Forest Service Air Program
Monitoring Strategy to Support CL and CL Exceedance Refinement for Forest Planning

Version 2.0 July 2014

Introduction

During the process of conducting the critical loads (CLs) assessment for Forest 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
    - Monitoring Nutrient Nitrogen Effects.

Responses to issues identified at specific Steps in the CL Strategy

ISSUE	RESPONSE
From Step 1 of the CL Strategy	
• Forests in Alaska and Puerto Rico will not see any information in the National Forest Exceedance Table.	Alaska and Puerto Rico were not included due to the lack of geospatial deposition estimates. Go to ***Improving Deposition Estimates.***
• Fields in the NF Exceedance Table are blank, indicating unavailable CLs.	Go to the part of Section 2 that corresponds to the missing values for your forest.
• Only a few data points were relied upon to make a "No Exceedance" determination of aquatic ecosystem CLs of acidity for your forest.	May not be representative of larger area. Go to ***Monitoring Acidification Effects – Aquatic Ecosystems*** and consider developing a surface water monitoring plan to increase coverage across your forest.
• There is concern that the deposition values used in the national exceedance calculations do not adequately represent conditions on the forest.	Go to ***Improving Deposition Estimates***.
From Step 7 of the CL Strategy	
CL exceedance information indicates low risk of detrimental effects, but deposition trends are increasing. (See CL Strategy Step 2 to help define forest concerns between acidification and nutrient nitrogen saturation.)	• If acidification is your primary concern, go to ***Monitoring Acidification Effects – Aquatic Ecosystems*** and develop a surface water monitoring plan. • If excess nutrient nitrogen is your primary concern, go to ***Monitoring for Nutrient Nitrogen Effects***
Assessment showed exceedance of CLs, but information is not considered reliable enough to support development of Target Loads (TL). Monitoring recommended to improve reliability of CLs.	
• Surface water CL exceedances rated as unreliable due to an insufficient number of water sample sites.	Go to ***Monitoring Acidification Effects – Aquatic Ecosystems*** and develop a surface water monitoring plan.
• CLs of acidity for forested ecosystems are exceeded. *AND* • Water samples are not available *or* are insufficient for a reliable surface water CL exceedance calculation.	Indicates area is at risk of acidification. First step is to acquire reliable surface water CLs. Go to ***Monitoring Acidification Effects – Aquatic Ecosystems*** and develop a surface water monitoring plan using the terrestrial CLs to prioritize sample locations.
• CLs of acidity for forested ecosystems are exceeded AND surface water CLs of acidity are exceeded (and considered reliable).	Go to ***Monitoring Acidification Effects – Forested Ecosystems*** and consider soil chemistry monitoring to improve terrestrial CL calculations, contribute to dynamic modeling for setting target loads, or better understand the severity and extent of the problem before making management recommendations.
• Empirical CLs of nutrient nitrogen are exceeded.	Go to ***Monitoring Nutrient Nitrogen Effects***. • Consider improving lichen CL estimates. • Next consider other receptors that have exceeded these CLs. Work with appropriate scientists to determine whether an N gradient or addition study will improve the reliability of these CLs for your forest.

Improving Deposition Estimates

The CL Implementation Strategy recommends using the standardized modeled deposition information available on the Portal to determine CL exceedance. These deposition products combine measured and modeled wet and dry deposition to produce estimates of total (wet+dry) deposition across the lower 48 states. For a few forests, regional deposition modeling and mapping efforts may provide enhanced estimates by incorporating data from snowpack samples in high elevation areas, nitrogen deposition from throughfall samplers, or cloud and fog deposition from other sources. Regional mapping efforts may also utilize different models such as ClimCalc in the northeastern US or modeled wet deposition by Grimm for the eastern US.

After considering all available options for deposition information, some forests will still seek improvement, given the known deficiencies and/or absence of estimates. The only way to improve the modeled estimates is often obtaining additional measured deposition data. Obtaining measured deposition information would be most important in areas where initial analysis shows that critical loads are likely to be exceeded and deposition is underestimated.

There are several methods available for measuring deposition:

- Establish a long-term monitoring site as part of an existing network (NTN monitoring for measurement of wet deposition, CASTNET for dry deposition). This requires an initial investment in equipment and a long-term commitment to fund sample analysis, site operations, and maintenance. The benefits include a well-established structure of protocols and procedures, central laboratory analysis of samples, and centralized data analysis and reporting.
- Bulk or throughfall measurements, especially using "passive" collectors, allow for shorter-term deposition measurements. Passive throughfall collectors based on ion exchange resin (IER) columns were developed to provide a lower cost method of obtaining deposition measurements in remote areas.
- Lichen tissue can be collected and analyzed for nitrogen, sulfur, and other elements, and these results provide an indirect avenue for obtaining deposition information. Recent work by Forest Service scientists shows annual N deposition can be estimated from the nitrogen content of lichen tissue, once the relationship has been established for a region. This technique is available for use in the western states and Alaska.

