



# Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Acidification Effects from Atmospheric Sulfur and Nitrogen Deposition

## *Mojave Desert Network (MOJN)*

Natural Resource Report NPS/NRPC/ARD/NRR—2011/363



#### **ON THE COVER**

Some ecosystems and vegetation types, such as remote high-elevation lakes, sugar maple trees, headwater streams, and red spruce trees, are sensitive to the effects of acidification from atmospheric nitrogen and sulfur deposition.

Photograph by: National Park Service

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# **Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Acidification Effects from Atmospheric Sulfur and Nitrogen Deposition**

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This report received peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from Air Resources Division of the NPS (<http://www.nature.nps.gov/air/Permits/ARIS/networks/acidification-eval.cfm>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

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## Mojave Desert Network (MOJN)

National maps of atmospheric S and N emissions and deposition are provided in Maps A through D as context for subsequent network data presentations. Maps A and B show county level emissions of total S and total N for the year 2002. Maps C and D show total S and total N deposition, again for the year 2002.

There are five parks in the Mojave Desert Network that are larger than 100 square miles: Death Valley (DEVA), Great Basin (GRBA), Joshua Tree (JOTR), Lake Mead (LAME), and Mojave (MOJA). There is only one park smaller than 100 square miles: Manzanar (MANZ).

Total annual S and N emissions, by county, are shown in Maps E and F, respectively, for lands in and surrounding the Mojave Desert Network. County-level S emissions within the network were mostly less than 1 ton per square mile per year, although a few counties within the network, and to the southwest of the network, had S emissions values up to 5 tons per square mile per year (Map E). One county to the southwest had S emissions values in the range of 5 to 20 tons per square mile per year. County-level N emissions within the network ranged from less than 1 ton per square mile to between 5 and 20 tons per square mile in the southwestern corner of the network. In general, annual N emissions were less than 1 ton per square mile in the northern part of the network, including most of DEVA, and 1 to 5 tons per square mile in the south, including JOTR, MOJA, and parts of LAME. Individual S point sources within and around the network are shown on Map G. There was one S point source within the network that emitted in the range of 20,000 to 40,000 tons per year. In general, however, the network contains point sources that emitted 5,000 tons S per year or less (Map G). Several S point sources exist to the west of the network in the greater Los Angeles metropolitan area, San Diego, and slightly further north in the Central Valley, but none emit more than 5,000 tons of S per year. Point source emissions of oxidized (nitrogen oxides,  $\text{NO}_x$ ) and reduced (ammonia,  $\text{NH}_3$ ) N are shown in Map H. There are only two N point sources within this network that emitted more than about 2,500 tons per year. Both were sources of oxidized N. Outside the network boundary, the larger point sources of oxidized N were mainly to the east, and there were numerous small reduced N sources to the west (Map H).

Urban centers within the network and within a 300-mile buffer around the network are shown in Map I. There are several population centers larger than 100,000 people, located near LAME. No other population centers of any magnitude occur within the network. Los Angeles and San Diego are very close to the southwestern network boundary, and there are also large urban areas in the San Francisco Bay area to the northwest and Phoenix to the east, all within the network buffer.

Total S and N deposition in and around the network are shown in Maps J and K, respectively. Included in this analysis are both wet and dry forms of acidic deposition and both the oxidized and reduced N species. Total S deposition was generally less than 2 kg S/ha/yr throughout the entire network (Map J). Total N deposition in the network ranged from less than 2 kg N/ha/yr in the northern portion to as high as 10 to 15 kg N/ha/yr in one small area on the southwestern border (Map K). Total N deposition was generally less than 5 kg N/ha/yr throughout the network.

Land cover in and around the network is shown in Map L. The predominant cover type within this network is shrubland, with small areas of developed, barren land, and forested cover types spread throughout the network.

The average slope of the park lands in the network is variable (Map M). Much of the park land is moderately steep. Some areas in DEVA, JOST and LAME have HUCs with average slope more than 30°. All of GRBA has slope greater than 40°; one of its HUCs has average slope greater than 50°.

Park lands requiring special protection against potential adverse impacts associated with acidification from atmospheric deposition are shown on Map N. Also shown on Map N are all federal lands designated as wilderness, both lands managed by NPS and lands managed by other federal agencies. The land designations used to identify this heightened protection included Class I designation under the Clean Air Act Amendments and wilderness designation. JOTR is classified as Class I, and much of it is also designated wilderness. The eastern portion of LAME is also Class I. DEVA, MOJA, and LAME include substantial amounts of designated wilderness. There are large areas of designated wilderness outside NPS jurisdiction throughout much of the southern portion of this network (Map N).

Network rankings are given in Figures A through C as the average ranking of the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection metrics, respectively. Figure D shows the overall network Summary Risk ranking. In each figure, the rank for this particular network is highlighted to show its relative position compared with the ranks of the other 31 networks.

The Mojave Desert Network ranked in the middle of the second lowest quintile among networks in Pollutant Exposure (Figure A). Sulfur and N emissions and deposition within the network were fairly low. The network Ecosystem Sensitivity ranking was moderate, at the top of the middle quintile among networks (Figure B). This network ranked at the top of the second highest quintile in Park Protection, having substantial amounts of protected lands (Figure C).

In combination, the network rankings for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection yielded an overall Network Risk ranking that is near the middle of the distribution among networks (Figure D).

Similarly, park rankings are given in Figures E through H for the same metrics. In the case of the park rankings, we only show in the figures the parks that are larger than 100 square miles. Relative ranks for all parks, including the smaller parks, are given in Table A and Appendix A. As for the network ranking figures, the park ranking figures highlight those parks that occur in this network to show their relative position compared with parks in the other 31 networks. Note that the rankings shown in Figures E through H reflect the rank of a given park compared with all other parks, irrespective of size.

The five I&M parks within this network that are larger than 100 square miles were well distributed across the lower half of the spectrum of Pollutant Exposure, from the middle quintile (JOTR) to the lowest quintile (DEVA and GRBA; Figure E). MANZ, which is smaller than 100 square miles, was ranked in the lowest quintile. Ecosystem Sensitivity for two of the six I&M parks (DEVA and GRBA) was ranked in the highest quintile (Figure F) due largely to the

presence of very steep slopes and many low-order and high-elevation streams. The three other large parks (LAME, MOJA, and JOTR) were ranked as High, while the small park, MANZ, was ranked Very Low. Park Protection was ranked Very High for all parks except GRBA and MANZ, which were ranked Moderate (Figure G, Table A). The park Summary Risk ranking was High for all of the large parks except GRBA, which was ranked Moderate. MANZ was ranked Very Low (Figure H, Table A).

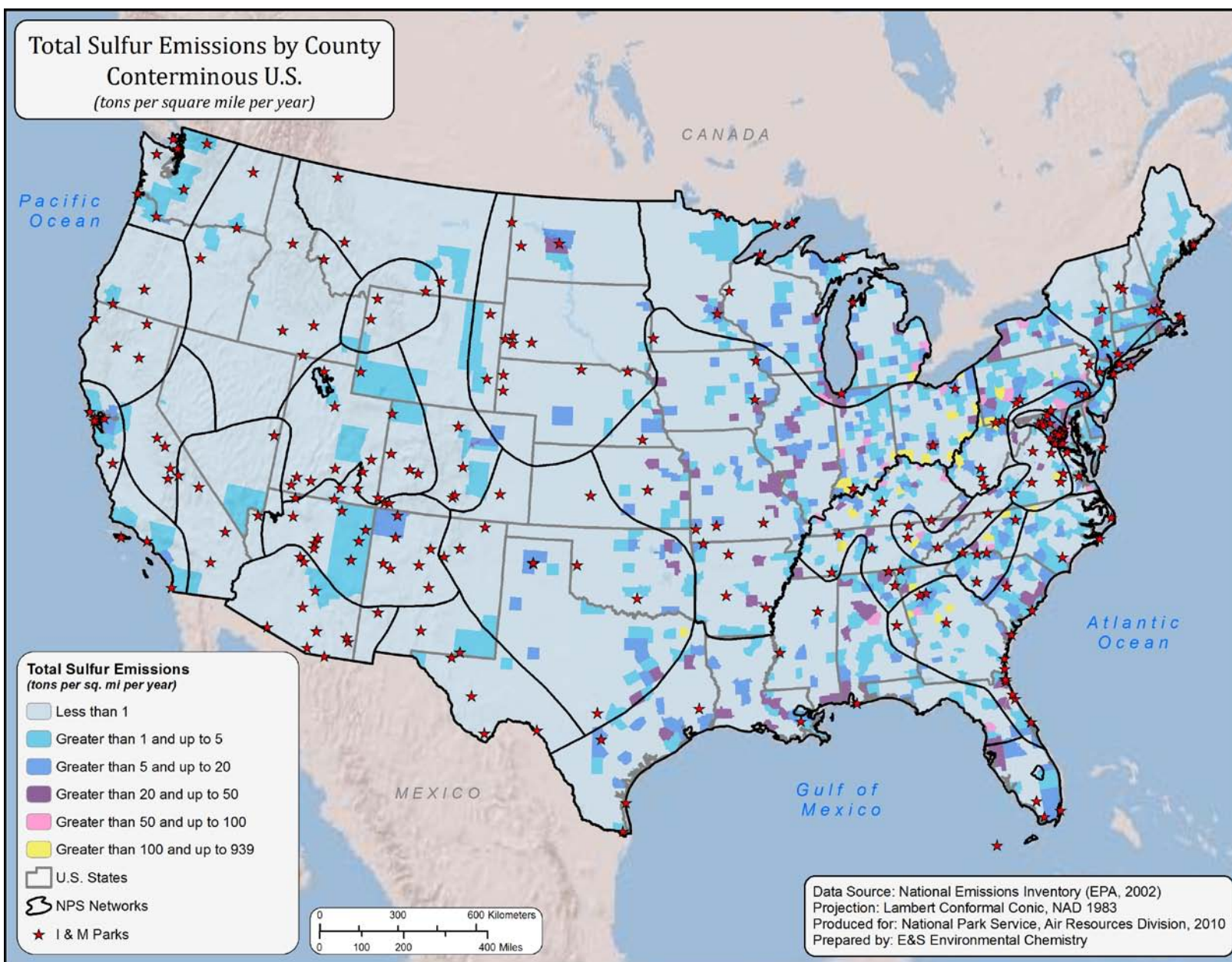
| <b>Table A.</b> Relative rankings of individual I&M parks within the network for Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and overall Summary Risk from acidic deposition. |                                                         |                              |                        |                     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|------------------------------|------------------------|---------------------|
| <b>I&amp;M Parks<sup>2</sup> in Network</b>                                                                                                                                                   | <b>Relative Ranking of Individual Parks<sup>1</sup></b> |                              |                        |                     |
|                                                                                                                                                                                               | <b>Pollutant Exposure</b>                               | <b>Ecosystem Sensitivity</b> | <b>Park Protection</b> | <b>Summary Risk</b> |
| <b><i>Death Valley</i></b>                                                                                                                                                                    | Very Low                                                | Very High                    | Very High              | High                |
| <b><i>Great Basin</i></b>                                                                                                                                                                     | Very Low                                                | Very High                    | Moderate               | Moderate            |
| <b><i>Joshua Tree</i></b>                                                                                                                                                                     | Moderate                                                | High                         | Very High              | High                |
| <b><i>Lake Mead</i></b>                                                                                                                                                                       | Low                                                     | High                         | Very High              | High                |
| Manzanar                                                                                                                                                                                      | Very Low                                                | Very Low                     | Moderate               | Very Low            |
| <b><i>Mojave</i></b>                                                                                                                                                                          | Low                                                     | High                         | Very High              | High                |
| <sup>1</sup> Relative park rankings are designated according to quintile ranking, among all I&M Parks, from the lowest quintile (very low risk) to the highest quintile (very high risk).     |                                                         |                              |                        |                     |
| <sup>2</sup> Park name is printed in bold italic for parks larger than 100 square miles.                                                                                                      |                                                         |                              |                        |                     |

