GIS Project: Wildfire Risk Assessment for Taos, New Mexico

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CE 547- GIS in Water Resources
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I. Introduction

Wildfires incidents are increasing more and more over the years and they are becoming more severe. The increasing temperatures and dry conditions from global warming are creating the necessary conditions for severe wildfires. In addition, we are experiencing a considerable increase in population that has moved urban development into forest areas increasing the ignition risk from humans. Assessing the risk of a wildfire occurring in a specific location can help authorities mitigate the risk and in the case it occurs, respond faster and better prepared.

Geographical Information Systems (GIS) are increasing in use because of their ability to represent spatially distributed data with a high degree of accuracy and making it easier to identify trends. Within Wildfire management, GIS has been found to be a very helpful tool when integrated with other programs and/or technologies such as GPS and Remote Sensing, Fire Area Simulator (FARSITE) and FlamMap. The results from the analysis can assist agencies in recognizing areas at risk, educating communities, managing real-time response and most importantly, saving lives.

Personally, I have grown very interested in the topic of how technology can assist agencies manage their assets. Searching for a topic for my Master's thesis I narrow the options to the use of technologies such as GIS and Building Information Modeling (BIM) to model wildfire risks and create a management plan to protect and manage agencies' resources such as utilities and structures. For the class final project I decided to get acquainted with wildfires terminology and the basic concepts to build a wildfires risk assessment (WRA) in GIS. The objective will be to identify areas in Taos, New Mexico where conditions are more prone to wildfire occurrence by preparing a WRA. Some research will be conducted to understand the wildfires terminology its behavior for proper risk classification.

II. Data Sources

For the purpose of building the model I had to define the required data. All of the datasets used for the WRA were obtained from the New Mexico Resource Geographic Information System Program (RGIS) and the available from the CEGIS FTP folder. The datasets obtained for the analysis are:

- USA Counties Dataset- The data was downloaded from the CEGIS FTP folder. By using the select by attribute and export data tools, the Taos County boundary layer was created. The layer will be used as the Mask for the raster analyses.
- National Land Cover Dataset- The layer was downloaded from RGIS site. It was used to obtain the fuel models covering the Taos County.
- Taos County Roads and the Fire Stations in New Mexico Layers - Both layers were downloaded from the Transportation Folder and the Emergency Management Folder, respectively, in the RGIS site . The datasets will be used to reduce the risk of wildfires assuming that areas near the sources have less risk of wildfire since the response time should be less.
- Statewide Digital Elevation Model (DEM) - The layer was downloaded from the Elevation folder in RGIS. The layer was used to obtain the slope and aspect rasters for Taos County.
- Ignition Probability, Flame Length and Rate of Spread- All three layers were downloaded from the State Forestry folder in the RGIS site. They each describe fire intensity and behavior. A more detailed description of each layer is given in Appendix B.

The projection used for the model was the Projected Universal transverse Mercator (UTM) Zone 13N with NAD 83 Datum. The projection was chosen because most of the downloaded datasets were already in this projection and it is also a good representation for the State of New Mexico.

III. Methodology

The actual process of defining how to perform the analysis was a challenging one given all the tools available in ArcMap to perform the analysis. After some trial and error I decided to use the Model-Builder (MB) which is an application within ArcMap that helps "*create, edit, and manage workflows that string together sequences of Geoprocessing tools, feeding the output of one tool into another tool as input*" (ESRI 2013). The main reason for using the MB is its ability to create parameters within the workflow and visually understand and optimize the analysis process. Also, identifying and resolving a workflow error is much easier.

For the analysis all layers required the use of the same tools, therefor the MB made it a lot easier. After all the layers were projected to the selected projection their boundaries were masked using the "*Extract by Mask*" Tool. The "*Euclidian Distance*" Tool was used on the roads and fire stations ShapeFiles to obtain the layer with distance values. Then, the results for each layer was reclassified within an interval from 1 to 5, 1 being less risk and 5 more risk of fire (For more information regarding the reclassification criteria please refer to the Appendix B). The "*Reclassify*" tool was used for this purposes. The MB gives the option of setting a tool as a model parameter so its value can be specified in the model tool dialog box. For the analysis purposes, each reclassification process was set as a Model parameter to give the convenience to the user of changing the ranking criteria when running the tool (See Figure 1).

After all the layers were reclassified I used the "Weighted Overlay" tool to overly each raster to obtain an integrated analysis. The best thing about overlay the tool is it that you can give a different percent of influence for each one of the criteria and visually understand how the risk changes given different percent values.

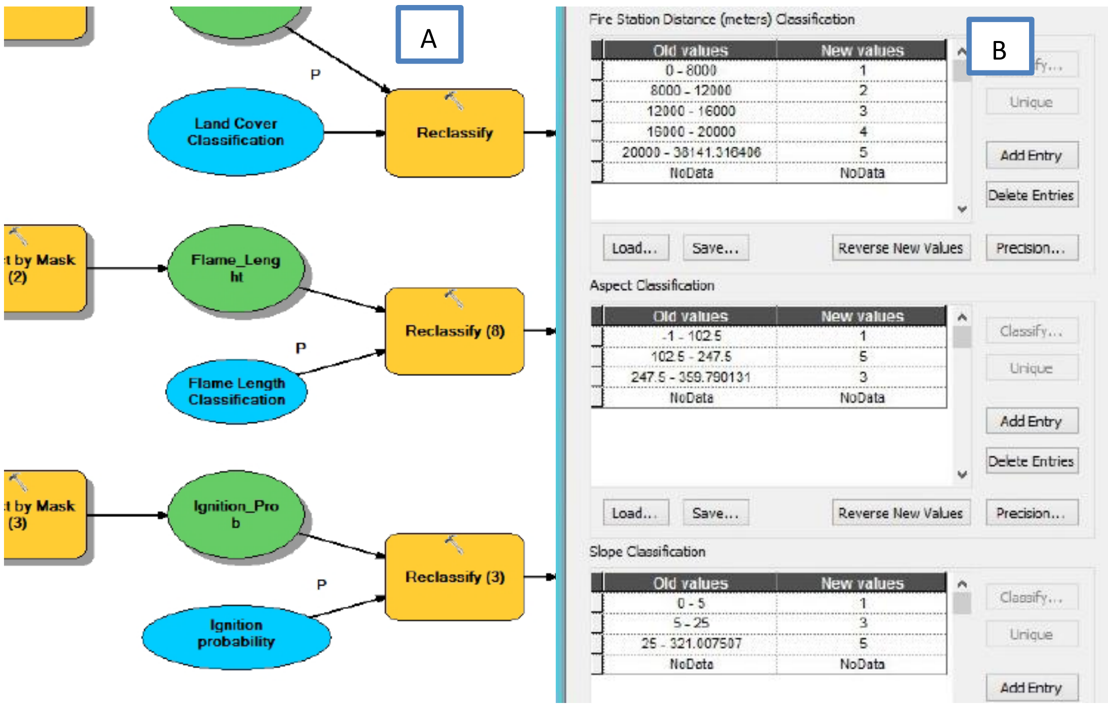


Figure 1:The figure shows and example of how the tools parameter are defined in the model workflow (A) and how they are appear when the model is run as a tool (B)

IV. Results and Limitations

After the MB workflow was run, the analysis results were obtained. Different weight values where given to the criteria but in general most of the risk in Taos County appears to be on the east side of the Rio Grande River (See Figure 2). The results does makes sense since this areas have dense forest areas and higher slopes are mostly in the East of Taos including the Carson National Forest and Wheelers Peak, highest peak in New Mexico. Refer to Appendix D for more WRA results given different weights to each layer.

Wilfire Risk Assessment
Taos, New Mexico

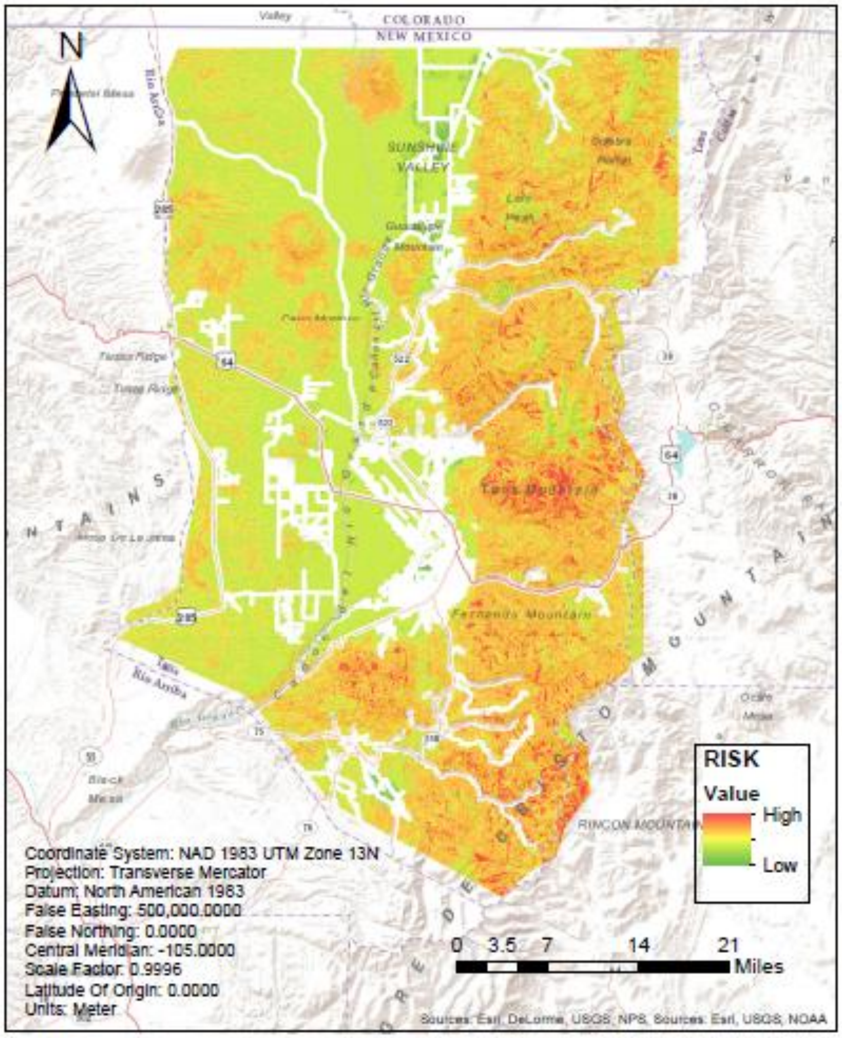


Figure 2: Risk Assessment Results

There were some limitations to the analysis, first and foremost my lack of expertise with Wildfires concepts to properly understand each criterion's behavior and contribution to fire risk. In terms of data sources, other layers can be included such as weather datasets (e.g. temperatures, droughts level and wind direction), forest canopy coverage, soil types, etc. Also, I only limited fire stations and roads inside Taos's County when there are probably other sources from other counties near the borders of Taos County. More consideration on how firefighter's response should be given to properly attain the suppression capabilities.

V. Conclusions

The use of GIS for WRA is not a new concept. Many states such as New Mexico, Virginia and Florida have implanted GIS analysis to properly manage wildfire risks. My intentions were to familiarize with wildfire concepts and understand how GIS could be support fire risk analysis and at the end of the project I met my expectations. For future work I am really interested in integrating BIM for assets management before, during and after a fire. Also, I would like to understand how these tools can help predict fire behavior.

VI. References

ESRI (2011). *GIS Technology: Supporting the Wildfire Mission.* Esri White paper (9) (http://www.esri.com/industries/public-safety/wildland-fire-management)

Calkin, D. E., Thompson, M. P., Finney, M. A., & Hyde, K. D. (2011). A real-time risk assessment tool supporting wildland fire decisionmaking. *Journal of Forestry*, *109*(5), 274-280.

Rothermel, R. C. (1983). *How to predict the spread and intensity of forest and range fires* (p. 161). Ogden, UT, USA: US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Scott, J. H., & Burgan, R. E. (2005). Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. The Bark Beetles, Fuels, and Fire Bibliography, 66.

