FORESTRY BEST MANAGEMENT PRACTICES IN MARYLAND:
Implementation and Effectiveness for Protection of Water Resources

Maryland Department of Natural Resources Forest Service

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Executive Summary

Best Management Practices (BMPs) were evaluated on 75 forest harvesting sites statewide in 2004 to 2005, with seven sites revisited for quality control assurance. BMPs to control erosion and sedimentation are required in Maryland. Overall compliance with State water quality BMPs on 39 sites were water was present was 81%, similar to the overall 82% rate found in an earlier 1995 study. This study selected for sites with water features, representing the harvests areas with the greatest vulnerability for pollution, particularly erosion and sediment deposition.

- Maryland had 81% compliance overall with forest harvest BMPs, considering the most vulnerable 20% of sites harvested in 2003 to 2004.
- Over 90% of harvests avoided stream crossings statewide.
- With averages weighted to consider harvests without streams or crossings, compliance averaged 87%.
- Compliance on 24 State Forest harvests performed throughout Maryland averaged 99%.
- BMPs were 77% effective in preventing sediment delivery on the most vulnerable sites. Weighting the average to account for the harvests avoiding streams, BMPs in practice avoided contributing sediment over 95% of the time.
- Trace amounts of sediment were seen on 4% of sites, and measurable amounts of sediment reached the water on 19% of sites.
- On the 19% of sites with measurable sediment reaching the water, the median sediment delivery observed was 8 cubic feet of sediment, considering both crossings and approaches.
- Over 48,000 linear feet of riparian forest buffers were sampled, and sediment was observed entering the water at 6 locations, with a total estimated sediment delivery of 1 cu. ft. Sediment entered the buffer at 39 locations, but the buffers effectively filtered 85% of the sediment trails and greatly diminished volume.
- 71% of riparian areas had some tree removal, leaving an average of 78% crown closure and 82 ft^2/acre of basal area, greater than the required 60 ft^2/acre. Average diameter at breast height of the largest leave tree per plot was 18 inches.
- Most harvests (71%) avoided wetland areas.
- Where wetlands were crossed, most sediment movement was in trace amounts; 3% of sites had measurable deposition of sediment and 20% of sites had rutting.

Areas that would benefit from additional training on BMP implementation include installing and closing out stream crossings, managing road and skid trail approaches and cross-drainage, and properly installing harvest road entrances. The Maryland/Delaware Master Logger Program offers continuing education on timber harvesting BMPs in partnership with Maryland Cooperative Extension Service.

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Introduction

Forests are the native vegetation in most of Maryland, and the least polluting major land use. Lands converted to other uses typically generate more runoff and nutrients, making retaining forest land a priority for keeping healthy streams and watersheds in this region. Forests frequently are managed for a variety of products and services from timber and firewood to recreation. Over ¾ of the forest land in Maryland is privately owned. Periodic harvesting allows landowners to capture significant value, a strong incentive to keep land in forest. Forests provide public benefits for clean water, clean air, and wildlife habitat while also providing renewable resources for a sustainable society. Forest management can provide these multiple benefits and avoid significant impacts to water quality only if harvest operations are carefully conducted. Forestry Best Management Practices (BMPs) to minimize sediment and stream impacts include stream buffers, water bars, avoiding wet-weather logging, and careful road design and landing locations that avoid steep slopes (Lynch et al., 1985).

Forestry BMPs are used to meet the 1972 Clean Water Act requirements to maintain water quality standards and prevent sediment from entering waterways during harvest operations and other forest management activities. Properly applied BMPs have been widely shown to be effective in minimizing damage to streams and water quality (Aust and Blinn, 2004; Pannill, et al., 2000, Kochenderfer et al., 1997). Timber harvesting activities have been exempt from the National Pollutant Discharge Elimination System permitting process of the federal Clean Water Act provided that BMPs are used and are effective in protecting water quality and aquatic systems, based on early research on the effectiveness of harvesting BMPs (e.g., Patric, 1976; Hornbeck, 1968). Where BMPs are not used, properly applied, and maintained, significantly more water quality impacts are likely and can impair watersheds over longer time periods, particularly from sediment contributions (Wynn et al., 2000; Arthur et al., 1998; Kochenderfer and Hornbeck, 1999). Consistent and reliable data on the use and effectiveness of BMPs remains the most important evidence of a State's enforcement of and compliance with the Clean Water Act.

Maryland's BMPs for sediment and erosion control have been required by state law since 1985, and are implemented through the Soil Conservation Districts and Maryland Department of the Environment, with delegation to some county governments. Statewide assessments have been used periodically to track overall BMP compliance (Koehn and Grizzel, 1995). Maryland collaborated with a new BMP assessment effort, the Northeastern Area Harvesting BMP Monitoring Protocol, to support a methodology that would assess effectiveness of BMPs as well as regulatory compliance, and allow regional information to be compiled (Ryder and Edwards, 2005).

Methods and Protocol Background

The U.S. Forest Service Northeastern Area Harvesting BMP Monitoring Protocol was designed as an economical, standardized and repeatable monitoring process that could be easily incorporated into State BMP programs. It allows states to generate information that is quality controlled and able to be compared directly to other states in the region. Maryland-specific monitoring information was collected using a BMP checklist developed in conjunction with the Master Logger Program.

Further information, manuals, software program and training in the protocol procedures and report generation can be obtained from the U.S. Forest Service, Northeastern Area http://na.fs.fed.us/watershed/bmp.shtm .

The NA BMP Monitoring Protocol was used to collect information on the effectiveness of BMPS as applied in the field in preventing sediment from entering water bodies. Sample units are defined around stream crossings or other water features, so results offer information on those sites most likely to contribute sediment. A total of 75 sample units were assessed in Maryland. Seven of those sites were revisited for a quality control check and assessment of repeatability of observations. The Maryland-specific BMP implementation checklist was used to determine whether BMPs were applied as required by state law, complementing the NA BMP Protocol information on how effective those BMPs as applied were in preventing sediment pollution. Since some of the harvest operations afforded more than one opportunity for the NA BMP Protocol samples, only 39 unique sites were evaluated for compliance, with an additional 24 sites on state lands.

Each NA BMP Protocol sample unit contains the potential for approximately 200 observations and includes a number of observations of some types of data. Proportions presented in the charts and graphs in the standard data summaries are based on the total number of possibilities for a condition to occur. Null observations are included in the calculations to ensure that the proportions total 100%, and the frequency of problems is accurately reported.

The data collection procedure is described in the Best Management Practices (BMP) Protocol Field Guide: Monitoring Implementation and Effectiveness for Protection of Water Resources which includes the question set, instructions for sampling, diagrams, and definitions.

Data Summary generation, quality control, risk analysis and statistical sample design information are described in the Best Management Practices (BMP) Protocol Desk Reference: Monitoring Implementation and Effectiveness for Protection of Water Resources.

Background of the NA BMP Protocol

The Best Management Practices Protocol was a cooperative effort of the Northeastern Area State and Private Forestry (NA) and the Northeastern Area Association of State Foresters - Water Resources Committee (NAASF-WRC), and funded by the USDA Forest Service (NA) and the US Environmental Protection Agency (EPA). The original concept and question sequence was developed by Roger Ryder and Tim Post of the Maine Forest Service in collaboration with Dave Welsch and Al Todd, USFS. Dave Welsch, NA Forester/Watershed Specialist, served as project coordinator through the development, testing and implementation of the project. The data summary and analysis phases of the project were developed by Kristina A. Ferrare and Paul K. Barten of the University of Massachusetts - Amherst, Watershed Exchange and Technology Partnership. The development and testing of the BMP Monitoring Protocol are described in Ryder and Edwards (2005).

State forestry agencies from ME, NH, VT, MA, NY, WI, WV, MD, IN, DE, OH, PA, VA and the New York City Watershed Agricultural Council, Forestry Program as well as U.S. Forest Service Northeastern Area and U.S. Forest Service Northern Research Station personnel have collaborated in the development and testing of the BMP Protocol.

The NA BMP Protocol is designed to follow the evidence of erosion and transport of sediment to determine effects of the harvest on water bodies, so the protocol sampling is defined around water crossings (Figure 1). On a large harvest site with multiple stream crossings, the BMP effectiveness can be measured separately at each crossing. The protocol focuses on the most likely points of entry for sediment, crossings and approaches. Approaches are assessed separately for areas inside the buffer and outside the buffer to allow the effect of proximity to the stream to be evaluated (Figure 2).

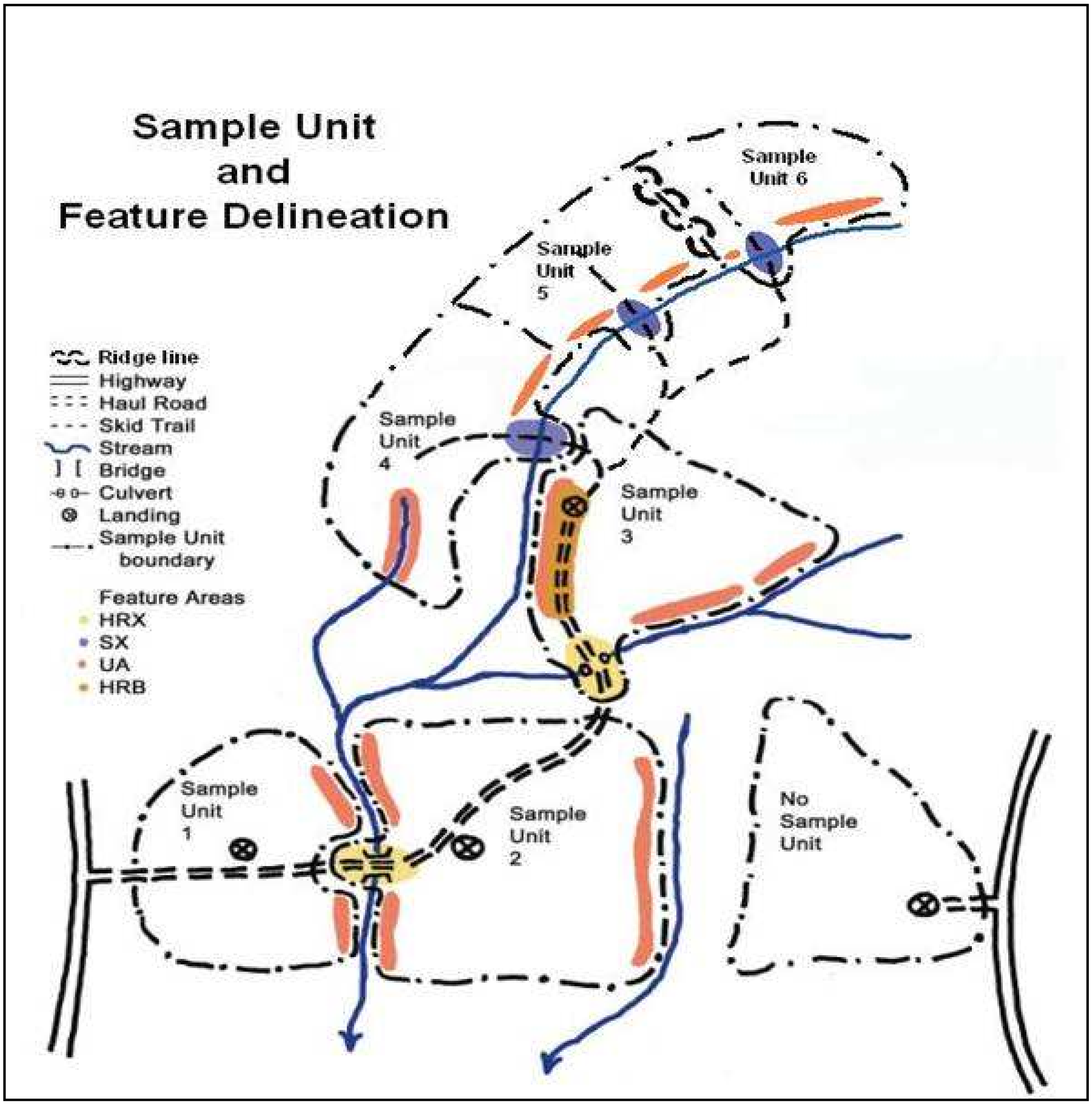

Figure: 1 Sampling approach for the Northeastern Area Harvesting BMP Assessment Protocol

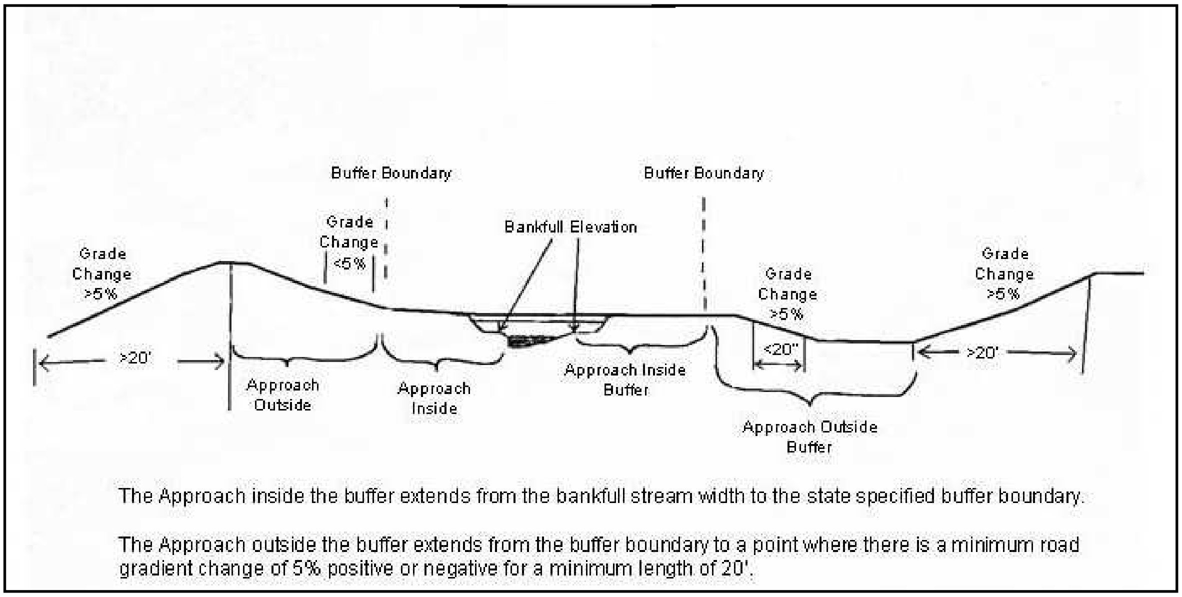

Figure 2: Length of approaches sampled based on buffer location and grade change (from NA BMP Protocol Manual)

Sampling

Harvests were sampled based on sediment and erosion control permits required for timber harvesting operations in Maryland. Copies of permits were collected from each Maryland county's authorizing agency for the application period of 2001 to mid-2004. Applicants have two years from the time approved to carry out the harvest. To be able to apply the NA BMP protocol, the applications were screened for the presence of a water feature, including a stream crossing, stream buffer, or wetland. Over 90% of Maryland harvests avoided stream crossings, a fundamental BMP to limit impact of harvests on water quality (Figure 3). **Consequently, compliance data in this study is collected on the 10% of harvests where it is most difficult to implement BMPs.** All sites with stream crossings were selected. To meet the minimum number of sites for the regional protocol pilot, sites in addition to stream crossings were selected based on presence of a wetland or stream buffer, randomly sampled within physiographic province (Mountain, Piedmont, Coastal Plain). Because soils, slopes, and other factors that affect what BMPs apply vary among the physiographic provinces, the sampling assured that all provinces would be represented.

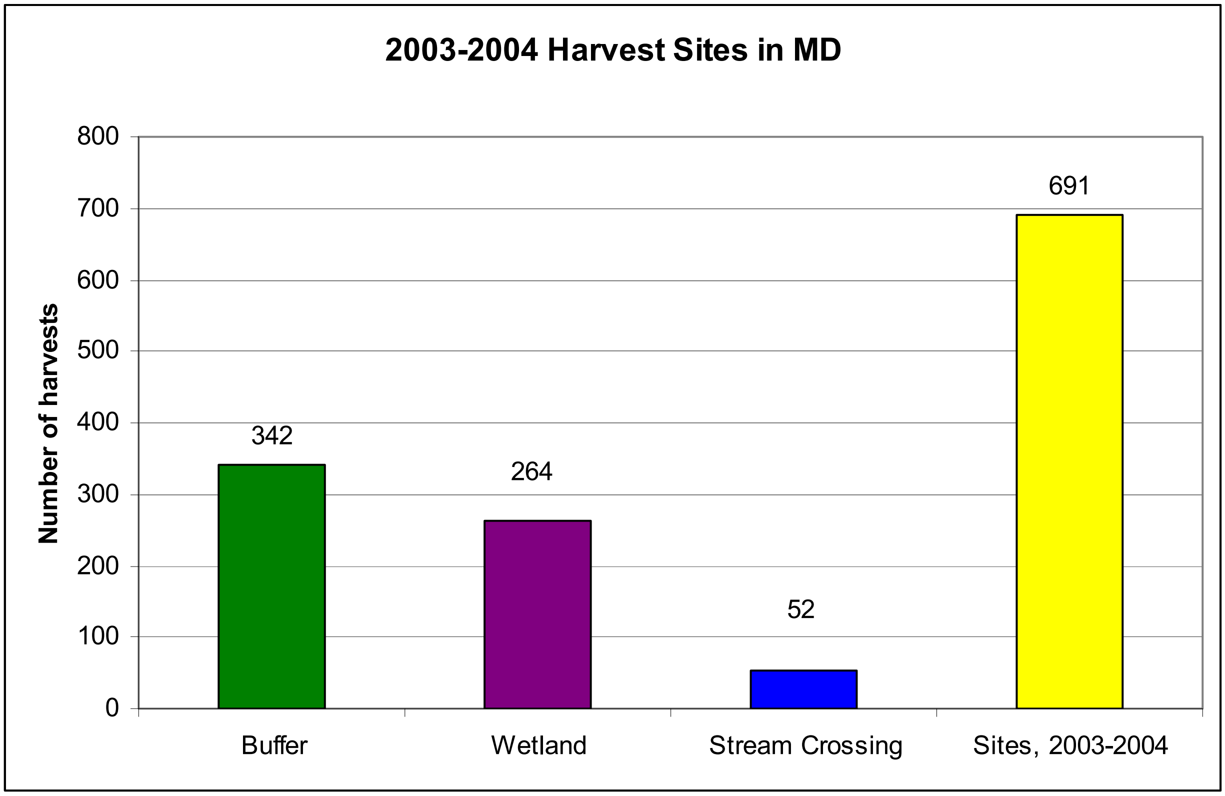

Figure 3: Harvests with streams, buffers and wetlands relative to total harvests

Harvest sites were visited between Summer 2004 and Spring 2005, choosing sites harvested within the previous year, and with the harvest completed so that final close-out practices could be evaluated. Data were gathered in the field by a contractor, Sustainable Solutions, LLC, and MD DNR staff. Quality control checks were provided by MD DNR Forest Service.

