Attachment 1

Analysis of Forest Road Conditions and the Impact on Water Quality and Aquatic Organisms in the Pisgah-Nantahala National Forests

Report by Kara Grosse †, Antje Lang ‡, and Caitlin Ryan †

Supervised by Sam Evans, Staff Attorney with Southern Environmental Law Center, and Hugh Irwin, Landscape Conservation Planner with The Wilderness Society

† Duke University Nicholas School of the Environment, Masters Candidate
‡ Duke University, Undergraduate Candidate

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I. Introduction

National Forests encompass some of America's most scenic, visited, and ecologically important public lands. Unlike many public lands, however, such as National Parks, the National Forests are managed for "multiple uses," which include not only scenery, ecological values, and recreation, but also extractive uses like timber harvest. Timber production is one of the accepted uses of national forest land and is also a useful tool in ecological restoration. Timber harvest requires access for logging equipment, and it therefore usually involves road construction and maintenance. However, the ground disturbance from roads and skid trails, especially when appropriate best management practices (BMPs) are not used, installed, and maintained, can damage critical habitats, isolate populations of aquatic organisms, cause landslides and mass wasting, and pollute water systems on which humans and wildlife rely.

To combat potential detrimental environmental impacts of logging, including logging on National Forest lands, the state of North Carolina has implemented the Forest Practices Guidelines Related to Water Quality (FPGs), a set of mandatory performance standards for forest harvesting practices intended to protect aquatic resources. In order to facilitate FPG execution, North Carolina also developed a set of more specific BMPs. While BMPs are voluntary, loggers who employ the techniques outlined in BMP documents are expected to meet the performance standards in the FPGs. National Forests are operated under a “Forest Plan,” which usually requires mandatory adherence to state forestry BMPs, as well as other BMPs developed by the Forest Service.

North Carolina’s FPGs and BMPs apply to both private lands and the National Forests, but the impacts of logging on national forests go beyond the aquatic impacts addressed by those standards. Logging and logging roads are often in tension with recreational and ecological goals of the national forests. To the extent that national forest land managers view their job as harvesting and growing new crops of trees, they must build and maintain an extensive network of roads which sometimes reach into remote backcountry areas of the forest. These backcountry areas are generally much more healthy and undisturbed, and logging in them often introduces invasive species, causes degradation of soil resources, leads to shifts in species composition, and ultimately degrades the area as a wildlife habitat. It also interferes with backcountry recreation, a use that continues to grow in importance. This study addresses these types of impacts only indirectly, revealing that roads into sensitive backcountry areas are often inadequately constructed and maintained.

The primary focus of this study is the direct impact of national forest roads to aquatic resources. Forest roads are the most significant contributors of pollution to the mountain streams in the national forests of western North Carolina (Fulton and West 2002). As discussed herein, forest roads are not adequately maintained. In fact, the Pisgah National Forest has the funds to maintain less than 13% of its road network, resulting in a $41 million backlog in road maintenance (Pisgah National Forest Transportation Analysis Process 2012). This implies that BMPs and erosion control devices are not being routinely maintained and replaced. The implications are that failing BMPs may be allowing sediment to flow into streams, harming water quality and damaging habitat for sediment-sensitive aquatic species like trout.

Many forest road stream crossings utilize culverts that, either through neglect due to maintenance backlog or poor initial design and construction, create barriers to aquatic organism passage and/or contribute to accelerated erosion and stream sedimentation. Many of the streams originating on the national forests, and especially in backcountry areas, are designated as outstanding resource waters, water supply waters, or high quality waters. There are several characteristics of culverts that cause negative impacts, including “perching,” blockages, steep grades, lack of natural substrate, inadequate size, and excessive lengths. Aquatic organisms including fish, salamanders, and macroinvertebrates are often unable to pass freely through culverts as a result of these characteristics, fragmenting habitats and populations. Furthermore, these characteristics can lead to erosion problems. For example, a steep grade increases the velocity of water flow through a culvert and, especially if the culvert is perched, can erode the bed area around the culvert outfall. Blocked or undersized culverts often lead to redirection of streamflow over the road surface and road fill, causing an increased accumulation of sediment and, occasionally, entire road washouts at the site.

The Nantahala and Pisgah National Forests have estimated that 88.5% of stream crossings on national forest system roads meet or exceed BMP requirements (NC Forest Service 2014). Research in other national forest units in the Southern Region, however, has shown a much lower compliance rate. In 2005, researchers surveyed 297 stream crossings in national forest units in four states (not including the Nantahala or Pisgah NF). Of those, 239 were considered to be barriers to aquatic passage for fish (Coffman et al. 2005). Only 36 were passable for fish, and the remaining 22 were indeterminate. In other words, almost 80% of stream crossings were not in compliance with BMPs. Furthermore, this research addressed only barriers to aquatic passage, and it did not document other types of BMP violations. A major goal of this study, therefore, was to either confirm or refute the assumption that Nantahala and Pisgah NF roads are generally in good compliance with BMPs. It would be remarkable if, with such a dramatic maintenance backlog, BMP compliance was as high as reported by the Nantahala and Pisgah NFs. Instead, we consider it more plausible that the lack of road maintenance funding has also left Forest Service staff without the resources to accurately assess the degree to which its roads are out of compliance with BMPs.

Our observations suggest that the backlog of maintenance has caused many forest roads to become impassable and riddled with BMP violations, yet they remain on the national forest's official road system. This study is intended to document the extent to which forest roads in backcountry areas are in violation of the Forest Service's BMP requirements. We focused on backcountry areas because the roads in these areas are generally closed to public use and therefore BMP failures are less likely to be addressed for public safety purposes. Our observations confirmed that BMP failures often go unremedied for years after they occur: "out of sight; out of mind." We are also mindful of the Forest Service's agency-wide emphasis on ecological restoration, which can be summarized as an initiative to use logging and other management to improve the ecological integrity of aquatic and terrestrial ecosystems. Our working assumption is that backcountry ecosystems with less history of abusive management are less likely to benefit from restoration logging and, to the extent that the Forest Service cannot afford to maintain its entire road system, it should consider divesting roads in areas where the need for logging is lowest.