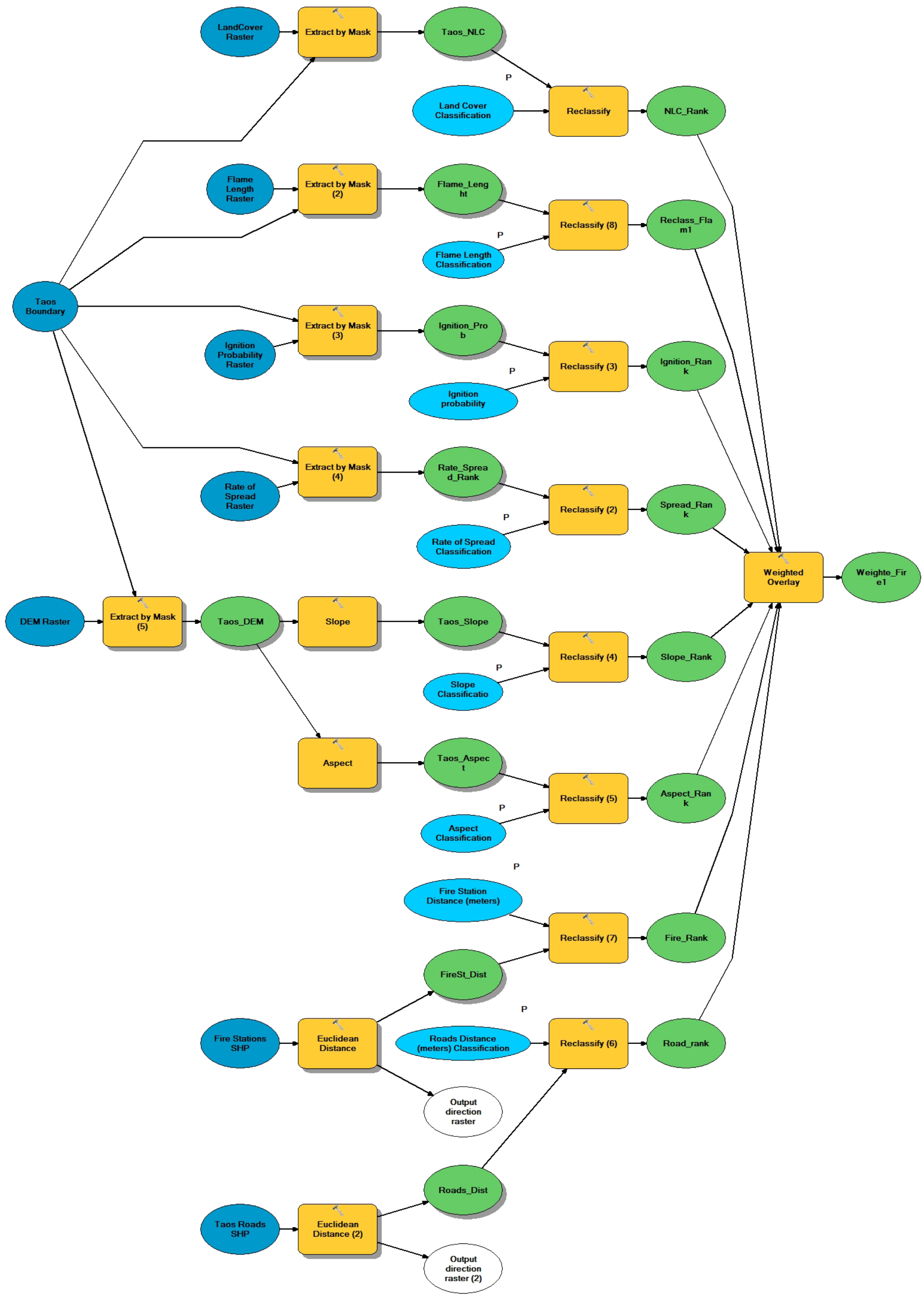
Websites:

ArcGIS Resources- http://resources.arcgis.com/

New Mexico Resource Geographic Information System Program (RGIS)- http://rgis.unm.edu/

The Virginia Department of Forestry- http://www.dof.virginia.gov/stforest/index.htm

Appendix A WORKFLOW MODEL


LandCover Raster
Extract by Mask
Taos_NLC
Land Cover Classification
Reclassify
NLC_Rank
Flame Length Raster
Extract by Mask (2)
Flame_Length
Flame Length Classification
Reclassify (8)
Reclass_Flam1
Taos Boundary
Ignition Probability Raster
Extract by Mask (3)
Ignition_Prob
Ignition probability
Reclassify (3)
Ignition_Rank
Rate of Spread Raster
Extract by Mask (4)
Rate_Spread_Rank
Rate of Spread Classification
Reclassify (2)
Spread_Rank
Weighted Overlay
Weighte_Fire1
DEM Raster
Extract by Mask (5)
Taos_DEM
Slope
Taos_Slope
Slope Classificatio
Reclassify (4)
Slope_Rank
Aspect
Taos_Aspect
Aspect Classification
Reclassify (5)
Aspect_Rank
Fire Station Distance (meters)
Reclassify (7)
Fire_Rank
FireSt_Dist
Fire Stations SHP
Euclidean Distance
Roads Distance (meters) Classification
Reclassify (6)
Road_rank
Output direction raster
Roads_Dist
Taos Roads SHP
Euclidean Distance (2)
Output direction raster (2)

Appendix B RANKING CRITERIA

1. **Land Cover Data Set Reclassification**: The land cover data set was classified considering the information research for Fuel Models. Each fuel type was ranked from an interval of 1 to 5. Five (5) represent a high risk for fire (Ex. Forest) and one (1) very low risk (Ex. Grasslands). Also, data such as waters and developed zones were changed to No Data because wildfires usually don't occur in these areas and have no Fuels to be considered for fire risk.

Definition	Value
Open Water	No Data
Perennial Ice Snow	No Data
Low Intensity Residential	No Data
High Intensity Residential	No Data
Commercial/ Industrial/ Transportation	No Data
Bare Rock/ Sand/ Clay	1
Quarries/ Strip Mines/ Gravel Pits	1
Transitional	2
Deciduous Forest	5
Evergreen Forest	5
Mixed Forest	5
Shrublands	4
Orchards/ Vineyards/ Other	2
Grassland/ Herbaceous	2
Pasture/Hay	1
Row Crops	1
Small Grains	1
Fallow	1
Urban/Recreational Grasses	1
Woody Wetlands	2
Emergent Herbaceous Wetlands	2

2. Slope (Percent Rise) Dataset: As research has shown, wildfires tend to advance uphill and the ability of firefighters to suppress uphill fires lowers significantly. Therefore, higher slopes where given higher rank value for fire risk.

Slope (% Rise)		Rank
From	To	
0	5	Class 1
		Class 2
5	25	Class 3
		Class 4
25	375	Class 5

3. Aspect (Degrees) Dataset: The ranking criteria for this data set were obtained from the Virginia State Wildfire risk Assessment. They describe slopes facing south as to be receiving more direct light from the sun making them more conductive to wildfires.

Direction	**Azimuth (Degrees)**	**Rank**
N, E, NE	0-102.5	Class 1
W, NW	247.5-337.5	Class 3
S, SE, SW	102.5-247.5	Class 5

4. Roads Layer: The roads classification was based more on common sense. I assumed that areas bordering the roads had easy access for firefighter's therefore lower fire risks.

Distance (meters)		**Rank**
From	**To**	
0	400	Class 1
400	1000	Class 2
1000	2000	Class 3
2000	5000	Class 4
5000	Higher	Class 5

5. Fire stations: The classification fire stations were based on my common sense. I assumed areas closer to a station where of lower risk since the response time for fire fighters was much faster.

Distance (meters)		**Rank**
From	To	
0	8000	Class 1
8000	12000	Class 2
12000	16000	Class 3
16000	20000	Class 4
20000	Higher	Class 5

6. Ignition Probability: The data set was readily available in RGIS website. As the metadata describes, the raster gives values to areas where fires are likely to occur assuming that there will be an increase in probability of a fire occurring in areas where they have occurred in the past. The State Forestry procured the fire data from 1987 to 2008 and combined it into a density grid where each pixel represented a number of fires that have occurred per square kilometer. For reclassification purposes it was assumed that areas where the fire occurrences have been lower, there was less risk of a wildfires.

Probability (# fire occurrences per km^2)		**Rank**
From	To	
1	2	Class 1
2	5	Class 2
5	10	Class 3
10	20	Class 4
20	37	Class 5

7. Rate of Spread: The data set was readily available in RGIS website. The data set was readily available in RGIS website. As the metadata describes, the rate of spread represent the horizontal distance that a flame zone moves per unit of time. The classification method was obtained from the metadata, assuming that higher speeds increase the fire risk.

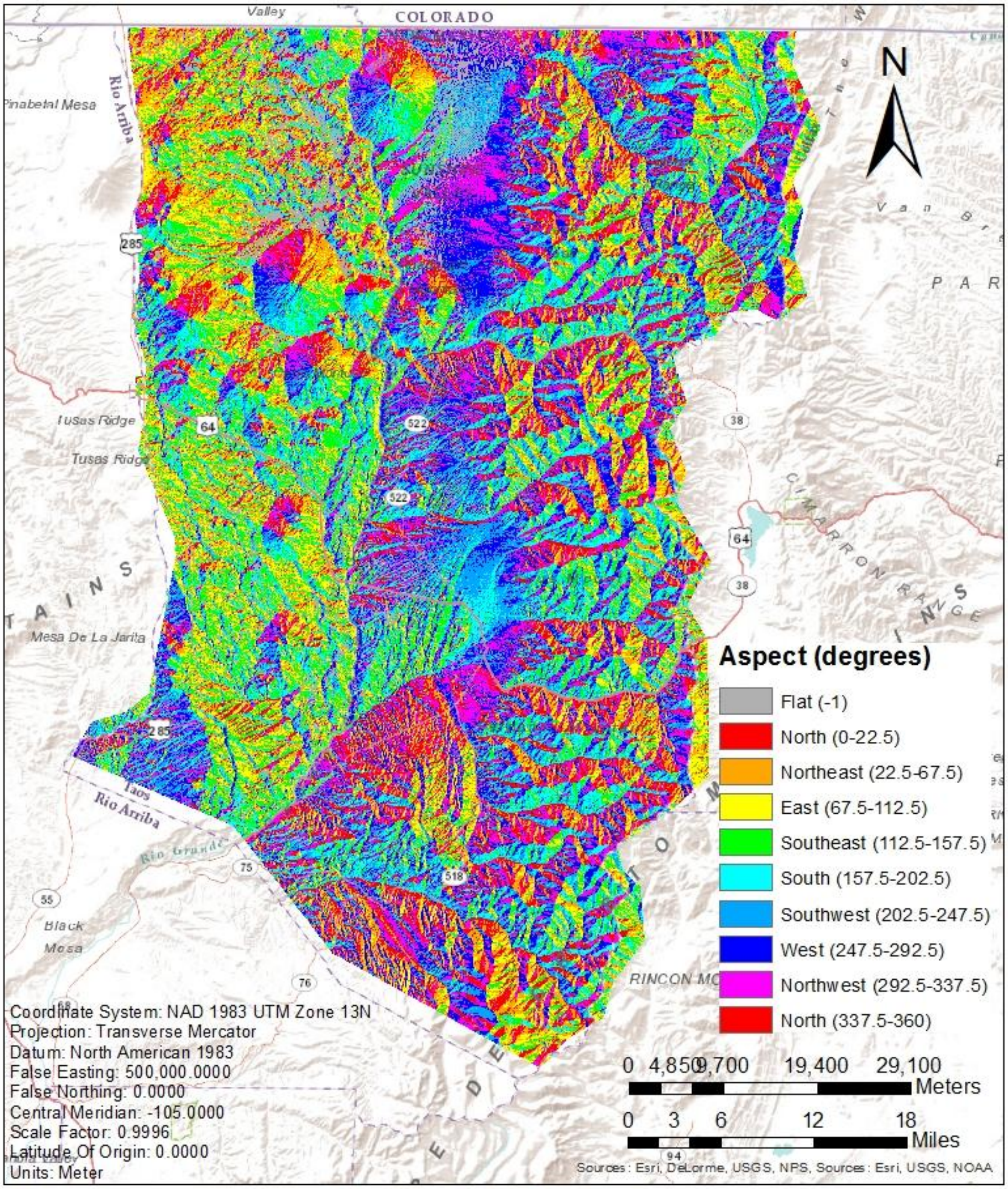
Speed (ft./min)		**Rank**
From	To	
0	5.5	Class 1
5.5	55	Class 3
55	Higher	Class 5

1. Flame Length: Rate of Spread: The data set was readily available in RGIS website. The data set was readily available in RGIS website. As the metadata describes, the flame length is the distance from the base of the flame to the tip of the flame. It is an indicator of fire intensity. The classification method was obtained from the metadata, assuming that shorter flames are easier to suppress.

