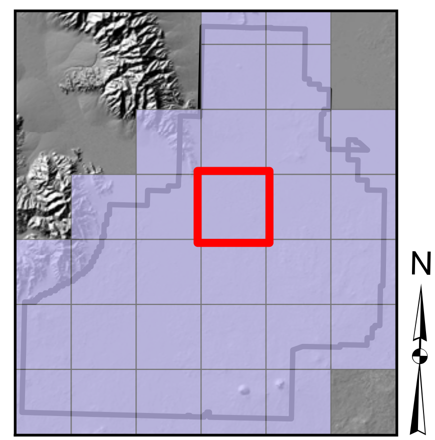

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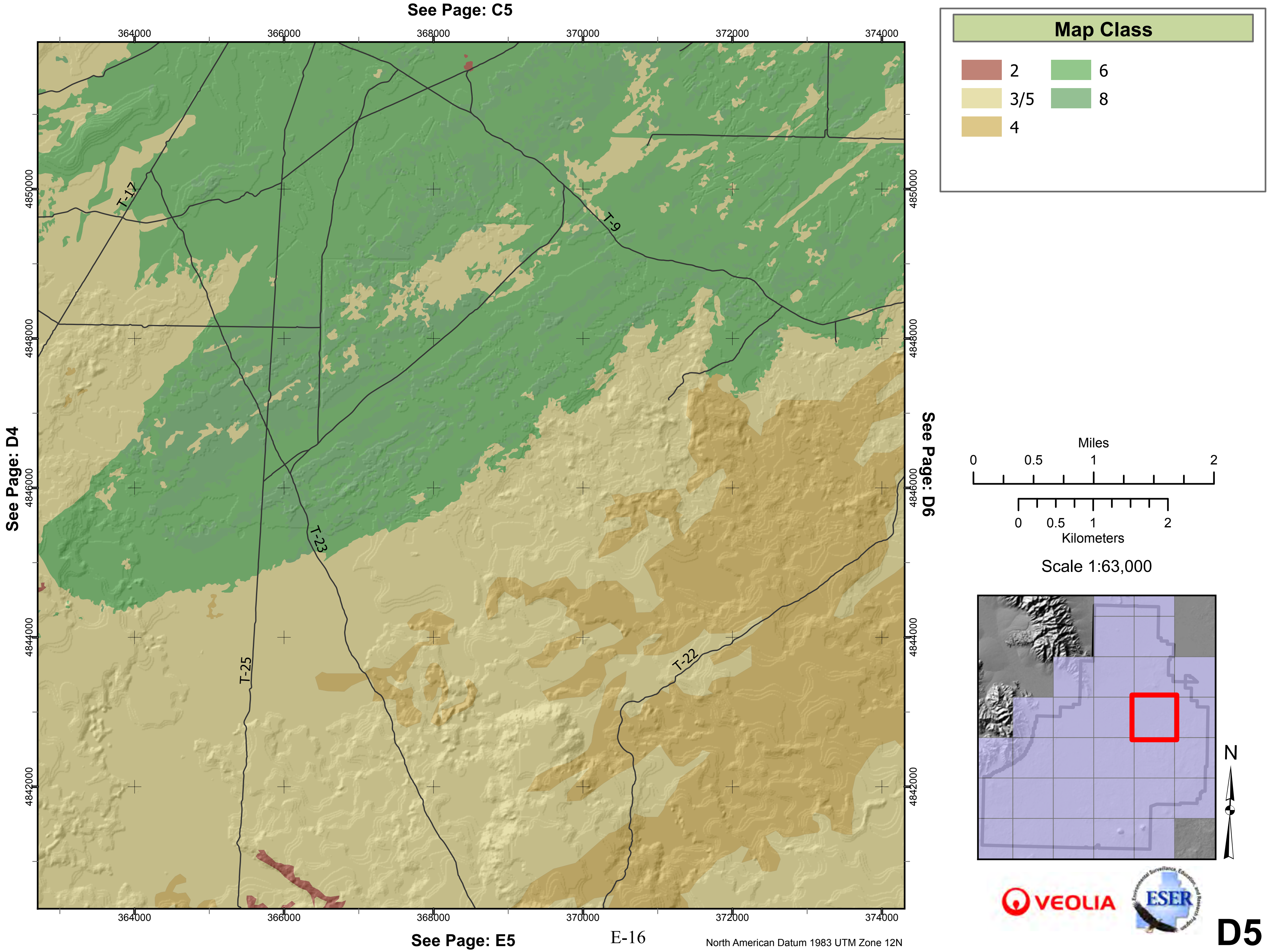
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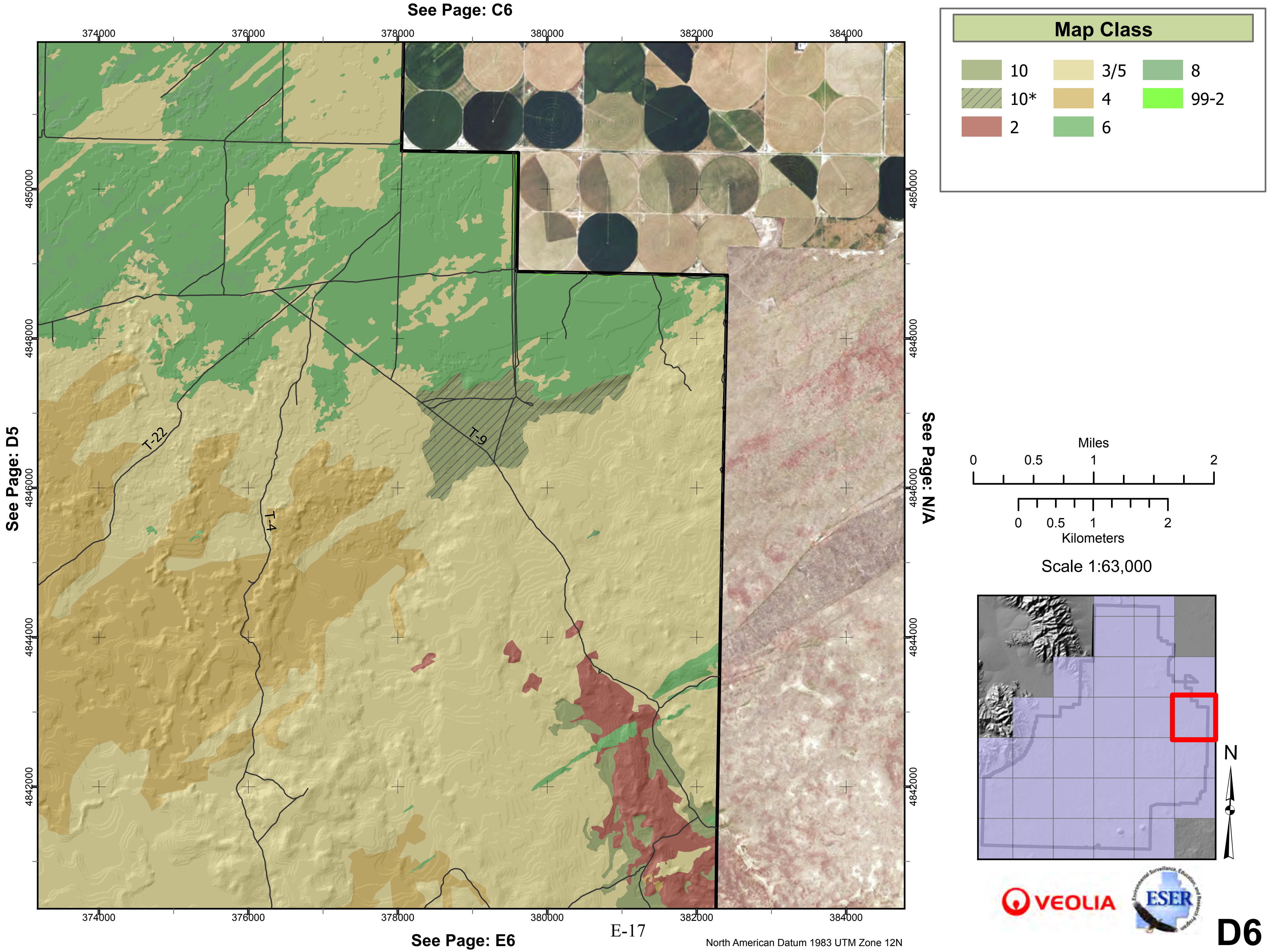
D5
North American Datum 1983 UTM Zone 12N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See Page: D5
See Page: N/A
See Page: E6
374000
376000
378000
380000
382000
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4850000
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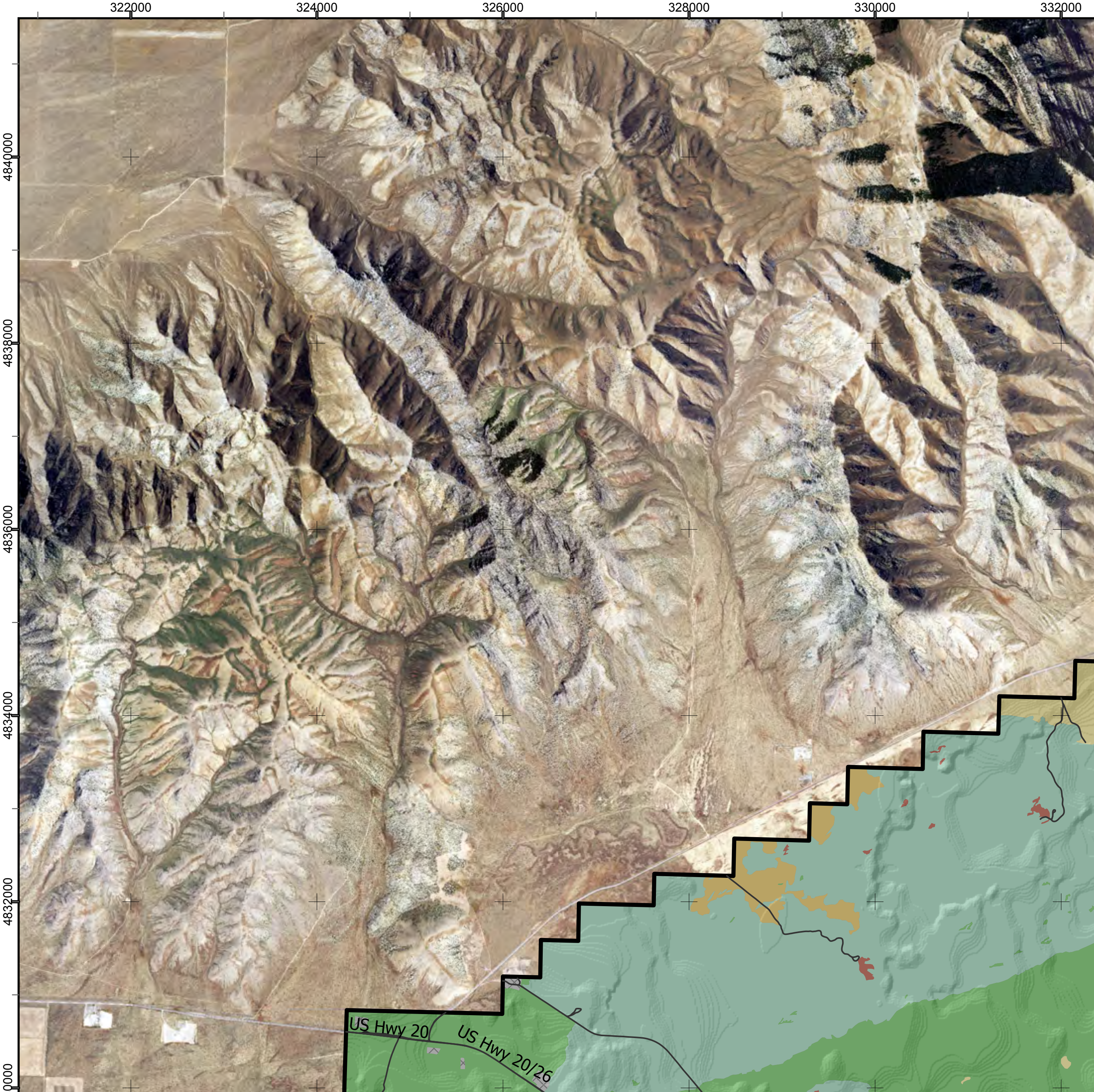
4846000
4844000
4842000
T-22
T-9
T-4
Map Class
10
10*
2
3/5
4
6
8
99-2
Miles
0
0.5
1
2
Kilometers
Scale 1:63,000
N
VEOLIA
ESER
Environmental Surveillance, Education, and Research Program
D6
North American Datum 1983 UTM Zone 12N

