National Park Service
U.S. Department of the Interior

Natural Resource Program Center

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

Heartland Network (HTLN)

Natural Resource Report NPS/NRPC/ARD/NRR—2011/359

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.

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NPS 920/107395, April 2011

Heartland Network (HTLN)

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 15 parks in the Heartland Network. Only two (Buffalo [BUFF] and Ozark [OZAR]) are larger than 100 square miles.

Total annual S and N emissions, by county, are shown in Maps E and F, respectively, for lands in and surrounding the Heartland Network. County-level S emissions within most of the network ranged from less than 1 to up to 50 tons per square mile per year (Map E). There were several counties that had higher S emissions, some more than 100 tons of S per square mile per year. These high S emissions counties were located in the eastern part of the network, predominately in Ohio and Indiana. However, in most of the network, annual S emissions were less than 20 tons per square mile. County-level N emissions within the network generally ranged from less than 1 ton per square mile to between 20 and 50 tons per square mile (Map F). There was one county, located in eastern Missouri, that had N emissions greater than 100 tons per square mile per year, but in most of the network, county N emissions were less than 20 tons per square mile per year. Individual point source emissions of S are shown in Map G. There were numerous point sources of considerable magnitude. Many emitted more than 20,000 tons of S per year (Map G). Most of the largest S emission point sources were in Ohio and Indiana. Point source emissions of oxidized (nitrogen oxides, NO_x) and reduced (ammonia, NH_3) N are shown in Map H. There were many relatively large (larger than about 4,000 tons per year) point sources of oxidized N in and around the eastern portion of the network. There were also many smaller point sources of both oxidized and reduced N. The reduced N point sources were primarily in the western part of the network, in Kansas and Minnesota.

Urban centers within the network and within a 300-mile buffer around the network are shown in Map I. The largest population centers within the network are Indianapolis and Columbus. However, there are numerous large urban centers within the 300-mile buffer around the network, including Philadelphia, Houston, Dallas, and Chicago.

Total S and N deposition in and around the network are shown on 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 within the network generally ranged from 2 to 5 kg S/ha/yr to between 20 and 30 kg S/ha/yr, with small areas exceeding 30 kg S/ha.yr (Map J). Total S deposition increased from relatively low values in the west to high levels of deposition in the east. Total N deposition within the network ranged from as low as 5 to 10 kg N/ha/yr to above 20 kg N/ha/yr at some locations (Map K). Throughout most of the network, total N deposition was between about 10 and 15 kg N/ha/yr.

Land cover in and around the network is shown in Map L. The predominant cover types within this network are generally row crops and pasture/hay. There are also forested and developed areas scattered throughout the network, and a considerable amount of wetland in the southern part of the network.

Land slope across the park lands within and surrounding the network is displayed on Map M. Park lands within the network generally have low relief, with slopes less than 20º across most of the parks (Map M). One park, Hot Springs (HOSP), has average slope in the range of 20º to 30º.

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. There are no NPS Class I areas in this network and only scattered small areas designated as wilderness, none of which is managed by NPS.

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 Heartland Network ranked at the bottom of the highest quintile, Very High among networks, in Pollutant Exposure (Figure A). Sulfur and N emissions and deposition within the network were relatively high. However, the network Ecosystem Sensitivity ranking was slightly lower, ranked as High, in the second highest quintile among networks (Figure B). This was partly because there is vegetation coverage in this network that includes the vegetation types expected to be especially sensitive to acidification effects from S and N deposition, and there is one high-elevation lake and some high-elevation streams. This network ranked at the top of the lowest quintile in Park Protection, having limited 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 moderate among networks (Figure D). The overall level of concern for acidification effects on I&M parks within this network is considered Moderate.

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 I&M parks in this network that are larger than 100 square miles (BUFF and OZAR) were ranked as Moderate and High, respectively, in Pollutant Exposure (Figure E). Smaller parks in the network were ranked Moderate (four parks), High (six parks), and Very High (three parks) for this theme. BUFF was ranked Very High, the only park in the network with that ranking, and OZAR was ranked Moderate, in Ecosystem Sensitivity (Figure F). The smaller parks in the network varied, and were ranked from Very Low to High in Ecosystem Sensitivity. BUFF was ranked High among parks for Park Protection (Figure G), whereas all other parks in the network were ranked Moderate for this theme (Table A). Four parks, including BUFF, were ranked High for overall Summary Risk. The other parks were ranked Moderate in overall Summary Risk, except for Arkansas Post (ARPO), which was ranked low.

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
Arkansas Post	Moderate	Very Low	Moderate	Low
Buffalo	Moderate	Very High	High	High
Cuyahoga Valley	Very High	High	Moderate	High
Effigy Mounds	High	High	Moderate	High
George Washington Carver	High	Very Low	Moderate	Moderate
Herbert Hoover	High	Very Low	Moderate	Moderate
Homestead	High	Low	Moderate	Moderate
Hopewell Culture	Very High	Low	Moderate	Moderate
Hot Springs	Moderate	Moderate	Moderate	Moderate
Lincoln Boyhood	Very High	Low	Moderate	Moderate
Ozark	High	Moderate	Moderate	Moderate
Pea Ridge	High	Moderate	Moderate	Moderate
Pipestone	Moderate	Low	Moderate	Moderate
Tallgrass Prairie	High	High	Moderate	High
Wilson's Creek	Moderate	Low	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.

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, NH_3) 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, 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, NO_x) and reduced (ammonia, 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 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, NO_x) and reduced (ammonia, 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: 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, NH_3) 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. Some parks in this network are slightly larger than 100 mi^2, but yet too small to readily see the color within the park outline. These parks are represented on the map with a colored circle and a line from the circle indicating the park location. (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.

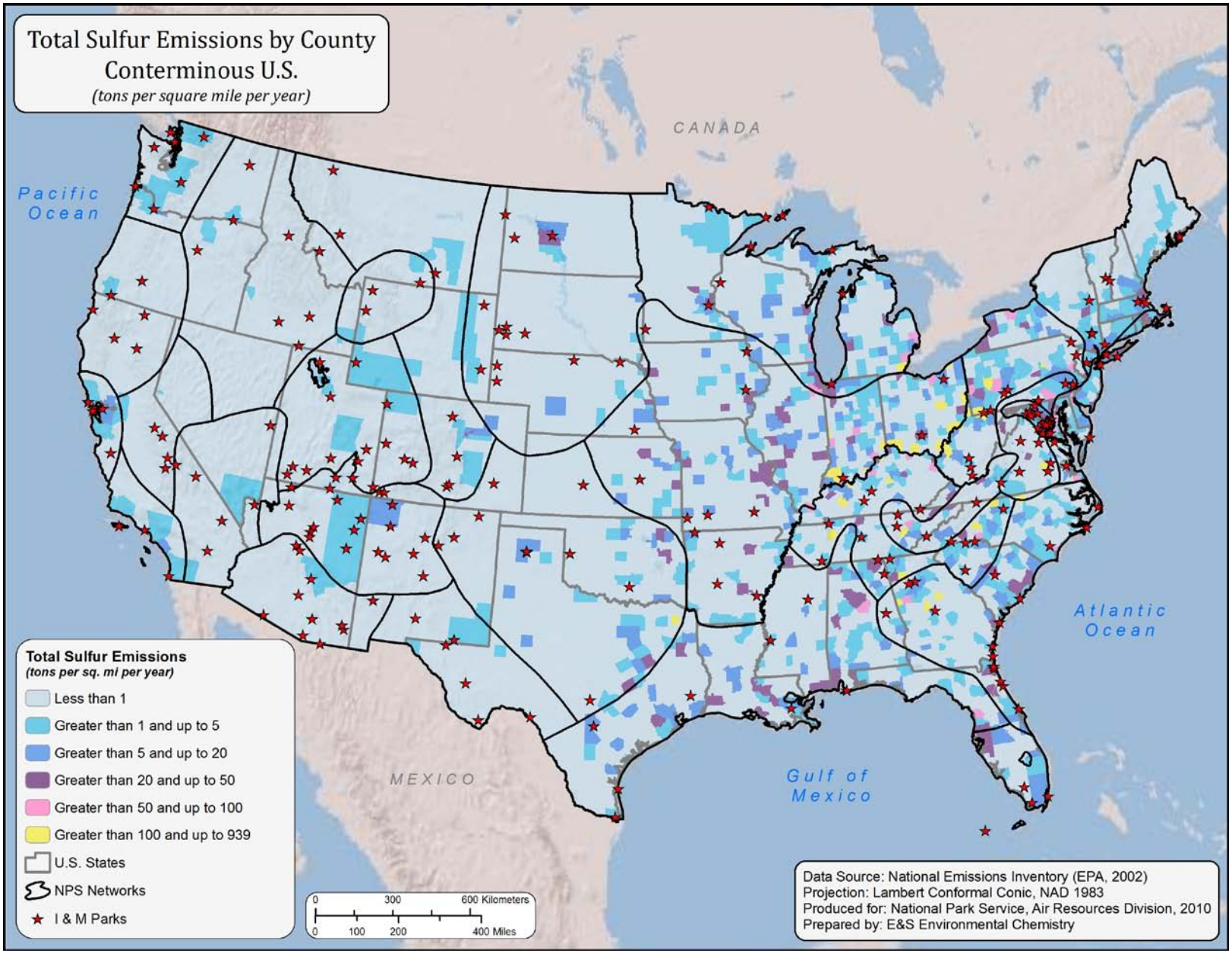
Figure D. Network Summary Risk rankings, calculated as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.

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.

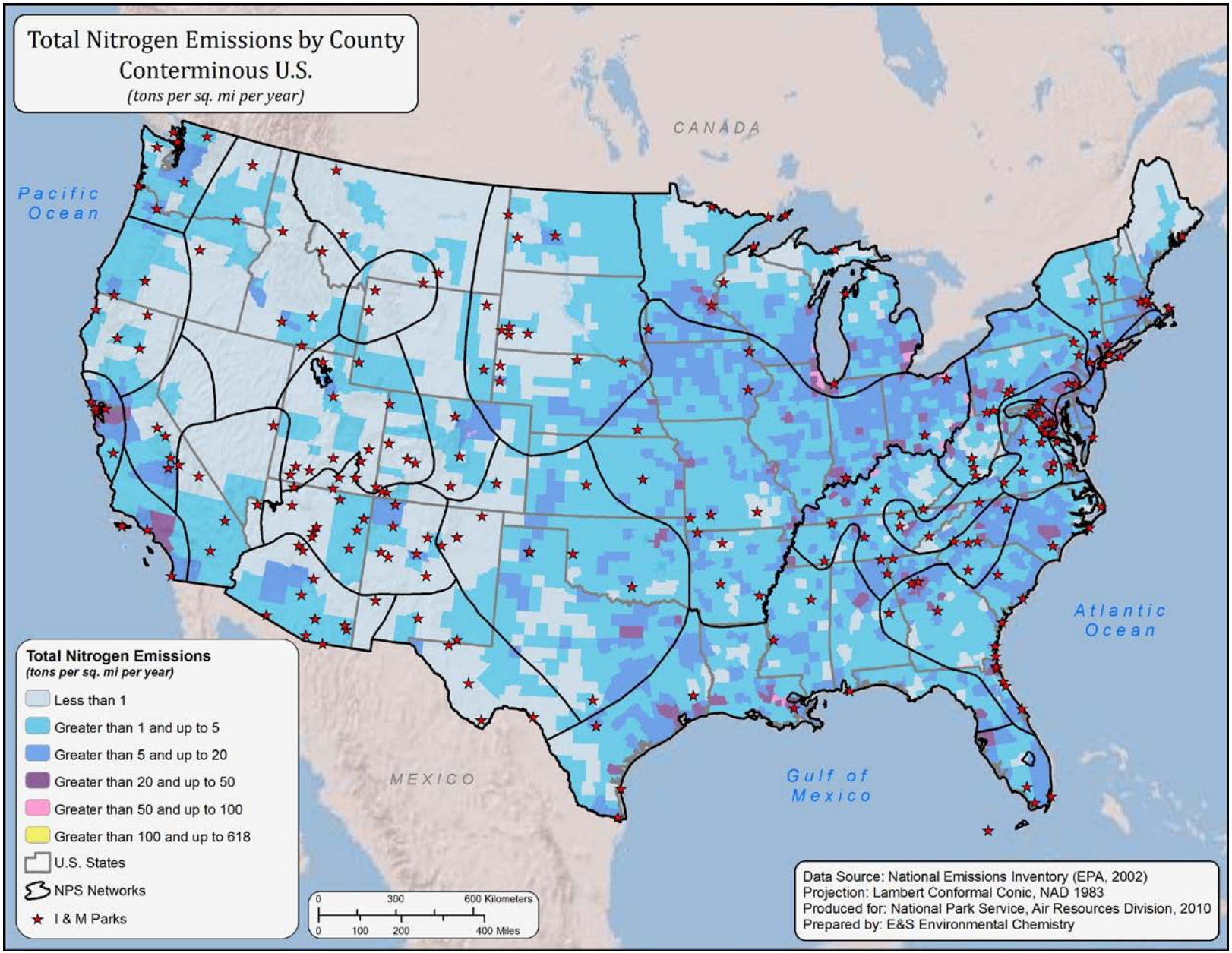
Figure F. Park rankings for Ecosystem Sensitivity for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of scores for all Ecosystem Sensitivity variables.

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.

