12/5/2016

LANDSLIDE HAZARD ANALYSIS AND ITS EFFECT ON ENDANGERED SPECIES HABITATS, GRAND COUNTY, UTAH

GIS Final Project

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1. Introduction and Problem

A well-known geologic hazard that can cause significant damage both physically and economically are landslides. This project focuses on landslides in the state of Utah, which has caused significant physical damage to some of its outdoor attractions as well as extreme economic losses in years with above average rainfall. In 1983, a particularly wet year for Utah, landslides cost an estimated $250 million. This direct cost was mainly attributed to the Thistle landslide in Utah County, which is recognized as the most expensive individual landslide in North America to date.

In 2007 the Utah Geological Survey did a study on the landslide susceptibility of the entire state of Utah. This study was based on a statewide 1:500,000 scale geologic map and a 30-meter slope map derived from the National Elevation Dataset Digital Elevation Models for the state of Utah. Although a geologic map was said to be taken into consideration, the final map that was produced was based mainly on slope, with lithology only taken into consideration to obtain an average slope per geologic unit.

The fact that only an average slope per geologic unit was used and barely taken into consideration for the final landslide susceptibility categories is insufficient to accurately characterize how landslide susceptibility can vary with lithology. Another issue with the 2007 study was the lack of inclusion of precipitation data. My goal for this project is to answer the question; will the inclusion of lithological variations as well as precipitation data add or subtract areas of moderate to high landslide susceptibility when compared to the 2007 study? This study aims to answer this question through creation of a reclassification scheme that takes into account lithology, slope, precipitation, and location of previous landslides to create a composite map of these parameters to identify areas of moderate to high risk of landslides.

Instead of focusing on the entire state of Utah, it was decided to perform this study on the data available for Grand County, Utah. This county was chosen due to the majority of the Book Cliffs being present in this county, but Grand County is also home to two national parks (Arches and Canyonlands), part of the Manti-La Sal National Forest, part of the McInnis Canyons National Conservation Area, and the La Sal Mountain Range. Grand County is also the location of fourteen endangered and threatened species' habitat areas. It is safe to say that outdoor attractions in Grand County could be economically affected if landslides were to occur, as well as the habitat areas of these threatened and endangered species. A case study within the overall landslide susceptibility analysis is also included and addresses the problem of identifying which endangered and threatened species' habitats are in moderate to high landslide susceptibility areas.

2. Data Collection

Layer Name	Data Type	Original Projection	Source	Description
Mosaic_Raster	ArcGrid	GCS_NAD_1983	National Elevation Dataset: USGS	1 X 1 extent, 1/3 arc-second mosaic of raster DEMs of N 40 W 110, N 39 W 110, N 40 W 111 and N 39 W 111
Counties	Shapefile	NAD_1922_UTM_Zone_12N	Utah AGRC	Shapefile of the counties of Utah
Geol_Poly	Shapefile	NAD_1922_UTM_Zone_12N	Utah Geological Survey	Shapefile of the geology of Utah
Geol_Arc	Shapefile	NAD_1922_UTM_Zone_12N	Utah Geological Survey	Shapefile of the geologic contacts of Utah
UTunits	Excel file	N/A	Utah Geological Survey	Supplemental spreadsheet to the Geol_Poly shapefile; used to reference lithology type of each geologic unit
Precip_Utah	Shapefile	NAD_1983_UTM_Zone_12N	USDA	Shapefile of annual precipitation in inches for the state of Utah from 1981-2010
LandslideSusceptibility_UT	Shapefile	NAD_1922_UTM_Zone_12N	Utah Geological Survey	Shapefile of landslide susceptibility created by the UGS in 2007
HabitatAreas_shp	Shapefile	NAD_1983_UTM_Zone_12N	Utah AGRC	Folder containing the shapefiles of the habitat area of the endangered and threatened animals in Utah

Table 1: GIS Data Compiled

3. Data Preprocessing

a. The first step was to download all the relevant data (rasters & shapefiles, see Table 1 for dataset). These were then imported into ArcMap with their associated spatial reference. All of the data imported was ArcMap compatible and did not require georeferencing.

b. The second step was to make sure all the shapefile data layers were projected to the same spatial reference as the Data Frame. This was done using the Define Projection (Data Management Tools > Projections and Transformations) tool within ArcToolbox. The spatial coordinate system for this project is NAD_1983_UTM_Zone_12N.

c. A new folder was created to contain new processed data and was named GIS_Project.

d. Four DEM's were imported, as was stated in part a. and coordinates are stated in Table 1, and these were combined into one DEM mosaic. This was done using the Mosaic to New Raster (Data Management > Raster > Raster Dataset) tool in ArcToolbox. The new raster was named Mosaic_DEM.

e. All shapefiles listed in Table 1 were clipped to the Grand County boundary using the Clip (Analysis Tools > Extract) tool in ArcToolbox and the DEM mosaic raster was clipped to the Grand County boundary using the Extract by Mask (Spatial Analyst Tools > Extraction) tool in ArcToolbox.

f. The Geol_Poly shapefile was then dissolved to combine the polygons with the same Unit Name as one feature. This was done using the Dissolve (Data Management Tools > Generalization) tool in ArcToolbox.

g. Since new rasters will be generated for part of the preprocessing, a mask for setting the analysis area was set. This was done through the Geoprocessing menu > Environments > Raster Analysis > Mask. The mask was set to the Grand County boundary.

h. To determine which endangered and threatened species' habitats were located in areas with different levels of landslide susceptibility, the shapefiles from the HabitatAreas_shp folder needed to be displayed to see which habitats fell within Grand County. The list of endangered and threatened species with habitats within Grand County and the area in mi^2 for the habitat is listed below in Table 2.