Length (feet)		**Rank**
From	To	
0	1	Class 1
1	4	Class 2
4	8	Class 3
8	11	Class 4
11	Higher	Class 5

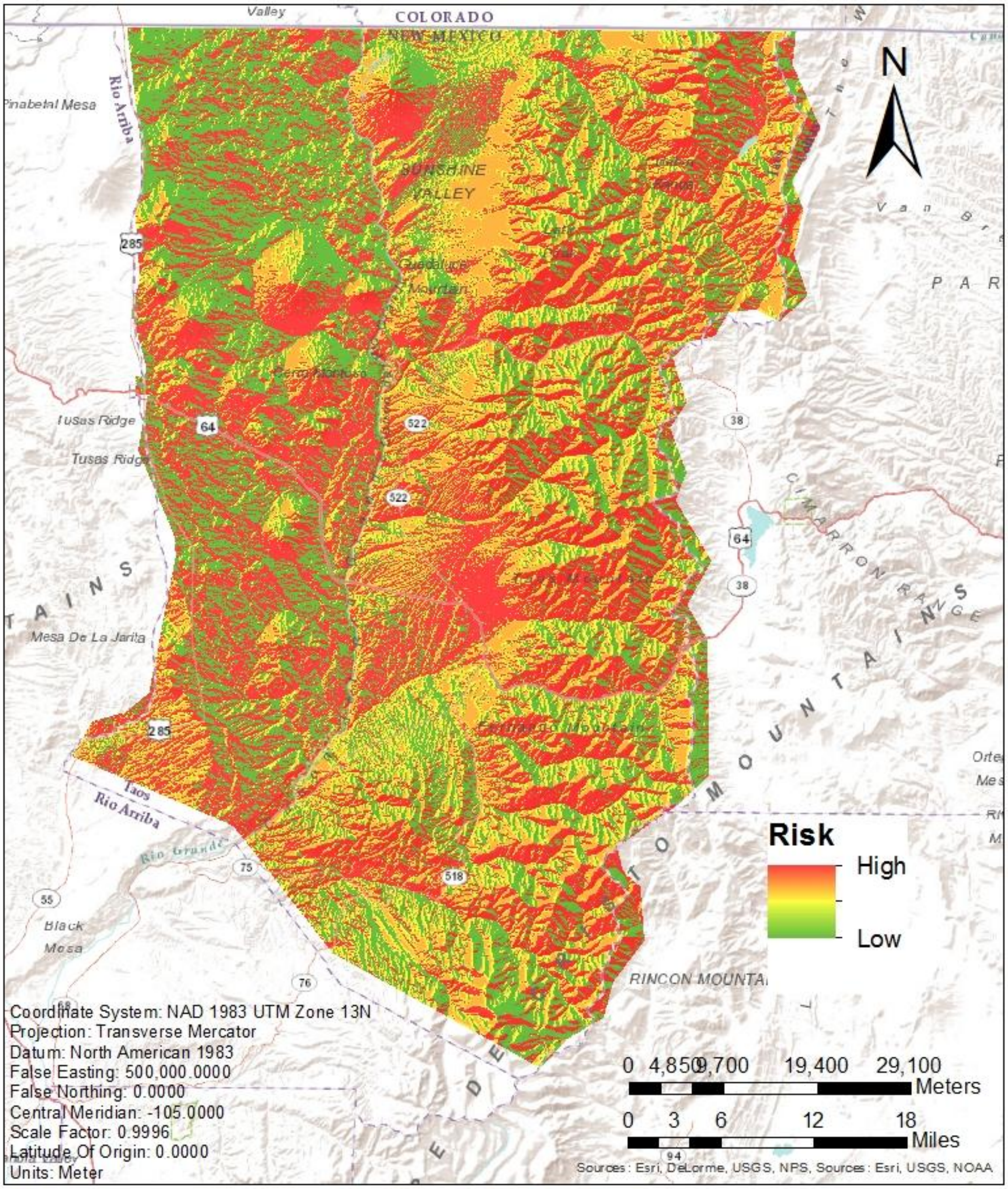
Appendix C RELASSIFIED LAYERS

Aspect
Taos, New Mexico



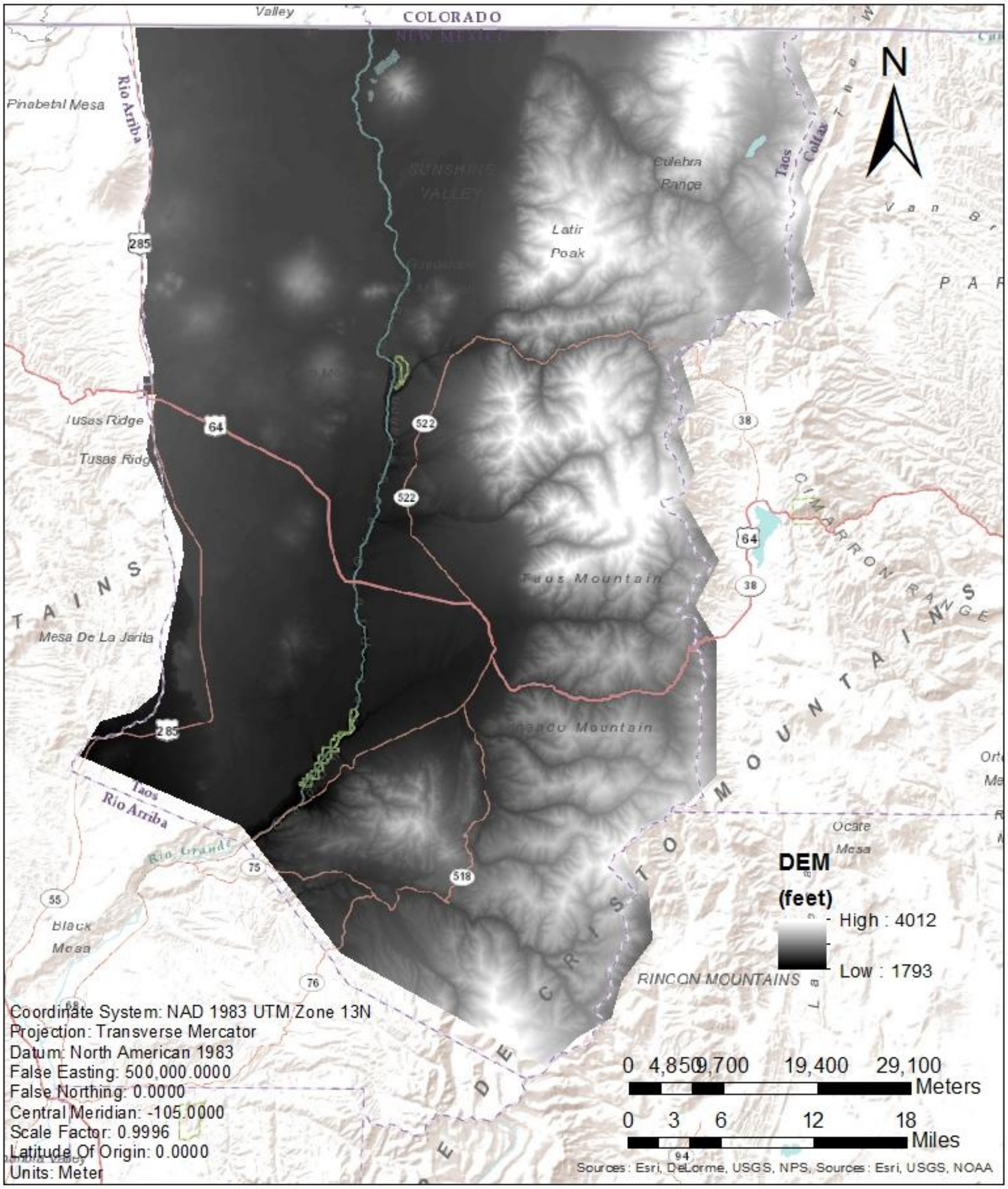
Author: Natalia M. Sanabria Date: 5/2/2013

Aspect Risk Layout
Taos, New Mexico



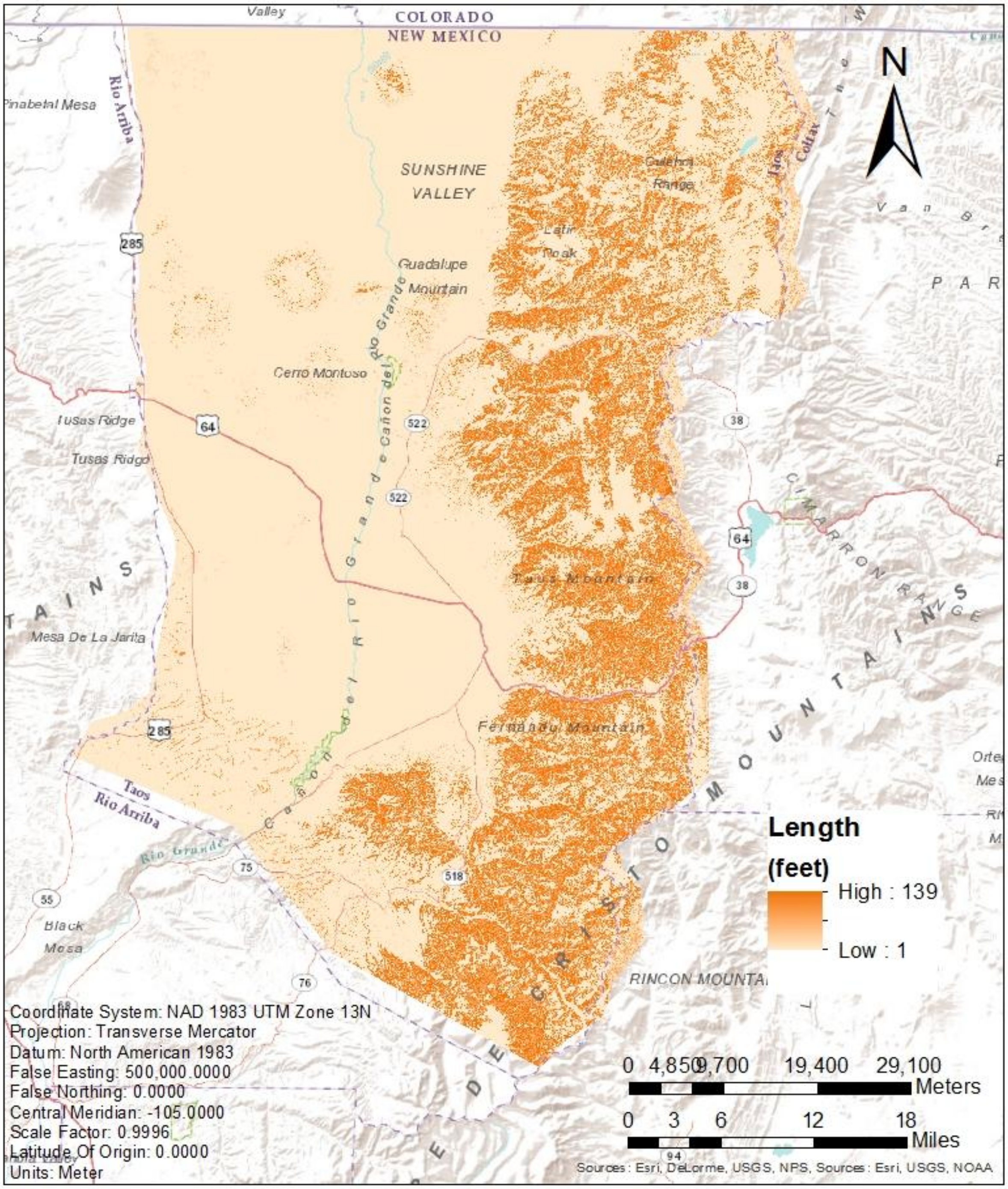
Author: Natalia M. Sanabria Date: 5/2/2013

Digital Elevation Model (DEM)
Taos, New Mexico



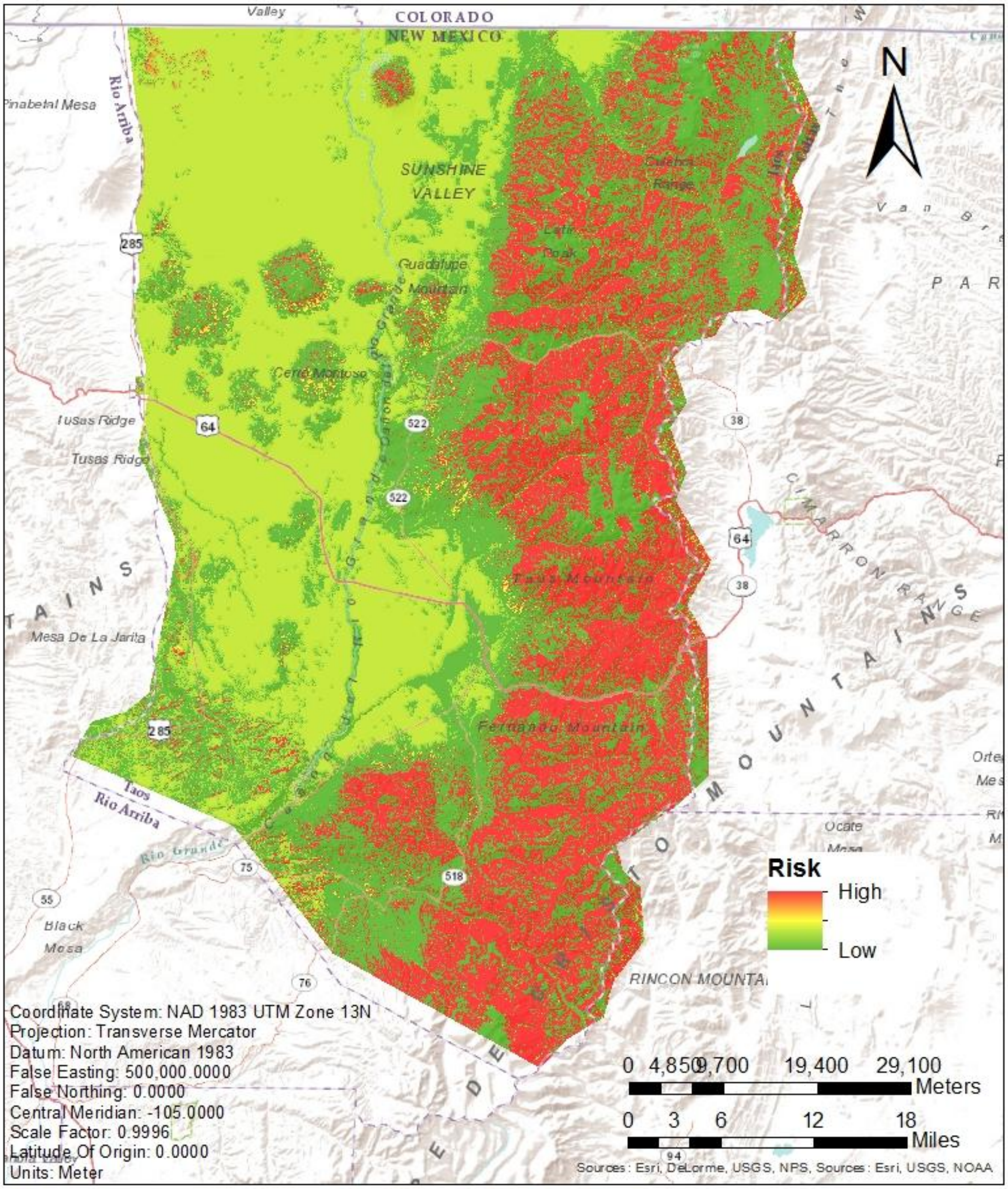
Author: Natalia M. Sanabria Date: 5/2/2013

