APPENDIX L:

GIS DATA SOURCES AND METHODOLOGY

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L.1 INTRODUCTION

Geographic information system (GIS) technology was instrumental in much of the analysis and all of the maps created for the "Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States" (Solar PEIS). GIS is a computer system for performing geographical analysis. GIS has four interactive components: (1) an input subsystem for converting into digital form (digitizing) maps and other spatial data; (2) a storage and retrieval subsystem; (3) an analysis subsystem; and (4) an output subsystem for producing maps, tables, and answers to geographic queries (Encyclopædia Britannica Online 2010a).

L.1.1 The Need for Geographic Information System Technology in the Solar PEIS

Within the six-state study area evaluated in the Solar PEIS, the U.S. Department of the Interior (DOI) Bureau of Land Management (BLM) administers almost 120 million acres (486,000 km^2) of public lands covering approximately 7,355 paper topographic maps at a scale of 1:24,000. Not counting base data (roads, cities, county boundaries, etc.), approximately 50 separate layers of geospatial information—each covering a different topic—were analyzed and/or mapped in support of PEIS analyses.

These statistics highlight the fact that the broad geographic region being discussed by the Solar PEIS, coupled with the detailed analysis needed for the proposed solar energy zones (SEZs), made GIS technology essential both in the preparation of the document and in clearly presenting the document's information to the public.

L.1.2 Data Standards and the Solar PEIS Master Geospatial Database

Geospatial data acquired for analysis in the Solar PEIS were assembled into a Master Geospatial Database residing on its own secure server. To the extent possible, the database adheres to applicable federal data standards.

Naming conventions and directory structures were derived from the Spatial Data Standard for Facilities, Infrastructure, and Environment (SDSFIE) established by the U.S. Department of Defense (SDSFIE 2010).

When feasible, metadata have been attached to geospatial data in accordance with the Content Standard for Digital Geospatial Metadata endorsed by the Federal Geographic Data Committee (Federal Geographic Data Committee 1998). However, much of the data received from various sources were not accompanied by metadata. In these cases, an attempt was made to fill in a minimum of information before releasing the data to the public.

All data in the Master Geospatial Database were referenced to the Albers Equal Area Conic projection with the central meridian at 114° west.

Along with the Master Geospatial Database, all data received for the project were inventoried and kept in separate state-specific directories.

L.2 DATA SOURCES AND LIMITATIONS

GIS technology is only as good as the geospatial data that it uses for calculations and analysis. Geospatial data consist of points, lines, polygons, and images, each with a special data attribute that places features in their correct locations on the Earth, using one of the many coordinate systems that have been established for this purpose.

While any piece of information with a specific location can become geospatial data, all geospatial data must be digitized specifically for use in a GIS. Certain satellite, aerial, and ground survey systems have been developed to create geospatial data from the survey data automatically. However, most of the land use data needed for the Solar PEIS have been digitized into geospatial data from conventional sources such as paper maps or aerial photos.

The accuracy of geospatial data digitized from conventional sources is difficult to express in numerical terms. Although the accuracy of a U.S. Geological Survey (USGS) topographic map (for instance), is stated to conform to U.S. National Map Accuracy Standards, the registration of that map to a digital geospatial coordinate system is not always perfect, due to the instability of paper caused by temperature and humidity. The skill of the person digitizing the data is another factor in data accuracy, as that person makes constant decisions about how closely to follow a jagged line or just where the center of a printed dot really is. Geospatial data also include attributes such as feature names or other text entries that can be misspelled or incorrectly entered. Finally, geospatial data are usually digitized for a certain purpose and may not be appropriate for other uses.

Usually, part of the purpose of digitizing geospatial data is to be able to view them at a certain map scale. Map scale refers to the size of the representation on the map as compared to the size of the object on the ground (Encyclopædia Britannica Online 2010b). Large-scale maps show the most detail and the least area. Small-scale maps show the least detail and the most area.

