**NOx/SOx/PM Risk and Exposure Technical Appendices**

Summary and Status moving towards completion in FY2021

**Purpose:** To summarize the status and results of the NOx/SOx/PM Risk and Exposure Assessment technical appendices and anticipated completion dates.

**Background**

We anticipate that OAQPS will release the NOx/SOx/PM Policy Assessment pursuant to Section XXX of the Clean Air Act for the Secondary NAAQS:

* The first action was the release of the NOx/SOx/PM Integrated Review Plan in XX/XXXX. This included a proposal for the entire NAAQS review, including the Integrated Science Assessment (ISA), Risk and Exposure Assessment (REA) and the Policy Assessment (PA). For REA purposes, the key components of this were:
  + Defining the ecological endpoints to be analyzed
  + Proposing a general outline of the analyses
* The second action was the release and CASAC review of the REA Planning Document (XX/XXX), which further outlined the risk and exposure analyses. This was reviewed in conjunction with the ISA.
* The ISA was finalized in XX/XXXX
* The next action will be the release of the PA and associated REA technical appendices in XXX 2021.

**Overview of the REA Technical Appendices**

The REA for the NOx/SOx/PM review consists of 6 appendices and 5 Sub-Appendices. Appendices A-E are national in scale while Appendix F and the 5 Sub-Appendices focus on the Case Study Areas.

* National-Scale Appendices
  + These appendices are intended to inform the PA regarding the adequacy of the current standards. Using data from 2017—2019, three counties have measured design values that exceed the annual-average PM2.5 secondary NAAQS and 18 counties have measured design values that exceed the annual-average PM2.5 primary NAAQS. There are no counties that have measured design values that exceed the 3-hour SO2 secondary NAAQS, and 16 counties that exceed the 1-hour SO2 primary NAAQS. There are no counties that have measured design values that exceed the annual or 1-hour NO2 primary or secondary NAAQS. Because of this, potential risks and impacts under current conditions can be interpreted as indicating the current standards are possibly not adequate and indicate the need to perform more refined case study analyses.
    - Appendix A: Current Air Quality
    - Appendix B: Aquatic Acidification
    - Appendix C: Tree Growth and Survival
    - Appendix D: Terrestrial N Enrichment
    - Appendix E: Summary of Effects in Class I Areas
  + There were potential risks across the country based on exceedances of aquatic acidification and terrestrial N enrichment Critical Loads (CLs) and widespread impacts to tree growth and survival. This indicated the need for more refined Case Study Analyses.
* Case Study Analyses
  + These analyses are intended to inform the PA regarding the adequacy of the current standards using more refined AQ scenarios just meeting the current primary and secondary PM2.5 standards of 12 µg/m3 and 15 µg/m3 and 1 alternate PM2.5 level of 10 µg/m3.
    - Appendix F: Summary of case study results
    - Sub-Appendix FA: Description of case study areas.
    - Sub-Appendix FB: Description of AQ Scenarios
    - Sub-Appendix FC: Aquatic Acidification case study results
    - Sub-Appendix FD: Tree growth and survival case study results
    - Sub-Appendix FE: Terrestrial N enrichment case study results

**REA Technical Appendices Summary**

* Appendix A: Air Quality
  + This appendix provides technical information on TDEP, a model-measurement fusion technique for estimating deposition, and evidence in measurements and models for the linkage between air concentrations and deposition
  + Data and Analyses
    - Updated TDEP: this section describes the TDEP approach, improvements to better capture spatial variability, and an assessment of uncertainty
    - Linking air concentration and deposition: using data from 1990 – 2019, this section assesses the linkage between air concentrations and deposition using models, measurements, and an assessment of uncertainty
  + Results
    - Deposition uncertainty is larger in areas further from monitoring stations and those influenced by ammonia dry deposition. Many ecologically sensitive areas have monitoring stations and are not near large sources of ammonia emissions.
    - There is considerable variability in the relationship between air concentrations and deposition. In the East, large changes in emissions of N and S have clearly led to declining concentrations and deposition; estimates of the change in deposition due to a change in concentration are less uncertain. Mountain regions in the West have significant interannual variability, and there is more uncertainty in predictions of the change in deposition due to a change in concentration when assessing the historical record.
  + Quality Assurance/Control