- Map A. National map of total S emissions by county for the year 2002, in units of tons of S per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map B. National map of total N emissions by county for the year 2002. Both oxidized (nitrogen oxides, NO<sub>x</sub>) and reduced (ammonia, NH<sub>3</sub>) forms of N are included. The total is expressed in tons per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map C. Total S deposition for the conterminous United States for the year 2002, expressed in units of kilograms of S deposited from the atmosphere to the Earth surface per hectare per year. For the eastern half of the country, wet deposition values were derived from interpolated measured values from NADP (three-year average centered on 2002) and dry deposition values were derived from 12-km CMAQ model projections for 2002. For the western half of the country, both wet and dry deposition values were derived from 36-km CMAQ model projections for 2002. NADP interpolations were performed using the approach of Grimm and Lynch (1997). CMAQ model projections were provided by Robin Dennis, U.S. EPA.
- Map D. Total N deposition for the conterminous United States for the year 2002, expressed in units of kilograms of N deposited from the atmosphere to the Earth surface per hectare per year. Wet and dry forms of both oxidized (nitrogen oxides, NO<sub>x</sub>) and

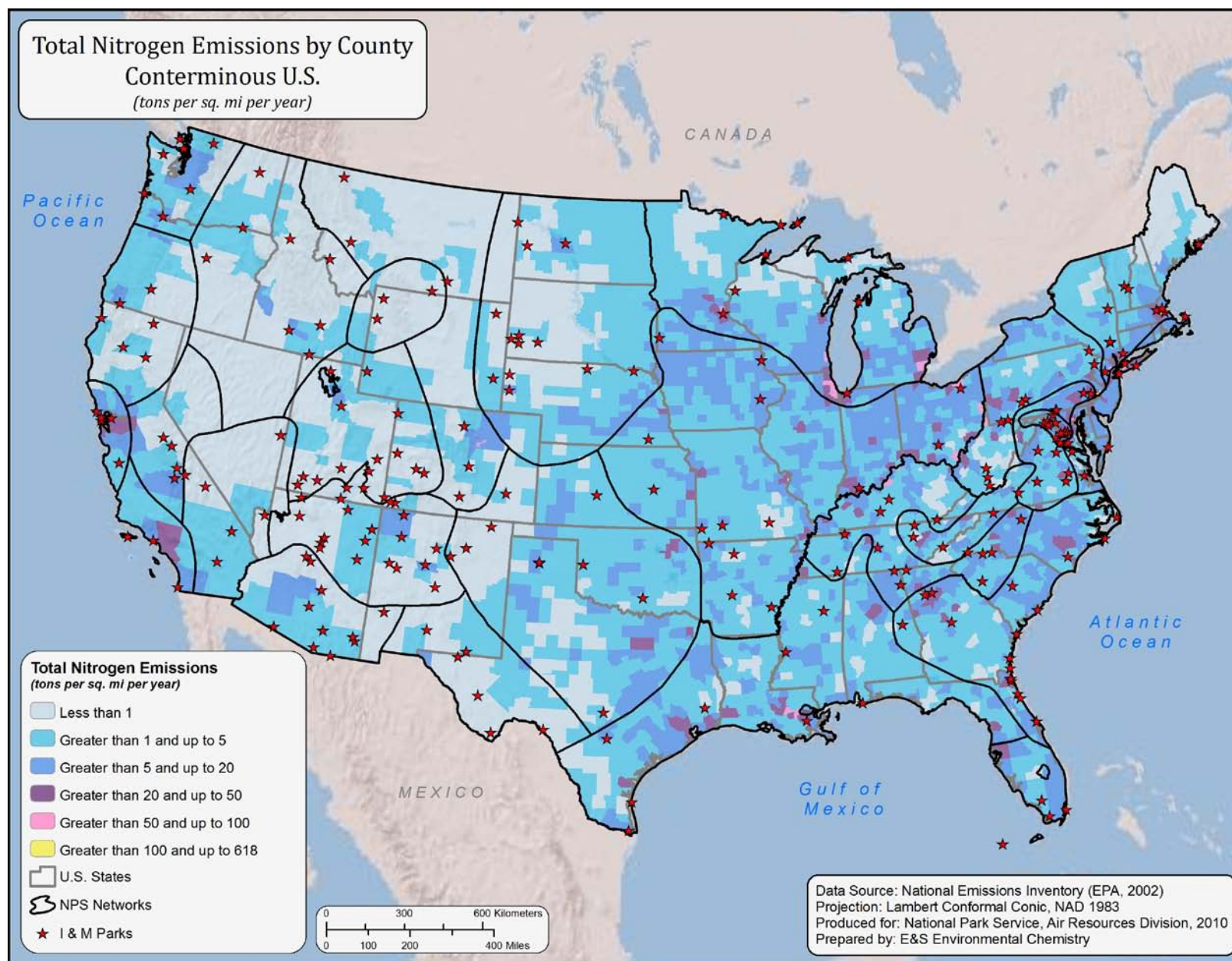
reduced (ammonia,  $\text{NH}_3$ ) N are included. For the eastern half of the country, wet deposition values were derived from interpolated measured values from NADP (three-year average centered on 2002) and dry deposition values were derived from 12-km CMAQ model projections for 2002. For the western half of the country, both wet and dry deposition values were derived from 36-km CMAQ model projections for 2002. NADP interpolations were performed using the approach of Grimm and Lynch (1997). CMAQ model projections were provided by Robin Dennis, U.S. EPA.

- Map E. Total S emissions by county for lands surrounding the network, expressed as tons of S emitted into the atmosphere per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map F. Total N emissions by county for lands surrounding the network, expressed as tons of N emitted into the atmosphere per square mile per year. The total includes both oxidized (nitrogen oxides,  $\text{NO}_x$ ) and reduced (ammonia,  $\text{NH}_3$ ) N. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map G. Major point source emissions of  $\text{SO}_2$  for lands surrounding the network. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map H. Major point source emissions of oxidized (nitrogen oxides,  $\text{NO}_x$ ) and reduced (ammonia,  $\text{NH}_3$ ) N in and around the network. The base of each vertical bar is positioned in the map at the approximate location of the source. The height of the bar is proportional to the magnitude of the source. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map I. Urban centers having more than 10,000 people within the network and within a 300-mile buffer around the perimeter of the network. (Source of data: U.S. Census 2000)
- Map J. Total S deposition in and around the network. Values are expressed as kilograms of S deposited per hectare per year. (Source of data: CMAQ Model wet and dry deposition data for 2002; see information for Map C above for details)
- Map K. Total N deposition in and around the network. Included in the total are wet plus dry forms of both oxidized (nitrogen oxides,  $\text{NO}_x$ ) and reduced (ammonia,  $\text{NH}_3$ ) N. Values are expressed as kilograms of N deposited per hectare per year. (Source of data: CMAQ Model wet and dry deposition data for 2002; see information for Map D above for details)
- Map L. Land cover types in and around the network, based on the National Land Cover dataset. (Source of data: National Land Cover Dataset, [http://www.mrlc.gov/nlcd\\_multizone\\_map.php](http://www.mrlc.gov/nlcd_multizone_map.php))

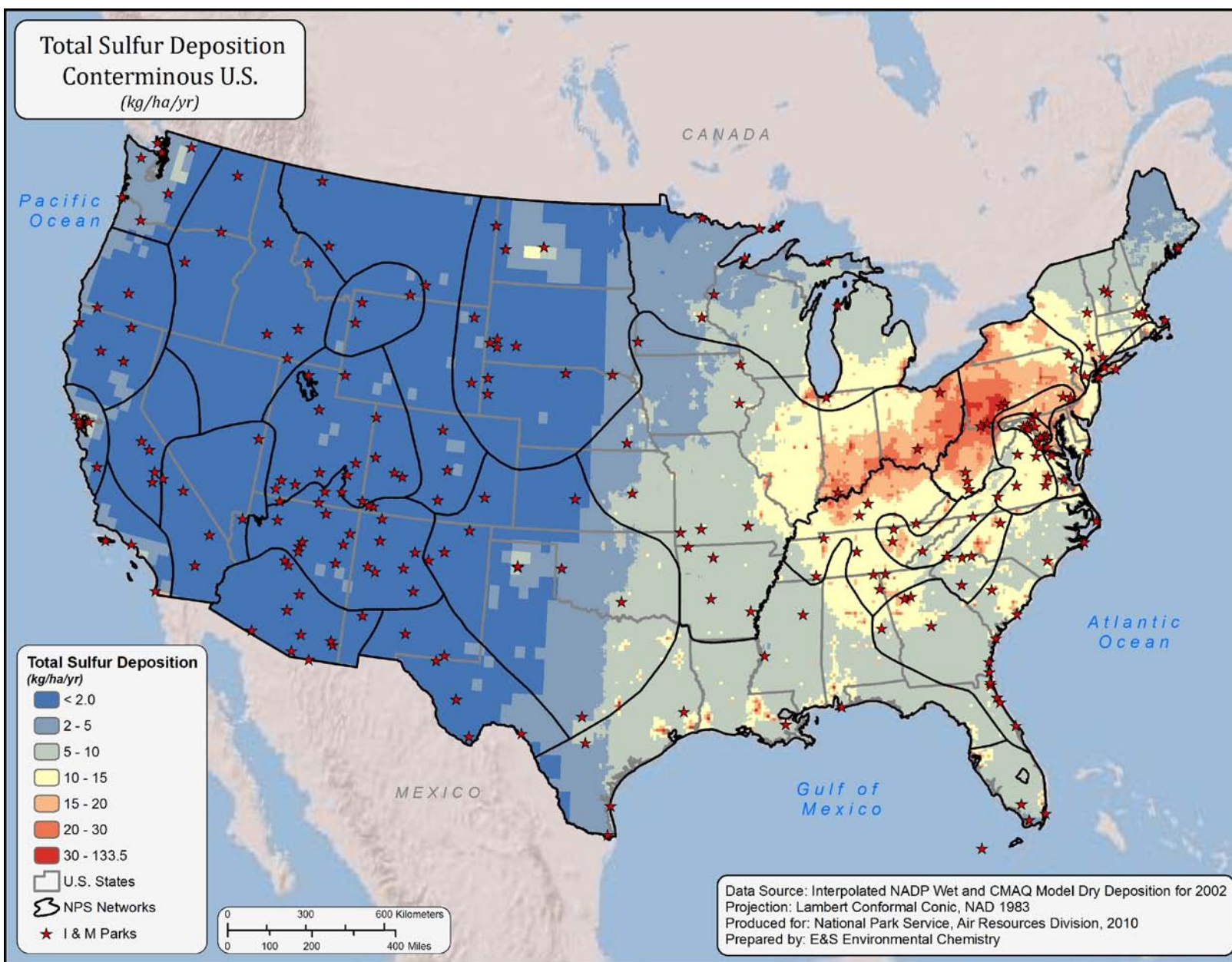
- Map M. Average land slope within park units that occur within the network, by 10-digit HUC. (Source of data: U.S. EPA National Elevation Dataset [<http://ned.usgs.gov/>])
- Map N. Lands within the network that are classified as Class I or wilderness area. (Source of data: USGS 2005 [National Atlas; <http://nationalatlas.gov>] and NPS)
- Figure A. Network rankings for Pollutant Exposure, calculated as the average of scores for all Pollutant Exposure variables.
- Figure B. Network rankings for Ecosystem Sensitivity, calculated as the average of scores for all Ecosystem Sensitivity variables.
- Figure C. Network rankings for Park Protection, calculated as the average of scores for all Park Protection variables.
- Figure D. Network Summary Risk rankings, calculated as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.
- Figure E. Park rankings for Pollutant Exposure for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Pollutant Exposure variables.
- Figure F. Park rankings for Ecosystem Sensitivity for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Ecosystem Sensitivity variables.
- Figure G. Park rankings for Park Protection for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Park Protection variables.
- Figure H. Park rankings for Summary Risk for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.



