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Modeling Mohave Ground Squirrel Habitat

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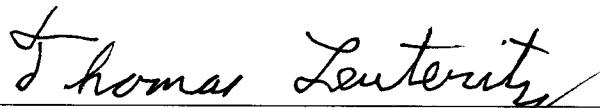for the degree of Master of Science in Geographic Information Systems

By
Ernesto Carreras-Díaz

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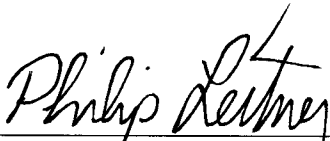
December 2006

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Modeling Mohave Ground Squirrel Habitat

The report of Ernesto Carreras-Diaz is approved.

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December 2006

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ABSTRACT

Modeling Mohave Ground Squirrel Habitat

By
Ernesto Carreras-Diaz

The Mohave ground squirrel (*Spermophilus mohavensis*) is endemic to the northwestern region of the Mojave Desert. It is currently considered a threatened species by the state of California. Habitat loss due to human development within the species' limited geographic area has been identified as a major contributor to the species' threatened status. Habitat degradation due to livestock grazing, military training, and the increased abundance of invasive and non-invasive plant species are also serious conservation issues. It is important to be able to identify remaining areas of suitable habitat in order to conserve and manage viable Mohave ground squirrel populations.

This project consisted of developing a habitat suitability model for the Mohave ground squirrel. The weighted overlay model approach was chosen after reviewing its effectiveness in similar case studies. This model allowed the combination of selected variables for integrated analysis that have been identified as important for the occurrence of the species. The Weighted Overlay tool from the Spatial Analyst toolbox – ArcGIS 9.1 was used to accomplish this task.

The model was designed by assigning values of relative importance to the datasets as well as to layers themselves. The variables used were: elevation, slope, land cover, vegetation, geomorphology, mean winter precipitation (1976 – 2006), percentage of dry periods (1976 – 2006), and consecutive dry winter periods (1976 – 2006).

The results obtained from the model will help to identify areas that are important for the conservation of the Mohave ground squirrel. It can be tested for accuracy against actual field data and modified to upgrade its predictive performance. This model will serve as a tool to help understand habitat variables that are critical for the survival of the species. It will also aid researchers in gathering more information on the species itself and its habitat requirements.

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List of Acronyms

ASCII	American Standard Code for Information Interchange
BLM	Bureau of Land Management
CNDDB	California Natural Diversity Database
COM	Component Object Model
DFG	Department of Fish and Game
DOQ	Digital Orthophoto Quadrangle
DRG	Digital Raster Graphic
EROS	Earth Resources Observation Systems
ESRI	Environmental Systems Research Institute
GAP	Gap Analysis Program
GCS	Geographic Coordinate System
GHz	Gigahertz
GIS	Geographic Information Systems
Mb	Megabyte
MDEP	Mojave Desert Ecosystem Program
MGS	Mohave ground squirrel
NAD	North American Datum
PRISM	Parameter-elevation Regressions on Independent Slope Model
RAM	Random Access Memory
RI	Redlands Institute
SOMA	Single Output Map Algebra
USDIFWS	United Stated Department of Interior Fish and Wildlife Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VBA	Visual Basic for Applications
WGS	World Geodetic System

1. Introduction

The Mohave ground squirrel *(Spermophilus mohavensis)* is endemic to the northwestern Mojave Desert and occupies the smallest geographic range of the seven species of *Spermophilus* ground squirrels in California (Gustafson, 1993). It is currently listed as a threatened species by the state of California because of destruction and loss and degradation of habitat within its limited geographic area (Brooks & Matchett, 2002).

Gustafson (1993) reported that the Mohave ground squirrel is found at elevations up to 1,707 meters, and has been recorded in all natural habitats within its 19,684 square kilometers range. The term "habitat" is usually defined broadly, to include all of the environmental variables that are associated with the distribution and occurrence of a particular wildlife species; it would include the vegetation communities, soil types, topography and landforms, elevation range, and climatic regime (P. Leitner, personal communication, February 16, 2006). Wessman (1977) determined that "[the most favorable] habitats at lower elevations include open desert scrub, creosote-burrobush, and saltbush communities, [and] optimal habitats at higher elevations include Joshua tree woodland and monotypic blackbrush" (p. 10). Aardahl and Roush (1985) stated that preferred habitats for this species were "large alluvium-filled valleys with deep, fine-to-medium-textured soils vegetated with creosote scrub, shadscale scrub, or alkalai sink scrub and with no desert pavement …" (Methods section, ¶ 4). According to Best (1995), "[Mohave ground squirrels] typically construct burrows in the sandy soils of desert washes, [basins, and alluvial slopes]," while steep slopes and rocky terrain are generally avoided (Zembal & Gall, 1980).

According to Leitner (2001), there have been declines in the distribution and abundance of this species even in areas where there is no obvious habitat disturbance. It is known that Mohave ground squirrel populations decline in abundance after extended periods of low winter rainfall (Leitner & Leitner, 1998). However, an analysis of field studies conducted during the period 1980 – 2000 has indicated a significant reduction in trapping success over most of the range in spite of an increasing trend in winter rainfall (Brooks & Matchett, 2002). Leitner (1999) identified a number of factors that may be related to the reduction of the species' population in the desert. These include climatic changes, the increased abundance of invasive and non-native plant species, increasing predation, disease, and toxic contaminants. A better understanding of the distribution and habitat needs of the Mohave ground squirrel is crucial for its conservation. As recognized by Leitner (1999), "… little is known about the habitats needed by the squirrel or even where it still occurs" (p. 2). This information is important in order to develop a viable effective conservation plan for the species (P. Leitner, personal communication, February 16, 2006). For this reason, potentially significant habitat variables were selected for this study in order to predict suitable Mohave ground squirrel habitat. The method used for this study was weighted overlay analysis, which combines multiple datasets by assigning assessment scale values and the amount of influence to the values in each variable. The analysis of these different variables in determining the Mohave ground squirrel's suitable habitat will be explained in Chapter 3.

1.1. Client

The client for the study is Dr. Phil Leitner, a wildlife biologist and a professor of biology at St. Mary's College in Moraga, California. Dr. Leitner began studying the ecology and natural history of the Mohave ground squirrel in 1978. He directed the only long-term study of this endemic California desert species at four sites in the Coso Range of Inyo County (1988 – 1996). Since 1999, he has conducted surveys for the Mohave ground squirrel at numerous other locations throughout the western Mohave Desert. He has served as Project Director for the Mohave Ground Squirrel Research & Monitoring Program based at California State University, Stanislaus and funded by the California Department of Fish and Game (2001 – present). Dr. Leitner has more than 30 years of experience as a biological consultant on numerous wildlife species throughout California.

1.2. Client Expectations

The main purpose of this study is to develop a predictive habitat model for the Mohave ground squirrel that will help the client to resolve management issues, especially:

1. Identification of public lands to manage for the conservation of the species, and;

2. Identification of private lands to acquire for conservation when they become available.

The predictive model will improve the ability to locate areas that still support Mohave ground squirrel populations. When these areas are identified, researchers will be able to obtain a better understanding of their habitat requirements and assess their conservation status.

The historic range of the Mohave ground squirrel encompasses approximately 19,684 square kilometers in the western Mojave Desert. For the purpose of this study, the area was buffered 10 miles to guarantee that the whole Mohave ground squirrel range was included. When buffered, the area surrounding the Mohave ground squirrel range increases to 32,585 square kilometers. The map on the next page (Figure 1) shows more precisely the study area being located within the western Mojave Desert. This model will be based on a raster representation in which each cell would be at least 4 km on each side.
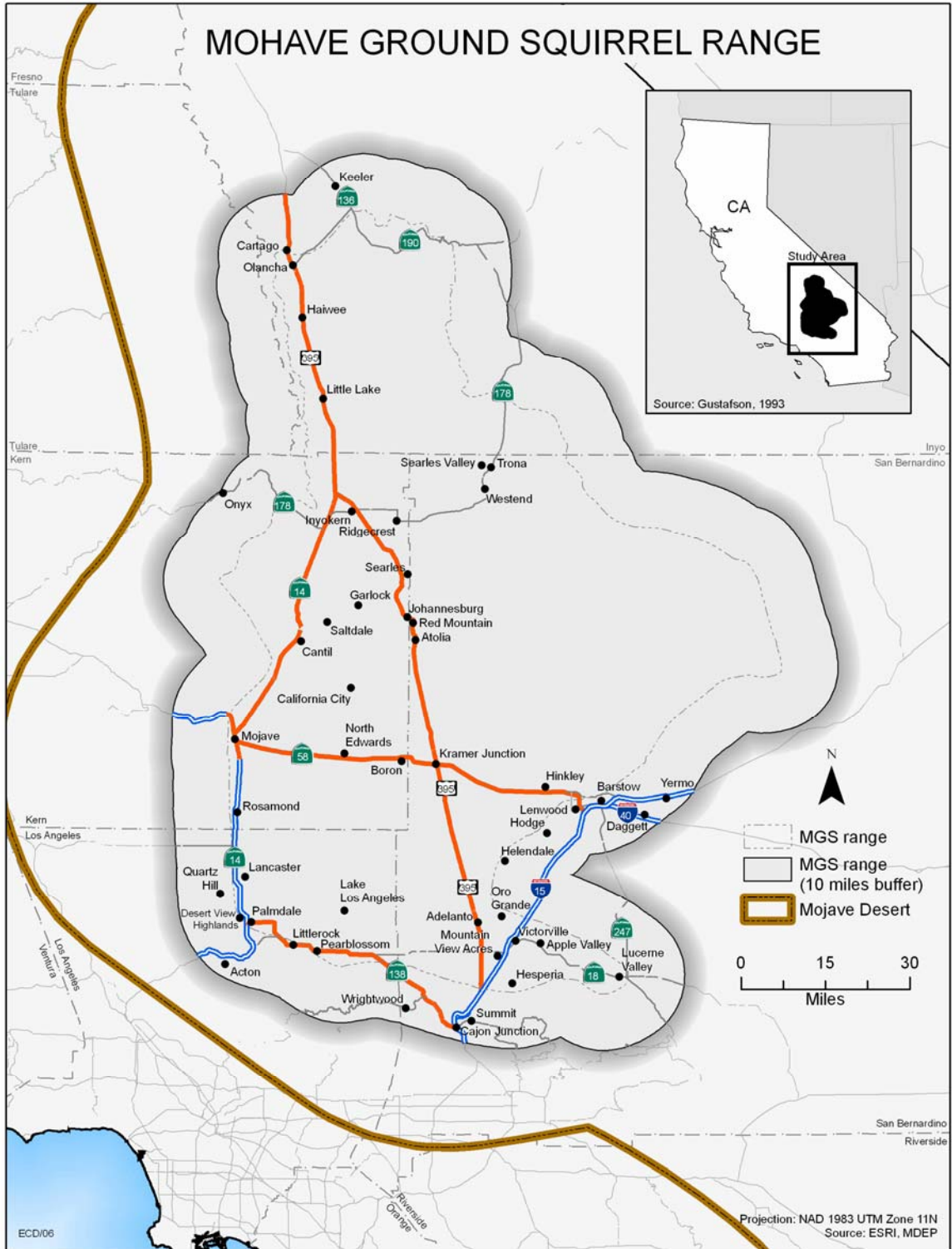
Figure 1: Mohave ground squirrel range.

2. Background and Literature Review

The Mojave Desert covers more than 32 million acres within four states: California, Nevada, Arizona, and Utah. The map on Figure 2 shows the extent covered by what is known as the Mojave Desert Ecoregion. World Wildlife Fund (2005) defines "ecoregion" as a relatively large unit of land or water that is characterized by a distinctive climate, ecological features, and plant and animal communities.

Figure 2: Mojave Desert Ecoregion.

The Mojave Desert includes 20 million acres within California, making-up one-fifth of the state (California Department of Fish and Game [CDFG], 2006). The Wildlife Action Plan report (CDFG, 2006), indicates that "[federal agencies manage] about 80% of the desert in California." The study, *Conservation and Trust Lands dataset* (2004), by the California Resources Agency (as cited in CDFG, 2006) states the following:

1. The Bureau of Land Management (BLM), the largest land manager of the region, … [manages] 41% of the [federal land of the desert area in California].

2. The National Park Service manages … 26% of the [desert] region.

3. The Department of Defense manages five military bases … [which comprise another] 13% of the region.

4.	[California] State Parks and [California Department of] Fish and Game …
[manage another] 0.32 percent of the [area], and about 18% of the region
belongs to private landowners or municipalities. (p. 55).
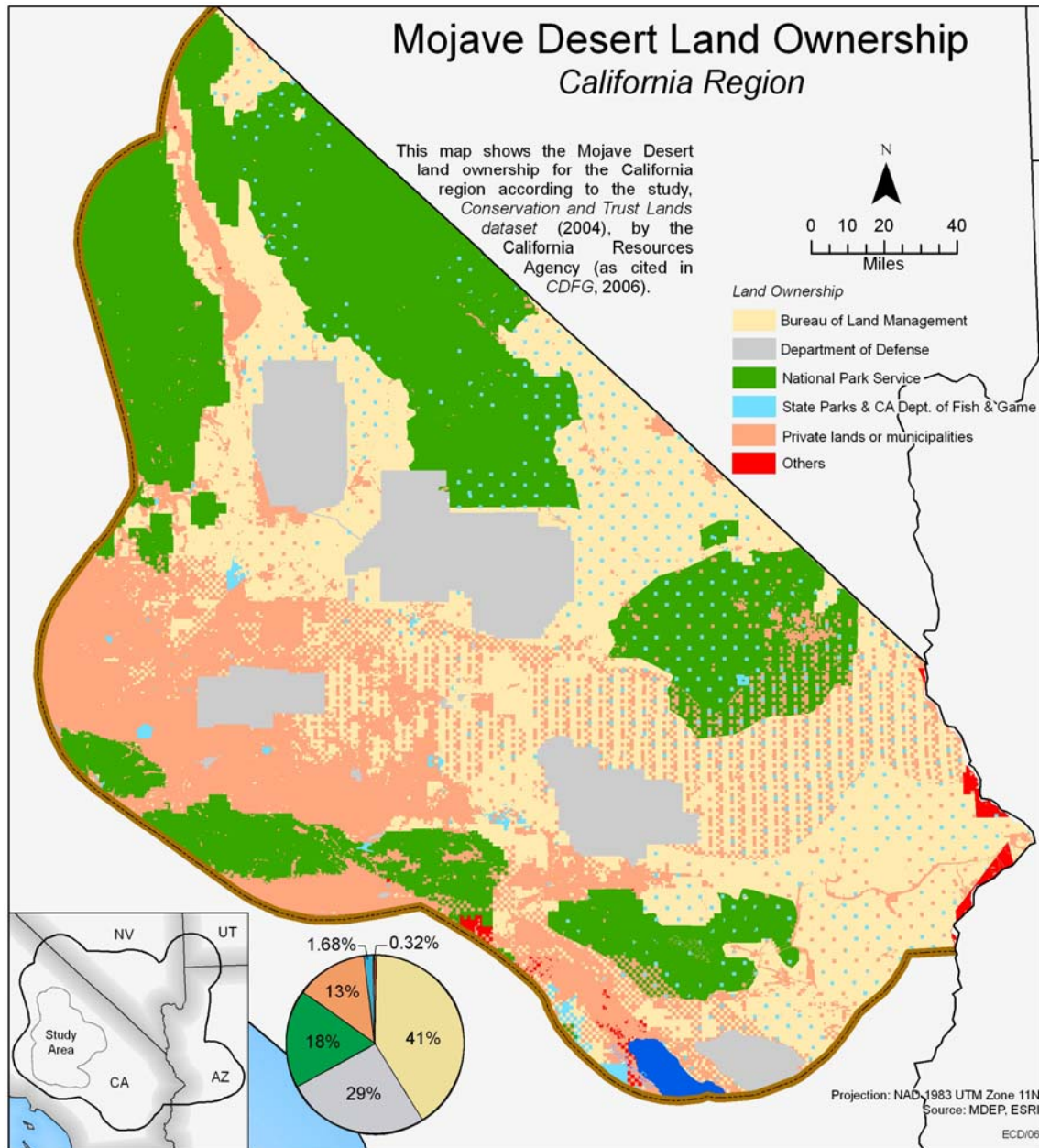
Figure 3: Mohave Desert Landownership, CA Region.

The map on Figure 3 shows the land ownership distribution across the Mojave Desert
within California. It is crucial to understand the pattern of land ownership across the
Mojave Desert in order to appreciate the complexity of conserving biodiversity here.

A great number of plants and wildlife species are found within the Mojave Desert
ecoregion. Historically, the threats to the desert's wildlife populations have increased
steadily throughout the years. Since the enactment of the Federal Land Policy and
Management Act, new threats have become apparent (CDFG, 2006). Multiple studies

have recognized diverse threats to the desert's biodiversity. Among the threats recognized by the CDFG Wildlife Action Plan report are: rapid urban growth, off-highway vehicle activity that adds to thousands of miles of dirt roads and trails, cattle and sheep grazing, overdrawn groundwater, and increasing dominance of invasive plant species (CDFG, 2006). As a result, there has been increasing ecosystem fragmentation, wildlife habitat degradation, and desert ecosystem disruption (CDFG, 2006). While the Mojave Desert is home to a vast biodiversity of species, many desert species have been declining because of the continuing destruction of their environment. Thus, some species have been identified as species at risk (CDFG, 2006).

The Mohave ground squirrel is recognized of being at risk, like the desert tortoise (*Gopherus agassizii*) and the Amargosa vole (*Microtus californicus scirpensis*). As stated in CDFG (2006), "[being] endemic to the western Mojave Desert, the Mohave ground squirrel is especially adapted to the hot, dry desert" (p. 64). Studies have determined that spring and early summer are their most active seasons (CDFG, 2006). After periods of sufficient winter rain, there is an abundance of food resources and the squirrels produce their young (CDFG, 2006). According to Harris and Leitner (2004), "[A] winter drought makes it difficult for adult females to meet the energy demands of reproduction and [instead they] accumulate fat reserves needed for dormancy" (p. 518). "The squirrel's desert survival adaptations, long seasonal inactive periods, and the skipping of reproduction in drier years make it very difficult for biologists to conduct studies of its distribution and abundance" (CDFG, 2006, p. 113).

According to Gustafson (1993), the major threats to the survival of the Mojave ground squirrel are drought, habitat destruction, habitat fragmentation, and habitat degradation. He stated that drought is a natural phenomenon which "result[s] in decreased productivity of annual plants and shrubs in local areas" (Gustafson, 1993, p. 22). Best (1995) confirmed that "[Mohave ground squirrels] may respond to drought by failing to reproduce" (p. 5). Consecutive winter droughts may result in no young being recruited for two or more years. Best (1995) also stated that "prolonged periods of drought result in extinction of local populations" (p. 5). It can be difficult for Mohave ground squirrel populations to become re-established once they are extirpated or locally extinct because of the concomitant population impacts occurring in the region (Gustafson, 1993).

Several types of human impact are recognized as the main causes for the destruction of the squirrel's habitat. Urbanization is the main threat in certain parts of the range. Human developments, such as the construction of suburban housing, agricultural fields, military training areas, and others have resulted in the loss of almost 165,000 acres (258 sq miles) of habitat (Gustafson, 1993). Once the delineated spheres of influence of the urban areas are finally developed, over 750,000 acres (1,172 sq miles) of previously suitable habitat will be lost (Gustafson, 1993).

Another threat for Mohave ground squirrel populations is habitat fragmentation. As stated by Gustafson (1993), "the phenomenon of fragmentation occurs when blocks of habitat become separated by destruction of the intervening habitat …, [impeding] the gene flow between these populations" (p. 25).

Last but not least, habitat degradation is also recognized as another main threat for Mohave ground squirrel local populations. Gustafson (1993) establishes that "this occurs when the habitat is not destroyed but is damaged by natural or human induced-means" (p. 26). Some examples provided by Gustafson (1993) are off-highway vehicles and livestock overgrazing. "Livestock grazing from February to June coincides with the squirrel's active period" (CDFG, 2006, p. 65). As acknowledged in the study *The status of rare, threatened, and endangered plants and animals of California* (2005), from the California Department of Fish and Game [CDFG], "sheep and cattle consume some of the same plants that are important forage and cover for squirrels" (p. 196).

As a result of habitat degradation and loss within its small range, the species was listed as threatened under the California Endangered Species Act in 1984 (CDFG, 2006). Brooks and Matchett (2002) concluded that "over the last two decades, a decline in biologists' trapping success has raised concern that the species is still declining." In 1995, the U.S. Fish and Wildlife Service found that a petition for federal listing as threatened did not present substantial information to warrant the listing of the Mohave ground squirrel (U.S. Fish and Wildlife Service, 1995). This finding was based upon the uncertainties associated with urban growth and other threats in the Mojave Desert and the lack of credible studies documenting the true biological status of the species.

2.1. Habitat Modeling

Geographic Information System allows researchers to use spatial data to develop models that predict the geographic distribution of suitable habitat for plant and animal species. A model is defined as an abstraction and representation of reality used to represent objects, processes, or events (Kennedy, 2001). The outcomes produced by habitat models can play a significant role in the development of species-specific conservation plans.

The continuing urbanization occurring in the desert as well as many other threats represents a clear danger to the conservation and long-term persistence of the Mohave ground squirrel. The creation of a predictive habitat model will be of great utility in identifying the lands critical to the survival of the species. The habitat model will use important habitat variables to create a practical spatial representation of suitable habitat.

2.2. Case Studies

2.2.1. The Desert Tortoise Project

The desert tortoise (*Gopherus agassizii*) is a threatened species whose populations are declining in the western Mojave Desert (Redlands Institute Decision Support Team, 2004). "Land managers and desert tortoise scientists are tasked with formulating responses to this decline by recommending policies and carrying out actions that would lead to species recovery" (RI Decision Support Team, 2004, p. 1). As established in the RI's study, *The Desert Tortoise Habitat Potential Knowledge Base* (2004), "… the Institute … [has dedicated its efforts] to assist scientists and managers in understanding the interrelationships, uncertainty, and relative influence of scientific knowledge on modeling desert tortoise habitat" (RI Decision Support Team, 2004). The model created by the Redlands Institute assisted in identifying those "… biophysical factors that

contributed to habitat quality …; … when [integrated with specific] geographic data, … analyses [can be made in terms] of the distribution and quality of the desert tortoise habitat" (RI Decision Support Team, 2004, p. 3).

There were five main variables used on the Desert Tortoise Habitat Model: precipitation, retreat sites, geomorphology, elevation, and food resources. Each of these variables is significant in the process of determining an accurate and efficient suitability habitat model. The RI Decision Support Team (2004) defined the variables as follows:

1. Precipitation: Average mean seasonal precipitation, variability in seasonal precipitation, and average cumulative drought years are [important variables] for tortoise habitat. [Experts on the topic have recognized] an increase in tortoise activity after high rainfall and increase in tortoise mortality after periods of low rainfall and / or drought (Corn, 1994; Duda et al., 1999; Longshore et al., 2002, as cited in RI Decision Support Team, 2004). [Three main aspects of the precipitation were analyzed to determine its effectiveness in support of tortoise habitat:] amount of rainfall in a given season, the variability in the amount of that rainfall, and the drought pattern (pp. 7-8).

2. Retreat sites: Soil conditions are suitable for burrowing or geomorphologic type is suited to the formation of caves, overhangs or rock outcroppings that the tortoise could use for shelter. [The] model [exemplifies the existing] relationships between [the] soil … and landform characteristics [associated] to desert tortoise habitat quality (p. 16).

3. Geomorphology: Landform type is an acceptable [variable] for desert tortoise habitat. [Studies have determined the presence of tortoises] on valley bottoms and bajadas, [although they may also be located] on hillsides and rocky substrates (Germano et al., 1994, as cited in RI Decision Support Team, 2004, p. 25).

4. Elevation: Elevation [was another factor for determining] desert tortoise habitat. [Research studies have determined that] tortoise [populations are not found] above certain elevation points. Elevation is an important variable in determining the tortoise habitat because it is associated with the availability of food resources (p. 29).

5. Food Resources: Food resources are of suitable quality and quantity for a tortoise population. Food resources are defined by the quality and quantity of the available vegetation (Oftedal, 2002, as cited in RI Decision Support Team, 2004, p. 32).

The main objective of the Desert Tortoise Habitat Model was to obtain better knowledge about the species' ecosystem, and its habitat, to educate researchers and related groups concerned with desert tortoise conservation efforts, to create a method for assessing threats to tortoise habitat, and to support decisions that would contribute to species recovery (RI Decision Support Team, 2004).

2.2.2. Habitat Suitability Index Models: Gray Squirrel

Allen (1987) "provides habitat information useful for impact assessment and habitat management" of the gray squirrel (*Sciurus carolinensis*). The gray squirrel habitat model focuses on the data that can be used to correlate main ecological factors with the species' habitat suitability (Allen, 1987).

"The gray squirrel inhabits deciduous and mixed deciduous-coniferous forests" (Uhlig, 1955; Golley, 1962, as cited in Allen, 1987, p. 1). In the study, Allen (1987) analyzed some variables that determine the species' habitat. These variables were food, water, and cover.

1.   Food: Tree seed, or mast, is the most important food of gray squirrels (Gurnell, 1983, as cited in Allen, 1987). Availability of this resource is highly correlated with adult and juvenile gray squirrel survival (Heaney, 1984, as cited in Allen, 1987). The accessibility of mast has a direct influence on the length of the gray squirrel's breeding season, the number of adults and juveniles that produce litters, the number of adults that produce more than one litter, and litter size (Gurnell, 1983, as cited in Allen, 1987). The rising mortality rate of newborn squirrels is also correlated with the decline of its population (Nixon & McClain, 1969, as cited in Allen, 1987, p. 1).

2.   Water: Gray squirrels can satisfy water needs from free water or succulent plant materials (U.S. Forest Service, 1971; Flyger & Gates, 1982, as cited in Allen, 1987). Surface waters should be available within normal home range. Without the availability of near surface waters, pregnant and lactating females cannot feed their young. If the newborn squirrels are not fed properly this decreases the young squirrel's survival rate (p. 2).

3.   Cover: Gray squirrels are primarily associated with extensive, mature hardwood forests that provide an abundance of potential den sites (tree cavities) and contain dense under-story vegetation (Flyger & Gates, 1982, as cited in Allen, 1987). Gray squirrels were associated with extensive, ungrazed forests. Tree cavities are used by gray squirrels for nurturing their winter litter (Barkalow, unpublished, as cited in Allen, 1987, p. 2).

The results obtained from the model can be understood as indicating the "relative abundance of gray squirrels that can be supported within the evaluation area on a long-term basis" (Allen, 1987, p. 6). According to Allen (1987), areas with a low habitat suitability score suggested habitat with poor den locations or scarce winter food supplies that may not be able to support gray squirrels on a long-term basis. Higher suitability index values suggested areas that could support greater numbers of gray squirrels (Allen, 1987). This case study shows another method to identify high and low suitability areas within a region based upon the species' survival requirements.

2.3. Proposed Solution

The *Desert Tortoise Project* and the *Habitat Suitability Index Models: Gray Squirrel* are examples of different habitat suitability analyses. Both of these studies show different ways of determining possible occurrence of certain species according to selected variables. With references from the *Desert Tortoise Project* (RI Decision Support Team, 2004) and the *Habitat Suitability Index Models: Gray Squirrel* (Allen, 1987), a conceptual model has been produced for Mohave ground squirrel habitat prediction visualization analyses. To accomplish and create an effective and reliable model, a geodatabase was created, populated with data concerning the Mohave ground squirrel and its associated habitat variables. This geodatabase includes information regarding precipitation, geomorphology, elevation, slope, land ownership, land cover, and vegetation.

A predictive habitat suitability model for the Mohave ground squirrel has been generated by combining all these variables. A final map has been created delineating the areas that best meet the requirements for the species. It is categorized from least suitable to highly suitable. With the aid of this model, it will be possible to identify areas where Mohave ground squirrels are likely to be present. The model should indicate public lands that are important for the conservation of the species and prioritize private lands for acquisition. By identifying areas that support significant Mohave ground squirrel populations, it will be possible for researchers and managers to improve the squirrel's conservation status.

2.4. Scope of Work

The following study was carried out to determine: (a) the distribution of potential suitable areas for the Mohave ground squirrel; (b) compare the results with historic Mohave ground squirrel occurrences; and (c) evaluate the current land ownership within the species range to identify areas of suitable habitat that should be managed or acquired for conservation purposes.

2.5. System Description

The Mohave ground squirrel habitat model system will work as follows. The client will initiate the system by opening ArcMap GIS application. Once ArcMap is opened, the client will launch the habitat suitability model located in the ArcToolbox pane. Then, the required variables will be selected to execute the model. The major inputs needed to run the system include: elevation (raster), slope (raster), land cover (raster), 30-year period mean precipitation (raster), 30-year period consecutive dry winters (raster), 30-year period frequency of dry winters (raster), vegetation (vector), and geomorphology (vector). The next step is to select the parameters for each dataset. The major output that the model will produce is a raster dataset showing suitable habitat areas for the Mohave ground squirrel populations. The following is a step-by-step description of the major tasks:

1. Open ArcMap

2. Open the Mohave ground squirrel habitat model located in the ArcToolbox pane

3.   Input required data

4.   Select respective parameters for each of the variables

5.   Run model

6.   Visualize output data in ArcMap viewer

7.   Create map

The system will be delivered to the client with a manual that will explain the step-by-step procedure on how to execute the complete process.
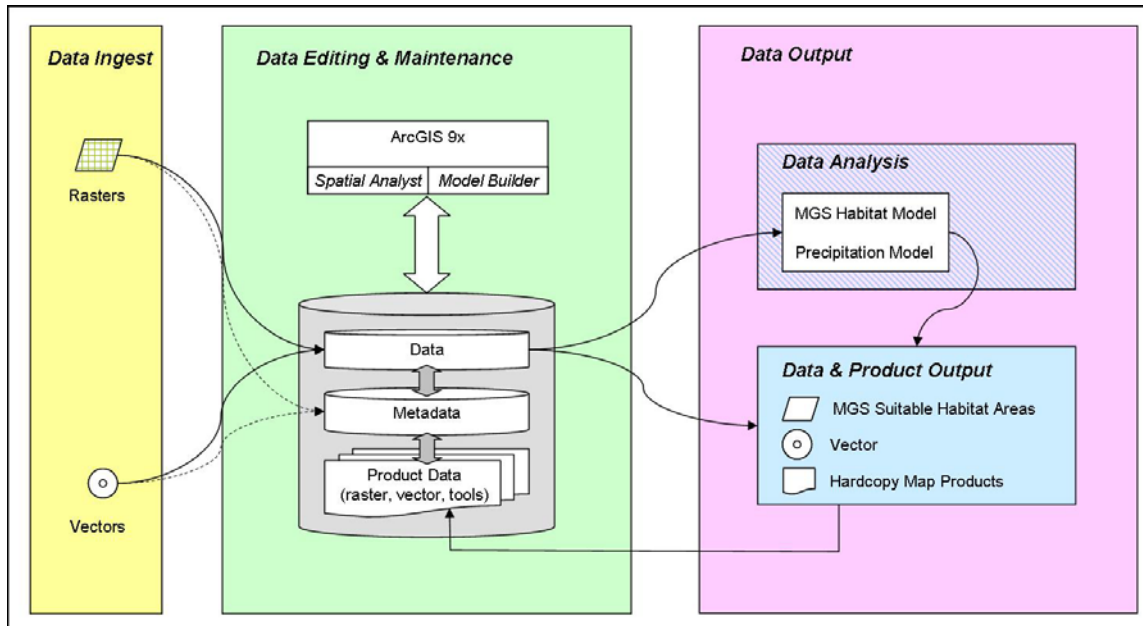
Figure 4: System Architecture for the Mohave ground squirrel habitat model.

Figure 4 shows how the system architecture for the Mohave ground squirrel habitat model is going to be organized. The system's architecture consists of three main tiers: (a) Data Ingest, (b) Data Editing & Maintenance, and (c) Data Output.

The first tier describes the type of data used for the study. This data consists of multiple raster and vector datasets. The second tier describes how the data will be stored. Using ArcGIS 9x, the data will be edited and maintained in a geodatabase. This geodatabase will hold all the data needed for the analysis along with their metadata and the tools created for the analyses. It is required that that system have available the Spatial Analyst extension and the Model Builder application. The third tier describes the two main data analysis models: the precipitation model and the habitat suitability model. Afterwards, multiple maps will be generated from the final output obtained after executing the suitability model. This dataset will be overlaid with different vector datasets to make some overlay analysis as well.

2.6. System Environment

Client should have access to a computer with the following software:

o   ArcGIS ArcInfo 9.1 application

Also recommended:

- o Video card: 64 Mb or higher, OpenGL 1.2 or higher
- o RAM: 512 Mb or higher
- o Processor: 1.5 GHz or higher

3. Methodology

3.1. Data Collection and Preparation

Data needed for this study consisted of the following datasets: (a) Mohave ground squirrel range, (b) digital elevation model (DEM), (c) slope, (d) land cover, (e) vegetation, (f) geomorphology, and (g) precipitation. Other ancillary data used were land ownership and Mohave ground squirrel occurrence locations. These data were obtained from different sources, such as the United States Geological Survey (USGS), United States Army Corps of Engineers: Topographic Engineer Center, and the Spatial Climate Analysis Service at Oregon State University. More information on these datasets is provided in Appendix E: Metadata.

The following section describes all the datasets relevant to the Mohave ground squirrel habitat suitability model. All attributes of these datasets were evaluated. Once the data were considered appropriate for the study, they were exported into a geodatabase. As defined by Law, Simmons, and Taggart (2004):

> A geodatabase is a relational database that stores GIS data as a collection of tables. Geodatabases contain vector, [i.e., points, lines, and polygons], and raster data, and their associated attributes. (pp. 2-4).

Some elements related to the geodatabase structure will be explained before describing the data. As mentioned above, a geodatabase "is a container of geographic object … often referred as a workspace". Some objects contained inside this workspace are described by Law et al. (2004) in *Building geodatabases I*:

1. Tables: store non-spatial objects;

2. Feature classes: collections of lines, points or polygons;

3. Feature datasets: containers for feature classes [sharing] a common spatial reference;

4. Raster datasets: gridded data derived from a variety of source formats (IMG, JPG, GRID, etc.); and

5. Toolboxes: contain geoprocessing tools used in the ArcGIS geoprocessing framework, [such as tools, models, and scripts]. (pp. 2-7).

These examples are shown in Figure 5.
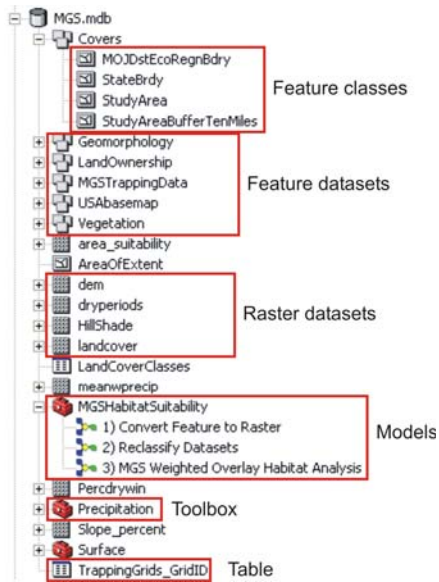
Figure 5: Geodatabase structure.

One thing that should be identified is the advantages of building models using the Model Builder. Model Builder is a tool used to build model diagrams that connects series of input datasets with specific spatial operations to obtain a final output (Chang, 2004). Childs, Kabot, and Murad-al-shaikh (2004) establish that an advantage of using Model Builder is that processes can be automated and geoprocessing work flows can be easily managed, as shown in Figure 6. Another advantage is that models can be modified to meet the requirements of a new study, such as changing tool parameters and adding or deleting processes (Childs et al., 2004).
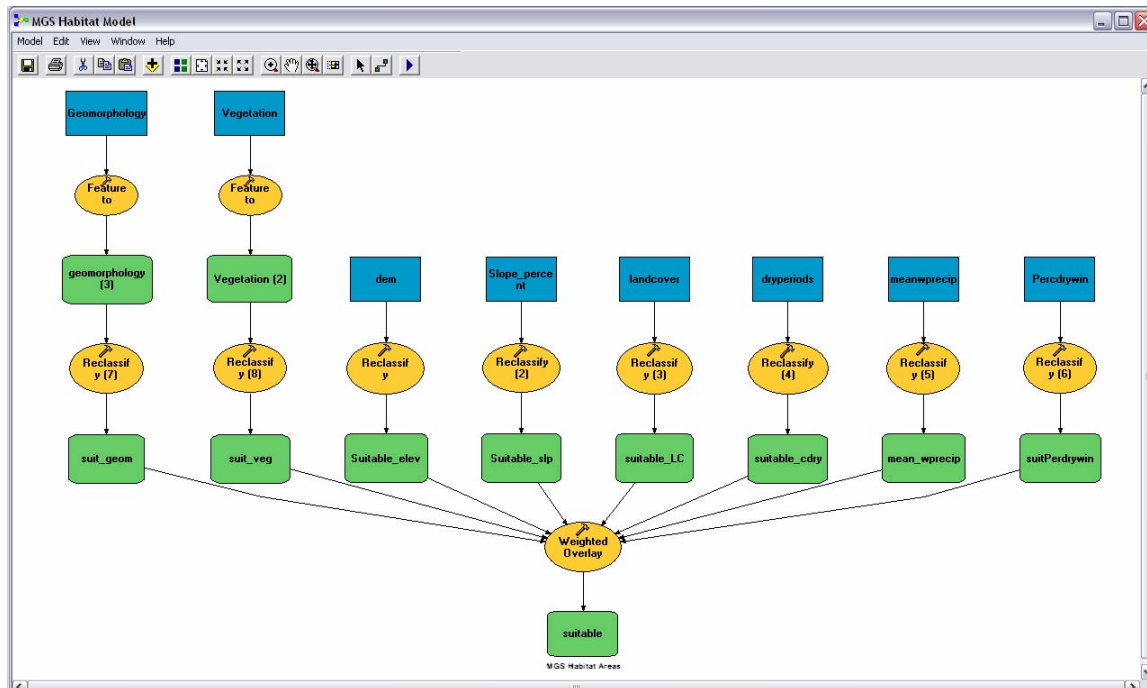
Figure 6: Model Builder model.

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Other data were used in the study but only for cartographic purposes. These included roads, county boundaries, water bodies, and city locations. It is also important to indicate that all the data used for the analyses and display purposes on the project are referenced in the Metadata section located in Appendix E.

3.1.1. Mohave ground squirrel range

The Mohave ground squirrel range is located in the northwestern portion of the Mojave Desert (Gustafson, 1993). The range was delineated based on locations where the species had been captured or observed (Gustafson, 1993). According to Gustafson (1993), some areas were eliminated from the range due to insufficient data confirming occurrence, as well as the loss of native vegetation cover due to agriculture and urbanization.

Since there was no GIS dataset available for the Mohave ground squirrel range, it was generated by digitizing the map created by BLM (Brooks & Matchett, 2002). Kennedy (2001) defines digitizing as the "process of creating shapes of geographic features from media such as paper maps or raster imagery into vector x, y coordinates" (p. 28). To accomplish this task, the map was scanned and then brought to a geographic information system (Figure 7). Because it was just scanned image, it did not have any geographic reference system. As a result, the image needed to be georeferenced so that it could be overlaid with related GIS datasets and the squirrel's habitat range could be digitized. Kennedy (2001) defines georeferencing as the process of assigning "coordinates from a known reference system, such as latitude and longitude, UTM, or State Plane, to the page coordinates of an image or a planar map." For this process, the county boundaries layer in the NAD 1983 UTM Zone 11 N projection was used as the base datum. A roads layer was also used as reference to assure the accuracy of the process, as shown in Figure 8.
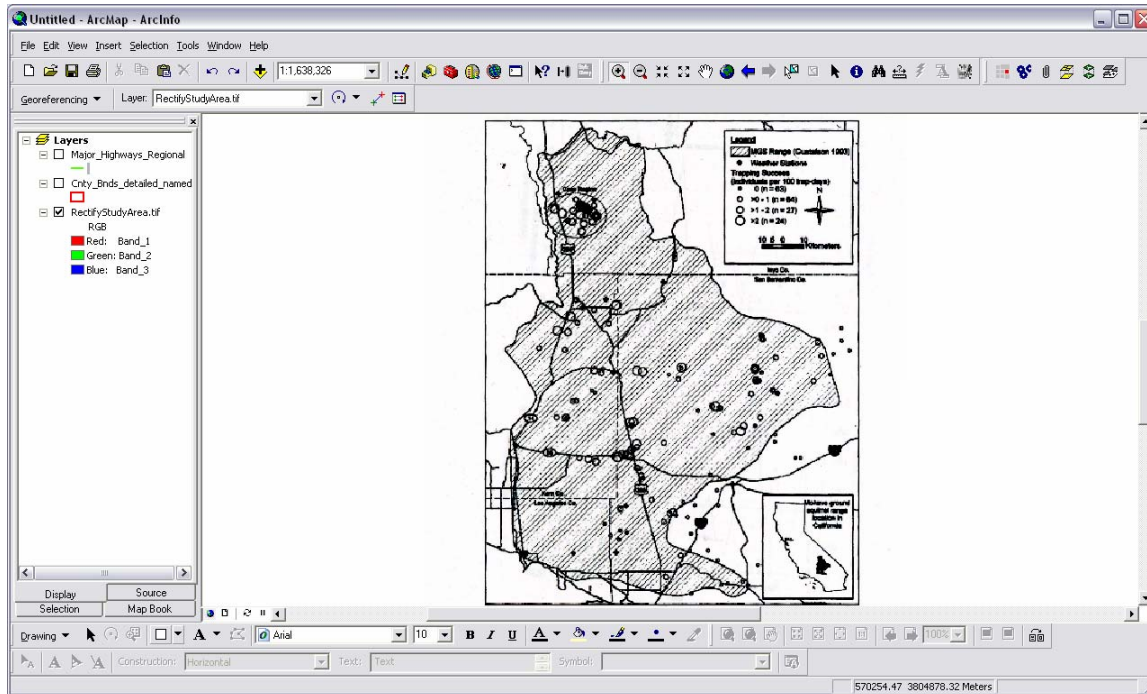
Figure 7: Scanned image of MGS range.
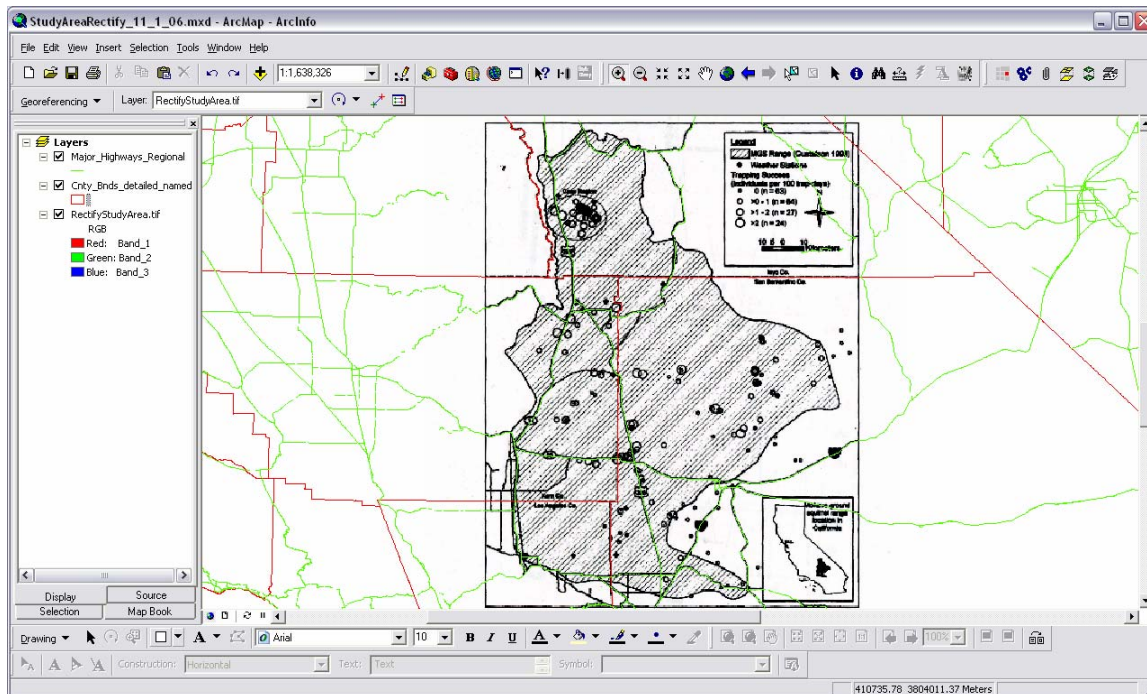
Figure 8: Scanned image of MGS range with base data.
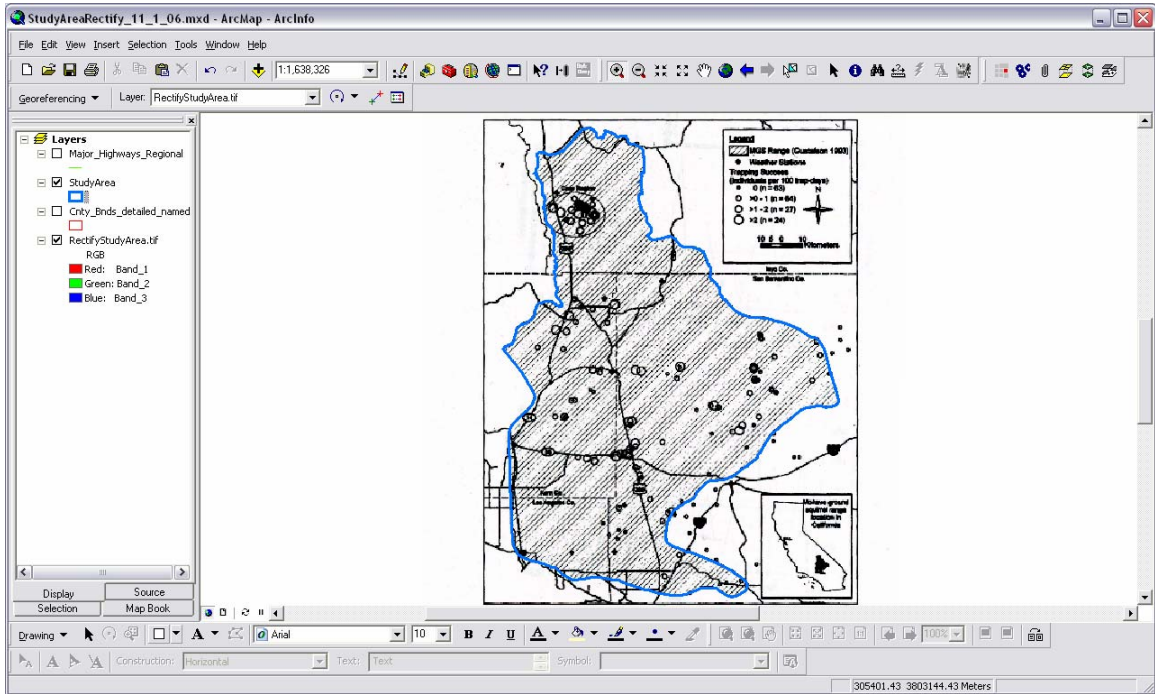
Figure 9: Scanned image with Mohave ground squirrel boundary.

Figure 9 shows the scanned image overlaid with the newly-generated squirrels' range dataset. According to the GIS, the Mohave ground squirrel coverage area is approximately 19,982 square kilometers. For the purpose of this project, this layer was buffered ten miles to assure that all the range was covered (Figure 10).
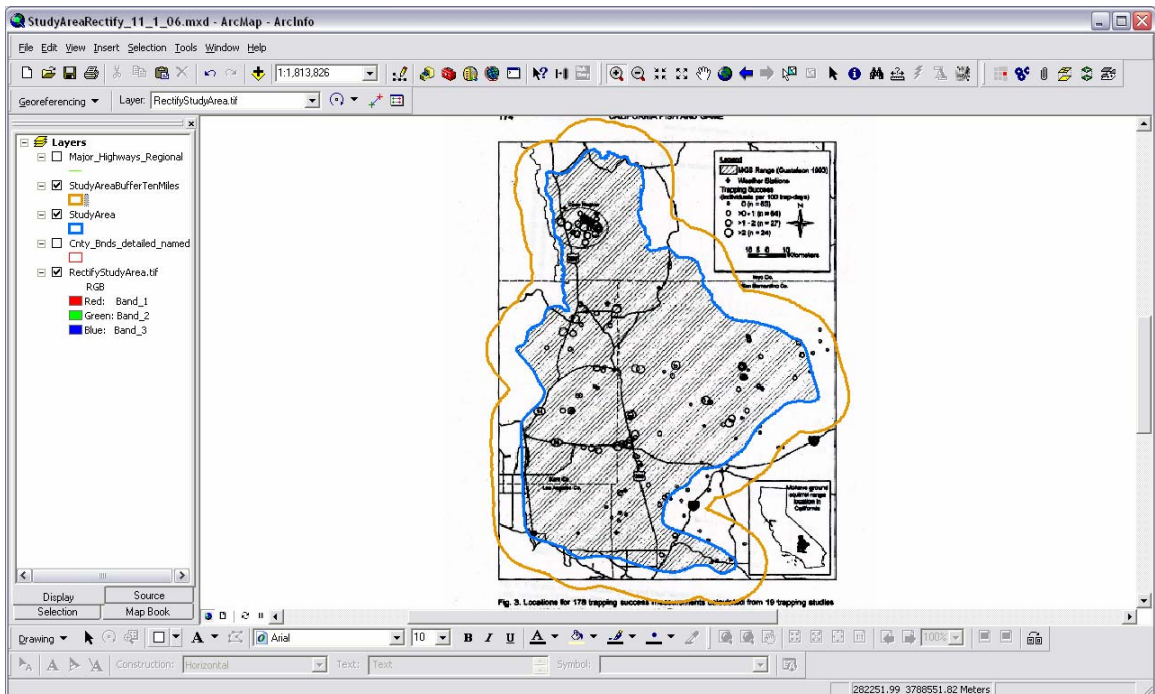
Figure 10: Mohave ground squirrel boundary with 10 miles buffer.

3.1.2. Digital Elevation Model (DEM)

A digital elevation model is a raster dataset with elevation values representing the terrain relief of a landscape (Kennedy, 2001). This dataset was prepared by the USGS EROS Data Center, but obtained from the Mojave Desert Ecosystem Program (MDEP) database. The resolution for each raster cell is 30 meter x 30 meter or 1 arc second.

The DEM was located on the Elevation CD under the DEM directory. It was saved under the file name dembil.gz and had to be uncompressed before using (MDEP, 1995). Then the extracted ARC GRID raster dataset was ready for use in GIS software (Figure 11).
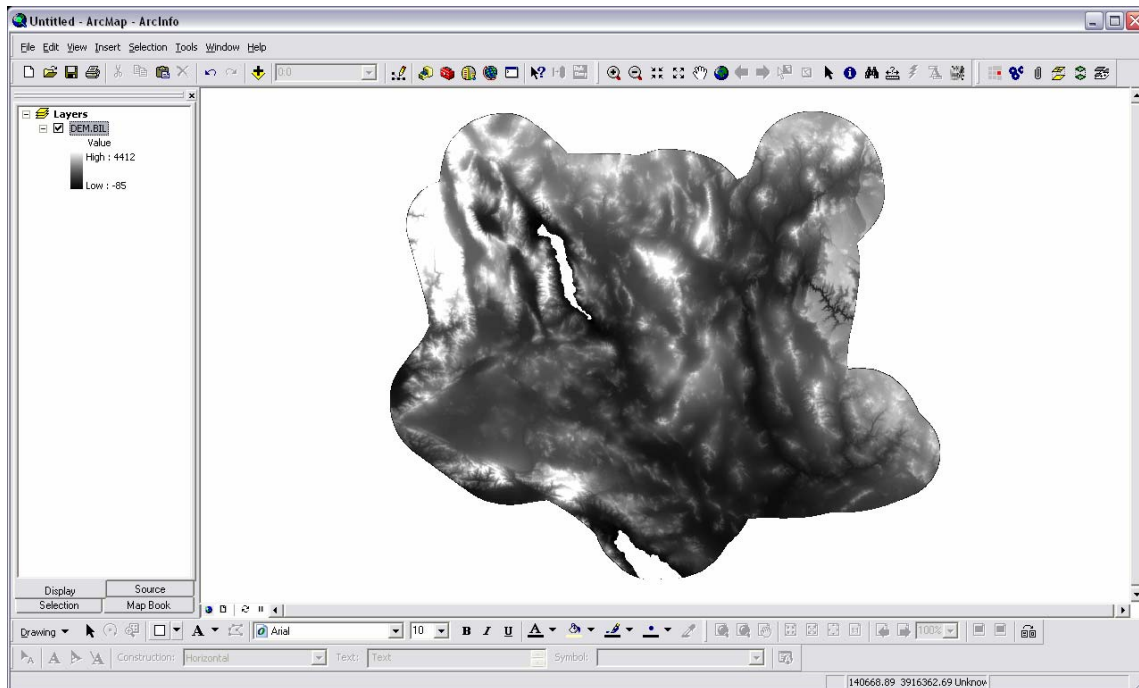
Figure 11: Mojave Desert Ecoregion - Digital Elevation Model (DEM).

Since the Mojave ground squirrel range comprises only a portion of the northwestern region of the Mojave Desert, the DEM had to be extracted in agreement with the study area. To accomplish this task, it was necessary to use the Extract by Mask tool located in the Extraction Toolset within the Spatial Analyst Toolbox (Figure 12).
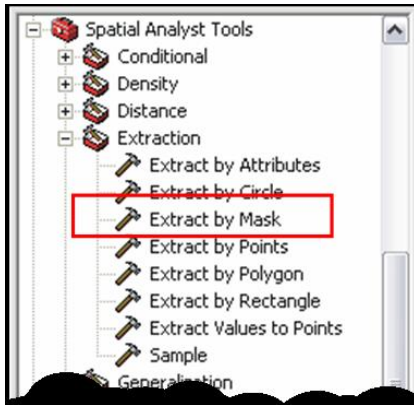
Figure 12: Extract by Mask tool.

Extract by Mask is a tool that "extracts the cells of a raster that correspond with the areas defined by a mask" (ArcGIS Desktop Help, 2005). For the purpose of this project, the mask was considered the Mohave ground squirrel range layer since that is the area used in the habitat analysis. Figure 13 shows how the Extract by Mask tool works.
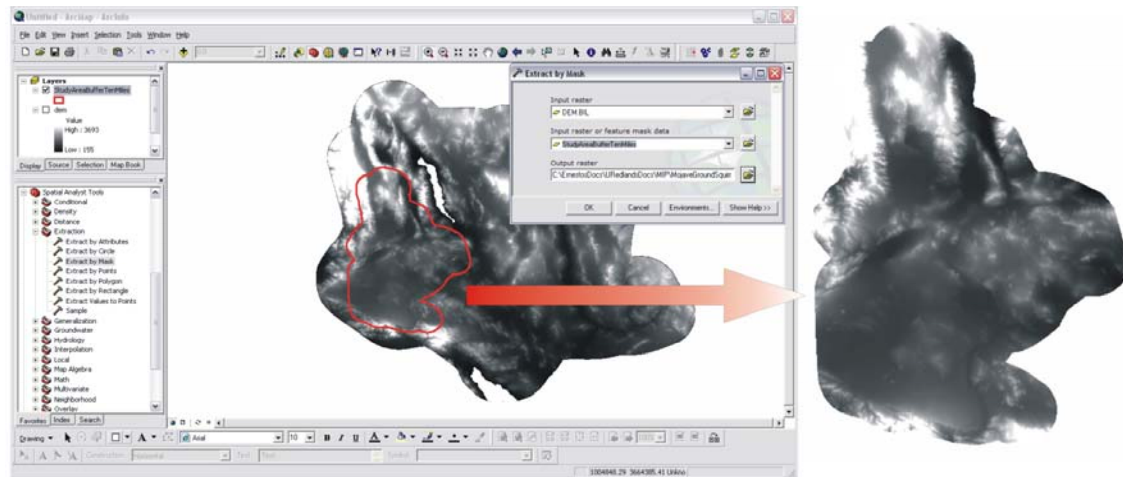
Figure 13: Extract by Mask tool process (DEM).

3.1.3. Slope

McCoy, Johnston, Kopp, Borup, and Willison (2004) define slope as follows:

… the incline, or steepness, of a surface at a specific location. The slope for a cell in a raster is the steepest downhill slope of a plane defined by the cell and its eight surrounding neighbors. Slope can be measured in degrees from horizontal (0 – 90) or percent slope. As slope angle approaches vertical (90 degrees), the percent slope approaches infinity. (p. 224).

This raster dataset was prepared using the USGS digital elevation model. Since it was derived from the 30m x 30m DEM, the slope was also generated with the same cell resolution.

The Slope tool located in the Surface Toolset within the Spatial Analyst Toolbox was used to create the slope raster (Figure 14). Figure 15 shows how the Slope tool process works. The output measurement was set to percent, as requested by the client.

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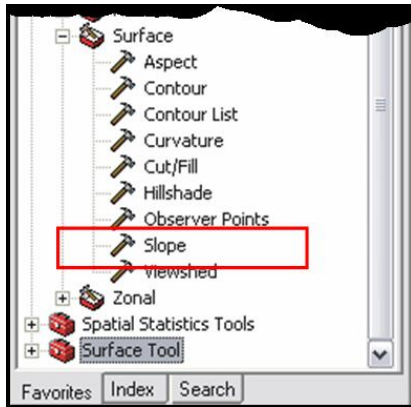
Figure 14: Slope tool.
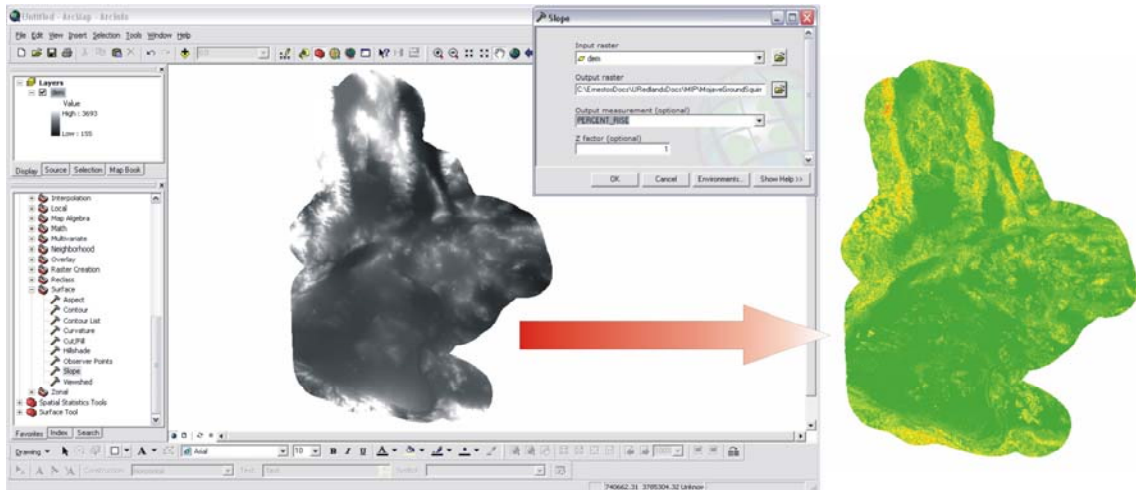
Figure 15: Slope tool process.

3.1.4. Land Cover

Avery and Berlin (1992) define land cover as a "[representation of the] natural and artificial compositions [that comprise] the Earth's [landscape] at a certain location" (p. 206). The land cover dataset was prepared by the USGS EROS Data Center and downloaded from the National Atlas webpage (http://www-atlas.usgs.gov/). This dataset was created at a 200 meter scale resolution for the conterminous United States using Landsat Thematic Mapper satellite data from 1992 (Figure 16). Table 1 shows the different land cover types classified in the raster dataset.
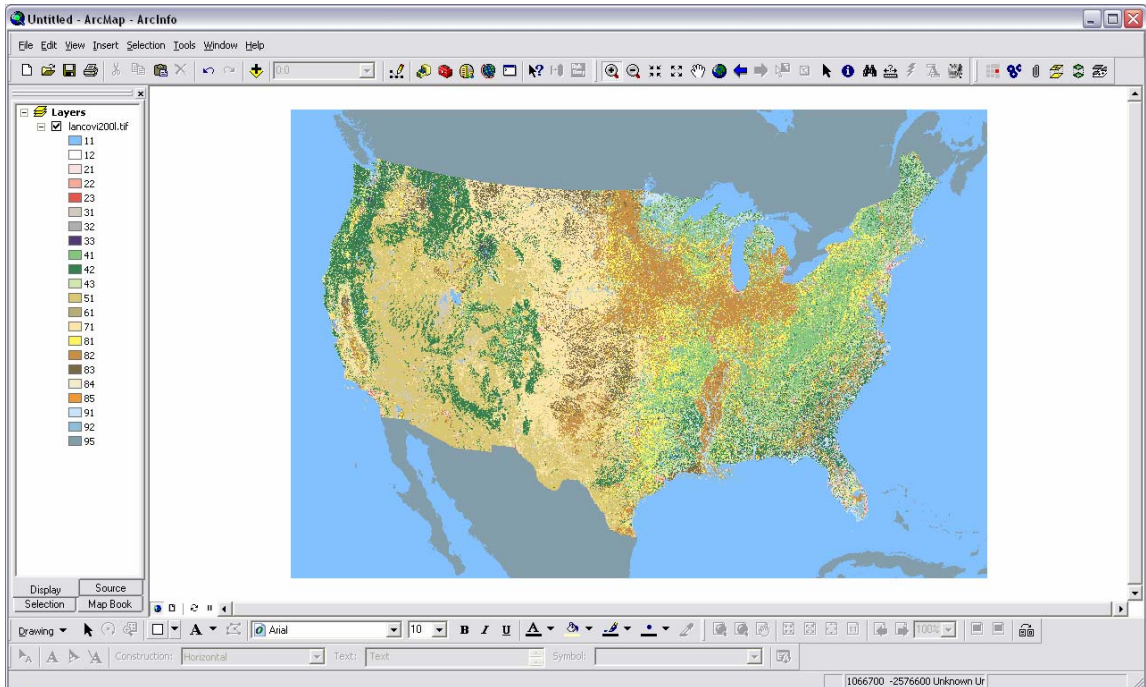
Figure 16: Land Cover for the conterminous United States.