Results

General Information on Harvest Sites

A total of **75** harvest areas were sampled, taken from harvests initiated in 2003 to 2005 (Figure 4). Sampling occurred in 2004 (22 sites) and 2005 (53 sites), generally within one year of completing the harvest and closing out the site. This timing allowed evaluation of practices like stabilizing the landing and functioning of water bars.

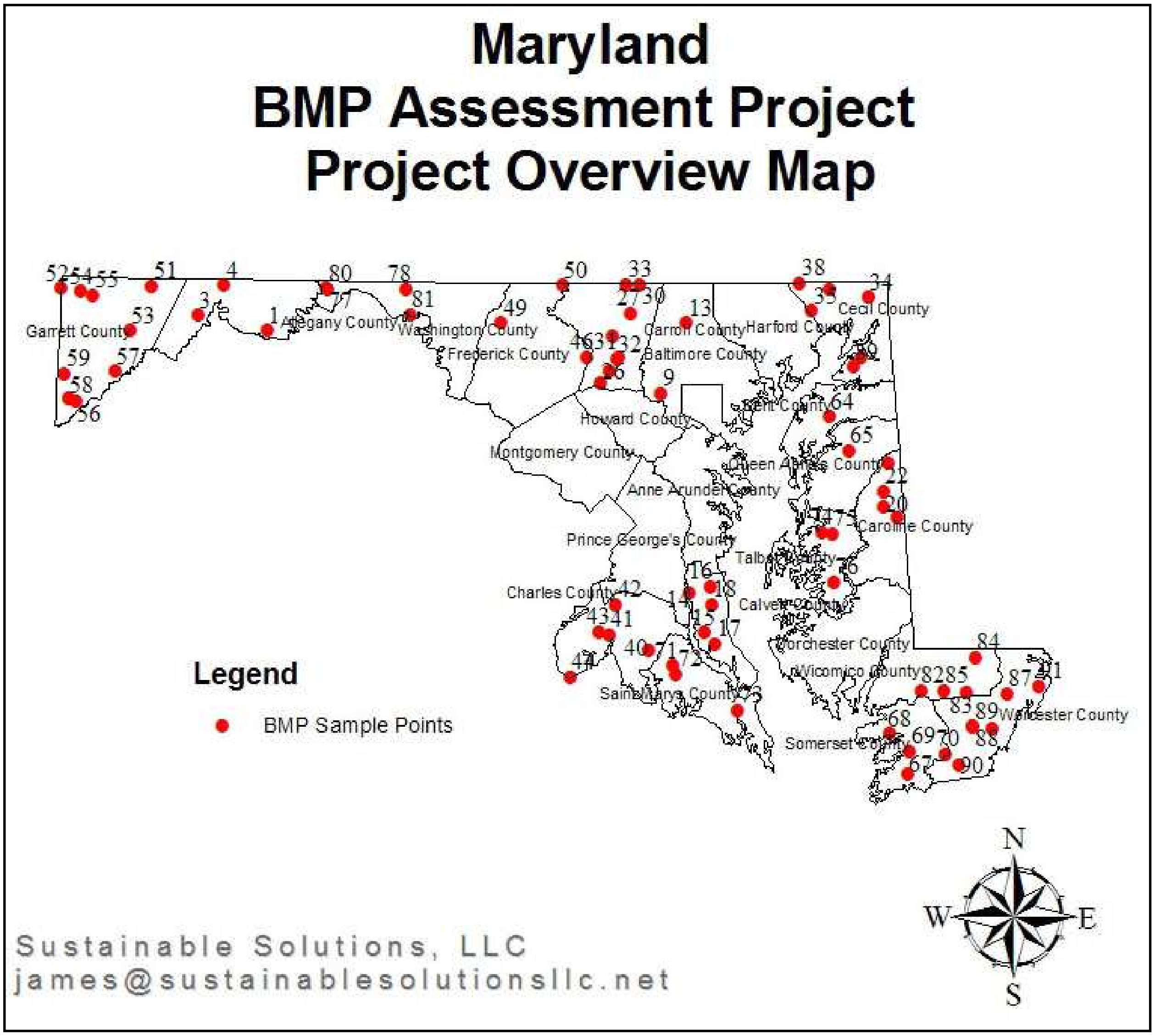

Figure 4: Locations of harvest sites monitored in 2004 and 2005

Ownership Category and Acres Monitored

Like Maryland's overall forest ownership, most of the areas evaluated for forest BMPs were on private land, 87%. Industrial ownership accounted for 5%, and 7% was on state ownership.

The forest tracts harvested in Maryland tended to be more than 50 acres in size, although harvests on less than 10 acres did occur (Figure 5). A variety of forest management practices were used, with partial harvesting predominating in hardwood areas and thinning and clearcuts being more common in pine stands. Almost all harvesting operations used skidders to remove logs from the forest to the landing, so logs were dragged rather than carried or suspended.

Total number of acres monitored: **1,562**

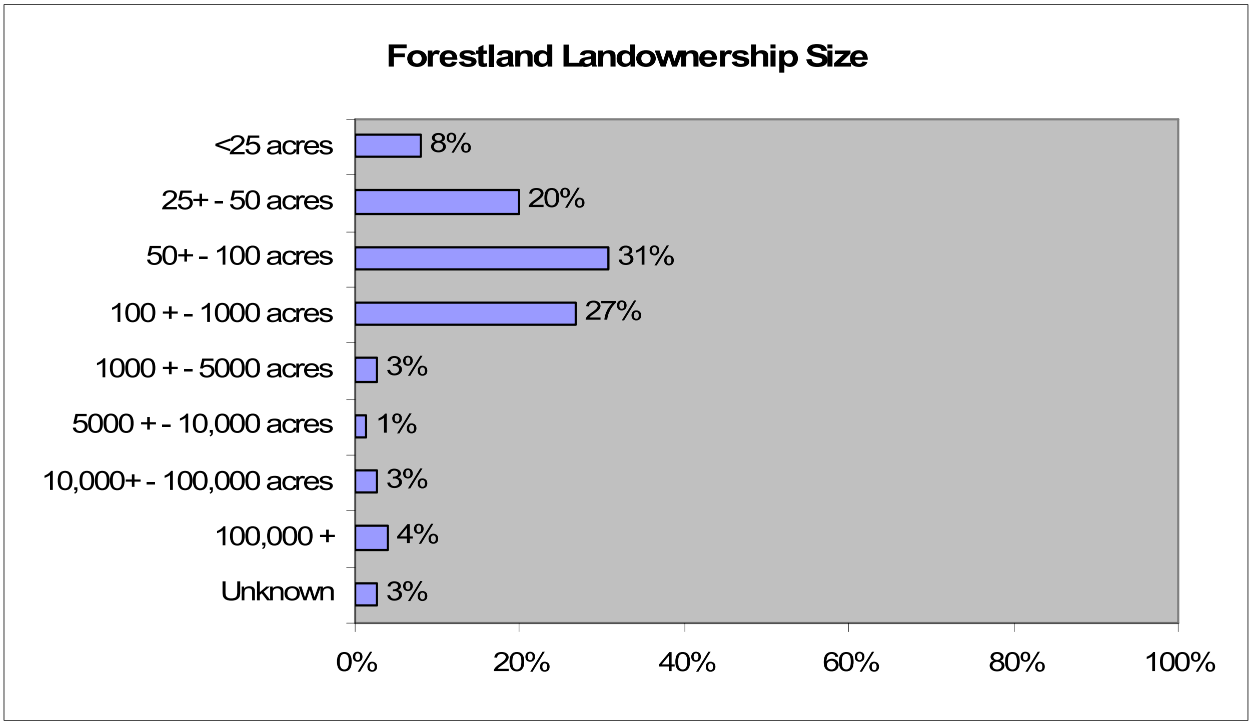

Figure 5: Forest Ownership size of sampled tracts (n=75)

Number and Proportion of Sample Units by Feature

For the Northeast Area BMP Protocol, the sample units evaluated more than one feature on a site, such as sediment movement at two approaches and a crossing structure for each location. Therefore, the total of activities and conditions will exceed the number of sample units (e.g. 170 activities and conditions in 75 sample units). Riparian areas were most commonly represented (Figure 6), reflecting the emphasis of the sampling on sites with water features. Skidder crossings were more common than haul road crossings, reflecting the much greater length of skid trails on a harvest site.

Since 90% of the harvests recorded from 2002 to 2004 avoided stream crossings and the monitored sites were chosen based on the presence of a stream crossing, wetland, or stream buffer, the features encountered on the monitored sites represent the harvests with the greatest vulnerability for sediment reaching streams. Maryland requires nontidal wetland permits for any new stream crossing, an incentive to access harvests without stream crossings if possible.

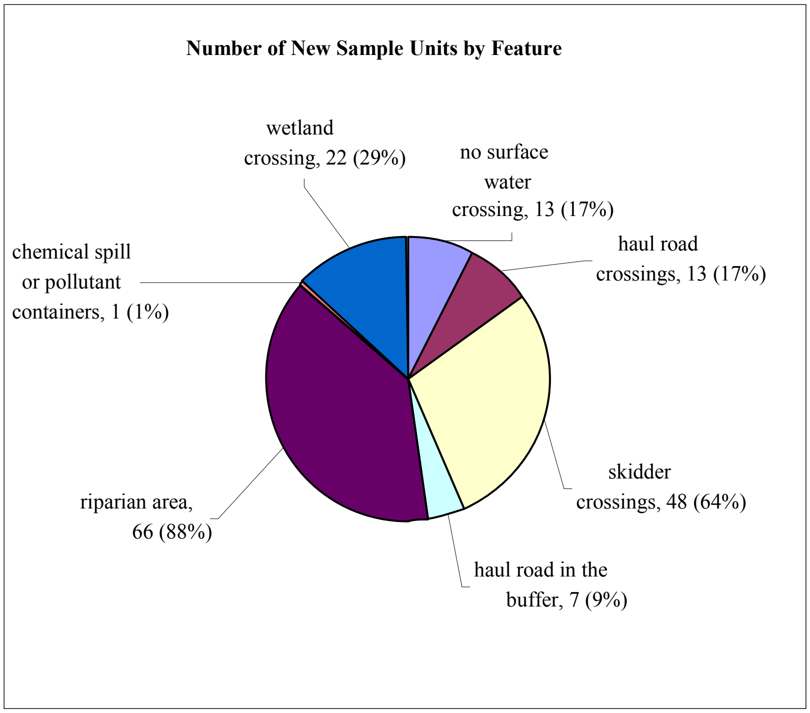

Figure 6: Number of new sample units by harvest site feature (n=75)

Compliance with Maryland Harvest BMPs requirements

The average compliance with harvesting BMPs in Maryland for 2003 to 2004 was 81%, focusing on harvest sites with water features and the greatest likelihood for water quality impacts (Figure 7). This rate is similar to the overall 82% harvest BMP compliance in Maryland found by Koehn and Grizzel (1995). Harvest landings had the highest compliance, located properly away from streams, on low slopes, and being kept free of trash. Haul roads consistently met slope restrictions, avoided rutting, and were located away from stream buffers; the greatest room for improvement lay in roads that needed more cross-drainage (16% of sites sampled). For harvest entrances, there was little evidence of road damage or mud tracked onto public roads, but improvements could have been made on cross-drainage at the entrance (32% of sites) and better stabilization at the entrance (23% of sites).

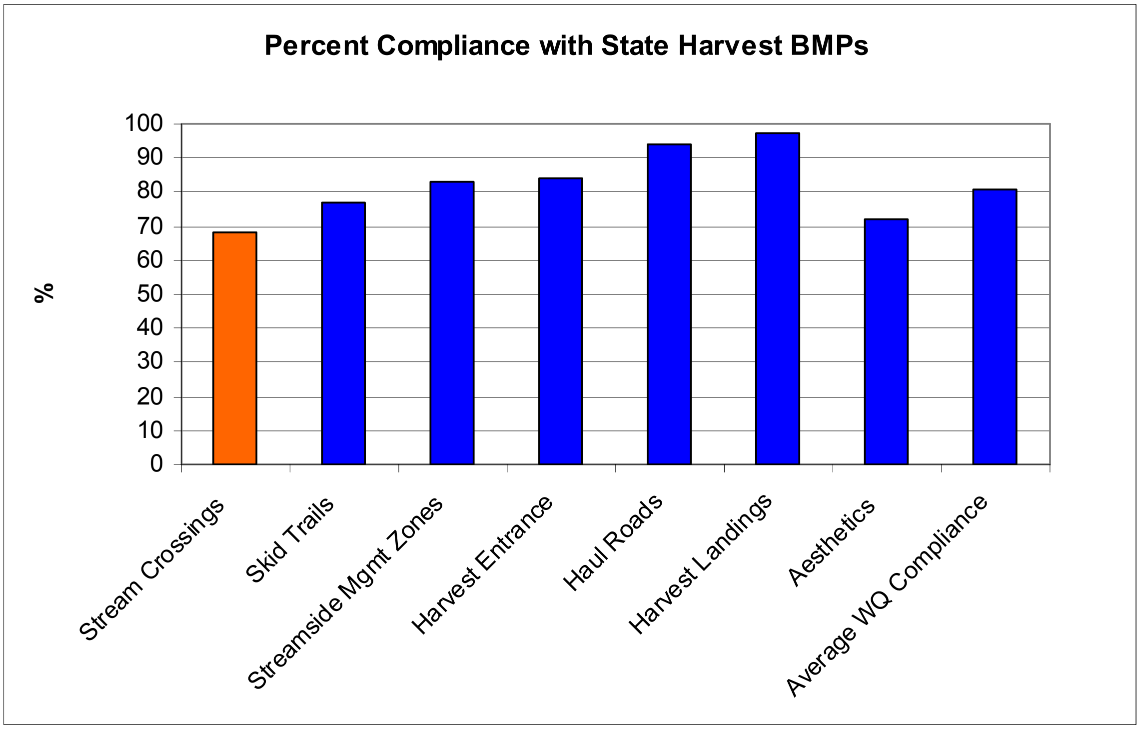

Figure 7: Percent compliance with Maryland Harvest BMPs, 2003-2004 (n=39)

Streamside Management Zones (SMZs) met State standards for buffer width (Figure 8) and basal area required to be retained (Figure 9) on almost every site. The minimum SMZ width is 50 feet, with expansions for slopes accounting for the much greater ranges in width. In Maryland, if any harvesting occurs in the SMZ, 60 square feet/acre of basal area must remain (typically half or more of the overstory). Almost ¾ of the sites had some harvesting in the SMZ, but the average retention, 82 ft^2/ac. of basal area, was well above the State minimum of 60 ft^2/ac. The minimum basal area is meant to retain the ability of the buffer to shade streams, and can also provide large woody debris for stream habitat. Measurements from the BMP protocol indicated that buffers averaged 78% forest canopy cover even after harvesting, retaining most of the pre-harvest stream shading. The functionality and stability of large woody debris in streams is strongly related to piece size, so bigger trees generally are better source of future woody debris. The largest tree diameter was measured in each buffer plot in the NA protocol. The average diameter of the largest tree left was 18 inches, large enough to be stable in almost any stream on the harvest sites. Areas for improvement with SMZ regulations were primarily related to better marking and maintenance of buffer width (41% of sites could improve).