Forests are advised to enlist the assistance of the Regional Air Program Manager and local research scientists to determine the most appropriate approach for deposition monitoring.

Improving Critical Loads: General Guidelines

1. Identify the CL exceedance estimates in need of refinement through additional monitoring (as opposed to estimates requiring the development of target loads).
    - *Examples include: CLs of acidity for surface waters, terrestrial CLs of acidity for forested ecosystems, or empirical CLs of nutrient nitrogen.*
2. If several CLs are exceeded and in need of refinement, prioritize monitoring efforts using the findings from Step 2 of the Critical Load Strategy. In Step 2 you determined whether acidification, nutrient nitrogen, or both were concerns for the forest.
3. Identify the resource(s) that must be monitored to refine the CL exceedance estimates identified above.
    - *Examples include: surface water chemistry samples to refine CLs of acidity for surface waters, surface water or soil chemistry samples to refine CLs of acidity for forested ecosystems, or lichen monitoring to refine empirical CLs of nutrient nitrogen.* More details are available in the following monitoring sections.
4. Have a clear objective for monitoring.
    - *For example: establish an initial surface water survey to calculate CLs of acidity across the forest, expand the existing surface water chemistry data to improve reliability of forest-wide CL estimates and allow development of a TL, refine terrestrial CLs of acidity for forested ecosystems in sensitive watersheds, refine the nutrient N CLs for lichens*.
5. Always use national and regional protocols when available.
    - *Examples include: National Protocols for Sampling Air Pollution-Sensitive Waters, Forest Inventory and Analysis Protocol for Lichen Community Analysis, Region 6 protocol for lichen elemental analysis.*
6. Use the CL Implementation Strategy to stratify potential monitoring sites.
    - *For example: the CLs of acidity for forested ecosystems can be used to identify area at high risk.*

Monitoring Acidification Effects - Aquatic Ecosystems

While there are many different sensitive receptors for aquatic ecosystems that can be affected by air pollution (e.g., water chemistry, fish, macrobenthic invertebrates, and diatoms), the receptor used to develop these CLs for Forest Planning is *surface water chemistry*. The following recommendations focus on improving CLs of acidity for surface waters.

The CLs of acidity for surface waters provided on the Air Quality Portal were only calculated for sites where surface water samples were collected and analyzed and the data reported in NRM Air. Even if a forest has several surface water CLs calculated within its boundary, the number of monitoring sites might be insufficient to warrant developing a target load; additional measurements might be needed. Fortunately, surface water chemistry is relatively easy to obtain. The Air Program supports surface water chemistry monitoring by developing national protocols, maintaining a laboratory equipped to analyze chemically dilute waters for air pollutants, and supporting NRM Air, a module within the national database, NRM, to store and report results.

Forests should follow the *Forest Service National Protocols for Sampling Pollution-Sensitive Waters* RMRS-GTR-278WWW (April 2012). The protocols provide a consistent framework for deciding where, when, and how to conduct water sampling for the purpose of evaluating and monitoring air pollution effects on aquatic ecosystems. The Missoula Technology and Development Center has developed stream and lake sampling videos to support field implementation of the protocol. The Protocol document and training videos are available online at: http://www.fs.fed.us/air/portal.htm.

Sample analysis support is provided by the Forest Service Air Program Biogeochemistry Lab. This lab specializes in analyzing dilute lake and stream water (which are highly sensitive to effects of air pollution), their procedures have been aligned with National Protocols, and data reporting into the national database, NRM AIR, is facilitated. Forests should therefore use this lab for air pollution related monitoring projects.

Create a clear objective for monitoring before developing a monitoring plan to support the objective. In this case you are either collecting the first surface water chemistry measurements for a forest, or expanding/updating existing data. In both cases, the terrestrial CLs of acidity for forested ecosystems can be used to identify watersheds at highest risk. If resources are limited, streams in these watersheds can be measured first. *This is possible because the soils of the watershed influence the buffering capacity of the stream water.*

Monitoring Acidification Effects - Forested Ecosystems

The CLs of acidity for forested ecosystems in the national database are not considered reliable enough to serve as the basis for land management decisions. These CLs were modeled with a simple mass balance equation using spatially extrapolated data. Several of the input parameters are soil-based, and the values are from modeled, rather than measured information. In addition, the scale of the soil data used in the nationwide calculations is too coarse to capture all situations, potentially missing the areas with most sensitive soils because soil type and chemistry varies widely across the landscape. This is particularly a concern in complex, mountainous terrain, where soils vary widely over short distances. While these CLs have value for regional assessments and identifying areas of risk, they lack the site specificity needed when making land management decisions at the scale of the national forest.

