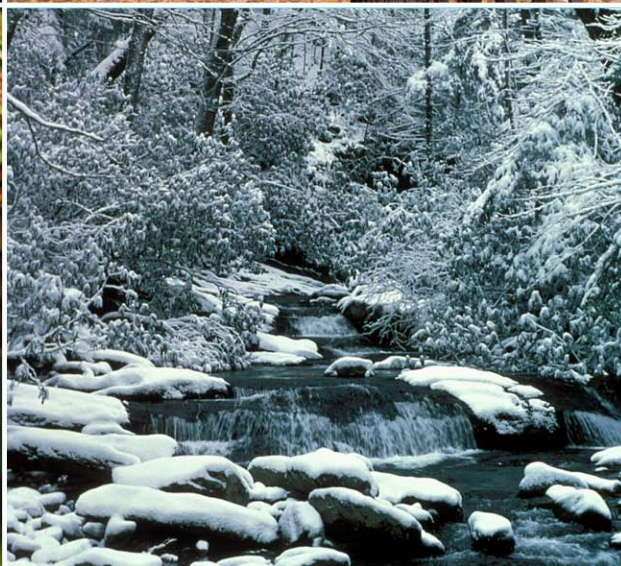
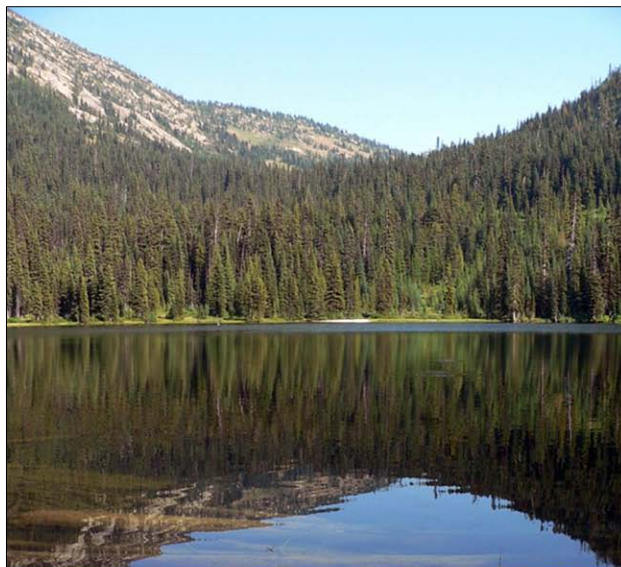




Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Acidification Effects from Atmospheric Sulfur and Nitrogen Deposition

Appalachian Highlands Network (APHN)

Natural Resource Report NPS/NRPC/ARD/NRR—2011/350



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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T. J. Sullivan
T. C. McDonnell
G. T. McPherson
S. D. Mackey
D. Moore

E&S Environmental Chemistry, Inc.
P.O. Box 609
Corvallis, OR 97339

April 2011

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Denver, Colorado

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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/>).

Please cite this publication as:

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Appalachian Highlands Network (APHN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/350. National Park Service, Denver, Colorado.

Appalachian Highlands Network (APHN)

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 Appalachian Highlands Network contains three parks that are larger than 100 square miles: Great Smoky Mountains (GRSM), Big South Fork (BISO), and Blue Ridge (BLRI). It also contains one smaller park: Obed (OBRI).

Total annual S and N emissions, by county, are shown in Maps E and F, respectively, for lands in and surrounding the Appalachian Highlands Network. County-level S emissions within the network were mostly less than 1 ton per square mile, although some counties within the network, and to the north and west of the network, had much higher S emissions levels. Several counties inside, or partially inside, the network had annual S emissions higher than 20 tons per square mile, and one county had emissions higher than 100 tons per square mile (Map E). County-level annual N emissions within the network ranged from less than 1 ton per square mile to greater than 100 tons per square mile. In general, annual N emissions from most counties were between 1 and 20 tons per square mile. Individual point source emissions of S are shown in Map G. There were only two S point sources within the network that were larger than 20,000 tons per year, and none were larger than 40,000 tons per year. However, there were many such large point sources of S surrounding the network. Point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH_3) N are shown in Map H. All relatively large (larger than 1,000 tons per year) N point sources within the network, and most large point sources near the network, were oxidized N sources. Only one large point source of reduced N was located in proximity to the network; it was in Virginia, to the northeast of the network. There were two large point sources of NO_x within the network in Tennessee, situated between GRSM and BISO; each emitted more than 4,000 tons per year of oxidized N. Many other relatively large point sources of oxidized N occurred in the vicinity of the network boundary.

Urban centers within the network and within a 300-mile buffer around the network are shown in Map I. Few population centers of any magnitude are found in this network. However, there are several cities with populations over 500,000 within the 300-mile buffer.

Total S and N deposition levels in and around the network are shown in Maps J and K, respectively. Included in this analysis were both wet and dry forms of deposition, and both the oxidized and reduced N species. Total S deposition throughout much of the network, including in and around GRSM, ranged from about 10 to 15 kg/ha/yr (Map J). Some locations within the network had estimated S deposition higher than that. Total N deposition within the network ranged from as low as 2 to 5 kg N/ha/yr per year to as high as 10 to 15 kg N/ha/yr (Map K). In addition, it is known that cloud deposition, which is not represented in the total deposition values depicted on the maps, can be quite high at high-elevation sites (especially higher than 1,500 m) in and around GRSM. At the highest elevation locations, the total S and N deposition, including cloud inputs, might be as much as double the wet plus dry deposition values that are mapped from NADP interpolations and CMAQ simulations in Maps J and K.

Land cover in and around the network is shown in Map L. The predominant cover types within this network are generally forest and pasture/hay. Land cover within the major parks that occur in this network is primarily forested.

GRSM contains vegetation types that likely include red spruce and sugar maple, the two tree species thought to be most sensitive to acidification and accompanying soil base cation depletion. The vegetation types most likely to contain these two tree species are not found in BISO. Sensitive vegetation in GRSM is mapped at the park rather than the network scale.

Land slope tends to be fairly steep in GRSM, with most of the park having terrain steeper than 30° (Map M). In addition, some land along the Blue Ridge Parkway is steeper than 30°. Other park lands within the network generally have land slope less than 20°.

Park lands requiring special protection against potential adverse impacts associated with acidic 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. GRSM is designated as a Class I area. There are also substantial areas scattered throughout the network that are designated as wilderness.

Maps P-1 through P-3 are park-specific maps for GRSM, which show sensitive vegetation (Map P-1), high-elevation lakes and streams (Map P-2) and low-order streams (Map P-3). Nearly the entire park is covered by vegetation types likely to contain sugar maple, with the exception of lands around parts of the park boundary. Red spruce is confined to the higher elevations, generally higher than about 1,300 m. Much of this higher elevation land is distributed along the Appalachian Mountain ridgeline.

High-elevation lakes might be more prone than lakes at lower elevation to acidification, and therefore are considered potentially more susceptible to atmospheric S and N input. As shown in Map P-2, there are some lakes along the boundary of GRSM. In addition, elevations in GRSM are among the highest in the eastern United States, with the majority of the park land being higher than 1,000 m elevation. Nevertheless, the few lakes that are found within GRSM are generally not located at high elevation, and are therefore not considered likely to be especially sensitive to acidification impacts. Most streams in the park are located at relatively high elevation (greater than 1,000 m; Map P-2) and are first through third order (Map P-3). 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 Appalachian Highlands Network ranked High in Pollutant Exposure, near the median of the second highest quintile (coded orange), among networks (Figure A). Sulfur emissions in and surrounding the network, and S deposition within the network, were both relatively high. The

network is also surrounded by many relatively large urban areas and point sources of both S and N. Nitrogen emissions within and upwind of the network and N deposition within the network were both high. The data available for estimating deposition at the national scale of this assessment did not include cloud deposition, which is known to be important at the high elevations of GRSM. As a consequence, the Pollutant Exposure rankings for GRSM, and for the network as a whole, were likely biased low.

The Ecosystem Sensitivity ranking of this network was Very High, the highest among all networks (Figure B). This is because vegetation is primarily forest expected to contain sugar maple, one of the tree species thought to be especially sensitive to acidification effects from S and N deposition. In addition, there are many high-elevation and low-order streams on relatively steep terrain. This network ranked in the third quintile in Park Protection (Figure C), having moderate amounts of protected lands.

In combination, the network rankings for Pollutant Exposure, Ecosystem Sensitivity, and Park Protection yielded an overall network Summary Risk ranking that was High among all networks. The overall level of concern for acidification effects on I&M parks within this network can be considered High. Because the Pollution Exposure ranking is likely underestimated for this network, the network Summary Risk ranking was probably also biased low, and perhaps might more properly be considered Very High.

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 rankings, the park rankings 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.

All four parks in this network were ranked High in park-specific Pollutant Exposure (Table A, Figure E), indicating high levels of atmospheric S and N deposition. The Ecosystem Sensitivity ranking for each of these parks was Very High (Figure F, Table A), mainly because the vegetation in these parks is predominately types that contain sugar maple or red spruce, and there are abundant acid-sensitive streams. The Park Protection ranking was High for BLRI and Very High for GRSM (Figure G), but only moderate for BISO and OBRI. The overall park Summary Risk ranking (Table A, Figure H) for the parks in this network was Very High for BLRI and GRSM and High for the other two parks.

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.

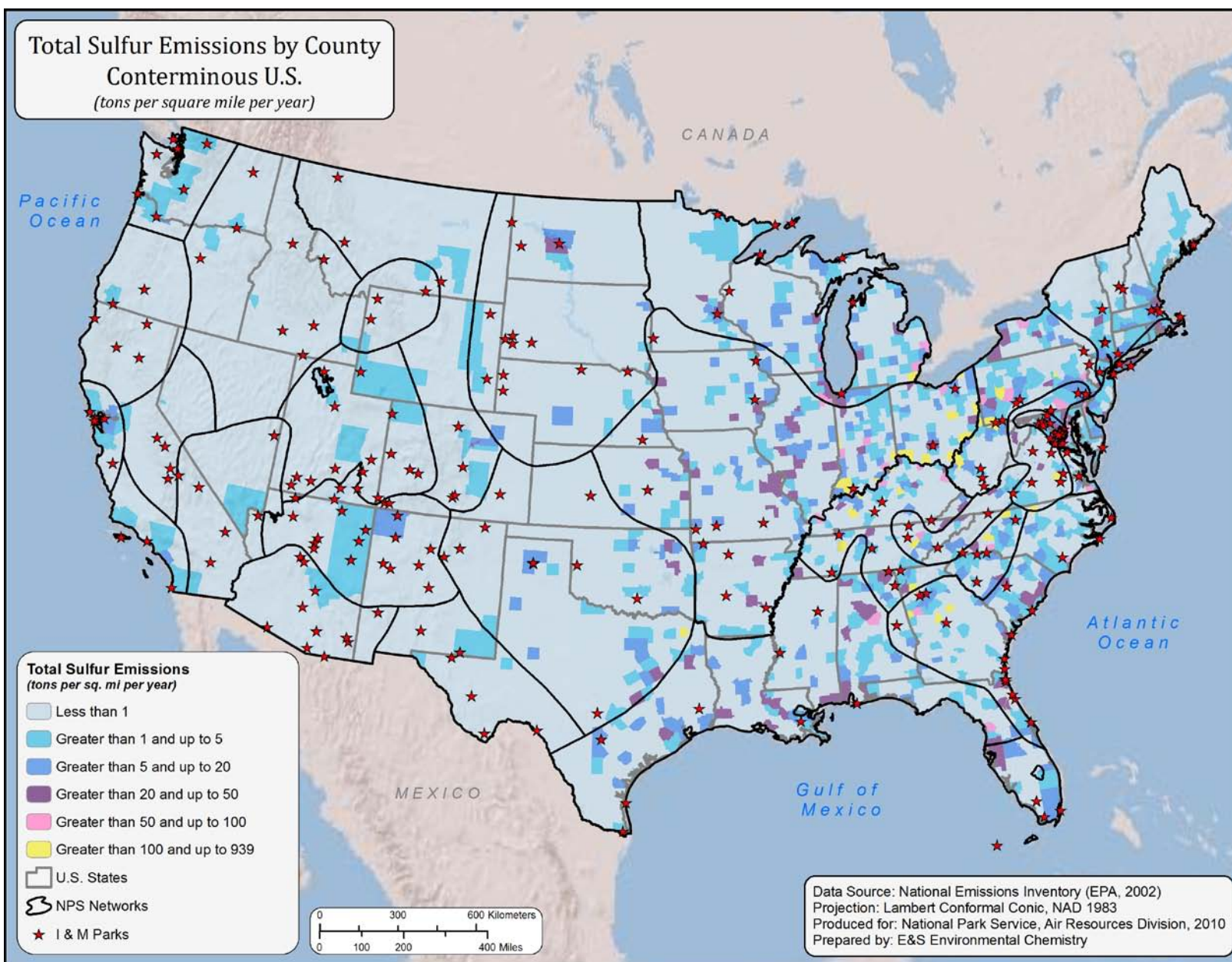
I&M Parks ² in Network	Relative Ranking of Individual Parks ¹			
	Pollutant Exposure	Ecosystem Sensitivity	Park Protection	Summary Risk
<i>Big South Fork</i>	High	Very High	Moderate	High
<i>Blue Ridge</i>	High	Very High	High	Very High
<i>Great Smoky Mountains</i>	High	Very High	Very High	Very High
Obed	High	Very High	Moderate	High

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.

