



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

Klamath Network (KLMN)

Natural Resource Report NPS/NRPC/ARD/NRR—2011/360



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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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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Klamath Network (KLMN)

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.

The Klamath Network contains three parks larger than 100 square miles: Crater Lake (CRLA), Lassen Volcanic (LAVO), and Redwood (REDW). There are also three smaller parks: Lava Beds (LBE), Oregon Caves (ORCA), and Whiskeytown (WHIS).

Total annual S and N emissions, by county, are shown in Maps E and F, respectively, for lands in and surrounding the Klamath Network. County-level S emissions within the network were generally less than 1 ton per square mile per year, with two counties in or partially in the network having emissions levels in the range 1 to 5 tons per square mile (Map E). 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 (Map F). In general, annual county N emissions were less than 5 tons per square mile throughout most of the network. Individual point source emissions of S are displayed on Map G. There were no SO₂ point sources of any magnitude within the network; all documented SO₂ point source emissions were less than 5,000 tons of S per year (Map G). The majority of these were located in the Central Valley of California, in the southern half of the network. Point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) N are shown in Map H. There are no large N point sources in this network.

Urban centers within the network and within a 300-mile buffer around the network are shown in Map I. There are no population centers in this network larger than 500,000 people, and only two larger than 100,000 people. However, within the 300-mile buffer around the network boundary are San Francisco and San Jose to the south, and Portland and Seattle to the north, all of which have populations over 500,000.

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 S and N deposition and both the oxidized and reduced N species. Total S deposition throughout most of the network was less than 2 kg S/ha/yr. Some portions of the network, mainly along the coastline, had S deposition values in the range of 2 to 5 kg S/ha/yr (Map J). Total S deposition values in and around LAVO and CRLA were less than 2 kg S/ha/yr. The northern portions of REDW had estimated S deposition in the range of 2 to 5 kg S/ha/yr. Total N deposition within the network ranged from less than 2 kg N/ha/yr in the east to as high as 5 to 10 kg N/ha/yr at scattered locations (Map K). Total N deposition was below 5 kg N/ha/yr throughout most of the network, including the locations of most of the national parks.

Land cover in and around the network is shown in Map L. The predominant cover type within this network is forest. There are also substantial areas of shrub/scrub in the east, pasture/hay in the north, and row crops in the south. The national parks are largely forested.

Land slope of most park lands within the network, shown on Map M, tends to be moderate to steep. Average slope in CRLA and LAVO ranges from 10° to 40°. REDW and WHIS are

predominately in the 30° to 40° range, and average slope in ORCA exceeds that, reaching slopes up to 40° to 50°. LAVE has very low relief, with slopes less than 10° throughout the park.

Park lands requiring special protection against potential adverse impacts associated with acidification from atmospheric S and N 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. The three large parks in the network are designated as Class I. There are also many wilderness areas, one of which (in LAVO) is managed by NPS.

High-elevation lakes and streams in CRLA and LAVO are shown at the park scale on Maps P-1 and P-2, respectively. High elevation lakes may be more prone to acidification than lower elevation lakes, and therefore are considered potentially more susceptible to atmospheric S and N input. CRLA only contains one high-elevation lake, Crater Lake (Map P-1), whereas LAVO contains numerous high-elevation lakes (Map P-2). Both parks contain a moderate length of streams considered to be at high elevation and all are first through third order (Maps P-3 and P-4). These low-order, high-elevation streams on steep terrain are often particularly sensitive to acidification impacts from both S and N deposition.

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 Klamath Network ranked at the top of the second lowest quintile among networks in Pollutant Exposure (Figure A). Sulfur and N emissions and acidic deposition within the network were low to moderate. However, the network Ecosystem Sensitivity ranking was High compared with other networks, at the top of the second highest quintile (Figure B). This was because there are high-elevation lakes and streams in some of the I&M parks that occur in this network (mainly LAVO), all the streams in LAVO and CRLA are low-order, and the park lands within this network contain moderately steep slopes. This network ranked in 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 Summary Risk ranking that is moderate 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.

Table A. Relative rankings of individual I&M parks within the network for Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and overall Summary Risk from acidic deposition.

I&M Parks ² in Network	Relative Ranking of Individual Parks ¹			
	Pollutant Exposure	Ecosystem Sensitivity	Park Protection	Summary Risk
Crater Lake	Low	Very High	Very High	High
Lassen Volcanic	Low	Very High	Very High	High
Lava Beds	Very Low	Very Low	Very High	Low
Oregon Caves	Low	Low	Moderate	Low
Redwood	Low	High	Very High	High
Whiskeytown	Low	High	Moderate	Moderate

¹ 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).

² Park name is printed in bold italic for parks larger than 100 square miles.

The three parks in the Klamath Network that are larger than 100 square miles all ranked Low, in the second lowest quintile, in Pollutant Exposure (Figure E). The smaller parks had Pollutant Exposure rankings ranging from Very Low (LAVE) to Low (ORCA, WHIS; Table A). Ecosystem Sensitivity was more variable, with CRLA and LAVO ranking in the highest quintile and REDW and WHIS in the second highest quintile (High), but ORCA ranking in the second lowest quintile (Low) and LAVE ranking in the lowest quintile (Very Low; Table A). Among-park differences in Ecosystem Sensitivity were due to differing slopes and to the presence of high-elevation lakes and streams throughout some of the park lands. LAVO has a large number of high-elevation lakes (37). Crater Lake itself, within CRLA, is a high-elevation lake. The three larger parks and LAVE all ranked Very High for Park Protection; the other two parks ranked Moderate for this theme (Figure G, Table A).

The Summary Risk ranking was High for the three large parks (CRLA, LAVO, and REDW; Figure H). Among the smaller parks, the overall Summary Risk was Low for LAVE and ORCA and Moderate for WHIS (Table A).

- 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_x) and reduced (ammonia, NH₃) 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.

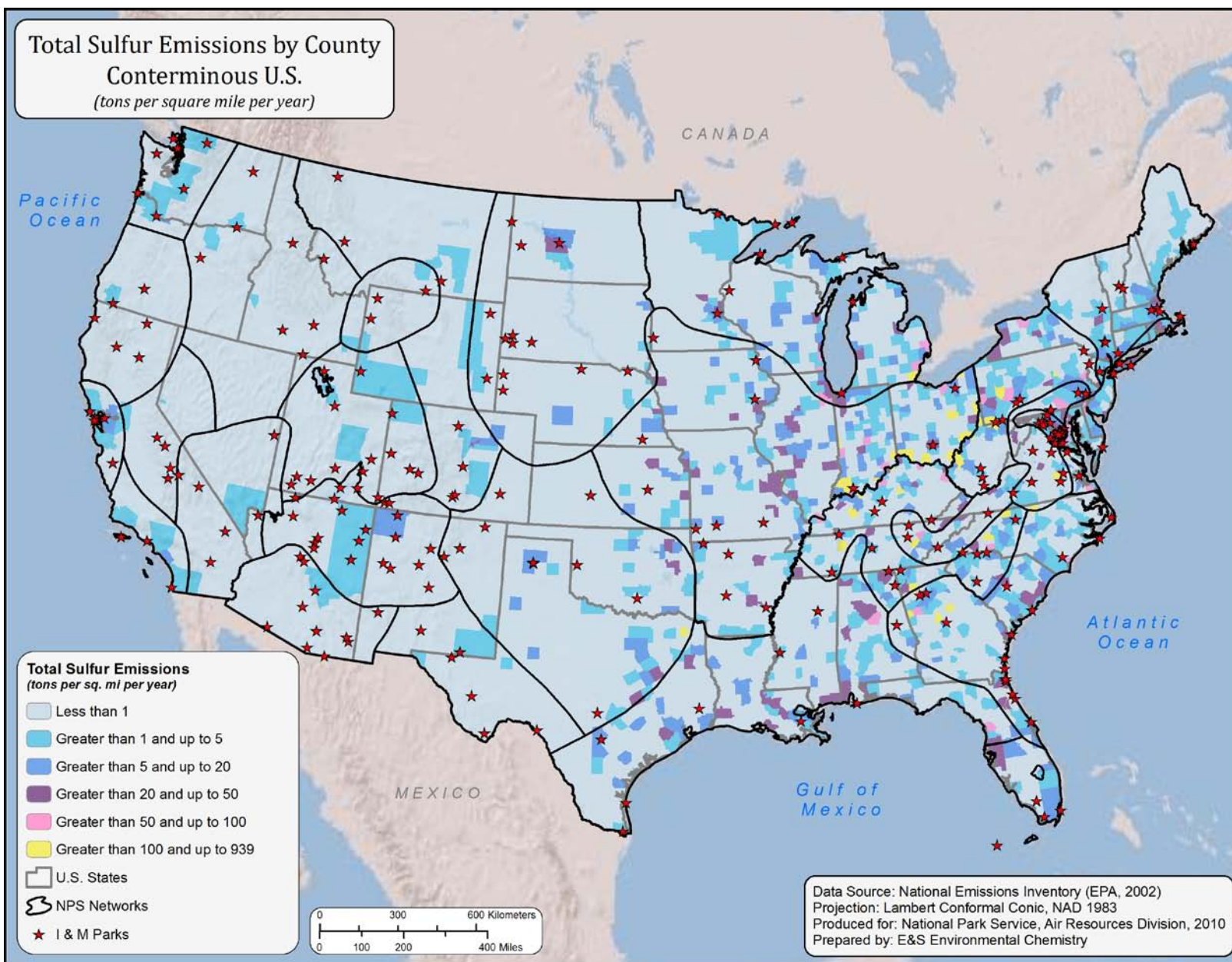
- Map D. Total N deposition for the conterminous United States for the year 2002, expressed in units of kilograms of N deposited from the atmosphere to the Earth surface per hectare per year. Wet and dry forms of both oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH₃) N are included. For the 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, NO_x) and reduced (ammonia, NH₃) N. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map G. Major point source emissions of SO₂ 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, NO_x) and reduced (ammonia, NH₃) 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, NO_x) and reduced (ammonia, NH₃) 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)
- 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)
- Map P-1. Park-specific map: high-elevation lakes and streams in CRLA. (Source of data: U.S. EPA National Elevation Dataset [<http://ned.usgs.gov/>] and U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Map P-2. Park-specific map: high-elevation lakes and streams in LAVO. (Source of data: U.S. EPA National Elevation Dataset [<http://ned.usgs.gov/>] and U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Map P-3. Park-specific map: low-order streams in CRLA. (Source of data: U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Map P-4. Park-specific map: low-order streams in LAVO. (Source of data: U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- 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.

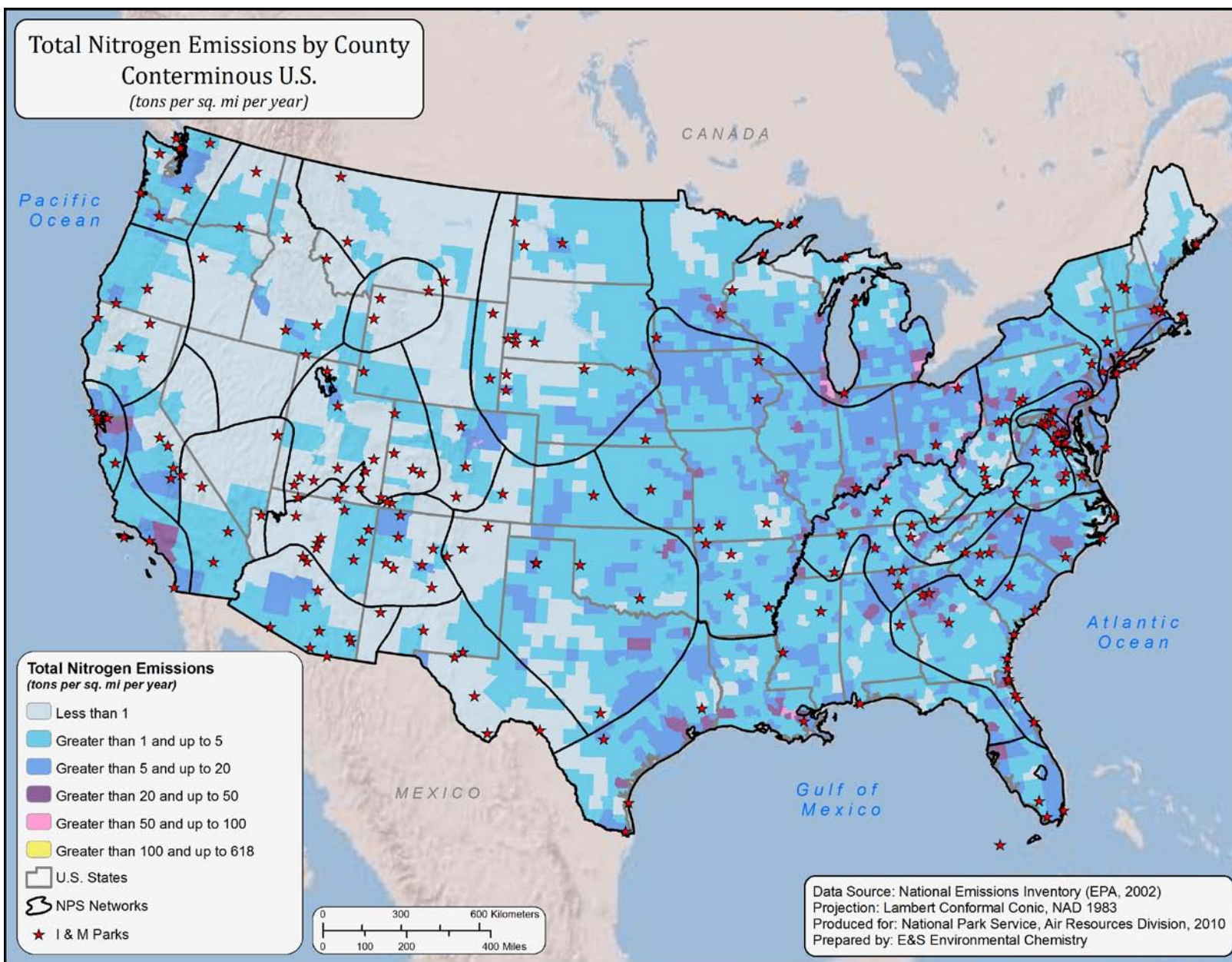
Figure F. Park rankings for Ecosystem Sensitivity for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Ecosystem Sensitivity variables.