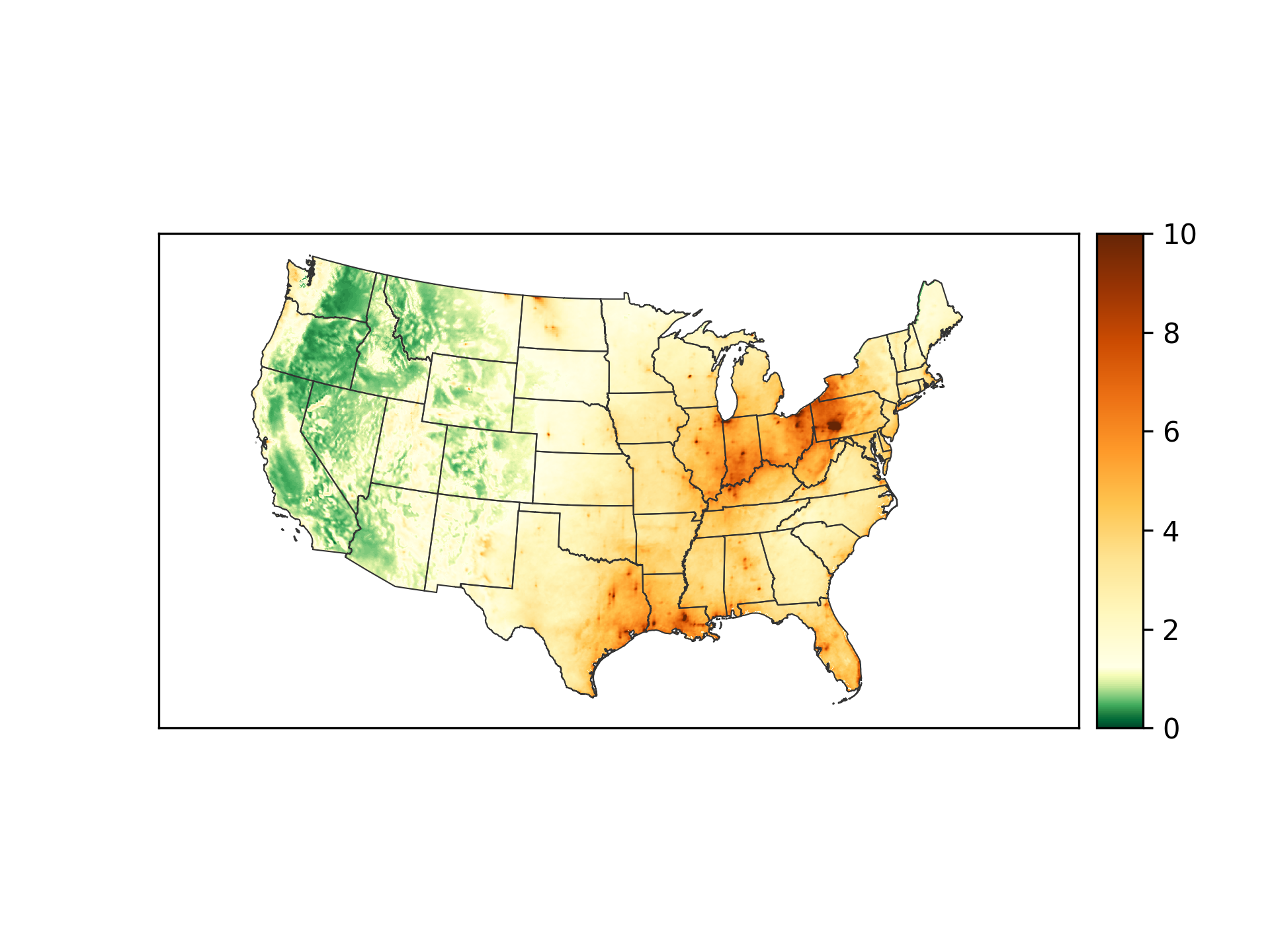


Figure 2‑5: Annual total deposition of sulfur, kg S ha-1, annual totals averaged across 2014 -- 2016. The methods used to develop these deposition estimates are described in Appendix A.