See Page: N/A



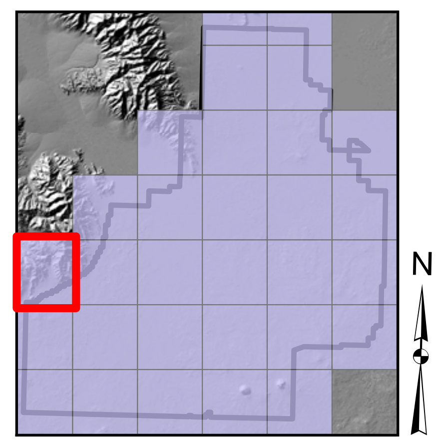
See Page: N/A
See Page: E2
See Page: F1

Map Class

	1		6
	2		99-4
	3/5		99-6
	4		

Miles
0 0.5 1 2
0 0.5 1 2
Kilometers

Scale 1:63,000



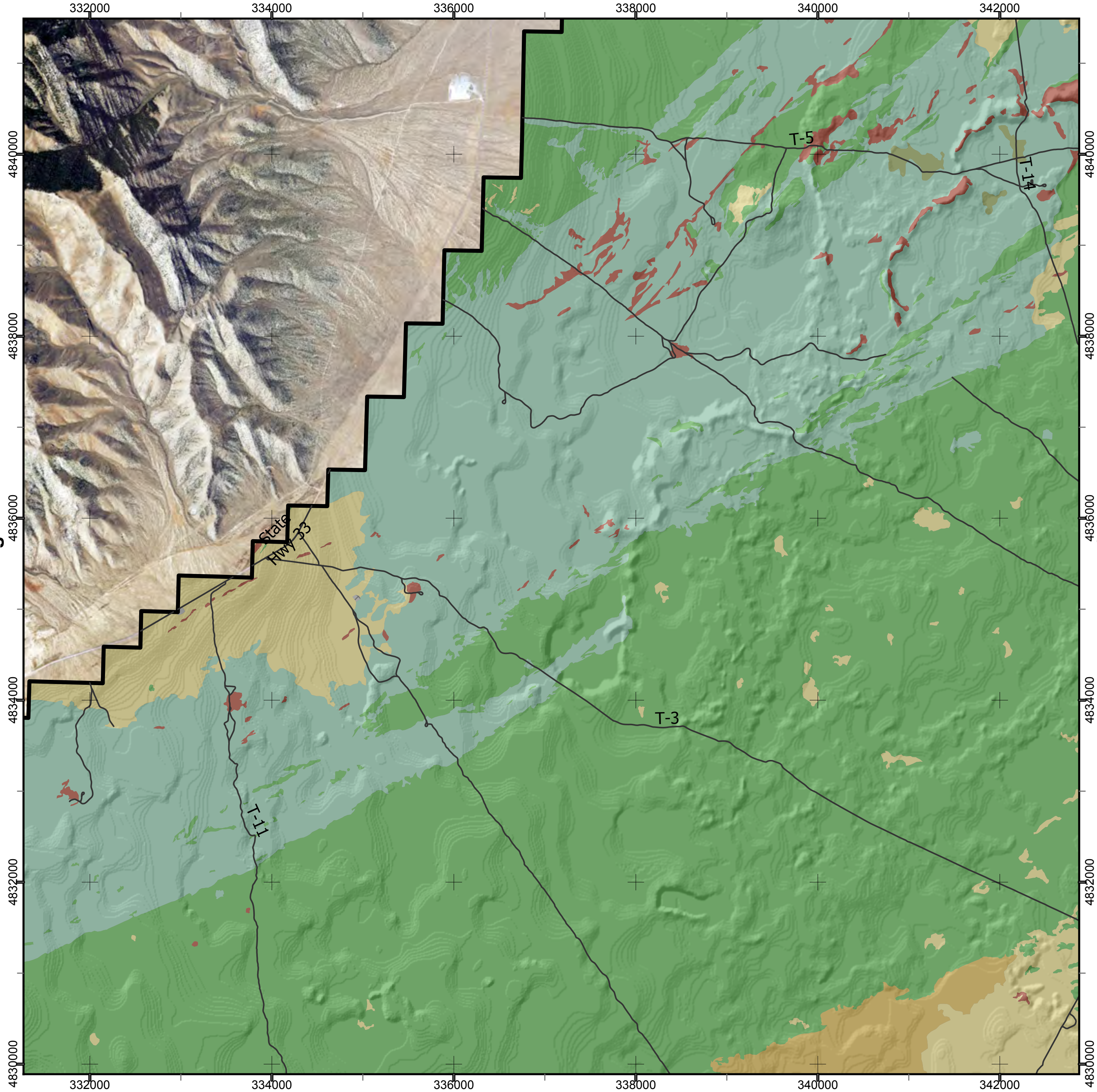
VEOLIA
ESER

E1

North American Datum 1983 UTM Zone 12N

See Page: D2

See Page: E1



See Page: E3

Map Class

1	3/5	7
10	4	99-4
2	6	99-6

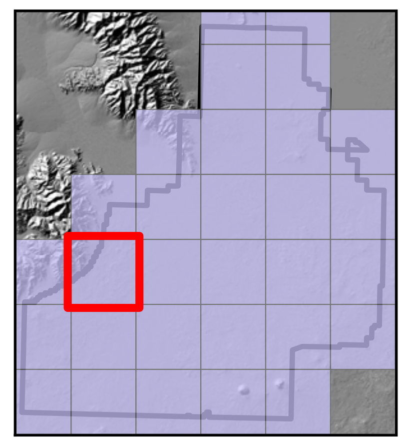
Miles

0 0.5 1 2

0 0.5 1 2

Kilometers

Scale 1:63,000



N

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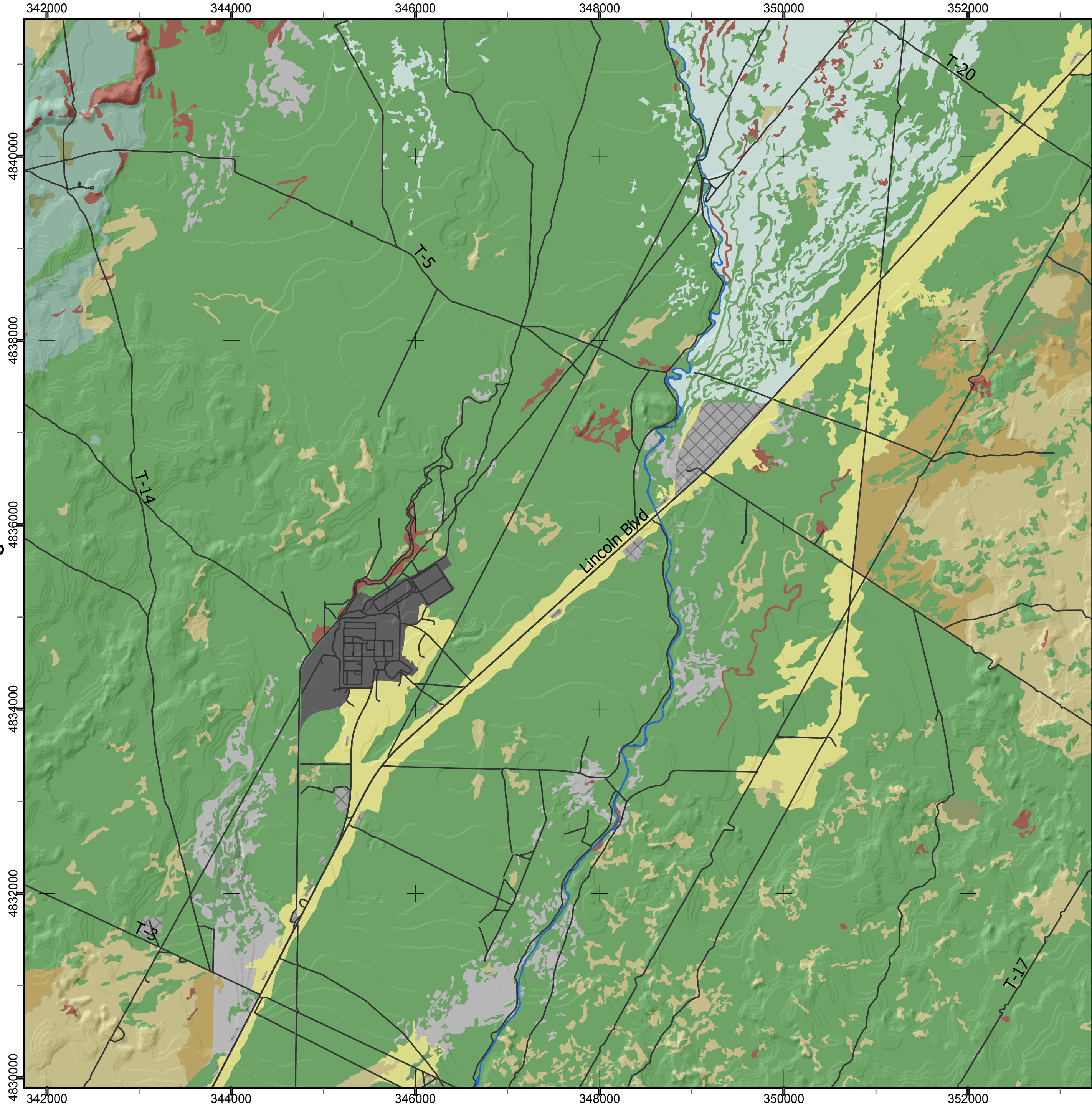
ESER