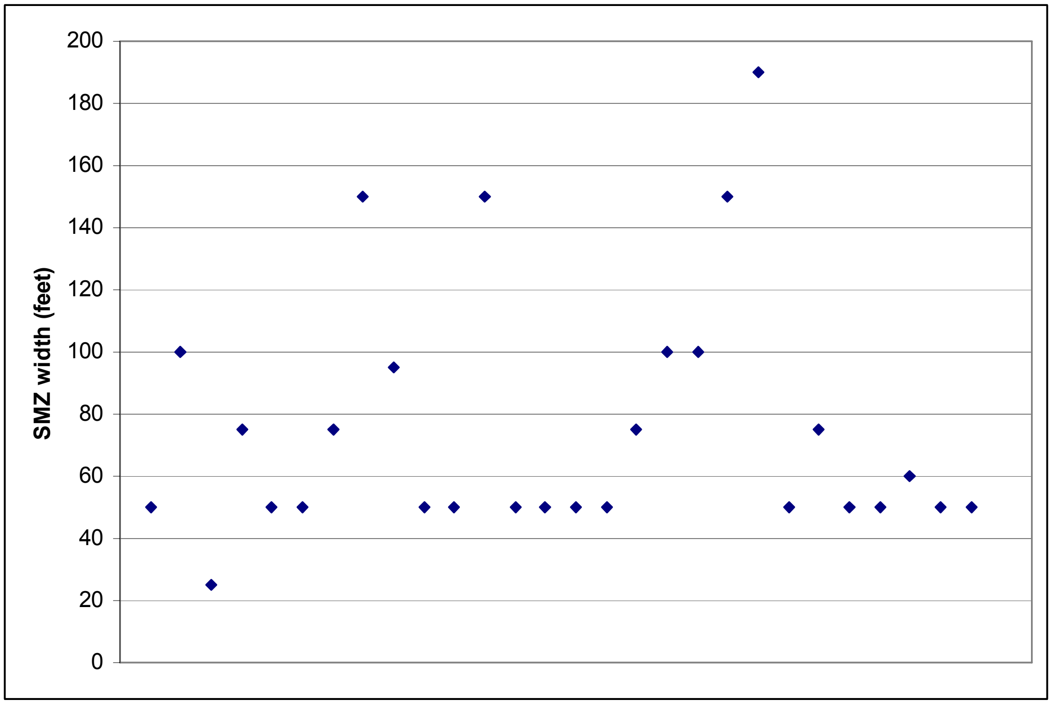

Figure 8: Streamside Management Zone width at harvest sites with buffers, 2003-2004 in Maryland (50 foot is minimum)

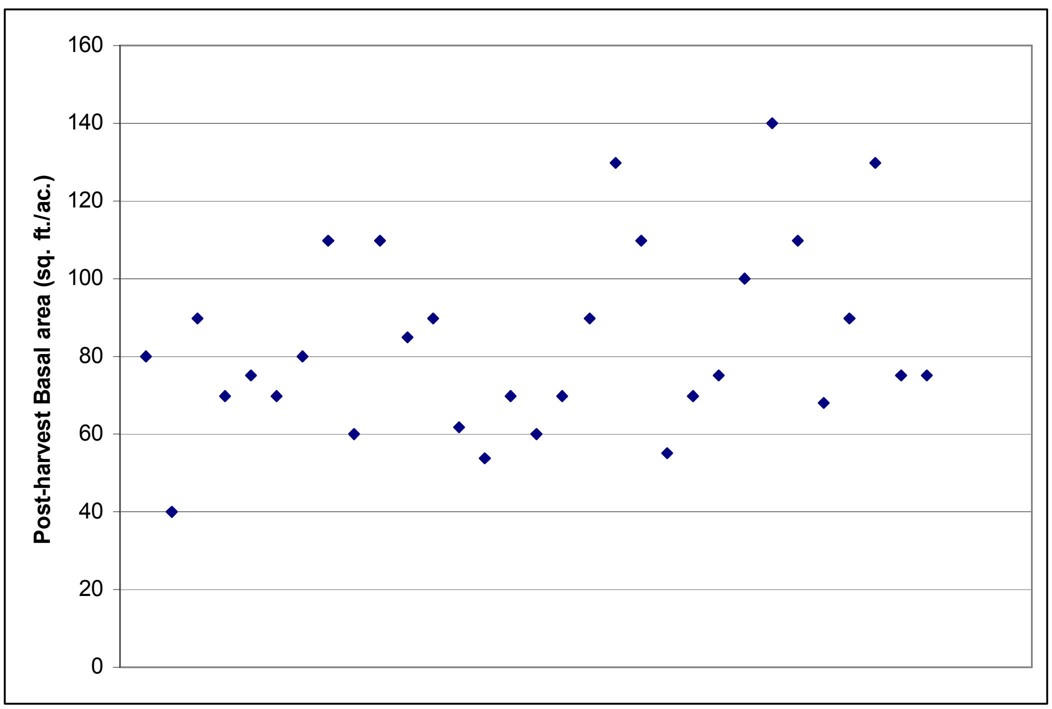

Figure 9: Basal area (square feet/acre) of trees retained in Streamside Management Zones in Maryland after harvest (60 ft^2/ac minimum)

Stream crossings are the most difficult area for BMP compliance in Maryland, similar to the situation in most states. Many of the basic BMPs like minimizing stream crossings and installing crossings at right angles to streams were consistently implemented (Figure 10). More improvements were needed on properly sizing crossing structures such as culverts, stabilizing approaches, and diverting runoff prior to approaches to the stream. These could be focus areas for future BMP trainings and the Master Logger Program.

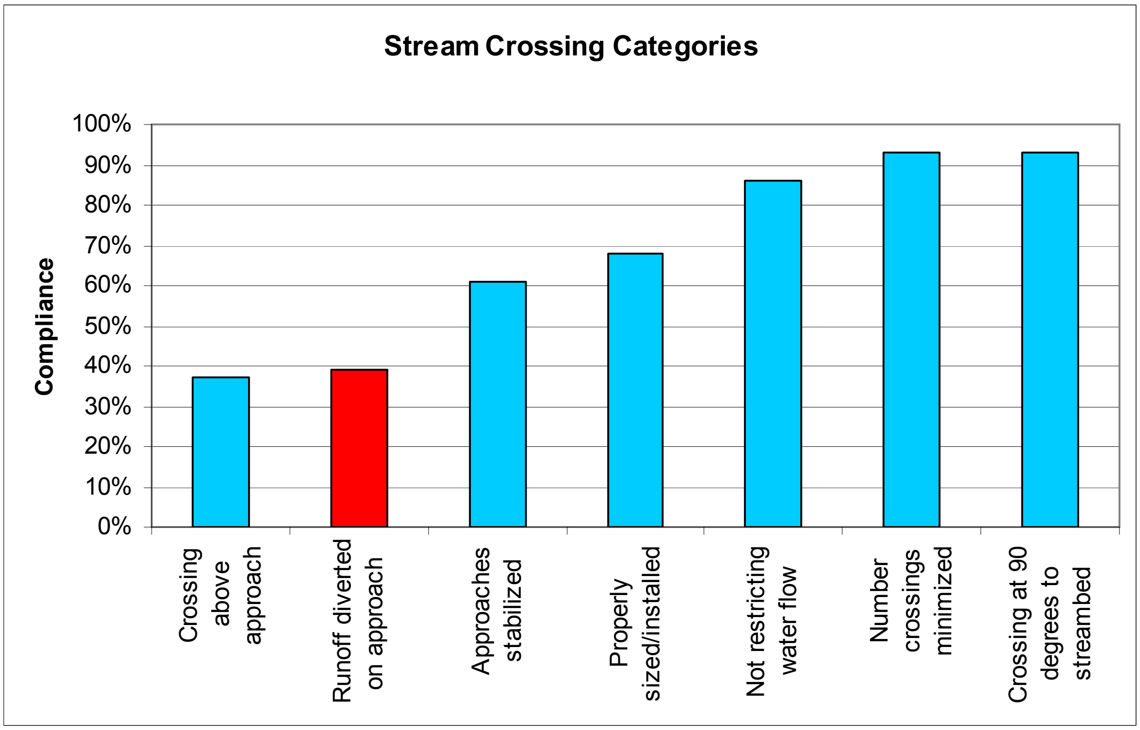

Figure 10: Compliance categories and rates with Stream Crossing BMPs in Maryland, 2003-2004

BMP Compliance on State Forests in Maryland

State Forest lands in Maryland are actively managed for multiple resources, including timber. Harvests on State Forests are overseen by State Forest staff, and written checklists of BMP compliance are completed. The BMP checklists on additional 24 sites on State Forest harvests were evaluated to develop a more accurate figure of compliance on State lands. Forest locations were in Western, Eastern, and Southern Regions: Green Ridge State Forest, Pocomoke State Forest, Cedarville State Forest, and Doncaster Demonstration Forest, evaluated between 2002 and 2006.

BMP compliance with water quality BMPs on State lands was 99%, higher than the statewide average (Figure 11). Stream crossings were avoided on all sites. Rutting on skid trails was identified at 2 of 24 sites. Other BMPs for streamside management zones, harvest entrances, haul roads, and landings were consistently followed. Safety guidelines were also evaluated. Most safety equipment and operations guidelines were followed very consistently and rates of compliance with each item were over 70%. There was room for improvement in safety equipment regarding use of hearing protection, hard hats, and leg protection during chain saw operations. For equipment operations, posting notices of harvest entrances off of public roads was missed at several sites. BMP evaluators on State Forests also ranked the overall performance qualitatively. Application of BMPs consistently met minimum standards, so most harvests were ranked good and above, but some sites had superior implementation, reflected in the range of rankings (Figure 12)

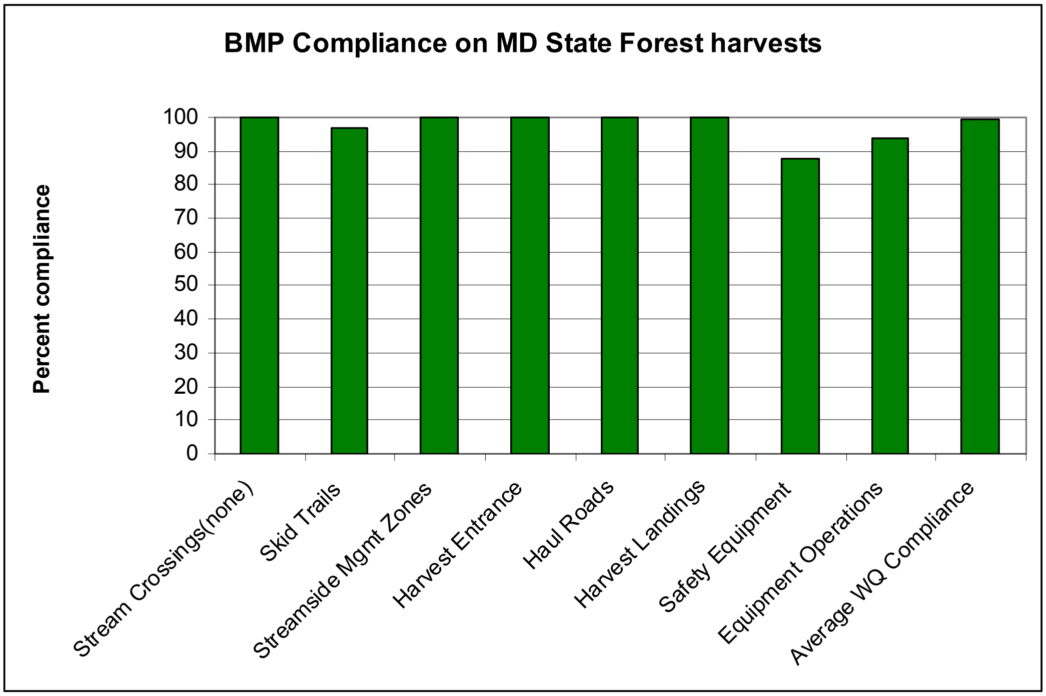

Figure 11: Average BMP compliance on Maryland State Forest harvests (24 sites)

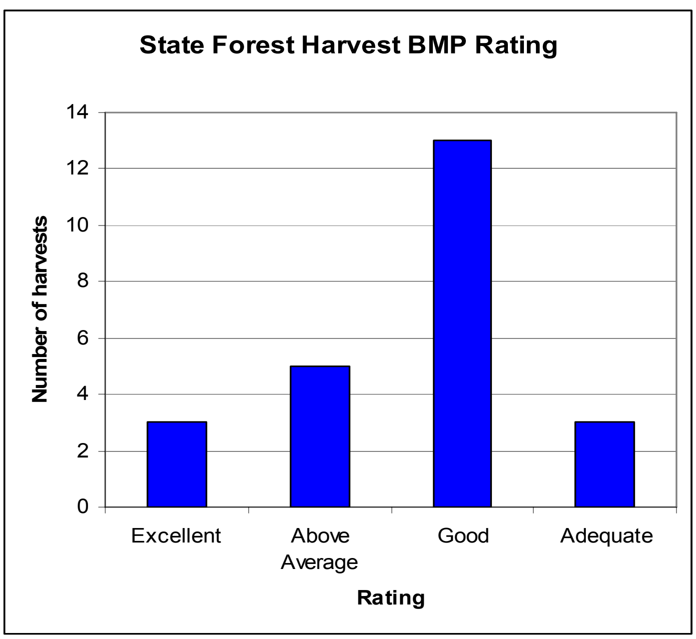

Figure 12: Comparative rating of water quality and safety BMPs on State Forest harvests

Soil Movement, Sedimentation and Stabilization

Sediment is the most common pollutant associated with forest harvests, and most erosion usually is associated with forest roads, (Aust and Blinn, 2004). In the NA BMP Protocol, there are five opportunities to observe the occurrence of soil movement, soil sedimentation, or stabilization for each sample unit. They are on the harvest roads or skid trails at Approach A outside the buffer, Approach A inside the buffer, the crossing structure, Approach B inside the buffer, and Approach B outside the buffer. The protocol uses estimates of eroded and deposited soil to quantify sediment, and includes observations of sediment films as trace sediment. Proportions in this section are based on the total number of opportunities to make observations about soil conditions. For the 75 sample units, there are 375 opportunities to observe soil conditions.

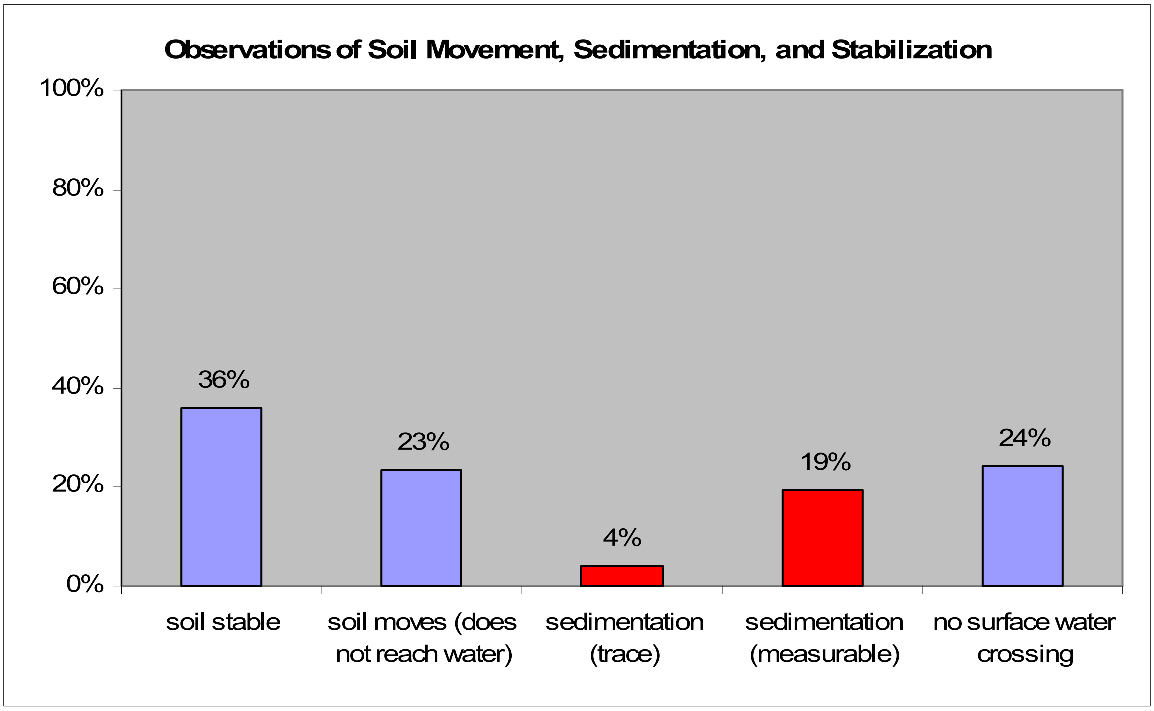

Figure 13: Observations of soil movement, sedimentation and stabilization as a proportion of total opportunities to observe soil conditions in the protocol (n=375)

The sites evaluated here included all known sites with stream crossings and a cross-section of other sites with water features, so that the study evaluated the harvest sites in the state with the greatest potential for sediment delivery to water and additional sampling would yield less opportunity for sediment entry into water bodies. The great majority (90%) of harvests avoided stream crossings, and thus met the most significant BMP for streams. Of 375 observations on this subset of harvests with water features, 59% did not deliver sediment, while another 24% of the sites further avoided stream crossings (Figure 13). Some sediment delivery to a water body was seen 23% of the time, including the 4% of observations with only evidence of trace amounts (15 instances of trace, 72 of measurable sediment). The median volume of sediment moved from rills and gullies at the crossings was 10 ft^3.

Sedimentation by Area of Origin

The NA BMP Protocol separates evaluation of sediment movement by approaches inside and outside the buffer and for the crossing structure (Figure 2), so observations can reveal the most common paths of sediment delivery. There are 87 observations of sediment reaching the surface water body or deposited within bankfull channel width of the water feature of the 375 opportunities to observe sediment.

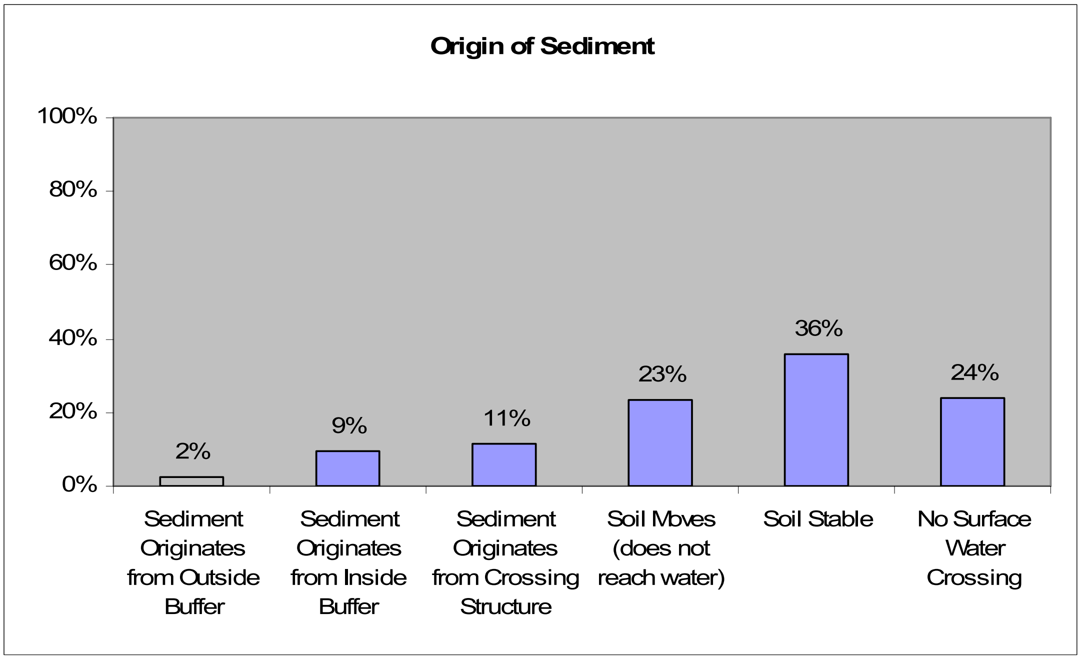

Figure 14: Sources of trace and measurable sediment at stream crossings on Maryland harvests, 2003-2004 (n=375)

There are 15 observations of trace amounts of sediment reaching the surface water body or deposited within bankfull channel width of the water feature. Most of these came from areas close to the stream, half within the road or trail inside the buffer, and half from the crossing structure itself. There are 72 observations of measurable amounts sediment reaching the surface water body or deposited within bankfull channel width of the water feature.

