Analysis of Air Quality information for Vital Signs Selection

Yellowstone and Grand Teton National Parks

Bighorn Canyon National Recreation Area

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INTRODUCTION

Atmospheric deposition of pollutants and the impacts of climate change on aquatic and terrestrial ecosystems are human-activity related issues that have been identified as a concern for Grand Teton and Yellowstone National Parks, and Bighorn Canyon National Recreation Area. There is a need to better understand controls on spatial and temporal variability of hydrologic and biogeochemical processes in the alpine/subalpine ecosystems of the Greater Yellowstone Network (GRYN). Physical characteristics of high-elevation basins, such as thin and rocky soils, sparse vegetation, and short growing seasons make them susceptible to damage from atmospheric deposition of pollutants. Current conditions as well as proposed changes, including increasing emissions from power plants and energy production nearby GRYN have the potential to alter the chemistry of aquatic ecosystems through nitrogen saturation and episodic acidification. This could lead to declining fish populations, leaching of acid minerals from soils into surface waters, forest decline and increased plant disease.

Compilation of historical air and water quality data collected in Yellowstone and Grand Teton National Parks indicates that limited chemical data exists. Average annual atmospheric deposition maps of the Rocky Mountains identify regions of high nitrate and ammonium deposition within GRYN, as well as patterns of nitrate, sulfate, ammonium, and acid deposition throughout the Rocky Mountains (Figures 1-4) (Nanus et al., in review). Areas of elevated atmospheric deposition may result from combined local and regional sources of air pollution. Air quality and surface water monitoring is needed within GRYN to assess current conditions and evaluate the long-term effects of potential natural and anthropogenic alterations. Differences in deposition patterns and environmental attributes such as topography, geology and vegetation between Yellowstone and Grand Teton National Parks (Zelt et al., 1999), as well as Bighorn Canyon National Recreation Area, support the need for specific vital-sign monitoring efforts within each of the individual parks and recreation areas.

OBJECTIVES

The purpose of this project was to document and evaluate existing air quality data relating to the atmospheric deposition of pollutants for Grand Teton and Yellowstone National Parks and Bighorn Canyon National Recreation Area. Air quality datasets compiled with focus on spatial and temporal variability of atmospheric deposition in GRYN included as follows: the National Atmospheric Deposition Program/National Trends Network (NADP/NTN)(NADP/NTN, 2003), plus one Mercury Deposition Network (MDN) site in Yellowstone National Park; the United States Geological Survey/National Park Service (USGS/NPS) Rocky Mountain Snowpack Chemistry Synoptic (RMS) (Ingersoll, 2002 and Turk, 2001); and the Clean Air Status and Trends Network (CASTNet) operated as part of a joint NPS-EPA program. The results of this study can be used by the Park Service to help define vital sign monitoring objectives and priorities.

METHODS

USGS/NPS RMS site locations were overlaid in a Geographic Information System (GIS) on a map of air quality monitoring sites and networks produced by the Intermountain GIS Program Office (Figure 5). Site locations were identified from Figure 5. To evaluate regional as well as local GRYN air quality trends, all stations located in Montana, Wyoming, Yellowstone and Northwestern Utah (northern Rocky Mountain region) were included in the data documentation.

The NADP/NTN program was developed to monitor acid deposition. Annual NADP/NTN deposition data for a 10-year period of record from 1993-2002 at 20 sites located in Idaho (2), Montana (7), Utah (2), and Wyoming (9) for the following constituents (calcium, magnesium, potassium, sodium, ammonium, nitrate, chloride, sulfate, and acidity) were downloaded and compiled into a single data file (NADP/NTN 2003). Average concentrations of nitrate (Figure 6), sulfate (Figure 7), ammonium (Figure 8) and chloride (Figure 9) were calculated for the 10-year period and data layers were created in ArcInfo GIS for each of the constituents. The layers were then overlaid on a National 30m Digital Elevation Model, to identify changes in deposition with elevation. Other constituents, including all other major cations can easily be plotted from the data file in a GIS for the 10-year period of record or for individual years.

Winter RMS major anion and cation data for 1993-2002 at 26 sites located in Idaho (1), Wyoming (16) and Montana (9) were compiled into a single data file. Average concentrations of nitrate (Figure 10), sulfate (Figure 11), ammonium (Figure 12) and chloride (Figure 13) were calculated for the 10-year period and data layers were created in ArcInfo GIS. The layers were then overlaid on a National 30m Digital Elevation

Model. NADP/NTN and RMS data were not plotted in single map layers even though they cover the same geographic region due to the fact that Rocky Mountain snowpack samples represent winter wet deposition and annual NADP/NTN data represent deposition for the entire year.

CASTNet was initiated in 1990 by the Environmental Protection Agency to monitor ozone levels and dry acid deposition, particularly weekly average atmospheric concentrations of sulfate, nitrate, ammonium, sulfur dioxide, and nitric acid. In addition, hourly concentrations of ambient ozone levels are also collected. There are a total of four CASTNet sites located in the northern Rocky Mountain region. CASTNet sites include GLR468, Glacier National Park, YEL408, Yellowstone National Park; PND165, Pinedale, WY and CNT169; Centennial, WY. Sites in Glacier and Yellowstone are operated by the National Park Service. CASTNet data was downloaded into a single data file and ozone and average annual dry deposition of nitrate, sulfate and ammonium were evaluated. A map of the four CASTNet sites, with summary data, will be included in the final report.

RESULTS

Air quality monitoring sites and networks in the Rocky Mountains CESU intermountain region are presented in Figure 5. Networks include IMPROVE (visibility monitoring), Gaseous Pollutant Monitoring Program (NPS), CASTNet, MDN, NADP/NTN, and USGS/NPS RMS. Figure 5 identifies spatial gaps in monitoring networks. According to Figure 5, Bighorn Canyon National Recreation Area does not have any air quality monitoring sites within its boundary. However, there are several in the vicinity, including an NADP/NTN site in Little Bighorn Battlefield National Monument. Yellowstone and Grand Teton National Parks have established long-term monitoring sites, including over 10 years of deposition data at the NADP/NTN site in Yellowstone, and over 10 years of data at the USGS/NPS RMS sites within the Park boundaries.

Figures 6-9 present NADP/NTN data from 1993-2002 as 10-year average nitrate, sulfate, chloride, and ammonium concentrations and are useful for identifying hot-spots and spatial trends. The NADP/NTN nitrate maps (Figure 6) display hot-spots of nitrate in northeastern Utah (15-18 µeq/L) as well as eastern Wyoming (15-18 µeq/L) and southern Wyoming (12-15 µeq/L). NADP/NTN sulfate deposition is highest in northeastern Utah (greater than 18 µeq/L) and northeastern Montana (greater than 18 µeq/L) (Figure 7). NADP/NTN chloride concentrations are typically low throughout the northern Rocky Mountains ranging from 0-5 µeq/L throughout the region. One hot-spot is found in northeastern Utah (greater than 10 µeq/L). NADP/NTN ammonium concentrations are highest in northeastern Utah (greater than 18 ueq/L).

Figures 10-13 present RMS data from 1993-2002 as 10-year average concentrations of nitrate, sulfate, chloride and ammonium. RMS average nitrate concentrations (Figure 10) are highest in Yellowstone National Park (12-15 µeq/L) and southern Wyoming (12-15 µeq/L). Snowpack sulfate concentrations are highest in southern Wyoming (12-15 µeq/L) (Figure 11). RMS chloride concentrations are low throughout the northern Rocky Mountains, ranging from 0-5 µeq/L. Snowpack ammonium concentrations are highest in West Yellowstone (12-15 µeq/L).

The average annual deposition maps (for 1992 through 1999) indicate that there are regions of high atmospheric deposition not only in Colorado but also in the northern Rocky Mountains (Figures 1- 4). Highest nitrate (2.5 - 3.0 kg/ha N) and sulfate (4.0 – 8.0 kg/ha SO_4) deposition in the northern Rocky Mountains is in Yellowstone and Grand Teton National Parks. High nitrate (2.0 -2.5 kg/ha N) and sulfate (8.0 –10.0 kg/ha SO_4) deposition is also found along the Wasatch Front in northeastern Utah (Figures 1 and 2), which is adjacent to a large urban corridor. Other areas of high nitrate and sulfate in the northern Rocky Mountains include northern Montana (Figures 1 and 2). High ammonium deposition (1.5-2.5 kg/ha N) is documented in Yellowstone and Grand Teton National Parks. Relatively high acid deposition (0.10 – 0.25 kg/ha H^+) is present in south-central and northwestern Wyoming, and northwestern Montana (Figure 4).

