An Assessment of Forestry Best Management Practices in North Carolina 2012-2016

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We are grateful to the landowners and forest operators who allowed us to visit their tracts, gave us insight on their harvests, and warned us of safety hazards. This survey would not have been possible without the cooperation of NCFS staff at the region, district, and county offices. Staff from every area of the state assisted with this survey by giving us background information on tracts, escorting evaluators to sites, and making introductions. The field work was conducted by a total of seven staff members of the NCFS Water Resources Branch. During this four-year survey cycle, there was turnover in staff, but cross-training and development of survey protocols that were shared by outgoing to incoming employee(s) provided a smooth transition to promote consistency and repeatability.

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Executive Summary

Between December 2012 and November 2016, the North Carolina Forest Service conducted detailed site survey examinations to evaluate the implementation of voluntary forestry Best Management Practices (BMPs) on logging sites statewide. This survey is periodically carried out by the NCFS Water Resources Branch to help us understand which BMPs are used effectively to protect water quality and which BMPs may need to be revised or emphasized in different parts of the state. This report reviews our actions to address previous survey report recommendations, and provides new recommendations to enhance our efforts in the future. This is the first report following major amendments to the North Carolina Forestry BMP Manual that were made in September 2006.

We used standardized Southern Group of State Foresters (SGSF) methodology to determine a sample size of 204 sites statewide, stratified by the land area in each of the four ecoregions within North Carolina: Blue Ridge or Mountains, Piedmont, Southeastern Plains, and Mid-Atlantic Coastal Plain. To identify many of the sites included in this survey, we used the Southern Forest Area Change Tools (SouthFACT), which analyzes periodic remote sensing data to locate areas of dramatic vegetation change. When SouthFACT was not practical, we identified potential sites by randomly selecting from recent NCFS records, or by assessing sites we came across while traveling through a county.

During the 4-year assessment, we completed 210 unique surveys on 204 sites in 94 of North Carolina's 100 counties. When we encountered a BMP implementation opportunity, we assessed whether the BMP had been properly implemented, and whether the situation presented a risk to water quality. We surveyed some BMPs on an individual basis, which differs from the approach used in the previous 2006-2008 BMP implementation survey project.

In total, evaluators assessed 28,491 BMP implementation opportunities statewide, including 9,671 in the Mountains, 11,206 in the Piedmont, 3,230 in the Southeastern Plains, and 4,384 in the Coastal Plain. Overall BMP implementation was 84 percent statewide, 82 percent in the Mountains, 87 percent in the Piedmont, 79 percent in the Southeastern Plains, and 84 percent in the Coastal Plain. When BMPs were properly implemented, risks to water quality were very rare, only occurring in 36 out of 23,907 observations. Evaluators associated a potential water quality risk to 30 percent of the improperly implemented BMPs, which constituted for less than five percent of all BMP implementation opportunities.

Statewide, when BMPs were not properly implemented, risks to water quality were more likely in the categories of Rehabilitation of the Project Site (54%), Streamside Management Zones (SMZs) (64%), and Stream Crossings (49%). This would infer that the BMPs in these categories are of greater importance for their value of protecting water quality. Specifically, BMPs related to stabilizing stream crossing approaches, removal of logging debris from streams, and overall site stabilization were noted as areas for improvement.

Bridgemats were found to be the stream crossing type that best protected water quality, as well as the most commonly used stream crossing type. Ford and pole type crossings were associated with a risk to water quality in more than 75 percent of cases.

Evaluators estimated the average width and total length of every SMZ encountered during a survey. Our results indicate that risks to water quality decreased as SMZ width increased. For a given probability of a risk to water quality, SMZ width must be greater in the Mountains than in the other ecoregions. In watersheds with a special riparian buffer rule, the BMPs for stream crossings and SMZs were implemented at higher rates on average, and risks to water quality were lower. Risks to water quality from improperly implemented SMZ BMPs decreased moving from west to east across ecoregions, as the terrain changed from steeper to flatter ground.

The highest rates of BMP implementation were found in the White Oak, Pasquotank, Tar-Pamlico, and Hiwassee river basins, and the lowest were in the Lumber, New and Cape Fear River basins.

Evaluators also collected information on the ownership and harvest characteristics at each survey unit. Implementation of BMPs was higher on publicly-owned and conservation land (96%) and on land owned by timber investment/management groups (94%), as compared to other privately-owned land (79%). When BMPs were improperly implemented, risks to water quality were more frequent on “other public” land (48%) or state land (36%) as compared to federal lands (3%). Survey units with naturally regenerated stands had lower BMP implementation and more frequent risks to water quality than those managed as artificially regenerated timber plantations.

Harvesting areas that were active, ranging from 26 to 75 percent completed, had lower rates of BMP implementation and higher rates of risks to water quality. BMP implementation was higher and risks to water quality were lower on all sites larger than 100 acres, regardless of their operational phase of activity.

Our findings support the conclusions of many forest operation research studies that have found bridgemats to be the best type of temporary stream crossing for timber harvests when appropriate site conditions exist. Installed correctly, bridgemats require less soil disturbance near streams than other stream crossing types. If BMPs are implemented throughout the operation, the needed rehabilitation measures are minimal. The NCFS loans bridgemats to loggers for temporary use in many parts of the state. Considering our findings, and conclusions of other research, this program has likely reduced impacts to water quality at stream crossings around the state.

During water quality outreach and education programs, more emphasis may be needed for proper rehabilitation of project sites. Specifically, we found that forest operators did not consistently rehabilitate stream crossings by stabilizing banks and approaches, removing debris or old culverts when necessary. Particularly in the mountains, the risk of erosion from skid trails and other areas of bare soil likely could have been reduced if operators had applied leftover logging debris atop of skid trails, as is often recommended. This issue is supported by our findings on harvest progress, which showed that BMP implementation was lowest, and risks to water quality were highest, on sites that were 26 percent to 75 percent complete. Ideally, rehabilitation and site stabilization should occur throughout the operational phases of a harvest, and not simply be left until the harvest is concluded.

This survey supports other findings and research that demonstrate the function of SMZs in protecting water quality. Our data show a convincing inverse relationship between SMZ width and the probability of a risk to water quality, as illustrated in Figure 3. However, on average statewide, SMZs that were approximately 30 feet wide, or more, along perennial streams resulted in no risk to water quality. For intermittent streams, the width was 20 feet wide, or more. In all cases, when SMZs were 10 feet wide or narrower, there was a risk to water quality in 21 percent of our observations.

Many of the observed risks to water quality associated with stream crossings and SMZs could have been avoided if the operator had used proper preharvest planning to avoid or minimize stream crossings from the outset. Preharvest planning can make the operator or landowner aware of problematic soil conditions, special regulations, or threatened/endangered species in the area. The NCFS produced a freely available online Forest Preharvest Planning Tool that can assist in this strategy.

The information contained in this survey on BMP implementation helps inform our outreach programs, BMP technical assistance, forest management projects on state-owned land, and future revisions to the state’s forestry BMP manual. We will soon start preparing for the next BMP implementation survey, and hope to make improvements in survey quality, data collection technology, and applicability.

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NORTH CAROLINA
FOREST SERVICE
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1: Introduction

Best Management Practices (herein abbreviated as BMPs) for forestry activities are recognized as the primary non-regulatory approach to achieve compliance with the water protection goals set forth by the federal Clean Water Act, and subsequent state standards. Abundant research has shown that when implemented correctly, forestry BMPs limit erosion and sedimentation, maintain aquatic habitat, control runoff, and prevent adverse stream impacts. Using forestry BMPs allows for timber to be harvested and regenerated while achieving water quality standards. The North Carolina Forest Service (NCFS) develops and promotes BMPs, provides technical assistance, assists with training of forest operators, and inspects forestry sites to see that operators are following applicable regulations related to water quality.

In North Carolina, forestry-related, land-disturbing activities (such as logging) must comply with the standards described in the “Forest Practice Guidelines Related to Water Quality”, codified in N.C. Administrative Code T.02 NCAC 60C .0100 to .0209 (herein abbreviated as FPGs). Compliance with the FPG standards allows forestry activities the ability to operate in a manner that is consistent with accomplishing the objectives of protecting waterways from excessive sedimentation as required by the N.C. Sedimentation Pollution Control Act, General Statute Ch.113A.

The implementation of suitable BMPs often leads to compliance with the FPG standards; however, there is no ‘automatic’ compliance granted. Each site operation must comply with the FPGs regardless of the number, type and extent of BMPs that are (or are not) implemented. This BMP implementation survey only assessed the degree to which applicable BMPs were implemented, and did not assess FPG compliance. For comparison, during this survey period, NCFS field-office personnel conducted 10,075 FPG inspections on timber harvest sites statewide, and determined a 98.5 percent FPG compliance rate.

1.1 Follow-up from Previous Recommendations

This is the first assessment following major amendments to the North Carolina Forestry BMP Manual that were effective in September 2006. Field work for this cycle of BMP surveys was conducted from December 2012 to November 2016. The findings of this survey should not be directly compared with those from prior reports (2005 and 2011) of BMP implementation. Those prior surveys assessed implementation of the first-generation North Carolina forestry BMP manual that was effective from its date of issue in 1989 to September 2006.

The previous survey report, published in 2011, contained several recommendations based on the findings of that survey. In the years since that report was released, the NCFS has worked to address each recommendation.

The following actions were taken to “encourage, promote, and increase technical forestry assistance and preharvest planning”:

- The NCFS has developed and released an online Forest Preharvest Planning Tool, which allows users to create maps and receive information that will help them prepare for timber harvests. The tool is free and applicable to any parcel of land in the state, providing information on soils, topography, hydrology, local NCFS contacts, and nearby threatened and endangered species. This tool has been presented to approximately 385 resource management professionals and NCFS staff; usage continued to grow during 2017.
- When properly installed on suitable sites, bridgemat stream crossings have the least amount of stream and soil disturbances, which tend to minimize risks to water quality. Since bridgemats can be expensive to initially purchase, the NCFS loans portable bridgemats to loggers for temporarily crossing streams and ditches when harvesting timber. This provides a sustainable stream crossing choice for operators in the process of saving funds to purchase their own set of mats. During the 2011-2016-time period, NCFS-loaned bridgemats were used on 267 sites, providing access to more than 12,000 acres of forestland.

- The NCFS has worked to ensure that every county in the state is served by a Water Quality Forester, an employee that is specifically assigned to address water quality concerns and provide technical assistance in a designated area. Many other NCFS employees, including Service Foresters, County Rangers, Assistant County Rangers, and other staff at the district and region level, provide BMP technical assistance and inspect sites for FPG compliance.
- In cooperation with the U.S. Forest Service, the NCFS Water Resources Branch carried out a multi-year paired watershed study examining the effects of a timber harvest on water quality and quantity in the Piedmont ecoregion. The findings did not show any pervasive or biologically significant negative impacts to water quality after two clearcut timber harvests were conducted. The findings of this study have been published in multiple peer-reviewed journals. These articles, and other related information, are available from the NCFS Water Resources Branch website at the following link: http://ncforestservice.gov/water_quality/pairedWatershed.htm.

The following actions were taken to "develop new outreach programs for forest practitioners that highlight the three-phased BMP implementation approach":

- During the 2011-2016-time period, the NCFS instructed 625 forest operators on environmental concepts of harvest planning, aesthetics, insects and disease, BMPs, and water quality regulations in North Carolina as part of the ProLogger program.
- In 2016 and 2017, the NCFS held several one-day water quality refresher meetings throughout the state. These meetings included presentations on a wide range of topics connecting forestry and water quality. Meetings have been attended by 440 people, including forest operators, private landowners, NCFS staff, and other state and federal employees.
- During the 2011-2016-time period, the NCFS staff instructed 250 N.C. State University and Wayne Community College students on BMPs, forest hydrology, and preharvest planning.
- The NCFS has provided outreach at other events, including the North Carolina State Fair, Society of American Foresters meetings, the Southern Farm Show, the Mid-Atlantic Logging & Biomass Equipment Expo, and a variety of water resource conferences.
- Multiple BMP-themed publications have been developed and distributed, including:
    - Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads (with USFS and EPA)
    - Managing Forests for Water: A Guide to Developing a Forest Watershed Management Plan.
    - Riparian & Wetland Tree Planting Pocket Guide for North Carolina
    - A series of Water Quality Forestry Leaflets that explain Forest Practice Guidelines Related to Water Quality and the state's special Riparian Buffer Rules
- Since January 2013, the NCFS has developed and distributed a quarterly BMP newsletter, which discusses topics related to the implementation of successful BMPs, such as reporting petroleum spills or protecting soil resources.