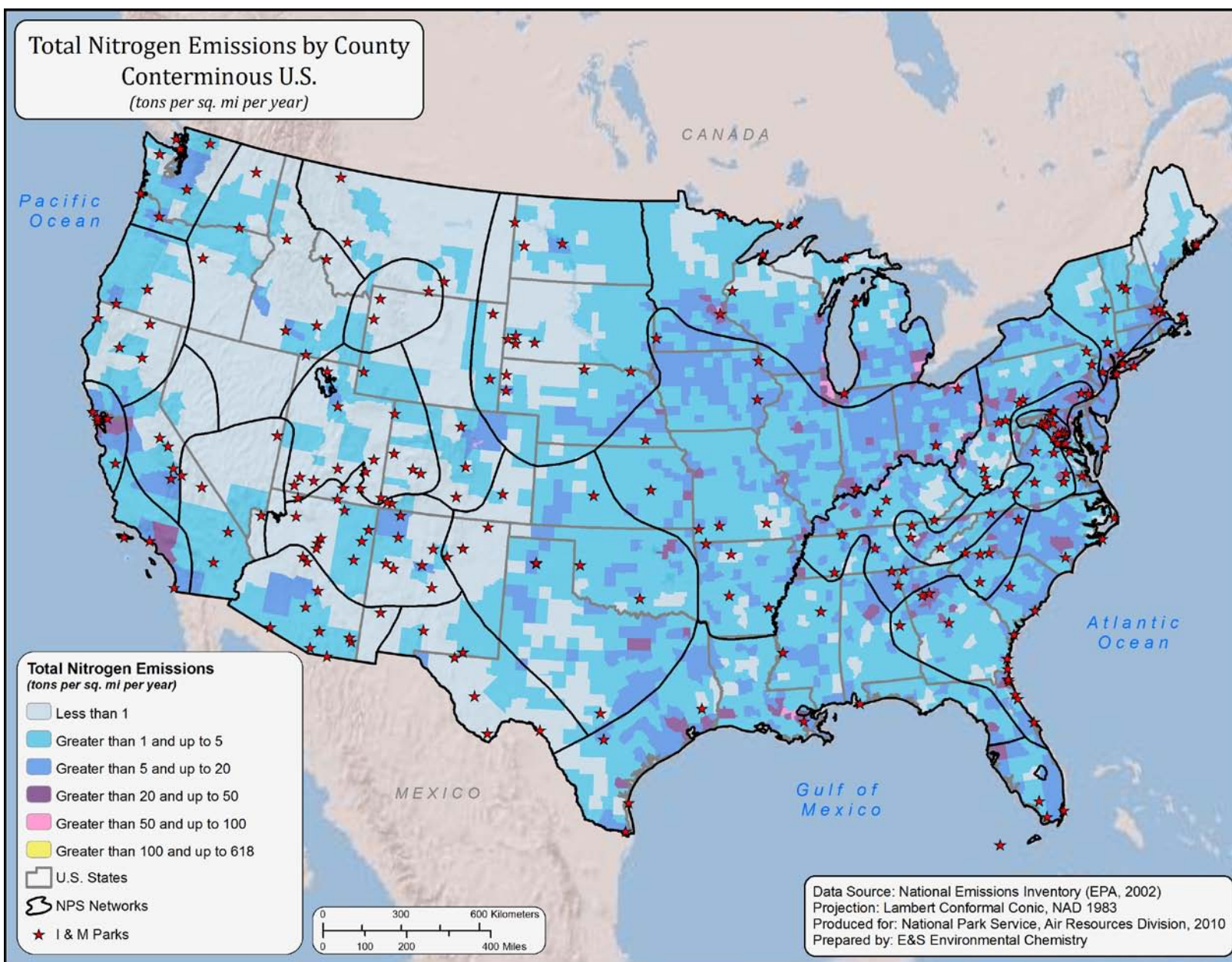
- Map A. National map of total S emissions by county for the year 2002, in units of tons of S per square mile per year. (Source of data: EPA National Emissions Inventory, <http://www.epa.gov/ttn/chief/net/2002inventory.html>)
- Map B. National map of total N emissions by county for the year 2002. Both 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: Interpolated NADP wet and CMAQ Model 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: Interpolated NADP wet and CMAQ Model 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: sensitive vegetation types in GRSM. (Source of data: Landfire [<http://www.landfire.gov/>] and NPS Vegetation Survey)

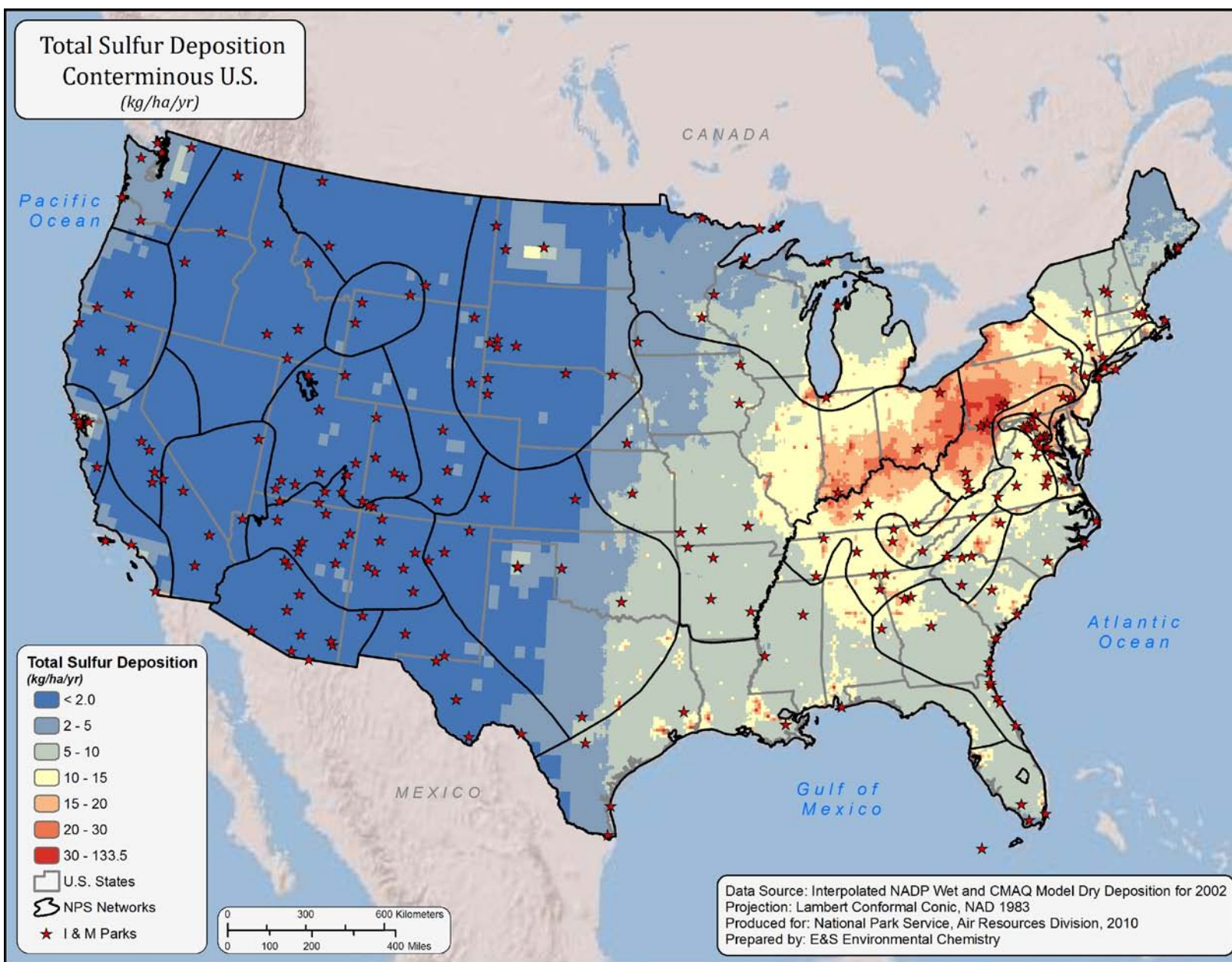
- Map P-2. Park-specific map: high-elevation lakes and streams in GRSM. (Source of data: U.S. EPA National Elevation Dataset [<http://ned.usgs.gov/>] and U.S. EPA/USGS National Hydrography Dataset Plus [<http://www.horizon-systems.com/nhdplus/>])
- Map P-3. Park-specific map: low-order streams in GRSM. (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.