The project was a joint project of The Wilderness Society and Southern Environmental Law Center. The authors of this report are two graduate students at Duke University Nicholas School of the Environment and one undergraduate student at Duke University. The authors worked with staff from The Wilderness Society and Southern Environmental Law Center on field study design, field work, and analysis. The study also brought in two water quality experts, Barry W. Sulkin and Dr. Richard Urban to help design the study and to train the interns and staff in the field methodology to be used for the study. Mr. Sulkin's long experience in water quality issues include his position as Water Quality Specialist and later as Special Projects Assistant to the Director with the Tennessee Department of Environment and Conservation. His duties in these positions dealt with issues of water quality impacts of forestry practices and implementation of BMPs including the inspection of logging sites. He also has served as state-wide manager of the Enforcement and Compliance Section for the Division of Water Pollution Control. In this capacity he was responsible for investigating and preparing enforcement cases, supervising the inspection programs and permit compliance monitoring. Dr. Urban worked also had a long career with the Tennessee Department of Environment & Conservation, Division of Water Resources, Chattanooga Field Office. Both Dr. Urban and Mr. Sulkin also have extensive experience consulting on water quality issues and BMPs. Following a one week professional training period in the field with the consultants, we conducted our road prioritization analysis. Once at risk roads were identified, the research team proceeded to survey the roads by foot in order to identify road quality issues.

II. Methods

A. Prioritization Analysis

In order to choose which roads to survey, we conducted a prioritization analysis in ArcGIS by acquiring data from different sources, including the NC Roads Analysis Project for The Wilderness Society by Ben Riegel, Ann Ingerson and Brent Martin (2011). This analysis used the system roads layer from the United States Forest Service, elevation data from the United States Geological Survey, soil data from the Natural Resources Conservation Service, precipitation data from Oregon State University, streams and water supply data from the NC State Department of Water Quality, and Natural Heritage data from the NC State Department of Environment and Natural Resources to create six erosion-potential criteria in ArcGIS.

The road risk analysis used the following criteria: 1) slope of the terrain, 2) erodibility of the soil, 3) precipitation amount, 4) road gradient, 5) proximity of the road to streams, and 6) number of stream crossings per mile. For each road and each criterion, a binary evaluation was made: high risk for each criterion received a value of one (1), and low risk received a value of zero (0). For the slopes statistic, for example, the top half of the events with the steepest slopes were noted as having high erosion risk. The same method of evaluation was used for the soil erodibility criterion, precipitation, stream proximity, and stream crossings. The road grade criterion was identified as high risk by comparing the grade to a threshold for each surface type. The total number of positive values were then calculated for each road, thus giving each system road a score of 0-6, 6 being the highest total erosion potential. In our prioritization analysis, we included roads that had erosion scores from 4 to 6. We imported the road risk layer to ArcGIS and extracted all roads with values of 4 and above and created a new layer file to use for the analysis.

The second item we considered was maintenance level. Each road in the forest system has an objective and an operational maintenance level between 1 and 5. Operational maintenance level, which is the category utilized in this study, is defined as *"the maintenance level currently assigned to a road considering today's needs, road condition, budget constraints, and environmental concerns; in other words, it defines the level to which the road is currently being* maintained." (USDA, 2005).These maintenance levels are defined as:

- ML 5 roads are the highest maintenance roads that include roads that provide a high degree of user comfort and convenience. These roads are normally but not always double-lane, paved facilities.
- ML 4 roads provide a moderate degree of user comfort and convenience at moderate travel speeds. Most ML 4 roads are double lane and aggregate surfaced.; However, some ML 4 roads may be single lane.
- ML 3 roads are open roads maintained for travel by prudent drivers in a standard passenger cars. User comfort and convenience are low priorities.
- ML 2 roads are roads suitable for high-clearance vehicles. Passenger car traffic is not a consideration. ML 2 roads in some portions of the national forest system are open roads.

However on Nantahala-Pisgah NF most ML 2 roads are closed year round. A few ML 2 roads are seasonally open.

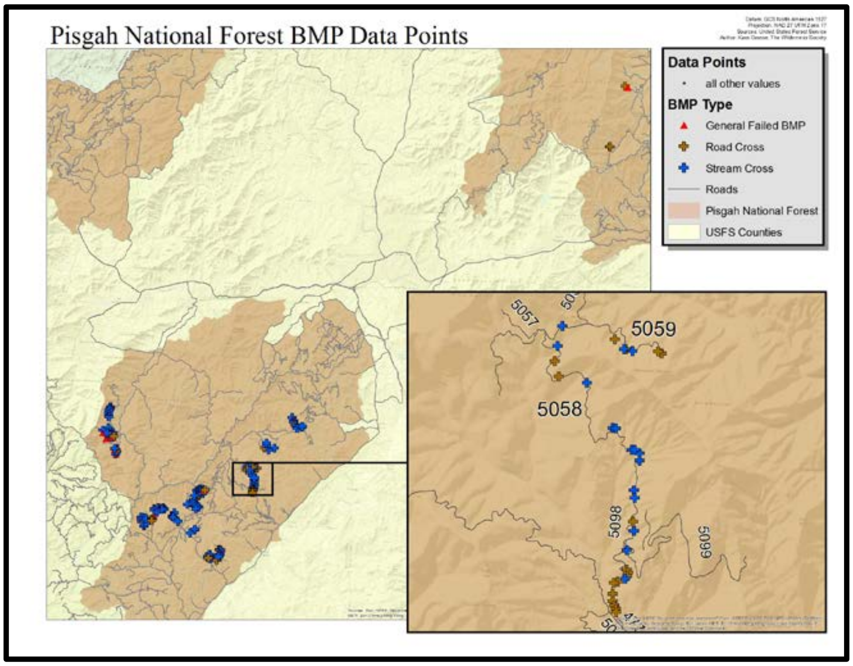
- ML 1 roads are intermittent service roads which have been closed for longer than one year to vehicular traffic. These roads are also referred to as roads in storage. ML 1 roads can be any level of road when not closed. However, ML 1 roads on Nantahala-Pisgah are almost always very low maintenance roads that have not been used for any purpose in a long time.
(USDA, 2005)

