Assessment of Water Diversion Options on Forest Roads and Trails in the United States and Canada

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College of Natural Resources
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Executive Summary

Timber sale administrators and loggers need better information about the various options for diverting water off of forest roads and trails. Those diversions can protect water quality, facilitate road stabilization and long-term use, and facilitate use of the road or trail during all weather conditions. This report summarizes information from a questionnaire sent to public and private timber sale administrators and consultants in the United States and Canada regarding their personal experiences applying standard and alternative water diversion methods. The 144 survey responses were summarized over each of four US and two Canadian regions. While the number of responses from each region was relatively small, a number of national and regional trends emerged.

Water diversions are used most frequently on active and closed haul roads and least frequently on active skid trails. Their application appears to be most consistent in the western US regions, where the majority of timber sales fall under federal supervision and the terrain is predominantly mountainous. Water diversions are also used much more frequently in Western than in Eastern Canada. Loggers are frequently unaware of the need for water diversions or do not use them because they feel that the situation does not require them. Road operability and access requirements as well as equipment availability determine the choice of diversion options on active roads or skid trails. Water diversion structures on closed roads can serve both to restrict access and facilitate drainage, in order to promote rapid stabilization and revegetation of the road surface. Measures used on closed roads can include earth berm or slash water bars or surface recontouring. On roads that are frozen, over rock, or below grade the majority of respondents recommended combinations of fill, road crowning, or roadside ditching.

Road crowning is the most frequently used method for high-use, gravel surfaced roads, while outsloping is more likely to be applied on temporary or unsurfaced roads. Insloping has the most stringent design requirements and is most used in special situations such as on switchbacks or curves. Both crowned and insloped roads typically require the addition of roadside ditches while outsloped roads depend on diffuse discharge of water onto stable downslope areas. Roads that are constructed perpendicular to the contour require a water diversion device to move the water off the road into a stable, vegetated area. All ditches and impermeable water bars should discharge into stable, vegetated areas.

Earth berm or log water bars, broad-based dips, open-top culverts or any of the road shaping methods require heavy equipment to construct and maintain.

Slash water bars and straw bales have less stringent equipment requirements and therefore are easier to install where access may be limited, but are more temporary because slash and straw can decompose rapidly. Proper angle to the road surface, depth, and height of the berm are especially critical with impermeable water bars such as earth berms, broad-based dips and open-top culverts. Damage of water bars can occur due to improper construction, excessive runoff, sediment deposition or, in some cases, vandalism.

Frequent maintenance is most important for water diversion options installed on active roads exposed to heavy traffic. These include road crowning, insloping and outsloping, as well as broad-based dips. However, any impermeable water diversion will require periodic maintenance even if it is not exposed to heavy traffic. Maintenance is recommended but less critical for

semi-permeable water diversions such as slash water bars or straw bales, which are designed to be temporary.

Numerous alternative water diversion and road stabilization methods were identified. For decommissioned roads, these included variants on road obliteration and recontouring (reshaping to the original landscape contours), cross-ditching, and slash mulches. Culvert installation was the most frequently recommended water diversion option for active roads, although a number of respondents also suggested conveyor-belt water bars. The need for careful road location and engineering (to avoid wet spots) was frequently mentioned. Many respondents also noted that one of the most effective methods for protecting the road surface was to time operations to coincide with dry or frozen road conditions. In many cases good road layout and careful timing can obviate the need for water diversion structures.

Introduction

Water must be diverted off of forest haul roads, skid roads or skid trails before it gains sufficient velocity and volume to cause erosion, with its attendant degradation of road surfaces and sedimentation impacts on water quality. Individual state or provincial water quality Best Management Practices (BMPs) provide various options, such as road shaping (crowning, insloping or outsloping), permeable and impermeable water bars, broad-based dips, open-top culverts and hay bales, for diverting water off of roads or trails (Appendix B). These methods are intended to either divert flowing water into ditches, from which it can be discharged onto stable (vegetated) surfaces, or slow down water and trap sediment, to prevent erosion of the road surface. The standard methods work well in most applications but may not be effective under all circumstances. In addition, the options depicted in most BMP handbooks may not address some less common situations where diversion structures are needed, such as over frozen or thin soils or where the road surface is below grade. There is a need to identify and summarize information about the various options for diverting water off of active or closed roads or trails as part of timber harvesting operations in real-world settings. The availability of such information will help timber sale administrators make better decisions to protect their investments in road and trail construction, while also protecting water quality.

In order to collect information regarding the use of standard and alternative water diversion methods, a questionnaire was developed and mailed (Appendix A) to over 600 public and private timber sale administrators and consultants throughout the United States and Canada. The questions focused on the personal experience of the respondents in the application and maintenance of a list of nine standard water diversion methods. Respondents were also asked to list and describe any alternative methods commonly employed within their jurisdiction, along with applicable commentary regarding installation and maintenance issues.

The following report summarizes the information obtained from these questionnaires. It does not constitute a quantitative survey of application frequency for road BMPs, although some quantitative data are provided, but rather an informal compilation of insights drawn from the aggregate experiences of a wide range of forest and road administrators. As such it provides a valuable real-world perspective on the use and application of both standard and alternative water diversion methods.

Following a description of how the survey was developed, administered and compiled (Procedures), there is a brief summary of survey results (Survey Highlights). In the Respondent Commentary section, all the written comments received for each individual option are encapsulated. Each question is then treated individually, with regional breakdowns of responses, in the Regional Summaries of survey results.

Procedures

A questionnaire was developed to document the application of water diversions under a range of North American conditions. Because of the unique conditions faced by forest managers in tropical areas, regions such as Puerto Rico and Hawaii were not included in this survey. Survey drafts were reviewed by individuals familiar with both the topic and the target audience. The survey was comprised of 13 questions in a mixture of multiple-choice and short-answer formats. The cover letter (Appendix A) was addressed, by name if possible, to the most senior person in the office of interest (e.g., District Ranger, head of the state Department of Forestry). The survey format followed a modified Dillman[1] approach. Return envelopes, which were postage-paid in the US, were included with all mailings.

The first two questions assessed frequency of use of water diversions in general, while questions 3–6 asked respondents about the frequency of use of specific options on active or closed haul roads or skid trails. "Active" referred to haul roads and skid trails during timber sale operations, while "closed" referred to the post-sale condition, generally, though not always, closed to traffic. Questions 7 and 8 requested written responses describing the optimal conditions for use of these diversion options; 9 and 10 asked about problems related to the installation or maintenance of diversions. Finally, in questions 11 and 12 respondents were offered a checklist of options appropriate to special situations: where (1) the road is below grade or (2) soils are frozen or over rock. Additional space was provided for miscellaneous comments in question 13.

Between mid-February and late March, 1999, 375 surveys were mailed to US Forest Service (USFS), state, county and industrial forest managers in the US, and 318 surveys were mailed to provincial and industrial forest managers in Canada. US surveys were followed within 3 weeks by reminder cards. Canadian non-respondents were sent second copies of the survey in May, in an attempt to improve on a low response rate. For the convenience of survey respondents we also posted an interactive electronic version of the survey on the departmental web site. The URL (Web address) for this was included in the cover letter.

The mailing lists for the US surveys were obtained from the USFS and state Department of Natural Resources (DNR) personnel in Minnesota, Wisconsin, and Michigan, as well as publicly available forest industry lists. Essentially all the (US) county and industrial survey recipients were located in Minnesota and Wisconsin. All state DNRs received surveys addressed to department heads. At least two ranger districts in every national forest received surveys. Most of the Canadian recipients were identified via lists provided by the provincial Ministries of Natural Resources (or equivalent); these lists included Crown Lands license holders (industry) as well as provincial land managers. In most cases the lists of license holders were selectively reduced in order to obtain a more focused recipient group (i.e., companies presumed large enough to be responsible for their own road construction and maintenance). The relatively large group of recipients in British Columbia were compiled from a list provided by a private forestry consultant.

For logistical reasons the final effective deadline for receipt of survey responses was set at mid-June, 1999. The surveys were compiled and summarized using public-domain text-processing and database tools (the Sed and Awk utilities of the Linux operating system)[2] The respondent database was linked to the transcribed survey responses to allow data summaries by geographic region. No statistical analyses were performed due to the qualitative nature of the data and the small number of responses (144 total). Relevant respondent commentary has been reproduced as fully as possible, with paraphrasing as needed. Non-unique comments have been distilled and summarized for ease of reading.

[1] D.A. Dillman. 1978. Mail and Telephone Surveys. John Wiley & Sons, Inc., New York.
[2] D. Dougherty and A. Robbins. 1997. Sed & Awk, Second Edition. O'Reilly. Sebastopol, CA.

1. Survey Highlights

Response Rates

Completed surveys were returned by 144 recipients, comprising about 30% of the US survey population and 10% of the Canadian population. Nine survey respondents elected to use the electronic survey format provided on the departmental web site. Twenty-six of the Canadian surveys and 3 of the US surveys were returned due to invalid addresses. Seven surveys were returned but considered unusable either because no respondent information was provided, the survey was blank or it was returned too late to be included in the report.

Some of the respondents included copies of their state or provincial BMP manuals, or parts thereof, in order to clarify their descriptions. Other respondents provided sketches or engineering drawings of specific options not included in the survey list. These were very useful in understanding the descriptions of alternative options; where relevant, some of these sketches are reproduced in Appendix B.

In order to assess geographic variation in the implementation of water diversions, we divided the US into 4 geographic regions. Canada was divided arbitrarily into 2 zones, East/Central and Western. A breakdown of the states and provinces assigned to each region follows:
Region Codes (Letter codes used for reference in some tables):

USM. US Mountain States: AZ CO ID KS MT NB ND NM NV SD UT WY.
USW. US West Coast: AK CA OR WA.
USS. Southern US: AL AR FL GA KY LA MS NC OK SC TN TX VA.
USE. Eastern US: CT DE IA IL IN MA MD ME MI MN MO NH NJ NY OH PA RI VT WI WV.
CEC. East/Central Canada: LB MB NB NF NS ON PEI QC SK.
CW. Western Canada: AL BC.

A preliminary analysis shows a fairly even distribution of responses across the US and Canada. The low Canadian response rates may reflect the relatively higher proportion of surveys that were sent to forest industries, comprising a less focused target group. Table 1.1 provides a geographic breakdown of all responses received to date.

Region	USM	USW	USS	USE	CEC	CW
Surveys Sent	112	83	60	118	189	129
Surveys Received	33	20	17	41	21	12
% Response	29	24	28	35	11	9

Table 1.1: Summary of survey mailings and responses by region; Total=144.

The largest proportion of US survey responses were from National Forests in all regions except the Eastern US, where the largest proportion was from county land offices in Minnesota and Wisconsin. Approximately half of the 49 state forestry offices contacted returned surveys. In

Canada, the majority of responses came from private entities. In East/Central Canada 83% of these came from forest industry respondents and 16% from forest management or consulting firms. By contrast, most of the Western Canadian private respondents were from consulting/management firms (81%), rather than industry (18%). Table 1.2 provides an organizational breakdown by region.

Region	USM	USW	USS	USE	CEC	CW
Federal	79	95	53	15	0	0
State/Province	21	5	47	20	43	8
County	0	0	0	41	0	0
Private	0	0	0	21	57	92

Table 1.2: Summary of survey responses by type of organization, numbers are percentages within each region; Total=144.

Tabular Question Summaries

Questions 1–6, 11 and 12 were multiple choice or ranking questions that focused on rates of use of water diversion options on active or closed roads/trails. In addition to rating the frequency of use of specified options, respondents were provided space to rate and describe options not included in the list. All the questions except 1 and 2 referred to a specific list of water diversion options. Questions 11 and 12 included the same list plus some additional options. In summarizing the responses to these questions, we excluded any alternative options described by respondents that were strictly applicable to water-*crossings* (such as fords), because the focus of the survey was on options for removing water *from* the road. Detailed summaries of the responses for these questions are provided in Chapter 3. The standard list of options referenced in questions 3–6, 11 and 12 follows.

Earth berm water bars.

Broad-based dips.

Slash water bars.

Log water bars.

Straw bales.

Open-top culverts.

Road crowning.

Road outsloping.

Road insloping.

Other.

Water diversions are used most often on active and closed haul roads, and least frequently on active skid trails. On of the most frequently cited reasons for not using diversions was that loggers or contractors were unaware of the need for diversions. This issue was also raised in other parts of the survey in relation to the need for better operator training in the recognition of potential problem sites. Another reason was that regulations (road BMPs) or the situation did not require their use. Other frequently cited reasons were logistical or time-related (e.g., temporary nature of the road, restricted season of use, rapid revegetation, operations timing doesn't permit scheduling of installation). In the majority of cases the existence of mandatory BMPs had minor influence on the decision to install diversions. *Author's note: Although infrequently cited, liability is a growing (anecdotal) issue with respect to recreational trail use. Landowners fear that they will be held responsible for injuries caused by accidents resulting from high-speed use of cross-ditched or water-barred trails.*

Road crowning is the most frequently used method for diverting water off of active haul roads, although road outsloping is also widely practiced. Earth berm water bars, outsloping and slash water bars all receive some use on active skid roads. Slash is also widely used as a mulch for new roads or other exposed surfaces: slash is scattered over the road and flattened by equipment, to mitigate rutting. Road operability, equipment availability and need for access are significant factors in determining the choice of diversion options.

On closed haul roads, earth berm water bars are by far the most popular option, used at least moderately by over two-thirds of all respondents. Crowning, broad-based dips and outsloping also are frequently practiced. Post-sale diversion practices depend strongly on whether the road will see continued use for non-timber harvesting-related activities or will be completely decommissioned (rendered inaccessible by cross-ditching or gating, or obliterated). Roads that will continue in use after harvesting activities are completed are more likely to be (gravel) surfaced, crowned or outsloped, in conjunction with broad-based dips, while decommissioned roads may be recontoured or see aggressive water bar installation. Earth berm water bars and slash (as mulch or water bars) are also the most widely used option for closed skid trails, which are generally revegetated by seeding. On closed haul roads and trails, water diversion structures may serve a dual function of drainage and access restriction, which is desirable in order to facilitate revegetation of the road surface.

For active roads that are below grade, the majority of respondents recommend one or some combination of: fill to bring the road up to grade, roadside ditching, road crowning, or other diversion structures such as lead-off ditches. A narrow majority preferred the combination of diversion structures with roadside ditching. For below grade closed roads, earth berm and slash water bars were the most frequently cited options.

For active roads built on frozen or thin soils or over rock, road crowning is again the most favored method, while earth berm water bars are preferred for closed roads. Outsloping is also considered effective on both active and closed roads.

Respondent Commentary

In this section we summarize comments associated with the use, installation and maintenance of diversion options (questions 7–10). They have been summarized for ease of reading but do not reflect any interpretation (except where the respondent's meaning was unclear) by the authors. The respondents' <u>own words</u> have been used wherever possible. The descriptive terminology is as explicit as possible, but due to the wide range of interpretations provided by the respondents (e.g., "steep" may refer to slopes from 5 to over 50%) most of the descriptions are fairly general. Note that these summaries serve only to highlight the most salient features of respondents' comments; detailed summaries are provided for each question in Chapters 4 and 5.

The need for suiting the type of water bar to terrain characteristics was emphasized by nearly all respondents, as was the importance of operator training and equipment availability. Poorly sited or improperly constructed water bars may be worse than none at all, as failing water bars can cause secondary erosion problems.

Earth Berm Water Bars

Earth berm water bars are used much more on closed than on active roads, generally in steep topography. When used on active roads, the berms and excavated areas tend to be lower or shallower in order to avoid vehicle damage. On closed roads and trails they are an effective method of preventing access, but may be destroyed by recreational road use or livestock trampling, especially during wet weather. They may be effective in any location where topography poses a significant erosion risk and where the soils permit the necessary degree of compaction. Correct placement, height, alignment to the road surface, compaction and maintenance are all necessary for proper long-term function. Explicit guidelines for these parameters are provided in most water quality BMP handbooks. Properly constructed earth berms may effectively divert moderate to high runoff flows.

Heavy equipment with adjustable blades and well-trained operators are needed to construct these diversions. Installation can be difficult if soils are frozen, very shallow, sandy or rocky. The berms and excavations should be stabilized by seeding and mulching (closed roads) or with rock or rip rap. A lead-off ditch is required to ensure drainage.

On active roads the water bars need to be reshaped regularly; even on closed roads or trails they should be monitored to ensure continued drainage and proper revegetation. On recreational use roads the berms may need maintenance every 3 to 5 years in order to restore berm height and shape or to remove sediments deposited upslope.

Broad-Based Dips

Generally this option is not installed on a closed road or trail, although pre-existing installations may be maintained. It is a preferred option for heavier-use roads, especially those that need to accommodate log trucks, and in mountainous areas of the Western US. Dips are considered a means of exploiting or emphasizing natural drainages through careful road location. They are frequently used in conjunction with other methods such as insloping or water bars. They are not recommended for steeper grades or where heavy runoff is anticipated.

Cost of construction and the need to design this type of diversion structure into the road plan are limiting factors in the use of broad-based dips, as is the need for heavy earth moving equipment and trained operators. Frozen, shallow, very rocky or very wet soils are unsuitable for dip construction, and the dips may need to be lined with gravel or rock in unstable soils. The dips need to be shallow and long enough to permit truck navigation. They need to be maintained regularly (at least every 2-3 years) with use, and the drainage outlets must be kept clear to prevent water from ponding in the dip.

Slash Water Bars

Many respondents noted that they preferred to use (spread and flattened) slash as a mulch or mat on skid trails and landings. Slash water bars are rarely used on active roads/trails, except occasionally on steep sections with very shallow or frozen soils, and/or when traffic is light. They also may be used as roadside filter strips or at the outlets of water diversions. On closed roads they are useful for controlling access, often as a temporary measure pending revegetation. Advantages include minimal soil movement and equipment requirements and possibly a greater level of visual acceptability compared to ditches or earth berms. Slash water bars will handle only low to moderate amounts of runoff, and hence are likely to be used in conjunction with other types of diversions or in fairly level topography.