Geospatial data digitized for large-scale maps are not usually appropriate for use in small-scale maps because small areas may lose their shapes, lines may blend together, and jagged or curvy lines may look like thick lines. Once digitized, GIS tools can create a "generalized" version of the geospatial data so that they can be displayed on a small-scale map. However, the small-scale version will be less accurate than the original.

Likewise, geospatial data digitized for small-scale maps are usually not appropriate for use in large-scale maps because they are not accurate enough to show the details expected from a large-scale map. Once digitized for a small-scale map, geospatial data cannot be made more accurate without expending the time and effort to basically redigitize them.

In the discussion of specific geospatial data sources to follow, the intended map scale will be stated, if known. Otherwise, estimates of the digitized scale will be stated using the following categories:

- Small Scale: The data were created to map regional areas such as large parts of individual states (scales smaller than 1:2,000,000).

- Medium Scale: The data were created to map areas generally the size of a county or National Forest (scales between 1:500,000 and 1:2,000,000).

- Large Scale: The data were created to map areas generally smaller than a county or National Forest (scales larger than 1:500,000).

L.2.1 Bureau of Land Management GIS Data

The following is a discussion of the data received from the BLM, which form the basis for most of the geospatial analysis performed for the Solar PEIS.

L.2.1.1 Surface Management Agency Database

According to the metadata that accompanies it, the "Surface Management Agency data layer portrays tracts of federal land for the United States and classifies these holdings by administrative agency. Multiple federal agencies have contributed to the contents of this layer and it is in a continuous state of update. Source and date of feature updates are tracked to the feature level.

This layer provides an answer for the question of who is the administrator of a federally held parcel of land. It was created as a national reference theme for use with the GeoCommunicator's Land Manager Viewer (http://www.geocommunicator.gov).

This layer is a dynamic assembly of spatial data layers maintained at various federal and local government offices. The best known available data layers from these sources have been harvested and integrated into this layer. This layer represents a work in progress" (BLM 2010a).

As received from the BLM, the data are not topologically correct. This means that overlaps can occur, which can allow two features to cover the same area. For instance, this could mean that land administered by the U.S. Forest Service (USFS) can occupy the same area as land administered by the BLM. In some cases, two features administered by the same federal agency can also overlap.

Because acreage estimates using GIS technology must be based on topologically correct geospatial data (i.e., no overlaps), Argonne National Laboratory, in consultation with the BLM National Applications Office, developed GIS tools to essentially take the Surface Management

Agency data apart and put them back together again, giving preference to the most accurate data received from various federal agencies, in a topologically correct layer, with no overlaps.

The processed Surface Management Agency data form the foundation for all calculations, analysis, and maps regarding BLM land. It is important to note that these data were digitized at various scales by different local BLM offices for various uses. At one time, the data contained a caveat that they were not to be displayed at scales larger than 1:2,000,000. That caveat has been removed, but experience with the data indicates that their accuracy is still about the same.

The dynamic nature of the data is noted in the metadata. Updates to administered land parcels occur often at the local level. Updates to the Surface Management Agency data occur less frequently. Also, the National Applications Office was directed to discontinue updates of Surface Management Agency data in the fall of 2009. The last version of the data received for the Solar PEIS was dated September 14, 2009. All of these limitations explain why there may be discrepancies between data and maps produced for this PEIS using Surface Management Agency data, and data and maps produced at the local level. Nonetheless, the Surface Management Agency data were designed for planning purposes, making them appropriate for use in the Solar PEIS. They are considered to be appropriate for display at medium scales.

L.2.1.2 National Landscape Conservation System

The National Landscape Conservation System (NLCS) includes more than 886 federally recognized areas and approximately 27 million acres (109,265 km^2) of National Monuments, National Conservation Areas, Wilderness Areas, Wilderness Study Areas, Wild and Scenic Rivers, National Scenic and Historic Trails, and Conservation Lands of the California Desert (BLM 2010b).