The following actions were taken to "emphasize BMP implementation in the mountainous areas of North Carolina":

- In 2014, the NCFS published a Guide for Forest Access Road Construction and Maintenance in the Southern Appalachian Mountains, and provided copies to other cooperating states in the Southern Appalachian mountain region.
- In 2017, both vacant Water Quality Forester positions in the Mountain region were filled by experienced foresters with a renewed commitment to promote BMPs.

The following actions were taken to "consider how to evaluate BMPs and potential water quality risk when there is not water in a stream/waterbody or when these hydrologic features are not in close proximity":

- In 2017, new policy and procedure guidance was provided to NCFS personnel to aid in their FPG inspections, based on cumulative experiences from across the agency.

1.2 Survey Changes and Additions

The 2011 survey recommended several changes to survey data collection. The previous report proposed: 1) using tablet computers to collect survey data, 2) collecting information on biomass harvesting, 3) conducting the survey with fewer NCFS personnel, and 4) separating the survey by ecoregions rather than NCFS regional office boundaries.

Data for this survey was collected in the field with the use of ruggedized tablet-format computers. Evaluators examined BMPs and entered data while walking around the tract or immediately upon concluding the inspection, then backed up the data to a main database upon return to the office. This approach saved time, reduced errors, and kept the data organized.

Questions regarding biomass harvesting were included in the Logging Systems category, but evaluators were not always able to verify that a site was being harvested for biomass.

To address the third recommendation, field work was conducted by a total of seven staff members of the NCFS Water Resources Branch. During this four-year survey cycle, there was turnover in staff, but cross-training and development of survey protocols that were shared by outgoing to incoming employee(s) provided a smooth transition to promote consistency and repeatability.

Finally, this survey was separated by EPA ecoregion boundaries (Omernik 1987), rather than by regional NCFS office boundaries as in previous surveys. We took this approach to organize the data in a way that could better reflect topographical and ecological differences. The use of ecoregions, which capture landscape-scale differences, allows us to better understand how those differences can affect harvest success. We used the four different Level III ecoregions within the state of North Carolina, from west to east: Blue Ridge (level III ecoregion code 66), Piedmont (45), Southeastern Plains (65), and Mid-Atlantic Coastal Plain (63). In this report, we generally refer to the Blue Ridge ecoregion as the “Mountains”, and shorten the Mid-Atlantic Coastal Plain to simply the “Coastal Plain” (see Figure 1 map).

2: Methods

2.1 Sample Size

Since BMP implementation surveys are routinely carried out in states across the southeast, the Southern Group of State Foresters (SGSF) has provided recommendations for survey methodology, to standardize results for regional comparison. To determine appropriate sample size for our survey, we used their formula:

$$n = \frac{(4p\,(100-p))}{m^2}$$

Where n = sample size; p = estimated percent implementation of BMPs statewide (85%, based on the last survey); and m = margin of error (SGSF guidance suggests using 5%, which corresponds to a 95% confidence level). This method gave us a total statewide sample size of 204.

When an evaluator found that more than one harvest activity had taken place at the same site, and if time allowed, they assessed each activity separately, splitting up the area into multiple "survey units" at the same "survey site." This occurred on six separate occasions during the survey, giving us 210 survey units on 204 survey sites. For example, if a single survey site had one area of clearcut timber harvest, and a separate area of selective timber harvest, then there would be two survey units for that one survey site.

The survey was stratified by ecoregion area as a proportion of total land area in the state. Again, we took this approach, rather than stratifying by county timber yields, to capture the effects of topography and climate on successful BMP implementation. We did not seek to stratify sample size at a county level, since a county-level analysis would require a much higher sample size (300-400 samples statewide), but we did try to complete one survey in each county, as we worked toward our goal of 204 samples statewide. In the end, we completed surveys in 94 of 100 counties, but did not complete a survey in Currituck, Dare, Mecklenburg, New Hanover, Swain, or Wilson counties. Figure 1 shows the approximate survey locations in the context of North Carolina's four ecoregions. Figure 2 shows the number of surveys conducted in each county.

Table 1. Summary of survey units by ecoregion

Ecoregion	Timeframe	Survey Units
Blue Ridge/Mountains	07/2013 - 09/2016	35
Piedmont	12/2012 – 10/2015	79
Southeastern Plains	12/2012 – 09/2015	42
Mid-Atlantic Coastal Plain	01/2013 – 11/2016	54

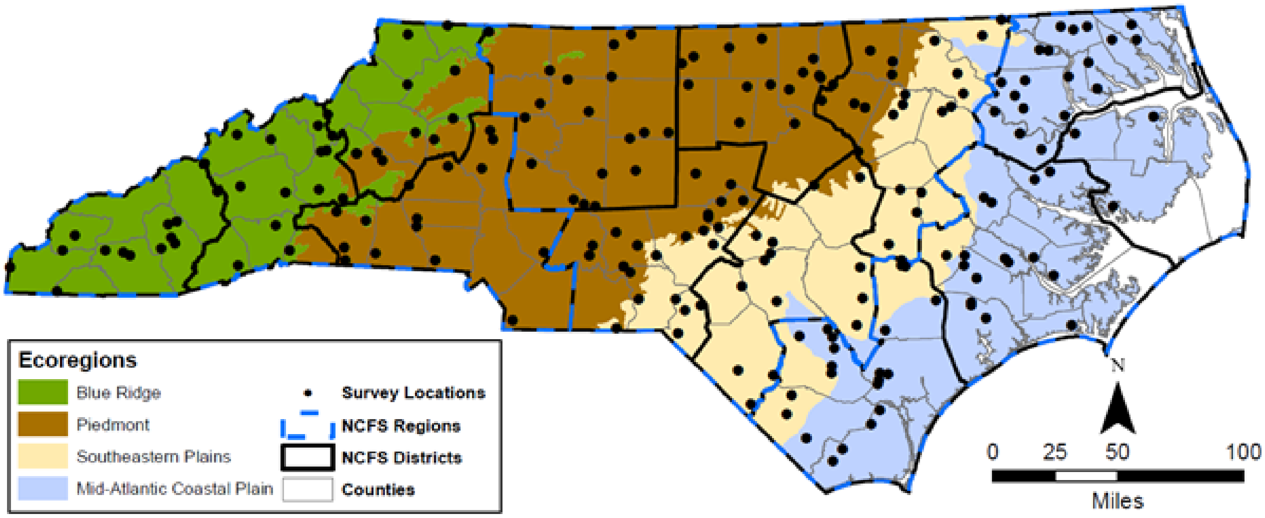


Figure 1. North Carolina ecoregions (Omernik 1987) overlaid with survey locations between 2012 and 2016, county boundaries, and North Carolina Forest Service region and district boundaries.

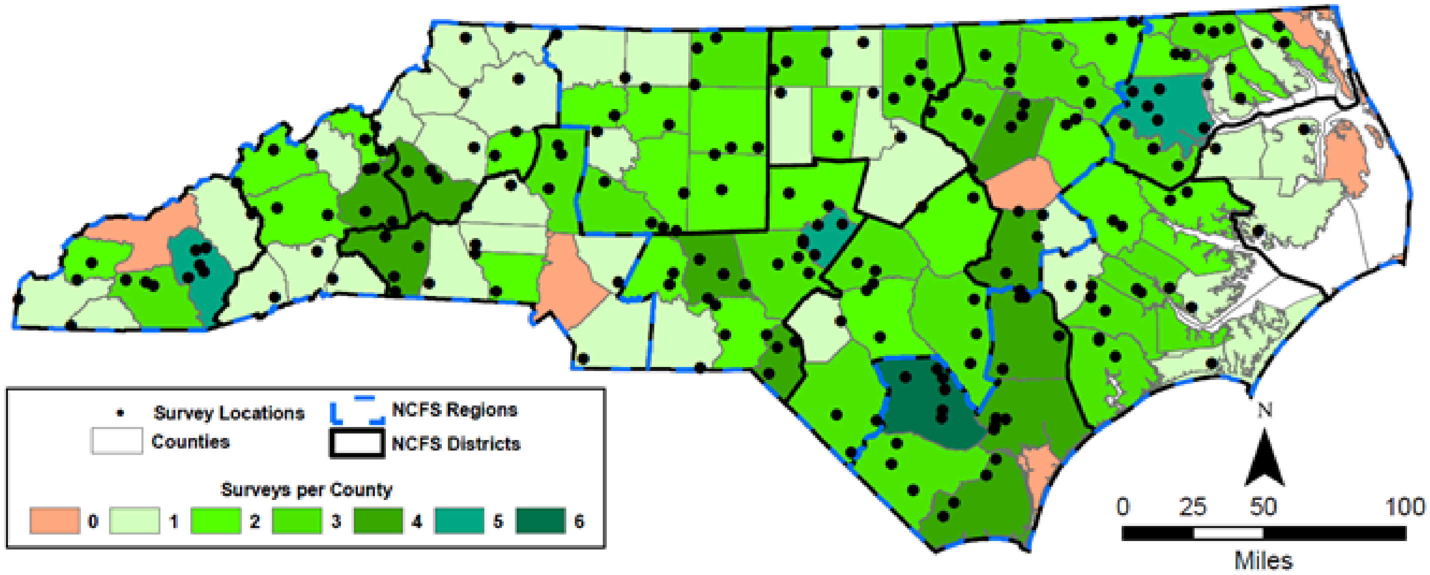


Figure 2. North Carolina counties color coded by the number of surveys collected between 2012 and 2016 and overlaid with survey locations and North Carolina Forest Service region and district boundaries.

2.2 Survey Procedure and Implementation

Before visiting forest operation sites, evaluators identified potential survey sites, prepared field maps, and noted other pertinent information, including: river basin, county, ecoregion, potential locations of streams or other surface water, and roads. Evaluators notified local NCFS staff that surveys would be taking place in their work areas, and gave them the locations of potential surveys. Often, evaluators visited the NCFS county office before completing surveys in that county, or were escorted to sites by the county staff. This approach gave evaluators additional information about each site, and kept field staff involved in the survey process. In another departure from the previous survey's methodology, evaluators included sites that were undergoing site preparation operations or had recently been completed, along with presently active harvest sites.

To locate sites, we used the online LandSat Forest Area Change Tools (then known as LandSatFACT, now known as SouthFACT), which analyze Landsat satellite imagery according to the shortwave infrared differencing (SWIR), normalized difference moisture index (NDMI), and normalized difference vegetation index (NDVI) methods. This tool collects the most recent LandSat 7 and LandSat 8 data, providing a temporal resolution of eight days. After comparing several different remote sensing analyses, we found that the SWIR analysis tended to best indicate dramatic vegetation changes between imagery collection periods. LandSatFACT supplied data that could be processed in ESRI® ArcGIS® to identify sites that had significant removals of vegetation. The NCFS does not always receive notification of forestry activities. However, satellite imagery data can help identify sites that are not captured by NCFS field staff. This new approach allowed us to quickly find potential survey sites in a way that reduced foreknowledge of BMP implementation and harvest compliance, increasing the statistical independence of the survey.

However, use of this tool has limitations. In the western, more mountainous part of the state, cloud cover was present in nearly every satellite image, which obscured ground vegetation and confounded the LandSatFACT analyses. Furthermore, while clearcuts dominate the Coastal Plain and Piedmont, it is much more common in the mountains to undertake selective timber harvests, often by removing the higher-value trees. When only part of the tree canopy is removed, remote sensing may not detect vegetation removal in the way that it would with a dramatic change like a clearcut. When searching for survey sites in the mountains, we abandoned the use of LandSatFACT, and relied on NCFS records, county staff, and incidental harvest discovery.