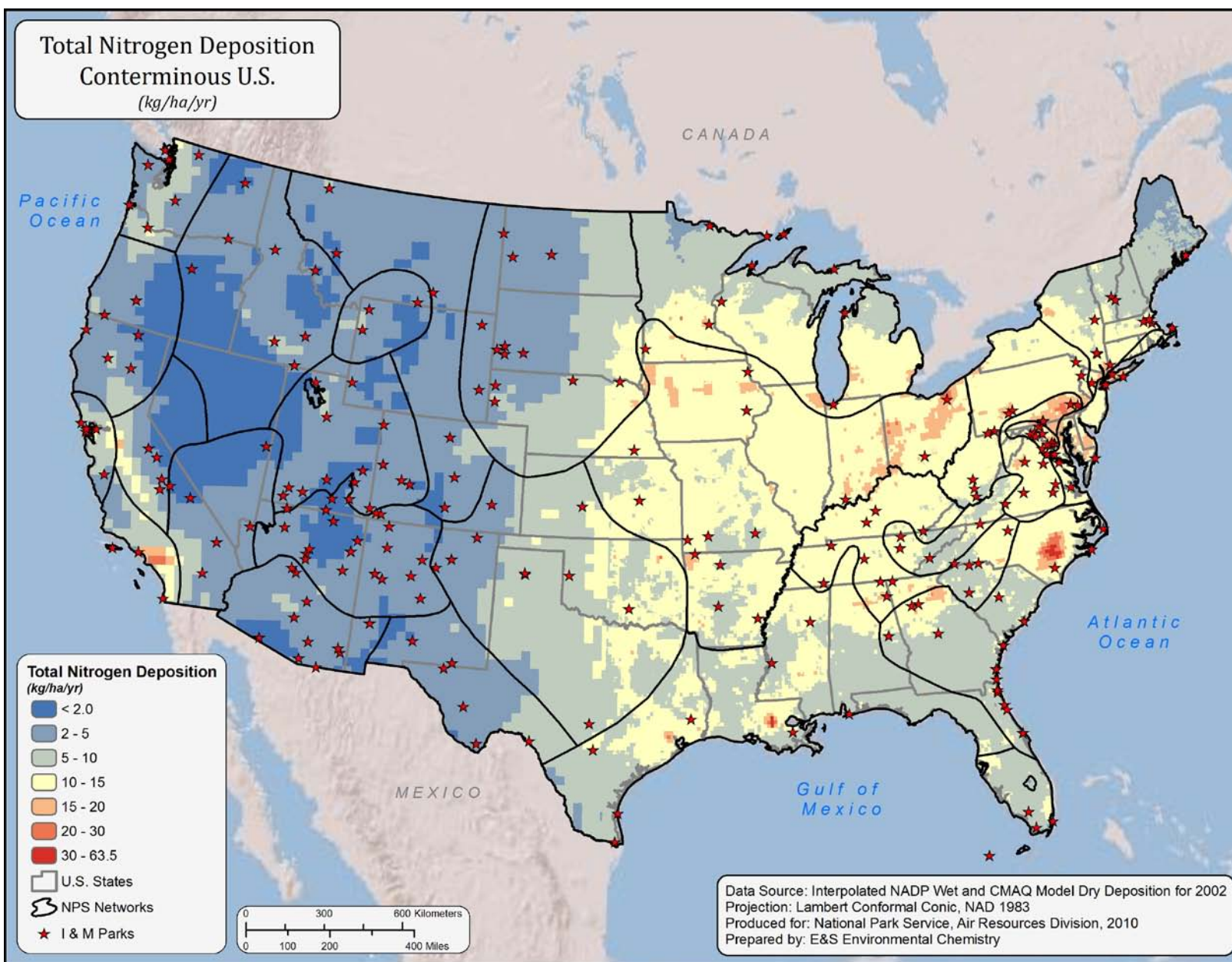
Map A



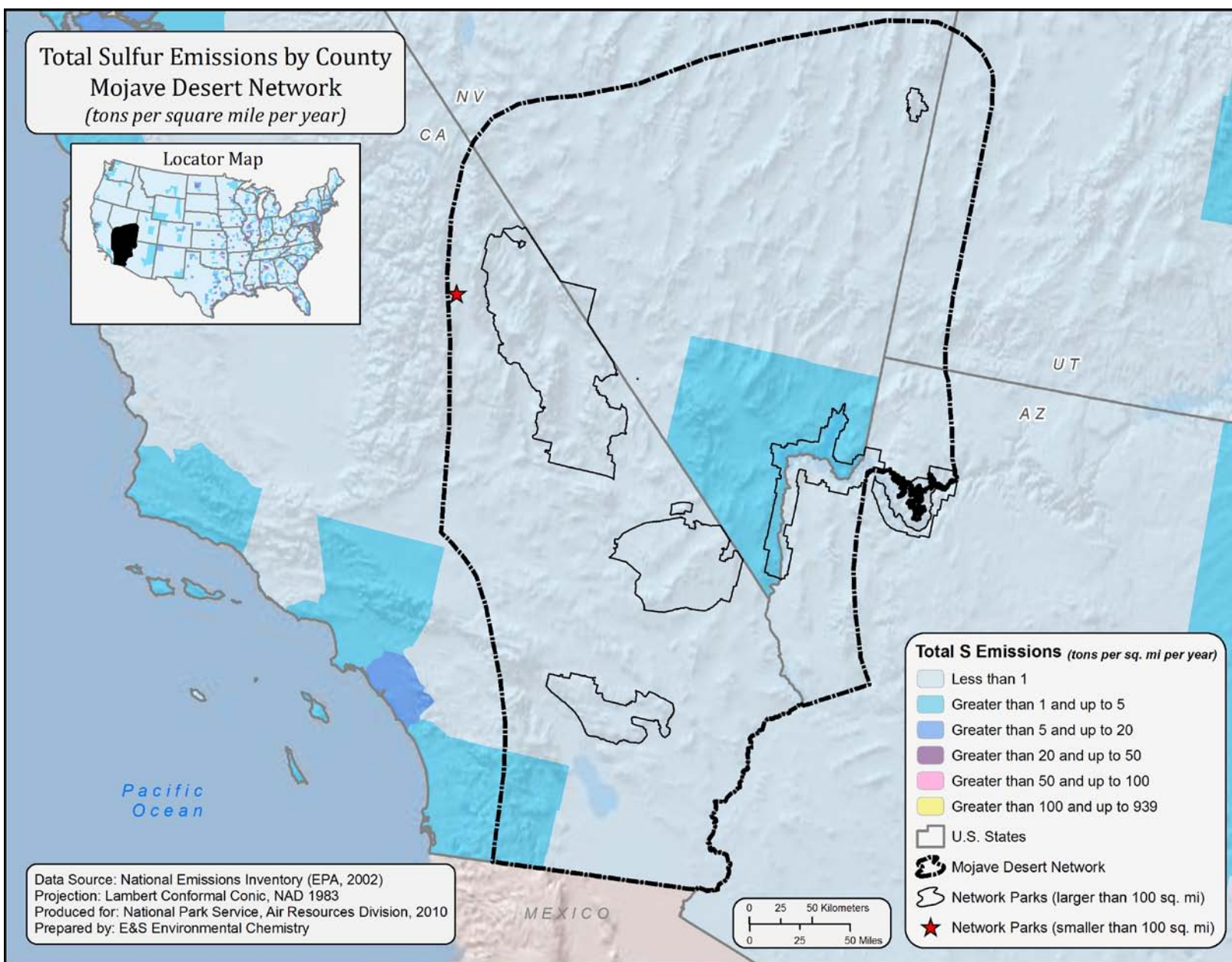
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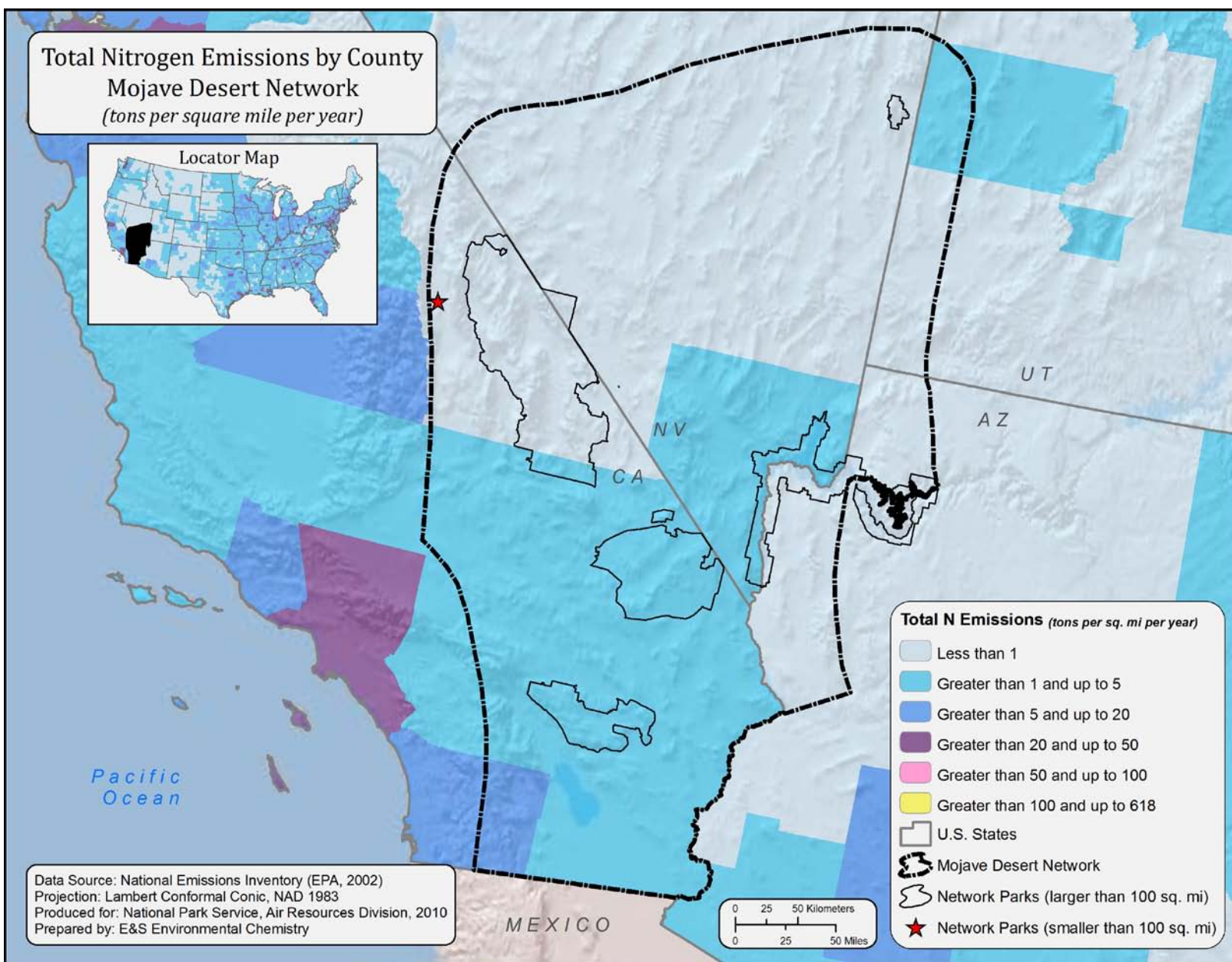
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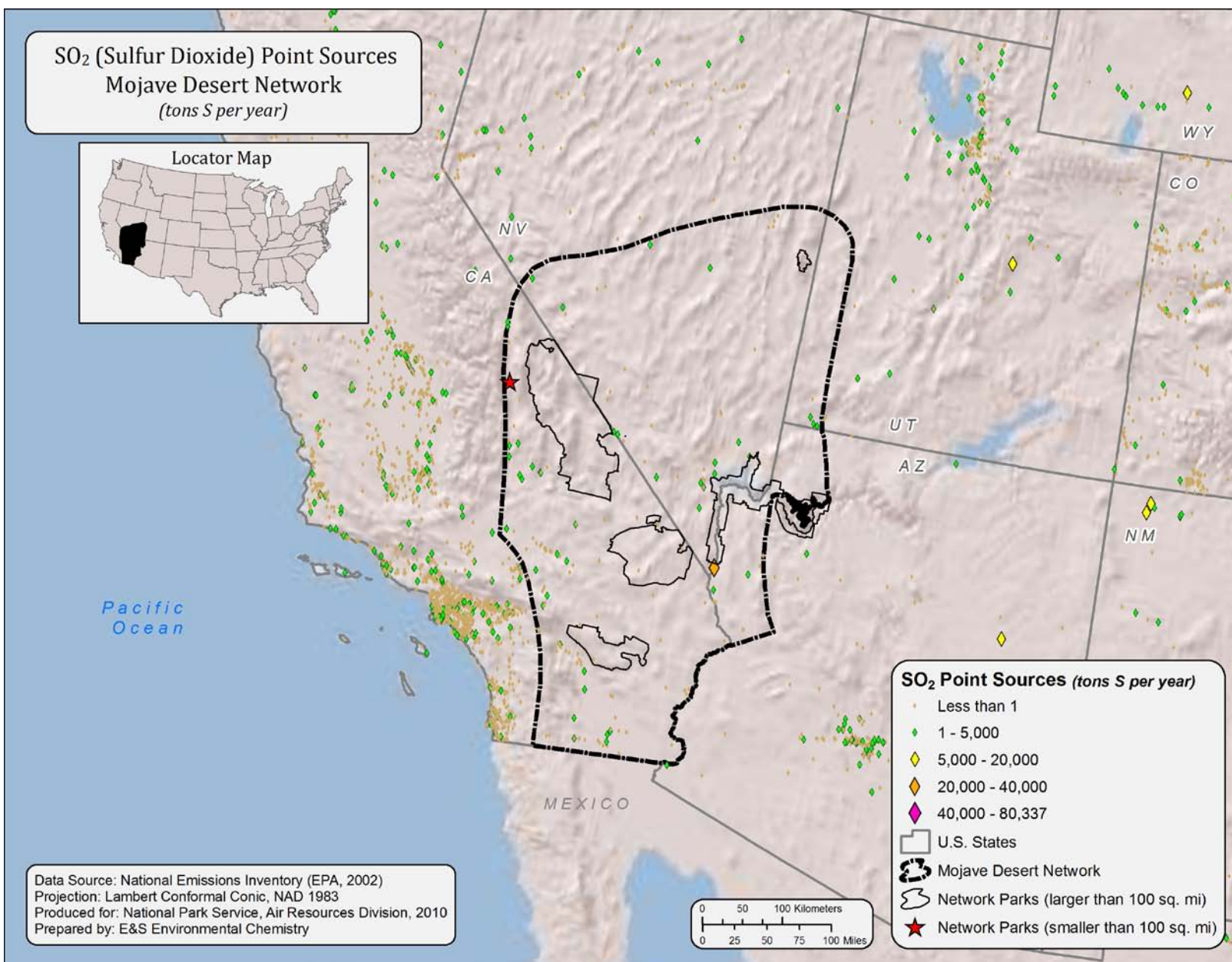
Map D