Flame Length
Taos, New Mexico



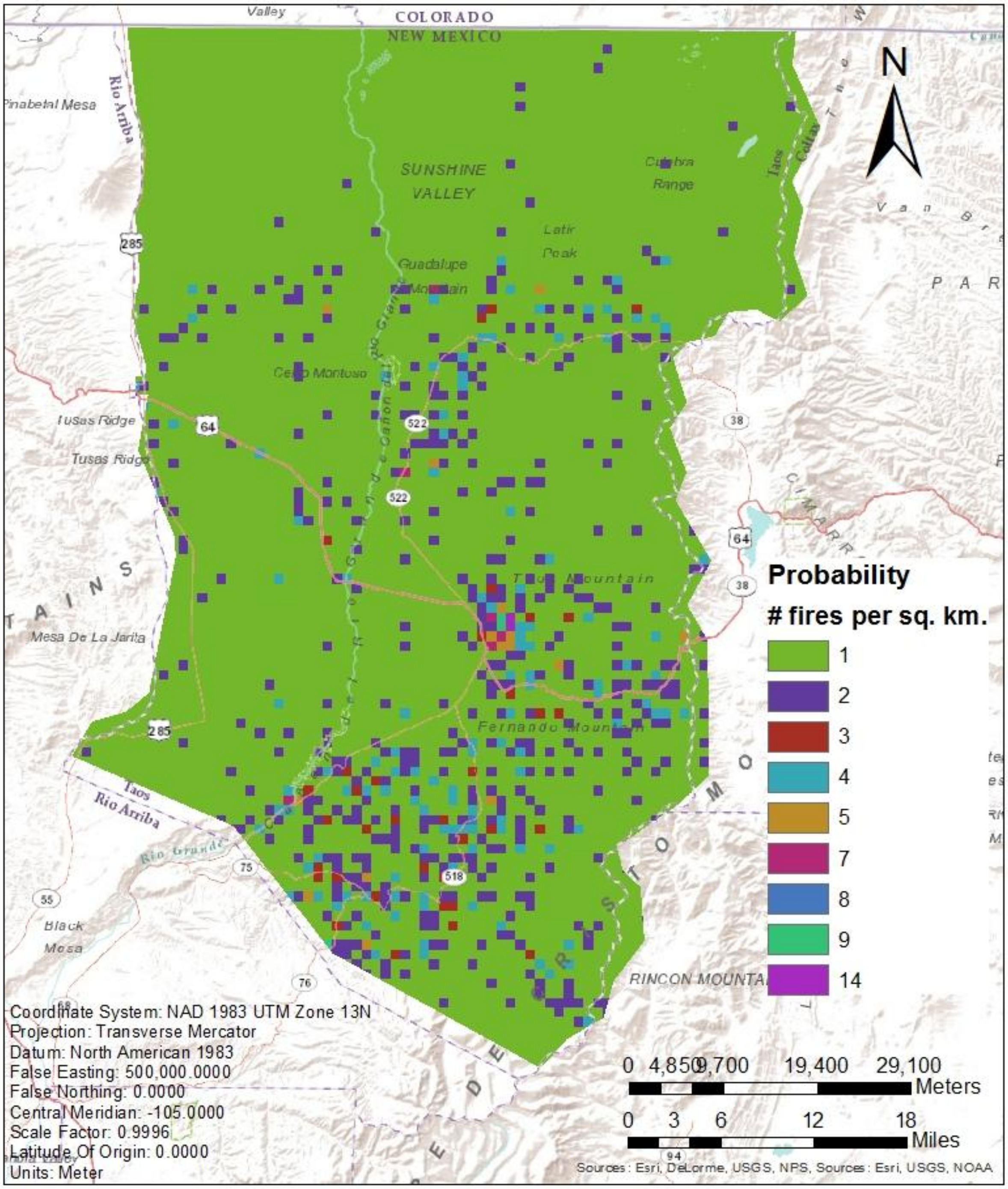
Author: Natalia M. Sanabria Date: 5/2/2013

Flame Length Risk
Taos, New Mexico



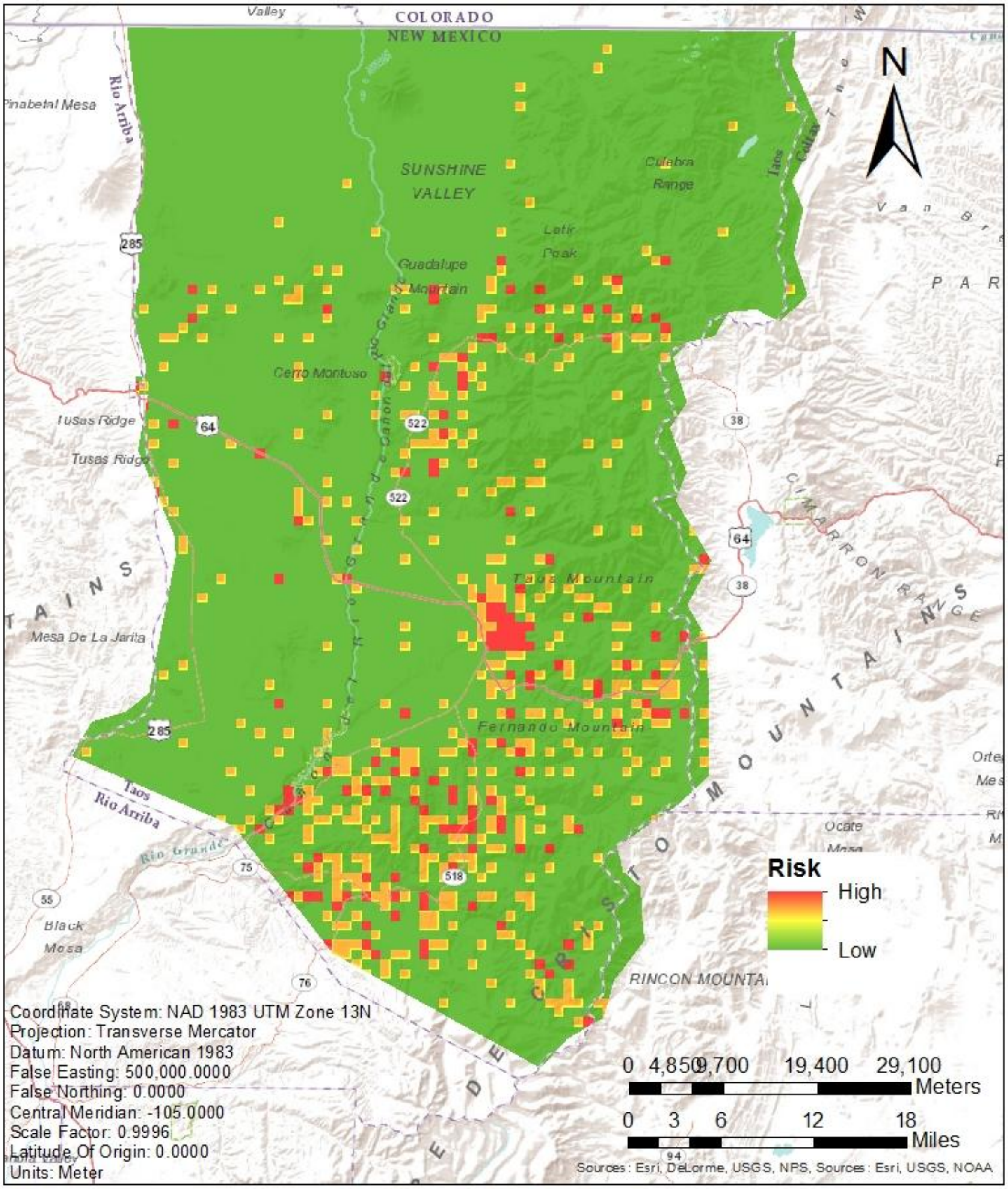
Author: Natalia M. Sanabria Date: 5/2/2013

Ignition Probability
Taos, New Mexico



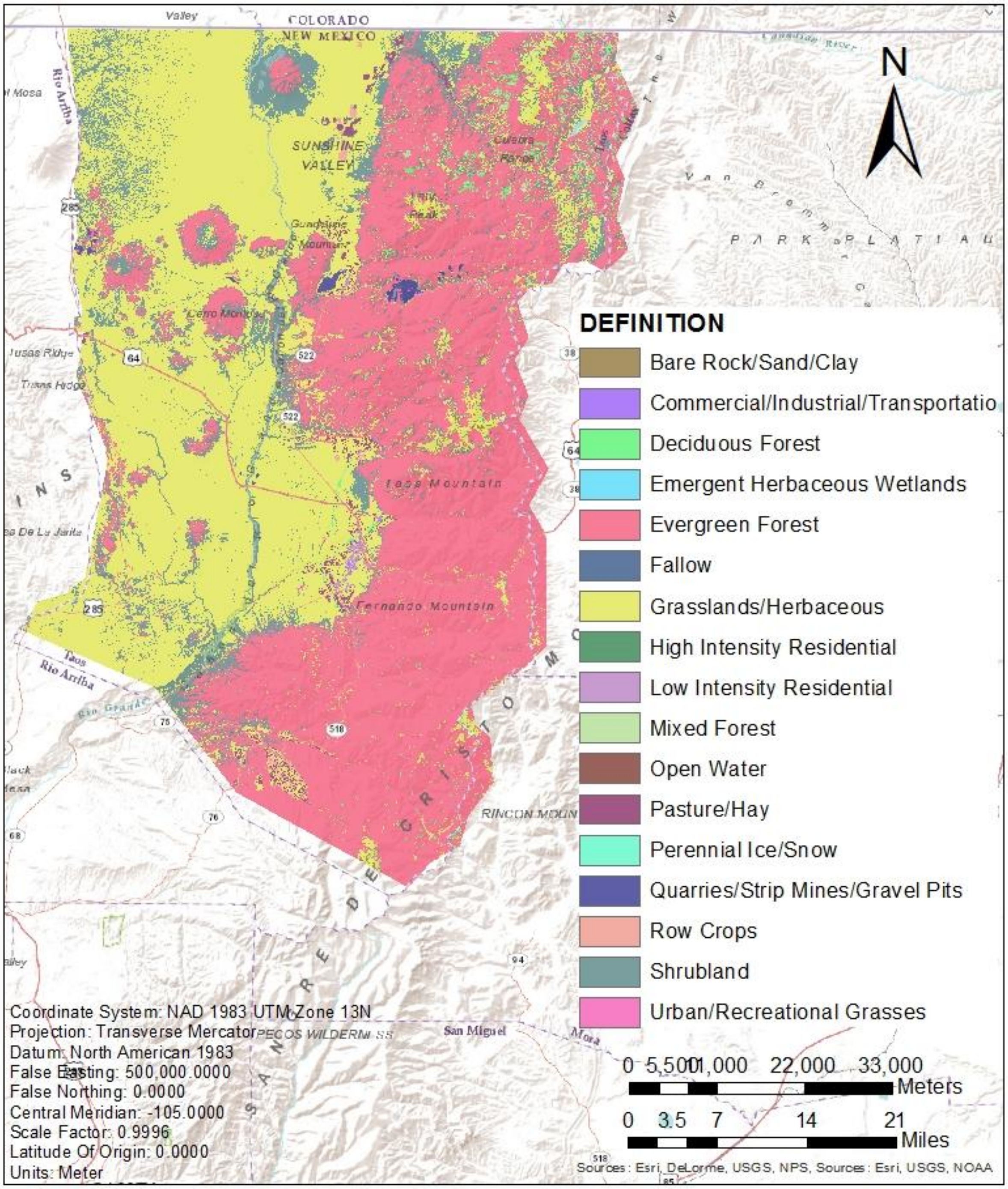
Author: Natalia M. Sanabria Date: 5/2/2013