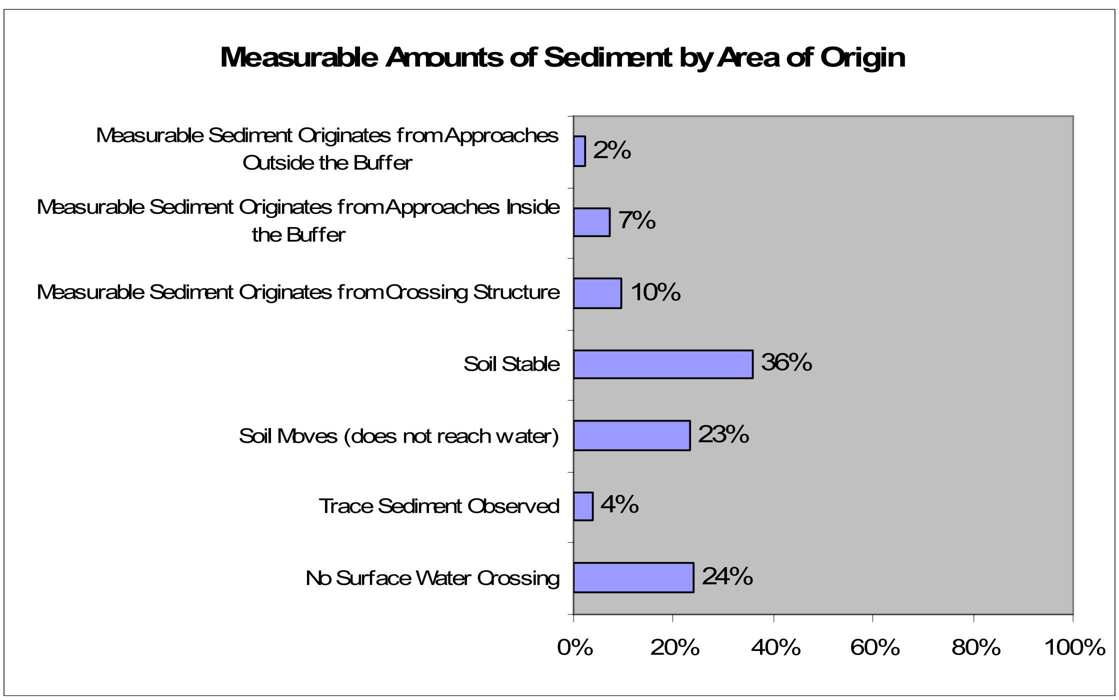

Figure 15: Sources of measurable sediment only on Maryland harvests (n=375).

Looking only at the measurable sources of sediment, the crossing structure again had the greatest likelihood of contributing measurable sediment (Figure 14). This is a typical outcome since there is usually little opportunity for sediment to be trapped elsewhere before entering the stream. The next greatest contributor of sediment was the approaches inside the buffer, again closer to the stream with less opportunity for being trapped and settling out before reaching a water body.

Sediment from approaches moved less than 20% of the time, but it was four times more likely to be measurable rather than trace amounts (Figure 15). Approaches were frequently seen to be stable (48$ of the 228observations), but another 34% of the observations had sediment that had eroded but redeposited before reaching the water.

Sediment from approaches outside the buffer area tended to be infrequent, only 2% of the 300 observations on approaches, but when they were present and continued to the water body, they carried almost twice the median volume of sediment (Table 1). This suggests that they are more likely to be gullies rather than rills, and more likely to remain from storm to storm. In these cases, diverting runoff with a well-placed water bar or ditch turn-out could address a persistent source of sediment if the topography allows downhill flow in a direction other than the road or trail. For measurable sediment from approaches outside the buffer, causes of sediment were noted as inadequate installation of BMPs and need for additional BMPs (Figure 16). Looking at the use of BMPs when sediment reached the water from stream crossing approaches, BMPs were frequently not applied, and less frequently inadequately applied (Figure 17).

Table 1: Measurable Sedimentation by Area of Origin (cubic feet)

	All Areas		Approaches Outside the Buffer		Approaches Inside the Buffer		Crossing Structure	
	Rill or gully	Sediment evident in water body	Rill or gully	Sediment evident in water body	Rill or gully	Sediment evident in water body	Rill or gully	Sediment evident in water body
Average	100	64	162	19	85	30	N/A	89
Median	10	8	163	15	10	8	N/A	8
Maximum	1250	606	320	50	1250	200	N/A	606

Note: Rill and Gully volumes are measurements of the volume displaced from the rill or gully and may be larger than the volume actually entering the bankfull channel. Sediment evident in the water body is a measure of the sediment attributable to the logging activity and present in the channel when the observation is made; it cannot account for sediment washed away prior to observation. Thus, there is a high probability that the actual volume of sediment reaching the bankfull channel of the water body is between these two estimates.

Specific Cause of Sedimentation from the Approaches

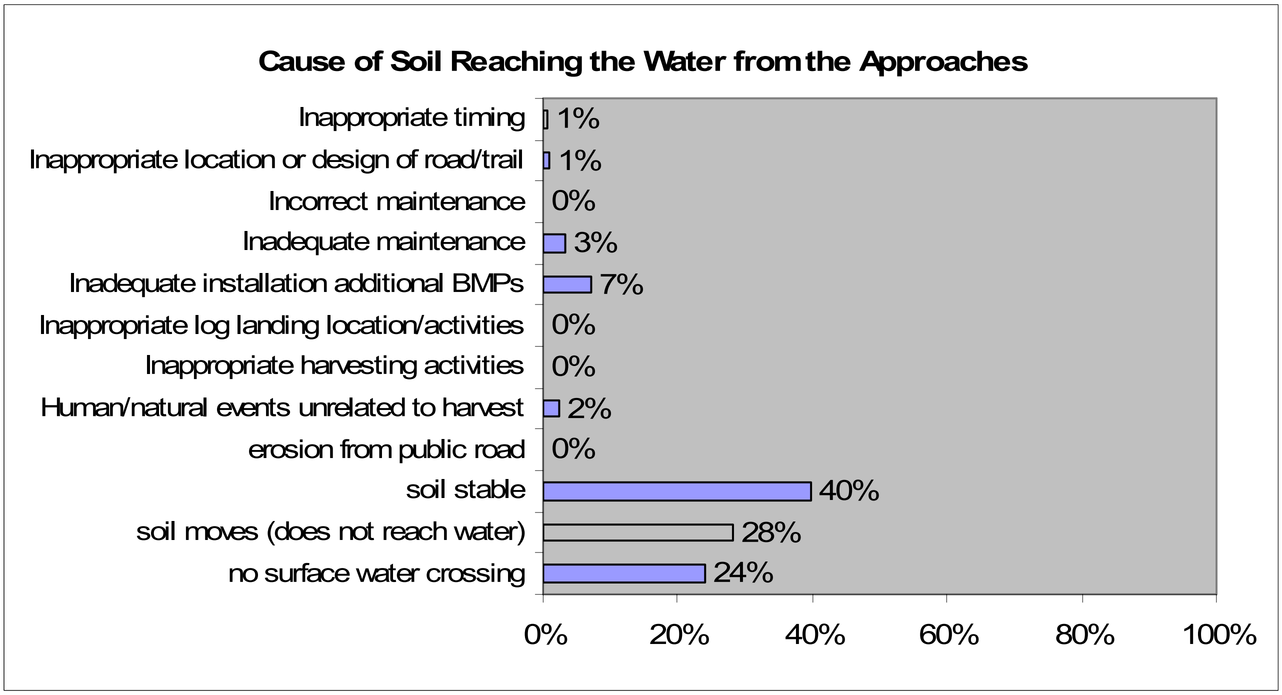

Figure 16: Cause of soil reaching water from the road and skid trail approaches (n=300)

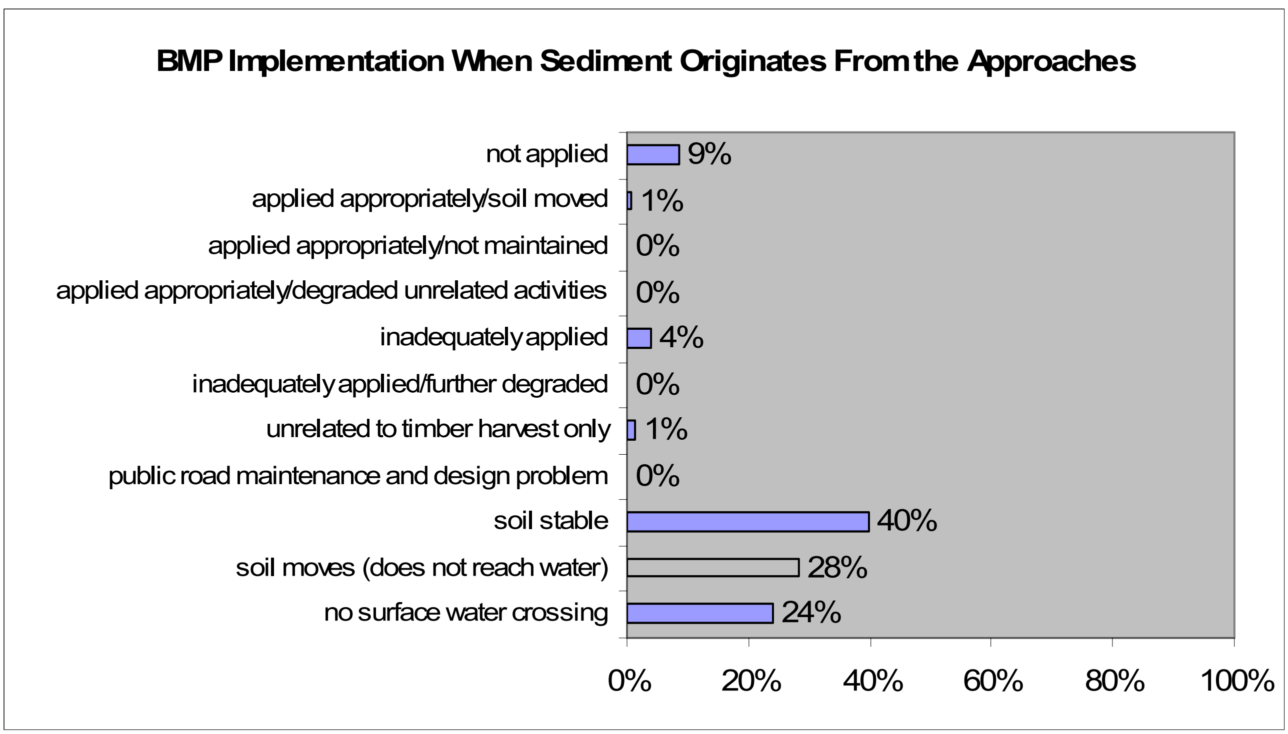

Figure 17: BMP Implementation status when sediment reaches the water from road or skid trail approaches (n=300)

Crossing Structures

Crossing structures were the most frequent contributor of sediment, since this area is within the stream cross-section. Although most harvests avoided stream crossings, when stream crossings had to be made, sedimentation was frequently seen (Figure 18). The protocol allows comparison of different types of stream crossings, whether it is associated with haul road or skid trail, and stream sizes. Crossing types are not uniformly represented, so results based on a small sample size should not be extrapolated broadly.

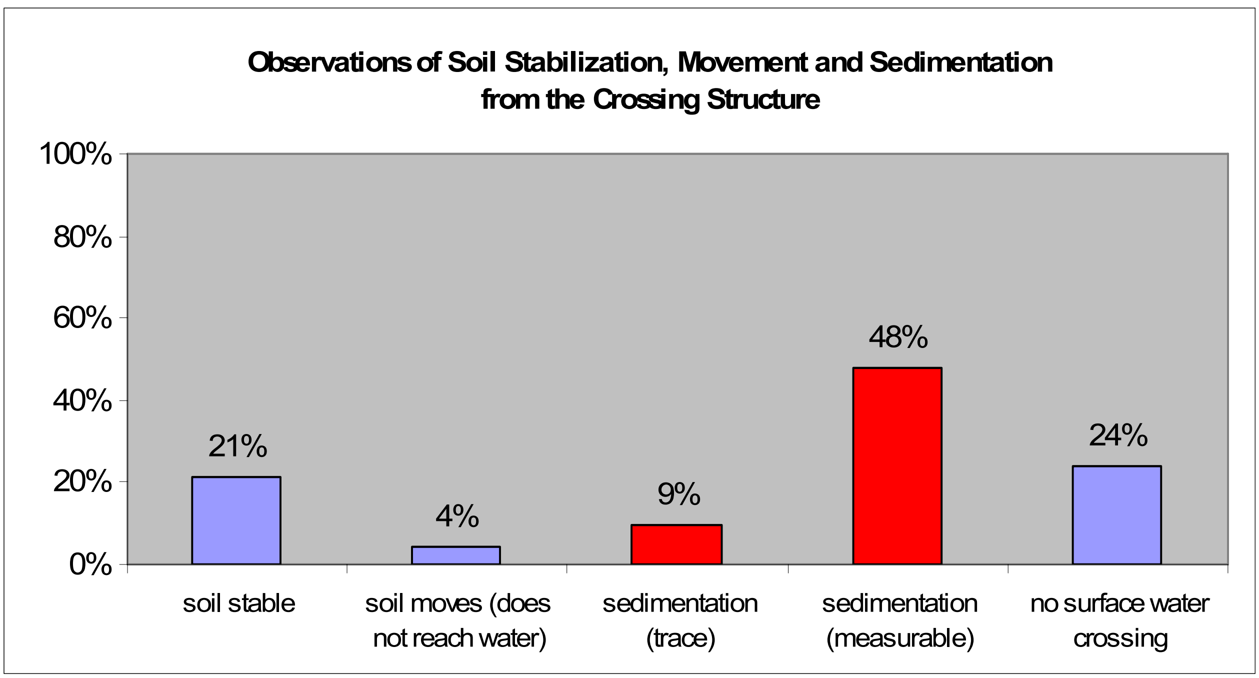

Figure 18: Sediment movement observed at crossing structures (n=75)

At crossings, sediment usually reached the water body or depositing within the bankfull channel in measurable quantities, observed at 57 locations at all types of crossings (Figure 18). The 7 observations of trace amounts of sediment were associated only with fords and culverts. Culverts were most commonly used on haul roads, while temporary crossings were most common for skid trails crossing streams (Figure 19).

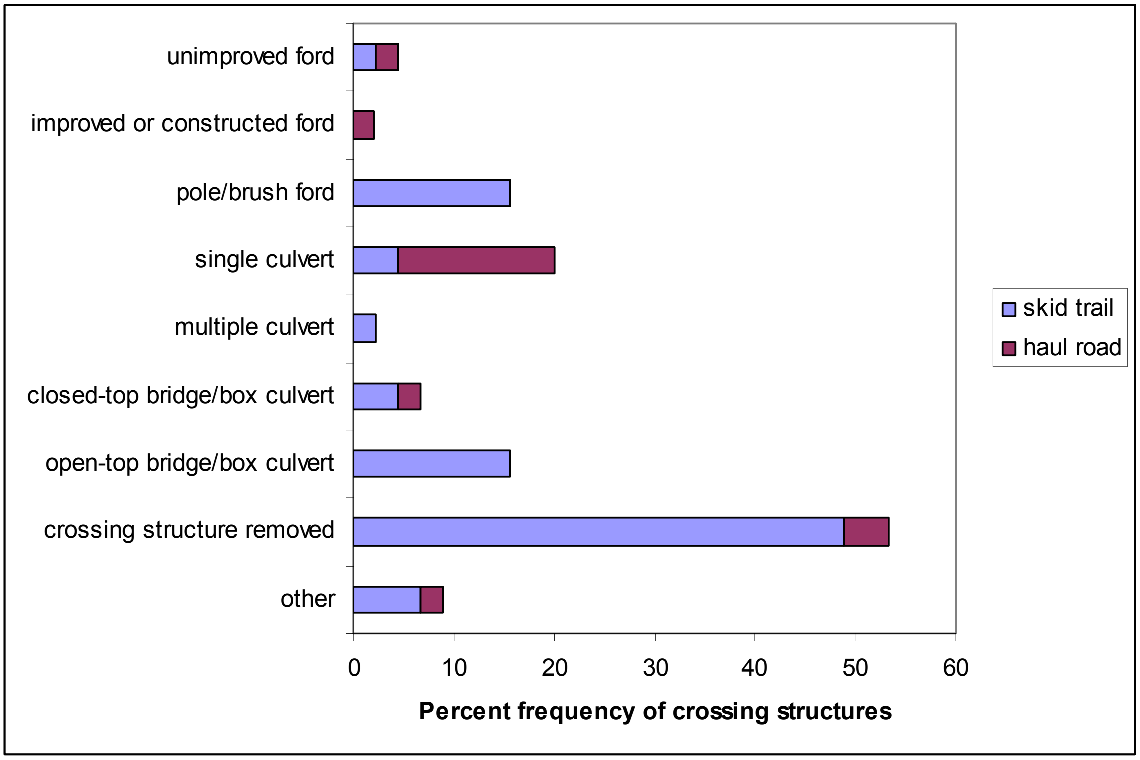

Figure 19: Crossing structures observed on sampled Maryland harvest sites, 2003-2004 (n=57)

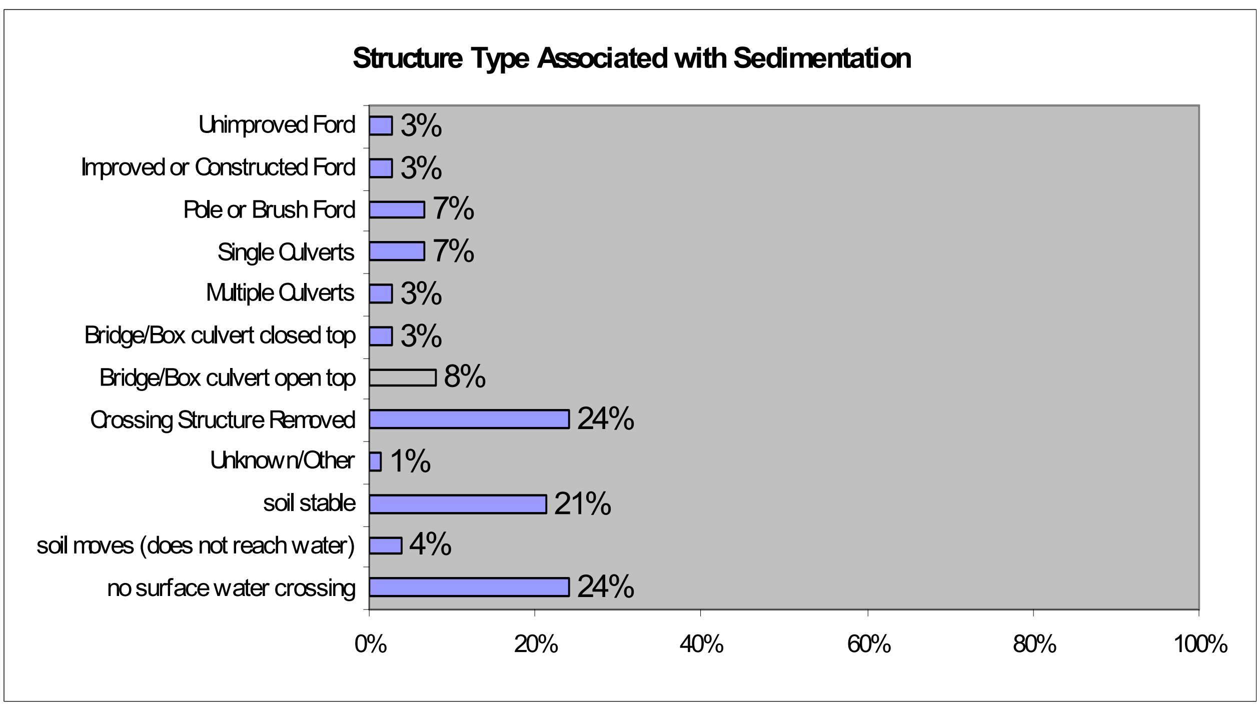

Figure 20: Observations of measurable and trace sediment at stream crossings by crossing type (n=75)

Bridges are generally the most preferred and most expensive method of stream crossing, allowing the greatest retention of the natural stream bottom and flow patterns and minimizing sediment within the stream cross-section. The use of bridges and temporary bridges has been increasing. Temporary stream crossings are removed following harvest, which can help avoid future problems with debris trapping and wash-out, particularly if maintenance is likely to be infrequent and access by others into the stand is not being encouraged. Culverts are very commonly used as a cost-effective crossing, especially on small streams, and can be quite stable if properly sized for the water flow, installed correctly, and maintained periodically.