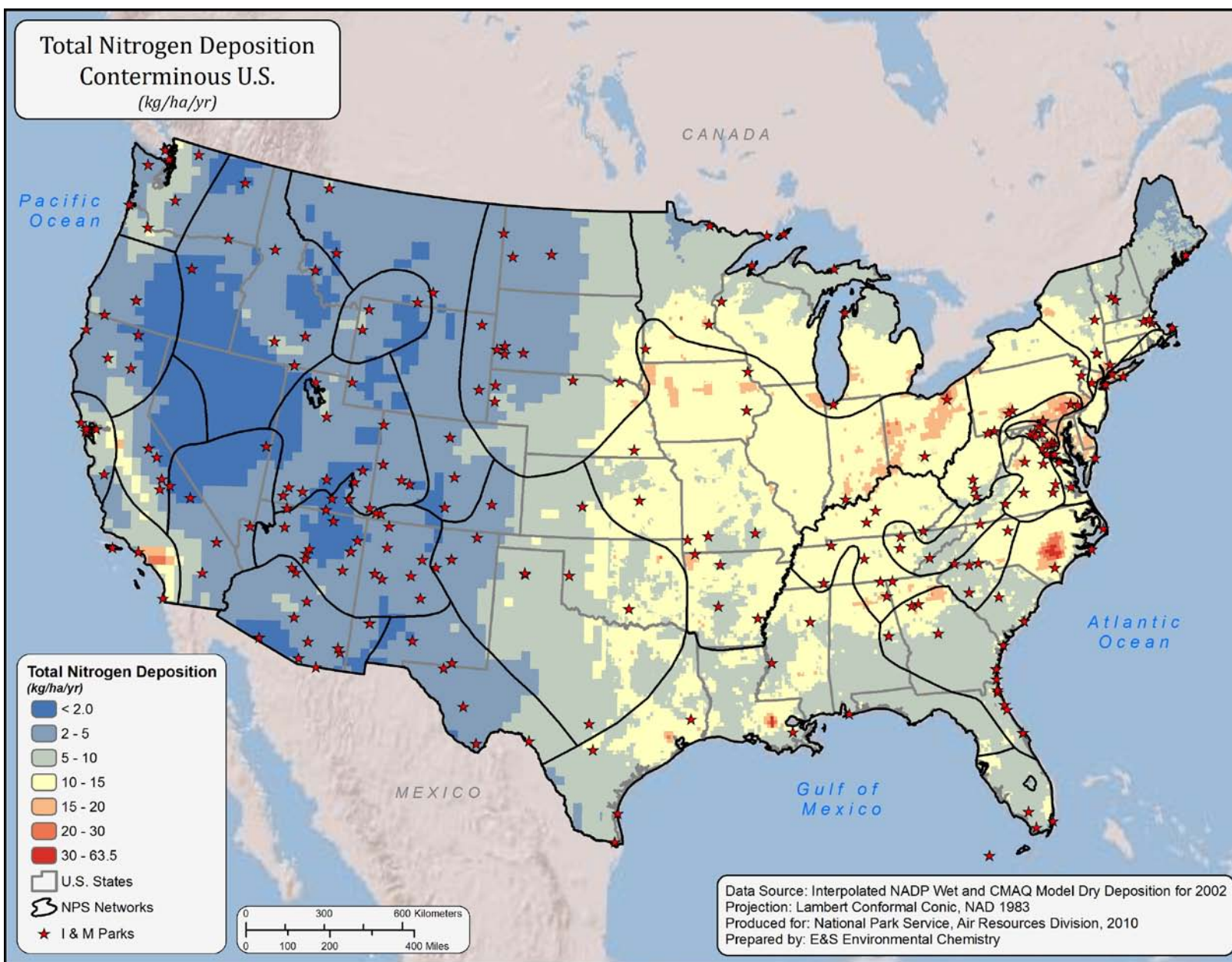
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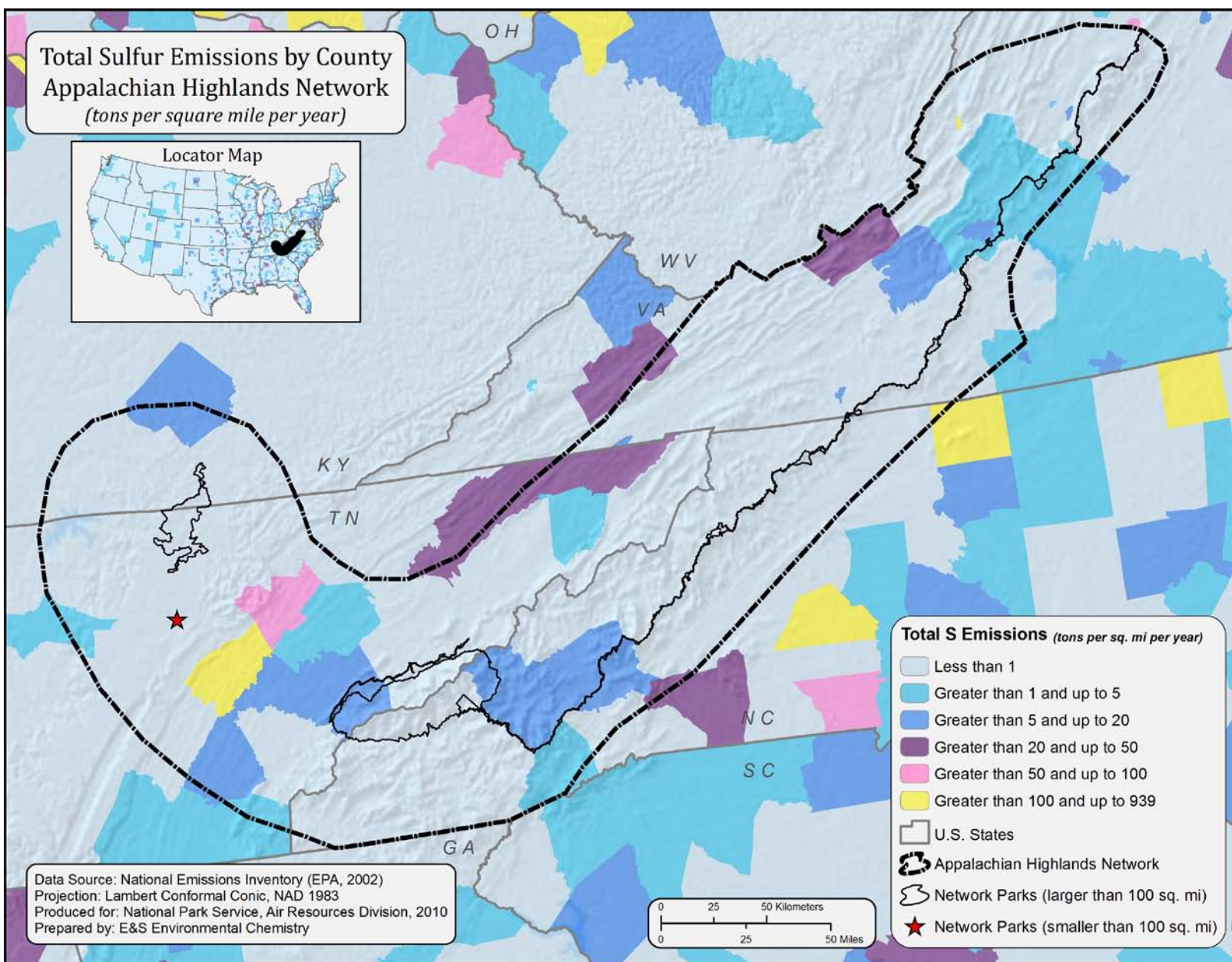
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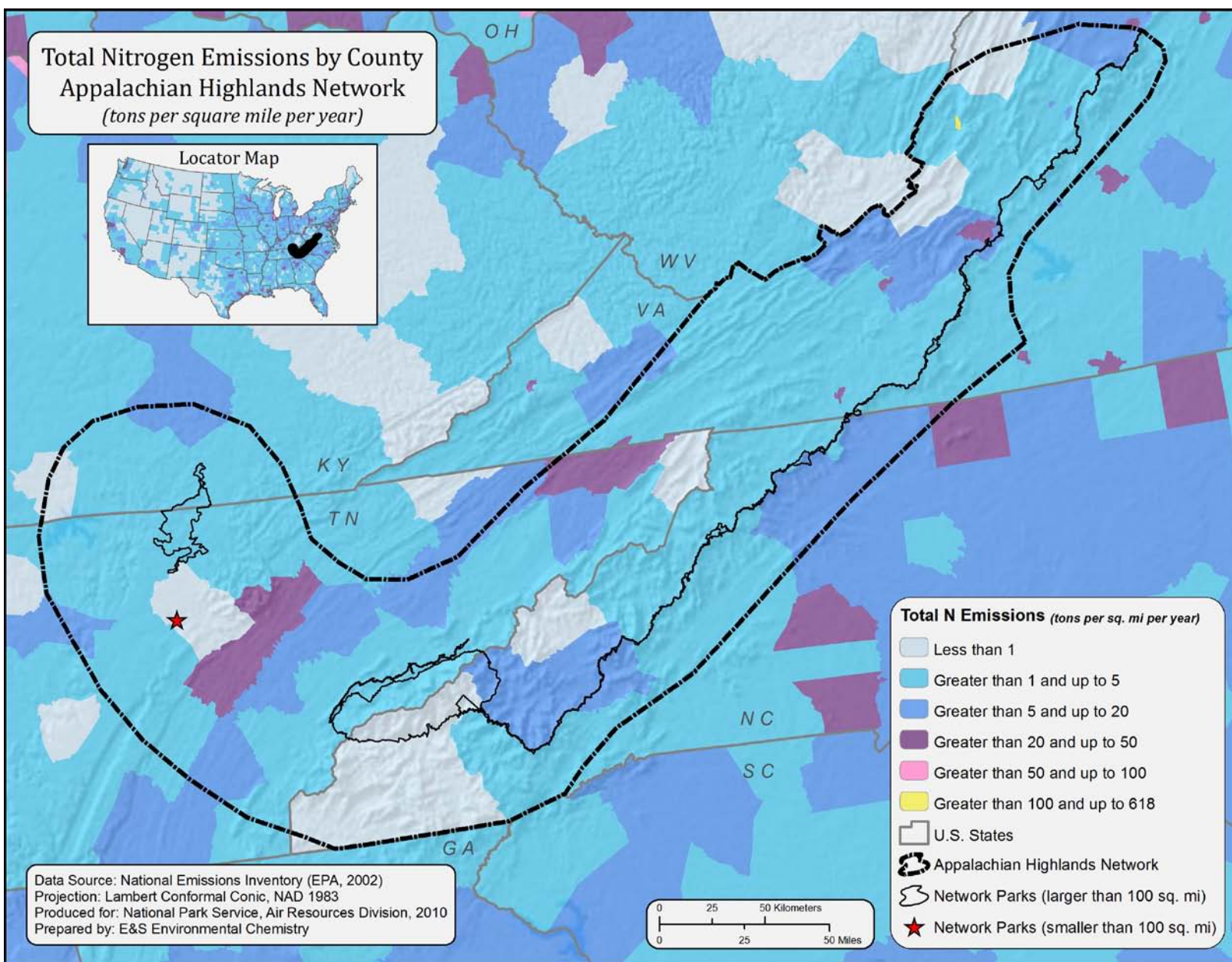
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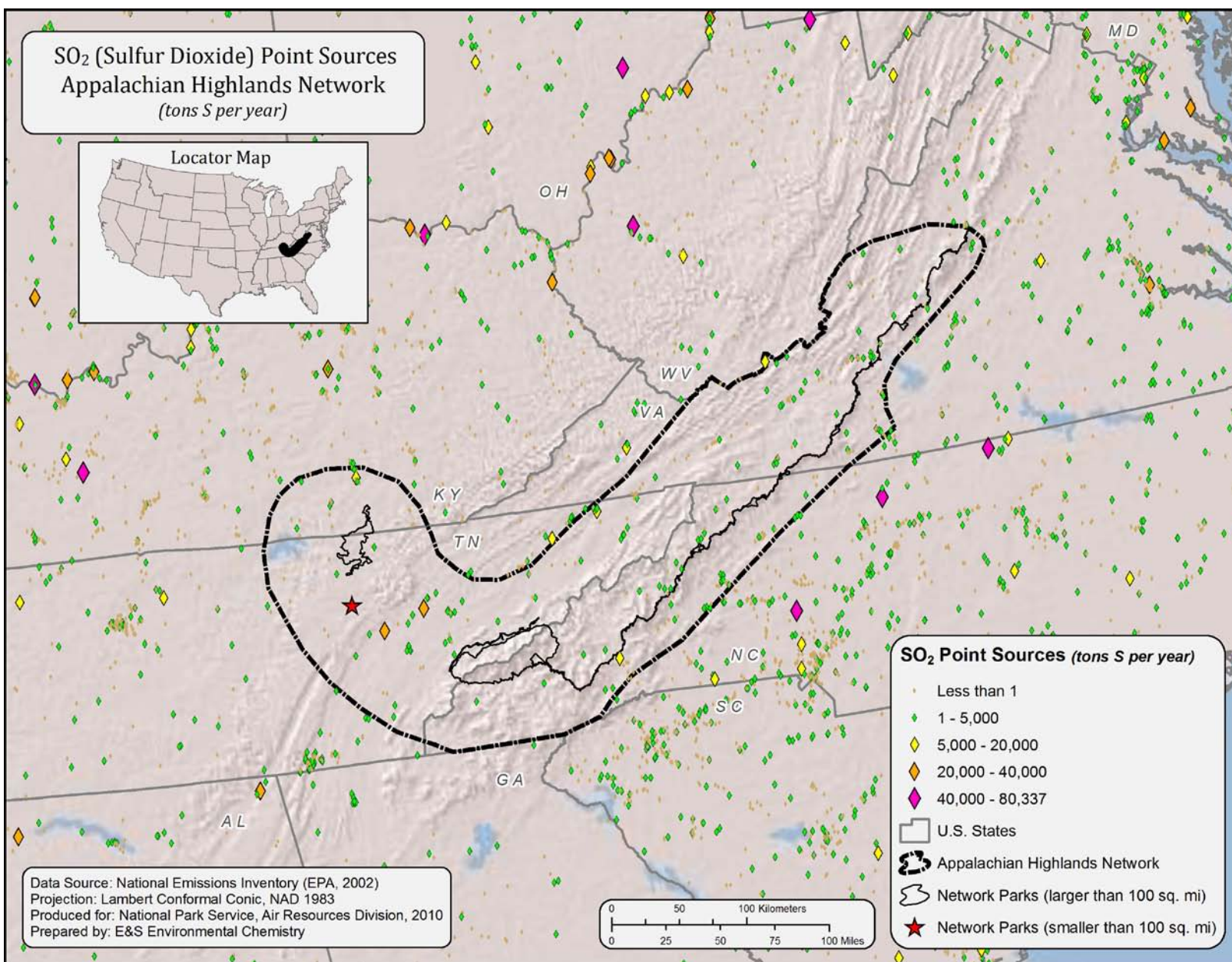
