Development and release of the Air Quality Portal for Land Management Planning: The application and use of critical loads for management and policy decisions

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Claire O'Dea, Air Quality Specialist, US Forest Service

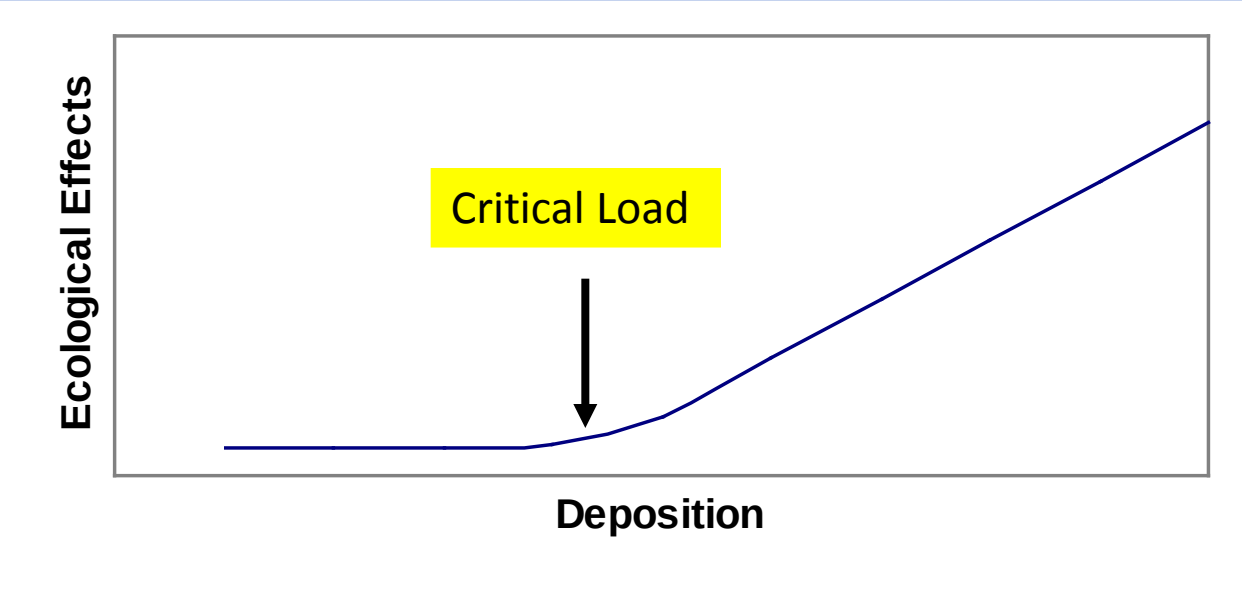
Background

- National Forest Management Act (NFMA) of 1976
- 2012 Forest Service Planning Rule
  - Revision from 1982
  - Requires air quality assessment
- Draft directives require National Forests to assess critical loads during Forest Plan Revision

Identify critical load exceedances for the plan area. If critical load exceedances occur on the plan area, assess the extent and severity of these exceedances.

Where critical loads of air pollution have been exceeded, develop plan components to help protect or restore key ecosystem characteristics within the plan area.

Critical load is the level of atmospheric deposition below which no harmful ecological effects occur for an ecosystem



Atmospheric Deposition Impacting Ecosystems

Acidification of soils and surface waters

Nitrogen Saturation/Eutrophication

*The Air Quality Portal is a decision support system that incorporates CLs into land management by helping managers determine **where** atmospheric deposition is negatively affecting ecosystems and **how** to start the process of mitigation and/or restoration based on this information.*

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Air Quality Portal for Land Management Planning

Welcome to the Air Quality Portal for Land Management Planning. To navigate around this Portal, hover over "Air" on the left column of the page. This will bring up a menu of pages related to the air quality assessment for forest planning. Hovering over any of these menu items in blue text will bring up sub-menus, for example all of the pages developed to support a critical loads assessment.

This web portal is an easy-to-use resource to guide national forests through assessing and treating air quality land management planning. The portal hosts decision trees to guide components of the air quality assessment process, protocols/instructions for following the assessment process, spatial data for download or web viewing, sample specialist reports, briefing papers/communications tools, and training tools. Although anyone is welcome to use this portal to conduct a national forest air quality assessment for forest planning, the Forest Service **Air Resource Management** (ARM) program recommends that national forests contact their **Regional Air Program Manager** to locate the appropriate air quality specialist to conduct this assessment for forest plan revision.

The National Forest Management Act (NFMA) of 1976 requires every national forest or grassland managed by the Forest Service to develop and maintain a land management plan (also known as a forest plan). The process for the development and revision of the plans, along with the required content of plans, is outlined in the planning regulations, or Planning Rule. Individual forests and grasslands follow the direction of the Planning Rule to develop a land management plan specific to their unit. The first US Forest Service Planning Rule was completed in 1982; subsequent attempts to revise the 1982 Planning Rule have been overturned in court. The Forest Service released a revised Planning Rule early in 2012. The **2012 Planning Rule** was signed by the Under Secretary of Agriculture for Natural Resources and Environment, and published in the Federal Register on April 9, 2012. Implementation of the final Planning Rule began in May, 2012.