Land Cover Class	Value
Water	11
Perennial ice and snow	12
Low intensity residential	21
High intensity residential	22
Commercial/industrial/transport	23
Bare rock/sand/clay	31
Quarries/strip mines/gravel pit	32
Transitional	33
Deciduous forest	41
Evergreen forest	42
Mixed forest	43
Shrubland	51
Orchards and vineyards	61
Grasslands/herbaceous	71
Pasture/hay	81
Row crops	82
Small grains	83
Fallow	84
Urban/recreational grasses	85
Woody wetlands	91
Emergent herbaceous wetlands	92
Non-U.S. land	95

Table 1: Land Cover classes.

The land cover was also extracted in agreement with the Mohave ground squirrel range, which represented the study area of interest. The Extract by Mask tool was used to accomplish this process (Figure 17).
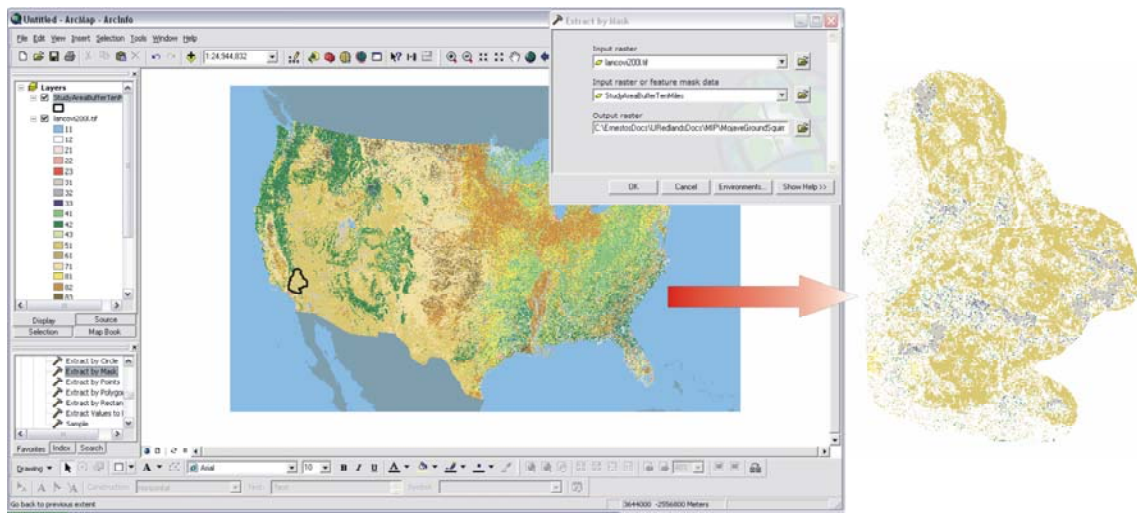
Figure 17: Extract by Mask Process (Land Cover).

3.1.5. Vegetation

The vegetation dataset was created by the "USGS Biological Resource Division's GAP Vegetation database from California, Nevada, Arizona, and Utah" (MDEP, 1995, p. 37). This layer was obtained from The MDEP database. According to MDEP (1995), the data was compiled following the standards of the National Vegetation Classification system at a scale of 1:250,000 (Figure 18).
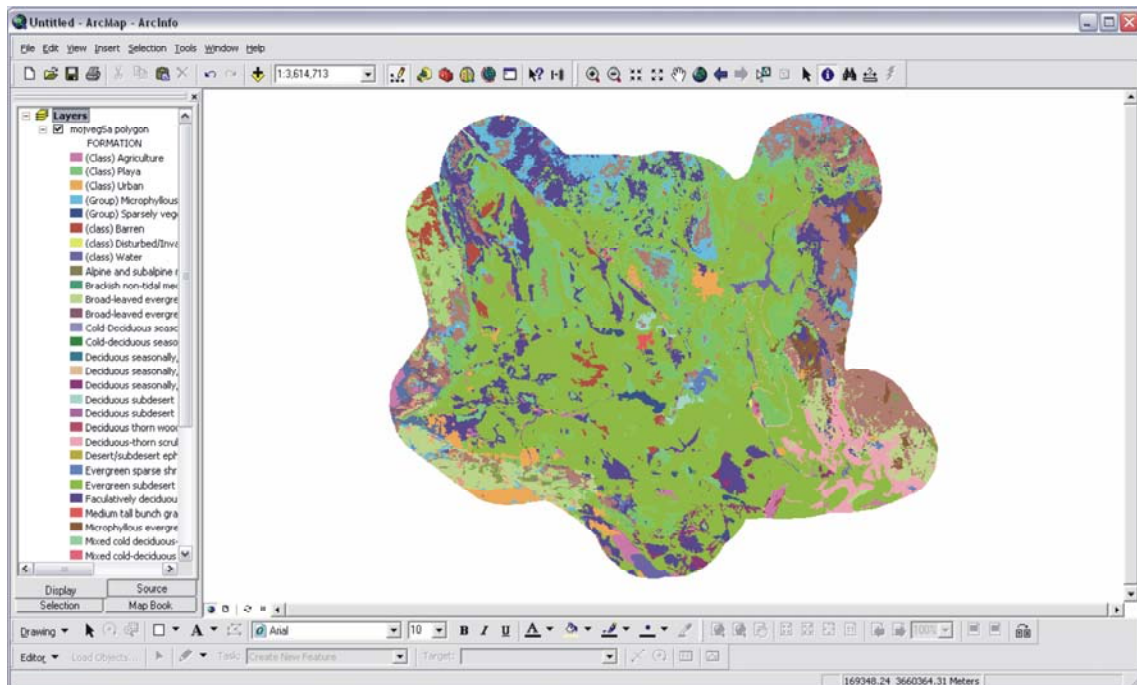
Figure 18: Mojave Desert Ecoregion – Vegetation.

The vegetation layer was then extracted in agreement with the Mohave squirrel range. To accomplish this task, the Clip tool was needed. The Clip tool is located in the Extract Toolset within the Analysis Tools Toolbox (Figure 19). Clip is a geoprocessing procedure that extracts features from one dataset, i.e., coverages, shapefiles, feature classes that are completely contained inside the boundary of another feature dataset (Kennedy, 2001). The vegetation result can be seen in Figure 20.
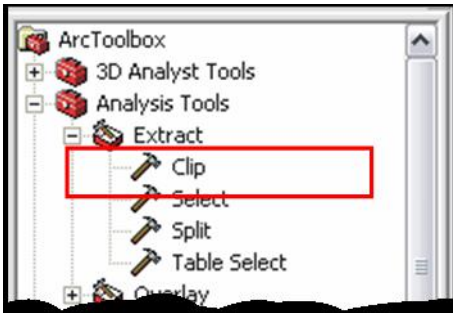
Figure 19: Clip tool.
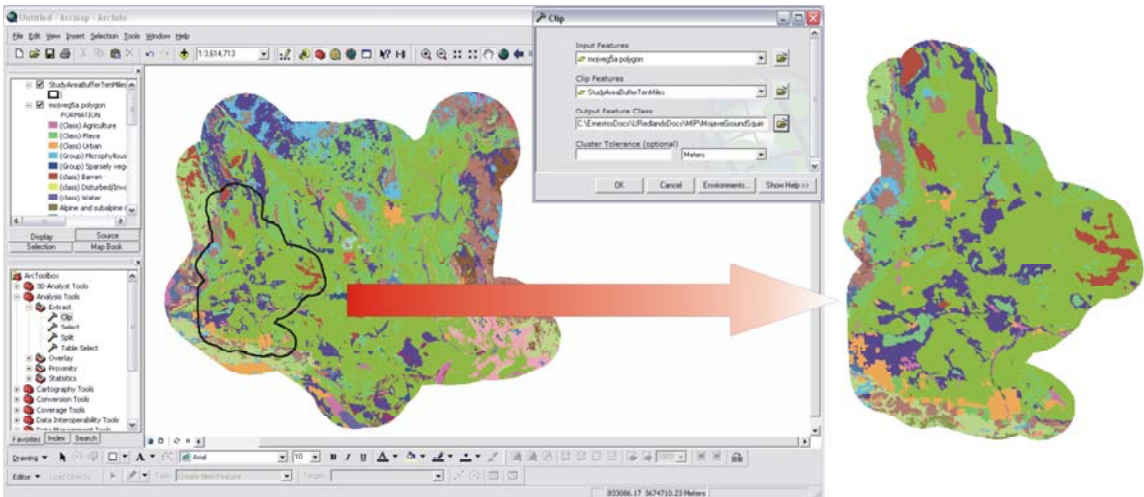
Figure 20: Clip tool process (Vegetation).

3.1.6. Geomorphology

The geomorphology dataset was created by the United States Army Corps of Engineers: Topographic Engineer Center and obtained from the Redlands Institute database. This dataset contains data related to earth materials and landforms of the Mojave Desert within the California desert region covering an area of approximately 150,000 square kilometers (Figure 21). The data were collected at a scale approximately of 1:19,000.
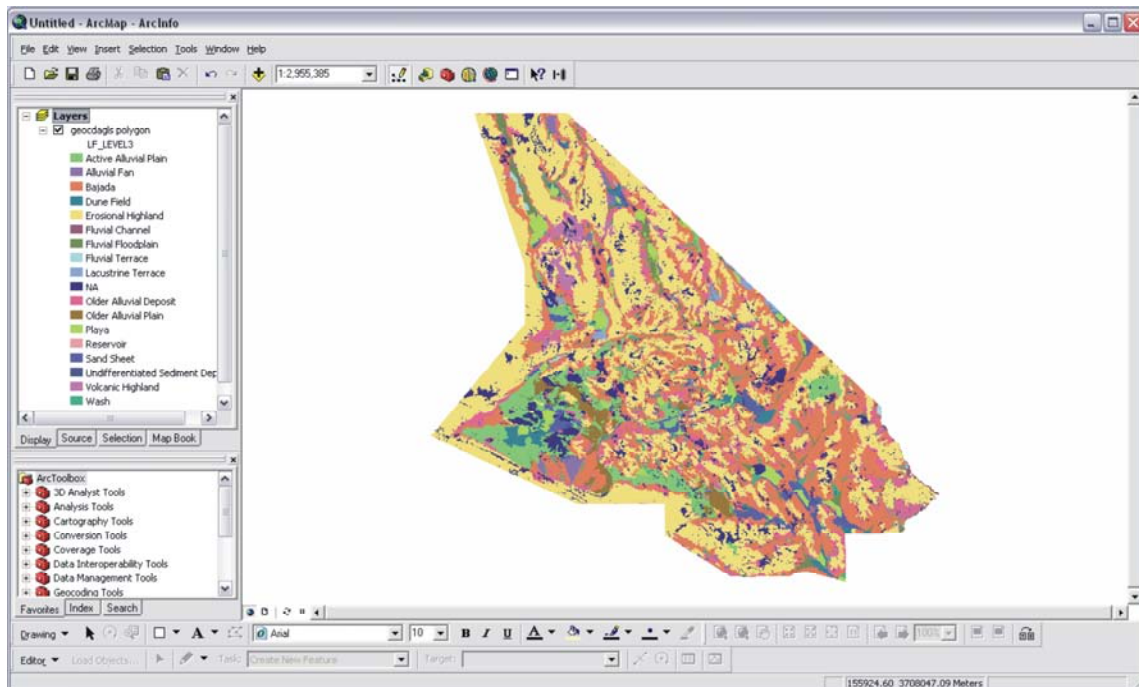
Figure 21: Mohave Desert Ecoregion, CA region – Geomorphology.

The geomorphology layer was then extracted in agreement with the Mohave squirrel range. As with the vegetation dataset, the Clip tool was used to perform this task. The geomorphology result is shown in Figure 22. It should be pointed out that this layer was only created for the Mojave Desert region of California; therefore, it does not cover the complete buffered Mohave ground squirrel range.
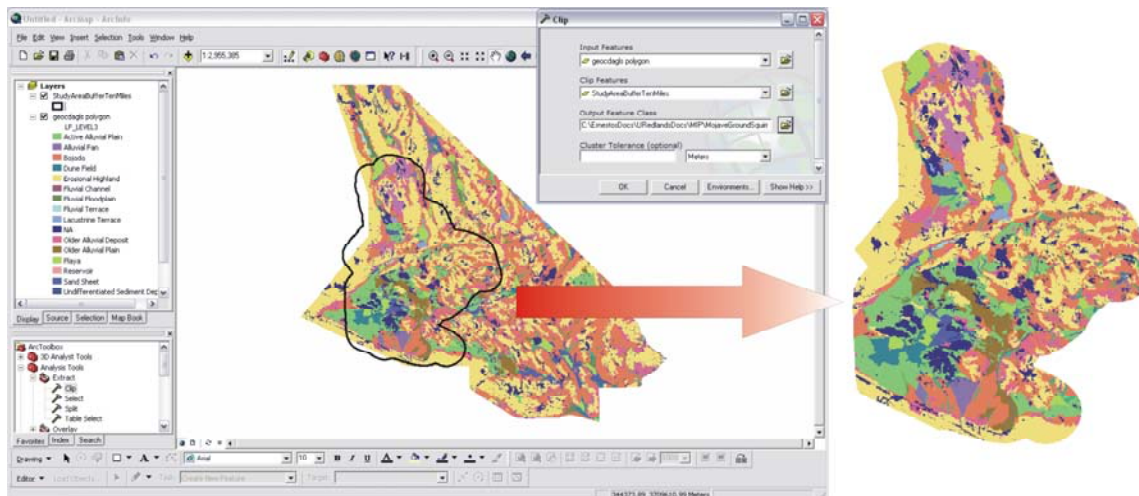
Figure 22: Clip tool process (Geomorphology).

3.1.7. Precipitation

The precipitation dataset was created by the Spatial Climate Analysis Service at Oregon State University. These data were downloaded from the PRISM Group website (http://www.ocs.orst.edu/prism/), a webpage sponsored by the Spatial Climate Analysis Service (Figure 23). The process of obtaining this dataset was more complex compared

with the other datasets since it was necessary to download the winter precipitation data for a 30-year period from 1976 – 2006. Since the winter precipitation period extends from October 1 through March 31, monthly data had to be downloaded for the 30-year period. A total of 180 precipitation datasets were downloaded. Figure 24 shows how PRISM Group distributes the datasets from their website. These are high-resolution precipitation datasets provided on a year-by-year basis, both by month and year. The data were prepared at a resolution of approximately 4km.

The PRISM (Parameter-elevation Regressions on Independent Slope Model) model was developed by Christopher Daly, Director of the Spatial Climate Analysis Service. The PRISM model is one of many methods of interpolating precipitation data. The Spatial Climate Analysis explains the model in their *Near-Real-Time Monthly High-Resolution Precipitation Climate Data Set for the Conterminous United States* metadata as follows:

> There are many methods of interpolating precipitation from monitoring stations to grid points. Some provide estimates of acceptable accuracy in flat terrain, but few have been able to adequately explain the extreme, complex variations in precipitation that occur in mountainous regions. Significant progress in this area has been achieved through the development of PRISM. PRISM is an analytical model that uses point data and a digital elevation model (DEM) to generate gridded estimates of monthly and annual precipitation (as well as other climatic parameters). PRISM is well suited to regions with mountainous terrain, because it incorporates a conceptual framework that addresses the spatial scale and pattern of orographic precipitation … (2004, Supplemental Information, ¶ 1).
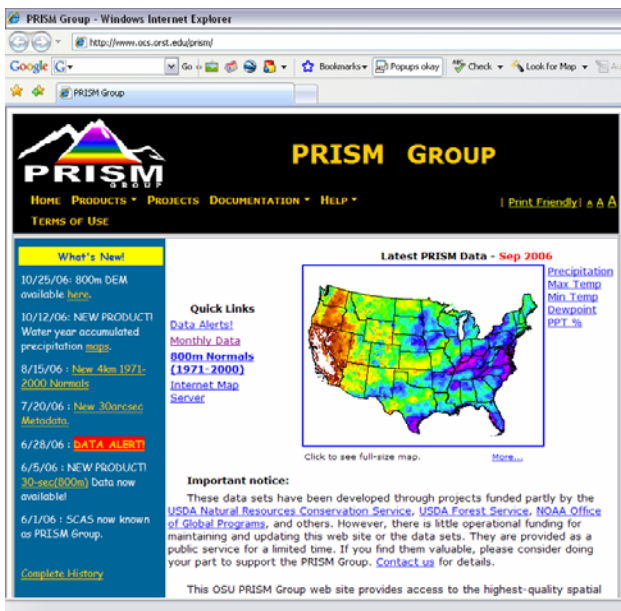
Figure 23: PRISM Group website.
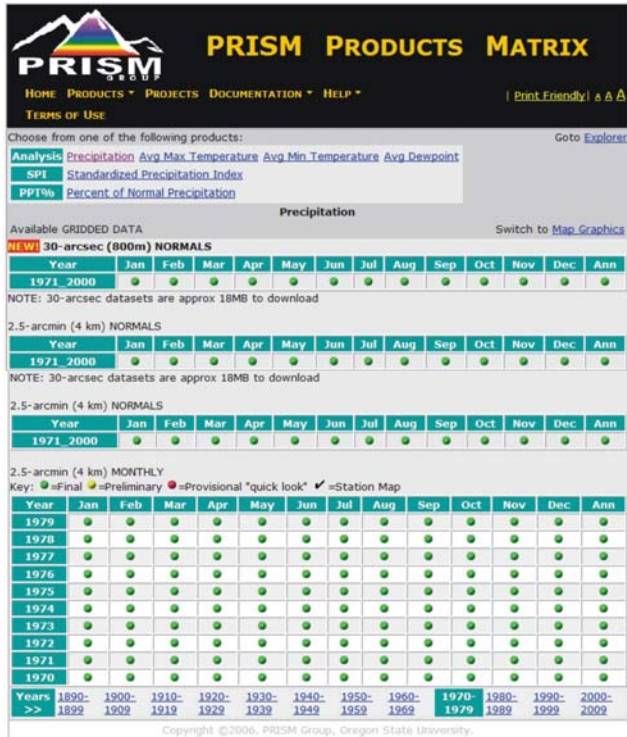
Figure 24: PRISM products matrix.

The downloaded precipitation datasets come in ASCII (American Standard Code for Information Interchange) format and, therefore, they must be processed to convert them into a meaningful dataset, i.e., raster grids. ESRI (2006) defines ASCII in their web dictionary as the "standard for the format of text files in computers and on the Internet that assigns a 7-bit binary number to each alphanumeric or special character."

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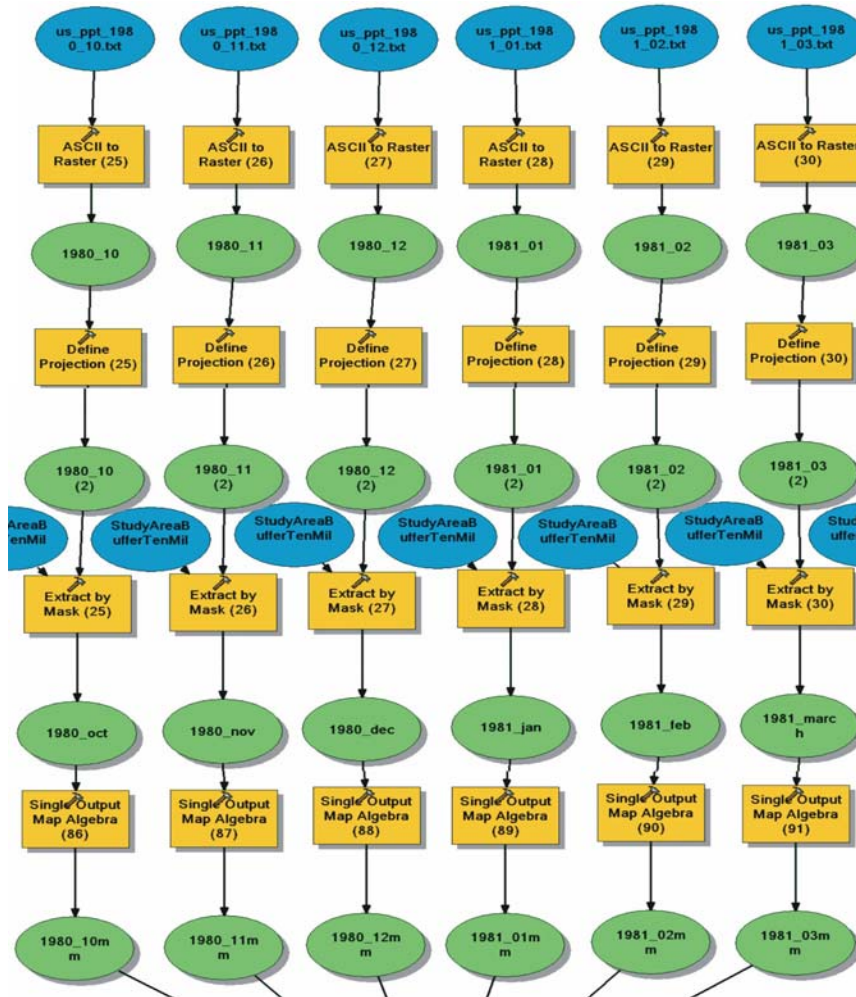
Figure 25: Enlarged portion of the Process PRISM ASCII files model.

Model Builder was used to automate the processing of the 180 datasets. Even though it was performed in Model Builder, the following section will describe each step separately to provide a better understanding of what the model does behind the scenes (Figure 25). The first step after downloading the precipitation data is to uncompress the files since they come in ".gz" compression format. After they are uncompressed, the files need to be converted from ASCII files to raster grids. To accomplish this task, it is necessary to use the ASCII to Raster tool located in the Conversion Tools Toolbox within the To Raster Toolset (Figure 26).
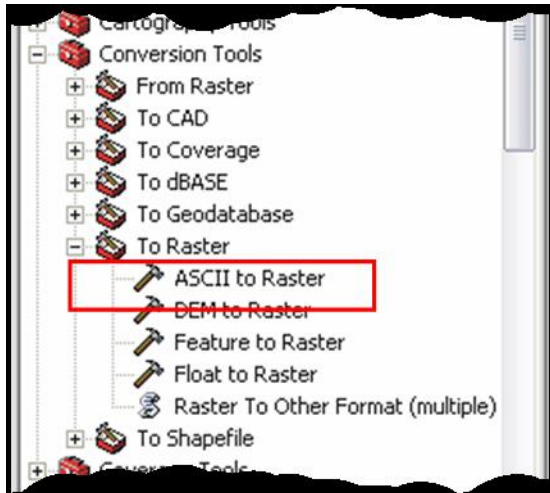
Figure 26: ASCII to Raster tool.

Once the tool is opened, the ASCII raster file to be processed is selected and the output data type is set to Integer. The output of this process is shown in Figure 27. As shown in the graphic below, the data created represents the precipitation for the contiguous United States.
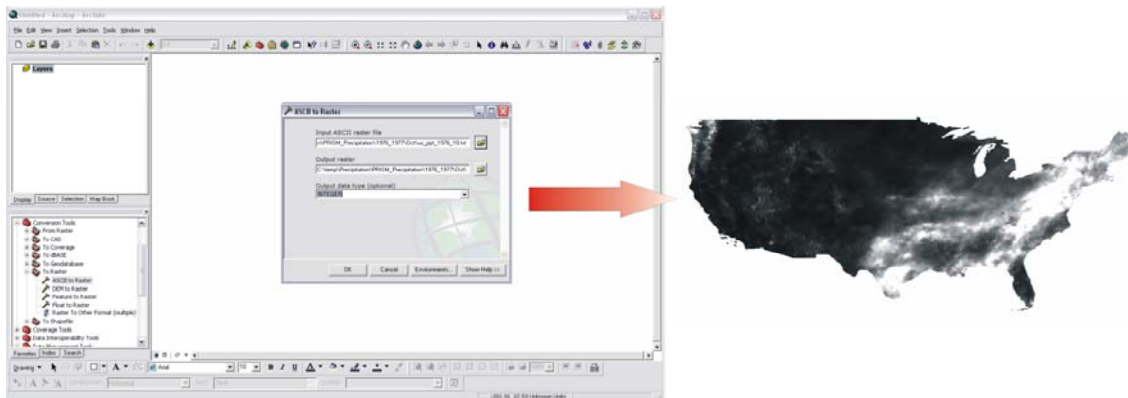
Figure 27: ASCII to Raster tool process (Precipitation).

After the ASCII file is processed into the raster format, the Coordinate System must be defined to GCS WGS 1972. This is achieved by using the Define Projection tool on the Projections and Transformations Toolset in the Data Management Tools Toolbox (Figure 28).
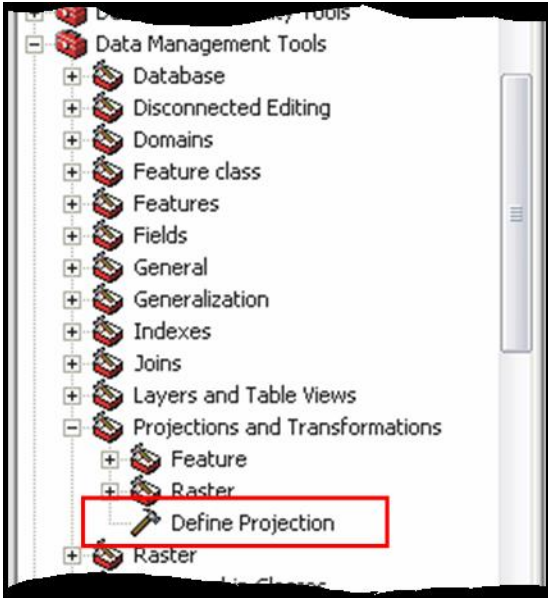
Figure 28: Define Projection tool.

Next, the raster dataset needs to be extracted so that it is in agreement with the study area boundary. As with the other raster datasets, the Extract by Mask tool was used to accomplish this process (Figure 29).
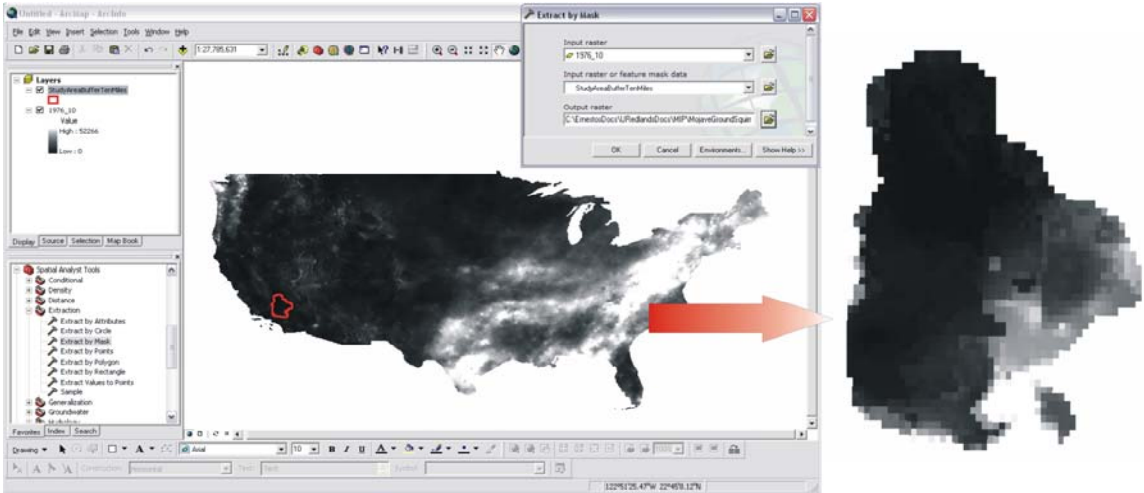
Figure 29: Extract by Mask Process (Precipitation).

The next step is to convert the data from hundredths of millimeters to millimeters. The Single Output Map Algebra (SOMA) tool located in the Map Algebra Toolset in the Spatial Analyst Tools Toolbox was used to accomplish this task (Figure 30). The SOMA tool uses Map Algebra to process raster data. As defined by Childs et al., (2004), map-algebra is math-like language for processing raster datasets. When performing a map algebra function, the pixel values of the output raster are calculated using a mathematical operation based on the pixel values of the input raster dataset.
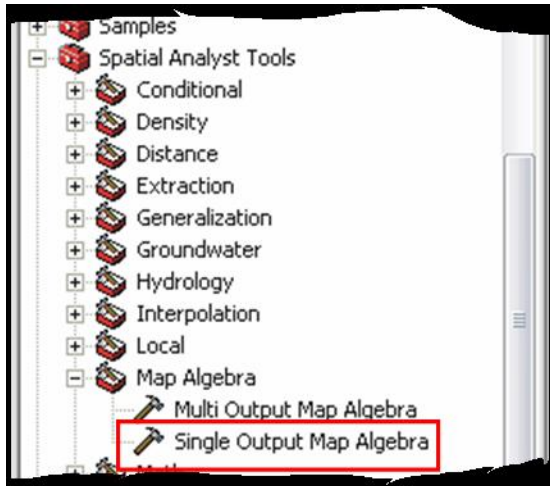
Figure 30: Single Output Map Algebra tool.

To change the pixel values from hundredths of millimeters to millimeters, the following map algebra equation was used: [PRISM] / 100. Figure 31 shows the result after converting the data from hundredths of millimeters to millimeters.
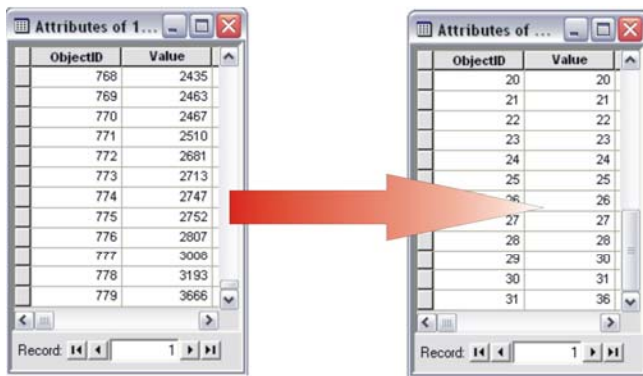
Figure 31: SOMA conversion to millimeters.

Once the conversion to millimeters is accomplished, the data are ready to create the precipitation datasets required for the Mohave ground squirrel habitat model. These datasets are: (a) mean winter precipitation, 1976 – 2006, (b) frequency of dry winter periods, 1976 – 2006, and (c) consecutive dry winter periods, 1976 – 2006.

3.1.7.1. Mean Winter Precipitation, 1976 – 2006
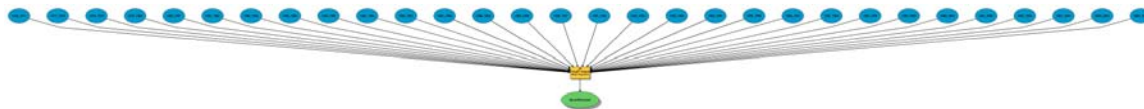
Figure 32: Model for mean winter precipitation, 1976 – 2006.

Figure 32 shows the model used to create the mean winter precipitation raster grid. The first step before calculating the mean winter precipitation was to calculate the annual winter precipitation for each year of the 30-year period. To accomplish this task, the SOMA tool was required. The SOMA equation used for creating the annual winter precipitation was the following: [PRISM 1976_Oct] + [PRISM 1976_Nov] + [PRISM 1976_Dec] + [PRISM 1977_Jan] + [PRISM 1977_Feb] + [PRISM 1977_March]. This

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equation will sum all those datasets together producing the annual winter precipitation grid. Figure 33 shows the SOMA equation and the portion of the model created to perform this task. This process was done for the 30-year period datasets.
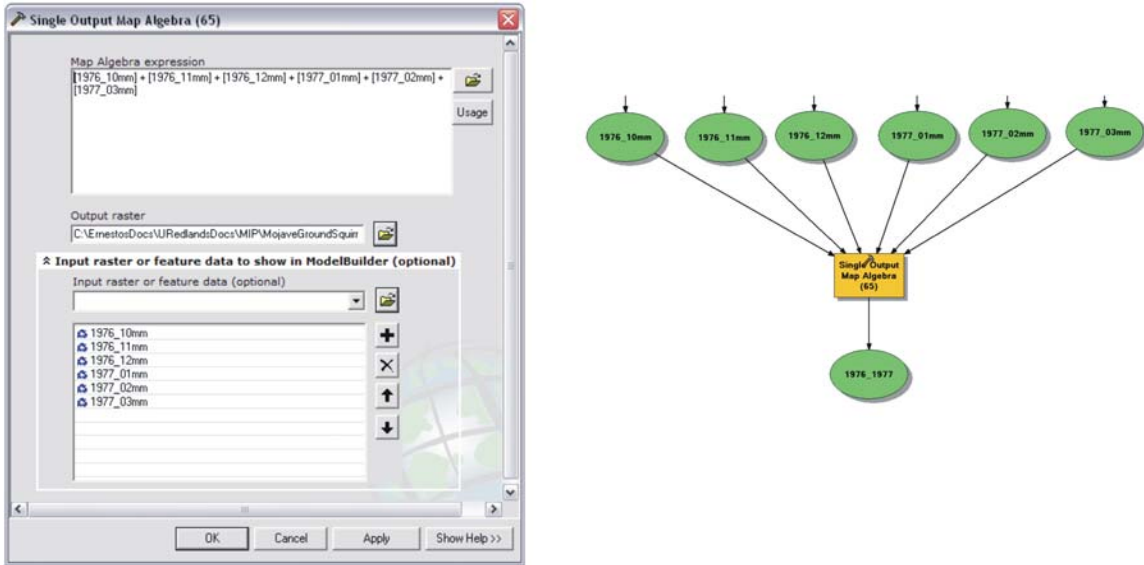
Figure 33: SOMA equation and model for annual winter precipitation.

After calculating the annual winter precipitation for the 30-year period, the mean winter precipitation can be created. The mean winter precipitation dataset was created by using the SOMA tool to sum all the annual winter precipitation dataset for the 30-year period and then dividing it by 30, e.g., ([1976-1977] + … + [2005-2006]) / 30 (Figure 34).
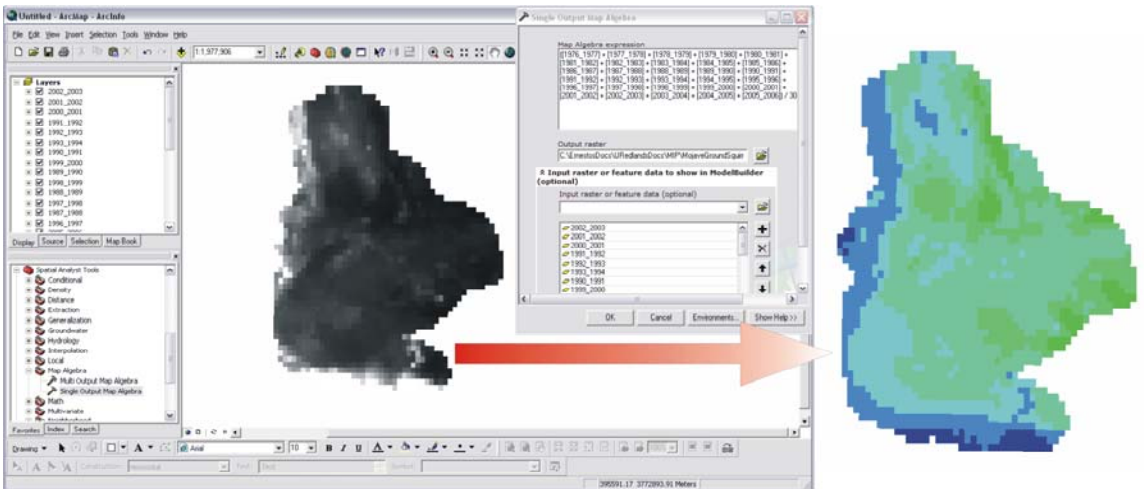
Figure 34: SOMA tool process for mean winter precipitation, 1976 – 2006.

3.1.7.2. Frequency of Dry Winter Periods, 1976 – 2006

Figure 35: Model for frequency of dry winter periods, 1976 – 2006.

Figure 35 shows the model used to create the raster grid that represents the frequency of dry winter periods. The first step was to reclassify the annual winter periods dataset. According to ArcGIS Desktop Help (2005), reclassifying a raster dataset "[replaces] input cell values with new output cell values … [this is done] to replace values based on new information [or] to group certain values together …" Each annual winter precipitation grid was reclassified into values of 0 for those grid cells that had 80 millimeters or more of rainfall and values of 1 for those that had <80 mm (Figure 36).
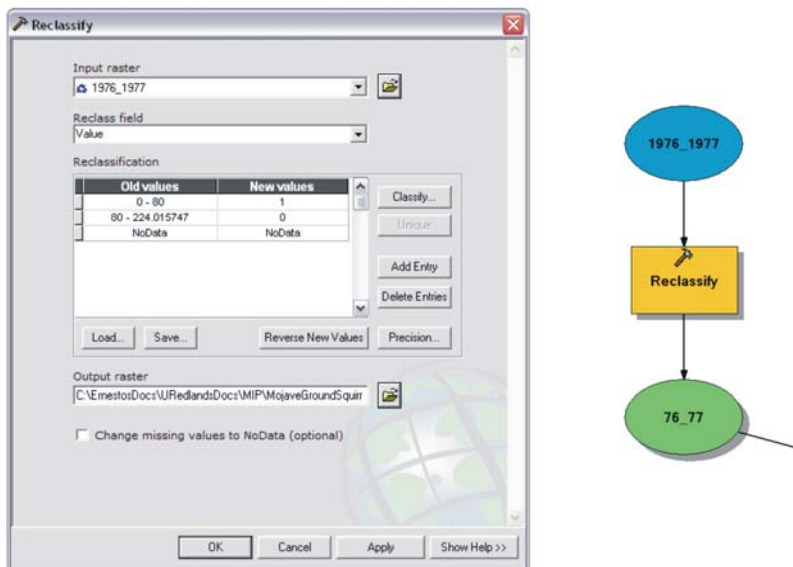
Figure 36: Reclassification of annual winter precipitation.

After reclassifying all the datasets, they were summed together using the SOMA tool and divided by 30. The result was then multiplied by 100 to convert it into a percentage, e.g., (([76_77] + … + [05_06]) / 30) * 100. Figure 37 shows the result obtained after running the process.
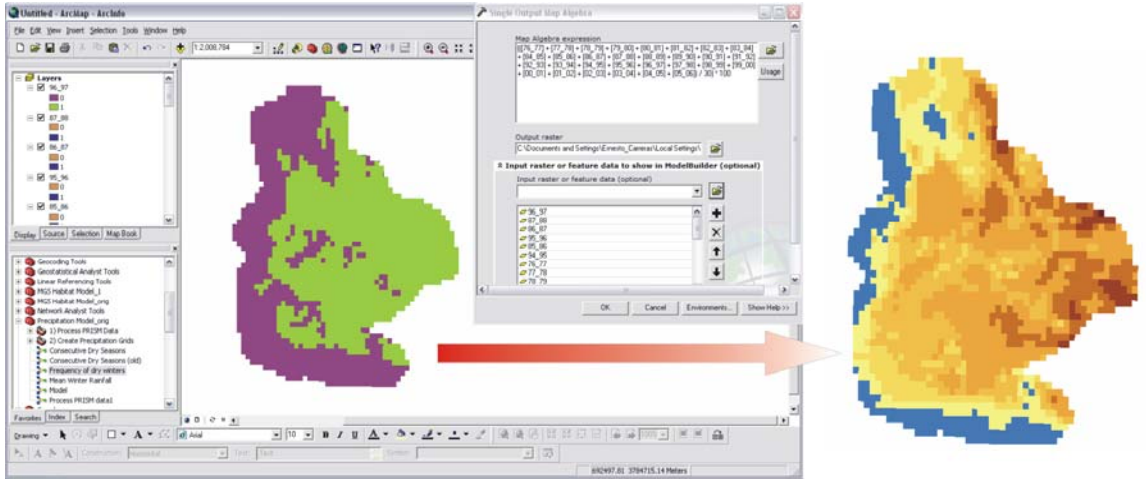
Figure 37: SOMA tool process for frequency of dry winter periods, 1976 – 2006.

3.1.7.3. Consecutive Dry Winter Periods, 1976 – 2006
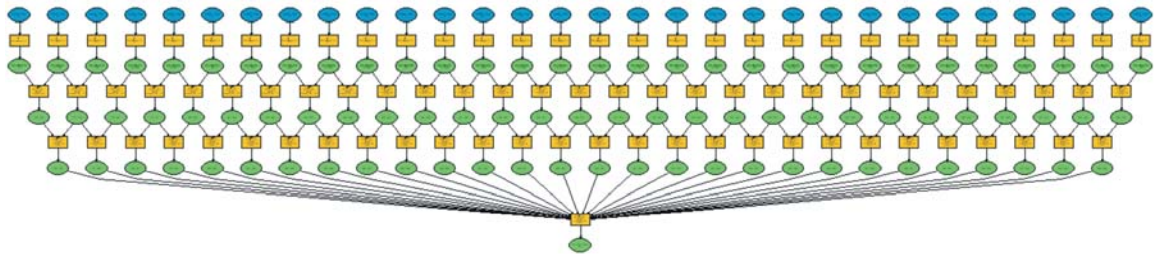
Figure 38: Consecutive dry winter periods model, 1976 – 2006.

Figure 38 shows the model used to create the raster grid representing consecutive dry winter periods. The first step was to reclassify the annual winter precipitation grid into values of 1 for those grid cells that had >80 millimeters of rainfall and values of 2 for those that had <80 mm (Figure 39).
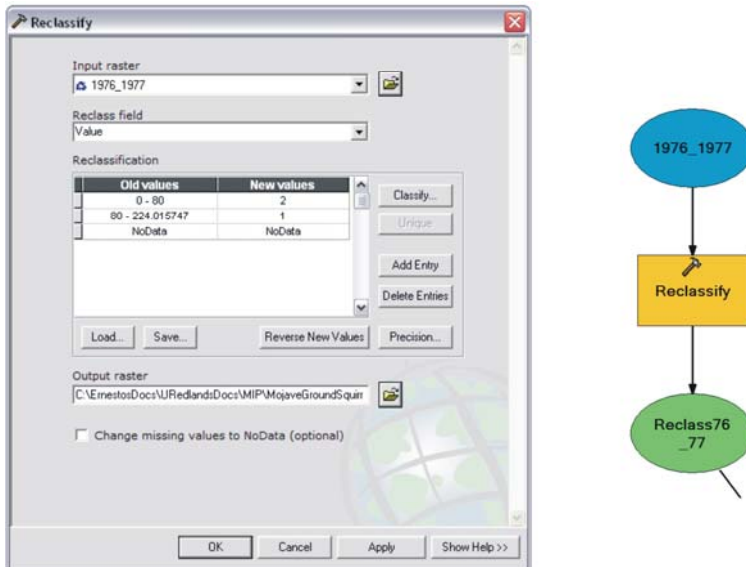
Figure 39: Reclassification of annual winter precipitation.

After reclassifying each dataset using the SOMA tool, two-year values were created by multiplying the values of the individual years, yielding values of 1, 2, and 4 (Figure 40).
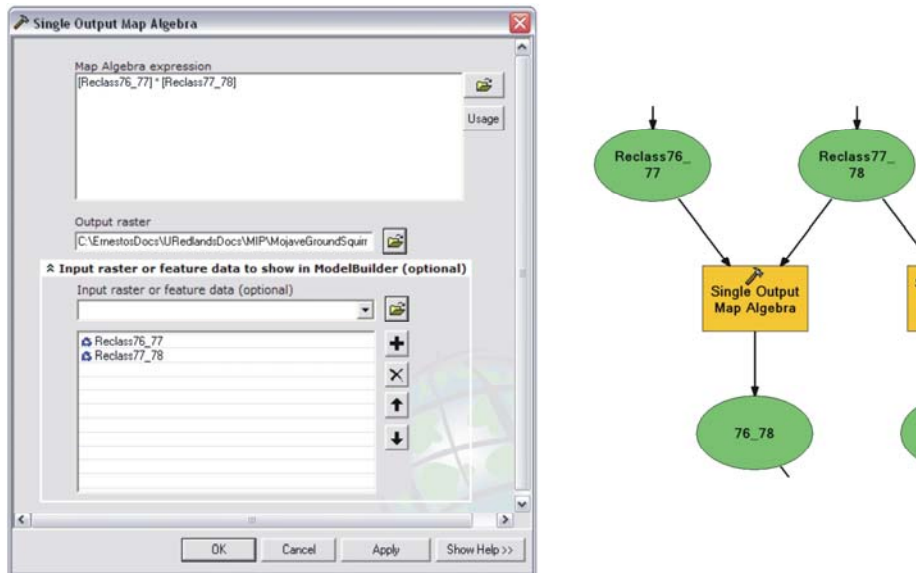
Figure 40: SOMA for two year values dataset.

Then, three-year values were created by multiplying the two-year values, yielding values of 1, 2, 4, 8, and 16 (Figure 41).
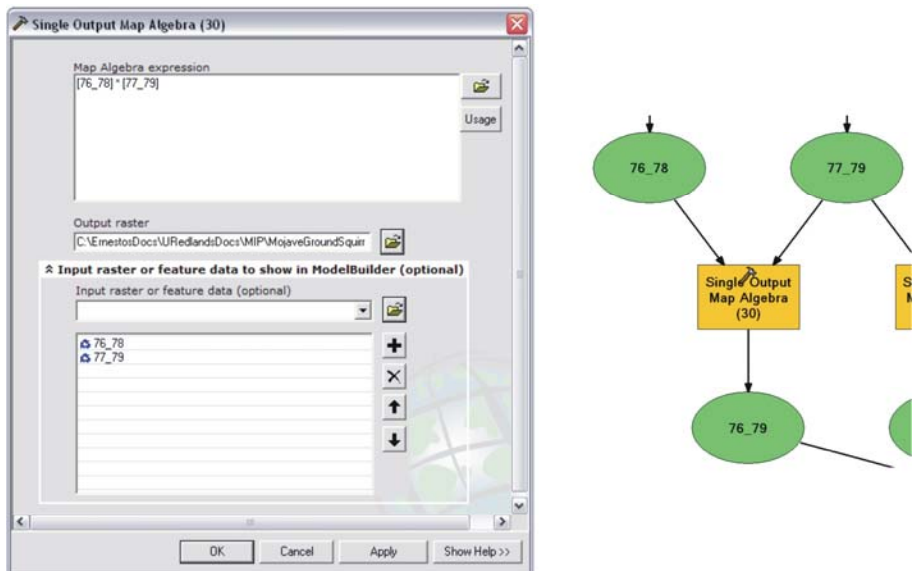
Figure 41: SOMA for three year values dataset.

Finally, the three-year values dataset were summed together using the SOMA tool, e.g. [76_79] + … + [03_06]. This process produced a raster grid with index values indicating consecutive dry winters (Figure 42).
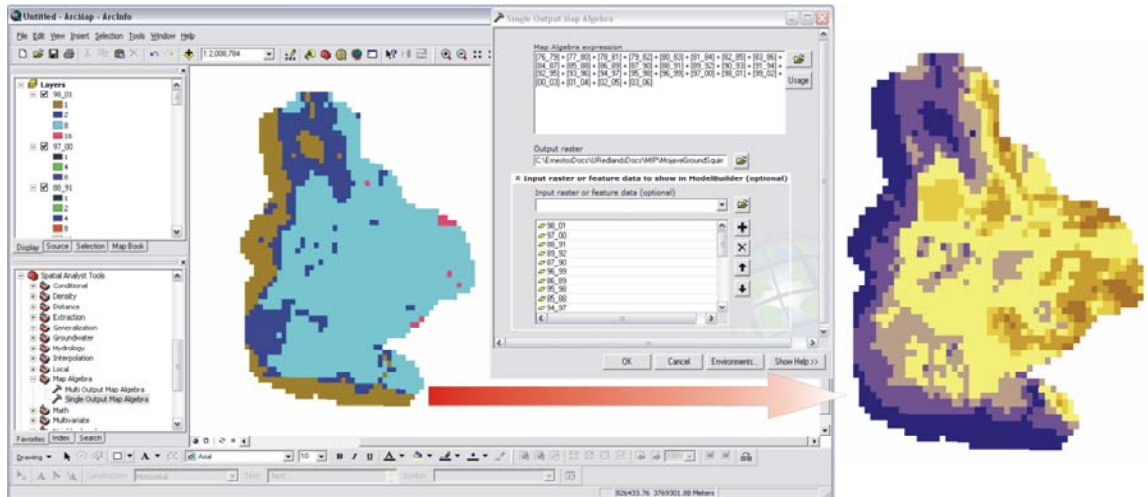
Figure 42: SOMA tool process for consecutive dry winter periods, 1976 – 2006.

3.2. Spatial Modeling

Smyth defines a model as an "abstract and partial representation of some aspect or aspects of the world that can be manipulated to analyze the past, define the present, and to consider possibilities of the future" (as cited in Clarke, Parks, & Crane, 2002). GIS has advanced the process of spatial modeling because it has the ability to simultaneously combine multiple datasets in assisting decision-making processes (Parrish, Parkinson, & Ramseth, 2005). Parrish et al., (2005) explain some advantages of models such as assisting workflow management and automation. Another advantage of creating models is that it is possible to document every step performed throughout the process. Other advantages of creating models are that parameters for a variable can be easily modified and processes can be easily deleted or included (Parrish et al., 2005).

As explained by Parrish et al., (2005), there are three types of spatial models: (a) representation models, (b) suitability models, and (c) process models. Representation models "describe the objects in a landscape, for example, buildings, steams, or forests" (Parrish et al., 2005, pp. 5-7). "Suitability models are often used to find the best location for something" (Parrish et al., 2005, pp. 5-7) like the best habitat areas for the Mohave ground squirrel in this project. There are two different kinds of suitability models, binary and weighted models (Parrish et al., 2005). The process models "attempt to describe the interaction of the objects that are modeled in representation models" (Parrish et al., 2005).

As mentioned above, the type of spatial model used for this study is the suitability model. This model was selected because the main purpose is to predict the locations of the most favorable habitats for the Mohave ground squirrels. For this study, the weighted overlay model was selected over the binary model. The following sections will describe each type of suitability model and will explain why the weighted model was selected.

3.2.1. Binary Suitability Model

The purpose of building suitability models is to find the best location for something, such as store, or where things happen according to certain variables, such as

habitats. Binary suitability models are considered an easy way to determine spatial concurrences or overlaps (Parrish et al., 2005). That means that it tries to look for those areas where all the variables happen together. In this model, the data used for the study are classified as "good (1) or bad (0) and combined in the reclassified layer; [it can be performed] with either raster or vector data]" (Parrish et al., 2005, pp. 5-8).

This type of model has both advantages and disadvantages. The main advantage is its simplicity, although it still requires some decision-making as to what is good or bad (Parrish et al., 2005, pp. 5-8). According to Parrish et al., (2005), some disadvantages are:

1. … all the input layers have the same importance in this form of suitability model, which is seldom [close] to reality …

2. … all the input values in a layer are reduced to simple good and bad measures, for example, there is no second-best [location], and

3. … there is no relative measure of suitability in the output data; there is only good and bad. (pp. 5-8).

3.2.2. Weighted Suitability Model

This type of model is more flexible than the binary since it allows the user to establish values of relative importance for the datasets and to assign relative importance values to the layers themselves (Parrish et al., 2005). These values are set according to the degree of influence each dataset has within the study. The output is a layer with values ranging from 1 to 9, where 9 represents the best value (Parrish et al., 2005).

The model is implemented by reclassifying the dataset values on a relative scale of suitability (Parrish et al., 2005). This step is required because not all the layers used for the model have the same attribute types. By reclassifying, all the layers are converted into a common scale of measurement that can be used for mathematical analyses (Childs et al., 2004). After reclassifying the datasets, each is multiplied by its relative importance, "expressed as a percentage of the total score, and the weighted layers [are added] together" (Parrish et al., 2005, pp. 5-8). As explained by Parrish et al., (2005), when all the weights are summed together, they should add up to 100. In that way, the output will have values on the same 1 to 9 scale as the input values (Parrish et al., 2005, pp. 5-8).

A crucial component when doing weighted models is the model calibration. The purpose of the model calibration process is to "improve the performance of a model by adjusting the numeric values of the parameters in an iterative process" (Chang, 2004, p. 307). Model calibration determines the effectiveness of the model (Parrish et al., 2005). As explained by Parrish et al. (2005), inaccurate results can occur without the appropriate suitability values and weights, even though the hypothesis used in the model is correct. The process of assigning the weights and values to the multiple layers involves much thought, knowledge, and caution. Uncertainty is always present when calibrating these types of models (Chang, 2004). A way of determining the model calibration is by comparing the results with known values (Parrish et al., 2005), such as historic data of Mohave ground squirrel occurrences.

A method known as sensitivity analysis is used to evaluate these uncertainties (Chang, 2004). What this means is that "some models are extremely sensitive to some layers, whereas other factors do not have as much influence in the model" (Parrish et al., 2005, pp. 5-12). Sensitivity analyses can be carried out by calibrating each dataset individually and comparing the results. After running several sensitivity analyses on the model, it can be determined if some of the layers are really needed (Parrish et al., 2005).

3.2.3. Mohave Ground Squirrel Weighted Suitability Model

The main objective in developing the Mohave ground squirrel habitat model is to assist in delineating the most suitable habitat areas for the species. The results obtained from the model will help the client to identify public lands to manage for the conservation of the species and private lands to acquire for conservation when they become available. Also, the model should improve the ability of researchers to locate Mohave ground squirrel populations. Furthermore, the results obtained will increase the knowledge of the species' habitat requirements allowing for the improvement of the model itself.

The weighted overlay model was chosen for the study. It allows the user to establish values of relative magnitude according to the influence of each variable in determining habitat suitability. This model was created using some Spatial Analyst tools along with Model Builder. The Spatial Analyst extension provides a variety of spatial modeling and analysis tools used for geospatial studies, such as suitability analyses (ESRI, 2001). The Model Builder was used to create the spatial model (ESRI, 2000). The model is represented as a diagram showing all the processes applied to obtain the final result. The Mohave ground squirrel habitat model was made possible by the combination of both applications. Figure 43 shows the model created to predict habitat suitability for the species.
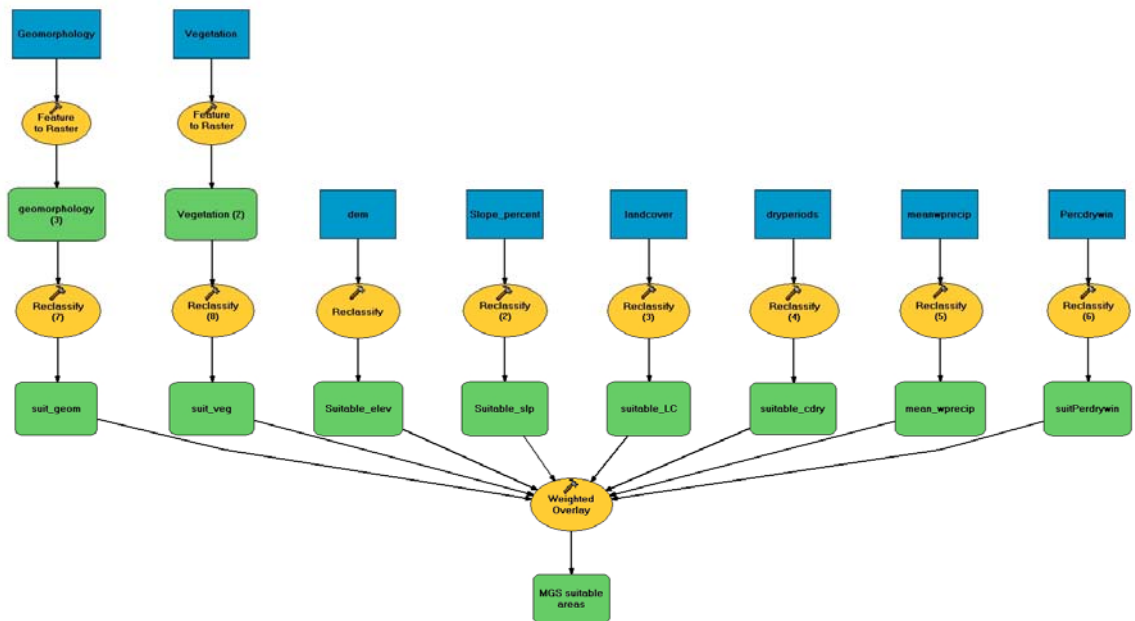
Figure 43: Mohave ground squirrel habitat model.

As with other suitability models, determining habitat suitability for the Mohave ground squirrel requires the analysis of many different variables. The variables identified by the client in determining habitat suitability are the following: vegetation, geomorphology, elevation, slope, land cover, mean precipitation (1976-2006), frequency of dry winter periods (1976-2006), and consecutive dry winter periods (1976-2006). It is important to point out that the datasets used for the study have different attribute scales, such as elevation in meters, slope in percentage, and so on. Therefore, these datasets cannot be added up together to yield a meaningful result. Moreover, the different variables used in the analysis vary in degree of importance. As a result, each class within a variable was assigned a value from 1 to 9, where 9 represents the most important. In some cases, it can range from 0 to 9, in which the zero means not suitable at all. Each dataset was also assigned a value to indicate the percent of influence it had on the weighted overlay model (Figure 44).
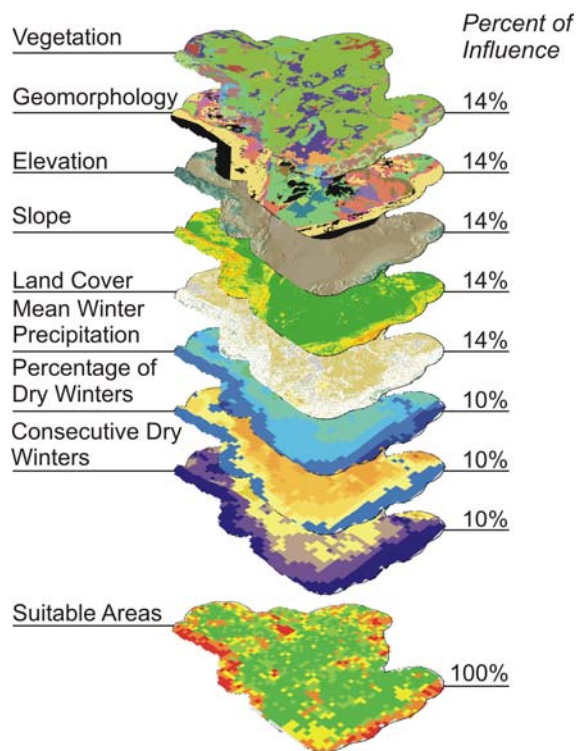
Figure 44: Mohave ground squirrel habitat variables with percent of influence.

3.2.3.1. Elevation

Mohave ground squirrels occur at elevations ranging from 610 – 1,707 meters (Scarry, Leitner, & Leitner, 1996). According to Scarry et al. (1996), it is found from the southern periphery of Owens Lake, in Inyo County, south along the eastern base of the Sierra Nevada to the vicinity of Lancaster and Palmdale. Mohave ground squirrels can be found "as far east as Fort Irwin, Barstow, and Lucerne Valley" (Scarry et al., 1996, p. 3). Figure 45 shows the elevations found within the Mohave ground squirrel's range.

In Meters

	160 - 620
	630 - 800
	810 - 960
	970 - 1,100
	1,200 - 1,300
	1,400 - 1,600
	1,700 - 1,800
	1,900 - 2,100
	2,200 - 2,500
	2,600 - 3,700
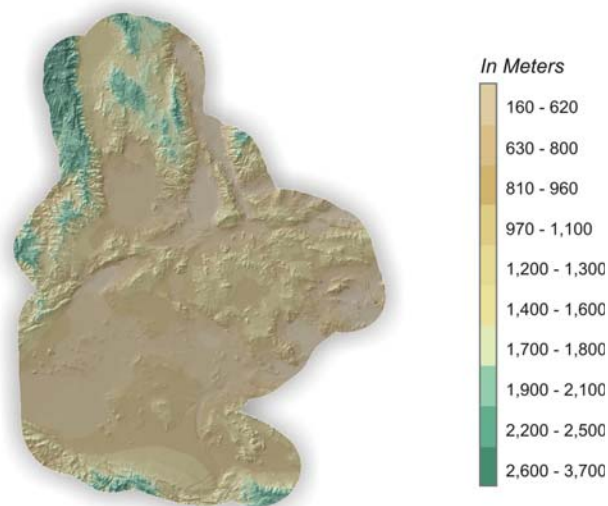
Figure 45: Elevation dataset.

The elevation dataset was reclassified to meet the suitable elevation range where the squirrel's population occurs. Figure 46 shows the scale values assigned to the dataset during the reclassification method. A value of nine was assigned to the elevation range of 610 – 1,707 meters, representing highly suitable areas. The rest was assigned a value of zero, meaning that they were not suitable.
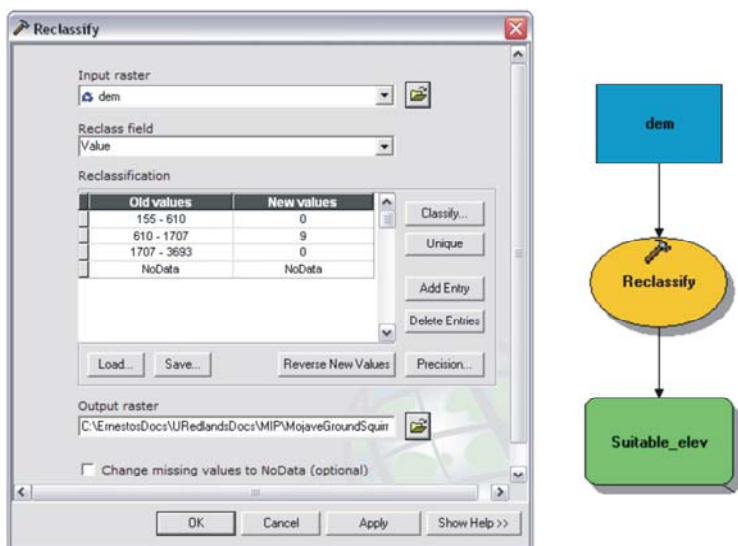
Figure 46: Reclassification of elevation dataset.

Figure 47 is a map showing the areas of suitable elevation within the squirrels' range. The suitable elevations dataset was assigned 14% of influence within the model.

Figure 47: Suitable elevation dataset.