At the forest level, finer scale soil and soil chemistry information can help improve the CLs of acidity estimates for forested ecosystem. Only a few forests, however, all with well-documented acidification problems for surface waters, have undertaken soil monitoring programs to improve their critical load estimates. Before embarking on a soil monitoring program, investigate whether surface waters are affected by acidification. Surface water monitoring should be conducted on the forest prior to considering a soil monitoring program. Forests with known acidification problems in surface waters could use the existing terrestrial CLs of acidity for forested ecosystems, in conjunction with surface water data, to identify vulnerable or high-risk areas to target for additional monitoring to refine CLs. Review the information provided in the previous section (Monitoring Acidification Effects - Aquatic Ecosystems) for assistance with surface water monitoring.

Soil monitoring programs can be expensive; forests may want to reserve soil monitoring funds for areas where surface water samples suggest acidification, <u>and</u> 1) the forest is considering active management, or 2) Class 1 or Wilderness Area protection status suggest the need for proactively mitigating damage or initiating restoration for ecological protection. Soil chemistry may also be required before performing dynamic modeling for target load calculation. Consult with a research scientist familiar with critical loads in your region before developing a monitoring plan to improve CLs of acidity for terrestrial ecosystems. The document, ***Approaches for Estimating Critical Loads of N and S Deposition for Forest Ecosystems on U.S. Federal Lands*** (Pardo 2010) should also be consulted. You will need to consider the requirements of the method you intend to use to calculate or refine the CLs; let these requirements guide the selection of parameters measured in the environment. Each method requires varying levels of data intensity.

Monitoring Nutrient Nitrogen Effects

The National Forest Exceedance Table displays exceedances of empirical CLs of nutrient N for several receptors and responses (fungi, lichens, herbaceous plants and shrubs, forests, and nitrate leaching) but the lichen receptor is generally considered the most sensitive to nitrogen pollution. Excess nitrogen causes acidification and/or eutrophication of the environment, shifts species composition within plant taxa, decreases biodiversity, increases fire frequency (e.g., favoring grasses over shrubs), and decreases growth and reproduction of sensitive species. Lichen species composition begins to shift at or below deposition ranges that affect the most sensitive species in other floral taxa (Geiser et al. 2010). Thus exceedance of lichen-based N critical loads is a reasonably conservative indication that adverse effects may already have occurred, or may eventually occur, to other plant and fungal taxa. For this reason it makes sense to consider improving the empirical CLs of nutrient N for lichens before other receptors, assuming that exceedances occur in communities known to support lichens; grasslands, rangelands, wetlands, and alpine areas are not known to support lichen communities and can therefore be removed from the lichens CL exceedance assessment. In addition, protocols are available for measuring community structure and nitrogen content of lichen tissue (*Forest Inventory and Analysis Protocol for Lichen Community Analysis*, *Region 6 protocol for lichen elemental analysis*), and databases exist to store the collected information. Any forest considering lichen monitoring should coordinate with Linda Geiser, lichenologist with the Air Program in Region 6, to develop a plan that fits into national efforts underway to improve these empirical CLs of nutrient N for lichens.

Another national effort is underway to refine the other empirical CLs of nutrient nitrogen using available land cover GIS layers. Linda Pardo, research scientist with the FS Northern Research Station, is coordinating this effort. A more immediate way to refine the empirical CLs of nutrient nitrogen for your forest is to work with a research scientist to conduct an N-addition or N-gradient study for a receptor of interest.

Additional Resources:

Monitoring plans for measuring air pollution effects to sensitive resources have been developed in many regions and could be helpful in developing monitoring plans to improve CL and CL exceedance calculations. Look for Air Quality Related Values - AQRV - Monitoring Plans for Class I areas in similar ecosystems or Air Quality Value Monitoring Plans developed for the Wilderness Challenge. Both sets of monitoring plans provide guidance for identifying the most sensitive areas and stratifying monitoring efforts. They also recommend incorporating the monitoring needs for air pollution effects into a broader interdisciplinary monitoring program when possible.