No crossing structure type is immune from sediment entry (Figure 20). Temporary crossings had the greatest number of observations of delivered sediment (24%), but also represented over 50% of the crossings (Figure 19), so it is not disproportionate to the level of use. Most instances where sediment was delivered were attributed to improper installation or closeout (Figure 21). Given the frequency of use of temporary crossings and potential of any crossing to contribute sediment, some additional guidance on how to leave banks in a more stable condition following removal of a temporary crossing structure might be useful in BMP training.

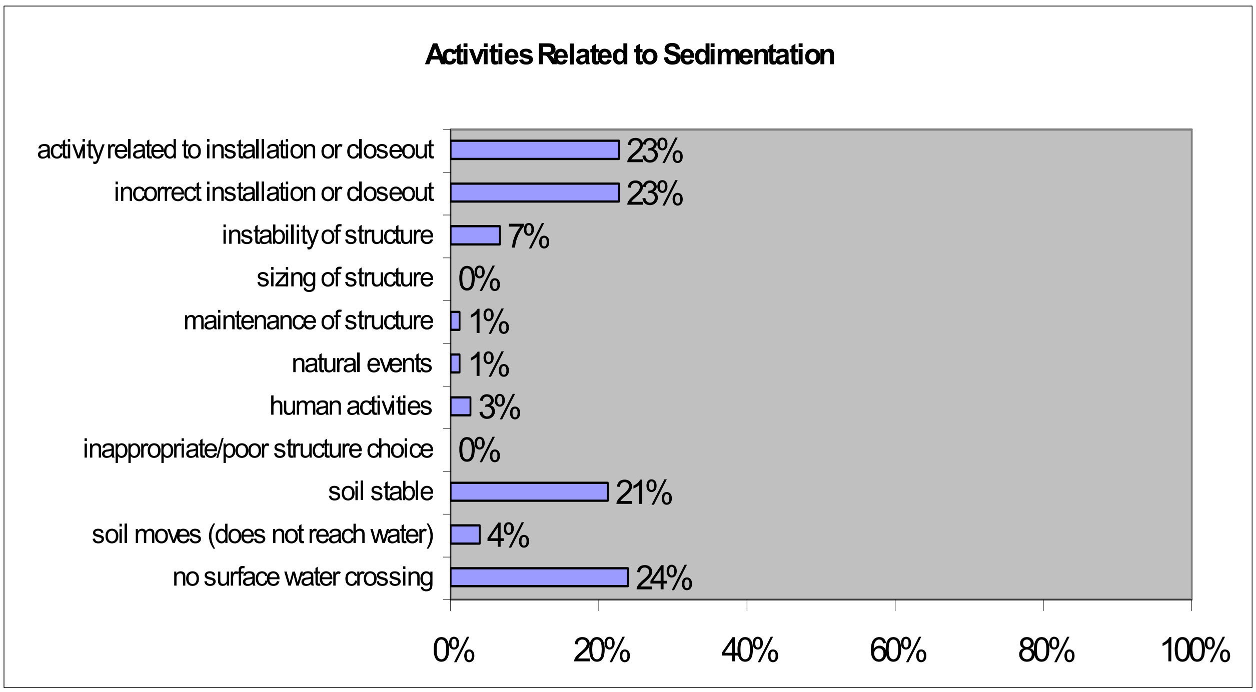

Figure 21: Attributed cause of sedimentation at crossings (n=75)

Quantities of Sedimentation by Crossing Structure Type

The types of crossing structures that were observed to have higher volumes of measurable sediment were the pole/brush ford, closed culvert, and removed structures (Table 2). More of these were associated with skid trails rather than haul roads (Figure 19). Sedimentation from removed structures typically results from leaving banks with steep sides and disturbed soil.

Sedimentation from both bridges and pole fords often occurs when material is carried onto them from approaches lacking reinforcement. The benefits of improving ford crossings were apparent in the sediment volume data, although a naturally stable ford could also perform well.

Table 2: Sediment volumes associated with stream crossing types

	Sediment Volumes (cu ft)		
	Average	**Median**	**Maximum**
unimproved ford	5	5	6
improved/constructed ford	0	0	0
pole/brush ford	372	500	600
single culvert	3	4	4
multiple culvert	0	0	0
bridge/box culvert, closed top	76	76	80
bridge/box culvert, open top	20	15	60
structure removed	80	7	606
Unknown/other	150	150	150

Less than 10% of the observed sediment movement at crossings was attributed to places where BMPs were not applied (Figure 22). More commonly, it was noted that BMPs were applied, but not well enough to prevent sediment delivery. In a few cases, BMPs were applied as well as they could be at a stream crossing, and some sediment still was contributed, pointing out the difficulties associated with preventing sediment at the crossing itself under a wide variety of weather conditions. Nonetheless, the substantial variation in sediment delivery confirm the usefulness of careful application of BMPs in minimizing that delivery.

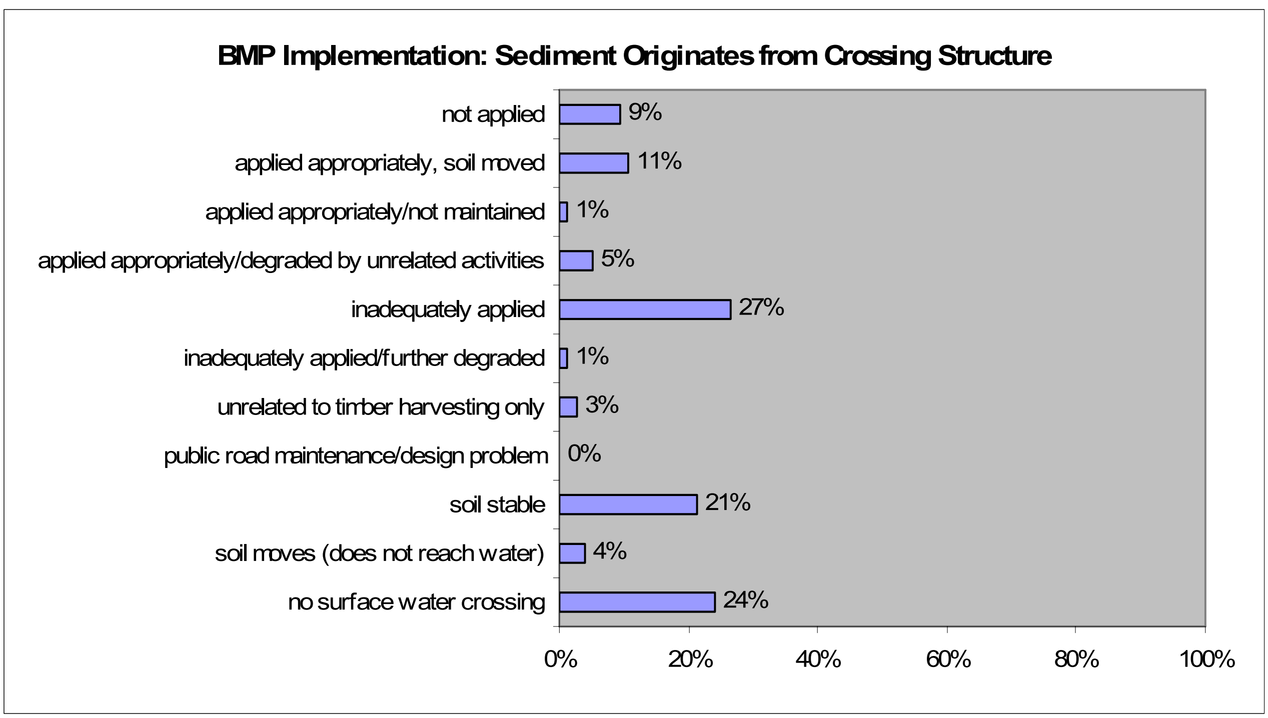

Figure 22: Sedimentation Related to Application of BMP Principles and Practices (75 samples, 57 crossings)

Crossing Structure Type by Road Type and Water Body Type

- There are **48** sample units with a skid trail at the water crossing.
- There are **13** sample units with a haul road at the water crossing.
- There are **40** crossings associated with a perennial water feature.
- There are **15** crossings associated with an intermittent water feature.
- There are **2** crossings associated with an ephemeral water feature.

The following charts compare crossing structure types associated with each water body type. Temporary crossing structures were most common in both perennial and intermittent streams (Figures 23, 24). Bridges were the next most frequent crossing type on perennial streams, with only slightly less in culverts. Fords were more common on intermittent streams.

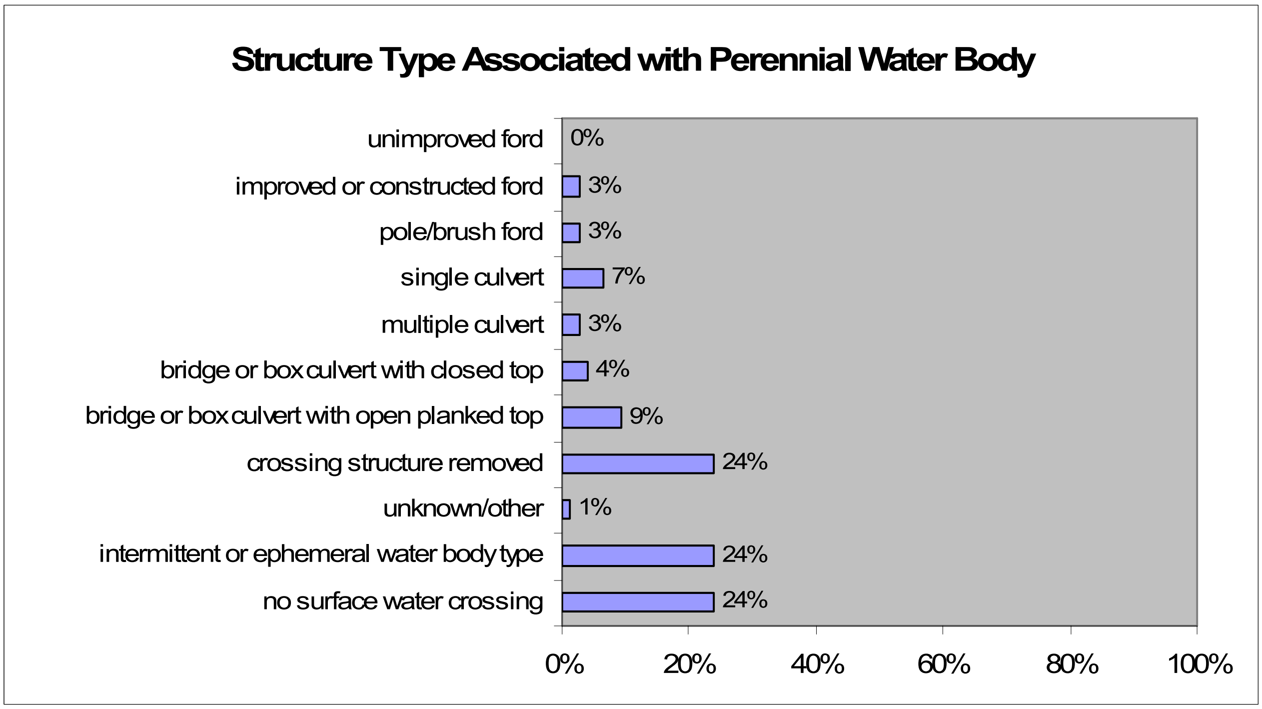

Figure 23: Stream crossing structures used for perennial water bodies (n=75)

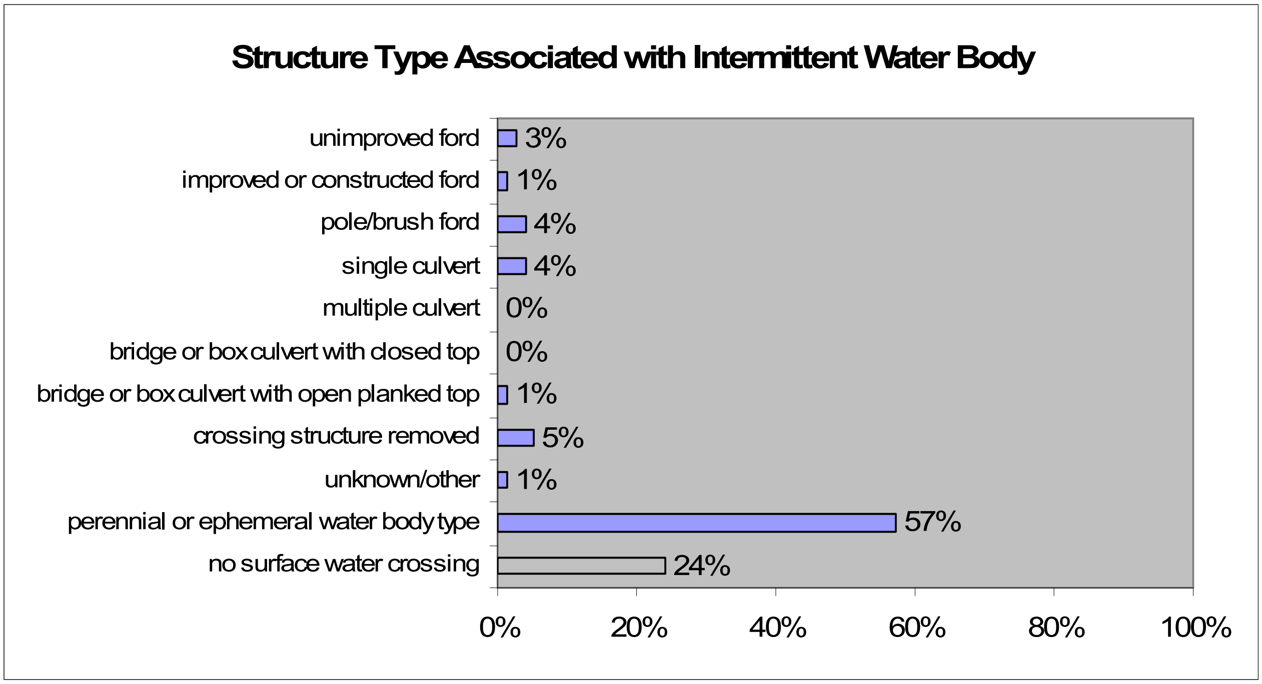

Figure 24: Stream crossing structures used for intermittent water bodies (n=75)

Crossing Structure Type with Down-cutting or Scouring within 100' of Outlet

There are 15 observations of stream downcutting or scouring within 100 feet of the outlet end of the structure, but 47 sample units show no evidence of stream downcutting or scouring (Figure 25). Although removed crossing structures were most frequently used, especially on skid trails, the practice was not strongly associated with scouring. Culverts and other closed-bottom structures have greater potential to cause scouring, but rates of association with scouring seemed proportional to use for culverts and fords. Bridges had proportionately less scouring than either single or multiple culverts.

Crossings were also evaluated on whether the width or remaining opening was at least as wide as the bankfull channel width. This condition allows the normal hydrologic functions operate over time, and reduces problems with debris build-up at crossings. Of the 57 crossings evaluated, 46 had a width or remnant opening equal to or greater than the bankfull channel, and 15 were less than this.