The protected lands of the NLCS have been excluded from BLM-administered lands being analyzed for solar energy development. Unlike the Surface Management Agency data, geospatial data for these protected lands were not available in a consolidated form during the time when the Solar PEIS was being prepared. This necessitated the compilation of data layers to represent each of the protected areas in the NLCS using the best available sources.

L.2.1.2.1 National Monuments. Geospatial data for National Monuments were compiled (assembled) from the best available data from the following sources:

- BLM Surface Management Agency data (see L.2.1.1., Surface Management Agency Database);
- U.S. Forest Service Inventoried Roadless and Specially Designated Areas (USFS 2010b);
- U.S. Fish and Wildlife Service;

- Administrative Boundaries of National Park System Units (National Park Service 2010);

- U.S. Geological Survey "fedlands" dataset (from the National Atlas [nationalatlas.gov 2009]); and

- National Trust for Historic Preservation (National Trust for Historic Preservation 2010).

These data are appropriate for display at medium scales.

L.2.1.2.2 National Conservation Areas. Geospatial data for National Conservation Areas were extracted from Surface Management Agency data (see L.2.1.1., Surface Management Agency Database) with additions from the BLM Utah State Office.

L.2.1.2.3 Designated Wilderness, Wilderness Study Areas, and Instant Study Areas. Geospatial data for Designated Wilderness, Wilderness Study Areas, and Instant Study Areas were compiled from the best available data received from the following sources:

- BLM state and/or field offices;

- U.S. Forest Service Inventoried Roadless and Specially Designated Areas; and

- U.S. Geological Survey "fedlands" dataset (from the National Atlas [nationalatlas.gov 2009]).

These data are appropriate for display at large to medium scales.

L.2.1.2.4 Wild and Scenic Rivers. Geospatial data for Wild and Scenic Rivers were acquired from the National Wild and Scenic Rivers System. According to the accompanying metadata, "Stream segment data [is] compiled from a variety of sources. Original National Wild and Scenic River system dataset [is] compiled by the USGS National Atlas in 2000. This source data is 1:2,000,000 scale. New segments added to the system since 2000 obtained and compiled at 1:24,000 scale" (USFS 2010a).

L.2.1.2.5 National Scenic and Historic Trails. Geospatial data for National Scenic and Historic Trails were compiled from the best available data received from the following sources:

- BLM state and/or field offices;

- U.S. Forest Service; and

- National Park Service.

The limitations of these data are noted in the metadata: “Accurate geospatial data on National Scenic and Historic Trails is difficult to acquire. Trails are administered by different federal agencies, each with their own structure of jurisdiction and data standards. The term “trail” is also used very loosely in regards to these designations. The Selma to Montgomery National Historic Trail, for instance, is described through driving directions… The Oregon National Historic Trail is the opposite condition, where the “trail” is really more of a corridor than a linear feature” (Argonne National Laboratory 2009).

These data are appropriate for display at small scales only.

L.2.1.2.6 Conservation Lands of the California Desert. The BLM California Desert District supplied geospatial data for Desert Wildlife Management Areas as well as habitat conservation areas for the Mojave ground squirrel, fringe-toed lizard, and flat-tailed lizard (BLM 2008). These data are appropriate for display at large to medium scales.

L.2.1.3 Other BLM Data Acquired from State and Field Offices

Areas of Critical Environmental Concern (ACECs) and Special Recreation Management Areas (SRMAs) were also excluded from BLM lands being analyzed for solar development. Geospatial data for each were compiled from data received from state and field offices and are generally appropriate for large-scale display.

L.2.2 U.S. Geological Survey

Most of the geospatial data for physical features used in analysis originated with the USGS. These include lakes and streams, digital elevation models, and land cover data.

L.2.2.1 The National Atlas

National Atlas data were used for maps and analysis of physical features such as:

- Ecoregions;

- Earthquakes and quaternary faults; and

- Aquifers, watersheds, and hydrography.