The 2012 Planning Rule requires national forests and grasslands to consider air quality when developing plan components, and to treat air resources similar to soil and water resources. Planning Rule directives provide further guidance on implementation of the final rule, specifically the evaluation of current conditions and the creation of land management plans. The Planning Rule **Directives** related to air quality are presented on this web portal, for reference. The Forest Service ARM program is taking the lead to develop a decision support system that will help Forests during forest plan Revision. We hope to standardize the way national forests view and manage air quality as a forest resource, by ensuring a nationally consistent air quality assessment methodology that incorporates the best available science and data and eases the burden on the forests during plan revision.

Currently, the Air Quality Portal hosts information on how to assess **critical loads of air pollution** for land management planning. In time, the portal will incorporate all aspects of air quality assessment for land management planning.

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Critical Loads - Background Information

Forest Service managers directly monitor and use models to measure or estimate the amount of atmospheric deposition occurring on National Forests and how this deposition is affecting forest resources. Long-term air quality and resource **monitoring** on and near national forests and **Class I areas** has helped establish air pollution trends and existing condition of the resources. Based on these existing conditions, and documented cause and effect relationships, Forest Service Air Specialists and partners have begun to identify critical loads and target loads.

The critical load (CL) is defined as "the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment are not expected to occur according to present knowledge" **(Figure 1)**. The critical load is scientifically determined based on expected ecosystem response to a given deposition level. When critical loads are exceeded, the environmental effects can extend over great distances. Projected emissions of both sulfur and nitrogen compounds are expected to have continuing negative impacts on forests, and to present serious long-term threats to forest health and productivity in the US, despite decreased sulfur emissions as a result of SO_2 abatement legislation. Critical loads can be used to determine the level of deposition expected to cause harmful ecological effects. Target loads are based on critical loads, but can include consideration of the timeframe needed to achieve a desired ecosystem condition as well as incorporating policy or management goals; depending on whether or not current critical loads values have been exceeded, a target load can be above or below the critical load. Defining the critical and target loads for a forest helps resource managers communicate the effects of air pollution on resources to Forest Service decision-makers as well as to **air regulators**. This information will also be used to assess how some management activities may exacerbate air pollution related problems or identify areas where mitigation may be an option for resources that have already been negatively affected (see **Management Strategy**). This information can be used in a regulatory context when consulting with and advising air regulatory agencies on effects to forest resources resulting from new and existing sources of air pollution.

This web page provides information on:

1. The **CLs concept**, and the use of multiple CLs
2. The approaches for calculating CLs

Information on atmospheric deposition, and negative ecological effects associated with deposition levels in exceedance of critical loads (acidification and nitrogen saturation/eutrophication), can be found by **clicking here**. The critical loads section of the portal also hosts a **glossary** and **frequently asked questions**.

Critical Loads - Atmospheric Deposition

Fossil fuel burning emits air pollution in the form of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), while agricultural activities are the primary source of ammonia (NH_3) released to the atmosphere. These emissions lead to the atmospheric deposition of sulfuric acids, nitric acids, and ammonium to ecosystems.

1. In sensitive ecosystems, these acid compounds can **acidify** soil and surface waters, affecting nutrient cycling and impacting the ecosystem services provided by forests. Underlying geologic parent material can make some ecosystems resilient to the effects of acidification.
2. In ecosystems resilient to the effects of acidification, nitrogen deposition can lead to chemical and biological changes through "**nitrogen saturation**," which also results in impacts to forest ecosystem services. The effects of N enrichment/eutrophication are generally more important than soil acidification in most areas of the Western US because of the higher amount of N deposition relative to S deposition.
3. Toxic air contaminants like mercury, are emitted primarily by coal-fired utilities, and may be carried thousands of miles before entering lakes and streams as **mercury deposition**. Sulfate affects conversion of mercury into biologically available methylmercury, which is one of the reasons mercury deposition is included in this discussion.

Sulfate is the primary pollutant of concern in the much of the eastern U.S. with the highest levels of emissions coming from the heavily industrialized Ohio River Valley. In spite of recent reductions across the eastern U.S., sulfate deposition is still higher than the ecosystems of the Appalachian states can tolerate. Nitrogen deposition is the primary concern in the mid and western United States.

Atmospheric deposition occurs as wet deposition (rain and snow), dry deposition (gases and particles), and cloud and fog deposition. Wet deposition forms when NO_x and SO_2 are converted to nitric acid (HNO_3) and sulfuric acid (H_2SO_4), or when ammonia is converted into ammonium. Dry deposition can be converted into acids when deposited chemicals meet water **(Figure 1)**. The amount of deposition received in a given area is affected both by the concentration of pollution in the atmosphere and the way in which it is deposited. General factors such as climate, meteorology, and topography influence how much pollution reaches the area from both local and distant sources, as well as how much of that pollution actually impacts the earth's surface via the various wet and dry forms of deposition.

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Critical Loads - Glossary

Acidifying deposition: Deposition of substances from the atmosphere as rain, snow, fog, or dry particles that have the potential to acidify the receptor medium, such as soil or surface waters. Emissions of sulfur and nitrogen oxides and ammonia are the most common sources of acidifying air pollutants.

Acid Neutralizing Capacity (ANC): A measure of the ability of a solution to neutralize inputs of strong acids, commonly applied to surface water or soil solution.