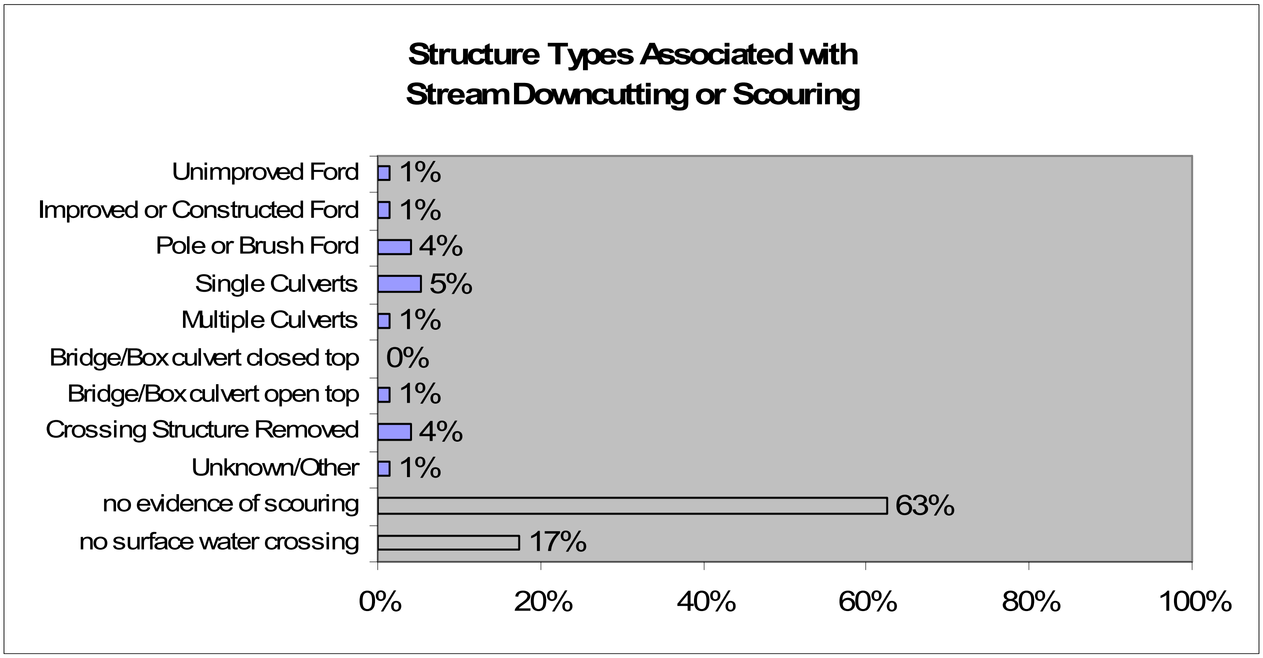

Figure 25: Stream crossing structure types associated with stream downcutting or scouring (n=75)

Fish Passage

Stream crossings have great potential to block passage of fish and other stream organisms that are part of a healthy forest ecosystem. The most preferred condition is to have uninterrupted stream bottoms, allowing fish of all ages and organisms of all sizes to move up and down stream as streamflow, instream conditions, and habitat needs change throughout the year. Stream crossing structures that are in place more than 3 months are considered to have greater potential to affect instream movement, since it is more likely that the structure will be there at the time when the fish or invertebrates normally migrate up- or down-stream. Some intermittent streams are very small and do not normally support in-stream organisms, so crossings here are considered to avoid impacts for fish passage.

Almost half of the surveyed sample units had longer-term crossing structures that could potentially interfere with instream movement (Figure 26). Most crossings did not restrict flow or disrupt passage (Figure 27), leaving the stream section open to the natural streambed. There were some sites (12%) with closed bottom crossings, like culverts, that were considered to have poor conditions for passage for stream organisms. These areas represent room for improvement for future habitat conditions. Areas critical to declining species like the native brook trout could be considered for priority actions for retrofitting existing crossings.

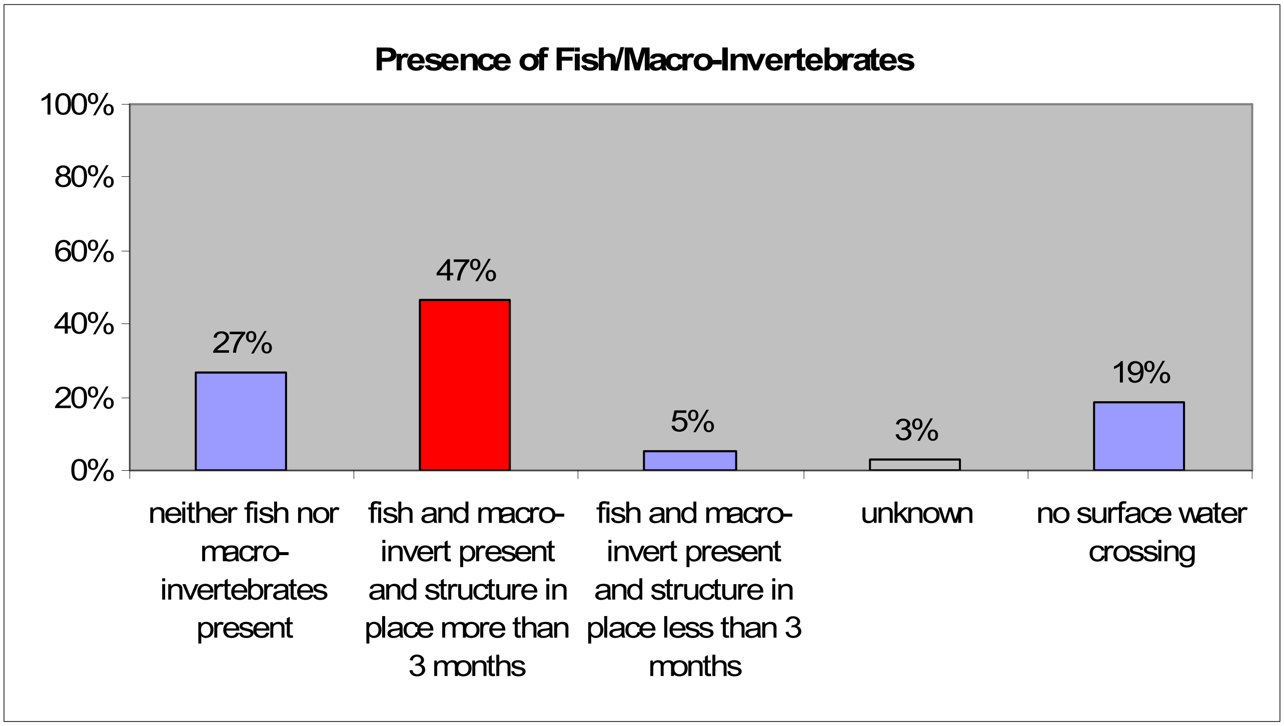

Figure 26: Presence of fish or benthic macroinvertebrate insects at haul roads and skid trail crossings (n=75)

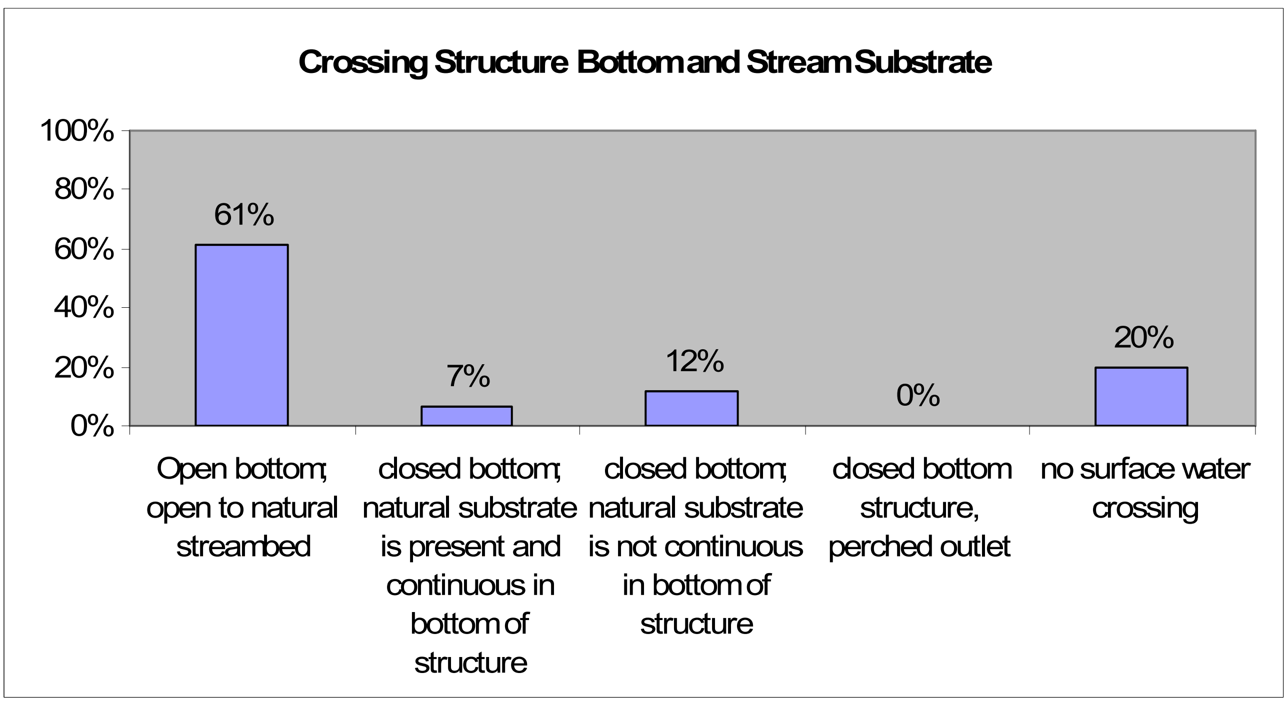

Figure 27: Streambed conditions when fish and macro-invertebrates present and crossing structure is in place more than three months (n=75)

Soil Movement through the Buffer/Filter Strip **(soil did not reach surface water body)**

The minimum streamside management zone for harvesting in Maryland is 50 feet, with expansions made of 4 feet for every 1% slope. For the **53** new sample units, there are **106** opportunities to observe soil movement through the buffer/filter strip on the two approaches of the stream crossings. Of these 106 observations, just over a third (37) involved sediment moving along the road or trail approaches towards the stream, but not reaching the water. Another third (34%) did not show evidence of any sediment movement (Figure 28). Just under a third of the observations involved either trace or measurable sediment moving along the roads/trails through the buffer. These were sometimes existing ditches that involved sediment movement, and other times rills or gullies that developed along the roads and water bars were not in place near enough to the stream to prevent their development. Most roads and skid trails met state standards for slope requirements and required spacing of water bars, but the water bars were not always at a location to prevent the development of near-stream erosion. Some approaches for haul roads or skid trails were observed with up to 22 to 26% slope for a short distance, above the 15% desired.

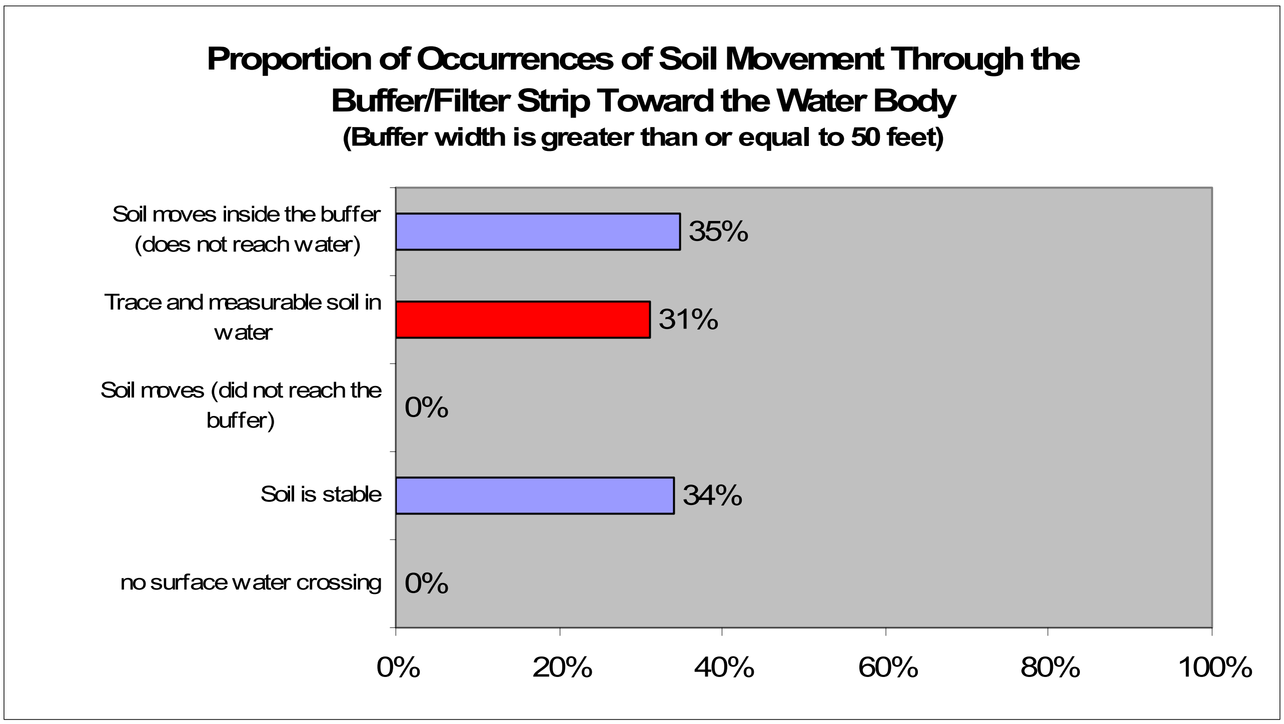

Figure 28: Effectiveness of stream riparian management zones in filtering sediment on road/skid trail approaches (n=106)

Percent Distance Soil Moved Through Buffer/Filter Strip Toward Water Body

Distance soil moved through the buffer along the road or skid trail approaches toward the water body was recorded as a percentage of the width of the buffer/filter strip, which is a minimum 50 feet in Maryland. Most sediment settled out within the first 60% of the stream buffer, even along the approaches where roadside ditches may be located (Table 3).

Table 3: Percent of buffer width that soil moved toward stream buffers along haul road or skid trail approaches to stream crossings

	Inside the Buffer (Approaches A and B combined)	Approach A– Inside the Buffer	Approach B– Inside the Buffer
Average	55	56	54
Median	60	50	60
Maximum	80	80	80

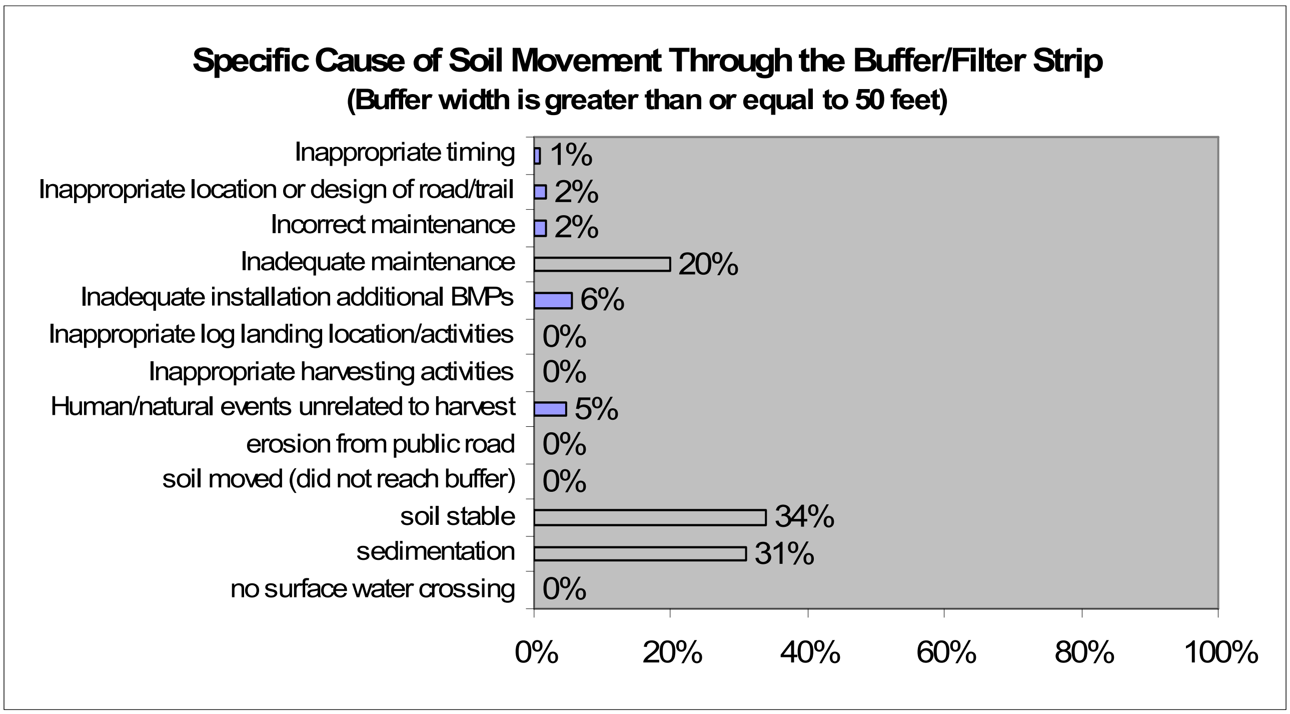

Figure 29: Cause of Soil Movement through the Streamside Management Zone along road/trail approaches (n=106)

Haul Road or Log Landing in Buffer

Most harvest operations (89%) followed Maryland requirements to keep log landings and haul roads out of streamside management zones (Figure 30). For the **75** harvest areas sampled, **7** sample units have a haul road or log landing located within the buffer/filter strip, including the expanded buffer. Of the 7 sample units, one was observed to contribute trace amounts of sediment and one involved measurable amounts of sediment. In the one instance 60 cubic feet of sediment was measured as removed from the gully reaching the stream channel.

Since Maryland already requires haul roads and landings to be located outside the buffer, improved education and enforcement would be needed to avoid the problem. Some site features, like adjacency of steep slopes to streams, can constrain road or landing location, and sometimes re-use of previously established roads and landings provides less impact than new grading and earthwork at a slightly farther distance from the stream.