3.2.3.2. Slope

According to Laabs (1998), Mohave ground squirrel populations occur in flat to moderate terrain, whereas steep slopes are avoided. For the purpose of this study, slopes up to 8.5% were considered suitable. Figure 48 shows the distribution of slope classes within the Mohave ground squirrel's range.
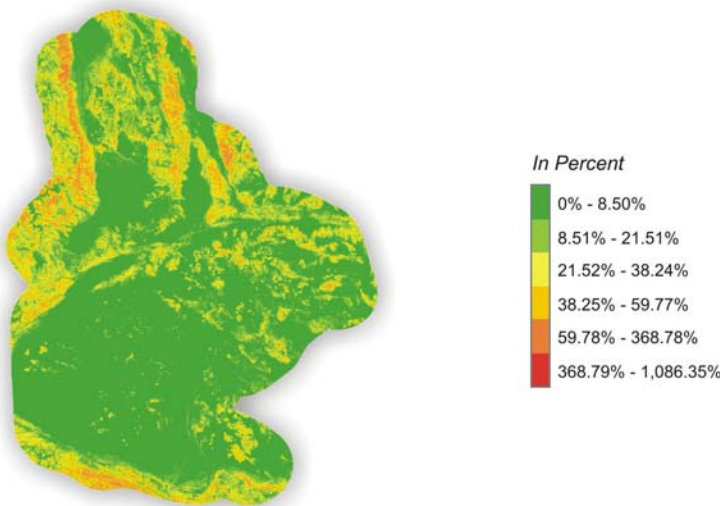
Figure 48: Slope dataset.

The slope dataset was reclassified to meet the suitable slope range for occurrence of the Mohave ground squirrel. Figure 49 shows the scale values assigned to the dataset during the reclassification method. A value of nine was assigned to the slope range of 0 – 8.5%. It was considered that the squirrel cannot occur beyond that percent slope range.
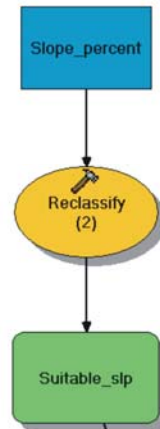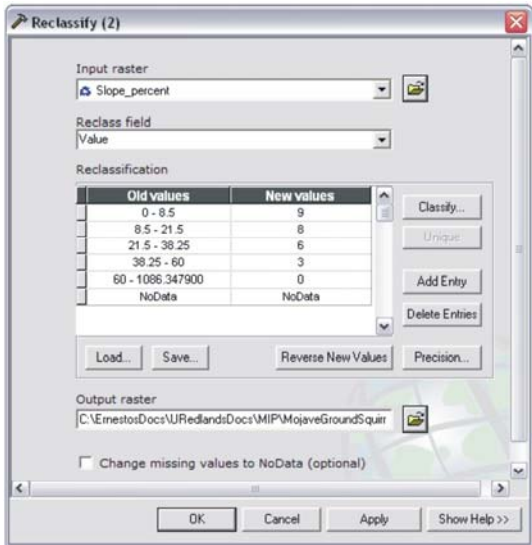
Figure 49: Reclassification of slope dataset.

Figure 50 is a map showing the suitable slopes within the squirrels' range. The suitable slope dataset was also assigned 14% influence.
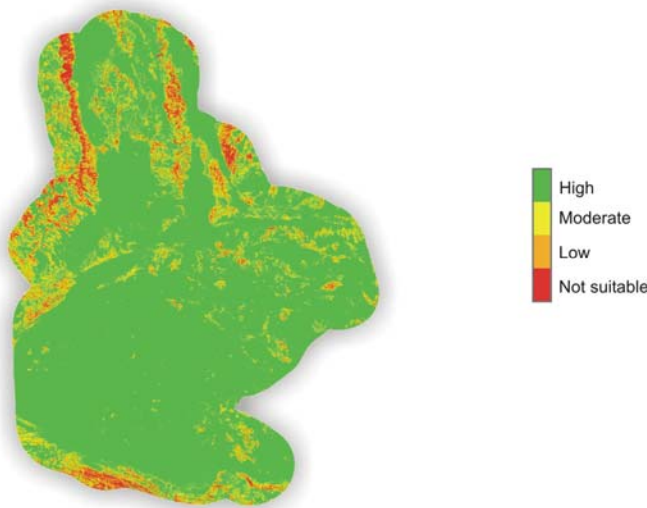
Figure 50: Suitable slope dataset.

3.2.3.3. Land Cover

The land cover dataset was used to determine where the shrublands were located within the squirrel's range. Gustafson (1993) establishes that Mohave ground squirrels may occur in almost all of the natural shrub communities of the western Mojave Desert. These plant communities include Saltbush Scrub (*Atriplex*), Creosote Bush (*Larrea divaricata*), Shadscale Scrub (*Atriplex confertifolia*), Joshua Tree Woodland (*Yucca tridentata*), and Sagebrush Scrub (*Artemisia tridentata*) (Gustafson, 1993).

Although the diet of the Mohave ground squirrel fluctuates throughout the active season, a significant portion of the diet is composed of the leaves of perennial shrubs

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when annual plants are not available (Laabs, 1998). Leitner and Leitner (1998) confirmed that this species is highly dependent on shrub foliage to survive under drought conditions.   Shrubs that are important in the diet include winterfat (*Krascheninnikovia lanata*), spiny hopsage (*Grayia spinosa*), and saltbush (*Atriplex sp.*). According to Leitner et al., (1998), they constituted about 45% of the squirrel's diet within the Coso region located in southwestern Inyo County.

The availability of food resources is critical for determining habitat suitability (Laabs, 1998). "The presence of shrubs that provide reliable forage during drought years may be critical for a population to persist in a particular area" (Laabs, 1998, p. 3), making this one of the main variables needed in evaluating habitat suitability. Unfortunately, neither the land cover nor vegetation datasets provide information about the occurrence of shrub species important in the diet. Figure 51 shows the different land cover classes found within the Mohave ground squirrel's range.

Water
Perennial ice and snow
Low intensity residential
High intensity residential
Commercial/industrial/transport
Bare rock/sand/clay
Quarries/strip mines/gravel pit
Transitional
Deciduous forest
Evergreen forest
Mixed forest
Shrubland
Orchards and vineyards
Grasslands/herbaceous
Pasture/hay
Row crops
Small grains
Fallow
Urban/recreational grasses
Woody wetlands
Emergent herbaceous wetlands

Figure 51: Land cover dataset.

The land cover dataset was reclassified to meet the suitable land cover classes for the occurrence of the Mohave ground squirrel. In this case, shrubland areas were considered the only suitable class (Table 2).

Land Cover Class	Scale Value
Shrubland	9
Water	0
Perennial ice and snow	0
Low intensity residential	0
High intensity residential	0
Commercial/industrial/trans	0
Bare rock/sand/clay	0
Quarries/strip mines/gravel	0
Transitional	0
Deciduous forest	0
Evergreen forest	0
Mixed forest	0
Orchards and vineyards	0
Grasslands/herbaceous	0
Pasture/hay	0
Row crops	0
Small grains	0
Fallow	0
Urban/recreational grasses	0
Woody wetlands	0
Emergent herbaceous wetland	0

Table 2: Land Cover classes and scale values.

Figure 52 shows the scale values assigned to the land cover dataset during the reclassification method. A value of nine was assigned to the shrubland class. The other classes were considered unsuitable for the squirrel's occurrence, therefore receiving a scale value of zero.
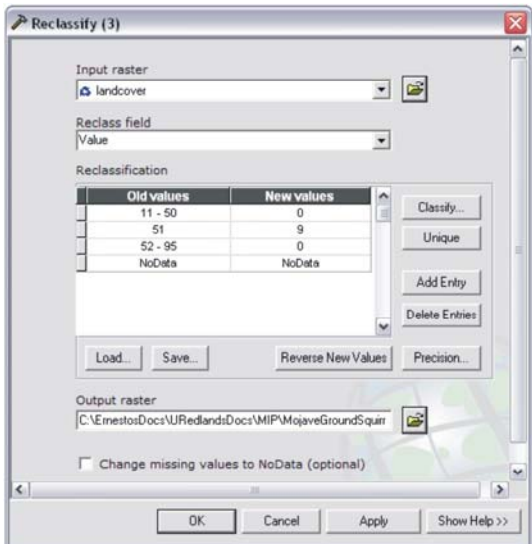
Figure 52: Reclassification of land cover dataset.

Figure 53 is a map showing the suitable land cover within the squirrels' range. The land cover dataset was also assigned 14% influence.
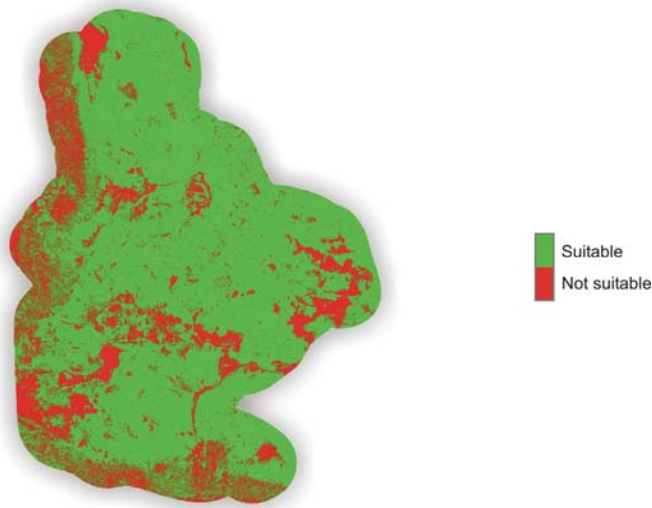
Figure 53: Suitable land cover dataset.

3.2.3.4. Vegetation

The vegetation layer was used to strengthen the land cover dataset since it contained more detailed vegetation classification. Nevertheless, it still was too generalized for the scope of the study. Neither the vegetation nor land cover datasets contained detailed information on the species composition of the desert plant communities, especially those plant species preferred in the Mohave ground squirrel diet. Figure 54 shows the different vegetation classes found within the Mohave ground squirrel's range, as displayed in the vegetation layer.
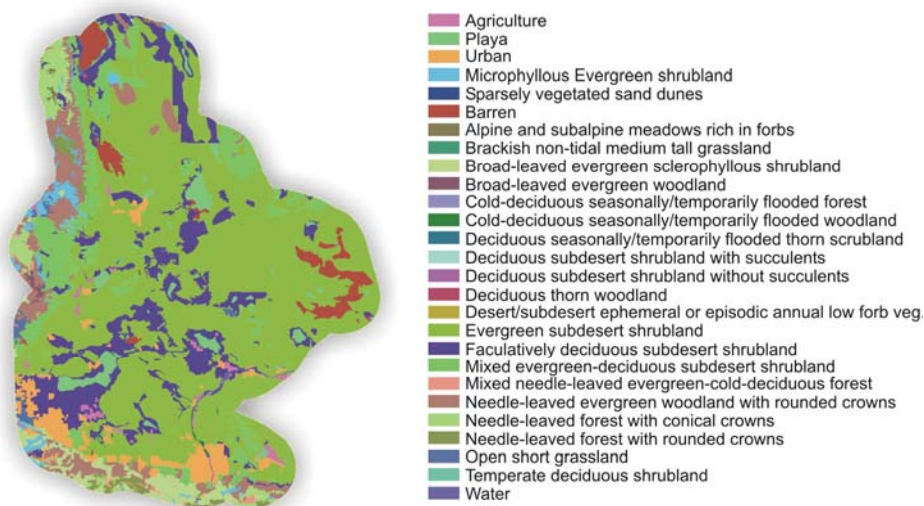
Figure 54: Vegetation dataset.

The first step was to add a field to the attribute table of the vegetation layer. This new field contained the scale values to be assigned later in the reclassification method.

Table 3 shows the scale values assigned to each vegetation class. This step was required since the dataset was in vector format. The next step was to convert the vegetation layer into raster format. This conversion allowed the use of the dataset in the weighted overlay analysis. This task was achieved by using the Feature to Raster tool (Figure 55).
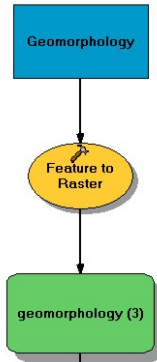
Figure 55: Feature to Raster tool (Vegetation).

Vegetation	Scale Value
(Group) Sparsely vegetated sand dunes	9
Deciduous subdesert shrubland with succulents	9
Deciduous subdesert shrubland without succulents	9
Desert/subdesert ephemeral or episodic annual low forb veg.	9
Evergreen subdesert shrubland	9
Faculatively deciduous subdesert shrubland	9
Mixed evergreen-deciduous subdesert shrubland	9
(Class) Agriculture	0
(class) Barren	0
(Class) Playa	0
(Class) Urban	0
(class) water	0
(Group) Microphyllous Evergreen shrubland	0
Alpine and subalpine meadows rich in forbs	0
Brackish non-tidal medium tall grassland	0
Broad-leaved evergreen sclerophyllous shrubland	0
Broad-leaved evergreen woodland	0
Cold-Deciduous seasonally/temporarily floode forest	0
Cold-deciduous seasonally/temporarily flooded woodland	0
Deciduous seasonally/temporarily flooded thorn scrubland	0
Deciduous thorn woodland	0
Mixed needle-leaved evergreen-cold-deciduous forest	0
Needle-leaved evergreen woodland with rounded crowns	0
Needle-leaved forest with conical crowns	0
Needle-leaved forest with rounded crowns	0
Open short grassland	0
Temperate deciduous shrubland	0

Table 3: Vegetation classes and scale values.

Figure 56 shows the scale values assigned to the dataset during the reclassification method. A value of nine was assigned to the suitable shrubland classes. The classes that were considered not suitable for the squirrel's occurrence were given a scale value of zero.
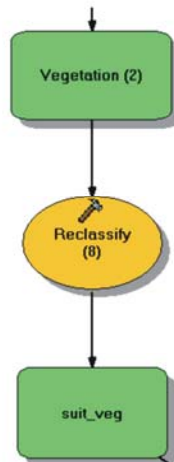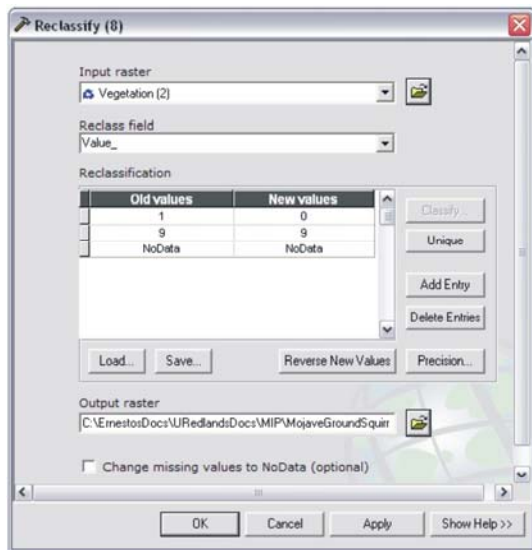
Figure 56: Reclassification of vegetation dataset.

Figure 57 is a map showing the suitable vegetation classes within the squirrels' range. This dataset also received 14% influence.
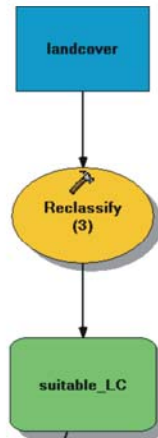

Figure 57: Suitable vegetation dataset.

3.2.3.5. Geomorphology

        (Wessman, 1977) reported that Mohave ground squirrels occur in sandy and alluvial soils. Even though they can be found in gravelly and some rocky soils, these are not their preferred habitat (Wessman, 1977). Wessman (1977) also established that Mohave ground squirrels were absent in very rocky areas and sterile playas. As described by Burt (1936), the topography where the species can be found is characterized as fairly level, where the soil is mixed with sand and coarse gravel. This makes it easier for the squirrels to excavate and construct their burrows. "Large alluvial- filled valleys with deeper fine to medium texture soils, absence of rocks (desert pavement) … appear to

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be their preference" (Aardahl & Roush, 1985, Habitat Features & Associated Ground Squirrel Populations section, ¶ 5). Figure 58 shows the types of landforms found within the Mohave ground squirrel's range.
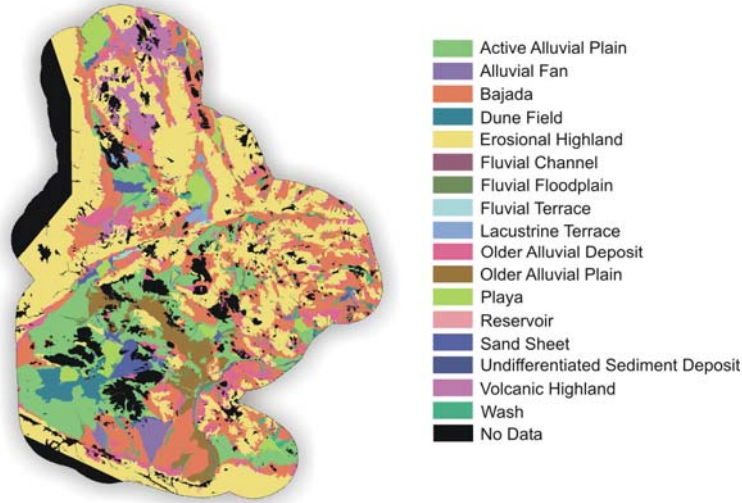
Figure 58: Geomorphology dataset.

As with the vegetation layer, the first step was to add a field to the attribute table so that scale values could be assigned to the different geomorphologic types. These values were used during the reclassification method. Table 4 shows the scale values assigned to each landform type. This step was required since the dataset was in vector format and it needed to be converted into raster for the weighted overlay analysis. This task was achieved by using the Feature to Raster tool (Figure 59).
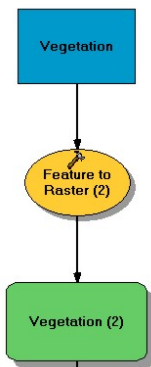
Figure 59: Feature to Raster tool (Geomorphology).

| Landform Types	Scale Value
Active Alluvial Plain	9
Alluvial Fan	9
Bajada	9
Older Alluvial Deposit	9
Older Alluvial Plain	9
Sand Sheet	9
Undifferentiated Sediment Deposit	9
Wash	9
Erosional Highland	4
Fluvial Floodplain	4
Fluvial Terrace	4
Volcanic Highland	4
Dune Field	0
Fluvial Channel	0
Lacustrine Terrace	0
Playa	0
Reservoir	0

Table 4: Landform classes and scale values.

Figure 60 shows the scale values assigned to the dataset while reclassifying it. A value of nine was assigned to the most suitable landform classes while the rest received either four for low suitability and zero for unsuitable.
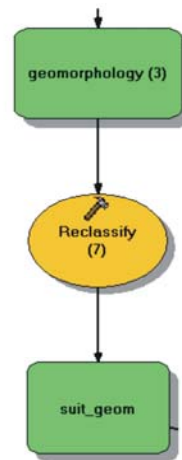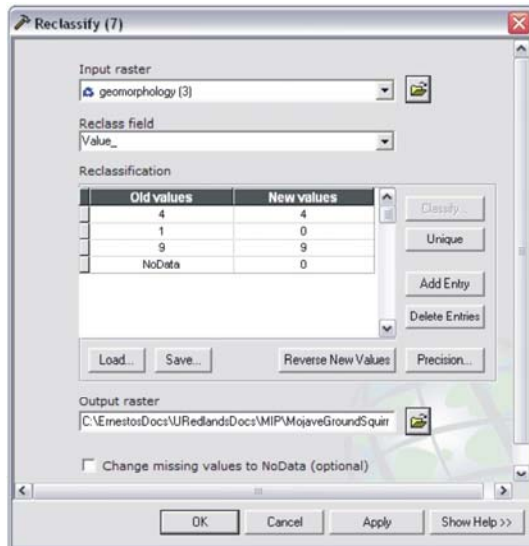
Figure 60: Reclassification of geomorphology dataset.

Figure 61 is a map showing the suitable landform classes within the squirrels' range. This dataset was also assigned 14% influence.
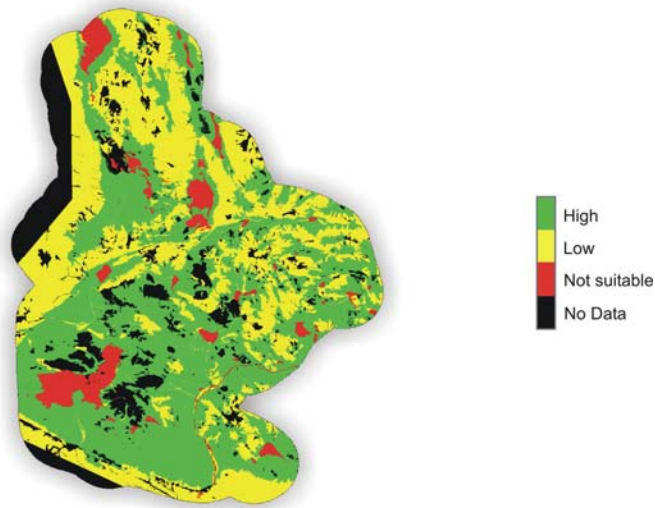
Figure 61: Suitable geomorphology dataset.

3.2.3.6. Mean Winter Precipitation, 1976 – 2006

The mean winter precipitation dataset was created to show the amount of precipitation that falls on the entire Mohave ground squirrel range (averaged over a 30-year period). Leitner et al., (1998) determined a correlation between reproductive failure and low winter precipitation. Reproductive success depends upon the amount of winter precipitation. If there is inadequate precipitation, insufficient food resources may result in complete reproductive failure (Leitner et al., 1998). Figure 62 shows the mean winter precipitation for the Mohave ground squirrel range during a 30-year period.
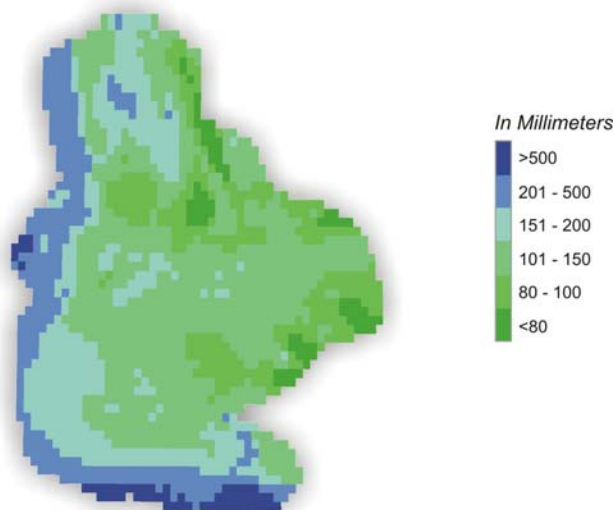
Figure 62: Mean winter precipitation (1976 – 2006) dataset.

The mean winter precipitation dataset was reclassified to meet the suitable precipitation range for the occurrence of the squirrel's population. Figure 63 shows the

scale values assigned to the dataset during the reclassification method. A value of nine was assigned to those areas that received an average of 100 millimeters or more during the 30-year period.
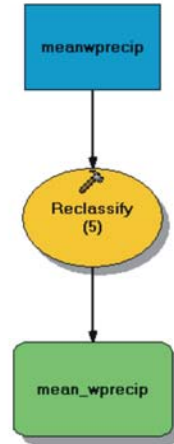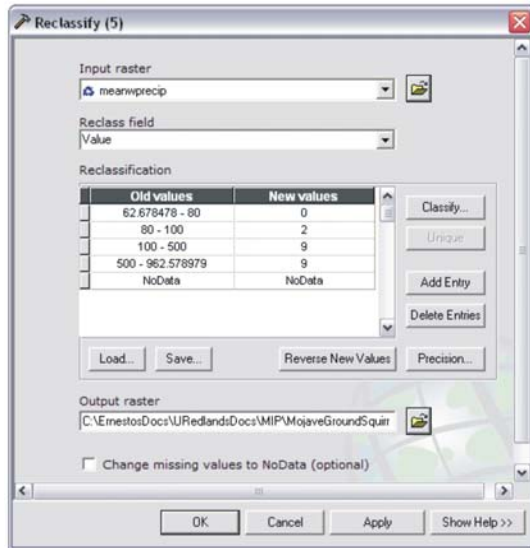
Figure 63: Reclassification of mean winter precipitation dataset.

Figure 64 is a map showing the suitability rankings for areas within the squirrel's range based upon mean winter precipitation. This dataset was assigned 14% influence. The precipitation datasets are considered to be the main variables in determining habitat suitability. Even though winter precipitation is a significant variable, there should be caution when assigning the percent of influence. If the percent of influence assigned is too high, it can affect the importance that the other variables have in the analysis.
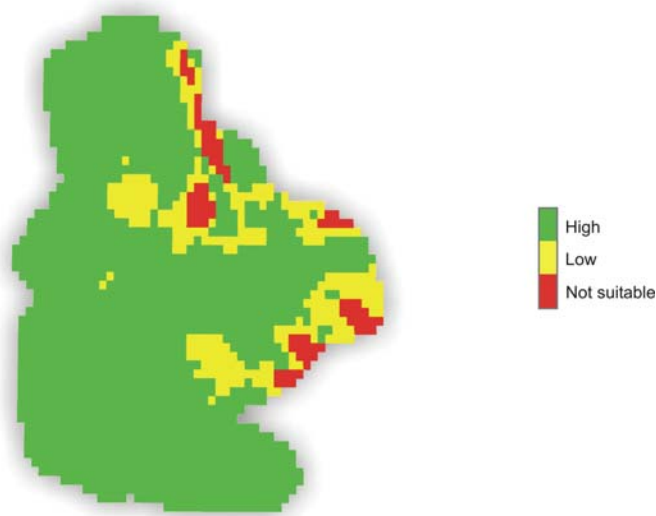
Figure 64: Suitable mean winter precipitation dataset.

3.2.3.7. Frequency of Dry Winter Periods, 1976 – 2006

The frequency of dry winter periods dataset was created to show the number of drought periods within the Mohave ground squirrel range over a 30-year period. Subsequently, this dataset was converted into percentages (Figure 65).

As mentioned earlier, Mohave ground squirrel reproductive success is closely related to the amount of winter precipitation (Leitner et al., 1998). Gustafson (1993) stated that just one year of low precipitation may cause a decrease in the productivity of annual plants and shrubs within the species' range. If there are not enough food resources, survival of adult Mohave ground squirrels may decease because of lack of nutrition (Leitner et al., 1998).
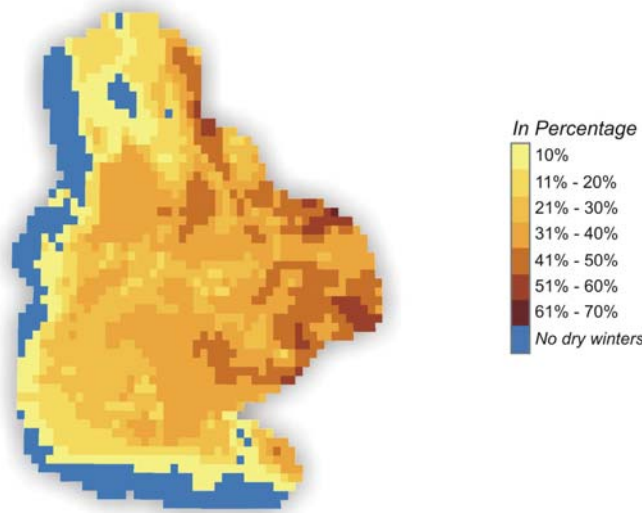
Figure 65: Frequency of dry winters (1976 – 2006) dataset.

The frequency of dry winters dataset was then reclassified to show the levels of suitability for the occurrence of Mohave ground squirrels. Figure 66 shows the scale values assigned to the dataset during the reclassification method. A value of nine was assigned to those areas that had 10% dry winters during the 30-year period. A value of zero was assigned to those areas that had no dry winters at all since they were areas located in rugged steep mountains with elevations not suitable for the species, i.e., Sierra Nevada and San Gabriel mountains.

Figure 66: Reclassification of frequency of dry winter periods dataset.

Figure 67 is a map showing the suitability level for the areas that had dry winters within the squirrels' range. It also shows areas with no dry periods at all but since these areas were located in unsuitable elevation and slopes, they were classified also as unsuitable. This dataset was also assigned 14% influence since winter drought is considered one of the main variables determining the survival of the species.
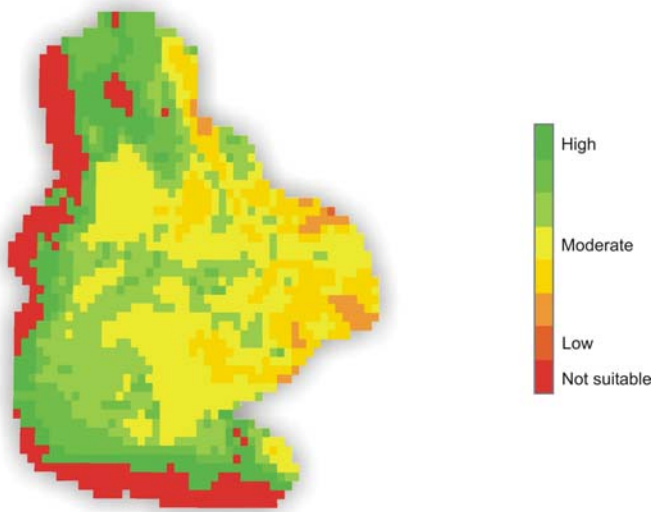
Figure 67: Suitable frequency of dry winter periods dataset.

3.2.3.8. Consecutive Dry Winter Periods, 1976 – 2006

The consecutive dry winter periods dataset was created by incorporating the frequency of dry winter periods model but taking it to another level to determine areas that have had two or more consecutive dry periods. This dataset is crucial when determining Mohave ground squirrel suitable habitats since two or more years can be devastating to the species' population. This dataset differs from the frequency of dry

winter periods in that it considers the timing of the dry winters by emphasizing the effect of consecutive dry winters.

Studies have proved that local Mohave ground squirrel populations can be extirpated after extended drought periods (Gustafson, 1993). Leitner, Leitner, and Harris' study, *Third year baseline report: Coso grazing enclosure monitoring study*, (as cited by Gustafson, 1993) determined that Mohave ground squirrels became extinct in the Rose Valley study area after two consecutive years of low winter rainfall. It can take several years for the squirrels to repopulate an area once they are extirpated, a process that can be adversely affected by increasing habitat fragmentation in the Mojave Desert (Gustafson, 1993). Figure 68 shows the consecutive dry winter periods dataset.
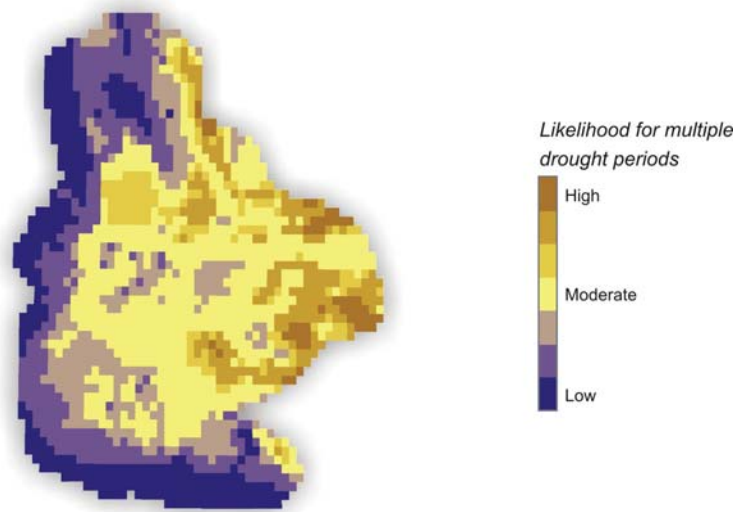
Figure 68: Consecutive dry winter periods (1976 – 2006) dataset.

As mentioned earlier, the difference between the dataset representing the frequency of dry winter periods with the dataset representing the consecutive dry winter periods is that is that the latter considers the timing of dry winters by emphasizing the effect of consecutive dry winters. The frequency of dry winter periods dataset just shows the percentage of droughts during the 30-year period without taking into consideration the timing factor. This can be better understood with the graphics below (Figure 69).

Figure 69 shows in the upper left dataset the frequency of dry winter periods and the consecutive winter drought periods in the upper right. The upper left dataset was created using a simple analysis to calculate just the frequency of dry winter periods. It suggests that the blue areas are wet enough and the brown too dry. The upper right dataset was created with the more complex model that considers the timing of dry winters. This model is able to detect those areas that had two or more consecutive drought periods during the 30-year period. The bottom dataset is the result of overlaying both datasets together using some transparency on one of the layers producing a combination of four colors. It suggests that the purple areas are considered as "wet enough" using the simple analysis, but the complex model suggests the dry areas occur consecutively, creating possible problems for Mohave ground squirrel survival. The olive cells are considered as areas that are "too dry" with the simple analysis, whereas the

complex model suggests that the dry years rarely occur consecutively, which is not that bad for the Mohave ground squirrel population.
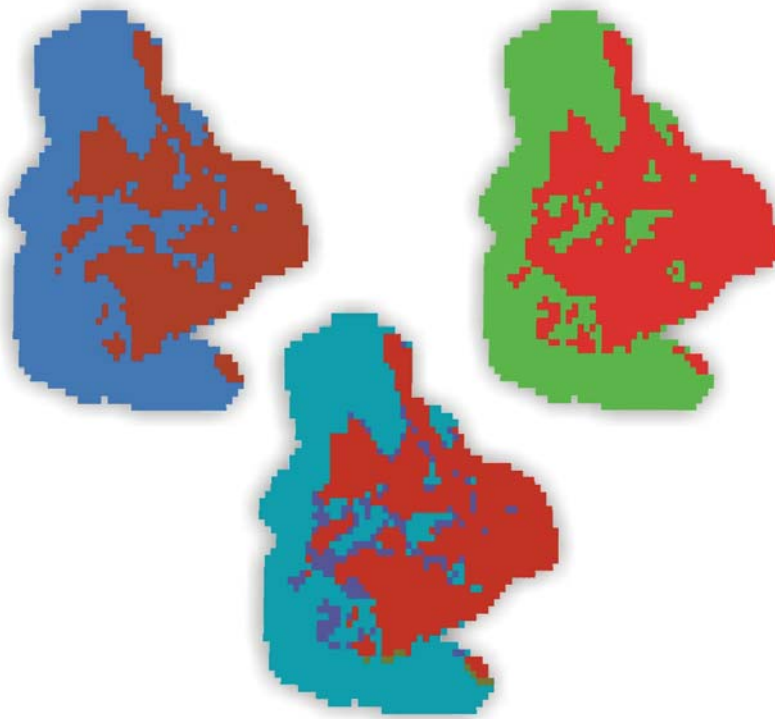
Figure 69: Frequency of dry winters and consecutive dry winters output analysis.

Going back to the Mohave ground squirrel model, the consecutive dry winter periods dataset was then reclassified to show the suitability level of consecutive drought periods within the Mohave ground squirrel range. Figure 70 shows the scale values assigned to the dataset during the reclassification method.
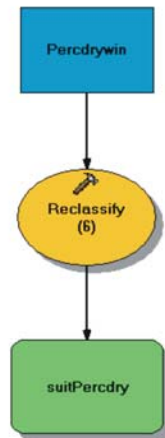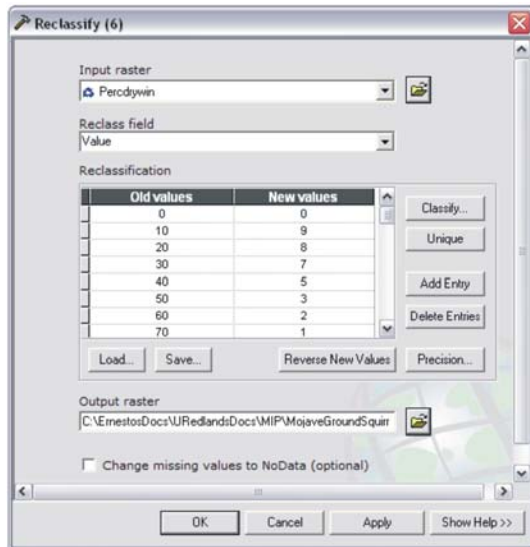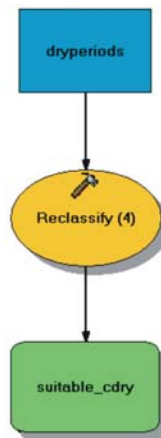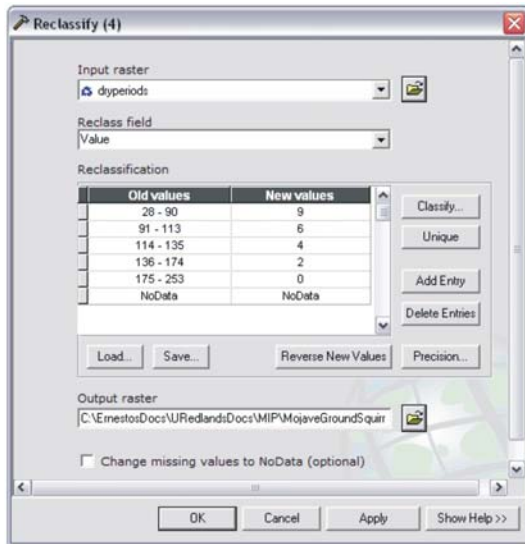

Figure 70: Reclassification of consecutive dry winter periods dataset.

Figure 71 is a map showing the suitability level for the areas that suffered consecutive drought periods within the Mohave ground squirrel range. A value of nine was assigned to those areas considered to be suitable. This dataset was also assigned 14% influence since two or more consecutive drought periods are considered an important factor that will determine the survival of the squirrel's populations.
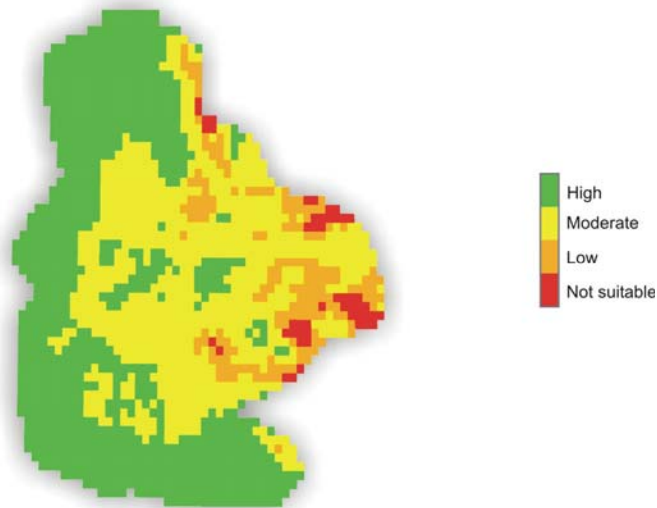
Figure 71: Suitable consecutive dry winter periods dataset.

3.2.3.9. Mohave Ground Squirrel Suitable Habitat Areas

The Mohave ground squirrel suitable areas dataset was created after running the weighted overlay analysis. Figure 72 shows the weighted overlay parameters used to generate the Mohave ground squirrel suitable habitats dataset. The weighted overlay table shows the percent of influenced assigned to each dataset and the scale value assigned to each class within the dataset. The weighted overlay analysis multiplies each dataset by its weight and then sums all of them using map algebra. The dataset created shows the habitat areas within the range classified from highly suitable to non-suitable (Figure 73). This dataset will be further explained in Chapter 4.

Figure 72: Weighted Overlay process for Mohave ground squirrel habitats.

Figure 73: Mohave ground squirrel suitable habitats.

4. Results

This chapter will explain the results of the Mohave ground squirrel habitat suitability model. This model was developed through many days of analyzing the multiple available datasets and through many discussions with the client. Like any model, this one was put through a number of testing stages known as model calibration and sensitivity analysis. The model calibration and sensitivity analyses will be described before presenting the final outcome, i.e., the Mohave ground squirrel habitat suitability dataset.

4.1. Model Calibration and Sensitivity Analysis # 1

The first step in testing the model consisted of using all the main variables: (a) elevation, (b) slope, (c) land cover, (d) vegetation, (e) geomorphology, (f) mean winter precipitation (1976 – 2006), (g) frequency of dry winter periods (1976 – 2006), and (h) consecutive dry winter periods, (1976 – 2006). At first, values of nine were assigned to those grid cells that were considered highly suitable for the occurrence of Mohave ground squirrels, and one to those areas that were considered to be of low suitability. Only one dataset, the percent of dry winters, had a class with a value of zero. The reason that this class was assigned a value of zero was based on previous knowledge of the topography of the area involved. The area with a value of zero was in the Sierra Nevada, a mountain range located to the west of the study area. Even though some of this area had no dry periods at all, the species was known to be absent because of the rugged terrain and extreme high elevations. Table 5 shows the parameters used during this stage.

Raster	% Influence	Field	Scale Value
Elevation	8	*Value*	
		155 - 610	1
		610 - 1707	9
		1707 - 3693	1
Slope	8	*Value*	
		0 - 8.5	9
		8.5 - 21.5	8
		21.5 - 38.25	6
		38.25 - 60	3
		60 - 1086.347900	1
Land Cover	8	*Value*	
		11 - 50	1
		51	9
		52 - 95	1
Vegetation	8	*Value*	
		1	1
		9	9
Geomorphology	8	*Value*	
		4	4
		1	1
		9	9
Mean winter precipitation	20	*Value*	
		62.678478 - 80	1
		80 - 100	2
		100 - 500	9
		500 - 962.578979	9
Percentage of dry winters	20	*Value*	
		0 - 10	0
		11 - 20	8
		21 - 30	7
		31 - 40	5
		41 - 50	3
		51 - 60	2
		61 - 70	1
Consecutive dry winters	20	*Value*	
		28 - 90	9
		91 - 113	6
		114 - 135	4
		136 - 174	2
		175 - 253	1

Table 5: Weighted overlay parameters with all variables – 1st stage.
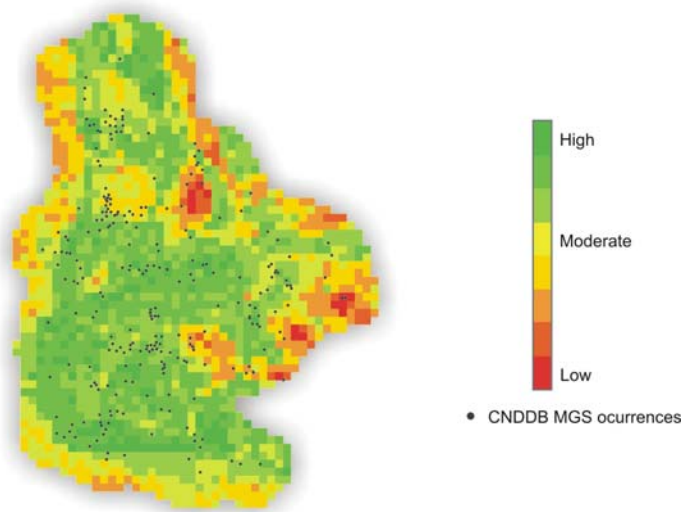
Figure 74: MGS habitat areas output - Test model # 1.

Figure 74 shows the result of the test model according to the parameters in Table 5. This map shows Mohave ground squirrel habitat suitability with the California Natural Diversity Database (CNDDB) layer of Mohave ground squirrel occurrences. In Bittman's article, *The California Natural Diversity Database: A natural heritage program for rare species and vegetation* (as cited by Brooks & Matchett, 2002), the CNDDB is a "statewide inventory of locations and condition of California's rare endangered plants, animals, and vegetation communities". According to Brooks and Matchett (2002), this database is reliable since it only contains location information of the places where the species was trapped or observed.

A visual accuracy assessment was conducted as part of the analysis. This is a qualitative assessment, in which the final output obtained from this model was compared with other datasets to test its accuracy. These datasets were the CNDDB MGS occurrences and the geomorphology layer. The CNDDB MGS occurrences dataset was used to show the locations where the species has been observed or captured. It can be assumed that the majority of these locations should fall within the areas considered as suitable areas. The geomorphology layer was used to delineate the playa formations, which are considered unsuitable areas for the occurrence of the squirrel.

It is noticeable that the Mohave ground squirrel occurrences follow the pattern obtained from the model. Even though the species occurrences seem to follow the pattern of suitable areas within their range, the model is not representing properly some areas that should be considered as unsuitable. Figure 75 shows landform types classified as playas that were shown as suitable areas, although they cannot support Mohave ground squirrel populations.

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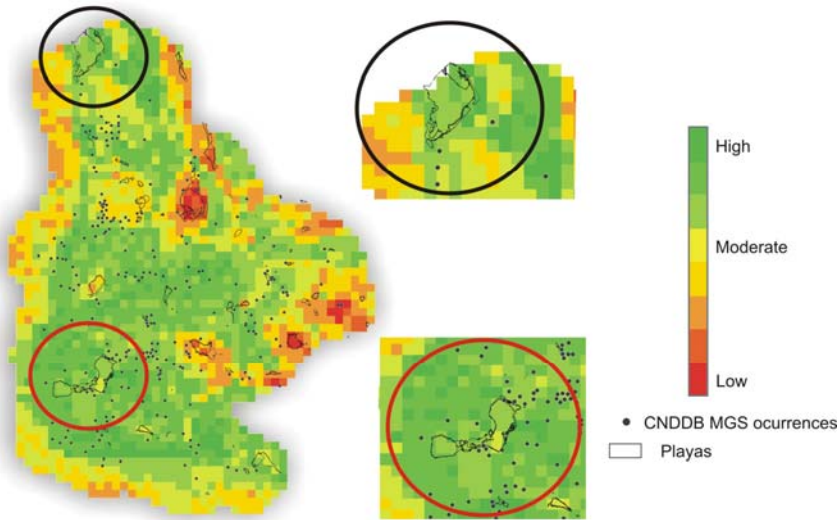
Figure 75: Playas.

This model was then modified as part of the calibration and sensitivity analysis process. This was done by excluding each of the first five variables one at a time, always retaining the precipitation and dry winter datasets. The purpose of this sequential exclusion was to determine whether the model was sensitive to any of these layers. By excluding datasets, it could be established whether there was any significant change from the pattern shown in the dataset created with the model that included all the variables. The precipitation and dry winter datasets were always kept at 20% influence, whereas the rest were increased from 8% to 10% to maintain equal impact of the four remaining candidate variables with a total influence summing to 100%. The scale values were not changed in any of these iterations.
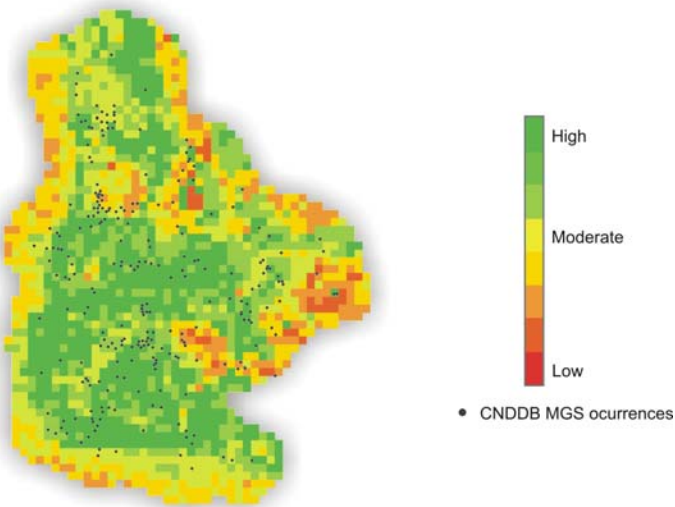
Figure 76: MGS Output test model # 1 (elevation excluded).

Figure 76 shows the suitable habitats after excluding the elevation dataset. After excluding this dataset, there was an increment in the grid cells classified as moderately suitable, as well as highly suitable. In both maps, the pattern shown for the suitable areas is similar even though the elevation was excluded from the model in the second iteration. After evaluating the results, it was determined that there were no significant changes.
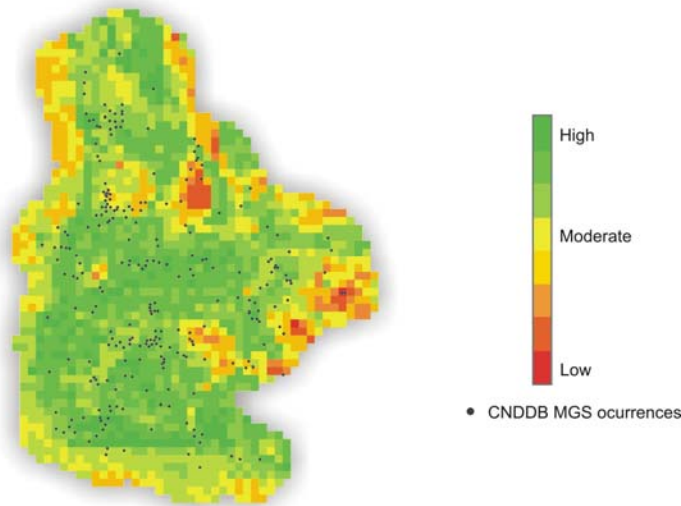
Figure 77: MGS Output test model # 1 (slope excluded).

Figure 77 shows the result after excluding the slope dataset. The only minor change that occurred in this third iteration was that some of the least suitable areas were changed to moderately suitable. Over all, the model does not appear to change significantly when the slope layer is excluded. It can be concluded, therefore, that the exclusion of the layer did not significantly affect the outcome of the model.
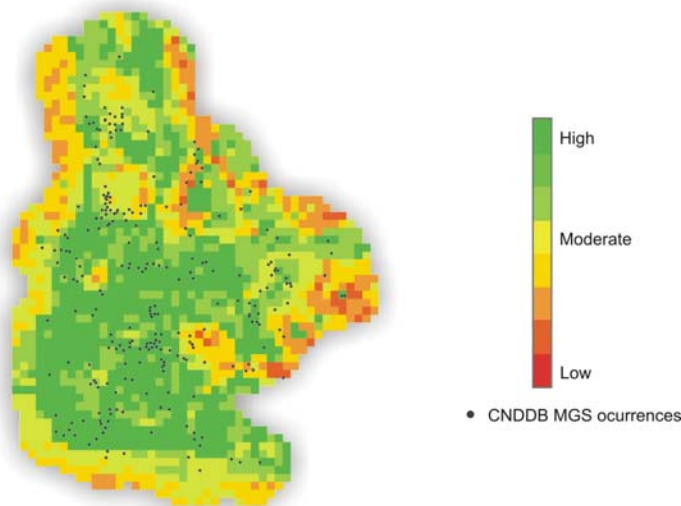
Figure 78: MGS Output test model # 1 (land cover excluded).

The fourth iteration consisted of eliminating the land cover dataset. Figure 78 shows the result obtained after running the model, excluding the land cover dataset. The changes that occurred were in the areas that are considered of low suitability. After excluding the land cover dataset, those areas appear as highly suitable.
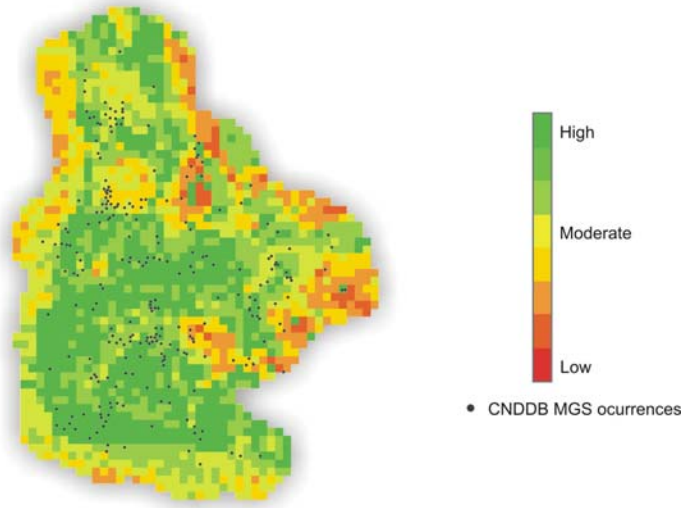
Figure 79: MGS Output test model # 1 (vegetation excluded).

Figure 79 shows the result obtained after running the model excluding the vegetation dataset. The results with this test demonstrate that some grid cells classified as low suitability moved up to high suitability level. This result may have come about because some classes, such as playas, were eliminated from the model. These were then classified as suitable areas. This model does not show what the real pattern should look like.
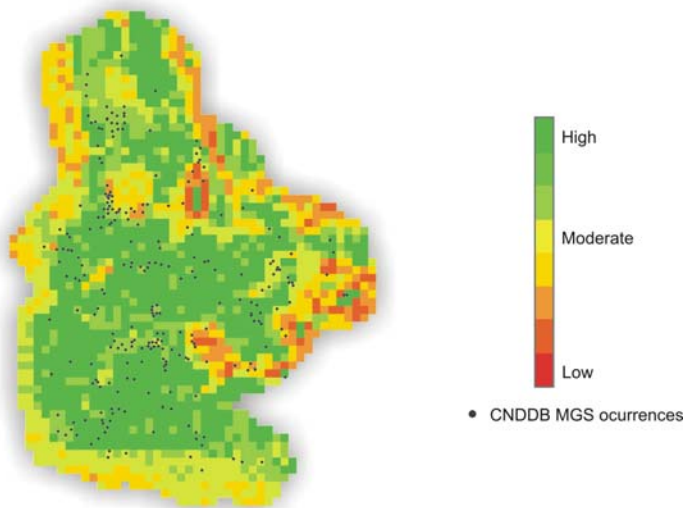
Figure 80: MGS Output test model # 1 (geomorphology excluded).

Figure 80 shows the result after running the model excluding the geomorphology dataset. As with the previous case, in which the vegetation dataset was omitted, non-suitable areas, such as playas, are shown as suitable areas. This model does not show what the real pattern should look like.

The first model calibration and sensitivity analysis demonstrated that the model was not as efficient as expected. For this reason, a second calibration and sensitivity process was executed for the purpose of refining and tuning up the model. It was decided that for the second calibration and sensitivity stage, all the datasets should be considered using the same percent of influences applied during the first model test, but with new scale values.

4.2. Model Calibration and Sensitivity Analysis # 2

For the second calibration and sensitivity analysis, the percent of influence assigned to the variables was not changed. However, the model was modified by setting to zero all the scale values that were formerly set to one. These zero values indicated that such areas are completely unsuitable. Table 6 shows the parameters used for this second model calibration and sensitivity analysis.

Raster	% Influence	Field	Scale Value
Elevation	8	*Value*	
		155 - 610	0
		610 - 1707	9
		1707 - 3693	0
Slope	8	*Value*	
		0 - 8.5	9
		8.5 - 21.5	8
		21.5 - 38.25	6
		38.25 - 60	3
		60 - 1086.347900	0
Land Cover	8	*Value*	
		11 - 50	0
		51	9
		52 - 95	0
Vegetation	8	*Value*	
		1	0
		9	9
Geomorphology	8	*Value*	
		4	4
		1	0
		9	9
Mean winter precipitation	20	*Value*	
		62.678478 - 80	0
		80 - 100	2
		100 - 500	9
		500 - 962.578979	9
Percentage of dry winters	20	*Value*	
		0 - 10	0
		11 - 20	8
		21 - 30	7
		31 - 40	5
		41 - 50	3
		51 - 60	2
		61 - 70	0
Consecutive dry winters	20	*Value*	
		28 - 90	9
		91 - 113	6
		114 - 135	4
		136 - 174	2
		175 - 253	0

Table 6: Weighted overlay parameters with all variables – 2nd stage.
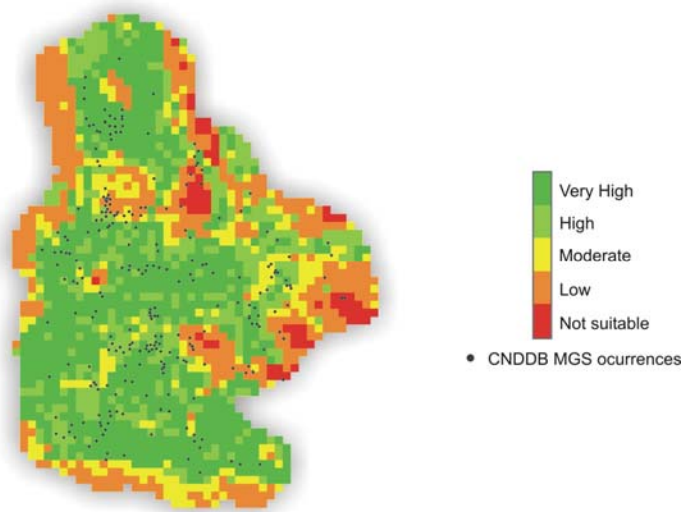
Figure 81: MGS habitat areas output - Test model # 2.

Figure 81 shows the result after running the model according to the parameters in the table above. As part of the visual accuracy assessment, the final output obtained with this model was overlaid with the CNDDB MGS occurrences and geomorphology (playas) dataset. Again, this model also interpreted areas that are not suitable for the occurrence of the species as moderately suitable or highly suitable. In particular, Figure 82 shows that the model failed to represent playas as unsuitable. For this reason, this model was discarded.
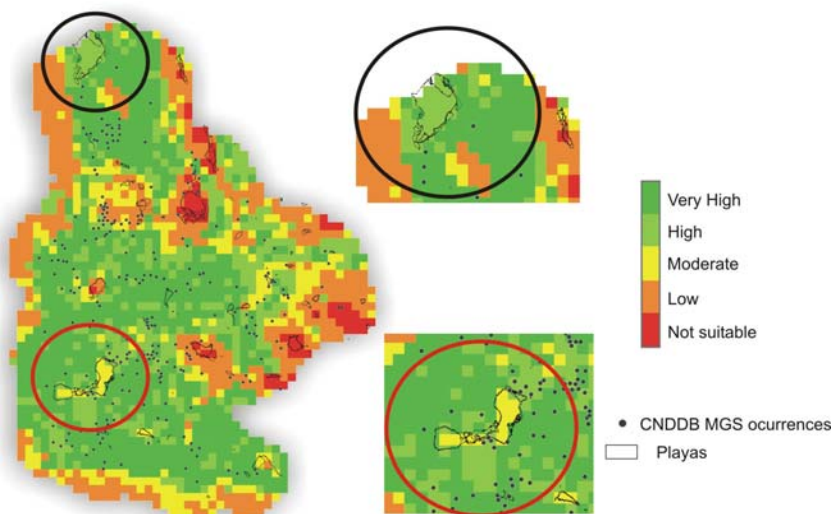
Figure 82: Playas.

4.3.   Final Output

After reviewing the previous model result with the client, a decision was made to modify the percent of influence for the variables. The elevation, slope, land cover,

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vegetation, and geomorphology influences were increased from 8% to 14%, and the precipitation and dry winter influences were decreased from 20 % to 10%. The scale values were kept as in the previous model, i.e., changing all the ones to zeroes. Table 7 shows the parameters used for this final model.

Raster	% Influence	Field	Scale Value
Elevation	14	Value	
		155 - 610	0
		610 - 1707	9
		1707 - 3693	0
Slope	14	Value	
		0 - 8.5	9
		8.5 - 21.5	8
		21.5 - 38.25	6
		38.25 - 60	3
		60 - 1086.347900	0
Land Cover	14	Value	
		11 - 50	0
		51	9
		52 - 95	0
Vegetation	14	Value	
		1	0
		9	9
Geomorphology	14	Value	
		4	4
		1	0
		9	9
Mean winter precipitation	10	Value	
		62.678478 - 80	0
		80 - 100	2
		100 - 500	9
		500 - 962.578979	9
Percentage of dry winters	10	Value	
		0	0
		10	9
		20	8
		30	7
		40	5
		50	3
		60	2
		70	1
Consecutive dry winters	10	Value	
		28 - 90	9
		91 - 113	6
		114 - 135	4
		136 - 174	2
		175 - 253	0

Table 7: Weighted overlay parameters with all variables – 3rd stage.

Figure 83 shows the final output of this model. The output obtained from this model was considered to best represent the distribution of habitat suitability for the

Mohave ground squirrel. The results on Figure 83 prove this statement, as they show that habitat suitability follows the pattern of the Mohave ground squirrel occurrences dataset.
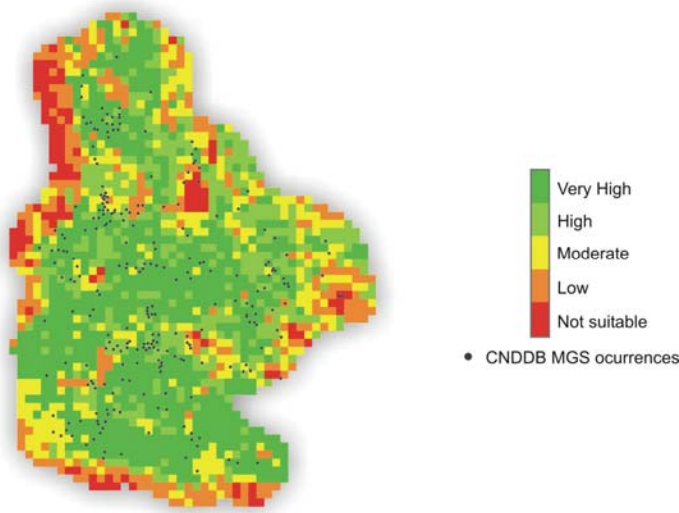
Figure 83: MGS habitat areas final output.

