Assessing Application and Effectiveness of Forestry Best Management Practices in New York

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ABSTRACT: *Forty-two forestry best management practices (BMPs) were assessed to determine the extent of voluntary application and their effectiveness in preventing water quality impacts in New York State. These BMPs were evaluated on 61 timber-harvested sites in the Catskill region (CR), and 53 timber harvested sites in the Adirondack region (AR) during the summers of 1997 and 1998. The overall application of suggested BMPs was 78% for haul roads, 87% for landings, 59% for skid trails, 88% for equipment maintenance/ operation, and 73% for buffer strips. Departures were common for BMPs concerned with draining water off haul roads and skid trails, and for stream crossings; more attention must be devoted to those practices. Effectiveness of BMPs was apparent when they were applied. Nonparametric statistical tests showed a strong relationship between BMP application and prevention of sediment movement. Limiting sediment movement protects surface water. In the CR, 27 of the 33 BMPs tested showed a statistically significant ($P < 0.10$) relationship between BMP application and sediment movement. Similar results were observed in the AR; 26 of the BMPs tested were significantly associated with sediment movement. Imperfect application of BMPs reduced effectiveness. Road drainage structures, for example, generally failed to adequately control erosion when spacing between drainage structures was excessive. North. J. Appl. For. 17(4): 125–134.*

Timber harvesting activities have been long recognized as potential sources of stream sedimentation and site degradation. Timber harvesting and associated forestry operations often disturb the forest floor, exposing soil. This exposed soil has a higher propensity for erosion, possibly leading to contamination of surface waters. Early reports identified sediment production as a major form of nonpoint source (NPS) pollution for forestry activities. However, its contribution to total NPS pollution was overestimated. An EPA (1991) report indicated that silviculture/forestry only account for 3% of total NPS pollution, while agriculture, the largest producer, generates 49%.

Since the passage of the Federal Water Pollution Control Amendments in 1972, considerable advances have been made to control NPS pollution. Section 208 of these amendments specifically identified silviculture as a source of NPS pollution and required states to develop guidelines to reduce NPS pollution. These guidelines are most commonly referred to as *best management practices* (BMPs). BMPs are defined as the collection of practices that limit the displacement of soil and maintain water quality. The Federal Water Pollution Control Amendments of 1977 stipulated that states could adopt either regulatory or voluntary programs for reducing NPS pollution. New York has adopted voluntary guidelines.

"Silviculture Management Practices Catalogue for Nonpoint Source Pollution Prevention and Water Quality protection in New York State" (NYDEC 1993) was the most recent report describing forestry-related impacts to surface waters in New York. This report listed 1,500 waterbody segments as having been affected by NPS pollution. Consistent with federal reports (EPA 1991), silviculture was identified as the primary source of NPS pollution in a relatively few number of sites. Seven sites were recognized, impacting an estimated 61 miles of streams or rivers and 20 ac of ponds and lakes. Twenty-two additional waterbody segments identified silviculture as the secondary source of NPS pollution. In all cases, sediment was the primary pollutant associated with silviculture.

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Sediment is generally accepted as the major form of pollution in forestry. Literature supports the concept that sediment sources make up a disproportionately small percentage of the total harvested area. While roads and skid trails usually account for less than 20% of the land area (Nyland 1976), reports suggest that 90–99% of the sediment comes from these sources (Hartung and Kress 1977, Rothwell 1983). Fortunately, eastern forests have the lowest erosion rates in the U.S. (Patric 1976, Megahan 1980).

New York is a large state that spans a number of physiographic regions. A complete field survey across the entire state was beyond our resources. Recognizing regional differences in soils, topography, and land ownership patterns, we chose to focus on two mountainous areas: the Adirondack region (AR) in the northeast and the Catskill region (CR) in the southeastern portion of the state. Our objective was to assess the application and effectiveness of BMPs on public and private lands in each region. Although we present our results by region, the myriad of differences between the two makes it impossible to directly compare the results.

Methods

A total of 114 timber-harvested sites were inspected to assess the levels of BMP application and their effectiveness in the AR and CR of New York. Fifty-three sites in the AR and 61 sites in the CR were visited during the summers of 1997 and 1998, respectively (Figure 1). Independent logging contractors commercially harvested each site within 18 months of the field assessment. Our goal was to obtain a snapshot of overall BMP application and effectiveness within these two regions. There was no attempt to constrain the range of silvicultural practices or logging methods among harvested sites sampled. In the CR, approximately 20% of the sites were clearcut conifer plantations. Sites ranged from about 5–300 ac. The occurrence of surface water on site was not a requirement of this study.

The AR field sites were selected from four private industrial landowners. Each landowner provided a list of sites harvested during the past 18 months, from which we randomly selected 15 sites from each. Due to time constraints, only 53 of the 60 sites were inspected.

Figure 1. Relative location of harvested sites inspected to assess BMP application and effectiveness in NY, 1997- 1998. Adirondack sites denoted by circles; Catskill sites denoted by triangles.

Potential study sites in the CR were identified on state and private nonindustrial lands with the assistance of staff from the New York Department of Environmental Conservation (NYDEC), New York City Department of Environmental Protection (NYCDEP), and the New York City Watershed Forestry Program (NYCWFP). These sites were identified from known harvest operations, state tax law (480a) harvest plans, or stream crossing permits. The final sample was a random selection of 31 state and 30 private sites.

Since New York only recently published a forestry BMP field guide (NYDEC 2000), those rated for this study were adapted from a list used by Champion International for internal compliance checks on their New York State lands. BMPs cited on that list are consistent with those utilized by other states (Anonymous 1987, Maine DOC 1992).

The application of 42 specific BMPs pertaining to haul roads, landings, skid trails, equipment maintenance/operation, and buffer strips was assessed during a visit to each of the 114 field sites. Individual BMPs were each assigned a number and letter in order to track them on field data sheets. For each site, all haul roads, skid trails, and landings were walked to assess BMP application. Buffer strips were inspected around perennial streams, wetlands, lakes, and ponds.

