IMPLEMENTATION OF FORESTRY **BEST MANAGEMENT PRACTICES** IN TENNESSEE

Results from the 2017 Forestry BMP Implementation Survey

TN Department of Agriculture | Forestry

UTEXTENSION INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

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BEST MANAGEMENT PRACTICES

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RESULTS FROM THE 2017

FORESTRY BMP IMPLEMENTATION SURVEY

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EXECUTIVE SUMMARY

A survey was conducted in 2017 by the Tennessee Department of Agriculture, Division of Forestry in cooperation with the University of Tennessee Department of Forestry, Wildlife and Fisheries to determine how frequently forestry Best Management Practices (BMP) were implemented. The implementation survey was designed to be consistent with methodology as described in the Southern Group of State Forester's (SGSF) *Silviculture Best Management Practices Implementation Monitoring: A Framework for State Forestry Agencies.*

A random sample of 213 harvest sites was distributed among Tennessee's Forest Inventory and Analysis (FIA) survey units based on the amount of timber harvested within each unit. Harvest sites were visited between spring and fall of 2017. Each site was evaluated for 43 individual BMP that were categorized by haul roads, skid trails, log decks, streamside management zones (SMZ), stream crossings, and applicable BMP in wetlands.

The 2017 implementation survey showed no significant change in overall BMP implementation rate (88.5 percent) when compared to the overall implementation rate from the 2010 survey (88.9 percent).

As indicated in the 2010 survey, the overall BMP implementation rates have been substantially improved since the first BMP implementation survey was conducted in 1996 (62.9 percent).

In 2017, all BMP categories had implementation rates higher than 70 percent. Wetlands was the BMP category with the lowest implementation rate (73.4 percent); however, this was a slight improvement from the results of the 2010 survey (70.4 percent). Log decks were the BMP category with the highest implementation rate for 2017 (93.2 percent).

All FIA survey units had implementation rates higher than 80 percent. The Plateau survey unit had the highest overall implementation rate (96.1 percent). The West survey unit had the lowest overall implementation rate (82.9 percent). The East survey unit had the greatest improvement in implementation rate (92.2 percent) compared to the 2010 survey (79 percent) in which it had the lowest implementation rate. The West Central survey unit had the greatest decline in implementation rate (84.3 percent) compared to the 2010 survey (92.5 percent) in which it had the highest implementation rate.

As a result of the information obtained through the 2017 BMP implementation survey, the practices that should be the focus of BMP education and training for the next planning phase include 1) problem areas not stabilized with seed, 2) improper approaches and treatment of stream crossings and 3) wetland areas. These issues will be addressed through additional courtesy check site visits, logger contacts, Master Logger classes, educational materials, technical guides and demonstrations.



2017 TENNESSEE FORESTRY BEST MANAGEMENT PRACTICES IMPLEMENTATION SURVEY REPORT

INTRODUCTION

Since the mid-1980s the State of Tennessee, Department of Agriculture, Division of Forestry (TDF) has been providing leadership in forestry Best Management Practices (BMP). The Division's water quality program assists the forestry community with BMP implementation through three major program areas: technical assistance, water quality complaint investigations and forestry BMP implementation monitoring.

Technical assistance is provided through a partnership with the Tennessee Forestry Association and the University of Tennessee. TDF participates in the Tennessee Master Logger program and forestry BMP workshops and field days. TDF is also engaged in courtesy check site visits to active harvest sites, servicing requests for site-specific technical guidance, logger contacts, and providing educational materials.

Water quality complaint investigations are handled through a memorandum of understanding (MOU) between the Department of Agriculture and the Tennessee Department of Environment and Conservation (TDEC), Division of Water Resources (DWR). Upon receiving a complaint of a possible water quality violation caused by silvicultural practices, TDF performs an initial site visit to determine if the complaint is valid. TDF subsequently provides technical assistance when corrective actions are needed at these sites. Problem sites are referred to TDEC/DWR.

Forestry BMP implementation monitoring is achieved through logger contacts, courtesy check site visits and periodic surveys. This report contains the results of the 2017 forestry BMP implementation survey. The purpose of the Tennessee BMP implementation survey is to periodically ascertain and document the extent that BMP are being applied on-site. BMP guidelines allow forestry activities to be conducted while protecting water quality from degradation by point source pollution such as soil erosion. Periodic surveys allow TDF to objectively evaluate the utilization of BMP and, of particular importance, where specific BMP are not being implemented. This information is the basis for developing training and education priorities for TDF and its partners.

Continuing educational programs, such as Tennessee's Master Logger Program, can increase loggers' knowledge of BMP as well as help them understand principles of forest management, logging safety and business.

PREVIOUS FORESTRY BMP IMPLEMENTATION SURVEYS

The TDF conducted BMP implementation surveys in 1996, 2004, 2007, 2010 and 2017 (Figure 1). Survey results indicate substantial improvement in BMP implementation between 1996 and 2007. BMP implementation has remained consistent at 88 and 89 percent in the 2007, 2010 and 2017 surveys. Beginning in 2007, to facilitate more consistency between surveys and compatibility with other southern states, the Division implemented methodology as described in the Southern Group of State Foresters (SGSF) *Silvicultural Best Management Practices Implementation Monitoring: A Framework for State Forestry Agencies*. Future BMP implementation surveys will be conducted on a 5-year cycle.