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.

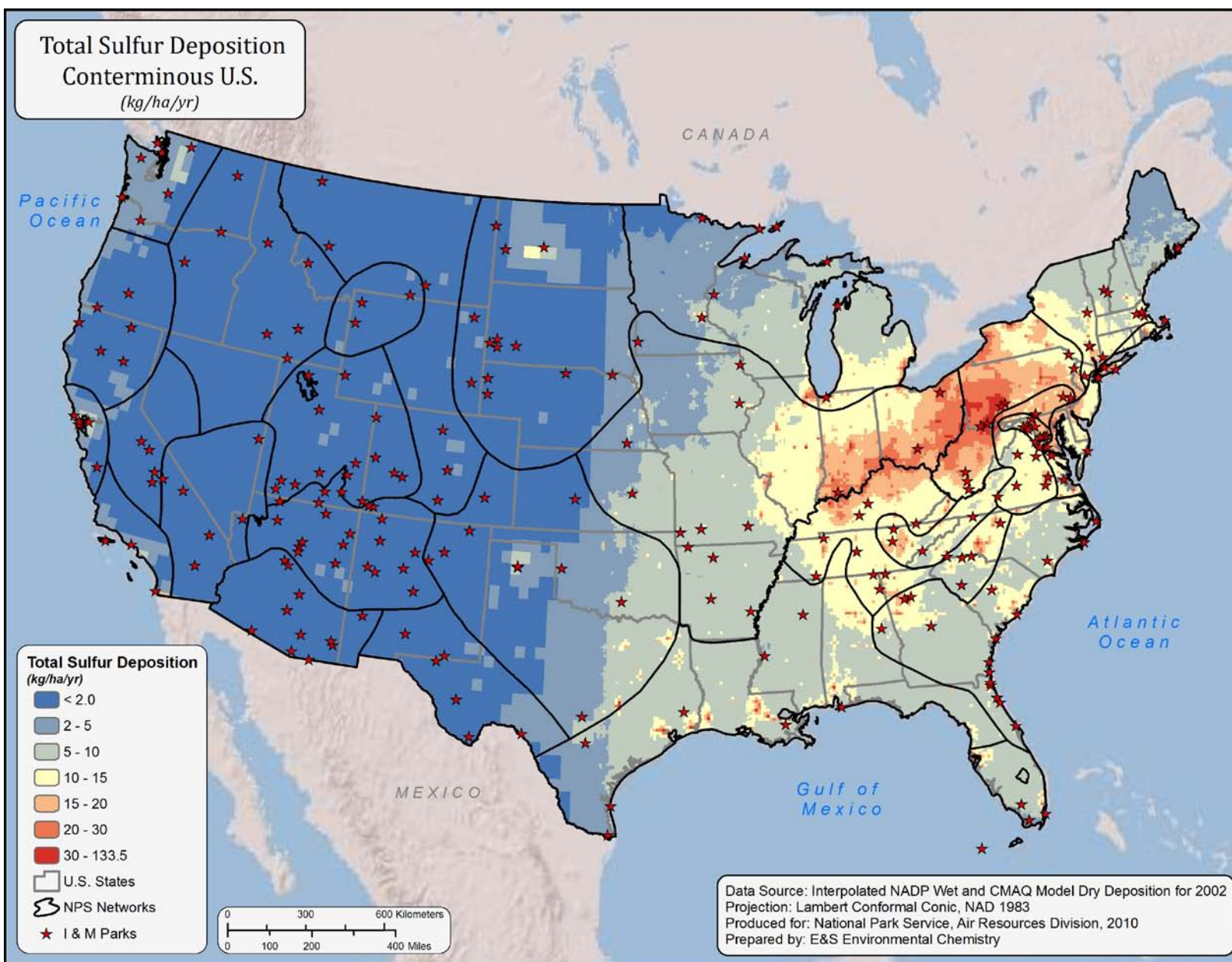
Figure H. Park rankings for Summary Risk for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.