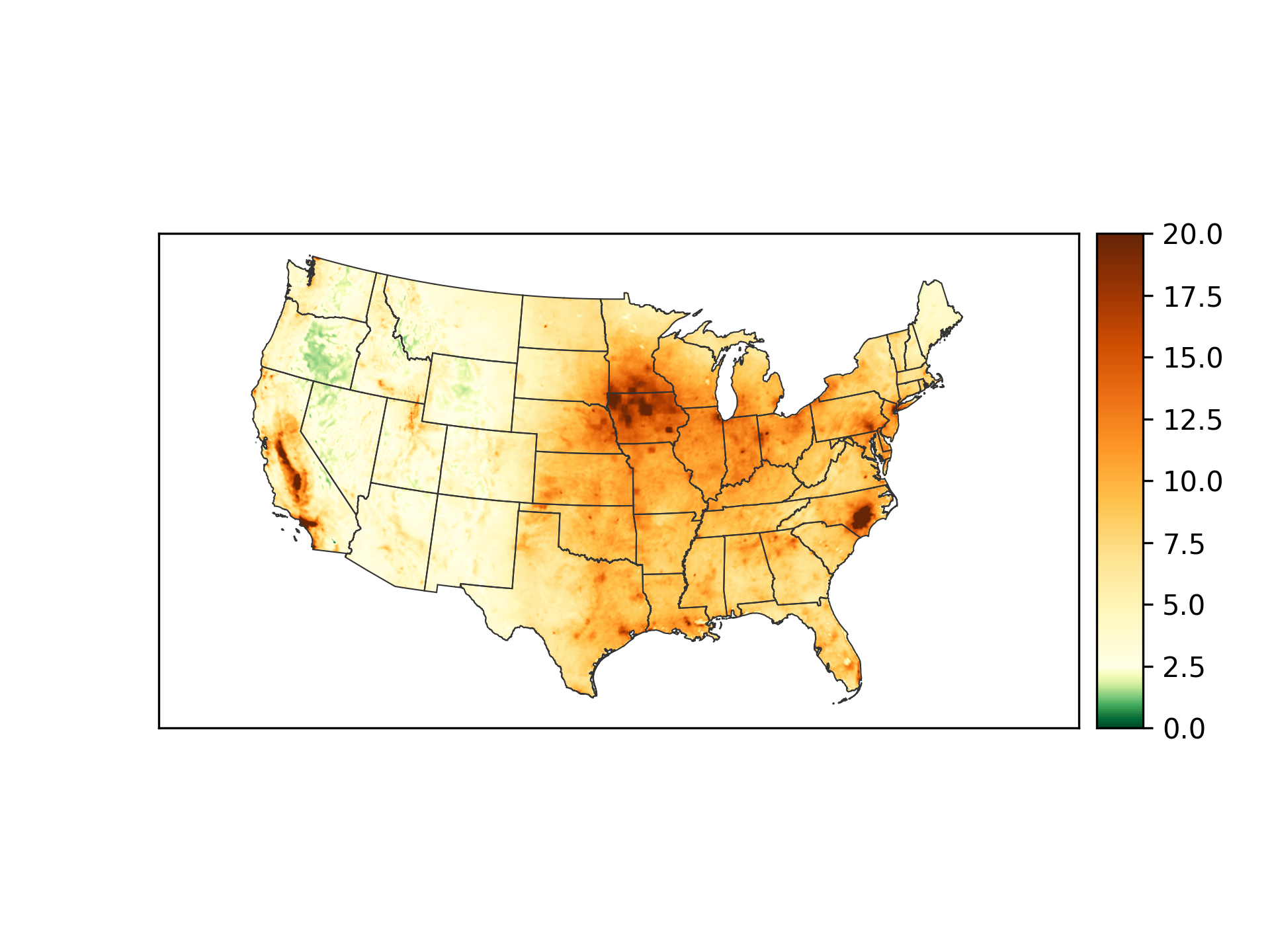
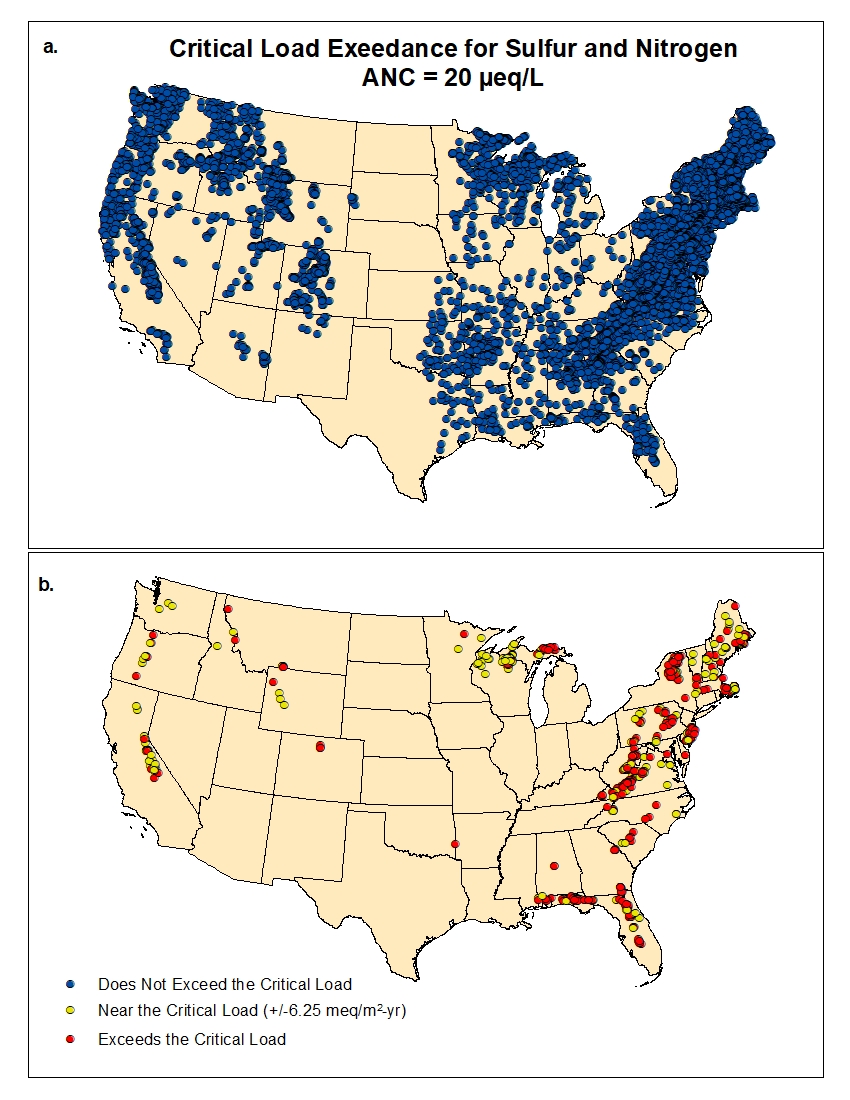