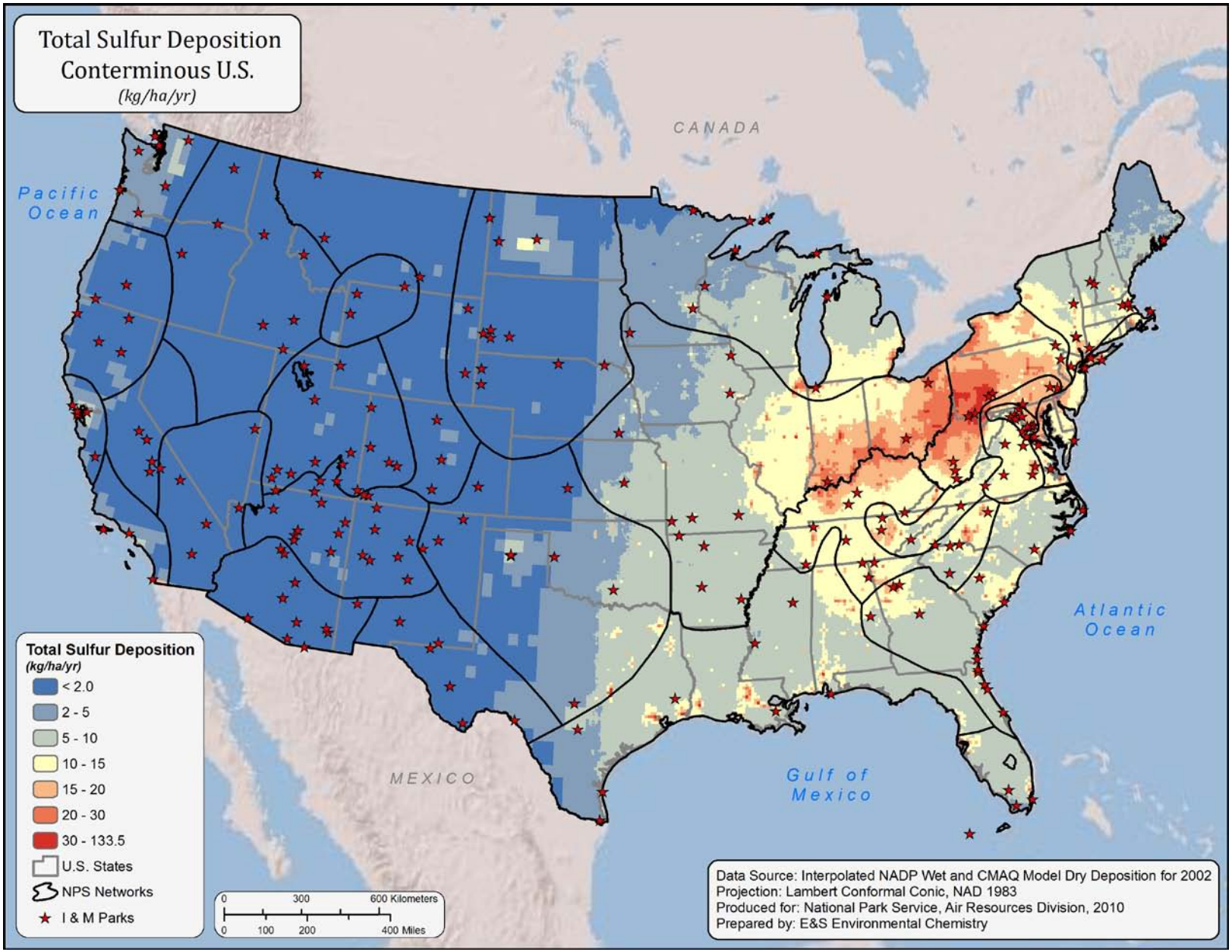
Figure H. Park rankings for Summary Risk for all parks larger than 100 square miles. Ranks for each park were calculated relative to all parks, regardless of size, as the average of the quintile ranks for the Pollutant Exposure, Ecosystem Sensitivity, and Park Protection themes.


Total Sulfur Emissions by County
Conterminous U.S.
(tons per square mile per year)
CANADA
Pacific Ocean
Atlantic Ocean
MEXICO
Gulf of Mexico
Total Sulfur Emissions
(tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 939
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
Data Source: National Emissions Inventory (EPA, 2002)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

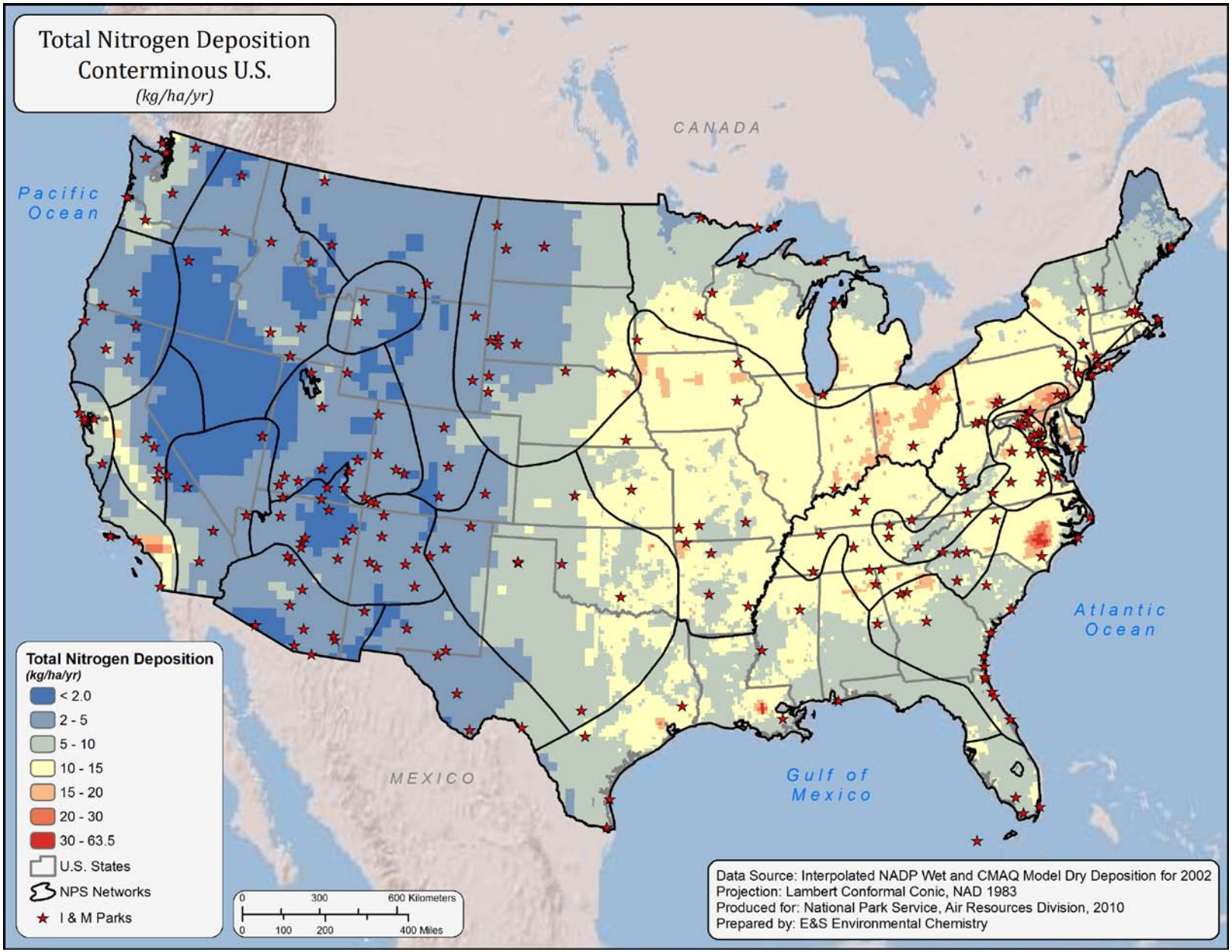
Map A


Total Nitrogen Emissions by County
Conterminous U.S.
(tons per sq. mi per year)
CANADA
Pacific Ocean
Atlantic Ocean
MEXICO
Gulf of Mexico
Total Nitrogen Emissions
(tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 618
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
Data Source: National Emissions Inventory (EPA, 2002)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

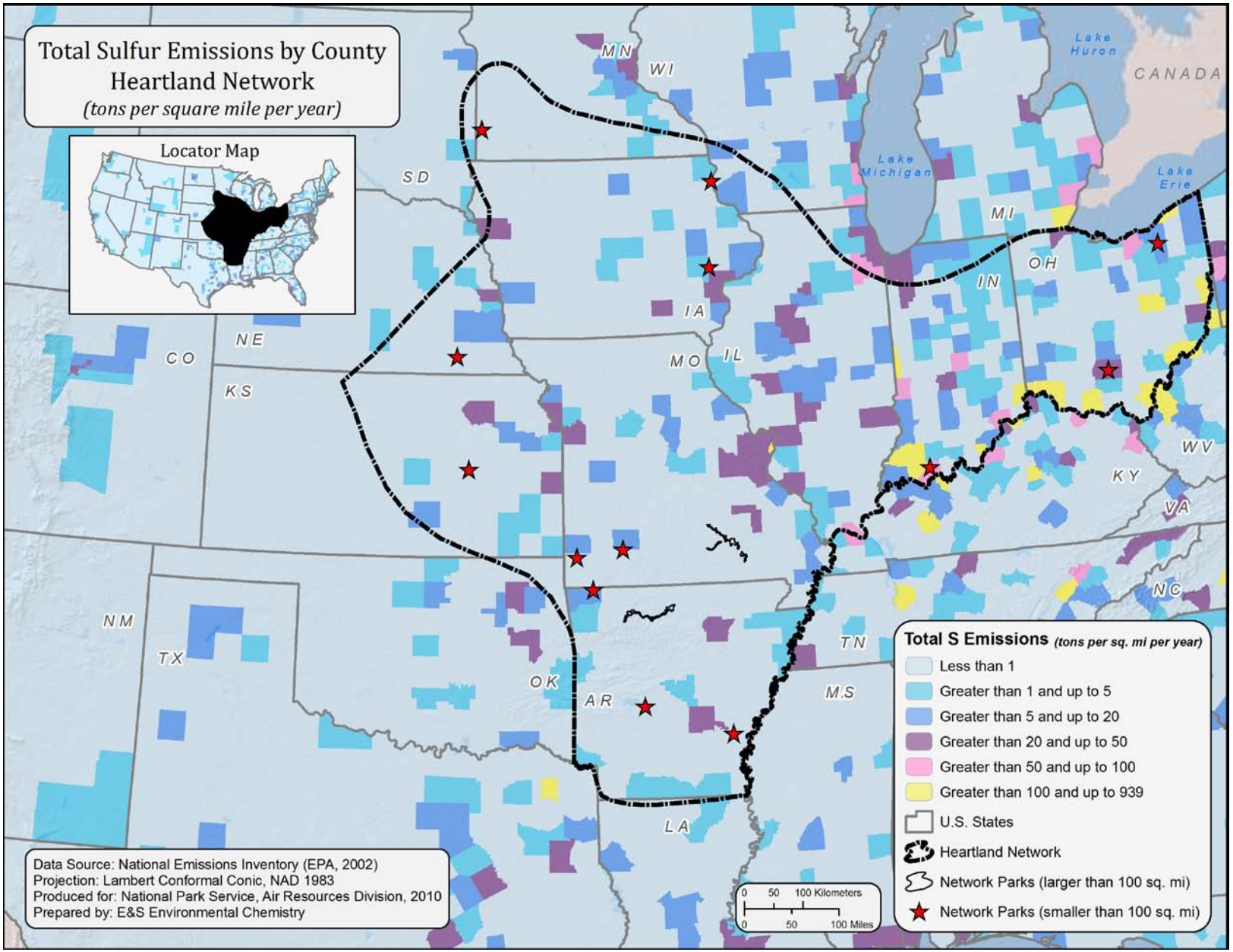
Map B


Total Sulfur Deposition
Conterminous U.S.
(kg/ha/yr)
CANADA
Pacific Ocean
Atlantic Ocean
MEXICO
Gulf of Mexico
Total Sulfur Deposition
(kg/ha/yr)
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 133.5
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
Data Source: Interpolated NADP Wet and CMAQ Model Dry Deposition for 2002
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