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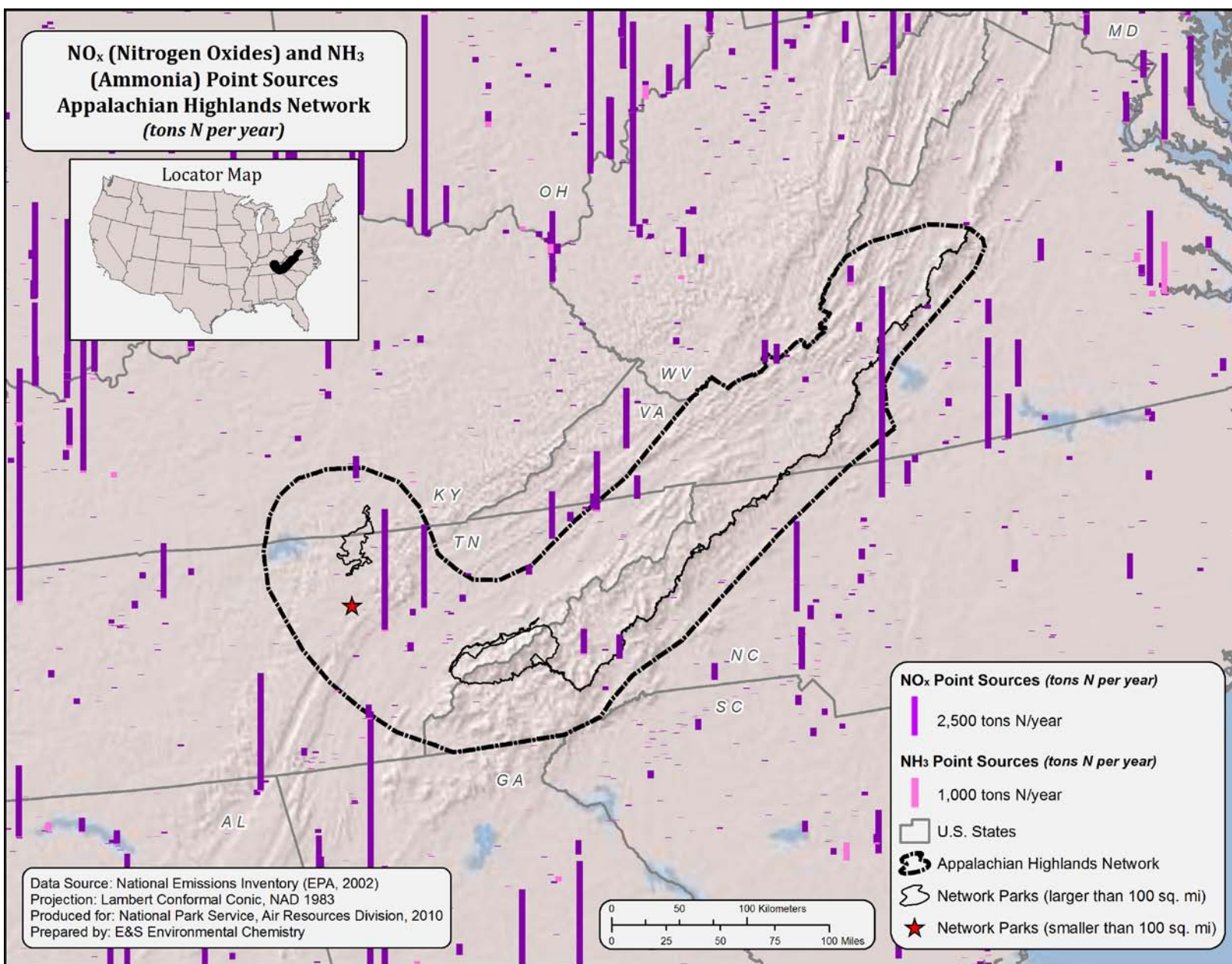
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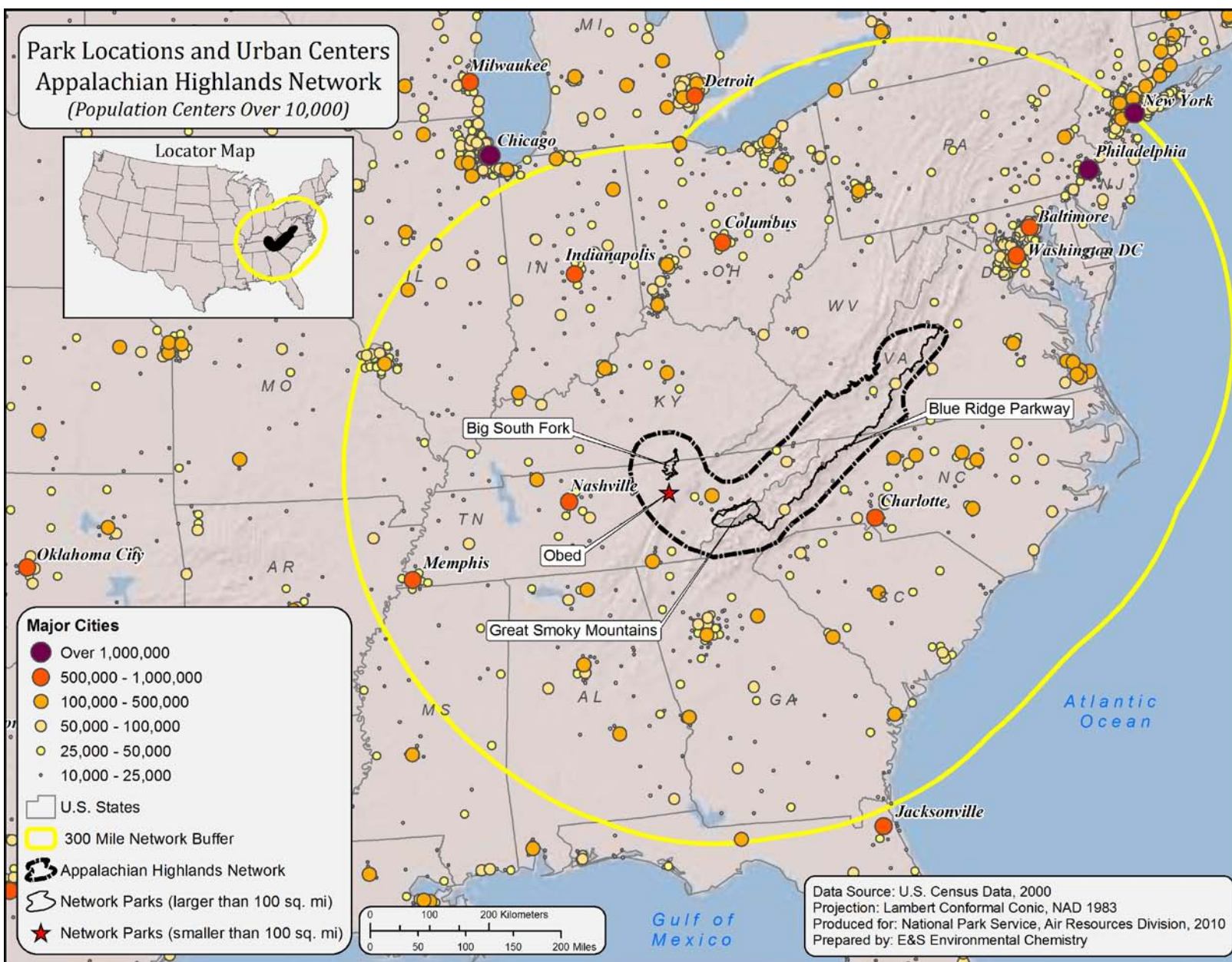
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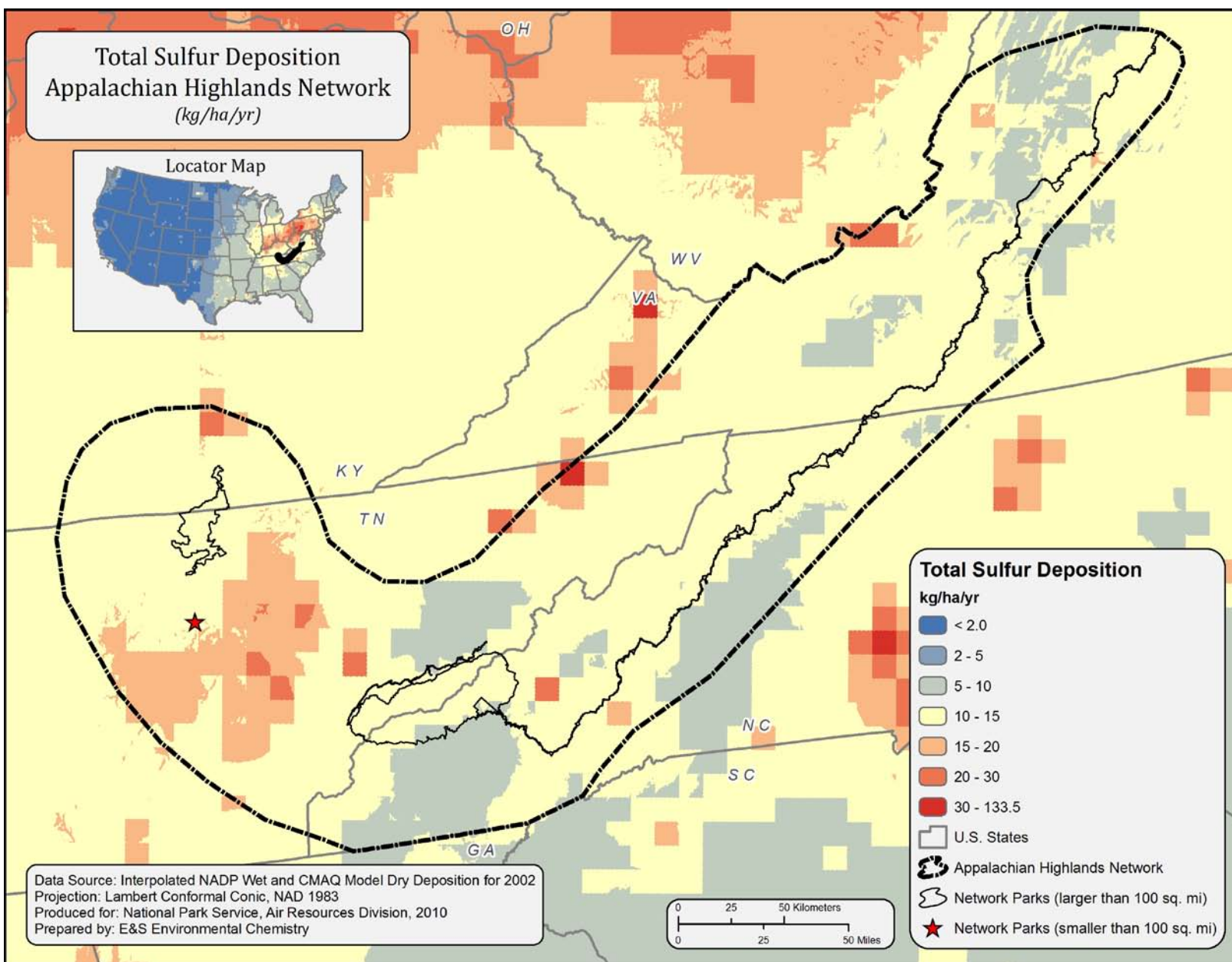