Adequate amounts of slash must be conveniently available (therefore slash water bars are more likely where processing happens at the stump). Easiest installation is with a grapple skidder; the slash needs to be adequately compacted and in full contact with the soil to prevent channeling under the bar. In many cases soil may be bermed up against the lower edge for this purpose. These water bars are essentially temporary, for use pending more permanent measures or road stabilization. The materials will rot, and are readily displaced/degraded if subjected to traffic. However, they usually require little maintenance during their lifetimes.

Log Water Bars

This type of diversion is used under similar conditions to those for slash water bars (i.e., on closed roads/trails where soils are not amenable to ditches or berms), but where erosion risks are more extreme (steeper grades, heavier runoff than can be managed with slash water bars). Log water bars are more durable diversions than slash, but may cause more damage if they fail. They are never used on active roads and rarely on active trails, due to traffic impedance and the likelihood of damage (to both vehicles and water bars), but may see occasional use on closed roads/trails, or where only foot/livestock traffic is expected. Their use is limited by log availability and the need for heavy equipment during installation. On some steep trails, skyline roads and fire roads, hand installation may be necessary. The logs need to be properly anchored into the sides of the trail, and are usually bermed up with soil on the uphill side.

Log water bars are relatively costly diversions, especially as the amount of waste wood on timber sales has been reduced, and are vulnerable to damage and breaching due to sedimentation, traffic, or vandalism.

Straw Bales

Straw bales comprise an easily installed and convenient type of water bar, which is most often used in temporary off-road filter strips, to slow runoff and trap sediment. Their on-road use is largely limited to roads/landings closed for rehabilitation. They are especially useful where equipment access is limited, excavation is undesirable or impractical (frozen/shallow soils), or slash is not available. On active roads or new construction, bales are mainly used to filter runoff in ditches or drainage outlets, especially near streams or other sensitive areas. They are not recommended for use alone where there are large amounts of runoff. They need to be properly positioned, in full contact with the soil surface, and staked in to be effective.

Advantages of straw bales include their ready availability, relative ease of installation, and usefulness for addressing unanticipated problems. Limitations include the cost of the bales, the short useful lifespan of straw, the necessity of importing materials to remote locations, and the possibility of introducing weed seeds. Straw may also be spread as a mulch to aid revegetation.

Open-top Culverts

Open-top culverts are no longer used in most locations due largely to expense and maintenance problems. These are generally removed on closed roads because of the likelihood of failure due to sediment/debris plugging. They are useful in special situations, such as wet areas, or where water crosses the road (although standard culverts and plastic pipe are more frequently used as cross-drainage devices in these situations). They work best if the road has a permanent (gravel) surface and the equipment or traffic is relatively light.

Problems with this option include the necessity for constant cleaning to maintain drainage, the necessity for heavy equipment (backhoe) installation involving extensive soil movement, and difficulty when grading with the culverts in place. The soil or fill needs to be deep enough for the necessary excavation. Generally the culverts should be lined with rock and have a sediment trap below the outlet.

Road Crowning

Road crowning is the most widely used option, especially for relatively permanent, designed haul roads with a gravel surface that is wide enough and has sufficient surfacing material to properly crown. Construction and maintenance are usually with a dozer or grader. The topography should not be too steep, and appropriate ditching and cross drainage (culverts) must be provided. Road crowns are rarely maintained on closed roads or installed on temporary skid trails. If not graveled, native soils need to be fairly dry, stable and well-drained.

Drawbacks to the use of road crowning include the necessity for appropriate equipment and well-trained operators to construct and maintain a crowned road, the desirability of gravel surfacing, which increases road cost, possible downslope terrain impacts of off-road drainage, and the difficulty of installing other diversion devices on crowned roads. Regular grading is important, but operators need to avoid leaving outside berms which can channel water on the road. Advantages include the relative durability of crowned roads under heavy traffic and the possibility of higher speeds of travel.

Road Outsloping

Outsloping is a fairly low-cost method that is useful on both temporary and permanent roads and skid trails, especially those that are too narrow to crown. Outsloping is limited to areas of slower traffic during dry conditions, as the roads may be hazardous when wet or icy. This method is best adapted to handling sheetwash or other low-volume, diffuse runoff on moderate grades and side hills with stable soils or rock. It is frequently used in conjunction with other methods such as broad-based dips, water bars, ditches or culverts, especially on steeper slopes. Heavy, bladed equipment is required for installation and maintenance, although de facto outsloping may develop as a result of skidding on narrow trails in steep terrain.

Drawbacks include the need for regular maintenance to avoid rut development, the likelihood that use or grading will leave outside berms, and safety concerns under slippery conditions. Downslope erosion risk must also be considered, especially on sidehills. The relatively low cost and wide adaptability of this method for maintaining drainage on both active and closed road surfaces make it popular.

Road Insloping

Insloping is generally a design feature of narrower permanent roads that will be surfaced with gravel. This option is costly because it requires the installation of additional drainage features such as inside ditches and culverts to handle the accumulated water. However, it is particularly useful on sideslopes and curves on moderate grades, or areas where the risk of downslope erosion impacts (unstable soils, riparian areas) make outsloping undesirable. Insloping allows runoff to be guided off the roadway and moved into an area where erosion risks are minimized, thus protecting sensitive areas that may be immediately downslope of the roadway. Construction requires heavy equipment and involves considerable soil disturbance. Insloping is rarely maintained on closed trails.

Disadvantages of road insloping include the need for more careful engineering and operator training. The more stringent design requirements of this method increase the risk of improper installation and subsequent failure. It is often difficult to provide sufficient maintenance to prevent channeling of water on the road, and to keep ditches and culverts open. The presence of steep slopes or bedrock can make construction problematic.

Other Methods

A variety of alternative methods were described with reference to Questions 3–10. Many of these were variants of the "standard" options listed above. Those that differed significantly are described in greater detail in the summaries provided in Chapters 3, 4 and 5. In addition, descriptions and, where possible, illustrations of most of the alternative methods are included in Appendix B. The most frequently cited "diversion" option for closed roads was obliteration and recontouring, generally including revegetation, possibly with mulch. Obliteration implies the complete reclamation of the road surface and may include ripping, subsoiling or scarification as site preparation for planting or seeding. Road cuts may also be recontoured to return slopes to their original configuration. This is the most effective means of preventing sediment loss on closed roads, but is expensive and requires earth moving equipment and follow-up to ensure success.

Other options for closed roads or trails where no further access is desirable included slash mulches or mats (see Slash Water Bars), cross-ditching, and various combinations of water bars with mulching, ditching and revegetation.

For both closed and active roads, a variety of options were recommended, including "flappers" (rubber conveyor belts buried across the roadway), aggregate surfacing, steel/plastic culverts, variants on the broad-based dip, and spreader ditches (variant on lead-off ditch). Seeding and mulching was frequently recommended to stabilize exposed areas (e.g., berms, road-banks). Another frequent suggestion was that operations should be timed to coincide with dry or frozen periods in order to minimize the need for water diversion.

For active roads, various combinations of road shaping with ditches and/or berms were suggested. Plank-lined dips and fill placement were also recommended. Proper road engineering (break slope/direction of road/trail to avoid long, steep grades) and location (avoidance of wet or unstable areas) also play important roles. The use of filter fabric fences or geotextile was suggested in addition to straw bales to filter runoff along roadsides and ditches, particularly in riparian areas.

2. Regional Summaries of Responses to Tabular Questions

In this chapter the responses to the multiple-choice and ranking questions are summarized in detail by geographic region. The regional breakout presented below was based partly on the distribution of survey respondents and partly on the more important physiographic distinctions between different parts of North America. For example, the US Mountain States tend to be mountainous and dry (exceptions: the Great Plains states), while the West Coast is is mountainous and wet. More constrained geographic groupings were not possible due to the relatively small number of survey respondents. The geographic groupings used are recapitulated below:

USM. US Mountain States: AZ CO ID KS MT NB ND NM NV SD UT WY.
USW. US West Coast: AK CA OR WA.
USS. Southern US: AL AR FL GA KY LA MS NC OK SC TN TX VA.
USE. Eastern US: CT DE IA IL IN MA MD ME MI MN MO NH NJ NY OH PA RI VT WI WV.
CEC. East/Central Canada: LB MB NB NF NS ON PEI QC SK.
CW. Western Canada: AL BC.

Note: when percentages of respondents are cited within a region, the percentage refers only to the number of responses received for a given question within that region. Percentages of overall responses are based on the total number of responses received for each question.

In the sections that follow, each question is first briefly restated in bold text, followed by any ancillary information necessary to clarify the responses. The format of the response summary depends on the format of the particular question. In general an overall summary will be followed by a regional breakdown of the responses, with tabular summaries as appropriate. See Appendix C for a complete listing of responses to the tabular questions.

General Use of Water Diversion Options

Q1. How frequently are water diversion options used on active and closed haul roads and skid roads/trail as part of timber harvesting operations?

The frequency categories were "Often" (at least 71% of the time), "Moderate" (41 to 70%), "Little" (1 to 40%) and "Never" (0% use).

General trends:

The overall trend mirrors that in the Mountain and Southern States, where diversion options are most frequently used on post-sale haul roads, and with less frequency on active haul roads and closed skid trails. The majority of regions reported "never" using diversions most frequently on active skid trails. The US West Coast and Western Canada were similar in reporting the most frequent use on closed skid trails and post-sale haul roads. East/Central Canada and the Eastern

Region	Frequency of Use (% of time)				Blank	n
	Often >70%	Moderate 41–70%	Little 1–40%	Never 0%		
Active Haul Roads						
USM	64	27	9	0	0	33
USW	74	5	21	0	0	19
USS	71	6	24	0	0	17
USE	22	42	30	5	0	40
CEC	40	20	20	20	0	20
CW	42	25	17	17	0	12
Overall	49	25	21	6	0	141
Closed Haul Roads						
USM	82	15	3	0	0	
USW	95	0	5	0	0	
USS	71	18	6	7	0	
USE	35	28	35	2	0	
CEC	25	0	40	35	0	
CW	92	8	0	0	0	
Overall	62	14	18	6	0	
Active Skid Trails						
USM	30	21	39	9	0	
USW	53	11	32	5	0	
USS	53	12	35	0	0	
USE	5	28	62	5	0	
CEC	0	25	30	35	10	
CW	17	35	33	17	5	
Overall	23	21	43	11	2	
Closed Skid Trails						
USM	71	15	15	0	0	
USW	89	11	0	0	0	
USS	11	1	5	0	0	
USE	28	35	45	2	0	
CEC	0	5	35	50	10	
CW	42	33	8	8	5	
Overall	48	16	26	9	2	

Table 2.1: Relative use frequencies of water diversions on different road or trail conditions, in percentage of respondents to each question in each region. The total number of respondents in each region is given by “n” and is only listed once. N=141.

US reported the most frequent use of options on active and post-sale haul roads. However, in some cases the road status where options were used most frequently was also the situation in which “never” was most frequently cited (e.g., active haul roads in the Eastern US), suggesting that application frequency varies widely within each region.

Respondent commentary associated with questions 1–6 suggested that in the Eastern US haul roads are more likely to be permanent roads that will continue in use after the sale closes. In those cases more effort is expended on the installation of permanent diversion structures, such as culverts and ditches, that will help maintain long-term road integrity. By contrast, in the Mountain and West Coast States the primary water diversions on closed roads are more likely to be berms, cross-ditches and other measures expressly intended to impede access and/or help revegetate the road surface (i.e., roads are more likely to be temporary).

Q2. When water diversions are not used or little used ($< 40\%$), what are the most frequently cited reasons?

The ten items listed below were offered on the survey as potential reasons why water diversions are not used. Respondents were asked to rank each reason on a scale of 1–10, where 1 indicated the most cited reason and 10 the least. In cases where respondents marked but did not rank one of the listed reasons, a rating of 0 was assigned, and those reasons were then ranked among the most frequently cited reasons. When "other" was selected as a reason, respondents were requested to provide an explanatory comment. Explanatory comments are summarized below. In some cases, the "other" option was selected but the explanation reflected one of reasons a–i. Those responses were simply coded to the appropriate category. A summary of responses is presented in Table 2.2.

a. Landowner or forester lack of awareness of the need to install water diversions.
b. Logger lack of awareness of the need to install water diversions.
c. Limited awareness of the water diversion options available.
d. Landowner or forester does not require installation of water diversion devices.
e. Disregard for the need to install water diversion devices.
f. Concern about the cost of installation of water diversion devices (real or imagined).
g. Site conditions prevent the installation of water diversion devices.
h. Concern about liability exposure from recreational users of roads or trails.
i. Lack of knowledge about how to install option.
j. Other (please specify).

The overall most frequently cited reasons for not installing diversion structures seem to reflect a response to regulations (d, not required), as well as cost (f). Concern about liability incurred by recreational trail use (h) is frequently cited as a secondary concern. Respondents in the US Mountain, West Coast and Eastern States and East/Central Canada also cited inappropriate site conditions (g) most frequently among their reasons for not using diversion options, although it was not always assigned the highest ranking.

The US Mountain and Southern States also ranked "other" (j) as an important disincentive to the use of diversions. The descriptive comments pertaining to part (j) in these two regions are summarized below.

Mountain States

1. Practice of restricted operating seasons, conditions, or location, timing of activities to avoid runoff.

Region	n	High Frequency	Low Frequency	Overall Most Cited
USM	23	g,j	h,i	g
USW	14	c,e,f,g	d,g,h	g
USS	12	b,d,j	h	d,i
USE	34	d	h	g
CEC	17	e,b	g	e,f,g
CW	10	d	i	b,d,f
All	110	d	h	d,f

Table 2.2: Most frequently cited reasons for non-use of water diversion structures. The reasons indicated by the letters listed under the category "High Frequency" were those most often assigned a rank of 0–5 by respondents, while those under "Low Frequency" were those most often assigned a rank of 6–10. Letters that do not appear in the table were not cited or ranked by a significant number of respondents. (N=110)

2. Structures are hard to maintain on main trails during active logging.
3. Infrequent need for structures on properly closed roads.
4. Not required on slopes $< 10\%$ or during dry season.
5. Not installed unless weather becomes wet and operations cease; not used when frozen.
6. Water diversion is usually not needed during active operations (dry conditions). However, it may be required depending on time of year.

Southern US

1. Time constraints–logger needs to move to next job.
2. Not used while active; contractor required to stabilize before leaving site.
3. Spot was missed during stabilization process.
4. Lack of proper equipment; devices impede traffic on active roads

A representative listing of relevant comments from other regions is provided below.

1. Field equipment not used in winter, dry summers obviate need.
2. Logging is restricted to dry season, so diversion not needed on active sites.
3. Plan access location/timing to avoid need for water diversion.
4. Problem sites are made to be frozen ground activity only.
5. Risk is low because skid trails are only open for a short time during use.
6. Timing; hauling until breakup, no access while thawing, then contractor questions need for options when the ground has dried.
7. Roads are built for winter use only; swampy conditions prohibit post-sale access.
8. Landowners don't want them (not to be confused with forester attitudes).
9. Damage to equipment; diversion devices are removed during skidding period.
10. No forester involved in planning the sale.
11. No time for planning of roads.
12. Don't take time to install.

13. Short duration, intensive use of trails causes structures to not hold up.
14. Skid trail protection only recently mandated by [Quebec] government (main landowner); plan to use slash mulch/mats.

Some of the comments from the Mountain States (1, 4, 5 and 6), as well as the first 7 items above, may generally be classed as a dependence on timing rather than structures for surface protection and erosion prevention. *Author's note: Restricting logging to dry or frozen seasons may not obviate the need for water diversions. Unless the site revegetates very quickly following activities and slopes are not steep, erosion may still occur.* Items 8 and 9 involve the preferences of landowners and sale operators; items 10–12, as well as items 1 and 4 in the Souther US, are logistical. Item 13 reflects a concern that structures will be wasted effort; item 14 suggests that the changing regulatory environment in Canada may result in more aggressive use of diversion options in the future.

Frequency of Use of Specific Water Diversion Options.

Survey questions 3–6 presented tables that allowed the ranking of relative use frequencies of water diversion structures on (respectively) active and closed haul roads and skid trails when soils are not frozen. Part (a) of each question was a table of options with 4 frequency categories: "Often" (used at least 71% of the time), "Moderate" (used 41 to 70%), "Little" (used 1 to 40%) and "Never" (0% use). Options receiving the highest percentage of "often" or "moderate" ratings are considered to be the most frequently used; options receiving the greatest number of "never" ratings are considered to be the least frequently used. Where respondents noted the "other" category, they were requested to provide descriptions, which are summarized for each question. Note that the tabular summaries list the absolute number of respondents that marked each use category for each option. However, percentages discussed in the text are based on the total number of respondents to the question, either overall or within each region (some of whom left several options blank). If all the blank options were coded as "Never" responses, then the reported percentages of "never" ratings for most options would increase. However, the authors felt that recoding the responses in this manner would result in misleading interpretations of the data, such as large percentages of respondents "never" using the "Other" option, when in fact that option had simply been left blank.

In part (b) of each question, respondents were asked to circle one or more letters representing the list of options (including "Other") from the table presented in part (a). The number of times each letter was circled was then tallied up for each region. The specific options listed in the tables are reiterated below.

Earth berm water bars.
Broad-based dips.
Slash water bars.
Log water bars.
Straw bales.
Open-top culverts.
Road crowning.
Road outsloping.
Road insloping.
Other.

Option	Frequency of Use (% of time)				Blank
	Often >70%	Moderate 41–70%	Little 1–40%	Never 0%	
Earth berm water bars	14	12	38	30	6
Broad-based dips	27	20	29	19	5
Slash water bars	3	7	14	67	8
Log water bars	3	3	17	69	9
Straw bales	2	7	28	56	8
Open-top culverts	3	4	27	59	8
Road crowning	48	25	16	7	4
Road outsloping	38	33	21	7	2
Road insloping	28	32	28	7	6

Table 2.3: Overall frequency of use of listed water diversion options on active haul roads. Data indicate the percentage of responses at each frequency for each option (N=138).

Q3(a). How frequently are options used on active haul roads?

A summary of the frequency ratings is provided in Table 2.3

Road crowning was the most frequently cited option in all regions except in the US Mountain and West Coast States, with 75% of all respondents rating crowning as used "often" or "moderately". In the latter regions the most frequently used method on active haul roads was road outsloping (89% of respondents in each region), while road crowning is the most frequently used in all other areas (from 79% of respondents in East/Central Canada to 66% of respondents in Western Canada).