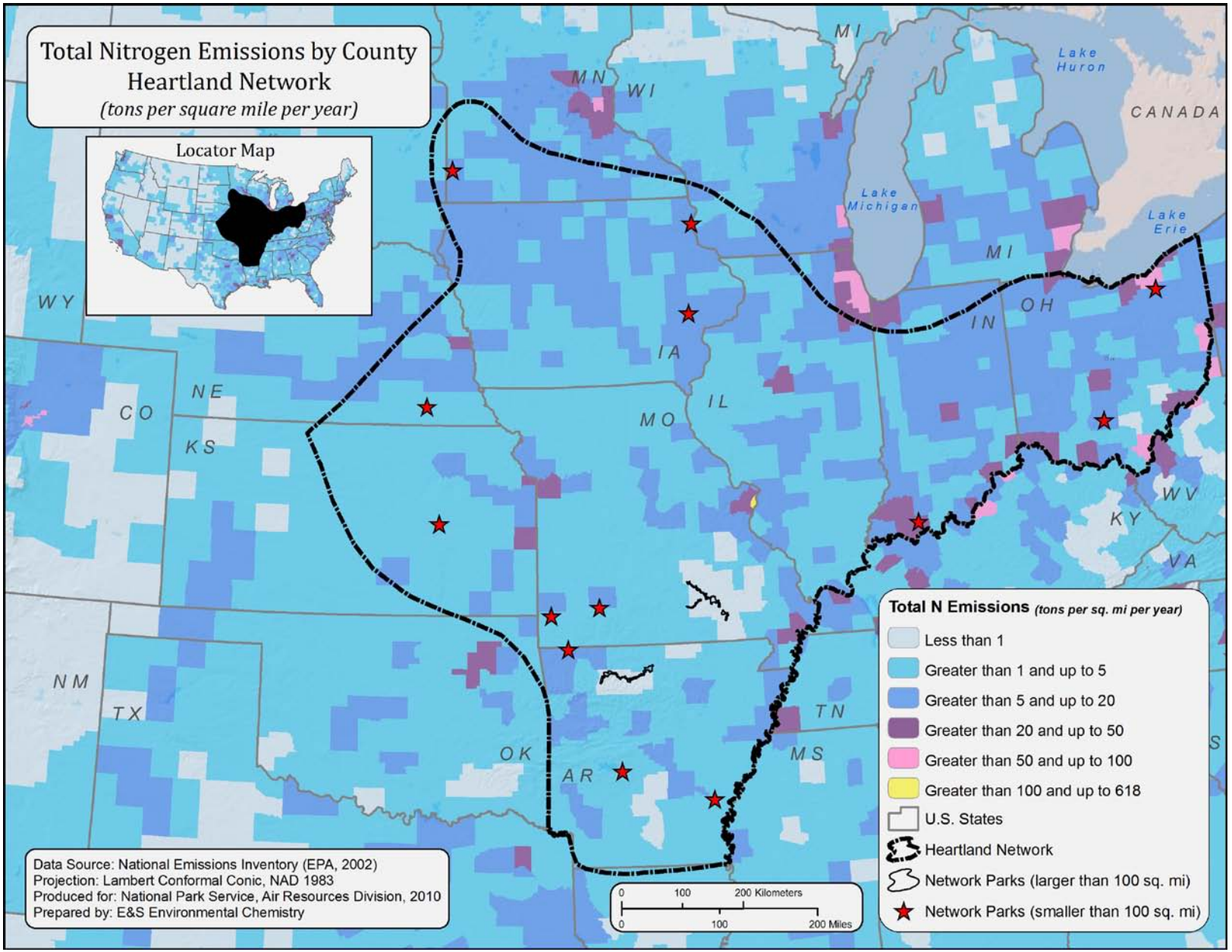
Map C


Total Nitrogen Deposition
Conterminous U.S.
(kg/ha/yr)
CANADA
Pacific Ocean
Atlantic Ocean
MEXICO
Gulf of Mexico
Total Nitrogen Deposition
(kg/ha/yr)
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
U.S. States
NPS Networks
I & M Parks
0 300 600 Kilometers
0 100 200 400 Miles
Data Source: Interpolated NADP Wet and CMAQ Model Dry Deposition for 2002
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

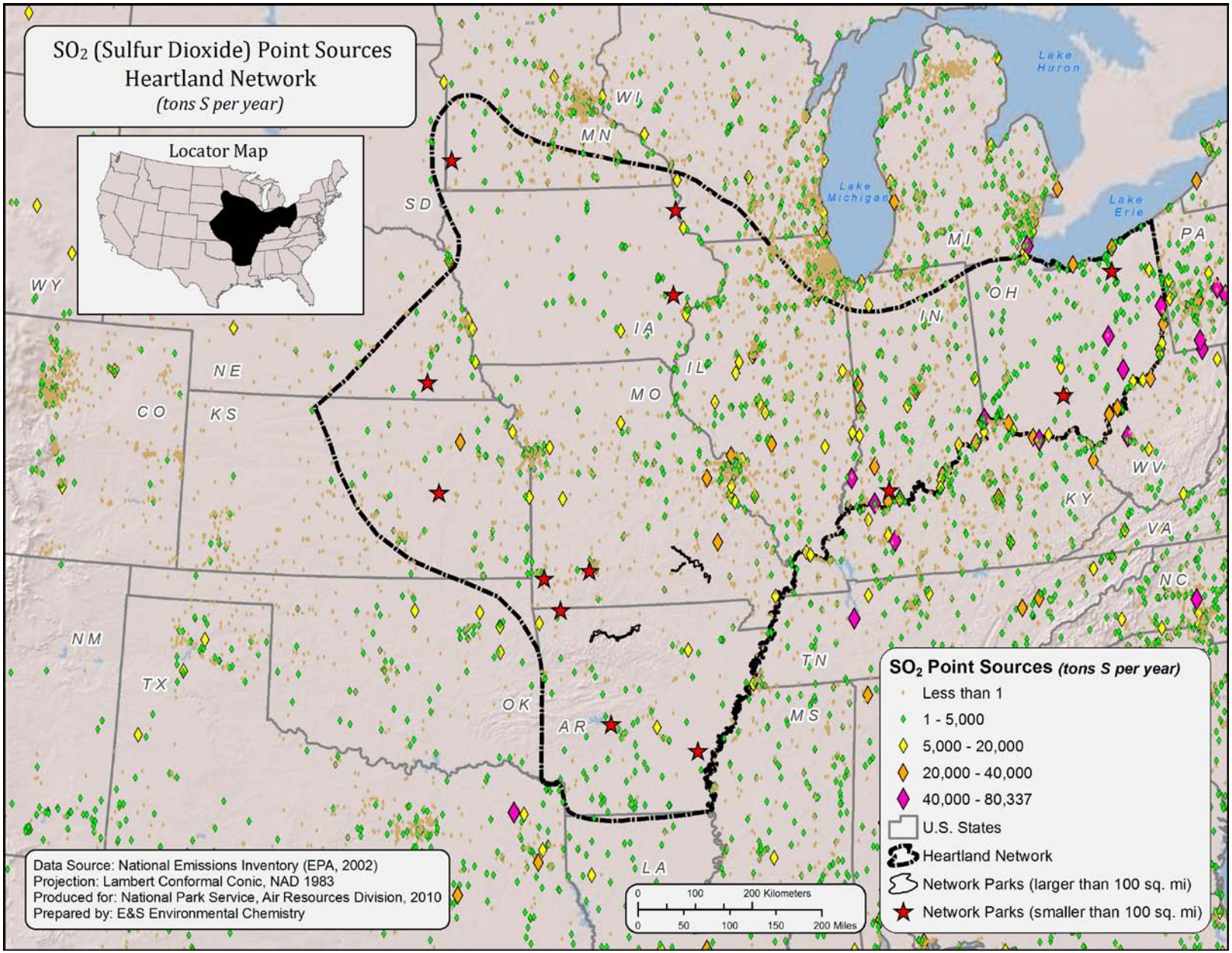
Map D


Total Sulfur Emissions by County
Heartland Network
(tons per square mile per year)
Locator Map
MN
WI
SD
NE
CO
KS
IA
MO
IL
MI
IN
OH
Lake Huron
Lake Michigan
Lake Erie
CANADA
WV
KY
VA
NC
TN
MS
AR
OK
TX
NM
LA
Total S Emissions (tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 939
U.S. States
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Data Source: National Emissions Inventory (EPA, 2002)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 50 100 Kilometers
0 50 100 Miles

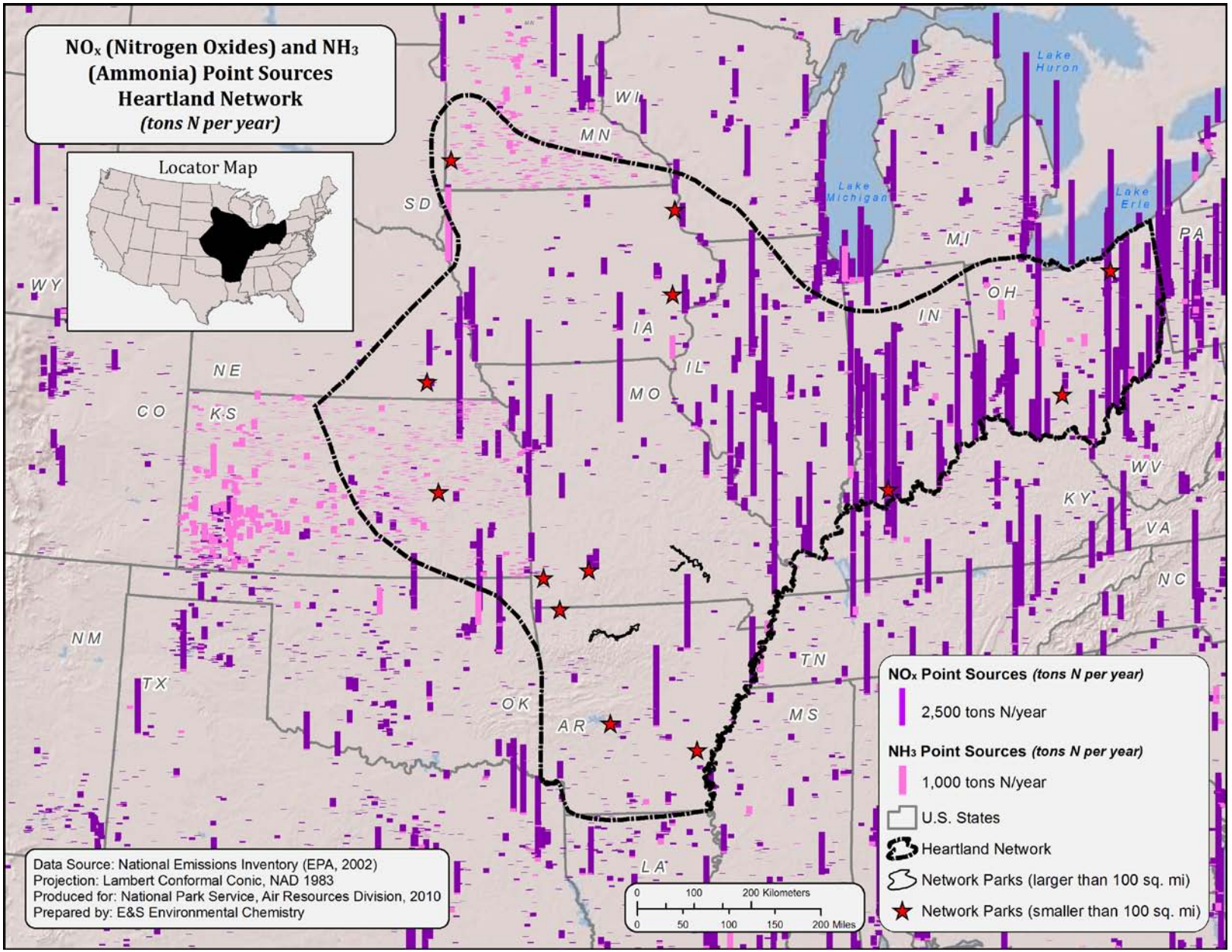
Map E


Total Nitrogen Emissions by County
Heartland Network
(tons per square mile per year)
Locator Map
MN
WI
MI
Lake Huron
CANADA
Lake Michigan
Lake Erie
WY
NE
CO
KS
IA
IL
MO
IN
OH
WV
KY
VA
NM
TX
OK
AR
MS
TN
Total N Emissions (tons per sq. mi per year)
Less than 1
Greater than 1 and up to 5
Greater than 5 and up to 20
Greater than 20 and up to 50
Greater than 50 and up to 100
Greater than 100 and up to 618
U.S. States
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Data Source: National Emissions Inventory (EPA, 2002)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 100 200 Kilometers
0 100 200 Miles