Air Quality Related Values (AQRV): A resource, as identified by the federal land manager (FLM) for one or more Federal areas, which may be adversely affected by a change in air quality. The resource may include visibility or a specific scenic, cultural, physical, biological, ecological, or recreational resource identified by the FLM for a particular area. "These values include visibility and those scenic, cultural, biological, and recreation resources of an area that are affected by air quality" (43 Fed. Reg. 15016).

Air regulator: State and federal officials charged with implementing the Clean Air Act and protecting air quality.

Atmospheric deposition: The transfer of air pollutants from the atmosphere to the Earth's surface. Atmospheric deposition occurs as wet (e.g., rainfall, fog, or snow) and dry deposition (e.g., gaseous or particulate deposition).

Base cations: Base cations are elements or ions with a positive charge (cations) that can neutralize acids. Calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}) are base cations; these base cations also serve as nutrients for forest ecosystems.

Base saturation (BS): Base saturation is a way of measuring the base cations are available to plants. Base saturation is given as the percentage of potential cation exchange sites that actually have exchangeable base cations on them. It is expressed as a percentage of the total cation exchange capacity. The higher the amount of exchangeable base cations in soil, the more acidity can be neutralized.

Bioaccumulation: The increase in concentration of a contaminant in an individual organism relative to the surrounding environment or medium (e.g., water, sediment).

Biomagnification: The increase in concentration of a contaminant from lower trophic levels to higher trophic levels in the food chain.

Critical load (CL): The quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. Critical loads and target loads can be calculated for different inputs: acidity (N and S combined), S, N, or N nutrient (to address detrimental

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Critical Loads - Frequently Asked Questions

Question: What should I do if my Forest is located in an area with incomplete or unavailable national critical loads data (e.g., Alaska, Puerto Rico, arid SW)?

Response*:* The Air Quality Portal for Land Management Planning does not host critical load and critical load exceedance information for Alaska or Puerto Rico, due to an absence of modeled deposition estimates across the landscape. The "**National_Critical_Load_Exceedances.mxd**" map has a "Monitoring Locations" layer that provides the locations of deposition monitors in Alaska and Puerto Rico. Even if deposition has not been modeled for your area, measured data can be used to calculate critical load exceedances. Review the attached **guidance document**, the **published regional CLs** for your region, and available **sample specialist reports** for neighboring forests to obtain relevant CL estimates for your forest. Empirical CLs for nutrient nitrogen might be available by following the methodology outlined in the **Empirical CLs for nutrient nitrogen user's guide**. Finally, if the above suggestions have been unsuccessful, consider contacting your **Air Program Regional Manager** for assistance tracking down additional information.

Question: Are critical loads and target loads set through the forest planning process compatible with **Federal Land Managers' Air Quality Related Values Work Group** (FLAG) and/or **FLM Interagency Guidance for Nitrogen and Sulfur Deposition Analyses** documents? Are we setting conflicting policy with the Chief's signature on the FLAG/DAT process? Or Does FLAG allow regional policy adjustments for deposition?

Response*:* The critical load implementation strategy located on the Air Quality Portal for Land Management Planning provides guidance for using critical loads, deposition, and exceedance information to help describe air pollution effects to natural resources. The strategy also provides for the use of different types of data (from the national critical load database or more localized critical load efforts) in the planning process. The strategy could be used to establish CLs specific to Class I areas, where none currently exist. There is nothing in the strategy that would limit the Federal Land Manager's ability to use critical loads that have been previously defined for Class I areas. The strategy includes a reminder that Forests should determine whether CLs have been calculated and used in Class I areas, and incorporate this information into their planning documents.

In addition, there is nothing in the FLAG and Interagency Deposition Analyses documents that conflicts with the critical load strategy developed to support land management planning. In fact, the 2010 FLAG guidance specifically includes a statement that "FLAG does not preclude more refined or regional analyses being performed under NEPA or other programs" (footnote on page ix of FLAG 2010).

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Critical Loads - Training Tools

Training webinars are being developed and will be added to this page when available

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Critical Loads - Spatial Data

This page hosts national published critical loads data sets (critical loads for the El Yunque National Forest in Puerto Rico, and the Chugach and Tongass National Forests in Alaska are not available as part of the spatial data hosted below – these National Forests should reference the "**User's Guide for Setting Empirical Critical Loads for Nutrient Nitrogen**"). These national GIS shapefiles contain CL exceedance calculations performed by the FS Air Program. When referencing this data, cite the relevant original references from the footnotes below and include the proper CLAD acknowledgment[1].

1. Nationwide CLs of acidity for surface waters[2]
2. Nationwide CLs of acidity for forested ecosystems[3], and
3. Nationwide empirical CLs of nutrient nitrogen[4] for ecosystem receptors and responses (fungi, lichens, herbaceous vegetation, forests, and nitrogen leaching)

Download this map to view and evaluate all of the above described CL exceedances, along with additional spatial data that might be useful during analysis (National Forest proclaimation boundaries, Class I and Class II Wilderness boundaries, 6th level hydrologic unit code (HUC) boundaries used in the FS Watershed Condition Framework, and NTN and CASTNet deposition monitoring stations). Follow these **instructions** to clip national data to your area of interest and run analyses recommended in the **Critical Loads Implementation Strategy**. JPG images of the national CL exceedances can be viewed and downloaded **here**.

The Portal hosts an explanation of the **multiple CLs concept** (how a given area can have multiple associated CLs), and how to **interpret multiple CLs simultaneously**. There is also a description of the different **approaches** for calculating CLs, including advantages and disadvantages associated with the different methods.