On the other hand, both slash and log water bars were in the least frequently used category in all regions except those in Canada. In all except the latter regions between 62 and 84% of respondents reported "never" using those options; the overall percentages were 67 and 69%, respectively, for slash and log water bars. In the US West Coast and Mountains States straw bales were also reportedly "never" used by 72 and 63% of respondents, respectively, while in the West Coast, and Eastern States and East/Central Canada between 67 and 68% "never" used open top culverts. The option for which "little" use was most often indicated (38% of all respondents) was earth berm water bars.

At least some use of one or more alternative ("Other") options was reported by 43 individuals (31% of all respondents). In many cases these responses simply referred to the use of aggregate surfacing or culverts (most frequent). However, there were some novel techniques. A summary by region of the described alternative options is noted below.

Mountain States

1. Rubber (conveyor) belts embedded across the road at appropriate angles, also referred to as "flappers"; possibly for use on steeper slopes where broad based dips don't work well. One description had the belts attached to a treated beam.
2. Inside ditch with culverts, and cross ditches.
3. Outslope drains.

West Coast

1. Conveyer belt or “rubber diversion” water bars.
2. Suspend operations until dry.
3. Utah dips (driveable waterbars).

Southern US

1. Plank-reinforced dips.
2. Filter-fabric lining.
3. Rolling dips.

Eastern US

1. Good ditches.
2. Seasonal restrictions on hauling.
3. Slash mulch.
4. Diversion ditches with pipe culverts or strikeouts.
5. Rip rap.
6. Lead-off water bars or water turnouts (lead-off ditches).

East/Central Canada

1. Diversion or off-take ditches, diversion berms in ditches (lead-off ditches).
2. Bridges.
3. CSP (standard), small (12 in.) metal or plastic culverts, diagonally across the road.
4. Rip rap.
5. Seeding.
6. Crown and ditch, often with straw bales, + earth berms in areas of high erosion potential

Western Canada

1. Cross ditches (3 ft deep) for temporary closure.
2. Steel or wooden culverts combined with good ditching.

Q3(b). Which of the options listed in 3(a) is the most effective for active haul roads?

In the US West Coast, Mountain and Southern States broad-based dips were rated “most effective” by the greatest number of respondents (at least 53% in each case), while crowning was rated “most effective” in all the other regions. However, in Western Canada “other” (the alternatives listed in 3(a)) options were rated equally effective as crowning.

Option	Frequency of Use (% of time)				Blank
	Often >70%	Moderate 41–70%	Little 1–40%	Never 0%	
Earth berm water bars	21	14	33	26	6
Broad-based dips	7	16	33	34	9
Slash water bars	6	18	28	41	6
Log water bars	1	8	28	53	10
Straw bales	1	4	20	65	10
Open-top culverts	0	2	16	70	12
Road crowning	1	4	18	64	12
Road outsloping	9	16	24	43	7
Road insloping	1	7	27	51	14

Table 2.4: Overall frequency of use of water diversion options on active skid trails. Data indicate the percentage of responses at each frequency for each option (N=138).

Q4(a). How frequently are options used on active skid roads/trails?

A summary of the frequency ratings is provided in Table 2.4

Earth berm water bars were used most frequently overall (35% "often" or "moderate") and outsloping the next most frequently (25%) on active skid trails. On a regional basis, earth berm water bars were the most heavily used option in the US West Coast, Mountain and Southern States (44–71% of respondents at least "moderate"), while outsloping was the most frequently used option in the Eastern US and Western Canada (26 and 35% of respondents). However in East/Central Canada 37% of respondents indicated the most frequent use of "other" options (see below).

Open-top culverts were the least-used option overall and in the US West Coast, Southern and Eastern States (at least 70% "never"). This option was also "never" used by 70% of the respondents in West Coast States, where straw bales and road crowning were "never" used by 73% each. Open-top culverts, straw bales and road crowning were similarly ranked as least used by 50% of respondents (each) in Western Canada. However, in East/Central Canada road crowning, outsloping and insloping were equally ranked as least used by 79%, each, of respondents.

At least some use of one or more alternative options was indicated by 19 individuals (14% of respondents). Their descriptions are summarized below.

Mountain States

1. Placement: choice of trail location (to avoid impact).
2. Slash mulch: spread slash over trail and roll over with equipment; or slash mulch in combination with earth berm water bars.

West Coast

1. Timing: suspend operations until dry; possibly with temporary installation of earth berms.
2. Backblade outside berms; outslope for drainage.
3. Break in pattern (direction of slope).
4. Slash mulch.

5. Metal culverts.

Eastern US

1. Steel culverts.
2. Seasonal restrictions on use.
3. Slash mulch.
4. Diversion ditches and pipe culverts.
5. Proper location of road (eliminates need).

East/Central Canada

1. Timing: harvest on wet sites only when frozen.
2. Corduroy.
3. Temporary bridges.
4. Mats.
5. Low ground pressure tires on skidders on wet ground.
6. Leave root mat undisturbed in wet areas.
7. Culverts (on roads).

Q4(b). Which of the options listed in 4(a) is the most effective for active skid roads/trails?

Overall and in the US West Coast, Mountain and Southern States earth berm water bars were rated as "most effective" by 39 to 75% of respondents, while in the Eastern US and East/Central Canada 39 and 45% of respondents rated slash water bars as "most effective" (24% overall). However, in many cases these were annotated to clarify that spread, or mulched, slash was more effective than slash piled into water bars. In Western Canada outsloping was rated as "most effective" by 45% of respondents.

Q5(a). How frequently are options used on closed haul roads?

A summary of the frequency ratings is provided in Table 2.5

Earth berm water bars were used "often" or "moderately" by 68% of all respondents, while outsloping was used the next most frequently (56%). Earth berm water bars were the most frequently used in the US West Coast, Mountain and Southern States and Western Canada (75–100% of respondents), but in the Eastern US road crowning was used by 67% of respondents. In East/Central Canada broad-based dips, slash water bars, crowning and "other" options were used with equal frequency (17% each).

The highest percentages of respondents reported "never" using slash or log water bars, straw bales, or open-top culverts on post-sale roads in all the US regions and Western Canada (F) (38–79%). Eastern/Central Canadians generally used the fewest diversion options on closed haul roads: at least half the respondents reported "never" using all the options listed. Open-top culverts were the least used of all options (88% of respondents) in this region.

At least some use of one or more alternative options for closed haul roads was indicated by 39 individuals (19% of respondents); these options are summarized below.

Mountain States

Option	Frequency of Use (% of time)				Blank
	Often >70%	Moderate 41–70%	Little 1–40%	Never 0%	
Earth berm water bars	50	18	18	11	4
Broad-based dips	21	30	23	19	7
Slash water bars	4	16	16	53	10
Log water bars	3	5	23	57	12
Straw bales	3	3	24	57	12
Open-top culverts	1	4	16	67	12
Road crowning	20	24	24	21	11
Road outsloping	26	30	24	15	5
Road insloping	15	29	27	19	10

Table 2.5: Frequency of use of listed water diversion options on closed haul roads. Data indicate the percentage of responses at each frequency for each option (N=136).

1. Obliteration and recontouring, possibly in conjunction with ripping, seeding, and slash mulching.
2. Rolling dips.
3. Flappers (conveyor belt water bars); possibly with slash mulch.
4. Inside ditch with culverts or cross ditching.
5. Crushed aggregate surfacing.
6. Outslope drains.

West Coast

1. Dirt spurs; scarify or subsoil.
2. Gate or block road to prevent access.
3. Conveyor belt water bars and earth berm water bars in conjunction removal of culverts and seeding.

Eastern US

1. Ditching.
2. Culverts.
3. Slash or other mulch with seeding (possibly clover/grass) and resurfacing.
4. Diversion ditches (lead-off ditches) with culverts.
5. Excelsior mulch.
6. Fords.

East/Central Canada

1. Water turnouts (lead-off ditches).
2. Culverts.
3. Remove culverts/bridges, perform site prep, seed or plant to close.

Western Canada

1. Cross ditches.
2. French drain (shot rock-filled ditch).
3. Complete reclamation or partial deactivation (removal of culverts, recontouring, restoration of water channels), in combination with earth berm water bars.

Q5(b). Which of the options listed in 5(a) is the most effective for closed haul roads?

Overall, the largest number of respondents rated earth berm water bars "most effective" (56%) followed by broad based dips (20%). In all regions except East/Central Canada, earth berm water bars were rated as the "most effective" option for post-sale haul roads (29-89% of respondents); however, in Western Canada straw bales and "other" were rated as equally effective (29% each). In East/Central Canada, road crowning was rated as most effective by 33% of respondents.

Q6(a). How frequently are options used on closed skid roads/trails?

A summary of the frequency ratings is provided in Table 2.6

Overall, 75% of respondents used earth berm water bars most frequently, followed by 37% who used slash water bars at least moderately. "Other" methods were used at least moderately by 20% of all respondents. In the US West Coast, Mountain and Southern States and Western Canada earth berm water bars were used most frequently (81–100% of respondents) on closed skid roads. Based on responses to later questions, in most but not all cases the use of this option is associated with at least partial deactivation of the road, but not obliteration. In the Southern US slash water bars or mats were used slightly more frequently than earth berms (44% vs 41%). Water diversion structures were rarely used on closed skid trails in Eastern/Central Canada; 22% of respondents used log water bars at least moderately, while 18% of respondents used slash water bars and straw bales.

The least frequently used option for post-sale skid roads overall was open-top culverts (73%"never"), followed by road crowning (62%). Exceptions to this trend were East/Central Canada, where 88% of respondents "never" used outsloping or crowning, and Western Canada, where 67% "never" used straw bales.

Of the 32 individuals (23% of respondents) who indicated at least some use of one or more alternative options, most assumed complete trail closure with varying degrees of reshaping and rehabilitation to encourage rapid revegetation. Extensive use of spread slash, both to prevent erosion and accelerate revegetation, was reported in most US regions. The options are detailed below.

Mountain States

1. Seeding.
2. Ripping of main skid trails.
3. Obliterate and recontour to match surrounding side slopes.
4. Slash spread or mulched in the trail, with or without water bars.
5. Slash or logs on trails of <15% slope, placed in the fall.
6. Cross ditch with slash mats.

Option	Frequency of Use (% of time)				Blank
	Often >70%	Moderate 41–70%	Little 1–40%	Never 0%	
Earth berm water bars	53	12	19	14	2
Broad-based dips	6	20	28	36	10
Slash water bars	13	24	20	36	7
Log water bars	4	9	28	47	12
Straw bales	2	3	26	58	12
Open-top culverts	0	0	13	73	14
Road crowning	1	6	17	62	14
Road outsloping	12	15	22	42	8
Road insloping	3	4	27	51	15

Table 2.6: Frequency of use for water diversion options on closed skid trails. Data indicate the percentage of responses at each frequency for each option (N=137).

West Coast

1. Backblade outside berms.
2. Scarification and slash mulch.
3. Subsoiling and seeding.

Southern US

1. Seeding with mulch.

Eastern US

1. Seeding with or without mulching (slash, hay or excelsior).
2. Diversion ditches and pipe culverts.
3. Replace topsoil and sod.

East/Central Canada

1. Culverts.
2. Rehabilitation (remove culverts/bridges, perform site preparations, seed or plant).

Western Canada

1. Cross ditches.
2. Rehabilitation.

Q6(b). Which of the options listed in 6(a) is the most effective for closed skid roads/trails?

In all regions except East/Central Canada, earth berm water bars were considered to be the "most effective" by 59 to 100% of respondents. In East/Central Canada, slash water bars were rated the most effective by 75% of respondents.

Use of Water Diversions in Special Situations

In question 11 respondents were given an expanded list of water diversion options (see below) to rate for use on roads cut below grade. In question 12, only the first nine items (plus "Other") were listed for a similar rating with respect to their application on frozen soils or over rock. In each case, respondents were asked to place a letter "A" in front of all options applicable to active roads, and a "C" in front of all options applicable to closed roads, then to circle the letter(s) placed in front of the option that was the most effective for that situation. Therefore we collected 6 categories of data for these questions: (1–3) all options used on active/closed/both types of roads; (4–5) the options considered most effective on active/closed/both types of roads. The "both" category was invoked when two letters were placed before an option, and is a separate consideration from either active or closed. However, the "both" ratings were added into the separate "active" and "closed" tallies when the responses were being tabulated. Following the overall and tabular summaries of responses for these questions, we have summarized, by region, any descriptions that were provided when the "Other" category was marked. Only those regions in which respondents used this option are included in the list. The list of options for Q11 is provided below; Q12 used only the first nine items of the list as well as "other" (the acronyms are used in Tables 2.7 and 2.8).

Earth berm water bars (EWB).
Broad-based dips (BBD).
Slash water bars (SWB).
Log water bars (LWB).
Straw bales (SB).
Open-top culverts (OTC).
Road crowning (RC).
Road outsloping (RO).
Road insloping (RI).
Diversion structures with lead-off ditch (DLD).
Diversion structures with roadside ditching (DRD).
Place fill to raise road surface (FILL).
Other

Q11. Which diversion options are used in areas where the road or trail surface is cut lower than the surrounding landscape, making it difficult to immediately divert water off the road?

The use of diversion structures in conjunction with roadside ditching received the overall highest ranking for active roads, and was among the highest ranked methods in the US West Coast, Mountain and Southern States and Western Canada (see Table 2.7). Road crowning was the most frequently used option for active roads in the Eastern US and East/Central Canada. US Eastern and West Coast respondents also assigned a high rank to the use of fill to raise the grade.

The majority of respondents (all US regions and overall) used earth berm water bars most frequently on closed roads. In East/Central Canada slash water bars and straw bales were used most frequently. Diversion structures with lead-off ditches were also among the most frequently

Road Status	Option EWB	BBD	SWB	LWB	SB	OTC	RC	RO	RI	DLD	DRD	FILL
MOST USED ON:												
Active							E,D				A,B, C,F, O	A,D
Closed	A,B, C,D, O		E		E					F		
Both	C						E			B,C, F,O	A,D, E	
MOST EFFECTIVE ON:												
Active		C					E			B,D, O	C,F	A
Closed	A,C, D,E, O	E	E		E						B,F	B
Both	C	B						B	B	A,B, F,O	B,D, E	B

Table 2.7: Summary of the most frequently used options and most effective options where roads/trails are below grade. In addition to the region codes, O is used to indicate overall highest percentage of responses. "Other" is not included since it did not receive the greatest number of citations in any region. See the list preceding Q11 for interpretation of the option acronyms. (N = 117)

used options in Western Canada. The latter were the overall most-cited option for use on both active and closed roads, and the most frequently used in the US West Coast and Southern States and Western Canada. In the Mountain and Eastern States and East/Central Canada diversion structures are most frequently used in combination with roadside ditching for both active and closed roads.

The options rated the most effective on active roads were diversion structures with lead-off ditches (West Coast and Eastern States and overall), and with roadside ditching (Southern US and Western Canada). These are the options labeled DLD and DRD in Table 2.7. Also rated most effective were the placement of fill (Mountain States), crowning (East/Central Canada) and broad based dips (Southern US). For closed roads, earth berms water bars were rated the most effective in the US Mountain, Southern and Eastern States and East/Central Canada and overall. Earth berm and slash water bars, broad-based dips and straw bales were rated equally effective in East/Central Canada, and diversion structures combined with roadside ditches and fill placement were rated equally effective on the US West Coast and in Western Canada. The options generally rated most effective for both active and closed roads were diversion structures with lead-off ditching (US Mountain States, West Coast, Western Canada and overall) and roadside ditching (West Coast, Eastern US and East/Central Canada).

Descriptions and commentary, where provided, for "Other" options used during these below-grade situations are summarized below by region.

Mountain States

1. Try to avoid draws where water won't drain.
2. Obliterate and recontour (closed roads).
3. Earth berm and broad based dips with ditches.
4. Log water bars, straw bales and crowning with diversion ditches.
5. We only have to deal with this on legacy [older] roads.

West Coast

1. Surface with aggregate or pavement, with curb and lead-off ditch.
2. Slash mulch in conjunction with crowning and lead-off ditches.

Southern US

1. Avoid these spots: relocate road.
2. Surface with #2 stone.

Eastern US

1. Culverts.
2. Use rip rap to divert water to a culvert.
3. Lead-off ditches alone.
4. Seeding.

East/Central Canada

1. Culverts.
2. Crown road with granular material.

Western Canada

1. Replace fill and recontour.
2. Install ditchline drain at best location.
3. Install diversions to limit flow velocity in ditches.
4. Crossditch upslope and downslope of sensitive area.

Q12. Which diversion options are used on frozen or thin soils or over rock?

The preferences of respondents regarding options to use when the road is located on thin or frozen soils or over bedrock are detailed in Table 2.8.

For active roads, crowning was among the most frequently cited methods overall and in all regions except the US Mountain and Southern States. Respondents in the Southern States indicated the most frequent use of broad-based dips, while outsloping was used most in the US Mountain States. Western Canadian respondents also ranked "Other" (see below for descriptions) among the most used methods for active roads. Earth berm and slash water bars were most frequently used on closed roads overall, and in all regions except the Eastern US. In the Eastern US, straw bales were cited with equal frequency. Outsloping was the method most used for both

Road Status	Option									
	EWB	BBD	SWB	LWB	SB	OTC	RC	RO	RI	Other
MOST USED ON:										
Active		B,C					B,D, E,O	A		F
Closed	A,B, C,F, O		A,D, E,F		D					
Both	C	C	C				C,E	A,B, C,D, F,O		
MOST EFFECTIVE ON:										
Active		C					B,D, E,O	A,F		F
Closed	B,C, E,F, O		A,D, E		E	F				F
Both		A,B, E					D,E, F,O	A,B, C,O	F	

Table 2.8: Summary of responses for roads/trails over thin or frozen soils or rock. Region codes are given for all options receiving the highest number of responses (there may be several options with an equal number of positive responses in any given region). In addition to the standard region codes, "O" stands for the overall highest number of responses. (N = 102)

active and closed roads overall and in all regions except the Southern US and East/Central Canada, where crowning is used with equal or greater frequency. Earth berm and slash water bars and broad-based dips were also cited with equal frequency in the Southern US.