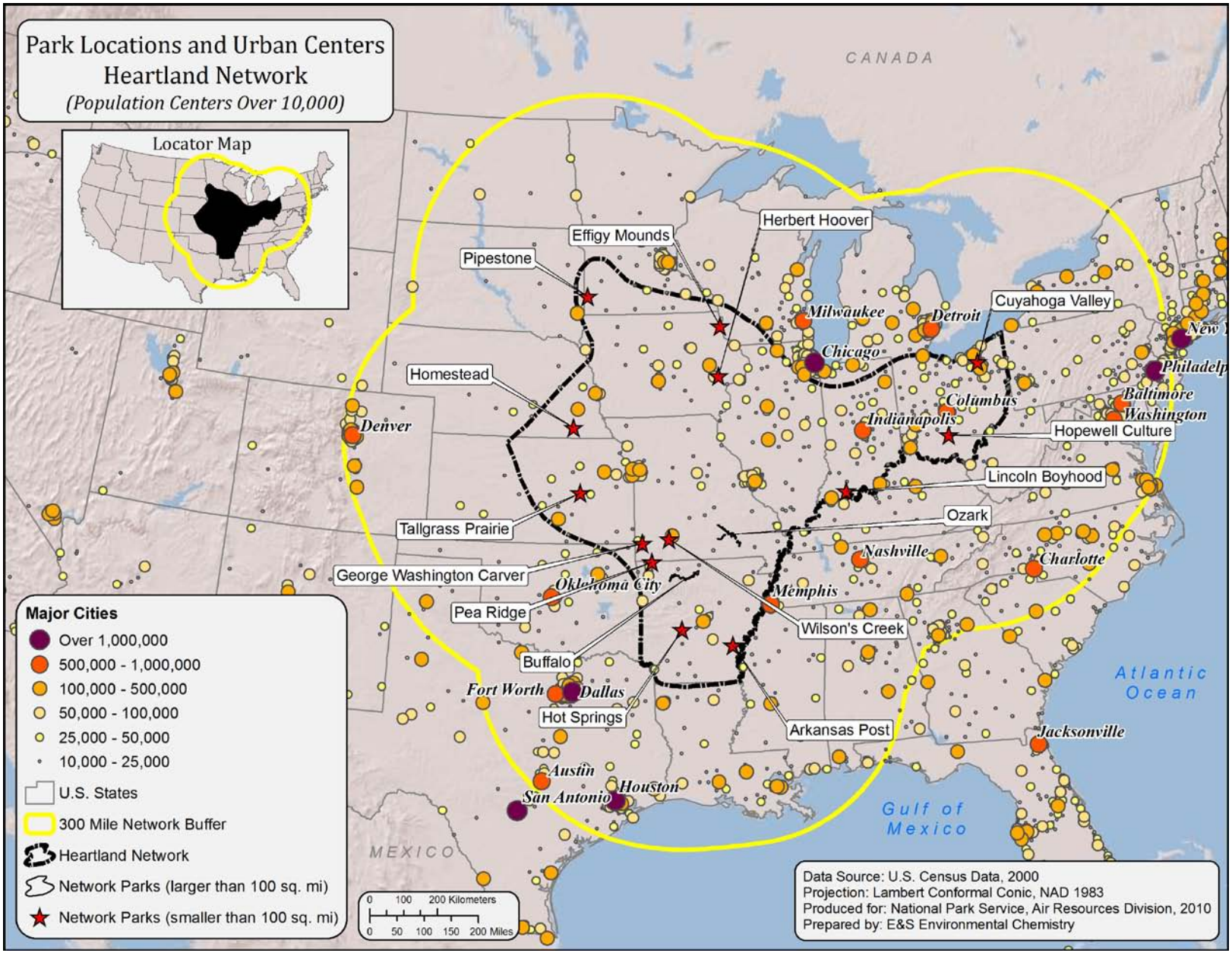
Map F


SO2 (Sulfur Dioxide) Point Sources
Heartland Network
(tons S per year)
Locator Map
Lake Huron
Lake Michigan
Lake Erie
WI
MN
SD
WY
MI
PA
OH
IN
IA
IL
MO
NE
CO
KS
WV
KY
VA
NC
NM
TX
OK
AR
TN
MS
LA
SO2 Point Sources (tons S per year)
Less than 1
1 - 5,000
5,000 - 20,000
20,000 - 40,000
40,000 - 80,337
U.S. States
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Data Source: National Emissions Inventory (EPA, 2002)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 100 200 Kilometers
0 50 100 150 200 Miles

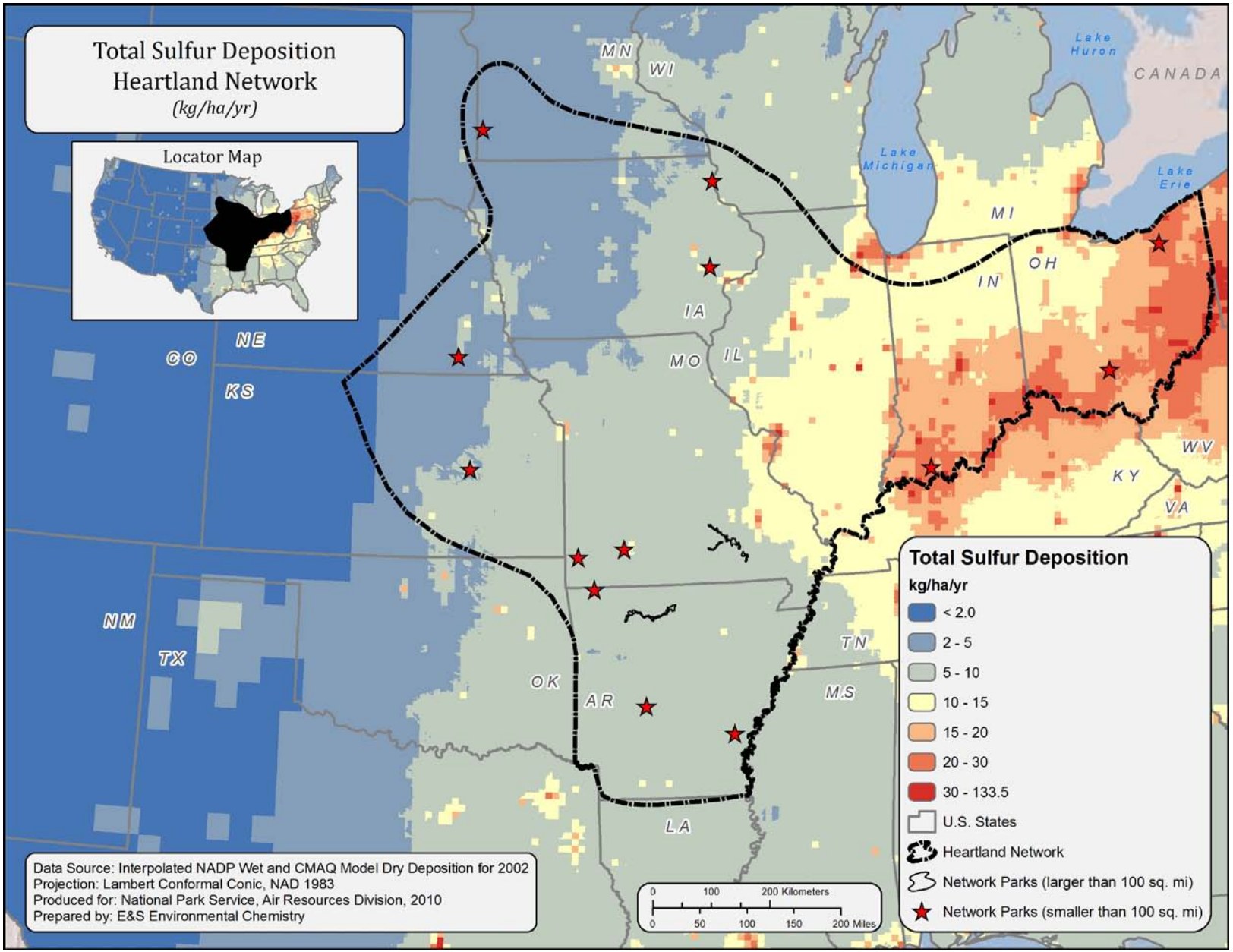
Map G


NOx (Nitrogen Oxides) and NH3 (Ammonia) Point Sources
Heartland Network
(tons N per year)
Locator Map
WY
SD
WI
MN
Lake Huron
Lake Michigan
Lake Erie
MI
PA
OH
IN
IA
IL
MO
NE
CO
KS
WV
KY
VA
NC
NM
TX
OK
AR
TN
MS
LA
Data Source: National Emissions Inventory (EPA, 2002)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 100 200 Kilometers
0 50 100 150 200 Miles
NOx Point Sources (tons N per year)
2,500 tons N/year
NH3 Point Sources (tons N per year)
1,000 tons N/year
U.S. States
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)

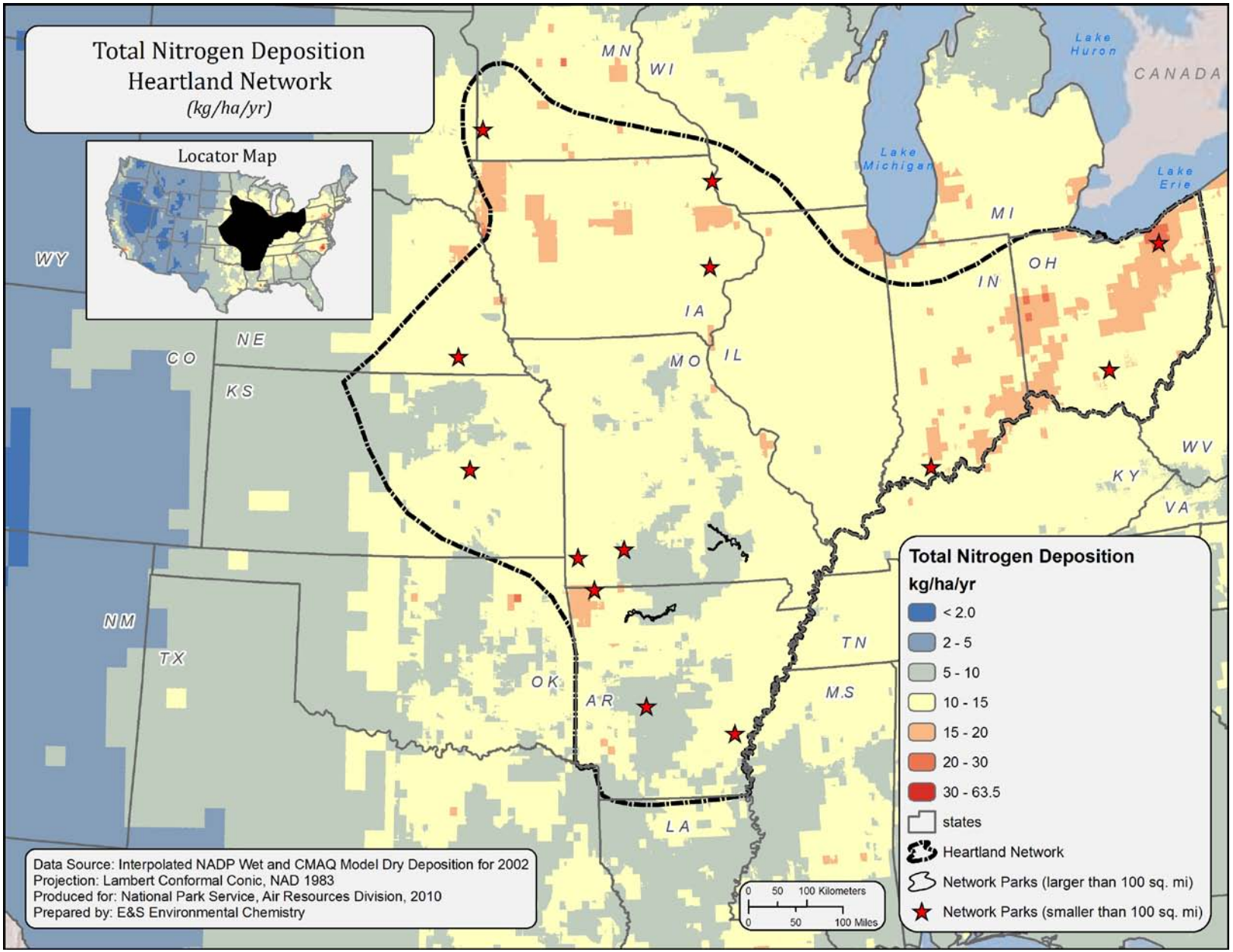
Map H


Park Locations and Urban Centers
Heartland Network
(Population Centers Over 10,000)
Locator Map
CANADA
Herbert Hoover
Effigy Mounds
Pipestone
Cuyahoga Valley
Milwaukee
Detroit
Chicago
Homestead
Columbus
Indianapolis
Hopewell Culture
Denver
Lincoln Boyhood
Ozark
Tallgrass Prairie
Nashville
Charlotte
George Washington Carver
Oklahoma City
Memphis
Pea Ridge
Wilson's Creek
Buffalo
Fort Worth
Dallas
Hot Springs
Arkansas Post
Jacksonville
Austin
San Antonio
Houston
Atlantic Ocean
Gulf of Mexico
MEXICO
Baltimore
Washington
Philadelp
New
Major Cities
Over 1,000,000
500,000 - 1,000,000
100,000 - 500,000
50,000 - 100,000
25,000 - 50,000
10,000 - 25,000
U.S. States
300 Mile Network Buffer
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 100 200 Kilometers
0 50 100 150 200 Miles
Data Source: U.S. Census Data, 2000
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