DISCUSSION

Air quality data has been collected for over 10 years at a number of sites in the northern Rocky Mountain region by NADP/NTN, USGS/NPS RMS, and EPA/NPS CASTNet programs. These sites are extremely valuable. Deposition and concentration maps can help define monitoring priorities for these vital signs by identifying hot-spots and gaps, as well as long-term spatial and temporal variability within and among the different networks.

Comparison of RMS and NADP/NTN data indicate there is better resolution with the RMS data and that the range of solute concentrations are comparable, but hot-spots are not always comparable. For example, higher nitrate and ammonium snowpack concentrations are present at West Yellowstone, than at the Yellowstone NADP/NTN site. Summer deposition and location of deposition collector may be important. Spatial variability in atmospheric deposition of acid solutes are driven by precipitation amount and superimposed on that is concentration, thus deposition does not necessarily reflect variations in concentration alone. Deposition maps indicate that acid solute deposition is greater at high elevations than mid to low elevations, due to orographically-enhanced precipitation amounts at high elevations. Thus, deposition may vary greatly over short distances due to abrupt changes in elevation. Sources contributing to high deposition include local and regional sources. Local sources of pollution may cause some small variation in trends, while regional pollution may result in a larger trend variation.

Atmospheric deposition and effects on response in sensitive headwater catchments is an important candidate vital sign specific to Grand Teton and Yellowstone National Parks. Limited chemical data exists for high-elevation lakes in sensitive regions of these National Parks (low acid neutralizing capacity) (Woods and Corbin, personal communication; Greater Yellowstone Clean Air Partnership, 1999). Only 7 samples were collected from alpine lakes in Yellowstone and Grand Teton National Parks during synoptic sampling in 1985 (EPA) (Landers et al., 1987) and again in 1999 (USGS/NPS) (Clow et al., 2002).

An aquatic ecosystem risk assessment will be conducted in Yellowstone and Grand Teton National Parks using GIS and multiple logistic regression to assess the relationship between atmospheric deposition and response in sensitive headwater catchments. The project will develop a model that assigns a probability for a high elevation lake to be sensitive to the atmospheric deposition of pollutants. Existing water-quality data will be related to basin physical characteristics (primarily vegetation, soils, elevation, and geology) and atmospheric deposition (inorganic nitrogen, sulfate, and acidity). Deposition will be included to help identify and separate out changes in water quality from those caused by atmospheric deposition from land-use, fire, and other changes.

Model validation can be accomplished by sampling water quality at a subset of lakes selected based on the results of the statistical analysis. The results can then be used to make recommendations regarding the design of a long-term water-quality monitoring program in sensitive headwater catchments within the Greater Yellowstone Network. This "ground truth" data collection will occur to a limited extent as part of an NPS-Air Resources Division project to be carried out in summer of 2004 and 2005.

The atmospheric deposition of nitrogen, sulfur, and all major anions and cations is another important candidate vital sign (stressor) specific to Grand Teton and Yellowstone National Parks. GRYN should place a priority on continued monitoring efforts of NADP/NTN and RMS on an annual basis at ongoing sites. With budget cuts some sites are disappearing. It is essential to the GRYN that none of the long-term deposition monitoring sites be cut in the northern Rocky Mountain region. The one NADP/NTN site in Yellowstone is funded with NPS-ARD dollars and appears to be secure. The RMS snow sites are funded year-to-year with project funds and need more stable funding in the coming years. GRYN should consider making a funding commitment to these synoptic snowpack sites.

The establishment of new deposition monitoring sites in places where there are limited data would significantly add to the understanding of atmospheric deposition of nitrogen, sulfur, and all major anions and cations in the northern Rocky Mountains. In particular, the one NADP/NTN site in Yellowstone (1912 m) has significantly lower nitrate and ammonium concentrations as well as all other major anions and cations than five of the nearby RMS sites, especially the RMS site in West Yellowstone. The establishment of at least one new high elevation (greater than 2000m) deposition monitoring site following the NADP/NTN weekly sampling protocols on an annual basis in Yellowstone National Park to measure atmospheric deposition, would aid in the understanding of why the NADP/NTN site that is currently in operation is lower than nearby sites. One possible hypothesis is that this site is not in the most ideal location for deposition monitoring. There are no NADP/NTN sites within the Grand Teton National Park borders. Due to the differences in the environmental setting of Grand Teton and Yellowstone, it would be beneficial to the GRYN to establish a deposition monitoring site in Grand Teton National Park (greater than 2000m elevation) as well.

Monitoring of dry deposition through the CASTNet program is expensive and equipment intensive. The dry deposition site at Yellowstone NP is secure via NPS-ARD funding; there is not a strong rationale to install more sites in the GRYN area.

Another important candidate vital sign is the monitoring of visibility deciviews. The air quality work group determined that there was a legal mandate for visibility to be monitored in the vicinity of all Class 1 areas. The NPS-Air Resources Division runs an IMPROVE monitoring station at Lake in Yellowstone NP, which satisfies the requirement for monitoring in both YELL and GRTE (BICA is a Class 2 park). If visibility is ranked as a critical vital sign in all three network parks, then paying for IMPROVE sites in both GRTE and BICA should be pursued-an expensive proposition for both set up and annual maintenance and operation.