Among the options rated most effective for closed roads were slash water bars (US Mountain and Eastern States and East/Central Canada) and earth berm water bars (US West Coast and Southern States, both Canadian regions and overall). The Canadian regions also rated straw bales, open-top culverts and "Other" as the most effective methods for closed roads. On active roads, crowning (US West Coast and Eastern states, East/Central Canada and overall), outsloping (US Mountain States and Western Canada), broad-based dips (Southern US) and "Other" (Western Canada) were rated the most effective. Broad-based dips (US West Coast and Mountain States and East/Central Canada), outsloping (US Mountain, West Coast and Southern States and overall), crowning (Eastern US, both Canadian regions and overall), and insloping (Western Canada) were rated the most effective for both active and closed roads.

Descriptions provided where "Other" options were indicated are summarized below.

Mountain States

1. Seeding (closed roads).
2. Obliterate and recontour (closed roads).
3. Scatter slash throughout (with or without water bars).

West Coast

1. Rip out culverts, rip & recontour (closed roads).
2. Slash mulch.
3. Fabric fences.

Eastern US

1. Culverts.
2. Tree tops with top of tree pointing uphill.
3. Snow roads (construct roads only in winter).
4. Gravel surfacing.
5. Slash mulch.

East/Central Canada Region E

1. Little planning used to date in these situations.

Western Canada

1. Use frequent culverts with insloping, or crowning with ditches.
2. Culverts.
3. Cross ditches.

3. Regional summaries of written responses: Effectiveness

Questions 7 and 8 asked: "For each of the individual water diversion options listed below describe the operating and site conditions on active and closed [haul roads/skid roads and trails] when the option is most effective. Consider factors such as maximum degree of slope, soil type, season of activity or installation, equipment available during installation, equipment used during timber harvest, and amount of water to be diverted." Each option listed provided separate spaces for comments applicable to closed or active roads. The written responses to these questions were compiled by region and distilled into the summaries presented below. Closed- and active-road responses were summarized separately. However, in cases where these categories overlapped (comments equally applicable to both conditions), the responses are presented in the general summary at the beginning of each section. Similar comments were combined to avoid redundancy, but essentially all unique perspectives have been included. Comments perceived as tangential or irrelevant to the purpose of the question were excluded. Comments referring strictly to water crossing devices were also excluded.

Region Codes

USM. Mountain States: AZ CO ID KS MT NB ND NM NV SD UT WY.
USW. West Coast: AK CA OR WA.
USS. Southern US: AL AR FL GA KY LA MS NC OK SC TN TX VA.
USE. Eastern US: CT DE IA IL IN MA MD ME MI MN MO NH NJ NY OH PA RI VT WI WV.
CEC. East/Central Canada: LB MB NB NF NS ON PEI QC SK.
CW. Western Canada: AL BC.

Q7. Options used on Haul Roads

Earth Berm Water Bars

Earth berms are relatively inexpensive options used mostly on closed roads or as a deactivation measure during temporary closure of active roads. Their use on active roads is generally restricted to steeper or sustained grades with high erosion potential. They are effective on moderate to steep slopes. Larger berms may be used on closed than on active roads, where vehicle damage is a consideration. As closure devices, they are fairly effective at deterring vehicle traffic. Berms subjected to traffic during wet weather will rut and degrade rapidly. *Author's note: The need to ensure open outlets for all water bars may require connection to lead-off ditches that allow runoff to be discharged on to stable areas of the forest floor. These will require regular maintenance; berms can wear down even under dry conditions.* Most soil types are suitable, though they should be compactable (not sand) and relatively stable. Installation may occur during dry conditions any time during the frost-free season, when significant (but not excessive) runoff is anticipated. Most respondents prefer a dozer or excavator for installation but a skidder blade may also be used. Experienced operators are critical. Correct (angle, depth, spacing) installation is important.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	19	9	5	11	3	8	56

- Respondents in Western Canada warned that the berms could be washed out by excessive rainfall and recommended this option for less extreme slope conditions.
- In the Southern US, respondents tend to consider earth berms a temporary measure for use during low traffic periods or temporary closure. Earth berms are also little used on active roads in Eastern Canada, except for installation in ditches as water barriers.
- Some Eastern US respondents suggested that earth berms should be used in conjunction with other measures such as drainage or lead-off ditches to prevent ponding on the road, which will reduce the longevity of the water bar.
- Installation/use during wet weather was more of a concern in the Mountain and West Coast States than in other regions.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	29	16	9	23	2	11	90

- In the West Coast states, earth berm water bars are used mostly on steeper grades (over 15%), where ditches may also be armored with rock. Soil erosivity criteria differ among regions; in the Mountain States respondents were more likely to specify soils of lower erosivity, while in the Southern Region respondents tended to recommend this option for more highly erosive soils.
- Relative runoff criteria differed among regions: while some respondents from the Mountain States did not recommend this option under very wet conditions, respondents in the Eastern and Southern US considered it adequate to handle large amounts of runoff. In Central Canada the berms may be used in a V formation on roads at the bottom of slopes near stream crossings (to divert water off to both sides of the road – V pointing uphill).
- Some Eastern US respondents suggested that earth berms may need to be used in conjunction with other measures such as straw bales to slow or pond runoff.

Broad-based Dips

These devices are somewhat more costly than earth berms due to the requirement that they be engineered into the road. However, they are preferred over earth berms for moderate to heavy traffic due to their greater resistance to breaching and easier navigability, although some types of trucks may have problems (especially if hauling tree-length material). Dips are generally not a preferred option for closed roads, although they may be maintained if already present, if the road is not to be obliterated. Their continued effectiveness under heavy traffic will depend on regular maintenance. These devices will handle low to moderate amounts of runoff or local drainage on more subdued topography than where earth berms might be used.

Installation should take place during fairly dry, unfrozen conditions. Equipment with adjustable blades is preferred over skidders for construction. Lack of operator training may limit the use of these devices, as proper installation angle, depth, spacing and drainage allowances are critical to effective operation. It is generally recommended that road outsloping or insloping be used in conjunction with dips.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	28	15	11	18	4	7	40

- Mountain States respondents recommend installation of dips at the top and bottom of steeper grades. A narrower (shorter) version of the broad-based dip is called a “rolling dip” in South Dakota.
- Eastern Canadian and US West Coast (particularly Alaska) respondents noted that it was preferable to exploit natural topographic dips to fulfill the function of broad-based dips, while augmenting with culverts or rock-reinforcement along the flowlines.
- Broad-based dips are rarely used on active roads in Central Canada.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	26	13	7	14	2	6	68

- Broad-based dips were not used at all by Eastern Canadian respondents and were little used in the Eastern US on closed roads.
- On the West Coast and in Western Canada, respondents suggest that broad-based dips work best when they mimic or exploit natural topographic dips. They may also be installed where culverts have been removed.
- Respondents in the Mountain States and Western Canada noted that it may be necessary to use this option in conjunction with other measures such as straw bales, or outsloping.
- Some Southern US respondents noted that the dips could be deeper on roads that would not be maintained, while Eastern US respondents suggest long-term stabilization with gravel or seeding. Some Western Canadian respondents recommended armoring the dip outslopes with rock.

Slash Water Bars

Slash water bars are a useful method for controlling access that may be visually more acceptable than ditches or water bars. They are rarely used on active roads, and then only when traffic is very light and restricted to logging equipment. Exceptions include short stretches of moderate to steep slopes, or winter operations when the soils are frozen, or other options are impractical. Most commonly they are used on gentle to moderate slopes with lower erosion potential, where adequate slash is conveniently available (e.g. delimber on site), and surfaces are hard or rocky. Spread (rather than piled) and crushed slash is widely used to protect soil surfaces and aid revegetation. It is also used during or following winter operations in areas where the soil freezes and other options can't be used. Slash water bars are frequently used in conjunction with other types of water bars such as earth berms, to provide additional protection.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	3	1	5	7	4	4	24

- In the Mountain States and Eastern Canada, slash water bars may more commonly be used as off-road filter strips in lead-off or roadside ditches.

- Southern US respondents note that slash use is only feasible if there is on-site delimbing.

- Central and Western Canadian respondents suggest the use of spread slash on fresh, unconsolidated road construction to filter spring runoff, before other options (such as culverts) can be installed. Slash water bars may also serve as a mitigation on the approaches to water crossings. They were generally not recommended for wet, steep coastal conditions.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	12	3	5	13	2	5	40

- Availability of slash is considered especially limiting in the Mountain States and Southern US, where this option is used only on pine sites.

- Failure due to excessive runoff volume or velocity is more of a concern for West Coast respondents.

- Slash water bars are not used in Eastern Canada. Some Western Canadian respondents suggested that slash or log water bars could be used if rock was not available to reinforce earth berms.

Log Water Bars

Log water bars are occasionally used on gentle to moderate slopes. If the road is active there should be only very light or slow-moving traffic, as the water bars may be damaged by regular use. They form more durable diversions than slash water bars, and are suitable for persistent wet conditions (such as springs) or frozen soils. The soils need to be firm and stable.

Installation requires heavy equipment (such as a backhoe, dozer or skidder). Log water bars may be used with slash or earth berms or near water crossings.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	4	1	2	4	4	3	18

- In Eastern States, some may be used in conjunction with earth berms and in lighter to loamy soils.
- In Canada, log water bars may be used as a water crossing mitigation, or on gentle slopes in finer textured soils. Another suggested use is on fresh, unsettled road construction or winter construction prior to the initiation of regular traffic.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	3	2	3	12	3	2	25

- They are most likely to be used on steeper slopes and over rock in the Eastern US.
- They are rarely used in Eastern/Central Canada, except possibly on the approaches to water crossings, and almost never in Western Canada, except in some low gradient, low rainfall areas.

Straw Bales

These are considered temporary measures due to the impermanence of straw, which will rot or be eaten by livestock. On most roads the bales are used in ditches and at drainage outlets on moderate to steep grades, to filter moderate runoff headed for a stream or water body. An advantage is that straw bales can be used to fix unanticipated problems (e.g., due to the sudden onset of heavy runoff causing sheetwash), and they do not require special equipment to install. They are useful where other options are impractical due to inaccessibility (to heavy equipment) or frozen conditions. Straw/hay may also be used as a mulch during revegetation. Additional measures are needed to handle large volumes of runoff.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	9	7	5	8	5	4	38

- They may be used in place of slash filter strips in the Mountain States.
- West Coast respondents use straw bales on particularly unstable surfaces such as fire roads, but weeds and damage by animal browsing are big problems.
- They are considered impractical for use on most active roads in the Eastern US due to their temporary character.
- In Canada they are used mainly for runoff filtration in roadside ditches in conjunction with crowning or insloping, but are considered to be costly and ineffective in areas of high precipitation.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	6	8	5	14	5	6	44

- Weed contamination is more of a concern in West Coast states.
- In the Eastern US, they are most often used on frozen soils, with seeding, or as an adjunct to other diversion measures. Labor availability for hand installation is an issue.

Open-top Culverts

These devices were used more in the past than currently on roads in most areas. Application is limited due to the expense of installation and maintenance concerns (sediment clogging, difficulty grading). They may be used in gentle to moderately sloping but wet terrain (drainages, wetlands, approaches to stream crossings) with permanent flow, on roads open for summer use, or where other options are infeasible.

Normally a backhoe is required for installation; soils should be deep, easily worked and stable. Some respondents thought that the culvert should be lined with rock along the flowline with a sediment trap below the outlet.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	10	6	4	7	4	3	34

- On the West Coast, they are used only in very wet areas, on off-season temporary draw crossings, or as a last resort to avoid drainage structure failure.

- In the Eastern US they are considered more effective than earth berm water bars for light to moderate runoff flows and occasionally in steep terrain or where a low road profile prevents regular culvert installation.
- In Canada, open-top culverts are used only at water crossings, or on gentle slopes.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	2	2	1	3	1	5	14

- Open-top culverts are considered a water-crossing device and generally not used on closed roads in Canada.

Road Crowning

This is the most common method for permanent roads that will be heavily used and regularly maintained, on gentle to moderate grades, with ditches and culverts as appropriate. Crowning may complicate the construction of water bars or dips. Crowning is generally employed on main system roads that may remain in use after sale closure. Restoration of a previously-installed road crown during closure can help maintain surface integrity during revegetation. Crowning should only be used on roads where there is no downslope risk for terrain failure due to runoff (a particular concern in mountainous areas).

According to some respondents, roads must be at least 12 ft wide to allow crowning, and are generally surfaced with gravel or rock. Dozers and/or graders are needed to construct and maintain the road crown. Regular grading will be needed during use, especially in the summer. Grader operators need to avoid the creation of outside berms that may channel water on the road. The crown should be restored just prior to road closure.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	22	13	8	25	12	10	90

- West Coast respondents note that this is not the best option for side slopes.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	13	8	8	17	5	6	57

- Eastern US and Canadian (Eastern and Western) respondents recommend the use of this method where roadbeds are built up above existing grade, and where lead-off ditches are constructed at appropriate locations. Gravel availability affects the quality of construction and maintenance.

Road Outsloping

Outsloping is a popular and low-cost method for preventing the concentration of runoff on temporary or permanent roads that are too narrow to crown. Its effectiveness is limited to slower traffic under relatively dry conditions due to maintenance and safety concerns (may become hazardous when slippery). It is effective on all but the steepest grades in stable substrates, and may be used on side slopes where the downslope area can safely absorb diffuse drainage, or where ditches are not feasible. Generally, outsloping is used in conjunction with broad-based dips and water bars. While outsloping is rarely constructed on closed roads that were not previously outsloped, the outslope may be restored prior to closure to prevent the channeling of water pending revegetation.

Outsloping may be accomplished during dry conditions by a skilled operator with an excavator, dozer or grader. It is important to avoid leaving ruts or outside berms that will channel water and cause gullying.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	26	13	8	22	8	10	87

- In the Mountain States, outsloping is used more in coarse to rocky soils or with gravel surfacing.
- West Coast respondents recommend no more than 5% outsloping and ensuring that no outside berms are formed during grading.
- In the Southern US, respondents noted that this method was unlikely to be implemented on smaller sales.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	22	11	6	13	2	10	64

- During outsloping of roads in the Mountain States, the surface may be cut narrower to limit access and to help drainage, although cross-ditching is considered a more effective long-term option for preventing vehicular traffic. Road bank sloughing may be a problem.
- Although this is the preferred method for roads on the West Coast, a new installation on a closed road is unlikely.
- Outsloping is rarely used in Eastern/Central Canada.

Road Insloping

Insloping is a design feature of narrower permanent roads. It is especially useful on steeper slopes and in special situations like on switchbacks, before culverts, where safety is a concern, or where drainage needs to be redirected away from vulnerable downslope areas. Its use is largely limited to active roads due to its relatively high cost and the need for supplemental diversion structures, as well as the higher risk of failure if it is not maintained. However, it may be left in place or maintained if justified by conditions, or if the road is to be left open or only temporarily closed.

Installation generally requires a grader, dozer or excavator. Insloped sections should incorporate inside ditching, with culverts and/or broad-based dips at appropriate locations to allow water to drain downslope away from the road. Water bars should also be installed where no further access is desirable.

Regional Notes

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	24	13	6	20	7	10	81

- In the Mountain States, insloping is considered effective on low to moderate slopes, where it may substitute for ditching in dry conditions. Soils may be deep fills or rocky substrate, but should not be erosive or poorly drained.
- In the West Coast states, insloping can have advantages under wet conditions and in high rainfall areas, where soils are stable and finer-textured and may have slow drainage.
- In the Southern US, the higher cost of insloping may limit its use to larger timber sales.
- Western Canadian respondents suggested that natural drainages should be mimicked or exploited wherever possible when designing insloped roads.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	11	10	3	8	1	9	42

- In the Mountain and West Coast States, insloping is considered more effective on lower grades for the local diversion of water away from sensitive areas. It is always used in conjunction with other measures such as ditches, water bars and broad-based dips, possibly with seeding to stabilize exposed surfaces.
- In the Eastern US, insloping is rarely used except when other methods are infeasible due to previous damage, topographic or safety concerns, or if road is to be left open.
- Insloping is not used in Eastern/Central Canada. It is considered effective in Western Canada where there are unstable fill slopes.

Other Methods

Respondents referred to or described numerous water diversion methods not listed in the survey. They are summarized below by region, along with accompanying commentary. Where noted, we have included relevant illustrations and definitions in Appendix B. While respondent comments and descriptions have been paraphrased to the best of our ability, in many cases few details were provided. Therefore some minor misinterpretations may have occurred.

ACTIVE ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	8	4	3	10	7	3	35

Conventional cross-drain culverts were cited for use under a wide variety of conditions in the Eastern US and Canada. It was suggested that outflows be stabilized with rocks, sandbags, geotextile or peatmoss.

Gravel, rock or aggregate surfacing is widely considered an important primary road stabilization method in the Mountain States, West Coast, Southern US. It prevents rutting and water infiltration into the road sub-grade. It was not explicitly emphasized in other regions.

Conveyor belt water bars are also widely used in the Eastern US, the Mountain States and West Coast; rubber conveyor belts are buried using a backhoe or excavator, at a slight angle to the road. These are effective on a wide range of slopes and soil types, and have the advantage that equipment can easily drive over them. Attaching lumber to the base of the belt prior to burial can help keep it in place. It is important to tightly pack soil around both the uphill and downhill side of the belt after it is installed.

Some techniques that were unique to one or two regions are noted below.

Mountain States

- Rolling dips, design features which are not as obtrusive as regular water bars and easier to maintain; can be installed with a dozer but require an experienced operator.
- Spreader ditches (lead-off ditches) are used to disperse flow and allow sediment to settle out when ditches or insloped roads accumulate excessive amounts of water.
- Outslope drains to remove water into areas that can absorb runoff.

West Coast

- Suspend operations until soils dry to operable levels.
- Pave the road, where historical roads are too close to creeks/streams. Use this on permanent specified roads only.

Southern US

- Concrete plank lined (broad-based) dips hold up in wet areas where most dips collapse, but are expensive to install.
- Geotextile fabric fences are good for diverting water off cut slopes and trapping sediment.