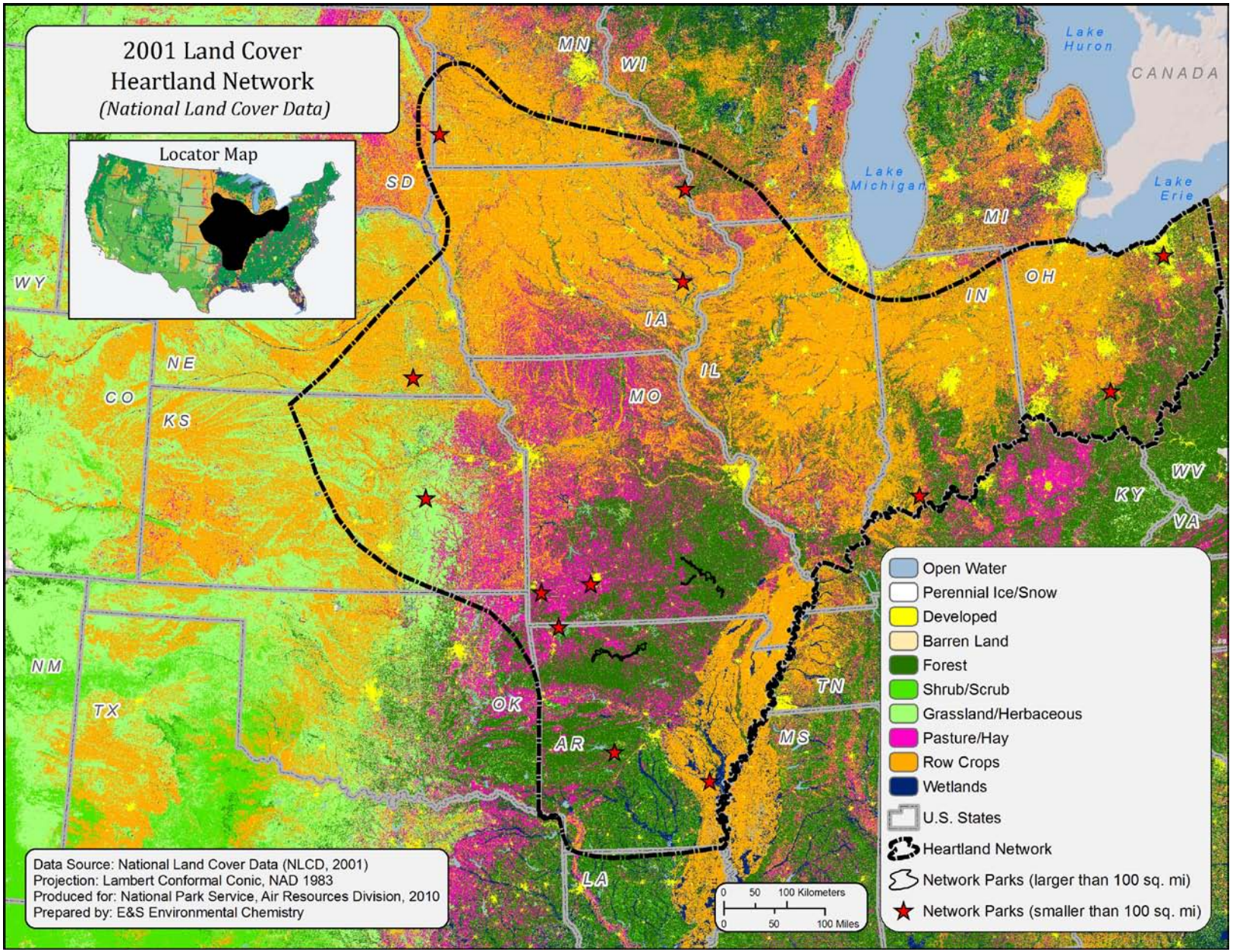
Map I


Total Sulfur Deposition
Heartland Network
(kg/ha/yr)
Locator Map
MN
WI
Lake Huron
CANADA
Lake Michigan
Lake Erie
MI
OH
IN
IA
MO
IL
NE
CO
KS
WV
KY
VA
NM
TX
OK
AR
TN
MS
LA
Total Sulfur Deposition
kg/ha/yr
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 133.5
U.S. States
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Data Source: Interpolated NADP Wet and CMAQ Model Dry Deposition for 2002
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 100 200 Kilometers
0 50 100 150 200 Miles

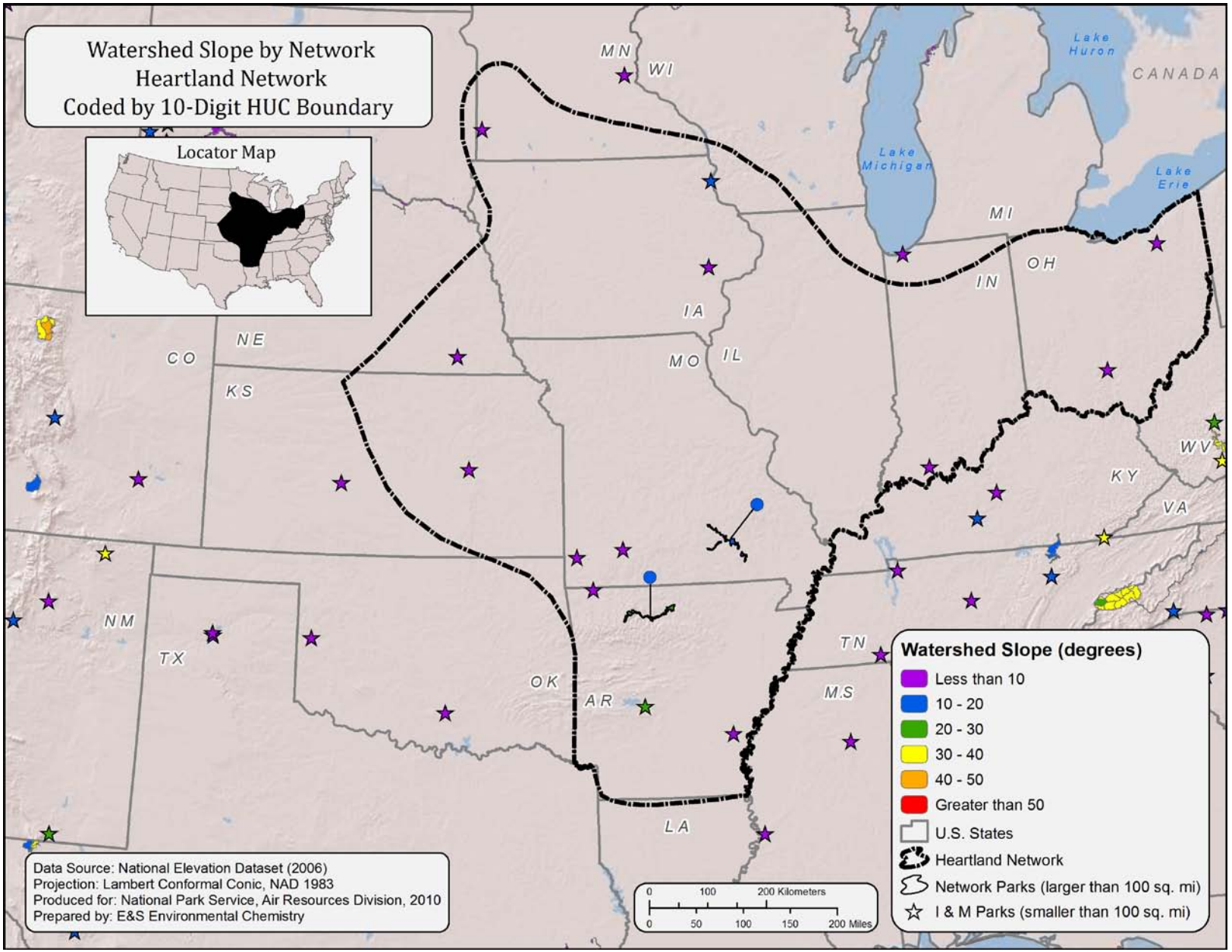
Map J


Total Nitrogen Deposition
Heartland Network
(kg/ha/yr)
Locator Map
MN
WI
Lake Huron
CANADA
Lake Michigan
Lake Erie
MI
WY
OH
IN
IA
NE
CO
MO
IL
KS
WV
KY
VA
NM
TX
TN
OK
AR
M.S
LA
Total Nitrogen Deposition
kg/ha/yr
< 2.0
2 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 63.5
states
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
0 50 100 Kilometers
0 50 100 Miles
Data Source: Interpolated NADP Wet and CMAQ Model Dry Deposition for 2002
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry

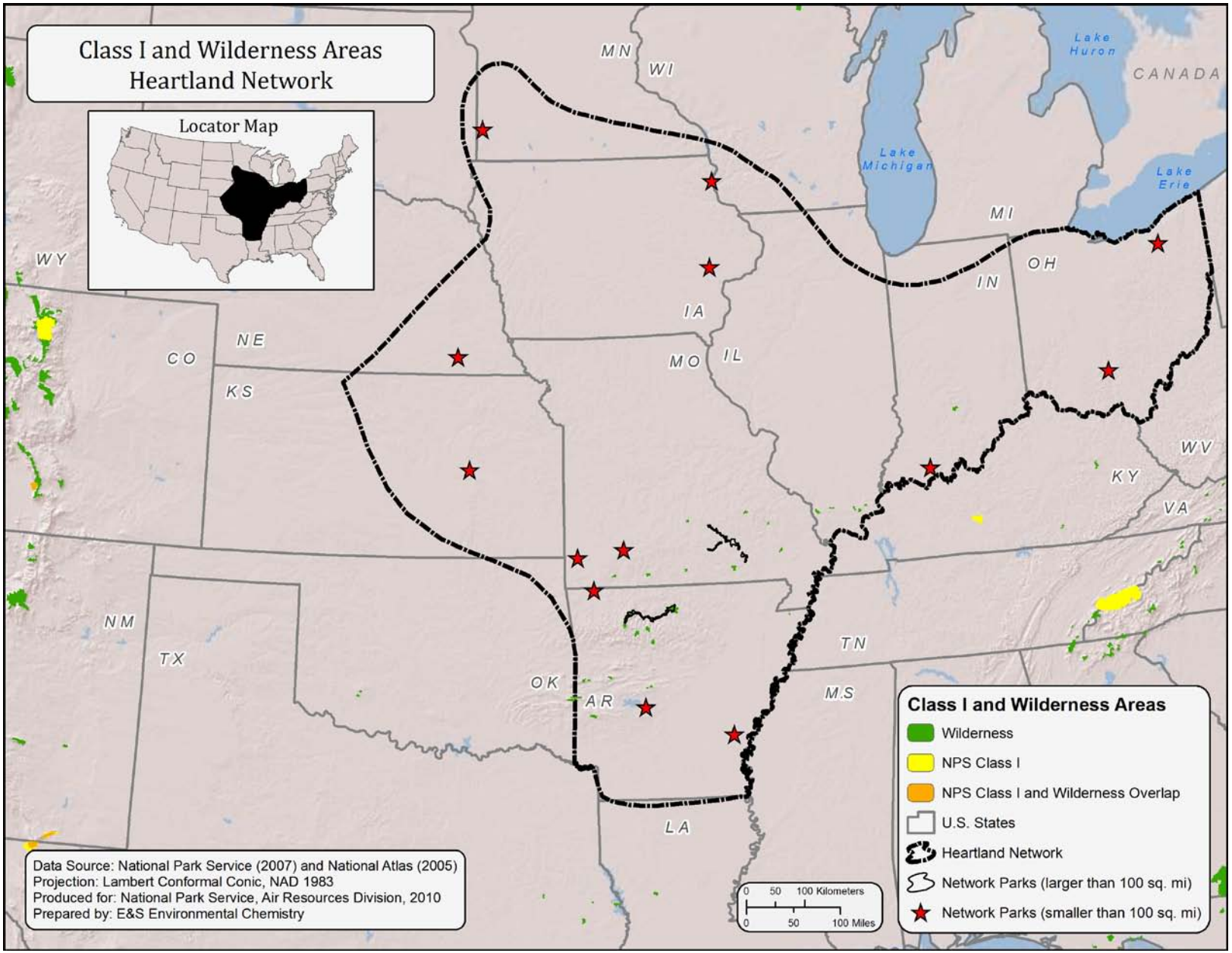
Map K


2001 Land Cover
Heartland Network
(National Land Cover Data)
Locator Map
MN
WI
SD
WY
NE
CO
KS
IA
IL
MO
MI
IN
OH
WV
KY
VA
NM
TX
OK
AR
LA
TN
MS
Lake Huron
CANADA
Lake Michigan
Lake Erie
Open Water
Perennial Ice/Snow
Developed
Barren Land
Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Row Crops
Wetlands
U.S. States
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)
Data Source: National Land Cover Data (NLCD, 2001)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 50 100 Kilometers
0 50 100 Miles

Map L


Watershed Slope by Network
Heartland Network
Coded by 10-Digit HUC Boundary
Locator Map
MN
WI
Lake Huron
CANADA
Lake Michigan
Lake Erie
MI
OH
IN
IA
NE
CO
KS
MO
IL
WV
KY
VA
NM
TX
OK
AR
TN
MS
LA
Watershed Slope (degrees)
Less than 10
10 - 20
20 - 30
30 - 40
40 - 50
Greater than 50
U.S. States
Heartland Network
Network Parks (larger than 100 sq. mi)
I & M Parks (smaller than 100 sq. mi)
Data Source: National Elevation Dataset (2006)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 100 200 Kilometers
0 50 100 150 200 Miles

Map M


Class I and Wilderness Areas
Heartland Network
Locator Map
MN
WI
Lake Huron
CANADA
Lake Michigan
Lake Erie
MI
WY
OH
IN
IA
NE
CO
MO
IL
KS
WV
KY
VA
NM
TX
TN
OK
AR
MS
LA
Data Source: National Park Service (2007) and National Atlas (2005)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2010
Prepared by: E&S Environmental Chemistry
0 50 100 Kilometers
0 50 100 Miles
Class I and Wilderness Areas
Wilderness
NPS Class I
NPS Class I and Wilderness Overlap
U.S. States
Heartland Network
Network Parks (larger than 100 sq. mi)
Network Parks (smaller than 100 sq. mi)