Figure 1. Average Annual Nitrate Deposition

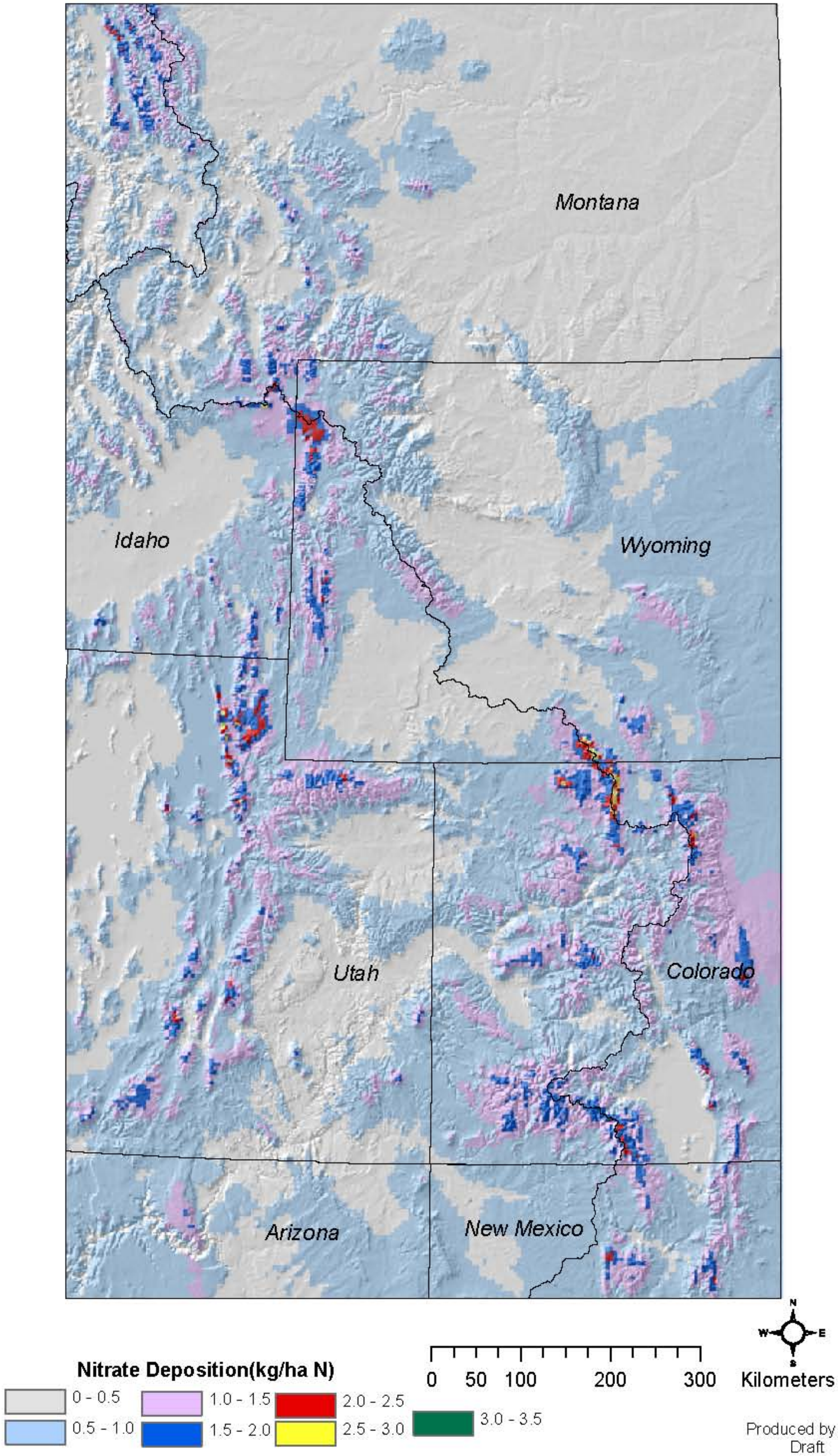

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Figure 2. Average Annual Sulfate Deposition

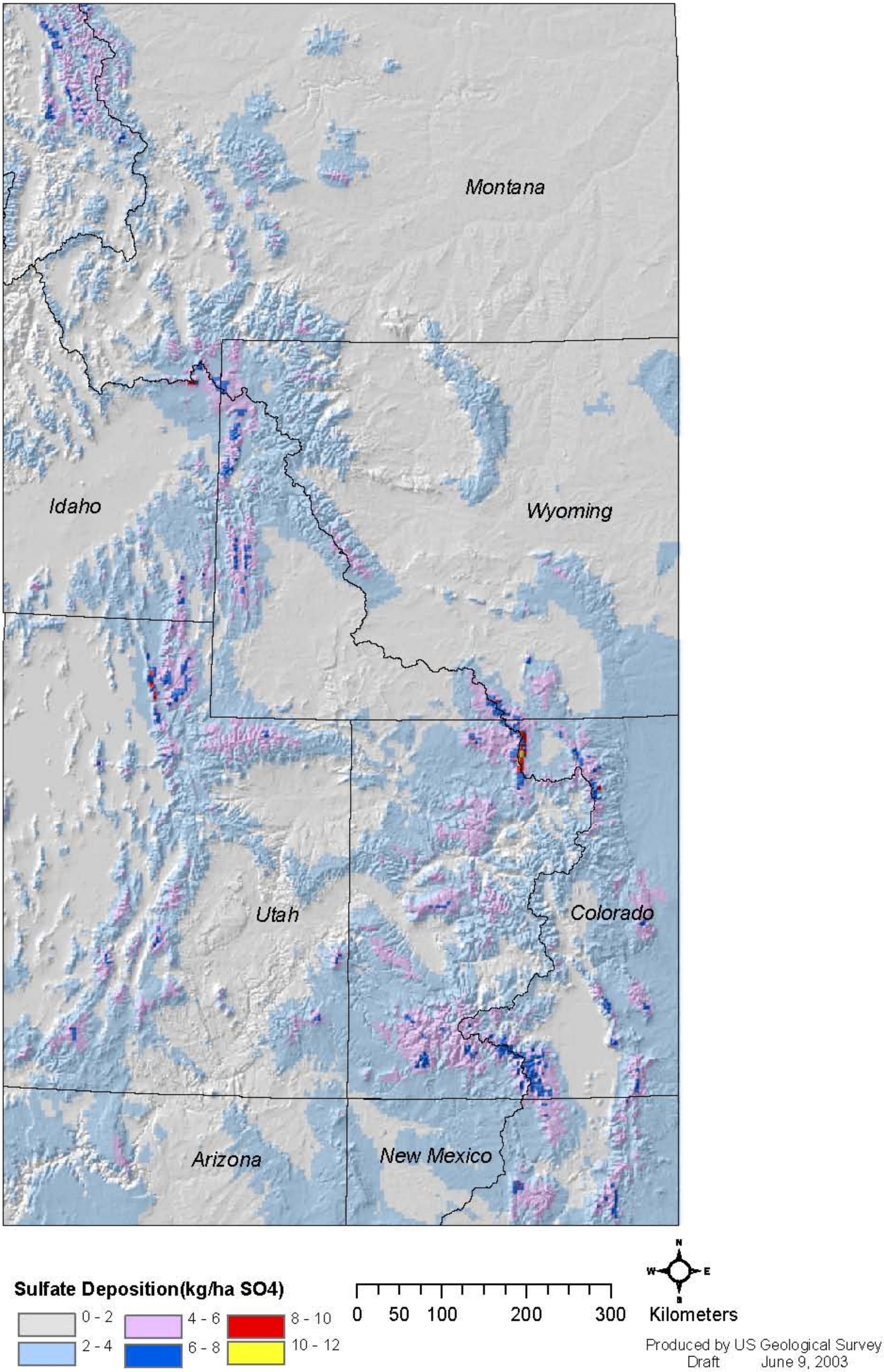

Figure 3. Average Annual Ammonium Deposition

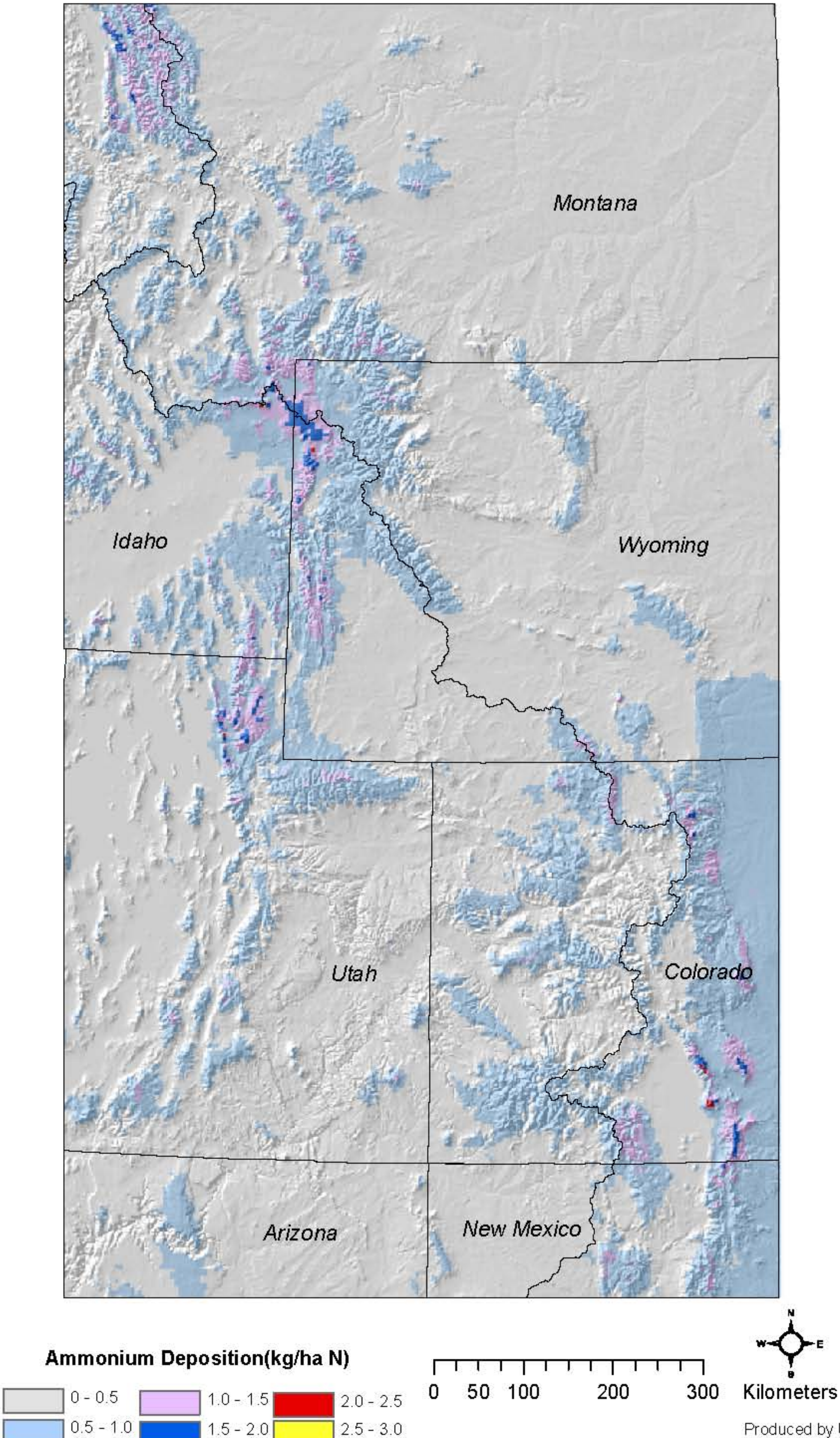

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Figure 4. Average Annual H+ Deposition