See Page: F2

North American Datum 1983 UTM Zone 12N

See Page: D3

See Page: E2



See Page: E4

See Page: F3

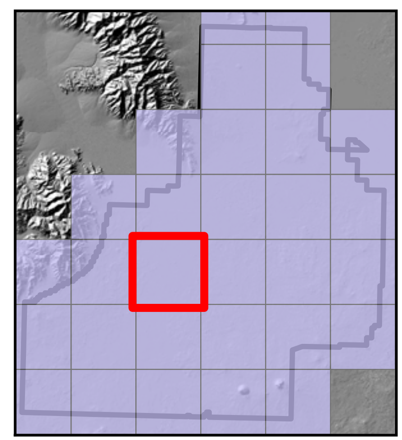
Map Class

	1		4		99-1
	10		6		99-3
	12/14		7		99-4
	2		8		99-6
	3/5		9		

Miles
0 0.5 1 2

0 0.5 1 2
Kilometers

Scale 1:63,000



N

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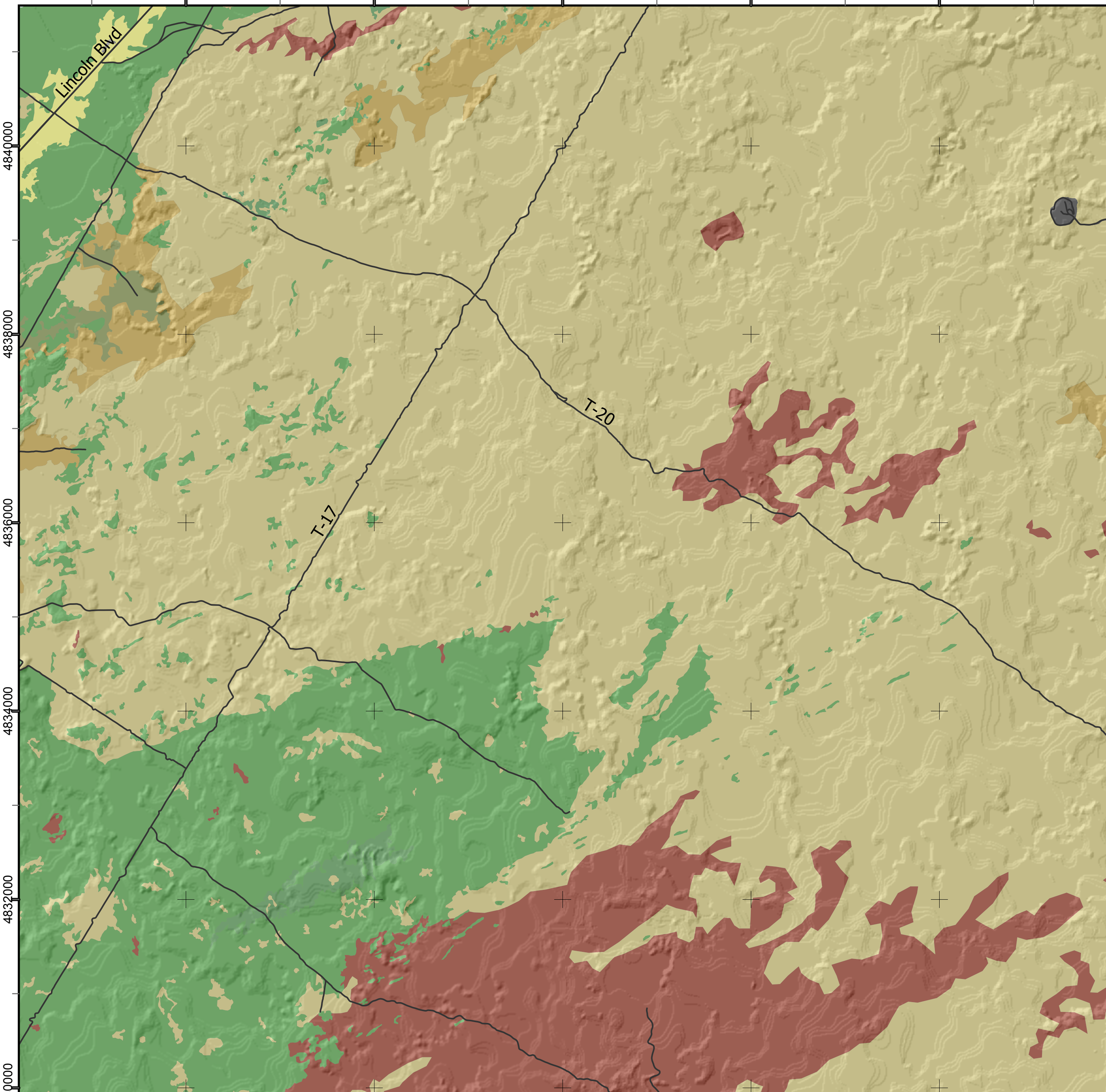
Environmental Surveillance, Education, and Research Program

E3

North American Datum 1983 UTM Zone 12N

See Page: D4



See Page: E3

See Page: E5

See Page: F4

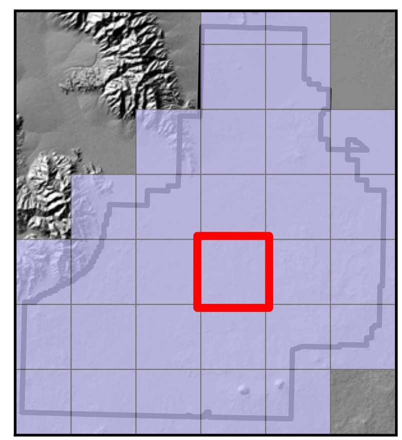
Map Class

	10		4		99-1
	12/14		6		99-4
	2		7		99-6
	3/5		8		

Miles: 0, 0.5, 1, 2

Kilometers: 0, 0.5, 1, 2

Scale 1:63,000



VEOLIA

ESER

E4

North American Datum 1983 UTM Zone 12N

See Page: D5

See Page: E4

See Page: E6

See Page: F5

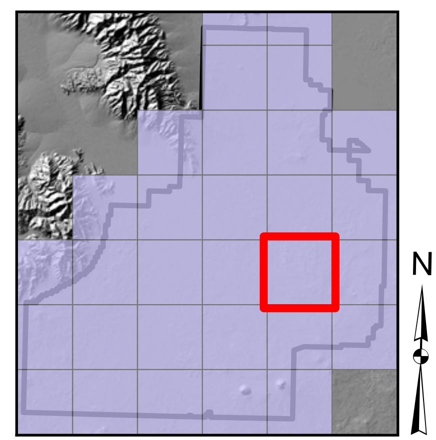
Map Class

10		6	
2		7	
3/5		99-1	
4			

Miles: 0, 0.5, 1, 2

Kilometers: 0, 0.5, 1, 2

Scale 1:63,000



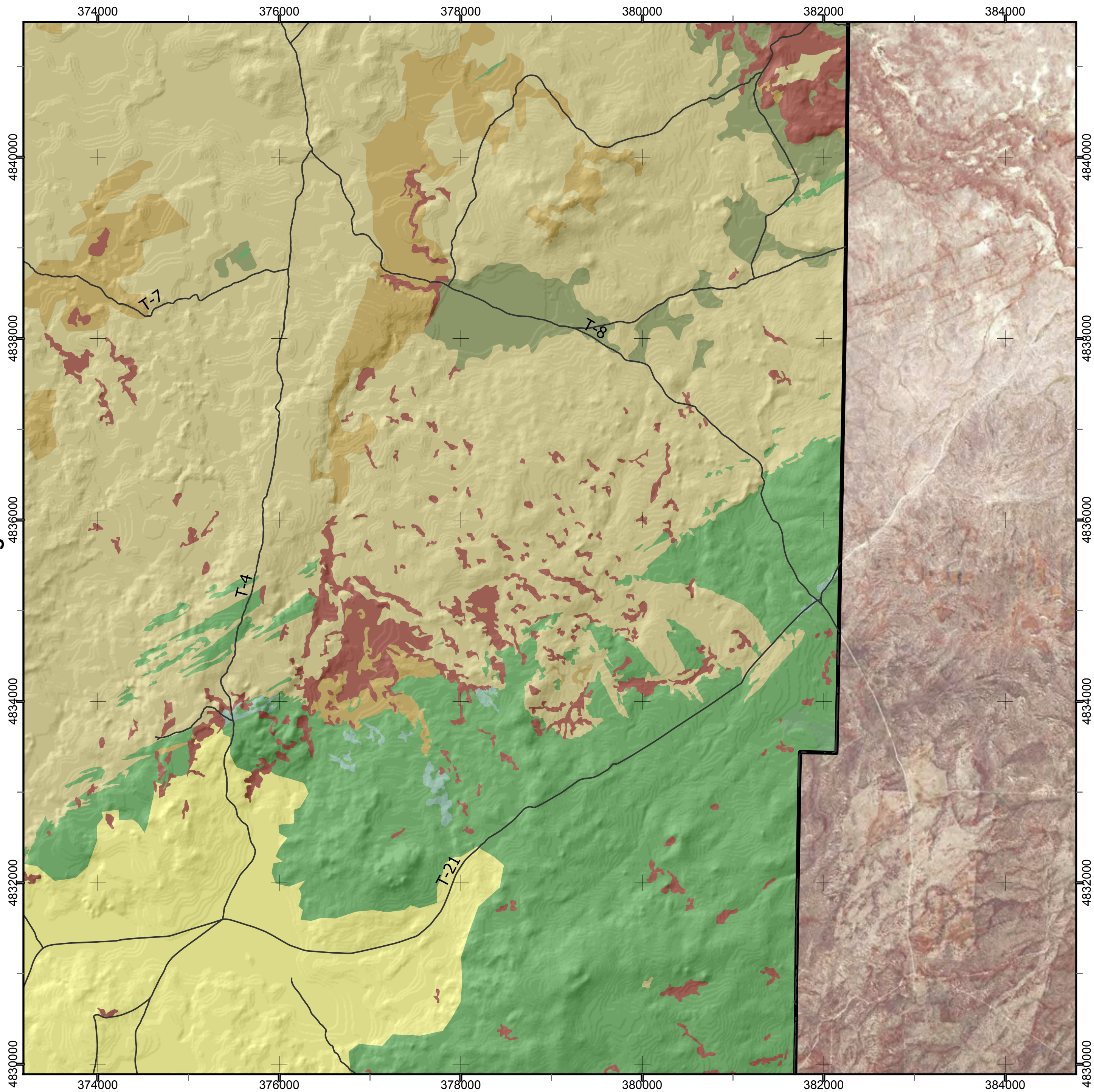
VEOLIA ESER

E5

North American Datum 1983 UTM Zone 12N

See Page: D6

See Page: E5



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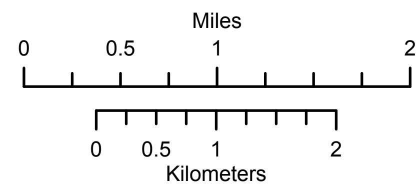
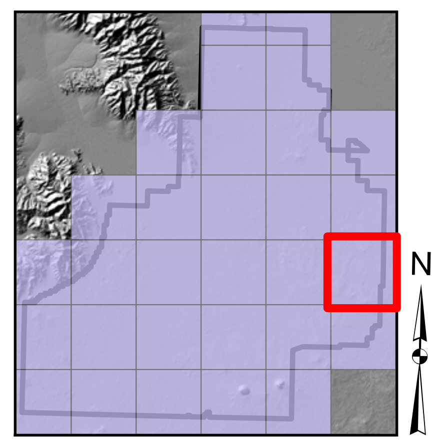
Map Class