National Atlas data are generally appropriate for display at medium to small scales. For certain detailed maps and analysis, individual state geological survey data were used instead of National Atlas data.

L.2.2.2 National Elevation Database

The digital elevation models used in viewshed calculations for the visual resources sections were taken from the National Elevation Database (NED) and acquired through the Natural Resources Conservation System maintained by the U.S. Department of Agriculture. These "10-meter" data (where each cell or pixel measures 10 meters by 10 meters) are appropriate for use in large-scale maps and analysis and are considered to have a vertical accuracy of better than 3 meters.

Shaded relief used in many of the maps was derived from "30-meter" digital elevation models, also a part of the NED, purchased through the USGS Earth Explorer (USGS 2007).

L.2.2.3 National Hydrographic Database

The National Hydrographic Database (USGS 2010a) was used only to a limited extent for Solar PEIS analyses, because it was considered too detailed for the level of analysis performed. It is appropriate for large-scale maps only, and the attributes are more oriented to hydrologic modeling than to land use planning. In most cases, streams and rivers from the National Atlas were used instead.

L.2.2.4 Gap Analysis Program Data

Gap Analysis Program (GAP) data are managed by the USGS and provide land cover and species data in uniform geospatial datasets derived from satellite imagery, existing maps and other records, air photos, air video, and ground points (USGS 2010b).

All land cover analysis and maps in the document use the GAP data, which cover the six subject states with a uniform 30-meter grid.

L.2.3 Bureau of Transportation Statistics

Most of the "base" data used in maps and analysis came from the National Transportation Atlas Data published by the Bureau of Transportation Statistics (BTS). It was the source of geospatial data for the following features.

L.2.3.1 Populated Place

According to the accompanying metadata, "These cities were collected from the 1970 National Atlas of the United States. Where applicable, U.S. Census Bureau codes for named populated places were associated with each name to allow additional information to be attached. The Geographic Names Information System (GNIS) was also used as a source for additional information. This is a revised version of the December, 2003, data set. These data are intended for geographic display and analysis at the national level, and for large regional areas. The data should be displayed and analyzed at scales appropriate for 1:2,000,000-scale data" (BTS 2010).

L.2.3.2 States and Counties

Geospatial data for state and county boundaries were compiled by the BTS from several different sources and are generally appropriate for display at large to medium scales.

L.2.3.3 National Highway Planning Network

Although some of the maps used in the transportation sections required more detailed data, the National Highway Planning Network compiled by the BTS was used in the Solar PEIS for maps and analysis of highways designated as county and above (state and federal).

According to the accompanying metadata, "The National Highway Planning Network is a comprehensive network database of the nation's major highway system. It consists of the nation's highways comprised of Rural Arterials, Urban Principal Arterials and all National Highway System routes. The data set covers the 48 contiguous States plus the District of Columbia, Alaska, Hawaii, and Puerto Rico. The nominal scale of the data set is 1:100,000 with a maximal positional error of ±80 meters" (BTS 2010).

L.2.3.4 Rail Lines

The rail lines put out by the BTS originate with the Federal Railroad Administration. According to the accompanying metadata: "The Rail Network is a comprehensive database of the nation's railway system at the 1:100,000 scale. The data set covers all 50 States plus the District of Columbia" (BTS 2010).

L.2.4 U.S. Bureau of the Census

U.S. Bureau of the Census Summary Files 1 and 3 from the 2000 Census were used in the analysis and mapping of environmental justice issues (minority and low-income populations).

Block group boundaries developed through the U.S. Bureau of the Census TIGER program were acquired through an Environmental Systems Research Institute (ESRI) data portal. According to the data for TIGER line files: "The positional accuracy varies with the source materials used, but generally the information is no better than the established national map Accuracy standards for 1:100,000-scale maps from the U.S. Geological (USGS); thus it is NOT suitable for high-precision measurement applications such as engineering problems, property transfers, or other uses that might require highly accurate measurements of the earth's surface" (U.S. Bureau of the Census 2010).