*Please reference the **Critical Load Exceedance Documentation for Nationwide CL Efforts** for documentation on how CL exceedances were calculated for the data hosted on the portal, as well as the **CL Exceedance Calculation Protocol** for instructions to calculate CL exceedances using site-specific CL or deposition information.

Critical Load Spatial Data

Critical load values can be downloaded directly from the Critical Loads of Atmospheric Deposition Science Committee (CLAD) **National Critical Loads Database**.

Atmospheric Deposition Spatial Data

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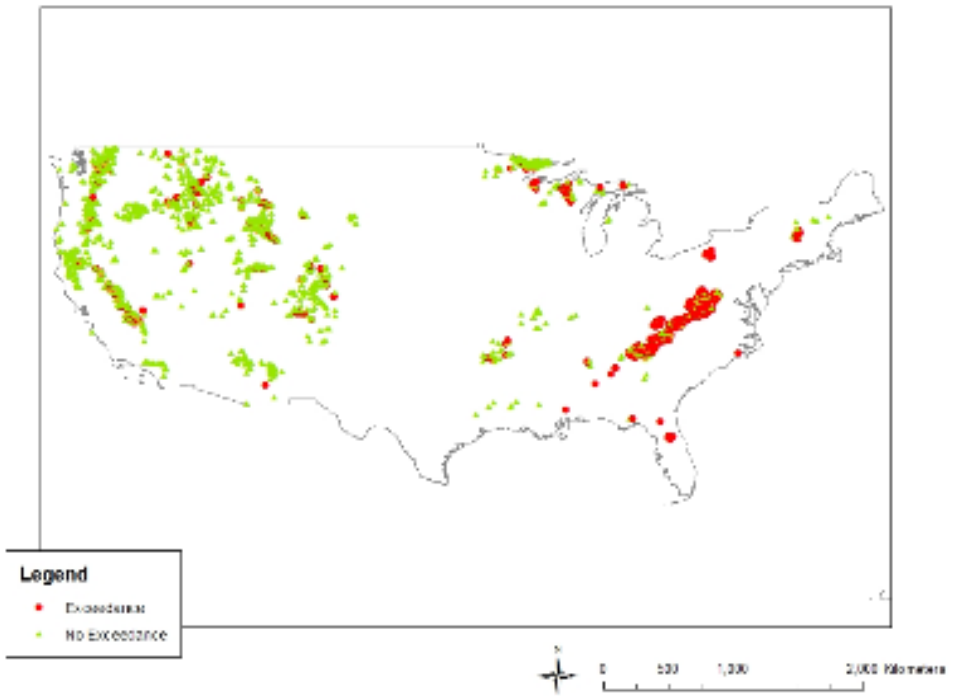
Critical Loads - Exceedance of Critical Loads of Acidity for Surface Waters on Forest Service Lands

Exceedance of Critical Loads of Acidity for Surface Waters on Forest Service Lands



Download the PDF

Exceedance Maps

- Exceedance of Critical Loads of Acidity for Surface Waters on Forest Service Lands
- Exceedance of Terrestrial Critical Loads of Acidity for Forested Ecosystems on Forest Service Lands
- Exceedance of Nutrient Nitrogen Critical Loads for Lichens on Forest Service Lands
- Exceedance of Nutrient Nitrogen Critical Loads for Mycorrhizal Fungi on Forest Service Lands
- Exceedance of Nutrient Nitrogen Critical Loads for Herbaceous Plants and Shrubs on Forest Service Lands
- Exceedance of Nutrient Nitrogen Critical Loads for Forests on Forest Service Lands
- Exceedance of Nutrient Nitrogen Critical Loads for Nitrate Leaching on Forest Service Lands

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Critical Loads - Implementation Strategy

A **critical load** (CL) is the level of atmospheric deposition below which no detrimental ecological effects occur over the long term, based on current scientific knowledge.

The Critical Loads section of the Air Quality Portal for Land Management Planning hosts information for the following **critical loads data sets**: 1) nationwide CLs of acidity for surface waters, 2) nationwide terrestrial CLs of acidity for forested ecosystems, and 3) nationwide empirical CLs of nutrient nitrogen for several ecosystem receptors and responses (fungi, lichens, herbaceous vegetation, forests, nitrate leaching). Information for **Alaska and Puerto Rico** are not available for the terrestrial CLs of acidity for forested ecosystems. The critical loads included in this strategy are thresholds for sulfur and nitrogen deposition. The Forest Service hopes to eventually incorporate critical levels for mercury and ozone deposition into this assessment process.

The portal also hosts information on **atmospheric deposition**. Nitrogen and sulfur deposition occur as wet deposition (rain and snow), dry deposition (gases and particles), and occult deposition (cloud and fog). Deposition information is measured and modeled from a variety of sources. The CL exceedances provided on the portal are based on the most recent **three-year average estimates** produced by the NADP Total Deposition Science Committee (TDEP) v2014.01 because these estimates incorporate both measured and modeled information. We are continuously working to refine nitrogen and sulfur deposition estimates, and will therefore accept exceedance calculations using more current regional deposition data sets, if available and appropriate. All deposition datasets must reflect total deposition (wet and dry) for CL exceedance calculation, because CLs are set as thresholds for total deposition, not wet or dry deposition on their own.