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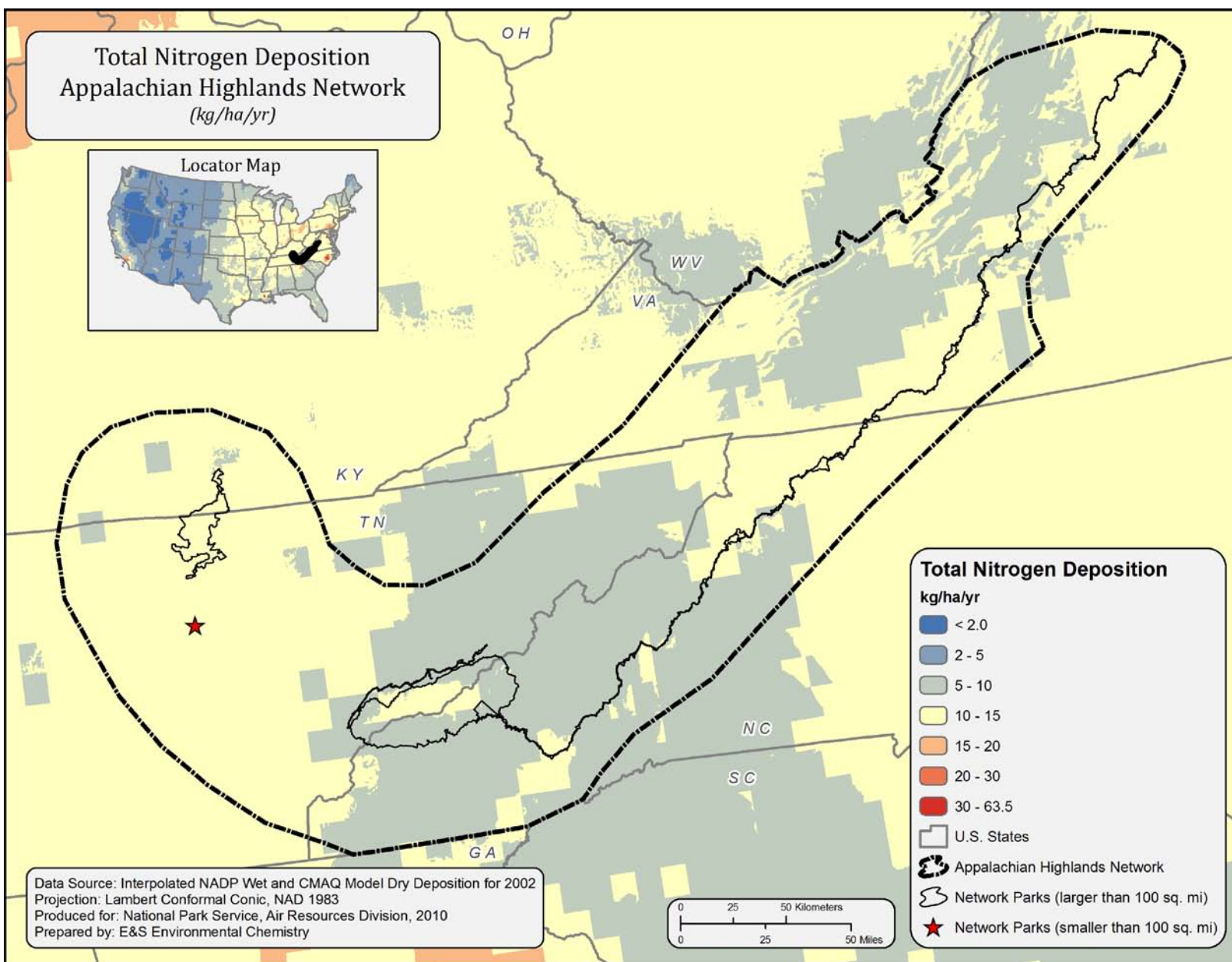
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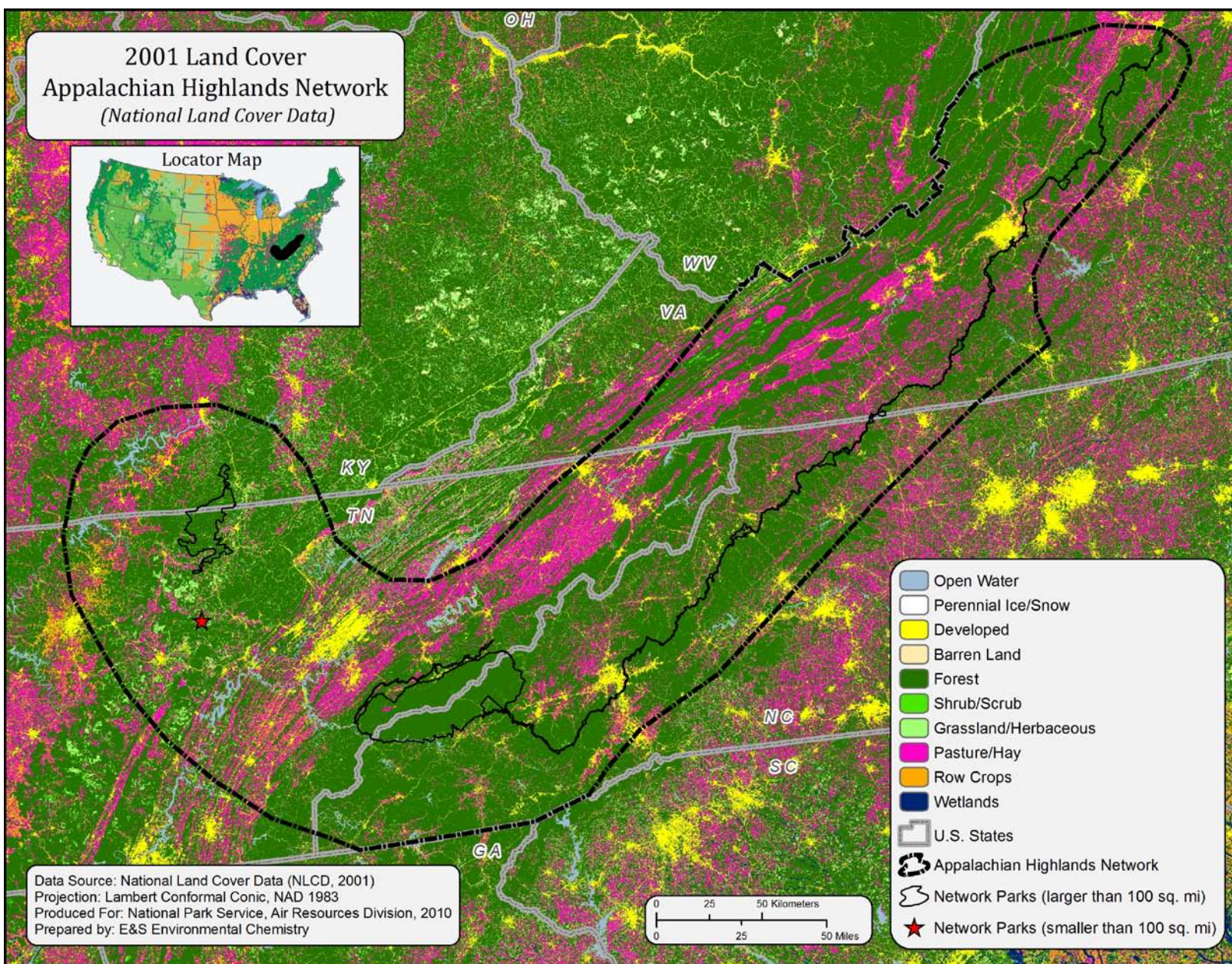
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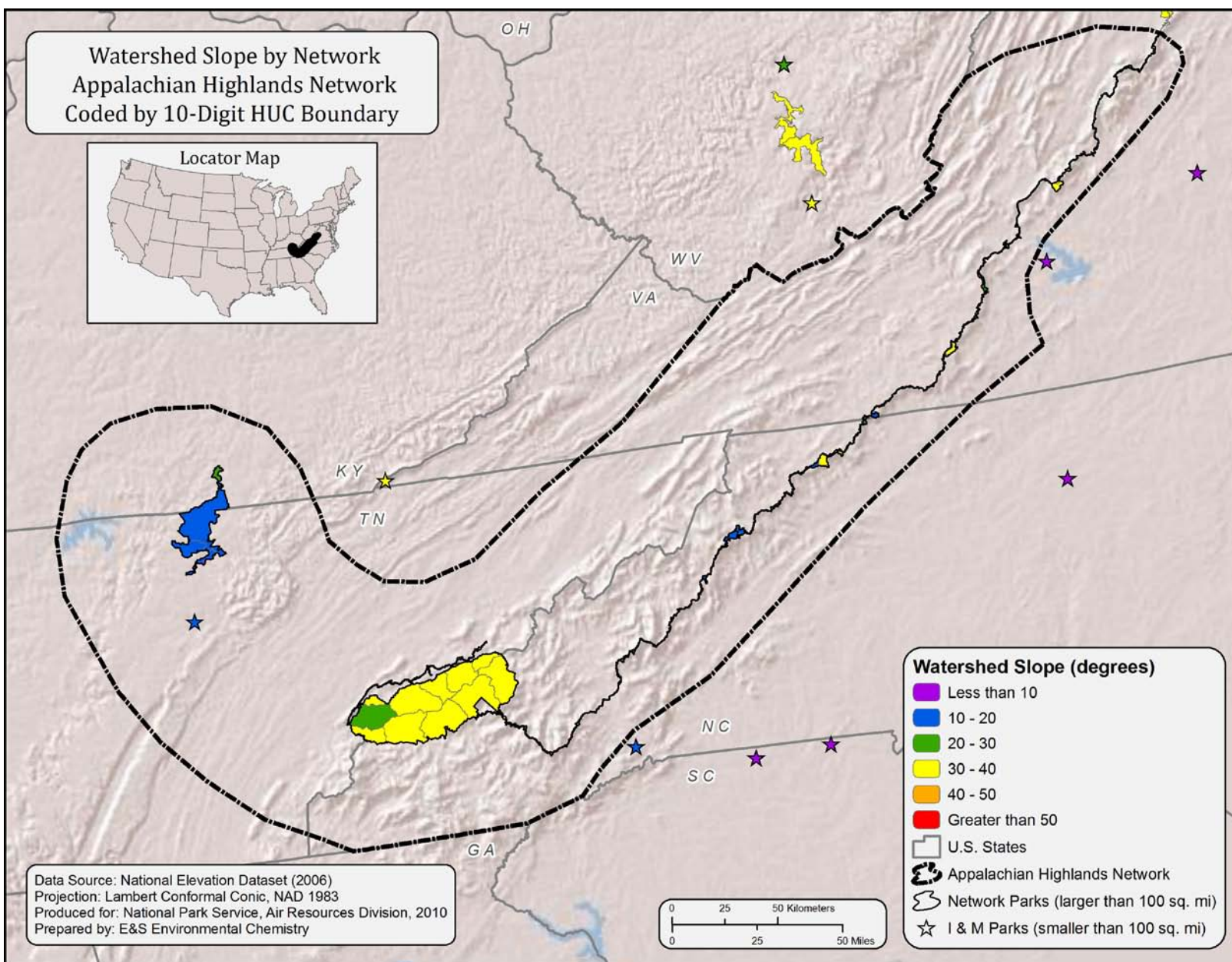
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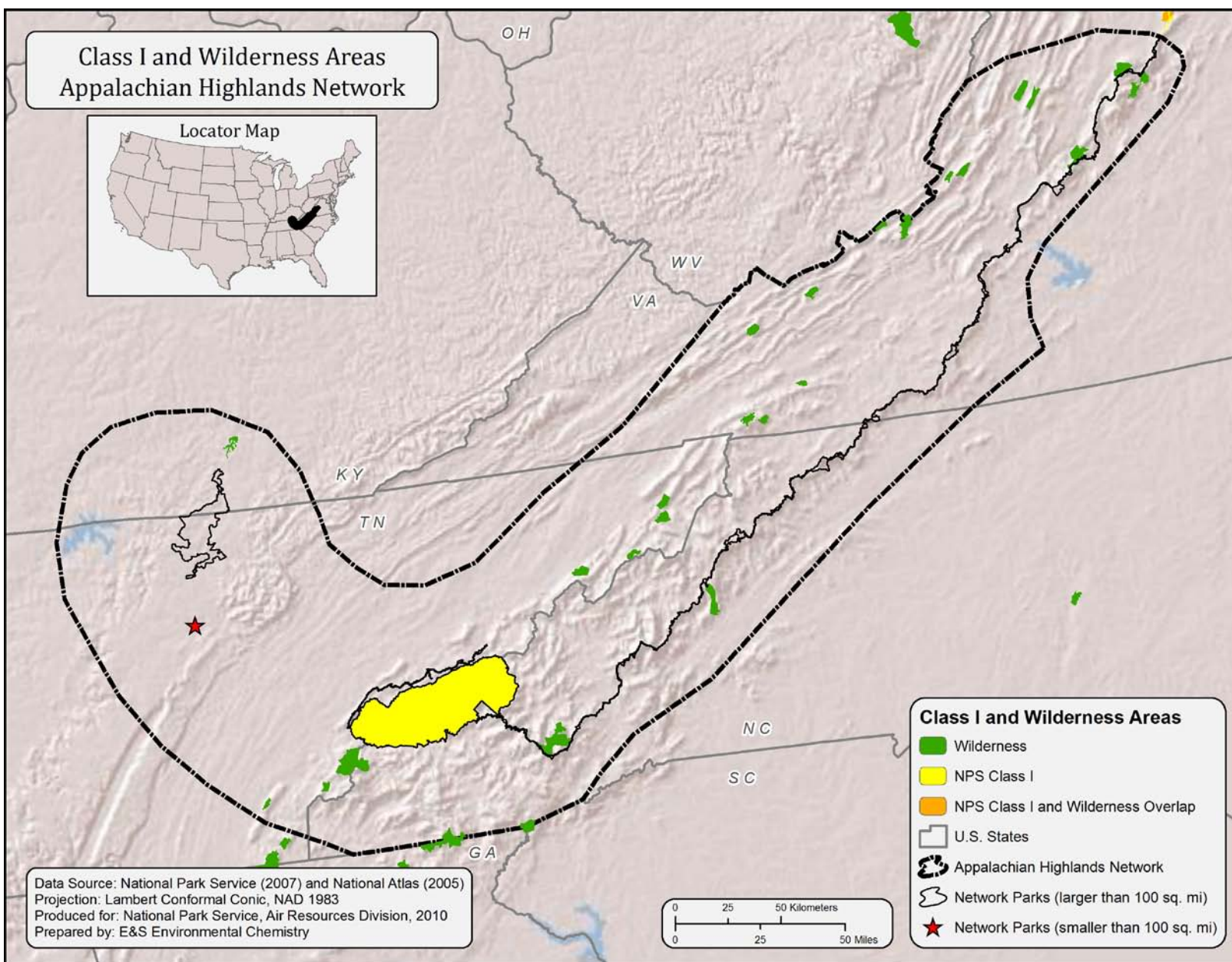