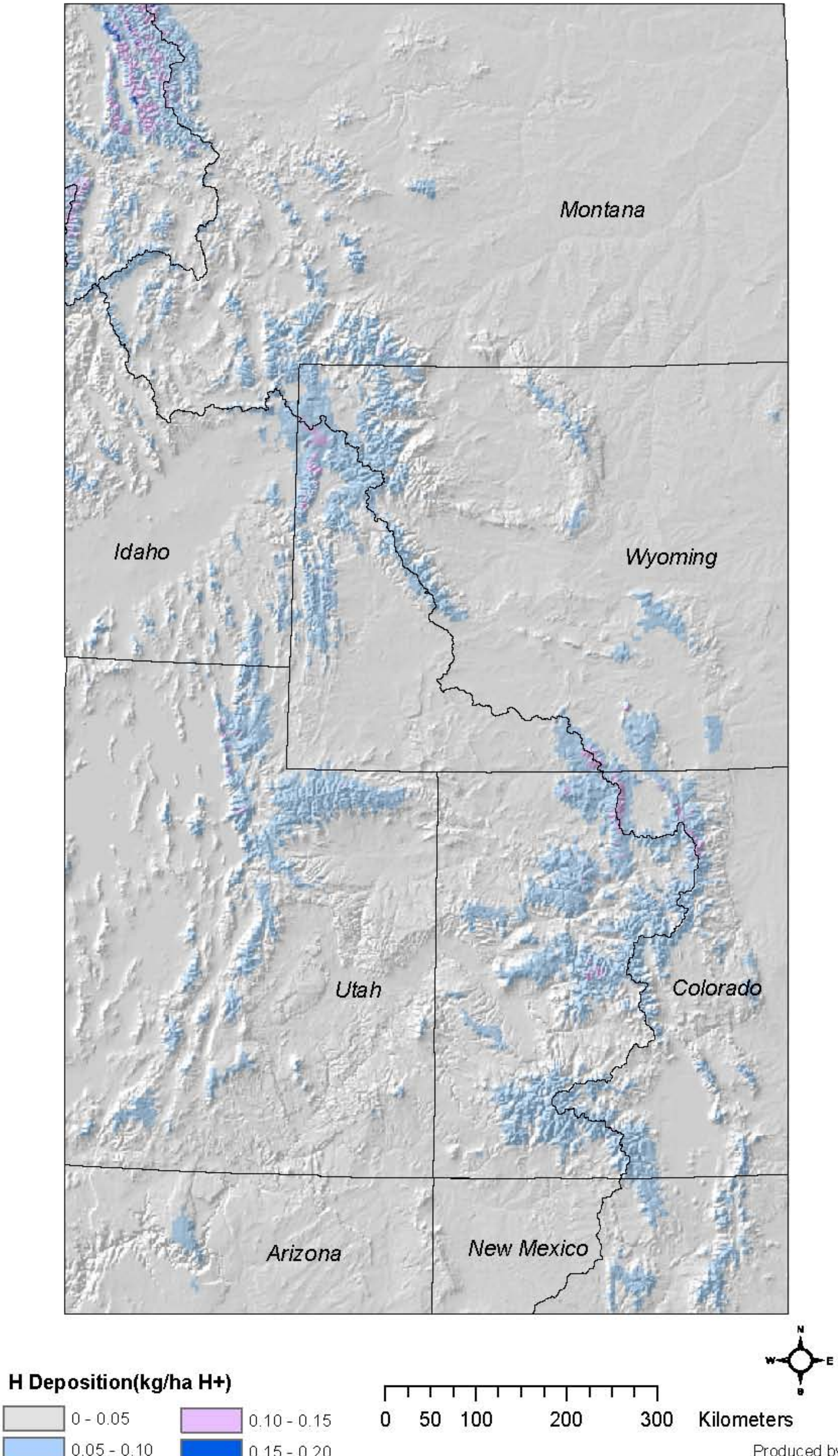

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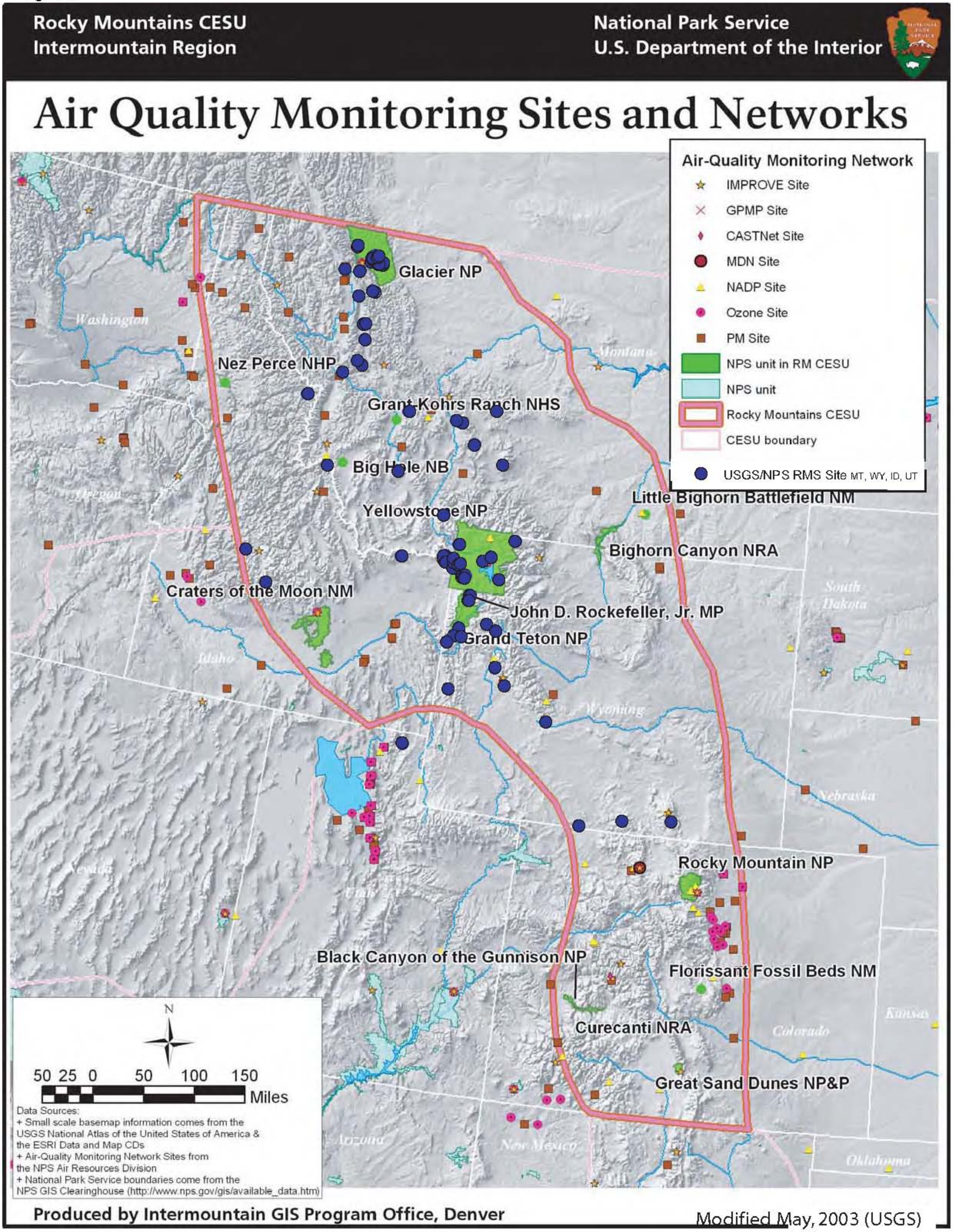
Figure 5.