Endangered/Threatened Species	Habitat Area (mi^2)
Bandtailed Pigeon	183
Bison	431
Black Bear	1188
Blue Grouse	614
California Quail	16
Chukar	2389
Desert Bighorn Sheep	644
Greater Sage Grouse	198
Muledeer	1677
Pronghorn	411
Ring Necked Pheasant	53
Rocky Mountain Bighorn Sheep	1217
Rocky Mountain Elk	1565
Wild Turkey	508

Table 2: Endangered/Threatened Species Habitats in Grand County, UT

i. All endangered and threatened species shapefiles listed in Table 2 were clipped to the Grand County boundary using the Clip (Analysis Tools > Extract) tool in ArcToolbox.

4. ArcGIS Processing

a. The first processing step was to create a new Slope raster from the DEM mosaic. This was accomplished using the Slope (Spatial Analyst Tools > Surface) tool in ArcToolbox (Figure 1).

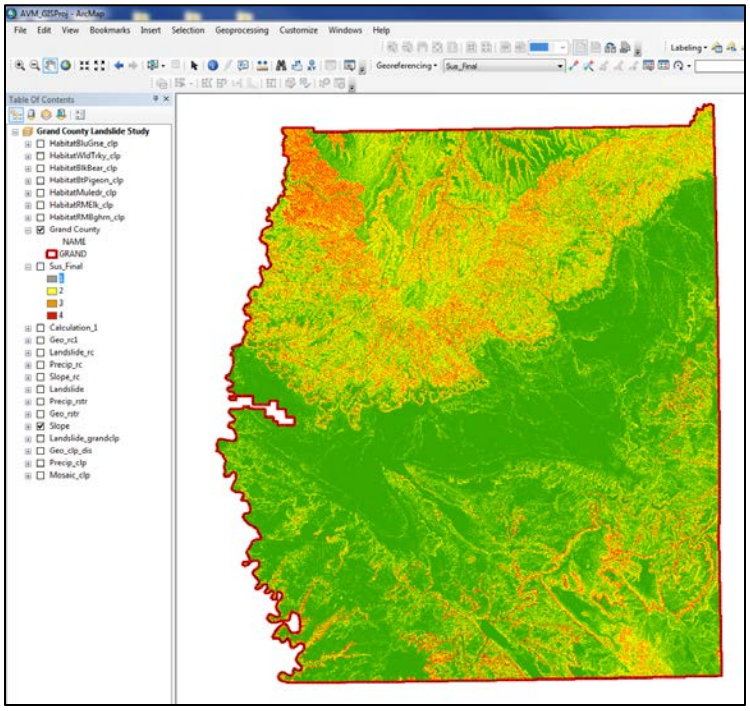


Figure 1: Screenshot of Slope raster created from DEM mosaic raster.

b. The next processing step was to convert the Geol_Poly clipped and dissolved layer to a raster layer. This was done using the Features to Raster (Conversion Tools > To Raster) tool in ArcToolbox, with an output cell size of 100 (Figure 2).

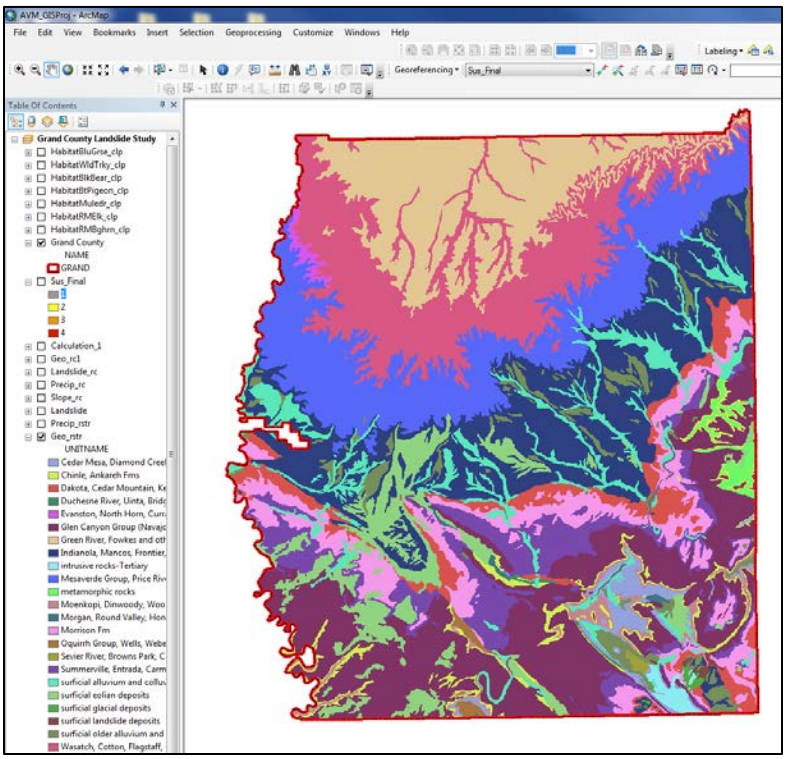


Figure 2: Screenshot of Geol_Poly raster created from shapefile.

c. Similar to part b., the clipped precipitation shapefile was also converted to a raster layer using the Features to Raster tool in ArcToolbox, with an output cell size of 100. This step was also completed for the LandslideSusceptibility_UT shapefile to convert it into a raster (Figure 3).