Eastern US

- Crown and ditch roads with a high amount of haul traffic, in areas of steep hills and/or slippery soils.
- Avoid the need for use of diversion options through proper layout, avoidance of wetland areas, and/or seasonal restrictions on use.
- Seeding road shoulders and mulching or piling slash offers effective long-term stabilization of the road.
- Lead-off ditches (water turnouts or diversion ditches), with spacing similar to water bars. Divert water off the road in small quantities. These ditches are less expensive than culverts and can be constructed with a grader blade.
- Using a backhoe to remove stumps and pile material from the ditch on to the driving surface works well in clay soil to keep the road above surrounding ground level.

Eastern/Central Canada

- Lead-off ditches, which should be installed during initial road construction.
- Use road crowning in combination with ditches. Also place bales of hay and rock/earth berms to divert water into stable areas when slopes exceed 15%, on all soil types.
- Diversion berms set in right-of-way off sides of road to redirect water to the side. They are also used on steeper slopes near water crossings.

Western Canada

- Geotextiles, hydro seeding and side-slope revegetation.

CLOSED ROADS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	4	1	3	6	1	6	21

There were few common features among alternative options described. Techniques are therefore summarized by region below.

Mountain States

- Obliteration and recontouring to accelerate revegetation is effective but costly. Slopes over 15% require the use of an excavator with a thumb, but under 15% grades can be done with a dozer.
- "Flappers" (conveyor belt water bars) are effective on all slopes and most soil types.
- Outslope drains are effective for redirecting water into areas that can absorb or filter runoff.

West Coast

- Conveyor belt water bars work in most situations but are rarely used on closed roads due to need for maintenance.

Southern US

- Concrete plank lined (broad-based) dips can hold up in wet areas where most dips collapse but are expensive and should be used in conjunction with water bars.
- Geotextile fabric fences are effective for trapping sediment and diverting water off of cut slopes and may work better than water bars near streams (but cost more).
- Aggregate surfacing is the best option for crowned, outsloped or insloped roads roads that will remain in use.

Eastern US

- Steel cross-drain culverts may be left in place on steep slopes on main haul roads.
- Straw, bark or leaf mulches are always effective, if the road surface was not stabilized.
- Seed all exposed soil to accelerate revegetation. It is most effective with mulching.

Western Canada

- Cross-ditches may be used in any natural draw (ephemeral, intermittent or permanent stream). They should be rock-reinforced in fine soils or if high flows are expected. They are also good for deterring access.
- Pull-back of fill (recontouring) where the fills are excavated and placed in the cut area.
- French drains (gravel/shot rock filled ditch) where the pull-back and recontouring of road materials is completed. The drain allows for subsurface collection of water for downslope discharge at reduced velocity.

Q8. Skid roads and trails.

Earth Berm Water Bars

Although most respondents report little use of this option on active skid trails, there is more use on active trails in steeper areas (e.g., on skyline rights-of-way or very steep skid roads with up to 50% slope), such as in the Western States. Small earth berms may be installed during active use on light-use, lower grade roads when conditions are not excessively wet. In most cases use on active trails seems to be confined to temporary installations during short suspensions of skidding activity, such as those resulting from very wet conditions or anticipated heavy runoff, but where there is significant erosion risk due to exposed soils or water draining onto a road.

Earth berm waterbars are among the most widely used closure devices on deactivated skid roads of up to 30% slope and most soil types. They are not effective in draws or where there is little relief. Risk of rutting (of the berm) during active operations is a consideration. Berms are often used in conjunction with rehabilitation measures such as seeding and mulching as part of final or temporary trail closure procedures. Earth berms may also be installed where complete obliteration and recontouring is not possible.

While earth berms water bars may be built by hand under extremely steep conditions (e.g., skyline rights-of-way or trails unsafe for equipment operation), they may be built with any heavy equipment with an adjustable blade, or occasionally with skidders. Correct height, spacing and angle are essential and should be determined by the road grade, traffic and amount of water flow expected. Earth berms should be constructed while conditions are dry and settled, in anticipation of heavy runoff or frozen conditions. Maintenance is essential to keep earth berm water bars functional. Traffic and excessive sediment deposition can result in breaching of the berms.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	12	9	4	9	1	5	43

- Western States and Southern US respondents view earth berm water bars as measures installed largely during suspensions of logging operations, not during active skidding.
- West Coast respondents note that recreational or logging traffic may detour around the water bars and widen the trail. In West Coast forests, hand-dug bars may be installed on skyline corridors after closure.
- Mountain States respondents point out that there must be sufficient soil depth to excavate a ditch and build the berm, therefore they will not work well in thin, rocky soils or where the road is cut lower than the surrounding terrain. They also suggest the addition of spreader (lead-off) ditches to diffuse the drainage outflow.
- Eastern Region respondents also recommend the installation of lead-off ditches where large amounts of runoff are expected. They note that a problem with water bars on active skid trails is that on steeper grades the required size (of the berms) would inhibit equipment operation.
- In Eastern/Central Canada water diversions are rarely used on active skid roads.
- In Western Canada (BC) water bars are required by the Forest Practices Code during wet weather.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	23	13	10	18	1	5	70

- Mountain States respondents observe that earth berm water bars are unnecessary where there is adequate residual duff or slash to protect the soil surface. Since they involve significant, permanent displacement of soil, they should only be used as closure devices if road obliteration is not possible. They are most effective in the elimination of public travel in conjunction with slash mulching.

- West Coast respondents note that the water bars work best if OHVs (Off-Highway Vehicles) can be kept off the road.
- Eastern US respondents recommend that they be installed immediately on road retirement in any moderate to steep terrain where erosion might be a problem (but not on slopes exceeding 30%). Areas near the tops of hills may be the most critical. The berms need to be compacted prior to use, and should be stabilized with mulching and an appropriate seed mixture.
- In Western Canada (BC), water bars are required by the Forest Practices Act on all deactivated skid roads in all terrain types, generally in conjunction with road rehabilitation. Water bars on closed roads may be larger than those on active roads.

Broad-Based Dips

Broad-based dips see limited application on active skid trails. Restoring the dip prior to trail closure may help stabilize it during revegetation. They are effective in most stable, well-drained soil types on grades up to 30%, where at least moderate traffic is expected (more permanent roads or trails), and regular maintenance is possible. In some areas the dips may be reshaped just prior to closure or maintained on an ongoing basis where continued access is desirable. Although they may be used to divert water away from stream crossings, they are not intended to handle heavy runoff or for steeper slopes. Dips may be most effective as methods to take advantage of natural breaks in the terrain, through trail location, not necessarily as constructed features. They may be used in conjunction with insloping, or on some temporary roads in conjunction with water bars. Dips can be constructed using most types of heavy equipment with adjustable blades.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	7	10	5	11	1	3	37

- In Mountain States they may be used where there is a need to improve an existing trail system.
- West Coast respondents report use on some temporary roads in conjunction with water bars. Road users have less tendency to detour around broad-based dips than around water bars.
- They are rarely used on skid trails in the Eastern and Southern US, apparently due to the cost of installation or the likelihood of skidding damage.
- In permanent installations in the Eastern US, the contractor will place gravel or seed to stabilize the dip.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	6	9	3	8	0	1	27

- On the West Coast dips are used where earth berm water bars are potentially difficult to maintain (e.g., cattle crossings). Road users have less tendency to detour around dips than around water bars.
- In the Mountain States they may be occasionally incorporated into the design through trail location, but not as constructed features. They may be maintained if already present, if road obliteration is not prescribed.
- Southern US respondents prefer earth berm water bars to broad-based dips on closed skid roads, except on some gentle slopes.

Slash Water Bars

Slash water bars are little used on active roads/trails due to the access limitations they create, the likelihood of displacement, and the consequent necessity for frequent maintenance. They are widely used on closed trails. Slash water bars can effectively filter or slow runoff on grades to 30%, or on shorter steep slopes. They are particularly useful on very rocky, shallow or frozen soils that make the installation of other diversions impractical. However, they are generally regarded as a temporary measure due to their rapid decomposition, and incompatibility with heavy skidding traffic.

An advantage of using slash is that no additional soil movement is required, and the water bars may be constructed with a skidder. However, proper function depends on good compaction of the slash to maximize contact with the soil.

The use of slash as a mat or mulch was cited frequently as a variant on water bars. It may be accomplished conveniently by depositing felled tops and smaller branches in the trail and running over them with the skidder to flatten the branches. Slash mats or mulches are most effective for slowing/filtering diffuse runoff or protecting soil surfaces in wet locations, on slopes up to 15%. Slash mulches can be a valuable adjunct to revegetation measures. The availability of slash is a limiting factor in some areas for both water bars and slash mats.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	6	4	3	12	6	1	32

- Incidental slash is dragged onto trails (as well as made into bars) in the Mountain States, especially during or after winter operations when the ground is frozen. They may be replaced with constructed earth berm water bars when the ground thaws.

- West Coast respondents noted that it was difficult to get sufficient compaction to withstand heavy runoff.
- Both West Coast and Eastern US respondents preferred to use slash mulches rather than slash water bars during active skidding.
- Slash water bars may be used on trails in the Eastern US where outsloping is not practical.
- Although East/Central Canadian respondents report their use mainly on steeper slopes, they are less used in steep areas in the Eastern US due to the likelihood of displacement.
- In East/Central Canada, limbs and tops from harvesting operations are maintained in rows for forwarders to travel over, providing a relatively continuous slash water bar. *Author's note: This practice is, in fact, widespread wherever forwarders are used.*
- In Western Canada slash water bars are used most frequently on fresh road construction, or new winter construction. During spring runoff, wheeled skidders leave slash on the main skid trails to mitigate development of ruts on steep slopes. Slash water bars are also used as a mitigation for water crossings.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	15	9	4	16	3	2	49

- On the West Coast slash water bars may be used for low surface flows on slopes up to 60% on trails under 8 ft wide, where OHV use is a problem, while in Western Canada their use is confined to low gradient, low rainfall areas. West Coast operators also spread slash in skyline corridors.
- West Coast respondents suggest the use of slash as an energy dissipater at the discharge points of waterbars, dips, and small culverts.
- In the Mountain States, they are generally considered temporary measures for use in conjunction with road obliteration, to obtain temporary stabilization while avoiding the additional soil disturbance that would be needed to dig water bars.
- Slash mats are particularly popular in the Eastern Region for use on frozen soils in locations with no summer access. Tops are felled into the trail and run over by the skidder as the harvest closes. Tops mixed with small branches work best. Slash water bars are most effective if the operator can berm up soils downslope of the slash, but installation is often not done correctly.

Log Water Bars

Log water bars are used only on low-traffic or closed skid trails, generally under severe conditions such as steep slopes or persistent wet conditions. They may also be used where a skid road terminates on a slope, or to protect fresh road construction from spring runoff. Log water bars can take a range of forms. Logs may be used to reinforce earth berm water bars, to handle heavy runoff. Alternatively, they may be simple log barriers on rocky or frozen ground.

are frequently used as adjuncts to road rehabilitation measures and other types of water diversion options. with slash or straw bales. They are most effective if installed with a backhoe or front-end loader, but can also be installed with logging equipment. Frequent maintenance will be necessary if the water bars are exposed to vehicle traffic.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	2	3	1	4	6	3	19

- Log water bars are rarely used on active skid trails in the Southern US, and generally are not considered compatible with heavy use, as they will need frequent maintenance. They are used to deter recreational (OHV) traffic in West Coast states, but vehicles may detour around the water bars.

- Respondents had varying opinions about maximum grades suitable for log water bar installation. In East/Central Canada, the Eastern US and the West Coast states, log water bars were considered best for slopes under 30%, while respondents from the Mountain States, and some from the Eastern US, considered log water bars an appropriate option on steep slopes. Hand installation was recommended for slopes steeper than 50% (such as skyline corridors). Other candidate sites for log water bar installation included fresh road construction, the ends of skid trails (East/Central Canada), or wet spots where positive drainage is required (Eastern US and Mountain States).

- Eastern US and West Coast respondents highlighted the need for proper construction, including anchoring the logs into the sideslope and compacting soil against the logs.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	8	7	3	15	3	1	37

- In the Mountain States, log water bars are mostly used on steeper slopes prone to erosion due to soil exposure, such as on bulldozed firelines, while Eastern US respondents also use them in areas of heavy soils.

- East/Central Canadians suggested their use on main skid trails where erosive soils have been exposed, or where a skid trail terminus is on a slope. While they generally work best where enough soil is present to anchor or berm up against the logs, Eastern US respondents also reported use over ledge-rock. They may also be used on trails that will continue in use for recreational purposes.

- In the steep West Coast forests, log water bars are used in conjunction with skyline operations, where they are hand-installed on steep skyline corridors. Occasionally logs are used to reinforce earth berms (West Coast and Southern US) and during trail rehabilitation. On gentler slopes, log water bars may be used to deter OHV traffic.

- Log water bars are rarely applied in isolation, and are more likely to be used in combination with slash water bars, straw bales (Eastern US), earth berm water bars, or road rehabilitation through seeding (Mountain States).

- Southern US and Mountain States respondents opined that log water bars were more costly compared to other options.

- Eastern US respondents did not find cost to be an important negative factor, but rather observed that the easy availability of reject logs on timber sales, or alternatively of timbers or railroad ties, made this type of water bar more feasible than some other options. In addition, since logs can be placed with standard logging machinery, no special equipment is required for installation. However, they noted that log water bars are often improperly installed, and are consequently subject to breaching due to excessive sediment deposition.

Straw Bales

Straw bales are mostly used to filter sediment from water draining off the roadway (through water bars and ditches) in the vicinity of active streams or other open water. On closed roads straw bales may also be placed on the road surface as temporary water diversions pending revegetation, especially in steep terrain with unstable soils and fairly low runoff flows. Many respondents noted that straw could also be spread as a mulch to aid seed germination and establishment during revegetation.

They are effective on moderate to steep grades, especially if the trails have developed gullies. Getting the bales properly anchored is critical. The use of straw bales is limited, according to some respondents, by their expense and the time required to properly install them. In addition, straw bales are considered short-term solutions, which can rot or be destroyed by browsing cattle or wildlife. Therefore they are usually used as adjuncts to other types of water diversions.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	3	3	3	3	2	1	15

- In the Southern US straw bales may be used to line the edges of cut slopes or to filter water from the discharge outlets of water bars. Some respondents preferred to use straw bales to slow runoff in conjunction with slash spread over the skid trail.

- Some Eastern US respondents considered that the cost of purchase, transportation and installation precluded the use of straw bales on skid trails.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	6	7	5	5	3	2	28

- West Coast installations may occur on steep skid trails that have been ripped or where other rehabilitation measures have been taken. These areas should not be exposed to traffic until the soil surface has stabilized.
- Southern US respondents also used straw bales to filter discharge at the open ends of water bars, and in situations where site characteristics did not permit the construction of earth berm water bars. Straw is also spread as a mulch on exposed soils.
- In the Eastern US, straw bales were considered adequate for large amounts of runoff, and are used to close trails in steep terrain. However, their use is limited by their cost and the time requirements for installation.
- An East/Central Canadian respondent observed that straw bales were particularly good for fixing unanticipated problems, since they can be installed quickly and conveniently after the fact.

Open-Top Culverts

In most areas, open-top culverts were used more in the past than today, due to the limitations they place on road grading. Generally they are more effective if the logging equipment is relatively light. Open-top culverts are rarely left in place on closed trails due to the likelihood that they will clog with sediment and debris. Cost and the necessity for constant maintenance are factors inhibiting their use.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	1	0	0	4	1	1	7

- Eastern US respondents were most familiar with the use of this option; some of them rated it useful for severe slopes and erodible soils. Open-top culverts don't limit vehicle movement as much as some diversion options. However, high maintenance (usually cleaning) requirements and the cost of construction were cited as reasons for discontinuing their use.
- An East/Central Canadian respondent suggested that corduroying short sections of drainages with logs could be as effective as installing a culvert.
- Occasional use was reported in Western Canada in areas where there was a risk of water flowing towards a sensitive structure such as a bridge or railroad grade.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	1	0	0	3	0	1	5

- Comments were generally to the effect that open-top culverts were not used on closed trails due to the disadvantages cited above.

Road Crowning

Crowning is most effective on heavily used or multi-use skid trails, with stable soils and minimal grades (under 10%), where no downslope risks exist for terrain failure due to runoff. Road crowns are rarely maintained on closed trails, but sometimes the crown is restored during road closure to prevent water channeling pending revegetation. Construction and maintenance may be done with a dozer, grader, forwarder or skidder. The addition of cross drainage and ditches may be necessary.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	2	3	2	7	0	1	15

- Mountain States respondents emphasized that ditches needed to be kept clear, while West Coast and Western Canadian respondents noted that there should be no erosive side slopes downslope of the road.

- In the Eastern US there was a preference for using crowning only in conjunction with gravel surfacing, which makes this and expensive and therefore rarely used option for trails. Construction and maintenance during active sales may be done by the municipality or by the logging contractor.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	1	2	1	6	0	1	11

- Eastern US respondents recommend that only the main trail be crowned, using bulldozers. Crowning is used where reforestation of trails is important, and where other methods are impractical.

- In the Southern US crowning may be practiced in conjunction with water bar installation and seeding.

Road Outsloping

Outsloping is frequently used on skid trails with low to moderate grades and side-hill cuts with non-erosive soils. In addition, it is the most widely applied technique for light-use or closed trails on moderate slopes with no concentrated runoff. Outsloping is perceived as a way of encouraging dispersed drainage by locating the road to take advantage of natural relief, as along contours. While it is usually a design feature, it may also develop as a result of skidding on narrow trails. The rapid development of ruts and side berms is the main obstacle to proper outslope drainage. Proper maintenance during use and restoration at closure are important to make outsloping effective.