Modified May, 2003 (USGS)

Figure 6. National Atmospheric Deposition Program/National Trends Network
Average Nitrate Concentration (1993-2002)

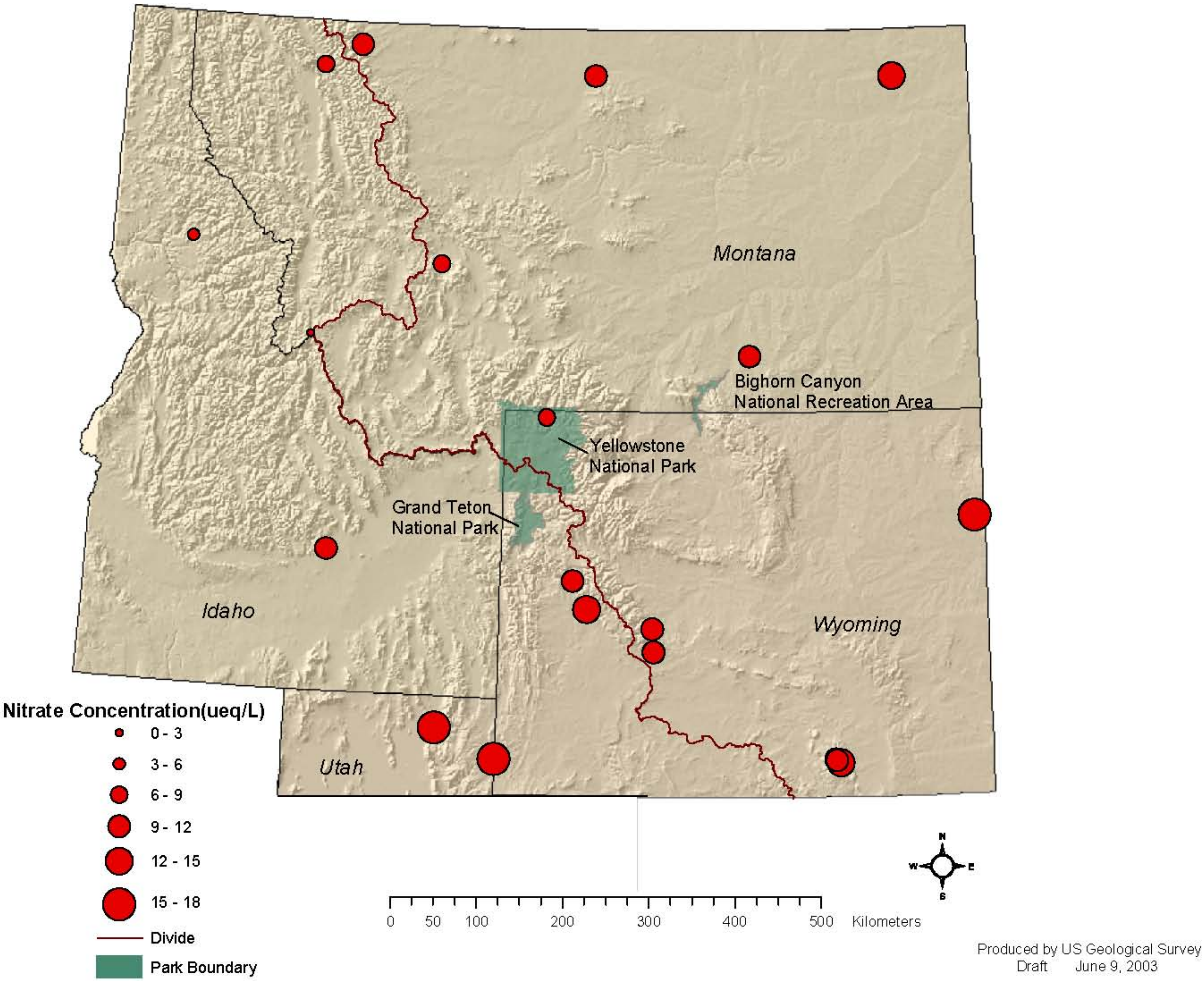


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Figure 7. National Atmospheric Deposition Program/National Trends Network
Average Sulfate Concentration (1993-2002)

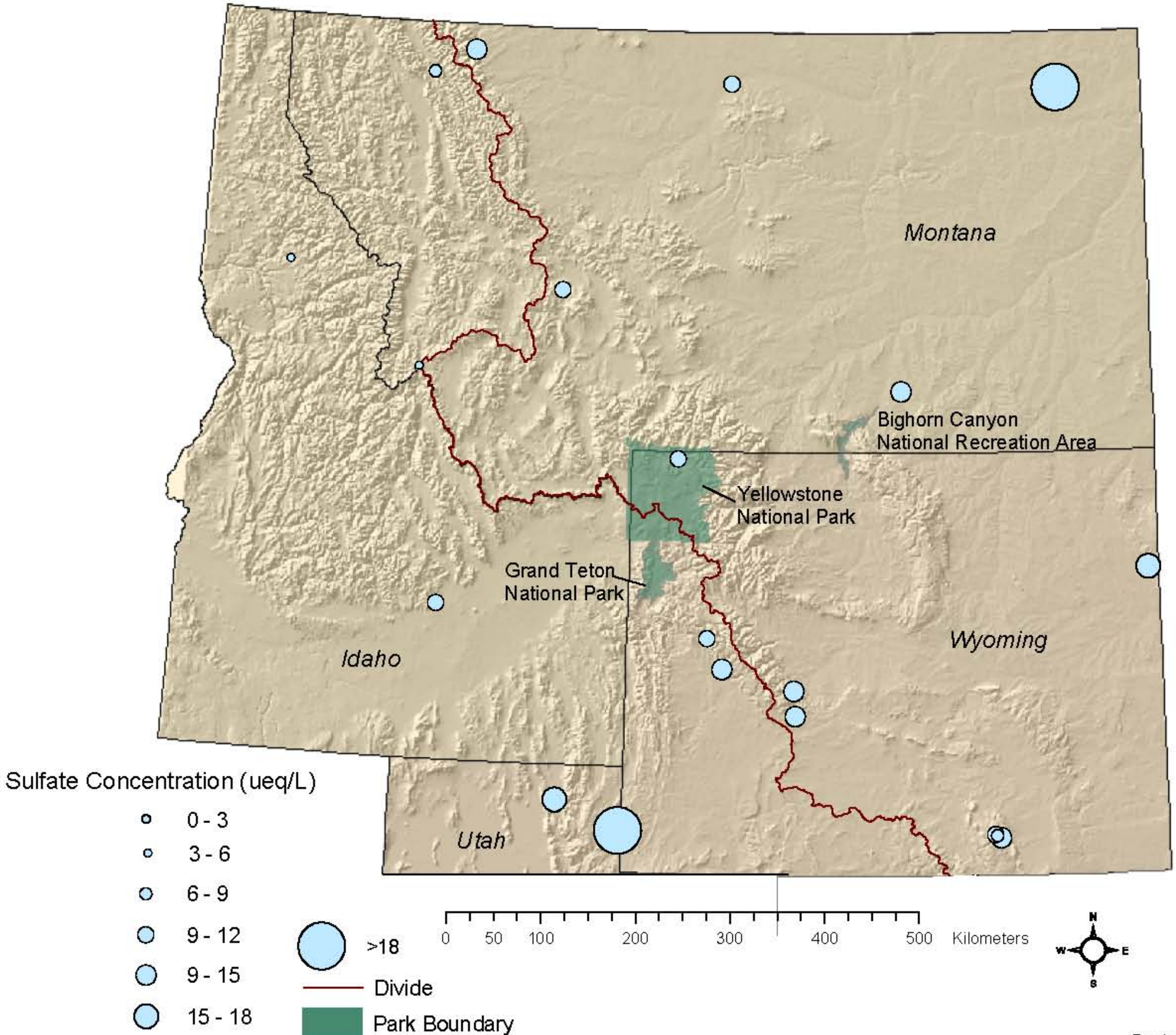

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Figure 8. National Atmospheric Deposition Program/National Trends Network
Average Ammonium Concentration (1993-2002)