For this analysis, we considered roads with an operational maintenance levels of 1, 2, and 3. To do this, we joined a maintenance level data table from the Forest Service with the system roads layer based on the CN number of the road. We then deleted all system roads that had a maintenance level of a 4 or 5. Because level 4 and 5 roads receive higher public use, we assumed they are more frequently maintained to protect public safety.

The third component we considered in our analysis were Mountain Treasures Areas (MTAs). The layer data for MTAs was obtained from The Wilderness Society. MTAs are areas within the Nantahala and Pisgah National Forests that are primarily wild and without passable roads. The Mountain Treasures provide the most inclusive dataset available for backcountry areas of the Nantahala and Pisgah NFs. Other potential datasets for backcountry areas include the Inventoried Roadless Areas (IRAs) delineated by the Forest Service and the Potential Wilderness Areas (PWAs or WIAs - wilderness inventory areas) which are currently being delineated to update the Forest Service's inventory of undeveloped areas. Neither of these datasets were deemed adequate. First, IRAs omit important wildland areas . Many of the Mountain Treasures areas have IRAs at their cores, but their boundaries are more inclusive than IRA boundaries and include areas not protected by the Roadless Rule. In other words, many of them have not been designated as protected and therefore remain available for timber harvest. ("North Carolina's Mountain Treasures" 2011). Yet areas outside the IRAs are certainly of similar backcountry character to the IRAs, as demonstrated by the current expansion of the PWA inventory. The WIA data is more inclusive, but it was not final when priority areas were being selected for this study. It was anticipated that most of the MTAs will be included as WIAs, and all the WIAs will be considered for possible wilderness recommendation and for other protective designation during the ongoing Forest Plan revision process (Irwin 2015). As a result, information about these areas gathered during our study is relevant and timely.

The final component we utilized in our prioritization were GIS layers on high quality waters, outstanding resource waters, and water supply waters, which we obtained as NCDENR datasets from NC One.

Using the “Intersection” tool in ArcGIS, we looked at which roads with maintenance levels 1, 2, and 3 fell within MTAs and have high erosion potential (between 4 and 6). The tool generated a list of 120 roads. These did not include roads bordering MTAs. After using the intersect tool a second time with the NC One high quality water (HQW), outstanding resource waters (ORW), and water supply waters (WSW) data it was found that 30 of the priority roads were in ORW watersheds, 31 were in HQW watersheds, 6 were in WSW watersheds, 2 were in both ORW and WSW watersheds, .



B. Data Collection

From June 1, 2015 to July 24, 2015 we collected data by foot on the priority roads. On the designated roads, each road and stream-cross culvert was examined for problems. For stream crossings, we identified perched culverts, accelerated erosion at stream crossings, and other BMP failures, such as blocked inside ditches causing road surface erosion and sediment entering streams. We focused on issues that would violate BMP requirements, and we therefore collected detailed information only for the problems that were affecting jurisdictional streams. In delineating jurisdictional streams, we followed the new definition of “waters of the United States” rule available at (“Clean Water Rule: Definition of ‘Waters of the United States’” 2015). In other words, we took detailed data for problems affecting streams with a clear bed and banks above the culvert. We took note of some other problems associated with inadequate maintenance, but the analysis provided in this study did not consider problems to be violations unless they affected jurisdictional streams. We documented four basic categories of violations: (1) barriers to aquatic organism passage, (2) undersized or obstructed culverts that are inadequate for expected flood flows, (3) accelerated erosion and/or visible sediment in stream crossings, and (4) visible sediment entering streams at locations other than stream crossings.

We included data on each road’s operational and, if available, optimal maintenance level from the Pisgah NF TAP in order to inform the GIS analysis. Additionally, the road maintenance objectives (RMO) were included. Operational maintenance level indicates the current road maintenance level with 1 being the lowest (road in storage) and 5 being the highest. RMOs essentially describe how the road is used within the forest system. Optimal Maintenance Level data were taken from the Pisgah TAP. A Nantahala TAP was not complete at the time of the study so this data was not available for Nantahala. Road condition found in the field often provided a clearer look into the true maintenance level. For example, many ML 2 roads, which by definition are “roads open to high clearance vehicles,” when surveyed were often not passable by a high clearance vehicle and, occasionally, barely passable by foot, indicating discrepancies between the operational ML and the objective and the actual conditions to which roads are being maintained. Often, these ML 2 roads appear to be treated as if they were in “storage,” with no maintenance being performed until they are used for logging access again in the future. However, these roads have not been put into storage per agency rules (by removing culverts and rehabilitating stream crossings), and our observations show that neglected stream crossings are the most likely locations of BMP violations.

We conducted further data collection for culverts that we deemed during field examination to have clear problems. For each site, we recorded the location using GPS. We also recorded a narrative describing each problem for future reference, and we collected pictures with annotations to further document the problems. The metadata for the pictures includes their GPS locations. Additional information was collected based on the type of problem we encountered.