BMP surveys were not carried out if any of the following conditions were discovered on the site:

- Harvesting equipment posed a safety risk to evaluators, to avoid causing a safety hazard or impeding the harvest. When possible, these sites were re-visited later and surveyed.
- The operation appeared to have been completed outside of the last six months. The re-growth of vegetation and/or presence of non-forestry land uses could obscure implemented BMPs or impacts from the logging operation.
- The operation appeared to be converting the site from forestry to another type of land use.
- The site was less than five acres.

Evaluators began by recording basic characteristics, such as latitude/longitude, dominant soil texture (per NRCS Web Soil Survey), and harvest activities, then separated the tract into multiple survey units if necessary. If forest operators were present on the site, attempts were made to contact them and discuss information about harvest progress, identify landowners and timber buyers, and gain insight on implemented BMPs and potential water quality issues. When evaluators believed they had enough relevant information about the site, they observed the entire site and examined all possible BMP implementation opportunities. Whenever possible, the primary evaluator was accompanied by another NCFS staff member with knowledge of BMPs and water quality risks. This reduced safety risks, saved time and effort, and allowed for discussion of complex situations. As they walked across the site, they took photographs, created a track of GPS points, and made notes for later reference.

When evaluators encountered a BMP implementation opportunity, they determined if:

1) The BMP was properly implemented, answering “Yes” or “No.” An answer of “No” indicated either (a) an applicable BMP was not implemented at all, or (b) a BMP was implemented, but done so incorrectly.
2) A risk to water quality was present, answering “Yes” or “No.”

When assessing a risk to water quality, a “Yes” response was recorded if any of the following were observed or expected to occur:

- Visible sediment is reaching (or could potentially reach) an intermittent stream or perennial stream or perennial waterbody due to accelerated erosion (water or wind);
- Water flow and/or water quality is being inhibited or degraded by debris in an intermittent stream or perennial stream or perennial waterbody;
- Inadequate stream shading causes large fluctuations in expected stream water temperatures and/or increases expected water temperature to above water quality standards;
- Vehicle fluids, pesticides, herbicides, fertilizers, or other chemicals/wastes are reaching (or could potentially reach) an intermittent stream, perennial stream, perennial waterbody, or groundwater;
- Site activities (e.g., ditching, deep-ripping) are extensive enough that they threaten dewatering of wetlands and create potential for converting them to non-wetlands.

In summary, every BMP implementation opportunity held four possible answers:

1) “Yes,” the BMP was correctly implemented, and “No,” there was no risk to water quality.
2) “No,” the BMP was incorrectly implemented, or not implemented, and “No”, there was no risk to water quality.
3) “Yes,” the BMP was correctly implemented, and “Yes,” there was a risk to water quality.
4) “No,” the BMP was incorrectly implemented, or not implemented, and “Yes,” there was a risk to water quality.

BMP implementation summary data was generated using the following formula:

BMP Implementation Percent = (Number of Implemented BMPs / Number of Applicable BMPs) * 100

A complete list of the BMP survey questions can be found in the Appendix tables, referenced at the end of the report. The scale at which each survey question was assessed is also provided in the table. For questions designated with an “X” in the “Overall” column, that question applies to the entire survey unit, and should only be answered once per survey unit. For questions designated with “X” in the “AU” (assessment unit) column, the metric should be assessed as many times as applicable for each survey unit. For example, if there are three skid trails on a survey unit, then the questions in category SKTR ("Skid Trails") should be answered three times (one for each of the three skid trails). Note that there are also categories associated with individual runoff control BMPs (broad-based dips, water bars, cross drains, etc.). This is a change from previous surveys, in which multipart features would be assessed as whole, rather than individually. We felt that this new approach would better identify potential issues with individual assessment units and BMPs. As another example, if a SMZ went through a tract, each side of the SMZ was assessed separately. If a stream acted as the partial boundary of a tract, only the side of the SMZ that was on the tract was assessed. SMZs were also separated into multiple assessment units if there was a confluence with a tributary, or a change in stream type, or a stream crossing.

After a survey trip was completed, evaluators returned to the office and backed up the collected data, including GPS tracks, photos, and implementation data. County and district staff were notified of the sites that were visited, and of any potential FPG compliance issues that were discovered. Data was analyzed using Microsoft Excel and open-source software R©, version 3.3.2.

All photos included in this report were taken while collecting data for this survey.

2.3 Quality Assurance/Quality Control

All improperly completed survey form data was identified and filtered out of the data analyzed in this report. Multiple copies of this data have been kept in a variety of locations within internal and external hard drives, network folders, and cloud-based storage services, to prevent the loss or corruption of data.

Not all BMPs listed in the manual were observed while carrying out this survey. Of the 392 BMPs that were included in the survey, 286 were examined at least once. We only encountered 38 BMPs in the Firelines category, and 30 BMPs in the Site Prep category. Additionally, in some ecoregions, we encountered a relatively small number of BMPs for particular categories. For example, though we found almost 9,000 BMPs in the "Erosion and Runoff" category, only nine of those were found in the Coastal Plain. In some cases, these small sample sizes created wide confidence intervals. More information about sample sizes and confidence intervals can be found in Appendix B.

3: Results

3.1 Overall BMP Implementation

Evaluators assessed 28,491 BMP implementation opportunities statewide, broken-down by ecoregion here:

Mountains:	**9,671**	**SE Plains:**	**3,230**
Piedmont:	**11,206**	**Coastal Plain:**	**4,384**

There were 210 unique survey units on 204 survey sites statewide, broken down by ecoregion here:

Mountains:	**35 survey units on 35 sites**	**SE Plains:**	**42 survey units on 41 sites**
Piedmont:	**79 survey units on 75 sites**	**Coastal Plain:**	**54 survey units on 53 sites**

Assessment questions were consolidated into the following categories for presentation in this report, corresponding with the categories outlined in the SGSF survey protocol:

- Harvesting
    - Capturing Runoff and Sediment
    - Decks
    - Logging Systems
    - Rehabilitation of the Project Site
    - Skid Trails
    - Wetlands
- Forest Roads
- Stream Crossings
- Streamside Management Zones (SMZs)
- Site Preparation and Reforestation
- Chemical Application
- Fire Management

Key Findings:

- Overall BMP Implementation was 84 percent statewide, 82 percent in the Mountains, 87 percent in the Piedmont, 79 percent in the Southeastern Plains, and 84 percent in the Coastal Plain.
- A total of 28,491 applicable BMPs were assessed statewide, with 84 percent implementation. Conversely, we observed 4,584 individual (applicable) BMPs as either not applied or improperly applied. Broken down by ecoregion:
    - Mountains: 9,671 total BMPs, with 82 percent implementation, and 1,733 BMPs not applied correctly
    - Piedmont: 11,206 total BMPs, with 87 percent implementation, and 1,462 BMPs not applied correctly
    - Southeastern Plains: 3,230 total BMPs, with 79 percent implementation, and 691 BMPs not applied correctly
    - Coastal Plain: 4,384 total BMPs, with 84 percent implementation, and 698 BMPs not applied correctly
- When BMPs were properly implemented, there was no risk to water quality in nearly every case.
- When BMPs were not implemented, or implemented improperly, it resulted in a risk to water quality in 30 percent of the BMP observations.
- Statewide, 74 percent of all risks to water quality were found in the Rehabilitation, SMZs, and Stream Crossings categories.
- Perennial or intermittent streams were observed in the survey unit on 67 percent of the surveyed sites.

Table 2. Overall Percent Implementation of BMPs by BMP Category and Region

BMP Category	BMP Implementation					Properly Implemented & NO RISK to Water Quality					Improperly Implemented BMP & RISK to Water Quality				
	S	M	P	SP	C	S	M	P	SP	C	S	M	P	SP	C
	--%--														
Overall	84	82	87	79	84	100	100	100	99	100	30	24	36	31	31
Harvesting: Capturing Sediment and Runoff	87	87	89	75	89	100	100	100	100	100	13	11	15	32	100
Harvesting: Decks	90	83	93	92	90	100	99	100	100	100	1	24	4	0	6
Harvesting: Logging Systems	86	89	93	90	72	100	100	100	99	100	24	44	27	0	24
Harvesting: Rehabilitation of the Project Site	71	53	70	60	83	99	98	98	96	100	54	40	66	70	47
Harvesting: Skid Trails	79	70	82	78	86	100	100	100	100	100	12	8	18	10	17
Harvesting: Wetlands	64	N/A	71	66	58	100	N/A	100	100	100	22	N/A	42	20	20
Chemicals, Fluids, and Solid Waste	77	71	82	76	68	100	100	99	100	100	6	0	7	5	10
Firelines	84	N/A	71	100	N/A	100	100	100	100	100	0	N/A	0	N/A	N/A
Roads and Access	85	89	86	85	76	100	100	100	100	100	14	27	16	6	10
Site Preparation and Reforestation	97	N/A	86	100	100	100	N/A	100	100	100	0	N/A	0	N/A	N/A
Stream Crossings	79	75	78	72	83	100	100	100	99	100	64	76	63	67	54
Streamside Management Zones (SMZs)	86	72	91	77	87	100	100	100	99	100	49	63	54	41	34
	Higher % is Optimal					*Higher % is Optimal*					*Lower % is Optimal*				

S: Statewide, M: Mountains, P: Piedmont, SP: Southeastern Plains, C: Coastal Plain

When BMPs were properly implemented, there were no risks to water quality in almost all cases statewide. On the other hand, a failure to properly implement BMPs led to a risk to water quality in more than half of the observed cases, for some categories. These results demonstrate the importance of BMP implementation on logging sites.

Some BMP categories were not observed throughout an entire ecoregion. Those instances are marked with "N/A" in Table 2. See Appendix B for more information on sample sizes and confidence intervals for this category.

3.2 Implementation of BMPs by Category

3.2.1: Harvesting: Controlling Runoff and Capturing Sediment

The BMPs evaluated in this category are the fundamental elements of erosion and sedimentation control that are frequently applicable on nearly every forestry operation. The key focus is to 'slow it down and spread it out', when thinking about soil movement and reducing the potential for sedimentation into waterways. The BMPs included in this section are those outlined in the North Carolina Forestry BMP Manual:

BMPs to Control Runoff:	BMPs to Capture Sediment
• Broad Based Dip	• Filter Area
• Turnout	• Silt Fence
• Cross Drain	• Brush Barrier
• Waterbar	• Sediment Pit / Trap
• Inside Ditchline	• Straw Bale
• Insloping, Outsloping, Crowning of road surface	• Check Dam

Statewide, there were 8,344 BMPs for controlling runoff assessed, with 87 percent overall statewide implementation, and 567 BMPs for capturing sediment assessed, with 82 percent overall statewide implementation.

There were 1,039 BMPs for controlling runoff and 100 BMPs for capturing sediment observed as not being properly applied. The break-down by ecoregion is below:

Table 3. Implementation of BMPs for Controlling Runoff by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	8,344	87	1,039
Mountains	5,772	87	759
Piedmont	2,485	90	256
SE Plains	85	73	23
Coastal Plain	2	50	1

Table 4. Implementation of BMPs for Capturing Sediment by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	567	82	100
Mountains	395	89	45
Piedmont	151	70	46
SE Plains	14	86	2
Coastal Plain	7	100	7

Key Findings and Discussion:

- When BMPs for controlling runoff and capturing sediment were properly implemented statewide, there was no risk to water quality nearly 100 percent of the time. When these BMPs were not implemented, there was a risk to water quality 13 percent of the time.
- While most of these BMPs were implemented in the Mountains and Piedmont, there were some situations observed in the Southeastern Plains in which improper BMP usage resulted in a risk to water quality. The BMP deficiencies noted in this region were associated with the spacing, design, and construction of water diversions. It is often taken for

granted that the relatively flat terrain of the Southeastern Plains may not cause much erosion or sedimentation concern. However, it may be warranted to focus attention on these BMPs for loggers who operate in this region, since they do not frequently use these BMPs, and therefore may not be familiar with the details of proper implementation.
- Overall implementation of erosion and sediment control BMPs was high across the state, but some aspects of installation and maintenance require attention to make sure the BMP functions as intended.