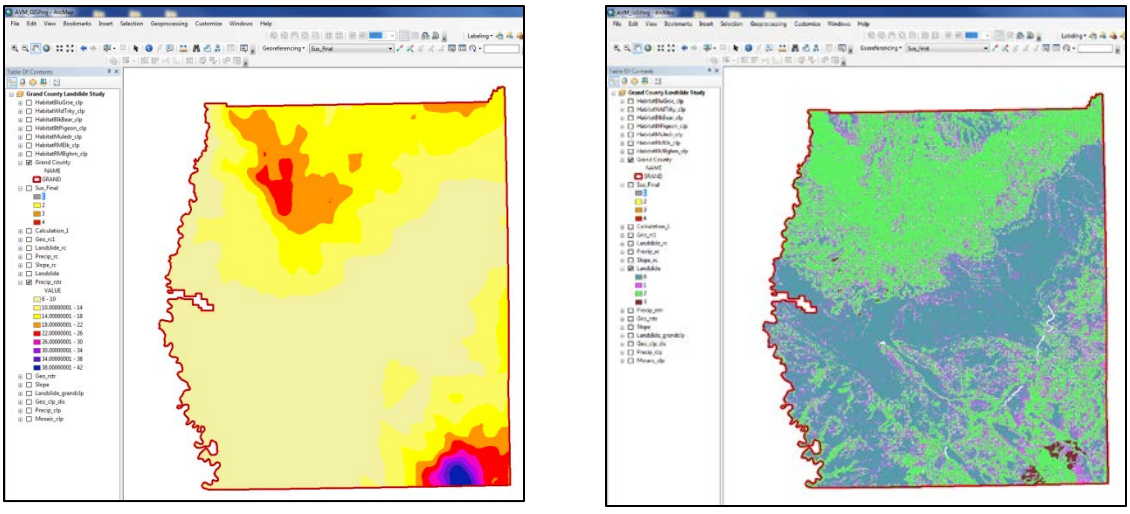


Figure 3: Screenshots of Precipitation and Landslide Susceptibility rasters created from shapefiles.

d. The next set of steps has to do with raster reclassification. Reclassification was based on the chart below (Table 3) outlining the ranking system to be used regarding landslide susceptibility. The rasters that were reclassified were the Geology raster, Slope raster, Precipitation raster, and Landslide raster. Reclassification was done using the Reclassify (Spatial Analyst Tools > Reclass) tool in ArcToolbox.

Rank	Geology	Slope	Precipitation	Existing Landslide Location
0	-	-	-	NO
1	Igneous/Metamorphic Rocks	< 10°	<15 inches	-
2	Sandstone/Limestone	10-20°	15-25 inches	-
3	Shale/Mudstone	20-30°	25-35 inches	-
4	Unconsolidated Rocks	>30°	35-45 inches	YES

Table 3: Susceptibility Analysis Parameters

e. After each of the rasters listed above in Table 3 were reclassified, the rasters were combined using the Raster Calculator (Spatial Analyst Tools > Map Algebra) in ArcToolbox. Each of the rasters were added together and a resultant raster was produced named Calculation_1 (Figure 4).

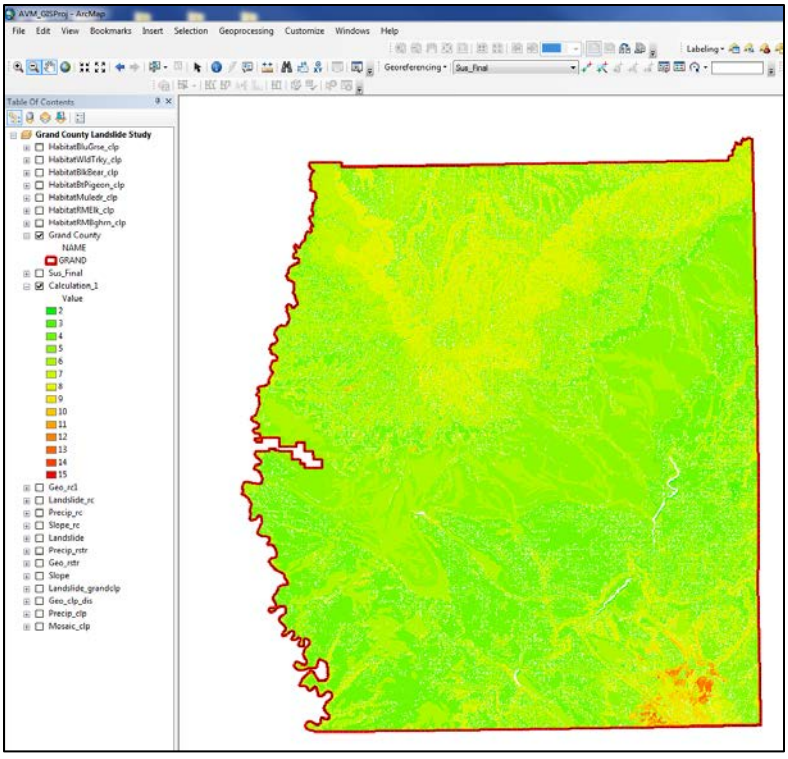


Figure 4: Screenshot of Calculation_1 raster created using the Raster Calculator.

f. Calculation_1 was reclassified to represent a raster with landslide susceptibility in four categories, which are listed in the Table 4 below.