L.2.5 Platts PowerMap

Maps and analysis involving existing or proposed transmission lines for the Solar PEIS use Platts PowerMap as the source of geospatial data. According to the metadata, "The Platts Transmission Lines geospatial data layer has been created to display the electric transmission grid of North America… The horizontal accuracy of Platts geospatial data meets or exceeds the National Map Accuracy Standards for geospatial data at a 1:250,000 map scale" (Platts 2010).

L.2.6 Designated Corridors

Designated corridors include both federally designated Section 368 corridors and BLM locally designated corridors; these corridors were developed for federal land use planning purposes only and are not applicable to state-owned or privately owned land. Since designated corridors indicate existing or planned rights-of-way (ROWs) for energy transmission on federal land, they were included (along with existing transmission lines) in the evaluation of access from potential solar energy development to the electrical grid.

L.2.6.1 Section 368 Corridors

Section 368 corridors were developed to address Section 368 of the Energy Policy Act of 2005 (DOE and DOI 2008). They cover 11 western states and include the six-state study area evaluated in the Solar PEIS.

These data are appropriate for display at medium scales.

L.2.6.2 BLM State Office-Designated Corridors

Arizona, California, Colorado, and Nevada State Offices supplied geospatial data for designated corridors under their jurisdictions.

These data are appropriate for display at medium scales.

L.3 METHODS

The following sections relate to analysis used in the Solar PEIS from a GIS standpoint.

L.3.1 Analysis of Potential Effects Using Geospatial Data

Except for discussions of environmental justice and visual resources, acreage estimates of the potential effects of alternatives being considered in the Solar PEIS rely on just three types of GIS tools: the buffer tool, the intersect tool, and the union tool.

The buffer tool builds an area (or polygon) that extends a given distance away from a given feature or features. The buffer created allows the analyst to select automatically any other features that fall within it. This allows for simple statements of which resources may be within 15 mi (24 km) of a proposed SEZ (for example). Figure L.3.1-1 uses wetlands as an example. The wetlands highlighted have been selected automatically because they fall within (or intersect) the 15-mi (24-km) buffer.

The intersect tool computes the geometric intersection of features from two or more separate layers of information. The new layer of information created shows only the areas of intersection, which can then be counted or measured for length and area. Continuing the wetlands example, notice that one of the wetlands is not only within the 15-mi (24-km) buffer, but also extends into the proposed SEZ. The intersect tool would create the new area shown in red in Figure L.3.1-2.

The union tool is a more sophisticated form of the intersect tool that adds two or more layers of information together into a single new layer, which holds all the information from each of the layers. This allows for the discernment of intersections while preserving the areas that do not intersect. Statements such as the total acres of a particular wetland compared to the acres intersected by a proposed SEZ are possible using the union tool. In Figure L.3.1-3, both the wetlands and the proposed SEZ are contained in one layer of information.

The examples given use vector GIS technology, which stores features as points, lines, or polygons. Continuous features such as land cover, elevation, or slope require analysis using raster GIS technology, which stores information in rectangular cells (similar to pixels in a computer screen) arranged in a matrix. The tools used to analyze vector data have equivalents used to analyze raster data.