Figure 2‑6: Annual total deposition of nitrogen, kg N ha-1, annual totals averaged across 2014 -- 2016. The methods used to develop these deposition estimates are described in Appendix A.

* Appendix B: Aquatic Acidification
  + This appendix presents the national-scale analyses of Aquatic Acidification. These are based on CL exceedances under current (2014 – 2016) conditions.
    - The analyses focused on 4 levels of Acid Neutralizing Capacity (ANC): 20, 30, 50 and 80 μeq/L
    - These ANC levels are discussed in the Appendix and are consistent with other agencies
    - Jason is the lead for this appendix
  + Data and Analyses
    - CL data for Aquatic Acidification are from the National Critical Loads Database v 3.1 (Lynch et al. 2020)
    - Deposition estimates are from 2014 – 2016 Updated TDEP (Appendix A)
    - Exceedances for Aquatic Acidification CLs were calculated using only S and with N and S combined
    - Exceedances were summarized at the EcoRegion III level to assess the percent of waterbodies protected using thresholds or 50, 70 and 90%
  + Results
    - Exceedances occur in the eastern and western U.S., even at the least protective CLs (ANC = 20 μeq/L) when looking at S alone or N and S combined (Figure below is for N and S combined)
    - At the most protective CLs (ANC = 80 μeq/L), 15% of modelled waterbodies are exceeding nationally when looking only at S. That increases to as much as 38% when looking at N and S combined
    - At the EcoRegion level, at least 50% of waterbodies were protected except at the most protective level (ANC = 80 μeq/L). Even at the least protective level (ANC = 20 μeq/L), less than 70% of waterbodies were protected in one EcoRegion.
  + Quality Assurance/Control
    - The NCLD is maintained by..
    - Updated TDEP is described in Appendix A
    - Exceedance calculations were..
* 
* Figure B-15. Critical load exceedance for S and N deposition from 2014-16 for an ANC threshold of 20 μeq/L. The contribution of N deposition to acidification is based on method A, the short-term leaching of nitrate to waters. a. Waterbodies (blue) where the total S deposition is not above the CL of <-3.125 meq/m2-yr. b. Waterbodies (red) where total sulfur is above the CL of >3.125 meq/m2-yr). Waterbodies (yellow) between -3.125 and 3.125 meq/m2-yr are near the CL and based on the CL uncertainty cannot be determine if they exceed or not.
* Appendix C: Tree Growth and Survival
  + This appendix presents the national scale analyses of tree growth and survival reductions related to N and S based under current (2014 – 2016) conditions
    - Analyses were focus on 4 endpoints, growth and survival for N and S
  + Data and Analyses
    - The response functions are from Horn et al. (2018) and include 94 tree species
    - Calculations were done at the individual tree level based on Forest Inventory Analysis (FIA) plot level data
    - Response were calculated as the relative to “Point A”, meaning that responses for N could be positive or negative
    - Analyses used thresholds of 0%, 1%, 2%, 3%, 4%, and 5% for survival effects and 0%, 5%, 7%, and 10% for growth
  + Results
    - There were N effects on growth across the U.S. with some more than a 10% reduction
    - There were N effects on survival, with some more than a 5% reduction
    - S effects were more widespread and larger in magnitude.
    - Over 50% of trees had some effect (>0%) on growth and survival from S
    - 20% of trees had more than a 10% reduction in growth from S
    - 9% of trees had more than a 5% reduction in survival from S
  + Quality Assurance/Control
    - Data from Horn et al. (2018)…
    - FIA Data is maintained by the U.S Forest Service…
    - Growth and Survival response calculations ….