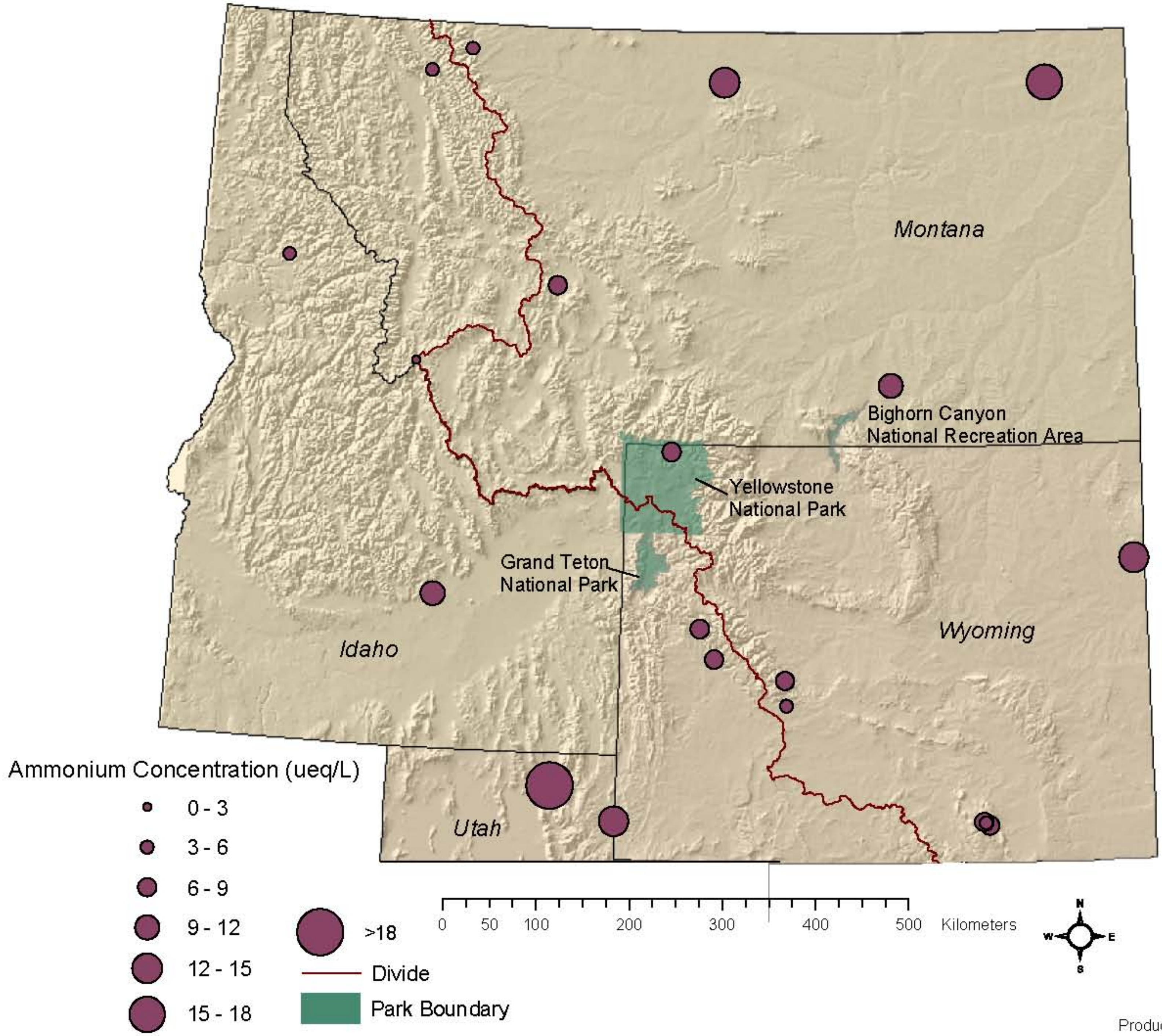

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Figure 9. National Atmospheric Deposition Program/National Trends Network
Average Chloride Concentration (1993-2002)

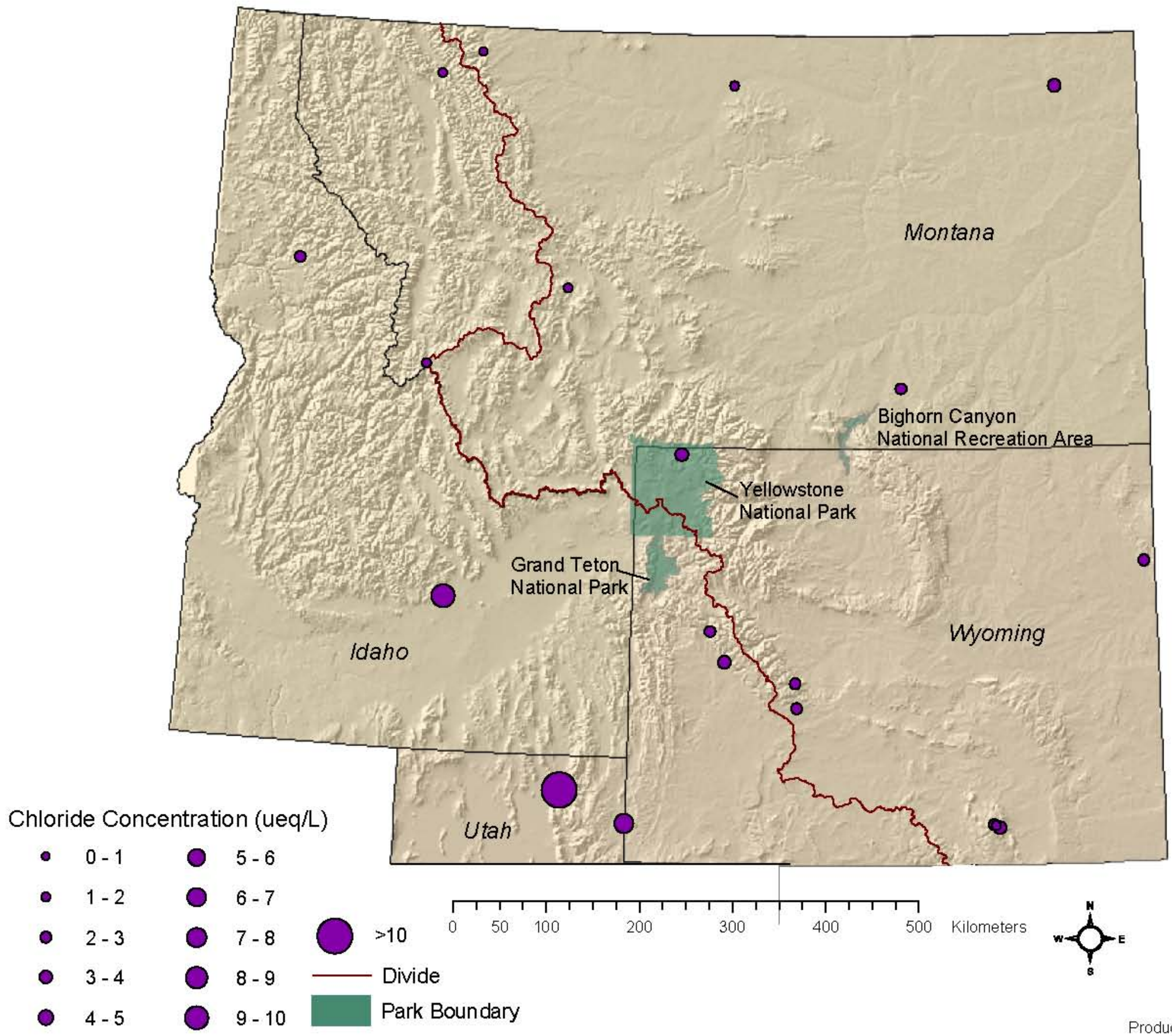

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Figure 10. Rocky Mountain Snowpack Average Nitrate Concentrations(1993-2002)