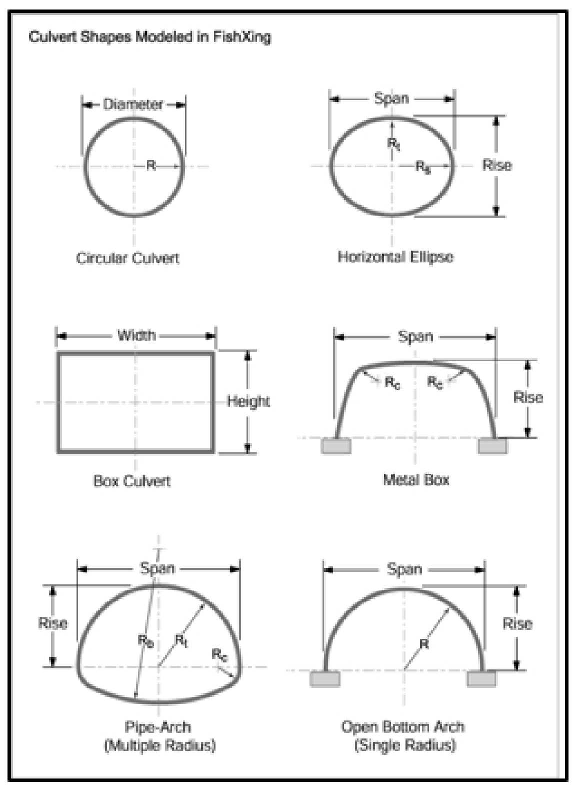
An explanation of measurements and terms used for culvert examination are as follows:

Purpose of culvert: Stream crossing or road culvert.

Stream crossings allow for the passage of a stream beneath a road. Road culverts divert water collected in an inside ditch under the road and the outfall should ideally disperse this water into foliage, rather than into or near a stream.

Type of culvert: Open bottom arch, vented ford, box, pipe arch, corrugated metal pipe (CMP)/circular (Fig. 1).

There are five common types of culverts, as listed above. CMP/circular was by far the most prevalent for both road and stream crossings. Many of the larger CMP/circular culverts were built inside of concrete stabilizers, but still lacked many ideal characteristics for aquatic organism passage.



Continuous Substrate: Substrate continuous through culvert and sediment flowing through the culvert.

The bottom of culverts should possess a substrate that mimics the natural bed of stream to enable easier organismal passage. Few culverts we examined possessed this attribute.

Length: The horizontal distance of the pipe from intake to outfall.

This measurement was taken using either a rangefinder or tape measure to ensure the horizontal distance was taken, not the “length” (hypotenuse). Taking the measurement straight down the hill would have produced a hypotenuse. Culvert length is a factor in calculating fish exhaustion factor calculated in the analysis.

Slope: The grade of the culvert in degrees.

This measurement was taken using a digital level application or "app." Slope also contributes to fish exhaustion factor.

Fig 1. Types of culverts. http://www.fsl.orst.edu/geowater/FX3/help/Graphics/CV_type.jpg

Diameter: Diameter was recorded for all stream crossing culverts of jurisdictional streams.

Problem description: Undersized, blocked/buried, perched.

An undersized culvert could not be definitely determined in the field as it required further GIS analysis, but suspected undersized culverts were marked. A culvert was marked as potentially undersized if it appeared that pooling above the intake had occurred or there was washout over the road, both of which imply that the flow capacity of the culvert was less than required by the amount of flow it received. GIS analysis of potential undersized culverts will be discussed later on. A blocked/buried culvert could occur at the intake or outfall, and was fairly obvious to assess as the intake or outfall could not be seen or could be seen but was full of debris. Perched culverts were also easy to assess. If the bottom lip of the culvert did not touch the stream bed below, it was considered to be perched. Many culverts were perched on to fill; that is, rocks that had been placed around the culvert for stabilization. Even if these culverts touch the top of a rock fill, they were still considered perched as they did not touch the natural stream bed. Not all perched culverts are barriers to aquatic organism passage, which will be discussed in our analysis section.

Perch: For perched culverts, the height of the perch was recorded

Flow condition: Dry, isolated pools, flowing.

Flow was assessed based on its condition at the time of inspection. Even if it was clear a stream was ephemeral and would be flowing in winter, it was assessed based on its condition at the time of observation (the summer dry season).

Flow depth: For flowing streams, the average flow depth was recorded.

Streambed width: The streambed both above and below the culvert were measured. If an upstream bed was largely braided, each separate channel was measured. If the width was variable, a representative or average width was used.

Aquatic organisms observed: Aquatic organisms included fish, crayfish, salamanders, and macroinvertebrates, the most common of which were caddisflies, stoneflies, and mayflies.

For visible sediment problems, we conducted the data collection as follows:

Flow condition of receiving water: Dry, isolated pools, flowing.

This measurement referred to the water that was receiving accumulating sediment. If, for example, a road culvert was contributing visible sediment into a larger stream, it would be the flow condition of that stream that would be marked, rather than the flow condition of the water exiting the culvert.

Streambed width: The streambed width of the receiving water.

Aquatic organisms observed: Followed the same criteria as mentioned above, but examined in receiving water.

Accelerated erosion occurring where: We recorded the location where the eroded material was originating: road surface, cut slope, inside ditch, stream bank, fill, or in-channel.

Absence of ground cover and size of bare area: Bare area refers to a largely unvegetated area caused by accelerated erosion (eg. water cutting a channel, road washout, etc.) This area was measured in square feet. The roads observed were not in construction or use, and they should therefore have been stabilized with vegetation or other appropriate cover to prevent erosion.

How was visible sediment movement detected: We took note of deltas in streams, buried vegetation trails, channels to stream, observed plumes of turbid water, accelerated erosion in stream crossings (where eroded material is directly entering waters), mass soil movement into stream, and embeddedness.