As with the other two models, this one was overlaid with the geomorphology dataset to perform a visual accuracy assessment. Figure 84 demonstrates the improvement of the model and its effectiveness in depicting the unsuitable areas that were not detected with the other two models.
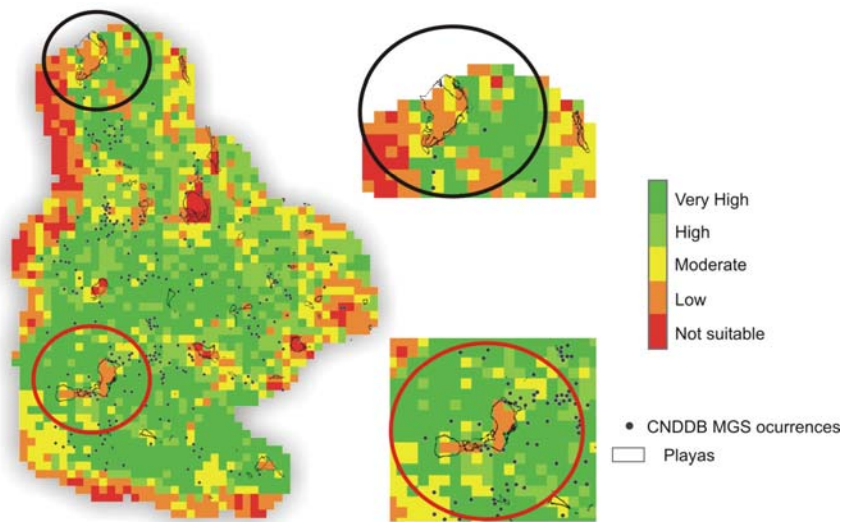
Figure 84: Playas.
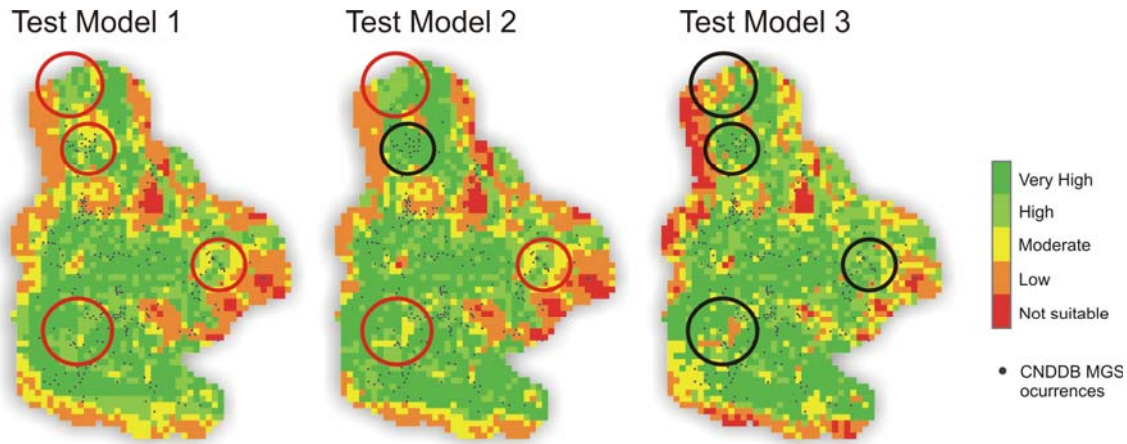
Figure 85: Output from the three models.

Figure 85 was prepared to compare the outputs obtained from each of the three models. The three outputs were classified using the same number of classes and the natural break method of classification. This method is based on identifying the natural breaks in the dataset and separating the values according to these breaks (Chapman & Monroe, 2000). This method of classification keeps similar values together and groups them into the same class while highlighting outliers and separating them into their own classes (Chapman & Monroe, 2000). Again, it is noticeable that all three models generally follow the Mohave ground squirrel occurrences pattern. The red circles show the areas in which the models failed to represent unsuitable areas, whereas the black circles show the areas in which the models succeeded in representing the suitable areas. It can be noticed the improvement of the models modifying the parameters in each iteration. The main point here is that the first two models fail to identify areas that should be considered to have low suitability or no suitability at all. On the other hand, the third model succeeded in this task.

4.4. Model Evaluation

This section discusses and sets the foundation for the initial stage of the model evaluation. Evaluating models are important when developing such models since it proves their effectiveness in producing reliable outcomes. Other than determining the quality of the model, model evaluations are useful for model quality improvement by identifying and correcting sources of error, and determining the utility of the data product in a decision-making context (Aronoff, 2005). For this project, the evaluation of the model should focus on how accurately the model classifies pixels according to their suitability.

The accuracy of the three models was evaluated by determining the relationship between the percent of Mohave ground squirrel occurrences and the percent of the land area in each habitat suitability level. This analysis was performed using the CNDDB Mohave ground squirrel occurrences dataset and the output obtained from each model. Tables 8 – 10 show the distribution of MGS occurrences within each suitability class in relation to the percent area within each class. Figures 86 – 88 show the distribution of MGS occurrences per habitat suitability level.

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Suitability	% Area per category	% MGS occurrences
Very High	34	44
High	24	28
Moderate	17	14
Low	23	12
Not suitable	2	2

Table 8: Model Evaluation - Model 1.

Suitability	% Area per category	% MGS occurrences
Very High	41	54
High	21	22
Moderate	13	10
Low	22	12
Not suitable	4	2

Table 9: Model Evaluation - Model 2.

Suitability	% Area per category	% MGS occurrences
Very High	40	58
High	22	22
Moderate	16	14
Low	15	5
Not suitable	6	1

Table 10: Model Evaluation - Model 3.
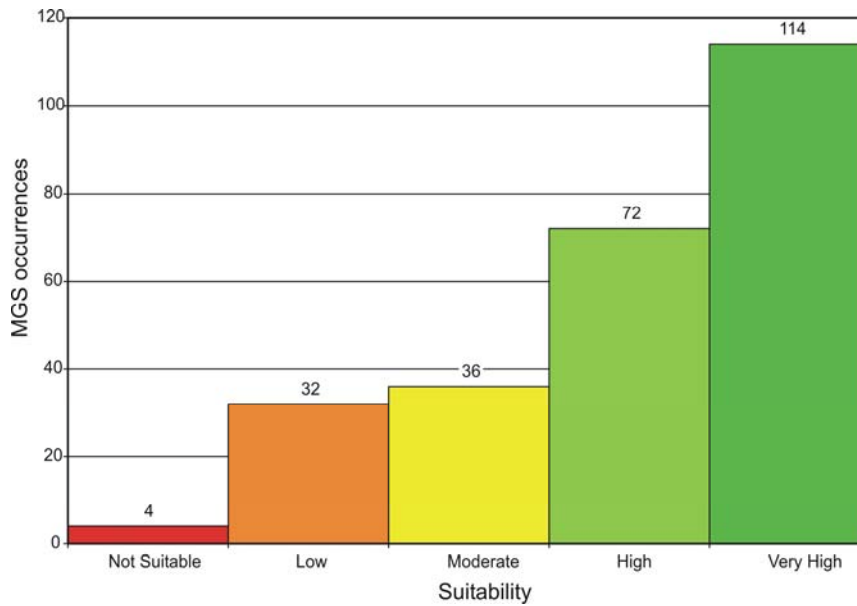
Figure 86: MGS occurrences per habitat suitability level – Model 1.
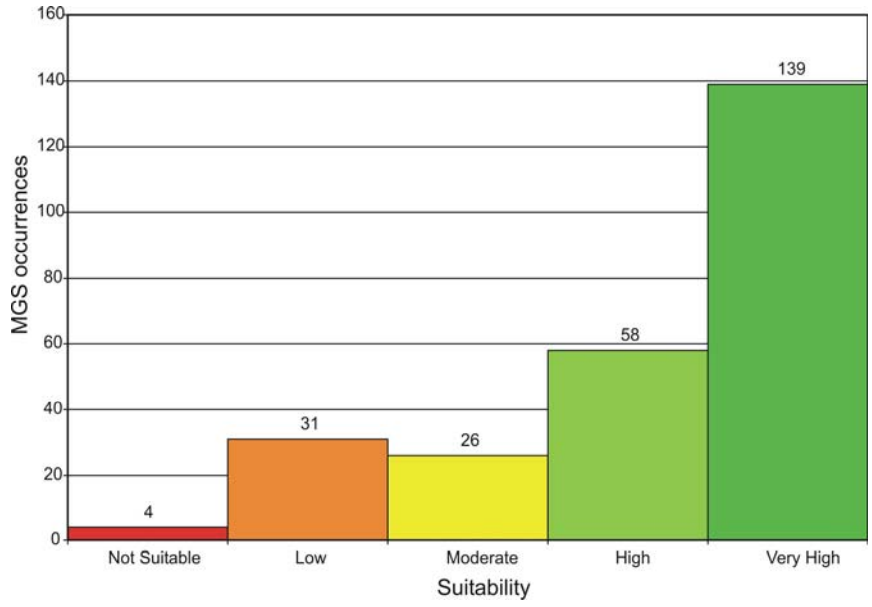
Figure 87: MGS occurrences per habitat suitability level – Model 2.
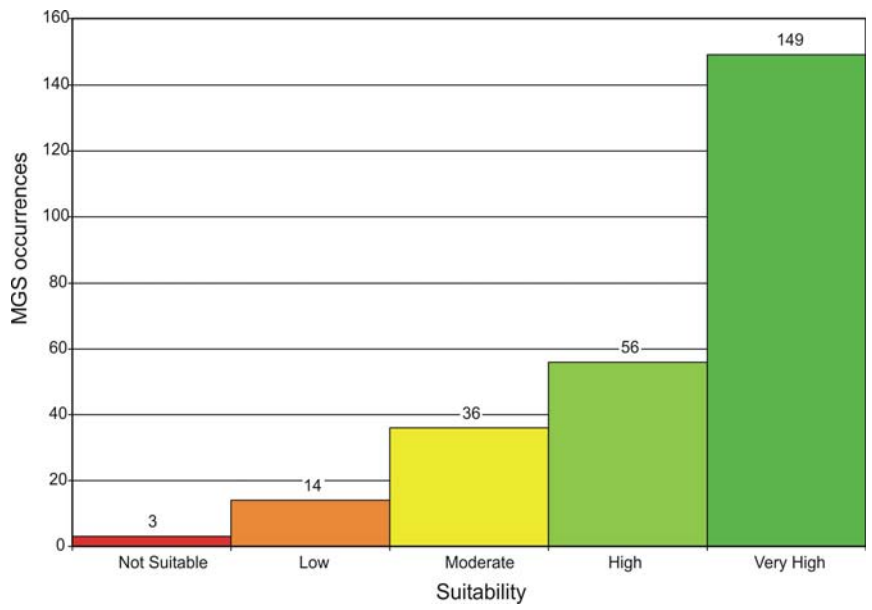
Figure 88: MGS occurrences per habitat suitability level – Model 3.

If the percentages of Mohave ground squirrel occurrences at different suitability levels were distributed in the same way as the percent of the total area assigned to those different suitability levels, it can be assumed that the model was not classifying pixels properly (P. Leitner, personal communication, December 4, 2006). Model 3 provided the best habitat representation of the three when classifying the pixels according to their suitability. According to Model 3, 80% of Mohave ground squirrel occurrences are found in the 62% of the area classified as Very High and High suitability. At the same time, only 6% of the occurrences fall within the 21% of the area classified as Low suitability and Not Suitable. This model demonstrates that species occurrences are more concentrated within the two highest suitability classes, as would be expected if the model classified pixels correctly according to their suitability.

5. ArcGIS Custom Interface

This chapter will describe how the ArcMap user interface was customized to meet the client's needs. The purpose of this customization is to make navigation of the software easier for the client, who lacks GIS experience. The customization of the interface involved the creation of a custom toolbar which will be used along with a map created for doing field work.

This toolbar contains useful tools that will help the client plan future field work. The maps prepared for this purpose will contain all the layers associated with the Mohave ground squirrel project. Some of these layers include the suitable areas raster grid, CNDDB MGS occurrences, Digital Elevation Model, land ownerships, Digital Raster Graphics (DRG's) and Digital Orthophoto Quadrangles (DOQ's). The DRG and DOQ datasets are derived from the Terraserver online database. This database contains data, such as aerial photos and satellite imagery that cover the entire United States.

5.1. MGS Toolbar

The MGS toolbar was developed in order to provide the client with useful tools that will assist him when using the software. This toolbar includes tools found in the out-of-the box Tools toolbar along with some other tools not available in that software. The following tools can be found in the MGS toolbar: Magnifier Window, Zoom In, Zoom Out, Continuous Zoom/Pan, Pan, Full Extent, Go Back to Previous Extent, Select Elements, Select Features, Clear Selected Features, Identify, Find, Measure, Create Map Book, Add Identifier Frame, Create/Update Map Grids, and Effects Layers: Adjust Transparency and Swipe Layer (Figure 89). The toolbar has a total of 19 tools. Examples of its uses are explained in more detail in Appendix A.

Figure 89: MGS toolbar.

5.2. Map Series: MGS Field Map

The MGS Field Map is a map document created for field studies. This map document is composed of a series of 498 maps. These maps were created using the DS Map Series toolbar, which can be downloaded free at the ESRI Developers Sample website (http://edndoc.esri.com/arcobjects/8.3/Samples/ArcMap/Map%20Production/DS%20Map%20Book/DSMAPBOOK.htm).

The purpose of the map series is to provide the client with a base map that can be used for doing field work. These maps were prepared to help the client plan and organize field work in advance. Since this map document has all the data related to the Mohave ground squirrel project, i.e., data concerning the Mojave Desert, the client will be able to create custom maps that will fit his needs for conducting field work. The client will be able to select the desired layers for his map and then will be able to print it. A more detailed explanation of how this map works can be seen in Appendix A.
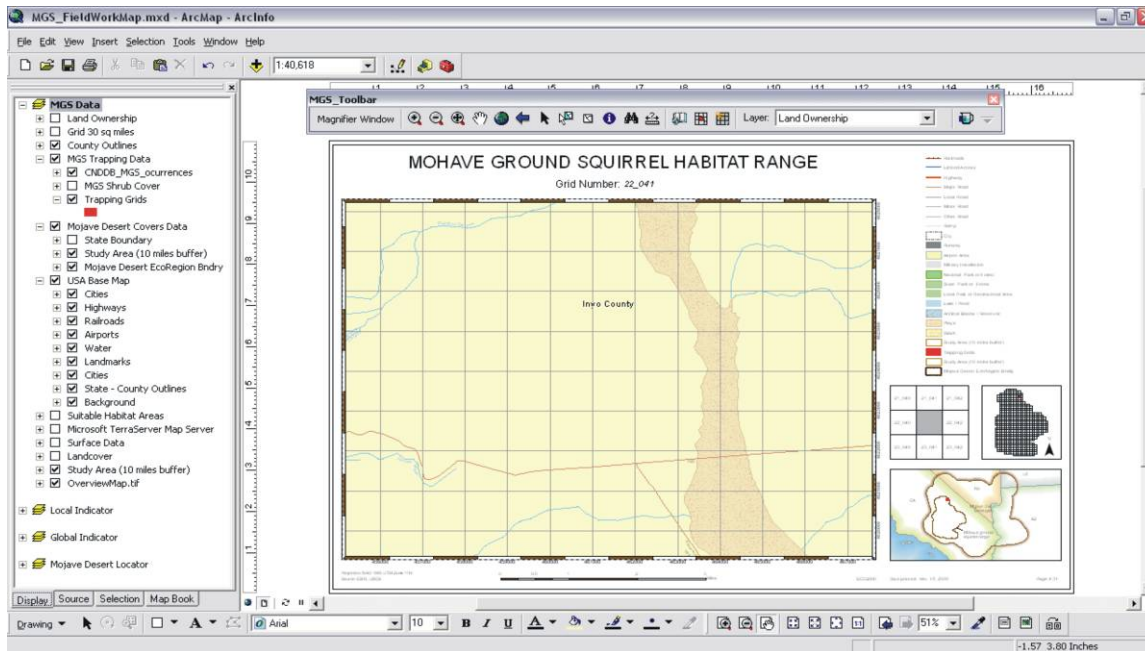
Figure 90: MGS Field Map document.

Figure 90 shows the MGS Field Map document prepared for the client. As mentioned previously, this map document has datasets from the Terraserver online database. These datasets are the DRGs and the DOQs. Figure 91 shows the datasets contained in the map document from the Terraserver database. It is important to note that these datasets will only work when an internet connection is established. If there is no internet connection at the time of displaying the map document, these datasets will not be available.
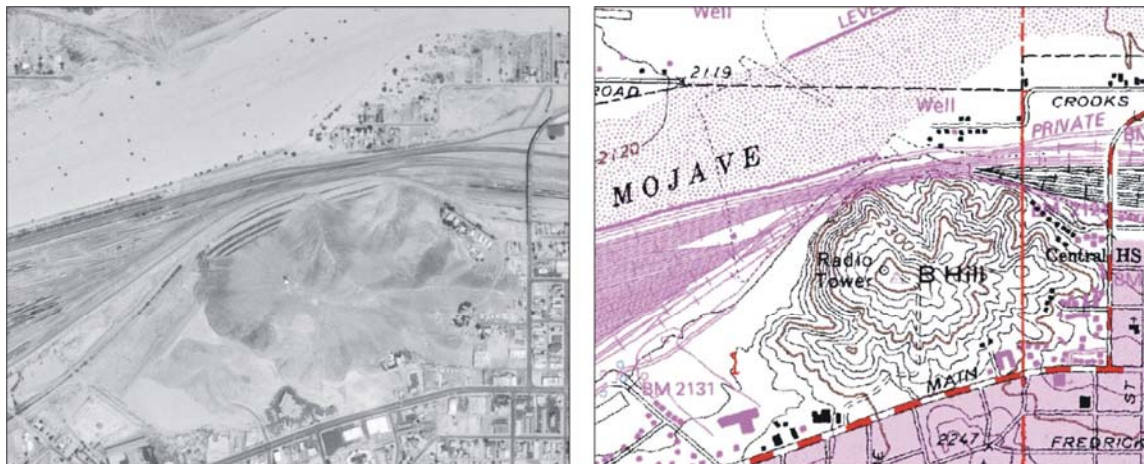
Figure 91: DOQ's and DRG's Terraserver USGS image datasets.

The following are some facts on these datasets (USGS, 1999):

1. Digital Orthophoto Quadrangles: (a) digitized aerial imagery, (b) 98% coverage conterminous United States, (c) one meter resolution, and (d) photos are less than 15 years old.

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2.   Digital Raster Graphics: (a) scanned topographic maps; (b) 100% United States coverage; (c) 1: 24,000, 1:100,000, 1: 250,000 scale maps; and (d) maps vary in age.

The use of these datasets in conjunction with the datasets contained in the MGS geodatabase will provide the client with enough data to create maps that fit his requirements.

6. Discussion

The goal of this project was to create a model that could show the locations of areas suitable for the occurrence of the Mohave ground squirrel. The weighted overlay method was selected since this method allows the integration of multiple datasets. Also, the powerful part of this model is the ability to establish weights and percent of influences for each of the selected variables. If the parameters are selected correctly, the model will be able to closely represent the reality present in nature.

It is important to understand that the effectiveness and accuracy of a model depends on the data, design, assumptions, and implementation (Childs et al., 2004). Errors can be reduced by undertaking proper implementation and planning procedures (Childs et al., 2004). It is also important to recognize that there is always some degree of error since models are abstractions of reality (Childs et al., 2004). The strength of models is that they help researchers, planners, and even the general public to better understand a problem.

6.1. Limitations

6.1.1. Variables

The most serious limitation that affected the model was the inadequate quality of some of the available data. Some datasets did not represent a problem, such as the digital elevation model and the slope data since it was derived from the DEM. However, there were important limitations in other datasets, including the scale at which some were created, as well as the accuracy and completeness of others. In particular, the land cover, vegetation, and geomorphology datasets did represent problems.

For example, the land cover data were generated for the contiguous United States. The small scale used for this dataset was not appropriate since the problem considered in the study is more localized than national. The level of uncertainty about the actual location and representation of geographic phenomena increases when data is created at such small scale. As a result, the generalization of some classes affected the study adversely. Even though, the land cover dataset was the best data available for this application.

The vegetation and the geomorphology datasets also presented limitations. The way in which the vegetation data was collected omitted many important vegetation classes that would have been desirable for the study. Many of the classes in the geomorphology dataset were either not created properly or were incomplete. These problems, which sometimes are inevitable, reduced the effectiveness of the model.

The precipitation and dry winter data also had some limitations. Even though the data used is considered to have high quality resolution, another precipitation dataset with better resolution was available. However, it was too expensive to purchase. It should be noted that this habitat suitability model was created using the best available free data.

6.1.2. Model Evaluation

Evaluating the accuracy of a model is an important step in creating predictive models. These analyses provide the means for measuring the performance of the model. These analyses are also significant when interpreting the final outputs. Evaluating the accuracy of models helps determine the reliability of the model output. Again, this is closely related to the quality of the data used. The output of a model will only be as good as the underlying data. If inaccurate or incomplete data are used, the model accuracy will be affected.

The vegetation dataset provides an example of incomplete or inadequate data. As explained by the client, certain plant species such as shrubs winterfat and spiny hospage are important food resources for the Mohave ground squirrel. With better information on the distribution of these habitat elements and a vegetation map showing their occurrence pattern, it would be possible to map habitat suitability more accurately. Since the available vegetation dataset is not that specific, the analysis lacks of that important information. According to the model and based on the available vegetation layer, the areas where these plant species may actually be found in low abundance appear as Very High or High. This resulted from assigning a scale value of 9 to all desert scrub vegetation. On the other hand, if those areas where these important plant species are found in low abundance were accurately mapped, their scale values would have been much lower, perhaps as low as 1 or 2. This could shift the suitability level of these areas to Moderate or Low, reducing the proportion of the total range in the Very High or High classes (P. Leitner, personal communication, December 4, 2006).

6.2. Further Work

There are ways in which these limitations can be overcome. Recommendations that could improve the model follow. The land cover data can be improved if generated at a more appropriate scale that fits the requirement of the study. This could be achieved by using high resolution satellite imagery, such as a 30 meter Landsat Thematic Mapper image or, even better, a one meter resolution Ikonos image. A more detailed land cover classification can be achieved with either of these two images. This classification process should be done by someone who is familiar with the area and knowledgeable with the vegetation types. This classification will deal with the problems presented by the land cover and vegetation datasets.

Either type of high resolution satellite imagery can also be used for the landform (geomorphology) classification. Again, this work should be done by someone familiar with the landscapes of the area and who is knowledgeable on the topic. These images, in combination with soils data, could be very helpful when classifying the landscape. This would deal with the problems related to the geomorphology data. Finally, another improvement would be to purchase the 2 km precipitation data available at the Climate Source, Inc. website (http://www.climatesource.com/).

7. Conclusion

This project was designed to develop a habitat suitability model for the Mohave ground squirrel. The results of the most suitable areas within its range will be used to help the client solve management issues, such as what public lands to manage for the conservation of the species and what private lands to acquire for conservation when they become available. Figures 92 – 96 show the different land ownerships within the Mohave ground squirrel's range and the habitat suitability within them.

The results obtained from this habitat suitability model ought to improve the ability to locate Mohave ground squirrel populations. Another main goal of this model is to provide researchers with more information about the species, especially their habitat requirements. Finally, this model will advance understanding of the current Mohave ground squirrel conservation status.

It has been shown that the model can delineate habitat suitability for the Mohave ground squirrel. The output of the model was compared with historical occurrence data for the species. The next step should be to verify the predicted results in the field. As mentioned earlier, all models have some degree of error and, therefore, the predicted level of suitability may not be accurate in all areas. The creation of this model should be seen as a prototype for future improved models. Researchers, like my client, who are concerned with the conservation status of the species, will use the model and its results to get a better understanding of the habitat requirements of the species. As more and better data become available, the model can be improved. Models are only as good as the underlying data, hence the acquisition of more reliable, complete, and accurate data should be a priority.
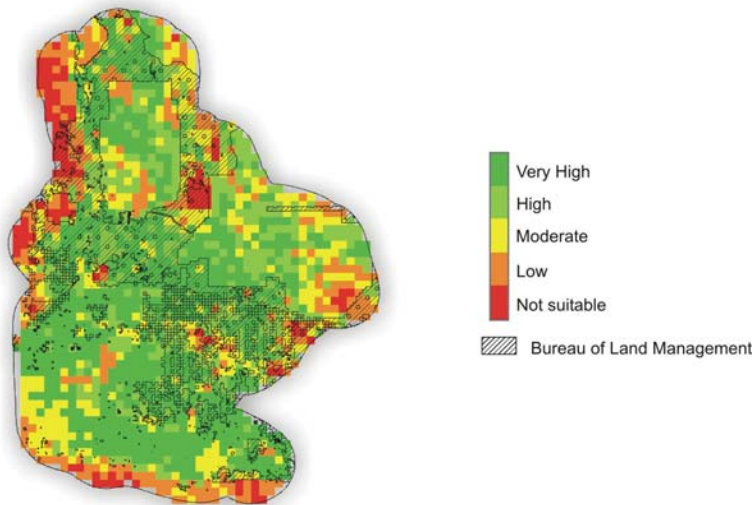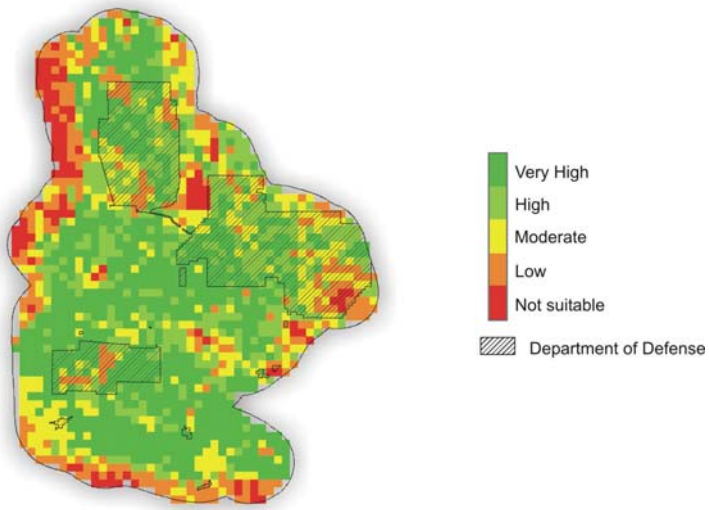

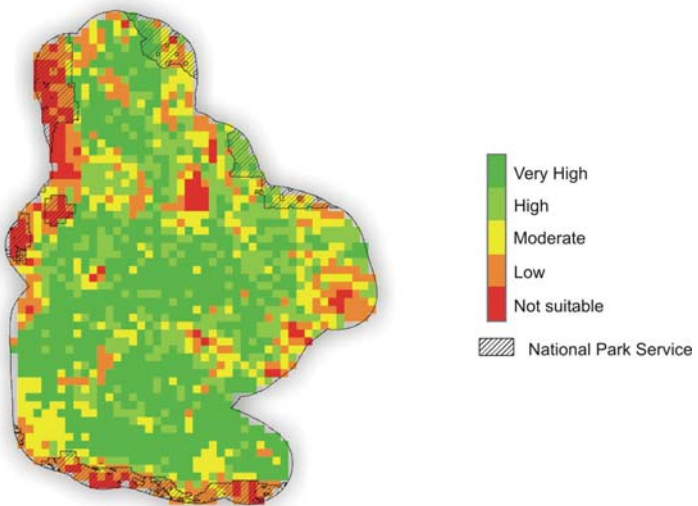**Figure 92: Bureau of Land Management.**

Figure 93: Department of Defense.
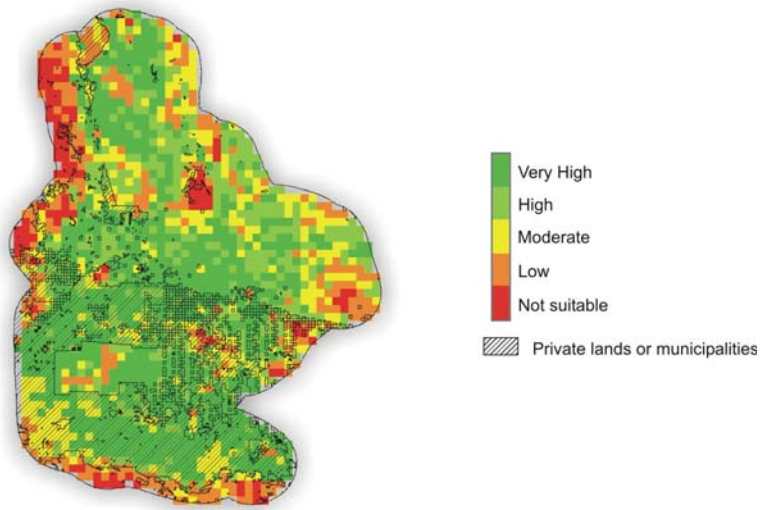

Figure 94: National Park Service.

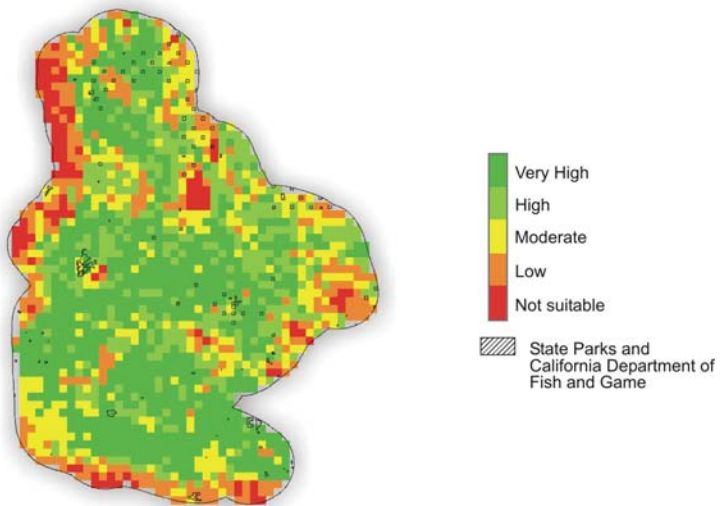**Figure 95: Private lands or municipalities.**

Figure 96: State Parks and CA Department of Fish & Game.

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Appendix A: VBA Programming Customization of ArcGIS Interface

1. Introduction

Burke (2003) defines Visual Basic for Applications (VBA) as a "simplified version of Visual Basic, and one of many object-oriented programming languages" (p. 3). According to Burke (2003), "many other programming languages can be used to program ArcObjects, but VBA comes included with ArcGIS Desktop" (p. 3). ArcObjects is the development platform of ArcGIS (Chang, 2005). "Because ArcObjects is built using Microsoft's COM (Component Object Model) technology, it is possible to use any COM-compliant development language with ArcObjects to customize applications" (Chang, 2005, p. 17). "[The development of new] applications for ArcGIS requires knowledge of both VBA and ArcObjects … VBA provides the programming language and ArcObjects provides objects and their built-in properties and methods" (Chang, 2005, p. 17). This section will describe briefly what object-oriented programming is, how Visual Basic for Applications and ArcObjects are related, and how can they be used to create new custom tools, as well as customize the ArcMap interface.

1.1. Object-oriented programming

"Object-oriented programming is a structure for computer programming languages" (Burke, 2003, p. 1). It is constituted by objects with properties and methods (Burke, 2003). The properties are the characteristics of an object while the methods are their behaviors. Some of these objects are the general elements found in software applications, such buttons, tools, windows, and dialog boxes (Burke, 2003). Figure A 1 shows some examples of objects found in ArcGIS Desktop.
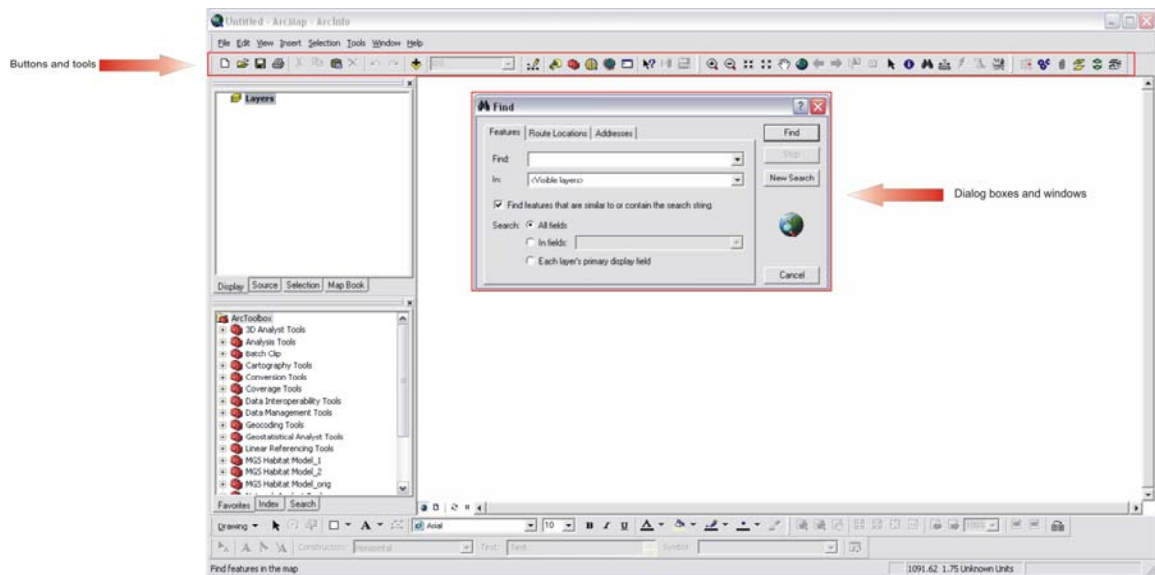

Figure A 1: Buttons, tools, windows, and dialogs.

Object-oriented programming works by establishing a set of rules for the diverse objects to make them carry out methods (Burke, 2003). An *object* is anything that can be manipulated and controlled (ESRI, 2006). Objects are controlled with their *properties* or

characteristics and perform actions with their *methods*, which are the actions that an object can perform (ESRI, 2006). Objects also have *events*, which are the actions the objects recognize (ESRI, 2006). It should be recognized that each object has its own unique methods.

1.2. Visual Basic for Applications (VBA)

As mentioned earlier, VBA is a programming application included in ArcGIS Desktop application. A characteristic that distinguishes VBA from other programming languages is that it is an application embedded within other applications, therefore if ArcMap is installed in a computer, VBA will get installed as well (Burke, 2003). A difference between VBA and other programming languages is that it was created to customize other applications, such as ArcMap, contrasting with other programming languages that are build to design and create new applications (Burke, 2003).
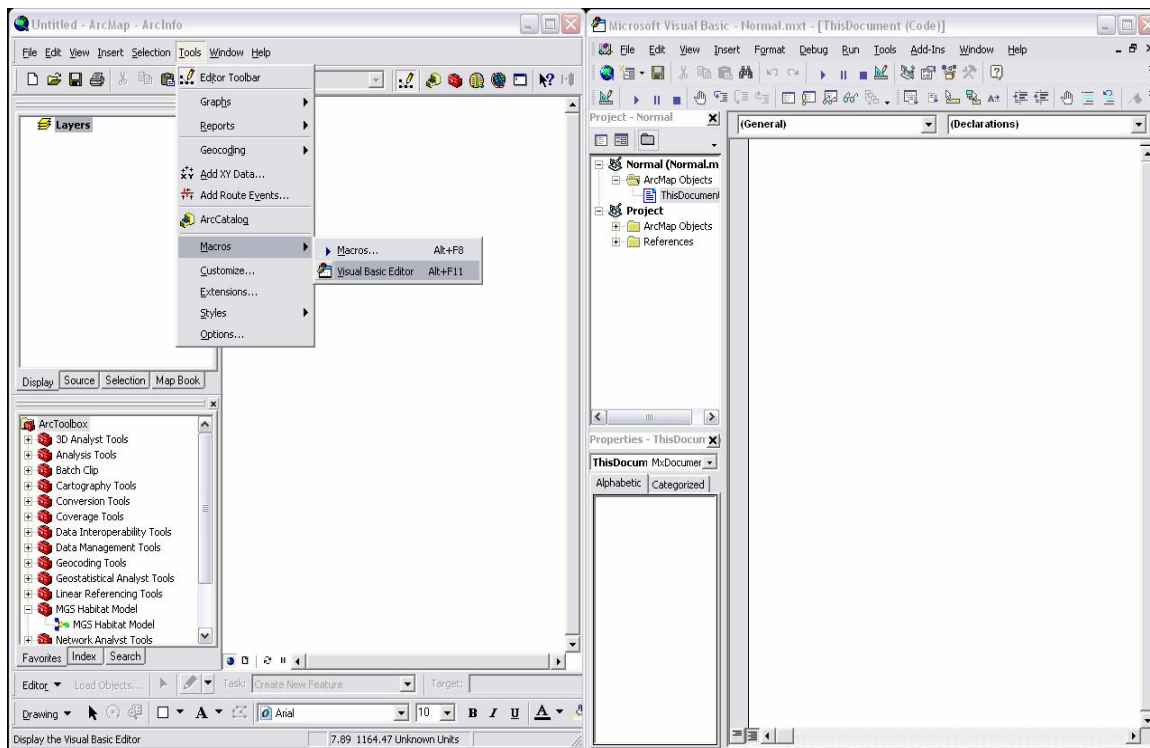

Figure A 2: Accessing VBA from ArcGIS Desktop.

VBA can be accessed directly from the ArcMap interface (Figure A 2). VBA is composed of "code organized in procedures … [containing] all the instructions needed to accomplish [a specific] task" (Burke, 2003, p. 3). All these codes are written down in the Visual Basic Editor (Figure A 2). The Visual Basic Editor is a tool used to create and execute the programs (Chang, 2005). Figure A 3 shows the Code windows where all coding is done.
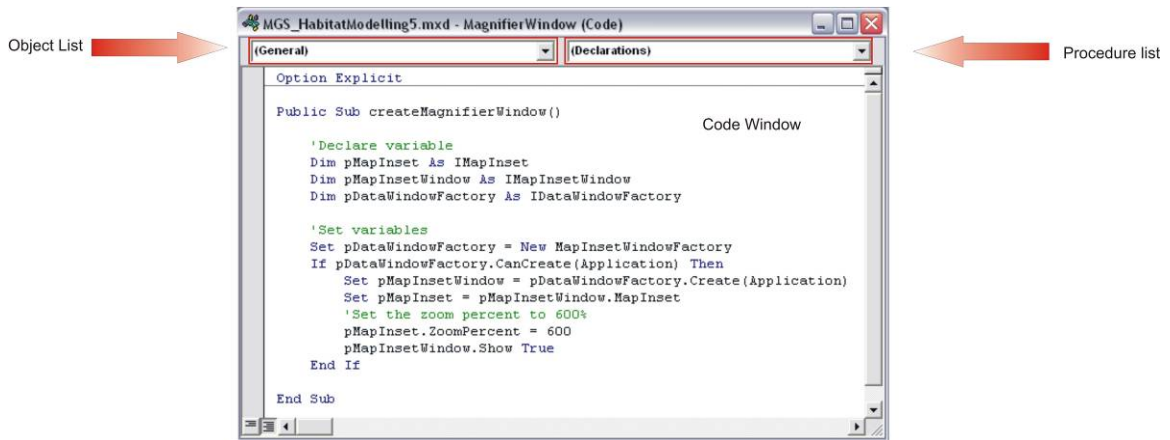
Figure A 3: Visual Basic Editor.

1.3. ArcObjects

ArcObjects is the collection of COM components including thousand of objects used to customize and create new ArcGIS applications (Jackson, 2000). Almost all the tools found in the ArcGIS interface are based on ArcObjects objects (Burke, 2003). Some examples are the Add Data, Save, Print, and so on. Every time any of those buttons are clicked, a procedure is executed behind the scene (Burke, 2003). The University of Durham Information Technology Service [DUITS] (2006) explains in its paper, *Programming in ArcGIS using ArcObjects and AML*, three reasons to use ArcObjects:

1. It provides access to functionality not available through the ArcMAp, ArcCtalog or ArcScene interfaces.

2. It allows customization of the interface for end users.

3. Provides the ability to add functionality written by a 3rd party (example from ESRI's ArcScripts). (p. 1)

Zeiler (2001) explains four different levels at which ArcMap can be customized:

1. You can add references to geographic data and define how the data is displayed.

2. You can create a map layout with a spatial reference and ancillary cartographic elements.

3. You can add, remove, or rearrange elements of the standard user interface.

4. You can write code in a Visual Basic for Applications project (p. 184)

"All the customization in ArcMap is stored in a map document or a map template" (Zeiler, 2001, p. 184).

1.4. Customizing the User Interface

It should be proper to introduce first the ArcMap user interface before explaining how to customize it. It also should be identified the difference between .mxd and .mxt

file extensions. These are two different file extensions provided in the ArcMap application.

In ArcMap, a map document contains the .mxd file extension. This file holds the map itself, with its layout, associated layers, tables, charts, and reports (ESRI, 2006). On the other hand, map templates have the .mxt file extension. This type of map document provides a quick way to create new maps (ESRI, 2006). Usually, map template documents are used to hold data, a custom interface, and a predefined layout that arranges map elements (ESRI, 2006). ESRI (2006) defines the Normal.mxt as follows:

> This document is the template that is automatically loaded in ArcMap and contains all the Standard toolbar and command default settings. User interface customization that is saved in the Normal template is loaded each time ArcMap is launched.

Figure A 4 shows the toolbars that can be found in the Normal.mxt map document.
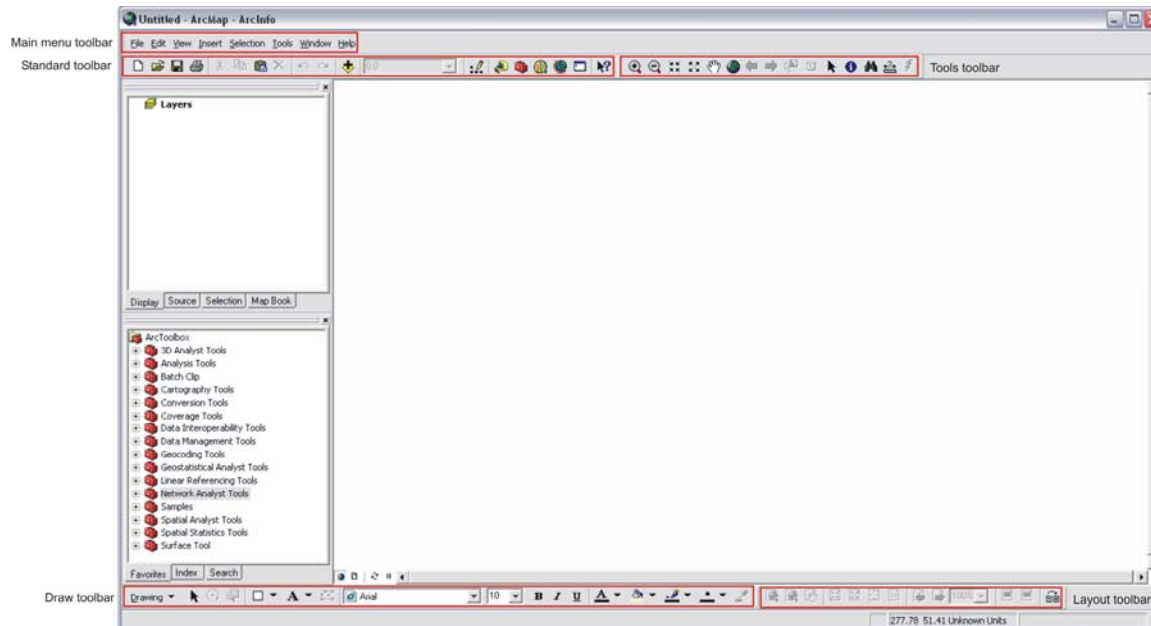

Figure A 4: Normal mxd interface.

1.4.1. Modifying an existing toolbar

Once ArcMap is opened, the first step in customizing a toolbar is to go to the Customize dialog box located under Tools in the Main menu toolbar (Figure A 5). Once this dialog is open, ArcMap will allow the modification of existing toolbars. Some modifications that can be done to existing toolbars include: (a) delete tool, (b) add new tool, (c) move tool, (d) change the button image, (e) display the text name only, (f) display the image only (g) display both, image and text, and (h) create a group.
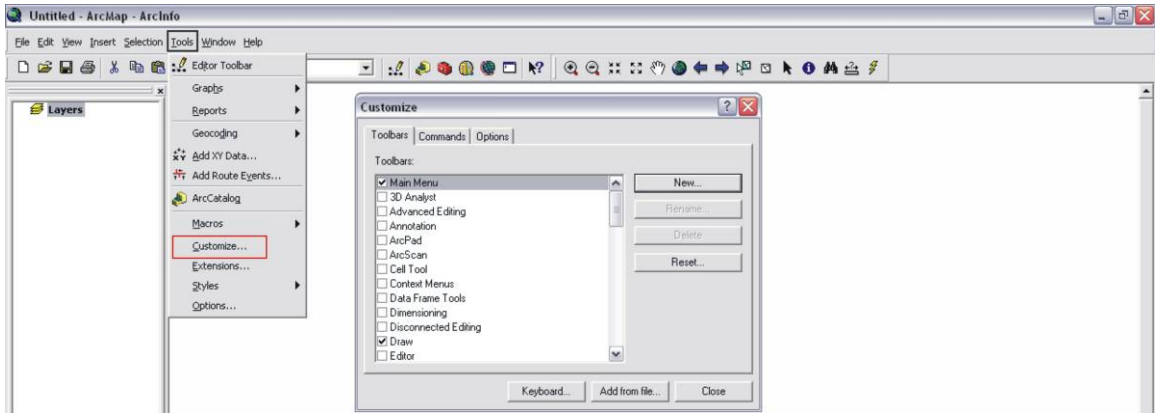
Figure A 5: Customize dialog box.

To delete a tool, just right click on top of the tool to be deleted and select Delete (Figure A 6). This function will remove that specific tool from the toolbar.
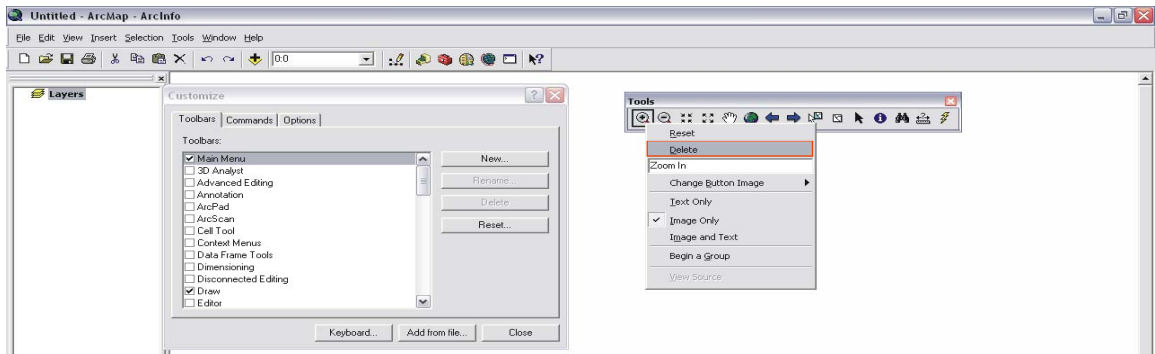

Figure A 6: Deleting a tool.

In the Customize dialog box, select the Commands tab to include a new tool in the toolbar. All the tools available that can be added to the ArcMap interface are found in the Commands tab (Figure A 7). The Commands tab includes two lists: Categories and Commands (Burke, 2003). The Categories list shows the commands by their functionality and the Commands list shows all the available commands that can be included in a toolbar (Burke, 2003).
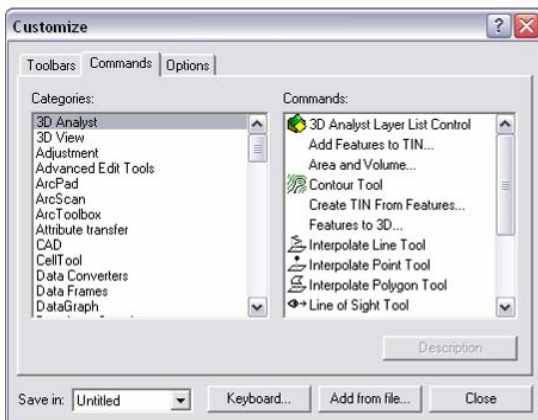

Figure A 7: Commands tab.

To add a tool onto a toolbar, just click the desired tool in the Commands list and drag it to the toolbar (Figure A 8).
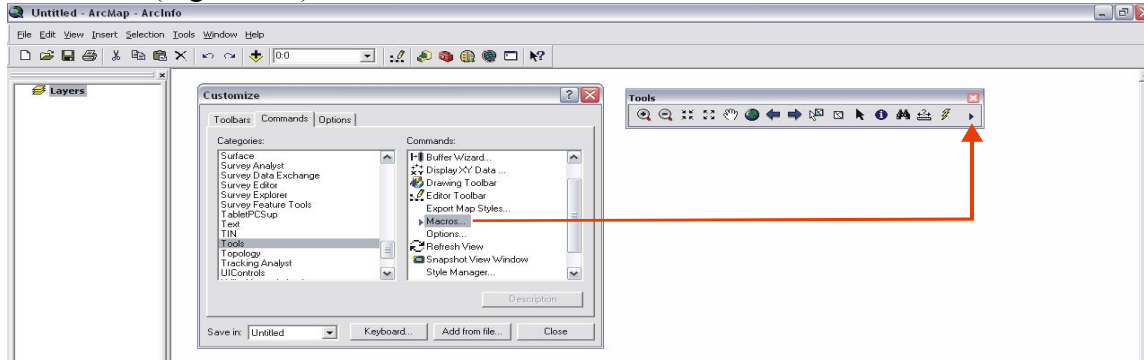

Figure A 8: Adding a tool.

If the order of the tools needs to be changed, just click the tool and move it to a new position.
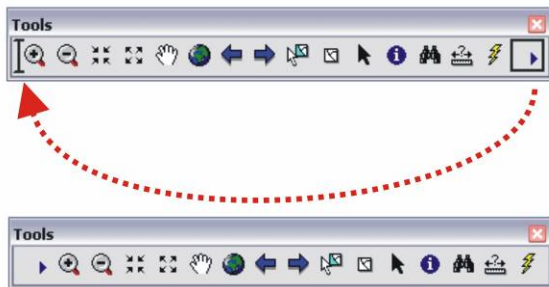

Figure A 9: Moving a tool.

The image that represents a tool can also be modified. Right click on the tool whose image you want modify and select Change button image (Figure A 10). There are some predefined images that can be selected but images can also be loaded from a file. The image must have a .bmp file extension if it is a custom image loaded from a directory. Once the image is selected, the existing image will change.
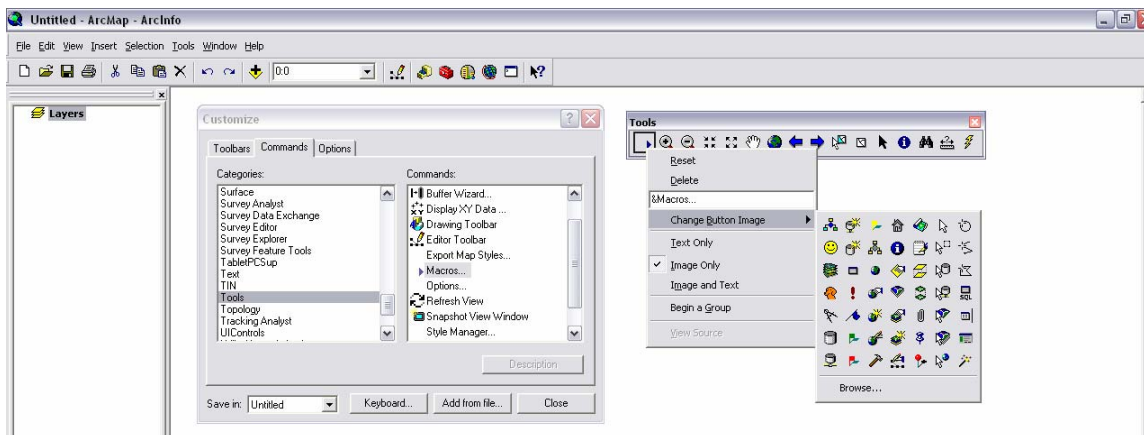

Figure A 10: Changing a button image.

Instead of displaying images, ArcMap allows the user to display: (a) the text only, which is descriptive name of the tool, (b) the image only, or (c) both, text and image (Figure A11).
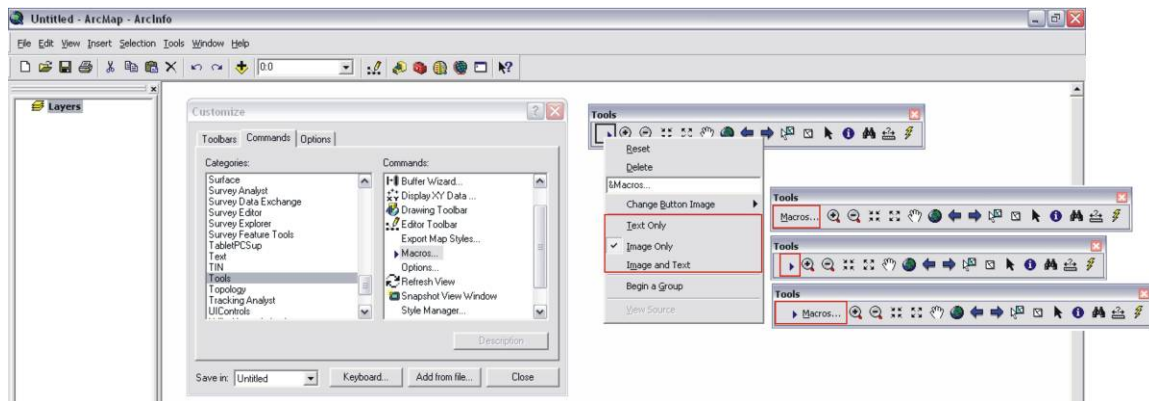

Figure A 11: Displaying Text, Image, or both.

ArcMap also allows the user to create groups. A group is a set of related tools that are sorted separately from the rest of the tools. To create a group, right click on any tool and select Begin a Group (Figure A 12).
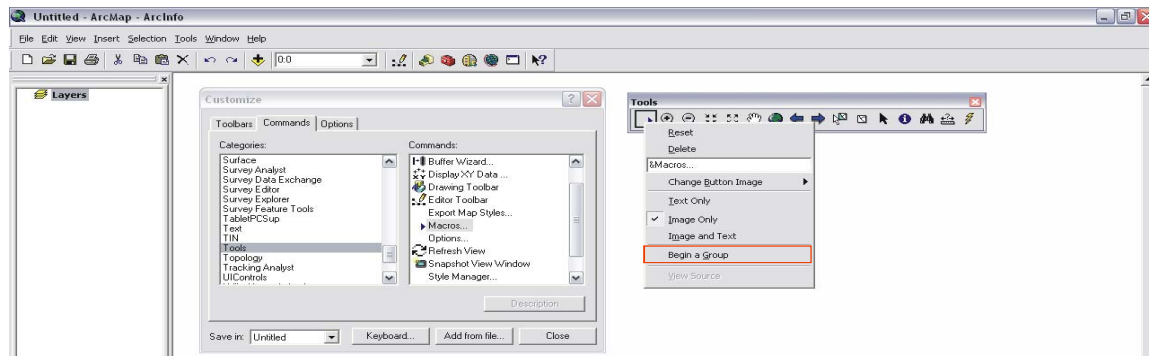

Figure A 12: Begin a Group.

Figure A 13 is an example of a group, where the zooming tools are put into their own separate group but still reside in the Tools toolbar.

Figure A 13: Adding a group.

All of these have been examples of customizing a toolbar. Usually, when toolbars are customized, they are modified to meet the end-user needs. Therefore, tools will be included, moved, deleted, and so on, depending on the user's requirements and level of experience. Some advantages of customizing interfaces is that it helps the end-user find tools that are used frequently faster and easier. It also accelerates the process since they are not required to go and find the tools for themselves. Also, if the end-user's level of experience with the software is minimum, some modifications like adding

meaningful texts or images are very helpful. The next section will explain how to create custom toolbars from scratch.

1.4.2. Creating a Custom Toolbar

There are many reasons to customize the ArcGIS user interface. It can facilitate and create a more user-friendly interface to end-users and reduce the number of clicking procedures. Custom interfaces can be very useful to users who are not familiar with the software. This section will explain how to create a new toolbar from scratch. Creating toolbars is a way of customizing the ArcMap interface by displaying only the tools needed for the end-user.

The first step in creating a new toolbar is to open the Customize dialog box and select the New button located in the Toolbars tab (Burke, 2003). This will open the New Toolbar dialog box (Figure A 14).
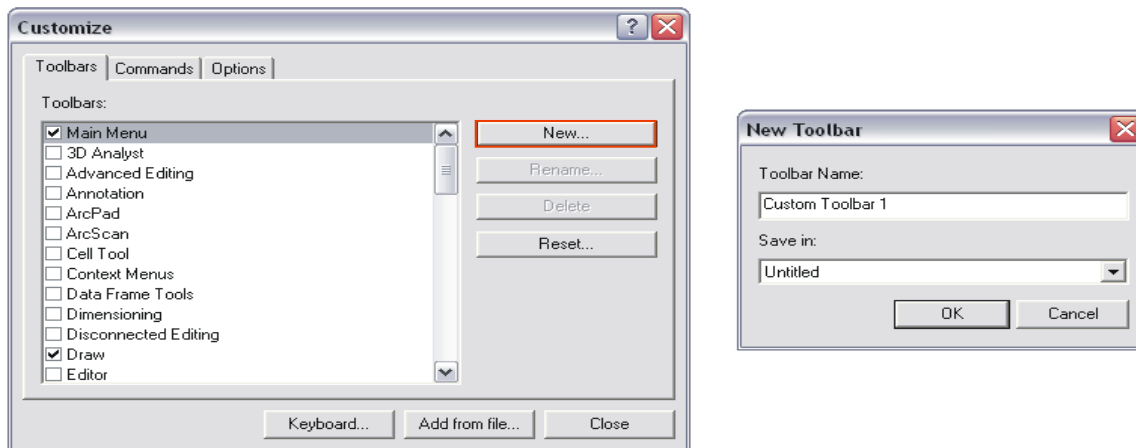

Figure A 14: New Toolbar dialog box.

This dialog box provides a textbox to write the toolbar name as well as the name of the document in which it will be residing. It can be saved in the Normal.mxt or in a new map document. If saved in the Normal.mxt, the toolbar will be loaded every time ArcMap is opened. The OK button should be clicked after setting the name and the location where the new toolbar is going to be saved. After doing so, the new toolbar will be loaded into the ArcMap document ready for adding the tools

To add the new tools, the Customize dialog box must be open. As mentioned earlier, it is in the Commands tab where all the tools can be found. After clicking the Commands tab, the desired tools can be clicked and dragged to the new toolbar.
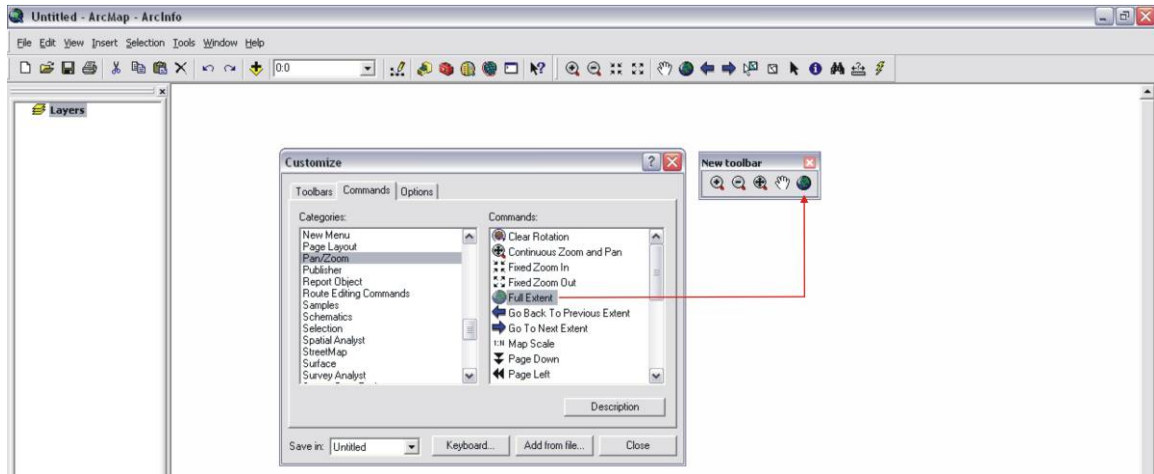
Figure A 15: Adding tools to new toolbar.

This step should be repeated until all the desired tools are included. When adding the new tools, it is important to decide whether the text or image associated with the tool should be displayed as well. Theses steps were shown the previous section, where the tool is right-clicked and the option is selected from the choices, Text Only, Image Only, or Image and Text.

1.4.3. Creating Commands

A command is a set of computer instructions to perform a specific task (ESRI, 2006). Commands are created when the application being modified needs to perform certain tasks not provided in the ArcMap application (Burke, 2003). These commands are written in VBA code using the Visual Basic Editor (Figure A 16). "VBA organizes the code into projects, code modules, and procedures" (Burke, 2003, p. 16).
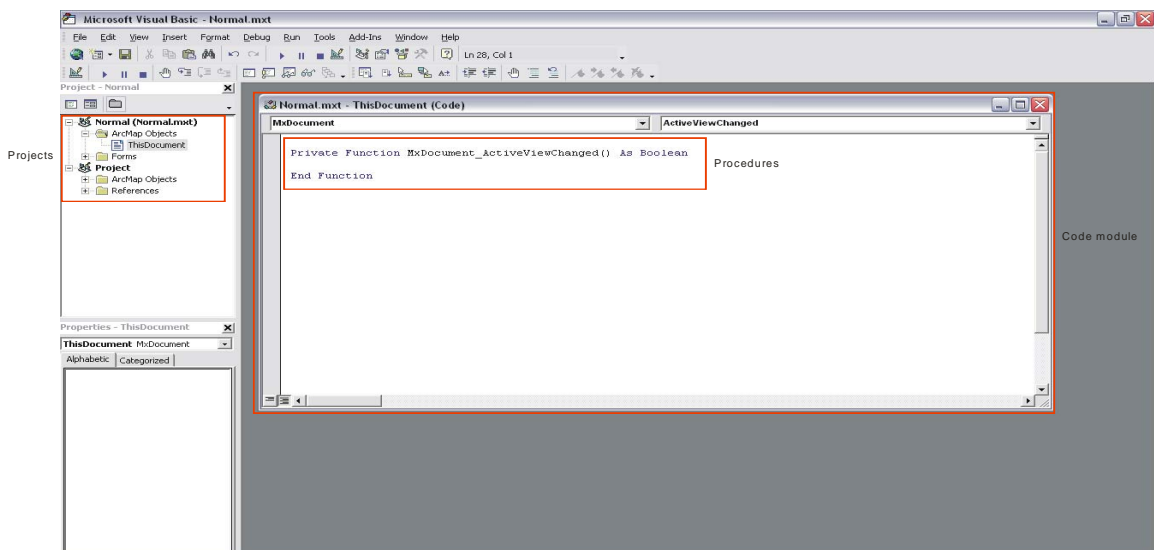

Figure A 16: Visual Basic Editor.
Burke (2003) explains that projects are the files that hold the UIControls and VBA code. UIControls is any "custom button, tool, text box, or combo box created with VBA" (ESRI, 2006).