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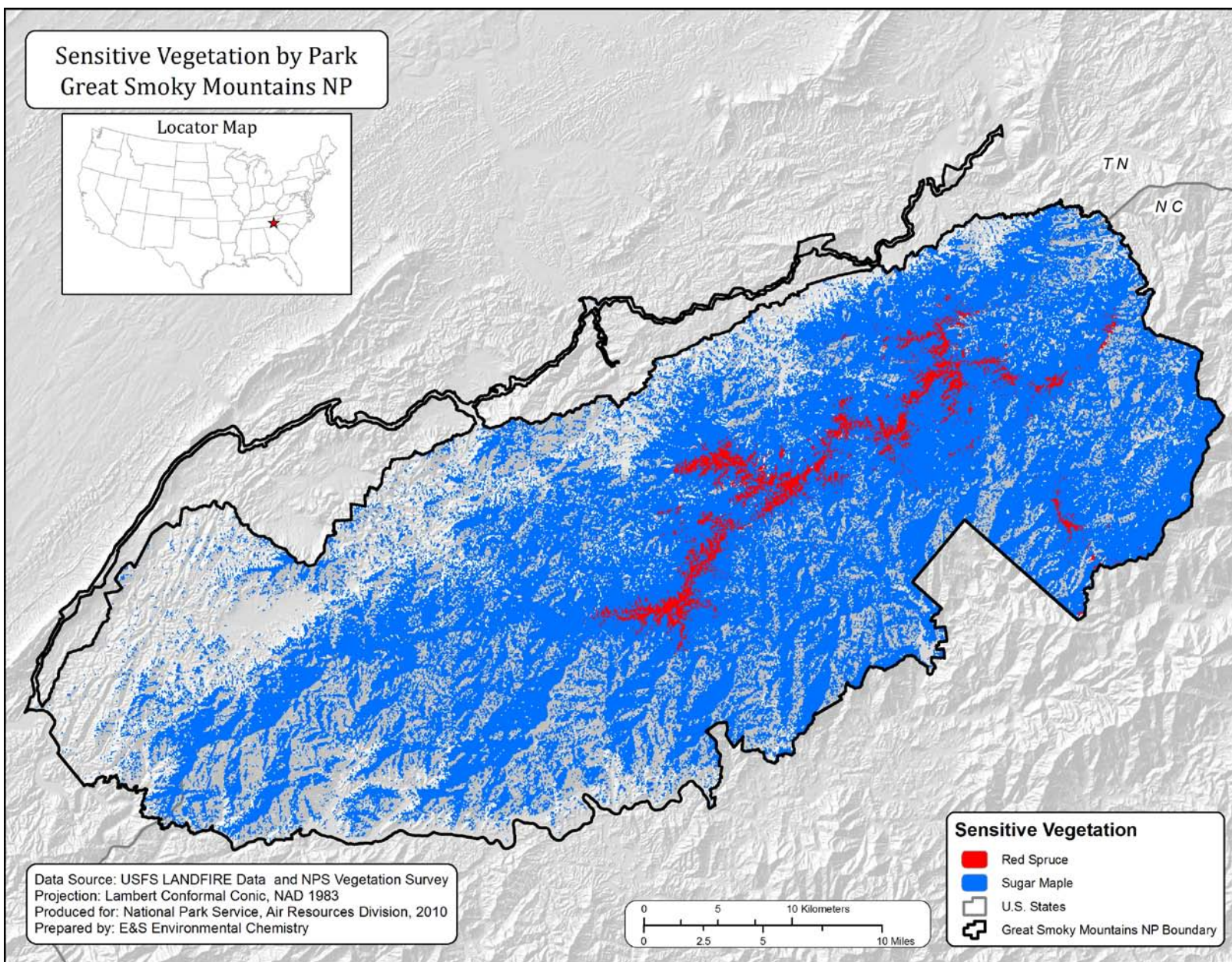
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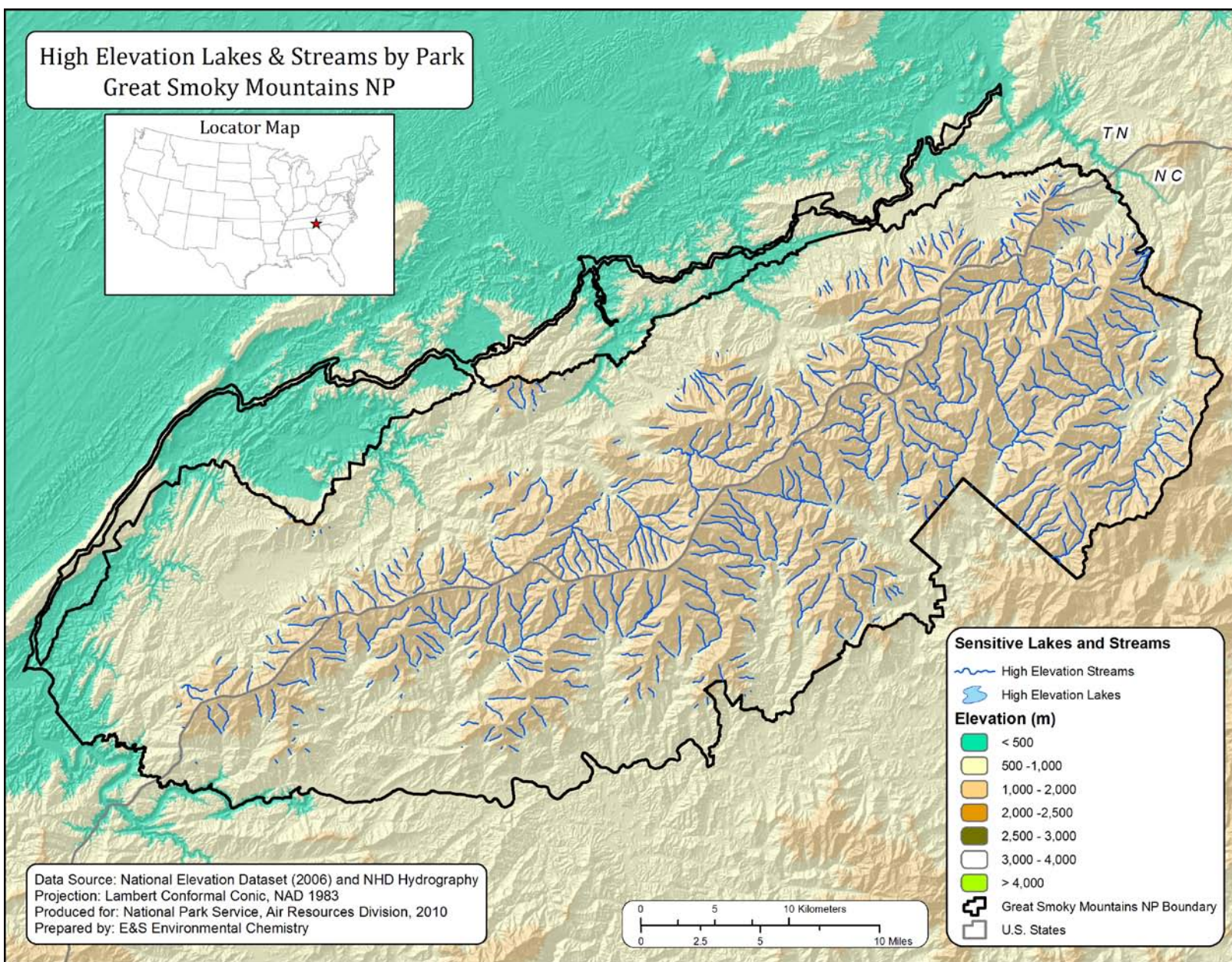
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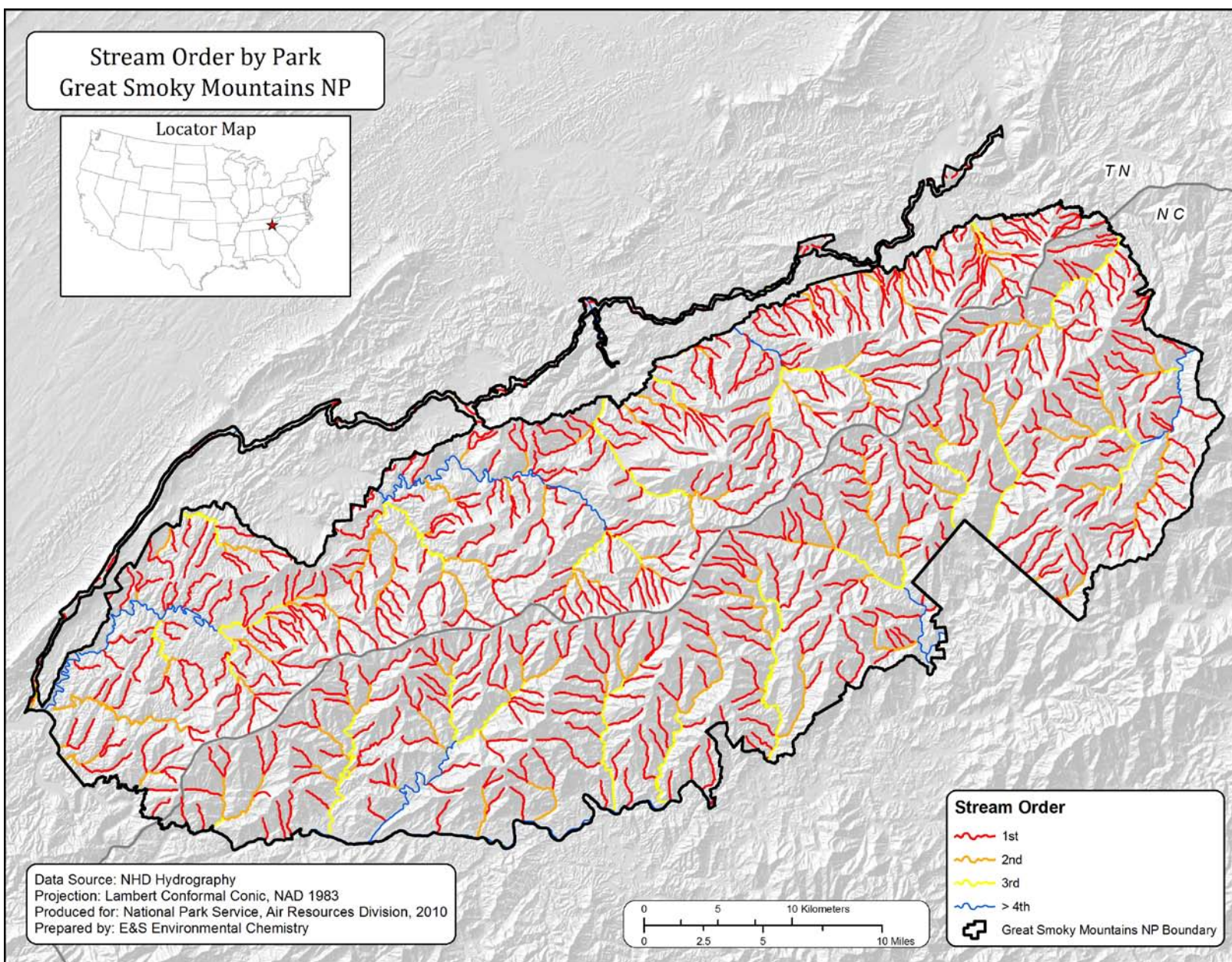
Map N