Map N

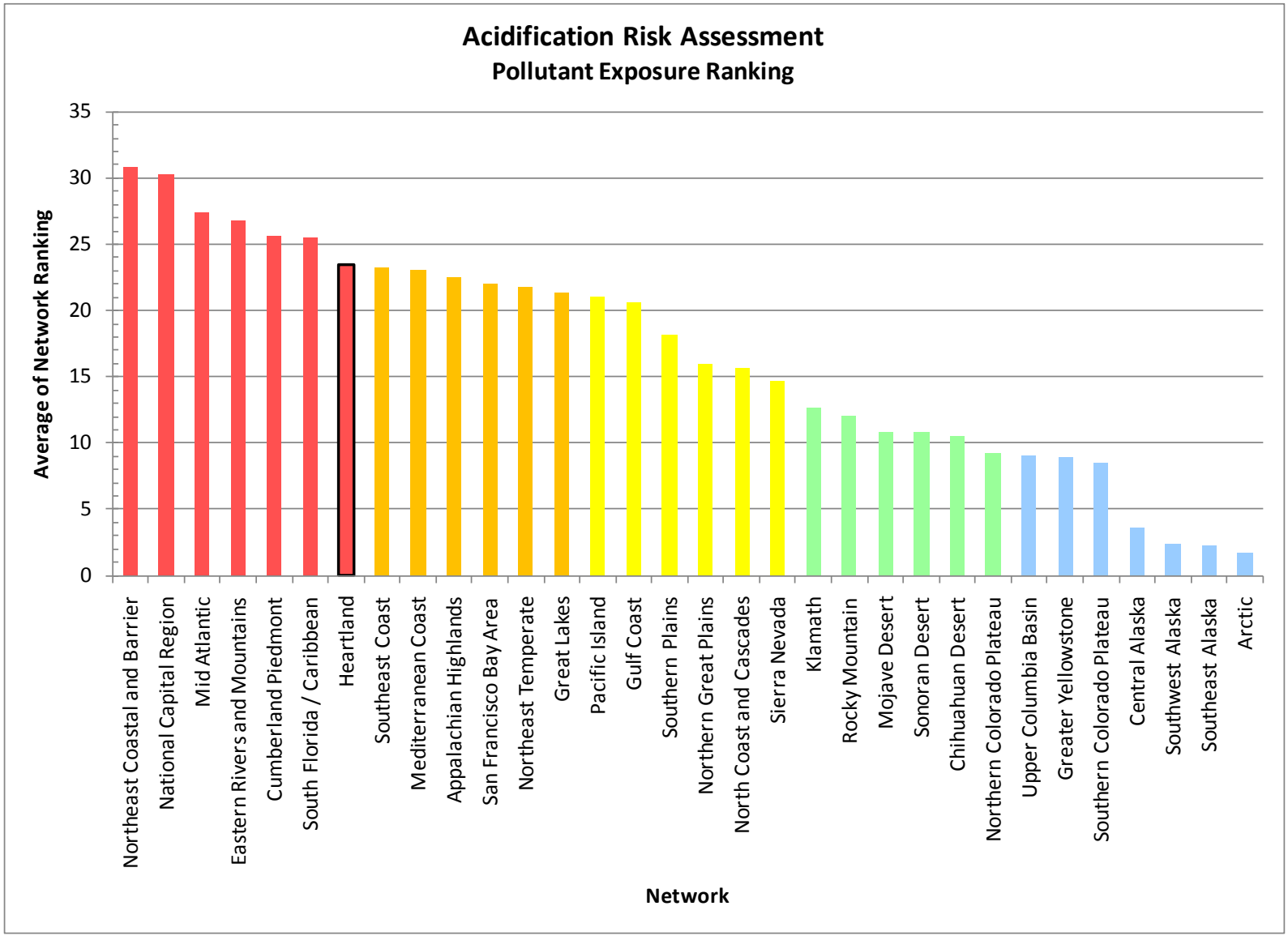

Acidification Risk Assessment
Pollutant Exposure Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
Northeast Coastal and Barrier
National Capital Region
Mid Atlantic
Eastern Rivers and Mountains
Cumberland Piedmont
South Florida / Caribbean
Heartland
Southeast Coast
Mediterranean Coast
Appalachian Highlands
San Francisco Bay Area
Northeast Temperate
Great Lakes
Pacific Island
Gulf Coast
Southern Plains
Northern Great Plains
North Coast and Cascades
Sierra Nevada
Klamath
Rocky Mountain
Mojave Desert
Sonoran Desert
Chihuahuan Desert
Northern Colorado Plateau
Upper Columbia Basin
Greater Yellowstone
Southern Colorado Plateau
Central Alaska
Southwest Alaska
Southeast Alaska
Arctic
Network

Figure A

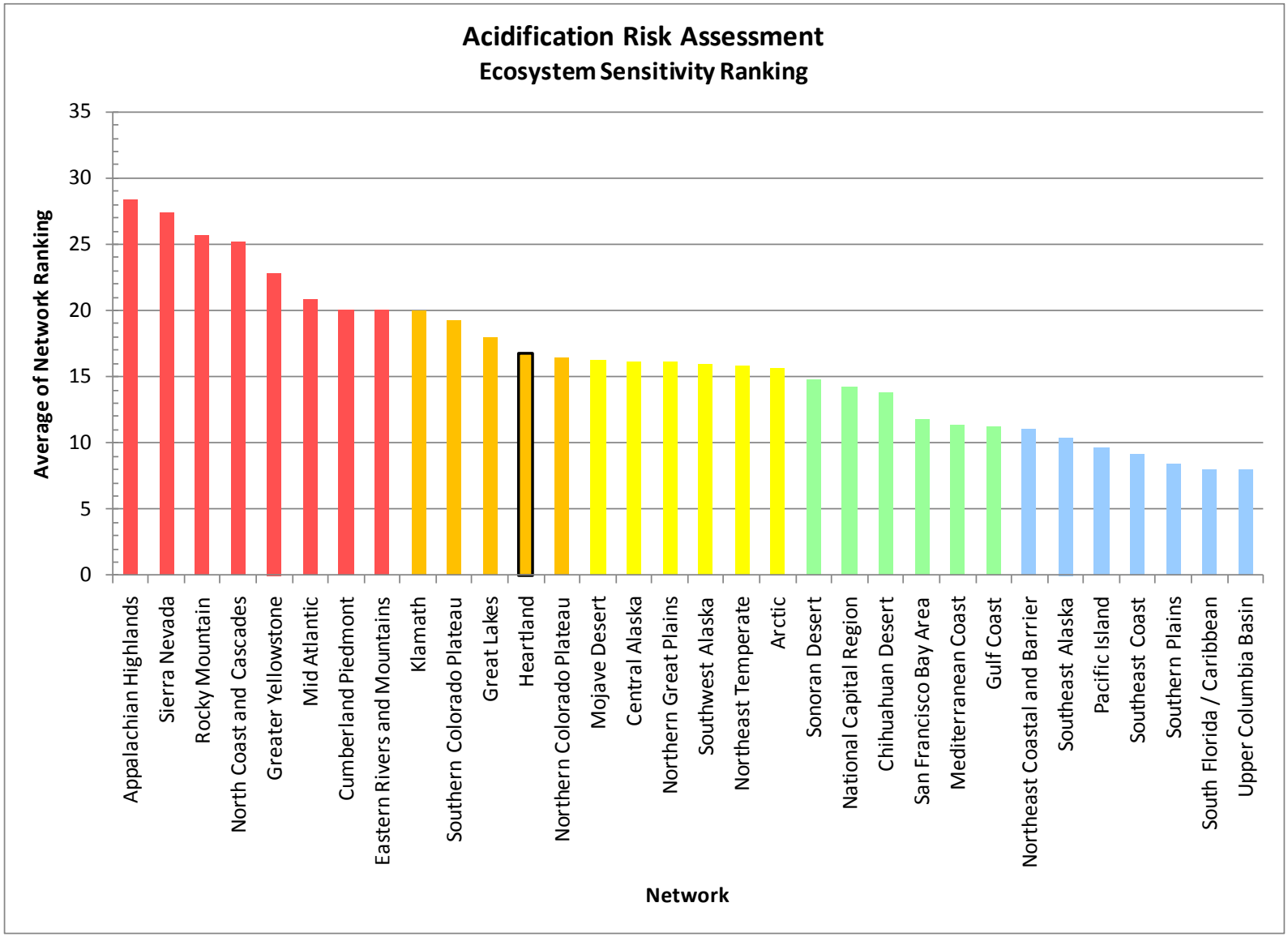

Acidification Risk Assessment
Ecosystem Sensitivity Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
Appalachian Highlands
Sierra Nevada
Rocky Mountain
North Coast and Cascades
Greater Yellowstone
Mid Atlantic
Cumberland Piedmont
Eastern Rivers and Mountains
Klamath
Southern Colorado Plateau
Great Lakes
Heartland
Northern Colorado Plateau
Mojave Desert
Central Alaska
Northern Great Plains
Southwest Alaska
Northeast Temperate
Arctic
Sonoran Desert
National Capital Region
Chihuahuan Desert
San Francisco Bay Area
Mediterranean Coast
Gulf Coast
Northeast Coastal and Barrier
Southeast Alaska
Pacific Island
Southeast Coast
Southern Plains
South Florida / Caribbean
Upper Columbia Basin
Network

Figure B

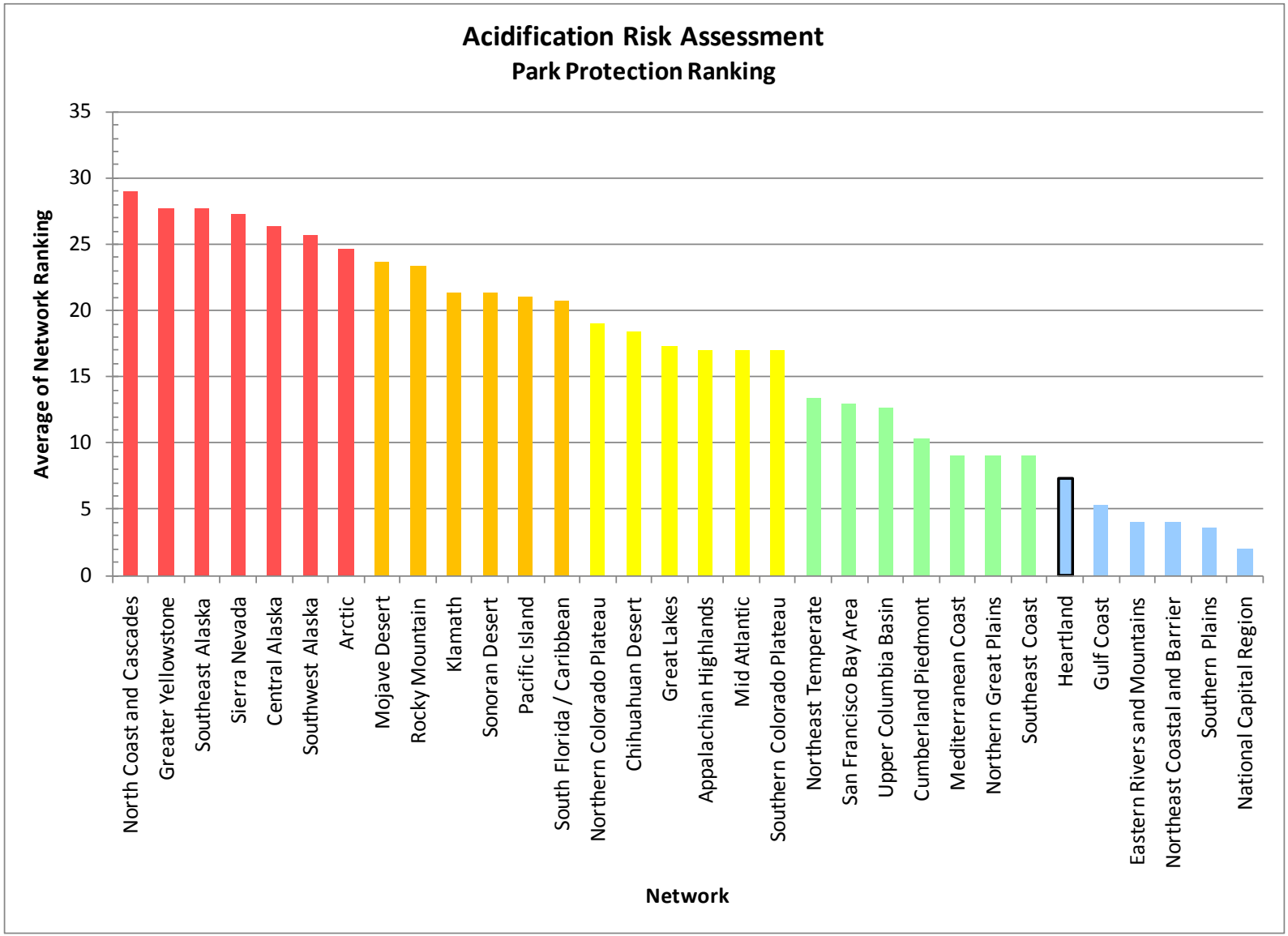

Acidification Risk Assessment
Park Protection Ranking
Average of Network Ranking
35
30
25
20
15
10
5
0
North Coast and Cascades
Greater Yellowstone
Southeast Alaska
Sierra Nevada
Central Alaska
Southwest Alaska
Arctic
Mojave Desert
Rocky Mountain
Klamath
Sonoran Desert
Pacific Island
South Florida / Caribbean
Northern Colorado Plateau
Chihuahuan Desert
Great Lakes
Appalachian Highlands
Mid Atlantic
Southern Colorado Plateau
Northeast Temperate
San Francisco Bay Area
Upper Columbia Basin
Cumberland Piedmont
Mediterranean Coast
Northern Great Plains
Southeast Coast
Heartland
Gulf Coast
Eastern Rivers and Mountains
Northeast Coastal and Barrier
Southern Plains
National Capital Region
Network