Ignition Probability Risk
Taos, New Mexico



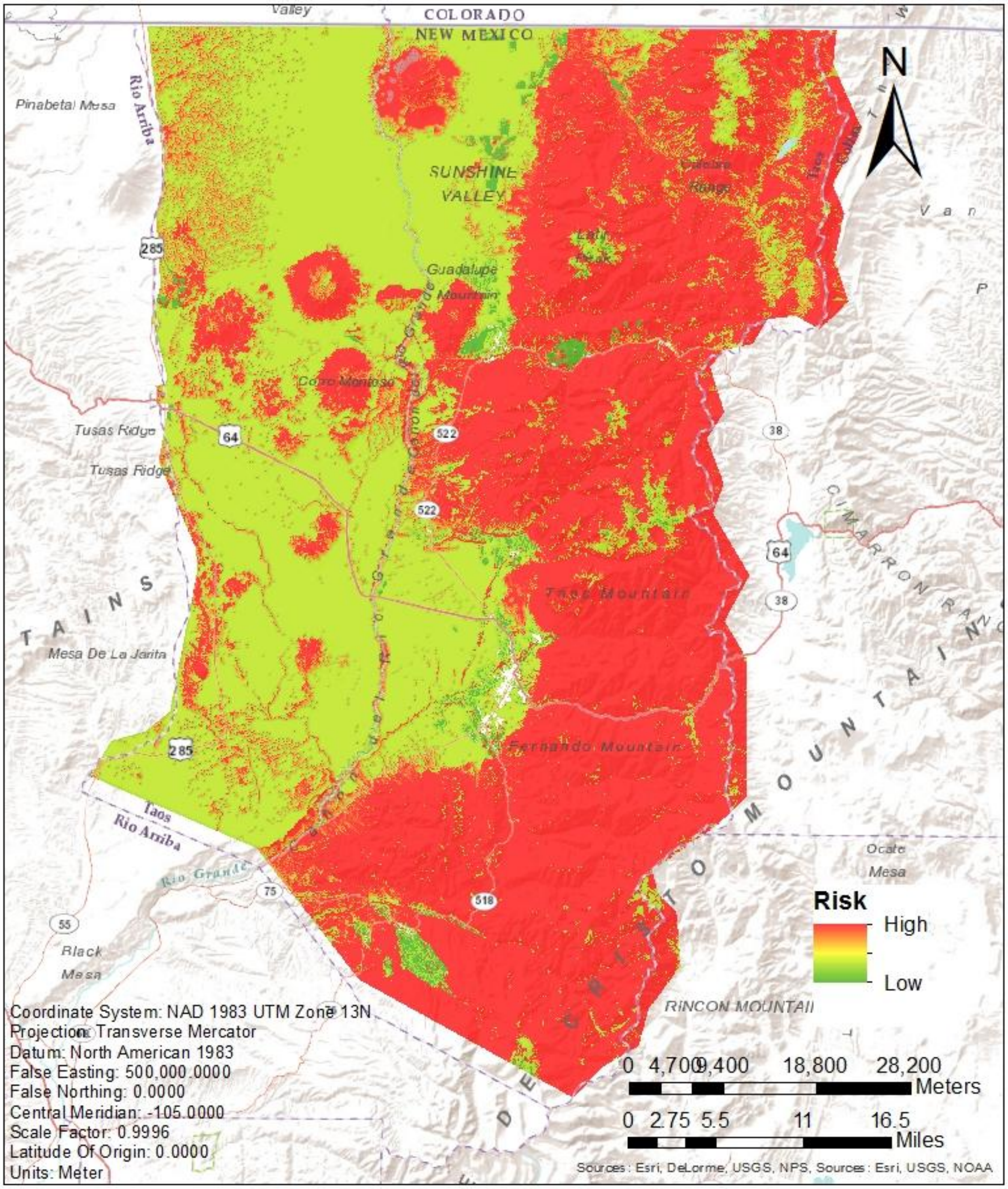
Author: Natalia M. Sanabria Date: 5/2/2013

Land Cover
Taos, New Mexico



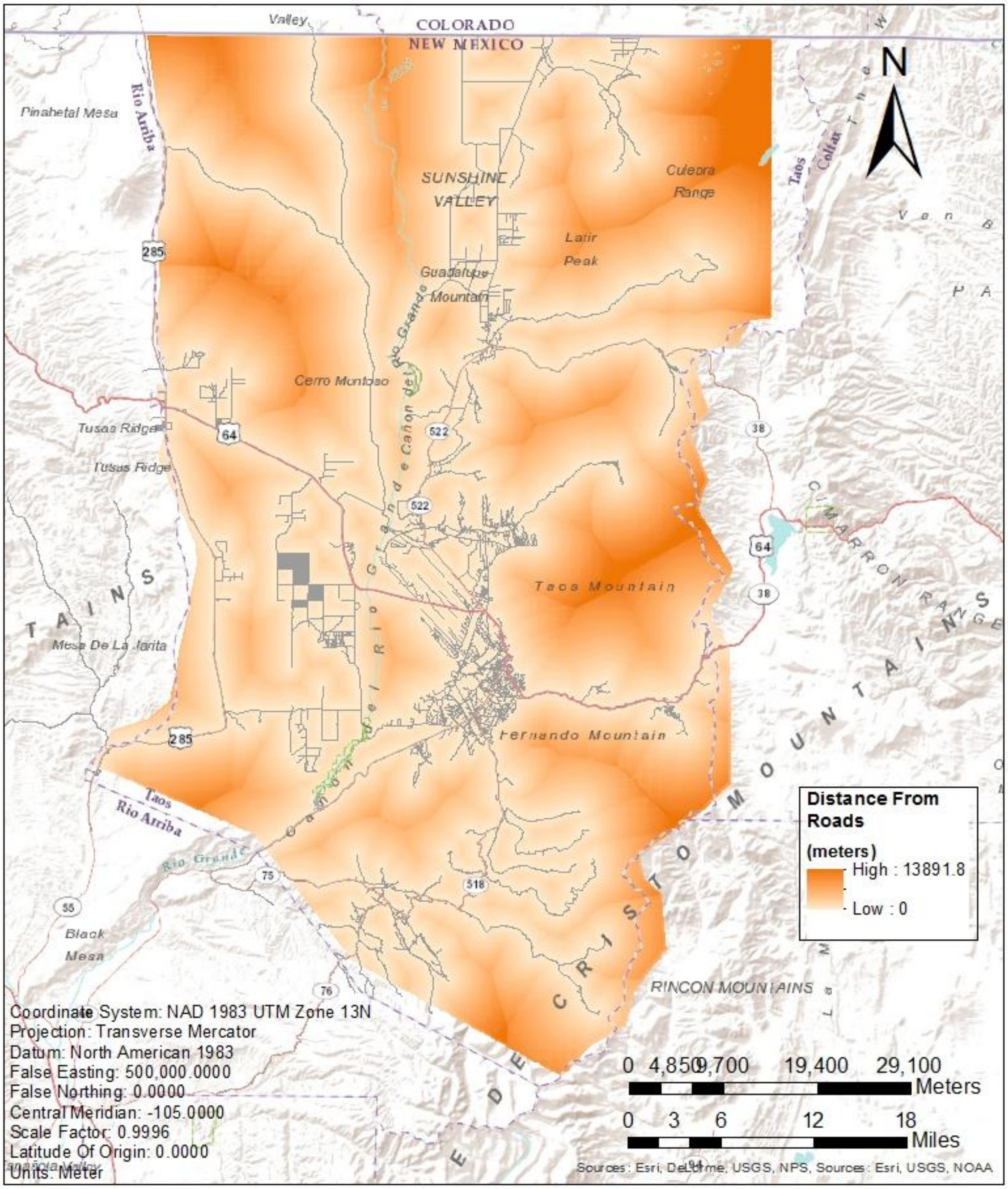
Author: Natalia M. Sanabria Date: 5/2/2013

Land Cover Risk
Taos, New Mexico



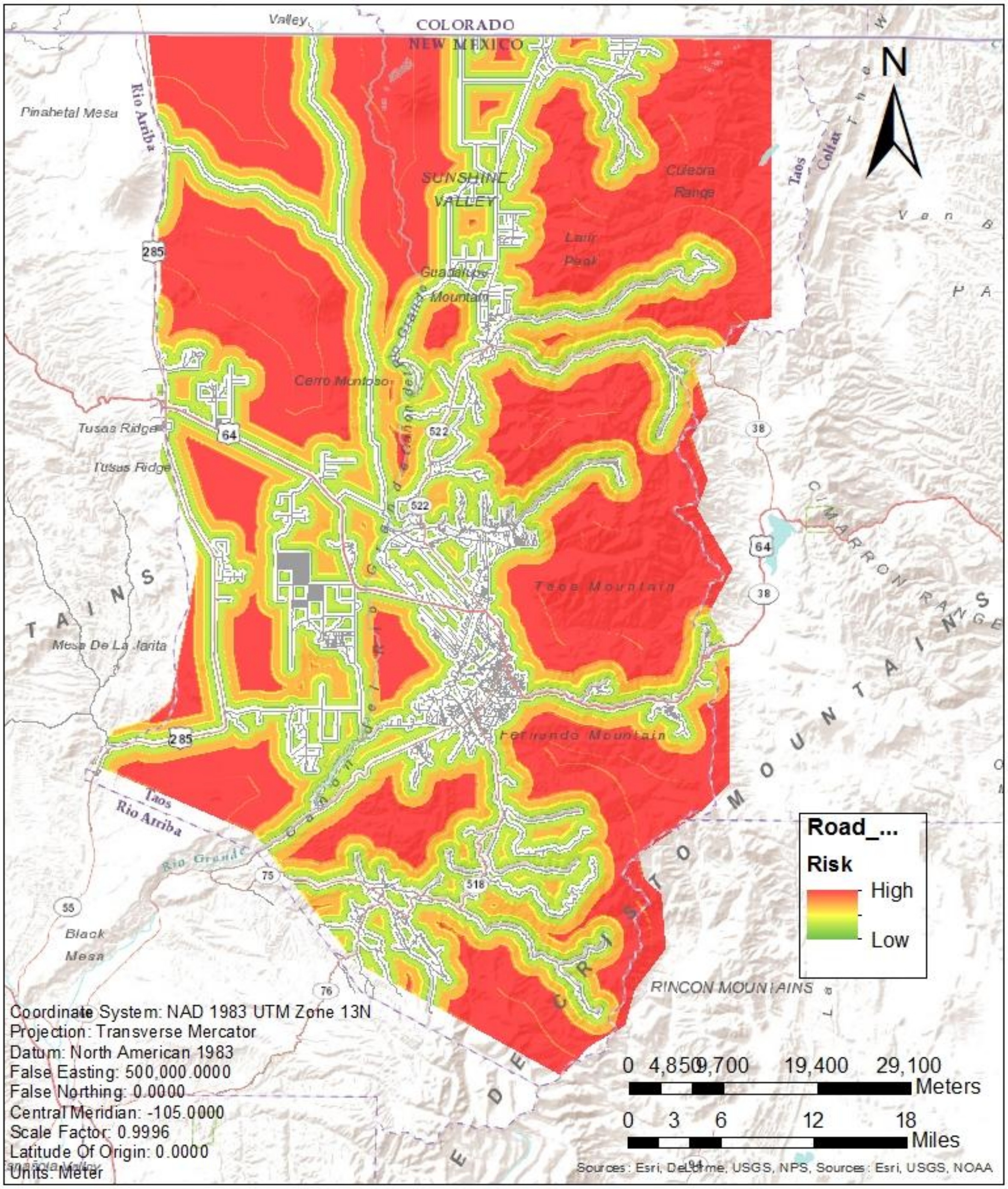
Author: Natalia M. Sanabria Date: 5/2/2013