The CLs and deposition data are used together to determine areas of CL exceedance. Examining CL exceedance is a "risk assessment" to evaluate the risk of sulfur and/or nitrogen deposition causing harm to the resource/ecosystem of concern. Exceedance is calculated as:

Exceedance = Deposition – Critical Load

Step 1
Initial Critical Load Exceedance Screening
Step 2
Define Your Concern
Step 3
Examine Available Data
Step 4
Review the Critical Loads Available for the Forest
Step 5
ID the Appropriate Deposition Info to Compare CL & Calculate Exceedances
Step 6
Use CL Exceedance to Conduct a Closer Examination of Atmospheric Pollution Impacts
Step 7
Interpret the CL Exceedance Information
Download

STEP 1: Initial critical load exceedance screening.

In this step, exceedance calculations will be used as a screening tool to identify the extent of CL analyses that forests will need to include in forest plans.

The Critical Loads section of the Air Quality Portal for Land Management Planning hosts a "National Forest Exceedance Table" that documents critical load exceedances for each national forest. Locate your forest in the table to see whether any of the seven nationwide CLs are exceeded, and follow the instructions in the boxes below.

NOTE: TDEP is known to underestimate nitrogen deposition in certain situations (high elevations and complex terrain, as well as areas with high cloud and fog deposition, and areas in the arid south and west). If your forest is concerned about the underestimation of atmospheric deposition you may want to complete the critical loads assessment, even if you do not have a CL exceedance on the forest. The assessment will show how close deposition is to calculated critical loads (magnitude of non-exceedance) and recent trends in deposition, which can help the forest interpret the likelihood of exceedance if accurate deposition was available. This information could be used to support monitoring recommendations.

No exceedance of any CL

If there are missing values in the National Forest Exceedance Table for your forest, developing a monitoring strategy for collecting information to calculate these missing CLs would ensure that the potential impacts are not being overlooked.

If there is NO potential for CL exceedance on a forest, this finding should be documented and no further assessment is required. The Portal hosts a description of the National Forest Exceedance Table and documents the protocols used to create this table. This information can be incorporated into the Air Specialist Report for forest plan revision. Annual reports from the National Atmospheric Deposition Program (NADP) should be monitored for deposition trends. If deposition is increasing, CL exceedance should be reevaluated during the next forest plan revision.

One or more CLs exceeded

If a forest shows the potential for CL exceedance, proceed to Step 2.

STEP 2: Define your concern.

The negative effects of atmospheric deposition occur on sites that are sensitive to acidification or nitrogen saturation/eutrophication AND have excessive amounts of deposition. Decide whether to focus on acidification or nitrogen saturation/eutrophication, or both, in the following analysis.

Include all CLs that showed exceedance in Step 1.

Consider the ecosystem characteristics that indicate sensitivity to deposition, referring to the "Acidity" and "Nutrient Nitrogen" boxes, below. Interdisciplinary discussion with ecologists, geologists, hydrologists, soil scientists, fisheries biologists, air specialists, etc. can help identify whether one, both, or neither of these CL categories might be of concern to the forest. Results of these discussions can reduce the list of CLs you address in your analysis. (Later you will see how maps of CL exceedance can be used to identify areas at greater risk of harm from deposition.)

If investigation indicates a focus on empirical CLs of nutrient nitrogen, review the "User's Guide for setting empirical critical loads for nutrient nitrogen" for an explanation of how to refine the broad CL ranges provided for each forest and incorporate the concept of data reliability.

Proceed to Step 3 to identify the types of data available for the assessment.

Does your forest have any of the characteristics of ecosystem sensitivity?

Acidity

- Is there elevated deposition of sulfur or nitrogen in the area?
- Does the lithology/geology of the area have a low buffering capacity for acidity?
- Does the area have shallow soils?
- Does the area have very old weathered soils?
- Is the area found at high elevation?
- Do you have water chemistry data that indicates low buffering capacity (i.e. ANC, pH values)

Nutrient Nitrogen

- Is there elevated deposition of nitrogen in the system?
- Did the area historically have low nitrogen deposition?
- Have there been observed shifts in species composition of sensitive species in the area?
- Are there elevated stream water nitrate concentrations?

STEP 3: Examine available data.

Before beginning your assessment of critical load exceedances, take stock of all available data. Most forests will use the nationwide CL exceedance information provided on the Air Quality Portal because this is the best information available. Some forests will have access to refined CLs and/or deposition data; this data should be used when available to reduce uncertainty inherent in nationwide efforts. If you are not aware of ongoing regional efforts to refine CLs or deposition information, please consult the list of published data sources, available on the portal. Once you have compiled all available data, follow the instructions in the boxes below.

Published regional/local data is available

If published regional/local CLs or regionally refined deposition estimates are available and preferable for use in this air quality assessment, proceed to Step 4 and Step 5 to create the exceedance maps you will use in Step 6.

Published regional/local data is not available

If regional/local CLs or deposition data are not available and you will be basing your analysis on the provided national data, proceed to Step 6.

STEP 4: Review the critical loads available for the forest.