Figure C

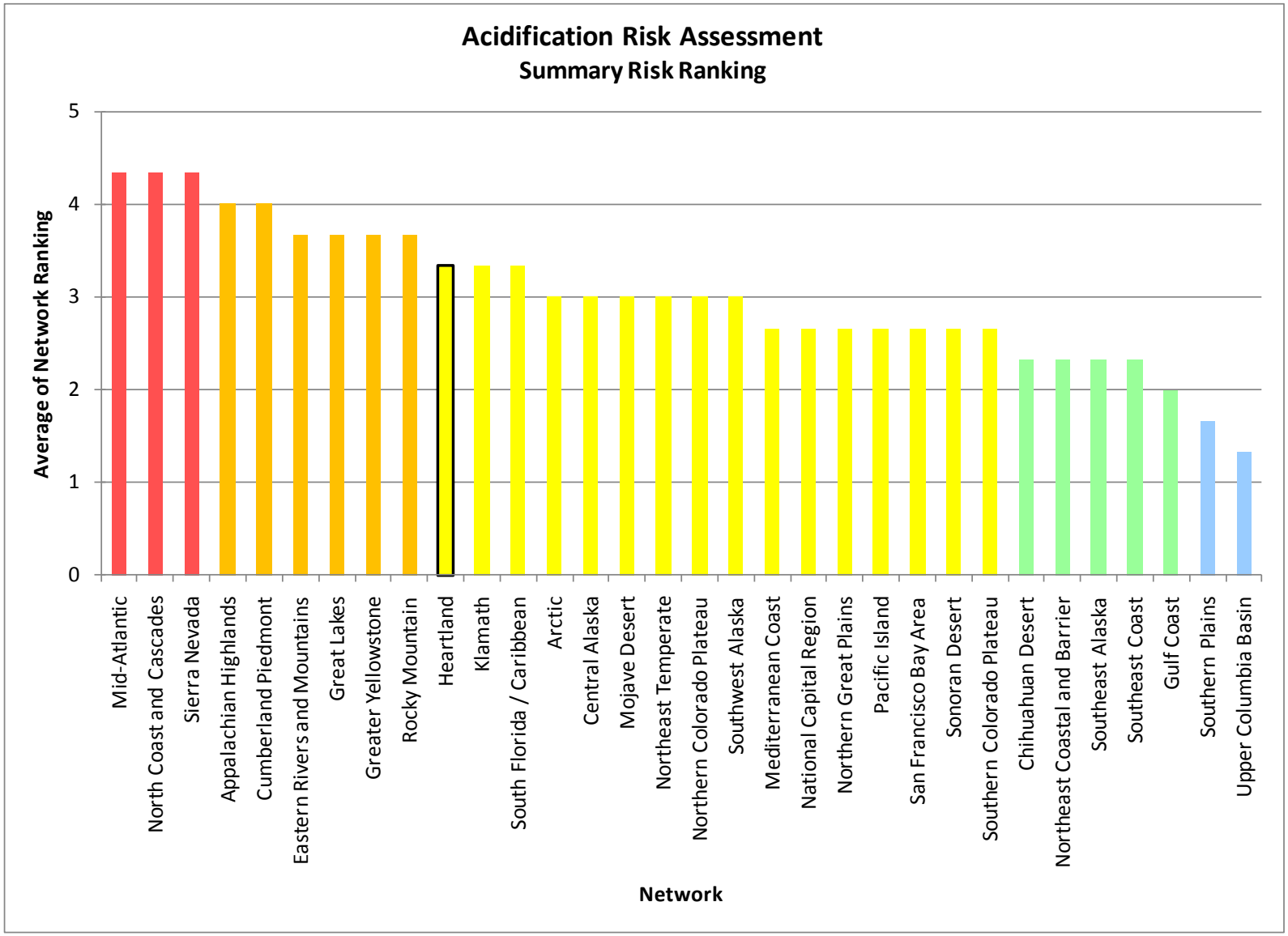

Acidification Risk Assessment
Summary Risk Ranking
Average of Network Ranking
0
1
2
3
4
5
Mid-Atlantic
North Coast and Cascades
Sierra Nevada
Appalachian Highlands
Cumberland Piedmont
Eastern Rivers and Mountains
Great Lakes
Greater Yellowstone
Rocky Mountain
Heartland
Klamath
South Florida / Caribbean
Arctic
Central Alaska
Mojave Desert
Northeast Temperate
Northern Colorado Plateau
Southwest Alaska
Mediterranean Coast
National Capital Region
Northern Great Plains
Pacific Island
San Francisco Bay Area
Sonoran Desert
Southern Colorado Plateau
Chihuahuan Desert
Northeast Coastal and Barrier
Southeast Alaska
Southeast Coast
Gulf Coast
Southern Plains
Upper Columbia Basin
Network

Figure D

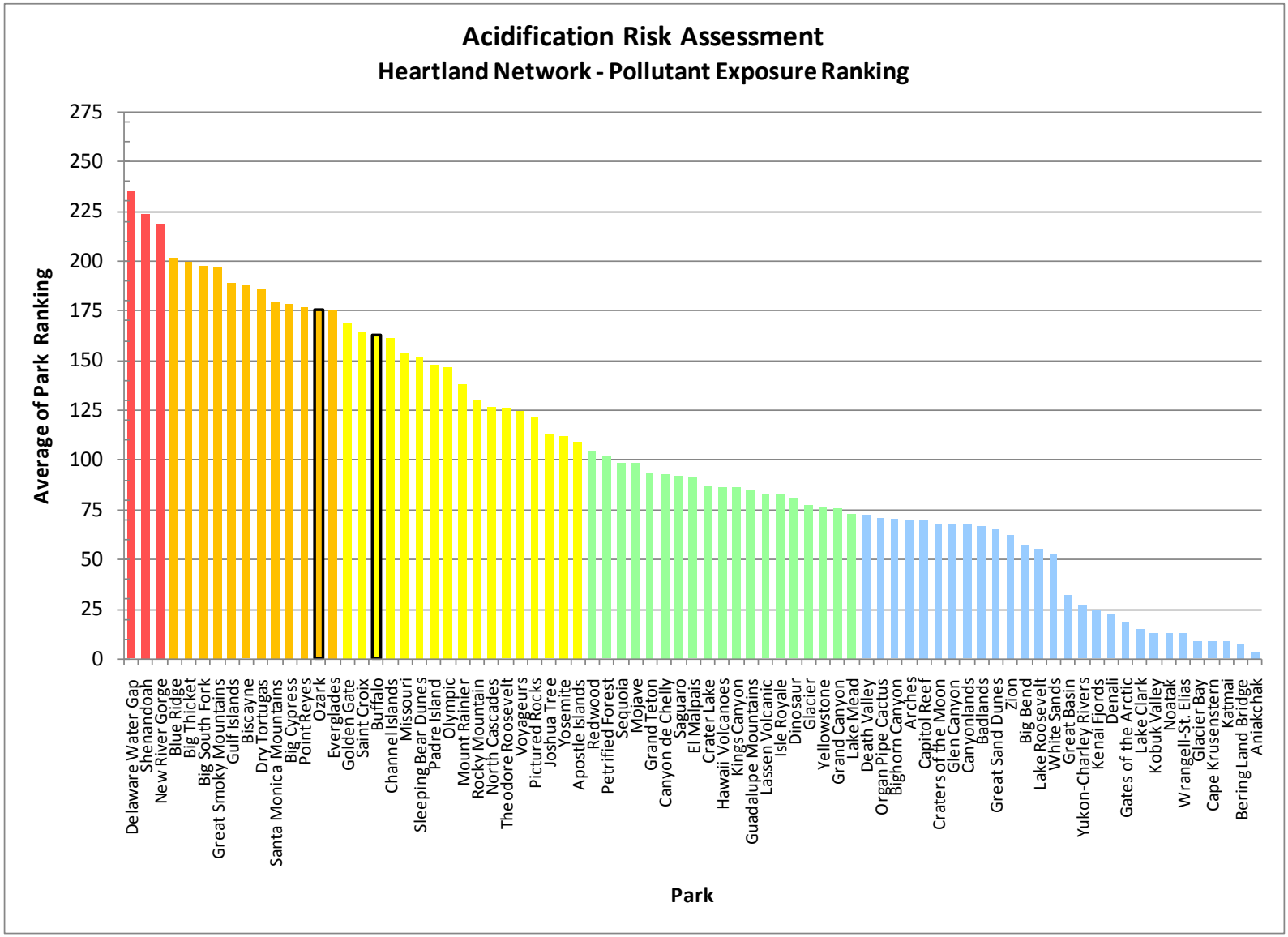

Acidification Risk Assessment
Heartland Network - Pollutant Exposure Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Delaware Water Gap
Shenandoah
New River Gorge
Blue Ridge
Big Thicket
Big South Fork
Great Smoky Mountains
Gulf Islands
Biscayne
Dry Tortugas
Santa Monica Mountains
Big Cypress
Point Reyes
Ozark
Everglades
Golden Gate
Saint Croix
Buffalo
Channel Islands
Missouri
Sleeping Bear Dunes
Padre Island
Olympic
Mount Rainier
Rocky Mountain
North Cascades
Theodore Roosevelt
Voyageurs
Pictured Rocks
Joshua Tree
Yosemite
Apostle Islands
Redwood
Petrified Forest
Sequoia
Mojave
Grand Teton
Canyon de Chelly
Saguaro
El Malpais
Crater Lake
Hawaii Volcanoes
Kings Canyon
Guadalupe Mountains
Lassen Volcanic
Isle Royale
Dinosaur
Glacier
Yellowstone
Grand Canyon
Lake Mead
Death Valley
Organ Pipe Cactus
Bighorn Canyon
Arches
Capitol Reef
Craters of the Moon
Glen Canyon
Canyonlands
Badlands
Great Sand Dunes
Zion
Big Bend
Lake Roosevelt
White Sands
Great Basin
Yukon-Charley Rivers
Kenai Fjords
Denali
Gates of the Arctic
Lake Clark
Kobuk Valley
Noatak
Wrangell-St. Elias
Glacier Bay
Cape Krusenstern
Katmai
Bering Land Bridge
Aniakchak
Park