Projects are then organized in code modules which are the windows where the code is written (Burke, 2003). It is in the code modules, that the VBA code is written as a set of procedures (Burke, 2003).

The first step for creating commands is to open the Customize dialog box and select the Commands tab. Then, the UIControls under the Categories list must be selected (Figure A 17). Again, just as when creating the toolbar, it is necessary to select where the new tool will be saved. It can be saved in the Normal.mxt or in a specific map document.
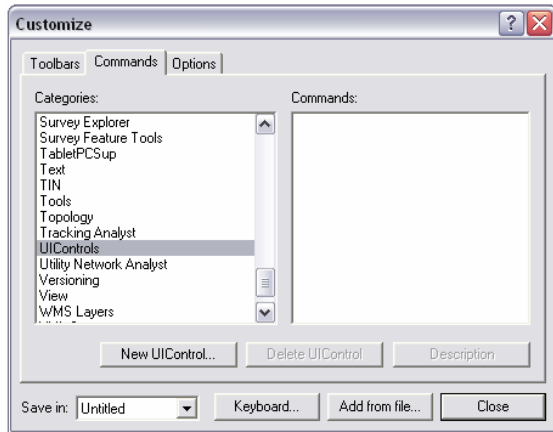

Figure A 17: UIControls.

After selecting the UIControl, the New UIControl button should be clicked. This will open the New UIControl dialog box (Figure A 18). The New UIControl dialog box has four options: UIButtonControl, UIToolControl, UIEditBoxControl, and the UIComboBoxControl. The UIButtonControl option should be selected to create a new control button.
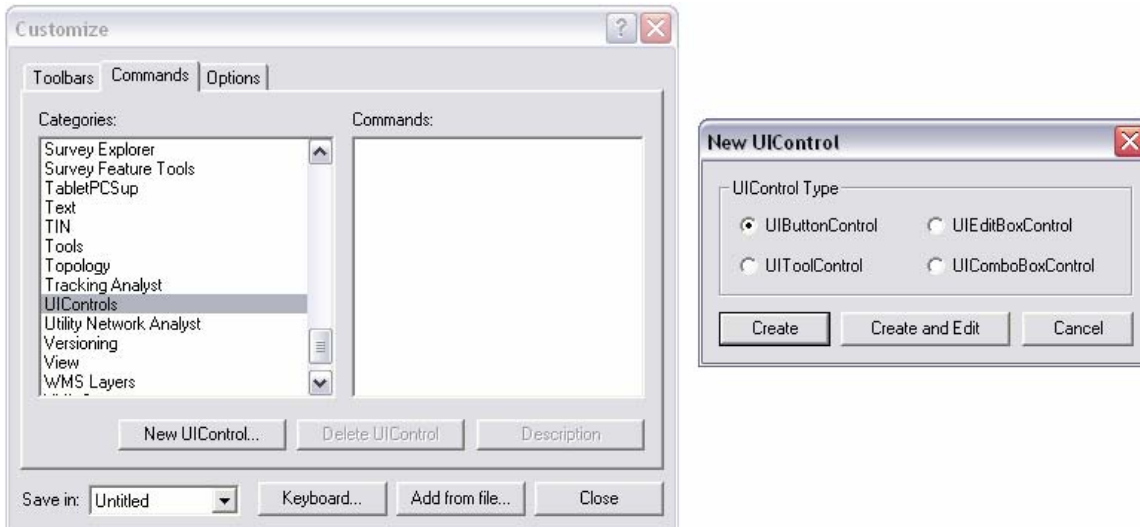

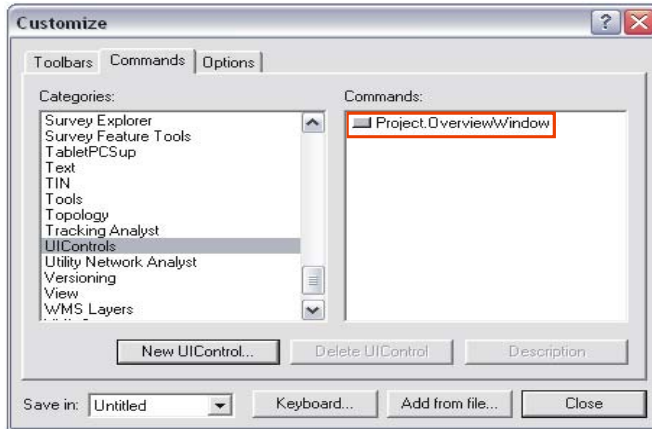**Figure A 18: UIControl dialog box.**

Figure A 19: New control button.

After creating the new button, it should be given a meaningful name that describes the task that it will perform (Figure A 19). After setting the name for the control button, the next step is to drag the button into a toolbar (Figure A 20). This toolbar could be either the Normal.mxd Tools toolbar or a custom toolbar created for the project.
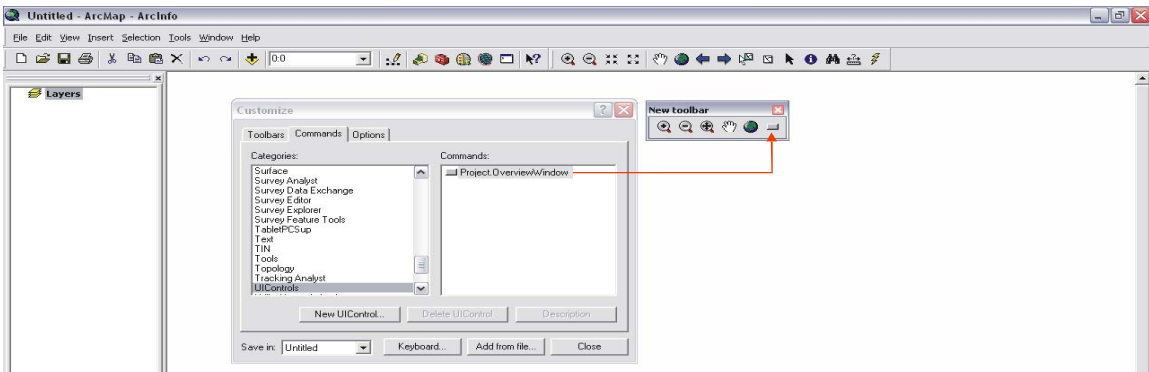

Figure A 20: New tool in custom toolbar.

The next step is to change the tool's appearance by displaying the tool's name or a meaningful image as shown in the previous section, Creating a Custom Toolbar. The result of this step is shown in Figure A 21.
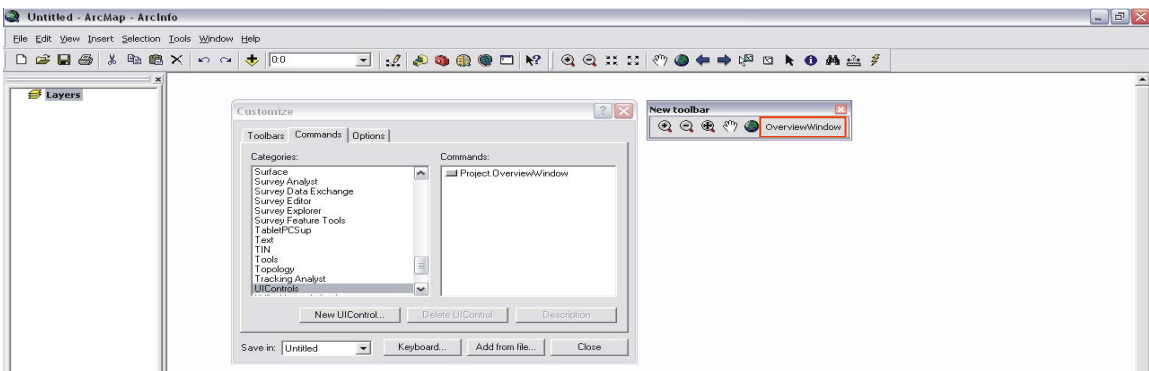

Figure A 21: Creating the tool's name.

After setting the name for the tool, the next step is to write the code. To accomplish this task, right click on the new control button. Then, the View Source choice should be selected (Figure A 22).
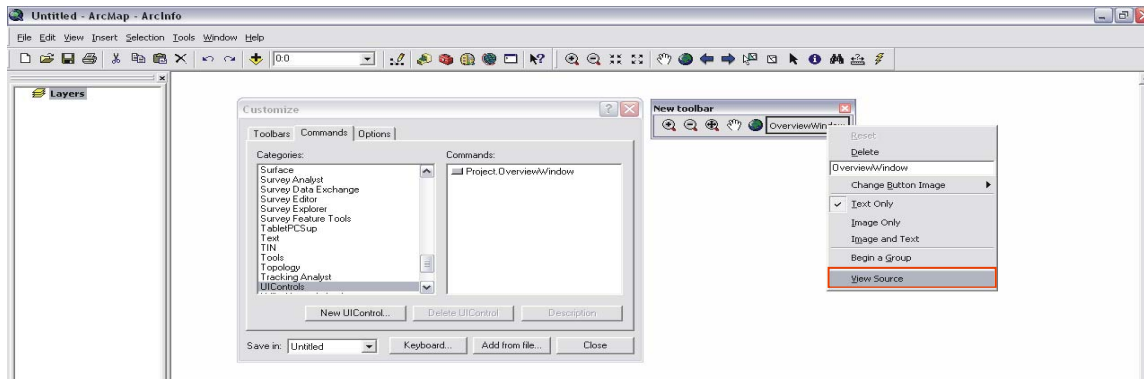

Figure A 22: Open the View Source.

This option will open the Visual Basic Editor with the code module open (Figure A 23).
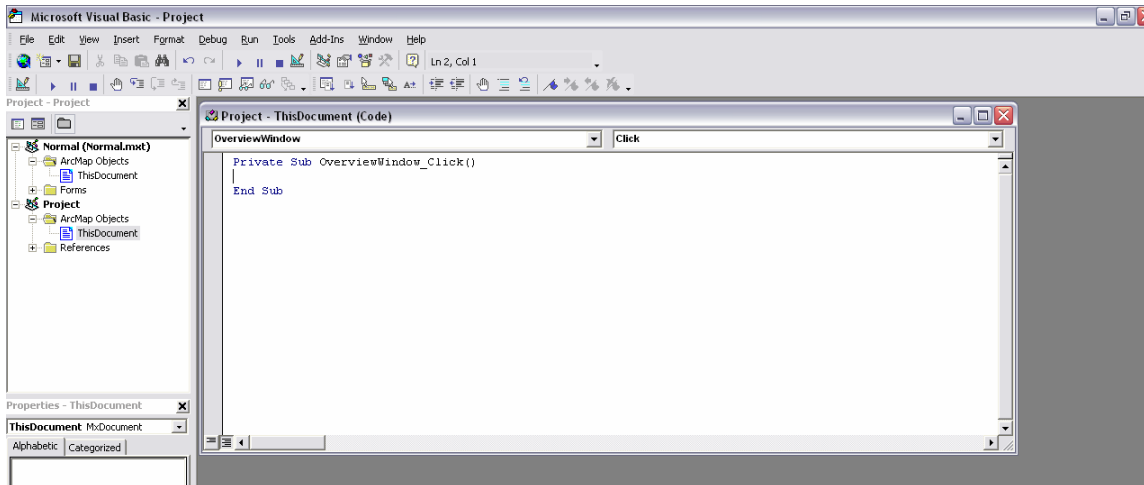

Figure A 23: Tool's code module.

The event procedures for the UIControl will be stored in this code module (Burke, 2003). Figure A 24 shows the code related to the new tool. Burke (2003) explains that "VBA has four [types] of procedures: event, subroutine, function, and property" (p. 18). Event procedures perform actions (Burke, 2003). The code used for this new control button corresponds to the event procedure since it is what is known as a Click event. The way event procedures work is that when the button is clicked, it will perform a specific task, i.e., whatever it was coded to perform. "The other three procedures are called into action by event procedures … [therefore] no code runs unless the user does something" (Burke, 2003, p. 18).

```
Project - ThisDocument (Code)

OverviewWindow                                    Click

    Private Sub OverviewWindow_Click()
    'From page 317 of "Exploring ArcObjects"

        'Declare variables
        Dim pOverview As IOverview
        Dim pOverviewWindow As IOverviewWindow
        Dim pDataWindowFactory As IDataWindowFactory
        Dim pFillSymbol As ISimpleFillSymbol
        Dim pLineSymbol As ISimpleLineSymbol
        Dim pRgbColor As IRgbColor

        'Set variables
        Set pDataWindowFactory = New OverviewWindowFactory
        If Not pDataWindowFactory.CanCreate(Application) Then Exit Sub
        'Create a new overview window
        Set pOverviewWindow = pDataWindowFactory.Create(Application)
        'Change the area of interest fill symbol
        'to hollow fill with blue color
        Set pOverview = pOverviewWindow.Overview
        Set pFillSymbol = New SimpleFillSymbol
        Set pLineSymbol = New SimpleLineSymbol
        Set pRgbColor = New RgbColor

        'Set object properties
        pRgbColor.Red = 255
        pLineSymbol.Color = pRgbColor
        pFillSymbol.Style = esriSFSNull
        pFillSymbol.Outline = pLineSymbol
        pOverview.AoiFillSymbol = pFillSymbol

    End Sub
```

Figure A 24: New control button code.

As seen in Figure A 24, procedures always have starting and ending lines called "wrapper lines" (Burke, 2003). Burke (2003) explains this as follow:

> The first line contains either the Public or Private keyword. Private procedures can only be called on by procedures in the same code module. Public procedures can be called on by procedures in other code modules. The first line also contains keyword identifying the type of procedure (Sub, Function, Property), the name of the procedure ..., and parentheses …The last line in a procedure contains the End keyword and the keyword identifying the type of procedure. (p. 18)

The following section will discuss how the ArcMap was customized to meet the client's needs. The interface was customized by creating a new toolbar containing just the tools that are believed necessary for the client and by the creation of a new tool. Although this new tool was not created from scratch, it was not provided in the Commands list on the Customize dialog box. As a result, it required some coding to create this tool.

1.5. Customizing the ArcMap User Interface

The following section will explain how the ArcMap user interface was customized to meet the client's needs. The reason for this customization is to make navigation of the software easier for the client due to his lack of GIS experience. This section will explain each tool included in the interface as well as give an example of its use. Since the tool was created for use on a particular map, the custom interface was saved in an .mxd instead of an .mxt map document.

The map that will be introduced in the following section is related to a map created for doing field work. This map will be helpful while doing field studies since it has all the layers related to the Mohave ground squirrel project. Some of these layers are USGS Digital Raster Graphics (Topo maps), Orthophotos, land ownership, and trapping grid locations, among many others.

1.5.1. MGS Field Map

As explained above, the following map document was created for field work studies. This map document is composed of a series of 498 maps. These maps were created using the DS Map Series toolbar, which can be downloaded free in the ESRI Developers Sample website (http://edndoc.esri.com/arcobjects/8.3/Samples/ArcMap/Map%20Production/DS%20Map%20Book/DSMAPBOOK.htm). This tool will be explained in the MGS toolbar section.

When doing field work, one of the first stages is planning and organization. This map is designed to assist with the preparation and organization stage. With this map, the client will be able to sit down at his computer and study the areas he plans to visit. The client will then be able to create custom maps and to print them.

Figure A 25 shows the custom interface prepared for the client. This graphic shows the Main Menu toolbar, the Standard toolbar, and the MGS toolbar. The Main Menu and Standard toolbars were not modified since they were considered useful as they were. The MGS toolbar is the main topic of the next section and it will be explained in detail. Figure A 25 also shows some of the layers included on the map. These datasets will be explained thoroughly in the metadata section.
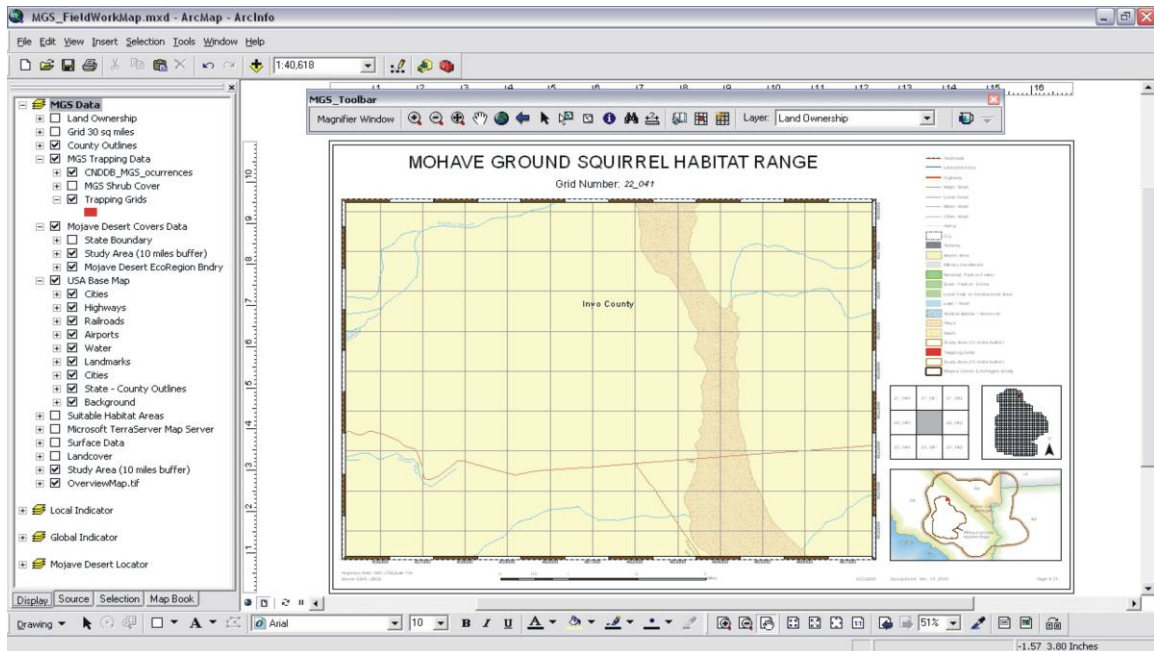
Figure A 25: Custom interface.

1.5.2. MGS Toolbar

The MGS toolbar contains some tools found in the out-of-the box Tools toolbar, although some of these tools were deleted and some included. The tools found in the toolbar are the following: Magnifier Window, Zoom In, Zoom Out, Continuous Zoom/Pan, Pan, Full Extent, Go Back to Previous Extent, Select Elements, Select Features, Clear Selected Features, Identify, Find, Measure, Create Map Book, Add Identifier Frame, Create/Update Map Grids, and Effects Layers: Adjust Transparency and Swipe Layer. The toolbar has a total of 19 tools and they are going to be explained in the order that they appear in the toolbar (Figure A 26).

Figure A 26: MGS toolbar.

1.5.2.1. Magnifier Window

ESRI (2006) defines the Magnifier Window as an extra window that can be included in the ArcMap Data View whose purpose is to show a magnified view of a small area. Moving around the Magnifier Window does not affect the actual map extent or geographic area displayed in the screen (ESRI, 2006).

It should be pointed out that this was the only tool that required code. The code used for this tool is shown in Figure A 27. To activate this tool, the user must be in the Data View window. The purpose of this window is to magnify a selected area six times, i.e., 600 %. Although, there is a similar tool offered in the ArcGIS interface, its magnifier level is 400%, lower than the one created for the MGS Field map document. Figure A 28 shows how this tool works.
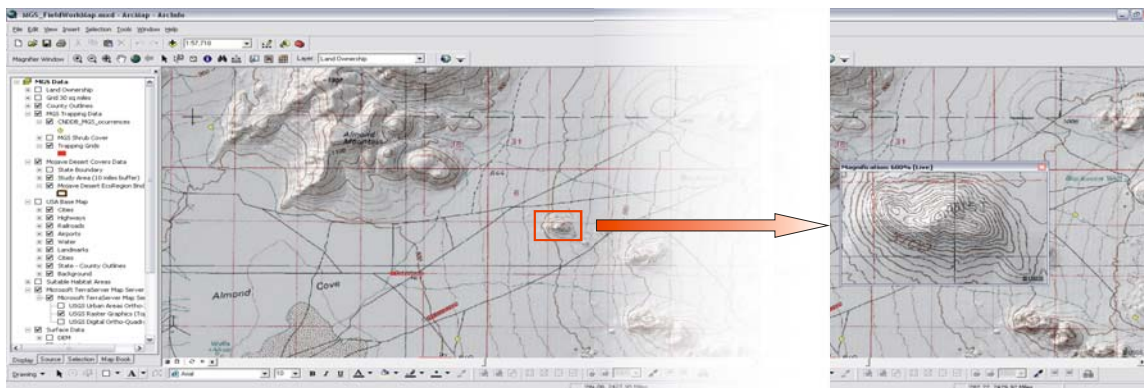
Figure A 27: Magnifier Window code.

Figure A 28: Magnifier Window.

1.5.2.2. Zoom In

ESRI (2006) defines Zoom In as the tool used to show a larger area of an on-screen map or image. It is offered in the Tools toolbar and was included in the MGS toolbar because of its usefulness. This tool is very convenient for easy zooming-in procedures. The difference between this tool and the Magnifier Window is that when zooming to a specific area, the Zoom In tool does affect the actual map extent displayed on the screen. That could be considered as a disadvantage if compared with the Magnifier Window. However, its advantage is that it can be used to zoom further than 600%. Figure A 29 shows how this tool works. Once it is activated, the next step is to draw a rectangle including the desired feature or geographic area.
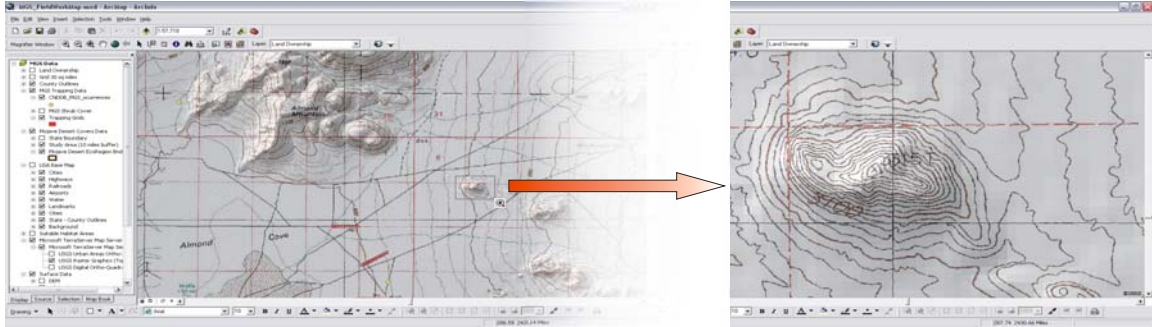
Figure A 29: Zoom In tool.

1.5.2.3. Zoom Out

ESRI (2006) defines Zoom Out as the tool used to show a smaller area of an on-screen map or image. Just like the Zoom In tool, this one is also offered in the Tools toolbar. It was also included in the MGS toolbar because of its convenience. This tool is useful for zooming-out procedures. Like the Zoom In tool, it also affects the actual map extent displayed in the screen. Figure A 30 shows how this tool works. Like the Zoom In tool, it is initiated by drawing a rectangle surrounding a geographic area or feature.
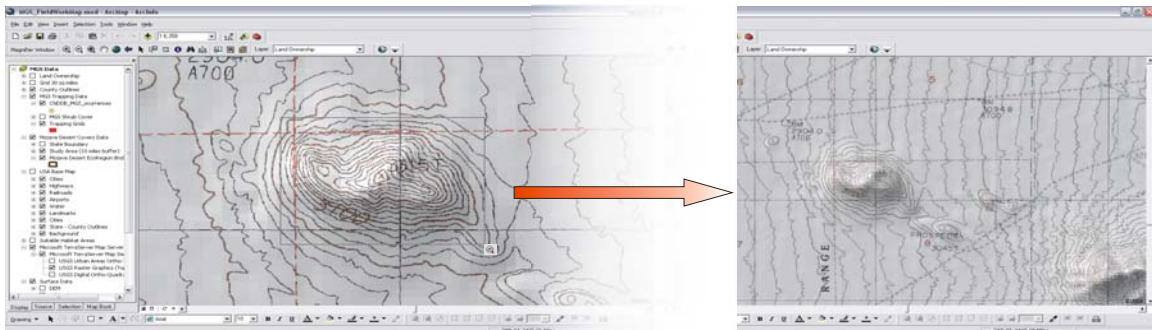

Figure A 30: Zoom Out tool.

1.5.2.4. Continuous Zoom/Pan

The Continuous Zoom/Pan tool is described by ESRI (2006) as a tool that is very convenient to do dynamic zooming and panning. It also is a practical tool if the mouse does not have a wheel (ESRI, 2006). This tool is not found in the Tools toolbar, therefore it was added from the Customize dialog box. This tool works as follows: (a) when zooming in or out, the left mouse button should be pressed until the desired extent is achieved, and (b) when panning, the right mouse button should be pressed until the desired location is reached.

1.5.2.5. Pan

The Pan tool is used to shift an onscreen display window up, down, or across a map image without changing the viewing scale (ESRI, 2006). This tool is also included in the Tools toolbar and was added to the MGS toolbar because of its usefulness. As an example, it can be used to re-center the map extent to a desired location or feature (ESRI, 2006). This tool works by clicking in the Data View and dragging the mouse until the desired location is reached. Figure A 31 shows how this tool works. The red circle was

included in the graphic to highlight the panning icon, which resembles a hand grasping an object.
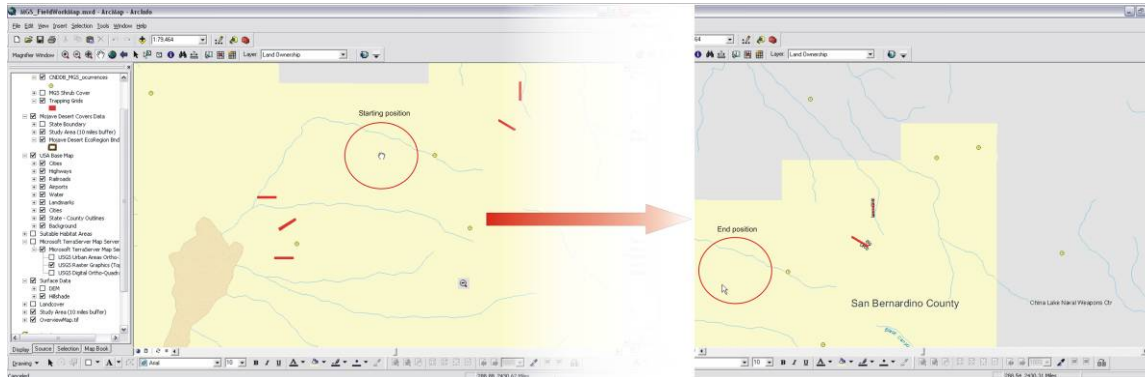

Figure A 31: Pan tool.

1.5.2.6. Full Extent

The Full Extent tool is sued to zoom to the full extent of the data in the map document (ESRI, 2006). This tool is also found in the Tools toolbar but because of its convenience was included in the MGS toolbar. For example, this tool could be used when an image was zoomed in farther than desired, and the sense of location was lost. Clicking the Full Extent tool will zoom out to all the layers in the map document. Figure A 32 shows how the Full Extent tool works.
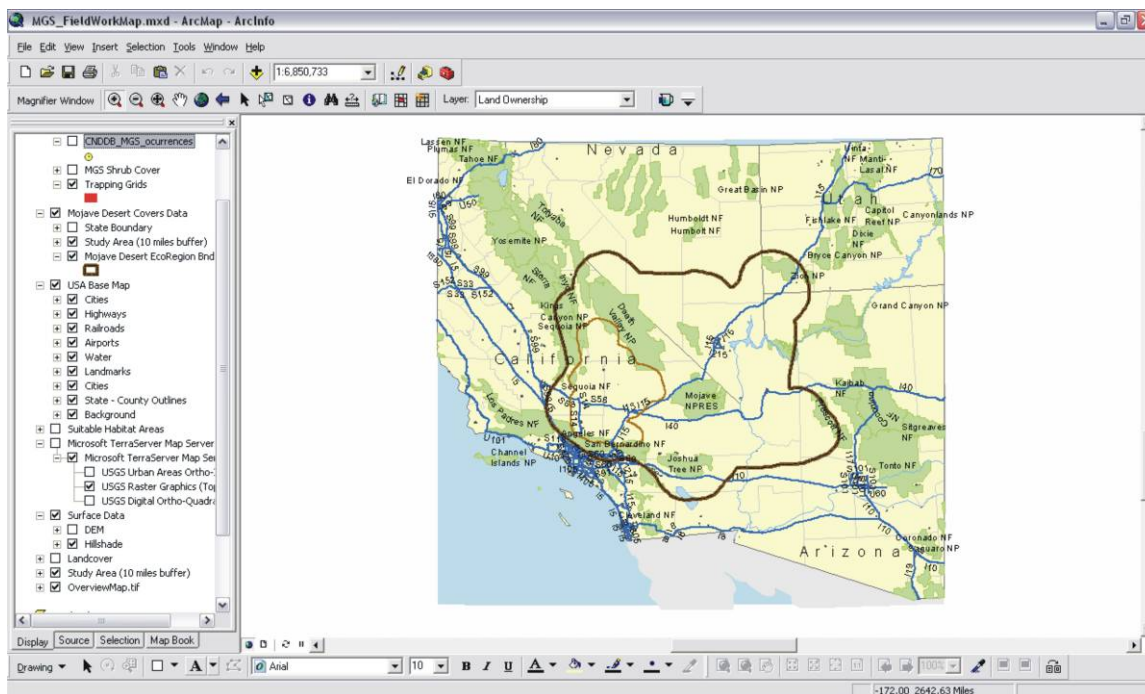

Figure A 32: Full Extent tool.

1.5.2.7. Go Back To Previous Extent

The Previous Extent tool returns to the prior extent viewed in the Data View (ESRI, 2006). This tool is also included in the Tools toolbar. This is a convenient tool when the data is zoomed further than desired and you want to return to the previous zoom extent. Figure A 33 shows how this tool works.
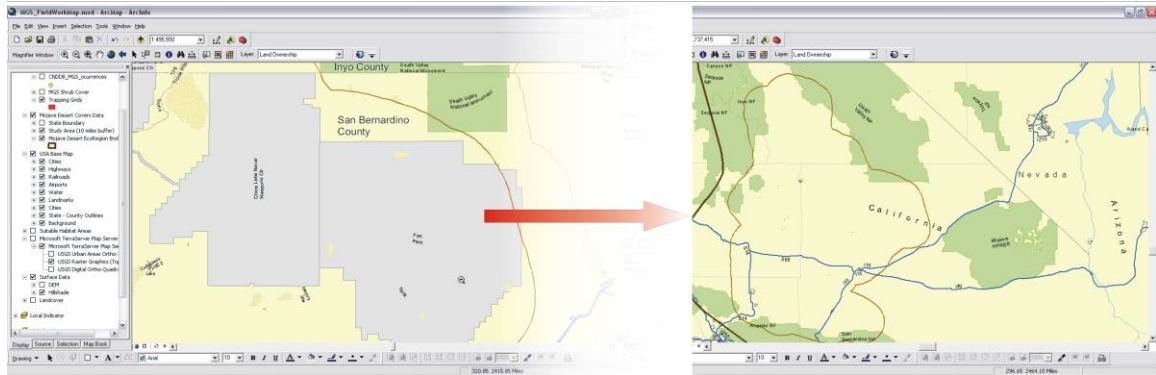

Figure A 33: Previous Extent tool.

1.5.2.8. Select Elements

The Select Elements tool is used to select, resize, and move: (a) map elements, e.g., title, north arrows, scale bars, and legends, (b) graphic elements, e.g., lines and boxes … and Text elements … (ESRI, 2006). To use this tool, click on the element to be selected. Multiple elements can be selected at the same time by holding down the SHIFT or CNTRL button or by dragging a box surrounding the elements (ESRI, 2006).

1.5.2.9. Select Features / Clear Selected Features

The Select Features tool is used to select geographic features in layers (ESRI, 2006). It should be recognized that this tool is not the same as the Select Elements tool. Although the Select Features tool is included in the Tools toolbar, the Clear Selected Features is not. This tool can be found in the Customize dialog box. It was necessary to include that tool in the MGS toolbar since both tools work well together. Usually, when a feature is selected, the user wants to un-select it after viewing the feature.

The Select Features tool is useful for several reasons. For example, this tool can be used when selecting a feature to zoom in to full extent of the feature. This is done by right clicking in the layer name in the Table of Contents and choosing the Selection>Zoom To Selected Features option. Before selecting a feature, the layers to be selected should be chosen in the list shown in the Set Selectable layers dialog box. Figures 34-36 describe these steps. The example consists of selecting any feature that represents a MGS occurrence location and then zooming in to that feature's full extent.
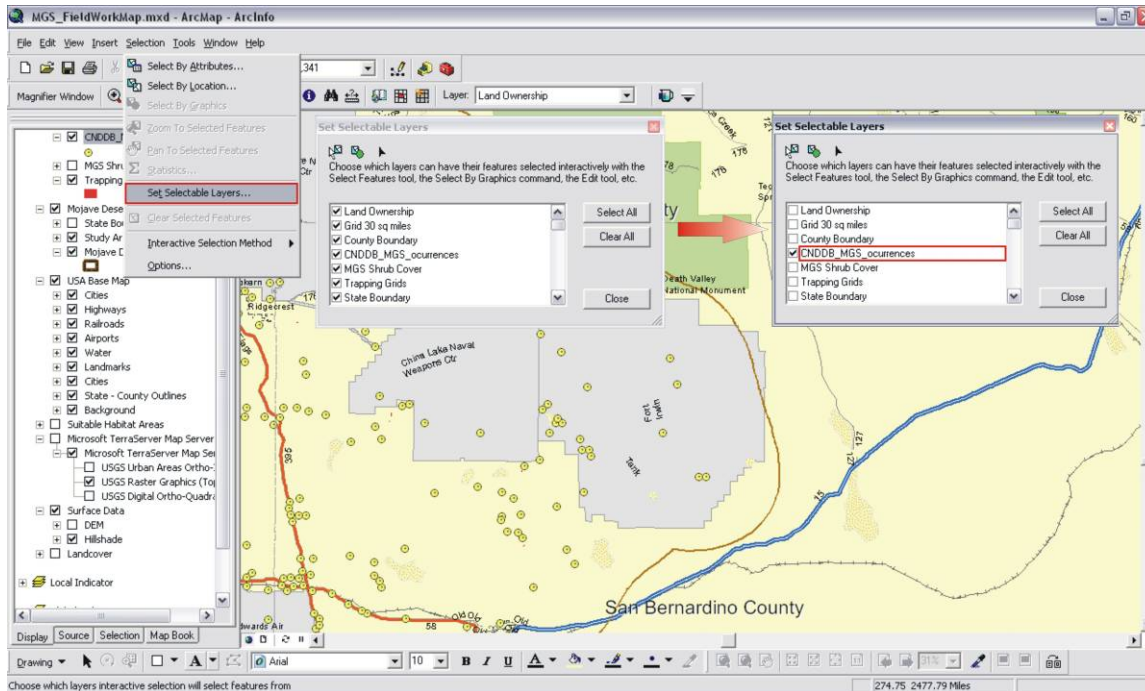
Figure A 34: Set Selectable Layers dialog box.

Figure A 34 shows how to set the selectable layers from the list of layers displayed in the Data View.
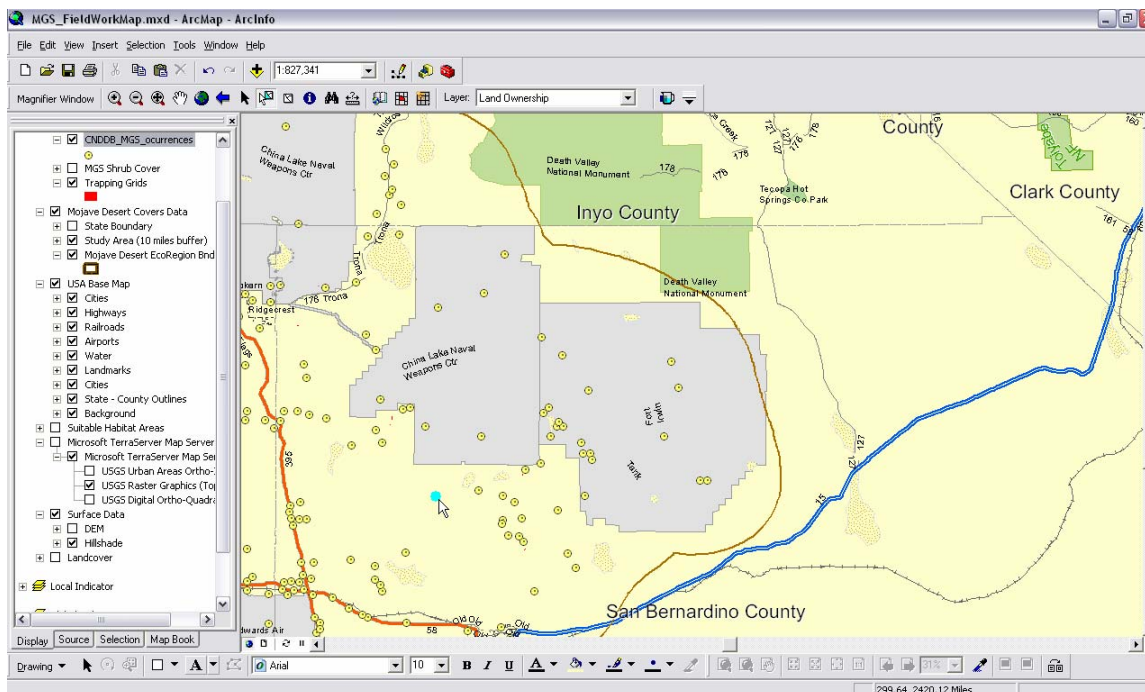

Figure A 35: Select Feature tool.

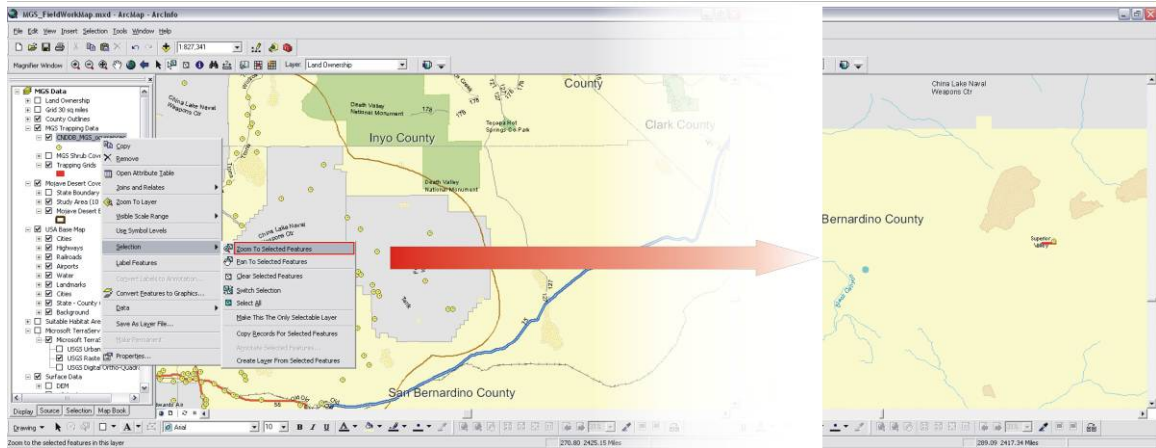Figure A 35 shows how to select a feature using the Select Feature tool.

Figure A 36: Zoom To Selected Features tool.

Figure A 36 shows how to zoom in to the selected feature. The Clear Selected Features Tool is used to clear the selection of any feature. It is used after the selected feature has been examined.

1.5.2.10. Identify

The Identify tool works by clicking a feature (ESRI, 2006). Once the feature is clicked, this tool opens the attribute table of that feature (ESRI, 2006). Although this tool is found in the Tools toolbar, it was added to the MGS toolbar because of its great utility. The tool provides the user an easy way to study the attributes related to a specific feature. Figure A 37 shows how the tool works.
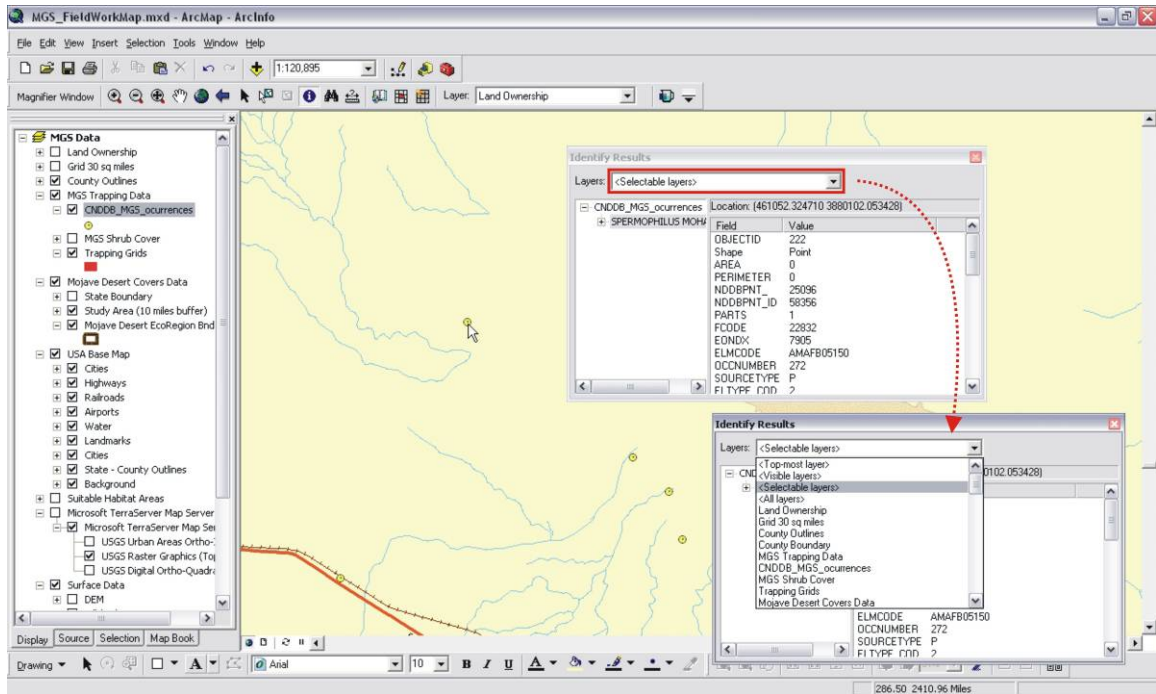

Figure A 37: Identify tool.

When the Identify tool is used, the Identify Results dialog box (which contains the attributes) allows the user to the select layer to be identified. An example of this can be seen in Figure A 37.

1.5.2.11. Find

The Find tool is used to locate specific features within the layers in the map document (ESRI, 2006). This tool is also provided in the Tools toolbar and was included in the MGS toolbar because of its usefulness. For example, if it is known the name of a trapping grid is known, but not its location, the search engine in the Find tool could use the name to search for the feature. A similar search can be done using any of the attributes of the feature. Figure A 38 shows an example of this case.
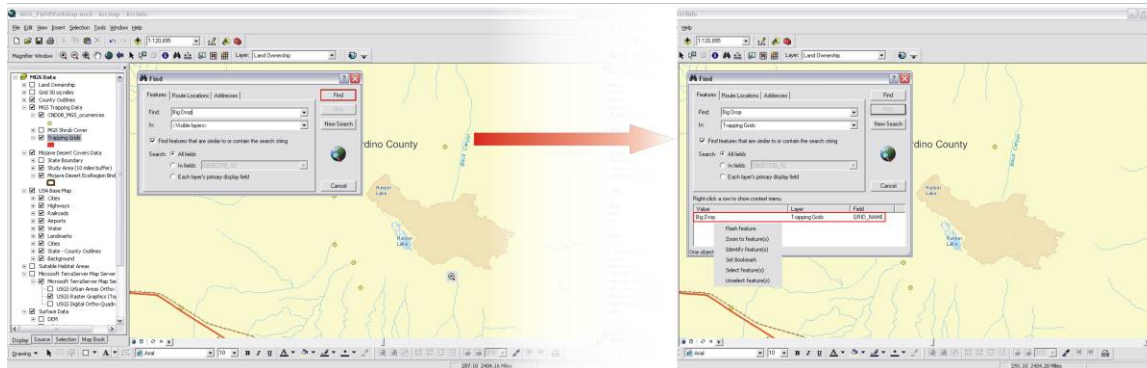

Figure A 38: Find tool.

A right click on top of the result will display a context menu with some useful options, such as Flash Feature, Zoom to Features, Identify Feature, Set Bookmark, Select Feature, and Clear Feature. This tool can also be used to locate addresses or routes.

1.5.2.12. Measure

The Measure tool allows the user to calculate distances within geographic features. The display units for the measured distance will be in the units of the data frame, which in this case of this map document are kilometers. Figure A 39 shows how to change the units of the data frame, while Figure A 40 shows how the Measure tool is used. It should be pointed out that when measuring distances, the result will show in the status bar located in the bottom left corner of the screen.
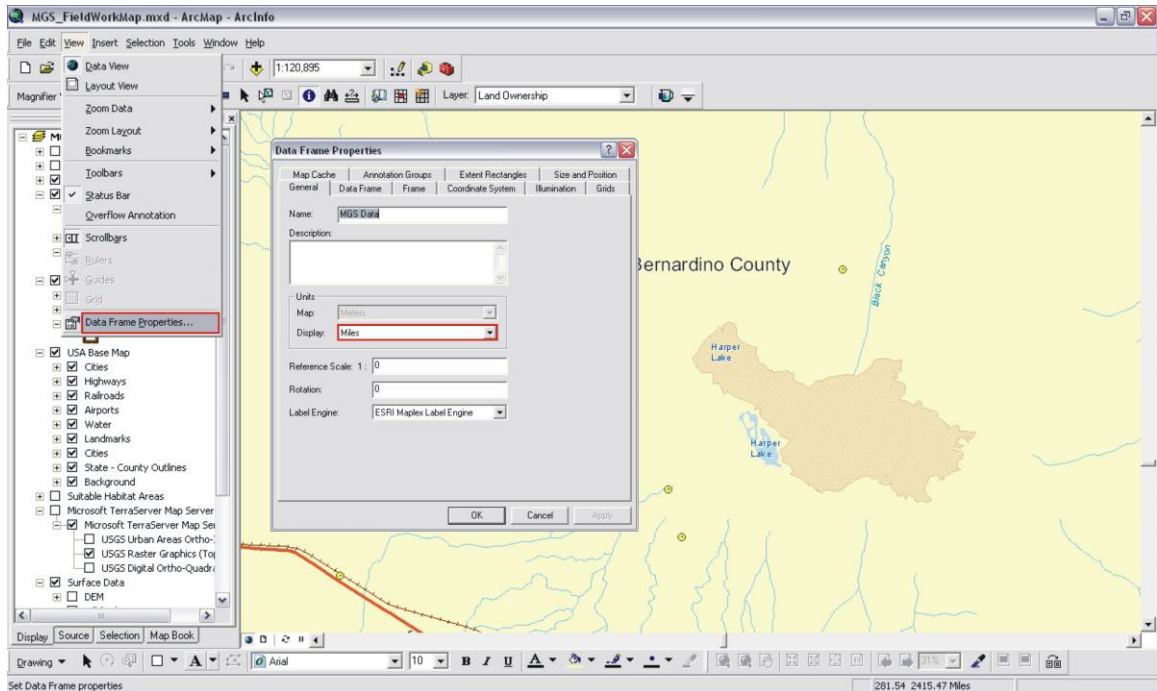
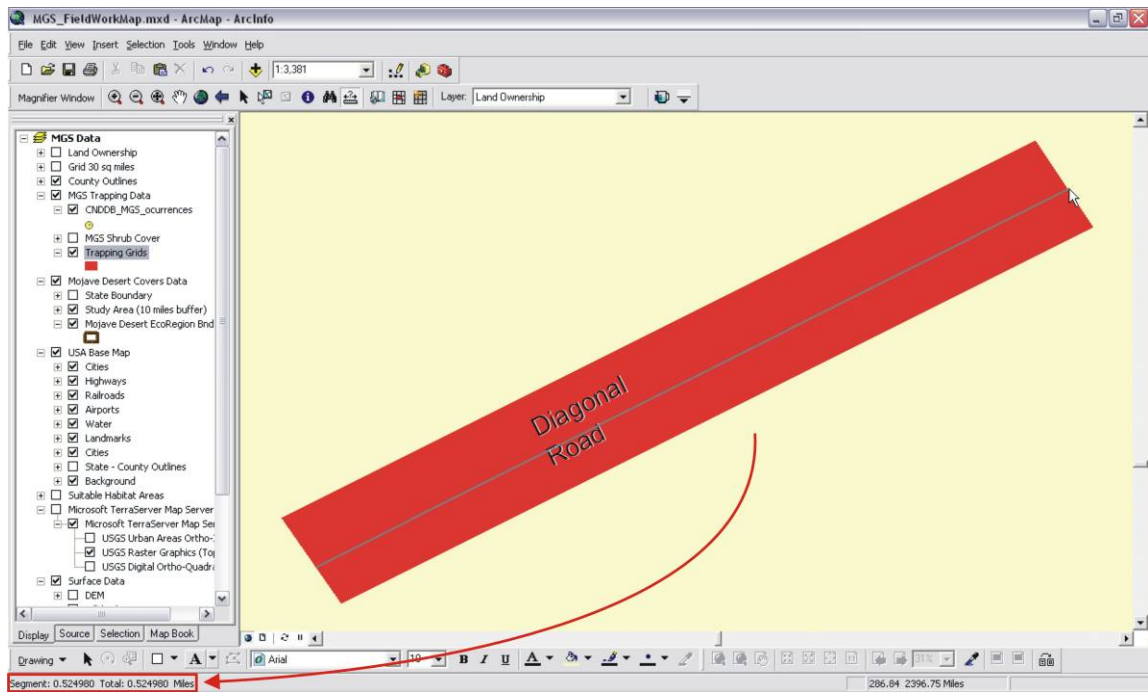**Figure A 39: Setting data frame units.**

Figure A 40: Measure tool.

1.5.2.13. Create Map Book, Add Identifier Frame, Create Map Grids

The following three tools are not included in the Tools toolbar. The reason for including this set of tools in the MGS toolbar is that they are needed for the map series document to work. If these tools are not loaded in the map document, the map series will be inactive.

ESRI Developers Sample (2002) describes the tool as follows:

This Developer Sample code is designed to allow for the creation of Map Books. A page is created in the book based on each feature in a grid/index layer specified by the user. Index layers must contain polygon features with a string field containing the name of each tile/page. The features in the index layer do not have to be of any particular size or shape, nor do they need to be continuous or non-overlapping. Several commands are included for generating index layers based on a uniform grid or based on selected, continuous line features.

Options on the toolbar include:
1. Create Map Book - Generate a new Map Series based on your index layer.
2. Add Identifier Frame - Add Local or Global Indicator frames to show the position of the page/tile in reference to the other tiles.
3. Create/Update Map Grids - Generate or Update index layers based on a uniform grid.

The use of this tool will not be explained since it is not intended that the client will need to use it. The map series has already been created for him. However, it should be pointed out that the manual prepared by the Developers Sample will be provided to the client in case he is interested in using it in the future.

This section is not going to show the step-by-step produce for creation of on how to create the map series since it has already been created. Instead, it will show how to use the map series document. It should be mentioned that the Mohave ground squirrel range layer was used to create the index layer (Figure A 41). The index layer is a layer that contains the specified grids on which to base the map series. For the purpose of this map, the area of coverage for each grid is of 8 km x 8 km.
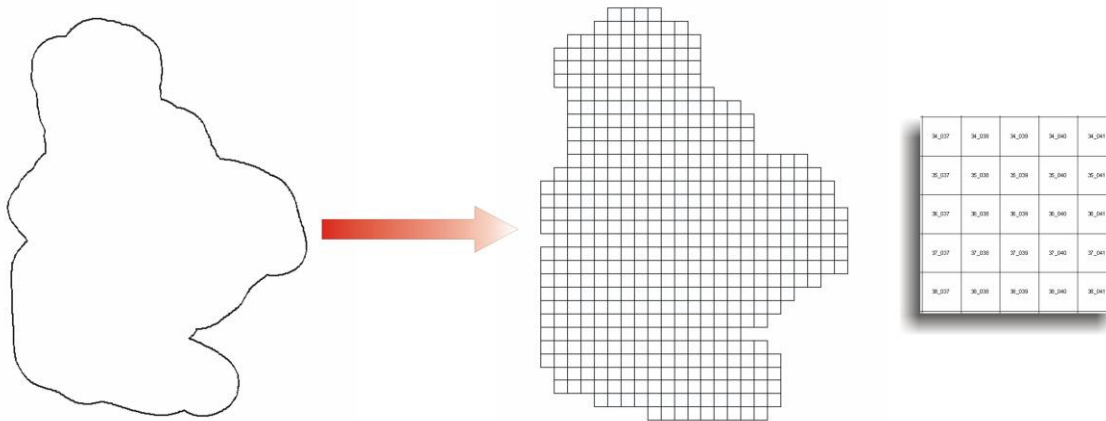

Figure A 41: Index layer.

The map series document works by clicking on the Map Series tab located at the bottom portion of the Table of Contents (Figure A 42). This will show the entire map series generated with the index grid. Here the user can select the desired map by double clicking it. Once the map is selected, the title for that particular map will be updated, displaying the grid selected. This is shown in Figure A 42.
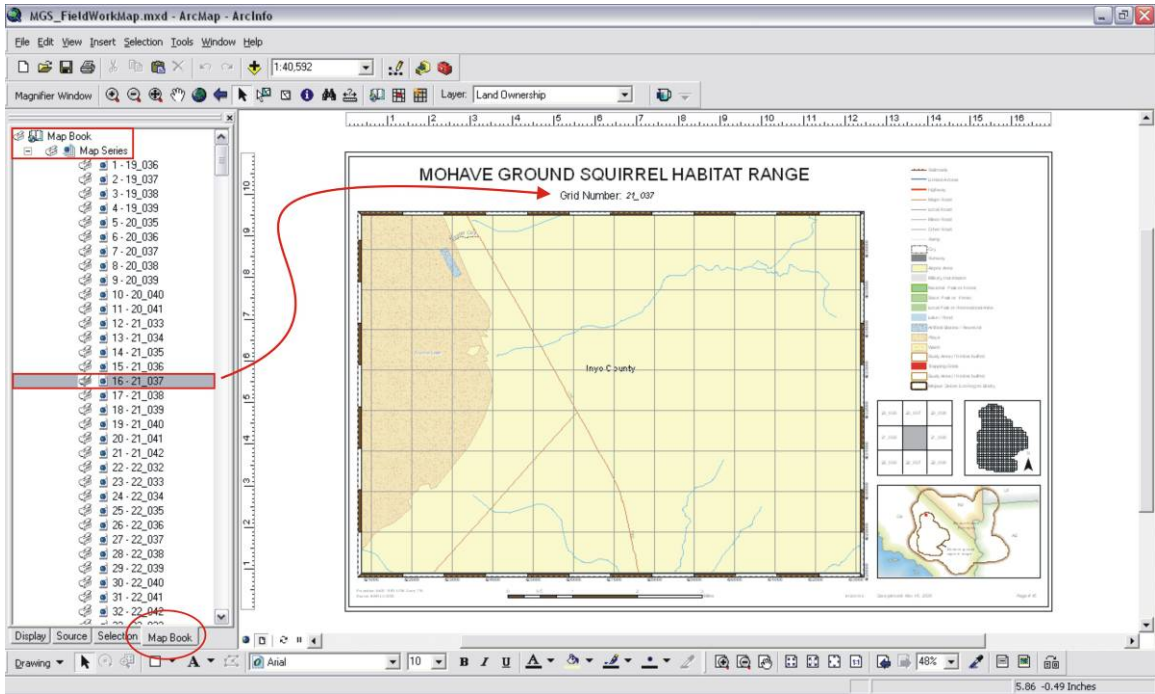
Figure A 42: Map Series.

Another feature provided with this tool is the locator map. This tool allows the creation of two sets of locator maps, one referred as global and the other as local. The global locator map shows all index grids for the entire Mohave ground squirrel range, index grid highlighting the selected one in red. The global locator map shows the selected grid in grey and the surrounding grids with their labels (Figure A 43).
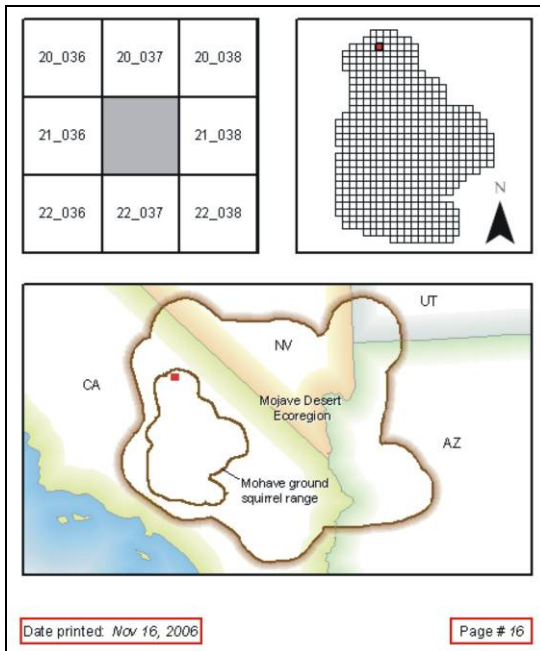

Figure A 43: Locator maps.

A third locator map was created to provide the map reader with a sense of where within the Mojave Desert the grid is located. The red square indicates the specific area of the desert that map. The Map Series tool also records the date when the map was printed and the page number in relation to the series of maps.

1.5.2.14. Effects Layers: Adjust Transparency & Swipe Layer

The Effects Layer tool allows the selection of a layer to be modified (ESRI, 2006). Any change made will apply only to the selected layer (ESRI, 2006). It should be recognized that these changes do not affect the dataset itself since they are only for display purposes. Two types of effects that can be applied to the layers are achieved by using the transparency and swiping tools. These tools are not found in the Tools toolbar therefore they were included from the Customize dialog box.

The Transparency tool is used to set the selected layers to some degree of transparency. The transparency can be set from 1 % up to 100%. Figure A 44 shows how this tool works. The following example uses the topographic map and the hillshade layers. When 35% transparency is added to the Topo maps, the relief can be seen through giving a more realistic view of the topography
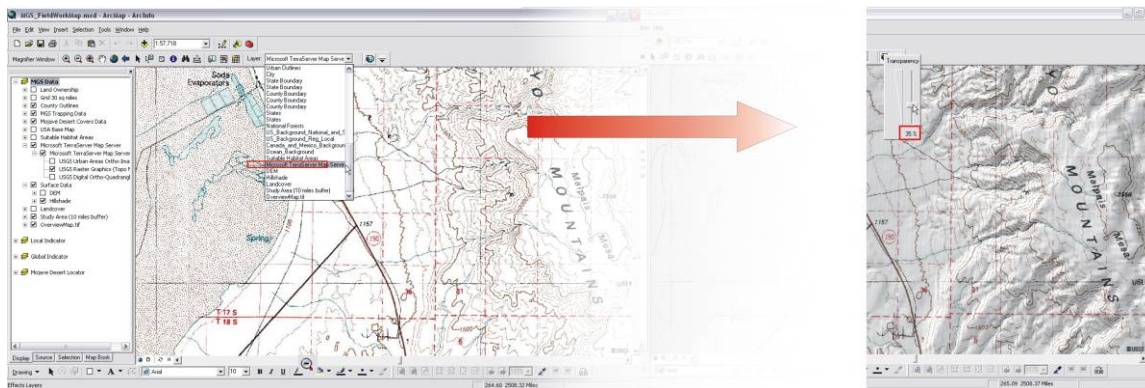

Figure A 44: Transparency tool.

The Swipe Layer tool is used to display any layer found below another layer without turning the upper layer off and on in the Table of Contents (ESRI, 2006). The advantage of this tool is that two related datasets can be activated at the same time and by using the Swipe Layer tool, the layer located underneath can be exposed without having to turn off the layer located above. Figure A 45 shows how this tool works. The Swipe Layer tool allows swiping the layer either horizontally or vertically, and from top to bottom and vice versa, as well as from right to left and vice versa.
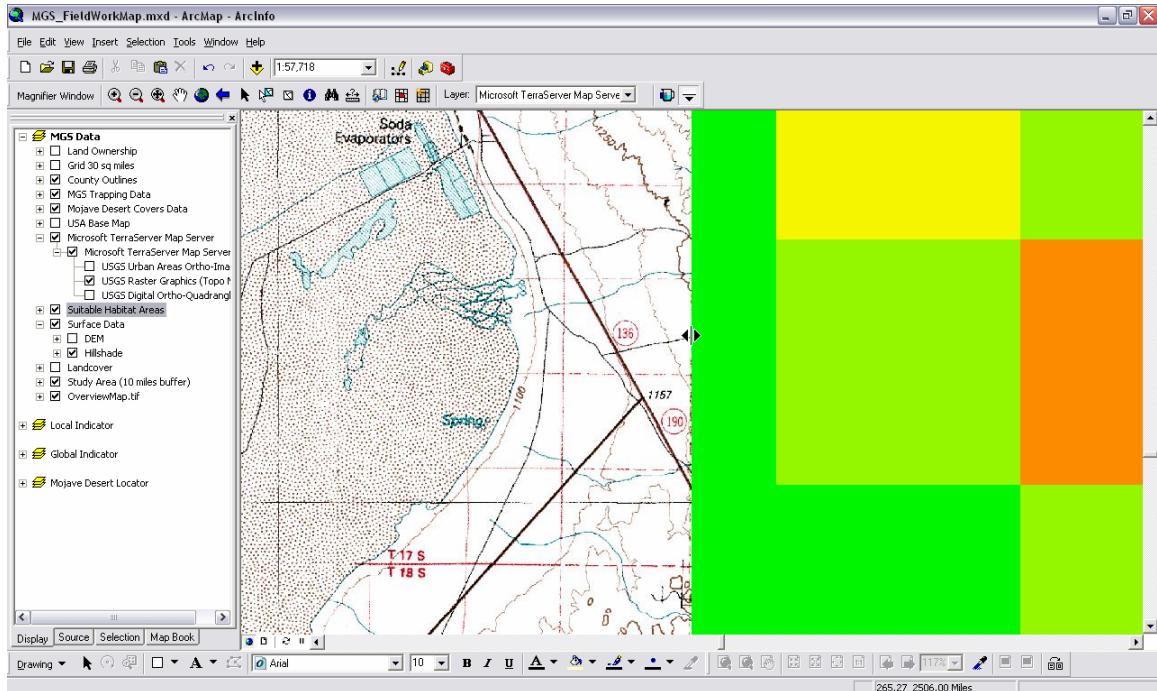
Figure A 45: Swipe Layer tool.