Distance from Road Newtwork Layout
Taos, New Mexico



Author: Natalia M. Sanabria Date: 5/3/2013

Risk from Road Network
Taos, New Mexico



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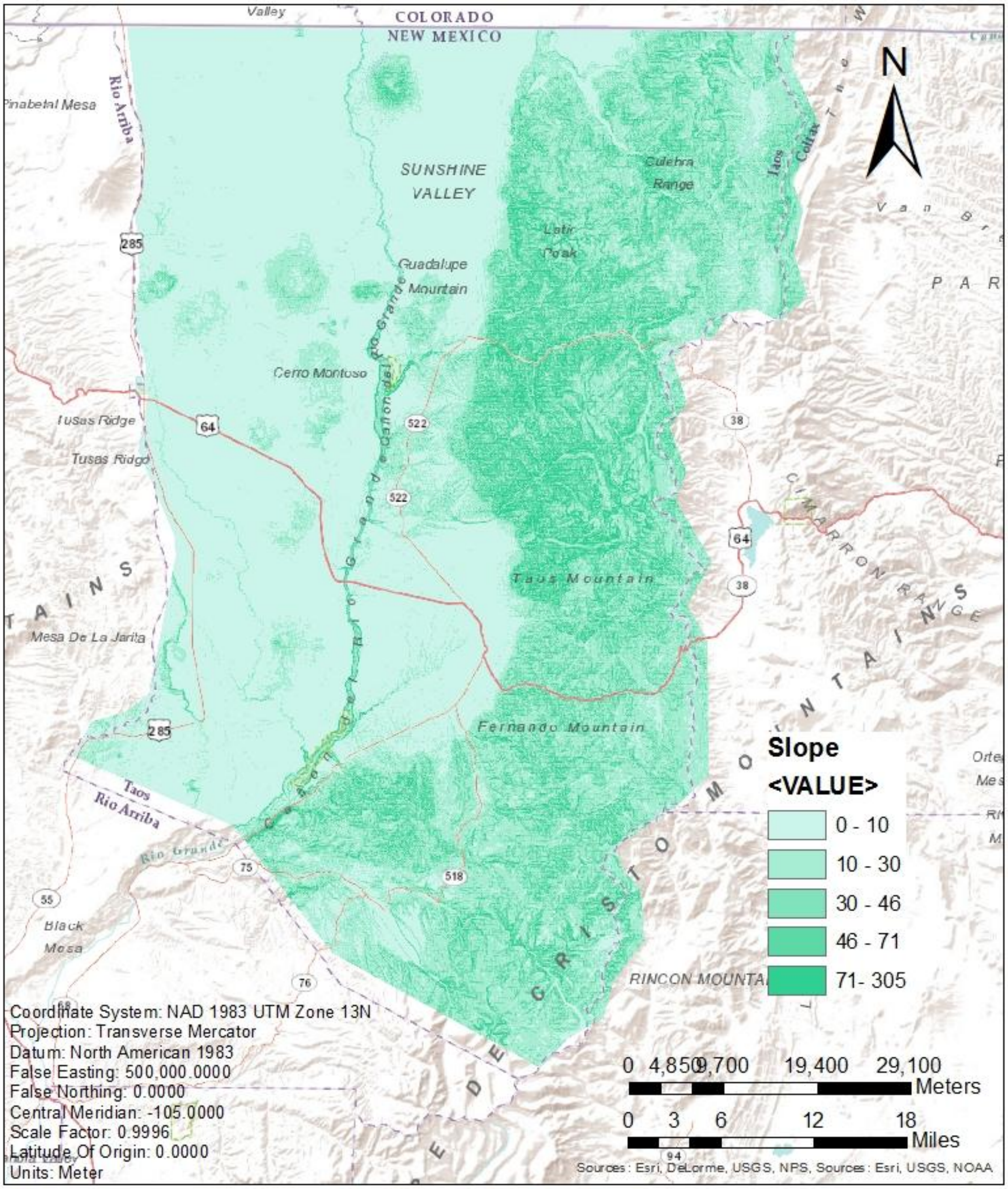
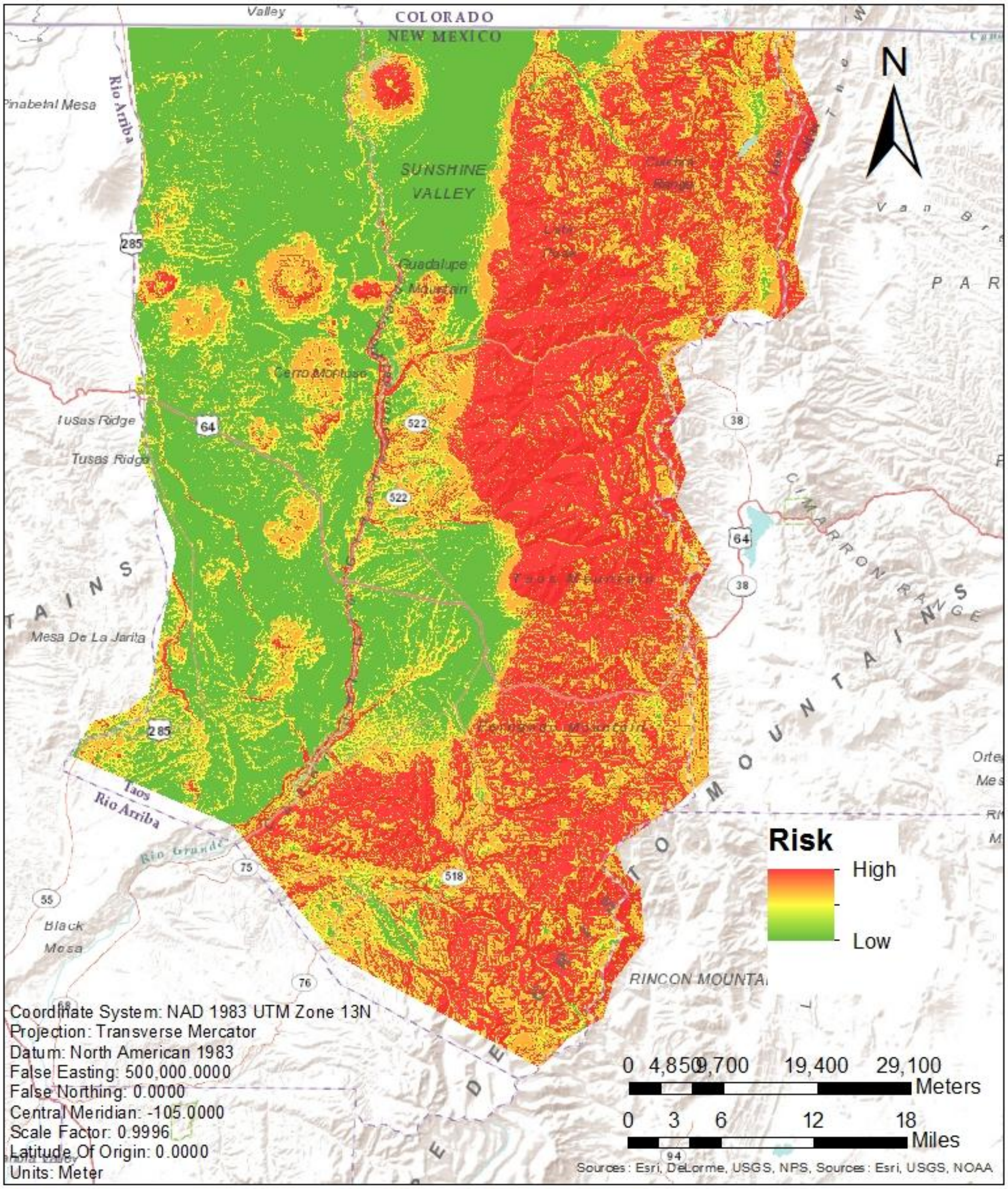
Slope in Percent Rise
Taos, New Mexico



Author: Natalia M. Sanabria Date: 5/2/2013

Slope Risk Layout
Taos, New Mexico



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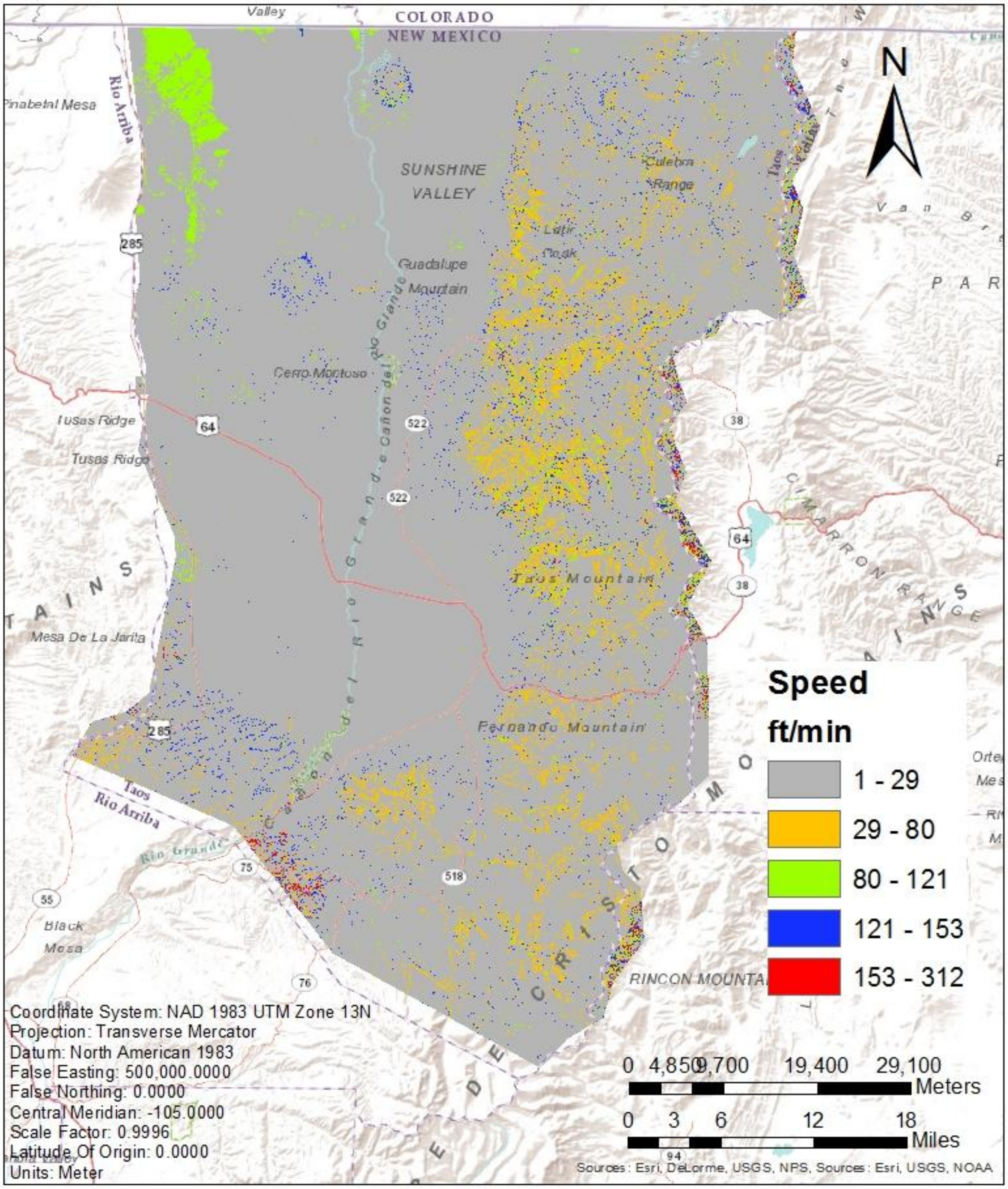
Rate of Spread
Taos, New Mexico