1	3/5	7
10	4	8
2	6	



Scale 1:63,000



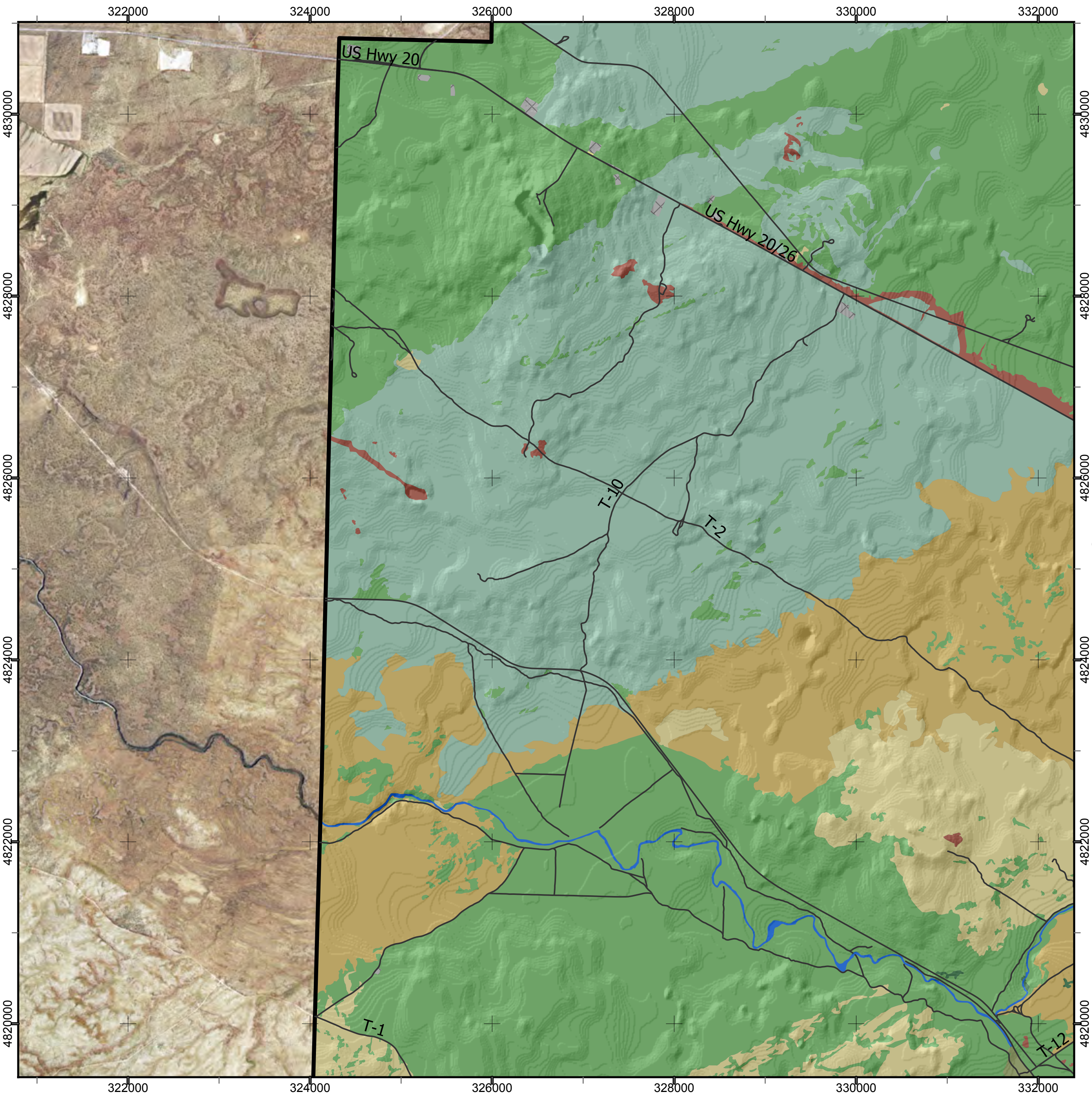
VEOLIA ESER

E6

See Page: F6

North American Datum 1983 UTM Zone 12N

See Page: E1



See Page: N/A

See Page: F2

See Page: G1

Map Class

1	3/5	99-3
10	4	99-4
11	6	99-6
2	7	

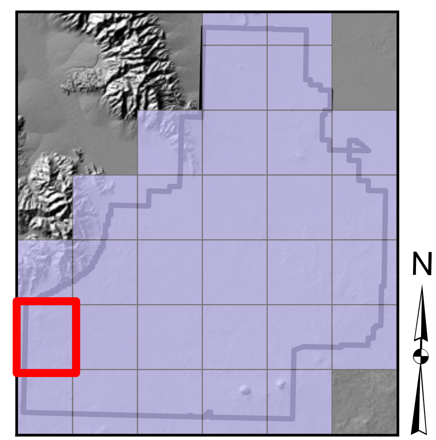
Miles

0 0.5 1 2

0 0.5 1 2

Kilometers

Scale 1:63,000

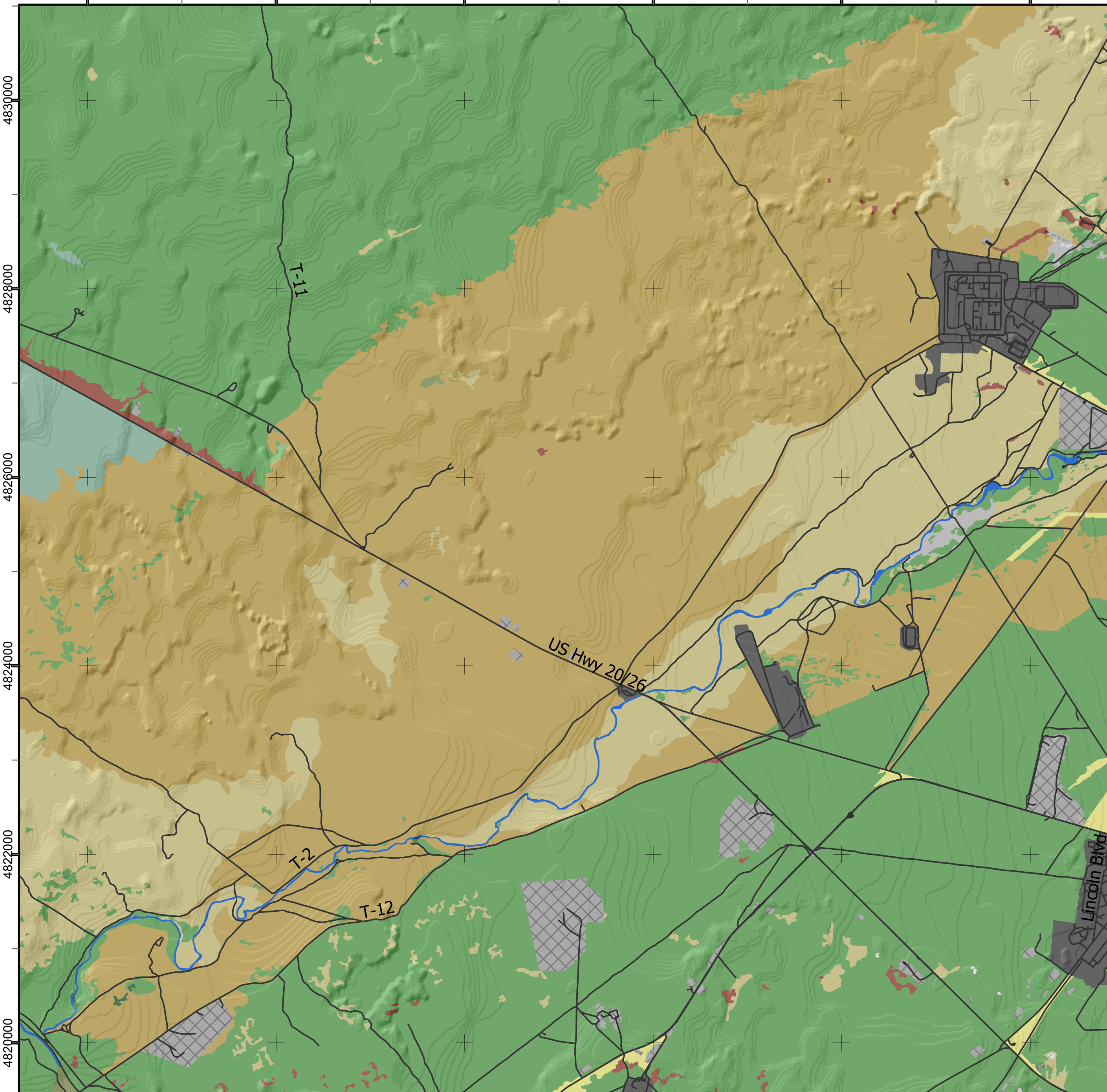


VEOLIA

ESER

F1

North American Datum 1983 UTM Zone 12N



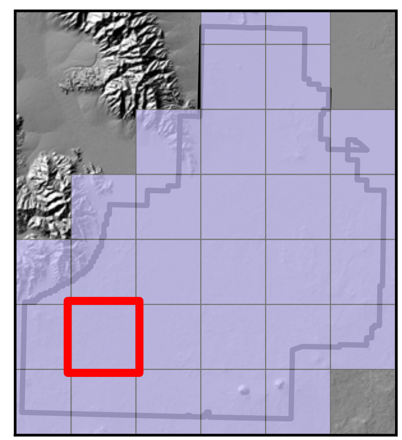
Map Class