1.6.   ArcToolbox

As defined by ESRI (2006), ArcToolbox is a container in which numerous toolsets and tools are organized according to their functionality. Another way the interface was modified in this map document was by removing toolsets and tools that the client will not be using. The only tools included were those prepared to perform analysis related to the Mohave ground squirrel. These tools include The Mohave Ground Squirrel Model Toolbox, the Precipitation Model Toolbox, and a Surface toolbox. These toolboxes will be explained more in detailed in Appendices B, C, and D.
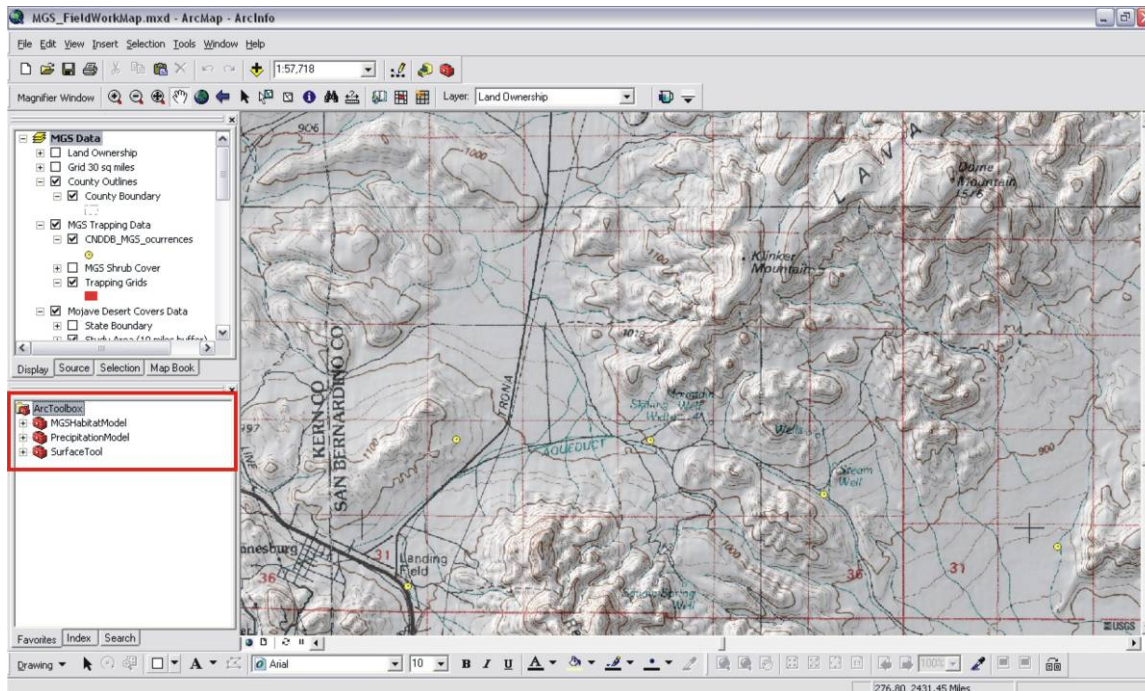
Figure A 46: Toolbox.

1.7. Conclusion

Customization of the ArcMap interface is beneficial for many reasons. One of the main reasons customization is performed is to meet the needs of the user organization. Modifying the interface in a user-friendly way makes it less intimidating for the user. Some of the processes done with the GIS can be enhanced by customizing the interface. Providing the needed tools in a readily accessible way reduces the number of clicking procedures and is more efficient.

The ArcMap interface can also be intimidating to non-GIS users because of the many tools displayed, such as the toolbars and the ArcToolbox tools. For the purpose of this project, the ArcMap interface was slightly modified so that the client will only sees some of the tools provided by the software. The rest of the tools will be explained in Appendices B, C, and D.

Appendix B: Mohave Ground Squirrel Habitat Suitability Model Manual

Mohave Ground Squirrel Habitat Suitability Model – User Manual

Prepared by: Ernesto Carreras, GIS Consultant and Project Manager

2. Introduction

The Mohave Ground Squirrel (MGS) Habitat Suitability Model is a tool developed to estimate the level of habitat suitability displayed by various areas within the range of the Mohave ground squirrel. The tool is based on a weighted overlay model that allows the user to set values of relative magnitude according to the degree of influence the selected variables have in determining the suitability of the habitat.

The MGS Habitat Suitability Model was created using the Spatial Analyst Toolbox along with the Model Builder application. The Spatial Analyst Toolbox was selected since it provides powerful tools for spatial modeling and analysis. The Model Builder was used to design the spatial model. This model was then prepared in such a way that the user would only see a form in which to input the selected variables. The MGS Habitat Suitability Model consists of seven steps. After performing each step successfully, the final output will be a raster dataset containing index values indicating the suitability level for a particular area.

As with suitability models in general, determining habitat suitability for the Mohave ground squirrel requires the analysis of many different variables. The following variables have been identified important in establishing habitat suitability: (a) vegetation, (b) geomorphology, (c) elevation, (d) slope, (e) land cover, (f) mean precipitation (1976-2006), (g) frequency of dry winter periods (1976-2006), and (h) consecutive dry winter periods (1976-2006). It is important to point out that the datasets used for the study have different attribute scales, such as elevation in meters and slope in percentage. Therefore, these datasets cannot be added together to yield a meaningful result. Moreover, the different variables used in the analysis vary in degree of importance. As a result, each class within a variable was assigned a value from 1 to 9, where 9 represents the most highest importance. Each dataset was also assigned a value to indicate the percent of influence it had on the weighted overlay model (Figure B 1).
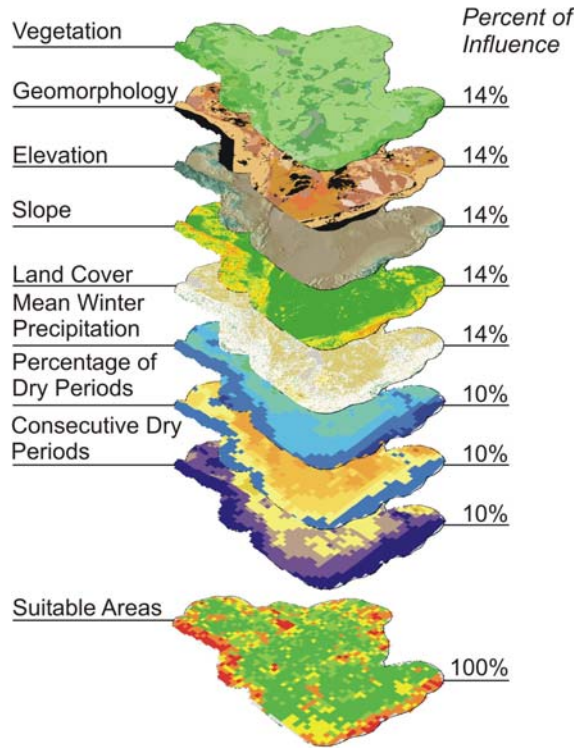
Figure B 1: Mohave ground squirrel habitat variables with percent of influence.

2.1. Step 1: Data Preparation

The first step is to collect the data and organize it in a geodatabase. The data on Table B 1 will be used as an example of how to execute the MGS Habitat Suitability Model. This does not mean that the datasets on that table are the only ones supported by the model. It should be recognized that as more study is done, the more variables are identified as important influences on habitat suitability, they can be added to the model as well. This manual will attempt to explain how the MGS Habitat Suitability Model works according to the data selected for the analysis.

Data Name	Description	Data Model	Attributes
Vegetation	Vegetation types	Vector	Type, Formation, Code
Geomorphology	Landform types	Vector	Code, LF_Level3: Land Form level 3
DEM	Digital Elevation Model	Raster	Surface Elevation
Slope	Slope in percent	Raster	Surface Slope
Land Cover	Land Cover Types	Raster	Land Cover Type (Value)
Mean Winter Precipitation	Average winter rainfall	Raster	Mean Winter Precipitation (Value)
Percentage of Dry Winters	Percent of dry winter periods	Raster	Percentage of Dry Winters (Value)
Consecutive Dry Winters Periods	Consecutive winter drought periods	Raster	Consecutive Dry Winter Periods (Value)

Table B 1: Data preparation.

Preparing the data is a crucial part of the project since it helps the user to create an organized directory with all the related data. Geodatabases serve as containers in which to store the data. The data related to the habitat suitability model was organized in a geodatabase called MGS.

Note: The following exercise will be used assuming that the data has already been collected and organized in a geodatabase. For this exercise, the geodatabase name is MGS and will be located in the *C:\MGS* folder. Since the data are going to be provided on a CD, you can create the same folder under the *C* drive and follow the same steps. Inside the *MGS* folder, create three more folders: (a) *ConvertToRaster*, (b) *Reclass,* and (c) *Suitable*.

2.2. Step 2: Open ArcMap and Create a New Map Document

The second step is to open the ArcMap application. ArcMap is composed of a main window to view the data, called the Data View, and a series of toolbars. It also contains the Toolbox, which is a container for the numerous tools used for geoprocessing tasks. Figure B 2 shows an example of the appearance of the ArcMap interface. Figures B 3 and 4 show the two main toolbars found in the ArcMap interface.
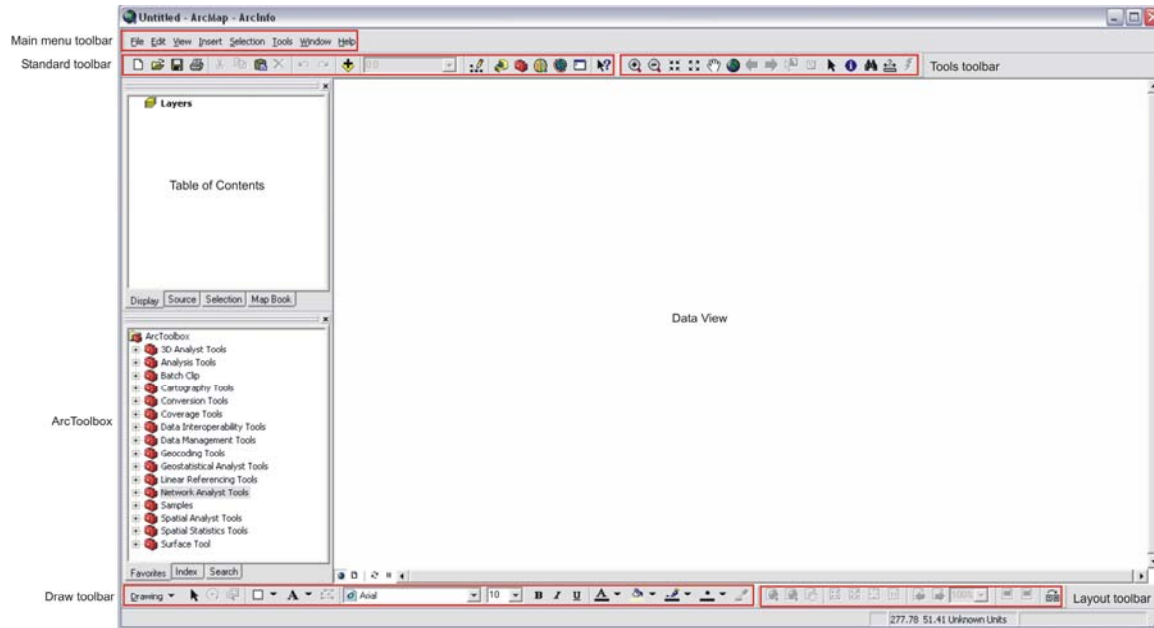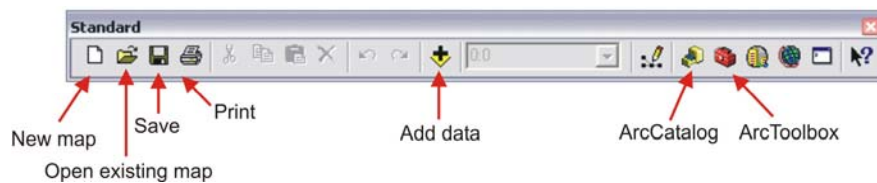
Figure B 2: ArcMap interface
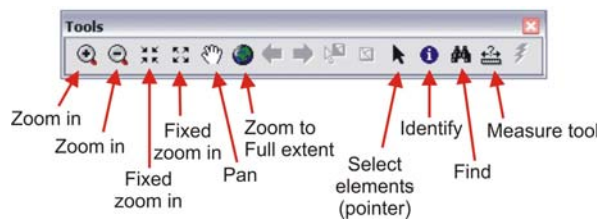

Figure B 3: Standard toolbar.

Figure B 4: Tools toolbar

Exercise Shortcut:

1. Open ArcMap

2. Create a new map document.

3. Save document in the directory related to the project.

Full Exercise Steps:

☐ Open ArcMap by going through the *Start* menu, *All Programs>ArcGIS>ArcMap* and double-click.

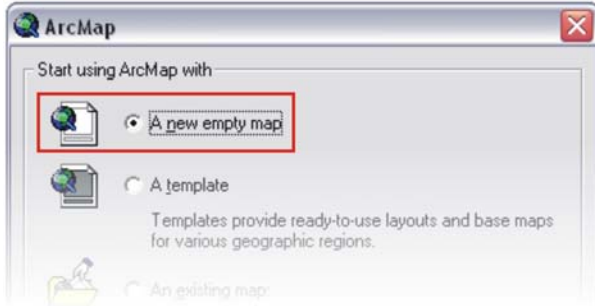☐ Select the *New empty map document* option (Figure B 5) and then click *OK*.

Figure B 5: A new empty map document.

☐ In the Main menu, go to *File* and select *Save As...* (Figure B 6).
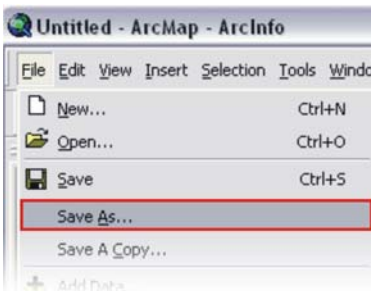
Figure B 6: Save As.

☐ Navigate to the directory where you want to save the map document.

! Make sure that this folder is the folder where your geodatabase resides (*C:\MGS*).

☐ Save your map as MGS_SuitableHabitats and the click *Save*.

! Make sure to constantly save your project by clicking the *Save* icon .

2.3. Step 3: Adding and Displaying Selected Variables in the Data View

The third step after saving the map document is to add the selected variables for the study, i.e., data, in the Data View. This is done by clicking the *Add Data* icon located in the Standard toolbar. Once the data are displayed in the Data View, they will be ready for the analysis process.

Exercise Shortcut:

1. Click the *Add Data* icon.

2. Navigate to the geodatabase directory.

3. Select datasets, i.e., (a) vegetation, (b) geomorphology, (c) elevation, (d) slope, (e) land cover, (f) mean precipitation (1976-2006), (g) frequency of dry winter periods (1976-2006), and (h) consecutive dry winter periods (1976-2006).

4. Change layer names.

Full Exercise Steps:

☐ Click the *Add Data* icon located in the Standard toolbar.

☐ Navigate to the godatabase directory folder (*C:\MGS*) and double-click on MGS.mdb to open the geodatabase (Figure B 7). This will display the data inside the geodatabase file.
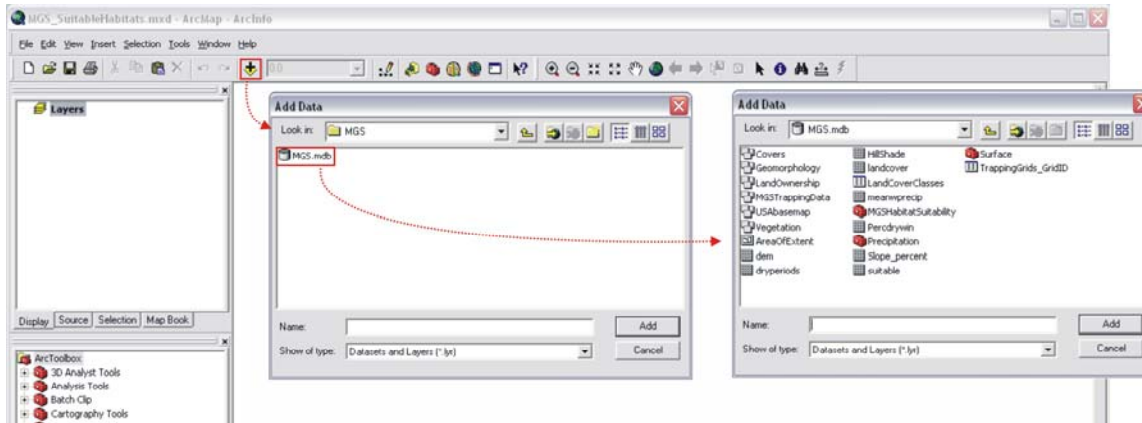

Figure B 7: Adding data from MGS geodatabse.

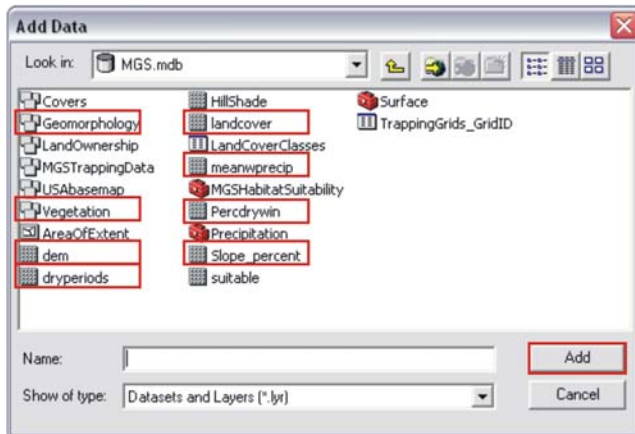☐ Add the required data by selecting the layers and then clicking the *Add* button (Figure B 8).

Figure B 8: Required data.

Note: By pressing *Ctrl* button, you can select multiple datasets at the same time. You will be able to this only with the raster datasets, i.e., *dem, dryperiods, landcover, meanwprecip, percdrywin,* and *slope_percent*. First, add the *vegetation* and *geomorphology* layers, and then add the raster datasets.

! If a warning messages is displayed alerting the user that there are some layers that has a different coordinate system from other data on the map, just click *OK to all*. By clicking this button, all the datasets will be projected on the fly with the projection of the first dataset added in the Data View.

☐ Change the layer names by right-clicking the layer and going to the *Properties* dialog box under the *General* tab (Figure B 9). Type the new name in the *Layer Name* text box. Change the name of only the following layers: *dem* to elevation, *meanwprecip* to MeanWinterPrecip, *dry periods* to ConsecDryPeriods and *Percdrywin* to PercDryWinters.
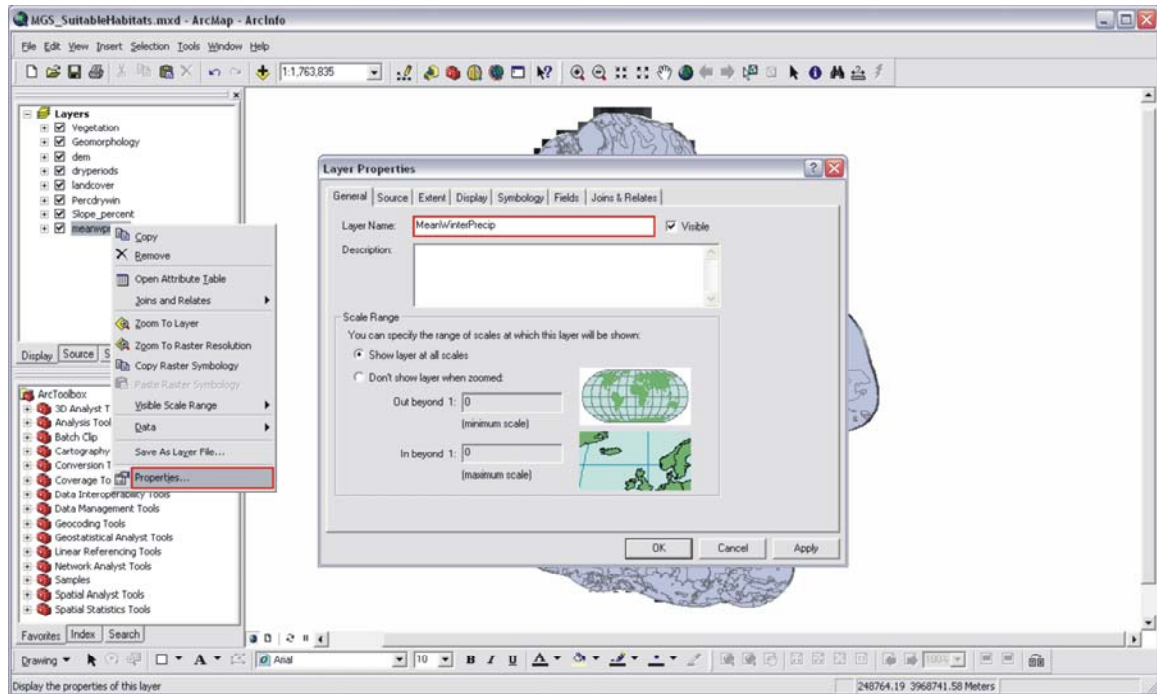

Figure B 9: Layer Properties dialog box.

☐ The layers can be turned off since they are not required to be active for the analysis. This can be done by checking the small box to the left side of the layer name (Figure B 10).
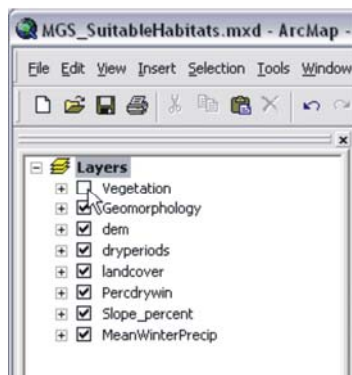
Figure B 10: Turning Layer Off.

Note: You can press the *Ctrl* button down and click on one of the boxes to turn them all off at the same time. The same can be done to turn them all on.

2.4. Step 4: Add the MGS Habitat Suitability Model Toolbox

Step four consists of adding the MGS Habitat Suitability toolbox to the ArcToolbox. This toolbox was created specifically to create a raster dataset showing habitat suitability of various areas for the Mohave ground squirrel. This toolbox is located in the MGS geodatabase located in the MGS folder (*C:\MGS*).

Exercise Shortcut:

1. Add ArcToolbox.

2. Add MGS Habitat Suitability toolbox from the MGS geodatabase.

3. Open MGS Habitat Suitability toolbox.

Full Exercise Steps:

☐ Click on the ArcToolbox icon located in the Standard toolbar to open the ArcToolbox window.

☐ Right-click on an empty space inside the ArcToolbox window to display a context menu prompting several options. Select the *Add Toolbox* option (Figure B 11).
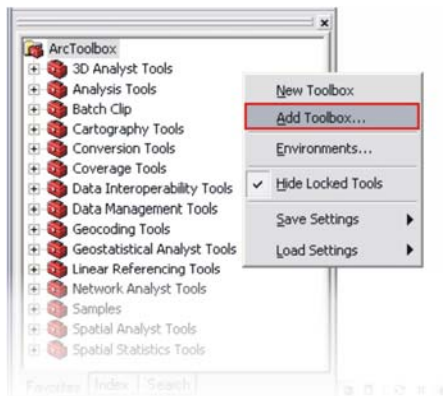

Figure B 11: Add Toolbox.

☐ Navigate to the godatabase directory folder (*C:\MGS*) and double-click on MGS.mdb to open the geodatabase. Inside the geodatabase, there are three toolboxes. Select the one named MGSHabitatSuitability and then click the *Open* button. The MGS Habitat Suitability toolbox will be added to the list of tools (Figure B 12).
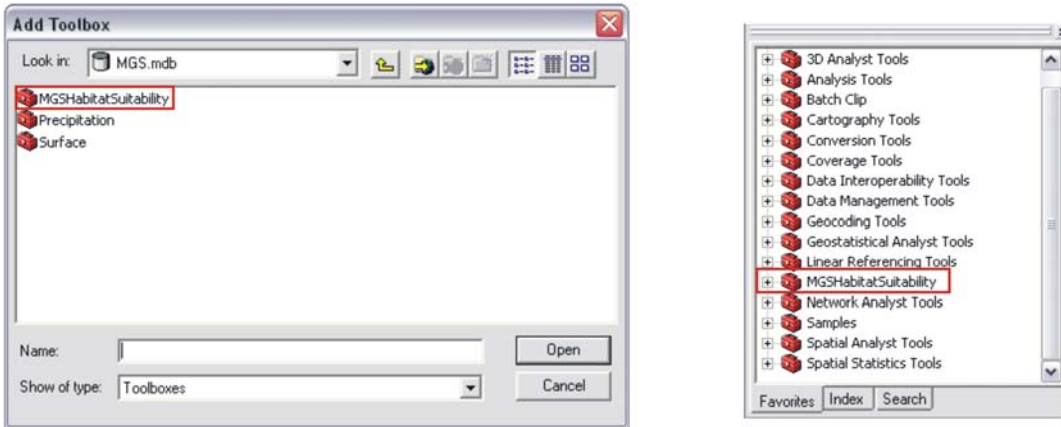
Figure B 12: MGS Habitat Suitability toolbox.

2.5. Step 5: Convert Feature to Raster

Step five consists of converting the vector datasets into raster format. The model created for the analysis requires that all the datasets are converted to the raster format. If they are not converted in this format, the datasets cannot be included in the analysis. If all the datasets needed are already in raster format, this step can be ignored.

Exercise Shortcut:

1. Open the MGS Habitat Suitability toolbox.

2. Open the *Convert Feature to Raster* model.

3. Input the vector layer.

4. Run the model.

Full Exercise Steps:

☐ Open the MGS Habitat Suitability toolbox by clicking on the plus sign located in the left side of the toolbox name. This will expand the toolbox, displaying the tools located inside (Figure B 13).

Figure B 13: Open MGS Habitat Suitability toolbox.

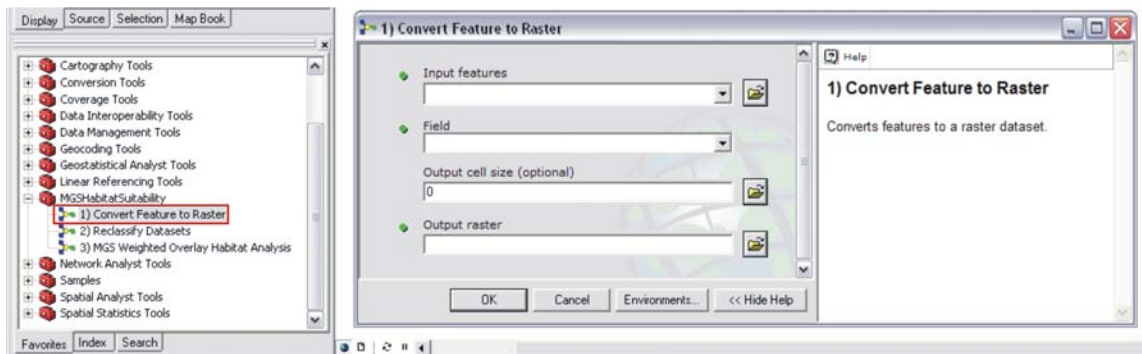☐ Double-click the *Convert Feature to Raster* model to open it (Figure B 14).

Figure B 14: Convert Feature to Raster model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input features* combo box, select the vector layer that is going to be converted into raster. This could be done by using the dropdown button [image] or by navigating to the folder.

☐ On the *Field* combo box, select the field in which to base this conversion, e.g., a field that represents the vegetation or geomorphology types. This could be either a coded value or the type names.

☐ For the *Output cell size* textbox, set the output cell size to 30. For the *Output raster*, click the folder icon and navigate to the *C:\MGS\ConvertToRaster* folder. Remember to save the new raster with a meaningful name, such as *vegetation* or *geomorphology*.

! The Convert Feature to Raster tool might take a few minutes to complete the process. If the process fails, you might try it again but with a larger output cell size, e.g., 75.

! Open the attribute table for the *vegetation* and *geomorphology* layers to see the coded values assigned to the fields used for the conversion to raster. The field name is *Code*.

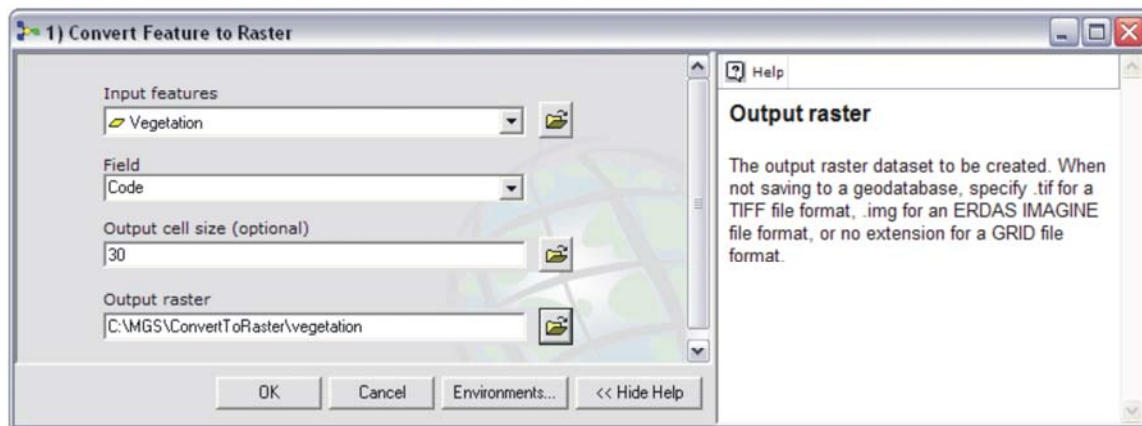☐ The *Convert Feature to Raster* dialog box should resemble Figure B 15.

Figure B 15: Convert Feature to Raster parameters.

☐ Follow the same steps to convert any other vector layer to raster, i.e., geomorphology layer.

! The new layers can be turned off if they are added to the Table of Contents.

2.6. Step 6: Reclassify Datasets

The sixth step consists of reclassifying the datasets with the new values. The reclassification method will group together values that are considered to have the same degree of influence.

Exercise Shortcut:

1. Open the *Reclassify Datasets* model.

2. Input the raster datasets.

3. Set reclassify values.

4. Run the model.

Full Exercise Steps:

☐ Double-click the *Reclassify Datasets* model to open it (Figure B 16).
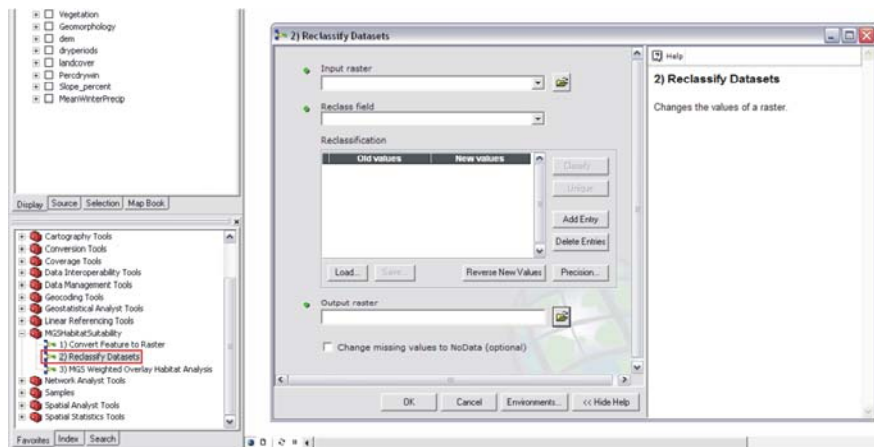

Figure B 16: Reclassify Datasets model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input raster* combo box, select the raster dataset that is going to be reclassified, i.e., selected variables. This could be done by using the dropdown button
[▼] or by navigating to the folder.

☐ In the *Reclass Field* combo box, select the field on which to base the reclassification method, e.g., a field that represents the elevation values.

! After selecting the *Reclass Field*, click the *Classify* button, then choose *Equal Intervals* for the *Classification Method* and depending on the range values to reclassify, select the appropriate number of *Classes*.

☐ For the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\Reclass* folder. Remember to save the new raster with a meaningful name, such as *elevreclass*.

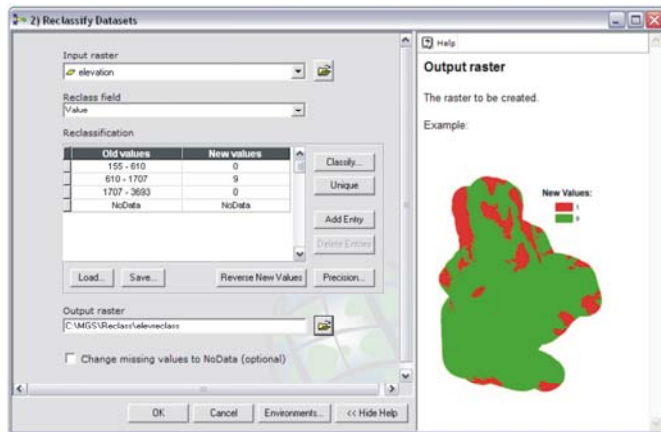☐ The *Reclassify Dataset* dialog box should resemble Figure B 17.

Figure B 17: Reclassify Datasets parameters

☐ Table B 2 has all the parameters that should be set for the required variables.

! When reclassifying the *vegetation* and *geomorphology* datasets, their values might not show up in the *Reclassification* table. To add their values, click the *Add Entry* button and add *Old Values* and *New Values*. After adding all the values, add a new row to each of the *Reclassification* tables.   For the vegetation, type *NoData* for both, the *Old Values* and the *Old Values* field. For the geomorphology, type *NoData* for the *Old Values* and 0 for the *New Values* field. This is required since these data are incomplete. If this is not done, the final output will have a lot of No Data values. After better data are obtained, this step can be ignored.

Input Raster	Reclass Field	Values	
Elevation	*Value*	*Old*	*New*
		155 - 610	0
		610 - 1707	9
		1707 - 3693	0
		NoData	NoData
Slope	*Value*	*Old*	*New*
		0 - 8.5	9
		8.5 - 21.5	8
		21.5 - 38.25	6
		38.25 - 60	3
		60 - 1086.347900	0
		NoData	NoData
Land Cover	*Value*	*Old*	*New*
		11 - 50	0
		51	9
		52 - 95	0
		NoData	NoData
Vegetation	*Code*	*Old*	*New*
		1	0
		9	9
		NoData	NoData
Geomorphology	*Code*	*Old*	*New*
		1	0
		4	4
		9	9
		NoData	0
Mean winter precipitation	*Value*	*Old*	*New*
		62.678478 - 80	0
		80 - 100	2
		100 - 500	9
		500 - 962.578979	9
		NoData	NoData
Percentage of dry winters	*Value*	*Old*	*New*
		0	0
		10	9
		20	8
		30	7
		40	5
		50	3
		60	2
		70	1
		NoData	NoData
Consecutive dry winters	*Value*	*Old*	*New*
		28 - 90	9
		91 - 113	6
		114 - 135	4
		136 - 174	2
		175 - 253	0
		NoData	NoData

Table B 2: Reclassify Datasets parameters

☐ After setting the parameters, click the *OK* button to run the model.

☐ All the datasets can be turned off if they have been added to the Table of Contents.

2.7. Step 7: MGS Weighted Overlay Habitat Analysis

Step seven consists of creating the Mohave ground squirrel suitable areas dataset. This dataset will be created after running the MGS Weighted Overlay Analysis tool, which consists of selecting the required variables, and assigning their scale values and percent of influence. The scale values range from 1 to 9, where nine is the most suitable value. In some circumstances, it can range from 0 to 9, where zero is assigned to the unsuitable areas. When establishing the percent of influence of the datasets, it is essential that all together must add up to 100%.

Exercise Shortcut:

1.   Open the *MGS Weighted Overlay Habitat Analysis* model.

2.   Input the selected variables.

3.   Assign scale values.

4.   Assign percent of influence.

5.   Run the model.

6.   Display and symbolize final output.

Full Exercise Steps:

☐ Double-click the *MGS Weighted Overlay Habitat Analysis* to open it (Figure B 18).
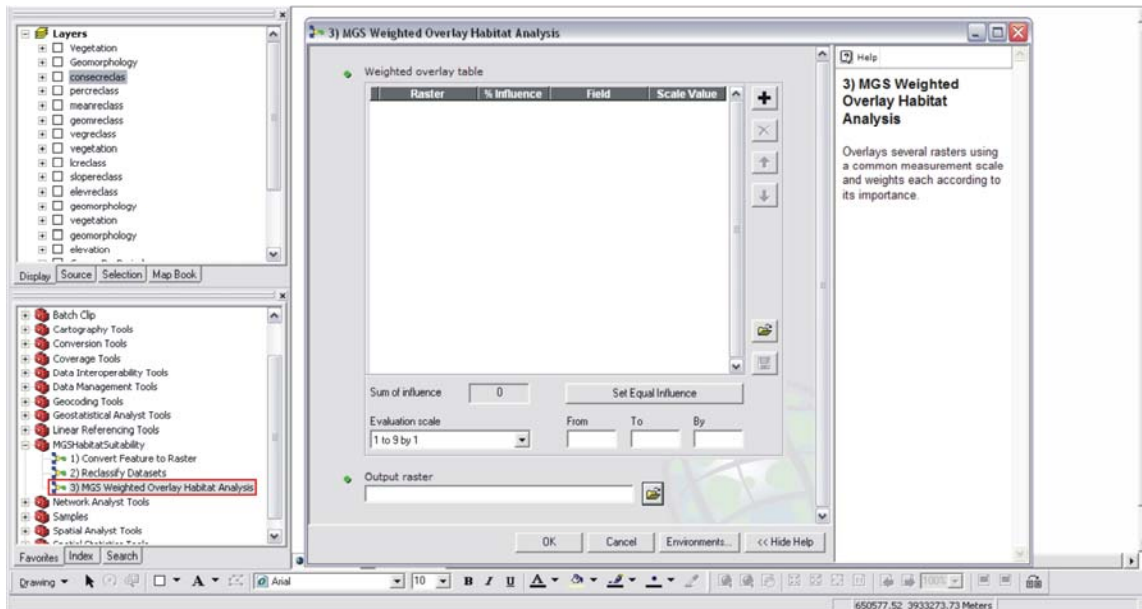
Figure B 18: MGS Weighted Overlay Habitat Analysis model.

Note: Click the *Show Help* button to display more information about this tool.

☐ To input the required datasets, click the *Add raster row* button ![plus button] located in the upper right side of the table. It will open the *Add Weighted Overlay Layer* dialog box. For the *Input raster* combo box, select a raster layer and for the *Input field* combo box, select the field that contains the values upon which that the weighted analysis will be based. Follow these steps when inputting all the variables.

☐ Set the *Evaluation scale* with the following values: *From:* 0, *To:* 9, *By:* 1. This will set the Scale Values to be from 0 to 9 going one by one. Note that these values were added to the *Evaluation scale* dropdown list.

! The *Evaluation scale* (suitability ranges) can be set to any desired scale, but only if the From, To, and By values are integers. They must all be on the same scale. The tool will not allow any value that exceeds the parameters assigned in the *Evaluation scale*.

Note: The Weighted Overlay table allows the user to classify the input values shown in the *Field* column and to assign output *Scale Values* to these classes. If the input raster is already classified, then this is not required. It should also be understood that classes can be defined using lists and ranges just as was done with the *Reclassify* tool.

☐ After setting the *Evaluation scale*, the suitability levels can be assigned to each class. These values are assigned in the *Scale Value* field. Click on one the *Scale Value* fields provided, and a dropdown list will show up. This list contains the values already set in the *Evaluation scale*.

☐ Set the relative importance assigned to each dataset in the *% Influence* field. The sum of all the percent influences values must equal 100%.

☐ For the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\Suitable* folder. Remember to save the final output raster with a meaningful name, such as *suitable*.

☐ The *MGS Weighted Overlay Habitat Analysis* dialog box should resemble Figure B 19.
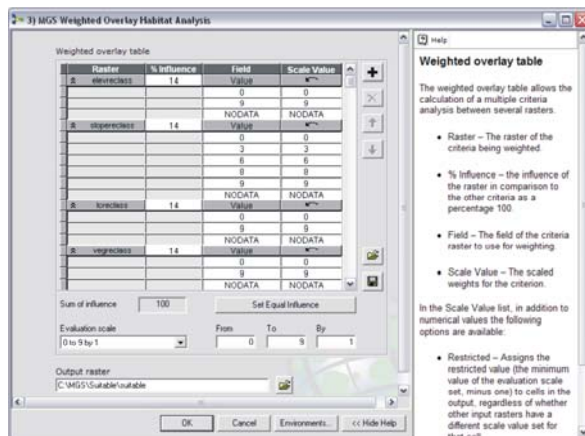

Figure B 19: MGS Weighted Overlay Habitat Analysis parameters.

☐ Table B 3 has all the parameters that should be set for the required variables.

Raster	% Influence	Field	Scale Value
Elevation	*14*	*Value*	
		0	0
		9	9
		NoData	NoData
Slope	*14*	*Value*	
		0	0
		3	3
		6	6
		8	8
		9	9
		NoData	NoData
Land Cover	*14*	*Value*	
		0	0
		9	9
		NoData	NoData
Vegetation	*14*	*Value*	
		0	0
		9	9
		NoData	NoData
Geomorphology	*14*	*Value*	
		0	0
		4	4
		9	9
		NoData	NoData
Mean winter precipitation	*10*	*Value*	
		0	0
		2	2
		9	9
		NoData	NoData
Percentage of dry winters	*10*	*Value*	
		0	0
		1	1
		2	2
		3	3
		5	5
		7	7
		8	8
		9	9
		NoData	NoData
Consecutive dry winters	*10*	*Value*	
		0	0
		2	2
		4	4
		6	6
		9	9
		NoData	NoData

Table B 3: MGS Weighted Overlay Habitat Analysis parameters.

☐ After setting the parameters, click the *OK* button to run the model. When the tool is executed, each layer's classified *Scale Values* are multiplied by the layer's percent influence and then they are added together and written to the output raster.

☐ Once the final output, i.e., suitable layers, is added to the Table of Contents, right-click the layer name and select *Properties* to open the *Layer Properties* dialog box.

Select the *Symbology* tab, and under *Show,* choose the *Classified* option. For the *Classification method*, click *Classify*. This will open the *Classification* dialog box. This is where the *Classification* method and number of *Classes* are chosen. For this exercise, the *Natural Breaks* will work well since it classifies the data into groups of similar values. Under *Classes*, select 5 and then click *OK* (Figure B 20).
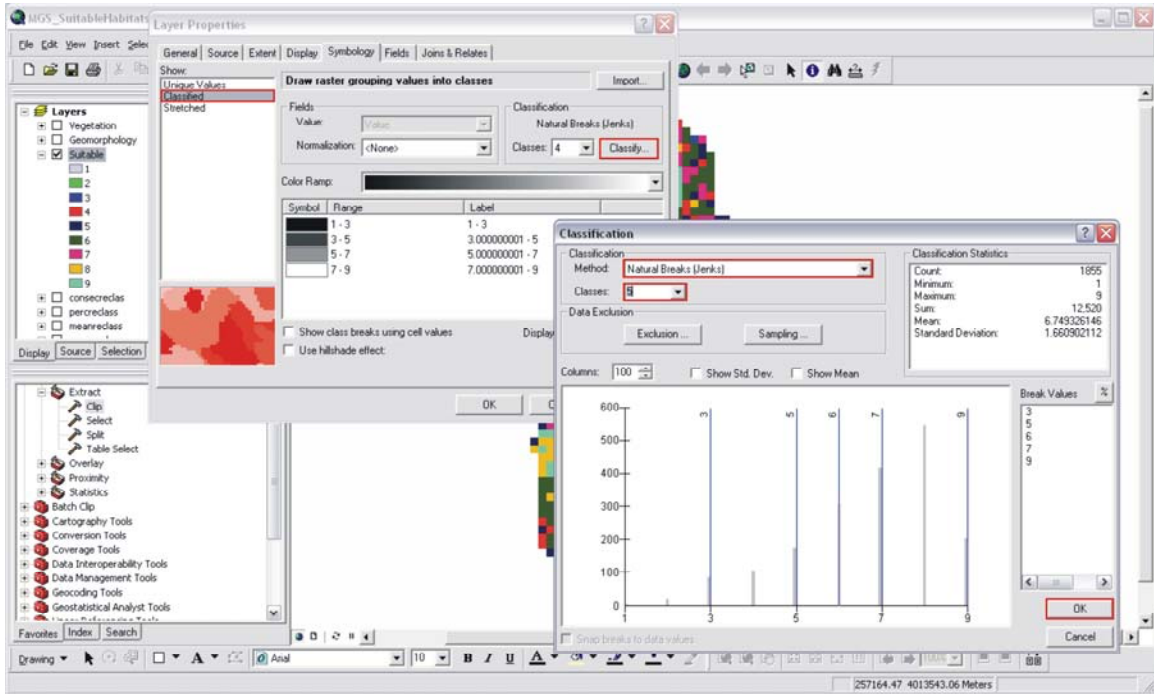

Figure B 20: Symbolizing and Classifying data.

☐ Select the *Color Ramp* that will be used for symbolizing the data by clicking the dropdown arrow and then clicking *OK* (Figure B 21).
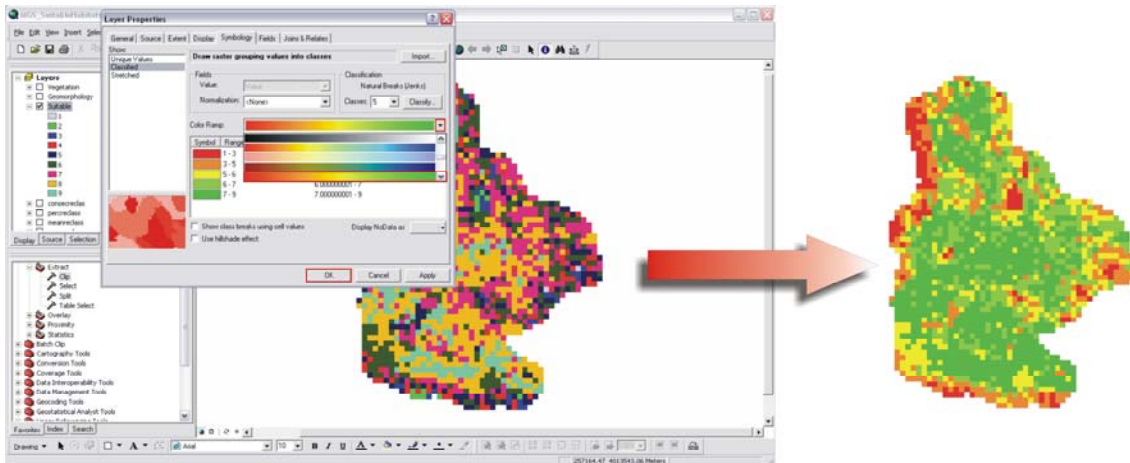
Figure B 21: Color Ramp.

☐ Click *Save* to save the map document.

Appendix C: Precipitation Model Manual

Precipitation Model – User Manual

Prepared by: Ernesto Carreras, GIS Consultant and Project Manager

3.   Introduction

The Precipitation Model is a tool developed to create three crucial datasets required in the Mohave Ground Squirrel Habitat Suitability Model. These datasets are the following: (a) mean winter precipitation (1976 – 2006), (b) frequency of dry winter periods (1976 – 2006), and (c) consecutive dry winter periods (1976 – 2006). The tool is based on a model that uses map algebra to calculate these variables. The tools used on the model were created using the Spatial Analyst and the Model Builder application. The Precipitation Model consists of six main steps: (a) processing the ASCII files, (b) converting the precipitation data to millimeters, (c) calculating the annual winter precipitation, (d) calculating the mean winter precipitation, (e) calculating the frequency of dry winter periods, and (f) calculating the consecutive dry winter periods. After performing each step successfully, the final output will be a raster dataset containing such indexes values for the Mohave ground squirrel range.

3.1.   Step 1: Data Preparation

The first step is to collect the data and organize it in a folder related to the Mohave ground squirrel habitat suitability study. These data will be complied into a geodatabase once they have been processed from ASCII files to raster grids. The data should be allocated to a folder called *PrecipitationData* inside the MGS folder (*C:\MGS\PrecipitationData*).

Note: The precipitation data can be downloaded for free from the PRISM website (http://www.ocs.orst.edu/prism/). This exercise will assume that the data are already downloaded and decompressed. For more instruction on how to decompress these files, referred to the PRISM website listed above. The precipitation data for the 30-year periods will be provided to the client along with the CD for training purposes. Since the data were already processed for use in the *MGS Habitat Suitability Analysis Model*, the final outputs will also be provided with the MGS geodatabase.

3.2.   Step 2: Open ArcMap and Create a New Map Document

The second step is to open the ArcMap application. This new map document should be saved as Precipitation_Model.

Exercise Shortcut:

1.   Open ArcMap

2.   Create a new map document.

3.   Save document in the directory related to the project.

Full Exercise Steps:

☐ Open ArcMap by going through the *Start* menu, *All Programs>ArcGIS>ArcMap* and double-click.

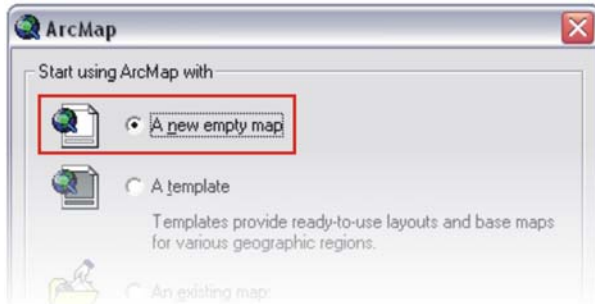☐ Select the *New empty map document* option (Figure C 1) and then click *OK*.

Figure C 1: A new empty map document.

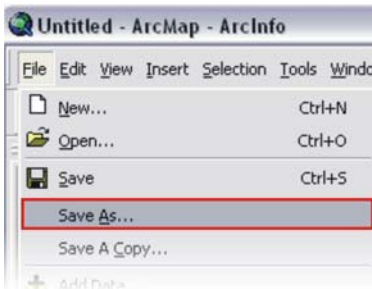☐ In the Main menu, go to *File* and select *Save As...* (Figure C 2).

Figure C 2: Save As.

☐ Navigate to the directory where you want to save the map document.

! Make sure that this folder is the folder where your geodatabase resides (*C:\MGS\PrecipitationData*).

☐ Save your map as Precipitation_Model and the click *Save*.

! Make sure to constantly save your project by clicking the *Save* icon .

3.3.   Step 3: Add the Precipitation Model Toolbox

Step three consists of adding the Precipitation toolbox to the ArcToolbox. This toolbox was designed specifically to create a series of raster datasets related to precipitation characteristics within the Mohave ground squirrel. This toolbox is located in the MGS geodatabase which is located in the MGS folder (*C:\MGS*).

Exercise Shortcut:

1.   Add ArcToolbox.

2.   Add Precipitation toolbox from the MGS geodatabase.

| 3. | Open Precipitation toolbox. |

Full Exercise Steps:

☐ Click on the ArcToolbox icon located in the Standard toolbar to open the ArcToolbox window.

☐ Right-click on an empty space inside the ArcToolbox window to display a context menu prompting several options. Select the *Add Toolbox* option (Figure C 3).
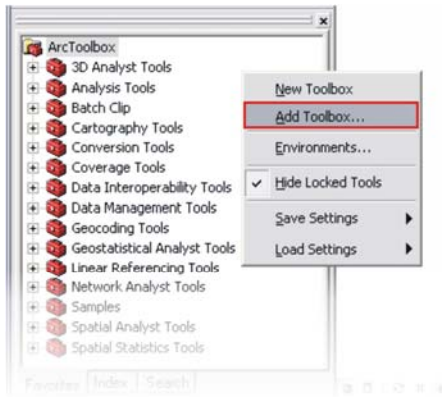
Figure C 3: Add Toolbox.

☐ Navigate to the godatabase directory folder (*C:\MGS*) and double-click on MGS.mdb to open the geodatabase. Inside the geodatabase, there are three toolboxes. Select the one named Precipitation and then click the *Open* button. The Precipitation toolbox will be added to the list of tools (Figure C 4).
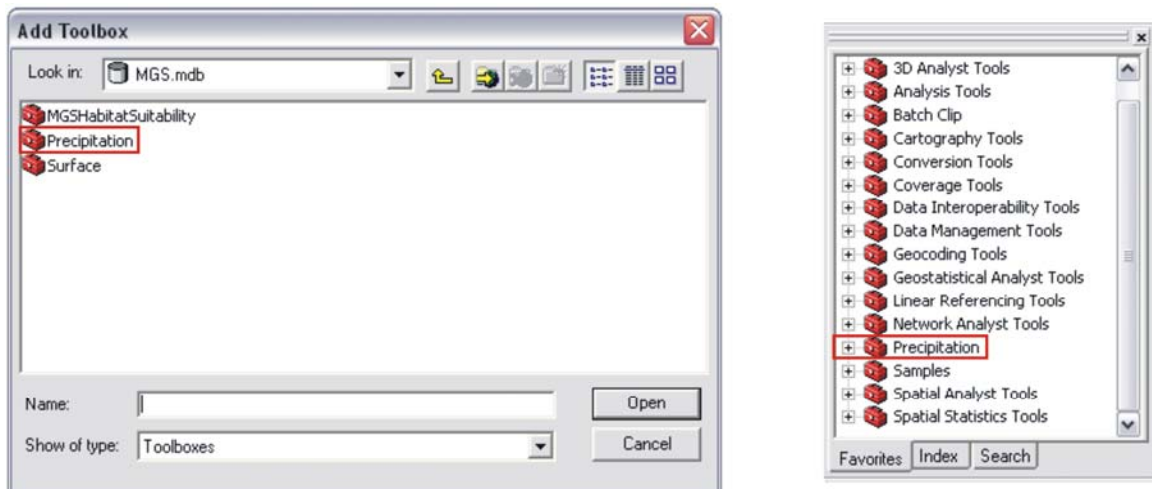
Figure C 4: Precipitation toolbox.

3.4. Step 4: Process PRISM data

PRISM precipitation data are downloaded as ASCII (American Standard Code for Information Interchange) file format; as a result, it must be converted to raster grids.

Exercise Shortcut:

1. Open the Precipitation toolbox.

2. Open the *Process PRISM data* model.

3. Input the ASCII files.

4. Run the model.

Full Exercise Steps:

☐ Open the Precipitation toolbox by clicking on the plus sign located in the left side of the toolbox name. This will expand the toolbox, displaying the tools located inside (Figure C 5).
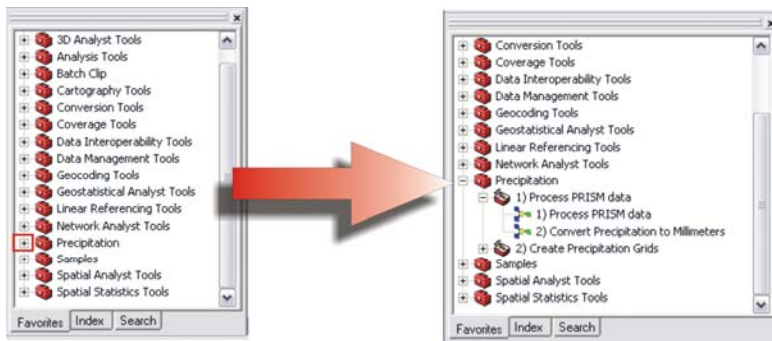
Figure C 5: Open Precipitation toolbox.

☐ Double-click the *Process PRISM data* model to open it (Figure C 6).
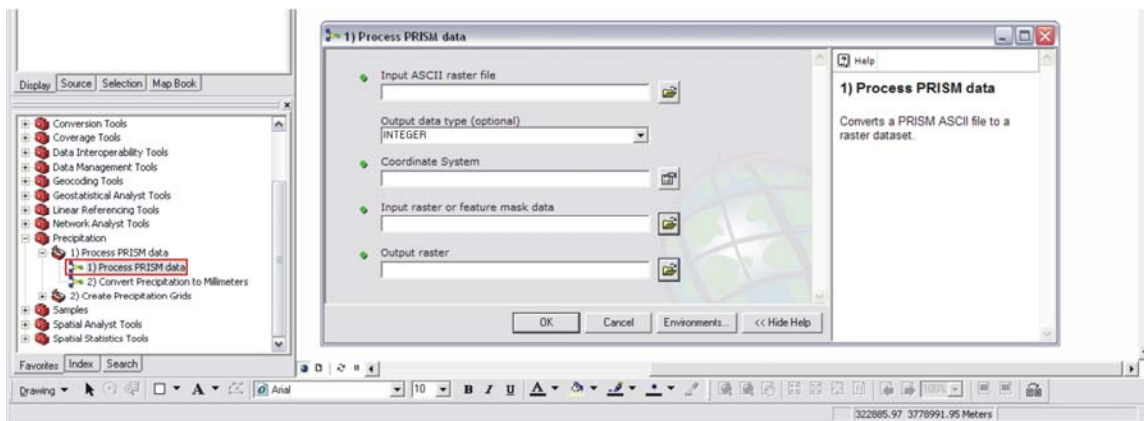
Figure C 6: Process PRISM model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input ASCII raster file* textbox, select the required file that is going to be converted into raster. This file is located in the following folder: *C:\MGS\PrecipitationData\1976_1977\Oct\us_ppt_1976_10.txt*.

Note: It important to note that the data to be processed covers a 30-year period from 1976 – 2006. Since these data are related to winter precipitation, each folder representing a

one-year period, e.g., 1976 – 1977, contains data for the six months, i.e., October, November, December, January, February, and March. All of these files must be processed individually. The naming convention for these datasets is as follows: *us_ppt_1976_10* means October 1976 PRISM ASCII file for continental United States.

☐ On the *Output data type* combo box, select *INTEGER*.

☐ Click the icon next to the *Coordinate System* textbox to open the *Spatial Reference Properties* dialog box. Then click *Select* to open the *Browse for Coordinate System Dialog*. Once this dialog opens, browse through the following folders: Geographic Coordinate Systems>World, and select the *WGS 1972.prj* (Figure C 7). Then click *Add*. The coordinate system information fills in the *Spatial Reference Properties* dialog (Figure C 8).
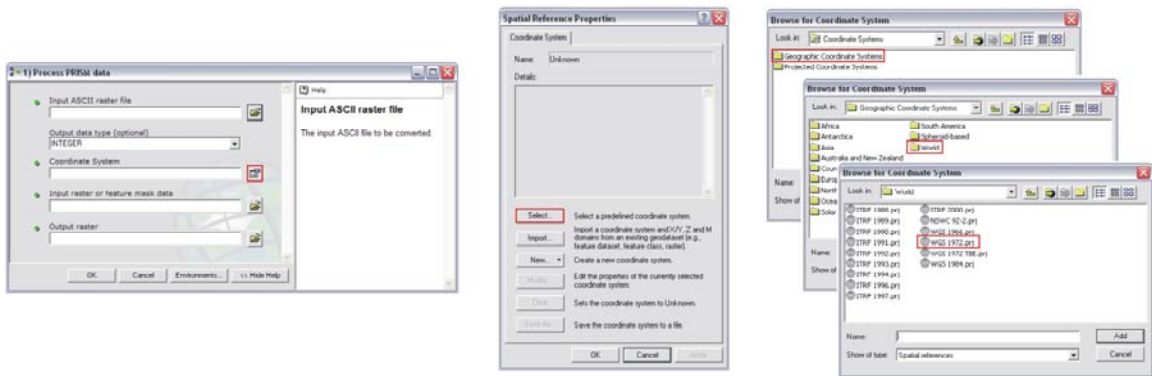
Figure C 7: Setting Coordinate System.
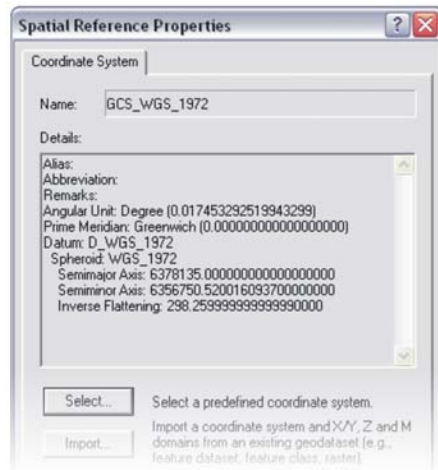
Figure C 8: Coordinate System information.

☐ For *Input raster or feature mask data* textbox, click the folder icon, navigate to the *C:\MGS\MGS.mdb\Covers*, and select the *StudyAreaBufferTenMiles* layer. This layer will be used to extract the cells of the precipitation dataset corresponding to the Mohave ground squirrel range since the data cover the entire United States.

☐ For the *Output raster,* click the folder icon, navigate to the *C:\MGS\PrecipitationData\1976_1977\Oct* folder, and save the new raster with a meaningful name, such as *1976_oct.*

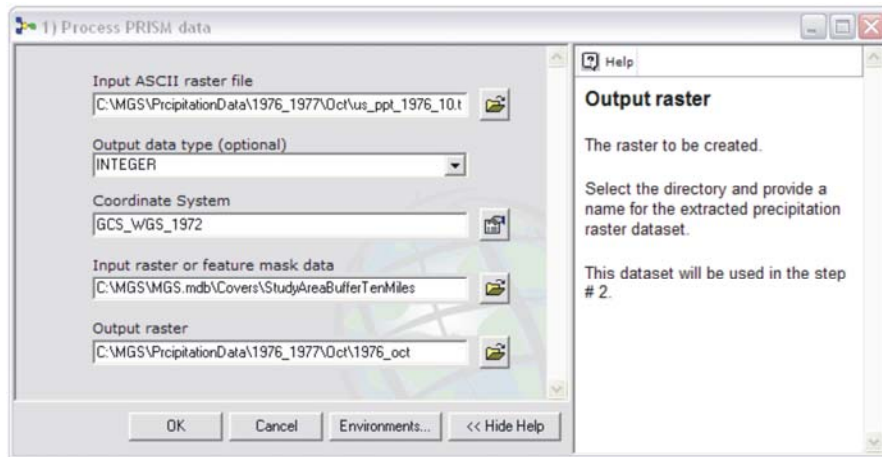☐ The Process PRISM data dialog box should resemble Figure C 9.