Areas for Improvement:

When evaluating the 92 BMPs for controlling runoff and capturing sediment, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Broad-based dips:
  - Situate the broad-based dip outlet in a manner that prevents runoff from flowing directly into streams or waterbodies (Mountains and Piedmont).
  - Construct and compact a slight hump across the downhill edge of the broad-based dip (Mountains).
- Turnouts:
  - Excavate the turnout with enough outlet gradient angle so runoff can drain in a controlled manner, generally from 1 to 3 percent is adequate (Southeastern Plains).
  - Situate turnout outlet in a manner that prevents runoff from flowing directly into streams or waterbodies (Mountains, Piedmont, and Southeastern Plains).
  - Capture the sediment below the turnout outlet as needed (Mountains, Piedmont, and Southeastern Plains).
- Waterbars:
  - Excavate and construct using equipment/techniques that assure proper angles and a firm waterbar hump (Mountains).
  - Situate waterbar outlet in a manner that prevents runoff from flowing directly into streams or waterbodies (Mountains and Piedmont).
  - Capture the sediment below the outlet as needed (Mountains and Piedmont).
  - Avoid siting the outlet onto soft soil or fill material, unless other BMPs are utilized to prevent erosion (Piedmont).

Photo 1. Though equipment traffic over this wet soil has the potential to cause rutting, the operator installed periodic turnouts on this skid trail to capture runoff, as seen on the right side of the skid trail.

Photo 2. The practice seen in this photo of covering bare soil with logging debris substantially reduces erosion and prevents sediment and runoff from reaching waterbodies.

Photo 3. At this site, the forest operator placed logging debris along the edge of a skid trail to prevent sediment from traveling downslope. However, sediment movement could be prevented further by placing some of that debris atop of the skid trail itself.

3.2.2: Harvesting: Decks

Statewide, there were 2,039 BMPs assessed for decks, including 374 in the Mountains, 783 in the Piedmont, 403 in the Southeastern Plains, and 479 in the Coastal Plain.

Table 5. Implementation of BMPs for Decks by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	2,039	90	195
Mountains	374	83	63
Piedmont	783	93	52
Southeastern Plains	403	92	31
Coastal Plain	479	90	49

Key Findings and Discussion:

- When BMPs for decks were properly implemented statewide, there was no risk to water quality nearly 100 percent of the time. When these BMPs were not implemented, there was a risk to water quality 1 percent of the time.
- Log decks generally were seen on stable, flat sites and were kept the minimum size and number needed to harvest the timber.

Areas for Improvement:

When evaluating the 10 BMPs for decks, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Establish deck at locations where soil disturbance is minimized. (Mountains).
- Situate deck outside ephemeral drainages. (Mountains).
- Situate deck outside SMZ. (Mountains, Piedmont, and Coastal Plain).
- Select side-ridge location if steep terrain is unavoidable and use additional BMPs as needed. (Mountains).
- Install sufficient erosion control measures to control runoff and capture sediment. (Mountains).

Photo 4. On this site in the Mountains, the deck is situated on a flat area near the top of a ridge, and a brush barrier on the right side of the picture helps to prevent sediment from traveling downslope into a ravine. However, more logging debris could be placed on the deck and the skid trail in the background, to further limit soil disturbance and erosion.

Photo 5. This deck was used for a timber harvest that utilized an in-woods whole tree chipper. The wood chips are scattered across the deck sufficiently to stabilize the flat ground and provide groundcover. Note the clean appearance of the deck, with most woody material having been utilized. Such thorough utilization of the timber can reduce the need for site preparation and associated costs for reforestation.

3.2.3: Harvesting: Logging Systems

Statewide, there were 522 BMPs assessed for logging systems, including 84 in the Mountains, 203 in the Piedmont, 105 in the Southeastern Plains, and 130 in the Coastal Plain.

Table 6. Implementation of BMPs for Logging Systems by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	522	86	72
Mountains	84	89	9
Piedmont	203	93	15
SE Plains	105	90	11
Coastal Plain	130	72	37

Key Findings:

- When the six BMPs for logging systems were properly implemented statewide, there was no risk to water quality in nearly every observed case. When these BMPs were not implemented, there was a risk to water quality 24 percent of the time.
- Operators working in steep terrain should consider slope aspect, recent rainfall, and soil conditions before installing skid trails, decks, and other features that may disturb soil, particularly when these features are in unfavorable locations.
- Cease operating when machine travel creates deep rutting due to wet ground. This can reduce erosion potential and protect future site productivity.
- Rutting and soil compaction can reduce future site productivity if natural or artificial ameliorative mechanisms are not present or implemented.

Areas for Improvement:

When evaluating BMPs for logging systems during this survey, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Cease operations when inclement weather and/or wet site conditions persist (Mountains and Piedmont).
- Harvest timber in a manner that minimizes significant changes to soil structure or organic matter (Coastal Plain).

Photo 6. Water is standing in the main skid trails on this harvested site. While the soil in the primary skid trails may exhibit signs of compaction, soil disturbance on the overall tract was minimized by concentrating skidding on the main skid trails and avoiding widespread, randomized skidding.

3.2.4: Harvesting: Rehabilitation of Project Site

Statewide, there were 954 BMPs assessed for rehab, including 189 in the Mountains, 301 in the Piedmont, 92 in the Southeastern Plains, and 372 in the Coastal Plain.

Table 7. Implementation of BMPs for Rehab by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	954	71	279
Mountains	189	53	88
Piedmont	301	70	90
Southeastern Plains	92	60	37
Coastal Plain	372	83	64

Key Findings:

- When BMPs for rehab were properly implemented statewide, there was no risk to water quality 99 percent of the time. When these BMPs were not implemented, there was a risk to water quality 54 percent of the time.
- Site rehabilitation is vital to bring a final resolution to the disturbance on the site that resulted from a timber harvest or other forestry operation. The BMPs in this category are fairly straightforward and simple to implement. The key to success appears to be the timing and extent of BMP application. In other words, the BMPs need to be deployed sooner, more often, and across a wider area of a job site.

Areas for Improvement:

When evaluating the 17 BMPs for rehab during this survey, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Remove debris from the stream channel (statewide).
- Re-contour the streambank edges and approachways to resemble natural conditions pre-installation (statewide).
- Install BMPs to control, divert, and/or capture runoff/sediment along approaches – preventing entry to stream (statewide).
- If temporary, remove the stream crossing itself (statewide).

Photo 7. Skid trails are stabilized with ample groundcover vegetation.

Photo 8. This roadway through a SMZ has new vegetation emerging that will stabilize the soil.

Photo 9. Stream crossing that was removed and still in need of BMP stabilization.

Photo 10. A properly stabilized stream crossing with ground vegetation established and water diversions installed.

3.2.5: Harvesting: Skid Trails

Statewide, there were 4,383 BMPs assessed for skid trails, including 1,288 in the Mountains, 1,378 in the Piedmont, 629 in the Southeastern Plains, and 1,088 in the Coastal Plain.

Table 8. Implementation of BMPs for Skid Trails by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	4,383	79	922
Mountains	1,288	70	388
Piedmont	1,378	82	250
Southeastern Plains	629	78	137
Coastal Plain	1,088	86	147

Key Findings:

- BMP implementation for skid trails was 79 percent statewide, 70 percent in the mountains, 82 percent in the Piedmont, 78 percent in the Southeastern Plains, and 86 percent in the Coastal Plain.
- When BMPs for skid trails were properly implemented statewide, there was no risk to water quality in nearly every case. When these BMPs were not implemented, there was a risk to water quality 12 percent of the time.

Areas for Improvement:

When evaluating the nine BMPs for skid trails during this survey, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Establish skid trails along land contours and keep slopes at less than a 25 percent grade (Piedmont).
- Install waterbars, brush barriers, turnouts, or use other methods as needed (Southeastern Plains).
- Concentrate skidding on as few skid trails as needed (Mountains).

Risks resulted from unnecessary skid trails, inadequate methods to capture runoff, and the placement of skid trails on steep slopes or within ephemeral drainages. Proper preharvest planning can help to establish an efficient and concise skid trail network. Covering skid trails with logging debris (treetops, branches, limbs), as the operation is ongoing, is a simple but effective method to prevent soil disturbance and manage runoff.

Photo 11. This main skid trail has ample logging slash (laps) applied atop of the ground surface. When applied at the onset of the harvest, and frequently added to, this material provides instant groundcover protection of exposed soil and reduces impacts to the soil.

Photo 12. This skid trail generally follows the contours of the land, which helps to limit the slope of any skid trail segments. However, the leftover logging debris could be placed on top of the trail to prevent erosion and runoff.

3.2.6: Harvesting: Wetlands

Statewide, there were 323 BMPs assessed for wetlands, including none in the Mountains, 42 in the Piedmont, 161 in the Southeastern Plains, and 120 in the Coastal Plain.

Table 9. Implementation of BMPs for Wetlands by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	323	65	112
Mountains	0	N/A	N/A
Piedmont	42	71	12
Southeastern Plains	161	66	55
Coastal Plain	120	58	45

Key Findings:

- Harvesting timber in wetlands can be done sustainably, but it requires careful attention to avoid damaging the site with equipment or negatively impacting water quality. This category saw the lowest BMP implementation rate, though some BMPs were observed only a handful of times.
- BMP implementation for wetlands was 64 percent statewide, 71 percent in the Piedmont, 66 percent in the Southeastern Plains, and 58 percent in the Coastal Plain.
- When BMPs for wetlands were properly implemented statewide, there was no risk to water quality in nearly every case. When these BMPs were not implemented, there was a risk to water quality 22 percent of the time.
- It should be noted that the recommended BMPs outlined for wetlands are supplemental and are not necessarily required for complying with the silvicultural exemptions provided in Section 404 of the Clean Water Act. The federally-mandated 15 BMPs for forest roads [as found in 33 CFR Part 323.4(a)(6)]; and the six BMPs for mechanical site prep (as found in the US-EPA / US-ACE November 28, 1995 joint memo to the field) are the baseline requirements, and were not assessed in this BMP survey. Those federally-directed BMPs come under the authority of U.S. Army Corps of Engineers.

Areas for Improvement:

When evaluating the 45 BMPs for wetlands during this survey, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Minimize heavy equipment use along the edge of ditches (Southeastern Plains and Coastal Plain).
- Rehabilitate areas of significant soil disturbance (Piedmont and Southeastern Plains).
- On frequently used roads, apply gravel or other suitable stabilizing material on areas where erosion and sedimentation may occur (Coastal Plain).

3.2.7: Forest Roads

Statewide, there were 1,228 BMPs assessed for logging roads, including 237 in the Mountains, 569 in the Piedmont, 217 in the Southeastern Plains, and 205 in the Coastal Plain.

Table 10. Implementation of BMPs for Forest Roads by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	1,228	85	185
Mountains	237	89	26
Piedmont	569	86	77
Southeastern Plains	217	85	33
Coastal Plain	205	76	49

Key Findings:

- BMP implementation for roads was 85 percent statewide, 89 percent in the mountains, 86 percent in the Piedmont, 85 percent in the Southeastern Plains, and 76 percent in the Coastal Plain.
- When BMPs for roads were properly implemented statewide, there was no risk to water quality in nearly every case. When these BMPs were not implemented, there was a risk to water quality 14 percent of the time.

Areas for Improvement:

When evaluating the 34 BMPs for roads during this survey, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Minimize soil disturbance and the amount of road at any stream crossing (Mountains, Piedmont, Southeastern Plains).
- Stabilize bare soil areas using suitable techniques (Mountains).
- Install diversion or other structures to control and capture runoff (Mountains).
- Minimize the number of stream crossings. Avoid stream crossings (Coastal Plain).
- Construct road to drain naturally - not into streams or waterbodies (Piedmont).