Many of the BMPs rated during this study have spacing requirements based on slope. For example, suggested spacing of cross drain culverts is 300–500 ft on roads with 0–2% slope gradient compared to 140–167 ft for gradients of 6–10%. Although spacing recommendations for BMPs were not included in the existing BMPs for New York State at the time of this study, they are included in the recently published BMP manual (NYDEC 2000). The spacing guidelines that were used in the current study have been in general use (Hartung and Kress, 1977, Maine DOC 1992). Slope gradients on our sites were measured using the average of two clinometer readings. Distances were paced on slopes less than 10%, and measured with a 100 ft. tape for slopes greater than 10% or where obstructions interfered with pacing.

For each site, some BMPs were needed more than once, while others were not needed at all. The degree of BMP implementation was determined only for those instances where a practice was needed. For each instance where a BMP was deemed necessary, one of the following BMP application ratings was recorded: (1) BMP not used or poor application; (2) BMP attempted with minor deviations; (3) BMP used and correctly applied.

Effectiveness was defined as the ability of the BMP to maintain preharvest water quality conditions as indicated by the lack of a visible sediment trail (or a turbid plume) originating from a missing or poorly applied BMP. For each BMP application rating, a corresponding effectiveness rating was assigned: (1) direct impact on water resource—a sediment trail was traced from a poorly installed or missing BMP to streams, lakes, or wetlands; (2) indirect impact—a sediment trail was traced from a poorly installed or missing BMP to a point on the land but did not extend into surface water; (3) adequate protection of water resource—sediment trail not apparent.

Sediment movement was used to indicate effectiveness (except for BMPs dealing with litter on landings and woody debris in streams). Delivery of sediment into any surface water or drainage was considered an impact. When the source of the impact was not clear, upstream sections were used for reference.

Data Analysis

BMP Application

The degree to which each BMP was implemented is referred to as the BMP application. BMP application is the percent of each BMP where the practice was applied (either correctly or with minor deviations).

Application was evaluated as follows:

$$P_c = n_c / n_a * 100 \quad (1)$$

where n_c is the total number of application ratings of 2 or 3, and n_a is the total number of ratings for each BMP.

Some sites had multiple applications of individual BMPs; the equation above is based on the total number of practices rated for the individual BMP.

The variance for BMP application was calculated as follows:

$$S^2_{Pc} = P_c((1 - P_c) / (n_a - 1)) \quad (2)$$

The 95% confidence interval was computed as follows:

$$P_c \pm (t_{(\alpha/2)}) (S_{Pc}), \text{ where } S_{Pc} = (S^2_{Pc})^{1/2}. \quad (3)$$

(Note: equations adapted from Cunia 1984, p. 67.)

Effectiveness

In order to determine the relationship between BMP application and effectiveness, chi-square tests for independence were employed. The null hypothesis states that surface water protection is independent of BMP application. A 2×3 contingency table was developed. The BMP ratings were categorized into applied (ratings of 2 and 3) and not applied (rating of 1). Effectiveness was grouped according to impact: surface waters protected (effectiveness rating of 3), indirect impacts (rating of 2), and direct impacts (rating of 1).

The effectiveness of several BMPs could not be determined using chi-square tests due to a lack of data resulting in incomplete cells in the contingency table. In some cases, direct and indirect impact cells were combined to overcome data deficiencies. This resulted in a 2×2 contingency matrix. Matrices with low expected values (less than 1) were tested for significance with Fisher's Exact Test. Fisher's Exact Test is a better predictor under these conditions (Everitt 1977).

In addition, effectiveness was illustrated visually with bar graphs showing the level of protection afforded surface waters when BMPs were applied versus not applied. Each BMP rating was separated into two categories: applied or not applied. The BMP ratings were paired with their corresponding effectiveness ratings. The percentage of impacts resulting from applying versus not applying BMPs was graphically displayed with bar graphs.

Results

Regional Characteristics

There are so many differences in physiography and land ownership patterns between the AR and CR that interpretation of differences in BMP compliance between the two is not possible. Sampling in the AR was restricted to private large industrial landowners because it was possible to draw a random sample across the region from that landowner group within the time available to complete the work. The existence of an active NYCWFP combined with available resources at NYCDEP and at NYDEC, facilitated a random sample of recently harvested sites from the CR of state lands and small, private nonindustrial landowners.

Not all sites rated during this study had streams or waterbodies. However, about 75% of the sites in the CR, and 85% in the AR contained at least one stream or waterbody within or adjacent to the harvested area. The most notable differences between the two regions were the higher occurrence of wetlands in the AR, and a greater number of ephemeral streams in the CR.

The AR and CR sites compared favorably concerning the maximum slope of each site. Of the 61 CR and 53 AR sites, 62% and 58% were classified as having steep conditions (slope gradient >20%) within the harvested boundary, respectively. Soil texture varied between regions, with finer textured soils in the CR. About 75% of the CR sites were classified as having loamy or finer textured soils. By contrast, about 90% of the AR sites had sandy loam or coarser texture.

BMP Application

Haul Roads

Haul road BMP application equaled or exceeded 75% for 10 of 18 BMPs in the AR and for 14 of 18 BMPs in the CR (Table 1). Temporary roads were used infrequently (BMPs 1r and 1s) in both regions. Unpaved haul roads were found on 42 of the 61 CR sites, and on 49 of the 54 AR study sites. Haul road BMPs were not rated for sites where the landing was located adjacent to paved roads.

Several BMPs were widely applied in both regions. BMPs 1a, 1c, 1d, and 1e, dealing with road construction and layout, were applied at least 95% of the time. The exception was for keeping roads below a 10% grade (BMP 1a) in the CR. The percentage of roads exceeding 10% grade was statistically higher in the CR ($P < 0.05$). Of the 46 haul roads inspected in the CR, 19 exceeded the 10% slope limit. Of the 49 haul roads rated in the AR, only 4 had more than a 10% grade.