Figure C 9: Process PRISM data parameters.

☐ After setting the parameters, click the *OK* button to run the model.

☐ Repeat these steps for any data that need to be processed.

☐ All the datasets can be turned off if added to the Table of Contents.

3.5. Step 5: Convert Precipitation to Millimeters

Step five consists of converting the precipitation raster grids from hundredths of millimeters to millimeters. This process is done by using a map algebra equation. It takes the precipitation for a particular month during the winter period and divides it by 100 just as it is done in a mathematical computation.

Exercise Shortcut:

1. Open the *Convert Precipitation to Millimeters* model.

2. Input the raster dataset.

3. Set the Map Algebra expression.

4. Run the model.

Full Exercise Steps:

☐ Double-click the *Convert Precipitation to Millimeters* model to open it (Figure C 10).
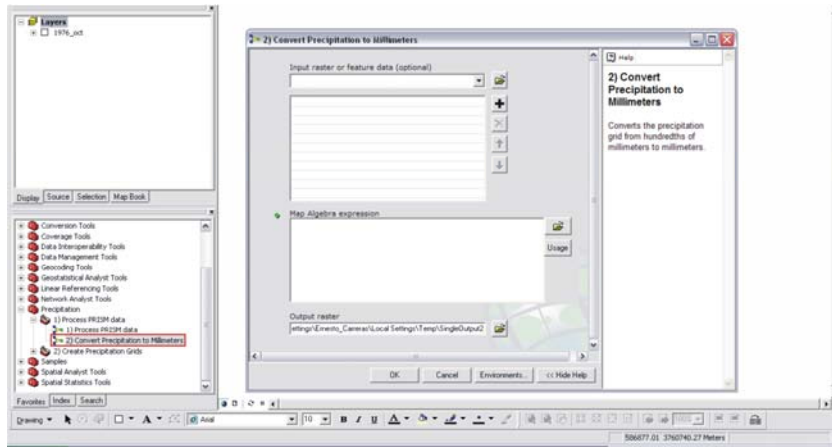
Figure C 10: Convert to Precipitation to Millimeters model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input raster or feature data* combo box, select the raster dataset that is going

to be converted. This could be done by using the dropdown button [▼] or by navigating to the folder. This raster dataset could be any of the monthly winter precipitation raster grids processed in the previous step, e.g., *1976_oct*.

! It is recommended that the raster grids to be converted to millimeters should be in the Table of Contents, although this is not required.

☐ In the *Map Algebra expression* box, type the appropriate expression. The expression will depend on the naming convention used for the raster grid. Following the example on Figure C 10, the expression should be: **[*1976_oct*] / 100**.

Note: The Map Algebra expression for this equation is: [grid name] / 100. If the grid is not between the brackets, the equation will not work.

☐ For the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData\1976_1977\Oct* folder. Remember to save the new raster with a meaningful name, such as *1976_oct_mm*.

☐ The *Convert Precipitation to Millimeters* dialog box should resemble Figure C 11.

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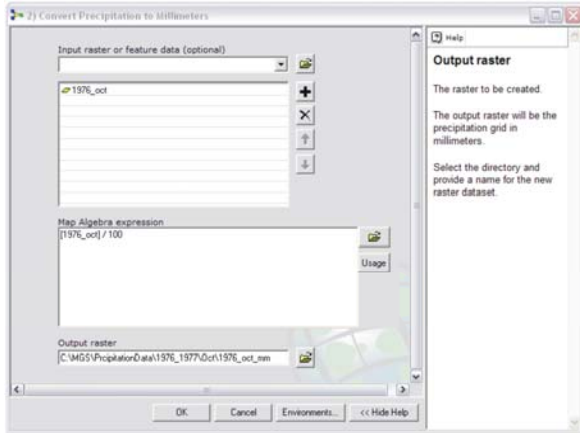
Figure C 11: Convert Precipitation to Millimeters parameters.

☐ After setting the parameters, click the *OK* button to run the model. The results should appear similar to Figure C 12.
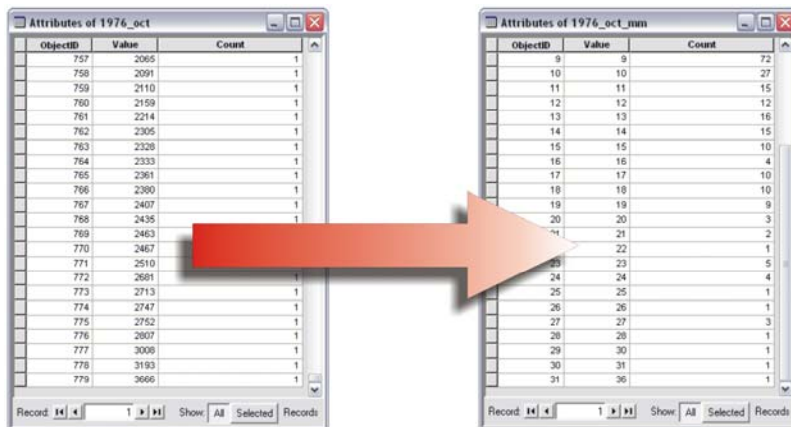

Figure C 12: Hundredths of millimeters to millimeters.

☐ Repeat these steps for any data that needs to be converted to millimeters.

Note: It should be recognized that this has already been done for all the datasets since they were needed to create the precipitation rasters for the *Mohave ground squirrel Habitat Suitability Analysis Model*. For the purpose of this exercise, it should be completed for all six of the winter precipitation months for one year, i.e., October through March.

☐ All the datasets can be turned off if added to the Table of Contents.

3.6. Step 6: Annual Winter Precipitation

Step six consists of creating the first of the precipitation raster grids required for the *MGS Habitat Suitability Analysis Model*. This dataset is the annual winter precipitation raster grid. To accomplish this process, data for the six winter precipitation months for a particular year are required. This process is also done by means of a map algebra equation. It sums the precipitation for each month of the winter period. This process generates a new raster grid using all the summed values.

Exercise Shortcut:

1. Open the *Annual Winter Precipitation* model.

2. Input the raster datasets.

3. Set the Map Algebra expression.

4. Run the model.

Full Exercise Steps:

☐ Double-click the *Annual Winter Precipitation* model to open it (Figure C 13).
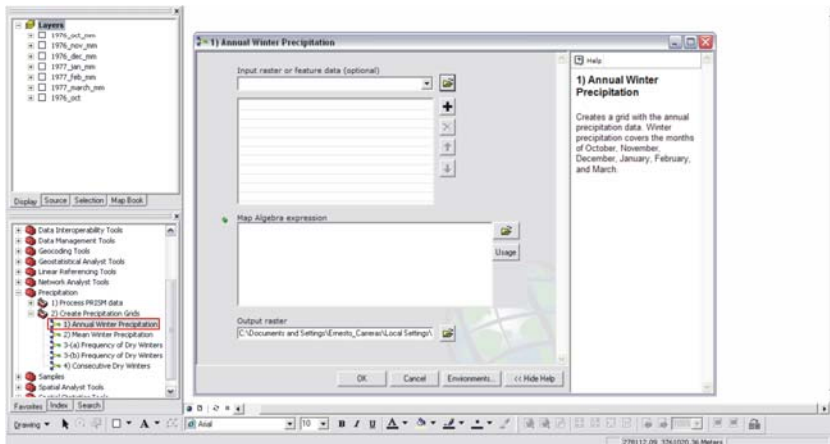

Figure C 13: Annual Winter Precipitation model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input raster or feature data* combo box, select the raster datasets required to calculate the annual winter precipitation, i.e., October, November, December, January, February, and March. This could be done by using the dropdown button

!image or by navigating to the folder. These rasters should be the monthly winter precipitation raster grids converted into millimeters in the previous step, e.g., *1976_oct_mm*, etc.

! It is recommended that the raster grids that are going to be used for the calculation are in the Table of Contents, although this is not required.

☐ On the *Map Algebra expression* box, type the following expression. The expression will depend on the naming convention used for the raster grid. If following the example on Figure C 11, the expression should be as follows: **[*1976_oct_mm*]** + **[*1976_nov_mm*]** + **[*1976_dec_mm*]** + **[*1976_jan_mm*]** + **[*1976_feb_mm*]** + **[*1976_march_mm*]**.

Note: The Map Algebra expression for this equation is: [year_oct_mm] + [year_oct_mm] + [year_oct_mm] + [year_oct_mm] + [year_oct_mm] + [year_oct_mm]. If the grid name is not between the brackets, the equation will not work.

☐ For the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData* folder. Create a new folder by clicking the *New folder* icon ![folder icon] in the *Output raster* dialog box and name it *AnnualWnterPrecip*. Remember to save the new raster with a meaningful name, such as *1976_1977*.

☐ The *Annual Winter Precipitation* dialog box should resemble Figure C 14.
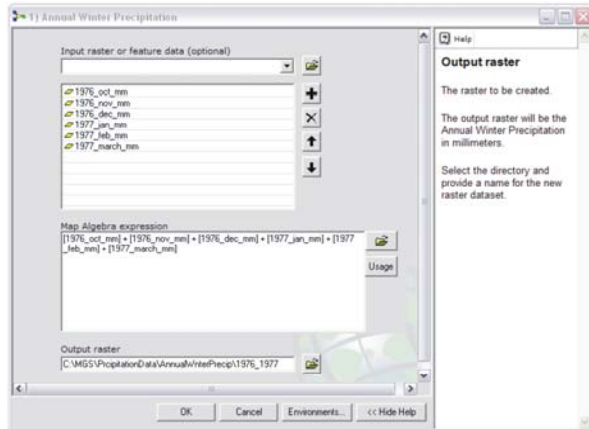

Figure C 14: Annual Winter Precipitation parameters.

☐ After setting the parameters, click the *OK* button to run the model.

☐ Repeat these steps to calculate the annual winter precipitation for all the years.

Note: It should be recognized that this has already been done for all the datasets since they were needed to create the precipitation rasters for the *MGS Habitat Suitability Analysis Model*. For the purpose of this exercise, annual winter precipitation should be calculated at least for one year.

☐ All the datasets can be turned off if added to the Table of Contents.

3.7. Step 7: Mean Winter Precipitation

Step seven consists of creating another of the precipitation raster grids required for the *MGS Habitat Suitability Analysis Model*. This raster grid is the mean annual winter precipitation.

Note: For the MGS Habitat Suitability Analysis Model study, the mean annual winter precipitation was generated for a 30-year period from 1976 – 2006, but this can be modified depending on the desired extent of the period.

To accomplish this process, the full set of thirty winter precipitation datasets is required. This process is also done by means of a map algebra equation. This equation takes the annual winter precipitation for each year during the 30-year period, adds them together, and then divides them by n, i.e., 30. This will generate a new raster grid with the average winter rainfall for that period.

Exercise Shortcut:

1. Open the *Mean Winter Precipitation* model.

2. Input the raster datasets.

3. Set the Map Algebra expression.

4. Run the model.

5. Display and symbolize final output.

Full Exercise Steps:

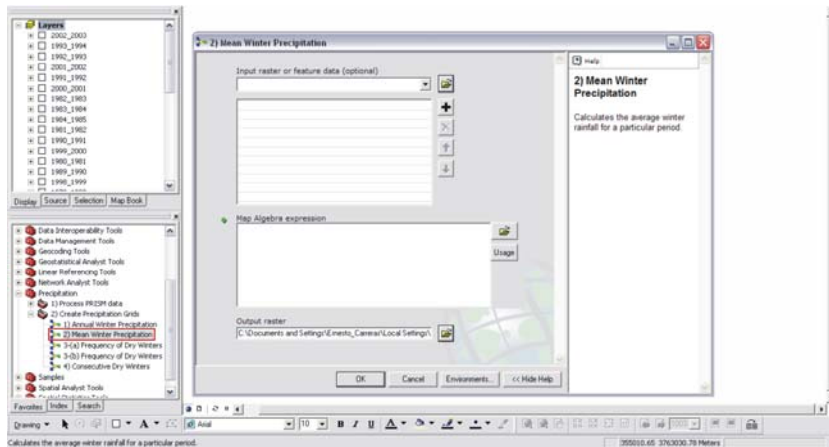☐ Double-click the *Mean Winter Precipitation* model to open it (Figure C 15).

Figure C 15: Mean Winter Precipitation model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input raster or feature data* combo box, select the raster datasets required to calculate the mean winter precipitation, i.e., 1976 -2006. This could be done by using the dropdown button [▼] or by navigating to the folder. These rasters should be the annual winter precipitation raster grids created during the previous step.

❗ It is recommended that the raster grids that are going to be used for the calculation are in the Table of Contents, although this is not required.

☐ In the *Map Algebra expression* box, type the following expression. The expression will depend in the naming convention used for the raster grid. If following the example on Figure C 15, the expression should be as follows: **([*1976_1977*] + … + [*2005_2006*]) / 30**.

Note: The Map Algebra expression for this equation is: ([year_year] + … + [year_year]) / n. If the grid name is not between the brackets, the equation will not work.

☐ For the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData* folder. Create a new folder by clicking the *New folder*

icon ![folder icon] in the *Output raster* dialog box and name it *MeanWnterPrecip*. Remember to save the new raster with a meaningful name, such as *MeanWPrecip*.

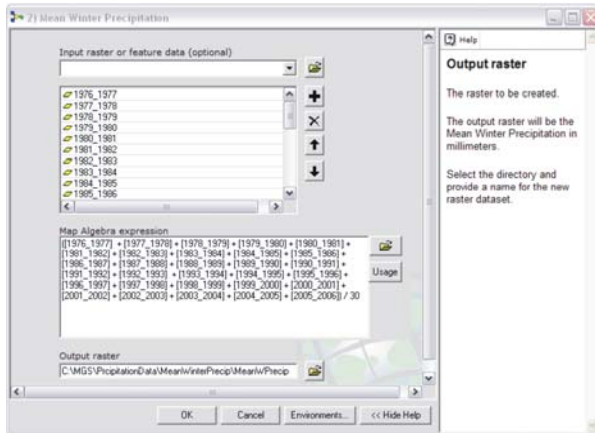☐ The *Mean Winter Precipitation* dialog box should resemble Figure C 16.

Figure C 16: Mean Winter Precipitation parameters.

☐ After setting the parameters, click the *OK* button to run the model.

Note: It should be recognized that this has already been done for all the datasets since they were needed to create the precipitation rasters for the *MGS Habitat Suitability Analysis Model*.

☐ Once the final output, i.e., mean winter precipitation, is added to the Table of Contents, right-click the layer name and select *Properties* to open the *Layer Properties* dialog box. Select the *Symbology* tab, and under *Show*, choose the *Classified* option. For the *Classification method*, click *Classify*. This will open the *Classification* dialog box. Here is where the *Classification* method and number of *Classes* are chosen. For this exercise, the *Natural Breaks* will work well since it classifies the data with groups of similar values. Under *Classes*, select 6 and then click *OK* (Figure C 17).
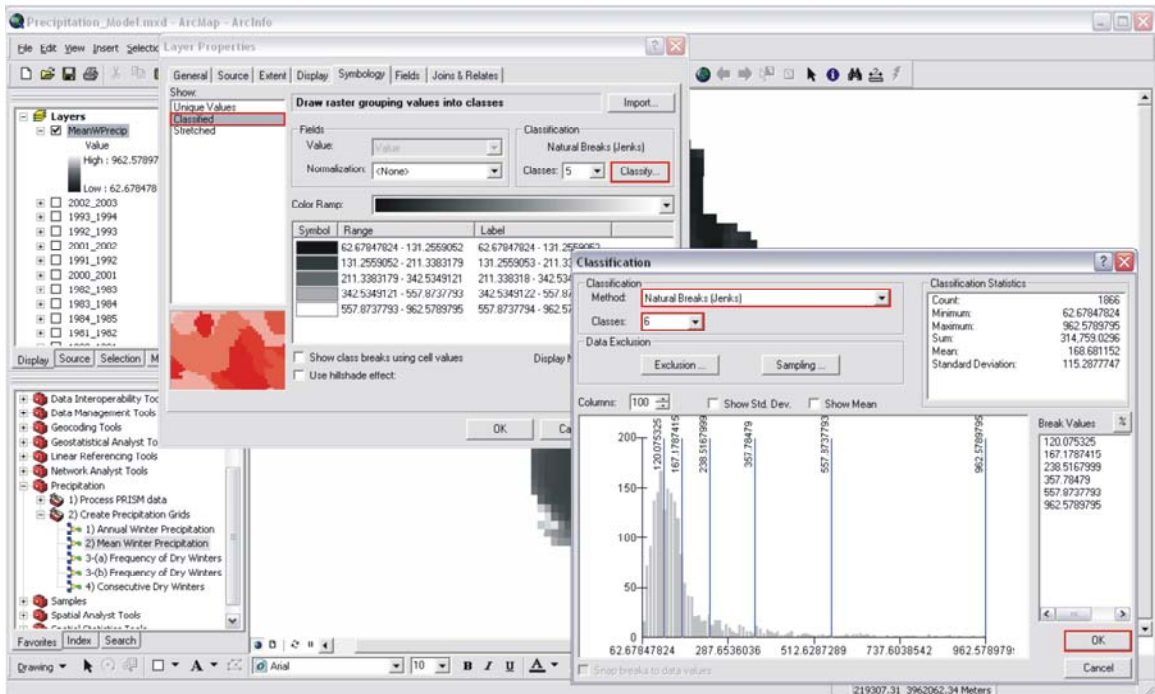
Figure C 17: Symbolizing and Classifying data.

☐ Select the *Color Ramp* that will be used for symbolizing the data by clicking the dropdown arrow [▼] and then click *OK* (Figure C 18).
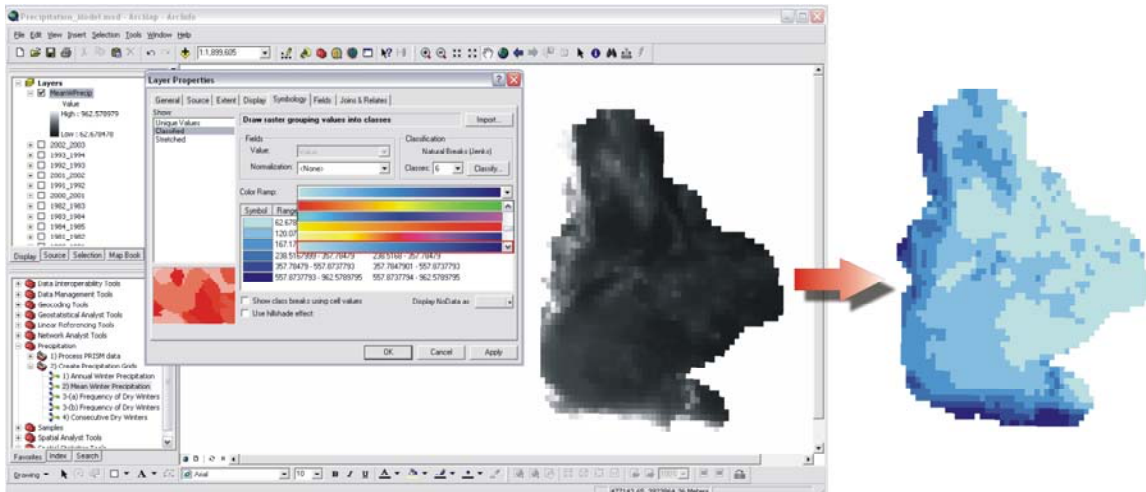
Figure C 18: Color Ramp.

☐ Click *Save* to save the map document but do not close the document.

3.8. Step 8: Frequency of Dry Winters (a)

Step eight consists of creating another of the precipitation raster grids required for the *MGS Habitat Suitability Analysis Model*. This raster grid is the frequency of dry winter periods.

Note: For this study, the frequency of dry winter periods for a 30-year period from 1976

– 2006 was generated but this can be modified depending on the desired extent of the period.

This dataset is created by reclassifying the datasets representing mean winter. The process consists of replacing grid cell values with 0 for those cells having 80 millimeters or more of rainfall and 1 for those having less than 80 millimeters. After reclassifying the datasets, the values added together using map algebra and then divided by n, i.e., 30. The result is then multiplied by 100 to convert the values into percentages. The final output is then converted into percentages. It should be noted that the *Frequency of Dry Periods* is composed of two models, one performs the reclassification and the other the map algebra expression.

Exercise Shortcut:

1.   Open the *Frequency of Dry Winters – (a)* model.

2.   Input the raster datasets.

3.   Set the reclassification values.

4.   Run the model.

Full Exercise Steps:

☐ Double-click the *Frequency of Dry Winters – (a)* to open it (Figure C 19).
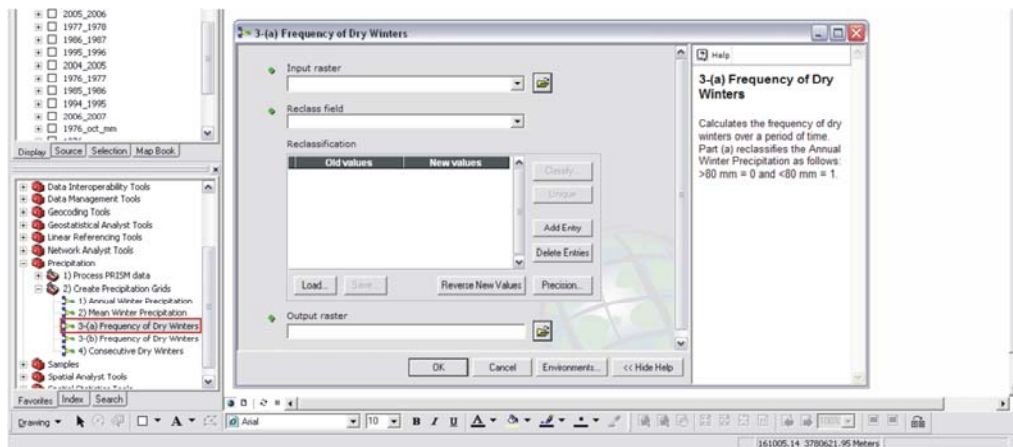
Figure C 19: Frequency of Dry Winters – (a) model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input raster* combo box, select the raster dataset that is going to be reclassified, i.e., annual winter precipitation datasets, e.g. *1976_1977*. This could be done by using the dropdown button or by navigating to the folder.

! It is recommended that the raster grids that are going to be used for the calculation are in the Table of Contents, although this is not required.

□ On the *Reclass Field* combo box, select the field on which to base the reclassification method, e.g., a field that represents the precipitation values.

! After selecting the *Reclass Field*, click the *Classify* button, then choose *Equal Intervals* for the *Classification Method* and depending on the range values to reclassify, select the appropriate number of *Classes*.

□ For the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData* folder. Create a new folder by clicking the *New folder* icon![folder icon] in the *Output raster* dialog box and name it *FrequencyDryWinters*. Remember to save the new raster with a meaningful name, such as *76_77reclass*.

□ The *Frequency of Dry Winters* dialog box should resemble Figure C 20.
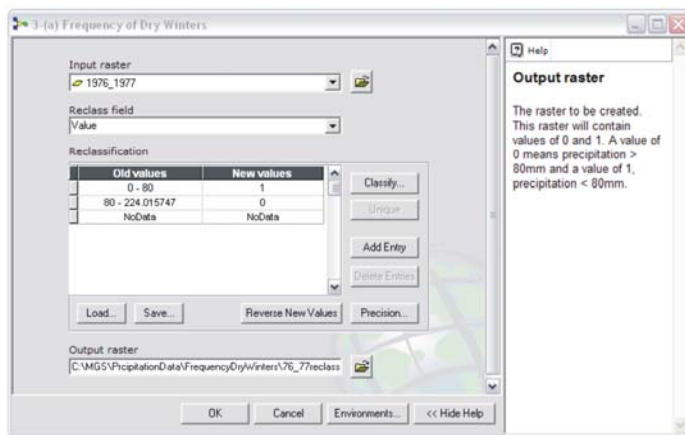
Figure C 20: Frequency of Dry Winters parameters.

□ Table C 1 has all the parameters that should be set for each of the annual winter precipitation datasets.

Old values	New values
≤ 80	1
≥ 80	0

Table C 1: Frequency of Dry Winters parameters

□ After setting the parameters, click the *OK* button to run the model.

□ All the datasets can be turned off if added to the Table of Contents.

3.9. Step 9: Frequency of Dry Winters (b)

Exercise Shortcut:

1. Open the *Frequency of Dry Winters – (b)* model.

2. Input the raster datasets.

3. Set the Map Algebra expression.

4. Run the model.

5.   Display and symbolize final output.

Full Exercise Steps:

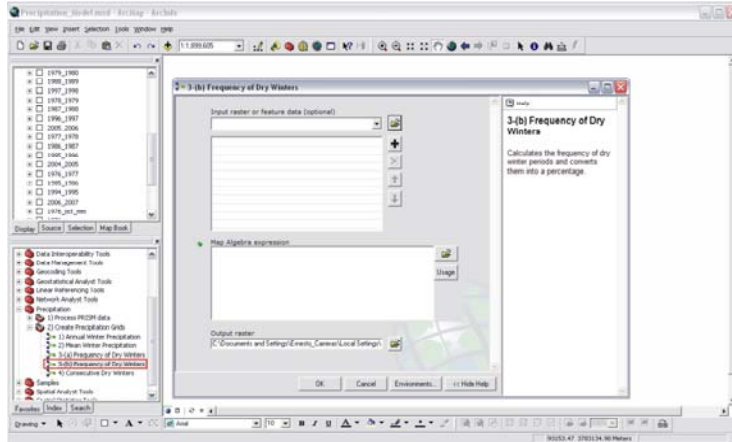☐ Double-click the *Frequency of Dry Winters – (b)* model to open it (Figure C 21).

Figure C 21: Frequency of Dry Winters - (b) model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input raster or feature data* combo box, select the raster datasets required to calculate the mean winter precipitation, i.e., *76_77reclass*. This could be done by

using the dropdown button ⬇️ or by navigating to the folder. These rasters should be the reclassified datasets of the annual winter precipitation created during the previous step.

❗ It is recommended that the raster grids that are going to be used for the calculation are in the Table of Contents, although this is not required.

☐ In the *Map Algebra expression* box, type the following expression. The expression will depend in the naming convention used for the raster grid. If following the example on Figure C 21, the expression should be as follows: *(([76reclass_77reclass] + … + [05reclass_06reclass]) / 30) * 100*.

Note: The Map Algebra expression for this equation is: (([yearReclass_yearReclass] + … + [yearReclass_yearReclass]) / n) * 100. If the grid is not between the brackets, the equation will not work.

☐ For the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData* folder. Create a new folder by clicking the *New folder*

icon 📁 in the *Output raster* dialog box and name it *FrequencyDryWinters*. Remember to save the new raster with a meaningful name, such as *freqdrywin*.

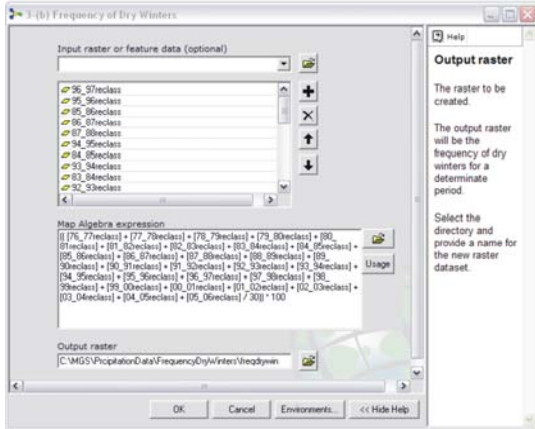☐ The *Frequency of Dry Winters – (b)* dialog box should resemble Figure C 22.

Figure C 22: Frequency Dry Winters - (b) parameters.

☐ After setting the parameters, click the *OK* button to run the model.

Note: It should be recognized that this has already been done for all the datasets since they were needed to create the precipitation rasters for the *MGS Habitat Suitability Analysis Model*.

☐ Once the final output, i.e., mean winter precipitation, is added to the Table of Contents, right-click the layer name and select *Properties* to open the *Layer Properties* dialog box. Select the *Symbology* tab, and under *Show*, choose the *Classified* option. For the *Classification method*, click *Classify*. This will open the *Classification* dialog box. Here is where the *Classification* method and number of *Classes* are chosen. For this exercise, the *Natural Breaks* will work well since it classifies the data with groups of similar values. Under *Classes*, select 8 and then click *OK* (Figure C 23).
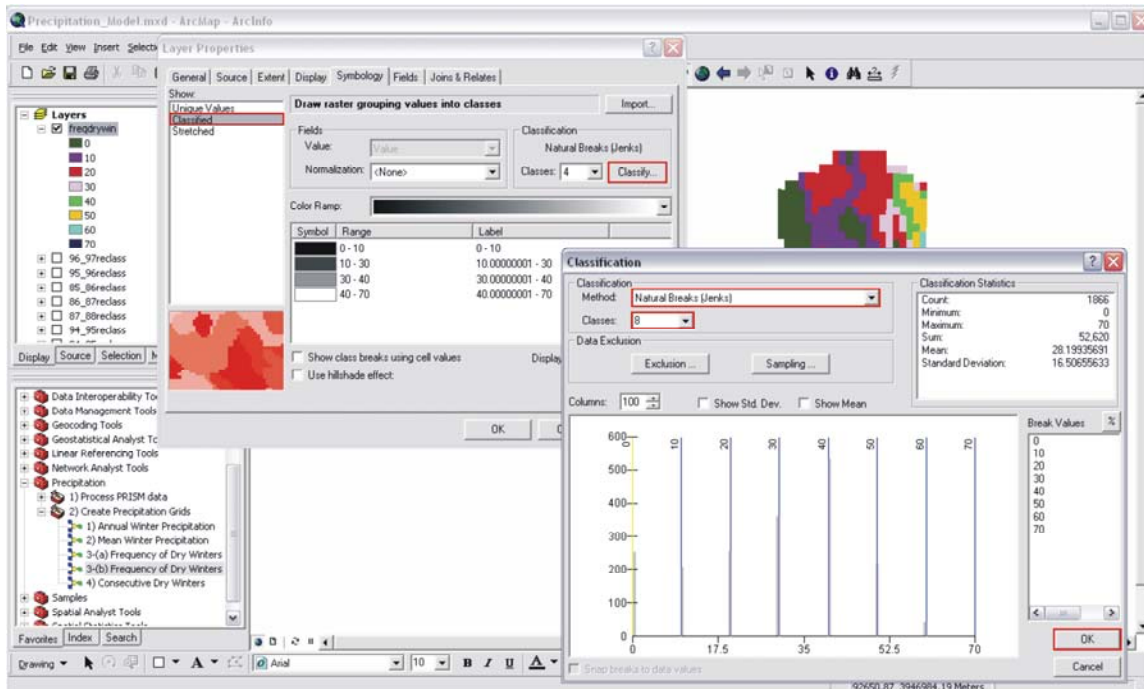
Figure C 23: Symbolizing and Classifying data.

☐ Select the *Color Ramp* that will be used for symbolizing the data by clicking the

dropdown arrow ___ and then click *OK* (Figure C 24).
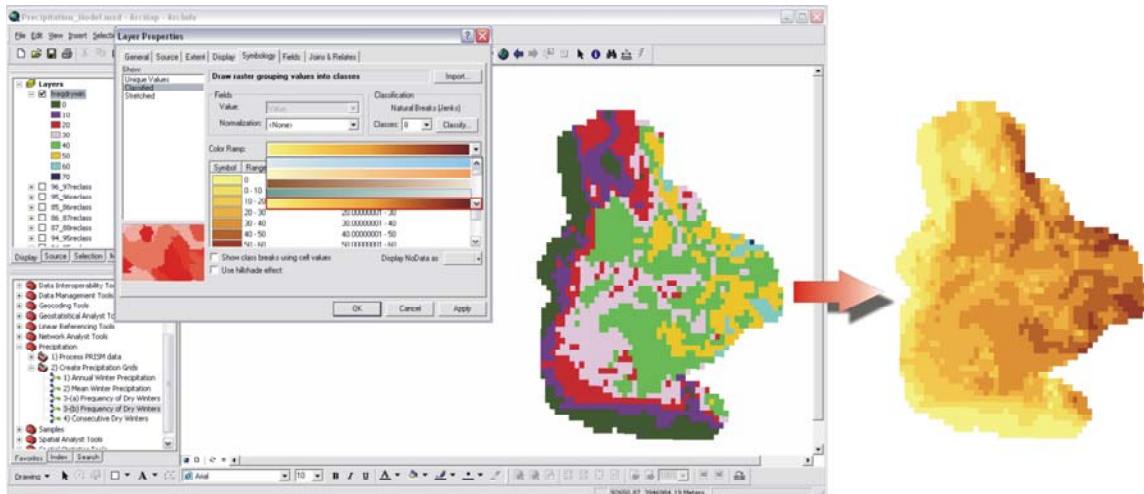
Figure C 24: Color Ramp.

☐ Click *Save* to save the map document but do not close the document.

3.10. Step 10: Consecutive Dry Winters

Step ten consists of creating the consecutive dry winter periods dataset. This dataset is created by using the frequency of dry winter periods model but taking it into another level to identify areas that have had two or more consecutive dry periods. This

dataset differs from the frequency of dry winter periods in that it considers the timing of the dry winters by emphasizing the effect of consecutive dry winters.

This dataset is created by reclassifying the annual winter precipitation grid by assigning values of 1 for those grid cells that had 80 millimeters or more of rainfall and 2 for those that had less than 80. After reclassifying each dataset, using the Single Output Map Algebra (SOMA) tool, two-year values were created by multiplying the values of the individual years, yielding values of 1, 2, and 4. Then, three year values were created by multiplying the two year values, yielding values of 1, 2, 4, 8, and 16. Finally, the three year values dataset from 1976 - 2006 was summed using the SOMA tool. This process generates a raster grid with index values indicating the frequency of consecutive dry winters.

Exercise Shortcut:

1. Open the *Consecutive Dry Winters – (b)* model.

2. Input the raster datasets.

3. Set reclassify values.

4. Set the Map Algebra expressions.

5. Run the model.

6. Display and symbolize final output.

Full Exercise Steps:

☐ Right-click the *Consecutive Dry Winters* model and click *Edit* to open it (Figure C 25).
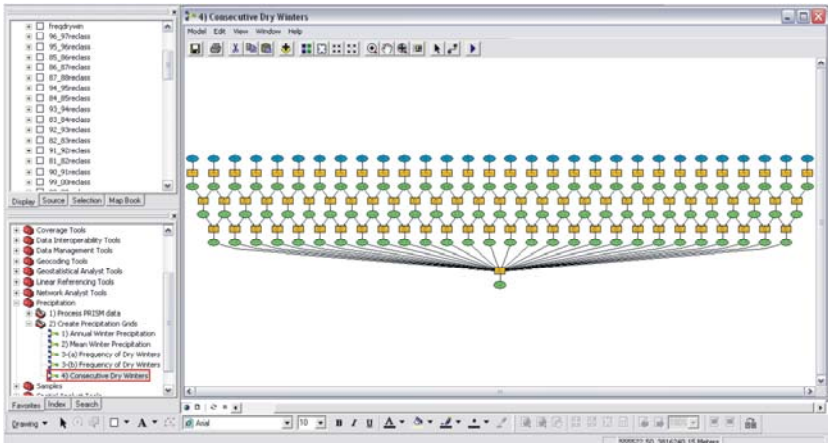
Figure C 25: Consecutive Dry Winters model.

Note: This tool will be accessed from the Model Builder canvas since is the most efficient way to create the consecutive dry winter periods dataset. As it is right now, it covers a period of 30 years but this period could be extended to more years as more precipitation data becomes available.

! It is recommended that the raster grids that are going to be used for the calculation are in the Table of Contents, although this is not required. For this model, the main datasets needed are annual winter precipitation datasets.

☐ The annual winter precipitation data can be added using two ways. It could be added by clicking the *Add Data* icon located in the Standard toolbar of the Model Builder window or by clicking and dragging the datasets from the Table of Contents. When clicking the *Add Data* button, navigate to the folder where the data are stored, i.e., *C:\MGS\PrecipitationData\AnnualWinterPrecip*. If the second option is preferred, just select the layer in the Table of Contents, press the left mouse button, and drag the dataset to the Model Builder canvas (Figure C 26).
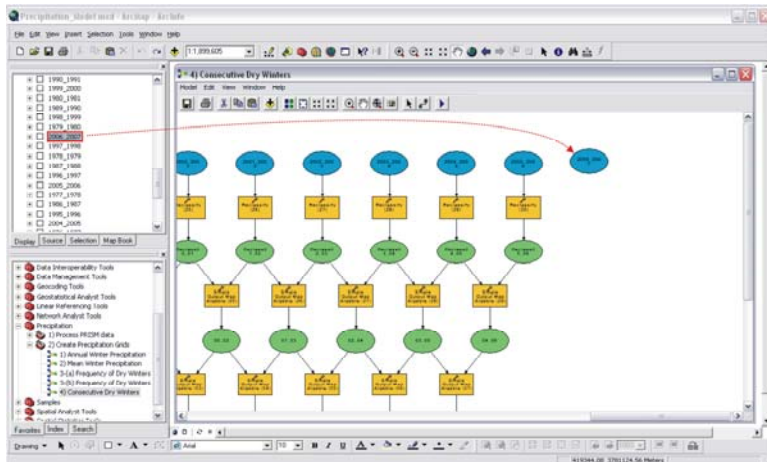
Figure C 26: Adding data.

☐ Make sure that the Spatial Analyst extension is on. Go to *Tools* in the Main menu toolbar and select *Extensions*. In the *Extensions* dialog box, check the option for *Spatial Analyst* (Figure C 27).
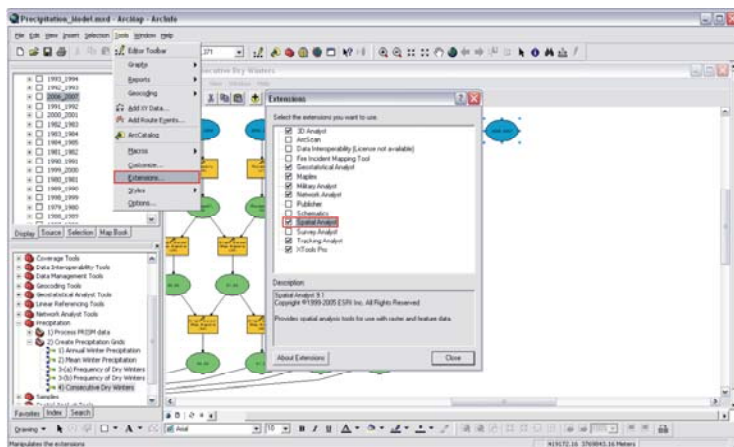
Figure C 27: Activating the Spatial Analyst extension.

☐ Add the Reclassify tool located in the Reclass toolset from the Spatial Analyst Tools. Just as was done with the dataset, click and drag the tool to the Model Builder canvas (Figure C 28).
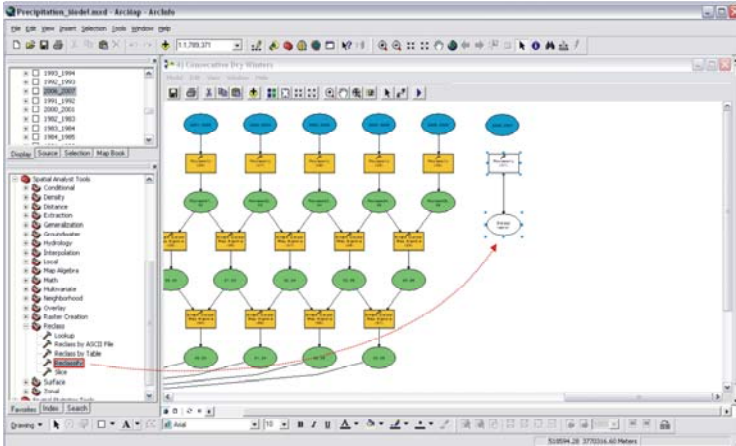
Figure C 28: Reclass tool.

☐ Using the *Add Connection* button , link the dataset to the tool. This button is located in the Standard toolbar of the Model Builder window (Figure C 29).
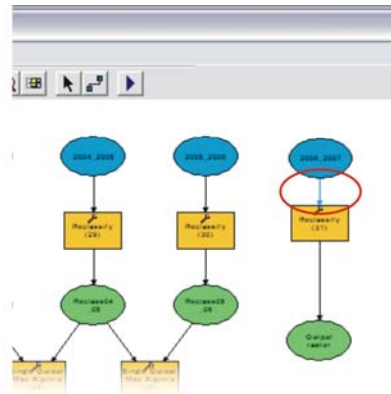

Figure C 29: Linking data with tool.

☐ Double-click the Reclassify tool to open it.

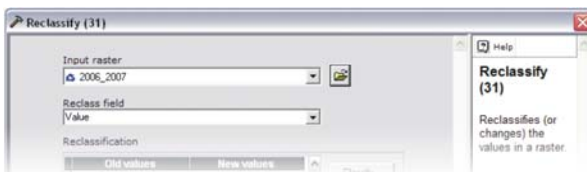☐ In the *Reclass Field* combo box, the *Value* field should (Figure C 30).

Figure C 30: Reclass field.

! After selecting the *Reclass Field*, click the *Classify* button, then choose *Equal Intervals* for the *Classification Method* and for *Classes*, select 2. The values should be reclassified according to Table C 2.

Old values	New values
≤ 80	2
≥ 80	1

Table C 2: Consecutive Dry Winters parameters.

☐ In the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData* folder. Create a new folder by clicking the *New folder* icon in the *Output raster* dialog box and name it *ConsecutiveDrySeasons*. Inside that folder, create another folder and name it *Reclassification*. Remember to save the new raster with a meaningful name, such as *Reclass06_07*.

☐ The *Consecutive Dry Winters* dialog box should resemble Figure C 31.
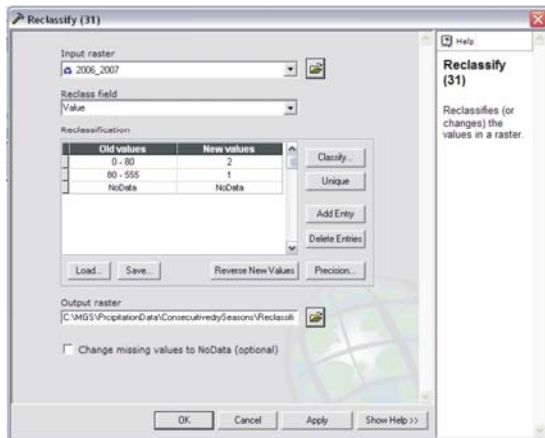
Figure C 31: Consecutive Dry Winters parameters.

☐ Add the SOMA tool, located in the Map Algebra toolset from the Spatial Analyst Tools by clicking and dragging the tool to the Model Builder canvas (Figure C 32).
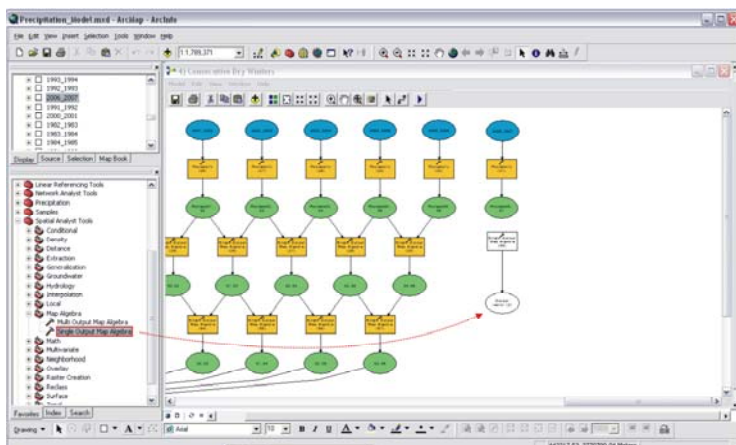

Figure C 32: SOMA.

☐ Using the *Add Connection* button , link the reclassified datasets from the two consecutive years to the tool (Figure C 33).
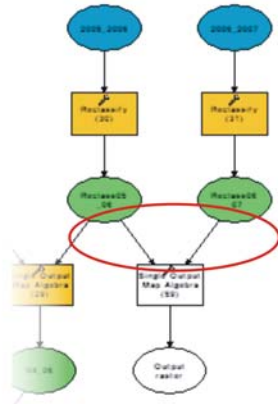
154

Figure C 33: Linking datasets with tool.

☐ Double-click the SOMA tool to open it.

☐ In the *Map Algebra expression* box, type the appropriate expression. If following the example on Figure C 11, the expression should be as follows: **[Reclass05_06] * [Reclass06_07]**. The expression will depend in the naming convention used for the raster grid.

☐ In the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData* folder. Create a new folder by clicking the *New folder* icon in the *Output raster* dialog box and name it *SOMA1*. Remember to save the new raster with a meaningful name, such as *05_07*.

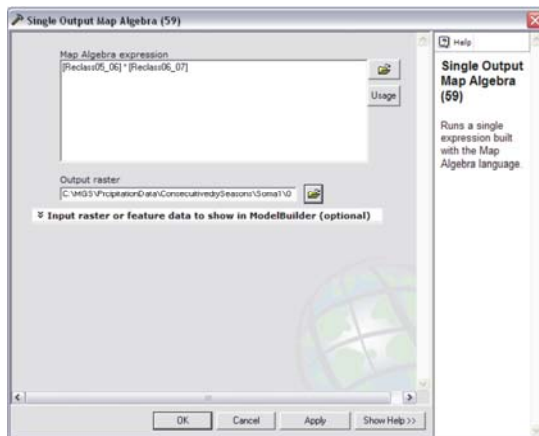☐ The *Consecutive Dry Winters* dialog box should resemble Figure C 34.

Figure C 34: SOMA parameters.

☐ Add another SOMA tool from the Spatial Analysts tools. Using the *Add Connection* button , link the datasets with the tool as shown in Figure C 35.
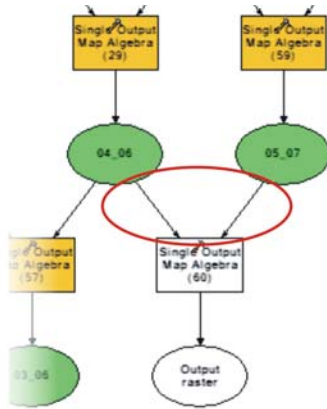
Figure C 35: Linking datasets with tool.

☐ Double-click the SOMA tool to open it.

☐ In the *Map Algebra expression* box, type the appropriate expression. If followed the example on Figure C 11, the expression should be as follows: **[Reclass05_06] * [Reclass06_07]**. The expression will depend in the naming convention used for the raster grid.

☐ In the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData\ConsecutiveDrySeasons* folder. Create a new folder by clicking the *New folder* icon in the *Output raster* dialog box and name it *SOMA2*. Remember to save the new raster with a meaningful name, such as *04_07*.

☐ The *Consecutive Dry Winters* dialog box should resemble Figure C 36.
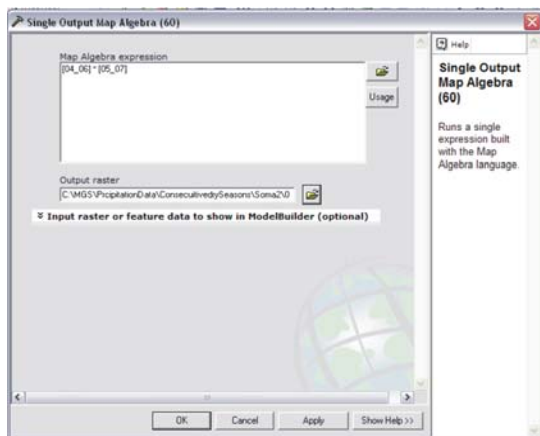

Figure C 36: SOMA parameters.

☐ The next step is to connect the dataset with the SOMA tool. Use the *Add Connection* button to accomplish this task (Figure C 37). This SOMA tool has the map algebra expression that calculated the consecutive dry winter seasons.
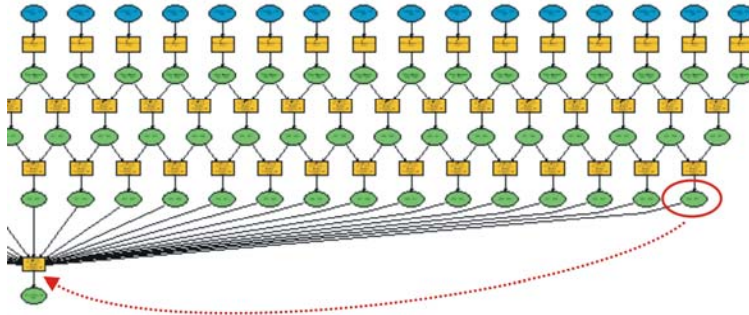
156

Figure C 37: Linking dataset with tool.

☐ Double-click the SOMA tool to open it.

☐ In the *Map Algebra expression* box, add the following statement to the map algebra expression. **+ [04_07]** (Figure C 38).
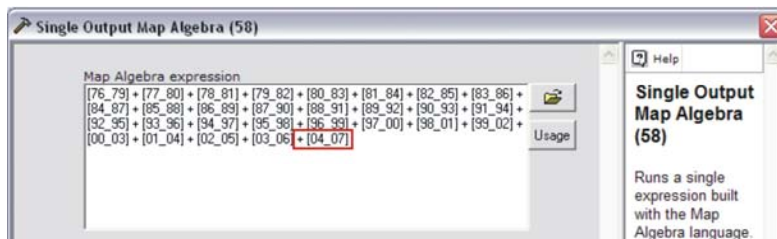

Figure C 38: Consecutive Dry Winters map algebra expression.

☐ In the *Output raster* textbox, click the folder icon and navigate to the *C:\MGS\PrecipitationData\ConsecutiveDrySeasons* folder. Create a new folder by clicking the *New folder* icon in the *Output raster* dialog box and name it *FinalOutput*. Remember to save the new raster with a meaningful name, such as *ConsecDryWin*.

☐ The *Consecutive Dry Winters* dialog box should resemble Figure C 39.

Figure C 39: Consecutive Dry Winters parameters.

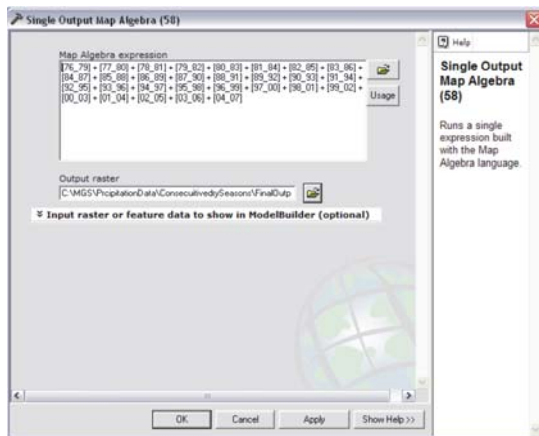☐ The last step is to arrange the model layout and then run the model. Use the *Auto Layout* icon to organize the model. Then click the Run icon to execute the model. This process may take a few minutes.

Note: It should be recognized that this dataset has already been created since it was needed for the *MGS Habitat Suitability Analysis Model*.

☐ Once the final output, i.e., consecutive dry winters, is added to the Table of Contents, right-click the layer name and select *Properties* to open the *Layer Properties* dialog box. Select the *Symbology* tab, and under *Show*, choose the *Classified* option. For the *Classification method*, click *Classify*. This will open the *Classification* dialog box. Here is where the *Classification* method and number of *Classes* are chosen. For this exercise, the *Natural Breaks* will work well since it classifies the data with groups of similar values. Under *Classes*, select 7 and then click *OK* (Figure C 40).
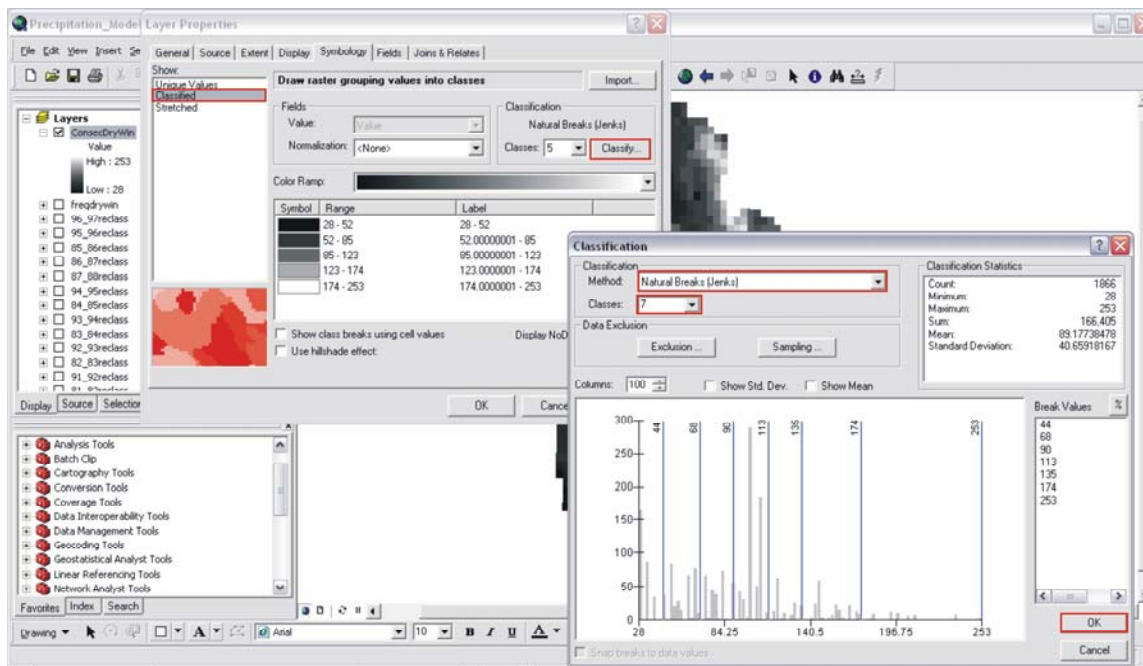

Figure C 40: Symbolizing and Classifying data.

☐ Select the *Color Ramp* that will be used for symbolizing the data by clicking the dropdown arrow and then click *OK* (Figure C 41).
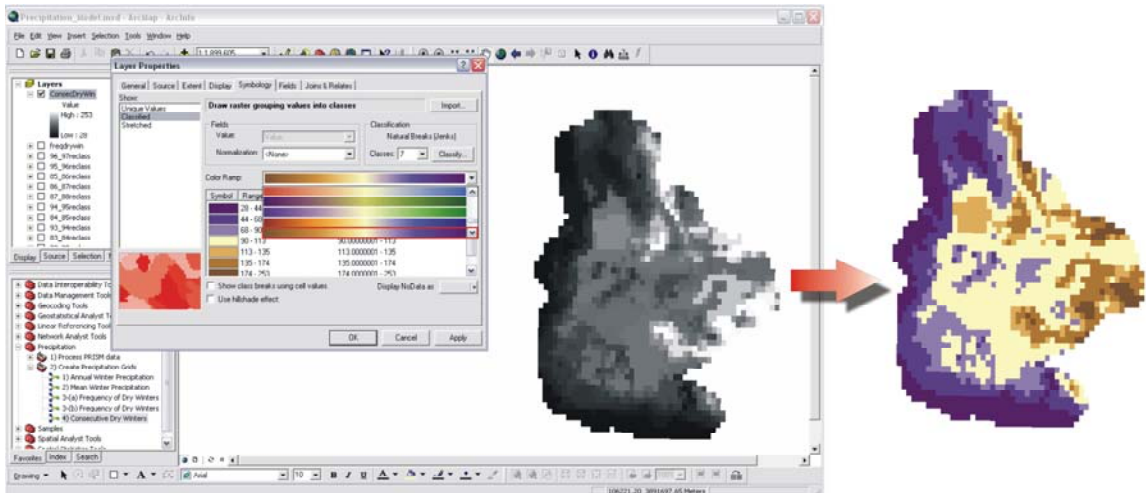
Figure C 41: Color ramp.

☐ Click *Save* to save the map document but do not close the document.

Appendix D: Surface Toolbox manual

Surfaces Model – User Manual

Prepared by: Ernesto Carreras, GIS Consultant and Project Manager

4.   Introduction

The Surface Model is a tool developed to create the hillshade and slope in one single step. The main purpose of this tool was to create the slope, which is one of the required datasets for the Mohave ground squirrel Habitat Suitability Analysis Model and the hillshade, which can be used for cartographic display purposes.

4.1.   Step 1: Open ArcMap and Create a New Map Document

The first step is to open the ArcMap application. This new map document should be saved as Surface_Model.

Exercise Shortcut:

1.   Open ArcMap

2.   Create a new map document.

3.   Save document in the directory related to the project.

Full Exercise Steps:

☐ Open ArcMap by going through the *Start* menu, *All Programs>ArcGIS>ArcMap* and double-click.

☐ Select the *New empty map document* option (Figure C42) and then click *OK*.

Figure C 42: A new empty map document.

☐ In the Main menu, go to *File* and select *Save As...* (Figure C 43).

Figure C 43: Save As.

☐ Navigate to the directory where you want to save the map document.

❗ Make sure that this folder is where your geodatabase resides (*C:\MGS*).

☐ Save your map as Surface_Model and then click *Save*.

❗ Make sure to constantly save your project by clicking the *Save* icon .

4.2. Step 2: Add the Surface Model Toolbox

Step two consists of adding the Surface toolbox to the ArcToolbox. This toolbox was designed specifically to create a series of raster datasets related to the hillshade and slope within the Mohave ground squirrel range. This toolbox is located in the MGS geodatabase located in the MGS folder (*C:\MGS*).

Exercise Shortcut:

1.   Adding ArcToolbox.

2.   Add Surface toolbox from the MGS geodatabase.

3.   Open Surface toolbox.

Full Exercise Steps:

☐ Click on the ArcToolbox icon located in the Standard toolbar to open the ArcToolbox window.

☐ Right-click on an empty space inside the ArcToolbox window to display a context menu prompting several options. Select the *Add Toolbox* option (Figure C 44).
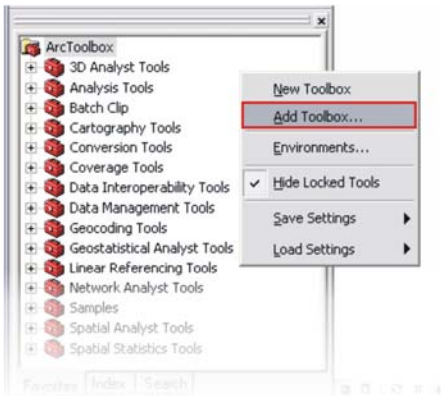
Figure C 44: Add Toolbox.

☐ Navigate to the godatabase directory folder (*C:\MGS*) and double-click on MGS.mdb to open the geodatabase. Inside the geodatabase, there are three toolboxes. Select the one named Surface and then click the *Open* button. The Surface toolbox will be added to the list of tools (Figure C 45).
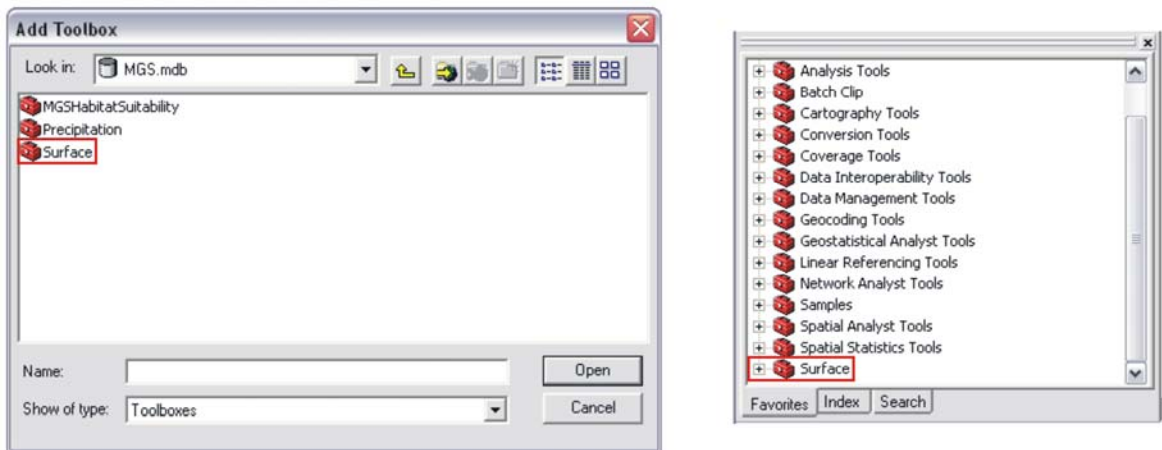
Figure C 45: Surface toolbox.

4.3.   Step 3: Create Hillshade and Slope Surfaces

A Digital Elevation Model (DEM) is required to create the hillshade and the slope datasets. The DEM can be found the MGS geodatabase under the *C:\MGS* folder.

Exercise Shortcut:

1.   Open the Surface toolbox.

2.   Open the *Hillshade & Slope Surface Creator* model.

3.   Input the DEM.

4.   Run the model.

Full Exercise Steps:

☐ Open the Surface toolbox by clicking on the plus sign located in the left side of the toolbox name. This will expand the toolbox, displaying the tools located inside (Figure C 46).
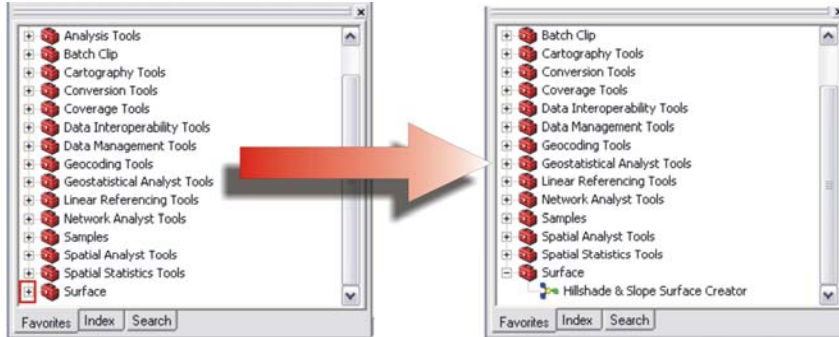
Figure C 46: Open Surface toolbox.