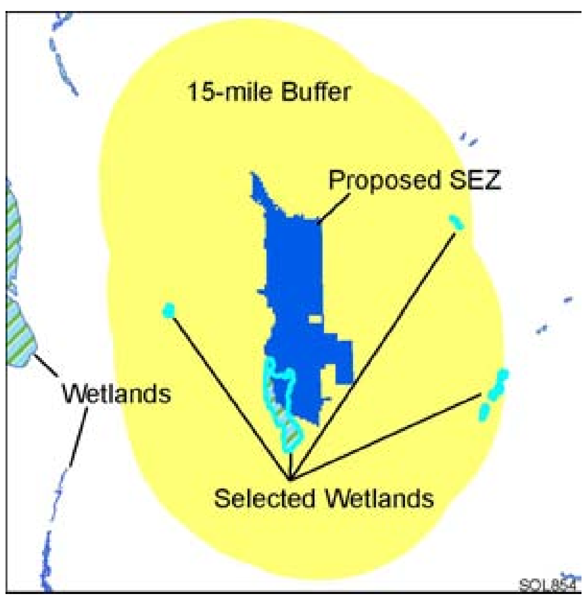

FIGURE L.3.1-1 Example of Buffer Tool

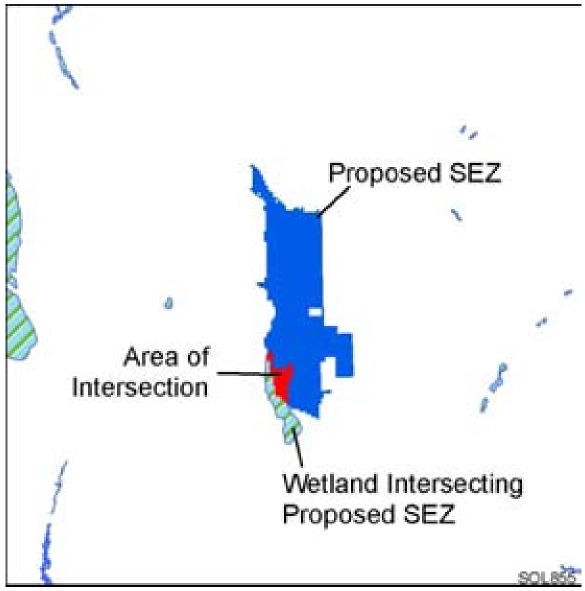

FIGURE L.3.1-2 Example of Intersect Tool

FIGURE L.3.1-3 Example of Union Tool

L.3.1.1 Environmental Justice

Environmental justice tables and maps involve a combination of GIS tools and Relational Database Management System (RDBMS) tools.

Block group boundaries were downloaded by county from the ESRI data portal, which offers a version of the U.S. Bureau of the Census TIGER data that is easier to use (ESRI 2010).

A 50-mi (80-km) buffer was created around the subject proposed SEZ (proposed SEZs were analyzed one at a time). Because the buffer always intersected several counties, the block group boundaries from each state were appended together using the append tool. The append tool merges data from different areas into one area with the same data structure.

The geospatial data representing block group boundaries contain only spatial data and a "key field" to match each individual block group to whatever tabular census data are associated with it.

Tabular census data for the 2000 Census were downloaded for each subject state from the U.S. Bureau of the Census Web site (U.S. Bureau of the Census 2010). Because Summary File 1 and Summary File 3 tables contain detailed census information down to the level of a census tract, which is smaller than a block group, the data first must be summarized at the block group level. The summarized data are then joined to a geographic table containing the "key field" using RDBMS tools to create a new table that can be joined to the geospatial data.

Summary File 1, Table 1, was used to summarize minority population data and then joined to the Summary File 1 geographic table. The results of the join were then joined to the geospatial data using GIS tools.

Summary File 3, Table 7, was used to summarize minority population data and then joined to the Summary File 3 geographic table. The results of the join were then joined to the geospatial data using GIS tools.

With geospatial data for a state's block groups containing the correct population data, block groups were selected if they were within the proposed SEZ's 50-mi (80-km) buffer. The data from these block groups were then summarized per proposed SEZ into environmental justice tables. Also, the geospatial data were used to map block groups with populations above certain threshold percentages.

L.3.1.2 Visual Resource Analysis

Detailed analysis of the potential impacts on visual resources from the development of solar facilities within proposed SEZs required raster GIS tools, which were not needed for other resources, and in some cases, needed to be developed for the Solar PEIS. The viewshed tool determines whether there is a line of sight between a target and the area surrounding the target.