Map P-I



Map P-2



Map P-3

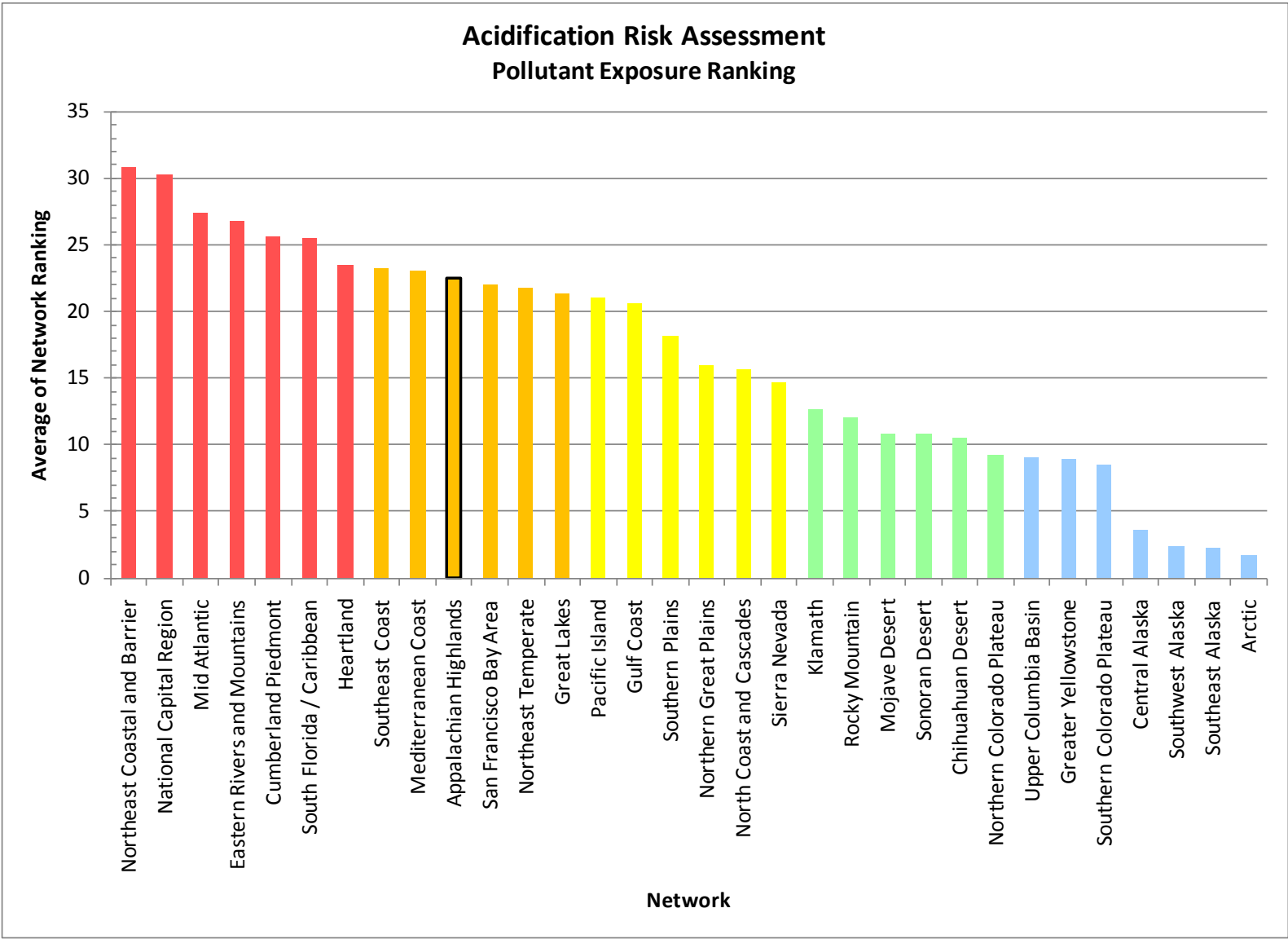


Figure A

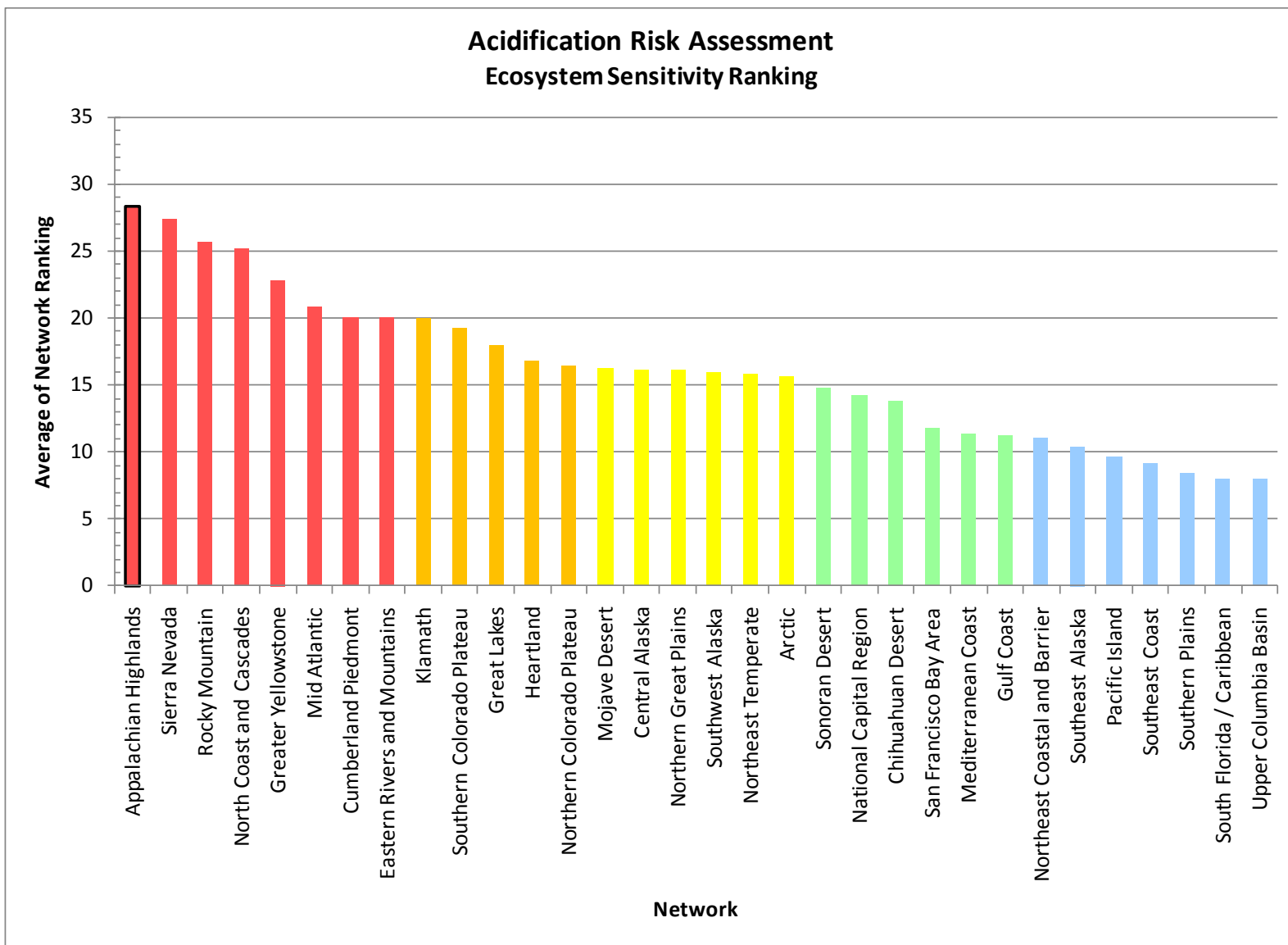


Figure B

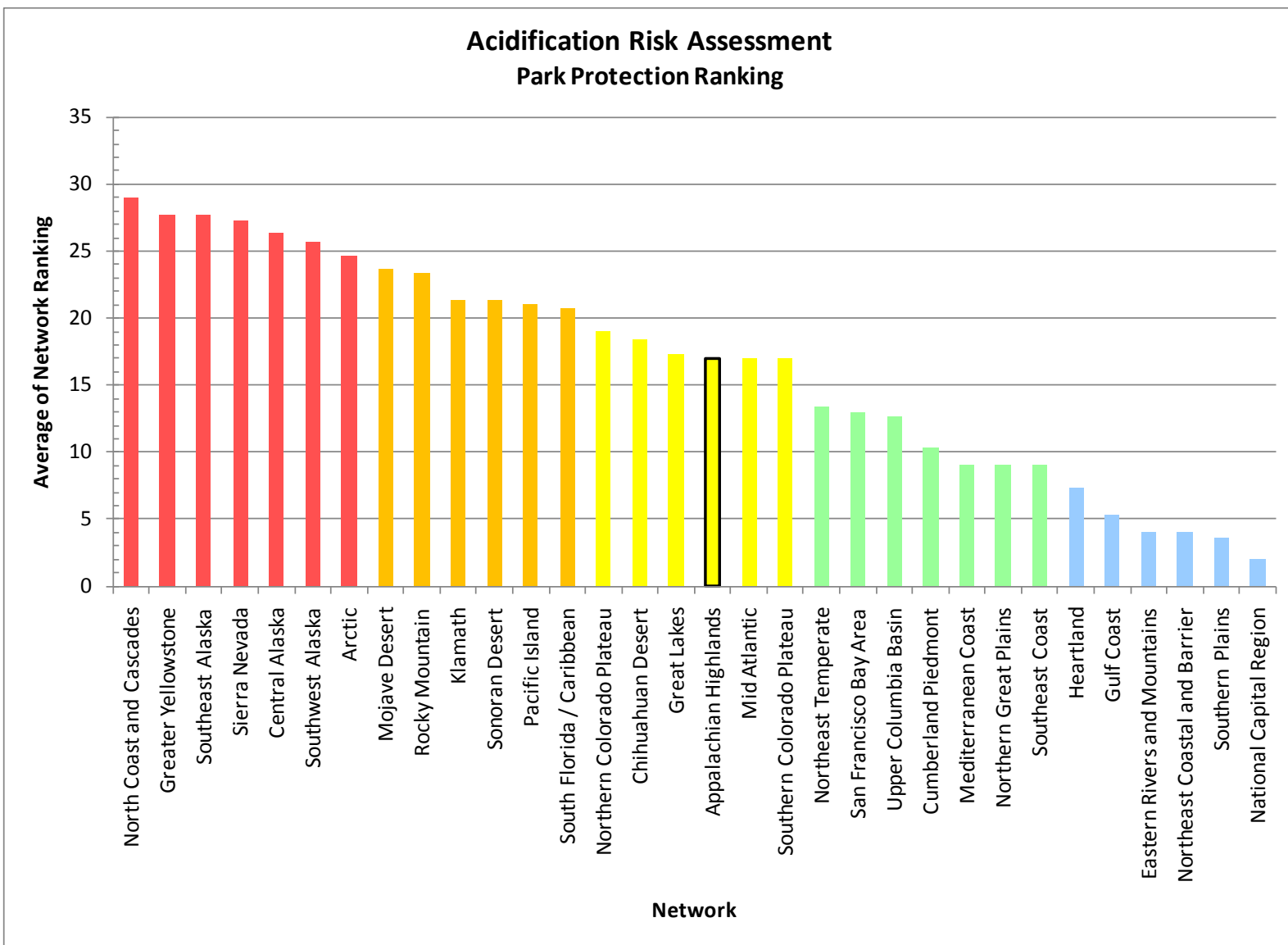


Figure C

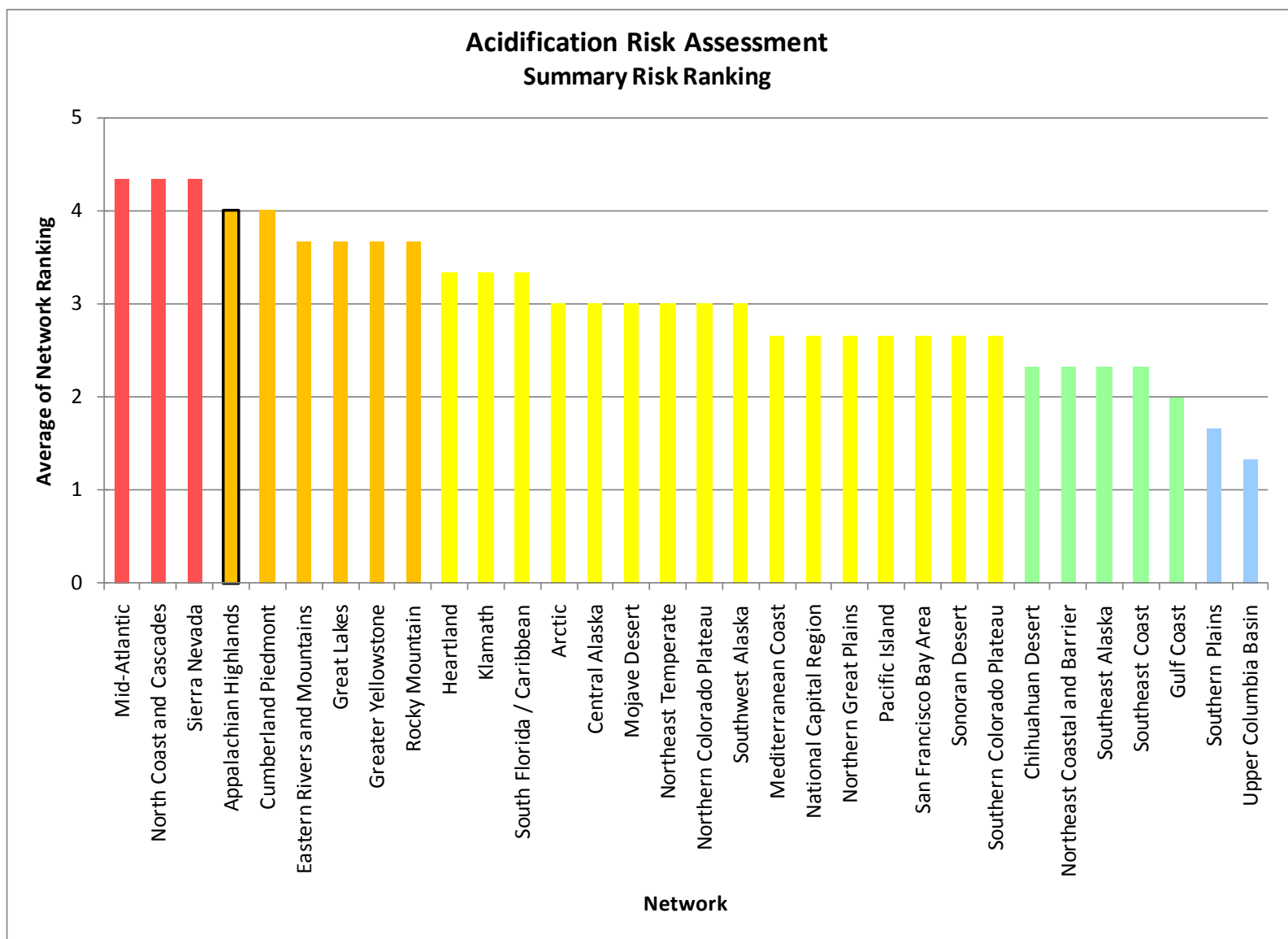


Figure D

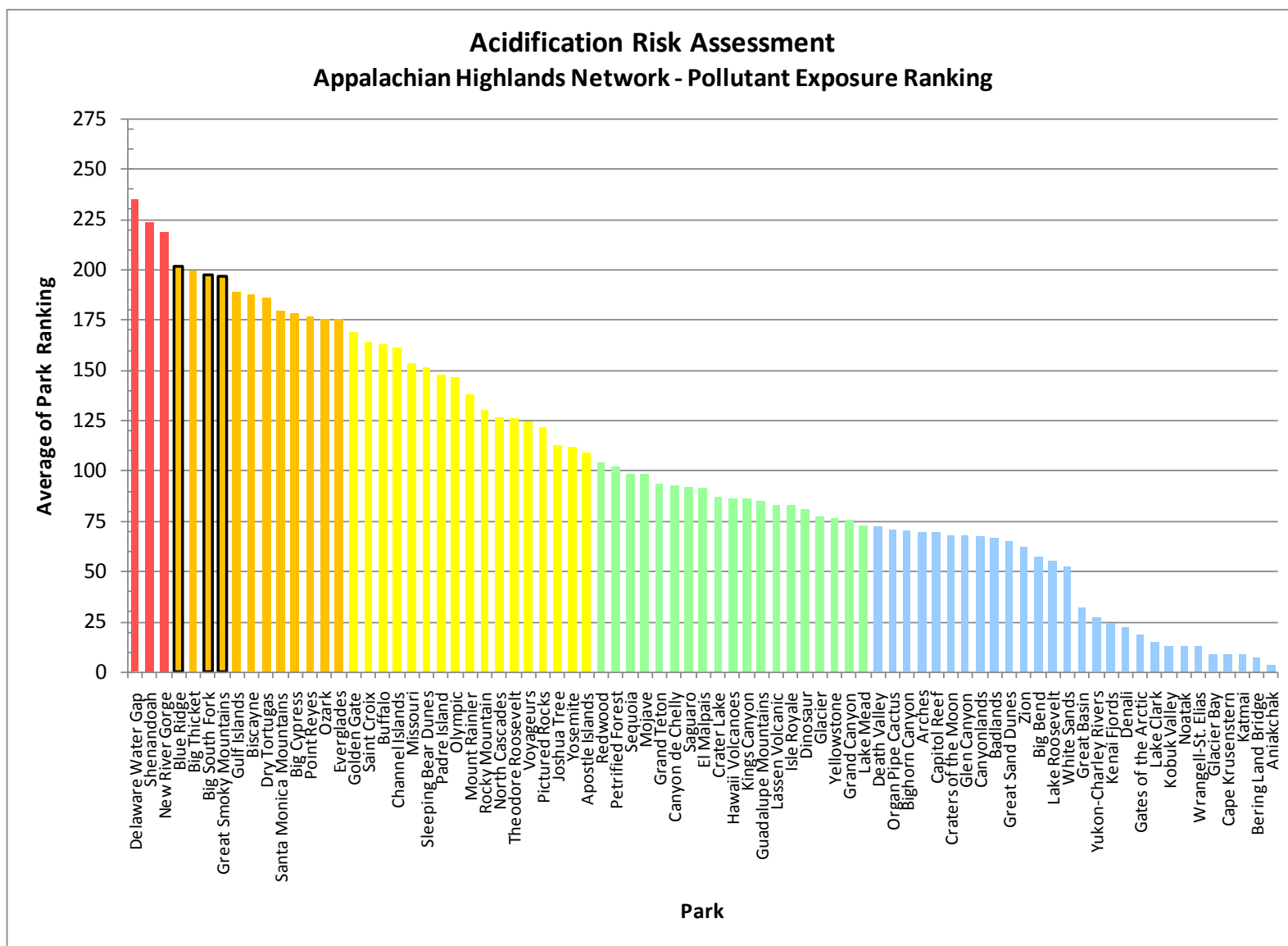


Figure E

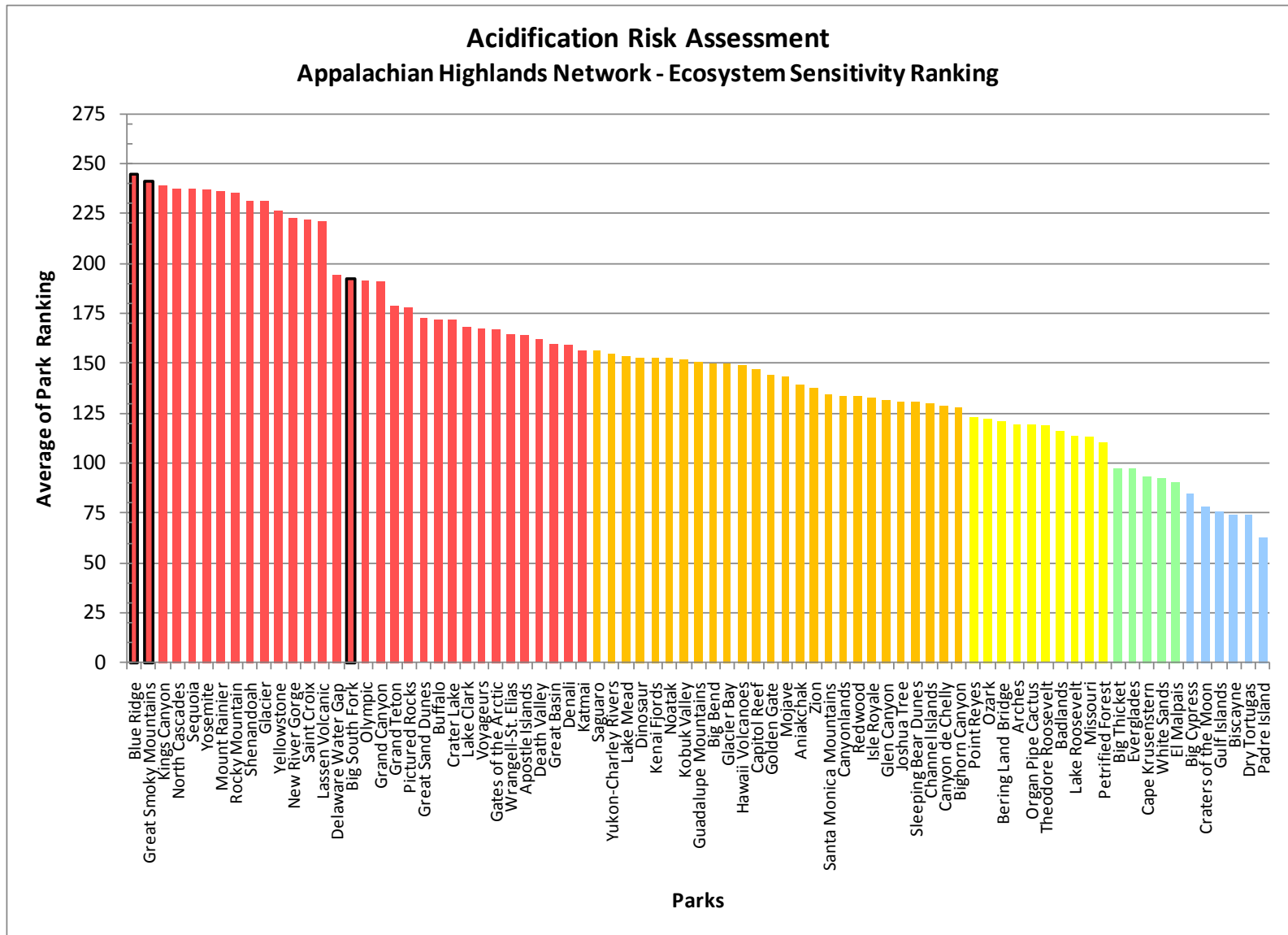


Figure F