BMPs, in general, were applied at moderately high levels (75–90%). However, BMPs dealing with road drainage typically had low to moderate levels of use in both regions. Outsloping or insloping the road surface (BMP 1j) is recommended to remove water from the surfaces of haul roads. The application of BMP 1j was more than 20% higher in the AR compared to the CR. Other practices recommended to divert water from road surfaces include open-topped culverts, water bars, and broad-based dips (BMP 1g). These were applied on only 46% of CR

Table 1. Descriptive statistics for BMP application[a] on forest haul roads in the Adirondack and Catskill regions.

Catskill Region						Adirondack Region		
Total number	Use[b] (%)	95% CI bound			Best management practice[c]	Total number	Use[b] (%)	95% CI bound
3	0	—	*	1r	Temporary water crossings properly located and installed.	8	50	45
23	26	19		1n	Drainage structures (ditches, culverts, retention areas, water bars, and broad-based dips) used on roads and trails prior to their stream entrance to a stream buffer strip.	25	48	21
42	33	15	*	1p	Road access restricted during wet periods and spring breakup.	49	76	12
11	46	35		1s	Temporary water crossings properly stabilized.	4	75	75
54	46	14		1g	Proper water and erosion control structures installed and in working order.	27	59	20
46	59	15	*	1a	Roads follow contour with grades between 2%–10%.	49	92	8
71	61	12		1j	Roads outsloped where gradient permits. Where insloped, cross drainage is provided.	55	80	11
16	69	26		1l	Roads cuts properly sloped and seeded.	11	46	36
46	76	13		1q	Road surface maintained to prevent soil erosion or sedimentation.	48	77	12
9	78	34		1k	Appropriate gravel/stone used in critical erosion areas.	15	87	19
93	82	8		1h	Drained surface water into vegetated filter area.	40	93	9
102	82	8		1o	Roadway drainage system and water control structures free of debris, windfalls and other obstructions and in working order.	71	79	10
106	86	7		1f	Culverts properly sized and installed.	90	83	8
20	90	14		1m	Proper use of energy dissipaters and sediment control devices at culvert ends.	22	82	18
44	96	7		1c	Obstacles- avoided gullies, seeps, springs, wetlands, poor drainage areas, ledges and rocky areas where possible.	50	96	6
22	96	10		1d	Minimized number of water crossings.	41	100	—
39	100	—		1e	Road constructed/reconstructed in appropriate season with regard to soils.	50	98	4
24	100	—		1i	Water crossings at a 90° angle, where possible.	33	100	—

[a] Application refers to those practices applied correctly (rating = 3) as well as those with minor deviations (rating = 2). The application percent was computed as n_c/n_a *100, where n_c is the number of practices rated "2" or "3," and n_a is the total number of ratings for the respective BMP.
[b] Use % refers to application percent.
[c] An asterisk (*) indicates a significant difference ($\alpha = 0.05$) between the Adirondack and Catskill regions as indicated by nonoverlapping confidence intervals.

and 59% of AR roads. Diverting water from roads prior to crossing streams had poor application in both regions. Combined, BMPs 1g, 1j, and 1n indicate the overall use of erosion control structures/ practices on haul roads. All together, 50% of CR roads and a 67% of AR roads were adequately drained.

Landings

Most sites had one or two landings (one site had four). In addition, some contractors skidded their logs roadside. In those cases, no landing BMPs were rated. BMP application ranged from 60–100% in the CR and 73–97% in the AR (Table 2). Diverting water around landings (BMP 2d) had the lowest application.

Landings receive heavy vehicle traffic, which compacts soil and reduces infiltration. Therefore, landings should be located on gentle slopes and well-drained soils to facilitate drainage (BMP 2c). Since many of the soils in the AR are coarse textured, finding adequately drained sites was not difficult. However, CR soils generally have a silt loam texture, which drains more slowly than sands when saturated. For this reason, it was important to construct landings on slight grades to ensure adequate drainage. Most landings were suitably located.

Stabilizing landings when logging operations end (BMP 2e) minimizes soil displacement. Landings, on average, were stabilized well in both regions. Stabilization and/or revegetation was observed on 75% of AR landings and on 81% of CR landings.

Skid Trails

Skid trails link the area being harvested to a landing or roadside area. Skid trail BMP applications ranged from 29–85% (average of 52%) in the AR and 30–91% (average of 62%) in the CR (Table 3).

Table 2. Descriptive statistics for BMP application[a] on landings in the Adirondack and Catskill regions.

Catskill Region					Adirondack Region		
Total number	Use[b] (%)	95% CI bound		Best management practice	Total number	Use[b] (%)	95% CI bound
21	62	23	2d	Diverted water away from landings.	48	73	13
52	81	11	2e	Revegetated/stabilized landings following operations.	55	75	12
43	86	11	2b	Located landings outside buffer strips.	48	88	10
71	93	6	2c	Located landings on well drained soils, sloped surface to facilitate drainage.	59	97	5
65	99	3	2a	Landing size and location appropriate for the harvest method and stand condition.	58	97	5
6	100	0	2f	Drainage structures free of logging debris.	18	83	19

[a] Application refers to those practices applied correctly (rating = 3) as well as those with minor deviations (rating = 2). The application percent was computed as n_c/n_a *100, where n_c is the number of practices rated "2" or "3," and n_a is the total number of ratings for the BMP.
[b] Use % refers to application percent.

Table 3. Descriptive statistics for BMP application[a] on skid trails in the Adirondack and Catskill regions.