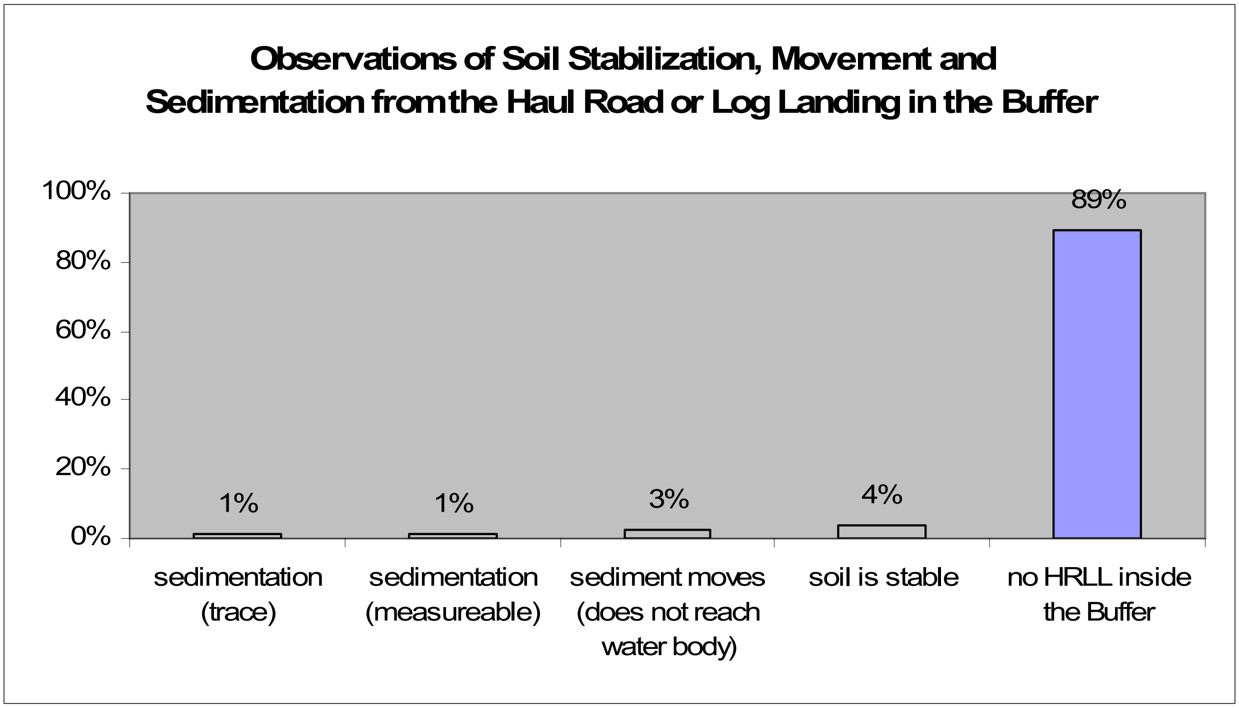

Figure 30: Soil movement related to haul roads or log landings in the buffer (n=75)

Minimum and Maximum Positive Gradient of Haul Road/Log landing Inside the Buffer/Filter Strip

The landings observed in the buffer did not exceed 3% slope. One of the roads observed in the buffer had up to 25% slope, much steeper than desired for haul roads. Some areas had steep slopes around streams, and road gradients steepened only when making the preferred perpendicular crossing. Complete re-building of roads often could improve the situation, but most harvests were in areas with existing roads and re-used older roadbeds to minimize soil disturbance. Where sediment reached the stream from the roads or landings in the buffers, incorrect maintenance of the road and inadequate installation of BMPs were identified as causes of the erosion problems. BMPs were noted as having been appropriately applied but not maintained, and as not applied in other cases.

Five of the seven observations of roads or landings were not associated with sediment reaching the stream. At two locations, sediment moved partway through the buffer, but was trapped before reaching the water. Soil moved an average of 40% of the way through the buffer, with 60% being the farthest travelled. There were three observations of stable soil inside the buffer/filter strip, sites noted as having appropriate application of BMPs. There was also an instance of BMPs not being applied but soil being stable, which can happen where terrain is very flat, and risk of soil erosion and movement is low. BMPs are generally more involved and expensive on steeper terrain (Aust et al., 1996).

Riparian Area Analysis

A total of 66 sample units had a water body adjacent to the buffer/filter strip, and 63 had a 50-foot or greater streamside management zone. Ephemeral streams where water is present only during storms are not generally protected with a buffer, although they were evaluated with the protocol for thorough coverage. A total of 48,923 feet of streamside management zones were walked to sample performance of the buffer areas. Most of the streams were first order streams (73%) that did not have any other streams feeding into upstream (Figure 31). These streams usually comprise most of the stream miles in any watershed, and forest areas are often in steeper headwater areas, further increasing likelihood of streams in harvest areas being first order. Second order streams, where two first-order streams join, were still 11% of the sample, and third order, where two second-order streams join; and larger were 5% of the sample.

Stream Order

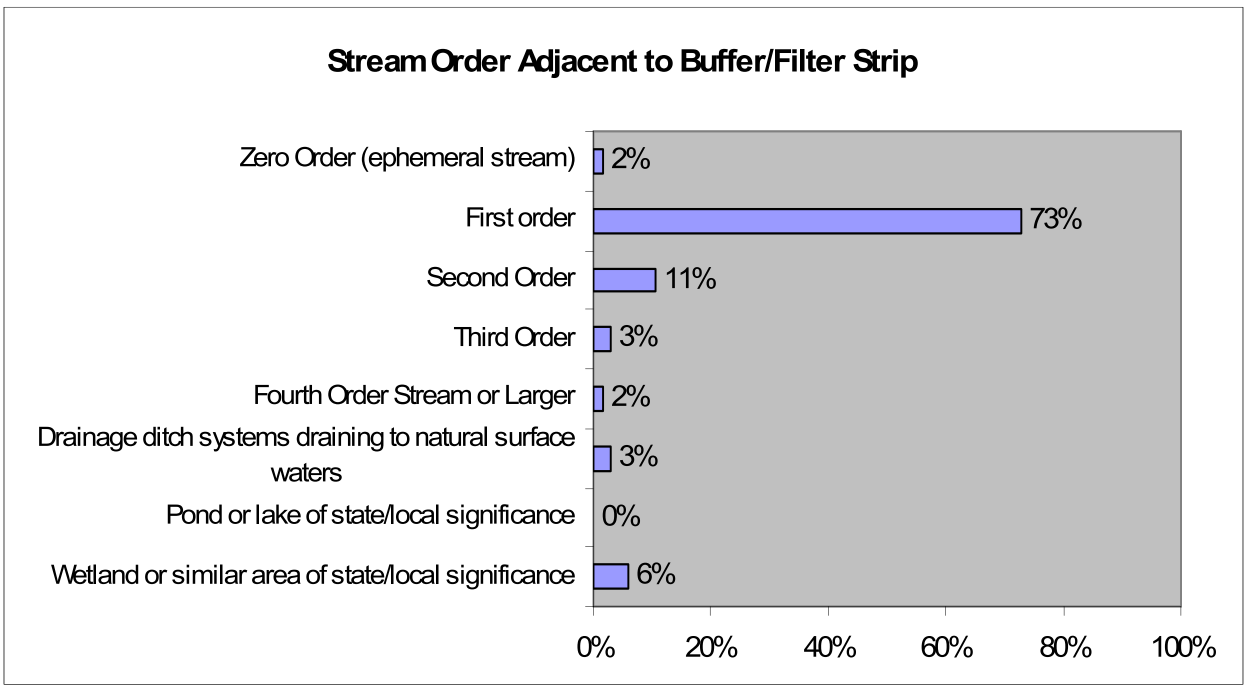

Figure 31: Stream order at harvest sites with buffers (n=66)

An essential function for streamside management zones is trapping sediment to prevent delivery to streams and other water bodies. Of the almost 49,000 linear feet of stream management zone sampled, sediment was observed entering and moving more than half-way across the SMZ at 39 locations, and reached the water at 6 locations (Table 4). Total estimated sediment delivery was 1 ft^3, considering all entry points. There were 8 instances of gouges made in stream banks that could set up increased susceptibility to erosion.

Large woody debris was also assessed because it is important to instream habitat and stream morphology. Woody debris was counted if it was greater than 4 inches in diameter at the small end and longer than the stream was wide, or still attached by roots to make a stable piece of debris. The average count was 24 pieces per 1000 feet of stream of naturally occurring debris and 20 pieces per 1000 feet that were added during harvest operations(Table 4). Many Maryland

Table 4: Occurrence and volumes of sediment delivery, large woody debris, erosion channels, and logging slash in 48,923 feet of sampled streamside management zones

Sediment Delivery	
total number of locations where sediment delivered to within bankfull width of the channel as a result of harvest operation	6
number of locations per 1000 feet of buffer monitored	0.123
Sediment Volume (cubic feet)	
total volume of sediment currently evident within bankfull width of the channel resulting from harvest operations	1
volume per 1000 feet of buffer monitored	0.020
Rills, Gullies, Sediment Trails	
total number of times rills, gullies, or sediment trails resulting from the harvest operation reach more than halfway across the buffer/filter strip	39
Rills, gullies and sediment trails per 1000 feet of buffer monitored	0.797
Naturally Occurring Large Woody Debris (LWD)	
number of pieces of naturally occurring LWD in the water body	1201
number of pieces LWD per 1000 feet of buffer monitored	24.549
Large Woody Debris (LWD) – Harvest Related	
number of pieces of LWD occurring in the water body as a result of the harvest	1012
number of pieces of LWD per 1000 feet of buffer monitored	20.686
Potential Erosion Channel	
number of times a potential erosion channel has been gouged into the bank as a result of harvesting activities	8
number of times per 1000 feet of buffer monitored	0.164
Slash Volume (cubic feet)	
Less than 100 cubic feet per 1000 feet of buffer monitored	0.838
100-200 cubic feet per 1000 feet of buffer monitored	0.143
more than 200 cubic feet per 1000 feet of buffer monitored	0.102

NOTES: Large woody debris is defined as debris found within bankfull width of the channel which are greater than 4 inches diameter at the small end and either longer than the stream width or anchored to the bank by roots or other means.
Slash is defined as limbs, brush, tree tops, or similar relatively small woody logging debris which is left in the channel below bankfull elevation as a direct result of the current harvest.

streams have less than the desired amount of large woody debris, so additions of large, stable pieces could be beneficial. However, logging slash that is composed of small branches, twigs, or leaves can contribute to low dissolved oxygen levels as the fine materials decompose, and should be minimized. Less than 10% of sites had more than 200 cubic feet per 1000 feet of stream, and the majority, over 80% had less than 100 cubic feet of slash.

Shade Reduction/Basal Area Evaluation

Another major function of stream buffers is to keep streams cool, maintaining shade over the water. The protocol assessed basal area of remaining trees, percent existing shade, and whether shade to the stream was reduced by the harvest. Maryland allows some removal of trees within the SMZ, but requires maintaining an average of 60 ft^2/acre of basal area trees, usually at least half of the pre-harvest basal area. The average basal area in SMZs was 82 ft^2/acre, well above the 60 required (Table 5). About ¼ of the sites did not have shade reduced the harvest (Figure 32). The lowest basal area was 32 ft^2/acre at one measurement point, and 20% of observations did not meet State minimum standards for buffer retention, which allow averaging along the buffer length. Over ¾ of the plot observations, 77%, met or exceeded buffer requirements (Figure 33), and when site-wide compliance was assessed, 90% of the harvests were judged to comply with overall buffer width and basal area requirements. Shade to streams frequently was reduced by harvesting (76% of observations), but average crown closure was 78% after harvest, compared to a typical crown closure of 85-90% in a mature forest.

Table 5: Shade and potential large woody debris in sampled streamside management zones

Crown Closure (percent)	
Average	78
Minimum	32
Maximum	100
Basal Area (square feet)	
Average	82
Minimum	32
Maximum	142
Diameter of Largest Riparian Leave Tree	
Average	18
Median	18

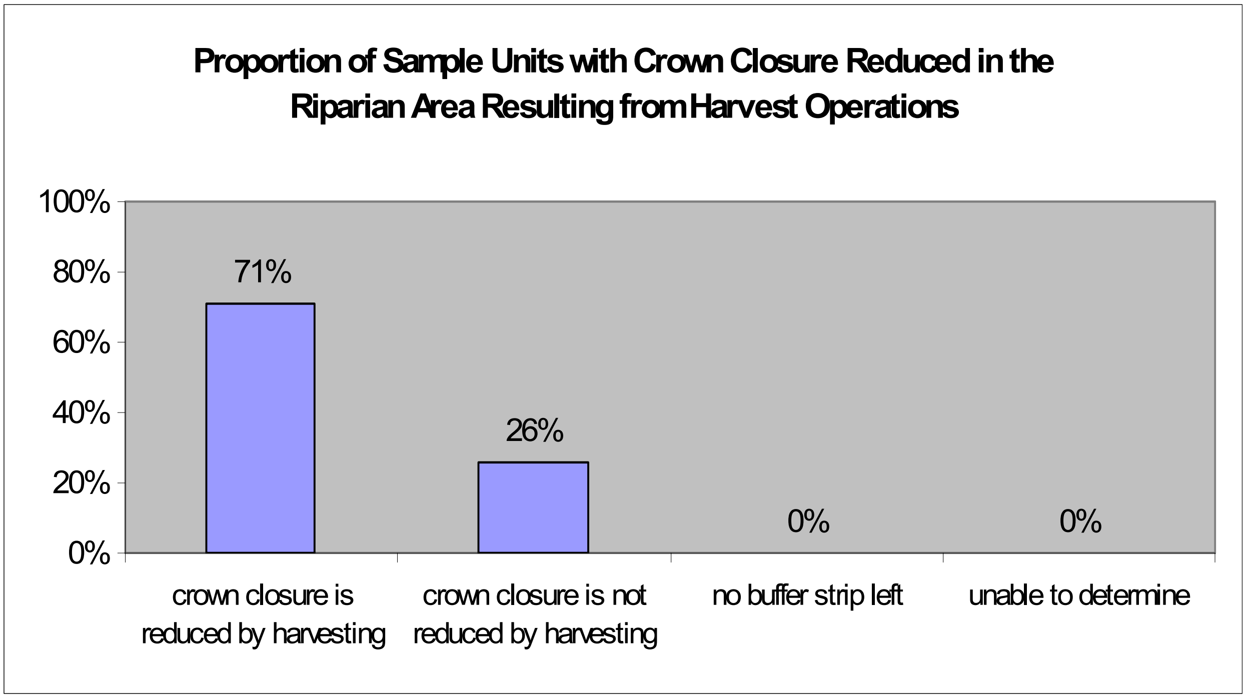

Figure 32: Crown closure reductions from harvesting (n=66)

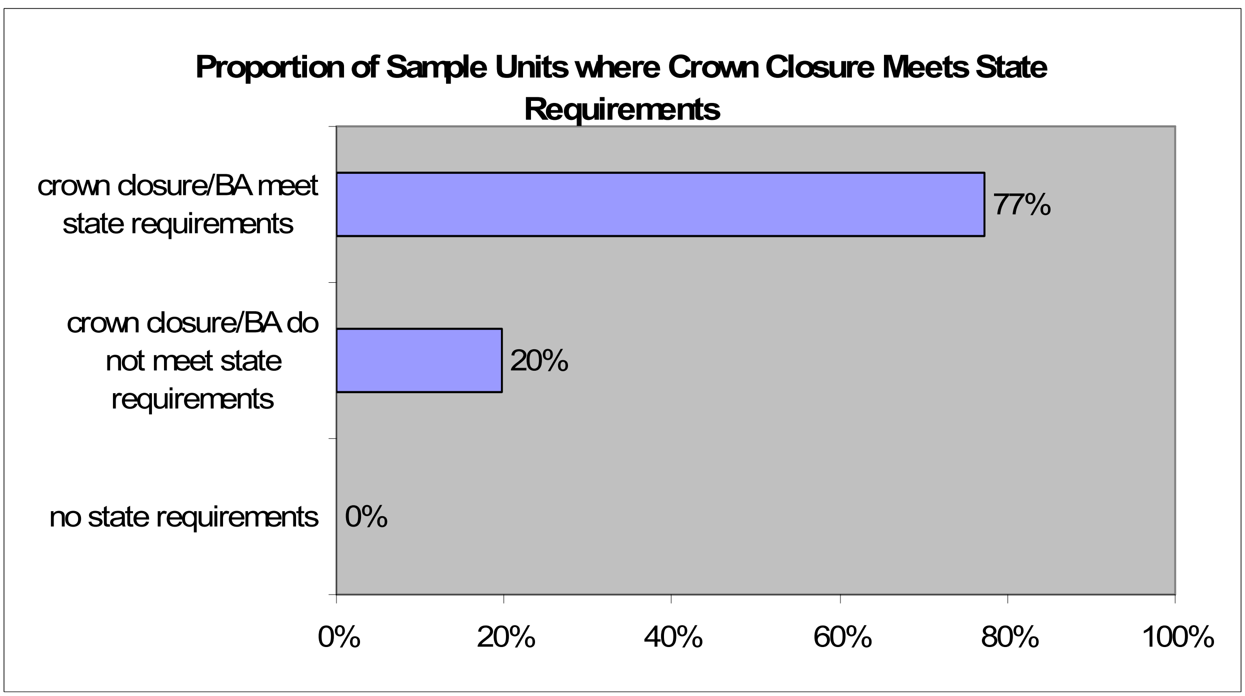

Figure 33: Compliance of harvest sites with streamside management zone requirements for an average of 60 sq. ft./acre basal area (n=66)

Chemical Pollution Prevention

Hazardous chemicals during forest harvesting are often associated with equipment use, repairs, and maintenance. Signs of chemical contamination could be identified anywhere on the site using the protocol but were actively surveyed for at the landing and along roads. Trash was one of the more frequent complaints in the 1995 BMP survey, but was less commonly seen in this survey.

Evidence of Potential Pollutants

Of the 75 sample units**,** 3 sample units had evidence of lubricant, fuel, hydraulic fluid and/or anti-freeze spillage resulting from harvest operations. 89% of sites had no evidence of any chemical pollution or trash. No stains greater than 10 sq. ft. were seen (Figure 34).

Four sample units had evidence of potential pollutant containers present. Over 84% of harvests had no trash or pollutant containers, and another 9% had trash that was not related to the logging activity (Figure 35). 5% of sites still had trash or pollutant containers that were associated with logging. One sample unit had evidence of both chemical spills and/or other potential pollutant containers present.