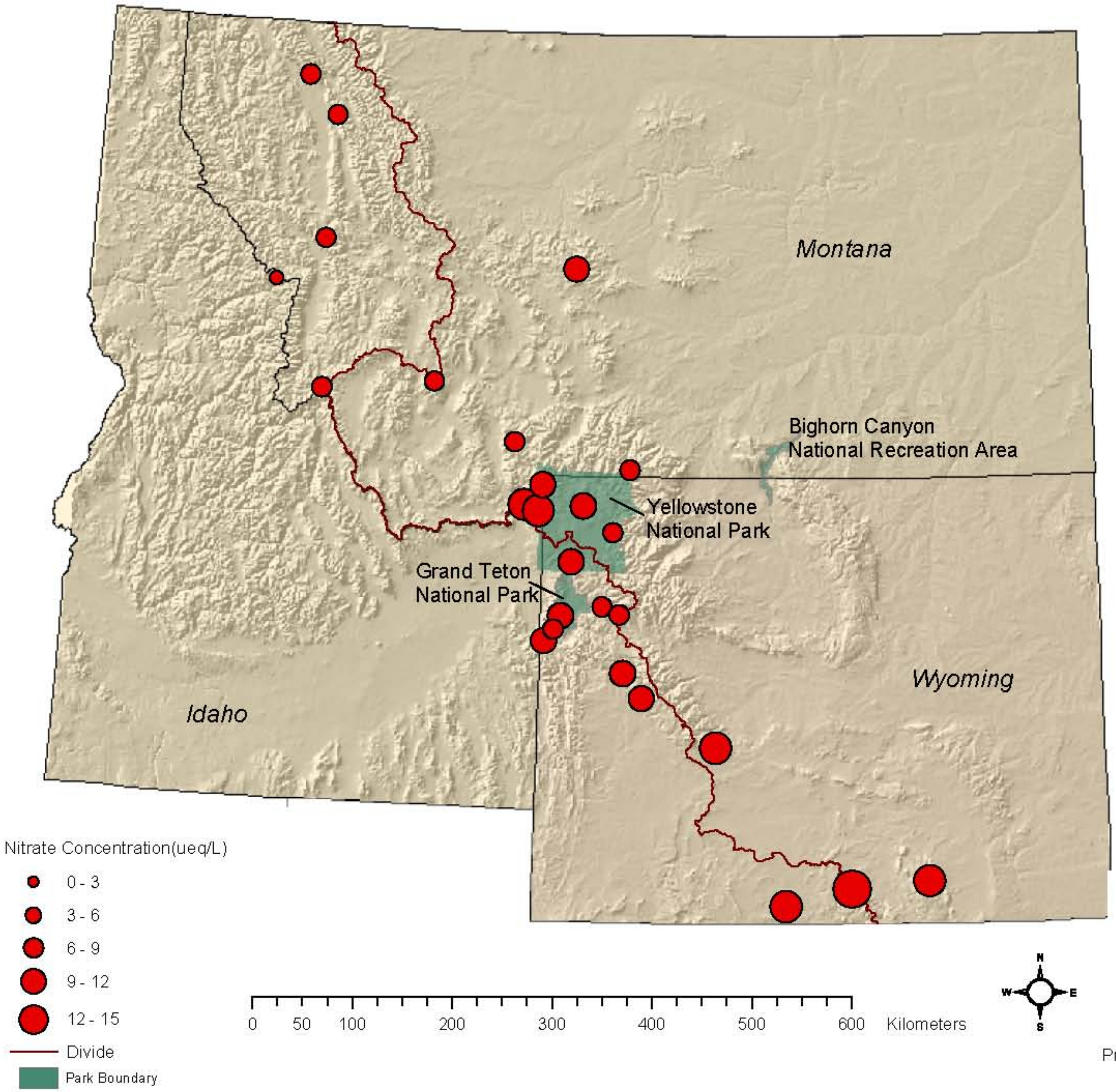

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Figure 11. Rocky Mountain Snowpack Average Sulfate Concentrations(1993-2002)

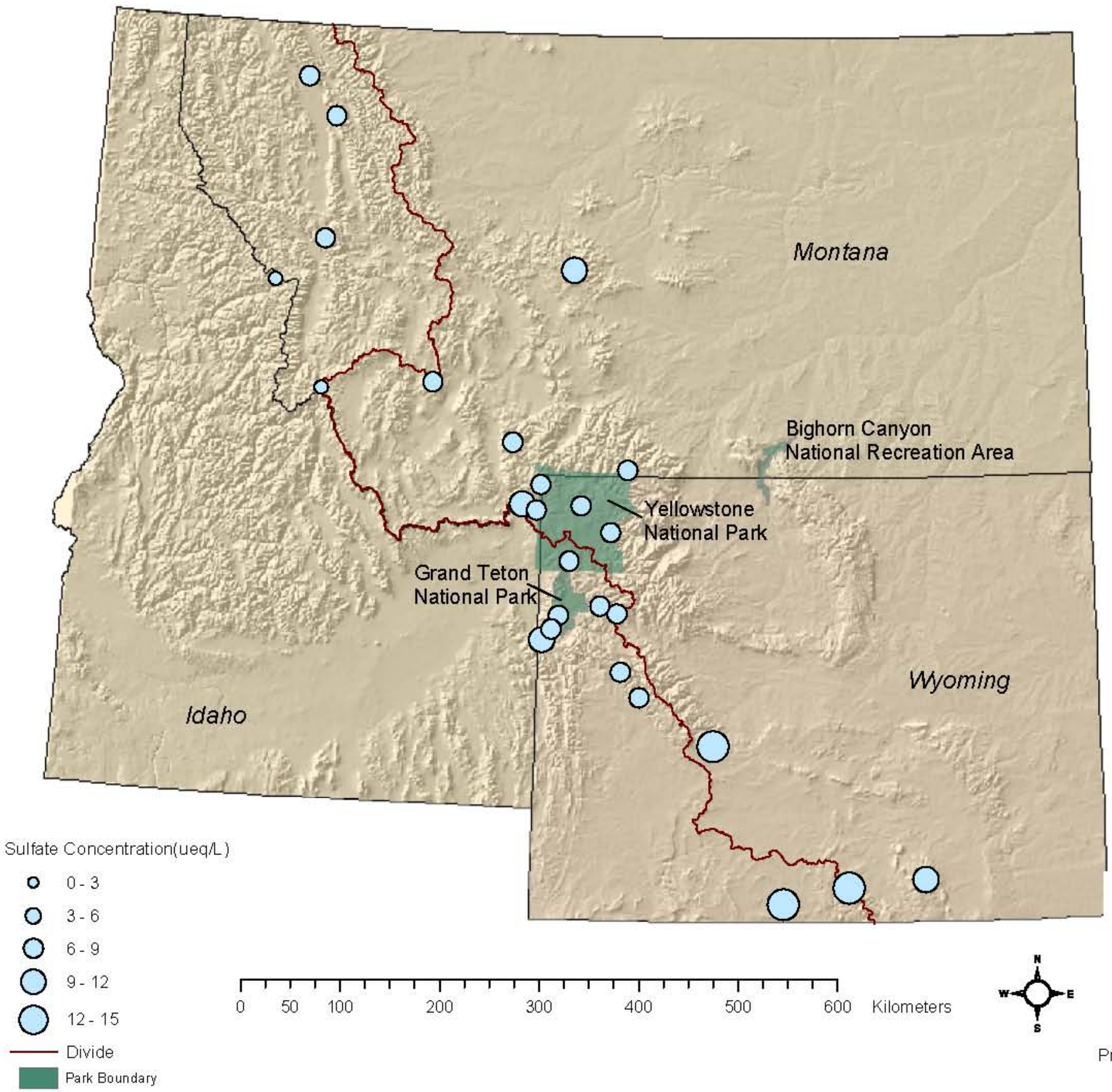

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Figure 12. Rocky Mountain Snowpack Average Ammonium Concentrations(1993-2002)