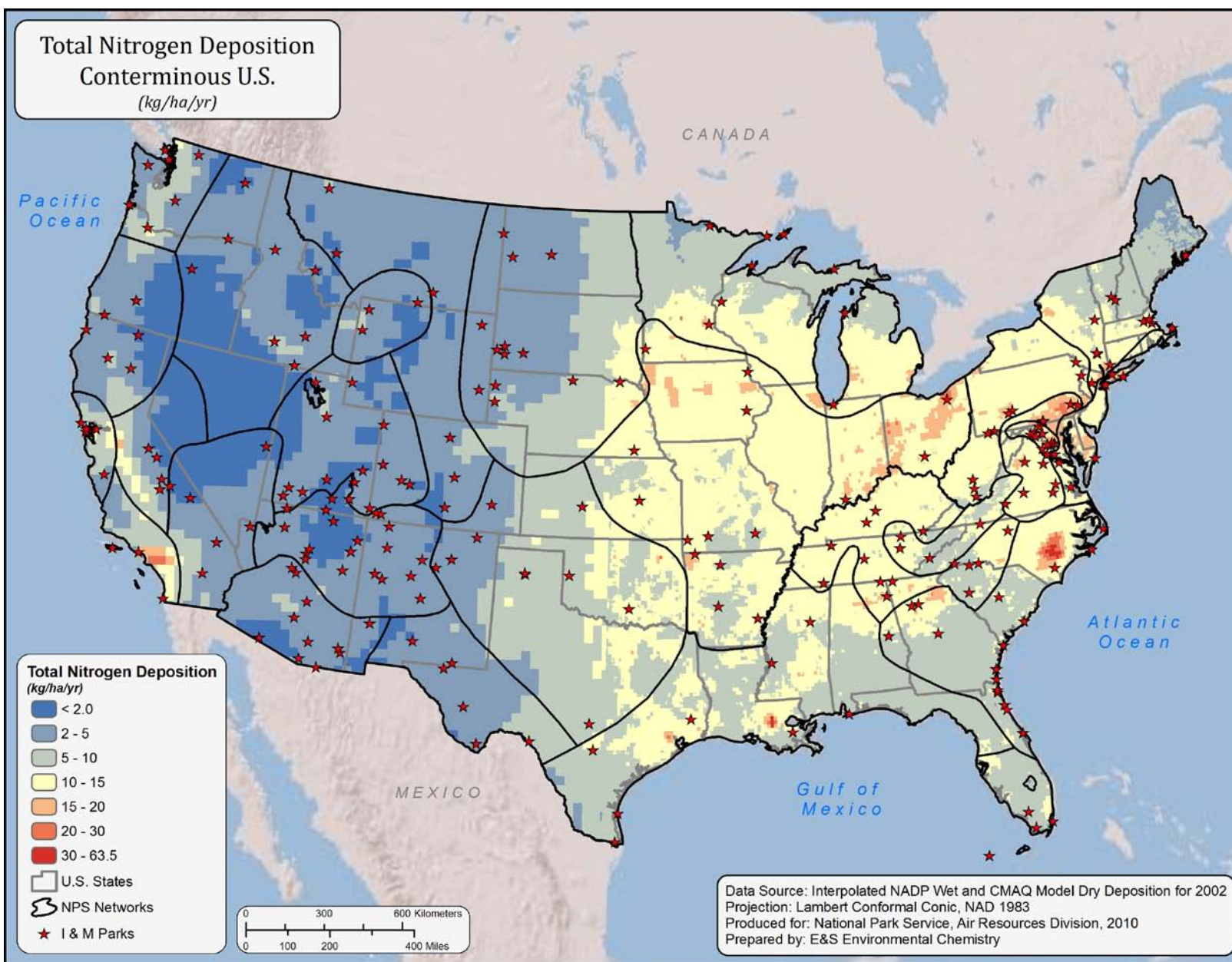
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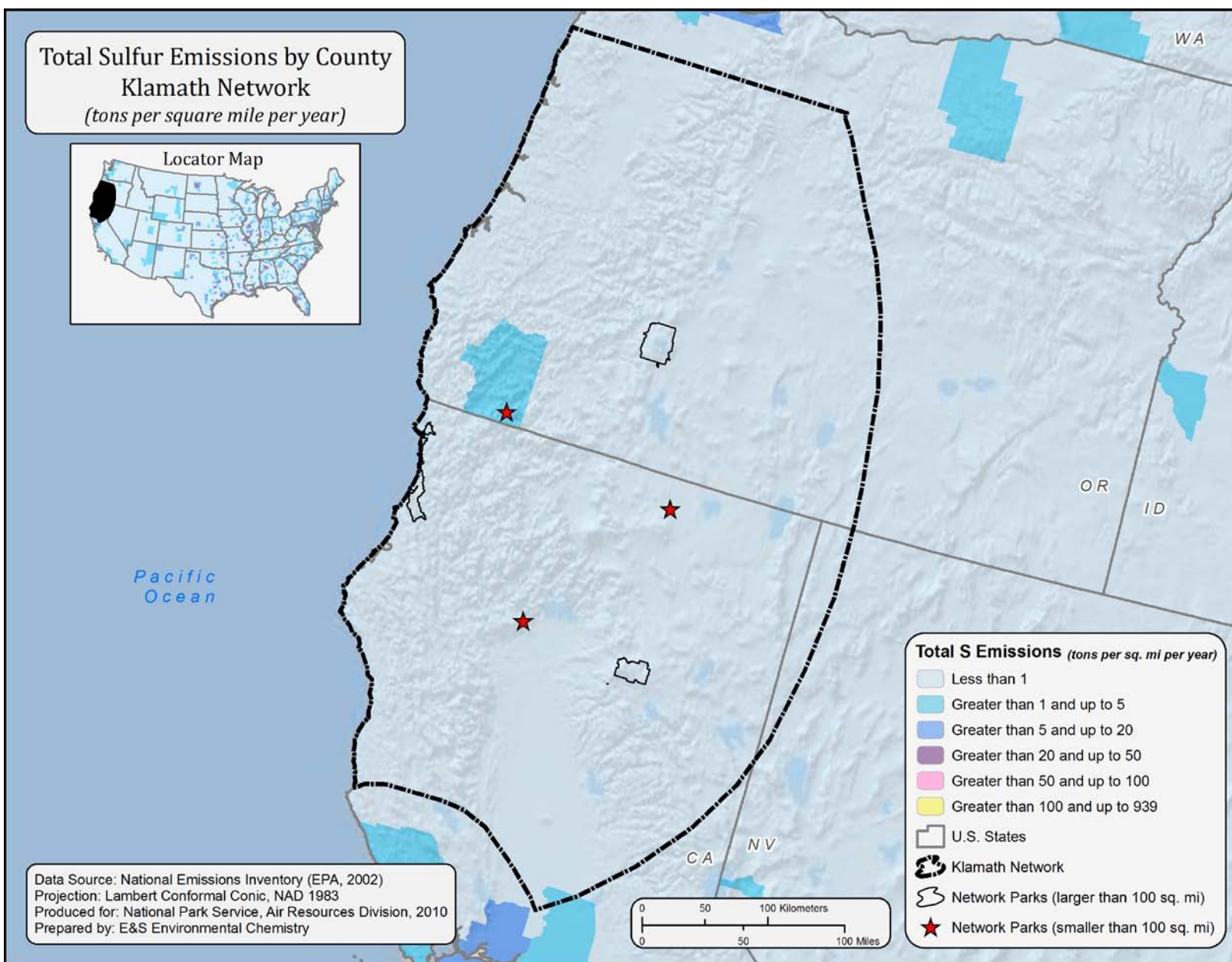
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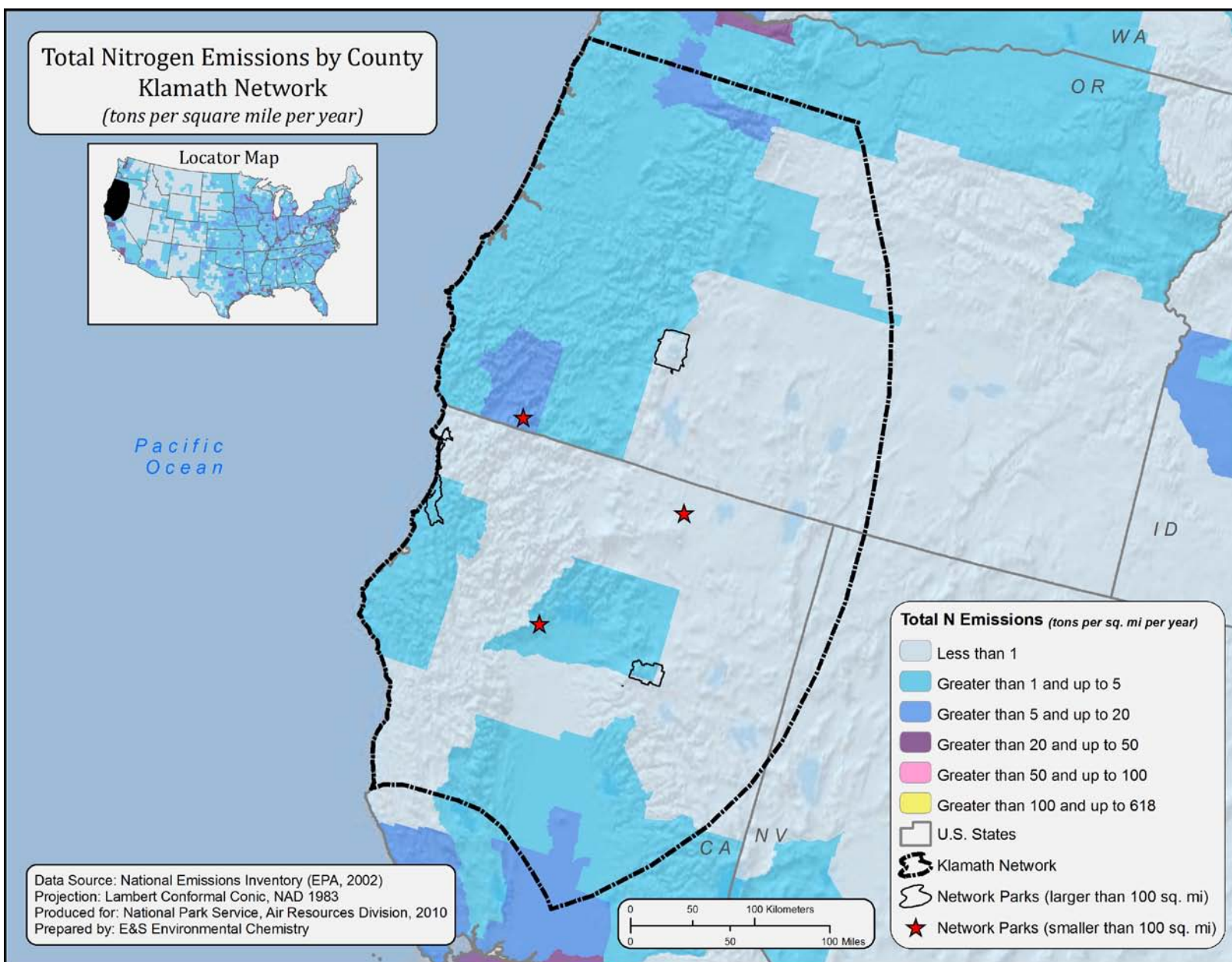
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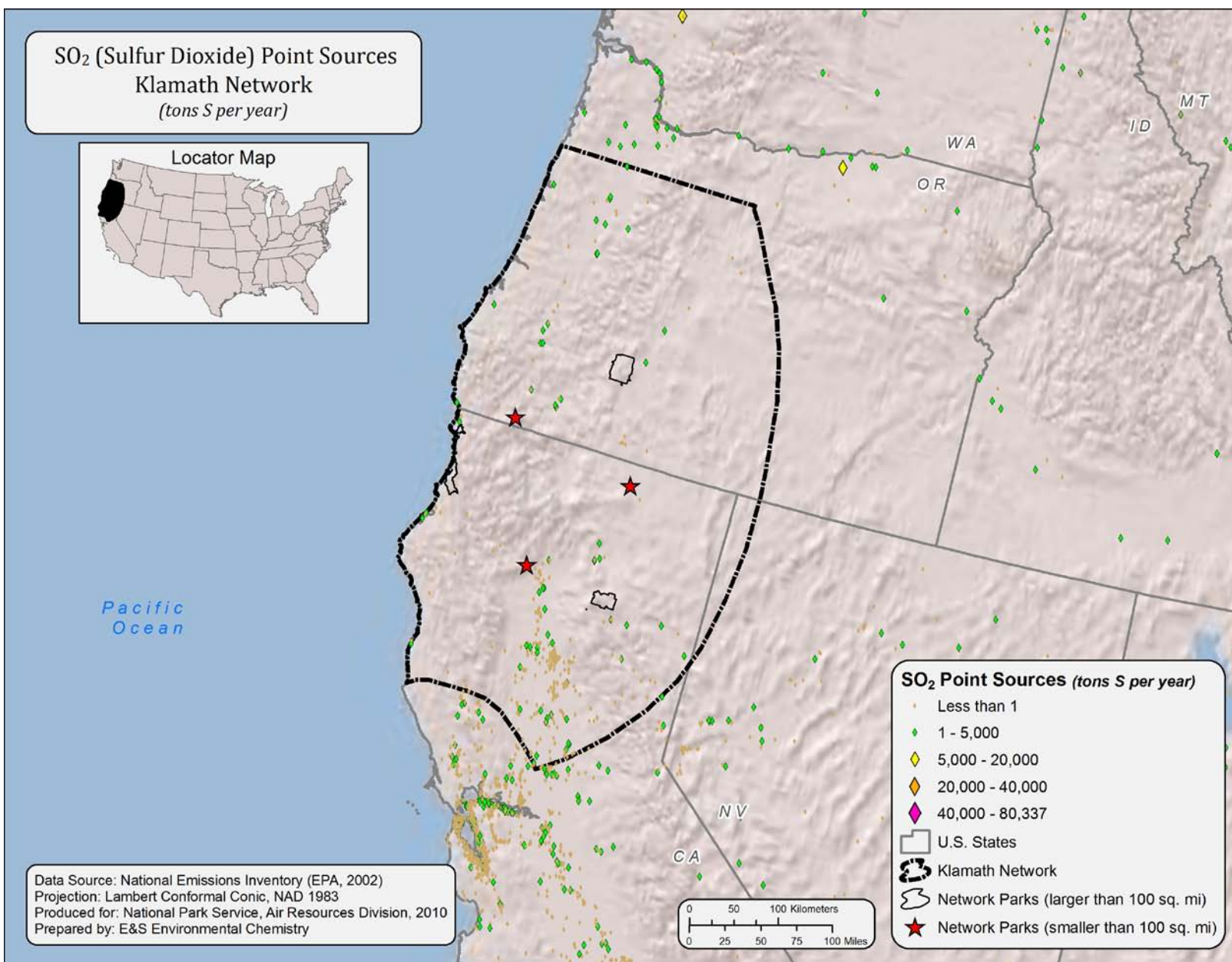
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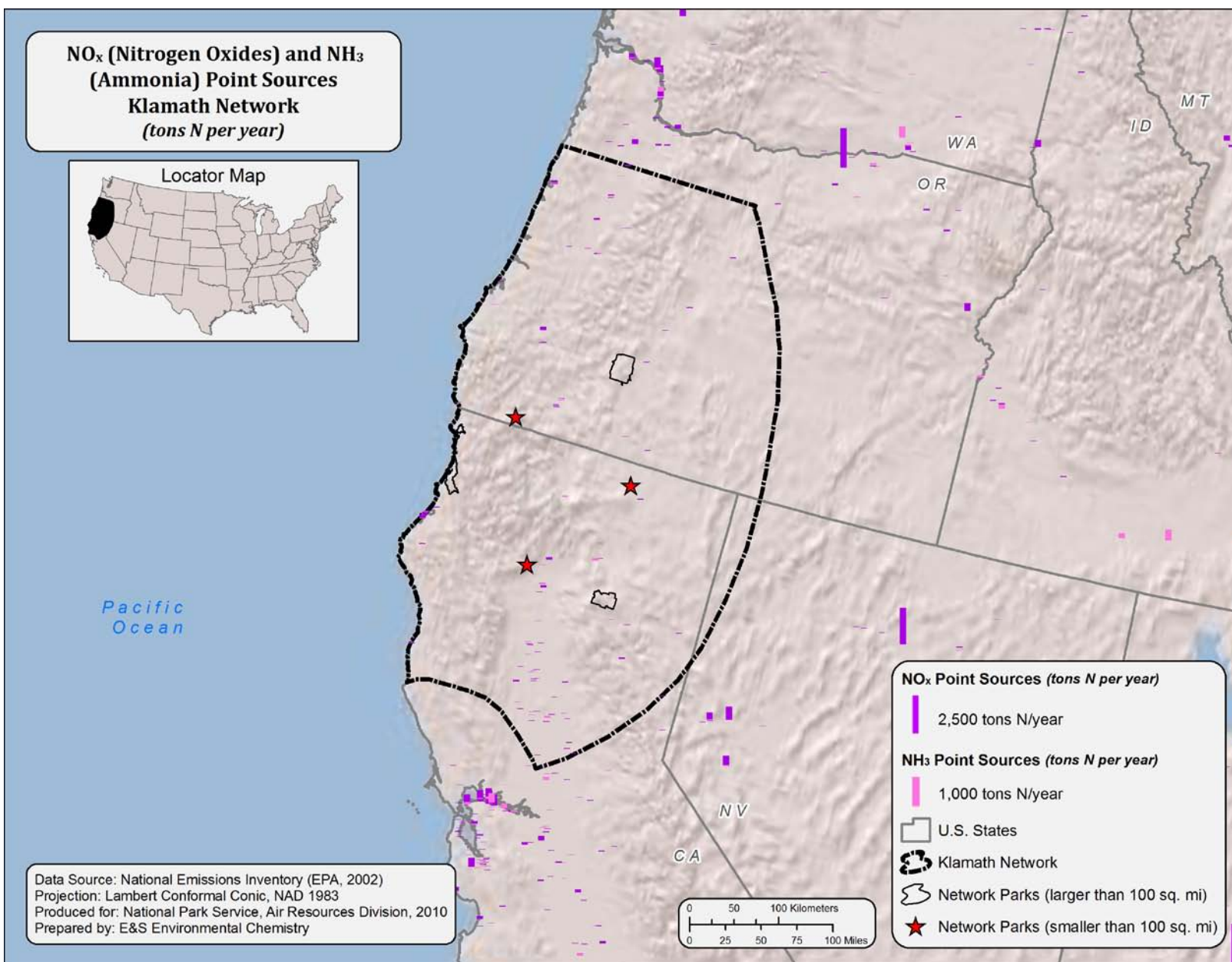