The Critical Loads section of the Air Quality Portal for Land Management Planning hosts the following critical loads data sets: 1) nationwide CLs of acidity for surface waters, 2) nationwide CLs of acidity for forested ecosystems, and 3) nationwide empirical CLs of nutrient nitrogen for several ecosystem receptors and responses. Only published critical loads are used in this process. If more site-specific CLs are available for your forest, determine whether they provide better information for the assessment than the associated national CL effort. The Portal hosts a description of the different approaches for calculating CLs, including advantages and disadvantages associated with the different methods.

Important Concept: The degree of uncertainty associated with the different critical loads calculations will vary with environmental variability (i.e., the high degree of variability in soils) and the method of critical load calculation (i.e., the use of site-specific data versus extrapolated/modeled data). Step 6 incorporates uncertainty and reliability into future recommendations.

After you have assembled all available published CLs for your forest, proceed to Step 5 where you will identify the best deposition data to use in your analysis, and calculate exceedances.

STEP 5: Identify the appropriate deposition information to compare with critical loads and calculate exceedances.

To understand the threat of negative effects of deposition to your forest you must compare the CLs from Step 4 with current levels of total deposition (wet +dry). Deposition information is measured and modeled from a variety of sources. Absent specific rationale to the contrary, we recommend using the 3-year average TDEP deposition data provided on the portal to maintain nationwide consistency. Regionally-refined deposition models that have documented QA/QC methods can be substituted where appropriate. In addition, you can analyze recent trends in deposition to assess the accuracy of the deposition data used to calculate CL exceedances.

After the appropriate deposition has been selected, exceedance is calculated using the following equation:

$$\text{Exceedence} = \text{Deposition} - \text{Critical Load}$$

Instructions for calculating CL exceedances are available on the portal.

You now have critical loads and critical load exceedance values specific to your forest or region.

Proceed to Step 6 for guidance on examining and interpreting exceedance information.

STEP 6: Use CL exceedance to conduct a closer examination of atmospheric pollution impacts.

In this step you will examine CL exceedance patterns across the forest to better understand the extent and severity of potential impacts to resources, as well as the reliability of the CLs exceedance information. CL exceedance data for each of the nationwide CL efforts are hosted on the portal. If you have used site-specific data to create refined exceedance information, we recommended using that data to examine the extent, severity, and reliability of CL exceedance. For each type of CL identified in Steps 1 through 5, examine the extent, severity, and reliability of the exceedances. "Extent" refers to the percent of landscape in exceedance, while "severity" refers to the amount/quantity of exceedance. For example, one forest may exhibit exceedance in only 1% of land area while another forest exhibits exceedance in 75% of land area (extent); deposition in one forest may be only slightly above the CL while deposition in another forest may exceed the CL by a large amount (severity). Reliability is an expression of the certainty of the CL and exceedance estimates. Understanding the extent, severity, and reliability of exceedance on your forest can help you interpret patterns and make appropriate management recommendations.

Spatial representation of CL exceedance information is provided on the portal for the three nationwide CLs efforts. The portal also hosts important Forest Service boundaries including national forest, Class I Area, wilderness area, 6th level HUC, and landscape-scale analysis units, so that exceedance information can be examined by unit for management purposes. Special attention should be given to national forest and Class I boundaries.

Detailed instructions on assessing these CL exceedance metrics are available on the portal. A tabular description and example of this analysis is shown below.

Exceedance Metrics	Critical Loads			
	Acidity: Surface Waters	Acidity: Forested Ecosystems	Nutrient N: lichens	Nutrient N: others
Extent	Number of Streams/ Lakes exceeding CL and Number of Streams/ Lakes sampled	% of land exceeding CL	% of land exceeding CL	% of land exceeding CL
Severity – Range of exceedance amount	Minimum & Maximum Exceedance Values (meq/m^2/yr)	Minimum & Maximum Exceedance Values (eq/ha/yr)	Minimum & Maximum Exceedance Values (kg/ha/yr)	Minimum & Maximum Exceedance Values (kg/ha/yr)
Severity - 95% exceedance value	95% of sites exceed by X meq/m^2/yr (only relevant when number of data points > 25)	95% of grid cells exceed CL by X eq/ha/yr	95% of grid cells exceed CL by X kg/ha/yr	95% of grid cells exceed CL by X kg/ha/yr
Reliability	High	Low	High	Variable*

**The variable reliability rating for the empirical CLs of nutrient nitrogen (non-lichens) will be important when interpreting exceedance information and making management recommendations in Step 7.*

Complete this analysis and proceed to Step 7 for guidance on interpreting exceedance information.

STEP 7: Interpret the CL exceedance information.

Interpretation of CL exceedance must consider the type of CL (empirical vs. modeled), the site specificity of the data used in calculating the CL, and the quality of the deposition estimates. Management recommendations will vary with the reliability or certainty of the CL exceedance estimates.

For example, the CLs of acidity for surface waters provided on the portal are based on water chemistry measurements from specific sample sites and have a high level of reliability. Coupled with modeled-deposition information, CL exceedances for surface water have one of the higher levels of certainty which allows land managers to develop target loads. Target loads represent a policy or management decision about the amount of deposition that is an acceptable level of resource protection, and will be discussed further in the Target Load Strategy). On the other hand, the terrestrial CLs of acidity for forested ecosystems are created from geospatially extrapolated information that is acceptable for understanding risk across the landscape, but does not have the adequate site specificity necessary to make management recommendations. Exceedance of the CLs of acidity for forested ecosystems should therefore only be used for creating a monitoring plan to gather site-specific data.