Deltas in stream refer to areas in which large amounts of unnatural sediment have collected and created deltas. Buried vegetation trails are areas in which sediment movement have buried the vegetation and can be visibly followed to receiving waters. Channels to stream occur from water eroding new, unnatural paths to a stream. Plumes of turbid water are areas in which the water was clearly contained more sediment than other areas as a result of accelerated erosion. Embeddedness was not determined through pebble counts or detailed examination of substrate, but instead we roughly assessed the degree of sediment input based on whether there seemed to be much more silt/sediment below the site of accelerated erosion or culvert outfall than there was above, usually by gauging the depth of silt in pools. We often found many of these issues all occurring at a single site.

C. AOP Barrier Analysis

Aquatic organism passage is a requirement under section 404 of the Clean Water Act. Logging roads are exempt from 404 permitting requirements, but only if they provide for adequate passage (along with other BMPs) (Federal Water Pollution Control Act of 1977). If a permit is required, moreover, aquatic organism passage is generally a condition of receiving that permit (Corp of Engineers Nationwide Permit 14 2012). Blocking aquatic organism passage is therefore considered to be a violation of BMP requirements.

All types of stream crossings have the potential to negatively affect AOP (aquatic organism passage), but by far the most common type of crossing we observed was the corrugated metal pipe culvert. To determine whether a culvert was functioning as a barrier to AOP, two questions were assessed: (1) what are the relevant organisms for the stream, and (2) what thresholds (height, length, slope) would cause a culvert to block passage of those species?

We first determined which fish were relevant organisms for which streams. We focused on categories of species based on their stratified abilities to pass obstacles: trout, small fish including darters, sculpin, minnows, and juvenile trout, and salamanders. We chose these groupings of small fish based on the 2005 work of a group of graduate students at U.S. Forest Service (USFS) Aquatic Ecology Unit -- East at James Madison University, who published a set of filters to determine AOP barriers for three categories of fish: species with strong leaping capabilities, species with moderate leaping capabilities, and species with weak leaping capabilities. These simple models allow researchers and land managers to quickly assess whether a stream crossing is passable, impassable, or indeterminate (requiring further biological analysis) for representative groupings of species (Coffman et al. 2005). We added salamanders because they are also important members of aquatic communities and because salamander diversity (and, consequently, the importance of habitat protection for salamanders) is higher in this region than anywhere else in the country (Jenkins et al. 2015).

The “filters” for these species groupings are thresholds beyond which the relevant species are not expected to be able to pass. These filters are described in Appendix I.

While ditch lines and road crossings may support aquatic organisms, the purpose of this research was to assess how BMPs in jurisdictional stream crossings affected AOP. Thus, while data was collected involving road culverts, road culverts were not included in the assessment of of AOP barriers.

Filter A: Trout

Trout are not only an important indicator species for healthy water conditions within mountain streams, but the southern strain of brook trout is genetically unique to the waters of western North Carolina, providing an appropriate proxy for strong jumping fish in streams near surveyed roads (NC Wildlife Resources Commission 2015).

We had sufficient data to associate particular streams with trout habitat. We identified streams expected to support trout by first removing all dry or dripping stream crossings from consideration. We then ran Filter A for species with strong leaping capabilities to determine barrier candidates (Coffman et al 2005). Filter A uses the following decision tree:

1. A culvert with continuous substrate is considered passable by adult trout. If it lacks continuous substrate:
2. An outlet drop less than 24 inches is passable. If higher;
3. A slope of less than 7% is passable. If steeper;
4. A slope x length of less than or equal to 50 is passable. More than or equal to 600 is impassable, and 50-600 is deemed indeterminate.

In other words, Filter A was used to determine which stream crossings would be barriers to trout (if trout were present). We then took the potential trout barriers and compared them to the NC Wildlife Resource Commission Public Mountain Trout Waters GIS data. The barrier candidates that fell in trout waters were marked; the rest were discarded.

Finally, we visually confirmed that any culverts marked passable or indeterminate were passable by fish (i.e.- not blocked, buried, or flowing onto rocks) by reviewing pictures of those sites.

Filters B and C: Designation of Darters, Sculpin, Minnows, and Juvenile Trout as Fish Proxies

These fish were largely chosen because of their use in the Coffman et al. 2005 study, providing a basis for data comparison. Minnows and darter species were chosen as a proxy for small fish within the streams of western North Carolina because of their specific habitat range and frequency within the types of streams examined in this study, representing more than 70% of southeastern freshwater fish diversity (Warren et al. 2000). Additionally, these species account for “65% of the imperiled fish taxa in the Southeast” (Warren et al. 2000). Minnows, furthermore, are an important part of the food web of freshwater ecosystems (Lee et al. 1994). While there is insufficient data to specifically associate these species to the stream segments we surveyed, we were able to identify which streams are likely to support these fish or other fish with similar habitat requirements by using a minimum flow depth as a proxy (4 inches).

These small fish are broken into two groupings with associated thresholds or "filters" to determine whether passage is possible: Filter B (minnows and Juvenile trout) applies the thresholds for species with "moderate" ability to pass obstacles, while Filter C (darters and sculpins) applies the thresholds for "weak" swimmers and leapers (Coffman et al. 2005).

Filter B: Minnows and Juvenile Trout

We first removed all dry or dripping stream crossings from consideration. We then further removed all streams that were not observed with at least 4 inches of flow, because these were the streams deemed suitable for small fish. We considered the observed flow depth to be a minimum flow depth for the surveyed streams, because we took data during the summer dry season. The "Region 1 Fish Passage Evaluation Criteria" (Pacificorp 2008) outlines a literature review of suggested minimum flow depths for fish passage, and recommends a minimum flow depth of 4 inches for juvenile trout passage as a conservative average of previous studies. So, we only considered streams with at least 4 inches of average flow as candidates for barriers for minnows and juvenile trout.