1	3/5	8	99-4
10	4	9	99-5
11	6	99-1	99-6
2	7	99-3	

Miles: 0, 0.5, 1, 2

Kilometers: 0, 0.5, 1, 2

Scale 1:63,000



N

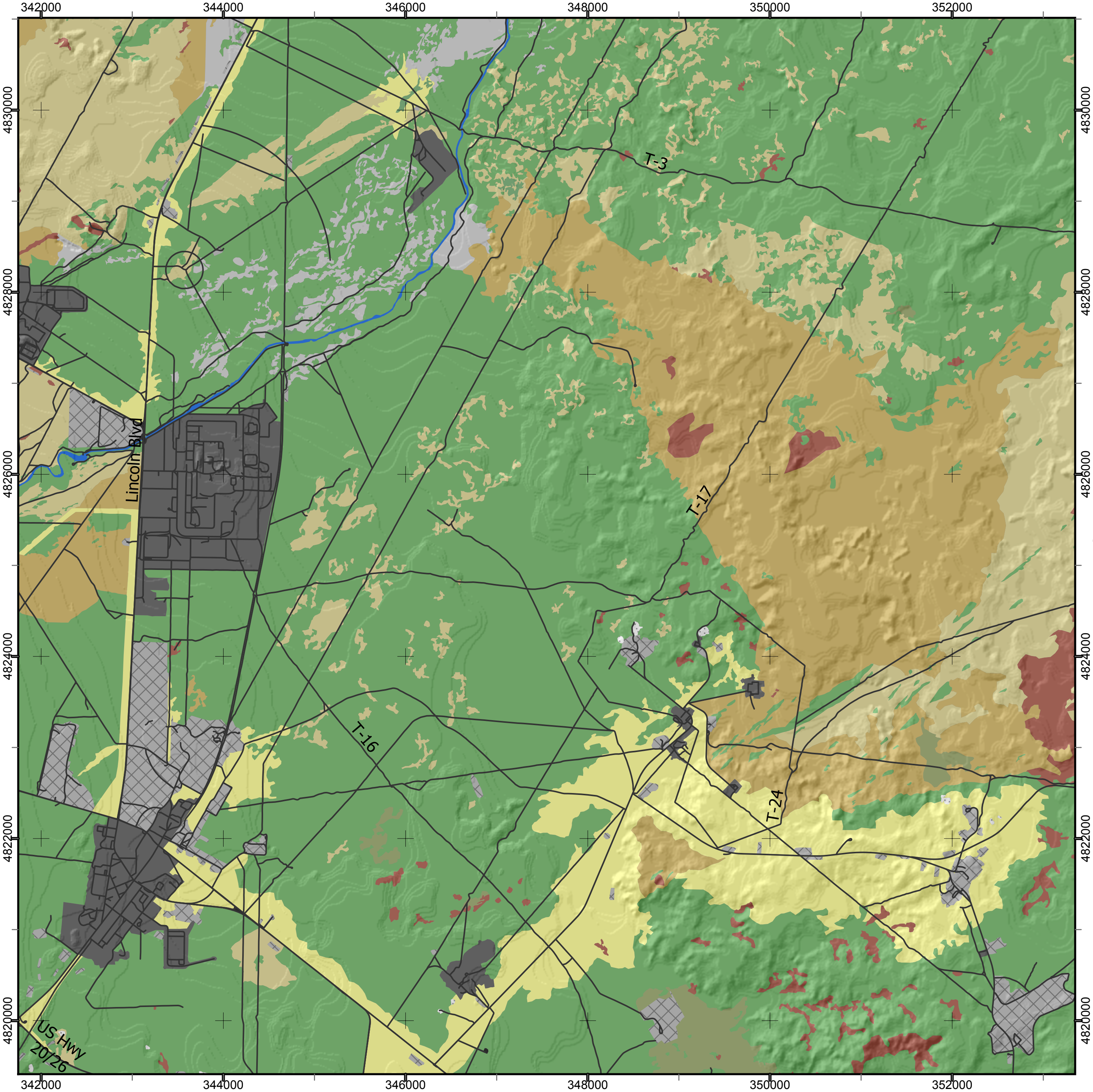
North American Datum 1983 UTM Zone 12N

F2

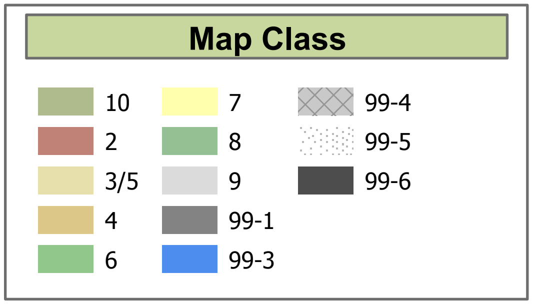
See Page: E3

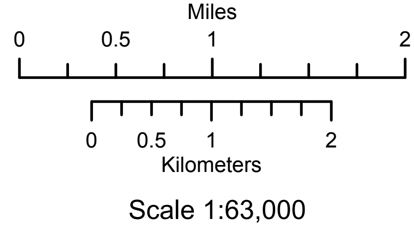
See Page: F2

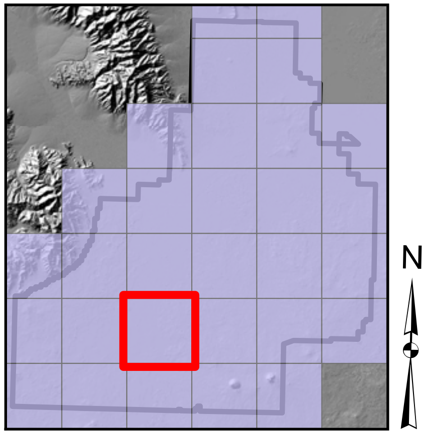
See Page: F4



See Page: G3

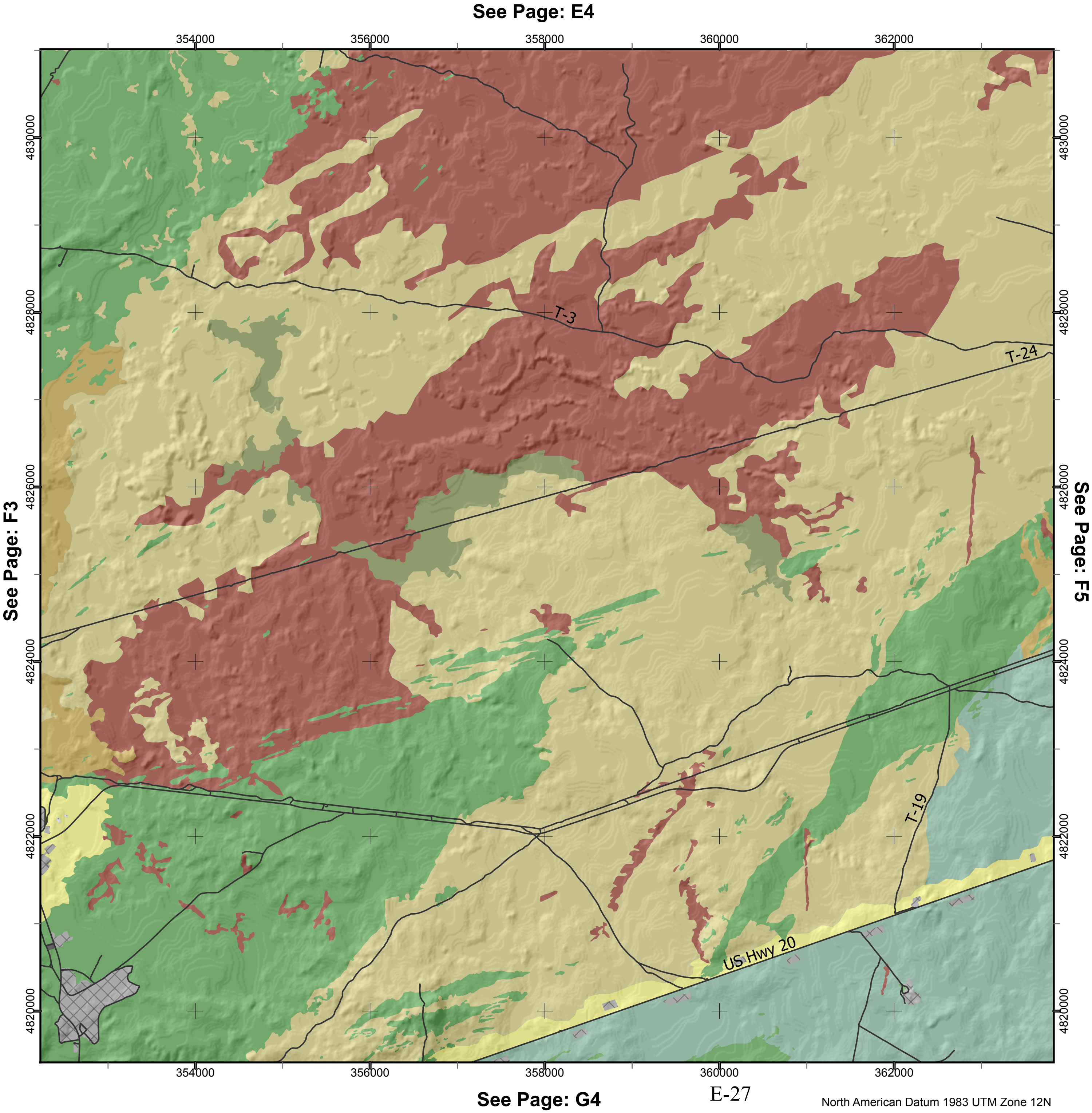






North American Datum 1983 UTM Zone 12N

F3



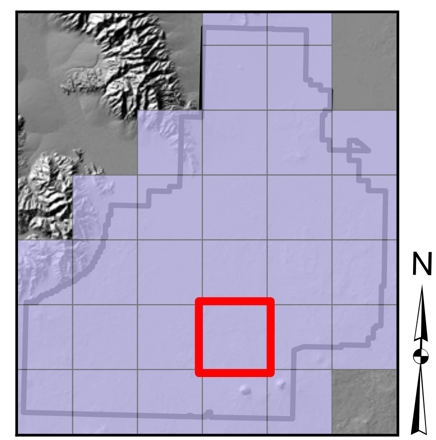