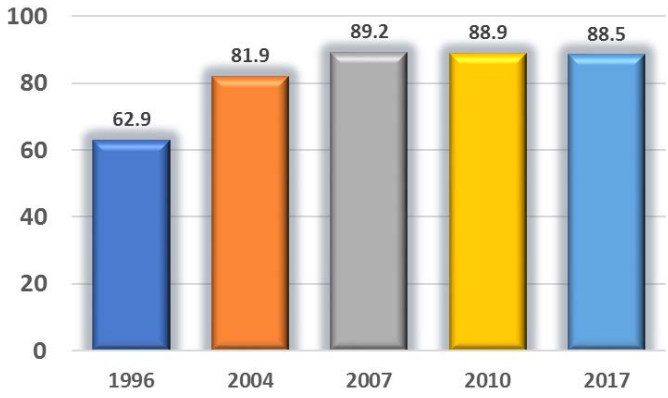

Figure 1. Overall forestry BMP Survey Results (Percent BMP Implementation) for Tennessee

2017 FORESTRY BMP IMPLEMENTATION SURVEY

HARVEST SITE SAMPLE SIZE

Sample size (the number of harvest sites evaluated) was determined by UT for statistical validity. For a margin of error at the 5 percent level and a probability of 90 percent, the smallest plausible sample size was 96. A sample size of 213 was used so there was adequate representation of forestry activity statewide (Refer to Appendix C for details).

FIA data were used to determine the volume of timber harvested statewide and within each FIA survey unit (Figure 2). Sample size within each FIA unit was based on the proportion of statewide timber harvest occurring within a respective FIA unit. Thus, more plots were taken in units where more timber was harvested, and likewise, fewer plots were taken in survey units where less timber was harvested (Table 1).

Specific harvest sites to evaluate were determined by dividing the state into a 4-mile by 7-mile grid. One grid was roughly the size of half a 7.5 minute topographic map. Statewide, there were 1,511 grids. Grids that were not at least 50 percent forested for all units were discarded with the exception of the West survey unit, where grids that were not at least 40 percent forested were discarded. Forested grids were numbered and catalogued by FIA survey unit and put together in a computer database. Grids for harvest sites were selected by FIA survey unit by a computer random

Figure 2. Forest Inventory and Analysis Survey Units

number generator. Thus, if a survey unit had a proposed sample size of 35 plots, the first 35 forested grids selected by the generator were used. Prior to selection of potential harvest sites to evaluate, locations of land use change that would indicate a timber harvest were determined within each randomly selected grid using satellite imagery in a geographic information system (GIS) database. This procedure differs from the 2010 survey in that the specific location of the possible harvest site within a grid was identified by satellite imagery, not ground visits by evaluators. Often forest disturbances identified by the imagery were other activities usually associated with changing land use or development rather than harvests that would remain in forests. If a grid had two or more possible harvest sites identified by the GIS, a random number generator was used to select a harvest site within a grid. When a possible harvest site did not meet evaluation criteria, that grid was omitted and another grid was added from the computer generator selection. If all computer-generated harvest sites were exhausted and sample size was not met for a FIA survey unit, evaluators followed the protocol from 2010 survey and visited another randomly selected forested grid to locate additional harvest sites for BMP assessment. The only data taken at this time were corrected global positioning system (GPS) coordinates for the site and location directions.

Site evaluation criteria included:

a. Harvest site must be at least 10 acres in size.
b. Land must have remained in a forested condition, i.e., harvest for change in land such as development, agriculture, etc. was not included in the study.
c. Landowner consent.
d. Harvest must be completed and loggers gone from the site.
e. Harvest must have taken place after January 2015.

If an evaluator had prior knowledge about a harvest site that they were assigned to visit, they were urged to give that site to another evaluator to maintain objectivity during the evaluation process. Evaluators used in this study took their judgments seriously and gave good written notes about the harvest sites.

HARVEST SITE EVALUATION

Harvest sites were visited by an evaluator to observe forestry BMP implementation. Individual BMP were evaluated by the following categories: haul roads, skid trails, log decks, streamside management zones (SMZ), stream crossings and applicable BMP associated with wetlands (Table 2). There existed a potential total of 9,159 observations on the 213 evaluated harvest sites. All the BMP survey

TABLE 1. STRATIFICATION OF HARVEST SITES BY FIA SURVEY UNIT BASED ON TIMBER HARVESTED, 2015 FIA DATA

REGION	HARVESTED ACRES (thousand acres)	PERCENT	# OF DESIRED SITES	ACTUAL SAMPLE SIZE
East	32.0	13.5	27	29
Plateau	52.2	22.0	44	48
Central	34.4	14.5	29	32
West Central	73.6	31.1	62	65
West	44.6	18.8	38	39

categories were not present on every harvest site. For example, haul roads were not present on sites that could be accessed by existing public roads. The harvest sites sampled for the 2017 survey resulted in evaluation of 5,463 individual BMP observations.

Observations where individual BMP were correctly applied were tallied as a "YES." Observations where individual BMP were absent but needed or incorrectly applied were tallied as a "NO." Observations where individual BMP were not needed were tallied as "NOT APPLICABLE."