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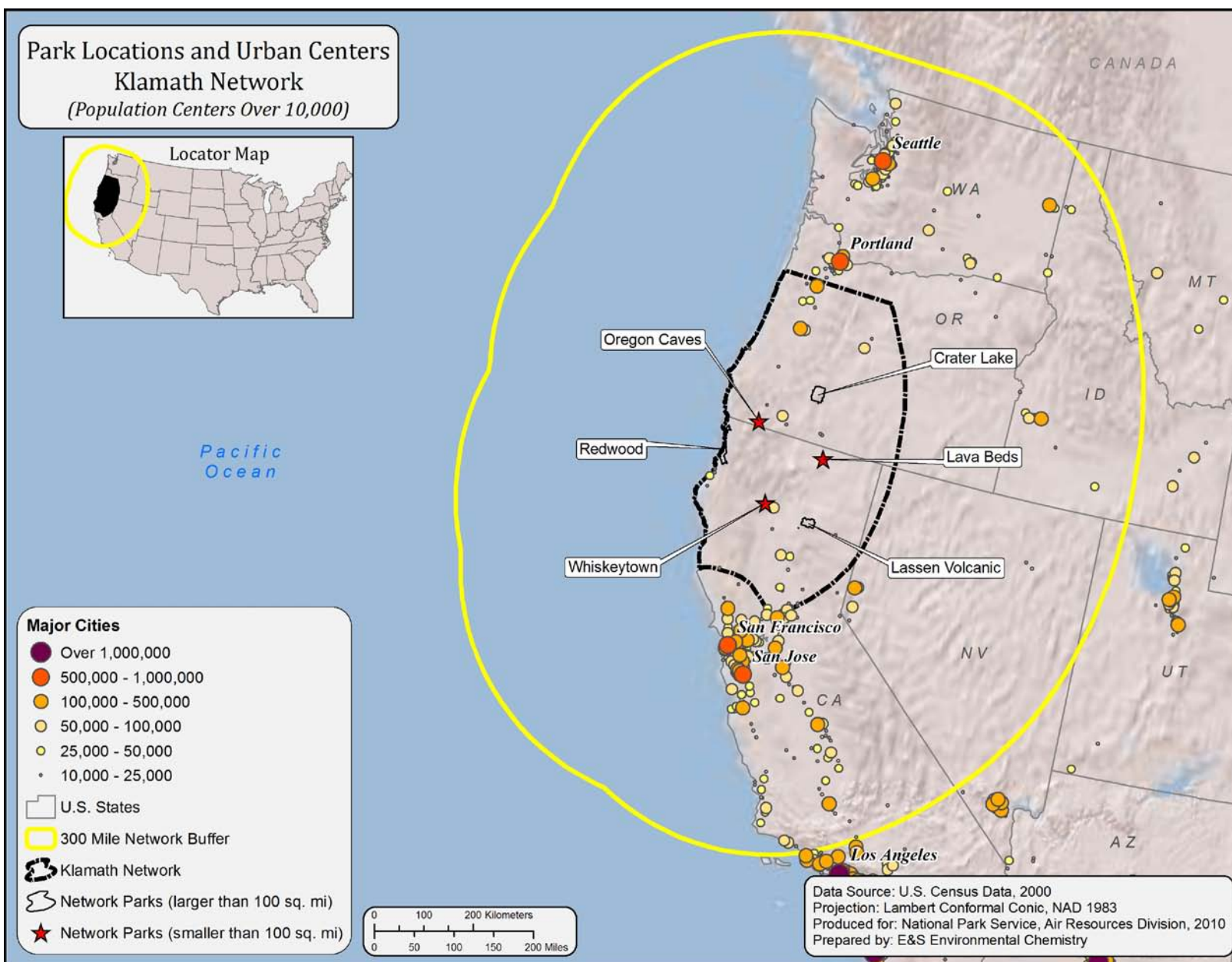
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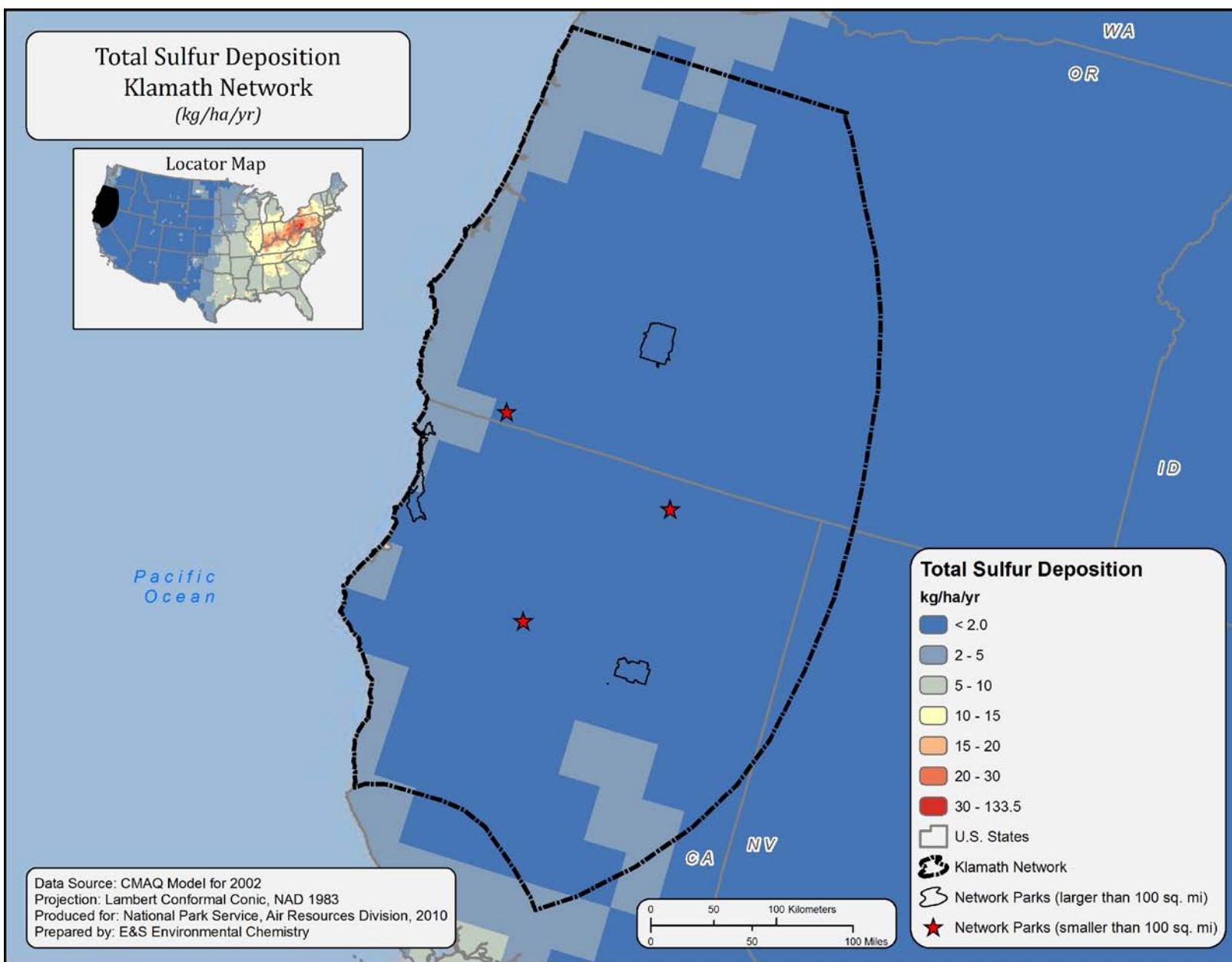
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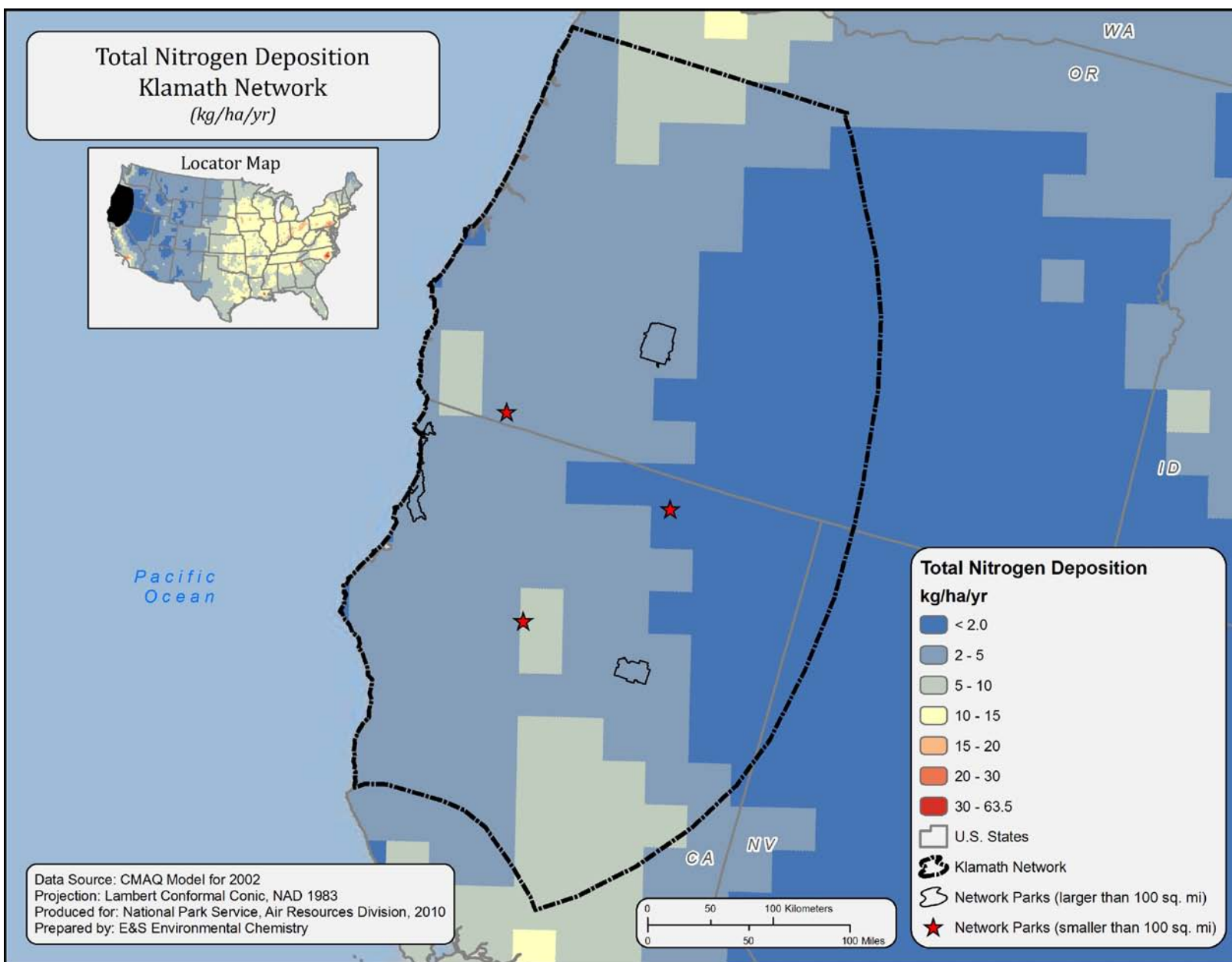
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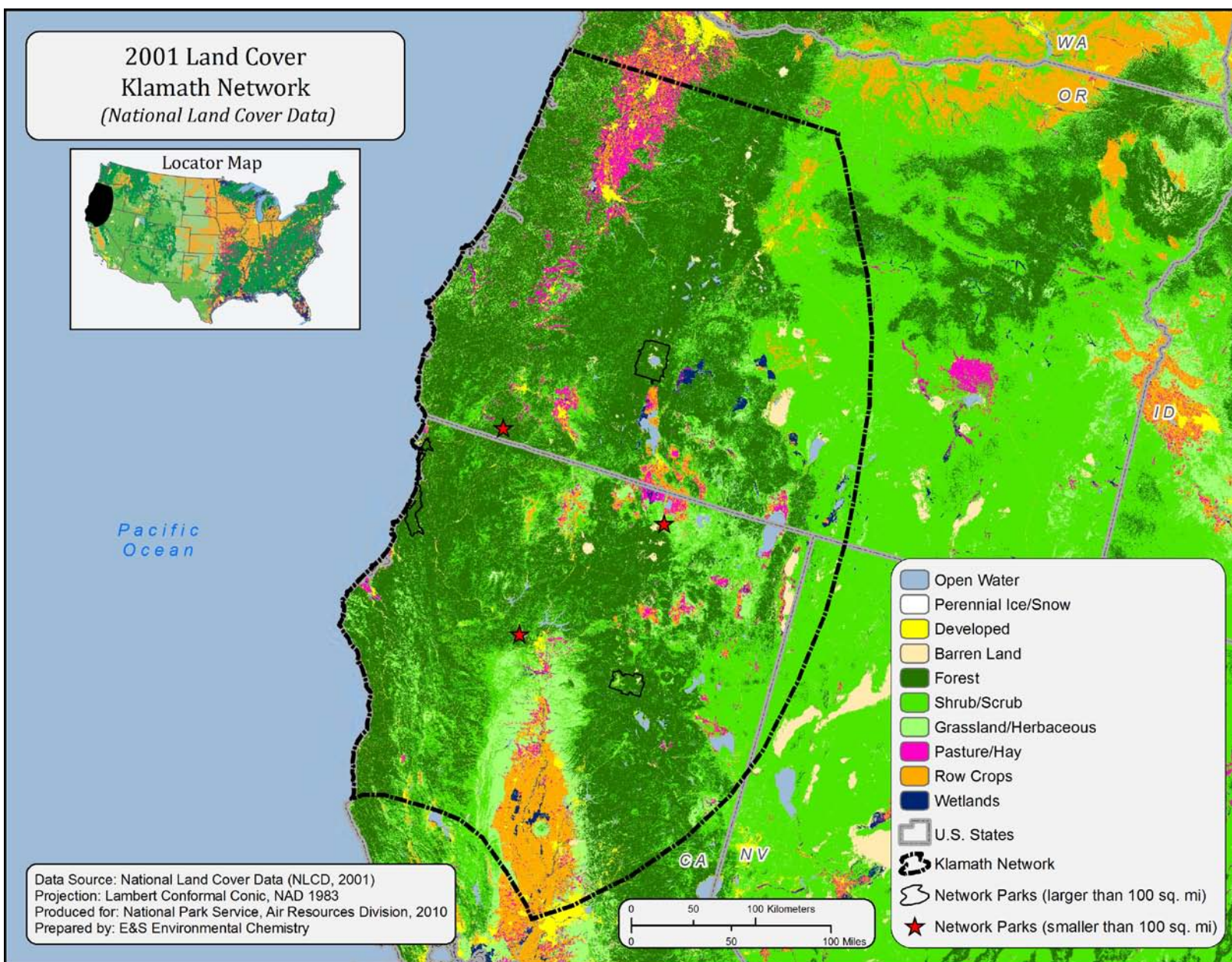
Map I