Calculation Value	Reclass Value	Landslide Susceptibility
2-5	1	Very Low
6-8	2	Low
9-12	3	Moderate
13-15	4	High

Table 4: Final Landslide Susceptibility Categories

5. Results

a. Landslide Susceptibility Map

According to my hazard analysis of landslide susceptibility, the southeastern portion of Grand County is most prone to landslides with the majority of the Moderate to High categories located there (Figure 5). There are a few locations within some of the canyons in the Book Cliffs that have a moderate susceptibility to landslides but minor in comparison to the southeastern portion of the county.

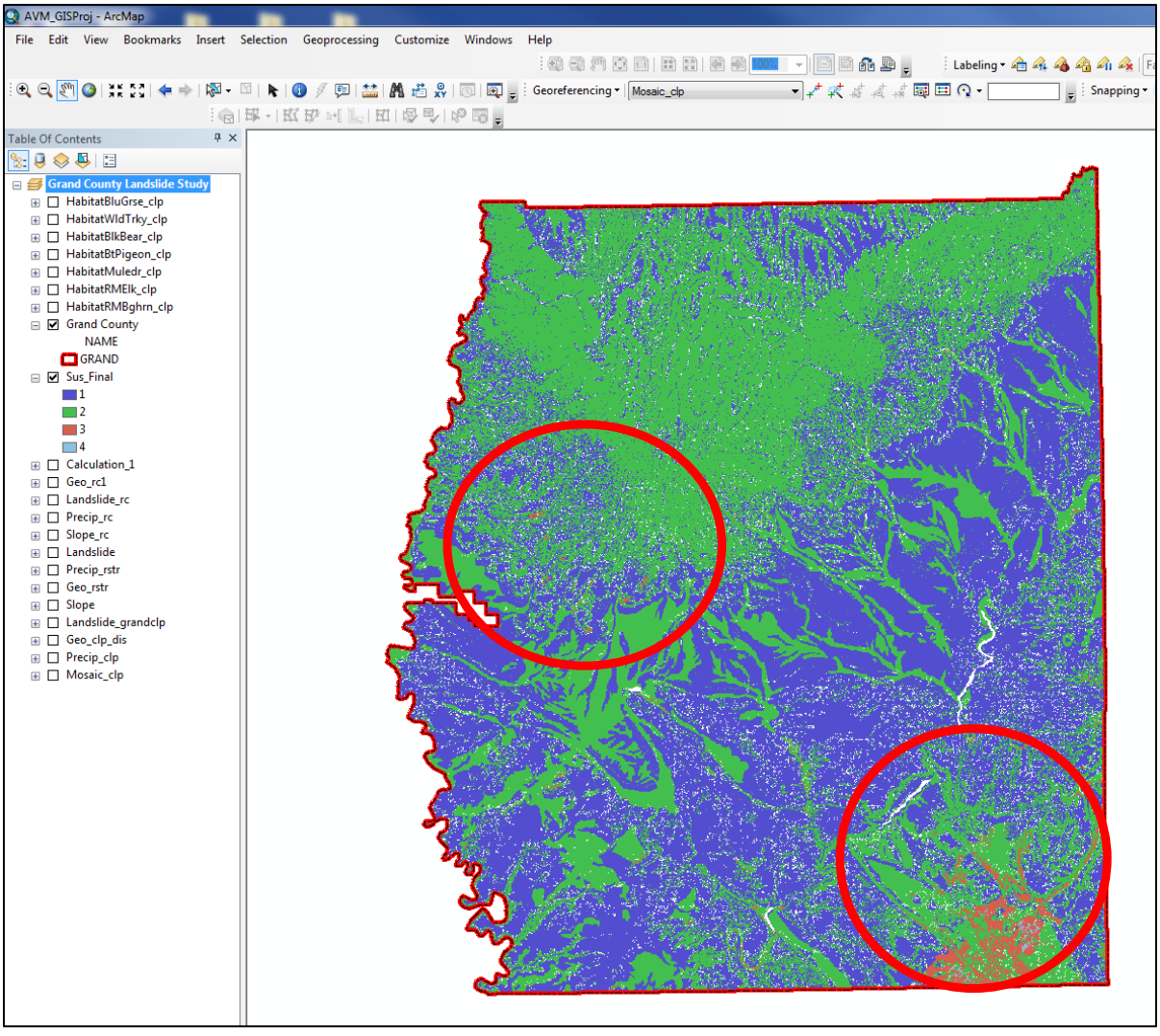


Figure 5: Screenshot from ArcMap of Grand County, Utah showing the final landslide susceptibility map with moderate to high prone areas outlined in the red circles.

b. Endangered and Threatened Species Habitat Case Study

One portion of this project was to analyze which endangered and threatened species habitats could be affected by landslides. To evaluate this, the final landslide susceptibility map shown in Figure 5 was overlain by each of the fourteen species outlined in Table 2 shapefile to see which species had habitats in areas with moderate to high landslide susceptibility. A composite map was created and a screenshot of this map is shown in Figure 6 below. The original list of fourteen species was narrowed down to seven species whose habitats were in areas of moderate to high risk of landslides.