☐ Double-click the *Hillshade & Slope Surface Creator* model to open it (Figure C 47).
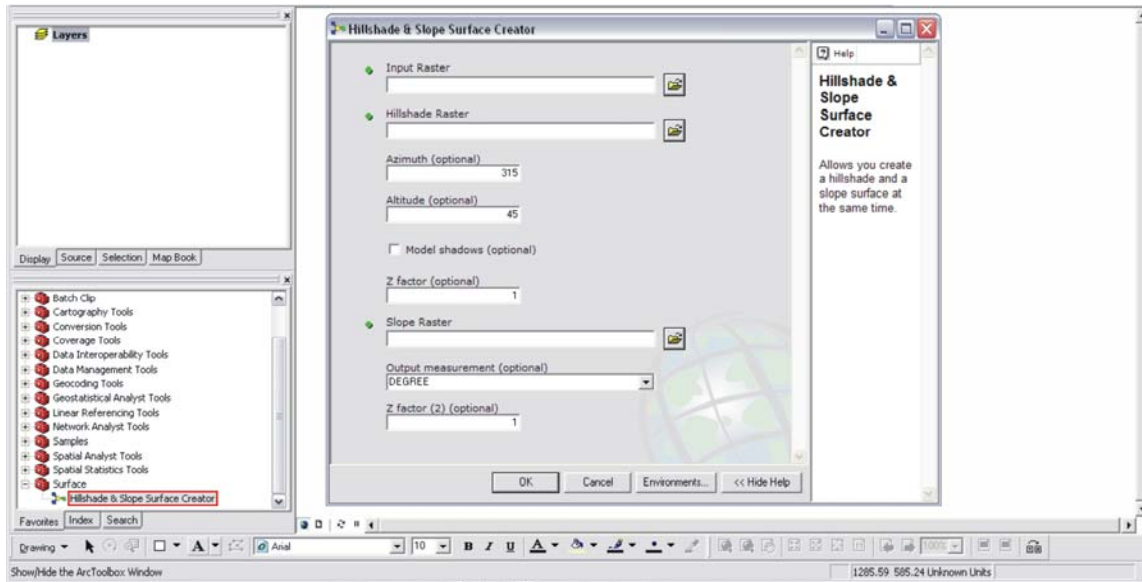
Figure C 47: Hillshade & Slope Surface Creator model.

Note: Click the *Show Help* button to display more information on this tool.

☐ For the *Input raster file* textbox, select the Digital Elevation Model (DEM). This file is located in the MGS geodatabase found in the following folder: *C:\MGS*.

☐ For *Hillshade Raster* select the output directory where the file will be saved. This could be the MGS geodatabase. Name the layer: *Hillshade*.

☐ Set the parameters as follows:

Azimuth: type 315

Altitude: accept the default of 45

164

Model shadows: accept the default of unchecked

Z factor: accept the default of 1

☐ For *Slope Raster* select the output directory where the file will be saved. This could be the MGS geodatabase. Name the layer *slp_perc*.

☐ Set the parameters as follows:

Output measurement: Percent_Rise.

Z factor: accept the default of 1

☐ The *Hillshade & Slope Surface Creator* dialog box should resemble Figure C 48.
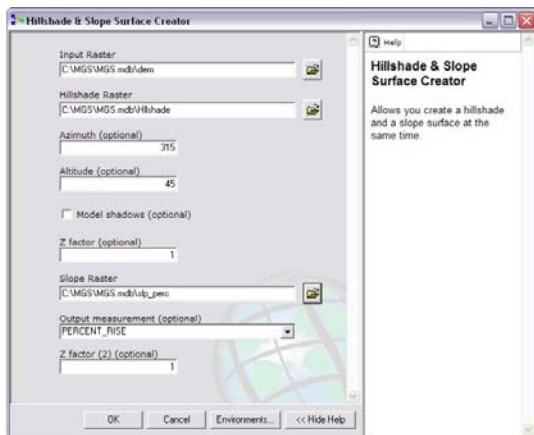
Figure C 48: Hillshade & Slope Surface Creator parameters.

☐ After setting the parameters, click the *OK* button to run the model.

☐ The new datasets will be added to the Table of Contents. They do not need to be symbolized since the defaults are good.

☐ Click *Save* to save the map document but do not close the document.

Appendix E: Metadata

The following section is a table containing information related to all the datasets used for the Mohave ground squirrel habitat suitability project. The datasets included in the table were used either for the analysis, or for cartographic purposes.

Legend	
Projection Name	*Code*
NAD 1983 UTM Zone 11N	1
GCS WGS 1972	2
GCS North American 1983	3
GCS WGS 1984	4
Purpose	*Code*
Analysis	1
Cartographic	2

Name	Abstract	Purpose	Spatial Quality	Projection
Airports	Airports boundaries and airport runways within the Mohave Desert.	2	Approx. +/- 167 feet	1
landmark_local	Common landmark areas within United States, such as military areas, within the Mojave Desert. The landmarks are represented at a local level.	2	Approx. +/- 167 feet	1
landmark_regional	Military areas within the Mojave Desert.	2	Approx. +/- 167 feet	1
Area of Extent	Defines the universal boundary for the MGS geodatabase.	2	N/A	1
Arizona_Vignettes	The state boundary vignettes symbolize the state from the boundary line outward. Multiple ring buffer (30 buffers, one mile each).	2	N/A	1
CA_Bndry	CA generalized boundary	2	Positional accuracy exceeds that of the ArcUSA 1: 25 data set (1,792 meters)	1
CA_BndryVignettes	The coastal vignettes symbolize the water from the shoreline towards open water. Multiple ring buffer (200 buffers, 0.5 miles each).	2	N/A	1
CA_dtlBndry	Boundary of the state of California.	2	Approx. +/- 167 feet	1
CA_MojDesertOwner	Landowners within the Mojave Desert.	2	Data is limited to scale 1:100,000.	1
California_Vignettes	The state boundary vignettes symbolize the state from the boundary line outward. Multiple ring buffer (30 buffers, one mile each).	2	N/A	1
mj_cities_state	Cities and towns within the Mojave Desert.	2	The horizontal positional accuracy is about 2 kilometers.	1
CNDDB MGS occurrences	Current information, data location, and condition of MGS occurrences.	1	N/A	1
Coastline_Vignettes2	The coastal vignettes symbolize the water from the shoreline towards open water. Multiple ring buffer (70 buffers, one mile each).	2	N/A	1
Coastline_Vignettes3	The coastal vignettes symbolize the water from the shoreline towards open water. Multiple ring buffer (72 buffers, one mile each).	2	N/A	1
Coastline_Vignettes	The coastal vignettes symbolize the water from the shoreline towards open water. Multiple ring buffer (20 buffers, one mile each).	2	N/A	1
consecdrywin	Raster grid with index value indicating consecutive dry winters (1976-2006).	1	Point data can be estimated at a spatial precision no better than 2km.	2
County_Bnds_generalized	US counties (generalized) within the Mohave Desert.	2	Approx. +/- 167 feet	1
cnty_bnds_detailed_named	US counties (detailed) within the Mojave Desert.	2	Approx. +/- 167 feet	1
Cnty_Bndry Annotation	Text labels referencing CA county names.	2	N/A	1

Cnty_Bnds_lines	Boundary lines of the counties within the Mohave Desert.	2	Approx. +/- 167 feet	1
dem	Digital Elevation Models, elevation values derived from the USGS topo maps.	1	30 meters	1
Drainage	Major drainage systems within the Mojave Desert Ecoregion range.	2	Unknown	1
freeway_system	Represents rural and urban interstate highways.	2	Unknown	1
Geomorphology	Earth materials and landforms of the California portion of the Mojave Desert.	1	The mapping base passes 1:24,000 accuracy standards.	1
grid30sqmiles	This layer contains a field with string values representing the name of each page (tile) in the Map Series.	2	N/A	1
Major_lakes_State_National	Major lakes within Mojave Desert.	2	Unknown	1
landcover	Land cover classes for the conterminous United States.	1	200 meters	3
landcoverclasses	Table with the different land cover classes found in the land cover raster grid.	1	N/A	
Major_Highways_Regional	Major highways within the Mojave Desert.	2	Approx. +/- 167 feet	1
major_rivers_states_national	Major rivers within Mojave Desert.	2	Unknown	1
meanwinprecip	Raster grid with mean winter precipitation for the MGS range (1976-2006).	1	Point precipitation can be estimated at a spatial precision no better than 2km.	2
MjCities_insideMGSrange	Cities and towns within the MGS range.	2	The horizontal positional accuracy is about 2 kilometers.	1
MjHighways_insideMGSrange	Major and minor highways within the MGS range.	2	Approx. +/- 167 feet	1
mgsrange_landownership	Landowners within the MGS range.	2	Data is limited to scale 1:100,000.	1
MGSrange_Vignettes	The MGS range boundary vignettes symbolize the study area from the boundary line outward. Multiple ring buffer (40 buffers, .0.1 mile each).	2	N/A	1
MGSrange_Vignettes_inside	The MGS range boundary vignettes symbolize the study area from the boundary line inward. Multiple ring buffer (70 buffers, 0.05 mile each).	2	N/A	1
mgs_shrubcover	Trapping grid locations within MGS range. Vegetation (shrub) counts and MGS occurrences.	2	6-8 meters or better	1
Minor_highways_regioonal_local	Major and minor highways within the Mojave Desert.	2	Approx. +/- 167 feet	1
studyarea	Boundary layer showing the MGS range.	2	The data was prepared at 1:74,000 scale.	1
studyareabuffertenmiles	Boundary layer showing the MGS range (10 miles buffer).	1	The data was prepared at 1:74,000 scale.	1
mojdstecoregnbdry	Mojave Ecoregion (50 km buffer).	2	Data was prepared at 1:7,000,000 scale.	1

MojDesert_vignettes	The Mojave Desert Ecoregion boundary vignettes symbolize the Mojave Desert range from the boundary line outward. Multiple ring buffer (10 buffers, one mile each).	2	N/A	1
national_forests_state	National Forests within the Mojave Desert. This dataset is compiled at a local level.	2	Unknown	1
natl_forests_regional_local	National Forests within the Mojave Desert. This dataset is compiled at a regional level.	2	Unknown	1
national_parks_state	National Parks within the Mohave Desert.	2	Unknown	1
Nevada_Vignettes	The state boundary vignettes symbolize the state from the boundary line outward. Multiple ring buffer (30 buffers, one mile each).	2	N/A	1
parks_local	Represents parks within the Mojave Desert. The parks are represented at a local level.	2	Approx. +/- 167 feet	1
parks_regional	Parks within the Mojave Desert. The parks are represented at a regional level.	2	Approx. +/- 167 feet	1
percdrywin	Raster grid with index value indicating number of drought periods within the MGS range (1976-2006).	1	Point data can be estimated at a spatial precision no better than 2km.	2
places_outline	Populated place areas that include census designated places, consolidated cities, and incorporated places within United States identified by the U.S. Bureau of the Census.	2	Approx. +/- 167 feet	1
railroads_local	Nation's railway system at 1:100,000 scale within Mojave Desert. This dataset is compiled at a local level.	2	The positional accuracy can be stated as being that associated with a 1;100,000 scale map.	1
railroads_regional	Nation's railway system at 1:100,000 scale within Mojave Desert. This dataset is compiled at a regional level.	2	The positional accuracy can be stated as being that associated with a 1;100,000 scale map.	1
Detailed_rivers	Detailed rivers and streams within the MGS range.	2	Horizontal accuracy, 90% of points tested are within 0.02 inch (at map scale) of their true position.	1
rivers_regional	Linear water features (e.g., aqueducts, canals, intercoastal waterways, and streams) within the Mojave Desert.	2	Unknown	1
HillShade	Raster that shows changes in elevation using light and shadows on terrain from a given angle and altitude of the sun.	2	30 meters	1
slope_percent	Information on the steepness of the MGS range surface.	1	30 meters	1
state_bnds_detailed	Boundary lines (detailed) of the states within Mojave Desert.	2	Approx. +/- 167 feet	1

states	States within Mojave Desert.	2	The positional accuracy of the ArcUSA 1:25M data set is 1,792 meters.	1
Area_suitability	Mohave ground squirrel suitable areas.	1	Point suitability can be estimated at a spatial precision no better than 2km.	1
TerraServer wms	Images and maps of the United States (DOQQ, Topos, Ortho Photos).	2	DRG: 2.4 meters; DOQ: 1 meter	4
TrappingGrids	Trapping grids location within the MGS range. Vegetation (shrub) counts and MGS occurrences.	2	6-8 meters or better	1
trappinggrids_gridid	Table with the grids IDs (used for the maps series grid layer)intersecting the MGS trapping grids.	2	N/A	
urban_outlines_regional	Census 2000 Urbanized Areas (UA) and Urban Clusters (UC) at a regional level.	2	Unknown	1
urban_outlines_states	Census 2000 Urbanized Areas (UA) and Urban Clusters (UC) at a state level.	2	Unknown	1
us_background_reg_local	Represents the US states (detailed).	2	Approx. +/- 167 feet	1
Utah_Vignettes	The state boundary vignettes symbolize the state from the boundary line outward. Multiple ring buffer (30 buffers, one mile each).	2	N/A	1
vegetation	Vegetation types within the MGS range.	1	Unknown	1
water_regional	Water feature areas (for example, bays, glaciers, lakes, and swamps) within the Mojave Desert. This dataset is compiled at a regional level.	2	Unknown	1
detailed_water	Detailed water feature areas (for example, bays, glaciers, lakes, and swamps) within the Mojave Desert.	2	Unknown	1

Appendix F: Map Series

        The following section contains a series of maps related to the Mohave ground squirrel habitat suitability project. Some of these maps are found in the text document but as smaller image sizes. They were included in this Appendix with a larger image size as extra information.
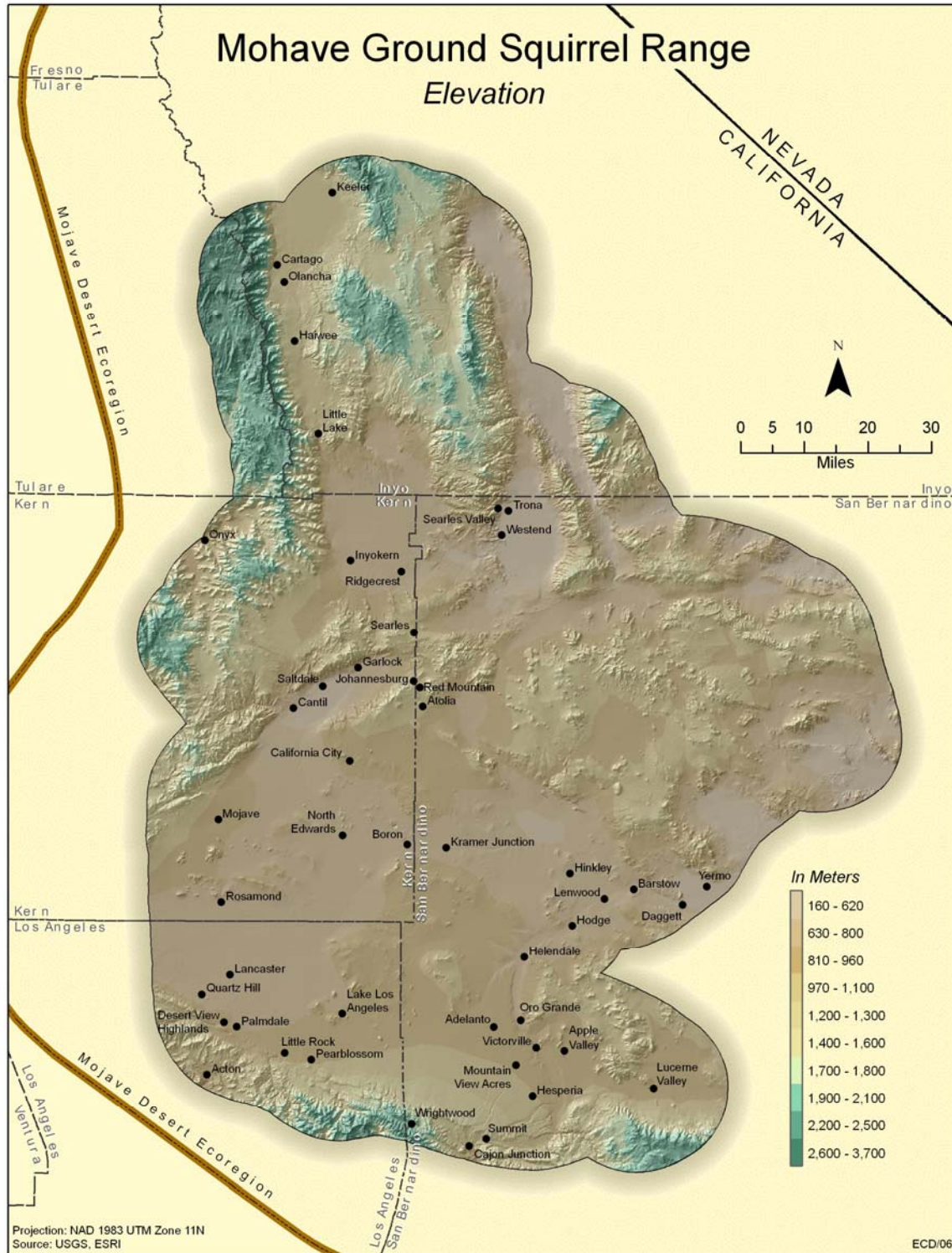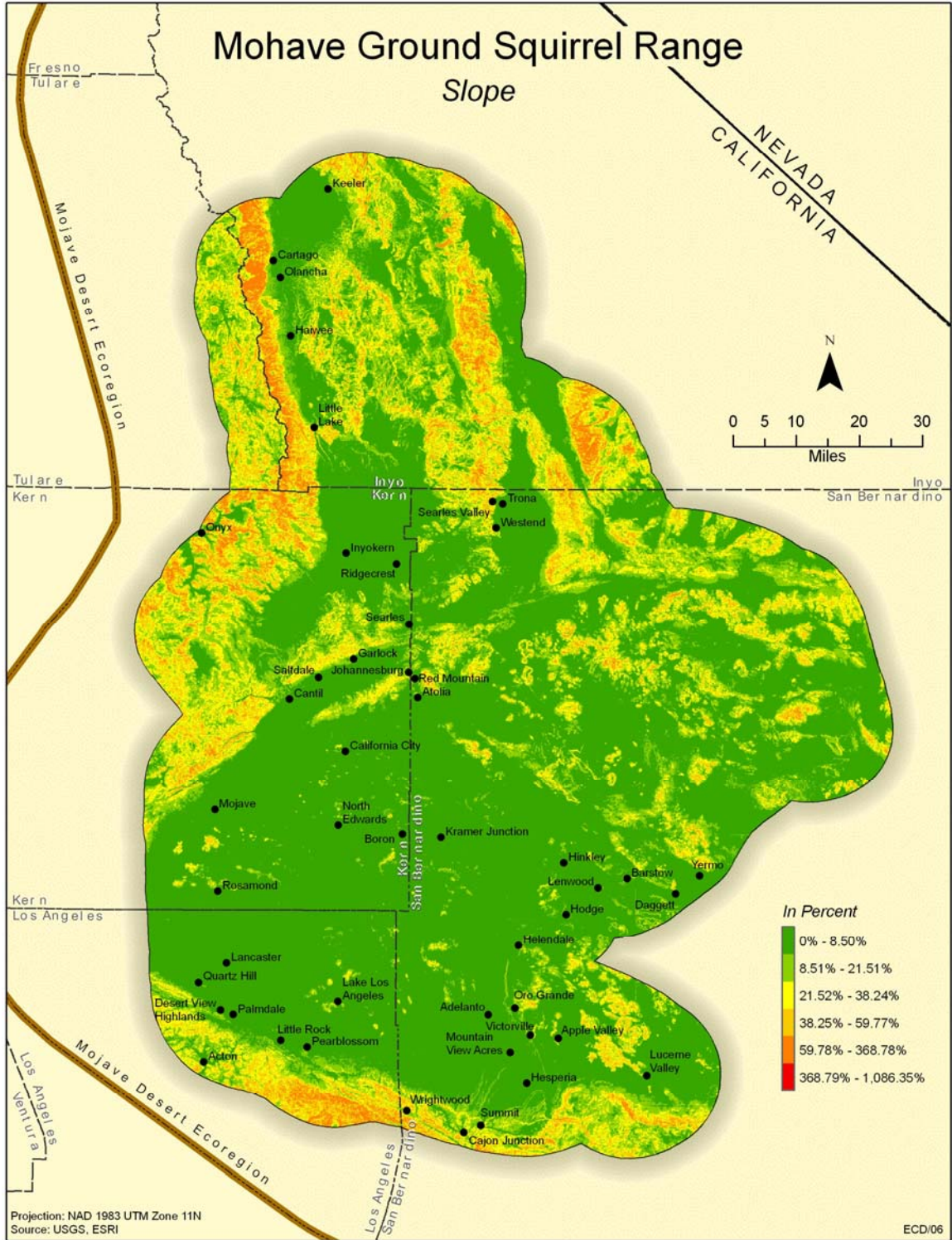
Figure F 1: Elevation dataset.
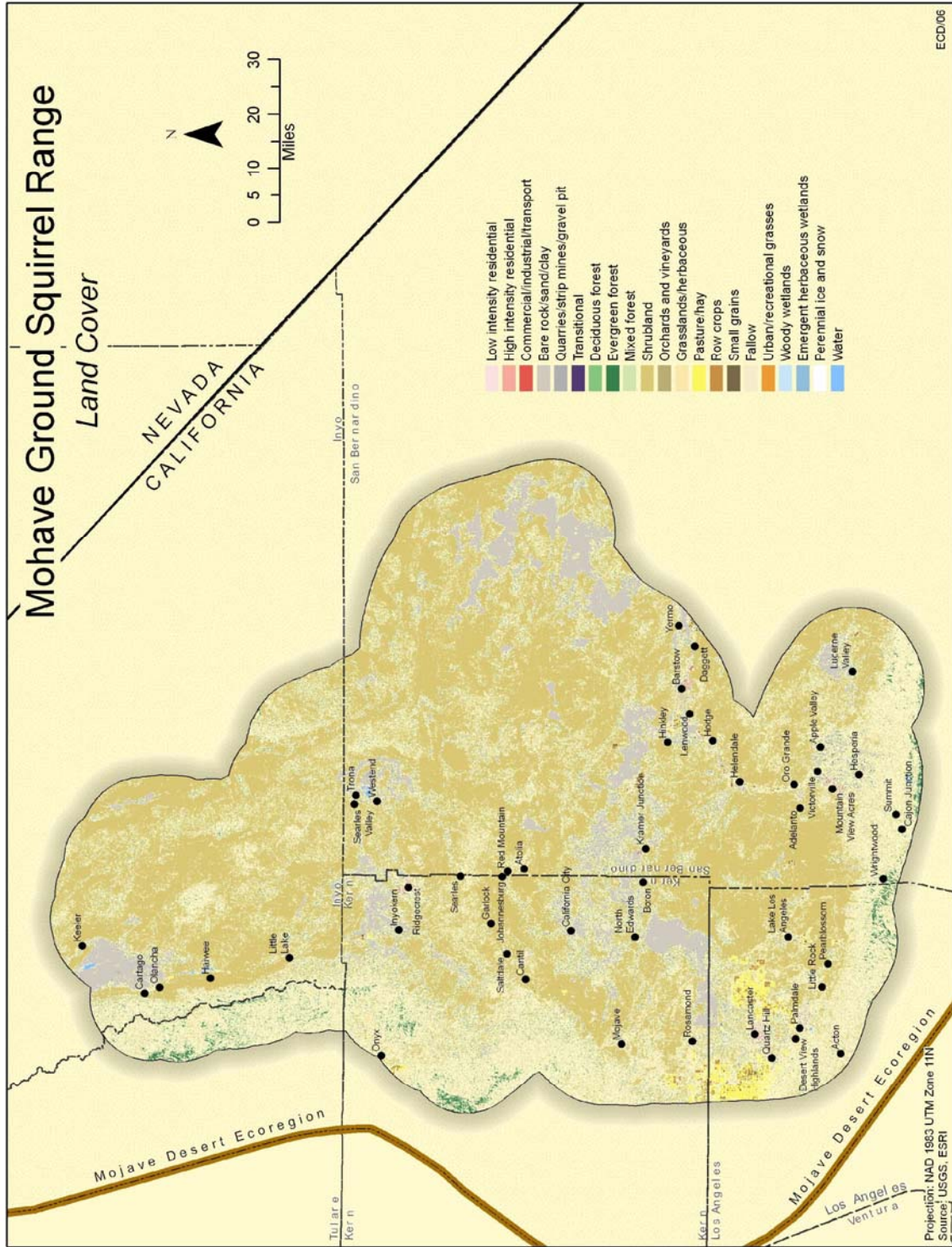
Figure F 2: Slope dataset.

Figure F 3: Land Cover dataset.

Figure F 4: Vegetation dataset.
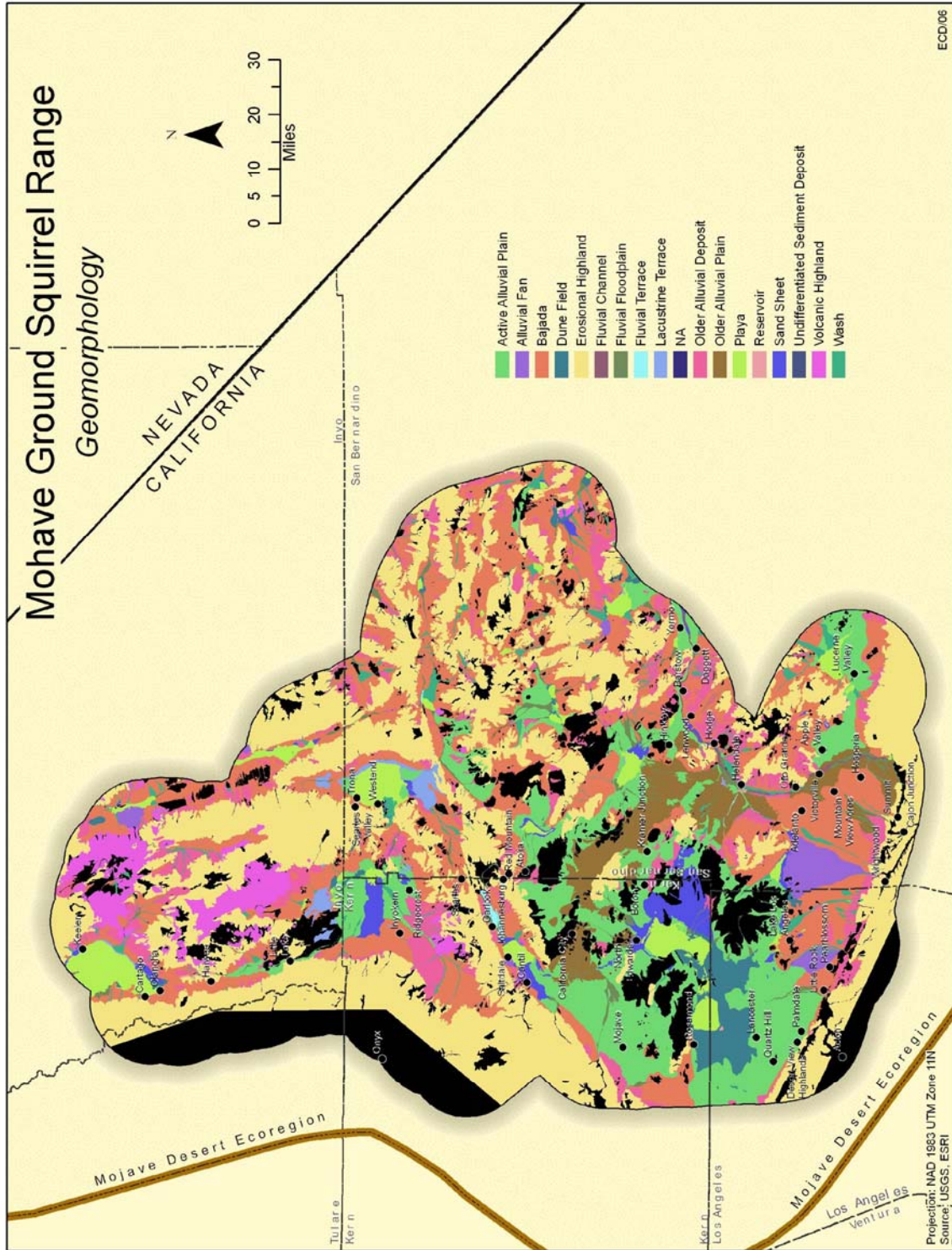
Figure F 5: Geomorphology dataset.
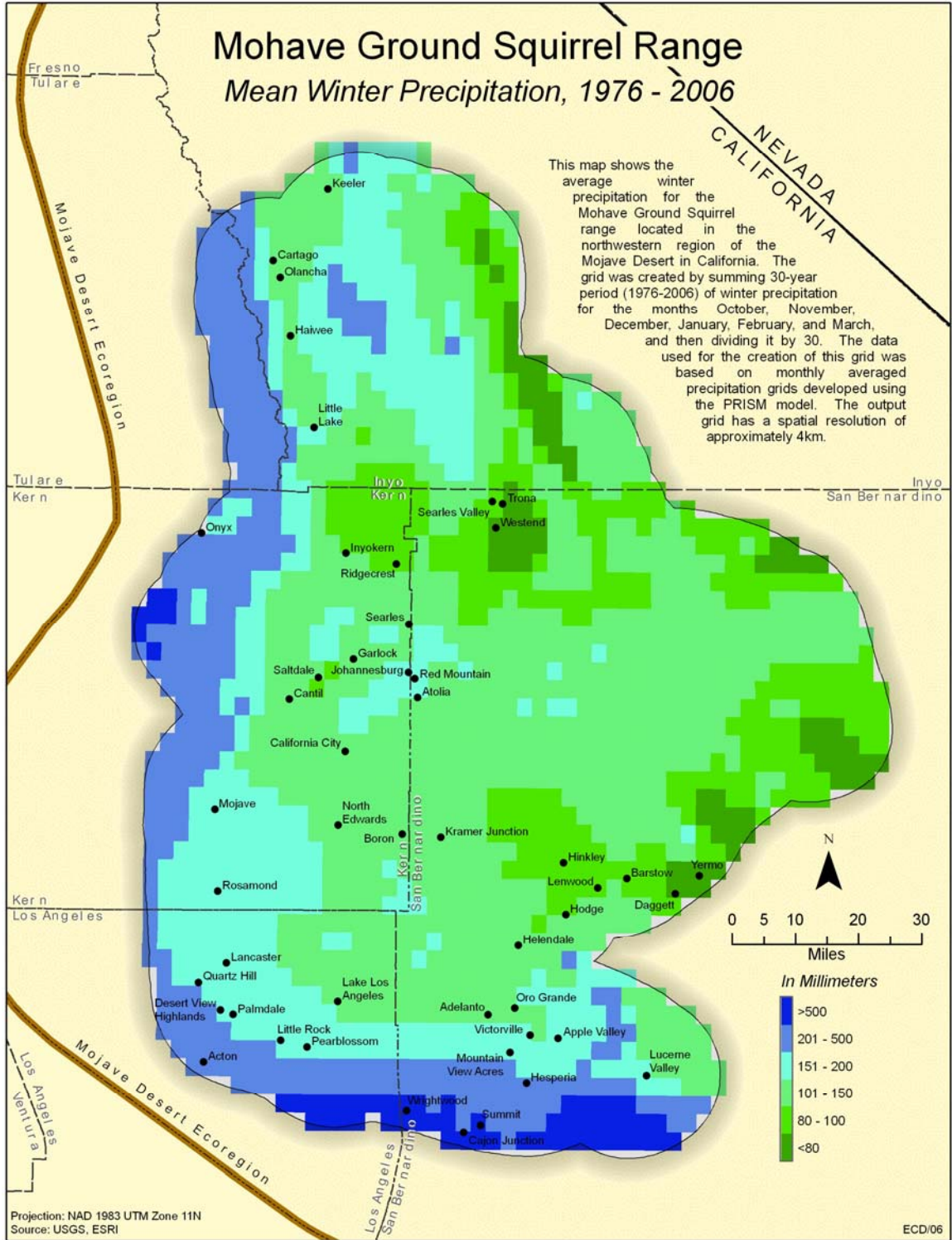
Figure F 6: Mean winter precipitation (1976 – 2006) dataset.
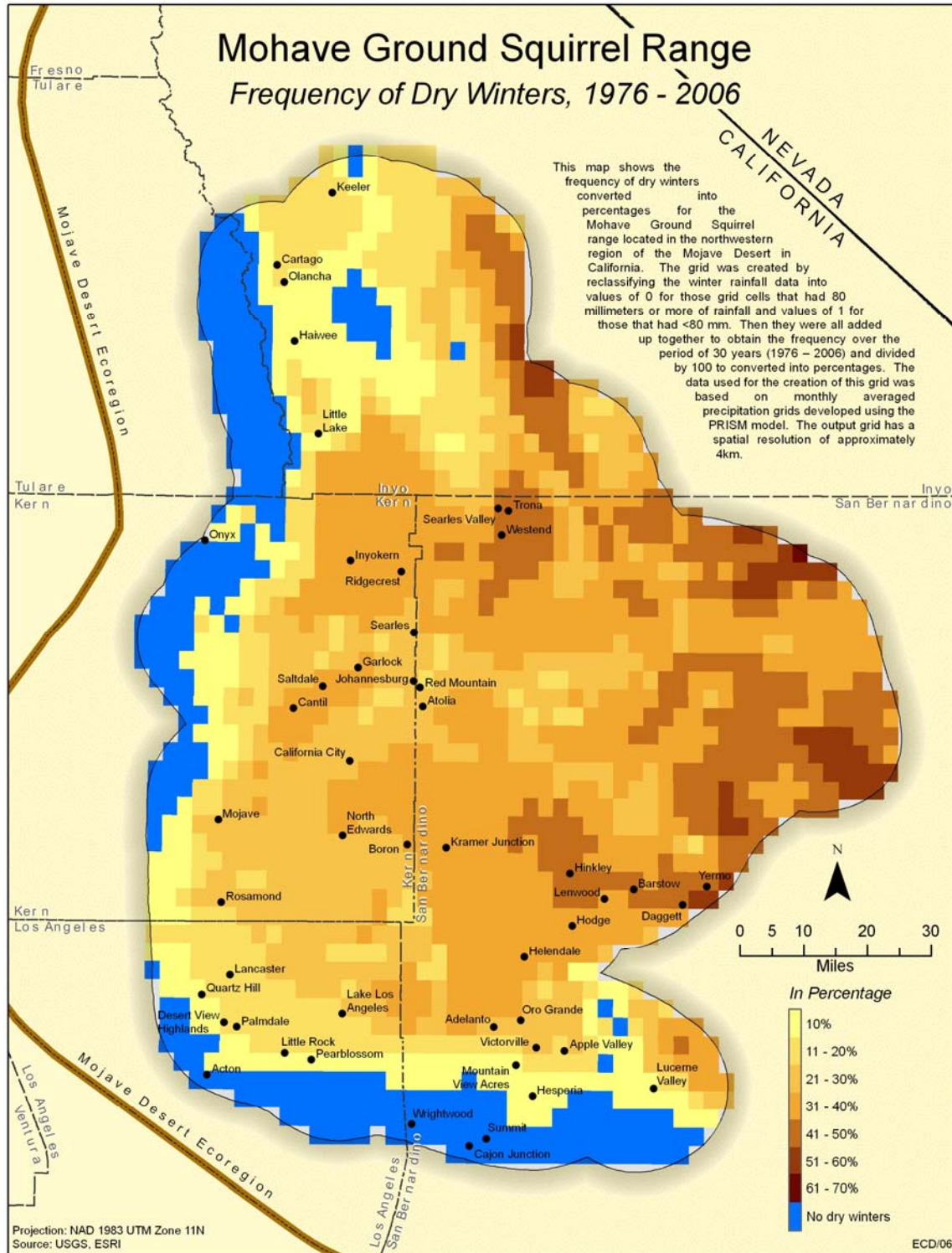
Figure F 7: Frequency of dry winters (1976 – 2006) dataset.
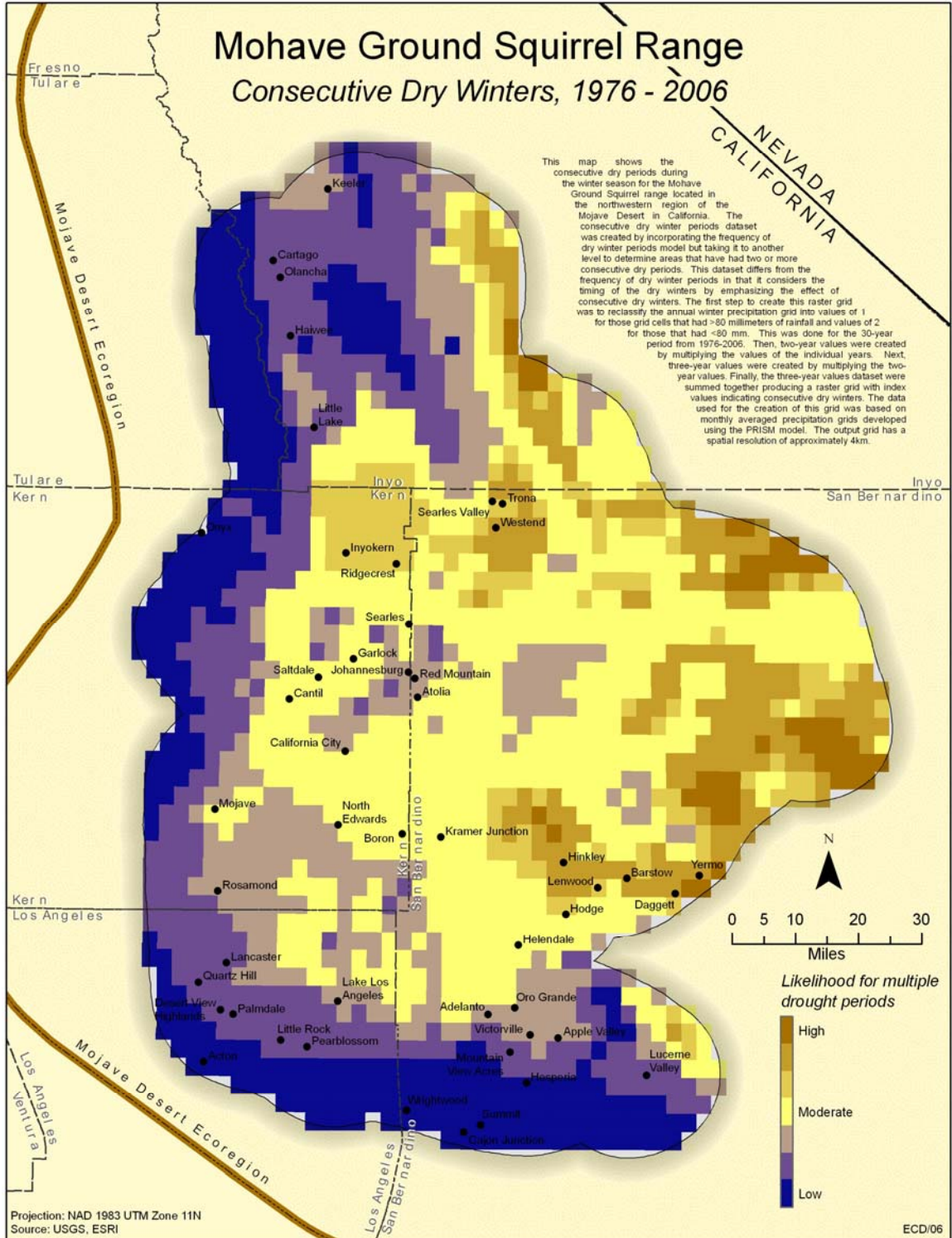
Figure F 8: Consecutive dry winters (1976 – 2006) dataset.
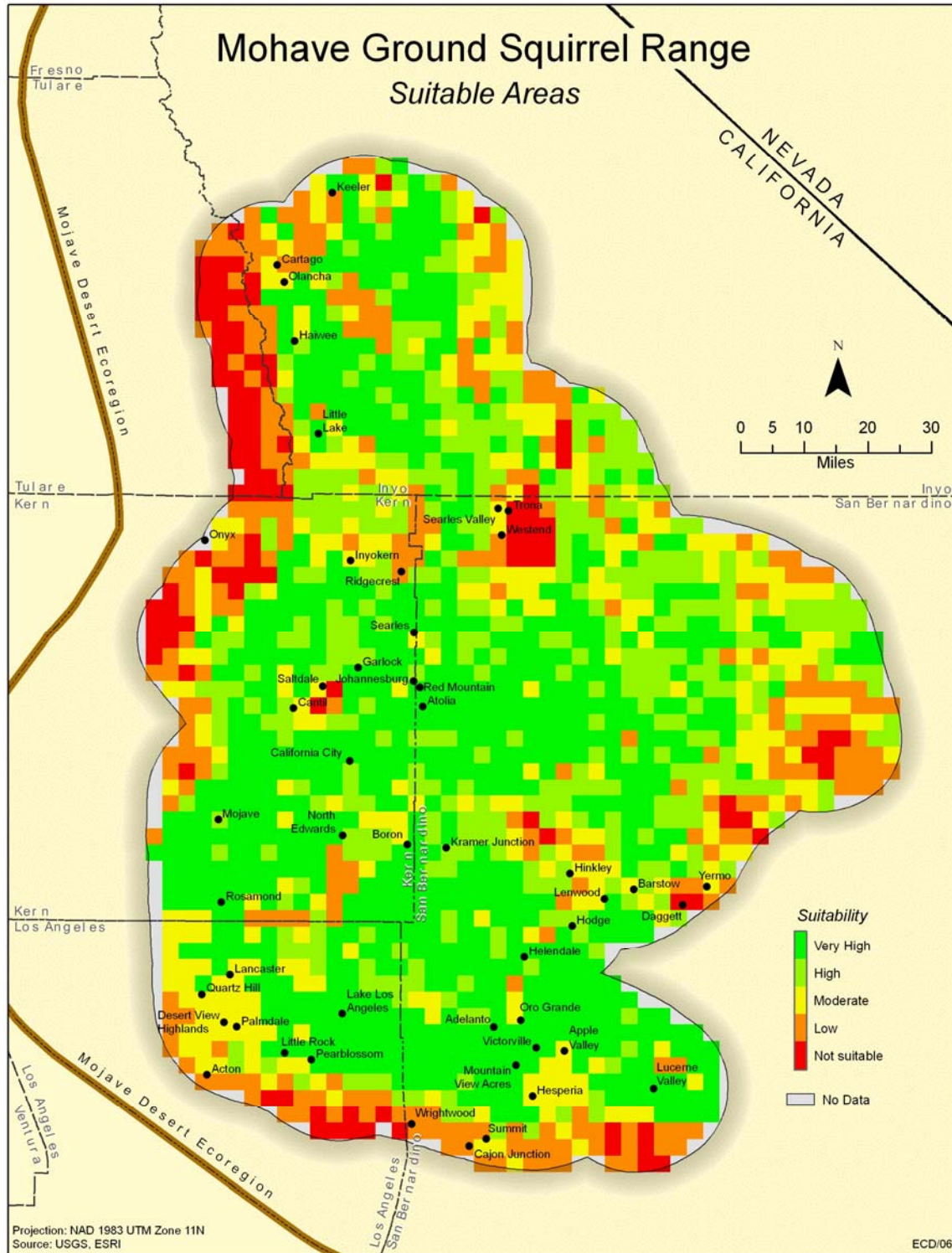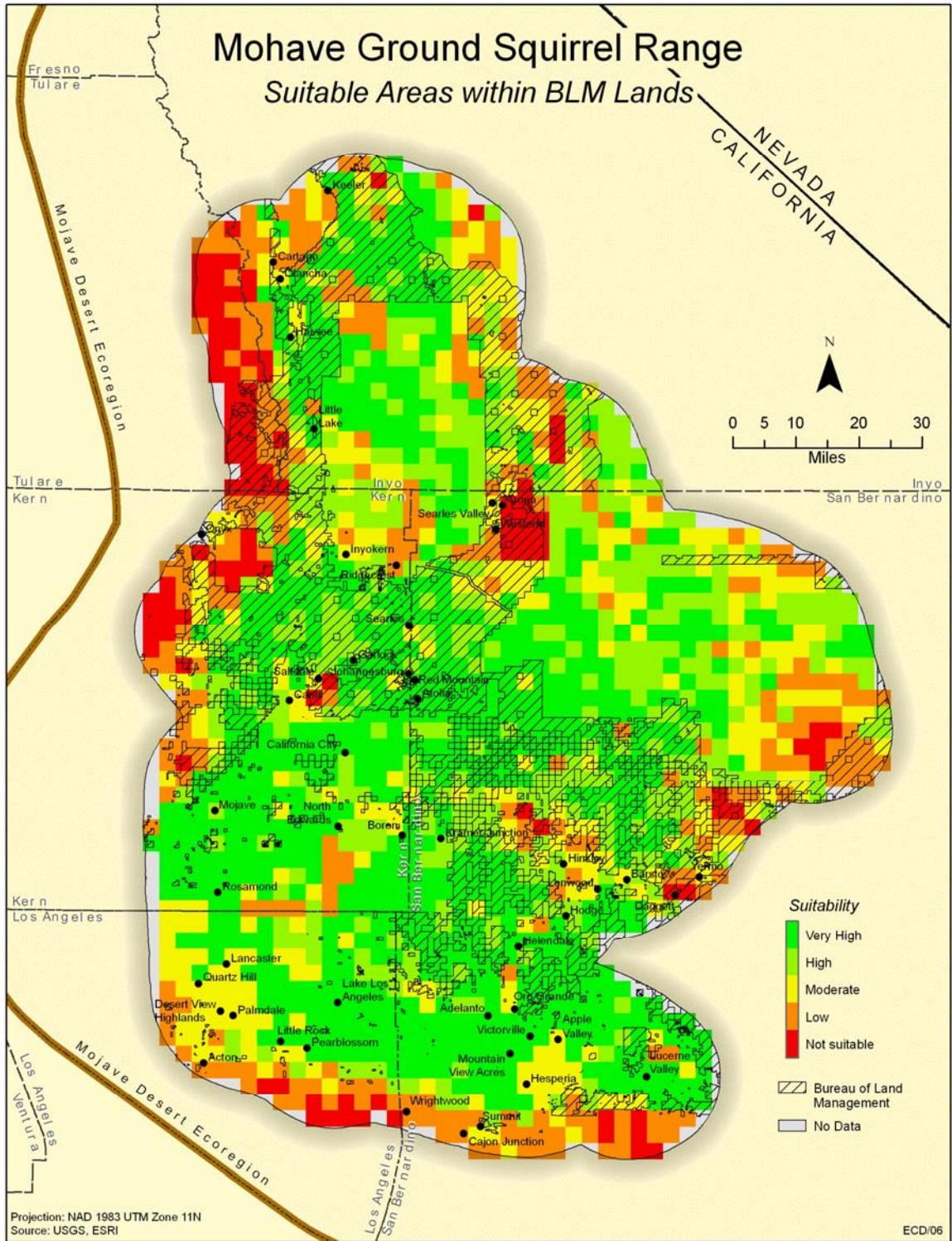
Figure F 9: MGS suitable habitat areas.
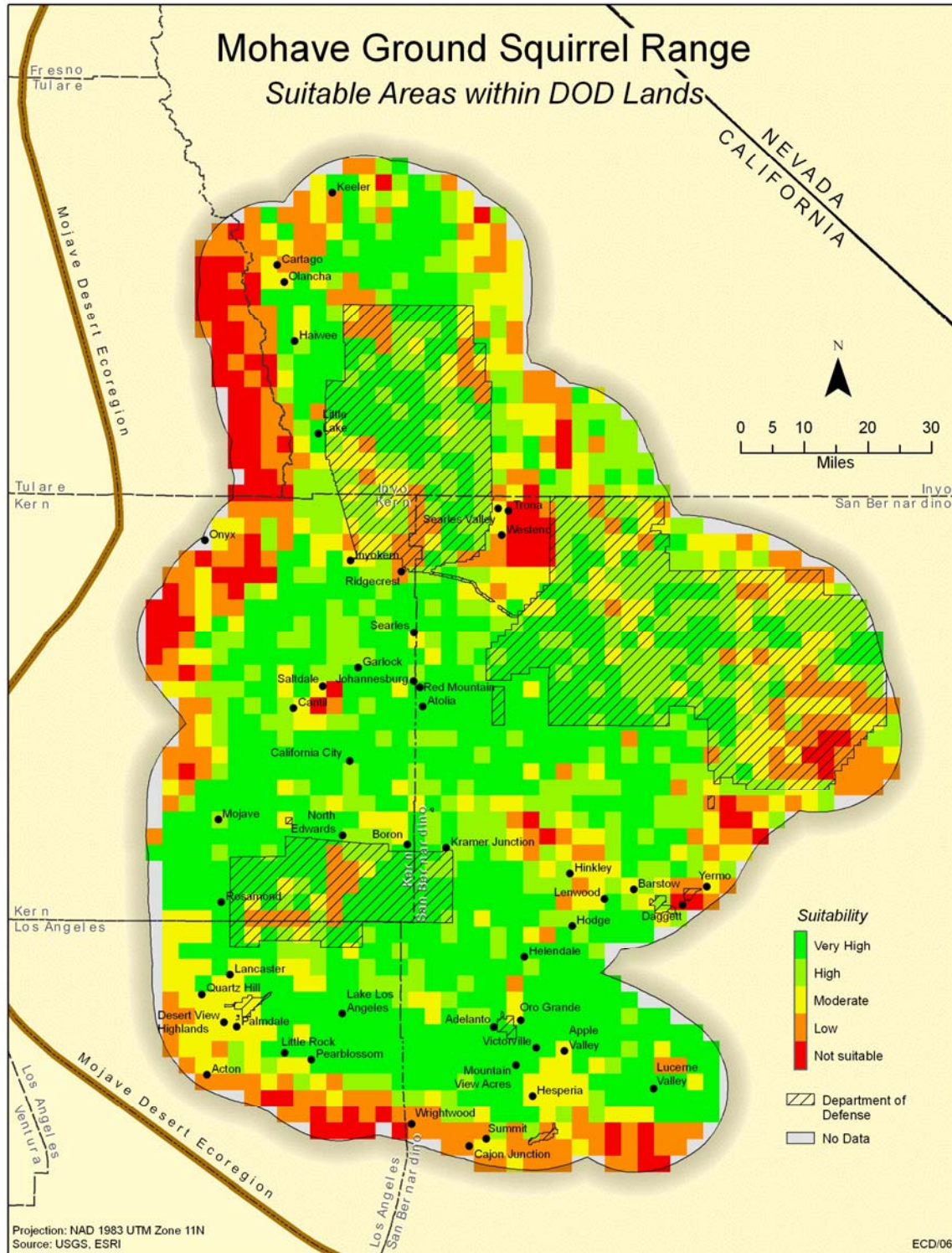
Figure F 10: Bureau of Land Management.

Figure F 11: Department of Defense.
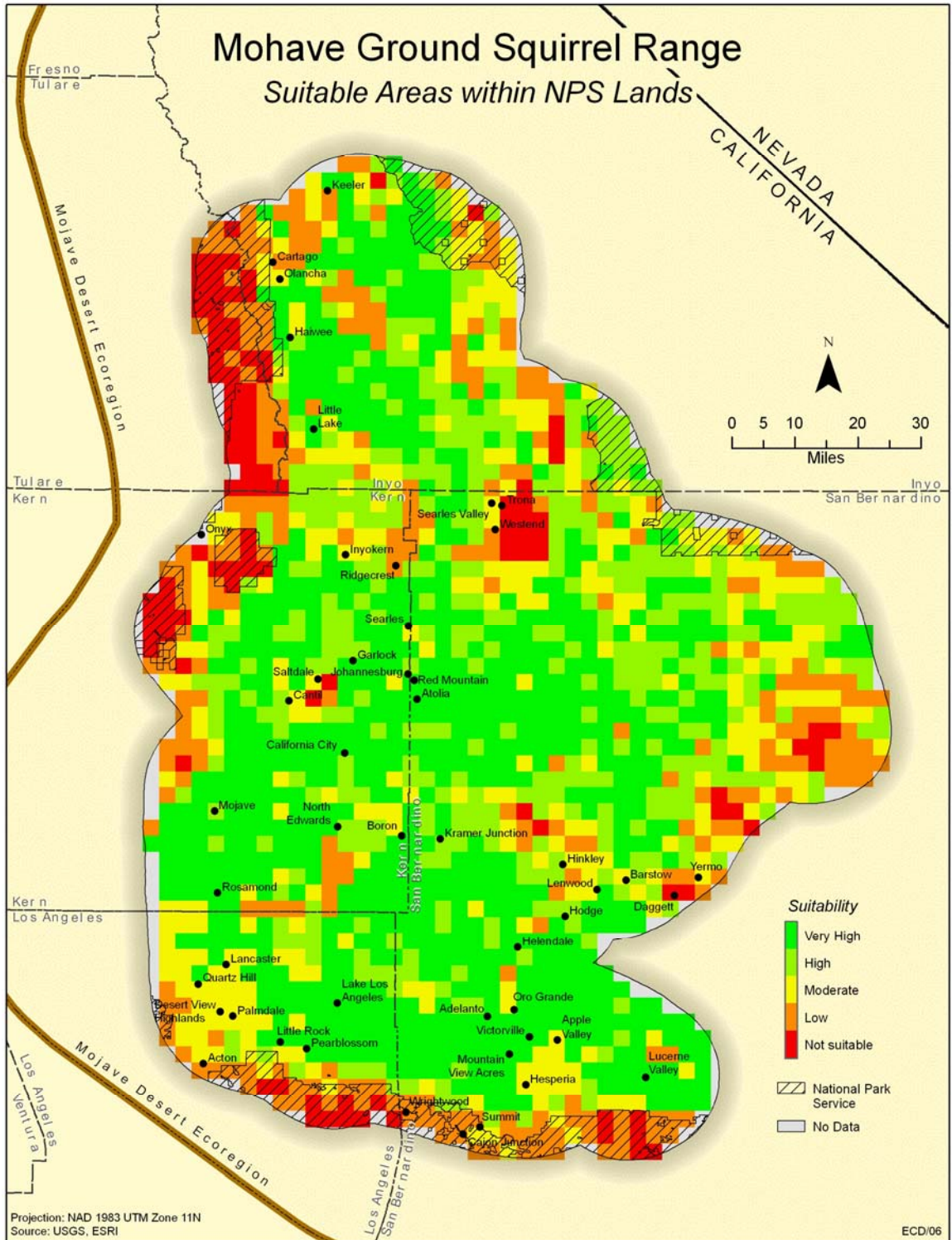
Figure F 12: National Park Service.
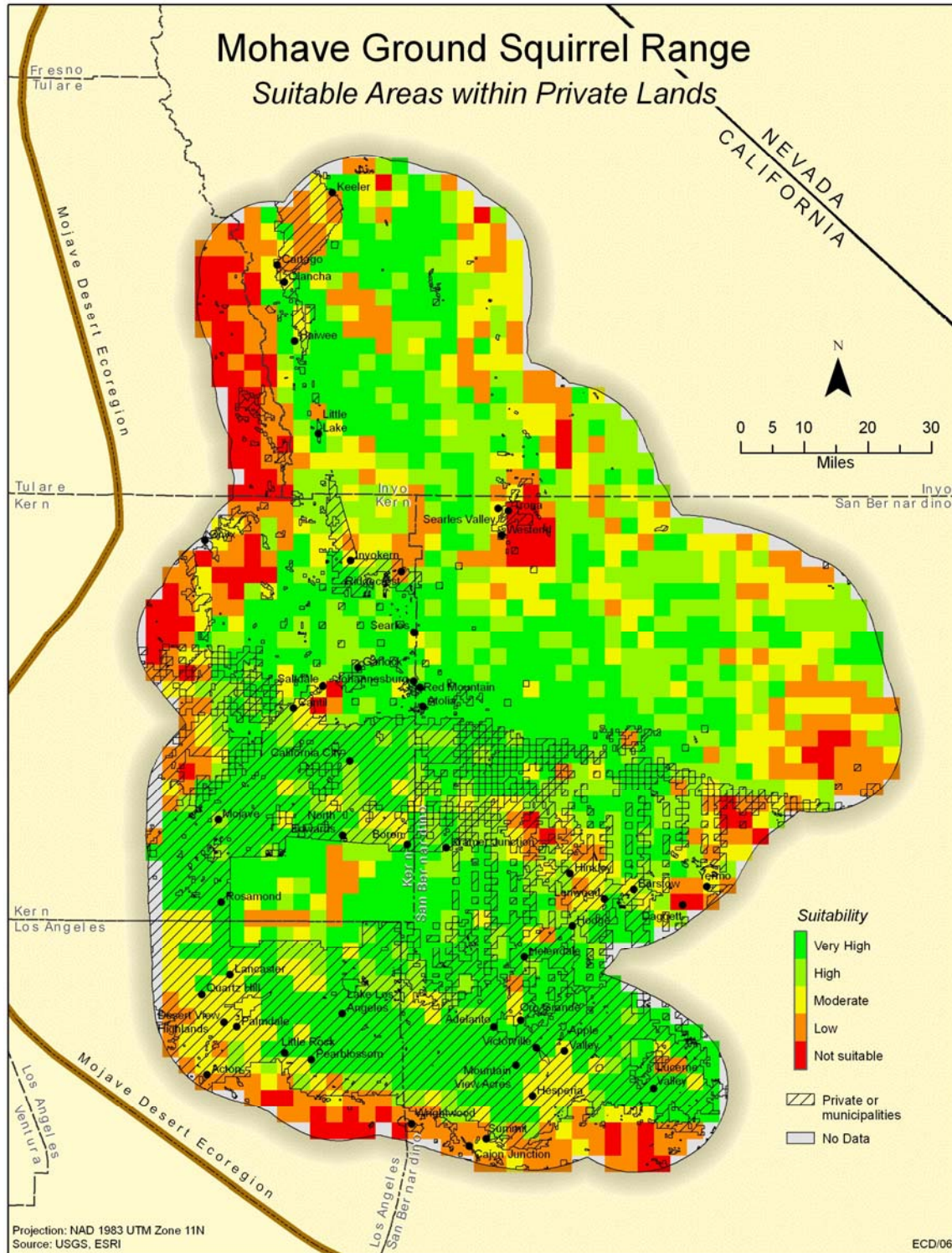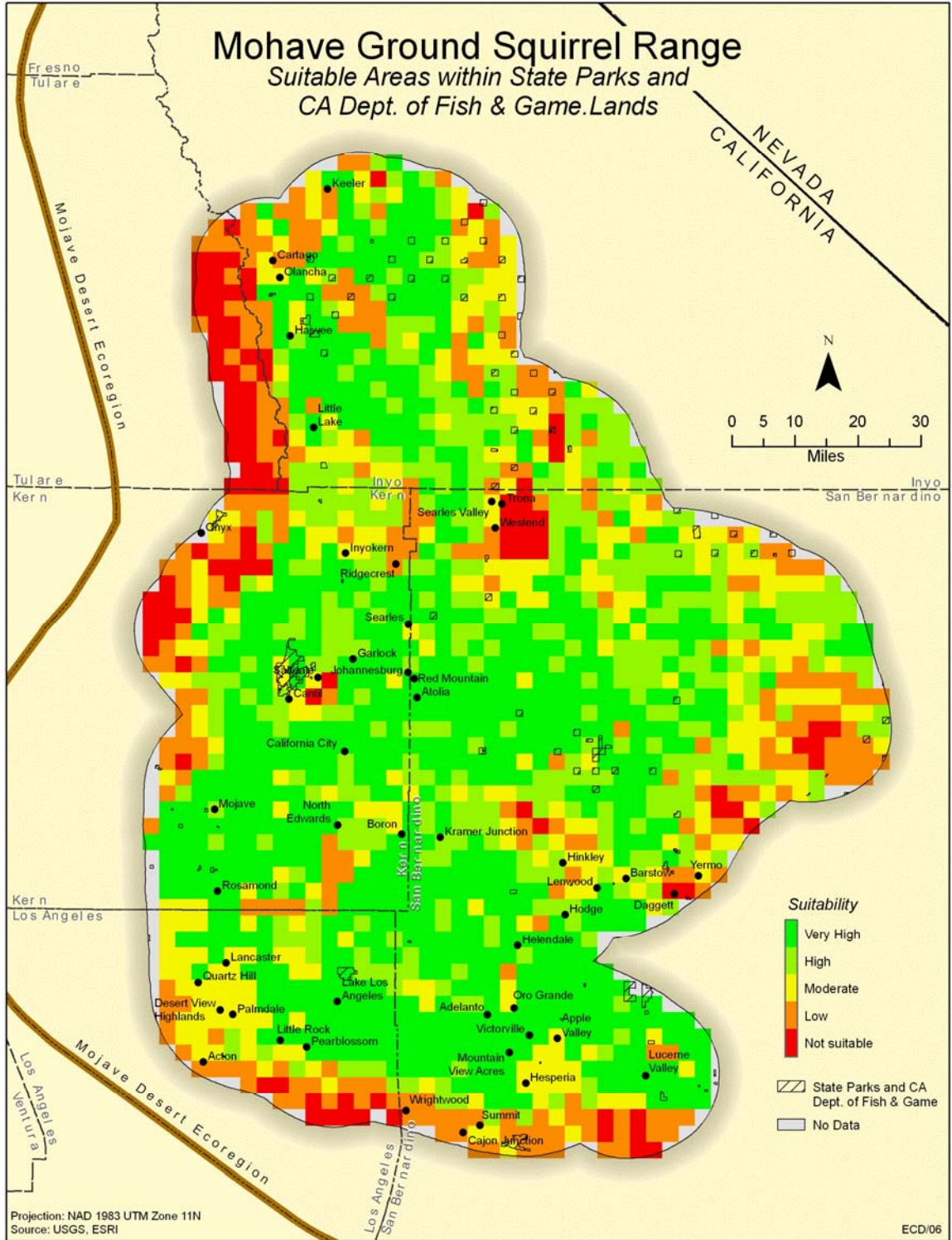
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Figure F 13: Private lands or municipalities.

Figure F 14: State Parks and CA Department of Fish & Game.