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Reduction | % of trees | Number of FIA trees | Number of U.S. trees (billions) |
| Survival | <0% | 18.05 | 476438 | 17.03 |
| <-1% | 9.82 | 259074 | 9.42 |
| <-2% | 5.85 | 154322 | 5.59 |
| <-3% | 3.62 | 95404 | 3.50 |
| <-4% | 2.46 | 64913 | 2.40 |
| <-5% | 1.83 | 48386 | 1.83 |
| Growth | <0% | 6.84 | 180537 | 7.49 |
| <-5% | 4.85 | 128113 | 4.87 |
| <-7% | 4.14 | 109161 | 4.23 |
| <-10% | 2.97 | 78434 | 2.95 |

Table C5. The percent and number of trees in FIA plots and across the lower 48 states experiencing various levels of reduction for survival or growth from 2014-16 average N deposition. Also shown is the estimated total number of trees in the U.S. based on the randomized design of the FIA.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Reduction | % of trees | Number of FIA trees | Number of U.S. trees (billions) |
| Survival | <0% | 56.55 | 1,492,171 | 55.61 |
|  | <-1% | 24.42 | 644,343 | 23.80 |
|  | <-2% | 17.02 | 449,030 | 16.91 |
|  | <-3% | 13.80 | 364,097 | 13.82 |
|  | <-4% | 11.23 | 296,242 | 11.46 |
|  | <-5% | 8.62 | 227,388 | 8.96 |
| Growth | <0% | 52.45 | 1,384,068 | 50.16 |
|  | <-5% | 33.21 | 876,302 | 31.1 |
|  | <-7% | 27.79 | 733,388 | 25.8 |
|  | <-10% | 19.78 | 521,942 | 18.1 |

Table C6. The percent and number of trees in FIA plots and across the lower 48 states experiencing various levels of reduction for survival or growth from S deposition.

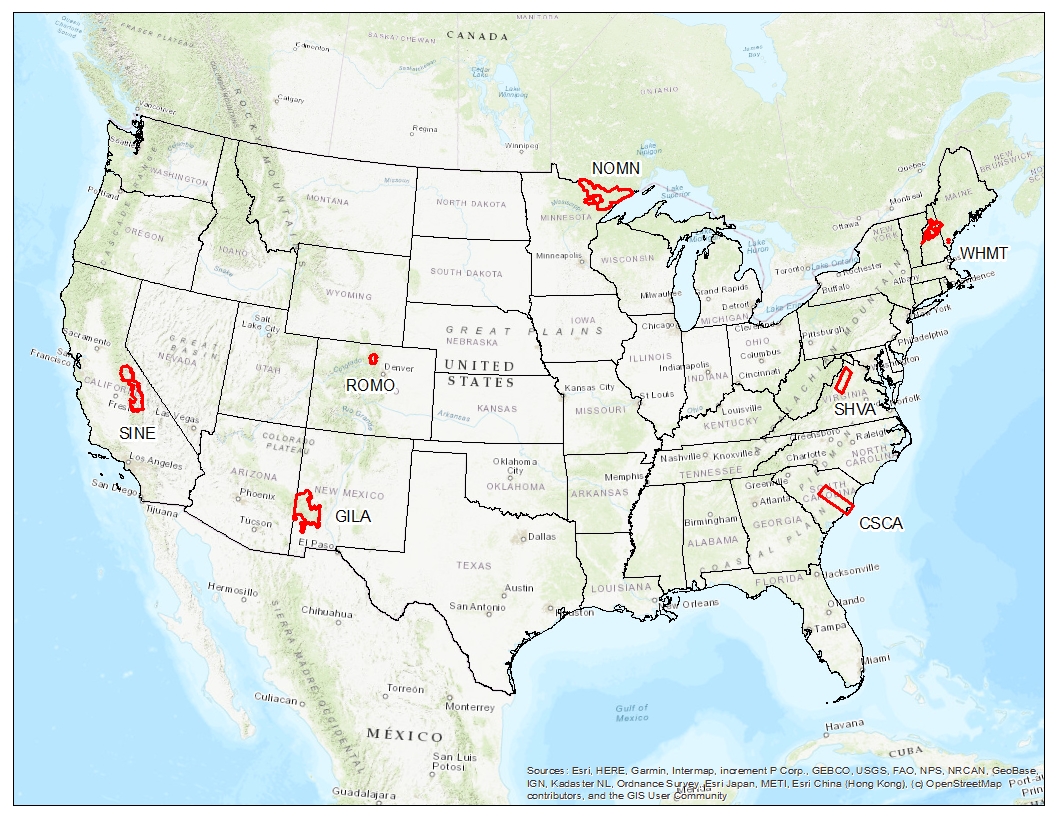
* Appendix D: Terrestrial N Enrichment
  + This appendix presents the national-scale analyses of Terrestrial N Enrichment. These are based on CL exceedances under current (2014 – 2016) conditions
    - The primary endpoints for these analyses are changes in herb and shrub biodiversity and shifts in lichen community composition
    - Travis is the lead for this appendix
  + Data and Analyses
    - Exceedance calculations for Herb and shrub CLs
    - CL data for herbs and shrubs and lichens are from the National Critical Loads Database v 3.1 (Lynch et al. 2020)
    - Deposition estimates are from 2014 – 2016 Updated TDEP (Appendix A)
  + Results
    - There were no herb and shrub exceedances in the western U.S
    - Widespread herb and shrub exceedances in the eastern U.S., especially in open-canopy areas
    - Widespread lichen exceedances in the western U.S.
    - Two areas with high levels of exceedances are related to very high N deposition that is related to NH3.
    - There is uncertainty associated with comparing TDEP estimates of N deposition to CLs developed using different methods of estimating N deposition (e.g. CMAQ), but we could not address that well at a national scale. We did assess that uncertainty in the case study areas.
  + Quality Assurance/Control
    - The NCLD is maintained by…
    - Updated TDEP is described in Appendix A
    - Exceedance calculations are …