Trails can be outsloped for minimal cost using a dozer, skidder or forwarder. Outsloping may constitute part of the recontouring process, and may also be used in conjunction with earth berm water bars and broad-based dips. The outslope is a temporary measure unless maintained. Pronounced outslopes may be hazardous to traffic during icy or wet conditions.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	8	7	4	10	1	4	34

- In the Mountain States is widely used on constructed trails, but also may develop as a result of skidding on narrow trails. Maximum slope may be up to 45% if the trail is built along a contour.
- Outsloping is less popular on the West Coast, where outslopes on skid trails are minimized, and generally used only on side hills, areas of steep slopes, draws and stream bank areas.
- Southern US respondents note that cross-drainage devices will need to be installed on outsloped roads.
- In East/Central Canada, outsloping is used on clay soils if the trail will be used during the summer, while in Western Canada it is considered most useful for road sections where there is bedrock near the surface, or there are areas of sheetwash during wet weather.
- This practice is most widely used in the Eastern, Mountain and West Coast states, where it is considered a lower cost method for skid trails as well as recreational trails. Outsloping alone may be more effective than water bars on some trails, although it works best in conjunction with broad-based dips. Removal of the outside berm created by traffic should be a primary goal of outslope maintenance.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	10	5	2	7	0	3	27

- In the Mountain States, the minimal soil disturbance of outsloping, compared to other construction techniques, is considered an advantage. The need for ongoing ditch maintenance is noted. Outsloping as a method for removing side-berms and ruts is particularly emphasized in this region.
- West Coast respondents consider outsloping a useful method for taking advantage of natural relief features to help drainage, and may use this method on steep slopes and near streams as well as on side hills.
- Closed, outsloped trail surfaces are usually revegetated in the Eastern US.

Road Insloping

Insloping is considered effective on moderate to steep slopes or where the trail is located on a contour or side hill cut, where it is desirable to avoid drainage to the outside of the road. In all cases it will be necessary to include inside ditches and frequent cross-drainage to move water away from the trail. The expense of constructing and maintaining these adjunct measures precludes the extensive use of insloping on closed trails, unless continued use is envisioned. It is most effective on moderate to steep side slopes with stable soils. Insloped roads can be constructed with a dozer, or possibly a pole skidder or forwarder, and involve considerable soil disturbance.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	4	4	4	8	0	1	21

- Insloping may be used on Mountain States skid trails of over 35% slope that are built along the fall line. In the Southern US insloping is practiced on grades too steep for outsloping. However, some West Coast respondents considered insloping a counterproductive measure.
- In the Eastern US, insloping may be used as a last resort when other methods, such as crowning or outsloping, are impractical or create safety concerns. However, the use of abundant cross-drainage, as well as roadside or wing ditches, is considered essential when insloping is used.
- In Western Canada insloping is practiced only upslope of areas at high risk for erosion impacts (e.g., fish streams), and only if the drainage can mimic natural drainage patterns.

CLOSED TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	4	3	1	5	0	2	15

- Most insloped trails in the Mountain States are obliterated, and the original contour is restored using an excavator. Likewise, on the West Coast it is not considered useful to maintain insloping on closed trails.

- Closed trails in the Eastern US are generally revegetated, even if insloping is left in place. The inslope is only maintained if other measures (outsloping or crowning) are impractical, and if ditches and cross-drainage devices can be maintained.

- In Western Canada, insloping may be maintained upslope of areas at high risk for erosion impacts (e.g., fish streams), and only if the drainage can mimic natural drainage patterns.

Other Methods

There were few common "Other" diversion options that were cited for active trails. On closed skid trails, mulching with slash or other materials is widely used, often in combination with seeding. A range of measures were also described for trail rehabilitation, to break up the soil surface, restore the original contours and accelerate revegetation.

Regional Notes

ACTIVE TRAILS

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	6	6	0	3	1	0	16

Mountain States

- Slash spread on the trail as a mulch. This is most effective when done early in the life of trail as it prevents destruction of vegetation and soil disturbance. The slash has to cover almost the entire trail. It is least effective when the slash is sparse and provides poor coverage.

- Whole-tree skidding, in which only the tops are in contact with the soil, can minimize damage and erosion problems.

- Pyramid closure (2-stage) stops public travel along with diverting water. Two dead large logs, 12" small end, 14' length, are placed 10" apart, with another large log placed on top. Cover the logs with soil using a backhoe.

- Avoid locating trails on steep slopes and draw bottoms.

West Coast

- Cover the trails with slash and run over with harvesters, forwarders or skidders.

- Backblade level to gentle slope areas to spread water flow.

- Break the slope and direction of the skid trail. This allows heavy runoff to get off the trail instead of creating a long gully down the middle.

- Metal culverts can be used these if there is active water flow during operations.

- Suspend operations until soil conditions are dry enough to minimize compaction.

Eastern US

- Steel culverts are installed on live water courses and removed prior to road retirement.
- Construct lumber matting by bolting 4–5 $10x10$ in timbers of variable length (16–24 ft) aspen or oak together, and place the mats over wet areas in the trail.
- Backblade any low or wet spots on skid trails that develop holes or ruts before the sale is closed.

Western Canada

- In response to new regulations, beginning in 1999, we will use slash mats on trails:

CLOSED

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	8	6	2	6	0	2	24

Mountain States

- Slash is spread as a mulch, usually in combination with trail obliteration, ripping, recontouring, and/or seeding. On steep ground, slash may be spread between water bars to reduce runoff velocity. Slash mulches are most effective when spread early in the life of the trail and when the whole trail surface is well-covered.
- Trail obliteration. This is usually accomplished through various combinations of (soil) ripping and recontouring, possibly followed by seeding and (slash) mulching. Slopes should not exceed 40%.
- Use spreader ditches in conjunction with water bars.

West Coast

- Cover the trail with slash and run over with harvesters, forwarders or skidders.
- Subsoiling or ripping is an effective site preparation technique that enhances the permeability of compacted soils on fairly gentle slopes, prior to seeding. The slope may be broken up by periodically leaving unripped stretches and placing water bars. This especially favors the re-establishment of tree cover.
- Scarification. Use this on compacted soils with rocks less than 6” in diameter, on gentle slopes.

Southern US

- Mulch and seed in conjunction with water bars.

Eastern US

- Mulching and seeding using a wildlife mix (e.g., clover) is commonly practiced on closed trails, often to encourage wildlife. Mulching is also effective on larger areas like landings that may develop erosion problems.

- Build small earth berm water bars coupled with slash from the landing and/or small diameter wood. This should be followed by seeding with a good wildlife mix.

Western Canada

- Roads, trails, and landings must be rehabilitated if allowable ground disturbance levels are exceeded.
- Cross ditching is good to deter access on temporarily or permanently closed trails. They should be placed at natural drainage locations where downslope (erosion) risks are not aggravated.

4. Constraints on Diversion Options

In questions 9 and 10, respondents were referred to the list of diversion options and asked to "describe any special problems associated with their installation/maintenance on active/closed closed haul roads or active/closed skid roads/trails". They were also asked to note whether the constraints they listed applied specifically to active or closed roads or trails.

In the majority of cases the respondent made no distinction between the active or closed condition, or the comments did not vary significantly between the designated conditions. Therefore most of the responses have been summarized across all road or trail conditions within each geographic region. Where constraints were unique to a particular circumstance the responses are summarized separately by region.

Region Codes

USM. Mountain States: AZ CO ID KS MT NB ND NM NV SD UT WY.

USW. West Coast: AK CA OR WA.

USS. Southern US: AL AR FL GA KY LA MS NC OK SC TN TX VA.

USE. Eastern US: CT DE IA IL IN MA MD ME MI MN MO NH NJ NY OH PA RI VT WI WV.

CEC. East/Central Canada: LB MB NB NF NS ON PEI QC SK.

CW. Western Canada: AL BC.

Q9. Constraints associated with installation of diversions.

Earth Berm Water Bars

A dozer with a tilt (6-way) blade and an experienced or trained operator do the best job of properly installing earth berm water bars. Skidders are much less efficient. *Author's note: As some operators do not have access to heavy equipment that can be on-site at all times, proper installation and maintenance of the water bars may be problematic.* The soils must be sufficiently deep to obtain adequate ditches and berms; installation will be difficult in excessively rocky soils or over bedrock. Rip rap or logs may be used to reinforce the bars on weak or erodible soils. Installation may also be difficult when the ground is frozen.

Proper installation is critical. The bars must be placed at appropriate spacings (depending on grade and runoff expected) and correct angle to the road, extending fully across the road or trail so that water cannot bypass it. The outlet must discharge into a stable area that permits the water to move away from the road. Operators commonly make them too deep or not deep enough, or make the berm too high or low. The berms must be compacted after installation. On active roads, the ditch and berm need to be gradual enough to prevent vehicle damage.

In many areas, these are considered a viable option only for closed roads or trails due to damage caused by traffic, which can flatten the berms. Livestock and OHV damage may be concerns on closed roads; traffic can circumvent the berms, which limits their effectiveness as closure devices. On active roads, these water bars are considered by some to create access restrictions and damage equipment unless they are low and gradual enough to allow easy passage.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	25	14	13	13	4	7	76

Mountain States

- The berm needs to be tied into the road bank, and well-compacted prior to use.
- Difficulties with the site may include extreme slopes, thin, rocky, very wet or very dry soils. Soil moisture needs to be adequate to allow compaction.
- Installation may be more successful when done by larger contractors who can provide trained, experienced operators.
- If the water bar is constructed downhill of the work zone, dozer passage will leave track imprints across the berm.

West Coast

- Over-building of the water bar can exacerbate erosion problems.
- Earth berm water bars can be hard to construct in very rocky locations or in shallow soils. They will need extensive lead-off ditches.
- There may not be enough dry weather to install them in wet climates.
- If installed to a drain ditch, it often cuts through a rocked roadbed and erodes native material. On some well-crowned roads it is impossible to cut the waterbar to work without making the road undrivable.

Southern US

- Site-related difficulties include excessive rock, overly dry conditions, or problems due to entrenched roadbeds.
- Excavation of material for berm leaves a hard packed area in front that must be mulched to ensure revegetation
- Inappropriately high berms for active use, or lead-off ditches inadequate to handle drainage, will cause the water bars to fail.
- The outlet must be placed far enough to prevent water from re-entering the roadway.

Eastern US

- The water bars must be in place and settled prior to road use. Gravel surfacing may be used in low areas to stop rutting. When installed in conjunction with revegetation on steep slopes, mulch mats may be used after placement to ensure seed germination.

- Earth berm water bars installed in deep road cuts may not be able to adequately discharge water.
- The typical weight of haul loads and speed of the trucks makes installation on active roads a waste of time .

East/Central Canada

- On clay soils, they must be seeded or rip rapped to prevent erosion.
- With the V-type berms that allow OHV access care must be taken to ensure that the center is high enough that after OHV use the water will not enter the water bar.

Western Canada

- Rock is used to reinforce the water bars.
- Recreational traffic can circumvent the structures.
- On active roads the uphill side of the water bar needs to be sloped to prevent the back end of vehicles from bottoming out, while on closed roads the downhill side (berm) should be adequately compacted after any protruding boulders are removed.

Broad-Based Dips

A dozer with a 6-way (tilt) blade or a grader are desirable for installing broad-based dips; skidders are not adequate. Lack of well-trained or well-supervised operators is a frequently cited problem. *Author's note: As some operators do not have access to heavy equipment that can be on-site at all times, proper installation and maintenance of the dips may be problematic.*

The dips are designed for roads with less than 10 or 15% grades. Steeper grades prohibit proper spacing. Dip installation may be costly and time-consuming, and the dips may be difficult to retrofit in an existing road. Improper construction is a frequent problem. Correct spacing, angle (to the road), depth, and an open outlet to a stable area are all critical. Frozen, shallow (over bedrock) or very rocky soils are unsuitable for dip construction. The excavated material needs to be properly compacted prior to use.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	23	11	12	16	3	4	69

Mountain States

- Poor construction techniques include failure to compact the fill portions, locating the outlet over fill material, and improper spacing or backslope length. The dips need to be shallow enough to accommodate vehicle traffic but deep enough to provide long-term drainage. In highly erodible soils the dip bottoms may need to be lined with rock.

West Coast

- It may be necessary to reinforce the dips or outlets with rock. Some relief is necessary, or water will pond on the road.
- The higher cost of this option (compared to earth berm water bars) and the potential need for regular maintenance (cleaning out the dip) may limit its use.
- Log truck drivers tend to request removal during operations due to the potential for vehicle damage. In addition, damage to the dips is likely to result from wet weather use.

Southern US

- The dips need to be carefully located and designed to be gentle enough to allow for haul truck passage. The need for extensive earth movement and rock-reinforcement are limiting factors.
- The high cost of construction limits use.

Eastern US

- In some cases it may be possible to use logging equipment to construct these.
- These require more time to install than some other options, but with the right soil conditions they may be less costly than earth berm water bars.
- Some gravel surfacing may help avoid rutting across the dips.

East/Central Canada

- Dip construction causes extensive soil disturbance, and may create access restrictions.
- The best results are obtained when constructed with excavators using "thumbs".

Western Canada

- They are time-consuming to install.
- The road should also be crowned in depressions to facilitate removal of water from the road surface.

Slash Water Bars

Soils need to be relatively stable where slash water bars are installed. The slash bars may actually aggravate erosion on very sandy or fine-textured (i.e., clay,silt) soils. They work best on slopes under 40%. Lack of available slash in close proximity to the road is a limiting factor.

Appropriate equipment to construct the water bars (grapple skidders, loaders) may not be available when needed. The slash must be compressed to maximize ground contact, or water can channel underneath. *Author's note: Slash water bars must be installed at closer spacings than earth berm water bars, as they will handle less water.*

Slash water bars are more temporary than earth berms and are difficult to install correctly. Their use is largely confined to closed roads and trails as they are difficult to keep in place with traffic unless they are very well compacted. They can create access restrictions.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	10	6	4	6	4	4	34

Mountain States

- Installation may be more labor intensive than other methods, although grapple skidders work very well.

West Coast

- Some types of terrain, such as steep slopes and ridge noses, are not suitable for slash water bars. Slash availability is also a factor, including excessive amounts of slash, which can be difficult to work with.
- In some cases these may be more costly than earth berm water bars.
- The outfall must be constructed through trees and brush.

Southern US

- These are not used for active roads due to the difficulty of keeping them in place.
- They are more likely to be used if there is a delimber on site.

Eastern US

- Installation is most effective if equipment such as a grapple skidder is available to place the slash and compact it into the soil surface.
- Timing is critical.

East/Central Canada

- They may create heavy secondary erosion on clay/silt soils.

Western Canada

- These are temporary structures which can be labor intensive and are not always effective, but tend to limit access.

Log Water Bars

Proper construction of log water bars requires heavy equipment and trained operators, and may be more labor intensive than other types of water bars. There may be difficulty in properly placing and anchoring the logs, which need to have soil banked up against them. Installation over bedrock or in excessively wet conditions can be problematic. Log water bars can create access restrictions for vehicles.

Some comments suggested that availability of logs may be an important limitation as more wood is utilized for chips and log waste is reduced. Cost and vulnerability to destruction (by traffic) are major concerns.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	6	7	4	5	4	2	28

Mountain States

- These can be quite effective on closed roads except when the public cuts them away to create access.

West Coast

- The logs should be buried or bermed up with soil (which makes them comparable to earth berm water bars.

Southern US

- These are little used as they are unsuitable for active roads and too costly for installation on closed roads.

Eastern US

- These will not work well over ledge rock.
- They may create safety concerns.

East/Central Canada

- Large-diameter poplar covered with geotextile works well.

Straw Bales

Straw bales require the scheduling of extra material and labor transport to a remote site. However, skidders may be used for transport and placement. It is essential that the bales be carefully placed in good contact with the ground and each-other. The must be well anchored with stakes, rope or rocks to minimize sediment leakage underneath.

Straw bales are very temporary due to rapid decomposition and the likelihood of livestock damage. Monitoring/maintenance will be necessary. To enhance rapid revegetation for long-term stabilization, straw bales can be installed in conjunction with other measures such as mulch, filter fabric and seeding.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	9	4	2	5	1	2	27

Mountain States

- The straw bales need to be properly located to maximize functionality, and tied in using stakes, ropes, rocks etc. They may be used in conjunction with filter cloth.
- There needs to be reasonable road access (to transport the bales) and dry conditions for installation.
- The straw bales can carry weed seeds and tend to be eaten by game and livestock.
- They are costly compared to cross-ditching on closed roads, but not practical for use on active roads except in deep gullies.

West Coast

- They may not be very effective except as sediment filters in ditches near riparian areas.
- Weed seeds are a problem.
- On removal, accumulated sediment must also be dug out of the ditches.

Southern US

- They often are not installed in the right location, or not enough are used.
- The bales must be staked in place, and may be subject to theft by locals.

East/Central Canada

- These are easy, though time-consuming, to install, but their use is limited by the need to transport materials to remote areas, and the access restrictions created by their presence.

Western Canada

- They create access limitations.
- In most cases bales are just thrown into the ditch and not staked in.

Open-Top Culverts

The likelihood that either heavy equipment or hand work will be necessary makes this option very time-consuming to install. Also, it may require the transport of lumber and other materials to the site. Finally, some respondents thought that the extensive soil disturbance involved could cause unacceptable sediment loss.

The culverts should be made wide enough for easy maintenance (clean out) with a shovel. They cannot be installed where depth to bedrock or rocky strata is too shallow.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	9	2	3	8	0	1	23

Mountain States

- These are obsolete due to problems with sediment clogging resulting from inadequate drainage;
- Getting adequate skew is especially difficult on steep slopes.
- The soil disturbance required in wet areas almost guarantees sediment loss.
- These are among the most expensive options to install; the cost needs to be part of the original road package.

Road Crowning

In most cases where road crowning is used, the road needs to have a compacted base, a stable gravel surface and adequate width for effective crowning. The crown must be designed into the road, and adds to the construction time. In addition, adequate provision must be made for the installation of cross-drainage structures and roadside ditches. Obtaining good surfacing material can be difficult, as native materials are generally not recommended. Temporary roads are frequently not built to this standard.

Proper construction and grading require heavy equipment (dozer, grader) and well-trained operators. Weather conditions can inhibit the scheduling of grading, as excessively wet or dry soils can cause problems.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	14	6	7	14	5	2	49

Mountain States

- The need for this feature to be part of the road or trail design makes it a somewhat costly option.
- Soils should not be either excessively rocky, very wet or very dry during construction. ”Powdering” may occur during very dry conditions.

West Coast

- Installation and crown maintenance should occur prior to rains and just before the end of hauling (allows compaction of the surface).
- In clay soils, crowning can result in a slippery road surface that tends to send passing vehicles off the road into ditches.