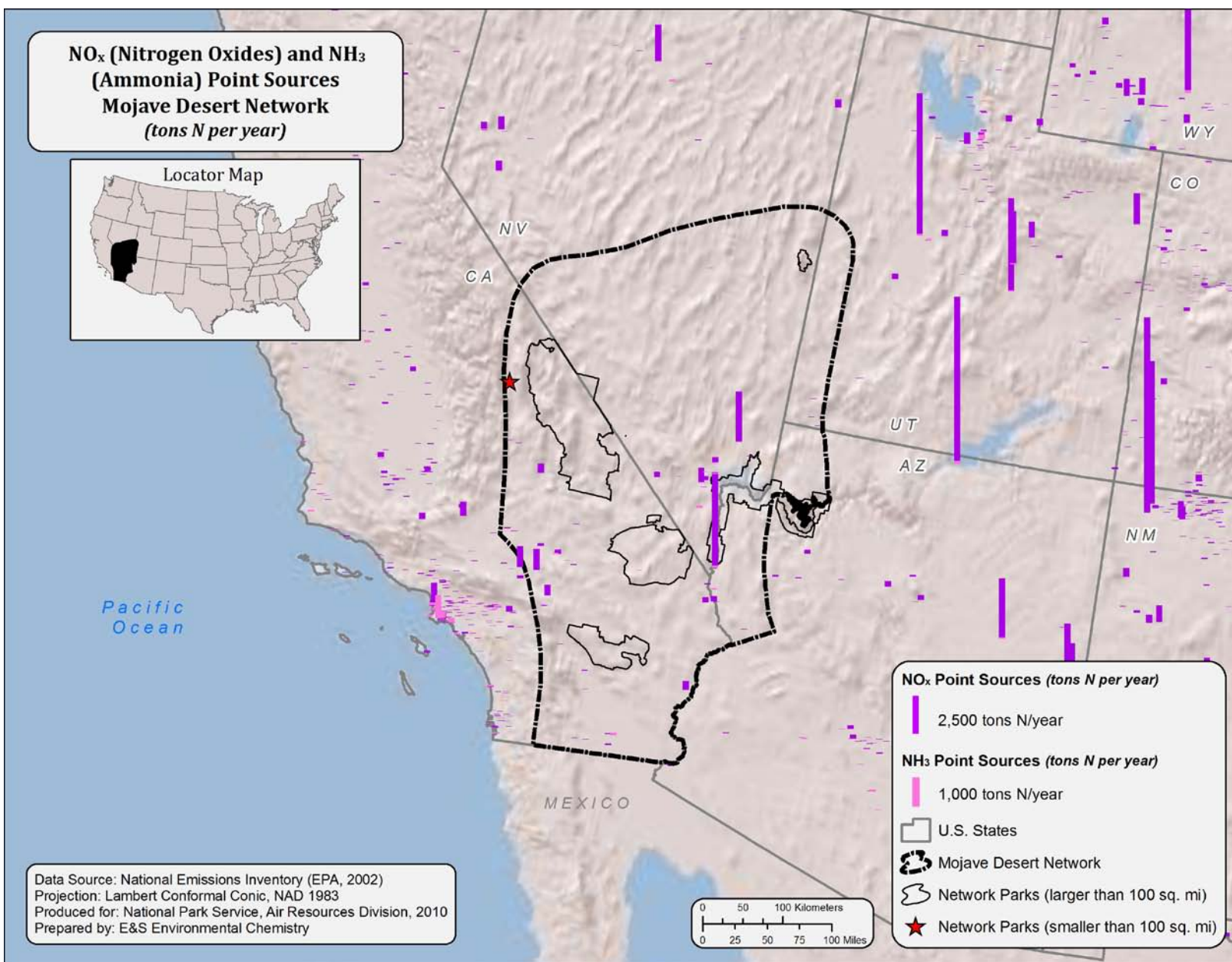
Map E



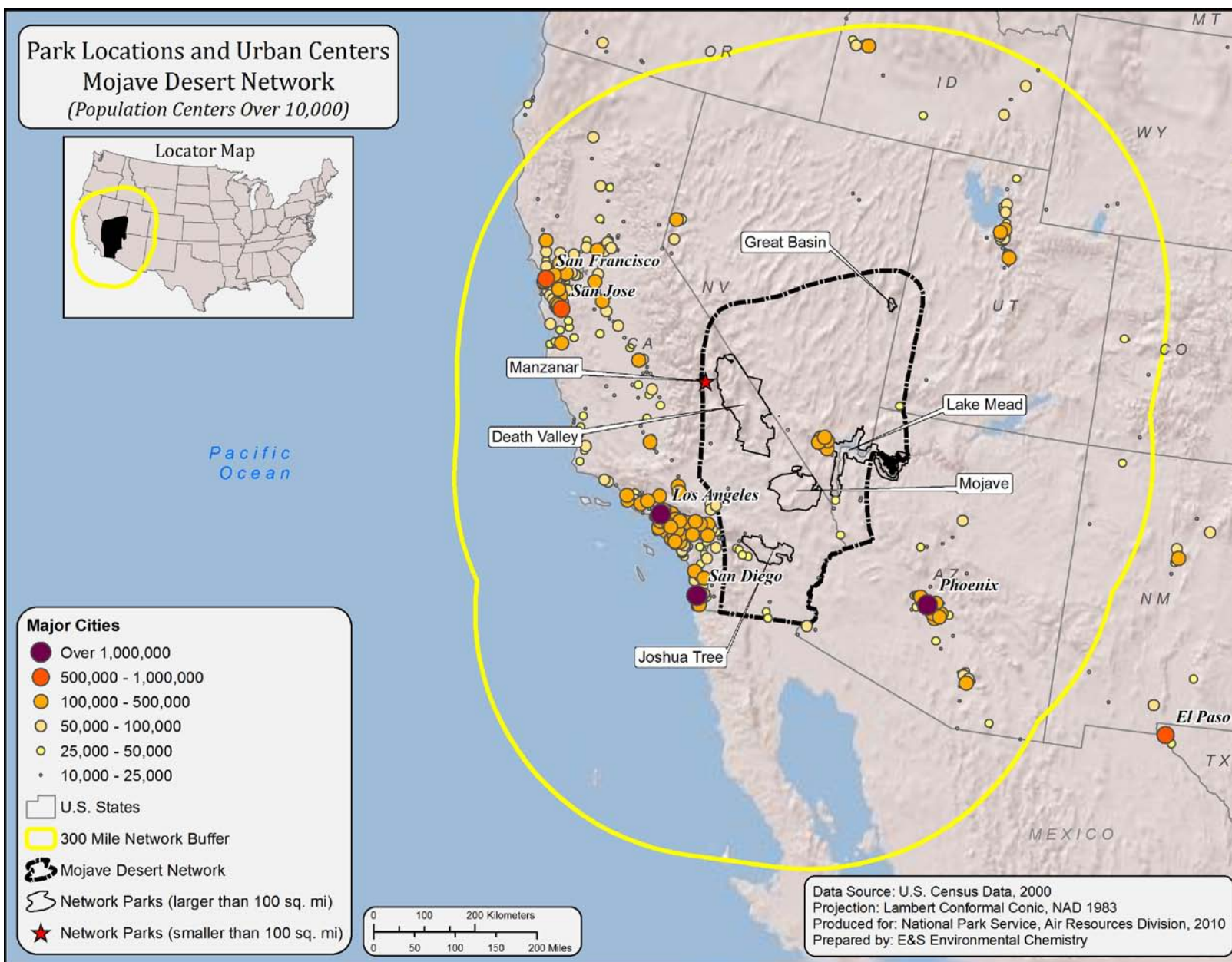
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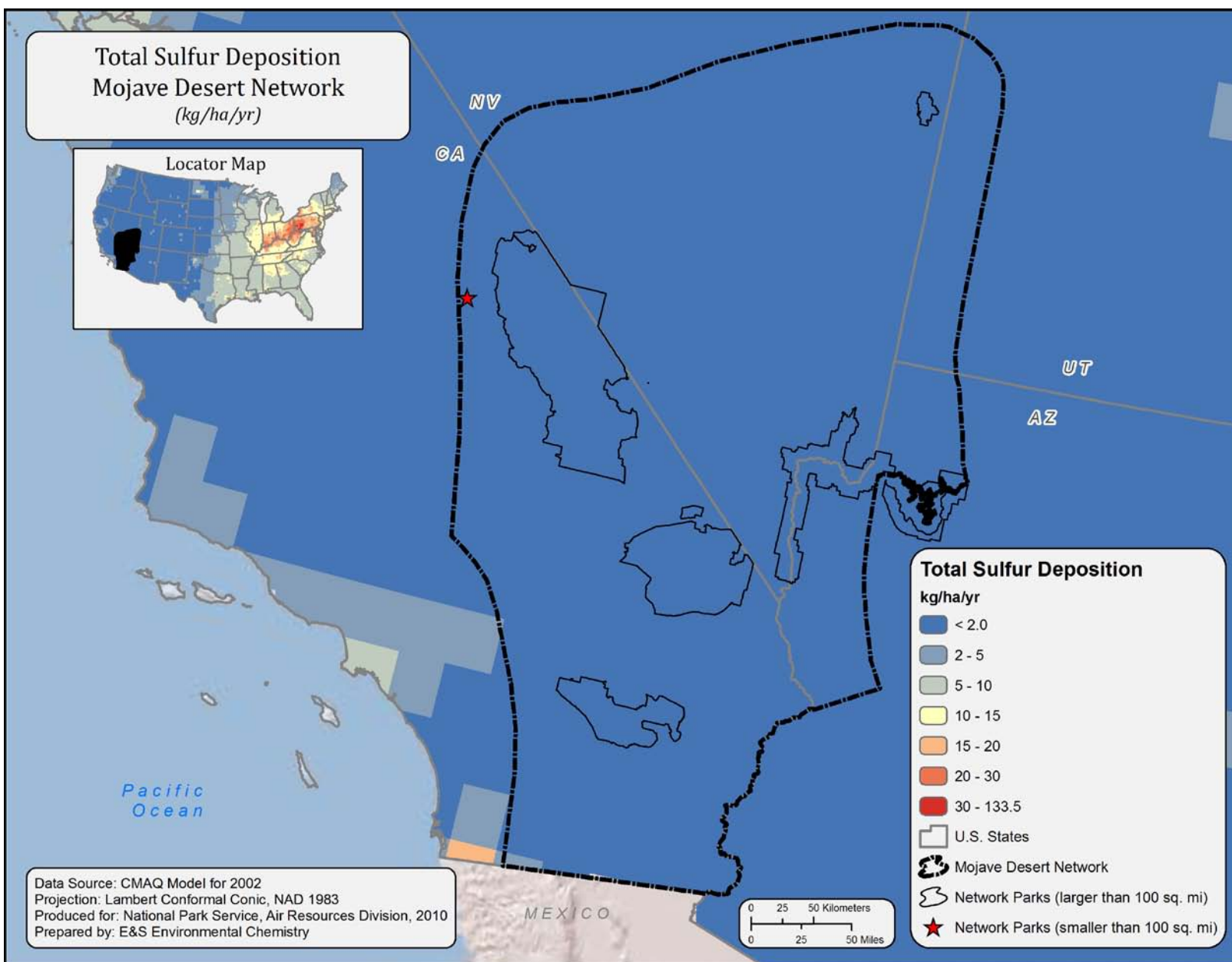
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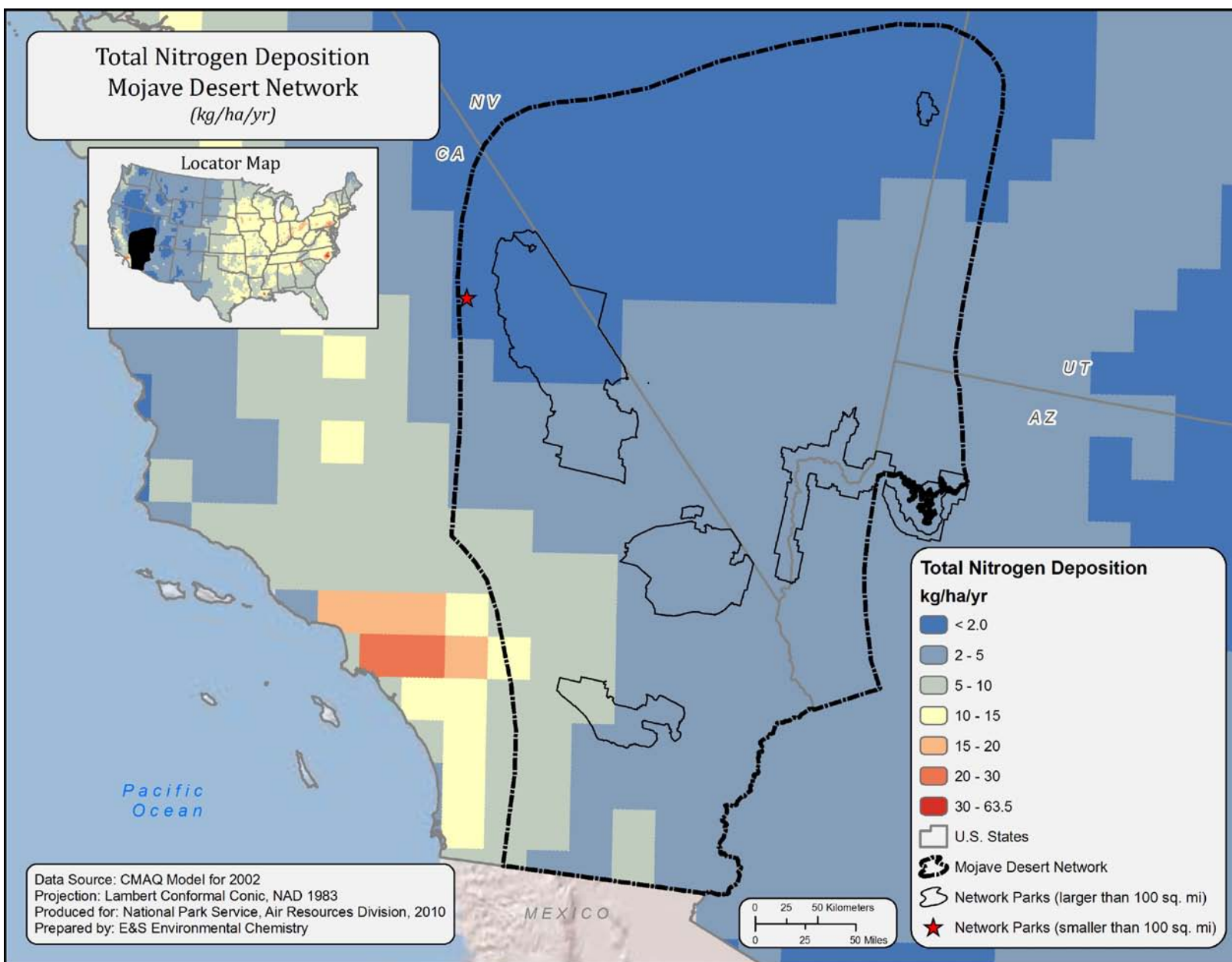
Map H