BMP implementation rates were calculated for individual BMP, BMP categories, FIA survey units and overall implementation. Implementation rates for individual BMP were calculated by dividing the number of observations where BMP were correctly applied (YES) by the total number of observations [YES/(YES+NO)]. Individual harvest site implementation rates were calculated using the same formula as for individual BMP.

Implementation rates for BMP categories, FIA survey units and overall implementation rate were then calculated by averaging individual harvest site implementation rates for each respective variable.

Harvest sites were also evaluated to determine if "significant risks" to water quality existed. A significant risk is an existing on-the-ground condition resulting from failure to correctly implement BMP, that, if left unmitigated, will likely result in an adverse change in the either the chemical, physical or biological condition of a water body.

A total of 23 BMP evaluators were used for this survey, including employees from TDF's four administrative districts, Mike Sherrill (TDF's water quality program specialist) and Wayne Clatterbuck (Professor, University of Tennessee, Department of Forestry, Wildlife and Fisheries). Harvest site visits began in the spring of 2017 and were concluded by October 2017.

TABLE 2. VARIABLES BY BMP CATEGORY

BMP CATEGORY	NUMBER OF INDIVIDUAL BMP	TOTAL
Haul Roads	12	2,556
Skid Trails	5	1,065
Logging Deck	5	1,065
SMZ	5	1,065
Stream Crossings	7	1,491
Wetlands	9	1,917
Total	43	9,159

RESULTS

BMP IMPLEMENTATION

The statewide average forestry BMP implementation rate for 2017 was determined to be 88.5 percent. Table 3 summarizes BMP implementation by BMP category. Table 4 summarizes BMP implementation by FIA survey unit. Tables 5 through 10 summarize BMP implementation by individual BMP. Details on statistical calculations can be found in Appendix C.

BMP Categories (Table 3) – All BMP categories had implementation rates higher than 73 percent. Wetlands was the BMP category with the lowest implementation rate (73.4 percent). Log Decks was the BMP category with the highest implementation rate (93.2 percent).

FIA Survey Units (Table 4) – All FIA survey units had implementation rates higher than 82 percent. The West survey unit had the lowest implementation rate (82.9 percent). The Plateau survey unit had the highest implementation rate (96.1 percent).

TABLE 3. BMP IMPLEMENTATION BY BMP CATEGORY

BMP CATEGORY OF SITES	NUMBER IMPLEMENTATION	AVERAGE %	NUMBER OF SIGNIFICANT RISKS[1]	MARGIN OF ERROR
Haul Roads	164	86.2	8	3.6
Skid Trails	210	87.6	18	3.1
Logging Deck	212	93.2	1	2.2
SMZ	124	85.5	5	5.2
Stream Crossings	73	78.8	9	8.4
Wetlands	18	73.4	4	16.1

[1] The 45 significant risks occurred on 13 of the 213 harvest sites.

TABLE 4. BMP IMPLEMENTATION BY FIA SURVEY UNIT

FIA SURVEY UNIT	NUMBER OF SITES	AVERAGE % IMPLEMENTATION	NUMBER OF SIGNIFICANT RISKS[1]	MARGIN OF ERROR
East	29	92.2	0	5.0
Plateau	48	96.1	0	2.6
Central	32	89.1	15	6.1
West Central	65	84.3	15	5.3
West	39	82.9	15	7.8

[1] The 45 significant risks occurred on 13 of the 213 harvest sites.

Haul Roads (Table 5) – The lowest implementation rate for individual haul road BMP was associated with stabilizing areas with seed (63.9 percent). The highest rate was associated with locating haul roads away from water (96.7 percent).

Haul roads were correctly within grade 95.1 percent of the time.

TABLE 5. IMPLEMENTATION OF BMP RELATING TO HAUL ROADS

BMP	YES	NO	N/A	% IMPLEMENTATION	NUMBER OF SIGNIFICANT RISKS	MARGIN OF ERROR
HAUL ROADS						
Broad Based Dips	62	25	78	71.3	2	9.7
Waterbars	42	21	102	66.7	1	11.9
Culverts	49	11	105	81.7	0	10.0
Turnouts (wing ditches)	105	24	36	81.4	0	6.9
Water Control Structures at Recommended Intervals	95	30	40	76.0	0	7.6
Crowned or Outsloped	119	23	23	83.8	0	6.2
Avoid Sensitive Areas & SMZ	131	7	26	94.9	1	3.7
Rock Used (BBD or other)	95	13	57	88.0	0	6.3
Problem Areas Stabilized with Seed	53	30	81	63.9	2	10.5
Follows Contour	140	15	10	90.3	0	4.7
Within Grade	154	8	3	95.1	1	3.4
Located Away from Water	147	5	13	96.7	1	2.9

Skid Trails (Table 6) – The lowest implementation rate for individual skid trail BMP was associated with stabilizing problem areas with seed (61.7 percent). The highest rate was associated with maintaining an appropriate grade (97.1 percent).

Logging Decks (Table 7) – The lowest implementation rate for individual logging deck BMP was associated with stabilizing problem areas with seed (69.3 percent). The highest rate was associated with appropriate hazardous waste management (97.9 percent).