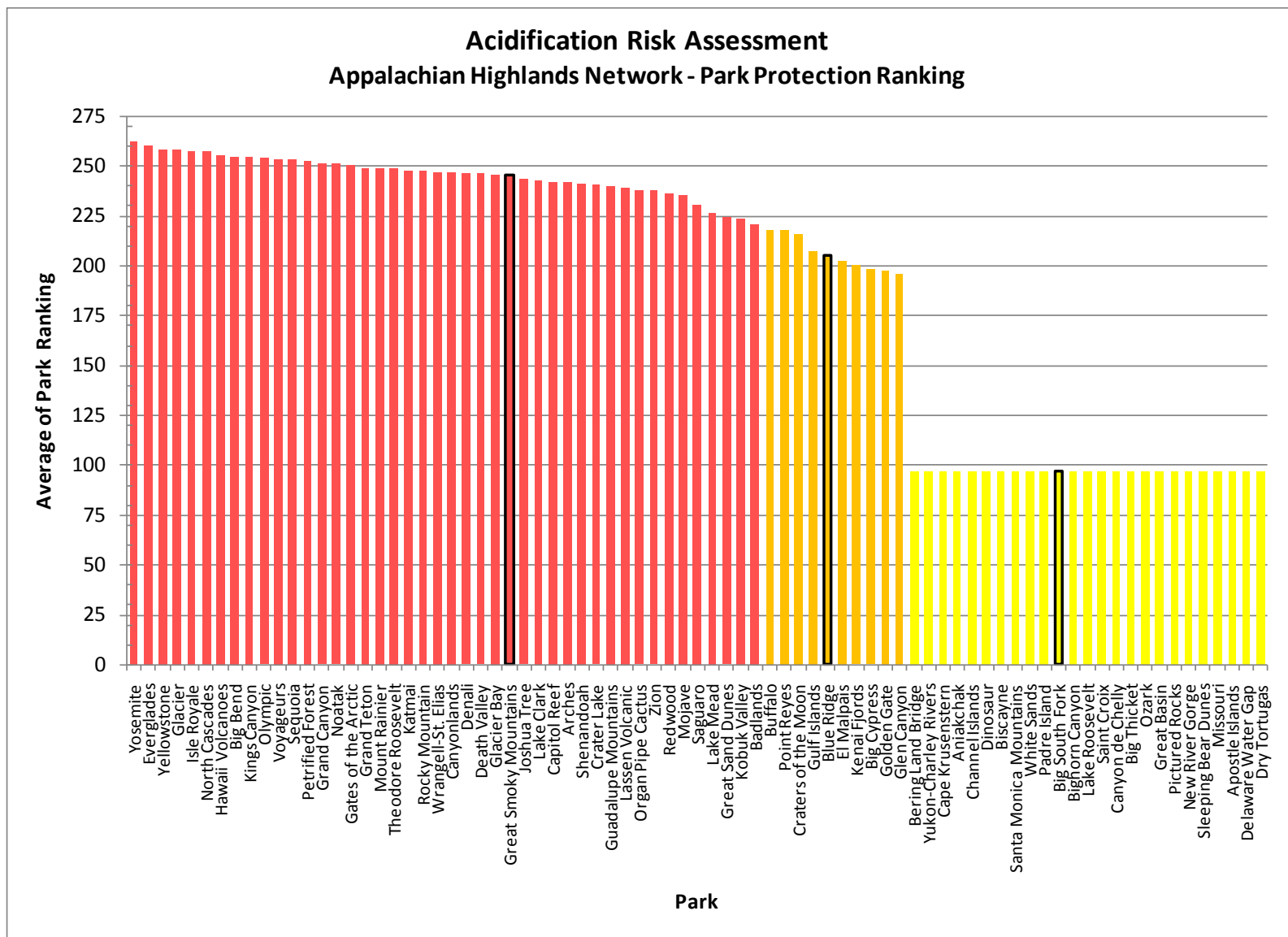


Figure G

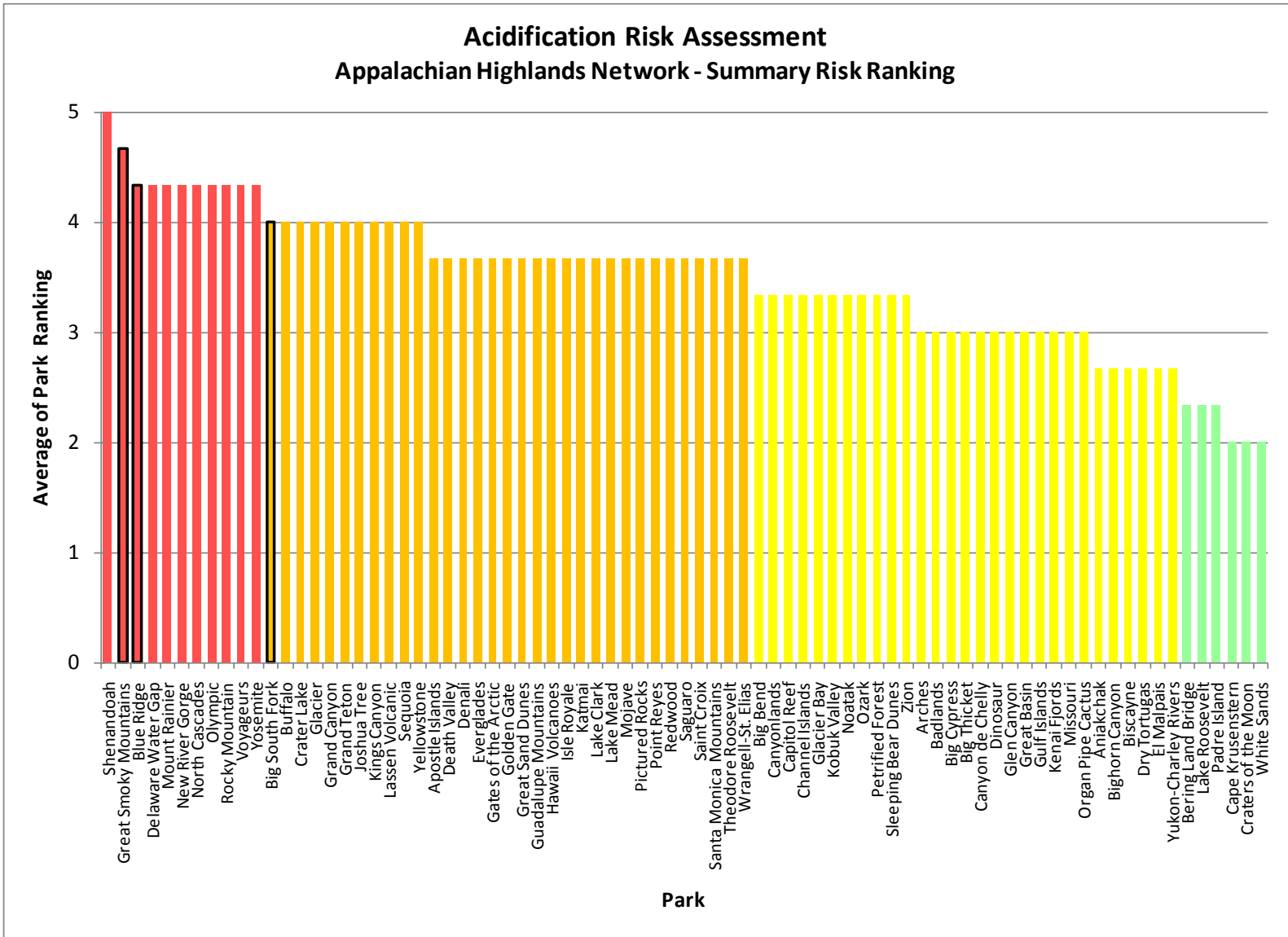


Figure H

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.

NPS 910/107384, April 2011

National Park Service
U.S. Department of the Interior



Natural Resource Program Center

Air Resources Division
PO Box 25287
Denver, CO 80225

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