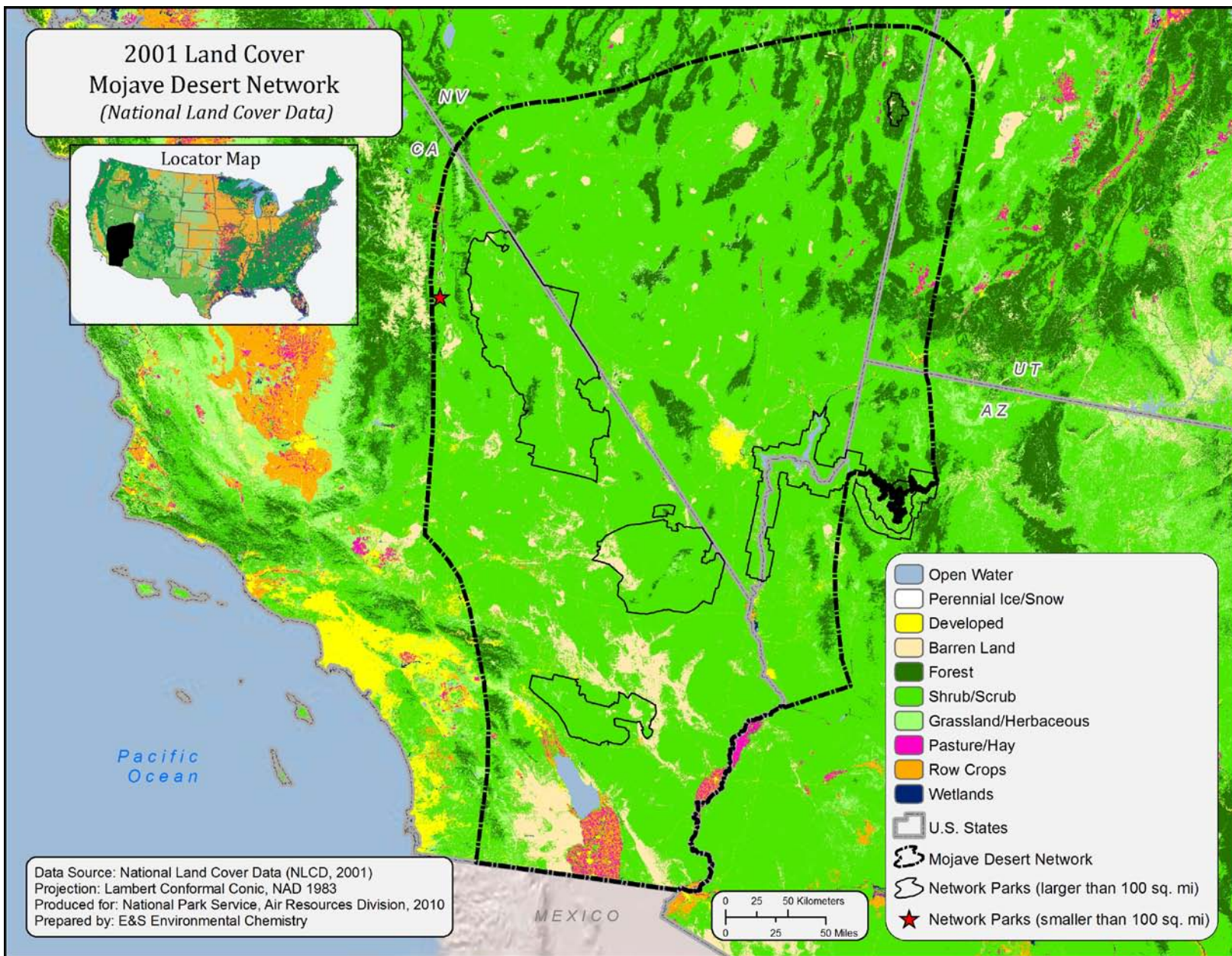
Map I



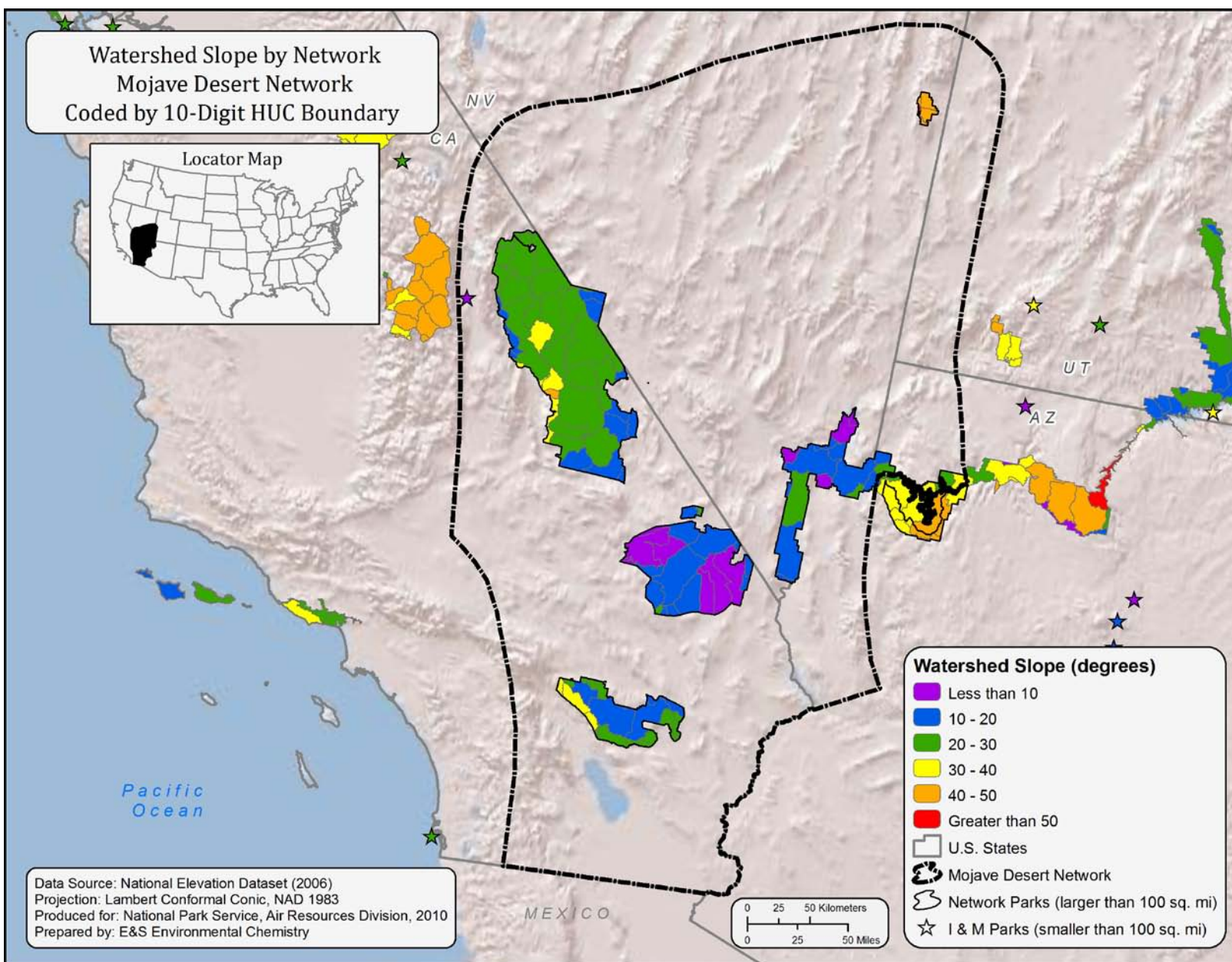
Map J



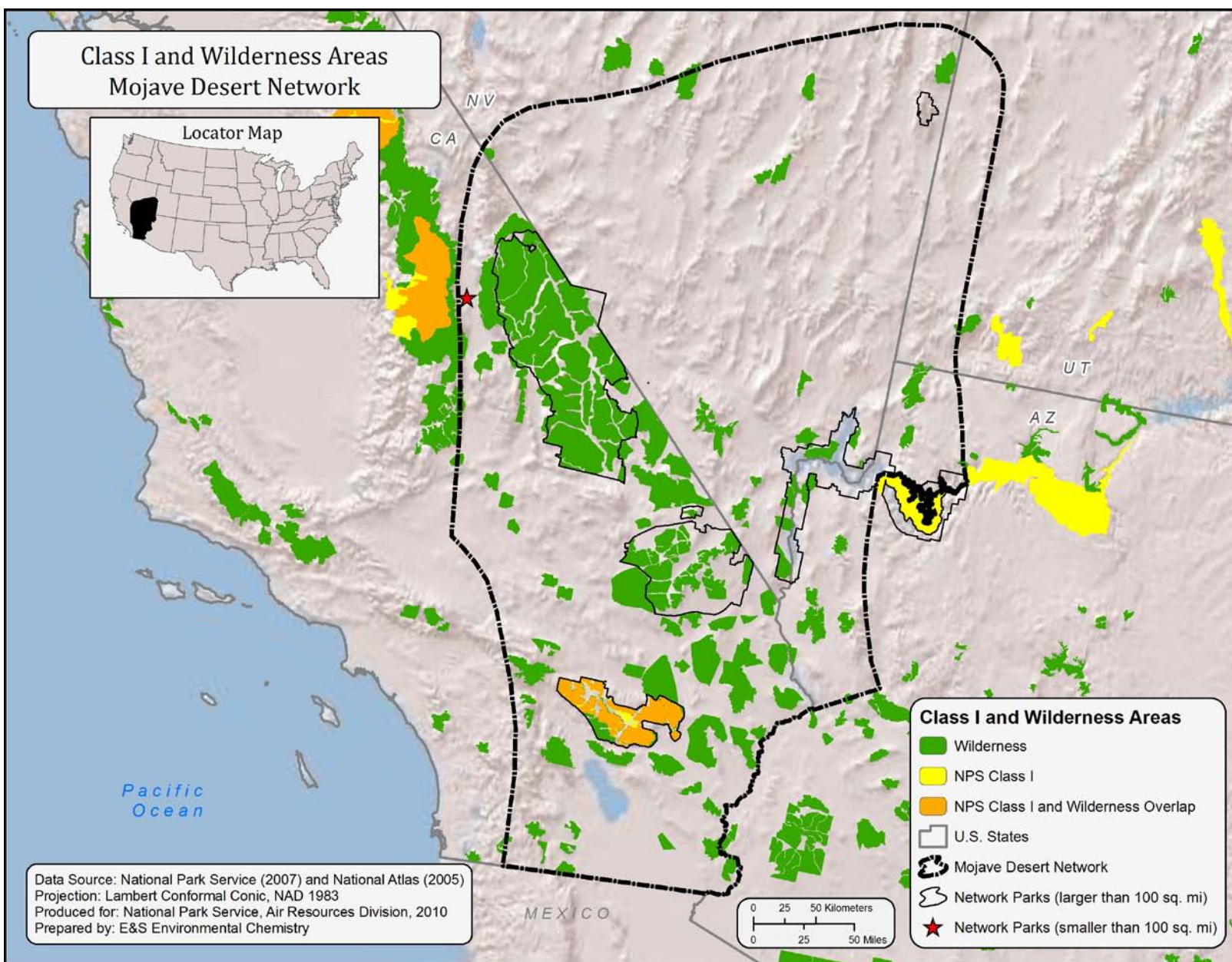
Map K



Map L



Map M



Map N

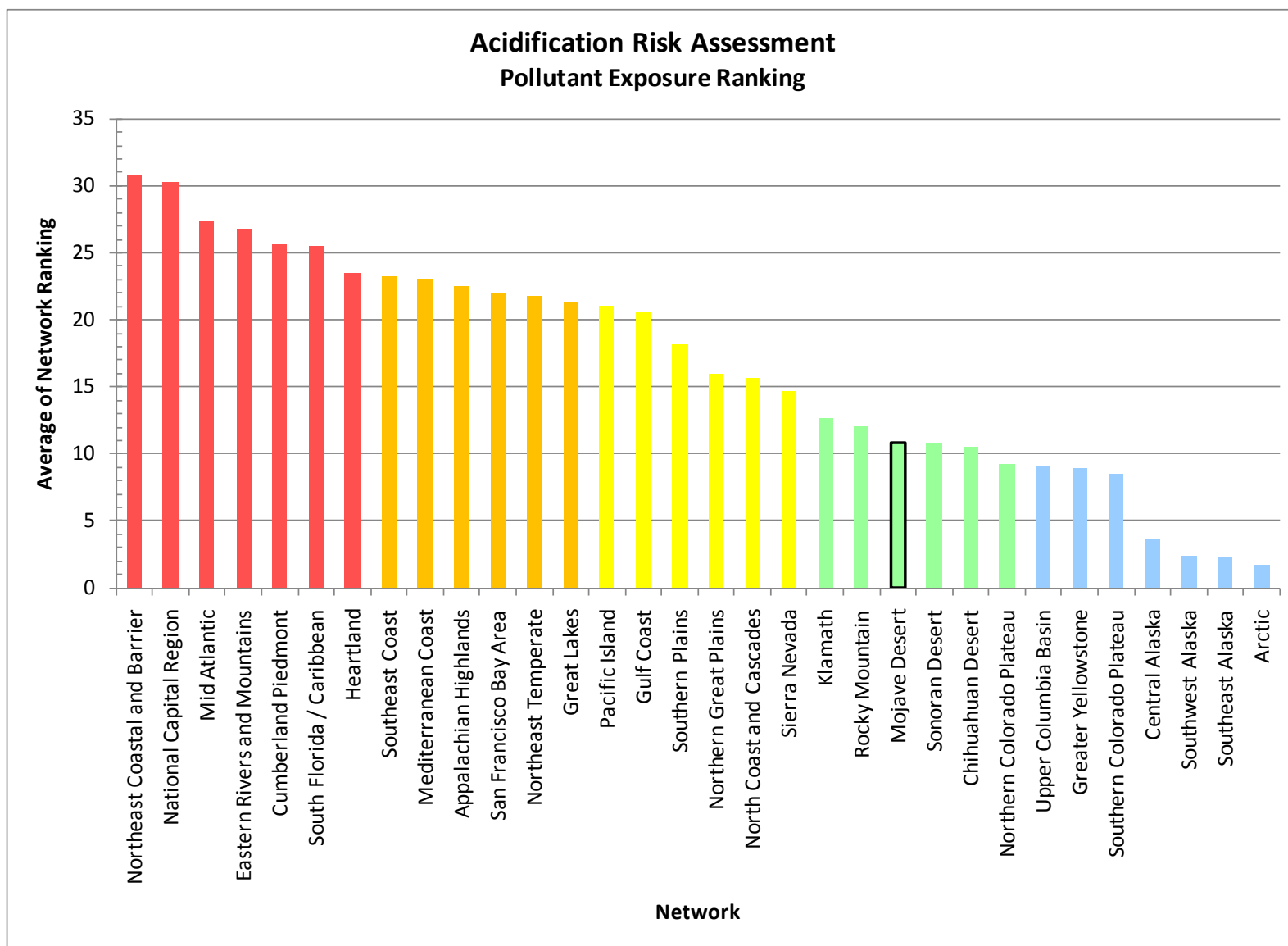