Catskill Region						Adirondack Region		
Total number	Use[b] (%)	95% CI bound			Best management practice[c]	Total number	Use[b] (%)	95% CI bound
53	30	13		3g	Installed water diversion devices where needed to reduce erosion and prevent sedimentation from entering streams.	16	38	26
47	47	15		3a	Operate all harvest equipment to prevent stream sedimentation. Maintain required distance from stream, per suggested BMPs.	57	42	13
70	47	12	*	3f	Stabilized abandoned skid trails where erosion is likely.	72	74	10
501	52	4	*	3h	Installed water diversion device where needed to reduce skid trail erosion.	191	29	7
59	53	13		3e	Minimized the number of water crossings. Where necessary, water crossings located and/or constructed to prevent stream sedimentation.	33	64	17
55	78	11		3d	Climbed slopes utilizing techniques and/or natural breaks in slope/grade to divert water flow wherever possible.	39	85	12
5	80	56		3b	Avoided negatively impacting wetlands.	24	67	20
75	80	9		3c	Approached water crossing at right angles to the stream.	39	80	13
207	91	4	*	3i	Drained surface water into vegetative filter strip.	48	67	14

a Application refers to those practices applied correctly (rating = 3) as well as those with minor deviations (rating = 2). The application percent was computed as n_c/n_a *100, where n_c is the number of practices rated "2" or "3," and n_a is the total number of ratings for the BMP.
b Use % refers to application percent.
c An asterisk (*) indicates a significant difference ($\alpha = 0.05$) between the Adirondack and Catskill regions as indicated by nonoverlapping confidence intervals.

Installing water diversion devices to reduce trail erosion (BMP 3h) was the most frequently needed BMP. The need for BMP 3h was higher in the CR (501 instances versus 191 instances in the AR). Water diversion structures were installed on 52% of CR sites and 29% of AR sites. Water bars, turnouts, and logs were the most frequently encountered structures shunting water from skid trails.

BMP 3g recommends that water diversion devices be installed on skid trails leading to streams. In both regions, one-third or less of the trails approaching streams had water diversion devices. To be effective, water diversion structures redirect water into a vegetated filter strip (BMP 3i). Application in the CR (91%) was significantly higher than in the AR (67%).

Skid trails can be stabilized with a variety of techniques ranging from using water bars or logging slash, to seeding and mulching. Skid trails were stabilized where erosion was likely (BMP 3f) in only 47% of the CR sites, and about 75% of those in the AR. This difference was statistically significant ($P < 0.05$).

Equipment Maintenance /Operation

Throughout the period of a timber harvest, large amounts of garbage and equipment parts may accumulate at a site. BMP 4a rated the extent that trash was removed. The CR sites were "cleaner" than sites in the AR. Trash was found on 23% of the AR logging sites and on only 3% of the sites of the CR site. This difference was statistically significant ($P < 0.05$) (Table 4).

Petroleum spills on sites indicated careless equipment maintenance or repair. No large spills were found on any site in either region. More often, oil leaked from skidding and forwarding equipment and was spread throughout individual sites. Each site was given a rating reflecting the amount of oil spills found. Overall, 84% of the CR sites and 91% of the AR sites were free from major oil leaks and spills (BMP 4b).

BMP 4c concerns the operation of logging equipment during the proper season with regard to soils. Deep rutting indicated logging during wet periods. For both regions, serious rutting was found on about 10% of the sites.

Buffer strips

Buffer strip BMPs, 5a–5f, were applied on 33–92% of the cases in the CR sites and 52–91% in the AR sites (Table 5). The average application of all BMPs was 77% for the CR and 70% for the AR. Where needed, buffer strips were retained on 75% of the AR sites and 85% of the CR sites. Selective removal of trees within buffer strips was allowed as long as integrity was retained. Significant differences ($P < 0.05$) were found between regions for keeping streams, lakes, and bogs free of logging debris (BMP 5d). Ninety-two percent and 66% of the surface waters were free of logging debris in the CR and AR sites, respectively.

Table 4. Descriptive statistics for BMP application[a] for equipment maintenance/operation in the Adirondack and Catskill regions.

Catskill Region						Adirondack Region		
Total number	Use[b] (%)	95% CI bound			Best management practice[c]	Total number	Use[b] (%)	95% CI bound
63	84	9		4b	Areas free of petroleum deposits.	53	91	8
63	91	7		4c	Skid trails constructed/reconstructed during proper season with regard to soils.	39c	87	11
63	97	4	*	4a	Areas free of logging trash (e.g.. oil cans, skidder cables, etc.).	53	77	12

a Application refers to those practices applied correctly (rating = 3) as well as those with minor deviations (rating = 2). The application percent was computed as n_c/n_a *100, where n_c is the number of practices rated "2" or "3," and n_a is the total number of ratings for the BMP.
b Use % refers to application percent.
c BMP 4c was added 2 wk after field work began, which is the reason for the smaller sample size. An asterisk (*) indicates a significant difference ($\alpha = 0.05$) between the Adirondack and Catskill regions as indicated by nonoverlapping confidence intervals.

Table 5. Descriptive statistics for BMP application[a] for buffer strips in the Adirondack and Catskill regions.

Catskill Region						Adirondack Region		
Total number	Use[b] (%)	95% CI bound			Best management practice[c]	Total number	Use[b] (%)	95% CI bound
27	33	19		5e	Stabilize all roads, cuts and fills in buffer strips by using appropriate seeding and mulching mixtures.	23	52	22
40	65	15		5b	Soil disturbance kept to a minimum within buffer strips.	51	61	15
41	85	11		5a	Buffer strips adjacent to streams, lakes, ponds and wetlands.	52	75	12
30	87	13		5f	Avoided operations within buffer strips when the soil was saturated.	32	91	13
34	91	10		5c	Maintained shading of the stream.	29	79	16
38	92	9	*	5d	Streams, lakes, and bogs free of logging debris.	55	66	13

[a] Application refers to those practices applied correctly (rating = 3) as well as those with minor deviations (rating = 2). The application percent was computed as n_c/n_a *100, where n_c is the number of practices rated "2" or "3," and n_a is the total number of ratings for the BMP.
[b] Use % refers to application percent.
[c] An asterisk (*) indicates a significant difference ($\alpha = 0.05$) between the Adirondack and Catskill regions as indicated by nonoverlapping confidence intervals.