Map Class

1		4		99-4	
10		6		99-5	
2		7		99-6	
3/5		99-1			

Miles
0 0.5 1 2

0 0.5 1 2
Kilometers

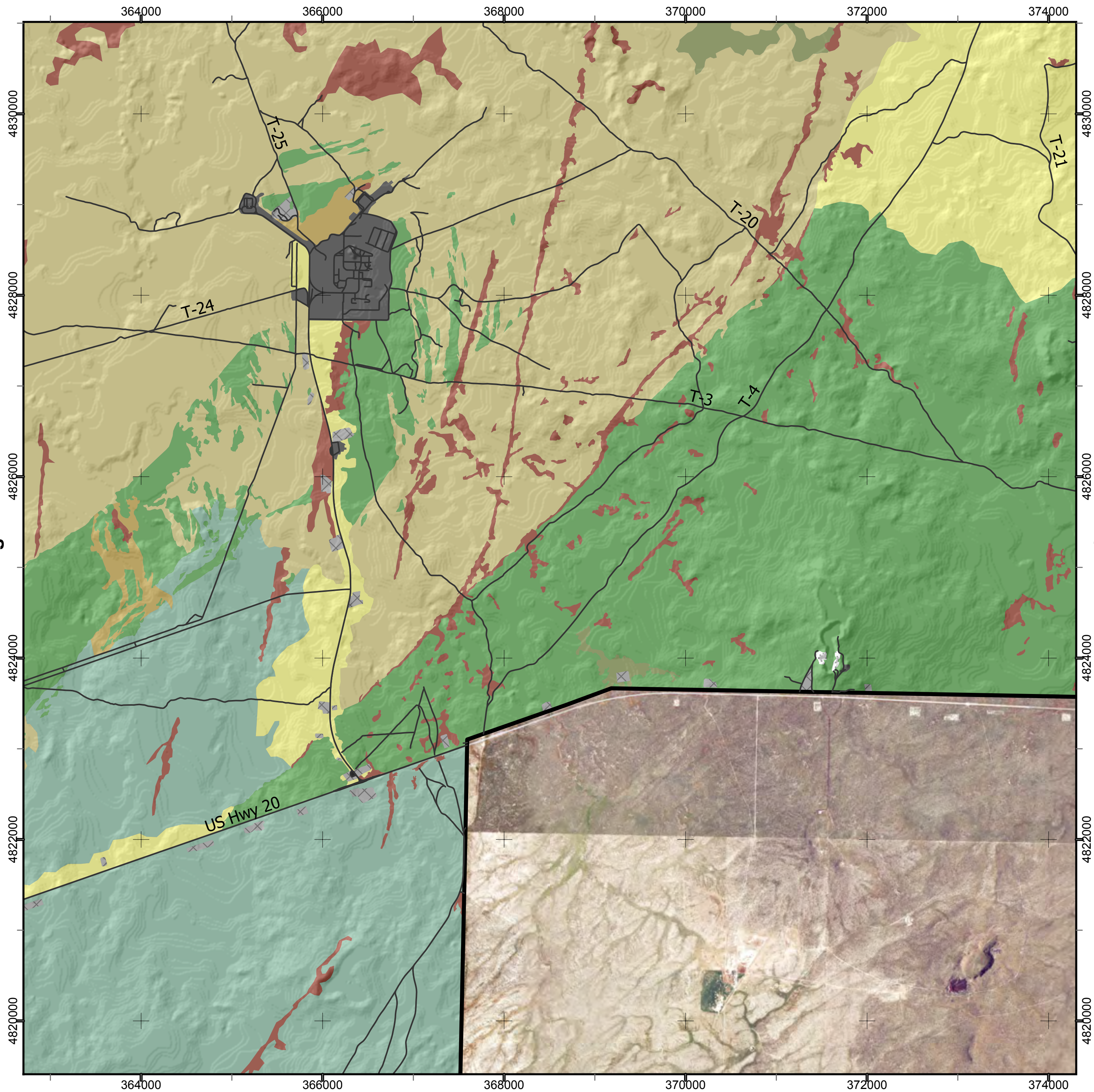
Scale 1:63,000



F4

North American Datum 1983 UTM Zone 12N

See Page: E5



See Page: F4

See Page: F6

See Page: G5

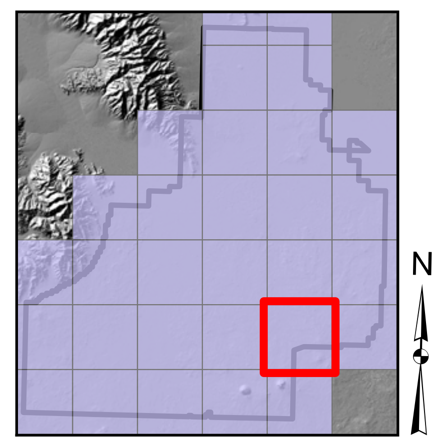
Map Class

1	4	99-4
10	6	99-5
2	7	99-6
3/5	99-1	

Miles: 0, 0.5, 1, 2

Kilometers: 0, 0.5, 1, 2

Scale 1:63,000



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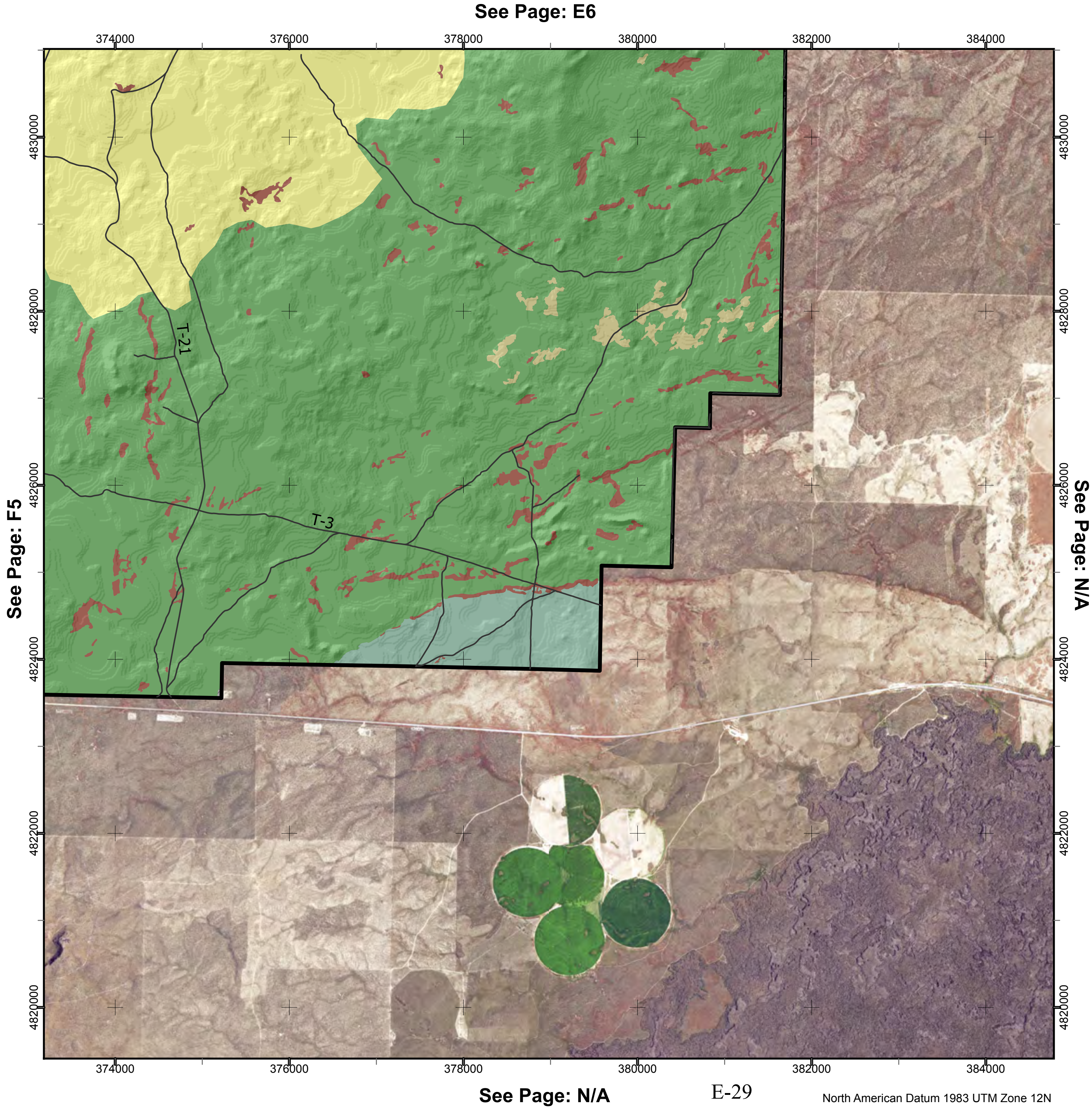
F5