Photo 13. This cross drain collects runoff from an inside ditchline into a small pipe. The pipe runs under the road, and a brush barrier is placed under the outlet. Additionally, because the road is constructed with an inslope, water running off the road surface flows into the ditchline, and then into the cross drain. These cross drains were placed periodically down the length of the road, to prevent runoff from accumulating and overwhelming a single drain. The ditchline in this photo needed stabilization work to reduce erosion and sedimentation.

Photo 14. Example of a switchback on a steep mountain road. Gravel was applied to stabilize the surface. Additional BMP work should occur on the exposed soil of the cut banks.

Photo 15. A well-maintained forest road. A shallow broad-based dip or similar water diversion is visible near the top of road. On sloping sections of road, it is important to frequently install diversions to control runoff and capture sediment before it can reach a waterway.

3.2.8: Stream Crossings

Statewide, there were 2,948 BMPs assessed for stream crossings, including 561 in the Mountains, 1,235 in the Piedmont, 202 in the Southeastern Plains, and 950 in the Coastal Plain. There were 510 BMPs assessed for bridgemats, 541 BMPs assessed for culvert crossings, 118 BMPs assessed for ford crossings, and 102 BMPs assessed for pole crossings.

Table 11. Implementation of General BMPs for Stream Crossings by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	2,948	79	631
Mountains	561	75	140
Piedmont	1,235	78	271
Southeastern Plains	202	72	57
Coastal Plain	950	83	163

Key Findings:

- Statewide BMP implementation was 92 percent for bridgemats, 83 percent for culverts, 53 percent for fords, and 43 percent for poles.
- When the 47 BMPs for stream crossings were properly implemented statewide, there was no risk to water quality nearly 100 percent of the time. When these BMPs were not implemented, there was a risk to water quality 64 percent of the time. This risk value is the highest of any category of BMPs.
- Of the four stream crossing types that we examined, bridgemats were the most commonly used, and caused risks to water quality at the lowest frequency. Fords and poles caused risks to water quality in more than 75 percent of observed cases.
- In cases when bridgemats are not available, or are not a suitable stream crossing option, critical care must be taken to properly implement BMPs. Even when bridgemats are used, they must be installed correctly to avoid gaps between the panels, and removed in a manner to minimize disturbance to the stream channel.

Areas for Improvement:

For almost every stream crossing BMP, risks to water quality were high when BMPs failed to be properly implemented. However, a particular risk was associated with the following BMPs when not properly implemented:

- Minimize alteration of stream depth, width, gradient, and capacity (statewide).
- Rehabilitate crossing area as soon as possible (statewide).
- Select a stream crossing location that has solid footing to support bridgemats and equipment (Piedmont and Southeastern Plains).
- Protect the inlet/outlet of the culvert/fill material with suitable stabilization measures (statewide).
- Do not use ford crossings as part of the skid trail network. Use ford crossings only for truck access (statewide).

The findings of the survey further demonstrate that stream crossings are a critical location during a timber harvest for water quality impacts to potentially occur. Many of the issues that we found could have likely been avoided by following the general guidelines: avoid having to cross streams; if necessary, minimize the number of crossing; and select a crossing type that best fits the natural stream channel. When stream crossings were conducted correctly, we found very few risks to water quality.

Ford and pole crossings should be avoided. There are some situations where these crossings would be suitable, but they lend themselves to enhanced water quality risks when they are poorly installed. Ford crossings should not be used for any reason on skid trails, since the regular traffic from muddy tires and dragged timber is certain to disturb banks and move sediment into the stream. North Carolina's forestry BMP manual specifically notes that "fords are not recommended for use on skid trail crossings."

Table 12. Stream crossing types by ecoregion				
Stream crossing type	Mountains	Piedmont	SE Plains	Mid-Atlantic Coastal Plain
Bridgemat	4	38	4	67
Culvert	26	35	3	5
Ford	6	7	1	5
Pole	0	10	3	3
Total	**36**	**90**	**11**	**80**

Table 13. Stream Crossing Types that Posed a Risk to Water Quality			
Stream crossing type	Stream Crossings Assessed	Risk to WQ	Frequency of Risk to WQ
Bridgemat	113	22	19%
Culvert	63	23	37%
Ford	19	15	79%
Pole	16	12	75%

Table 14. Stream Crossings in Buffer Rule Areas				
Basin Type	Survey Units	Stream Crossing BMPs Assessed #	Stream Crossing BMP Implementation (Percent)	Improperly Implemented BMP & RISK to WQ (Percent)
Buffer Rule	45	451	80	60%
Other	165	2,497	78	65%

Photo 16. This culvert headwall was well stabilized, and the culvert appears large enough to handle water flow. Vegetation has been maintained on the streambanks and above the culvert, and the road above the crossing receives plenty of daylight, all measures that can help to limit erosion.

Photo 17. Though the use of bridgemats is recommended, they must be used correctly. Bridgemats must be tightly bunched together to limit gaps between them as much as possible. In the current arrangement, sediment can wash through the gaps between the mats, and enter the stream.

Photo 18. This is a relatively well-constructed ford crossing. The wide, stable rocky streambed and gentle approach make this a favorable location for a ford. On this harvest, the ford crossing was only used for truck access and not for skidding.

Photo 19. On this crossing in the Coastal Plain, it appears that skidders traveled directly through the waterway, disturbing the banks, and dragging sediment and debris into the waterway. This was characterized as a ford crossing by our evaluators. Fords should not be used on skid trails. A bridgemat would have likely been the best option in this example, or perhaps a temporary culvert crossing.

3.2.9: Streamside Management Zones (SMZs)

Statewide, there were 6,668 BMPs assessed for streamside management zones, including 694 in the Mountains, 3,802 in the Piedmont, 1,225 in the Southeastern Plains, and 947 in the Coastal Plain.

Table 15. Implementation of BMPs for Streamside Management Zones by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	6,688	86	940
Mountains	694	72	193
Piedmont	3,802	91	341
Southeastern Plains	1,225	77	285
Coastal Plain	947	87	121

Key Findings:

- When BMPs for SMZs were properly implemented statewide, there was no risk to water quality in nearly every case. When these BMPs were not implemented, there was a risk to water quality 49 percent of the time.
- Wider SMZs tended to prevent risks to water quality. For any class of stream, in any ecoregion, successful SMZs were wider on average than those SMZs where a risk to water quality was observed.
- SMZs were, on average, widest in the mountains and on perennial streams.
- When SMZ width was less than 10 feet, risks to water quality were found 21 percent of the time. However, those risks fell to just 4 percent at SMZ widths greater than 30 feet.

Areas for Improvement:

When evaluating the 25 BMPs for SMZs during this survey, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Avoid roads, skid trails, decks, and portable sawmills inside the SMZ (Mountains).
- Limit heavy equipment use within 10 feet of the edges of streams and waterbodies (Mountains, Piedmont, and Southeastern Plains).
- Maintain approximately half of the pre-harvest vegetative canopy cover within the SMZ (statewide).
- Minimize disturbance to the mid-level and understory if removing significant overstory (Mountains, Piedmont, and Southeastern Plains).
- Avoid gouging the soil in a manner that could funnel runoff and transport sediment to the waterbodies (Mountains, Piedmont, and Southeastern Plains).
- Fell and remove trees away from the stream or waterbody (Mountains, Piedmont, and SE Plains).
- Keep logging debris out of stream or remove promptly if introduced when operating in the SMZ, not at a crossing (statewide).

Table 16. Average SMZ Width (ft.) by Region and Stream Type -- Risk or No Risk to Water Quality				
Region	Perennial Streams		Intermittent Streams	
	No Risk	Risk	No Risk	Risk
	--feet--			
Statewide	29	11	20	14
Mountains	45	9	31	19
Piedmont	29	14	22	17
SE Plains	21	3	14	5
Coastal Plain	25	NA	12	5

Table 17. Risk to water quality by SMZ width class			
SMZ Width class (ft.)	SMZs Assessed	Risk to WQ	Frequency of Risk to WQ
0-10	191	41	21%
11-30	282	38	13%
31-50	53	2	4%
>50	45	2	4%

Table 18. SMZs in Buffer Rule Areas						
	Survey Units	SMZ BMPs Assessed (#)	SMZ BMP Implementation (Percent)	Improperly Implemented BMP & RISK to WQ (Percent)	Avg. SMZ width (ft.): NO RISK to WQ	Avg. SMZ width (ft.): RISK to WQ
Buffer Rule	45	2,000	92	34	24	19
Other	165	4,657	83	52	25	11

Figure 3. Model of the probability of a risk to water quality as a function of SMZ width on perennial streams and intermittent streams, by ecoregion, with 95 percent confidence interval.