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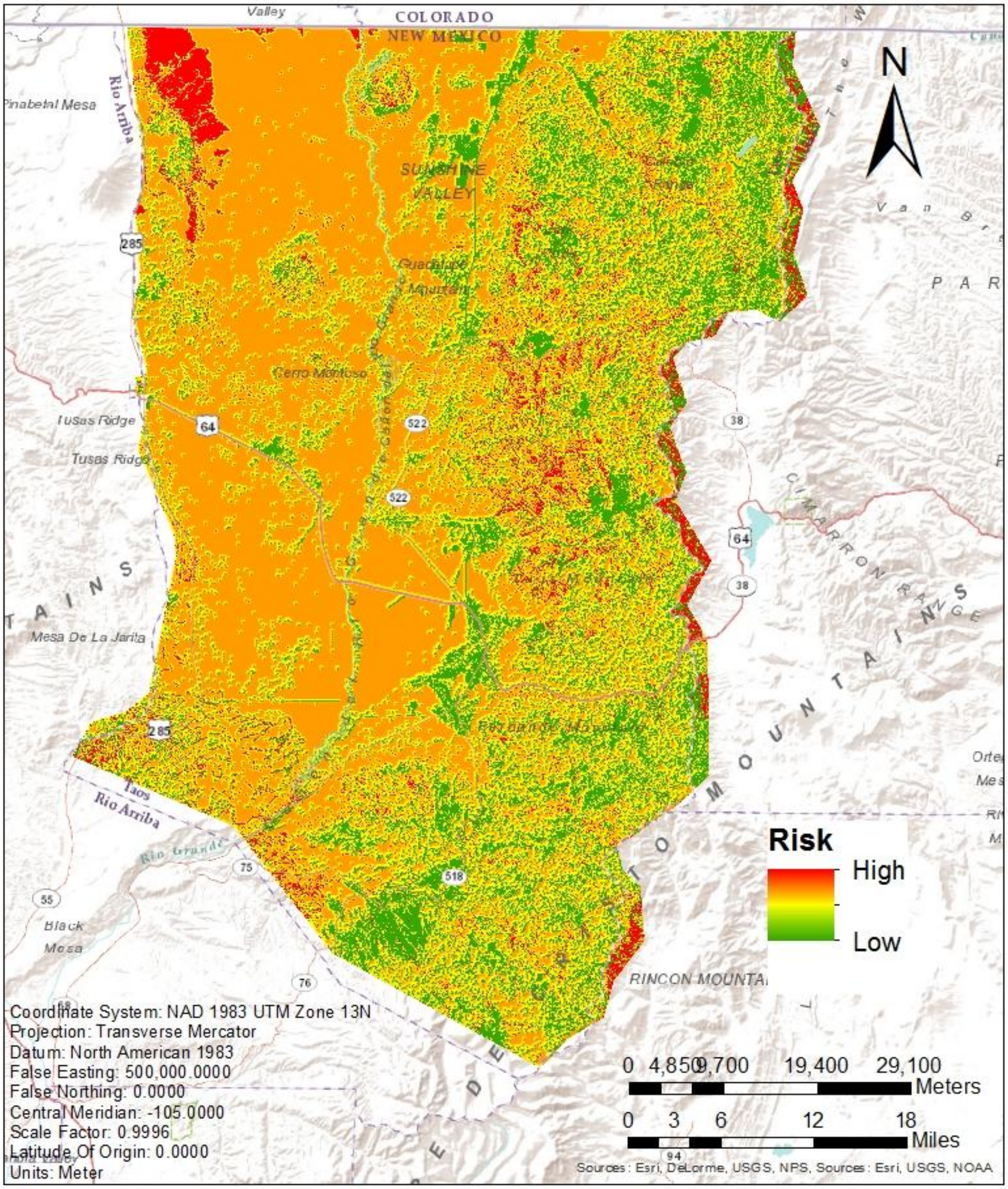
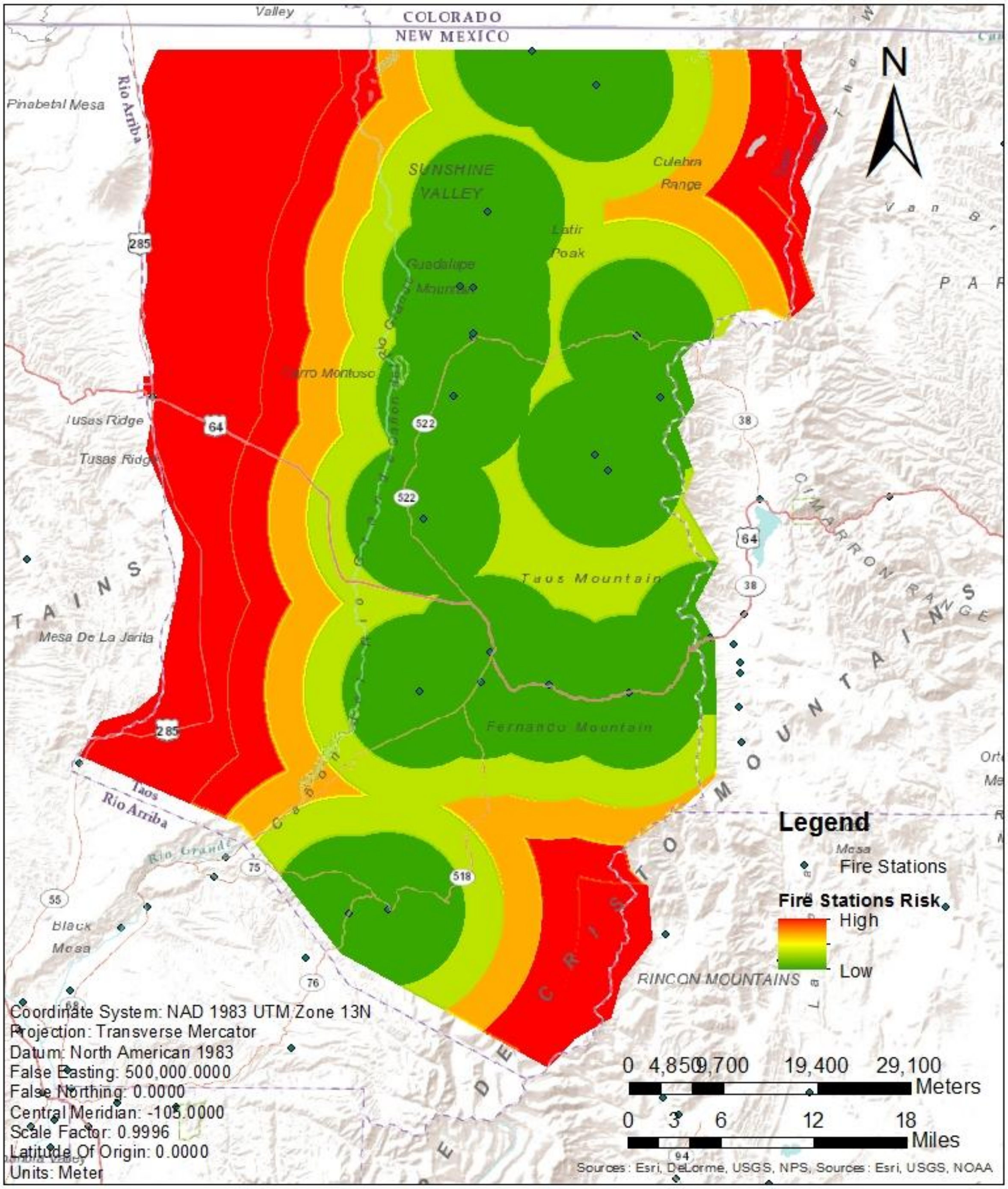
Rate of Spread Risk
Taos, New Mexico



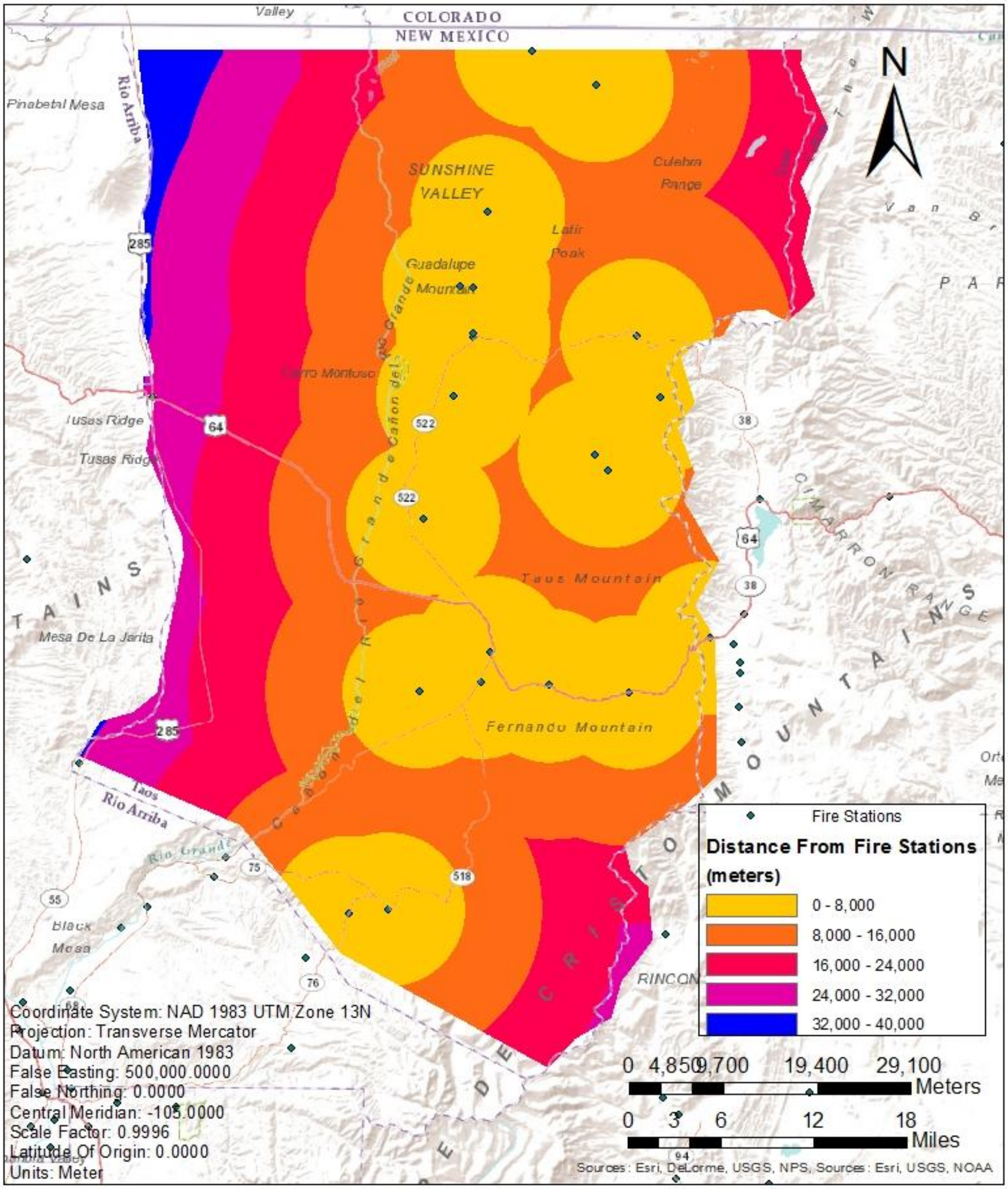
Author: Natalia M. Sanabria Date: 5/2/2013

Fire Station Risk
Taos, New Mexico



Author: Natalia M. Sanabria Date: 5/2/2013

Distance from Fire Stations
Taos, New Mexico



Author: Natalia M. Sanabria Date: 5/2/2013

Appendix D WEIGHTED RESULTS

Description:

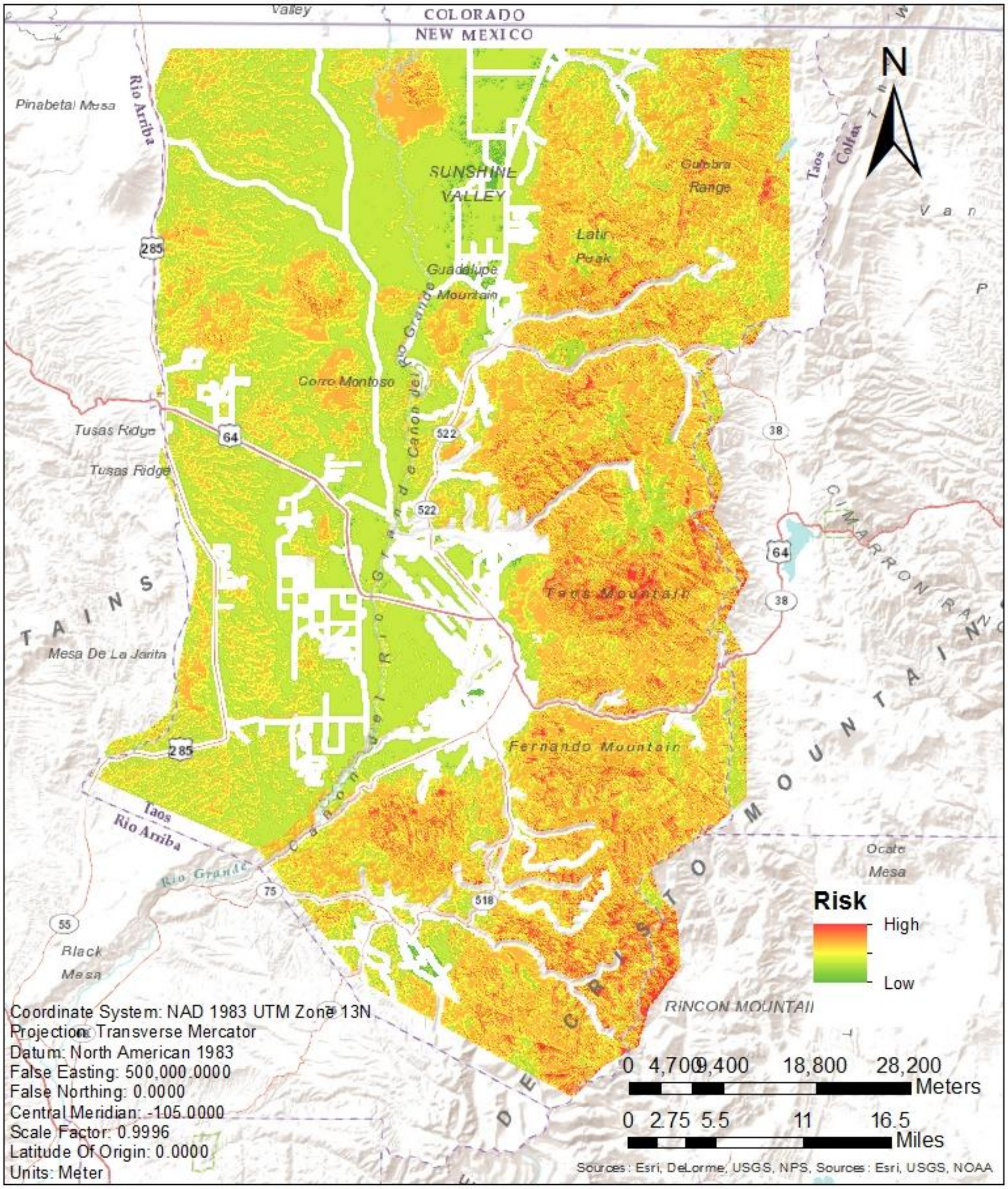
The Wildfire Risk Assessment (WRA) was calculated using the Weighted Overlay tool. The following layouts show the results using different weight values for each layer. Table D-1 shows the values for each WRA conducted. The values highlighted in yellow represent the higher value in the analysis