Southern US

- The lack of appropriate heavy, bladed equipment with skilled operators, and the need for regular maintenance limits the use of this option to roads built on company or large NIPF (non-industrial private forest) sales.

Eastern US

- Adequate clearance for the required equipment to operate is always a problem.
- The added expense and time for road crowning needs to be built into stumpage costs.
- Road maintenance projects often don't have the money to do adequate ditching.

East/Central Canada

- Construction is easiest using excavators with "thumbs" (can select material).

Road Outsloping

For the best results, it is helpful to have rock/gravel surfacing or dry, stable soils. Loose, sandy soils can cause problems. Outsloping should also be avoided on very steep terrain, as steep grades (over 15%) can track water down the road. Fill slopes must be stabilized, and sufficient cross-drainage must be provided. The road surface will be most durable if it is compacted or allowed to settle before use.

Although the grading may be done with logging equipment, equipment with tilt blades is generally preferred (dozer, grader) or an excavator. Training and monitoring of the operators is important. The grading work can be costly if it is not designed into the road.

Aggressive outsloping can result in overly rapid drainage, channeling and erosion. It may also create safety concerns for hauling during the winter or very wet conditions. The weight of trucks can erode the downhill side of the road, and log trucks may tip over. On flatter terrain, it may be difficult to obtain sufficient outsloping without creating a ditch on the outside shoulder.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	16	6	7	8	4	3	54

Mountain States

- Overly aggressive outsloping, which can be exaggerated as the weight of trucks erodes the downslope side of the road, can result in safety problems during slippery conditions.
- The outslope must be designed into the road or trail so as to avoid forming a ditch template on the outside shoulder of the road, while still making the outslope strong enough to properly drain the road.
- Dry conditions are best for installation but overly dry soils can cause "powdering" with heavy use.

West Coast

- The application of outsloping is limited to conditions of appropriate relief where suitable road materials are available. In some cases it should only be used on closed roads.

- Outsloping may result in hazardous conditions when the road surface is icy or wet, which operators don't like.

Eastern US

- The road must be located to avoid unsuitable terrain and sandy soils, and the fill slope must be well-stabilized..
- The cost must be built into minimal stumpage costs, so bidders know a priori.

East/Central Canada

- The best results are obtained using excavators with "thumbs" (can select material).
- The roads must be built to a standard that allows proper grading, including correctly surveyed superelevation on the curves.

Western Canada

- Outsloping may be expensive if not built into the road when new.
- If outsloped too much, log trucks tip over.

Road Insloping

Insloping is primarily recommended for use on curves or switchbacks. Ditches and cross-drainage (culverts or dips) are always needed in conjunction with insloping in order to avoid trapping water alongside the road. Ditches may be problematic in very rocky or steep (over 10% grade) terrain. Adequate ditch and culvert size and spacing are critical.

Construction of an insloped road requires equipment with tilt blades, such as a dozer, cat or grader. Proper training and monitoring of operators are important.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	14	7	7	8	3	2	41

Mountain States

- This method is more likely to be used on switchbacks where grades are under 10%. Conditions to be avoided include excessively wet, dry or rocky soils.
- Ditch relief must be adequate to prevent road erosion.
- Insloping may be unsafe under slippery conditions.

West Coast

- It is best if construction and maintenance work can be done before the onset of wet weather but just prior to the end of hauling, so that the road surface can be compacted.

- This method should be used on curves only.

Eastern US

- Insloping is hard to establish on a road while it is being used, especially if conditions are muddy.
- The extra cost should be built into minimal stumpage costs so bidders know a priori.

East/Central Canada

- Roads are often not built to standard to allow proper grading, which includes correct installation of superelevation on curves and good ditching.

Other Methods

The following comments were common to at least two of the the survey regions.

- Seeding and mulching need to be timed to coincide with weather favorable to germination.
- Obliteration/recontouring operation are constrained by the availability of proper equipment, high cost.
- Gravel/rock surfacing is costly.
- Belt waterbars (flappers) need to be installed during dry conditions. They will wear out over 5+ years, depending on traffic and condition of the used belt when installed.
- Drainage ditches must be adequately sized and oriented.
- Cross ditches will slump from the sides if made too narrow, and are generally appropriate only on closed roads.
- Culverts (metal, plastic)need to be buried deeply enough to prevent pipe collapse; also they are costly.
- Ditch diversion berms (lead-off ditches) need to be constructed so as to minimize ground disturbance and retain the existing vegetative mat.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	8	0	0	2	3	4	17

Mountain States

- Gravel is costly.
- Obliteration/recontouring is costly and requires that appropriate equipment be available. Seeding of exposed soils must coincide with favorable weather.

- Drainage ditches require adequate size and orientation.
- Belt waterbars (flappers) require dry conditions for installation and wear out over 5+ years, depending on traffic and condition of used belt when installed.

Eastern US

- Seeding and mulching all closed skid roads and trails is costly but effective.

East/Central Canada

- When installing ditch diversion berms (lead-off ditches) the operator needs to be careful to minimize ground disturbance and retain the existing vegetative mat.
- 12 in plastic or metal culverts need to be buried deeply enough to prevent (pipe) collapse.

Western Canada

- Cross ditches need to be made wide enough so that the sides don't slump, so that generally they prevent all access.
- Culverts are costly.

Q10. Constraints associated with maintenance of diversions

Earth Berm Water Bars

Earth berms need frequent maintenance with use, as the berms can be degraded by logging or OHV traffic. Inadequately drained water bars can create water pockets in the driving surface. On closed roads the berms must be monitored to ensure revegetation and continued drainage, as large amounts of runoff can fill in the upslope ditch or erode the berm. Ditches, berms and outlets need to be maintained as long as the road or trail is in use or the road surface is revegetated and stabilized.

Earth berms are hard on vehicles, and operators may inadvertently or deliberately grade out berms if they are viewed as obstacles. It is most efficient to make the logging contractor responsible for constructing/maintaining the water bars during operations and sale closure, and ensuring that appropriate equipment is on hand when needed.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	22	14	9	20	4	9	78

Mountain States

- Maintenance requires specialized equipment (not a road grader) and an experienced operator.

- The public may break down the berms for access to closed roads. Spreading slash mulch between the berms can help inhibit public use and facilitate revegetation.

- The water bars will not be durable if installed in the wrong place or not made large enough. Water not diverted into a filtering agent (e.g. the forest floor, slash or grass) will cause secondary erosion.

- Scheduling maintenance activities after sale closure is a problem, and generally is the responsibility of the landowner (not the contractor).

West Coast

- On closed roads the water bars tend to wash out, and can be degraded by livestock traffic.

- Weather, unstable soils, or incorrect initial construction can all cause rapid degradation of the water bars.

- The cost of mobilizing equipment to the road site limits maintenance.

Southern US

- Earth berm water bars work best on closed roads and trails in combination with seeding and straw bales.

- The water bars will have to be removed if the road is re-opened.

Eastern US

- These are difficult to maintain in sandy soils.

- On closed roads the water bars must be monitored to ensure continued effectiveness, especially following spring runoff. Revegetation needs to proceed rapidly; drainage outlets must open into vegetated areas to prevent further erosion. Gravel on the road and in drainage structures may also help stabilize surfaces.

East/Central Canada

- This method is not encouraged due to liability issues.

Western Canada

- Rip-rap can help stabilize the berm and cross ditch.

- The outlets can erode in steep terrain.

Broad-Based Dips

Relatively low maintenance is a positive feature of these structures, especially if they are armored with gravel or rock or revegetated (post-sale). Re-shaping may be required every 2–3 years on main haul roads. They are rarely used on skid trails.

Silt buildup in the dip impedes drainage and reduces its effectiveness. Seeding, rock or gravel can help with stabilization; avoiding use during wet conditions also prolongs their useful life. The discharge outlet or ditch must be kept open to ensure proper drainage, or the dip can become a mud hole. The dips need periodic maintenance until completely revegetated following sale closure.

Inexperienced operators are more likely to grade out or fill in the dips during road maintenance. The dips may be perceived as a inconveniences and be purposely filled in by the contractor during active hauling.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	19	11	8	14	1	8	61

Mountain States

- Lack of operator experience with these structures can result in dips that are not wide enough.
- The berms must be adequately hardened prior to use.

West Coast

- Although these require less frequent maintenance than earth berm water bars, proper maintenance can be more expensive and requires knowledgeable operators.
- The outfall can migrate down the grade.

Eastern US

- Dozer operators are frequently unfamiliar with broad-based dips and need more training to do proper installation and maintenance.
- The dips accumulate sediment faster in sandy soils.

Western Canada

- Dips are considered a durable and easily-maintained option for temporary road deactivation. The dips should be broadly swaled (gradual) for best results during use.

Slash Water bars

While short-lived, these may require less maintenance than earth berm water bars. However, continued usefulness would require repeated additions of slash as the existing material breaks down. Slash water bars are most appropriate on skid trails. Over-the-road vehicles are susceptible to damage by slash. For this reason, slash water bars are not generally considered compatible with heavy traffic of such equipment.

Slash may not be adequate for runoff resulting from high rainfall, or on very steep terrain. Water can channel under slash that is too coarse or not in full contact with the ground, causing secondary erosion problems.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	8	4	3	8	2	4	29

Mountain States

- The public can easily cut up and remove the slash for fuelwood or to gain access to a closed area.

West Coast

- Water bar function may be compromised as water channels under the slash and the outfall gets overgrown with brush.

Eastern US

- Slash water bars are susceptible to skidding damage on skid trails.
- The logger must remember to restore the water bars at sale closure, which requires keeping appropriate equipment on hand.
- The slash can plug up with silt.
- Scooping some soil up along the edges of the slash can help stabilize the water bar and keep it from sliding downhill.

East/Central Canada

- Water diverted by slash during heavy runoff periods can causing secondary erosion problems. Also, slash is unsightly.

Western Canada

- Slash water bars rot or plug in wet climates, requiring periodic reconstruction. Although they work well on stable road surfaces with under 20% slopes, they are inadequate on steep terrain.

Log Water Bars

Log water bars are more durable than slash water bars, but suffer from many of the same maintenance problems – the logs decay and compress, or allow water to channel under them, or are displaced or damaged by vehicle traffic. Use on active roads is limited due to access constraints and the impact on equipment.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	7	3	1	4	0	4	19

Mountain States

- The logs may need periodic replacement until the surface stabilizes, but less frequently than slash. The drainage outlets must be kept clear of debris.
- The public can easily cut up and remove the logs for fuelwood or to gain access to a closed area.

Southern US

- Log water bars are difficult to anchor.

Eastern US

- Log water bars don't work well with sandy soils on active skid trails.
- The logs should be delimbed or run over to maximize ground contact. Scoop a little dirt onto the trees with a skidder blade to stabilize them and prevent them from sliding down hill.

Western Canada

- The water bars may cause secondary erosion if not compacted well.
- They may be inadequate to handle large amounts of runoff in steep terrain.

Straw Bales

Straw bales are generally understood to be a very temporary measure, but with correct installation they should require no maintenance in the short run. Supplemental stabilization measures (e.g., seeding, mulch) may be required. The straw bales will have to be replaced if long-term water diversion is needed.

Straw bale barriers must be properly structured and staked in to be effective. Large amounts of runoff can cause blow-out (straw bales displaced), especially on steep slopes.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	4	3	2	5	1	3	18

Mountain States

- The straw is often eaten by livestock.

- For long-term stabilization, the landowner must take responsibility for replacing the straw bales.

West Coast

- Straw bales are short-lived and likely to rot or be eaten by livestock.

Eastern US

- Straw bales may introduce an unwanted seed source.

East/Central Canada

- The straw bales need to be cleaned out (remove bales and accumulated sediment) after their useful life is over.

Western Canada

- Straw bale installation and replacement can be labor intensive.
- Straw bales may cause secondary erosion if not compacted well (in good contact with the ground).

Open-Top Culverts

The main problem with open-top culverts is a tendency to plug up rapidly with sediment and debris. If not cleaned out regularly the plugged culverts will overtop and can create gully type erosion. The need for frequent cleaning results in high maintenance costs. In addition, open-top culverts can impede road grading.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	7	5	4	8	1	5	30

Mountain States

- Open-top culverts work best on surfaced roads. They require frequent cleaning where the road grade is steeper than the gradient through the culvert.

Southern US

- The culverts are difficult to clean out.

Eastern US

- Spacers may be inserted to maintain the width of the culvert, but wooden portions tend to rot.

East/Central Canada

- These are little used due to liability issues.

Road Crowning

Regular grading with appropriate equipment (usually road graders) is required to maintain the crown. Ditch maintenance is also important. Cost is therefore a factor that reduces the frequency of maintenance. Operator training is important; the crown can get flattened out during grading, or the grader may leave outside berms which impede drainage off the road. It is especially important that the road be properly crowned just prior to closure.

Crowning works best on gravel or rock-surfaced roads. Native materials are generally not recommended. Road crowning is inappropriate on clay soils or unstable materials, as wheel tracks and ruts can develop that channel water on the road.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	16	11	5	16	7	5	60

Mountain States

- The final blading should be done prior to the fall rains while still hauling, allowing traffic to compact and seal the surface.
- The ditches need to be kept clear.

West Coast

- The road surface tends to become insloped on steeper terrain.

Southern US

- Lack of time or equipment to maintain the crown are problems.

Eastern US

- On active roads gravel will need to be applied frequently in low areas, especially if there is beaver activity (that causes spring flooding). Closed roads should be rapidly revegetated.
- Crowned roads present a continual maintenance problem after closure since they are usually bermed.
- Packed roads divert water better and don't erode as easily. A logger is considering a packing roller for this use.
- Too much crown narrows the road surface and results in difficult trucking when slippery.

East/Central Canada

- On older roads, it may be difficult to find good surfacing material while grading.

Western Canada

- A maintainable road crown requires decent surface materials.
- There is a need to consider the downslope terrain impacts of off-road drainage.

Road Outsloping

Regular maintenance by an experienced grader operator is necessary. Improper grading can flatten the outslope or leave an outboard berm which impedes drainage. All ditches and culverts must be kept clear on both active and closed roads.

Use of the road during wet conditions can result in destruction of the outslope, especially in fine-textured or unstable soils. In addition, a pronounced outslope can create safety concerns when the surface is frozen and slippery.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	14	9	5	10	4	5	47

Mountain States

- During road grading, the operator needs to avoid undercutting the fill slopes or leaving outside berms. Blading on active roads just prior to suspension of activities (due to fall rains) allows traffic to seal and stabilize the surface.

Southern US

- This method is most effective and the least maintenance will be needed if there is gravel surfacing. There will be more maintenance in highly erodible soils.

Eastern US

- Lead-off ditches must be kept clean. Closed roads are generally bermed and should require little maintenance.
- The fill slope must settle prior to use and the cut slope should not be too high or it may destabilize the entire slope. Outslopes are difficult to maintain if there are steep slopes or shallow bedrock.
- Budget constraints limit maintenance frequency.

East/Central Canada

- The need for frequent maintenance of active roads results in high maintenance costs; funding is not always available.

Western Canada

- Abundant erosion may occur on steep grades, requiring the addition of water bars.
- Downhill areas and fill slopes must be stable or road runoff can erode downslope terrain.

Road Insloping

Keeping ditches and cross-drainage devices (e.g., culverts) clear of sediment and other materials is particularly important with insloped roads to avoid trapping water alongside the road. Frequent monitoring and maintenance (especially of ditches and culverts) is critical and results in higher maintenance costs. Grading by inadequately trained operators can flatten the inslope, and may leave an inside berm.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	15	10	4	11	4	4	48

Mountain States

- Catch basins should be armored (rocked) and cut slopes stabilized to avoid slumping.
- Roads with native surfacing composed of clay, volcanic or granitic soils are prone to rutting if open to public use, causing runoff and soil displacement. Hence, they require more frequent maintenance.
- The [landowner] must maintain the road after sale closure if the road is to remain open. Closed roads may experience clogged culverts and blowouts without monitoring and maintenance.
- The road needs to be bladed prior to fall rains while still hauling, to allow the surface to set up.

West Coast

- Regular use or recreational traffic during wet conditions will create ruts that require regular maintenance to keep the inslope, especially on steeper grades.

Southern US

- Little maintenance is required except in highly erodible soils and if the road is not surfaced with gravel.

Eastern US

- It is difficult to maintain inslopes on closed roads since they are usually bermed.
- Maintenance may be difficult where there are steep slopes or bedrock.

Western Canada

- Frequent water bars should be installed on road closure.

Other Methods

As there were few common alternative options, comments related to maintenance of these options are simply summarized by region.

Regional Notes

Number of responses received, by region.

Region:	USM	USW	USS	USE	CEC	CW	Total
Responses:	23	13	10	18	1	5	70

Mountain States

- Gravel surfacing requires appropriate equipment to apply and maintain the surface.
- Rubber belt diversion devices are is easily damage during road blading. Sediment may build up behind the belt or the belt material wears out and must be replaced.
- Lead-off ditches must be kept clear of debris and sediment.
- Seeds may wash away.

Southern US

- Concrete plank dips last well but are expensive.

Eastern US

- Conventional culverts should be at least 15 in diameter and must be cleaned out regularly on both active and closed roads. They may be difficult to clean.
- Mulch may occasionally wash out or blow away.
- Spraying herbicide after closure keeps vegetative material from ”growing in” on a road.

East/Central Canada

- Diversion ditches (lead-off ditches) on slopes work well when combined with cross drainage culverts, but the grader has a tendency to close the diversion ditches.
- Culverts freeze shut and flood roads in the spring.

Western Canada

- Cross ditches are too large a structure for active roads and limit access.

5. Miscellaneous comments related to the use of water diversions.

In Question 13 respondents were given space to include any additional comments or information they thought was relevant with respect to the application of water diversions. These comments have been transcribed more or less verbatim below, with minor editing as appropriate. Extraneous comments or those addressed to the survey administrators regarding the format of the survey itself were not considered relevant to this report and were therefore excluded. Remaining comments were sorted by region and are reproduced below. Comments that referred to specific questions are listed by question number, followed by general comments.