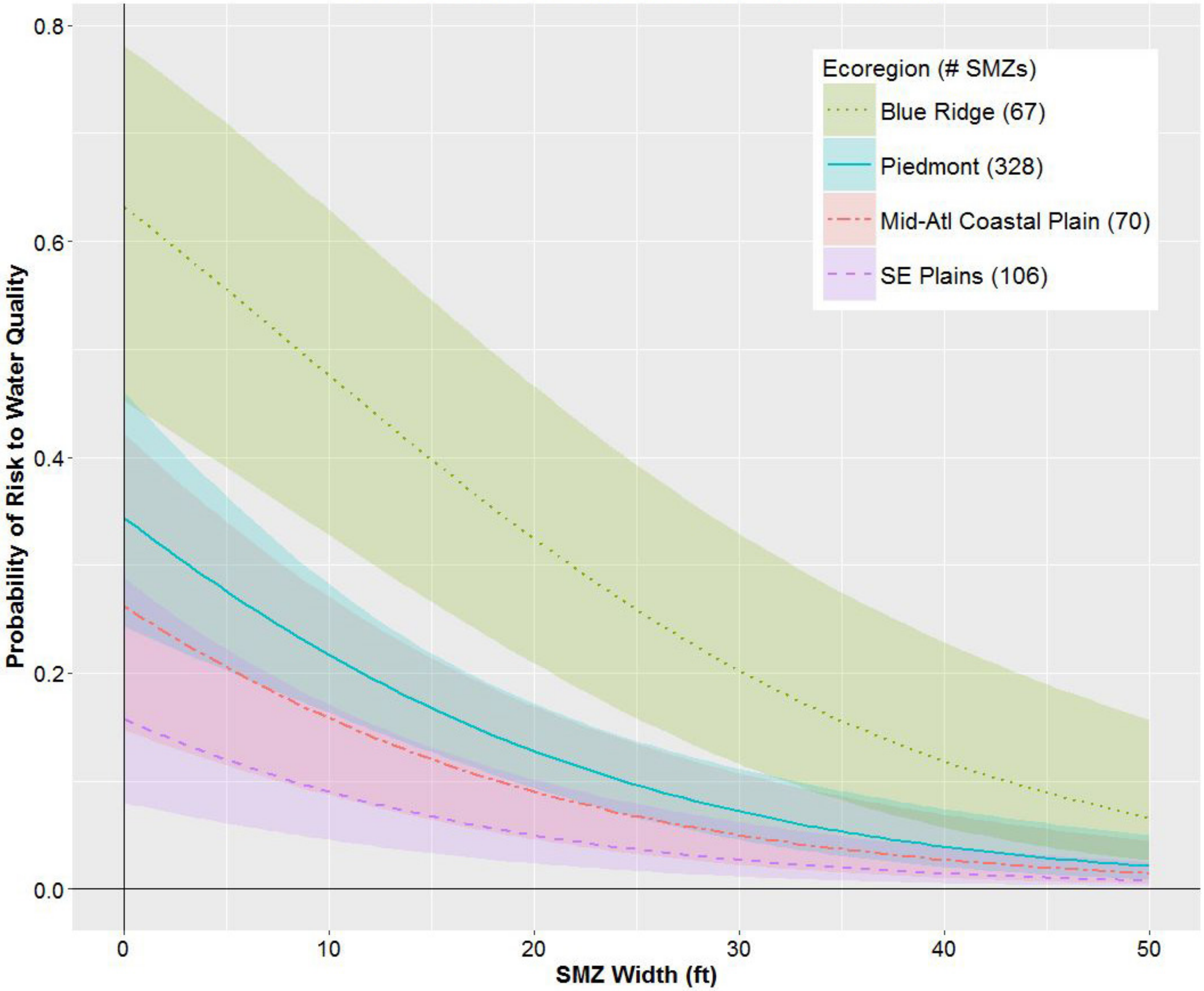


Figure 3 shows the predicted probability of a risk to water quality for each ecoregion by SMZ width, with a 95 percent confidence interval. A logistic regression model was used on our dataset of 571 SMZ widths. SMZ widths (independent variable) were used to predict the presence of a risk to water quality ("Yes" or "No;" dependent variable). In our data, wider SMZs tended to be associated with fewer risks to water quality. The chi-squared test statistic of 11.6, with one degree of freedom indicates that the overall effect of SMZ width on the probability of a risk to water quality is statistically significant ($p < 0.001$). The Mountains ecoregion has a higher probability of a water quality risk than all other ecoregions, but follows a similar inversely correlated trend (i.e., less water quality risk with wider SMZ width). Confidence intervals of the other three ecoregions overlap. The probability of a risk to water quality falls below 10 percent with SMZ widths greater than 8 feet in the Southeastern Plains, 19 feet in the Mid-Atlantic Coastal Plain, 25 feet in the Piedmont, and 43 feet in the Mountains. When a SMZ is 50 feet wide, our data suggest the probability of a risk is minimal in any ecoregion. This figure supports North Carolina's general BMP recommendation of 50 feet for a SMZ, however it should be noted that some SMZ widths less than 50 feet were found to have no risks to water quality. Therefore, this model should not be used as an exact prescription or endorsement of a specific width, particularly since failures can occur at any width. Each SMZ is unique, and may be subject to regulations requiring a certain width and/or other multiple-use objectives of the landowner.

Photo 20. A SMZ with no timber removed from within it.

Photo 21. A SMZ that has had timber removed, but minimal disturbance to the soil or streambank.

Photo 22. The forest operators installed a silt fence next to this skid trail and planted grass on the side of the trail, to prevent sediment from washing off the trail and into the SMZ. Timber was cut and removed with minimal disturbance. While this SMZ is relatively narrow, the additional BMPs that were implemented prevented visible sediment from reaching the stream.

3.2.10: Site Preparation and Reforestation

While this survey primarily focused on timber harvesting operations, some BMPs were assessed for site preparation as the opportunities arose. The majority of BMPs in this category center around 'mechanical' site prep practices, which involve the movement and consolidation of leftover logging debris and/or the tillage of soil to prepare it for reforestation. Statewide, there were 30 BMPs assessed for site preparation and reforestation, including none in the Mountains, 7 in the Piedmont, 1 in the Southeastern Plains, and 22 in the Coastal Plain.

Table 19. Implementation of BMPs for Site Prep by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	30	97	1
Mountains	0	N/A	N/A
Piedmont	7	86	1
Southeastern Plains	1	100	0
Coastal Plain	22	100	0

Key Findings:

- BMP implementation for site preparation and reforestation was 97 percent statewide, 86 percent in the Piedmont, 100 percent in the Southeastern Plains, and 100 percent in the Coastal Plain. No BMPs for site preparation and reforestation were observed in the Mountains.
- When the 35 BMPs for site preparation and reforestation were properly implemented statewide, there were no risks to water quality in the cases we observed.
- The only improperly implemented BMP was "Set windrows along the land's topographic contour." In this instance, there was no risk to water quality.

An observational note:

The main purpose of mechanical site prep in the Mountains and Piedmont is to knock down small unmerchantable trees and/or to consolidate leftover logging debris for re-planting new seedlings on the tract afterwards. In the Southeastern Plains and Coastal Plain, mechanical site prep for soil tillage is often needed to properly aerate the soil so that new seedlings can survive the inherently wetter terrain.

It has been the observation of NCFS staff that, under certain circumstances, the need for mechanical site prep in some areas (which do not require soil tillage) can be greatly reduced or eliminated altogether, thereby eliminating a secondary site disturbance and its associated potential to create risks to water quality.

Observations indicate that mechanical site prep is usually not necessary when a timber harvesting operation is conducted with the use of an in-woods chipper that can utilize nearly all woody material that otherwise would have been left over from the logging. The ability to utilize nearly all trees results in a cleanly-harvested site that can be promptly replanted with seedlings, as seen in Photo 5.

In addition, the need for mechanical site prep can be reduced when small to medium sized logging debris is used as a BMP stabilization material, and applied atop of skid trails and log decks. When logging slash is repeatedly spread atop of skid trails and decks, the soil is well-protected from accelerated erosion. This method of BMP stabilization has proven to be nearly as effective as other more labor-intensive BMPs, as demonstrated in research trials conducted in the foothills and piedmont regions of Virginia (Wade et al. 2012; Sawyers et al. 2012; Wear et al. 2013).

3.2.11: Chemical Application

The BMPs for this category are basic elements of protecting water quality from pollution.

Table 20. Implementation of BMPs for Chemical Application by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	447	77	103
Mountains	77	71	22
Piedmont	229	82	42
Southeastern Plains	79	76	19
Coastal Plain	62	68	20

Key Findings and Discussion:

- When BMPs for chemicals, fluids, and solid waste were properly implemented statewide, there was no risk to water quality in nearly every observed case. When these BMPs were not implemented, there was a risk to water quality 6 percent of the time.
- Even though the risk to water quality was low in this category, the poor management of waste containers and petroleum products is often why logging has a negative public perception. Taking time to pick up trash, manage fluid containers, and promptly fix equipment leaks can go a long way to maintain a professional image.

Areas for Improvement:

When evaluating the 26 BMPs for chemicals, fluids, and solid waste during this survey, a risk to water quality was most frequently observed when the following BMPs were not implemented in specific regions of the state:

- Equipment, vehicles, and machinery free of leaking fluids. No stains on the ground that indicate a leak (Piedmont, Southeastern Plains, and Coastal Plain).
- Service equipment in a way that minimizes potential for fluids to enter waterbodies or the groundwater (Piedmont and Coastal Plain).

Photo 23. Though chemicals and fluids at this site are sealed in containers, some are tipped over, which creates a risk for chemicals to spill and eventually seep into groundwater or flow into streams. Leaving this type of trash on the site also diminishes the professionalism perception of logging and forestry in general.

3.2.12: Fire Management

Statewide, 38 BMPs were assessed for fire management, including 21 in the Piedmont and 17 in the Southeastern Plains.

Table 21. Implementation of BMPs for Fire Management by Region

Region	# BMPs Assessed	% BMP Implementation	# BMPs Not Implemented
State Total	38	84	6
Mountains	0	N/A	N/A
Piedmont	21	71	6
Southeastern Plains	17	100	0
Coastal Plain	0	N/A	N/A

Key Findings:

- BMP implementation for fire management was 84 percent statewide, 71 percent in the Piedmont, and 100 percent in the Southeastern Plains.
- When the 24 BMPs for fire management were properly implemented statewide, there was no risk to water quality in nearly every observed case. When these BMPs were not implemented, there was no risk to water quality observed.
- The most notable BMP deficiencies were related to minimizing the overall depth and soil disturbance of firelines, especially when installed by fireplow or dozer blade. Firelines require erosion and sedimentation control. While effort to contain, control, and suppress wildfires must take precedent to protect life and property, the BMP rehabilitation after the wildfire remains an important step in the overall scope of protecting forest resources.

3.3: Implementation by River Basin

Table 22 displays the results for each of the 17 major river basins in North Carolina. A map of the major river basins is shown in Figure 4. The Cape Fear River basin contained 41 surveys, the most of any river basin, which correlates with the fact that this is the largest basin by area in North Carolina; and forestry management occurs frequently within this basin. No surveys were taken in the Savannah or Watauga river basins, both of which are relatively small and infrequently experience forestry management activities relative to other areas in the state. For these reasons, they had a small probability of being sampled given the survey design. When BMPs were not implemented or improperly implemented in the Chowan River basin, risks to water quality were found in 50 percent of observations. According to the data, the majority of risks in that basin were found at one of the seven surveyed sites, and dealt with SMZs and a stream crossing.

Table 22. BMP Implementation and Risk to Water Quality by River Basin

River Basin	Area (mi.2)	Surveys	BMPs Assessed	BMP Implementation (Percent) with 95% CI	Properly Implemented & NO RISK to WQ (Percent)	Improperly Implemented BMP & RISK to WQ (Percent)
Cape Fear	9,164	41	3,686	78 ± 1	100	32
Yadkin-Pee Dee	7,221	30	4,981	83 ± 1	100	35
Neuse	6,148	23	1,775	88 ± 2	100	23
Tar-Pamlico	6,062	19	2,470	90 ± 1	100	36
Roanoke	3,493	19	2,291	87 ± 1	100	38
Pasquotank	3,366	7	484	89 ± 3	100	28
Lumber	3,329	14	661	73 ± 3	100	32
Catawba	3,285	16	2,711	84 ± 1	100	29
French Broad	2,829	11	4,500	81 ± 1	100	26
Little Tennessee	1,797	8	1,804	88 ± 2	100	6
Broad	1,514	6	970	85 ± 2	99	34
White Oak	1,382	3	486	96 ± 2	100	17
Chowan	1,298	7	542	79 ± 3	100	50
New	754	2	595	77 ± 3	100	29
Hiwassee	644	4	535	89 ± 3	100	0
Watauga	205	0	0	N/A	N/A	N/A
Savannah	171	0	0	N/A	N/A	N/A
				Higher % is Optimal	Higher % is Optimal	Lower % is Optimal

"N/A" indicates that no survey sites were found in that river basin during the survey

Table 23. BMP Implementation and Risk to Water Quality by Watershed or River Designation

Designation	Surveys	BMPs Assessed	BMP Implementation (Percent) with 95% CI	Properly Implemented & NO RISK to WQ (Percent)	Improperly Implemented BMP & RISK to WQ (Percent)
*303(d)**	75	9,400	82 ± 1	100	32
Buffer Rule	45	4,545	89 ± 1	100	29
Coastal Shellfish	58	4,671	84 ± 1	100	36
*HQW***	22	3,259	78 ± 1	100	32
Nutrient Sensitive	46	4,387	89 ± 1	100	25
*ORW****	9	2,402	77 ± 2	100	26
Trout	33	10,189	83 ± 1	100	26
Water Supply	45	5,876	85 ± 1	100	31
Wild and Scenic	0	0	N/A	N/A	N/A
			Higher % is Optimal	Higher % is Optimal	Lower % is Optimal

"N/A" indicates that no survey sites were found in a watershed with that designation during the survey

* Classified as an impaired water under the Federal Clean Water Act Section 303(d)

** Classified as a High Quality Water by the NC Department of Environmental Quality

*** Classified as an Outstanding Resource Water by the NC Department of Environmental Quality

Table 23 shows results for harvests within specially designated watersheds or specially designated rivers. When the designation applied to the reach of a river, BMP survey sites were included if they were located in the same 12-digit *hydrologic unit code (HUC), upstream of the designated reach, since nonpoint source pollution in the watershed could potentially affect the designated body of water. No surveys were located in a watershed with a Wild and Scenic River. BMP implementation was higher in Buffer Rule and Nutrient Sensitive watersheds compared to Outstanding Resource and High Quality watersheds. Riparian buffer rules may cause operators to be more cautious, particularly when working close to streams.

*HUC – The United States is divided and sub-divided into successively smaller hydrologic units which are classified into four levels: regions, sub-regions, accounting units, and cataloging units. The hydrologic units are arranged or nested within each other, from the largest geographic area (regions) to the smallest geographic area (cataloging units). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system (U.S. Geological Survey). https://water.usgs.gov/GIS/huc.html.