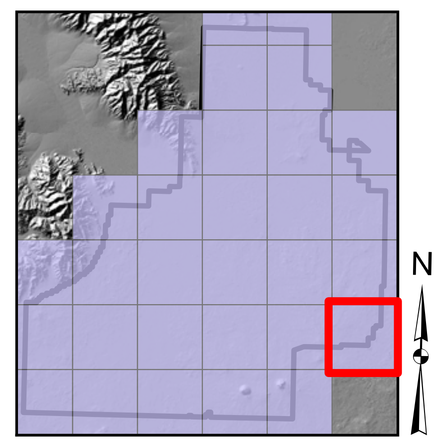
Map Class

	1		6
	2		7
	3/5		99-4

Miles
0 0.5 1 2

0 0.5 1 2
Kilometers

Scale 1:63,000



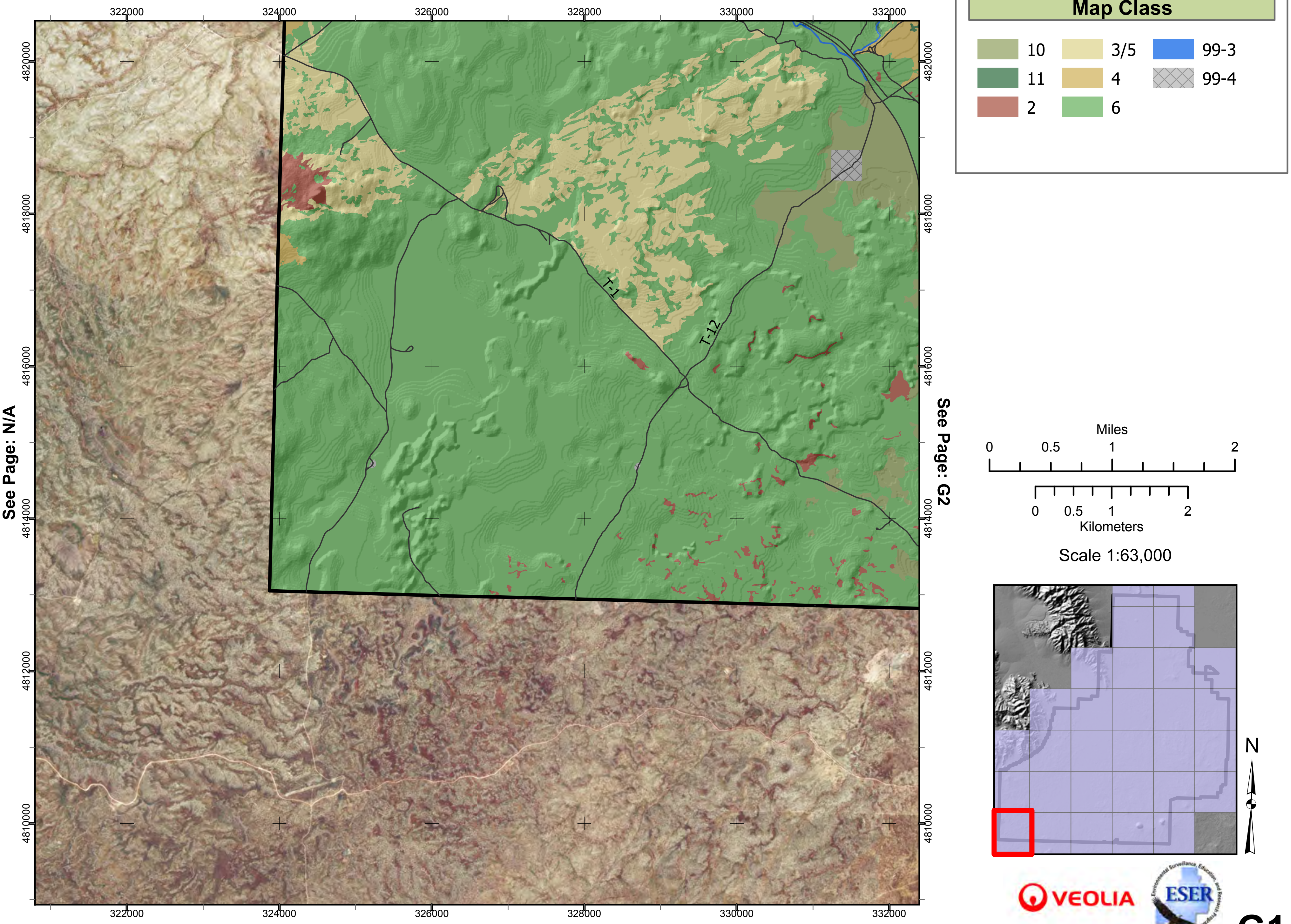
VEOLIA

ESER

F6

North American Datum 1983 UTM Zone 12N

See Page: F1



See Page: N/A

See Page: G2

See Page: N/A

North American Datum 1983 UTM Zone 12N

VEOLIA ESER

See Page: F2

See Page: G1

See Page: G3

See Page: N/A

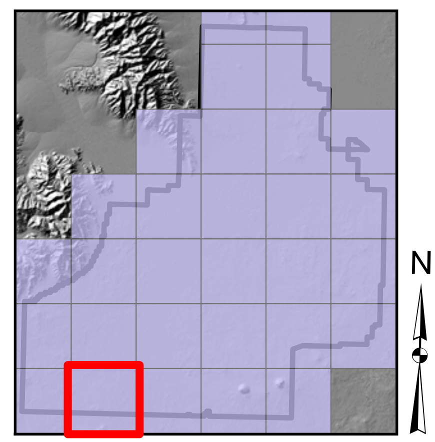
Map Class

10	4	99-3
11	6	99-4
2	7	99-5
3/5	99-1	99-6

Miles
0 0.5 1 2

0 0.5 1 2
Kilometers

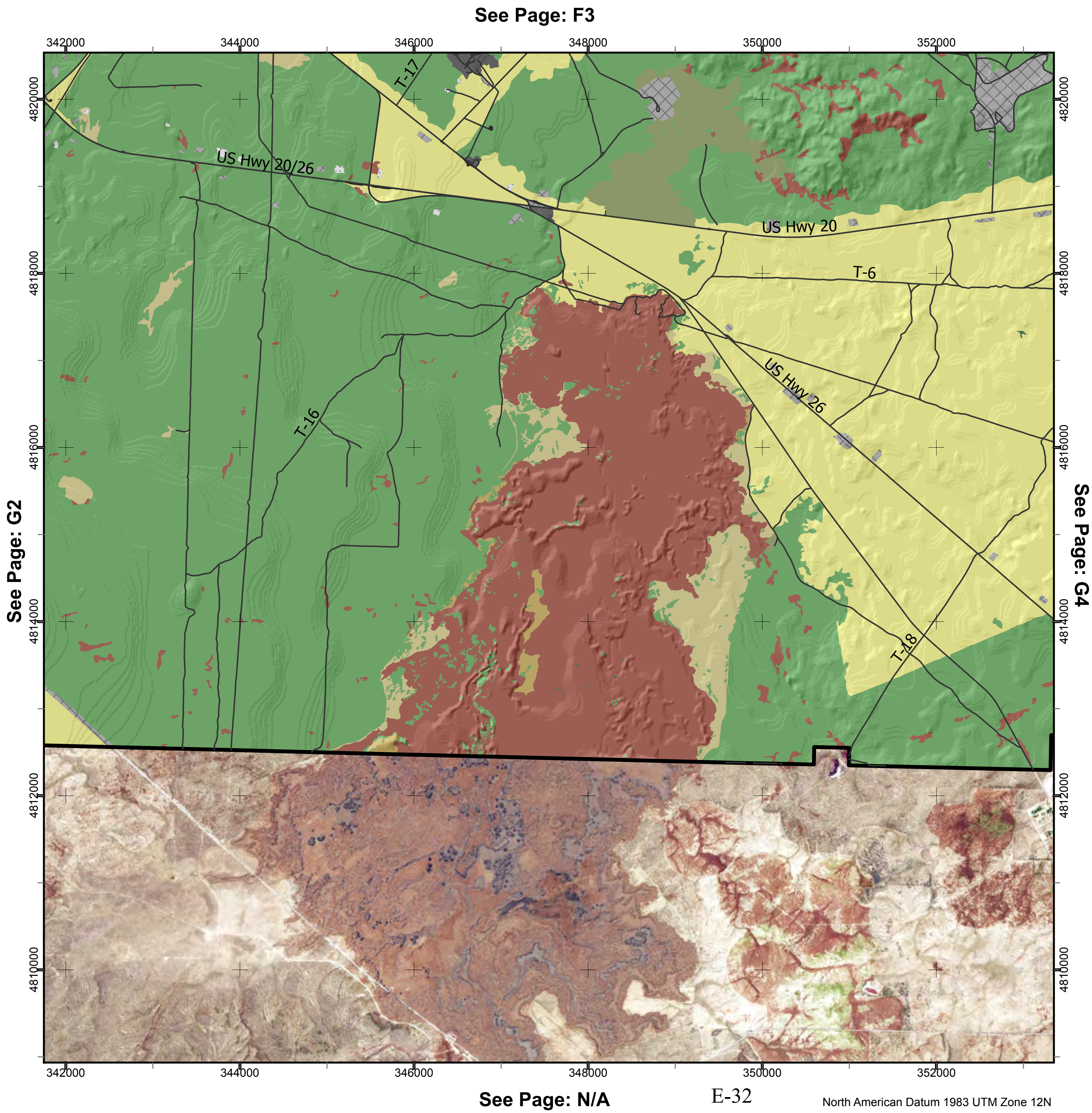
Scale 1:63,000



VEOLIA ESER

G2

North American Datum 1983 UTM Zone 12N



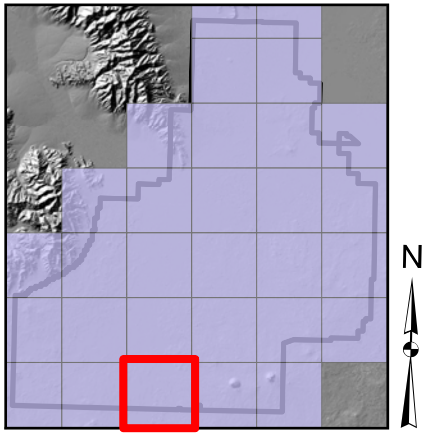
Map Class

10	4	99-4
11	6	99-5
2	7	99-6
3/5	99-1	

Miles: 0, 0.5, 1, 2

Kilometers: 0, 0.5, 1, 2

Scale 1:63,000

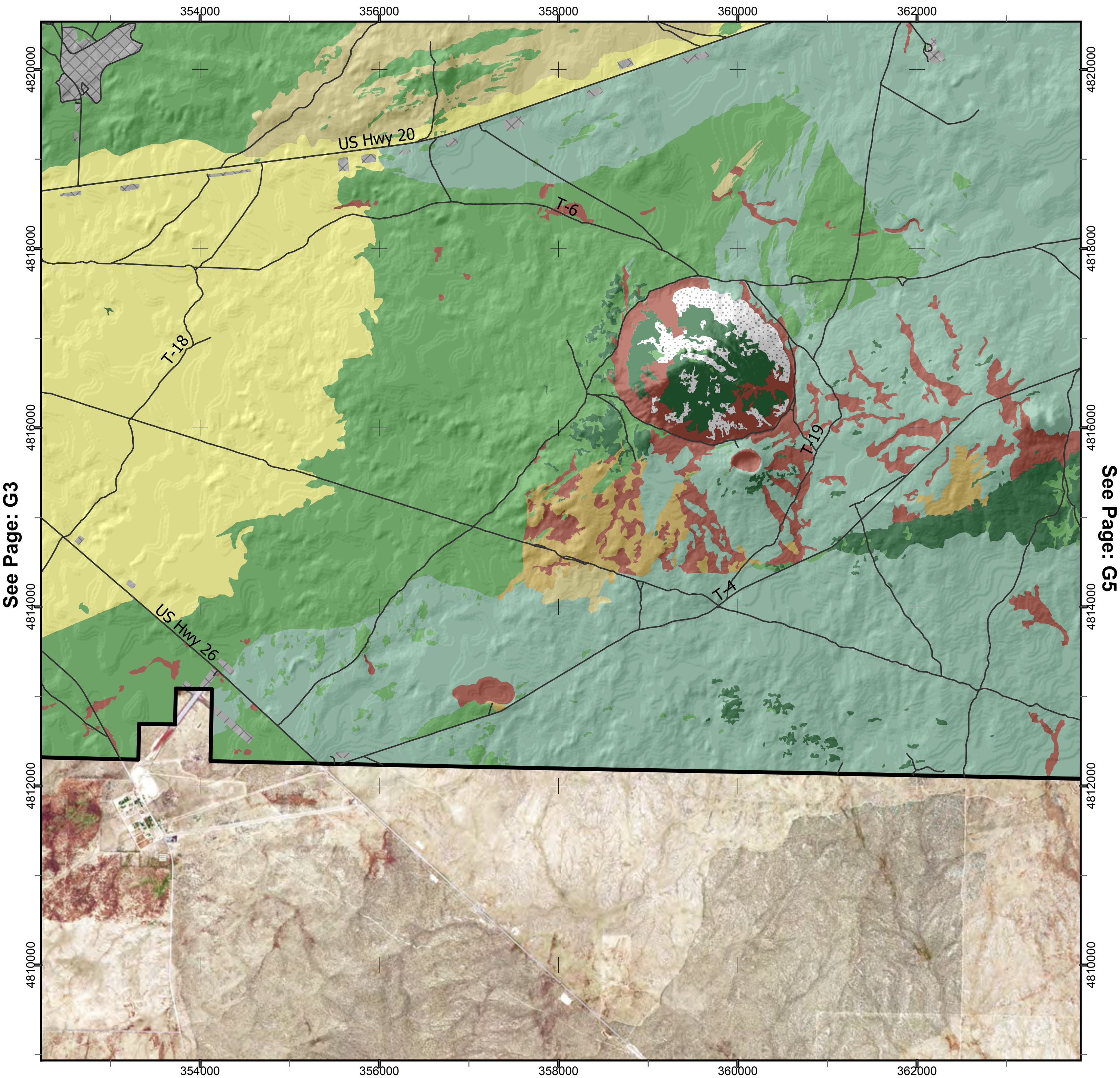


VEOLIA ESER

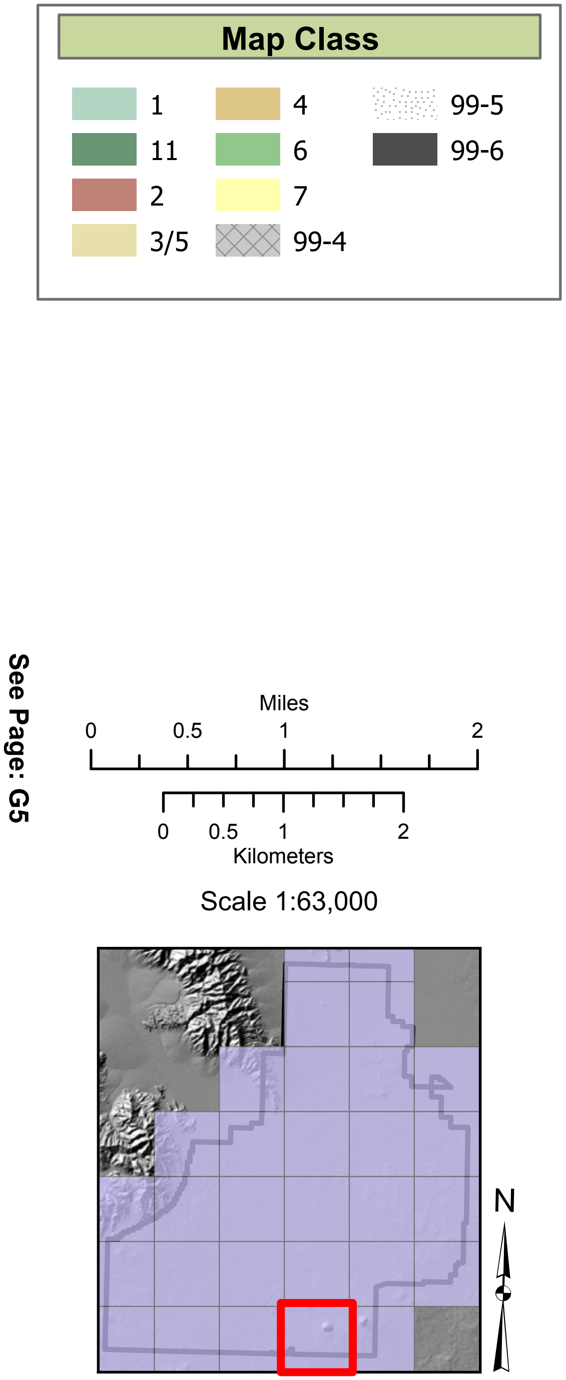
G3

See Page: F4

See Page: G3



See Page: G5



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North American Datum 1983 UTM Zone 12N