Haul roads and skid trails were not permitted within buffer strips (BMP 5b) except for stream crossings. Soil disturbance in buffer strips was kept to minimum in 65% in the CR sites and 61% AR sites. As a rule, all existing roads should be stabilized but only 33% in CR sites and 52% in AR sites were stabilized.

Effectiveness

Sediment movement, as evidenced by a trail of sediment that could be traced back to a location where a BMP was needed, was used as a surrogate for effectiveness. Although postharvest assessment cannot detect dissolved fine particles (clay) that may have moved during operations, it does provide a crude measure of impact.

Effectiveness of BMPs in the Adirondack region was statistically analyzed for 29 of the 39 BMPs for which effectiveness was rated (10 BMPs could not be evaluated due to insufficient data) (Table 6). Rejection of the null hypothesis (independence between BMP application and surface water protection) indicated a relationship between BMP application and the protection of water quality. Failure to reject the null hypothesis at $\alpha = 0.05$ occurred only for the following BMPs: BMP 1g (installing water diversion devices to reduce erosion), BMP1j (outsloping or insloping roads), BMP 1s (stabilizing temporary roads), BMP 2d (diverting water away from landings), and BMP 3i (surface water diverted into filter strips). Only BMPs 1j and 3i were not statistically significant at $\alpha = 0.10$. The percentage of sites exhibiting direct and indirect impacts when BMPs are applied (Figure 2) is substantially lower relative to those when BMPs are not applied (Figure 3).

In the Catskill region, BMPs also effectively protected surface waters (Table 6). Thirty-three of the 39 BMPs were statistically analyzed (7 BMPs could not be evaluated due to insufficient data). Failure to reject the null hypothesis at $\alpha = 0.05$ occurred only for the following BMPs: BMPs 1g (installing water diversion devices to reduce erosion), BMP 1j (outsloping or insloping roads), BMP 1l (road cuts and fills properly sloped and stabilized), BMP 1k (gravel/stone used in critical erosion areas), BMP 2d (water diverted around landings), BMP 3b (avoid impacting wetlands), and BMP 3h (install water diversion devices on skid trails to reduce erosion). All but BMPs 1j, 1k, 2d, 3b, 3g, and 3h were

Table 6. Chi-square tests[a] for independence used to test the hypothesis that effectiveness is independent of BMP application.

	Adirondack Region		Catskill Region	
BMP	χ^2	*P*-value	χ^2	*P*-value
1c	36.23	0.0001	44.44	0.0001
1d	—	—	—	0.0061[bc]
1e	—	—	—	—
1f	28.44	0.0001	22.381	0.0001
1g	—	0.0630[b]	1.537	0.4637
1h	26.00	0.0001	73.684	0.0001
1i	—	—	—	—
1j	1.72	0.4240	—	0.1006[bc]
1k	9.23	0.0099	0.3214	0.5708[c]
1l	—	—	—	0.0918[b]
1m	—	0.0317[b]	—	0.0213[b]
1n	21.30	0.0001	—	0.0443[b]
1o	—	—	14.595	0.0007
1p	—	—	—	—
1q	10.65	0.0049	10.317	0.0057
1r	—	0.0317[b]	—	—
1s		0.0888[bc]	4.4125	0.03568[c]
2a	—	—	—	—
2b	—	—	36.737	0.0001
2c	13.49	0.0012	13.3931	0.0003[c]
2d	—	0.0767[bc]	0.714	0.7002
2e	15.75	0.0004	23.221	0.0001
2f	—	—	—	—
3a	36.45	0.0001	23.19	0.0001
3b	26.69	0.0001	—	0.1557[b]
3c	39.00	0.0001	75	0.0001
3d	—	0.0371[b]	11.381	0.0034
3e	20.10	0.0001	45.824	0.0001
3f	22.98	0.0001	—	0.0372[b]
3g	9.79	0.0075	16.53	0.0003
3h	—	0.0046[b]	1.215	0.5446
3i	3.60	0.2013	158.087	0.0001
4b	9.74	0.0077	19.619	0.0001
4c	—	—	21.251	0.0001[c]
5a	24.15	0.0001	—	0.0009[bc]
5b	42.91	0.0001	—	0.0001[bc]
5d	36.73	0.0001	—	0.0001[bc]
5e	16.32	0.0003	—	0.0001[bc]
5f	18.48	0.0001[c]	—	0.0001[bc]

[a] Chi-square statistic analyzed with 2 df (2 × 3 matrix).
[b] Indicates that Fisher's Exact Test was used. Fisher's Exact Test better accounts for empty cells and matrices with small data sets.
[c] Denotes those matrices that were reduced from 2×3 to a 2×2 matrix due to a lack of data resulting from incomplete cells.