We then ran Filter B for species with moderate leaping capabilities to determine whether the stream crossings would act as a barrier (Coffman et al. 2005):

1. A culvert with continuous substrate is considered passable by minnows and juvenile trout. If it lacks continuous substrate:
2. An outlet drop less than 10 inches is passable. If higher;
3. A slope of less than 3.5% is passable. If steeper;
4. A slope x length of less than or equal to 25 is passable. More than or equal to 200 is impassable, and 25-200 is deemed indeterminate.

Finally, we visually confirmed that any culverts marked passable or indeterminate were passable by fish (i.e.- not blocked, buried, or flowing onto rocks) by reviewing pictures of those sites.

Filter C: Darters and Sculpins

We first removed all dry or dripping stream crossings from consideration. We then further removed all streams that were not observed with at least 4 inches of flow, because these were the streams deemed suitable for small fish. We considered the observed flow depth to be a minimum flow depth for the surveyed streams, because we took data during the summer dry season. Dewey (2008) recommends 0.1 meter (3.9 inches) as a minimum flow depth for Sculpin passage, so we considered only streams with at least 4 inches of average flow as suitable habitat for Darters and Sculpins.

We then ran Filter C to determine whether the stream crossings were barriers for species with weak leaping capabilities (Coffman et al. 2005):

1. A culvert with continuous substrate is considered passable by darters and sculpins. If it lacks continuous substrate:
2. An outlet drop less than 4 inches is passable. If higher;
3. A slope of less than 3.5% is passable. If steeper;
4. A slope x length of less than or equal to 15 is passable. More than or equal to 150 is impassable, and 15-150 is deemed indeterminate.

Finally, we visually confirmed that any culverts marked passable or indeterminate were passable by fish (i.e.- not blocked, buried, or flowing onto rocks) by reviewing pictures of those sites.

Salamanders

The Blue Ridge Mountains are a hotspot of amphibian diversity, with many endemic species, and the region containing the Nantahala and Pisgah NFs "is a major priority for [conserving habitat for] amphibians, mainly because of salamanders" (Jenkins, et al. 2015). Even well-functioning culverts that allow passage for most species are often passage barriers to salamanders, causing habitat fragmentation and posing serious risks to salamander populations. First, we narrowed salamander passage barrier candidates to culverted stream crossings that were flowing at the time of the survey. This is considered to conservatively limit the number of passage barriers, because salamanders occur in ephemeral stream habitats, too. As a qualitative observation, however, nearly all ephemeral stream crossings we observed would have been barriers to salamander passage because of high vertical drop (perch). Indeed, the ephemeral stream culverts were often the highest perched because they occur on steeper terrain.

In flowing streams, we used the criteria outlined in the Anderson et al. 2014 study to test for salamander passage.

1.Does the culvert have continuous substrate?

2.If so, is the culvert perched no more than 0.1m?

If the culvert fails either question, it is a barrier to salamander passage upstream.

D. NC FGP Violations in Stream Crossings

The North Carolina FPGs provide the following requirements for stream crossings (15A NCAC 01I .0203):

> Stream crossings shall be avoided when possible. Access roads and skid trails which must cross intermittent or perennial streams or perennial waterbodies shall be constructed so as to minimize the amount of sediment that enters the streams because of the construction. These crossings shall be installed so that:
>
> (1) stream flow will not be obstructed or impeded;
>
> (2) no stream channel or perennial waterbody shall be used as an access road or skid trail;
>
> (3) crossings are provided with effective structures or ground cover to protect the banks and channel from accelerated erosion;

(4) they shall have sufficient water control devices to collect and divert surface flow from the access road or skid trail into undisturbed areas or other control structures to restrain accelerated erosion and prevent visible sediment from entering intermittent and perennial streams; and
(5) ground cover, or other means, sufficient to prevent visible sediment from entering intermittent and perennial streams and perennial waterbodies shall be provided within ten working days of initial disturbance and will be maintained until the site is permanently stabilized.

North Carolina law also prohibits other impacts, such as obstruction by logging debris. NCGS 77-13; 77-14.

A stream crossing was determined to violate the NC FPGs if:
1.The receiving stream was at least intermittent (ie- flowing at the time of study); and
2. There was accelerated erosion in the stream crossing itself or there was accelerated erosion elsewhere (outside the stream crossing) but with visible sediment entering the stream.

E. Obstruction of flow

Similar to allowing for adequate aquatic organism passage, a stream crossing is eligible for the logging exemption under the clean water act only if it provides for adequate flow for expected storm events (NCGS 77-13; 77-14). This is an issue both of culvert installation (i.e. installing a big enough culvert) and maintenance. If roads are not maintained, culvert intakes can easily become blocked and therefore are unable to function and accommodate storm flows. We considered a culvert to be a flow obstruction violation if it was undersized (discussed later on) or if it was blocked to the degree that it would not accommodate heavy flows. Often, blocked culverts were already showing the effects of the blockage during storms because the road surface was being eroded when the culvert overflowed.

See Appendix II for examples of FGP Violations in Stream Crossings.

E. FPG Failures in Other Places

While FPG failures most often occur in stream crossings, they can also occur when a non-stream BMP causes harm to a nearby stream.

See Appendix III for examples of FGP Violations in locations other than stream crossings.

F. Other BMP Failures

Some culverts do not violate the FPGs but still cause serious problems for their surroundings. In addition, while FPG violations are largely restricted to streams that are intermittent or perennial, we marked BMP failures regardless of flow. We marked the following issues as BMP failures (North Carolina Forestry Best Practices Manual 2006).

- The inside ditch line flows into a stream crossing.
- The outlet of a runoff culvert flows into a stream.
- Use of open top drains or trenches to control runoff.
- Failure of an erosion control BMP.
- The BMP causes accelerated erosion.
- Lack of a BMP (e.g.- a stream crosses and erodes the road because there is no BMP).
- Use of check dams in a jurisdictional stream.
- Overflow as a result of an undersized or blocked culvert.
- Blocked and buried culverts.