TABLE 6. IMPLEMENTATION OF BMP RELATING TO SKID TRAILS

BMP	YES	NO	N/A	% IMPLEMENTATION	NUMBER OF SIGNIFICANT RISKS	MARGIN OF ERROR
SKID TRAILS						
Grade	203	6	2	97.1	3	2.3
Water Control	139	37	36	79.0	5	6.1
Avoided Wet & Sensitive Areas	173	17	21	91.1	3	4.1
Problem Areas Stabilized with Seed	58	36	118	61.7	2	10.0
Ruts do not Channel into Streams	162	19	29	89.5	5	4.6

TABLE 7. IMPLEMENTATION OF BMP RELATING TO LOGGING DECKS

BMP	YES	NO	N/A	% IMPLEMENTATION	NUMBER OF SIGNIFICANT RISKS	MARGIN OF ERROR
LOGGING DECKS						
Existing Landings Used	156	4	52	97.5	1	4
Location	200	12	1	94.3	0	12
Drainage	202	10	1	95.3	0	10
Hazardous Waste Management	190	4	19	97.9	0	4
Problem Areas Stabilized with Seed	70	31	112	69.3	0	31

Streamside Management Zones (Table 8) – The lowest implementation rate for individual SMZ BMP was associated with width of the SMZ (83.3 percent). The highest implementation rate was associated with limited equipment use within the SMZ (88.4 percent).

Stream Crossings (Table 9) – The lowest implementation rate for individual stream crossing BMP was associated with approaches to stream crossings (71.4 percent). The highest rate was associated with location of stream crossings (87.1 percent).

TABLE 8. IMPLEMENTATION OF BMP RELATING TO STREAMSIDE MANAGEMENT ZONES

BMP	YES	NO	N/A	% IMPLEMENTATION	NUMBER OF SIGNIFICANT RISKS	MARGIN OF ERROR
STREAMSIDE MANAGEMENT ZONES						
SMZ Matched to Stream Type	104	19	5	84.6	1	6.5
Canopy (50% overhead intact)	106	18	4	85.5	0	6.3
Tree Felling	108	16	4	87.1	1	6.0
Equipment Use	107	14	6	88.4	2	5.8
Width	100	20	8	83.3	1	6.8

TABLE 9. IMPLEMENTATION OF BMP RELATING TO STREAM CROSSINGS

BMP	YES	NO	N/A	% IMPLEMENTATION	NUMBER OF SIGNIFICANT RISKS	MARGIN OF ERROR
STREAM CROSSINGS						
Location	61	9	5	87.1	2	8.0
Approaches	50	20	6	71.4	2	10.8
Water Control Structures	44	16	16	73.3	2	11.4
Crossings Appropriate and Properly Installed						
Fords	37	10	29	78.7	2	11.9
Culverts and Fill	21	5	51	80.8	0	15.5
Bridges	11	3	63	78.6	0	21.9
Temporary Structures Removed	48	8	20	85.7	1	9.4

BMP evaluators seldom encountered situations where logging debris was left in streams.

Wetlands (Table 10) – The lowest implementation rate for individual wetlands BMP was associated with removal of harvested tree tops (56.3 percent) (from wetlands). The highest rate was associated with roads (100 percent).

TABLE 10. IMPLEMENTATION OF BMP RELATING TO WETLANDS

BMP	YES	NO	N/A	% IMPLEMENTATION	NUMBER OF SIGNIFICANT RISKS	MARGIN OF ERROR
WETLANDS						
Roads	13	0	7	100.0	0	N/A
Drainage Structures	10	2	7	83.3	1	21.5
Fill Material	8	4	7	66.7	1	27.2
Stream Crossings	12	2	5	85.7	1	18.7
Problem Areas Stabilized with Seed	8	6	6	57.1	0	26.5
Treetops	9	7	4	56.3	0	24.8
Deck Location	13	3	4	81.3	0	19.5
SMZ	9	6	5	60.0	0	25.3
Equipment Use	13	1	5	92.9	1	13.8

SIGNIFICANT RISKS

A total of 45 significant risks was observed statewide, or 0.8 percent of the 5,463 individual BMP observations that required BMP. These significant risks were observed on 13 separate harvest sites, or 6.1 percent of the 213 harvest sites evaluated. The skid trail category of BMP contained the most significant risks (18). Haul Roads, Logging Decks, SMZ, Stream Crossings and Wetlands contained 60 percent (27) of the significant risks observed. Tables 3 through 12, Figures 3 and 4, and Appendix B provide additional details to characterize significant risks for this survey.

Significant Risks by BMP Category

Table 11 and Figure 3 present information on significant risks by BMP category. The skid trails category of BMP had the greatest number of significant risks (18 significant risks on nine harvest sites). The stream crossings category of BMP had the second greatest number of significant risks (nine significant risks on three harvest sites). The logging decks category of BMP had the least number of significant risks (one significant risk on one harvest site). Additional details concerning significant risks by individual BMP are presented in Appendix B.

Significant Risks by FIA Survey Unit

Table 12 and Figure 4 present information on significant risks by FIA survey unit. The Central, West Central and West Survey Units each had 15 significant risks (on one, eight and four harvest sites respectively). No significant risks were observed in the East or Plateau Survey Units.