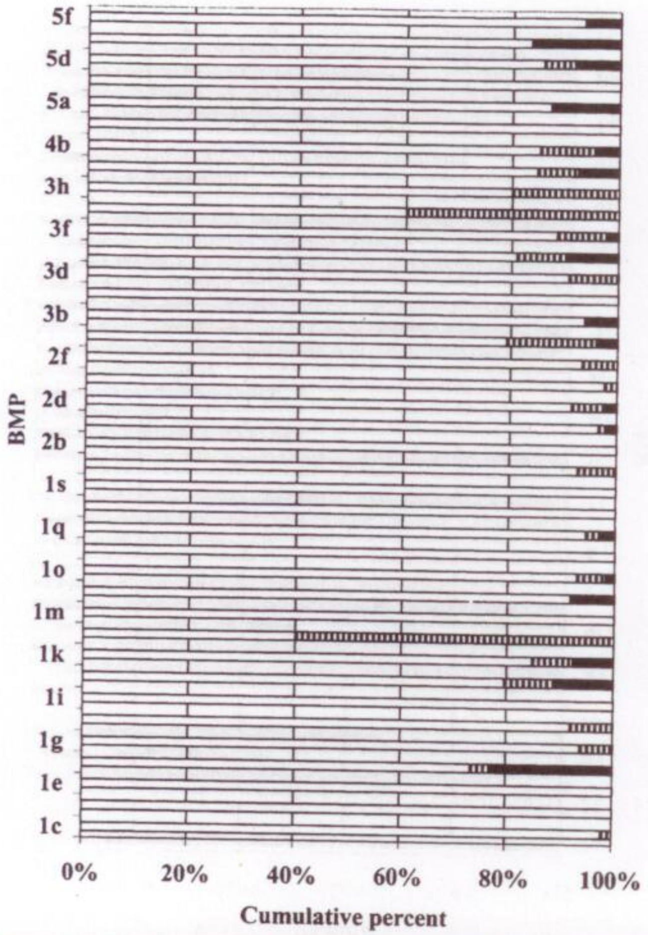

Figure 2. Effectiveness of applied forestry BMPs in protecting surface waters in the Adirondack region of New York. BMPs arranged in ascending alphanumeric order from bottom to top. Every other BMP is labeled to reduce crowding. (Bar color: white = no impact; striped = local sediment movement; black = sediment delivery to surface water).

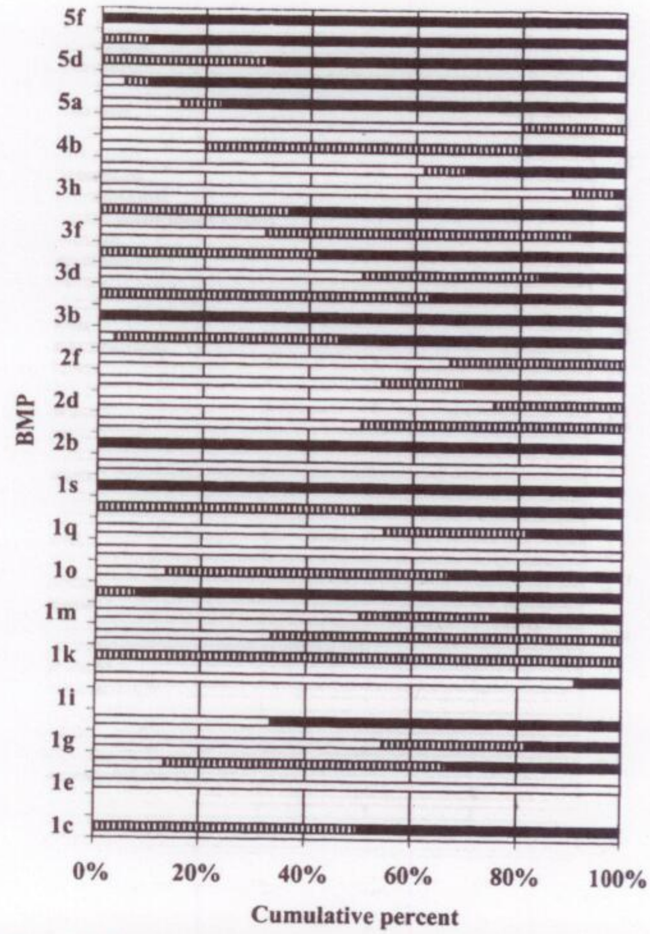

Figure 3. Impacts to surface waters in the Adirondack region of New York when BMPs are not applied. BMPs arranged in ascending alphanumeric order from bottom to top. Every other BMP is labeled to reduce crowding. In cases with 100% compliance, there are no bars for noncompliance. (Bar color: white = no impact; striped = local sediment movement; black = sediment delivery to surface water.)

significant at $\alpha = 0.10$. As was the case for the Adirondack region, the percentage of sites exhibiting direct and indirect impacts when BMPs are applied (Figure 4) is substantially lower relative to those instances when BMPs are not applied (Figure 5).

Discussion

BMP Application

Haul roads have been identified as a principle source of sediment triggered by harvesting operations. Rothwell (1983) reported that up to 90% of all sediment associated with timber harvesting originates from haul roads. Not surprisingly, the number of BMPs related to haul roads comprised almost half (18 of 42) of individual BMPs assessed for this study.

Erosion and sedimentation from haul roads were most often related to inadequate road drainage. These BMPs were applied with low frequency. Increased use of broad-based dips, open-topped culverts, or other water diverting structure is necessary. Diverting water from roads (BMP 1g) and redirecting drainage ditches into filter strips before entering buffer strips (BMP 1n) were not adequately applied in either region, and were probably responsible for a large proportion of the sediment generated from haul roads.

Culverts were the most commonly used structure for cross-drainage. Culvert use (BMP 1f) was calculated at about 85% in both regions. However, 53% and 31% of the culverts, while functional, were installed imperfectly in the Adirondack and Catskill regions, respectively. Common departures included unstable ends, culverts angled less than 30° downslope, or culverts not buried deeply enough. Drainage structures (BMP 1g) were also frequently incorrectly installed. Here, 88% and 31% of the drainage structures in the Catskills and Adirondacks, respectively, were imperfectly constructed.

Landings receive attention as sources of sediment because they represent large areas of exposed soil, usually with low infiltration rates. For these reasons, landings need to be suitably drained and located away from surface waters. Our results show that landing BMPs were generally well applied. Operations in steep topography, common in both regions, presented difficulties in locating landings on sites that will drain water and remain stable. The location of access roads also governed landing placement. Landings were often located at the bases of slopes, where grades were more level. At these sites, drainage ditches are necessary to divert water around landings. This will reduce erosion and will likely increase operational productivity on landings.