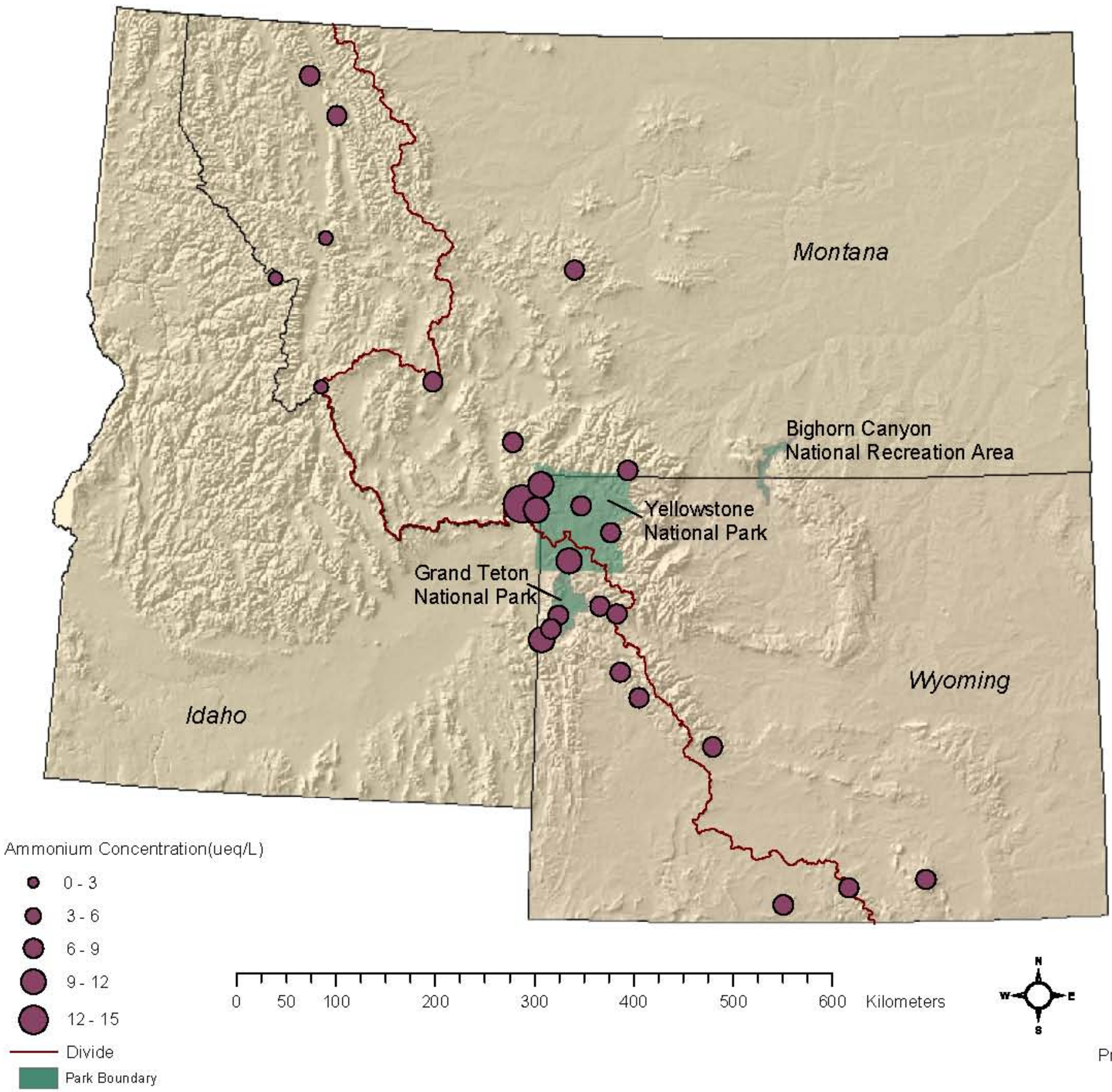

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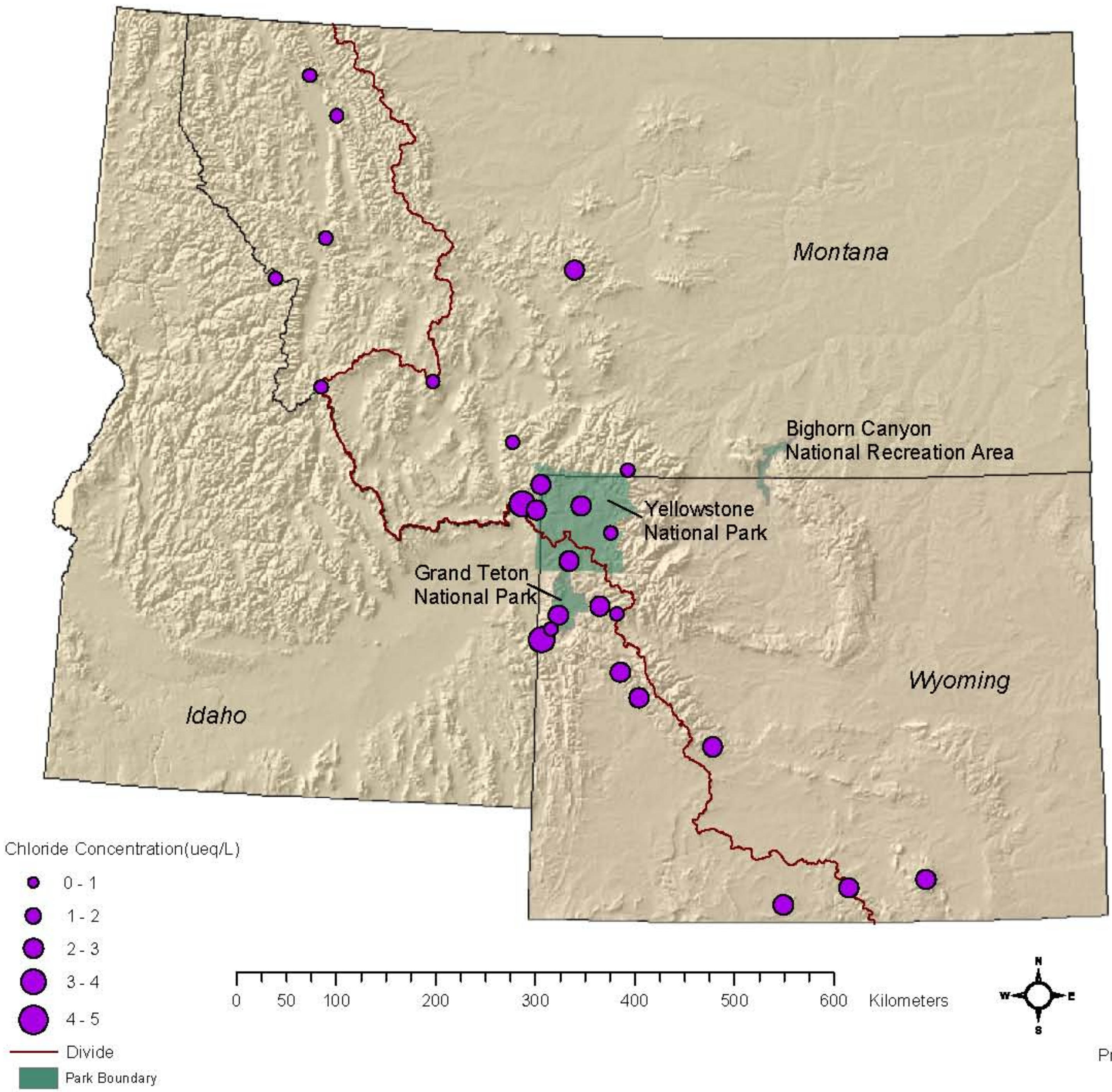
Figure 13. Rocky Mountain Snowpack Average Chloride Concentrations(1993-2002)



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