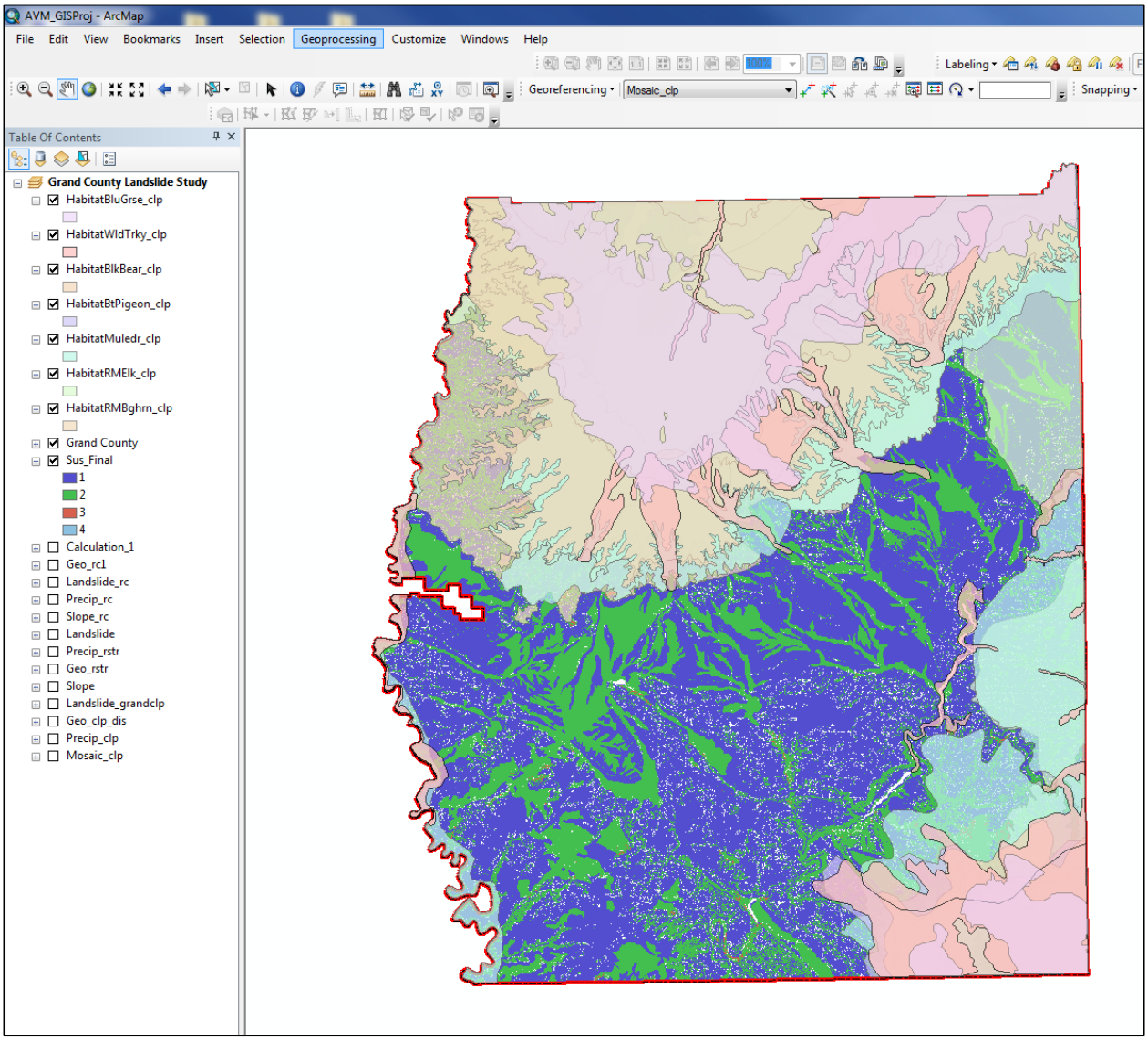
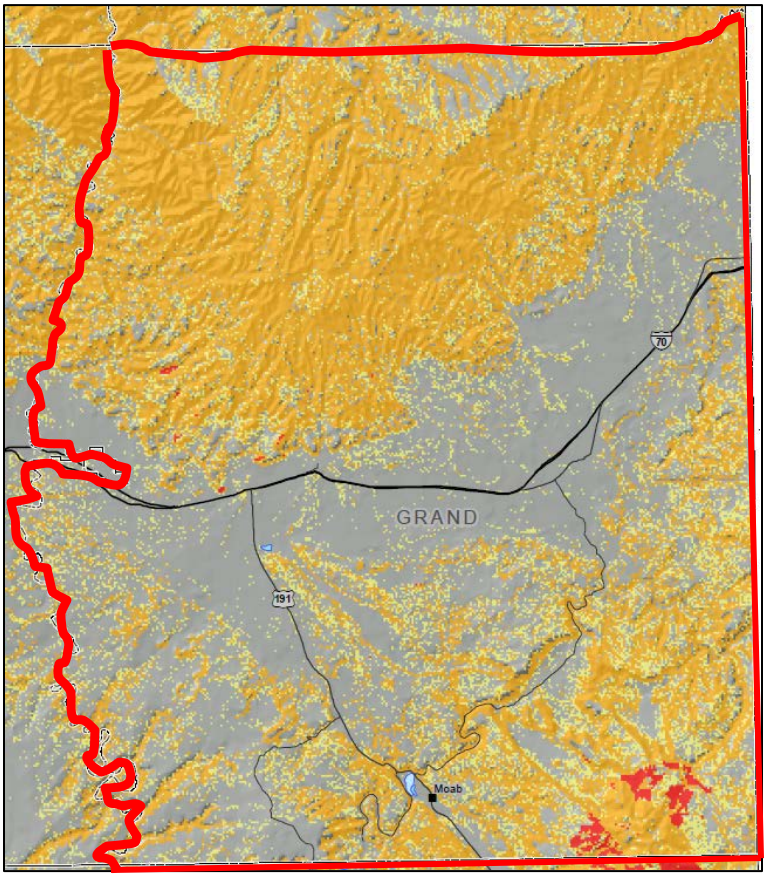
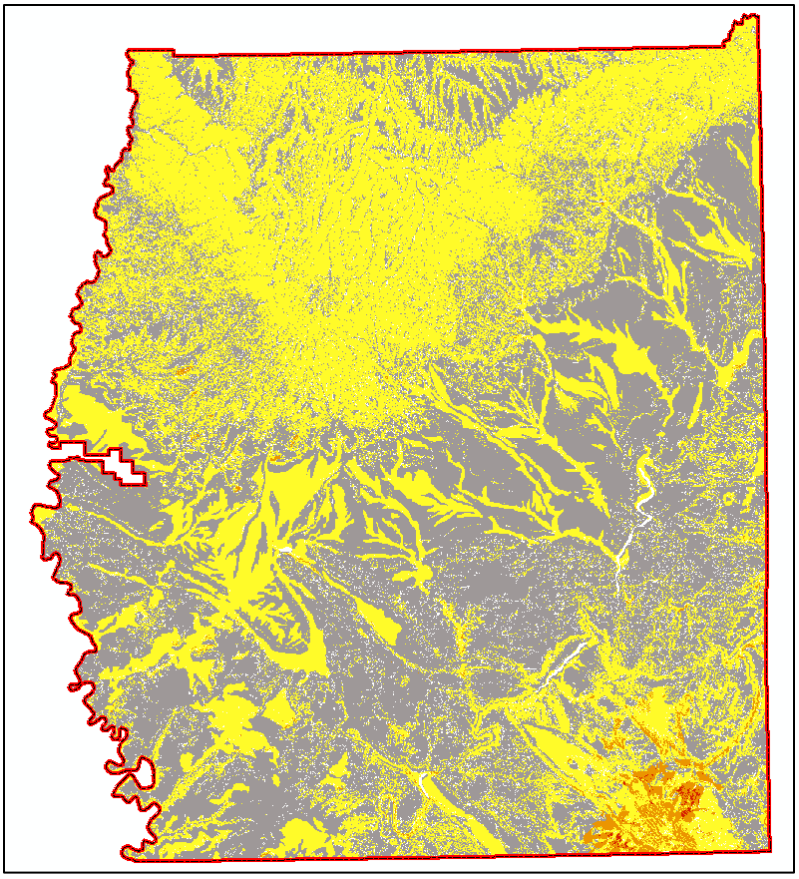