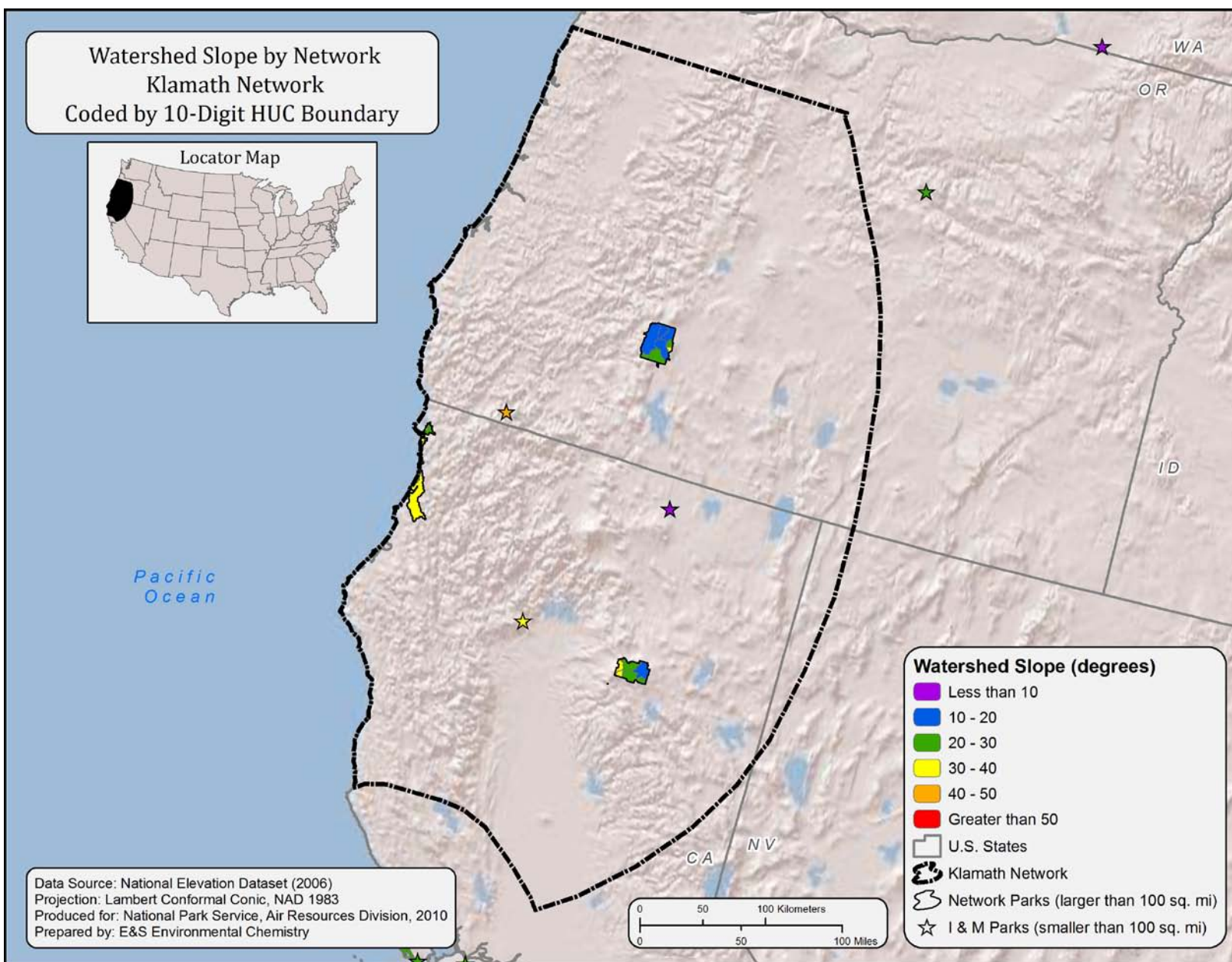
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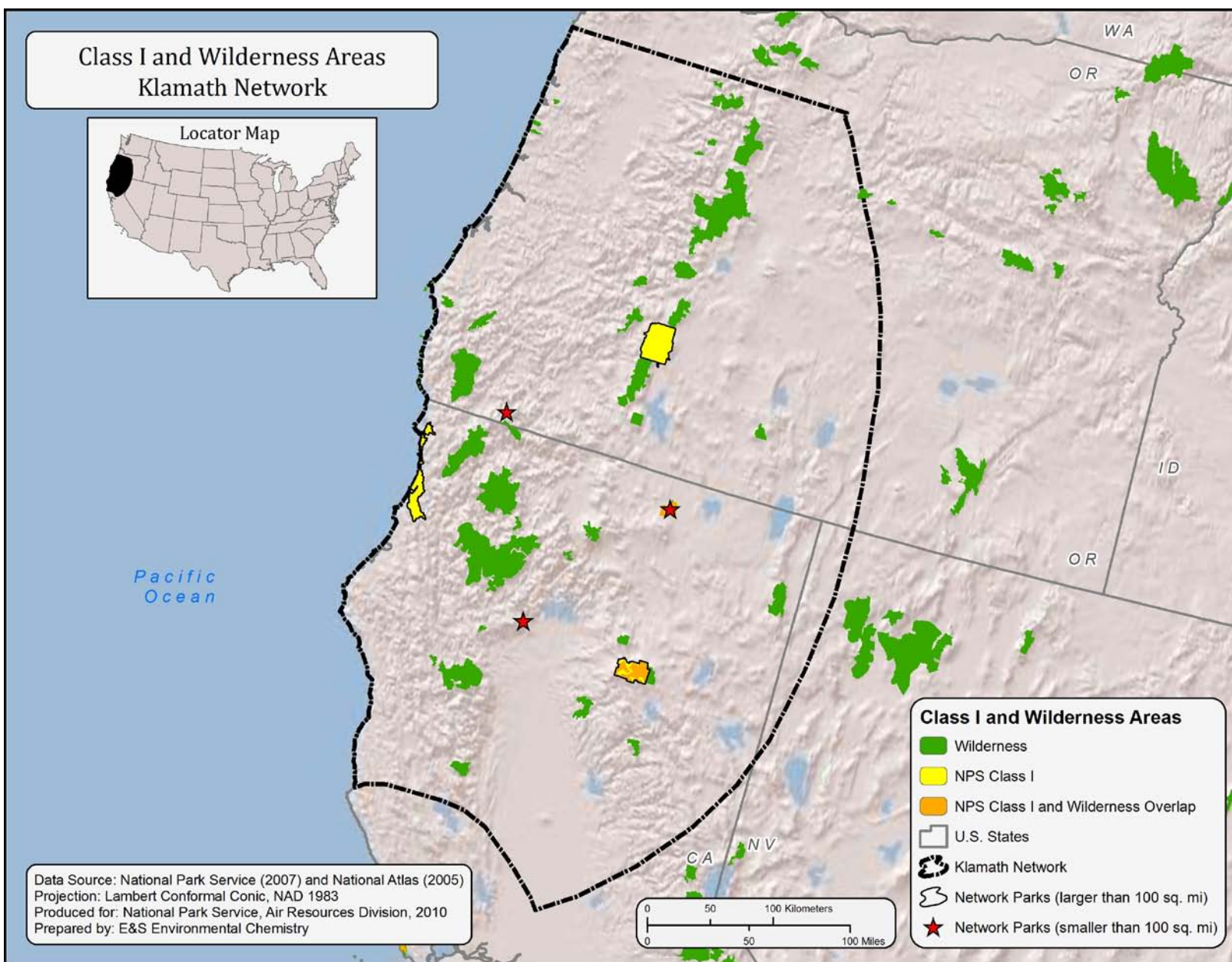
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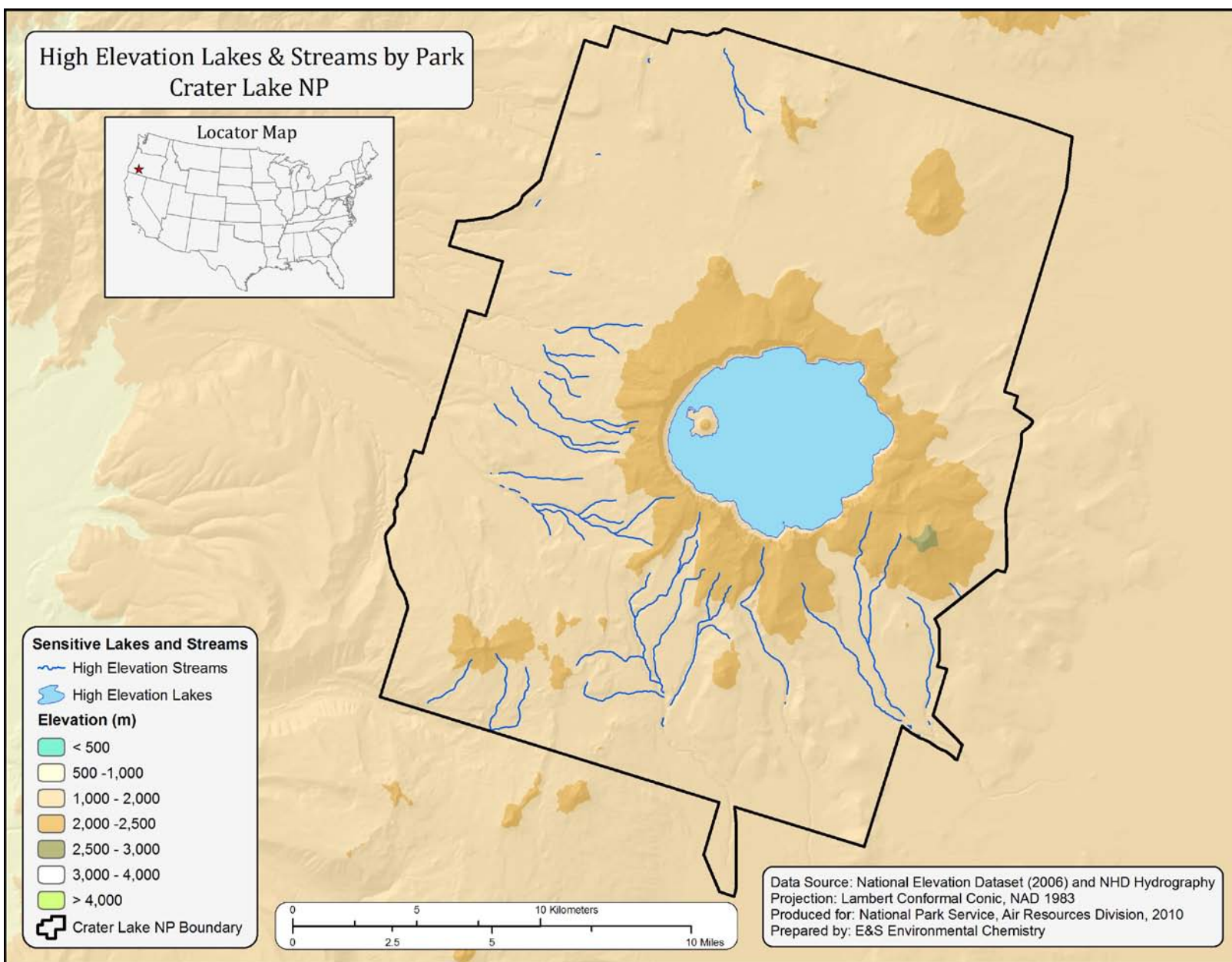