See Appendix IV for examples of other BMP failures.

III. Results

In total, 45 roads were surveyed. While we were not able to survey all 120 prioritized roads, we did visit all road maintenance levels and roads in all districts of the Nantahala and Pisgah National Forests. Additionally, there were several instances where we added roads to our priority list ad hoc. This occurred for several reasons: a need to walk a gated road to reach a prioritized road, roads on the border or between Mountain Treasures areas, or personal knowledge or interest of TWS and SELC staff. Of these 45 roads, 8 were in Outstanding Resource Waters/Water Supply Water zones, 16 were in high quality water zones, 5 were in water supply water zones, 8 were in outstanding resource water areas, and 10 were in general water quality standard zones. Water quality standard zones "define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provision such as anti-degradation policies to protect waterbodies from pollutants" (Water Quality Standards for Surface Water 2014).

On the 45 roads surveyed, we took data at 438 culverts and 67 BMP sites--a total of 505 sites.

	Total # of Candidates	Total Violations	%
FPGs	322	127	39.4%
Other BMPs	505	303	60.0%
Total	505	430	85.1%

Of those 505 sites, 322 affected streams that were at least intermittent, making them candidates for FPG violations. We considered streams to be at least intermittent if they were flowing at the time of observation, because we observed them during the summer dry season. (At the time of this writing, many counties in the region are considered to be in "moderate drought" because of low rainfall during the survey period.) Of the 322 candidates, 127, or approximately 40% constituted a violation of the North Carolina Performance Standards, with accelerated erosion in a stream crossing of an intermittent or perennial stream or visible sediment directly entering an intermittent or perennial stream. These violations are compromising the quality of the water and causing potential harm to aquatic biota. The majority of these violations occurred at stream crossings, with erosion commonly resulting from a perched culvert outfall. Furthermore, many culverts blocked or buried at the intake created an overflow of the upstream area, causing water to flow over the road and carry road and fill sediment downstream. Many areas that needed a culvert either did not have one, the culvert was malfunctioning (broken, crushed), or had been taken out without re-establishing natural stream channels.

BMP failures do not necessarily cause FPG violations, at least not immediately. BMP violations left unaddressed, however, are more likely to cause FPG violations in the future. Violations can include cutslope failures, inside ditch blockages, lack of inside ditch-line, erosion control failures, and issues regarding the placement of roads and the locations of BMPs. 314, or 62%, of the total sites surveyed contained BMP failures that did not currently constitute FPG violations. Many of these BMP failures involved visible sediment or eroded channels leaving the road surface and traveling downslope, but visible sediment was not detected entering streams because the streams were far enough away from the problem.

General Data Info						
Data Type	Total # points	Functioning Properly	# Problems	No Culvert	Culvert Problems	Vis. Sediment Problems
Road Crosses	98	6	92	24	16	8
Stream Crosses	340	50	290	56	192	55
Failed BMP's	57	N/A	42	N/A	N/A	2
Totals	**495**	**56**	**368**	**80**	**208**	**65**

Culvert Problems						
Data Type	Total #	Blocked/Buried	Perched	Flowing & Perched	Undersized (diameter)	Crushed
Road Crosses	71	29	38	13	0	1
Stream Crosses	216	23	189	172	8	1
Totals	**287**	**52**	**227**	**185**	**8**	**2**

Visible Sediment & Accelerated Erosion								
Data Type	**Total #**	**Flowing**	**Accelerated Erosion from Road**	**Embeddedness**	**ORW**	**HQW**	**WSW**	**ORW/WSW**
Road Crosses	8	7	2	4	6	3	0	2
Stream Crosses	90	52	27	34	9	40	10	4
Failed BMP's	15	2	2	1	1	1	0	5
Totals	**113**	**61**	**31**	**39**	**16**	**44**	**10**	**11**

Another factor that often contributed to visible sediment entering a stream was if the inside road ditch was draining directly into the stream crossing, which expressly does not meet with the North Carolina BMPs. Finally, a common issue occurred when the inside ditch was either blocked or there was no inside ditch or other design features to control runoff, forcing cut slope runoff to flow over the road and create a downhill erosion gully that many times led directly to a stream. Two common causes were observed for roads without an inside ditch: some roads appeared to be old temporary roads that did not have inside ditches installed in the first place, and some roads appeared to have had functioning inside ditches at one time, but slumping of the upslope fill had blocked the ditch.

Although it is difficult to quantify because our biotic surveys were not comprehensive, we did find that sediment accumulation in streams has an observable impact on the presence of benthic macroinvertebrates. Macroinvertebrates are essential to freshwater stream ecosystems and exist as a fundamental aspect of the food web. Macroinvertebrates are ubiquitous in mountain streams but highly sensitive to both point and nonpoint source pollution. Therefore, the presence of macroinvertebrates in mountain streams is an excellent indicator of stream health. We failed to find any aquatic organisms at 55 out of 194 culverted, flowing stream crossings, a failure rate of 28%. These were often streams with a high level of embeddedness.

AOP Barriers

	# of barrier candidates	# of barriers	# of passable culverts	% passage
Salamanders	192	164	28	14.5%
Darter and Sculpin	22	22	0	0%
Minnow and Juvenile Trout	22	22	0	0%
Trout	37	24	13	35.1%

Western North Carolina's streams may be famous for trout fishing, but they also provide critical habitats for many other kinds of aquatic organisms. To assess small fish passage, we only considered streams with at least 4 inches of flow to be candidates for small fish passage barriers because that was our designated minimum flow depth. Of 22 stream crossings with at least 4 inches of flow, one of the culverts had continuous substrate throughout, which usually signals that the culvert is passable, but the outflow fell onto rocks. Fish need a pool of water in order to initiate a leap. Of the 21 remaining candidates, none had a perch of 4 inches or less, making all potential candidates impassible by darters and sculpin. Of the 9 culverts that had a perch of 10 inches or less (the passable height for minnows and juvenile trout), all failed the 3.5% maximum slope. That constitutes a 100% failure rate for small fish.