Figure 6: Screenshot from ArcMap of Grand County, Utah showing a composite map of the habitats of the endangered and threatened species in moderate to high landslide susceptibility areas.

6. Conclusions





Landslide Susceptibility	Color on Map
High	Red
Moderate	Orange
Low	Yellow
Very Low	Gray

Landslide Susceptibility	Color on Map
High	Red
Moderate	Orange
Low	Yellow
Very Low	Gray

Figure 7: Landslide susceptibility maps in Grand County. The map on the left is from the 2007 statewide study by the Utah Geological Survey without taking into account precipitation and minimal lithology consideration (Giraud & Shaw, 2007). The map on the right is a screenshot from the landslide susceptibility map created for this project taking into account precipitation and lithology. The tables below each map correspond with the landslide susceptibility category and color on the map.

a. Landslide Susceptibility Map

Figure 7 illustrates the comparison of this project with the study done in 2007. The problem that this project set out to solve was how the addition of lithology and precipitation data would enhance the location of landslide risk areas in Grand County, UT in comparison to the statewide study done in 2007. As you can see in Figure 7, the moderate to high landslide susceptibility areas identified in the 2007

study are in the southeastern corner of the county which is mimicked by the map created for this study, as is shown by the orange and red colors in the southeastern corner of the map to the right. This area to the southeast is the La Sal Mountain Range, and explains the higher landslide susceptibility in this area due to increased precipitation here and steeper slopes. One difference is lower landslide susceptibility was identified at lower elevations in the La Sal range in this study in comparison to the map shown from the 2007 study. The addition of lithology and precipitation information here indicates that these areas are of lower landslide risk than was originally estimated in 2007. This is also apparent in the Book Cliffs area to the north. This area was mainly identified as a moderate risk in 2007 but has been lowered in most areas with the addition of lithology and precipitation information. Another feature that is prevalent in the updated study map in comparison with the 2007 map in Figure 7 is more detail through the middle of the map highlighting some of the canyons on the fringes of the Book Cliffs as low landslide risks where as these are not shown in the 2007 map. These canyons are large recreation areas and easily accessible to the public and should be included in a landslide hazard analysis of the area. A printable map with landslide susceptibility in Grand County, Utah is located in the Appendix (Map 1).