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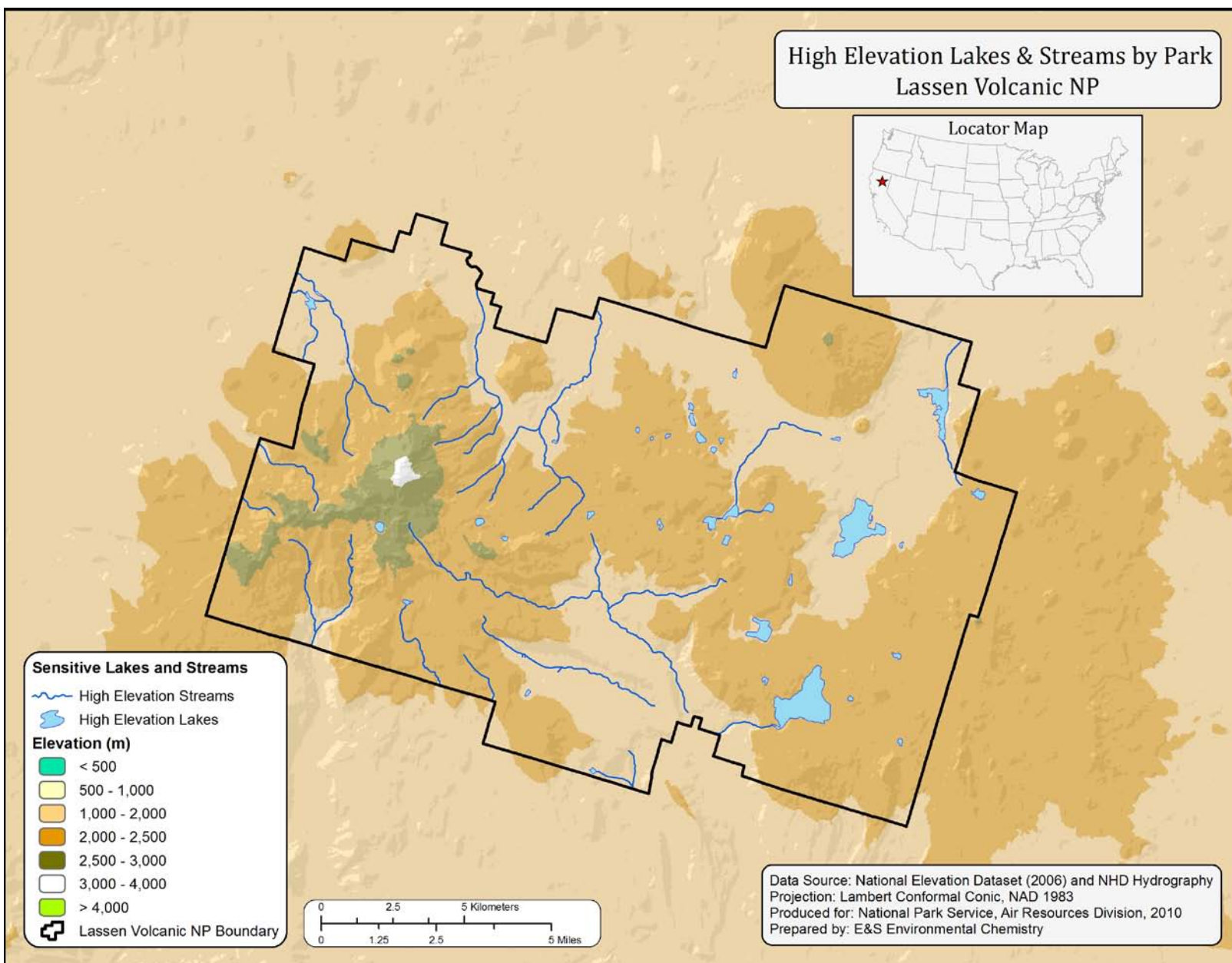
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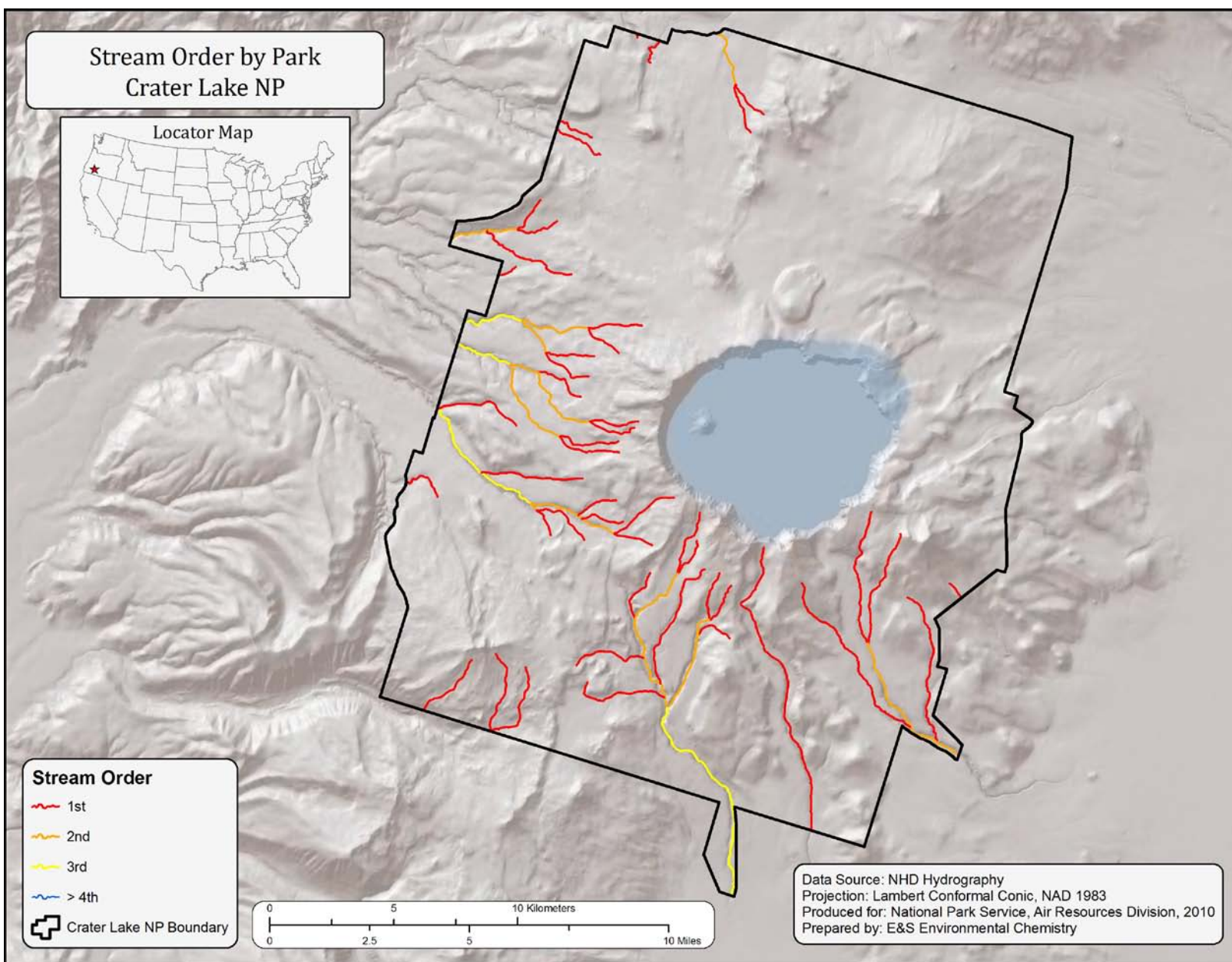
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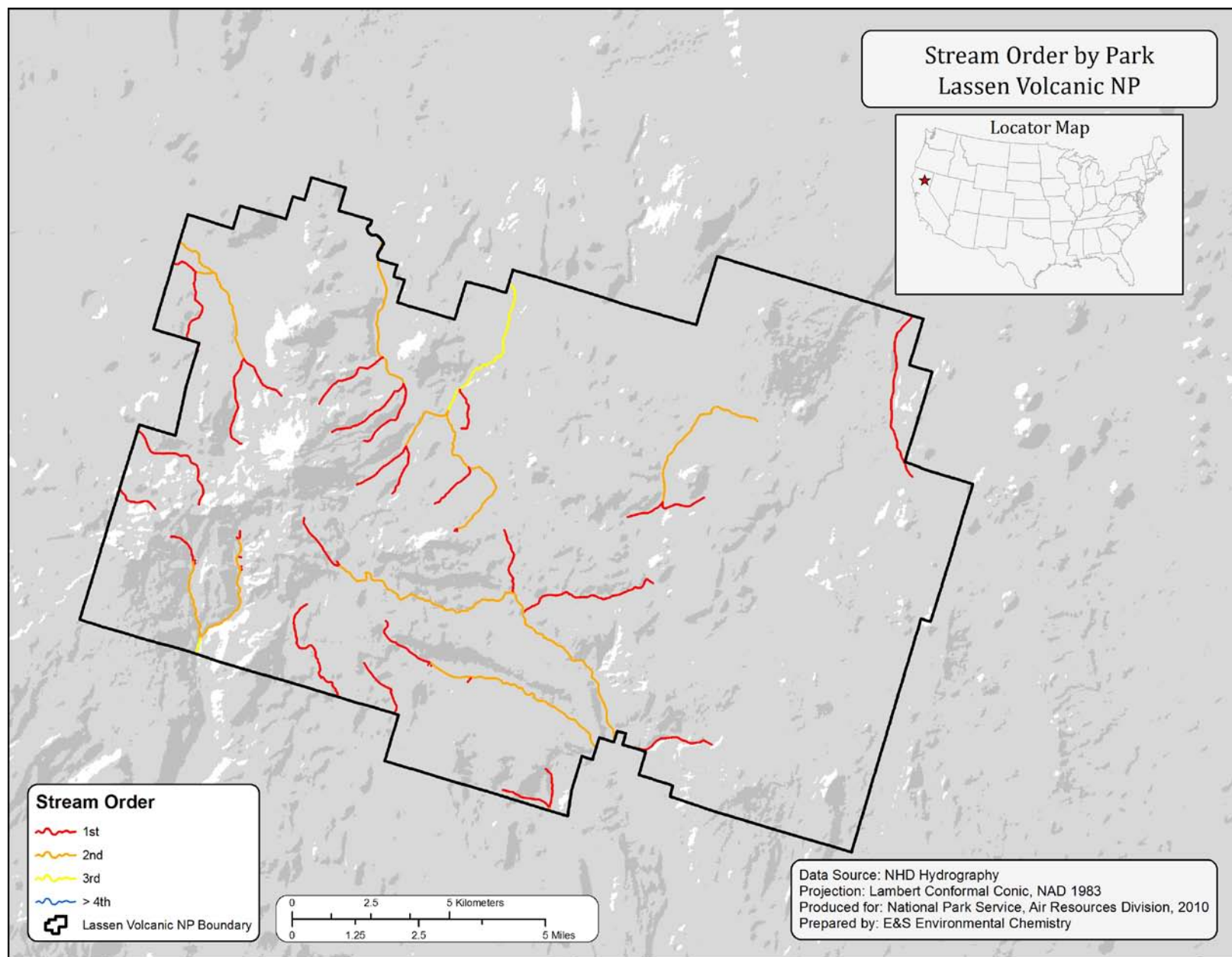
Map P-1