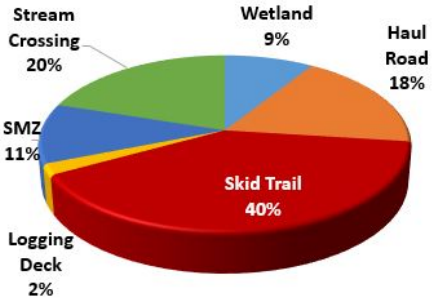

Figure 3. Percentage of Significant Risks by BMP Category

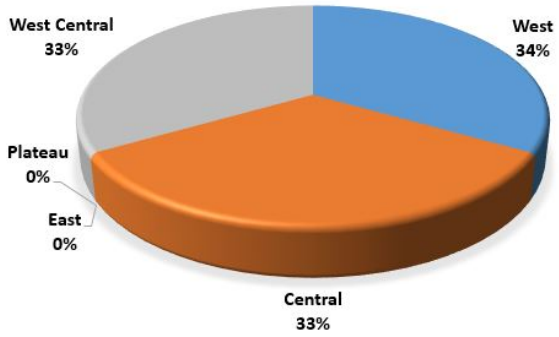

Figure 4. Percentage of Significant Risks by FIA Survey Unit

TABLE 11. NUMBER OF SIGNIFICANT RISKS BY BMP CATEGORY

Haul Roads	8
Skid Trails	18
Logging Decks	1
SMZ	5
Stream Crossings	9
Wetlands	4
Total	45

TABLE 12. NUMBER OF SIGNIFICANT RISKS BY FIA SURVEY UNIT

SURVEY UNIT	SIGNIFICANT RISKS
East	0
Plateau	0
Central	15
West Central	15
West	15
Total	45

SUMMARY AND CONCLUSIONS

The 2017 BMP implementation survey revealed an average overall BMP implementation rate of 88.5 percent. There was little change in overall BMP implementation rate between the 2010 survey (88.9 percent) and the 2017 survey. As with the 2010 survey, these results reflect substantial improvement in BMP implementation rate when compared to the Division's first BMP implementation survey conducted in 1996 (62.9 percent). The improvement in implementation rates from 1996 to the present can be attributed to greater awareness of water quality issues associated with forest practices and improved

understanding of correct BMP implementation. The resources invested over the past two decades to educate the forestry community about practices that protect water quality continue to show positive results.

The 2017 BMP implementation survey also represents the third cycle that utilized the methodology as described in the Southern Group of State Foresters (SGSF) *Silvicultural Best Management Practices Implementation Monitoring: A Framework for State Forestry Agencies*. Adoption of the SGSF methodology provides more consistency between surveys and compatibility with other southern states, resulting in a more objective and robust approach to BMP implementation monitoring.

The practices that will be the core items of BMP education and training for the next planning phase are 1) problem areas not stabilized with seed, 2) improper approaches and treatment of stream crossings and 3) wetland areas. These issues will be addressed through additional courtesy check site visits, logger contacts, Master Logger classes, educational materials, technical guides and demonstrations. Regardless of BMP category, special emphasis will also be given to highlight the importance of stabilizing disturbed areas.

The incorporation of GIS technology to randomly locate potential harvest sites to be included in the 2017 survey was also evaluated. The change to using GIS was made to reduce the potential bias that might result from selection bias. In past surveys, some sites were known to the technicians who also selected the sites, but not by the evaluators. There was also the potential that a number of sites were logged but unknown to the survey. A total of 125 of the 213 harvest sites included in this survey were selected from aerial imagery (National Agricultural Imagery Program (NAIP) 2012-2014). Many of the disturbed sites identified by the imagery did not meet the harvest site selection criteria, namely harvested sites were older than designated (more than two years since harvest), harvests were less than 10 acres in size, or land was harvested for another land use than forests. The overall BMP implementation rate for the computer-selected

sites (89.2 percent, confidence interval (CI): 86.0 through 92.4 percent) was not significantly different from the overall BMP implementation rate for sites selected on the ground by evaluators (87.4 percent, CI: 83.1 though 91.7 percent).

The goal of the TDF's BMP implementation survey is to accurately evaluate BMP use and identify areas for continued improvement. Tennessee Forestry BMP implementation surveys are planned on a five-year cycle. This provides information for timely assessment of forestry BMP use in Tennessee.

Increasing demands for clean water are coming from every corner of our society. Utilization of the forest from which this clean water is derived is also important. Balancing the task of protecting the waters of Tennessee as well as maintaining the use of the forest is a priority for the Division of Forestry.

This survey report is a tool that can be used to assure a proper course is chosen for the future of TDF's water quality program and position TDF to continue its leadership role in the forest BMP arena.

Focused education and training on identified issues will be addressed through demonstrations, workshops, and additional courtesy check site visits.

GLOSSARY

IMPLEMENTATION MONITORING – The process used to determine the proper application of BMP according to the specifications in *Guide to Forestry Best Management Practices in Tennessee*.

SIGNIFICANT RISK – An existing on-the-ground condition resulting from failure to correctly implement BMP, that if left unmitigated will likely result in an adverse change in the chemical, physical or biological condition of a water body.

BEST MANAGEMENT PRACTICES (BMP) – A practice or combination of practices which has been determined to be the most effective and practical means of preventing or reducing water pollution to a level compatible with water quality goals.