Table D-1. Summary of herb and shrub exceedances. Two different levels of exceedance are included, exceedance > 0 kg N/ha/yr and > 5 kg N/ha/yr to illustrate the magnitude of potential impacts.

|  |  |  |  |
| --- | --- | --- | --- |
| **Canopy Type** | **Sites** | **Percent of sites exceeding** | |
| **> 0 kg N/ha/yr** | **> 5 kg N/ha/yr** |
| Open | 3317 | 28% (928) | 9% (306) |
| Closed | 11820 | 4% (461) | 1% (57) |

Table D-2. Proportion of lichen grid cells exceeding CLs. Two different levels of exceedance are included, exceedance > 0 kg N/ha/yr and > 5 kg N/ha/yr to illustrate the magnitude of potential impacts.

|  |  |  |  |
| --- | --- | --- | --- |
| **Omernik Ecoregion I** | **Grids** | **Percent of Cells Exceeding** | |
| **> 0 kg N/ha/yr** | **> 5 kg N/ha/yr** |
| Marine West Coast Forest | 5288 | 49% | 3% |
| Mediterranean California | 9451 | 85% | 38% |
| North American Deserts | 766 | 21% | 3% |
| Northwestern Forested Mountains | 51543 | 45% | 1% |
| Southern Semi-Arid Highlands | 27 | 7% | 0% |
| Temperate Sierras | 6471 | 35% | 0% |

* Appendix E: Class I Area Summary
  + This appendix summarizes the results of Appendices A – D at the Federal Class I area level. This was intended to help inform the PA regarding the adequacy of the current standards.
    - 167 Class I areas were analyzed
    - Justin is the lead for this appendix
  + Data and Analyses
    - Ecological effects were taken from the analyses in Appendices B - D
    - AQ information was taken from the analyses in Appendix A
  + Results
    - 34 areas had some level of Aquatic Acidification exceedances
    - 45 areas had >5% reduction in growth due to N
    - 37 areas had >1% reduction in survival due to N
    - 117 areas had >5% reduction in growth due to S
    - 113 areas had >1% reduction in survival due to S
    - Very few CL exceedances for Herb and Shrub species richness (only occurred in 23 areas)
    - 59 areas had CL exceedances for lichen community composition
  + Quality Assurance/Control
* Appendix F: Case Study Summary
  + This appendix summarizes the case study results that are presented in full in the Sub-Appendices. The methods are described in this appendix, along with case study specific analyses and the development of the AQ scenarios
    - Based on Appendices A – E, potential impacts occurred across the country for all 3 endpoints (Aquatic Acidification, Tree Growth and Survival, and Terrestrial N enrichment), including significant potential impacts in Class I areas
    - The AQ analyses determined that the PM2.5 standard was the controlling standard, therefore AQ scenarios were developed for the current secondary standard (15 µg/m3), current primary standard (12 µg/m3), and one alternate level (10 µg/m3)
  + Selection of Case Study areas
    - 7 case study areas were selected based on a set of 5 criteria related to data adequacy and representativeness for AQ and ecological effects
    - The areas are: Coastal South Carolina, Northern Minnesota, Shenandoah Valley Area, and White Mountain National Forest in the eastern U.S and Gila National Forest, Rocky Mountain National Park, and the Sierra Nevada Mountains in the western U.S.
      * AQ monitoring data and historical ambient AQ levels in upwind areas were the most stringent criteria
* 
* **Figure F-1**: Location of the case study areas. Coastal South Carolina (CSCA), Gila National Forest (GILA), Northern Minnesota (NOMN), Rocky Mountain National Park (ROMO), Shenandoah Valley (SHVA), Sierra Nevada Mountains (SINE) and White Mountain National Forest (WHMT).
  + Data and Analyses
    - Development of AQ scenarios is described here and presented more fully in Sub-Appendix FB
    - Potential risk in the form of exceedances and reductions in growth and survival were calculated in each area using the AQ scenarios described in Sub-Appendix FB
    - This Appendix summarizes the Sub-Appendices where methods generally followed those laid out in Appendices B, C, and D with specific steps outlined in the Sub-Appendices below
  + Results
    - Aquatic acidification
      * No data for GILA but the area is not considered sensitive
      * 1 site for CSCA, so it was not included but the area is considered sensitive
      * 15 µg/m3: Widespread exceedances, even at ANC = 20 (>30% of sites exceeding in WHMT and SHVA regardless of method)
      * 12 µg/m3: WHMT still has >30% exceedance at ANC = 20, other areas have >20% exceedance at ANC = 50
      * 10 µg/m3: Exceedances at ANC = 20 are <10%, ROMO and WHMT have exceedances >20% at ANC = 50, and all areas except NOMN have significant exceedances when using ANC = 80
    - Tree Growth and Survival
      * Only WHMT and ROMO have N-growth effects. In WHMT, the % of trees exceeding varying thresholds decreases across AQ scenarios, especially at the highest impact levels (>15% and >20% reductions)
      * N-survival impacts are generally small, with only CSCA and SHVA having >10% of trees impacted. The % of trees in CSCA does not change significantly, but the % of trees in SHVA does decrease across AQ scenarios
      * All areas have S-growth effects. With the exception of GILA the % of trees decreases across AQ scenarios. The decrease from 15 µg/m3 to 12 µg/m3 is generally larger than from 12 µg/m3 to 10 µg/m3, but not always
      * S-survival effects also occur in all areas, with high % or trees exceeding all thresholds. In GILA and NOMN the % of trees does not decrease significantly across AQ scenarios. In CSCA, SHVA, and SINE there is a significant decrease in the % of trees at the highest level of impact (>5%), between the 15 µg/m3 and 12 µg/m3 scenarios and a decrease in mid-level impacts (>3%) between the 12 µg/m3 and 10 µg/m3 scenarios. WHMT only has decreases in the % of trees between the 12 µg/m3 and 10 µg/m3 scenarios.