Map P-2



Map P-3



Map P-4

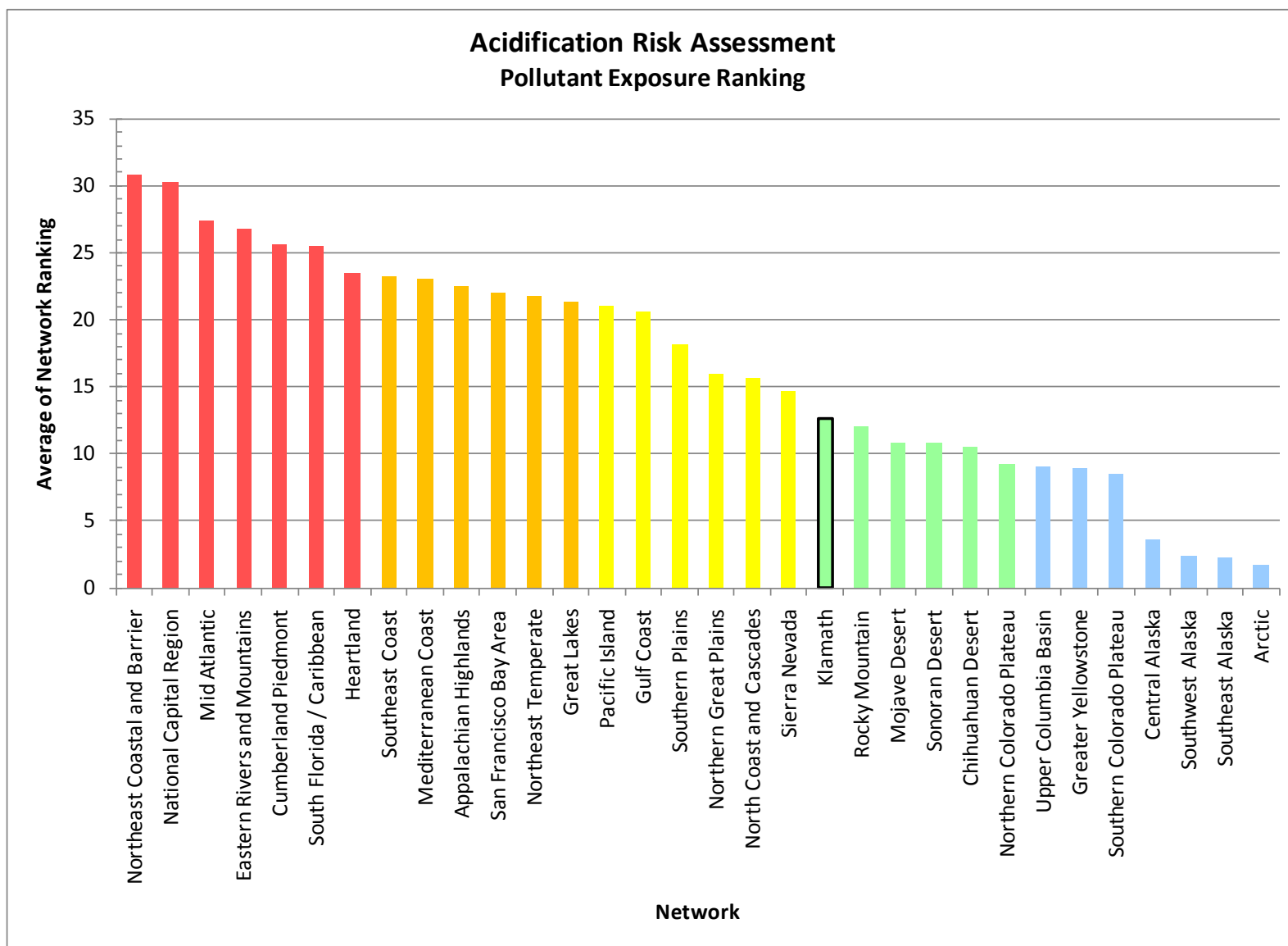


Figure A

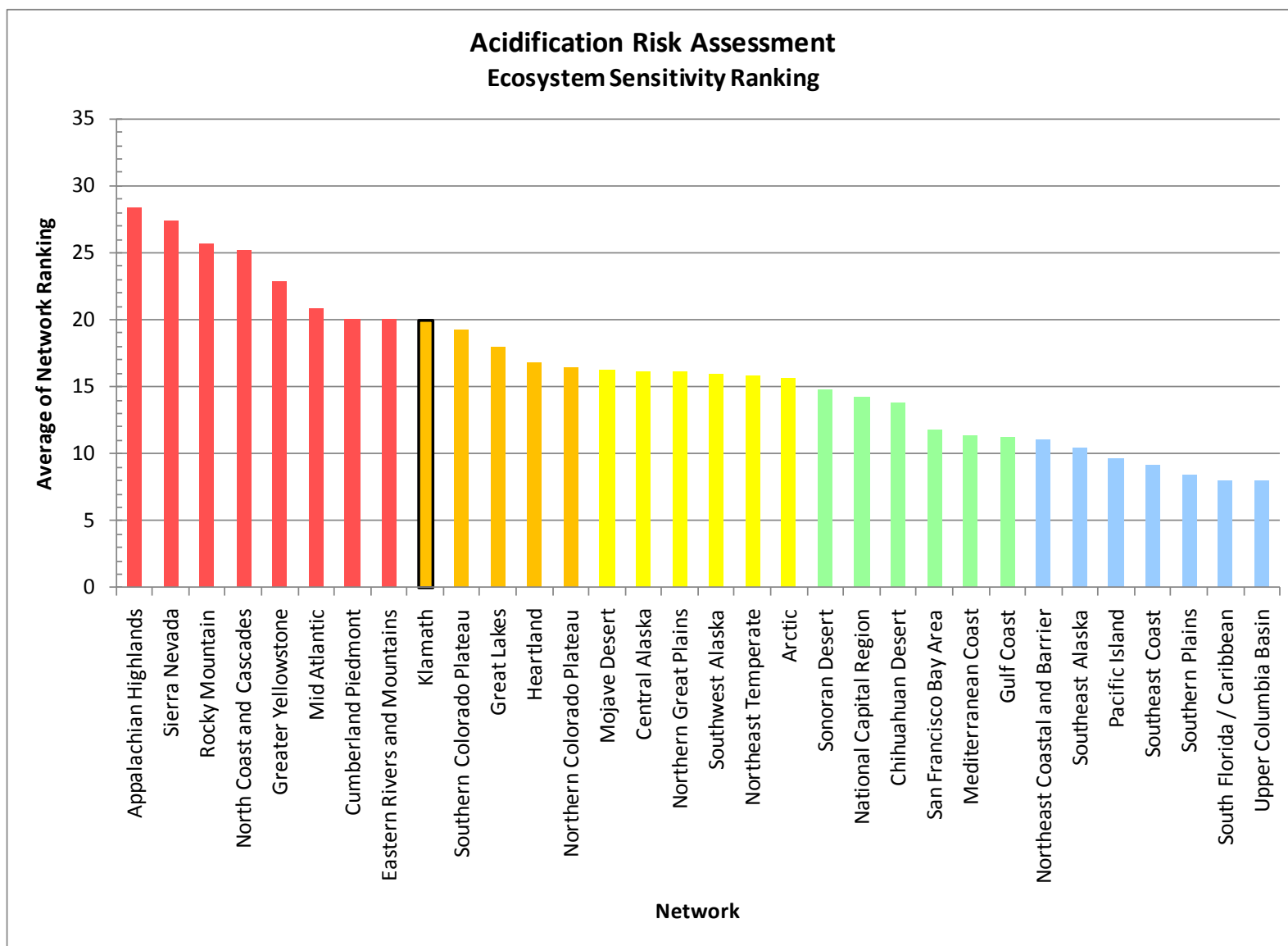


Figure B

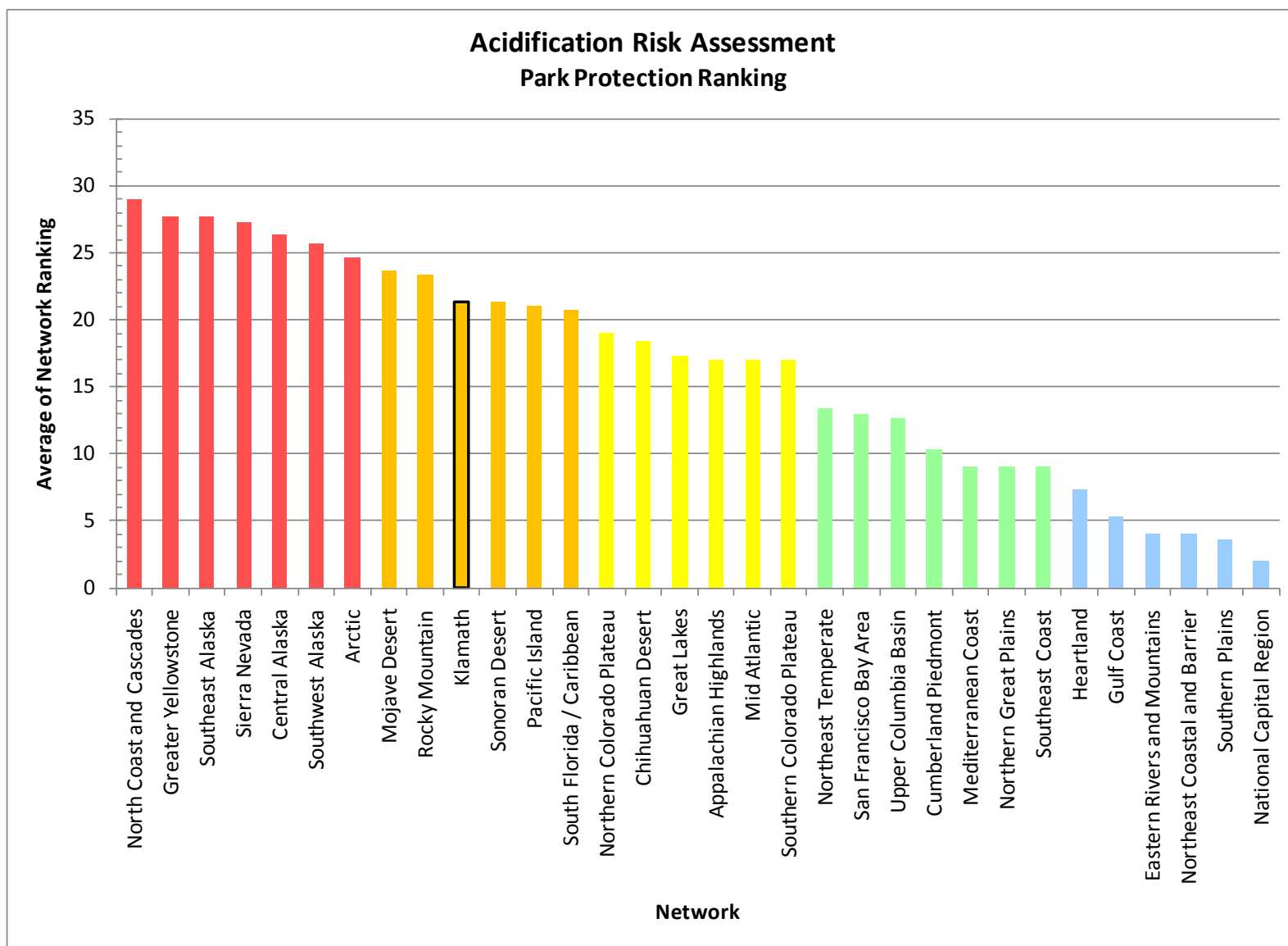


Figure C

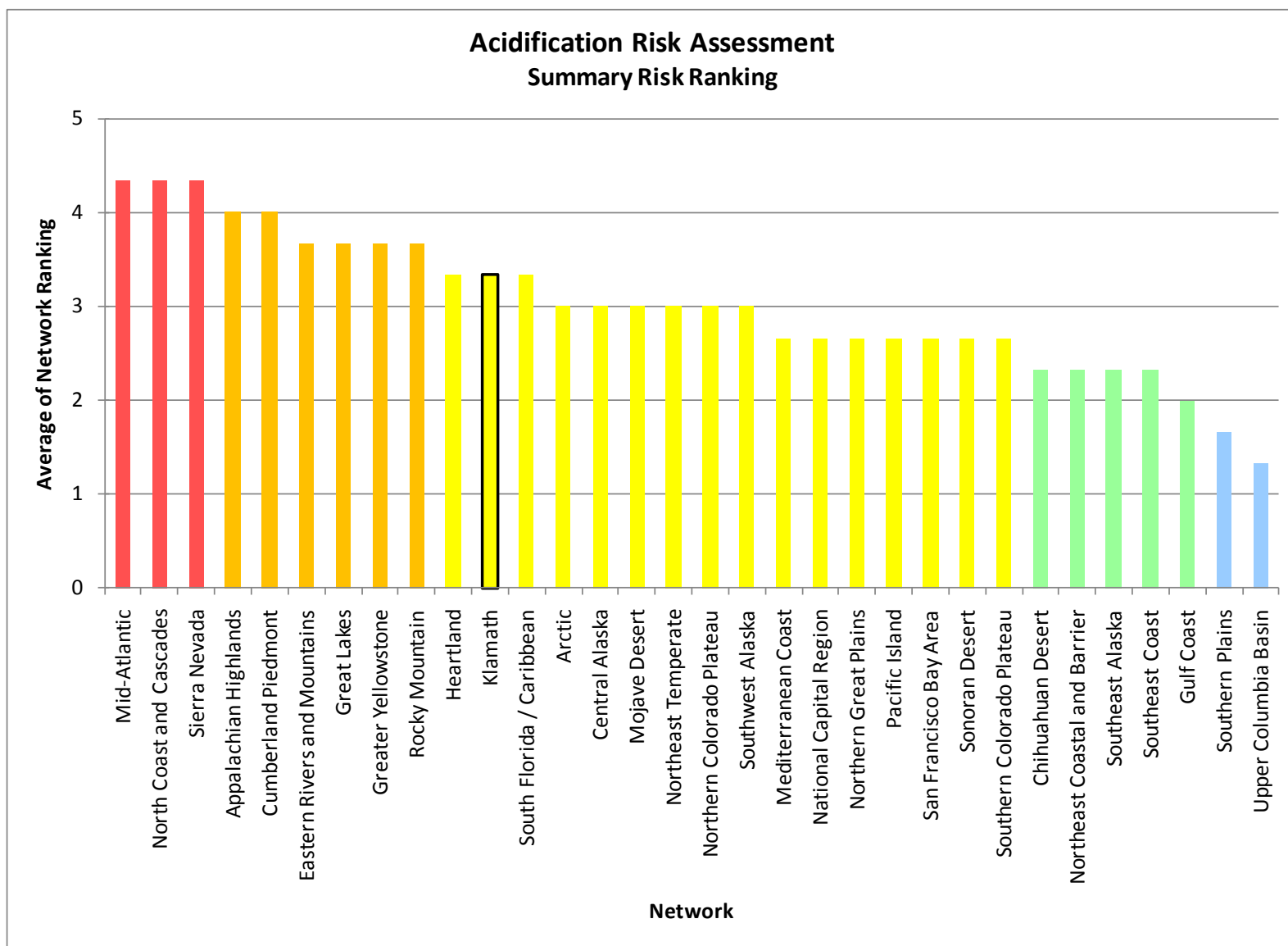


Figure D

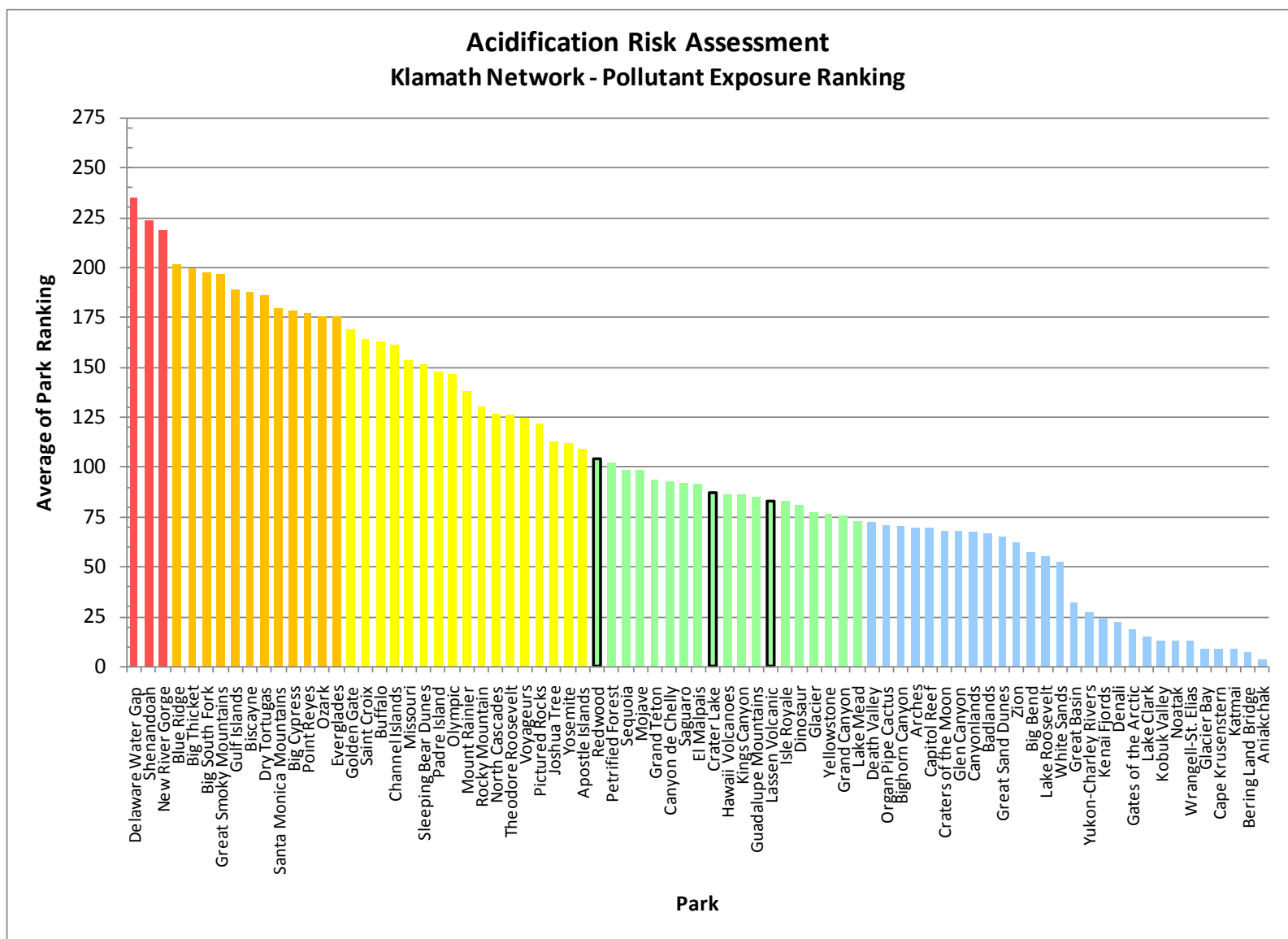


Figure E