EROSION – The process by which soil particles are detached and transported by water, wind, and/or gravity.

HAUL ROAD – A permanent or temporary woods road over which timber is transported from a harvest site to a public road.

NON-POINT SOURCE POLLUTION – Pollution of water which is:

- carried or conveyed by natural processes including precipitation, seepage, percolation, and runoff;
- not traceable to a distinct or identifiable source; and
- better controlled through the application of good management practices.

SILVICULTURE – The science and art of growing a forest. More particularly, the principles, theories and practices for protecting and enhancing the regeneration, growth and development and use of forests for multiple benefits.

STREAM – A watercourse having banks and channel through which waters flow, at least periodically. Stream types include perennial (continuous flowing) and intermittent (flows during wet periods).

STREAMSIDE MANAGEMENT ZONES (SMZ) – A designated area that consists of the stream itself and an adjacent area of varying width where management practices that might affect water quality or aquatic resources are modified. Streamside management zones are areas of closely managed activity, not areas of exclusion.

APPENDIX A: CLIMATOLOGICAL DATA (PRECIPITATION)

The following annual rainfall information is associated with selected climatological sites in Tennessee. This information is accessible from the National Oceanic and Atmospheric Administration's National Climatic Data Center web link (ncdc.noaa.gov/cdo-web).

Precipitation in 2015 was at normal levels in East Tennessee with surpluses on the Plateau and in Middle Tennessee, and slight deficits in West Tennessee. Rainfall was below normal in 2016 except for the Clarksville and Memphis areas. Severe drought in East Tennessee and on the Plateau contributed to the increased number of 2016 wildfires during the fall season. Precipitation was above normal during 2017 except for West Tennessee, which had slight deficits.

Rainfall events occurring during and after harvesting operations can lead to soil erosion, especially if bare soils are exposed. Although precipitation was variable by location for the three years evaluated, the number of significant risks to protection of water quality and the BMP implementation percentages were similar in the 2010 and 2017 surveys. These data suggest that annual rainfall, though variable by year and location in the state had minor impacts on BMP implementation.

LOCATION	INCHES OF PRECIPITATION						
	AVG. ANNUAL PRECIPITATION	2015	2015 DEPARTURE FROM NORMAL	2016	2016 DEPARTURE FROM NORMAL	2017	2017 DEPARTURE FROM NORMAL
Kingsport	43.1	44.6	1.5	35.9	-7.2	43.1	0.0
Knoxville	47.9	51.6	3.7	45.1	-2.8	51.8	3.9
Chattanooga	52.5	66.8	14.3	35.6	-16.9	58.5	6.0
Crossville	55.1	67.4	12.3	48.7	-6.4	61.7	6.6
Cookeville	56.0	67.0	11.0	50.6	-5.4	67.1	11.1
Nashville	47.3	50.8	3.5	42.8	-4.5	52.9	5.6
Clarksville	51.0	52.1	1.1	54.0	3.0	58.0	7.0
Jackson	54.2	48.2	-6.0	46.7	-7.5	49.5	-4.7
Memphis	53.7	52.7	-1.0	61.6	7.9	51.4	-2.3

APPENDIX B: SUMMARY OF SIGNIFICANT RISKS BY CATEGORY, ITEM AND FIA SURVEY UNIT

HAUL ROADS	EAST	PLATEAU	CENTRAL	WC	WEST	TOTALS
1. Broad Based Dips				2		2
2. Waterbars			1			1
3. Culverts						
4. Turnouts (wing ditches)						
5. Water Control Structures						
6. Crowned or Outsloped						
7. Avoid Sensitive Areas & SMZ			1			1
8. Rock Used (BBD or other)						
9. Problem Areas Stabilized with Seed			1	1		2
10. Follows Contour						
11. Within Grade			1			1
12. Located Away from Water			1			1
TOTALS			5	3		8

SKID TRAILS	EAST	PLATEAU	CENTRAL	WC	WEST	TOTALS
1. Grade				2	1	3
2. Water Control				4	1	5
3. Avoided Wet & Sensitive Areas			1		2	3
4. Problem Areas Stabilized with Seed			1	1		3
5. Ruts do not Channel into Streams			1	1	3	5
TOTALS			3	8	7	18

LOGGING DECKS	EAST	PLATEAU	CENTRAL	WC	WEST	TOTALS
1. Existing Landings Used					1	1
2. Location						
3. Drainage						
4. Hazardous Waste Management						
5. Problem Areas Stabilized with Seed						
TOTALS					1	1

STREAMSIDE MANAGEMENT ZONES	EAST	PLATEAU	CENTRAL	WC	WEST	TOTALS
1. SMZ Matched to Stream Type			1			1
2. Canopy (50% overhead intact)						
3. Tree Felling			1			1
4. Equipment Use			1		1	2
5. Width			1			1
TOTALS			4		1	5

STREAM CROSSINGS	EAST	PLATEAU	CENTRAL	WC	WEST	TOTALS
1. Location					2	2
2. Approaches			1		1	2
3. Water Control Structures			1		1	2
4. Crossings Appropriate and Properly Installed						
4a. Ford			1		1	2
4b. Culvert and Fill						
4c. Bridge						
5. Temporary Structures Removed					1	1
TOTALS			3		6	9