**Table F-21**: Summary of Trees likely to die from the combined effects of N and S. The results are presented as a percent of trees within the case study area. It is important to note that a small percentage can equate to millions of trees.

|  |  |  |  |
| --- | --- | --- | --- |
| Case Study Area | Percentage of trees likely to die | | |
|  | 10 µg | 12 µg | 15 µg |
| CSCA | 9% | 11% | 13% |
| GILA | 9% | 9% |  |
| NOMN | 13% | 14% |  |
| ROMO | 29% |  |  |
| SHVA | 6% | 6% | 8% |
| SINE | 20% | 20% | 20% |
| WHMT | 10% | 16% | 16% |

* + - Terrestrial N Enrichment
      * The main analyses used a scaled CL to account for the uncertainty related to comparing TDep estimates of deposition to CLs developed using different deposition estimates
      * WHMT and SHVA had closed-canopy exceedances under the 15 µg/m3 scenario, but these are reduced significantly under the 12 µg/m3 scenario and are 1% or less under the 10 µg/m3 scenario
      * CSCA and SHVA had open-canopy exceedances under the 15 µg/m3 scenario, but these are reduced significantly under the 12 µg/m3 scenario and are <1% under the 10 µg/m3 scenario in CSCA (Note that the 10 µg/m3 scenario in SHVA was the updated TDep, so in this case can’t be compared directly)

**Table F-23:** Summary of Terrestrial N effects in the case study areas. For areas with both open and closed herb and shrub sites, the percent exceeding scaled-CLs is listed as open/closed. For NOMN and WHMT, there were only closed-canopy sites. An asterisk indicates that at least one site was considered “At the CL” when accounting for uncertainty in the CL.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Case Study Area** | **CL Type** | **10 µg/m3** | **12 µg/m3** | **15 µg/m3** |
| CSCA | Herb and Shrub | 0%\*/0% | 36%/0% | 93%/0% |
| GILA | Lichen | 10% | 16% |  |
| NOMN | Herb and Shrub | NA/0% | NA/0% |  |
| ROMO | Lichen | 14% |  |  |
| SHVA | Herb and Shrub | 67%/1% | 48%/12% | 100%/60% |
| SINE | Lichen | <1% | <1% | 9% |
| WHMT | Herb and Shrub | NA/0% | NA/0%\* | NA/7% |