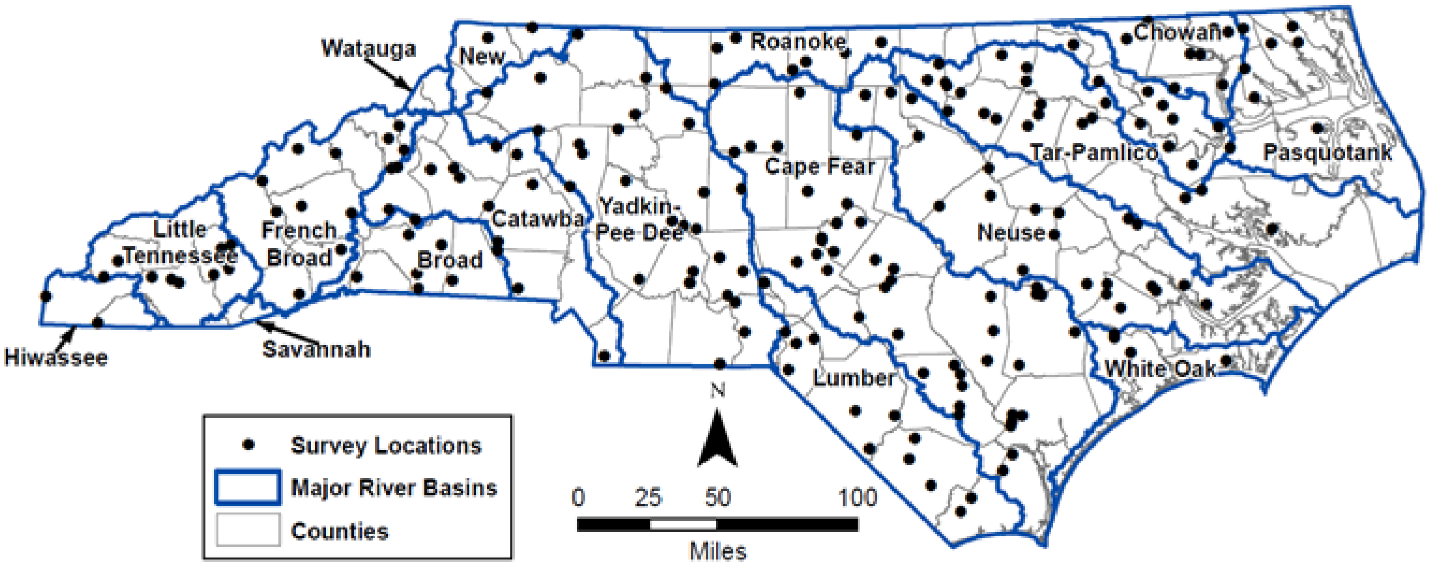


Figure 4. Major river basins of North Carolina overlaid with survey locations between 2012 and 2016, and county boundaries.

3.4: Implementation According to Ownership and Forest Management

3.4.1: Ownership

Survey units were located on a diversity of forest owner types, with the majority of surveys occurring on tracts owned by non-industrial private forest (NIPF) landowners. In North Carolina, 61 percent of forestland is owned by NIPF landowners, 19 percent by other corporate ownerships, 6 percent by forest industry, and the remainder by federal/state/local governments (Brown 2015). The breakdown of surveys according to ownership are shown in Table 24:

Table 24. BMP Implementation and Risk to Water Quality by Ownership

Owner Type	# of Surveys	% of Total	% BMP Implementation	#BMPs Assessed	#WQ Risks
Conservation/NGO*	3	1	96	342	5
Federal	7	3	96	1,352	3
Forest Industry	9	4	80	1,372	66
NIPF	165	79	83	22,460	1,212
Other Private	8	4	79	945	63
Other Public	1	<1	86	176	12
State	5	2	81	429	29
TIMO/REIT**	12	6	94	1,364	16

* Non-Governmental Organization

** Timber Investment Management Organization / Real Estate Investment Trust

3.4.2: Management Regime

Evaluators categorized each unit's management type as "natural" or "plantation", based on what they could observe of the site at the time.

Table 25. BMP Implementation and Risk to Water Quality by Management

Management	# of Surveys	% of Total	% BMP Implementation	#BMPs Assessed	#WQ Risks
Plantation	170	81	87	24,496	1,262
Natural	40	19	83	3,944	144

3.4.3: Harvest Progress

Evaluators attempted to determine the progress of each harvest at the time the survey was carried out.

Table 26. BMP Implementation and Risk to Water Quality by Harvest Progress

Progress	# of Surveys	% of Total	% BMP Implementation	#BMPs Assessed	#WQ Risks
0-25%	4	2	94	285	3
26-50%	7	3	80	1,430	106
51-75%	14	7	76	2,509	179
76-100%	43	20	85	7,156	374
Completed	142	68	85	17,060	744

3.4.4: Harvest Method

Survey units were categorized using one of the following timber harvest methods: clearcut, selection (e.g., diameter limit), seed tree/shelterwood, or thinning.

Table 27. BMP Implementation and Risk to Water Quality by Harvest Method

Harvest Method	# of Surveys	% of Total	% BMP Implementation	#BMPs Assessed	#WQ Risks
Clearcut	155	74	85	15,814	935
Selection	39	19	83	10,925	426
Thin	13	6	86	1,458	45
Seed Tree/Shelterwood	3	1	93	243	0

3.4.5: Acreage Class

Survey units covered a wide range of sizes, and evaluators classified each unit in terms of acreage ranges, as outlined in table 28. The average size of all survey units was 56 acres in size.

Table 28. BMP Implementation and Risk to Water Quality by Acreage Class

Acreage Class	# of Surveys	% of Total	% BMP Implementation	#BMPs Assessed	#WQ Risks
5-20	53	25	82	4,390	238
21-40	60	28	85	5,966	292
41-60	37	18	85	5,670	274
61-80	18	9	84	2,461	147
81-100	17	8	71	2,385	245
>100	25	12	87	7,568	210

Implementation According to Ownership and Forest Management -- Discussion

Ownership and forest management appear to exert some influence on BMP implementation, though it is difficult to make out a clear pattern. Given the lower rates of BMP implementation on naturally managed private land that has been clearcut, we may need to improve training and outreach to small-acreage landowners about the benefits of BMPs. Risks to water quality were lower on sites owned by the federal government, managed as plantations, recently started, harvested using a shelterwood method, or greater than 100 acres in size.

The findings on harvest progress reflect those on BMPs for rehab: Rehab is not occurring while many harvests are being carried out, and only some of the time after a harvest operation is complete. Rehabilitating a project site as it is being harvested can prevent problems from accumulating and thus becoming more cumbersome and expensive to implement after-the-fact.

4: Conclusions

4.1 Statewide Summary

Though the results from this survey cannot be directly compared to those of the previous study, conclusions can be drawn from the results of this new robust survey.

Preharvest planning can help to avoid problems before they arise. When going through the planning phase, forest operators should consider how they can avoid or minimize stream crossings, place decks and skid trails in optimal locations, and how weather could affect conditions at a given site.

Since stream crossings are generally the areas on a harvest with the greatest potential for water quality issues, they should be given a high amount of attention during planning, installation, use, and rehabilitation. In most stream crossing situations, bridgemats are the best option to protect water quality. However, the ideal strategy for protecting water quality is to avoid crossing streams as much as possible, as required by the North Carolina FPG standards.

Specifically regarding bridgemats, it is our observation that most loggers would prefer to use bridgemats, but simply lack them and/or do not feel they can afford to purchase bridgemats. It may be worthwhile for natural resource agencies to explore how bridgemats for forestry stream crossings could be included as an eligible practice in existing land, soil, and water conservation financial assistance (i.e., cost-share) programs. In addition, it may be beneficial for forest industry manufacturers to consider how to provide bridgemats to their logging contractors and/or timber suppliers, considering the lower water quality risks that are evident, which should translate to higher compliance with FPGs and other applicable environmental standards. Making an investment of $10,000 to $15,000 per set of bridgemats can pay dividends in long-term water quality protection, when purchasing and using fabricated steel bridgemats whose lifespan can approach 15+ years, if well-maintained.

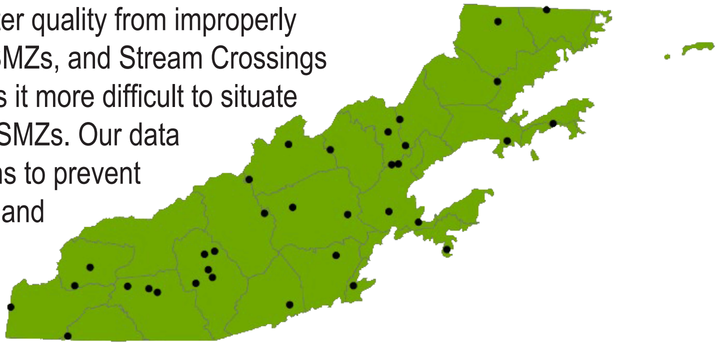
When educating loggers on SMZs, emphasis should be placed on width and stream crossings. Width is the main tool through which an SMZ protects water quality by stopping sediment and runoff, preventing temperature fluctuations, and helping to cycle nutrients. However, if a stream crossing goes through a SMZ of any width, a new opportunity develops for pollutants to enter a stream. Of notable interest is the observation that SMZs ranging in width from 20 to 30, and upwards to 50 feet were sufficient to prevent visible risks to water quality. Conversely, SMZs that were 10 feet or narrower showed a higher likelihood to be associated with a visible risk to water quality.

Another category that is important, though sometimes overlooked, is rehabilitation of the project site. Forest operators should think about ways to rehabilitate sites while the harvest is going on, instead of waiting until the end of the harvest. One simple but effective measure is repeatedly applying logging debris onto areas of bare soil.

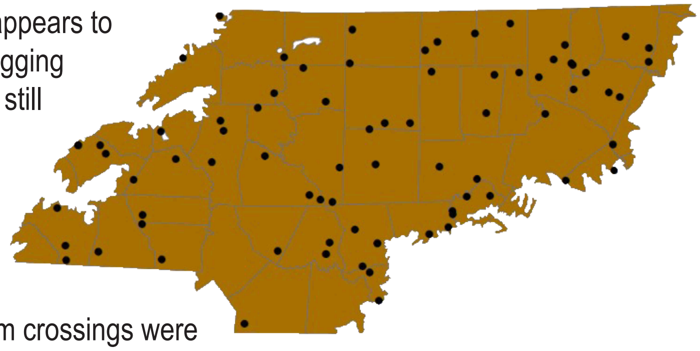
4.2 Regional Summaries

4.2.1 Mountains

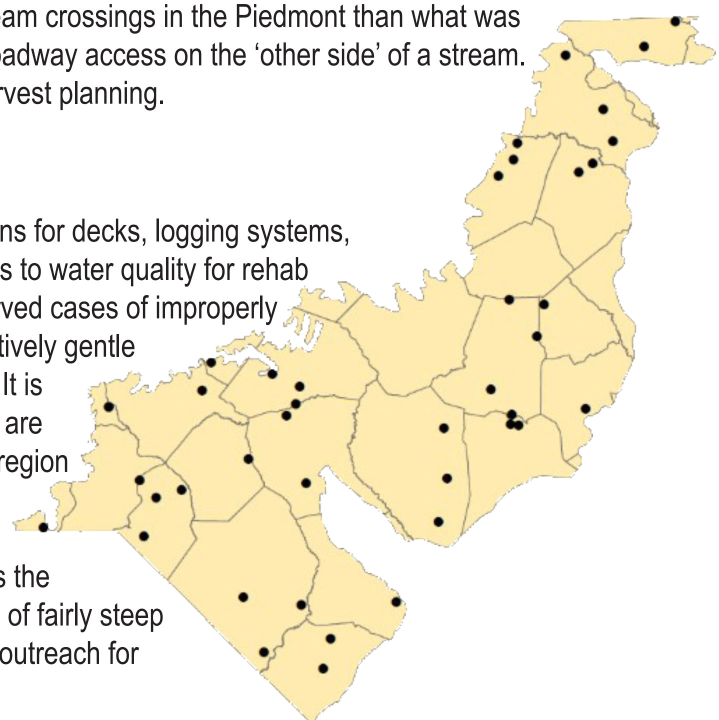
The Mountains ecoregion had the highest rates of risks to water quality from improperly implemented BMPs in the Decks, Logging Systems, Roads, SMZs, and Stream Crossings categories. The steep terrain in this ecoregion naturally makes it more difficult to situate roads and decks, establish stream crossings, and stay out of SMZs. Our data seems to indicate that SMZs need to be wider in the mountains to prevent risks to water quality, likely due to the effect that steep slopes and shallow soils can have on funneling sediment and runoff into streams. There are opportunities to expand the use of portable bridgemats for crossing streams. Doing so should improve the degree of water quality protection at crossings.