Figure A

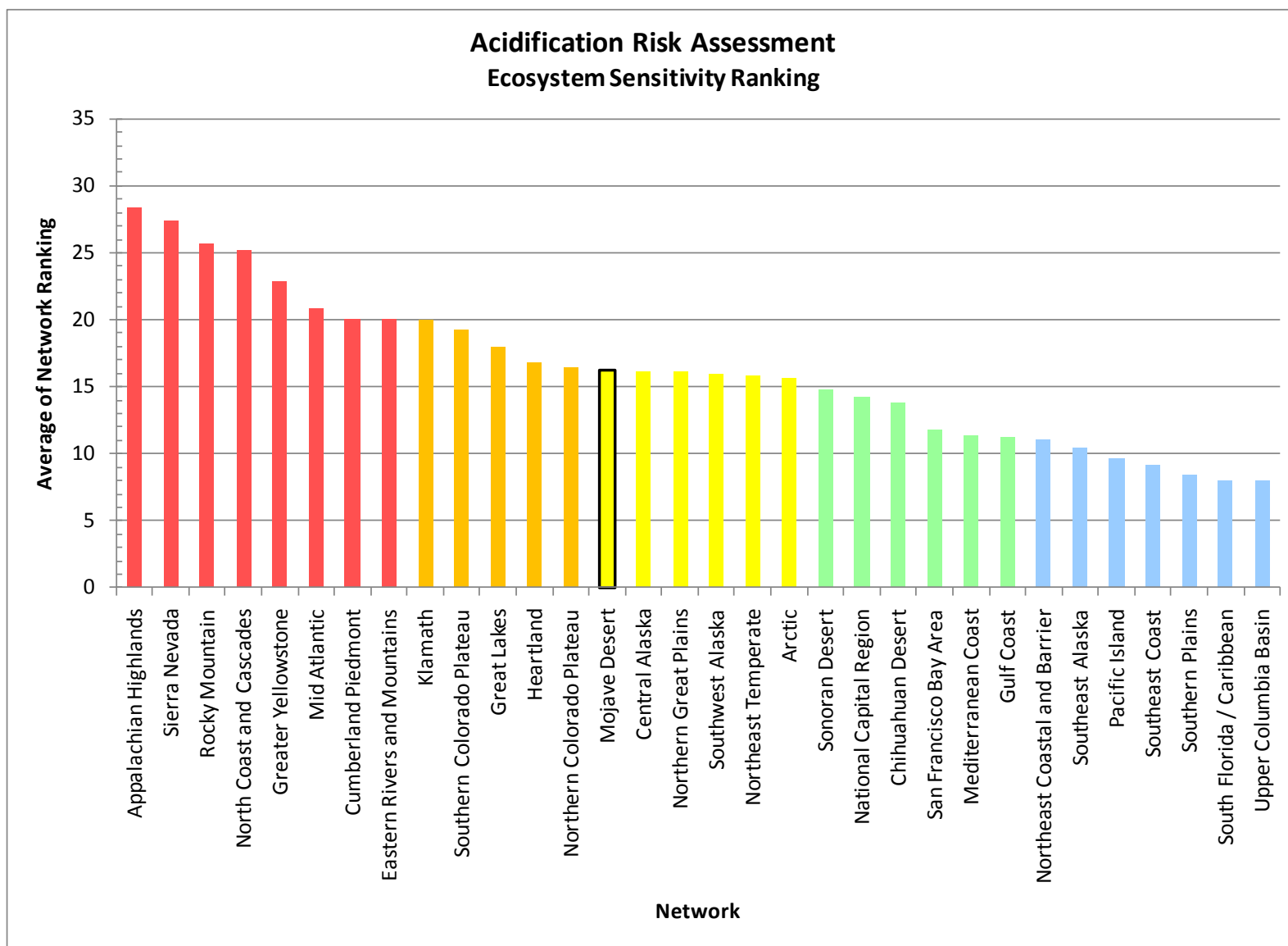


Figure B

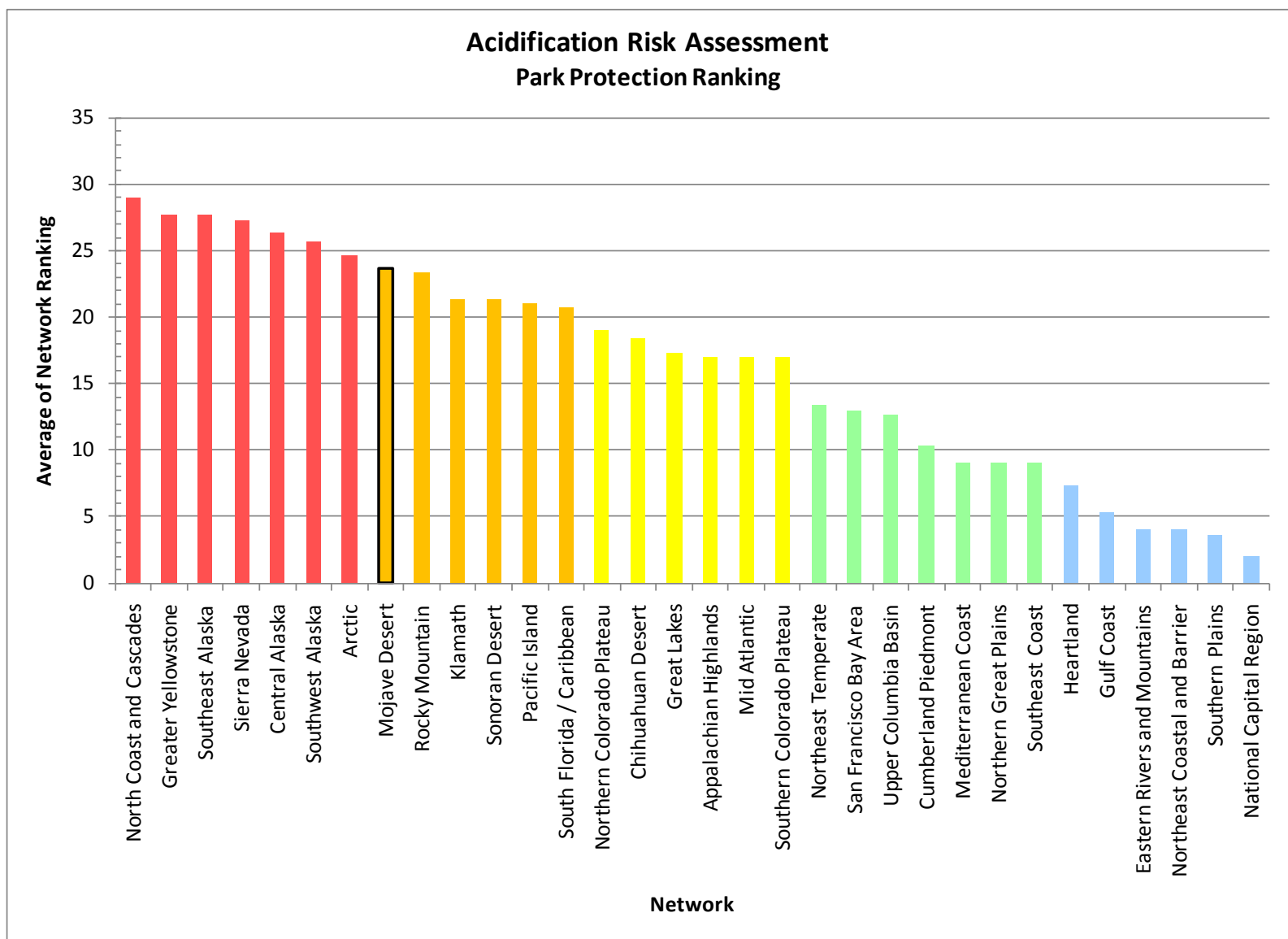


Figure C

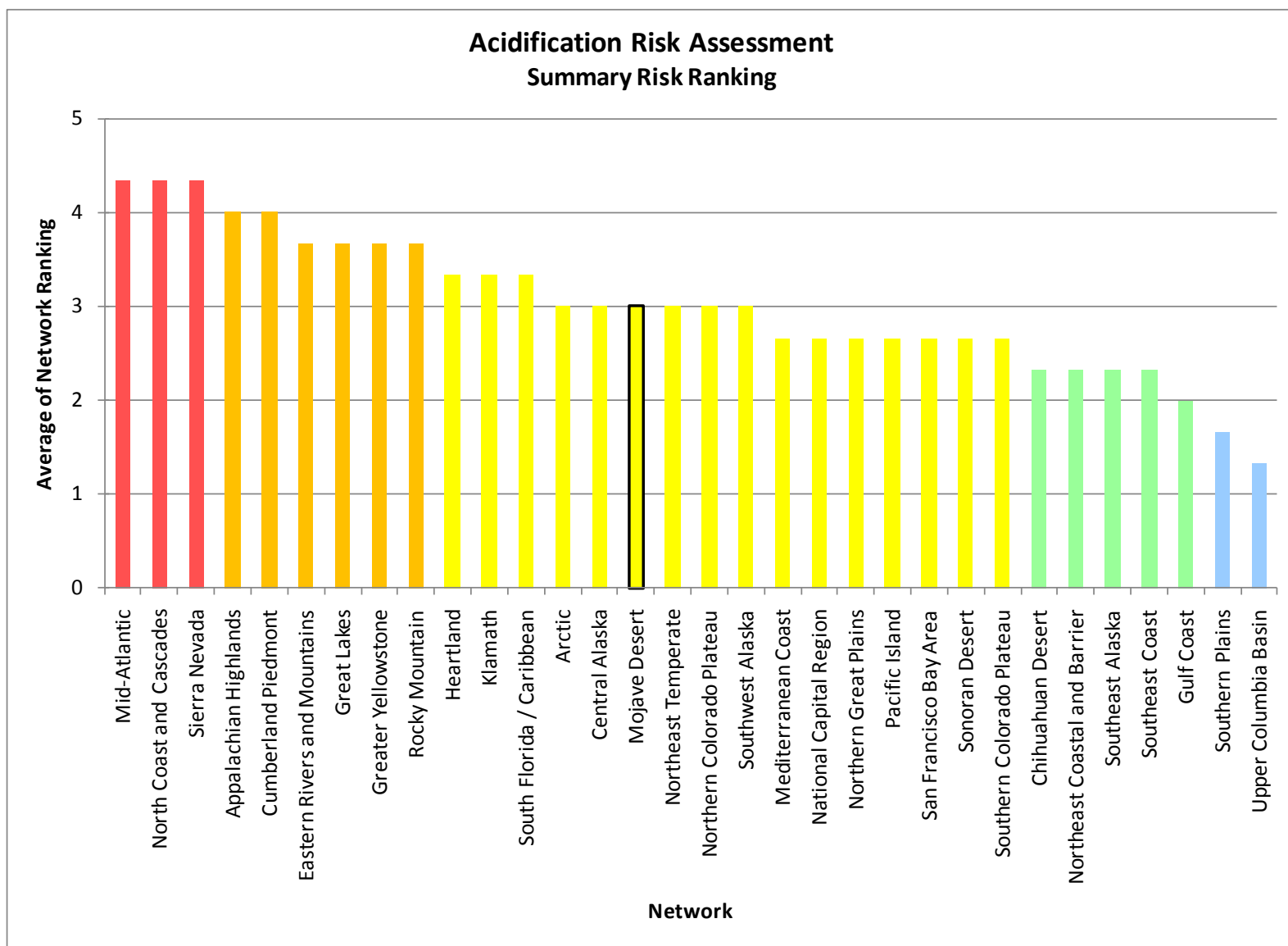


Figure D