The relatively high passage rate of crossing in Brook Trout waters (35%) may be an indication of prioritization of trout waters in ecosystem management. Smaller fish, however, are highly affected by the placement of culverts, with no culverts allowing for passage of darters, sculpins, minnow, and juvenile trout. Salamanders fell in the middle, with a passage allowance of 14%.

Undersized Culverts

We took data on culvert size and location for all stream crossings, even where the culvert was functioning without causing accelerated erosion and where it was not perched. Several culverts were identified as likely being undersized, but this was not confirmed by analysis. These data should be analyzed in the future to determine, based on upstream acreage, whether the culvert is adequately sized to provide for expected storm flows. Storm flows can cause tremendous damage quickly at stream crossings. We observed several crossings where it was evident that a storm had overwhelmed the culvert's capacity causing major washouts. In addition, although we noted that many culverts were fully or partially obstructed, we did not analyze the impact of these obstructions on flow capacity. Obstructed culverts, however, are more likely to cause problems during storm flows even if they were adequately sized when they were installed, and they should receive maintenance so that they do not result in resource damage.

IV. Discussion

> "High-quality water is one of the most important natural resources coming from the national forests and grasslands. National Forest System (NFS) lands, which represent about 8 percent of the land area of the contiguous United States, contribute 18 percent of the Nation's water supply (Brown et al. 2008; Sedell et al. 2000). About 124 million people rely on NFS lands as the primary source of their drinking water (USDA Forest Service 2008a). In addition to drinking water and other municipal needs, water on NFS lands is important to sustaining populations of fish and wildlife, providing various recreation opportunities, and providing supplies to meet agricultural and industrial needs across the country" (USDA 2012).

The Forest Practices Guidelines Related to Water Quality are a set of laws designed to preserve the quality of our natural resources and protect wildlife within our national forest land, specifically fresh-water resources and aquatic organisms. Failure to comply with these FPG standards results in the degradation of our natural resources and wildlife habitat. Of the 322 flowing, jurisdictional streams surveyed, 127 (40%) were found to be FPG violations. We found seven more violations in non-stream crossings. Aquatic organism passage is also very important throughout aquatic systems, because small streams provide the food organisms for species downstream, upstream movement is needed for spawning, and interconnectivity is important to recolonize areas after disturbances (Coffman et al. 2005). Nearly all the stream crossings we surveyed would have been barriers to passage for at least some aquatic organisms.

Our research and analysis refutes the Forest Service's estimate that 88.5% of stream crossings meet or exceed BMP standards. For (1) low maintenance level roads (2) with high risk factors for BMP failure (3) in or near backcountry areas, our study shows that very few stream crossings are in compliance with BMPs. The stream crossings most likely to be compliant are on perennial trout streams where bridging is used rather than culverting. Stream crossings on smaller streams and stream crossings with pipe culverts are the most likely to be out of compliance.

Conclusions

The roads in our survey were all closed to the public, they are mainly dead-ends not providing network connections, and they often go deep into remote areas where there is no motorized traffic. These roads are often not in passable condition. The Forest Service lacks the budget to maintain all of its roads, and neglect of these roads in particular is causing demonstrable, systematic degradation of aquatic resources. Neglected stream crossings, in particular, are the sites most likely to function as AOP barriers or sources of sediment. Under agency rules, placing roads into storage or decommissioning them while stabilizing and addressing problem areas. would address these issues at stream crossings. Proper maintenance and replacement of problematic culverts would also address these issues, but the Forest Service's budget is inadequate. It is therefore the conclusion of this study's authors that these roads should be considered for placing in storage or decommissioning.

Recommendations for Further Study

As noted in this report, we did not perform a comprehensive biotic survey at each stream crossing because of time constraints. We cannot therefore confirm which streams are in fact providing habitat for which species. Without detailed species data, our use of flow depth as a proxy to determine which fish were relevant species for a particular crossing was a necessary first approximation for the fish crossing assessment. We reviewed many sources, compared FishXing data, and chose a 4 inch minimum flow depth for small fish as a reasonable standard based on credible studies. Furthermore, the streams with 4 inches of flow during the summer dry season are likely to have considerably more flow during wetter seasons. Streams with 4 inches or greater of flow are expected to provide suitable habitat for at least some small fish, and Filters B and C, for smaller fish with weak and moderate passage abilities, should provide a useful gauge of which streams are in fact obstructing aquatic passage for small fish. The criteria used actually provide a conservative screen for fish passage barriers, and most failures significantly exceeded these criteria.

A more detailed field survey than that conducted could certainly be envisioned. A survey incorporating a detailed biotic survey component would add more specificity to the organisms identified that are being blocked by aquatic organism barriers. We were surprised that there was very little data available documenting the aquatic species that use specific stream segments, except for trout stream stretches. This aquatic organism use of Forest Service streams is essential information for maintaining and restoring aquatic organism habitat and passage and should be the focus of future research and monitoring efforts.

A more comprehensive survey could also be envisioned that documents the conditions of more roads and more road stream crossings. These surveys could be useful in better quantifying the extent of the BMP failures across all Forest Service system roads and prioritizing the maintenance and remediation of the issues identified. However, the road problems identified in this field survey point to pervasive and urgent issues on many Forest Service roads that should be addressed as soon as possible. More detailed surveys of road conditions involving all roads would seem to be most appropriate as a part of regular road monitoring and maintenance efforts on an ongoing basis.

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