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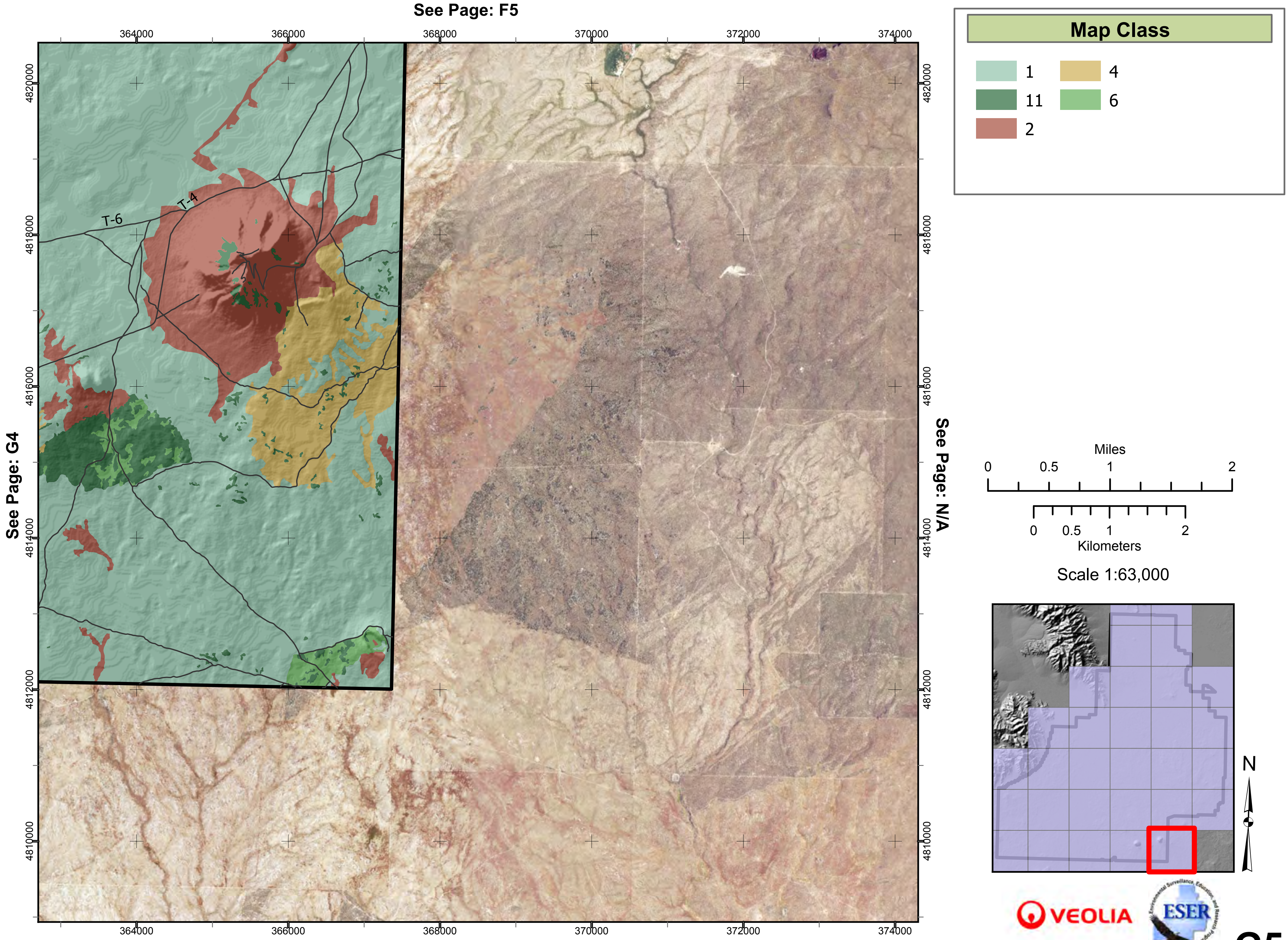

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North American Datum 1983 UTM Zone 12N

G5

Appendix F

Validation Plot Field Sampling Protocol

Field Sampling Protocol

Objective: The goal for this year's field sampling is to collect representative vegetation data across the INL Site that will be used to conduct a formal accuracy assessment of the most recent vegetation map. The vegetation community present at each sampling location will be used to compare against the vegetation map class assigned to the same location. The resulting class accuracy statistics will inform the map user of limitations or how much confidence is expected for each vegetation class across the map's extent.

Equipment List:
- Trimble GeoXH GPS receiver (primary data collection)
- Trimble Juno GPS receiver (backup-spare)
- Digital camera
- Rebar stake and mallet
- Accessory cord
- Trekking poles
- Compass
- Field data checklists

Prior to the start of the field season, each field technician will receive training on the operation and function of the Trimble GPS receivers. The data acquisition options (under *Setup* drop-down menu) will be set by a GIS Analyst at the start of the season, and should **NOT** be changed during the field season for any reason. If you have a question about the data collection process or if your GPS receiver malfunctions in the field, contact Kurt Edwards (office: 227-9022 or cell: 757-1902) or Jeremy Shive (office: 227-9032 or cell: 406-579-7212) for assistance.

Navigating to Plot Locations:

1. Open the waypoint file named *Accuracy Assessment Plots*, and select the *Plot ID* (plot identification) you intend to survey. For planning and reference, overview maps are provided in the field binder showing the distribution of all sampling plots. Field crews are expected to plan their day to sample plots clustered into groups within a region to minimize travel time between widely dispersed plots.

    a. Once the plot is selected, navigate as close to the plot on two-track roads as possible. An overview map of INL Site roads will be provided in the field binder, and there is also a data layer of roads that can be plotted on the GPS receiver. Review the network of roads in the vicinity of the selected plot and decide the most efficient path to drive there. Note: GPS navigation is direct line-of-sight and will not route you to the selected location on existing roads.

2. Once you've parked as close as possible to the plot, gather all of the required sampling equipment, and use the GPS navigation screen to hike the remaining distance to the actual plot location.

Plot Data Collection:
The Accuracy Assessment plots we are sampling this year are circular plots of two different sizes. The most common plot size will be a 0.25 ha plot (28 m radius), with a second slightly larger plot representing 0.5 ha (40 m radius). All plot identification numbers are sequentially assigned with no intended sampling order. The plot identification number assigned to each plot will inform the size of area you will sample in the field. An underscore followed by the number '40' will be assigned to any plot where the 40 m radius will be used (e.g. 120_40 would represent Plot 120 and will be sampled using the 40 m radius). If no underscore is present in the plot identification number, then you will use the more common 28 m radius to delineate the plot boundary.

A general overview of the data collection process will be: 1) establish the plot center point, and place four plot reference poles to help visualize the plot extent; 2) determine the vegetation class present using a dichotomous field key; 3) collect a GPS position at the plot center point and populate all associated data fields in the data dictionary; and 4) collect representative photos of the plot.

1. When you arrive at the plot waypoint location, you will need to visually scan the landscape within the local vicinity to determine whether the plot is located within a fairly homogenous region. Homogenous does not necessarily mean all of the same species present, but rather all the same general community type within the anticipated plot area. There may be exceptions for some weedy species (e.g. cheatgrass or crested wheatgrass) where the vegetation stand is truly a monoculture of primarily the same species. Accuracy Assessment plot locations are selected through a stratified random sampling scheme, and it's entirely possible that the random location falls on a distinct edge of two community types, or in a localized abnormal patch within the landscape (e.g. disturbed ground). If the plot area is located in an abnormal patch or contains a distinct edge, the plot should be shifted so the plot is more representative of the surrounding area.
    a. Limit the distance of plot shift to around 40 m when possible. We want to avoid moving plots too far where they may start to overlap with other random plot points and violate sample independence.
2. Once the plot location is confirmed, each crew member will begin placing reference poles in the four cardinal directions with the appropriate radius from the plot center point. Reference poles will be placed in four locations to help the observers better visualize the plot extent. Note: if the area is fairly homogenous at a spatial extent much larger than the

28 or 40 m radius circular plot, the crew may decide to forego marking the cardinal directions and proceed to determining the vegetation class present using the dichotomous key.

   a. Hammer the rebar stake into the ground at the plot center point. Each crew member will attach a length of accessory cord, and using a compass walk in one of the four cardinal directions until the cord is fully extended. Once the cord is outstretched, place one of the trekking poles into the ground to mark the plot extent. Gather the accessory cord as you walk back to the plot center and walk to a different cardinal direction and follow the same procedure to mark a second reference point. Each crew member will be responsible for marking two directional extents until all four are successfully marked. The outer reference poles will be used by visually connecting an arc between poles to approximate the circular extent of the sampling plot.

3. While you are walking throughout the plot to establish the reference points, start to identify the dominant and co-dominant species present. After each crew member spends an additional few minutes (or however long it takes) to examine the plot thoroughly, both will meet back at the plot center. Together the field crew will work through the dichotomous key and identify the vegetation class that best represents the plot.

   a. Use the vegetation class key provided in the field binder to identify the vegetation class present within the plot.

4. Open a new Rover File on the GPS receiver and under Dictionary Name select Accuracy Assessment. Once the Rover file opens choose the *Plot Center* point feature. While standing at the rebar stake in the plot center, the receiver will start logging coordinates at 1-second intervals. There is a data dictionary associated with each *Plot Center* point feature, and the appropriate information must be entered before the *Plot Center* point feature can be closed. There will be a drop-down menus for some data fields, but some will need to be manually entered using the keypad. The following information will be recorded at each plot.

   a. **Observer 1**- Select the name of the field crew member who is entering the data on the GPS receiver.

   b. **Observer 2**- Select the name of the other field crew member.

   c. **Plot ID**- Enter the plot identification number associated with the plot being sampled.

   d. **Vegetation Class**- Select the vegetation class identified using the dichotomous key.

    e. **Key Agreement**- This a binary (yes/no) field used to indicate whether the key worked well for the plot or if it was 'forced' because of difficult choices in the key.
    f. **Second Class**- This is an optional data field that will only be populated when the previous answer was 'No' for the Key Agreement field. If a different decision could be made when the key did not work well, enter the result of the second vegetation class identified for the plot.
    g. **Comments**- An optional field to record any notable observations or concerns about the plot.
5. After all of the data fields are populated, and you have logged at least 120 positions, you will close the *Plot Center* point feature and also the Rover File before navigating to the next plot.
    a. Once all positions are logged and the Data Dictionary is populated with data, close both the *Plot Center* point feature and the Rover File for the plot.
6. While one crew member is collecting GPS coordinates and filling out the Data Dictionary, the second crew member will take four digital photographs. Each photo will be taken from the center point looking toward the reference poles.
    a. The photos should be collected in a North-East-South-West order using the standard landscape orientation with the camera fully zoomed out.
7. The last step before leaving the plot is to fill out the plot checklist. The checklist serves to document all files collected at the plot, and provide a final check to ensure all the data were collected.
    a. The checklist will require you to manually record the Plot ID, date, Rover File name, plot photograph file numbers, and a place to verify the GPS positions and Data Dictionary were collected and all field equipment has been gathered. It may be most efficient for one crew member to call out the Rover File name when they start collecting GPS data while the second crew member writes it down on the plot checklist and records the photograph file numbers after they are taken.