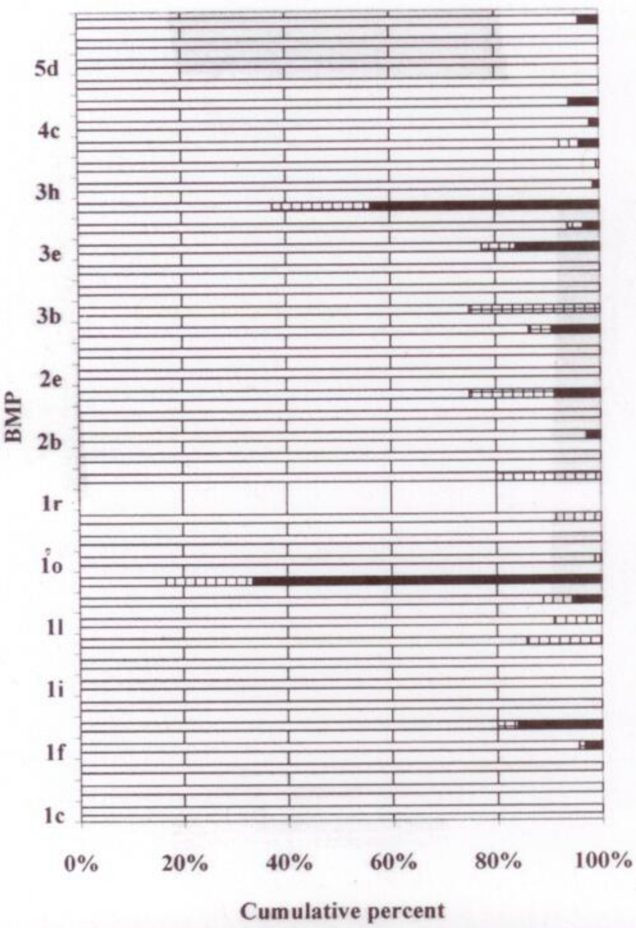

Figure 4. Effectiveness of applied forestry BMPs in protecting surface waters in the Catskill region of New York. BMPs arranged in ascending alphanumeric order from bottom to top. Every other BMP is labeled to reduce crowding. (Bar color: white = no impact; striped = local sediment movement; black = sediment delivery to surface water.)

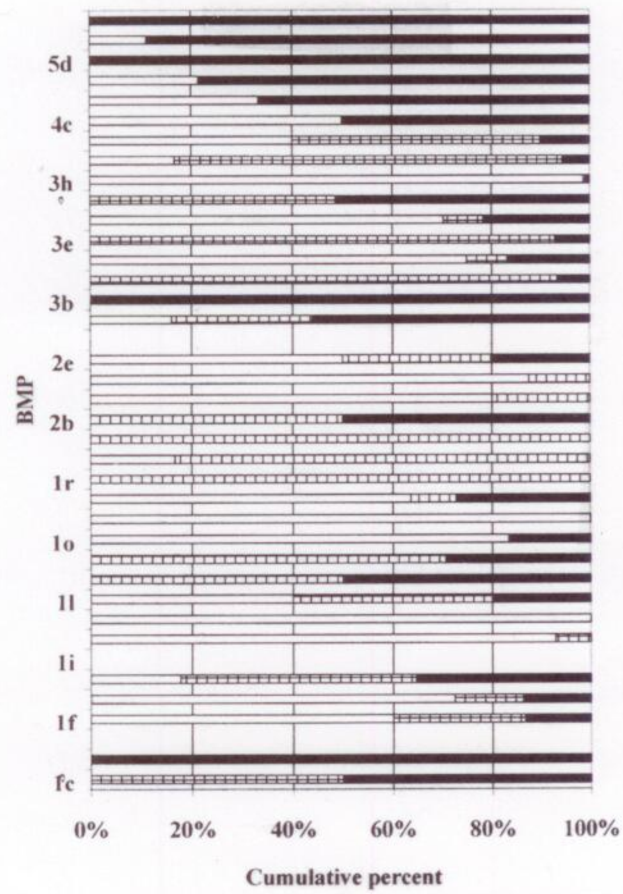

Figure 5. Impacts to surface waters in the Catskill region of New York when BMPs are not applied. BMPs arranged in ascending alphanumeric order from bottom to top. Every other BMP is labeled to reduce crowding. In cases with 100% compliance, there are no bars for noncompliance. (Bar color: white = no impact; striped = local sediment movement; black = sediment delivery to surface water.)

In addition to haul roads, skid trails tended to be major sources of sediment. Those BMPs intended to ameliorate impacts from stream crossing and skid trail erosion (BMP 3g and 3h) were among the least applied practices in both regions. Poor compliance for skid trail BMPs has also been documented in Vermont and Maine (Brynn and Clausen 1991, Briggs et al. 1998). In West Virginia, only 59% of skid trails surveyed were in compliance with water bar guidelines (Egan et al. 1998). Throughout this study, it was evident that stream crossing BMPs were not applied or used properly. When they were applied, they were used imperfectly in more than half of the instances. Consequently, erosion control on skid trails was limited in both regions. Stream crossing permits are only required on streams with C classifications (perennial streams capable of supporting fish) or higher classifications. Most stream crossings did not require state approval. Poor construction and inadequate location of water crossings were the primary sources of most departures.

While rating the 114 study sites, it became apparent that leaf cover on skid trails was an important factor in trail stabilization. Trails were fairly stable if covered by leaf litter. Water bars or other diversion devices aided in the establishment of leaf litter. Slash and other logging debris, while considered as having only a temporary effect (Patric 1977, Rothwell 1983), were also vital in reducing soil movement. It is important to point out that leaves and other debris must be cleared from water bars in order to maintain their effectiveness.

Buffer strips are recommended around lakes, ponds, streams, and wetlands. Advantages of retaining buffer strips are well documented (Comerford et al. 1992). Buffer strips were usually found where needed. Streams and other waterbodies were usually free of logging debris in the Catskill sites. However, logging debris was encountered on about one-third of the surface waters on sites in the Adirondack region. The ecological significance of this BMP (5d) remains unclear. Recent reviews of the literature dealing with stream water inputs have pointed out that both particulate matter and large organic debris were necessary for healthy stream systems (Castelle and Johnson 2000, Doloff and Webster 2000). Particulate matter (from leaves, twigs and cones) is the foundation for the food chain and influences stream productivity. However, excessive inputs can reduce dissolved oxygen concentrations, increase nutrient fluxes, and may restrict fish migration (Lantz 1971). Large woody debris maintains pools and reduces stream velocity. Additions of large woody debris may actually improve stream habitat and stream structure (Bryant 1985).