Through the addition of lithology and precipitation data, the landslide hazard analysis map produced in 2007 by the Utah Geological Survey was improved upon by creation of a more detailed map of landslide risks in Grand County, Utah.

b. Endangered and Threatened Species Habitat Case Study

One portion of this project was to analyze which endangered and threatened species habitats could be affected by landslides. To evaluate this, the final landslide susceptibility map shown in Figure 5 was overlain by each of the fourteen species outlined in Table 2. A composite map was created and a screenshot of this map is shown in Figure 6 above. The original list of fourteen species was narrowed down to seven species whose habitats were in areas of moderate to high risk of landslides. These species are the Bandtailed Pigeon, the Blue Grouse, Wild Turkey, Black Bear, Muledeer, Rocky Mountain Elk, and Rocky Mountain Bighorn Sheep. The majority of these habitat areas that are at risk for landslide interference are in the La Sal Mountain Range to the southeast and in the Book Cliffs area to the north. A printable map with landslide susceptibility overlain by at risk habitat areas is located in the Appendix (Map 2).

7. References

Giraud, Richard E., and Lucas M. Shaw. "Landslide Susceptibility Map of Utah." *Utah Geological Survey* (2007): 1-16. *Google Scholar*. Web. 25 Nov. 2016.

APPENDIX

Map 1: Printable map showing landslide susceptibility areas in Grand County, Utah

Map 2: Printable map showing endangered and threatened species habitats and landslide susceptibility areas in Grand County, Utah

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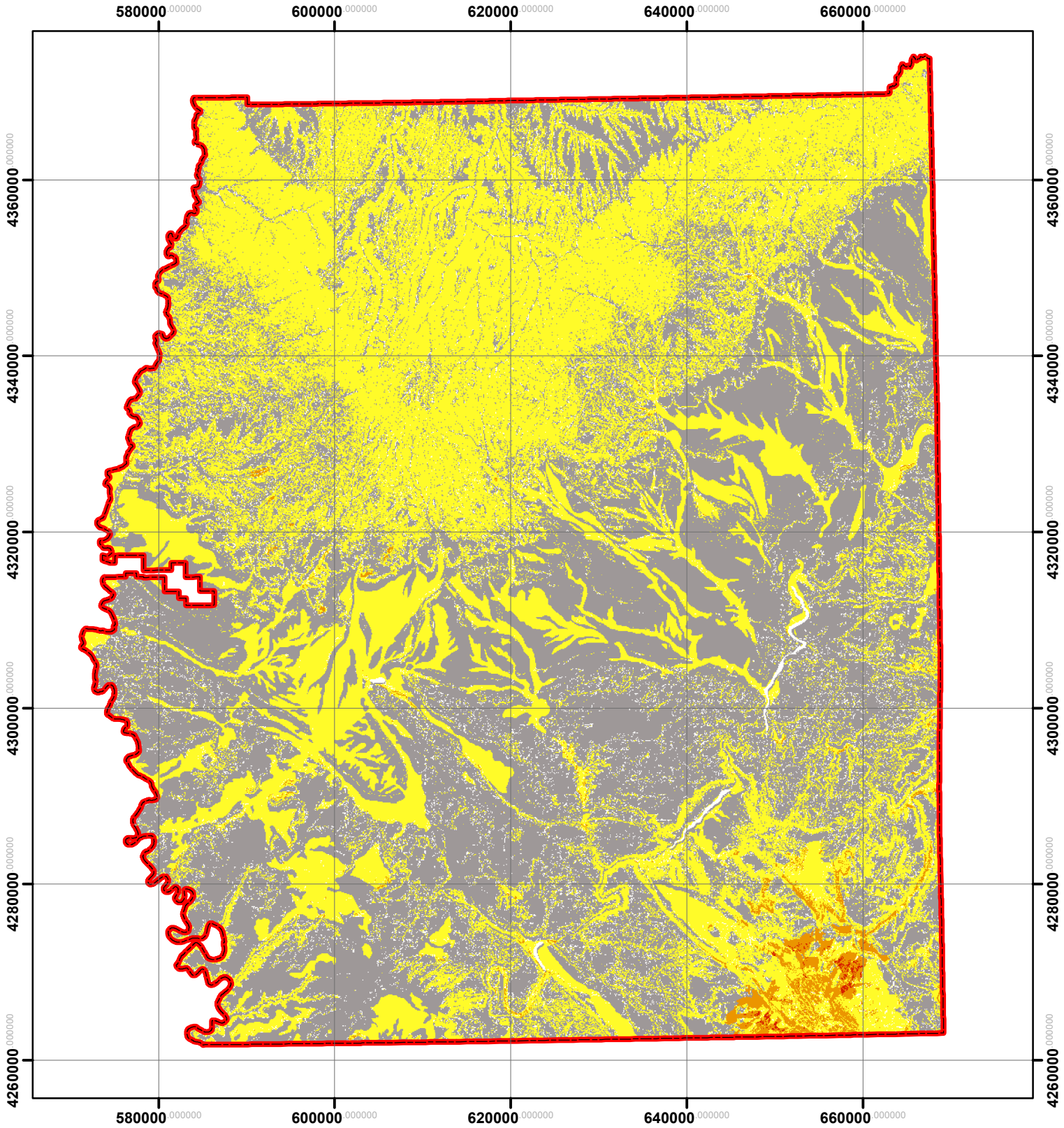
12/5/2016