You should now have a list of CLs that represent forest resources of concern, as well as information on the relationship between deposition and the CL (the CL exceedance). Your exceedance information may have changed as you refined your analyses (through investigation of exceedance metrics, empirical N CL guidance, or the use of local/regional CLs and deposition information). Review all CL exceedance information and decide whether the extent and severity of the CL exceedances indicate a potential for harm to the forest:

- *If the CL exceedance information suggests that the area is at low risk of any detrimental effects from S and/or N, conduct a deposition trend analysis to determine whether deposition has increased or decreased in recent years.*
  - *If the recent deposition trend is decreasing, continue to monitor NADP reports for deposition trends in the future. If deposition starts to increase, address possible needs for field measurements (e.g., water chemistry) in the next planning cycle and review the "Monitoring Strategy" in the Critical Loads section of the Air Quality Portal.*
  - *If the recent deposition trend is increasing, your exceedance metrics are likely underestimating the risk of detrimental effects. In this situation it is recommended that you proceed as though there is a higher risk of detrimental effects and implement instructions in the boxes below.*
- *If the CL exceedance information suggests a risk that the area is experiencing detrimental effects from S and N, implement instructions in the boxes below according to the type of CL used.*
- *If multiple CLs are in exceedance and indicate a risk of detrimental effects, review the "Interpreting Multiple CL Exceedances Protocol" and implement instructions in the boxes below.*

Surface Water CLs AND Reliable Empirical Nutrient N CLs (including lichen results from Mediterranean CA, PNW, Sierras) AND Appropriate Regional CL Efforts

Nationwide surface water CLs and reliable empirical nutrient N CLs (as determined in Step 2) have lower associated uncertainty because they were calculated with site-specific/locally relevant data. In addition, you may have access to regional CL results based on site-specific data.

Deposition ≥ CL : CL is exceeded, ecosystem is currently impacted, or likely to be in the future.
Action: IDENTIFY a TARGET LOAD to protect or restore key components of the ecosystem per FS Directives. Go to the "Target Load Strategy."

Critical Loads of Acidity for Forested Ecosystems AND Other Empirical Nutrient N CLs

These CLs were developed to assess regional differences in exceedance, not for land management decision-making. They should be used to guide further monitoring and/or research experiments in areas of predicted exceedance.

Deposition ≥ CL : CL exceedance is possible.
Action: Create a plan for collecting site-specific water chemistry, soil chemistry, and/or lichens as appropriate to refine analysis and confirm exceedance predictions. For other empirical nutrient N CLs you may want to work with FS research scientists to develop an N experiment or gradient study that will improve reliability of the CLs. Go to the "Monitoring Strategy."

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Critical Loads - Target Load Strategy

You have been directed to this Target Load Strategy because one or more critical loads have been exceeded on your forest. This Strategy will guide you through a process to develop target loads (TL) for incorporation into the forest plan, the final step in the critical loads (CL) assessment. Review all critical loads, deposition, and exceedance information developed under the **CL Implementation Strategy** before proceeding.

Critical loads are "quantitative estimates of exposure to one or more pollutants, below which significant harmful effects on specific sensitive elements (receptors) of the environment do not occur, according to present knowledge." Describing air pollution effects on ecosystems in terms of critical loads allows communication of this complex science to a broader audience. The effects of sulfur and nitrogen deposition most often considered are acidification of surface waters or forested ecosystems, or nutrient nitrogen enrichment impacting various receptors (e.g., diatoms, lichens, mycorrhizal fungi, herbaceous vegetation, and forests). Because receptors have varying sensitivities to air pollutant loads, multiple critical loads can be used to describe a **continuum of impacts** related to increasing deposition at a given location.

When deposition exceeds the CL, there is increased risk for negative ecosystem effects including changes in aquatic biota, decline in forest health, and changes in biodiversity. In Step 7 of the CL Strategy, areas where current deposition exceeds CLs were identified. CLs for these areas will now be used to develop target loads.

A target load (TL) is a level of deposition set by policy makers to meet their objectives; for natural resources managers, the objective might be to protect sensitive ecosystem components. The TL may be higher or lower than the CL based on the desired level of resource protection, economic considerations, "the life of the forest plan," and stakeholder input. Whereas the CL is a science-based threshold describing the amount of deposition an ecosystem can tolerate over the long term, the TL is a policy-based threshold that incorporates the concept of time (for example, the time required for a damaged ecosystem to recover if the total deposition does not exceed a specific load). Management should be engaged in the process of setting target loads, especially when determining the level of protection desired for key sensitive receptors and the timeline for achieving this protection.

Step 1
- Review Available CL Exceedances to Determine how to Set Target Load

Step 2
- Conduct Dynamic Modeling to Develop an Array of Target Loads

Step 3
- Line Officers Select a Target Deposition Load that Results in Acceptable Resource Protection

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Critical Loads - Monitoring Strategy

During the process of conducting the critical loads (CLs) assessment for Land Management Planning, additional monitoring may be recommended to enable the calculation of specific types of CLs and CL exceedances, or to refine, and therefore improve, the reliability of the existing CLs and CL exceedances available for your forest. For example, you may find that:

- You have very few (or no) surface water chemistry samples and therefore no CLs of acidity for surface waters,
- The CLs for nutrient nitrogen or terrestrial acidification are not reliable enough to serve as the basis for land management decisions, and/or
- Better estimates of deposition are needed for your forest in order to calculate more reliable CL exceedance estimates.
- Forests in **Alaska and Puerto Rico** have limited CL exceedance information due to the lack of available geospatial deposition estimates and/or resource information.