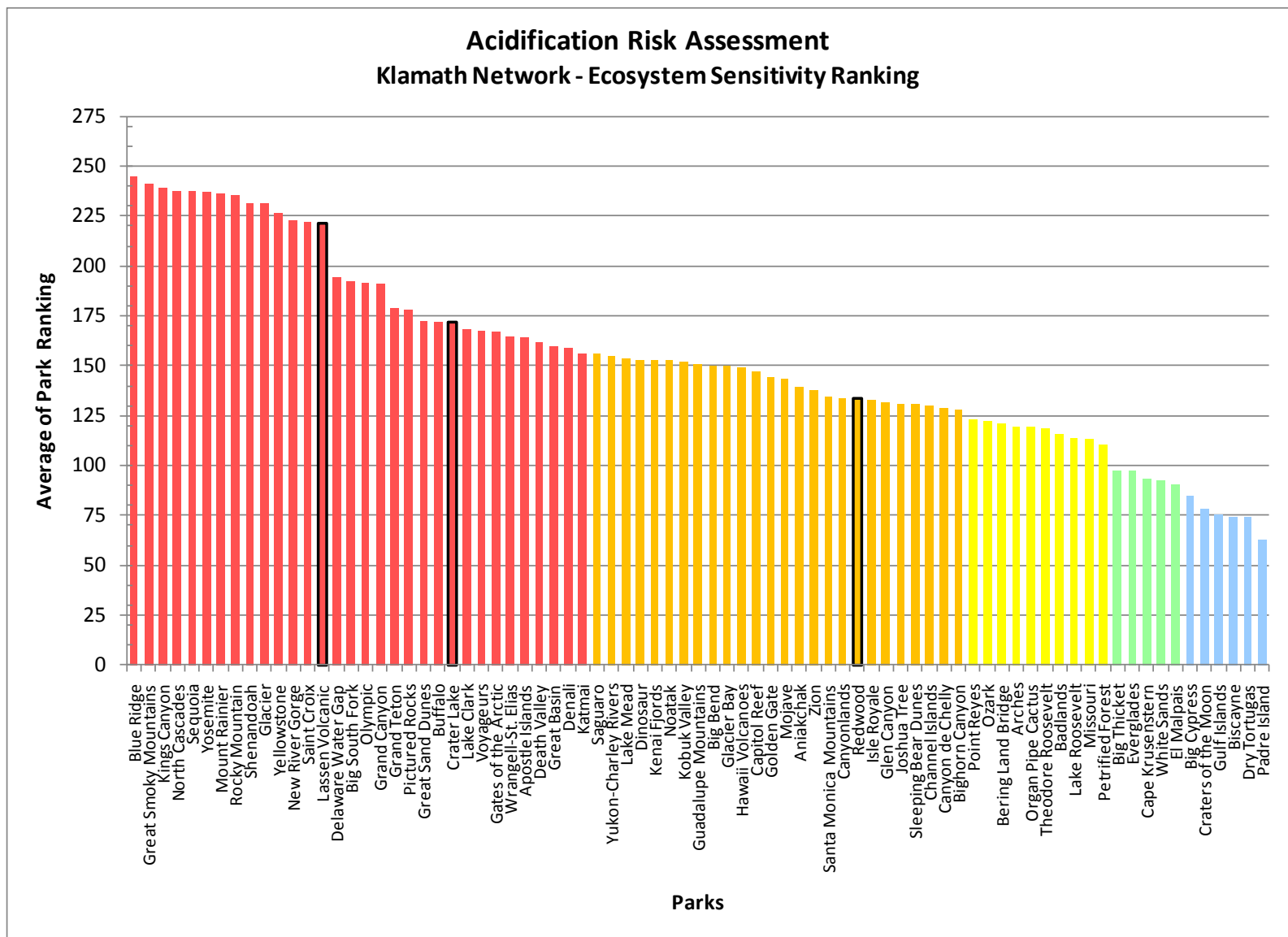


Figure F

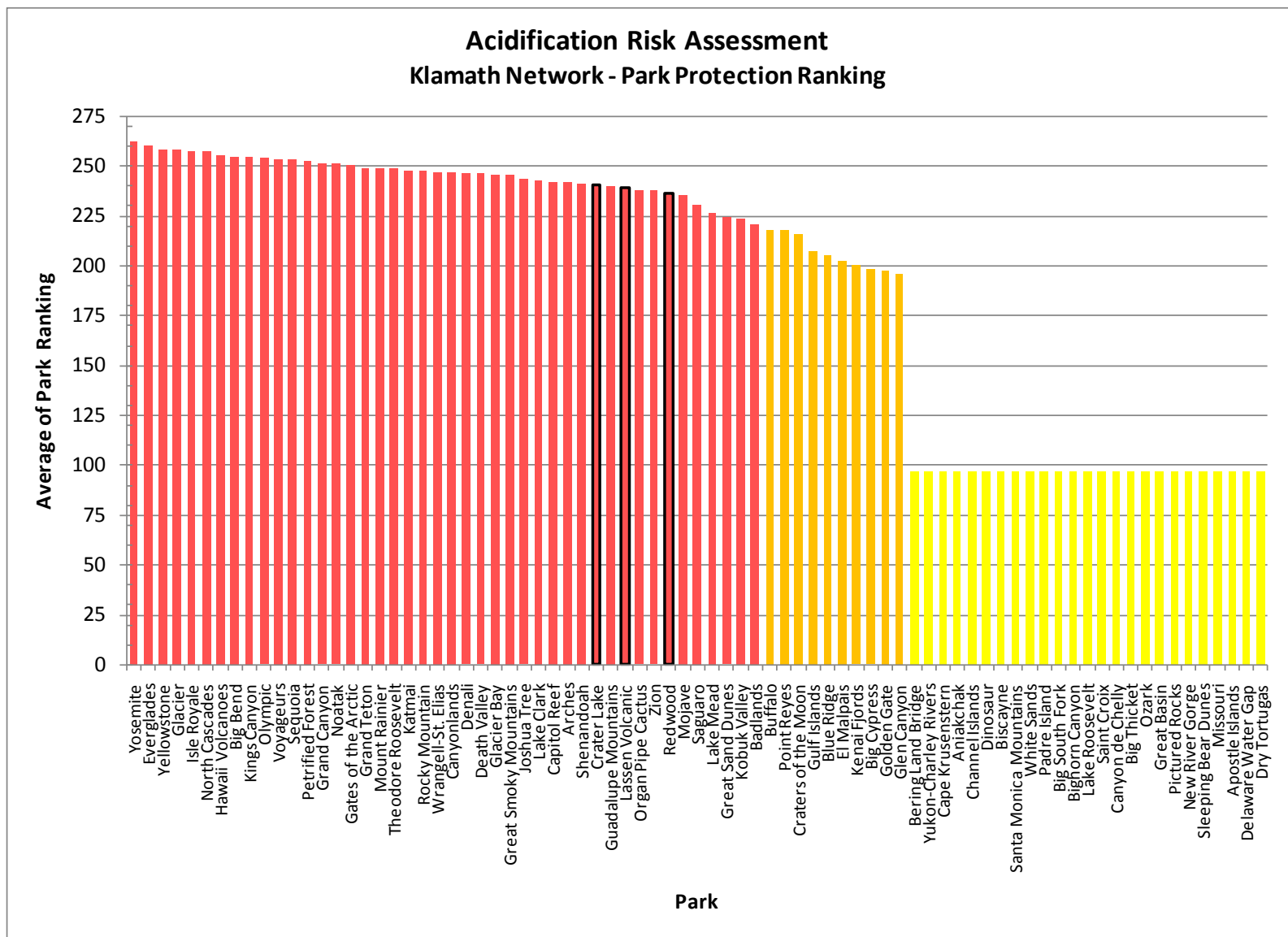


Figure G

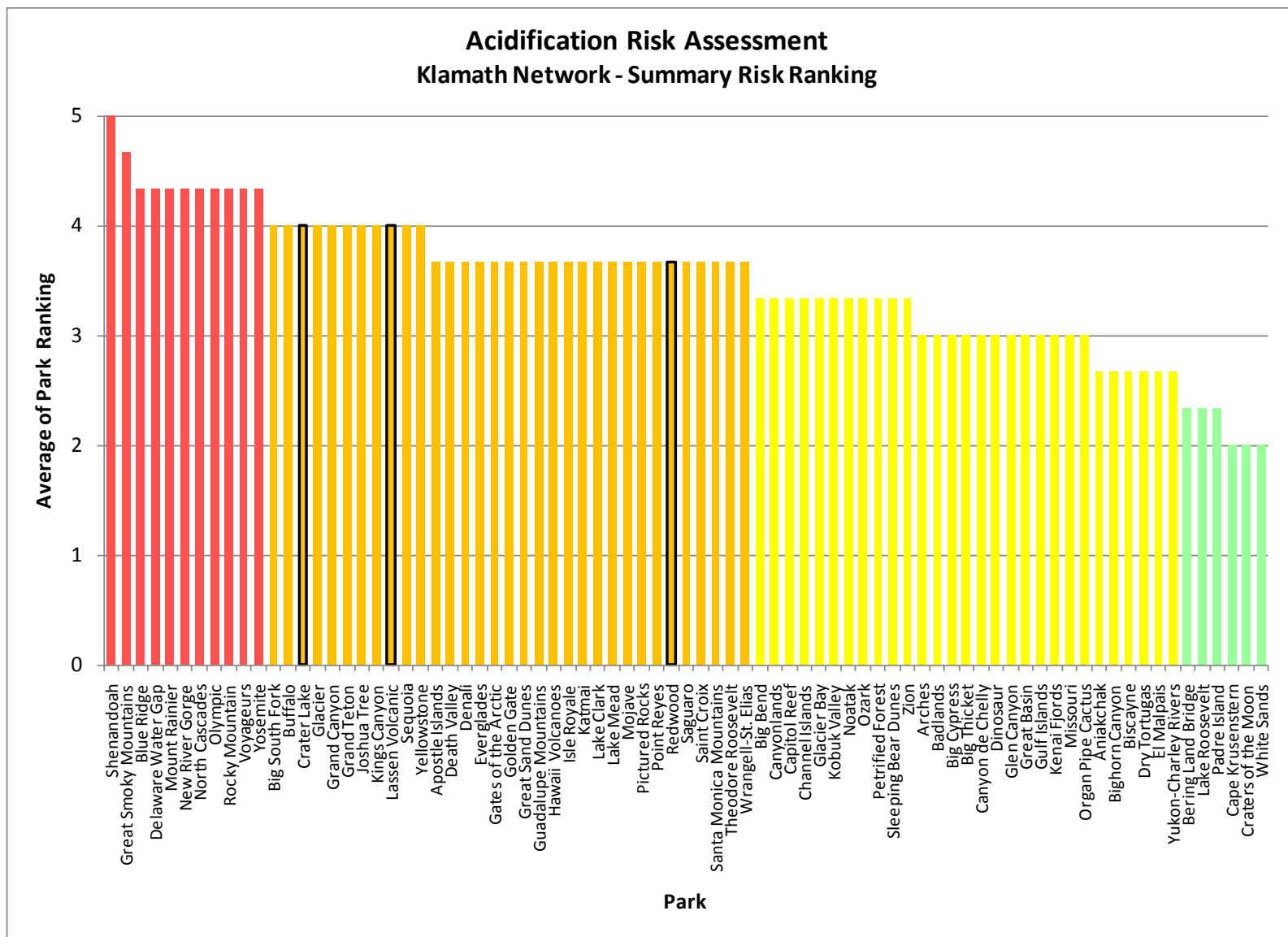


Figure H

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
U.S. Department of the Interior



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