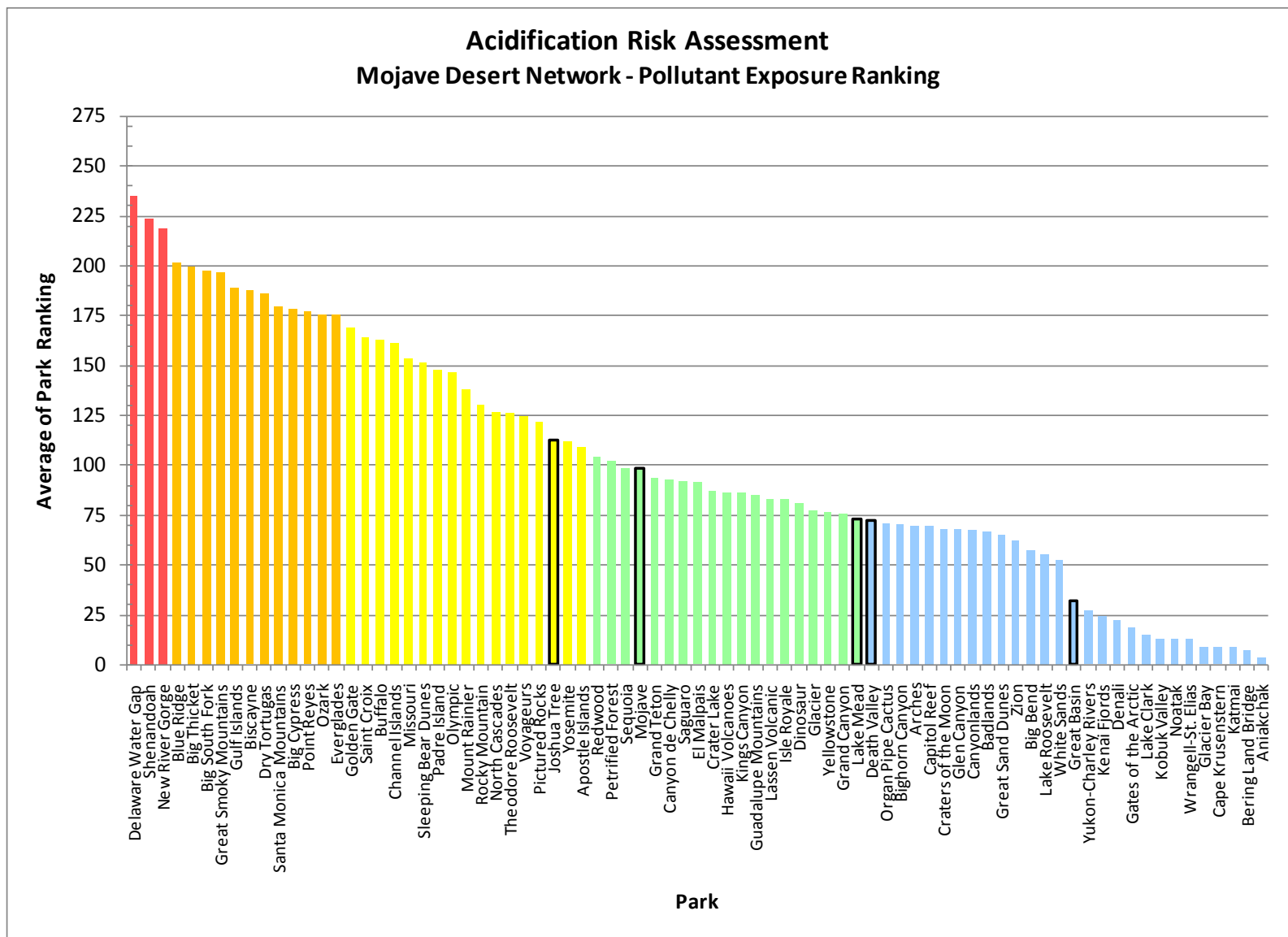


Figure E

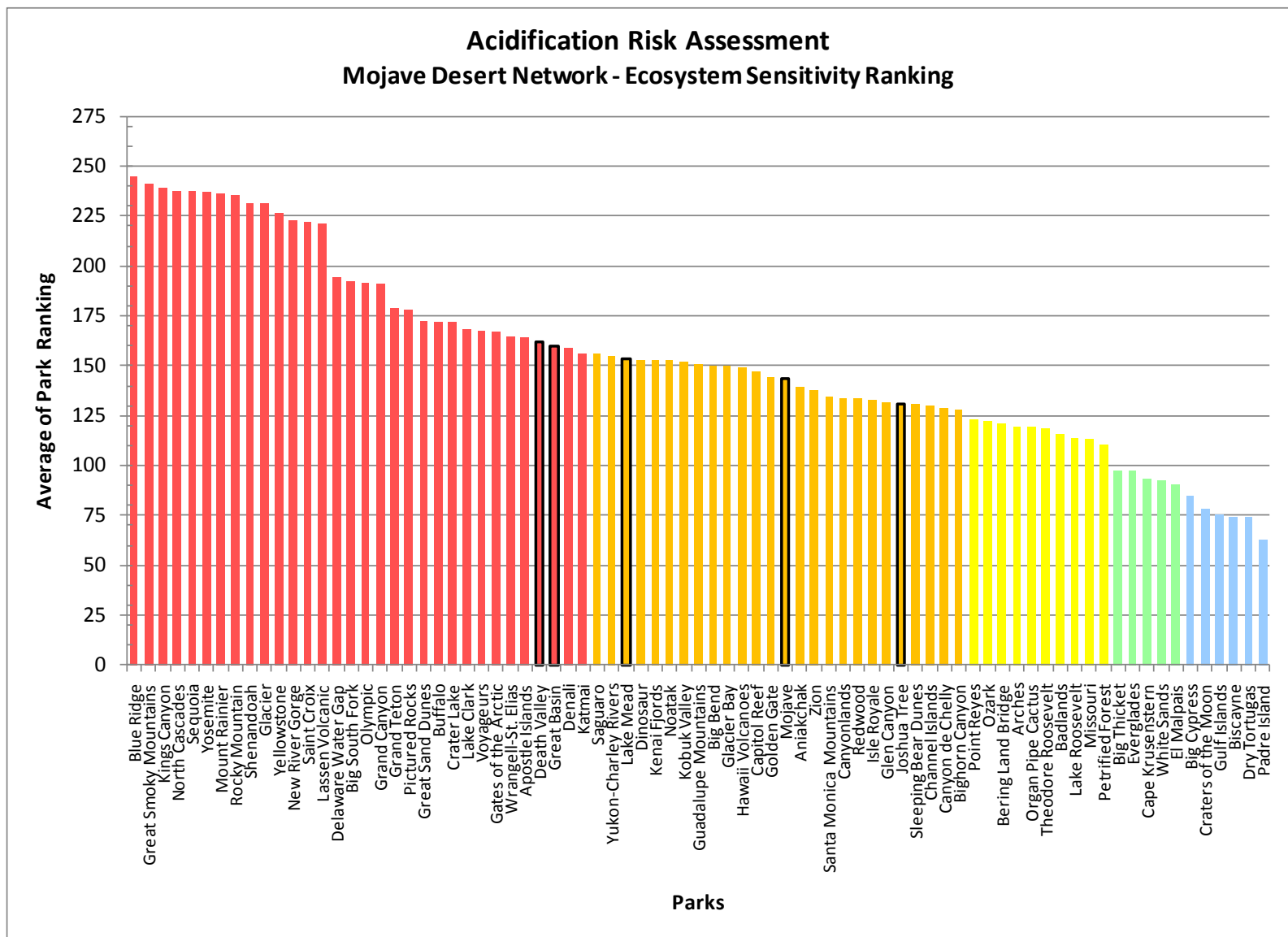


Figure F

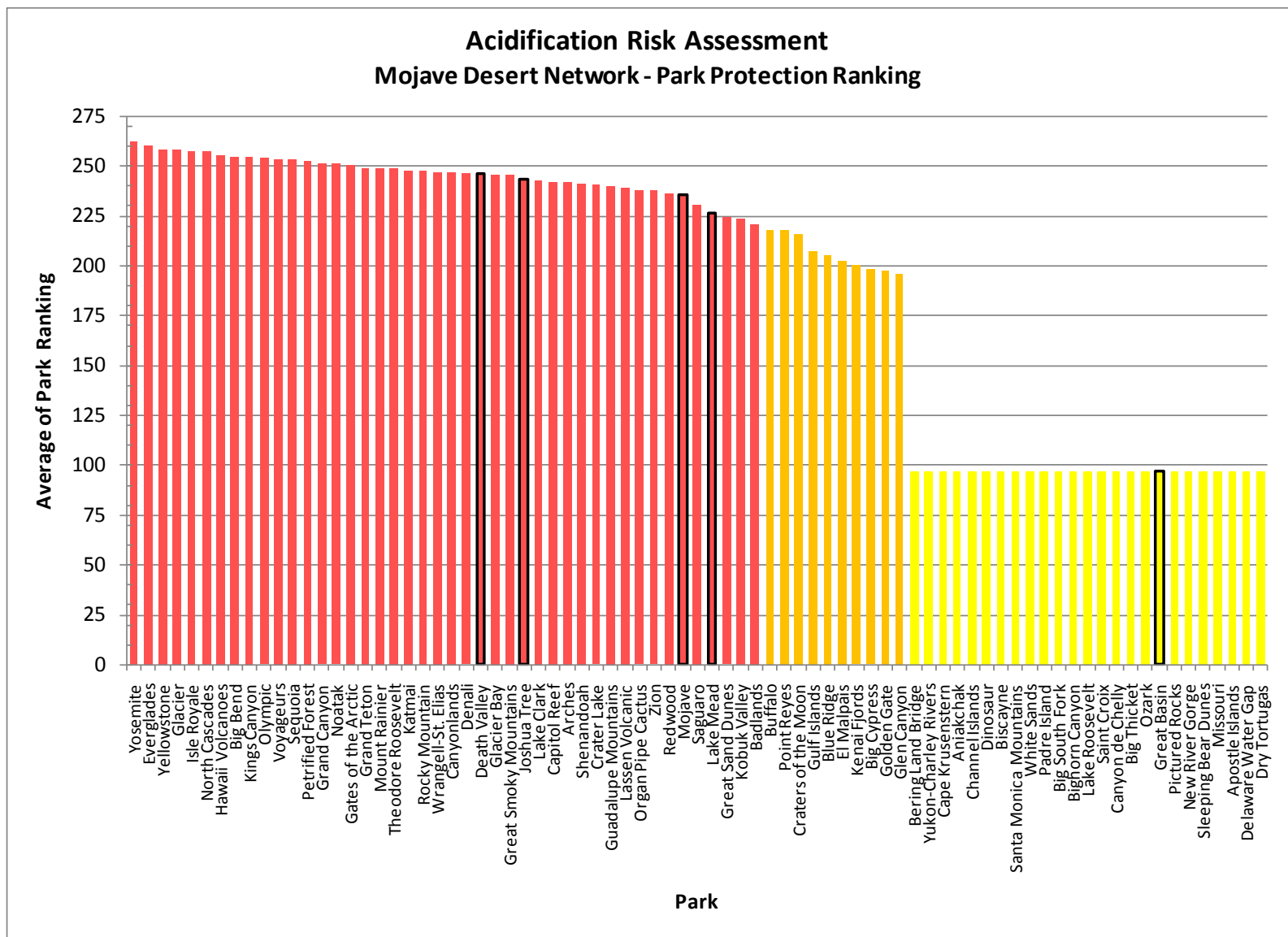


Figure G

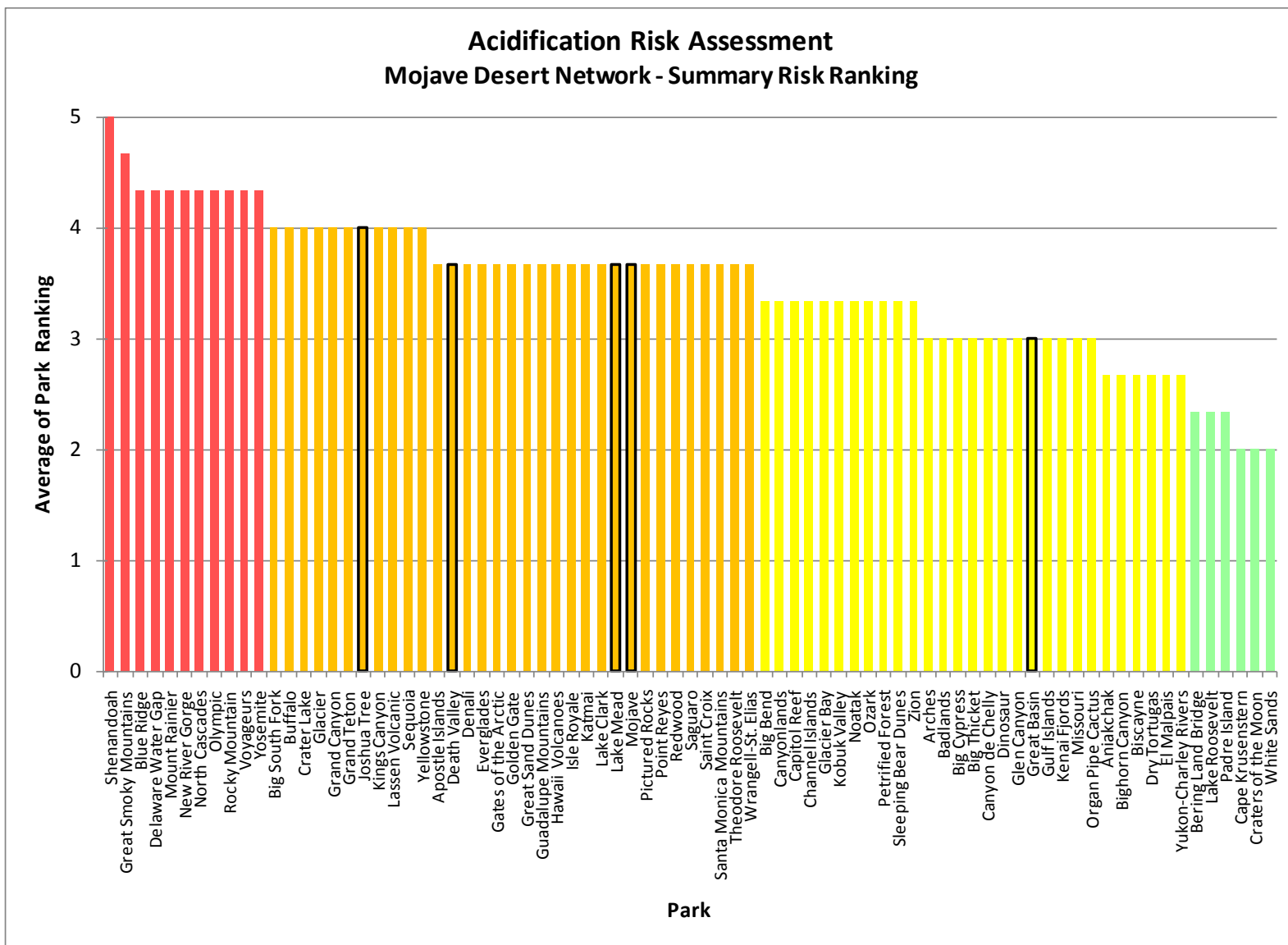


Figure H



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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**National Park Service**  
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