* + Quality Assurance/Control
    - AQ Scenario creation
    - Summary Tables
* Sub-Appendix FA: Case Study Area Descriptions
  + This Sub-Appendix is very descriptive presenting descriptions of the case study areas, with a focus on addressing the 5 selection criteria
    - These included: sufficient AQ monitoring, Historical AQ levels to allow analyses, sufficient ecological data (and potential impacts), representative of broad ecological areas, and representative of a range of AQ conditions nationally
    - Travis is the lead for this Sub-Appendix
  + Data
    - Federally designated areas included data for Class I areas, National Parks, National Forests
    - AQ monitoring sites are from…
    - Current conditions data for AQ and ecological endpoints were taken from Appendices A, B, C, and D
    - Historical AQ conditions come from XXX and TDEP
    - Ecological representativeness data came from the Forest Service for trees (Wilson et al. 2015), Omernik EcoRegions, and the National Land Cover Database (USGS)
    - AQ representativeness data are based on the updated TDep data from Appendix A
  + Results
    - The results are presented as a series of maps, descriptions, and tables for each criteria and case study area
  + Quality Assurance/Control
    - I don’t think this is applicable to this Sub-Appendix
* Sub-Appendix FB: Air Quality Scenarios
  + This Sub-Appendix describes the development of the AQ scenarios and the deposition within each case study area
    - Rob is the lead for this sub-appendix
  + Data and Analyses
    - Step 1: Define the are of influence for each case study area
    - Calculate the annual average PM2.5 for monitors within that area of influence
    - Identify the historical time period where the monitor with the highest annual average PM2.5 was at or near the scenario target
    - Estimate the N and S deposition for that time period using the corresponding TDep surfaces
  + Results
  + Quality Assurance/Control
* Sub-Appendix FC: Aquatic Acidification Case Study Results
  + This Sub-Appendix presents more in-depth details regarding the case study level analysis of Aquatic Acidification
    - Jason and Travis are the leads for this sub-appendix
  + Data and Analyses
    - Calculations followed the methodology described in Appendix B
  + Results
    - Main points are summarized in Appendix F
  + Quality Assurance/Control
* Sub-Appendix FD: Tree Growth and Survival Case Study Results
  + This Sub-Appendix presents more in-depth details regarding the case study level analysis of tree growth and survival effects
    - Travis is the lead for this Sub-Appendix (with notable contributions from Leigh before going on maternity leave!)
  + Data and Analyses
    - Calculations followed the methodology described in Appendix B
    - Tree level responses were calculated in each case study area for each AQ scenario
    - These responses were summarized using thresholds of 0%, 3%, and 5% for survival and 0%, 5%, 10%, 15%, and 20% for growth
    - This was repeated at the species level
    - For survival, we calculated the number and percent of trees likely to die across the case study area from the combined effects of N and S, with an additional analysis assessing whether the effect was influenced more by N or S
    - These analyses were repeated using only the most conservative response functions (XX species), excluding species responses with higher uncertainty
  + Results
    - Main points are summarized in Appendix F
  + Quality Assurance/Control
* Sub-Appendix FE: Terrestrial N Enrichment Case Study Results
  + This Sub-Appendix presents more in-depth details regarding the case study level analysis of Terrestrial N Enrichment effects
    - Travis is the lead for this Sub-Appendix
  + Data and Analyses
  + Results
    - Main points are summarized in Appendix F
  + Quality Assurance/Control

*REA Technical Appendices Status*

|  |  |  |
| --- | --- | --- |
| Appendix | Status | Anticipated Deadline |
| * Appendix A | Complete and in Group Leader (GL) Review | Ready for Group Leader Review: Done  Edits Complete:  Ready for Management Review: |
| * Appendix B | Complete and in Group Leader (GL) Review | Ready for Group Leader Review: Done  Edits Complete:  Ready for Management Review: |
| * Appendix C | Complete and in Group Leader (GL) Review | Ready for Group Leader Review: Done  Edits Complete:  Ready for Management Review: |
| * Appendix D | Complete and in Group Leader (GL) Review | Ready for Group Leader Review: Done  Edits Complete:  Ready for Management Review: |
| * Appendix E | Complete and in Group Leader (GL) Review | Ready for Group Leader Review: Done  Edits Complete:  Ready for Management Review: |
| * Appendix F | Complete and in Group Leader (GL) Review | Ready for Group Leader Review: Done  Edits Complete:  Ready for Management Review: |
| * Sub-Appendix FA | Pending final editing/completion (lowest tier priority) | Ready for Group Leader Review:  Edits Complete:  Ready for Management Review: |
| * Sub-Appendix FB | Pending final editing/completion (lowest tier priority) | Ready for Group Leader Review:  Edits Complete:  Ready for Management Review: |
| * Sub-Appendix FC | Pending Final Editing (Next priority) | Ready for Group Leader Review:  Edits Complete:  Ready for Management Review: |
| * Sub-Appendix FD | Pending Final Editing (Next priority) | Ready for Group Leader Review:  Edits Complete:  Ready for Management Review: |
| * Sub-Appendix FE | Pending Final Editing (Next priority) | Ready for Group Leader Review:  Edits Complete:  Ready for Management Review: |