4.2.2 Piedmont



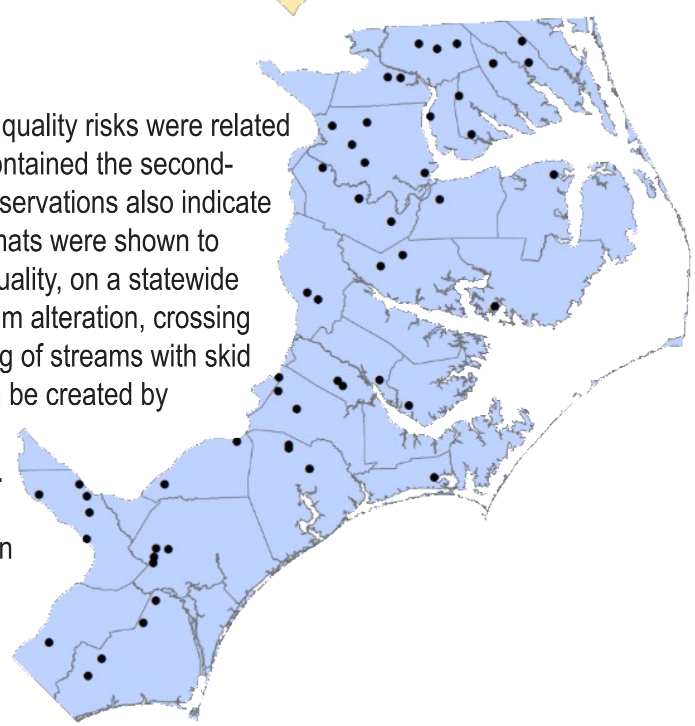
In the Piedmont, flatter terrain, as compared to the mountains, appears to have resulted in a reduction in risks to water quality related to logging systems, decks and roads. However, risks to water quality were still above 50 percent in this ecoregion for stream crossings, SMZs and rehabilitation of the project site. The rolling terrain, when coupled with the highly erodible shrink/swell red clay soils that are widespread in the Piedmont, require special attention to control runoff, capture sedimentation, and promptly establish groundcover stabilization material. The highest number of stream crossings were observed in the Piedmont. This is somewhat surprising, given the lengthy amount of time that the Piedmont region has been settled and populated, and the extensive network of current and legacy farm roads and trading path trails that still exist. We hypothesize that there are more opportunities to avoid stream crossings in the Piedmont than what was observed in this Survey by using (and/or improving) existing roadway access on the 'other side' of a stream. Identifying alternative access routes is a key element of preharvest planning.



4.2.3 Southeastern Plains

The risks to water quality were lowest in the Southeastern Plains for decks, logging systems, and roads, all of which are important BMP categories. The risks to water quality for rehab were the highest in the state, at more than 70 percent of observed cases of improperly implemented BMPs. This is somewhat puzzling, given the relatively gentle terrain and permeable soil types often found in this ecoregion. It is our speculation that when erosion and sediment control BMPs are needed (such as waterbars, turnouts, etc.), the loggers in this region are not as experienced with installing these types of BMPs, given they do not frequently need to use them. The transition between the rolling Piedmont and the flat Coastal Plain, across the Atlantic Seaboard fall line, can create relatively confined areas of fairly steep ground that may be overlooked or taken for granted. Targeted outreach for operators who work in this area of the state may be beneficial.

4.2.4 Mid-Atlantic Coastal Plain



In the Mid-Atlantic Coastal Plain, more than 40 percent of water quality risks were related to stream crossings. This is concerning, given that this region contained the second-highest number of stream crossings that were observed. Our observations also indicate widespread usage of portable bridgemats in this region. Bridgemats were shown to be the preferred crossing method for preventing risks to water quality, on a statewide basis. Specifically, in this ecoregion there were issues with stream alteration, crossing rehabilitation, and the use of fords as skid trail crossings. Fording of streams with skid trails is unacceptable. Given the soil disturbance issues that can be created by working in wet site conditions, care must also be taken to avoid saturated soil or inundated sites to the greatest degree possible. However, some Coastal Plain watersheds had the highest rates of BMP implementation and lowest risks to water quality of any in the state.

4.3 Limitations

Due to the changes to the BMP manual and the survey that have taken place since 2006-2008, when data was collected for the previous survey, we do not have that ability to compare the former survey with this report. For that reason, we do not recommend comparing these results with those in our previous survey report. We recognize that the ability to compare results over time is one of the strengths of this sort of survey, which is why we believe the process used to carry out this one will strengthen surveys in future years allowing us to make comparisons that are more robust in future reports.

5: Recommendations

The NCFS actively works to protect water quality and recognizes that some of these issues have been challenges for many years. The results of this survey give us the opportunity to make recommendations for the areas of improvement noted in this report. The aim of this section is not to point out failures, but to highlight those areas that were found to be most problematic and to suggest ways to make improvements.

It is important to highlight the BMPs that most critically prevent risks to water quality. These could include covering areas of bare soil with logging debris, avoiding stream crossings, or protecting streambanks and approachways. The NCFS is aware of the importance of these practices, but they must be put into practice by forest operators to be effective.

The Forest Preharvest Planning Tool (FPPT) is a freely available online tool that allows users to create customized maps of a tract, gain valuable information on soils and topography, and find contact information for local NCFS staff. Preharvest planning is an excellent way to avoid stream crossings, gain awareness of potential challenges, and strategize for the best possible timber harvest.

5.1 Proposed changes to next survey

We will soon start preparing for the next BMP implementation survey, and we hope to make improvements in survey quality, data collection technology, and applicability. To this end, below are anticipated changes:

1. We plan to use online tools such as ArcCollector, Survey123, and the FPPT to give us more information about each site and improve the data collection process.
2. We will document FPG compliance on each survey site.
3. We will explore the need and ability to capture more information on BMPs related to site prep, wetlands and firelines, since those activities were not well-represented in this survey.
4. Given the importance of SMZs and stream crossings, we may consider ways to collect more detailed information within these categories, to identify any root-cause issues that may be contributing to poor BMP implementation rates.
5. Future BMP surveys may be focused in specially-designated river basins or watersheds, as listed in Table 23. The intent would be to more fully assess the potential benefits of using BMPs in areas where water quality concerns are already identified; or protection of good quality water is of high priority.
6. We anticipate collecting soil erosion parameters on a sub-set of sites for the next BMP survey. These parameters would be used to conduct a soil erosion analysis via the Universal Soil Loss Equation. The intent is to begin linking specific BMP usage with measurable soil erosion and/or water quality protection metrics in an operational setting.

Appendix A: List of Supplemental Resources

An Assessment of Forestry Best Management Practices in North Carolina, 2012-2016: Map Journal
http://arcg.is/1PLvj5

Boggs, Johnny, Ge Sun, and Steven McNulty. "Effects of timber harvest on water quantity and quality in small watersheds in the Piedmont of North Carolina." Journal of Forestry 114.1 (2016): 27-40. https://www.srs.fs.usda.gov/pubs/49155

Brown, M.J. 2015. Forests of North Carolina, 2013. Resource Update FS–47. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 4 p. https://www.ncforestry.org/wp-content/uploads/2016/05/2013_NCFIAFactsheet_047.pdf

Implementation of Forestry Best Management Practices: 2012 Southern Region Report
http://www.southernforests.org/water/SGSF%20BMP%20Report%202012.pdf

NCFS Glossary
http://ncforestservice.gov/publications/Forestry%20Leaflets/FM01.pdf

North Carolina Forestry Best Management Practices Manual
http://ncforestservice.gov/publications/WQ0107/BMP_manual.pdf

Omernik, James M. "Ecoregions of the conterminous United States." Annals of the Association of American geographers 77.1 (1987): 118-125

Previous NCFS BMP Surveys
http://ncforestservice.gov/water_quality/wq_bmp_studies.htm

Sawyers, B. C., et al. "Effectiveness and implementation costs of overland skid trail closure techniques in the Virginia Piedmont." Journal of Soil and Water Conservation 67.4 (2012): 300-310.

USEPA National Management Measures to Control Nonpoint Source Pollution from Forestry
https://www.epa.gov/nps/national-management-measures-control-nonpoint-source-pollution-forestry

Wade, Charlie R., et al. "Comparison of five erosion control techniques for bladed skid trails in Virginia." Southern Journal of Applied Forestry 36.4 (2012): 191-197.

Wear, Laura R., et al. "Effectiveness of best management practices for sediment reduction at operational forest stream crossings." Forest Ecology and Management 289 (2013): 551-561.

Appendix B: Sample Size and Confidence Intervals for BMP Implementation Data

Table B-1. Sample Size and Confidence Intervals for Overall Implementation of BMPs by BMP Category and Region

BMP Category	Sample Size					BMP Implementation Rate & 95% Confidence Interval				
	Statewide	Mountains	Piedmont	SE Plains	Coastal Plain	S	M	P	SP	C
Overall	28,491	9,671	11,206	3,230	4,384	84 ± 0.4	82 ± 0.8	87 ± 0.6	79 ± 1.4	84 ± 1.1
Harvesting: Capturing Sediment	567	395	151	14	7	83 ± 3	88 ± 3	67 ± 7	78 ± 20	82 ± 25
Harvesting: Controlling Runoff	8,344	5,772	2,485	85	2	88 ± 1	87 ± 1	90 ± 1	72 ± 9	50 ± 41
Harvesting: Decks	2,039	374	783	403	479	90 ± 1	83 ± 4	93 ± 2	92 ± 3	89 ± 3
Harvesting: Logging Systems	522	84	203	105	130	86 ± 3	88 ± 7	92 ± 4	88 ± 6	71 ± 8
Harvesting: Rehabilitation of the Project Site	954	189	301	92	372	71 ± 3	53 ± 7	70 ± 5	59 ± 10	82 ± 4
Harvesting: Skid Trails	4,383	1,288	1,378	629	1,088	79 ± 1	70 ± 3	82 ± 2	78 ± 3	86 ± 2
Harvesting: Wetlands	323	0	42	161	120	64 ± 5	N/A	70 ± 13	65 ± 7	60 ± 9
Chemicals, Fluids, and Solid Waste	447	77	229	79	62	77 ± 4	70 ± 10	81 ± 5	75 ± 9	67 ± 11
Firelines	38	0	21	17	0	81 ± 12	N/A	68 ± 19	91 ± 14	N/A
Roads and Access	1,228	237	569	217	205	85 ± 2	88 ± 4	86 ± 3	84 ± 5	76 ± 6
Site Preparation and Reforestation	30	0	7	1	22	91 ± 11	N/A	73 ± 28	60 ± 44	93 ± 12
Stream Crossings	2,948	561	1,235	202	950	79 ± 2	75 ± 4	78 ± 2	71 ± 6	83 ± 2
Streamside Management Zones (SMZs)	6,668	694	3,802	1,225	947	86 ± 1	72 ± 3	91 ± 1	77 ± 2	87 ± 2

The remainder of Appendix B can be found online at: http://ncforestservice.gov/water_quality/wq_bmp_studies.htm

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