The only inputs required for the viewshed tool are targets (or points) from which to determine the line of sight and a digital elevation model (a grid of rectangular cells, each cell representing the elevation at its center). The viewshed tool examines each individual cell in the digital elevation model and determines whether or not there are one or more cells of higher elevation between it and the target point. If there are none, that cell will be included in the viewshed.

The result of the viewshed tool is another grid of rectangular cells; in this case, each cell represents how many of the targets used as inputs have a line of sight to that individual cell.

For all proposed SEZs except Imperial East, 10-m (32-ft) (the approximate height and width of each cell) digital elevation models from the USGS National Elevation Data were used as inputs. For Imperial East, 10-m (32-ft) data were not available; 30-m (98-ft) data were used instead.

The proposed SEZs represent large areas as opposed to specifically located targets. These large areas required the use of sample points placed throughout the area of each SEZ to be used as target inputs to the viewshed tool. The sample points were developed by dividing each proposed SEZ into rectangular zones measuring approximately 1 mi (2 km) on each side. Zonal sampling tools from the Spatial Analyst Extension were then used to calculate the location of the highest point in each zone. These sampling points were then used as target inputs for the viewshed tool. In some cases, more sampling points were added around the SEZ border, based on the analyst's visual inspection of the surrounding terrain (as seen in the digital elevation model.)

In addition to its geographical location on the ground, each target point can represent its own height as well as the height of a person viewing it. Heights representing each of the four potential solar energy technologies were used as target heights, and the viewer height remained constant at 1.75 m (5.74 ft) for each set of targets. This resulted in four separate viewsheds for each proposed SEZ, each representing a potential solar energy technology.

An additional parameter that is set in the viewshed tool is whether or not curvature of the Earth is to be taken into consideration. The viewsheds for the proposed SEZs were calculated to include the curvature of the Earth at a refractivity coefficient of 0.13.

More than a thousand hours of computer processing time were required to calculate all of the viewsheds analyzed in the Solar PEIS.

L.3.1.3 Distance Zones

Each viewshed was intersected with buffers around the subject proposed SEZ to develop distance zones. The distance zones then represented the area around the proposed SEZ, which had line of sight to development somewhere within the proposed SEZ from 5, 15, or 25 mi (8, 24, or 40 km).

Each distance zone was then overlaid on the 17 layers of data representing the different classes of visual resources (e.g., wilderness areas). This was accomplished with Python language scripting to automate the process. The intersection between each distance zone and each visual resource layer was measured, and acreage estimates for each individual resource were calculated by using the count of overlapping cells divided by the number of cells representing an acre.

L.4 GIS USED IN THE SOLAR PEIS

GIS tools discussed in preceding sections of this appendix are part of the main GIS platform used to analyze, map, and create other analysis products for the Solar PEIS. The main GIS platform is discussed in the following sections, along with other GIS technology that was used to help in the dissemination and analysis of geospatial data.

L.4.1 Main GIS Platform

The main GIS platform for the Solar PEIS was ArcGIS 9.3.1, a product of ESRI. This consists of Arc/Info licenses for desktop GIS using the ArcMap interface, as well as the Spatial Analyst extension used specifically for raster GIS tools.

L.4.2 ArcReader

ArcReader is similar to ArcMap as an interface to view and query geospatial data. ArcReader projects for each state were published from ArcMap master files for use by non-GIS staff.

L.4.3 GeoPDF

GeoPDF files are versions of Adobe's Portable Document Format (PDF) files, which allow simple analysis of geospatial data using lightweight extensions to Adobe Reader. Published from ArcMap, GeoPDF files were used extensively in field trips to proposed SEZs.

L.4.4 Google Earth

Google Earth was used extensively in visual resource analysis, as well as by many other disciplines, which benefited from access to satellite imagery. With Keyhole Markup Language (KML) files published from ArcMap, analysts were able to combine geospatial data from the project with the resources available in the Google Earth application. A selected set of these KML files will be available from the Solar PEIS website in the final draft.

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