WETLANDS	EAST	PLATEAU	CENTRAL	WC	WEST	TOTALS
1. Roads						
2. Drainage Structures				1		1
3. Fill Material				1		1
4. Stream Crossings				1		1
5. Problem Areas Stabilized with Seed						
6. Treetops (in streams)						
7. Deck Location						
8. SMZ						
9. Equipment Use				1		1
TOTALS				4		4

APPENDIX C: STATISTICAL ANALYSIS

SAMPLE SIZE

The formula for estimating sample size:

$$n = \left(\frac{t\ CV}{AE}\right)^2$$

Where n = the number of sites to evaluate
t = Student's t-value
CV = coefficient of variation
AE = allowable error

Thus given the following parameters:

t = 11.96 – as t at the 0.05 value approaches a degrees of freedom of infinity, the value is 1.96
CV = coefficient of variation – estimated to be 50% which means that the standard deviation is 50% of the mean
AE = 10% (90% probability)

These assumptions give the estimate of sample size as

$$n = \left(\frac{1.96*\ 50}{10}\right)^2 = 96$$

Sample size is 213. There are sufficient samples to make good statistical comparisons depending whether our estimate of CV is close.

The statistical parameters for this study are:

Test of Significance at the 0.05 level - (95% accurate) with a probability of 90%, i.e., 10% allowable error.

These procedures are from the following reference:

W.G. Cochran and G.M. Cox. 1957. Experimental Design. 2nd Edition, Wiley Publishing, New York. 611 p.

MARGIN OF ERROR CALCULATIONS FOR INDIVIDUAL BMP

The margin of error expresses the maximum likely difference observed between the sample mean and the true population mean with a 95% probability. The formula used to calculate margin of error for individual BMP is listed below. Refer to tables 5 through 10 for individual BMP margin of errors.

$$\boldsymbol{m = 2\sqrt{\frac{P(100 - P)}{n}}}$$

Where m = margin of error for a single BMP
P = the percent of implementation for a single BMP
n = the number of sites the BMP was evaluated on

Note: If the value of P is 100%, the margin of error is not zero. No calculation can be made.

Example of a calculation for BMP implementation for turnout use for Haul Roads:

Where P (% BMP implementation for turnouts) was evaluated to be 81.4% on 129 sites (Table 5).

$$\boldsymbol{m = 2\sqrt{\frac{P(100 - P)}{n}}}$$

$$\boldsymbol{m = 2\sqrt{\frac{81.4(100 - 81.4)}{129}}}$$

$$\boldsymbol{m = 2\sqrt{\frac{1514}{129}}}$$

$$\boldsymbol{m = 2\sqrt{11.73}}$$

$$\boldsymbol{m = 6.9}$$

MARGIN OF ERROR CALCULATIONS FOR BMP CATEGORIES AND FIA SURVEY UNITS

The margin of error expresses the maximum likely difference observed between the sample mean and the true population mean with 95% probability. The formula used to calculate margin of error by BMP category and FIA survey unit is listed below. Refer to Table 3 and Table 4 for BMP category and FIA survey unit margin of errors respectively.

$$\boldsymbol{m = \frac{2\,(SD)}{\sqrt{n}}}$$

Where m = margin of error for a BMP category or FIA survey unit
SD = the standard deviation for a BMP category or FIA survey unit
n = the number of sites evaluated

Note: If the value of P is 100%, the margin of error is not zero. No calculation can be made.

Example of calculation for BMP implementation for haul roads (Table 3):

$$\boldsymbol{m = \frac{2\,(SD)}{\sqrt{n}}}$$

$$\boldsymbol{m = \frac{2\,(23.2)}{\sqrt{164}}}$$

$$\boldsymbol{m = \frac{46.4}{12.8}}$$

$$\boldsymbol{m = 3.6}$$

CONFIDENCE INTERVAL FOR OVERALL AVERAGE BMP IMPLEMENTATION RATE

A confidence interval is a tool that statisticians use to demonstrate their confidence in the measured mean of a sample. For example, a 95% confidence interval provides a range for which you can be 95% confident (i.e., 19 times out of 20) that the actual mean will be found. To calculate the confidence interval, the mean variance, standard deviation, standard error, and margin of error must also be calculated. The formula used to calculate the confidence interval is listed below. The 95% confidence interval for the 2017 BMP survey overall BMP implementation rate (88.5%) across all sites was 85.9% to 91.1%.

$$\boldsymbol{95\%\ CI = Mean \pm Margin\ of\ Error}$$

APPENDIX D: FORESTRY BMP IMPLEMENTATION SURVEY TALLY SHEETS

BMP IMPLEMENTATION STUDY ---- 2017

I. Identification

FIA Region _____ Date of Inspection _____

County _____ Date of Harvest _____ (if known)

GPS Coordinates Latitude _____

Longitude _____

Ownership _____ (if known) Industry, Public, NIPF, Corporate

Inspector: _____ Acreage _____ (estimated)

Harvest Number _____ Type of Cut _____ (partial or clearcut)