Figure E

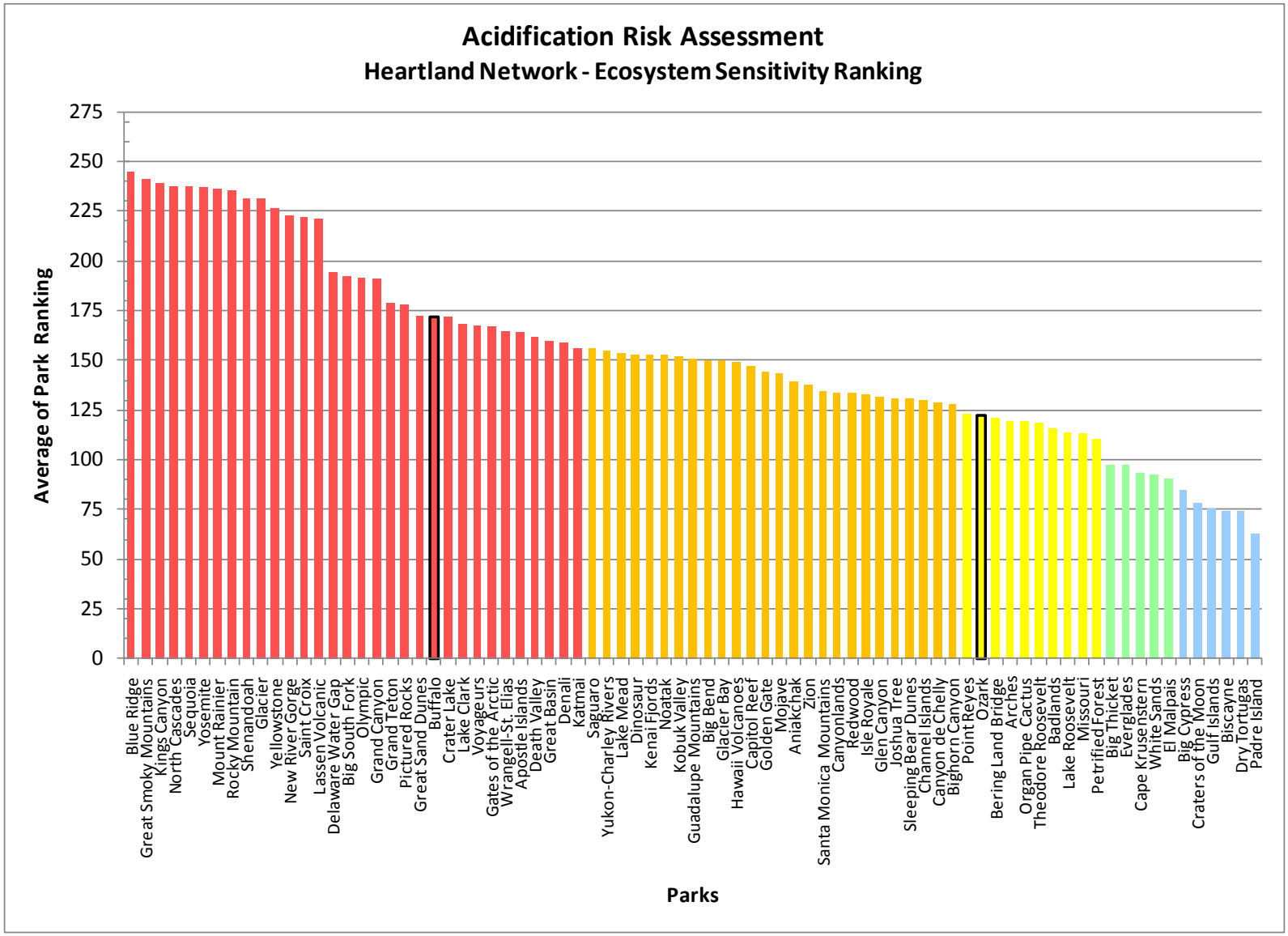

Acidification Risk Assessment
Heartland Network - Ecosystem Sensitivity Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Blue Ridge
Great Smoky Mountains
Kings Canyon
North Cascades
Sequoia
Yosemite
Mount Rainier
Rocky Mountain
Shenandoah
Glacier
Yellowstone
New River Gorge
Saint Croix
Lassen Volcanic
Delaware Water Gap
Big South Fork
Olympic
Grand Canyon
Grand Teton
Pictured Rocks
Great Sand Dunes
Buffalo
Crater Lake
Lake Clark
Voyageurs
Gates of the Arctic
Wrangell-St. Elias
Apostle Islands
Death Valley
Great Basin
Denali
Katmai
Saguaro
Yukon-Charley Rivers
Lake Mead
Dinosaur
Kenai Fjords
Noatak
Kobuk Valley
Guadalupe Mountains
Big Bend
Glacier Bay
Hawaii Volcanoes
Capitol Reef
Golden Gate
Mojave
Aniakchak
Zion
Santa Monica Mountains
Canyonlands
Redwood
Isle Royale
Glen Canyon
Joshua Tree
Sleeping Bear Dunes
Channel Islands
Canyon de Chelly
Bighorn Canyon
Point Reyes
Ozark
Bering Land Bridge
Arches
Organ Pipe Cactus
Theodore Roosevelt
Badlands
Lake Roosevelt
Missouri
Petrified Forest
Big Thicket
Everglades
Cape Krusenstern
White Sands
El Malpais
Big Cypress
Craters of the Moon
Gulf Islands
Biscayne
Dry Tortugas
Padre Island
Parks

Figure F

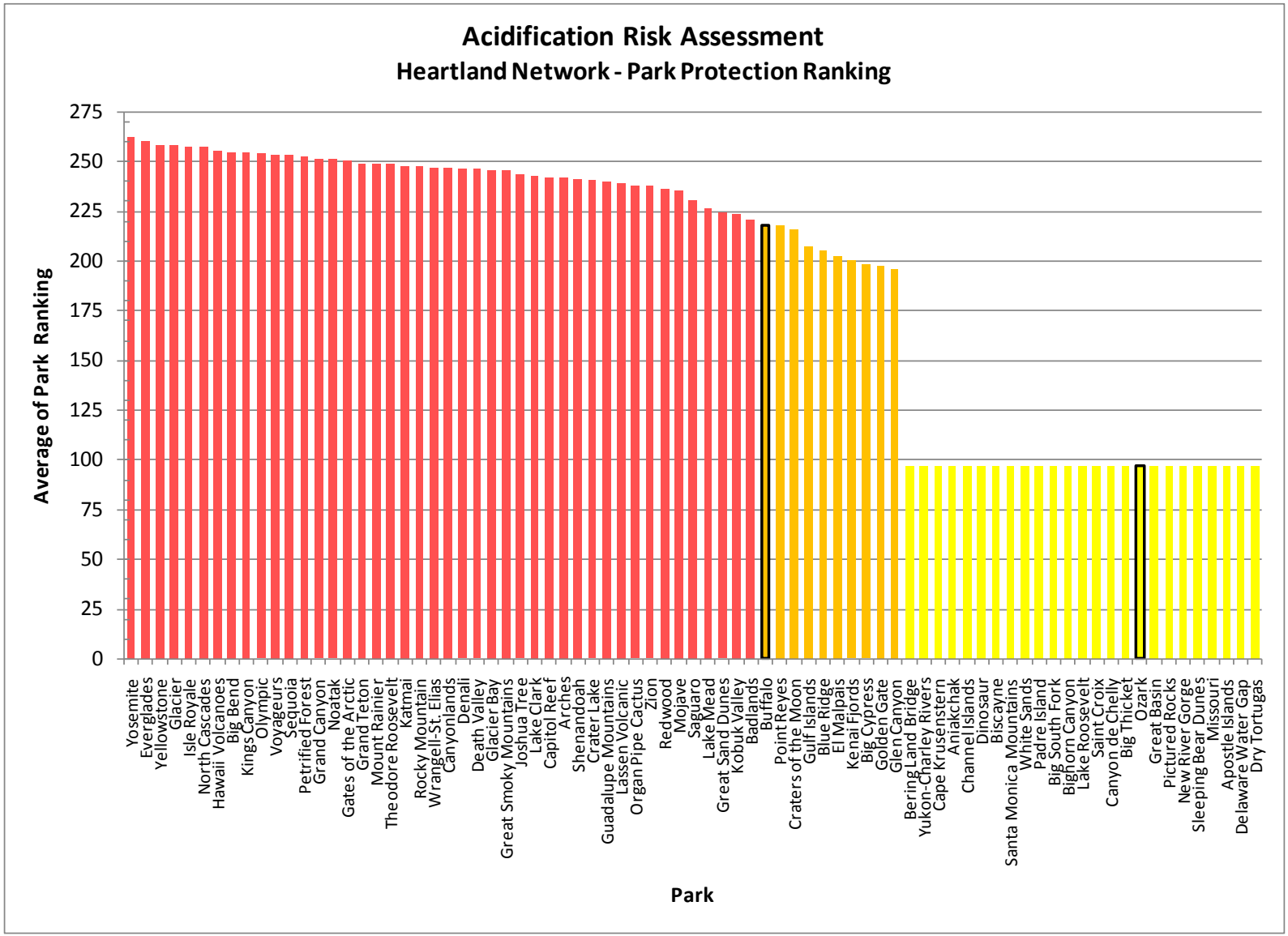

Acidification Risk Assessment
Heartland Network - Park Protection Ranking
Average of Park Ranking
275
250
225
200
175
150
125
100
75
50
25
0
Park
Yosemite
Everglades
Yellowstone
Glacier
Isle Royale
North Cascades
Hawaii Volcanoes
Big Bend
Kings Canyon
Olympic
Voyageurs
Sequoia
Petrified Forest
Grand Canyon
Noatak
Gates of the Arctic
Grand Teton
Mount Rainier
Theodore Roosevelt
Katmai
Rocky Mountain
Wrangell-St. Elias
Canyonlands
Denali
Death Valley
Glacier Bay
Great Smoky Mountains
Joshua Tree
Lake Clark
Capitol Reef
Arches
Shenandoah
Crater Lake
Guadalupe Mountains
Lassen Volcanic
Organ Pipe Cactus
Zion
Redwood
Mojave
Saguaro
Lake Mead
Great Sand Dunes
Kobuk Valley
Badlands
Buffalo
Point Reyes
Craters of the Moon
Gulf Islands
Blue Ridge
El Malpais
Kenai Fjords
Big Cypress
Golden Gate
Glen Canyon
Bering Land Bridge
Yukon-Charley Rivers
Cape Krusenstern
Aniakchak
Channel Islands
Dinosaur
Biscayne
Santa Monica Mountains
White Sands
Padre Island
Big South Fork
Bighorn Canyon
Lake Roosevelt
Saint Croix
Canyon de Chelly
Big Thicket
Ozark
Great Basin
Pictured Rocks
New River Gorge
Sleeping Bear Dunes
Missouri
Apostle Islands
Delaware Water Gap
Dry Tortugas

Figure G

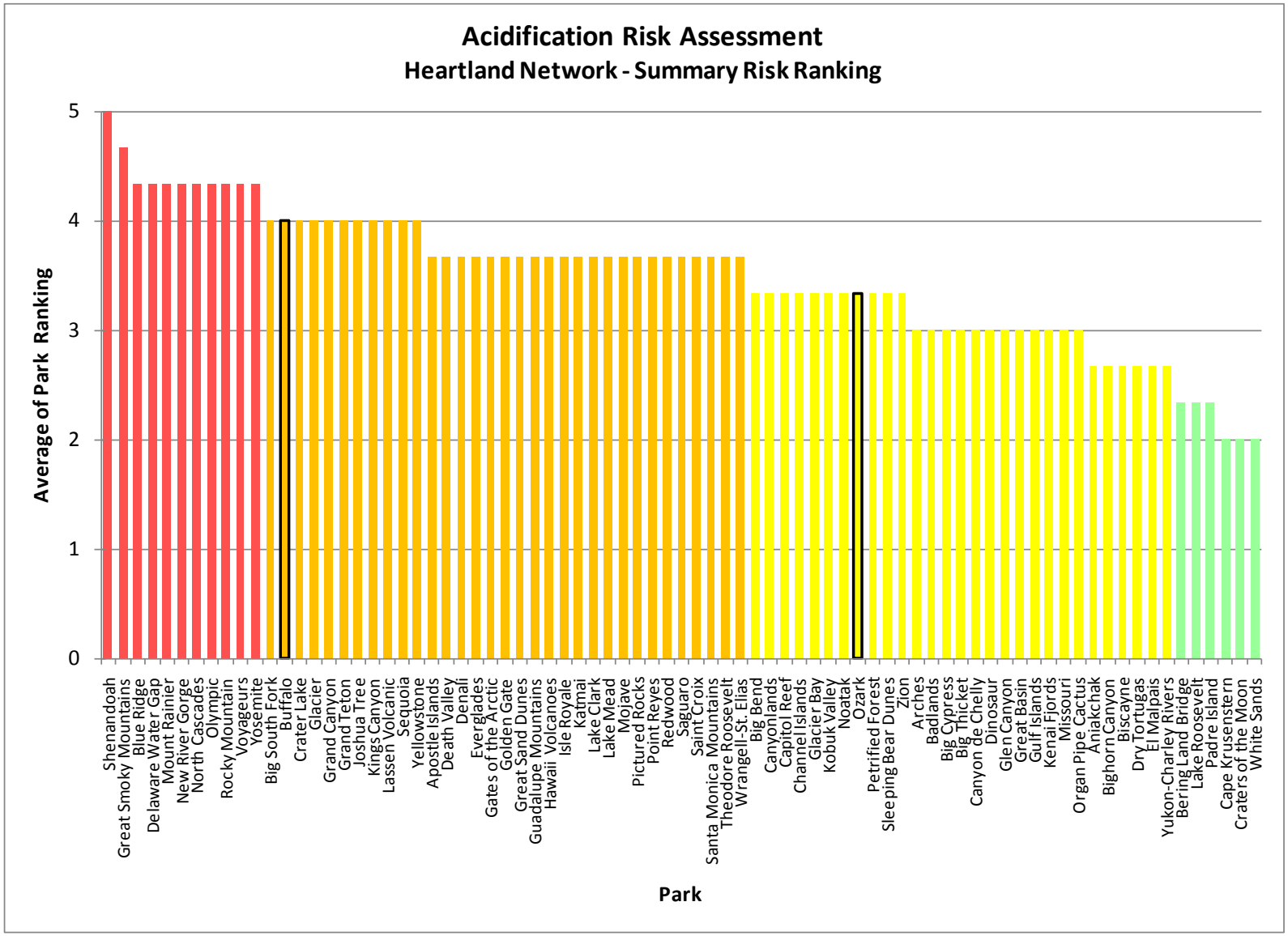

Acidification Risk Assessment
Heartland Network - Summary Risk Ranking
Average of Park Ranking
0
1
2
3
4
5
Park
Shenandoah
Great Smoky Mountains
Blue Ridge
Delaware Water Gap
Mount Rainier
New River Gorge
North Cascades
Olympic
Rocky Mountain
Voyageurs
Yosemite
Big South Fork
Buffalo
Crater Lake
Glacier
Grand Canyon
Grand Teton
Joshua Tree
Kings Canyon
Lassen Volcanic
Sequoia
Yellowstone
Apostle Islands
Death Valley
Denali
Everglades
Gates of the Arctic
Golden Gate
Great Sand Dunes
Guadalupe Mountains
Hawaii Volcanoes
Isle Royale
Katmai
Lake Clark
Lake Mead
Mojave
Pictured Rocks
Point Reyes
Redwood
Saguaro
Saint Croix
Santa Monica Mountains
Theodore Roosevelt
Wrangell-St. Elias
Big Bend
Canyonlands
Capitol Reef
Channel Islands
Glacier Bay
Kobuk Valley
Noatak
Ozark
Petrified Forest
Sleeping Bear Dunes
Zion
Arches
Badlands
Big Cypress
Big Thicket
Canyon de Chelly
Dinosaur
Glen Canyon
Great Basin
Gulf Islands
Kenai Fjords
Missouri
Organ Pipe Cactus
Aniakchak
Bighorn Canyon
Biscayne
Dry Tortugas
El Malpais
Yukon-Charley Rivers
Bering Land Bridge
Lake Roosevelt
Padre Island
Cape Krusenstern
Craters of the Moon
White Sands

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 920/107395, April 2011

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
Air Resources Division
PO Box 25287
Denver, CO 80225

www.nature.nps.gov/air