Table D-1: Weigth values in percent (%) for each WRA analysis

Layer	Influence (%)			
	WRA 1	WRA 2	WRA 3	WRA 4
Fire Stations	8	4	15	12
Rate of Spread	12	20	10	12
Road Distance	8	4	15	12
Land Cover	16	15	18	12
Ignition Probability	16	15	12	16
Slope	12	16	10	12
Aspect	12	16	10	12
Flame Length	16	10	10	12
Total	100	100	100	100

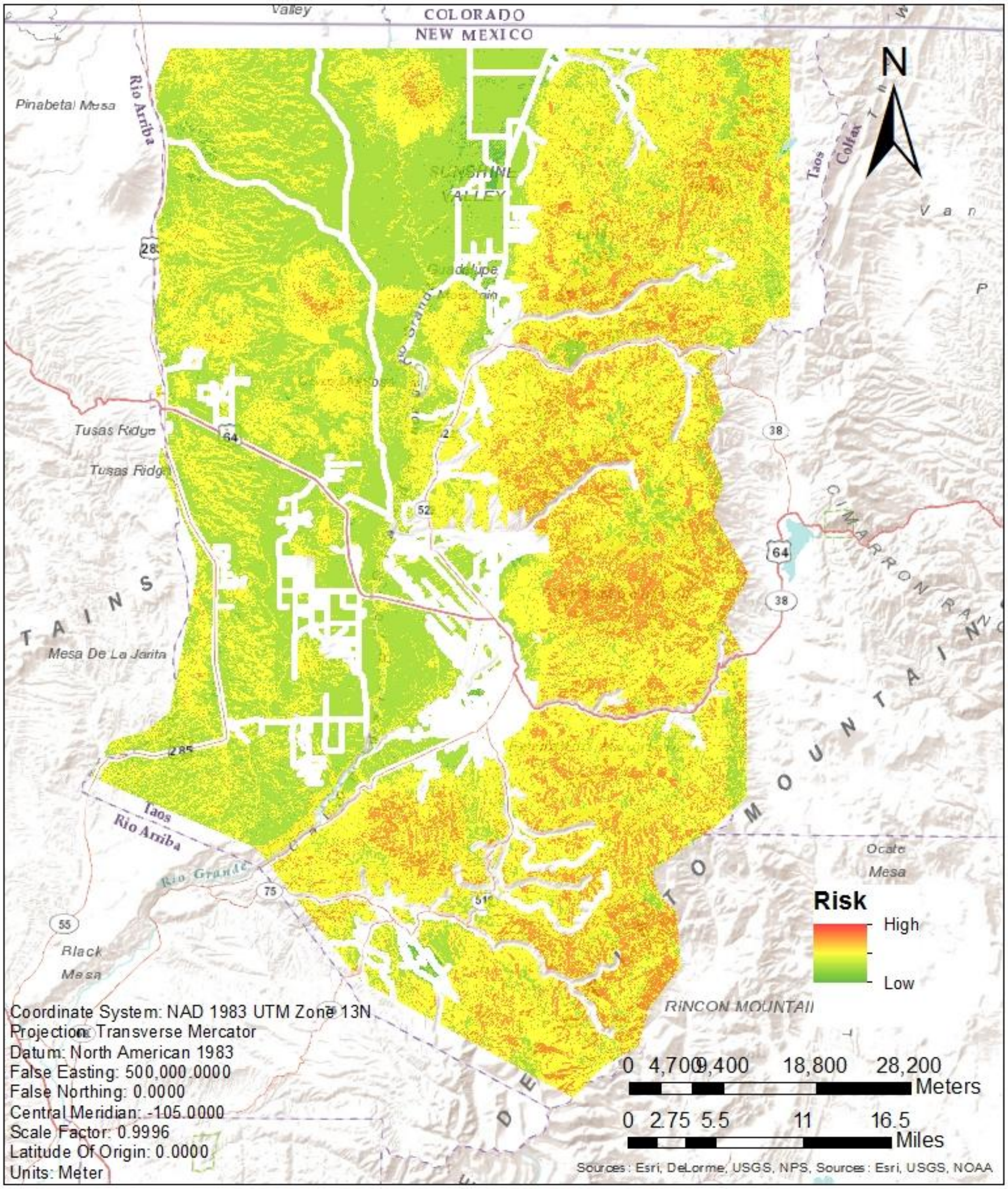
* WRA= Wildfire Risk Assessment

Wildfire Risk Assessment
Taos, New Mexico



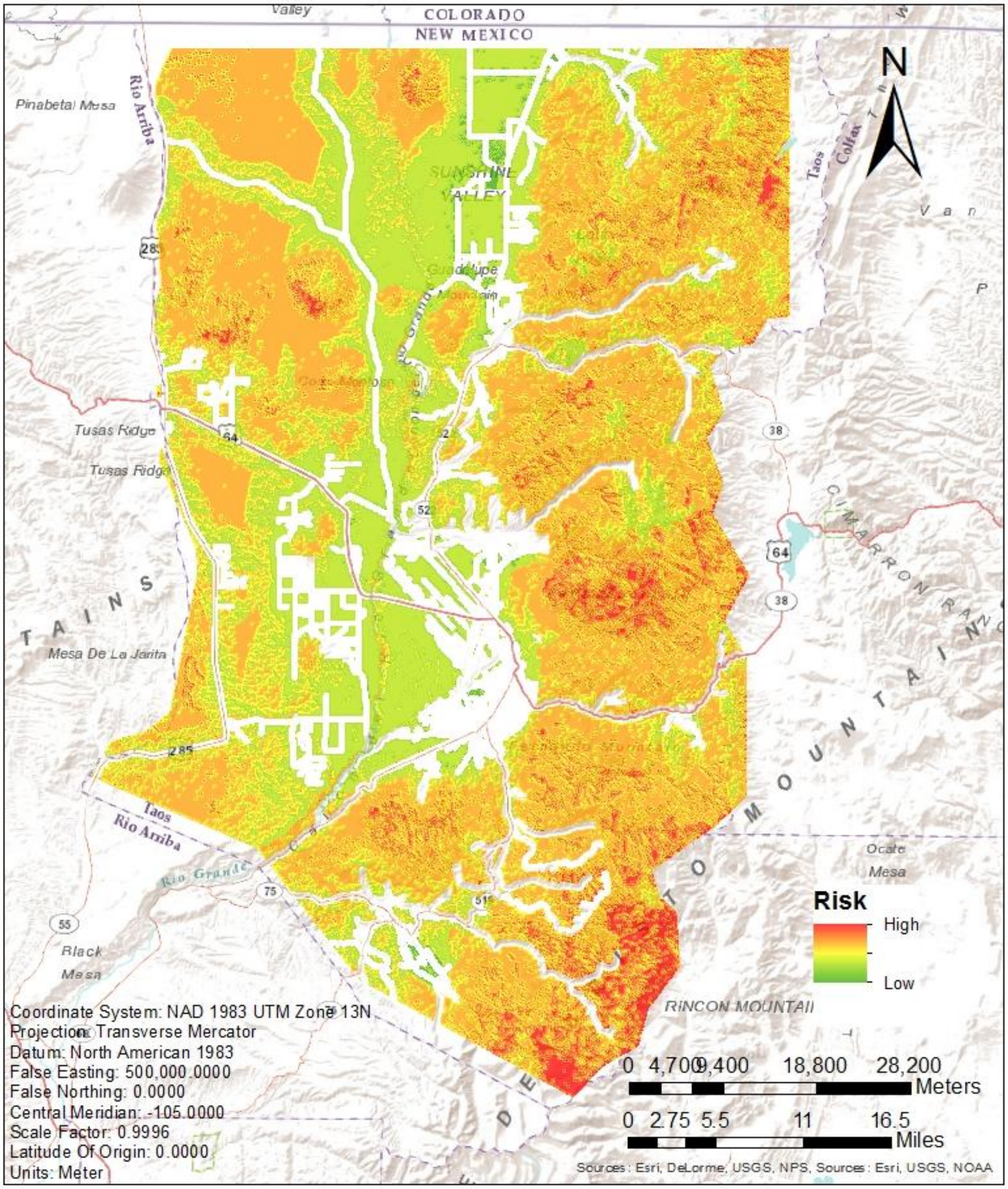
Author: Natalia M. Sanabria Date: 5/2/2013

Wildfire Risk Assessment 2
Taos, New Mexico



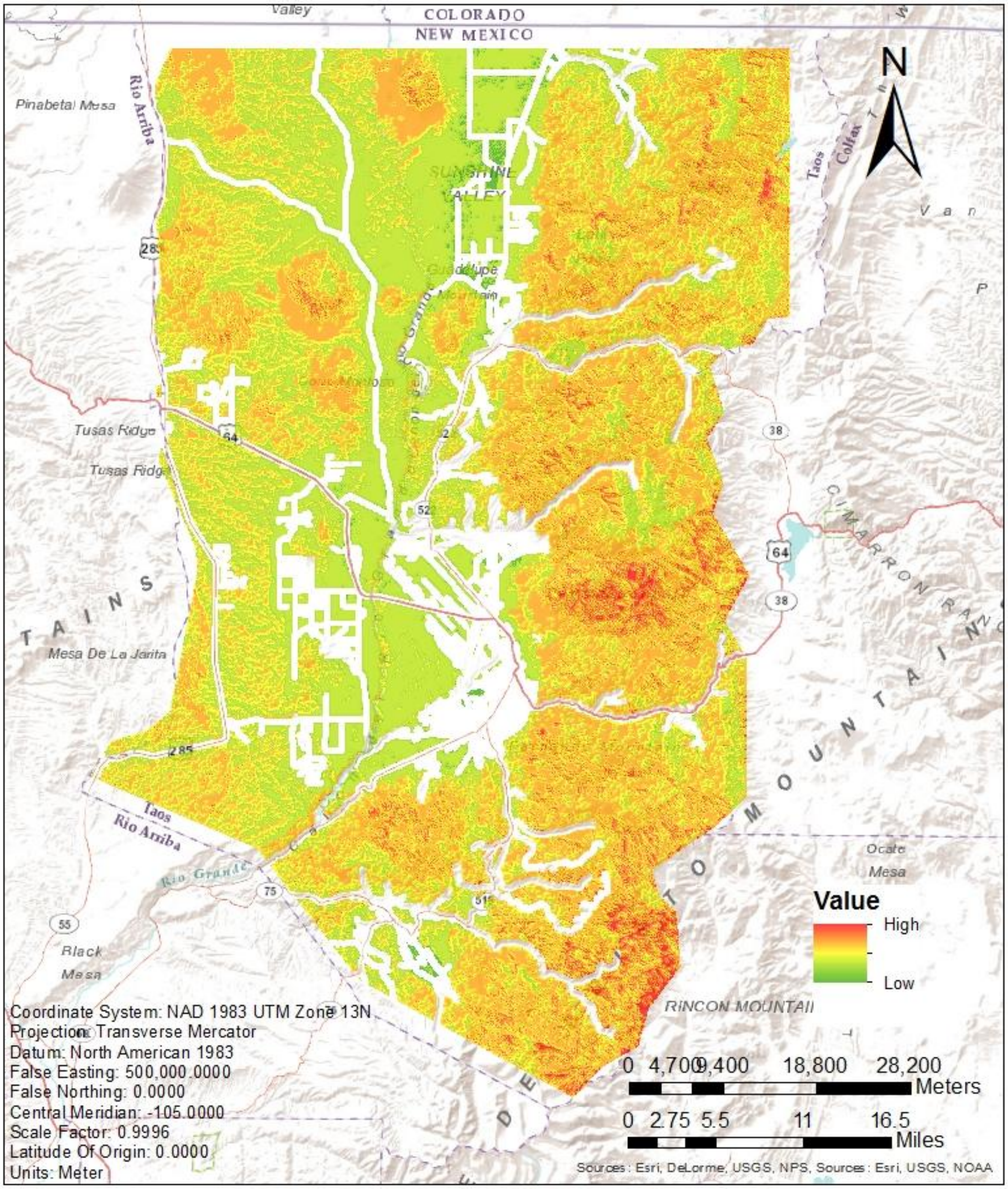
Author: Natalia M. Sanabria Date: 5/2/2013

Wildfire Risk Assessment 3
Taos, New Mexico



Author: Natalia M. Sanabria Date: 5/2/2013

Wildfire Risk Assessment 4
Taos, New Mexico



Author: Natalia M. Sanabria Date: 5/2/2013