All of these situations will require collection and analysis of site-specific information on resource condition and/or pollutant deposition. This Monitoring Strategy will help the forest identify and prioritize data collection and analysis needs in order to develop monitoring recommendations for the Plan with the intention of improving CL and CL exceedance estimates in future planning efforts.

The Monitoring Strategy is broken into three main parts:

1. The introduction table, below, helps users locate the appropriate monitoring response to issues from the steps in the Critical Load Implementation Strategy.
2. The first section focuses on **improving pollutant deposition estimates**.
3. The second section addresses how to improve critical load estimates and is presented in four parts:
   - **Improving Critical Loads – General Guidelines**,
   - **Monitoring Acidification Effects on Aquatic Ecosystems**,
   - **Monitoring Acidification Effects on Forested Ecosystems**, and

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Critical Loads - Management Strategy

Air pollution emitted from a variety of sources is deposited from the air into ecosystems. These pollutants may cause significant harmful ecosystem effects when exceeding a threshold, known as a critical load (CL). When a CL is exceeded, negative ecosystem effects are likely to occur, immediately or over time. Similarly, when deposition is reduced and exceedances eliminated, recovery occurs at different timescales. In some cases, improvements are unlikely even when deposition is eliminated; mitigation and restoration together might be necessary to enable ecosystem improvements. The **Clean Air Act** and the **Forest Service 2012 Planning Rule** require an understanding of the potential negative ecosystem effects of air pollution, as well as an understanding of how to preserve and protect ecosystem health in the face of these threats.

Air quality assessments are used to inform managers in national forests and grasslands about critical load exceedances within their boundaries, and to help them set target loads (TLs) when appropriate. This information can be used to communicate the risk of air pollution effects on various resources to Forest Service personnel, to the public, and to the air regulators who issue permits to air pollution sources. This document outlines some of the management options available to reduce critical load exceedances and mitigate the effect of air pollution on national forests and grasslands.

When discussing management alternatives with line officers seeking to minimize the ecosystem effects associated with air pollution, it is helpful to highlight the relationship between critical load exceedances and subsequent impacts to ecosystem services. Ecosystem services are defined as the benefits people obtain from ecosystems. Sullivan (**2012**) integrates the principles of ecosystem services with the use of critical loads for public land management and natural resource policy decision-making. Specifically, Sullivan suggests that a CL exceedance indicates an increased likelihood that there will be a loss of one or more ecosystem services. Examples of ecosystem services that can be affected by critical load exceedances are available in Fenn et al. (**2011**), summarized in **Table 1** and separated into potential acidification and nitrogen saturation impacts. Ecosystem services potentially affected by critical load exceedances in terrestrial ecosystems include decreased soil fertility leading to potential reductions in timber available for harvest. Similarly, aquatic ecosystems may exhibit decreased water quality causing reduced fish populations used for sustenance and recreation. The reductions in

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Critical Loads - Protocols

The following protocols and guidance documents are available on this page to provide additional instructions to end users of the Air Quality Portal.

- **Critical Loads Implementation Strategy**: This document outlines the process for calculating and assessing CLs and CL exceedances on a national forest.
- **Target Loads Strategy**: This document outlines the process for developing target loads on a national forest, when CL exceedances have been determined to be significant and reliable.
- **Monitoring Strategy**: This document outlines guidance specific to the resource and deposition data collection needs for improving CL estimates.
- **Management Strategy**: This document outlines some of the management options available to reduce critical load exceedances and mitigate the effect of air pollution on national forests.
- **National Forest Exceedance Table**: This table documents critical load exceedances occurring on every national forest and grassland on the continental U.S. For each type of national CL hosted on the Portal, if any part of the national forest or grassland exceeds the CL, the CL is considered to be in exceedance. Step 6 of the Critical Load Implementation Strategy guides examination of the extent and severity of this exceedance.
- **Critical Load Exceedance Calculation Protocol**: This document outlines the steps a user should follow when calculating their own CL exceedance values using CLs or deposition data not available in the Air Quality Portal.
- **ArcGIS Mapping Protocols**: This document outlines the protocols that should be followed to display and **map** the **CLs and CL exceedance data** provided on the Portal within ArcMap.
- **Critical Load Exceedance Metrics Protocol**: This document outlines guidelines for examining critical load exceedance patterns across a forest to understand the extent and severity of potential impacts to resources, including the reliability of specific critical load estimates.
- **Interpreting Multiple Critical Load Exceedances**: This document outlines guidelines for interpreting CL exceedances when **different types of CLs** (different approaches to CL calculation) yield exceedances simultaneously.
- **Deposition Trend Protocol**: This document provides additional information about the atmospheric deposition information available on the portal (2006 CMAQ), as well as guidance on evaluating trends in deposition (as discussed in Step 5 of the CL Implementation Strategy).
- **Empirical CL for Nutrient N GTR User's Guide for CL Refinement**: This document guides users through the process of identifying empirical CLs for nutrient nitrogen relevant to their both location and receptor(s) of interest, based on **NRS GTR-80**.

Questions?

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Claire O'Dea, USFS Air Quality Specialist
cbodea@fs.fed.us