Map of Landslide Susceptibility, Grand County, Utah



Explanation

Grand County

Landslide Susceptibility

- 1: Very Low
- 2: Low
- 3: Moderate
- 4: High

0 3 6 12 18 24 Miles

0 4 8 16 24 32 Kilometers

1:600,000

N

NAD 1983 UTM Zone 12N

Map 1

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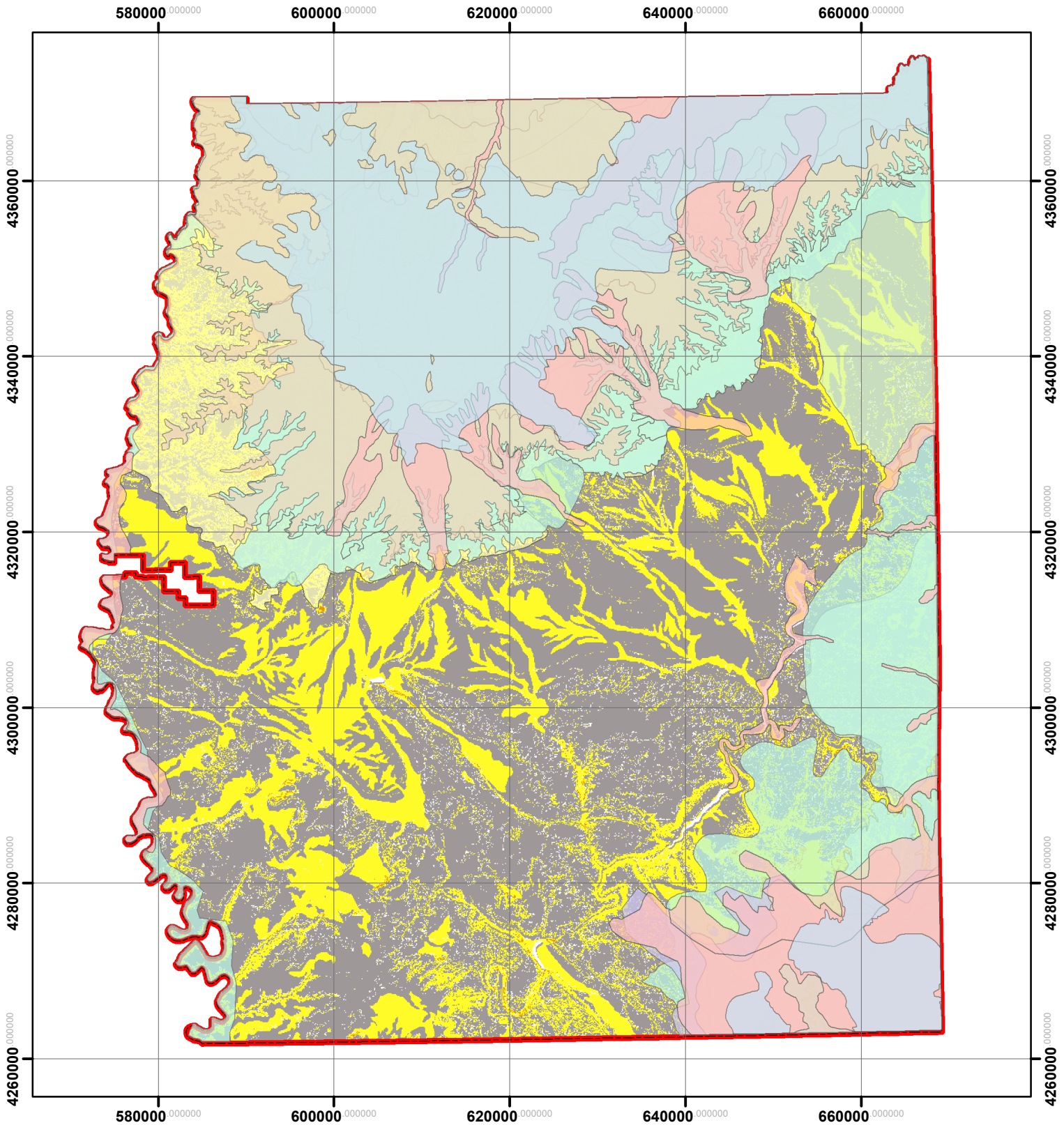
12/5/2016

Map of Endangered and Threatened Species Habitats and Landslide Susceptibility, Grand County, Utah



Explanation

- Grand County

Landslide Susceptibility

- 1: Very Low
- 2: Low
- 3: Moderate
- 4: High

- Blue Grouse Habitat
- Wild Turkey Habitat
- Black Bear Habitat
- Bandtailed Pigeon Habitat
- Muledeer Habitat
- Rocky Mountain Elk Habitat
- Rocky Mountain Bighorn Sheep Habitat

0 3 6 12 18 24 Miles

0 4 8 16 24 32 Kilometers

N

NAD 1983 UTM Zone 12N

1:600,000

Map 2