With the exception of stream crossings, haul roads and skid trails should not be located within buffer strips. Both skid trails and haul roads were found in 60%–65% of the buffers in the AR and CR. Compounding this problem, only about one-third to one-half of these roads were stabilized. New roads should not be constructed in buffer strips. Given adequate erosion control measures, the use of existing stable roads may be preferred, since additional road construction will likely generate more sediment than that produced by a properly maintained existing road.

The use of BMPs in NY, averaged across several categories, compares favorably with levels of compliance reported for several other states (Figure 6). Among the states examined, MN had the highest levels of overall BMP compliance. Specific details of individual BMPs as well as the number of sites evaluated vary among states. For example, WV BMPs recommend haul road grades do not exceed 15%, whereas ME BMPs use 10%. Furthermore, the number of BMPs within each category varied widely among states. The average level of haul road BMP compliance was based on 7 individual BMPs in WV compared to 18 in NY. Nevertheless, this comparison provides a general indication of relative levels of BMP use; NY is not very different from other states.

Effectiveness

The application of BMPs substantially decreased sediment movement, providing good protection for surface waters. This effect has been consistently demonstrated in other states (Florida DEP 1997, Kochenderfer et al. 1997, Arthur et al. 1998, Briggs et al. 1998).

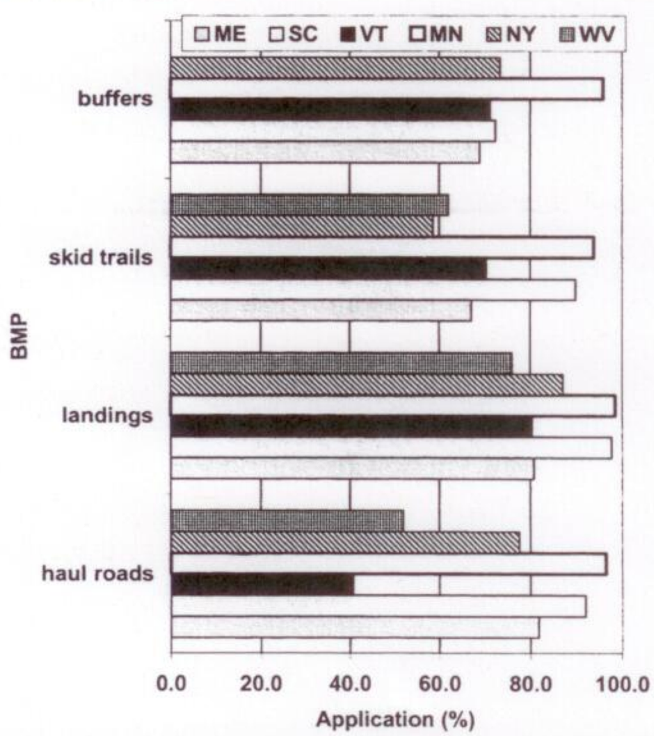

Figure 6. A comparison of overall BMP application levels among several states. The NY data are a composite of the Adirondack and Catskill regions. Data for Maine obtained from Briggs et al. (1998). Data for Minnesota obtained from Phillips et al. (1994).

Few aquatic impacts associated with landings were noted during this study. BMP 2d (divert water around landings) was the only practice on landings where effectiveness was not related to BMP application. The infrequency of direct water quality impacts from landings was likely due to the requirement that landings be located outside buffer strips. Therefore, few direct impacts resulted. However, given the large area of exposed soil and slow infiltration rates commonly found on landings, attention to indirect impacts is warranted.

Skid trails had the greatest number of impacts to surface waters. Most of these were from stream crossings and trails located near streams. Many stream impairments resulted from impacts to intermittent and ephemeral streams. Culverts, bridges, and fording were methods employed to cross streams. Each method has its proper application, and specific site features will dictate which is appropriate.

There is no doubt that properly installed BMPs effectively minimize soil movement. BMPs which are not used cannot be effective. It is clear that more attention needs to be focused on BMP use in NY, particularly with regard to diversion of water from haul roads and skid trails. Failure to improve voluntary compliance with these critical BMPs could ultimately lead to costly restrictions with minimal or marginal benefits, such as implementation of the concept of total maximum daily loads (TMDL). The recent attempt by EPA to declare silviculture as a point source pollution activity is another example of the potential difficulties that lie ahead if BMPs are not more widely used.

The large numbers of loggers and foresters that have been attending BMP training workshops during the past 2 yr suggests that there is significant professional interest in BMP education. Hopefully, this demonstrated interest will be translated into increased application of BMPs across NY.

Conclusions

The objectives of this study were (1) to assess the application of forestry BMPs in the Adirondack and Catskill regions of New York, and (2) to quantify the effectiveness of each individual BMP as evidenced by sediment movement.

BMP implementation varied within and between regions. For two-thirds of the cases, application of needed BMPs exceeded 70%. For both regions, BMPs dealing with landings, equipment maintenance/operation, and buffer strips were used more often than practices associated with haul roads and skid trails. Findings indicated that more attention should be directed toward improving drainage on haul roads and skid trails in both regions. Stream crossings were important contributors of sediment.

Many BMPs were imperfectly applied, reducing their effectiveness. Road drainage structures, when used, generally failed to adequately control erosion due to excessive spacing. Other imperfectly applied BMPs include culvert installation and stabilizing road cuts and fills. These and other misapplications should be addressed in future guidelines, workshops, and training programs.

The effectiveness of BMPs was clearly evident from the data collected. When BMPs were used appropriately, water resources were almost always protected. Even with imperfect application, many BMPs reduced erosion to some degree. Failure to use BMPs clearly results in unacceptable NPS pollution. In order to prevent implementation of mandatory regulations with questionable benefit, professional foresters and loggers must increase BMP application, particularly those dealing with diversion of water from haul roads and skid trails. Attending BMP workshops is an efficient way to become familiar with details of BMP installation.

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