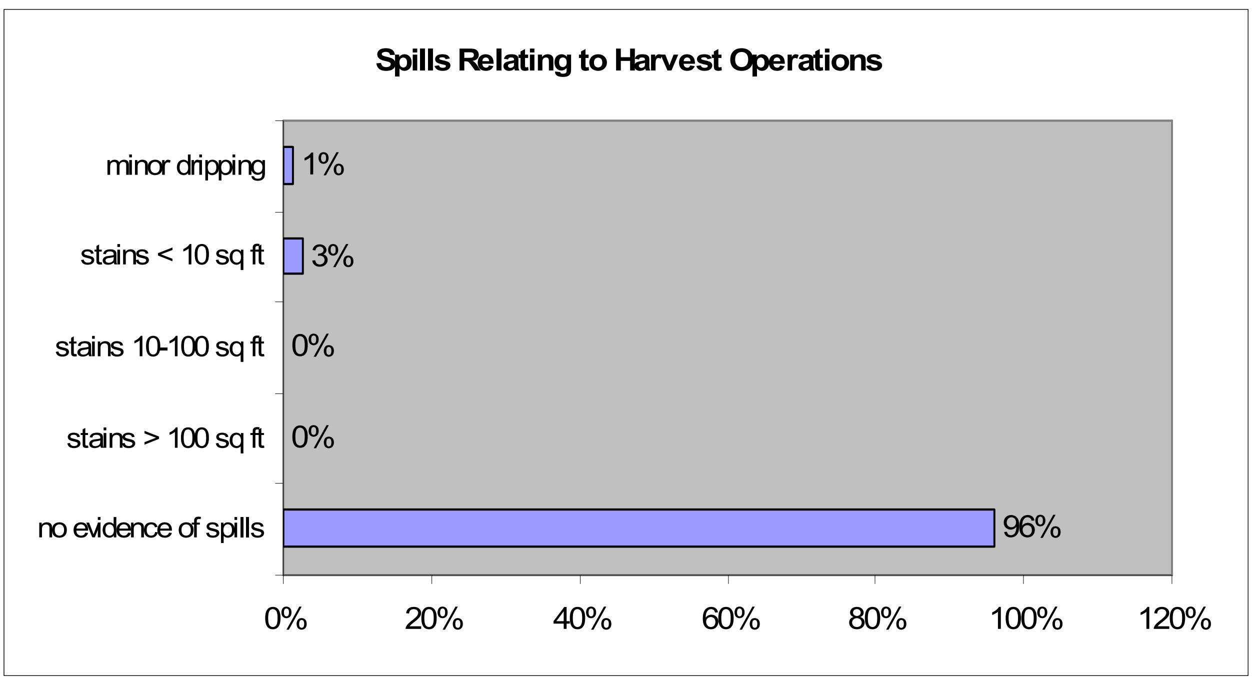

Figure 34: Evidence of Chemicals or other Pollutant Spills (n=75)

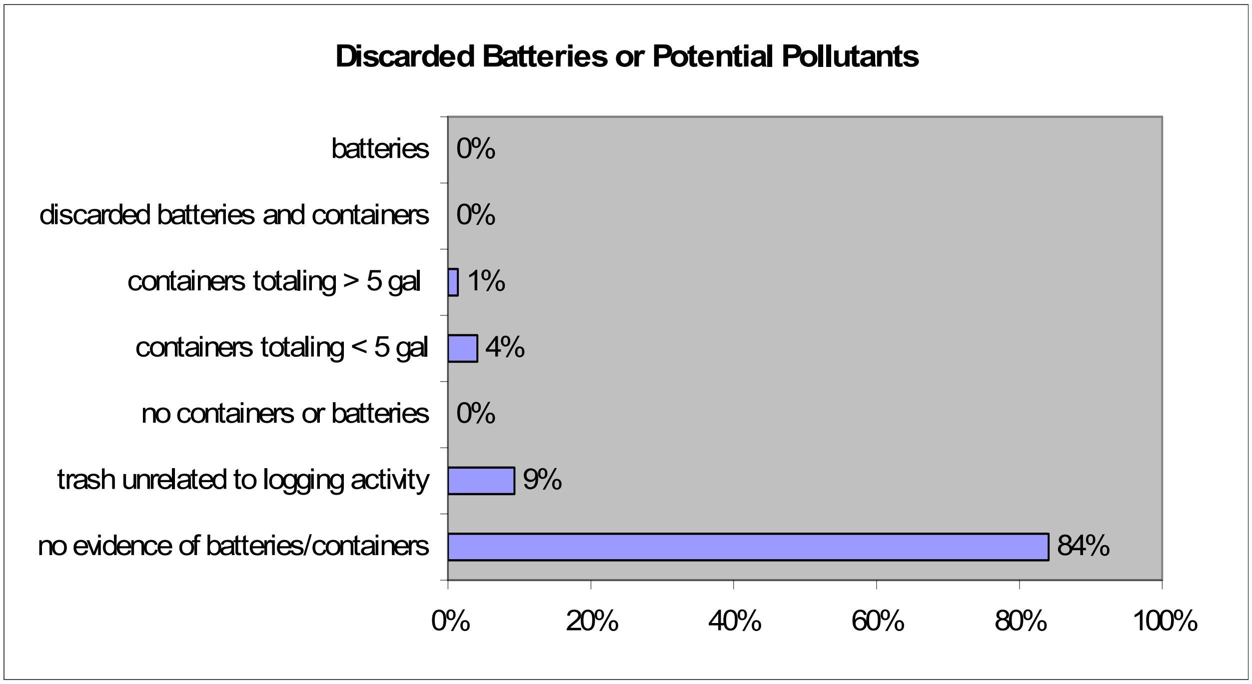

Figure 35: Evidence of discarded batteries or other potential pollutants and trash (n=75)

Soil textures were evaluated at the sites where any evidence of pollutants was found because of the difference in potential rates of transmission of pollutants. Three sites were on sandy soils, three on silt/loam soils, and one in organic material. Sandy soils with their rapid transmission rates would pose the greatest threat to groundwater contamination, if the spills had been larger. Two sites had some evidence that pollutants reached a water body, though five did not.

Wetland Crossings

All 75 sample units were assessed for wetland crossings and BMPs. Most harvest sites are likely to have at least limited wetland areas, such as small, linear wetlands along stream corridors. The Coastal Plain of Maryland features extensive seasonally wet woodlands, where wetlands are a significant portion of the landscape. Forests are often in the wetter areas that were not as conducive to farming. Many of the wetland areas are saturated during winter and spring and dry out during the active growing season.

Most of the harvest areas, 71%, avoided wetlands (Figure 36). Of the 75 sample units, 22 had a wetland crossing or operations in wetlands (29%). Most of Maryland has relatively mild winters, which limits the use of BMPs like operating on frozen soils that work well in more northern areas. Other BMPs were more common, like using a corduroy of slash and tops or pole-sized trees laid along skid trails, wooden mats along haul roads, and deferring harvest until soils were dry (Figure 36). The median length of a wetland crossing was 100 feet (Table 6).

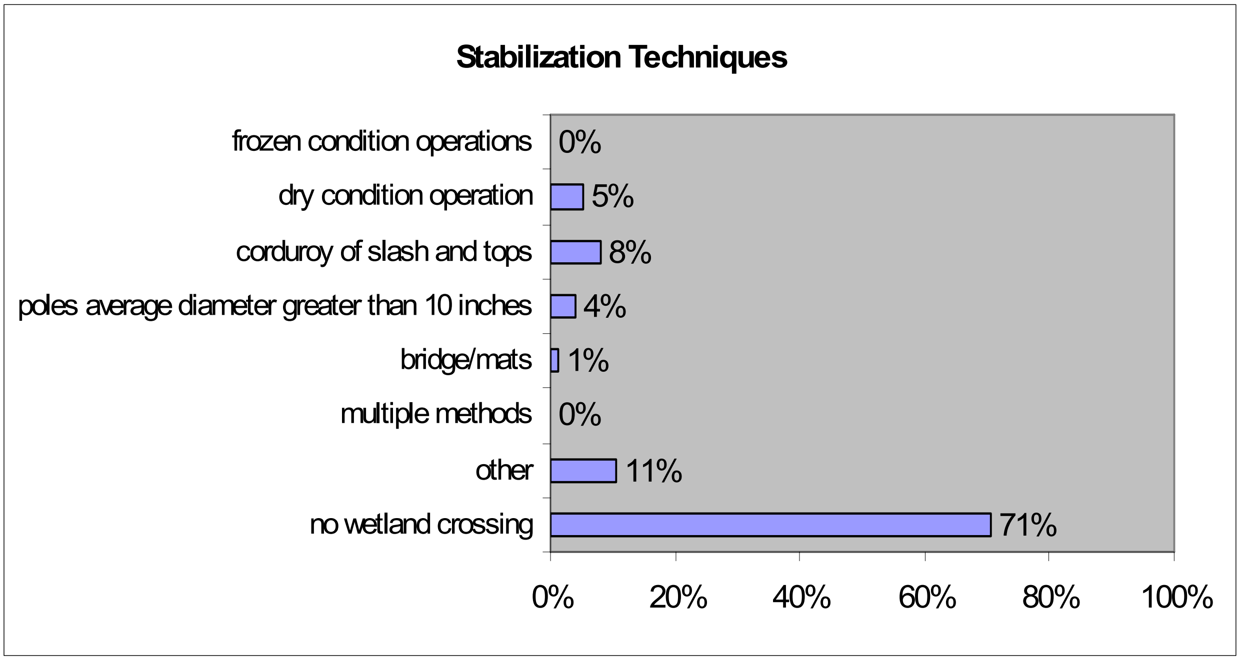

Figure 36: Techniques used to stabilize soils for wetland crossings in harvest operation (n=75)

Table 6: Wetland Crossing Length from Upland to Upland

	Length (feet)
Average	286
Median	100
Maximum	999

Rutting Depth and Sedimentation

Operations in wetlands are supposed to avoid creating ruts more than 6 inches deep. Although most operations avoided wetlands, 2/3 of the operations in wetlands created ruts that were not repaired before leaving the site (Figure 37). Sediment movement was also commonly noted, but mostly occurred in very small amounts (Figure 38).

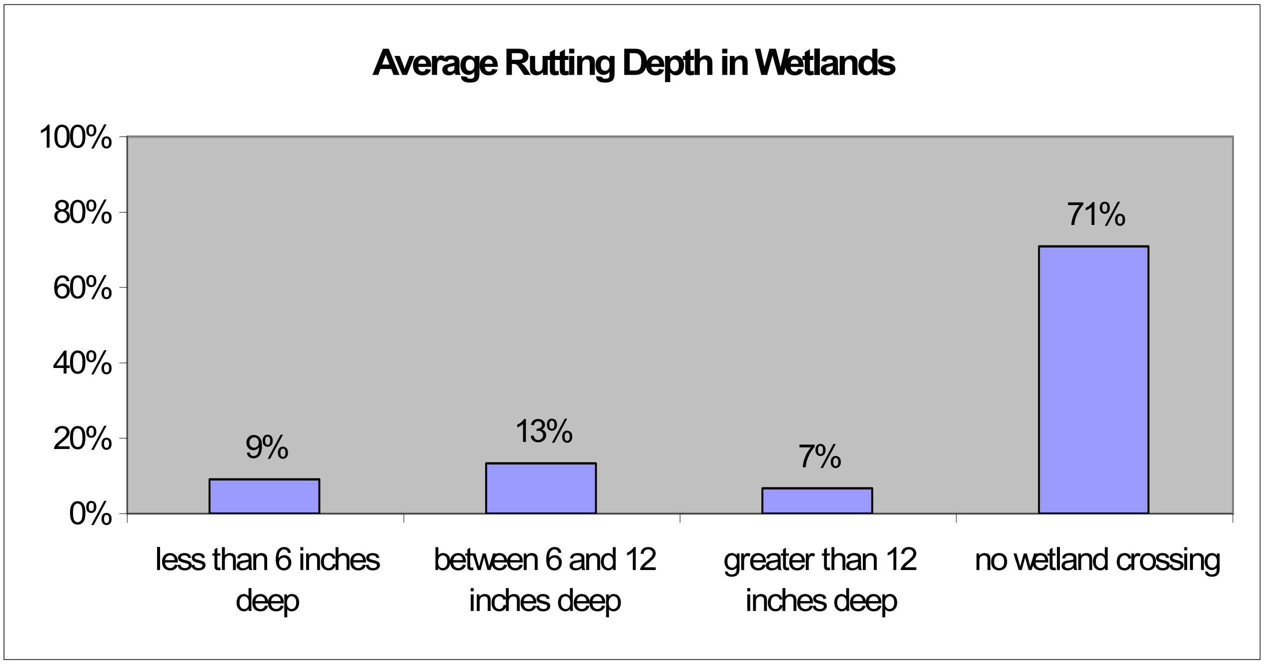

Figure 37: Average rutting depth for harvest operations crossing wetlands (n=75)

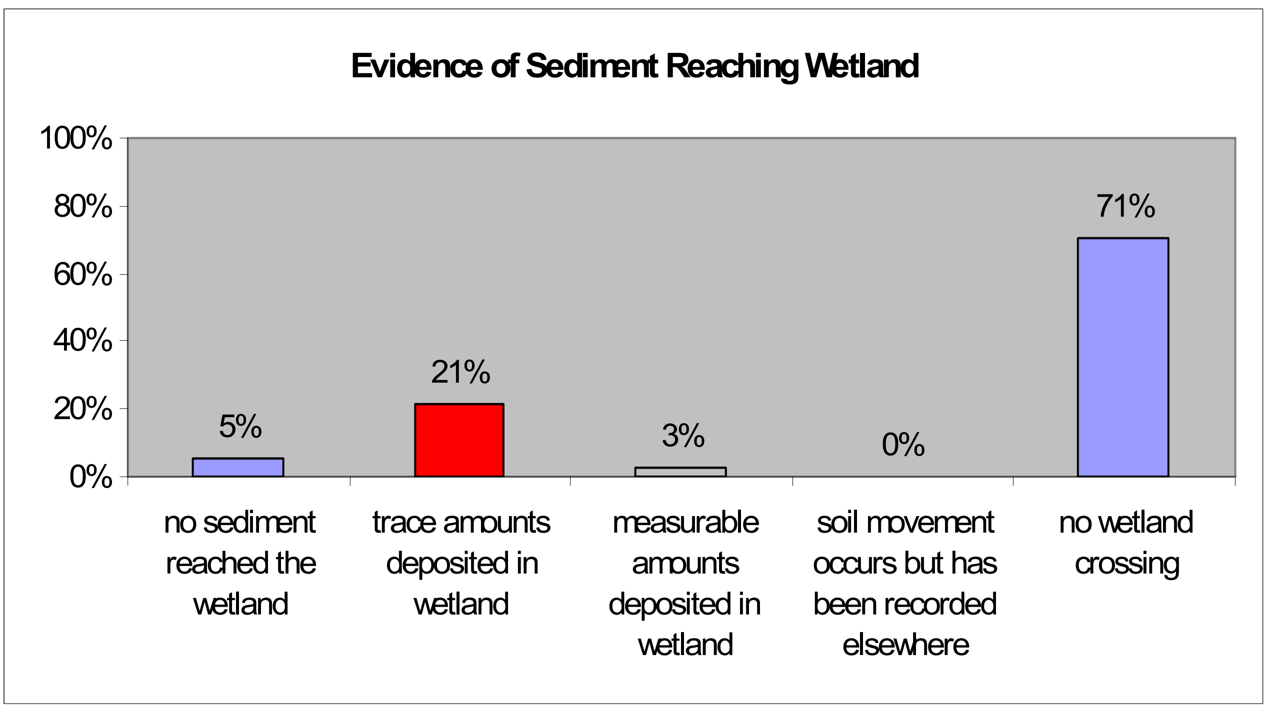

Figure 38: Sediment movement associated with wetland crossings in harvest operations (n=75)
Measurable sediment was estimated at 1 cubic foot.

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Appendix A: BMP Compliance check-list

BMP Assessment Project
BMP Implementation & Inspection Form

Date: 5/14/2009
Time:10:20 AM

I. General Harvest Information

1) Inspector Name:_____
2) Harvest Name:_____
3) Location:_____
4) Ownership:Private
5)Owner Name_____
5) Active job?: ☐Yes ☐No

II. Harvest Entrance

1) Harvest entrance signed?	☐Yes ☐No
2) Harvest entrance properly stabilized?	☐Yes ☐No
3) Materials used for stabilization?	2-3" Stone
4) Adequate cross drainage at Entrance?	☐Yes ☐No
5) Mud kept off public roadways?	☐Yes ☐No
6) Damage to public road signs etc?	☐Yes ☐No

III. Haul Roads

Average slope % of haul road	_____%
Haul roads in SMZ	☐Yes ☐No
Haul road rutting is not excessive	☐Yes ☐No
Haul roads well located and drained	☐Yes ☐No
Haul roads have adequate cross drainage	☐Yes ☐No
Type of water diversion method used	Broad based dip

IV. Harvest Landings

Number of harvest landings	
Landing not in SMZ	☐Yes ☐No
Landing properly drained	☐Yes ☐No
Landing slope <10%	☐Yes ☐No
Landing free of trash and spills	☐Yes ☐No

V. Skid Trails

Skid slopes 2%-15%	☐Yes☐No
20% skid slopes under 200'	☐Yes☐No
Skid trails properly stabilized	☐Yes☐No
Skid trail rutting is not excessive	☐Yes☐No

VI. Stream Crossing

Stream Crossing in harvest area?	☐Yes☐No
Number of crossing minimized?	☐Yes☐No
Stream order at crossing	0 order
Type of stream at crossing	Perennial
Type of crossing structure used	Ford
Approaches properly stabilized	☐Yes☐No
Crossing structure elevated above approach?	☐Yes☐No
Crossing properly sized and installed?	☐Yes☐No
Crossing at 90 degrees to streambed?	☐Yes☐No
Crossing does not restrict water flow	☐Yes☐No
Runoff diverted on approaches diverted?	☐Yes☐No

VI. Streamside Management Zone

SMZ is marked and maintained	☐Yes☐No
Average slope of SMZ	______%
Average width of SMZ	______feet
Silvicultural activity within SMZ	☐Yes☐No
Exposure of mineral soil was minimized	☐Yes☐No
Exposed mineral soil stabilized w/in 7 days	☐Yes☐No
Sampled basal area within SMZ	

VII. Harvest Aesthetics

Minimal damage to residual trees	☐Yes☐No
Tops and limbs are close to ground	☐Yes☐No
Standing snags or snapped trees?	☐Yes☐No
Stumps are cut low to ground	☐Yes☐No
Visual buffers used as needed	☐Yes☐No

Overall impression of harvesting activity:

☐Excellent ☐Above average ☐Good ☐Adequate ☐Poor

Other comments:

Martin O'Malley, Governor
Anthony G. Brown, Lt. Governor
John R. Griffin, Secretary

Steven W. Koehn, Director, Forest Service

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