II. Site Characteristics

A. Terrain Type (check all that apply)

1. Wetland _____
2. Stream Valley _____
3. Flatland _____
4. Rolling Hills _____
5. Steep Upland _____

B. Drainage Features

1. Perennial Stream _____
2. Intermittent Stream _____
3. Ephemeral Stream _____
4. Lake/Pond _____
5. Not Present _____

III. Haul Roads

_____ **NOT** Applicable ----- Haul Roads not present

	Correct	Incorrect	Not Used But Needed	Not Needed	Is Significant Risk	BMP Page
1. Broad Based Dips (BBDs)	_____	_____	_____	_____	_____	9-10
2. Waterbars (only on temporary roads)	_____	_____	_____	_____	_____	13
3. Culverts	_____	_____	_____	_____	_____	11-12
4. Turnouts (wing ditches)	_____	_____	_____	_____	_____	10
5. Water Control Structures at Recommended Intervals	_____	_____	_____	_____	_____	9-13
6. Crowned or Outsloped	_____	_____	_____	_____	_____	9
7. Avoided Sensitive Areas & SMZ	_____	_____	_____	_____	_____	7
8. Rock Used (BBD or other)	_____	_____	_____	_____	_____	10
9. Problem Areas Stabilized with Seed	_____	_____	_____	_____	_____	8, 11
10. Follows Contour	_____	_____	_____	_____	_____	7
11. Within Grade (2 to 12%)	_____	_____	_____	_____	_____	7
12. Located Away from Water	_____	_____	_____	_____	_____	7

If answered **Incorrect** or **Significant Risk**, describe the problem(s) below.

IV. Skid Trails

	Correct	Incorrect	Not Used But Needed	Not Needed	Is Significant Risk	BMP Page
1. Grade (2 to 30%)	_____	_____	_____	_____	_____	21
2. Water Control	_____	_____	_____	_____	_____	21
3. Avoided Wet & Sensitive Areas	_____	_____	_____	_____	_____	21
4. Problem Areas Stabilized with Seed	_____	_____	_____	_____	_____	21
5. Ruts Do Not Channel Water Into Stream	_____	_____	_____	_____	_____	21

If answered **Incorrect** or **Significant Risk**, describe the problem(s) below.

V. Logging Decks

	Correct	Incorrect	Not Used But Needed	Not Needed	Is Significant Risk	BMP Page
1. Existing Landings Used (if applicable)	_____	_____	_____	_____	_____	20
2. Location	_____	_____	_____	_____	_____	20
3. Drainage	_____	_____	_____	_____	_____	20
4. Hazardous Waste Management Oil & Gas Spills	_____	_____	_____	_____	_____	20, 23
5. Problem Areas Stabilized with Seed	_____	_____	_____	_____	_____	20

If answered **Incorrect** or **Significant Risk**, describe the problem(s) below.

VI. Streamside Management Zones

____ **NOT** Applicable --- Streams not present on logging site

	Correct	Incorrect	Not Used But Needed	Not Needed	Is Significant Risk	BMP Page
1. SMZ Matched to Stream Type	_____	_____	_____	_____	_____	14,15
2. Canopy (50% overhead canopy)	_____	_____	_____	_____	_____	15
3. Tree Crowns & Boles not in streams	_____	_____	_____	_____	_____	22
4. Limited Equipment Use	_____	_____	_____	_____	_____	15
5. Width of SMZ	_____	_____	_____	_____	_____	15

If answered **Incorrect** or **Significant Risk**, describe the problem(s) below.

VII. Stream Crossings

____ **NOT** Applicable --- Streams not present on logging site

	Correct	Incorrect	Not Used But Needed	Not Needed	Is Significant Risk	BMP Page
1. Location(s) & Number of Crossings Directed by Terrain & Topography	_____	_____	_____	_____	_____	17-19
2. Proper Stream Approaches & Road/Trail	_____	_____	_____	_____	_____	17
3. Water Control Structures	_____	_____	_____	_____	_____	17
4. Crossing Structure Appropriate, & Properly Installed						
A. Ford	_____	_____	_____	_____	_____	18
B. Culvert and Fill	_____	_____	_____	_____	_____	18
C. Bridge	_____	_____	_____	_____	_____	19
5. Temporary Structures Removed	_____	_____	_____	_____	_____	8,19,21

If answered **Incorrect** or **Significant Risk**, describe the problem(s) below.

VIII. Wetlands --- Those areas that are inundated or saturated by surface or ground water (hydrology) at a frequency and duration sufficient to support a prevalence of vegetation (hydrophytes) typically adapted for life in saturated soil conditions (hydric soils).

____ **NOT** Applicable --- Wetlands not present on logging site

	Correct	Incorrect	Not Used But Needed	Not Needed	Is Significant Risk	BMP Page
1. Roads	_____	_____	_____	_____	_____	31, 32
2. Drainage Structures	_____	_____	_____	_____	_____	31
3. Fill Material Stabilized	_____	_____	_____	_____	_____	31
4. Stream Crossings	_____	_____	_____	_____	_____	31
5. Problem Areas Stabilized with Seed	_____	_____	_____	_____	_____	31, 32
6. Remove Treetops from Streams	_____	_____	_____	_____	_____	32
7. Deck Location	_____	_____	_____	_____	_____	32
8. SMZ Adequate	_____	_____	_____	_____	_____	32
9. Limited Equipment Use in SMZ	_____	_____	_____	_____	_____	32

If answered **Incorrect** or **Significant Risk**, describe the problem(s) below.

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