Mountain States

Q. 2

- BMPs on private lands are voluntary and the responsibility of the Dept of Environmental Quality. If they are not installed on State lands someone was asleep at the switch.
- Appropriate NEPA regulations and mitigations are stringently enforced on all sales.
- We do not generally require diversion structures on slopes under 10%; also we don't require structures to be placed on skid trails/roads during the dry season (summer/fall) when they are being used. We do require installation of structures immediately following completion of operations in a harvest unit (within 48 hours).

Q. 4a

- Logging generally done during either dry or frozen periods (minimizes need for water diversions).
- Because of our semiarid climate on the two ranger districts east of the Rocky Mountain front I do not generally construct water diversion devices on active skid trails. West of the Rocky Mtns we generally skyline log or restrict tractors to winter use.

Q. 6a

- Generally, our contracts require that the main tractor skid trails will be ripped (plowed with a brush blade). Trails are seeded, operators scatter slash on the skid trails.

Q. 8

- Most sales are laid out where cut skid trails are not required. A cable operation or cut-to-length system may be specified. Feller/bunchers and log forwarders operate on a deep slash bed. Depending on location, side slopes and grade skid trails will be recountoured to natural slope. Temporary roads would have culverts removed, large waterbars constructed, the roadbed ripped and seeded after use.

Q. 10

- In general there are no funds available to maintain erosion control structures installed by purchasers.

Q. 11

- There isn't much you can do with a road cut three feet lower than surrounding landscape. It is usually in this condition from past erosion and blading. Another part of this survey that is difficult for me to determine is effectiveness. From my perspective water quality effectiveness relates to where the water goes after it leaves road diversions and how much sediment it is carrying. For an engineer effectiveness is getting the water off and away from the road. For this hydrologist it is increased runoff from roads and sediment entering the stream system.

MISCELLANEOUS

- Timber sales on private lands generally are small and don't require high standard road construction (hence crowning is not justified).

- On all skid trails and work roads I require the purchaser to re-shape the road or trail back to contour, then scatter slash throughout, or water bar depending on the slope, soil and water conditions. Where contouring is not practical, the operator is required to rip the road, seed and install water diversion structures.

- Logging operations are actively monitored during wet periods and suspended if any problems occur. We have had few problems with sedimentation in adjacent water courses. Sale layout and design are carefully planned to not affect water courses.

- The soils, road grade, side slope, subsurface flow and other factors are all considered in determining what option works best for the money. Usually combinations of structures are used. Every road is a drainage diversion structure across the hill in and off itself. In some cases allowance for subsurface drainage must be considered. Also where the water is diverted to must be factored in (i.e. not on to unstable, slide-prone fills, in draws or stream channels, or anywhere where sediment would enter streams). The stability of the road surface and cut/fill slopes needs to be addressed to predict sediment movement off these sites.

- Spreader [lead-off] ditches are used to disperse flow of water away from water bars, dips, cross drainage structures or ditches. Purpose is to diver flow from road surface into area where water may be absorbed; velocity is diminished, suspended sediment is filtered and settled.

- We have used rubber belt waterbars on steeper system roads and trails. While they work well they have a 5+/- year life on roads, longer on trails.

West Coast

Q.2

- We don't permit operations without appropriate BMPs since risk of erosion is pre-determined and pre-treatment would be required.
- When mechanical harvesters/forwarders are used, the limbs are often cut off and left in the skid trail to "pave" the trail with slash, thereby negating the need for water diversion.

Q. 3a

- We have used straw bales placed perpendicular to drain dip at critical locations, as traps. Broad-based dips almost always used in conjunction with outsloping and insloping where there are grades. The dips are usually rocked; grades can't be too steep.

Q. 4a

- When skidding operations are in progress we don't install erosion control structures.

Q. 6a

- Trails can be scarified using a winged ripper, lifting it periodically to break continuity. This breaks up compaction, allowing percolation.

Q. 12

- No winter logging occurs, as the ground doesn't freeze hard enough.

MISCELLANEOUS

- We are experimenting with cut-to-length mechanical harvester systems and leaving crushed slash on trails, working equipment on a slash mat.
- Ridge tops and swale locations are most prone to incremental entrenchment of the road. New construction should avoid such alignments as much as possible. Existing alignments should be analyzed for opportunities to reduce maintenance costs and resource impacts. A well-trained and motivated maintenance crew is necessary to avoid incremental alteration of drainage features, and to recognize and correct design flaws that will impair drainage.
- We are currently developing more comprehensive training on road construction and maintenance on private lands.
- We are in a fairly dry area with steep slopes. Broad-based dips hold up best and produce best results on active roads. Closed roads are generally water-barred to divert water and keep vehicles off. This stabilizes the road and promotes vegetation growth, which is best.
- Diligent maintenance is most critical. Drain dips are widely used: they should always be rocked with pit run rock to prevent erosion. Dips become less useful as the grade steepens; have to be built deeper and therefore are more difficult to negotiate with long loads. The reach on the log truck will drag on the crest of the dip.
- Scarification is performed with an attachment that has four teeth, capable of ripping grooves in the soil to a depth of 12-18 inches. This leaves 4 mini-trenches in road and allows increased water infiltration on compacted skid road surfaces.
- Sub-soiler: an attachment with an 18" wide curved blade that lifts the soil to a depth of 18 inches. Leaves the appearance of an 80–100% broken surface and allows maximum water infiltration. This method is not used much yet but shows potential.

Southern Region

Q.7

- Most of our loggers are not sophisticated enough or won't spend the time to worry about the above criteria [for selection]. [There are] no differences between active and closed roads. Straw bales are used only in remediation work. In my experience in the SE US, I would be surprised if these discretionary activities were widely used.

MISCELLANEOUS

- The issues you are trying to evaluate are important but Virginia loggers know water bars work, they can install them quickly and meet the BMP guidelines. You have gone a step or two beyond the decision-making capability most loggers want to deal with. Large-scale loggers hire contractors to install BMPs beforehand. We are seeing this more and more.
- In the Piedmont the broad-based dip is most effective on haul roads, and earth berm water bars are most effective on closed skid trails.
- The Alabama Forestry Commission mainly promotes BMPs and surveys their use.

Eastern Region

Q. 3a

- Crowning is most effective on good gravel roads which will hold a crown; outsloping works best on lower standard roads.

Q.4b

- Most skid trails are small and narrow and there isn't much room for these (diversion) applications. It is better to locate trails so you don't create a problem.
- Most of our soils will not hold structures with active use in an unfrozen condition.

Q.10

- Attempting to install any but the most basic diversion under heavy use is difficult and often short-lived. If roads are not constructed properly ahead of time and allowed to heal up before heavy use you are always going to have problems.
- In/outsloping is often removed by loggers as they feel that sloping causes trucking problems.

MISCELLANEOUS

- Proper road location will reduce the need for diversion options.
- Our area is relatively flat (outwash) and sandy, so most diversion options are not needed or often used.
- Our area does not have much topography. Most areas have short slopes, so with proper road and skid trail layout no water diversions are necessary.

- In Vermont we have a book of rules titled “Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont”. These rules have been established based on the best research on how to prevent negative impacts on water quality from harvesting. As in most states they are prescriptive in nature and involve use of all types of water diversion practices/structures. We receive 40+ legitimate water complaints and have a process involving the industry to mitigate. We actually take to court 45 cases a year where loggers do not follow the rules. We do not have surveys or data collections that answer the questions as they are posed. The answers to the [written] questions are much too complicated to write in the time that is available to do this questionaire.I believe that most of this information is much more accurate coming from the research world.

- Russ Briggs (SUNY-ESF) has done some recent survey work in 2 areas of NY. He’s got the most current and accurate info for NY.

- Although we use BMPs to an extent we don’t actually categorize these uses, making it difficult to relay this information.

- We follow best management guidelines. All timber sales have road deductions for the installations required to control erosion and sedimentation. All haul roads and skid trails are constructed, maintained and retired by the forester in charge of the sale. Buyers of Bureau of Forestry sales must complete sales according to a contract.

- All sites should be pre-planned with attention given to active and closed conditions desired. Flag problem areas for operators to pay attention to; select remedies that are applicable, insist on [proper] timing of structures.

- Water diversion devices are placed according to topography. Logs are pulled uphill away from streams to reduce erosion in stream-side zones. Stream crossings are only allowed in approved locations.

- Wood chips are used instead of straw in some cases in our county. Wooden mats are becoming very popular and compatible with local loggers.

- The only water diversion we use on active haul roads is crowning, and that not often. Usually erosion is not a real problem in our area. Problems may occur on steeper hills that have been skidded on consistently. Slash water bars work well but are not installed until the skidding is done (sale closure). We seed to clover and mulch with hay similar to highway construction crews.

- Most of our forest has a predeveloped road system and we are in the process of upgrading most of our haul roads to include all necessary options and surfacing where necessary. We use our contracts to force contractors to replace all damaged diversion options.

- I have not differentiated between open or closed because we are required by our County Board to keep all access roads on county lands open to public use. We do use gates to control access during breakup.

East/Central Canada

Q.2

- The SE corner of Manitoba is very flat and therefore there is little need for diversions. Emphasis is placed on access in riparian areas and stream crossings where erosion is a concern. Closed roads are rehabilitated as soon as possible to ensure that productive land base is not lost.

Q.9

- Our biggest problem is crossing water and ensuring that no particulates enter the watercourse in order to prevent damage to fish habitat. The challenge has been to ensure proper techniques of crossing with heavy equipment (e.g., portable bridges, mats).

MISCELLANEOUS

- We crown and ditch all forest logging roads. Roads are never closed, always open. When conditions require, slash/log water bars would be used on skid roads/trails to prevent water from reaching main haul roads.

- You should contrast the [guidelines and regulations] of MNRs [Ministries of Natural Resources] of Quebec and Ontario . FERIC [Forest Engineering Research Institute of Canada] has developed some innovative techniques and would be happy to communicate to the users your methods or options.

- Our use of diversion options is [limited to] crowning of haul roads and the occasional diversion in ditches on approaches to water bodies. Have these options been developed in the US as a result of regulations or are they voluntary?

- We build roads to harvest product. Once harvest is finished, roads are passed to Crown. Please send us information on options available.

- We are just beginning to address concerns with water diversion on access roads and trails with logging operators. Cross drainage metal or wood culverts have been historically used by industry for water diversion.

Western Canada

Q.2

- Roads and trails are either physically or naturally abandoned. Diversions in place are left. Where physical abandonment is required, water crossings are usually removed, but diversions are left.

Q.4

- No construction is done on skid trails. We mainly rely on good selection of trail location, putting natural topography to good use. No water bars are installed on closed roads/trails. Pre-existing options are left in place.

Q.6a

- We are using less and less skid trails and more hoe chucking, which requires little or no [trail construction] except for slash laid across wet areas, followed by complete restoration/deactivation.

Q.8

- These techniques are seldom used in the Canadian West Coast environment. Roads are constructed and usually totally deactivated (recontoured) as soon as logging is completed.
- Skid roads/trails are seldom used in coastal British Columbia – skidders are not used much. Temporary trails are constructed immediately before logging, then completely restored, with ripped surface and redistribution of stockpiled topsoil.
- No skidding allowed during heavy rains as we have too many fish streams. All work is done with back hoes – bulldozers are almost obsolete. Our skidding on Vancouver Island is on flat to rolling terminal moraine; we have a 30% slope restriction [for road construction?]. Various remedial activities usually happen after an event rather than as preventive measures. But we are improving.

MISCELLANEOUS

- We try to gravel roads on thin, silty, sandy or clay soils. This minimizes impact of water movement on/off the road. Use cross drainage or culverts where they are needed.
- We have been combining decompaction (up to 50 cm deep) in a patch application or broadcast seeding in combination with drainage control on closed roads. Seeding helps disperse water and increase infiltration.
- Geomembrane under gravel to keep diffuse (seepage) flow through road prism of active haul roads.
- Roads are designed for 150 T [trucks]; cable logging systems are the norm. Road construction and water management are tightly regulated by British Columbia Forest Practices Code.
- We have rain water ranging from [39–394 in]. Our roads have grades up to 24% (ballasted). Snowpacks can be as high as [27 ft]. We have a coastal plain which is elevated sea floor and/or terminal moraine, which is another set of parameters. Our loads range from 40 Tonnes highway to 100 T off-highway.

Appendices

A. The Survey

Office (612) 624-3788
E-Mail: cblinn@forestry.umn.edu

February 17, 1999

FIELD(add1) FIELD(firstname)FIELD(lastname)
FIELD(Company)
FIELD(company2)
FIELD(address1)
FIELD(address2)
FIELD(City)FIELD(State)FIELD(Zip)

Dear FIELD(add1) FIELD(lastname):

There are a variety of options for diverting water off of access roads and skid trails during and after timber harvesting operations. While some of those options are identified in Best Management Practices (BMP) or similar forest practice guideline manuals, others have not been promoted.

The enclosed survey will help us identify information about the various options for diverting water off of active and closed (post-sale) haul roads and skid roads or trails as a part of timber harvesting operations. Some of the more common types of diversion options are defined in an enclosed summary sheet on blue paper. If you identify any additional diversion options not described on the summary sheet, please include an illustration and/or description of each option with your response. If you are unable to answer the questions included within the survey, please forward it to someone else within your organization who can complete and return it by 30 April 1999.

The results of this survey will be used to expand the information presented within our on-the-ground BMP educational programming. If you would like a copy of the summary report, please circle the appropriate response on the Survey Respondent Information Form. The identification number associated with each form is for record-keeping purposes only; all personal information will be kept confidential.

For your convenience, this survey is also available online on the University of Minnesota College of Natural Resources website, at: www.cnr.umn.edu/FR/research/surveys/water_diversion_survey.htm.

We appreciate your participation in this survey. If you have any questions, please contact us.

Sincerely,

Charles R. Blinn
Professor and Extension Specialist

Karen Updegraff
Graduate Research Assistant

Enclosures

Survey Respondent Information

Name:

Position Title:

Primary job responsibility:

Extent of your jurisdictional area (e.g., statewide, provincial):

Organization name:

Mailing address:

Voice telephone number:

FAX telephone number:

E-mail address:

Date:

Would you like to receive a summary of the results of this study? No ? Yes ?

Please return your completed survey to:
Charles Blinn
Department of Forest Resources
University of Minnesota
1530 Cleveland Avenue North
St. Paul, MN 55108
Thank you for your participation

Water Diversion Options used During and after Timber Harvesting Operations

For each question below, please consider the state, province, or jurisdictional area in which you work when answering the question. **Whenever you indicate a water diversion option that is not defined within the survey (i.e., an "other" option), please provide descriptive information about that option (e.g., drawings, information from BMP or forest practice guideline manual, written description).** Please use additional space if needed.

1. How frequently are water diversion options used on active and closed **haul roads** and **skid roads and trails** as a part of timber harvesting operations?

Road or trail status	Frequency of use (place an X in the appropriate column for each option)*			
	Often	Moderate use	Little use	Not at all
Active haul roads				
Closed haul roads				
Active skid roads and trails				
Closed skid roads and trails				

* Often - more than 70% of the time, Moderate - 41 to 70%, Little use - 1 to 40%, Not at all - 0%.

2. When water diversion options are not used or little used (1 to 40%), what are the most frequently cited reasons? Please rank your response so that 1 = most frequently cited reason and 10 = least frequently cited.

_____ Landowner or forester lack of awareness for the need to install water diversions
_____ Logger lack of awareness for the need to install water diversions
_____ Limited awareness of the water diversion options available
_____ Landowner or forester does not require installation of water diversion devices
_____ Disregard for the need to install water diversion devices
_____ Concern about the cost to install water diversion devices (real or imagined)
_____ Site conditions prevent the installation of the water diversion devices
_____ Concern about liability exposure from recreational users of roads or trails
_____ Lack of knowledge about how to install options
_____ Other (please specify):

3 (a). On **active haul roads** when the soil is not frozen, indicate the relative frequency of use for each of the water diversion options listed by placing an "X" in the appropriate column. Refer to the summary of diversion options (blue sheet) for descriptions of each option.

Option	Frequency of use (place an X in one column below for each option)*			
	Often	Moderate use	Little use	Not at all
A. Earth berm water bars				
B. Broad-based dips				
C. Slash water bars				
D. Log water bars				
E. Straw bales				
F. Open-top culverts				
G. Road crowning				
H. Road outsloping				
I. Road insloping				
J. Other (please specify)				
K. Other (please specify)				
L. Other (please specify)				

* Often - more than 70% of the time, Moderate - 41 to 70%, Little use - 1 to 40%, Not at all - 0%

3 (b). Which of the options listed in 3(a) is the most effective on **active haul roads** when the soil is not frozen (circle letter)?

A B C D E F G H I J K L

+ (a). On **active skid roads and trails** when the soil is not frozen, indicate the relative frequency of use for each of the water diversion options listed below by placing an "X" in the appropriate column.

Option	Frequency of use (place an X in the appropriate column for each option)*			
	Often	Moderate use	Little use	Not at all
A. Earth berm water bars				
B. Broad-based dips				
C. Slash water bars				
D. Log water bars				
E. Straw bales				
F. Open-top culverts				
G. Road crowning				
H. Road outsloping				
I. Road insloping				
J. Other (please specify)				
K. Other (please specify)				
L. Other (please specify)				

* Often - more than 70% of the time, Moderate - 41 to 70%, Little use - 1 to 40%, Not at all - 0%

+ (b). Which of the above options is the most effective on **active skid roads and trails** when the soil is not frozen (circle letter)?

A B C D E F G H I J K L

5 (a). On **closed (post-sale) haul roads** when the soil is not frozen, indicate the relative frequency of use for each of the water diversion options listed by placing an "X" in appropriate column.

Option	Frequency of use (place an X in the appropriate column for each option)*			
	Often	Moderate use	Little use	Not at all
A. Earth berm water bars				
B. Broad-based dips				
C. Slash water bars				
D. Log water bars				
E. Straw bales				
F. Open-top culverts				
G. Road crowing				
H. Road outsloping				
I. Road insloping				
J. Other (please specify)				
K. Other (please specify)				
L. Other (please specify)				

* Often - more than 70% of the time, Moderate - 41 to 70%, Little use - 1 to 40%, Not at all - 0%

5 (b). Which of the above options is the most effective on **closed (post-sale) haul roads** when the soil is not frozen (circle letter)?

A B C D E F G H I J K L

6 (a). On **closed (post-sale) skid roads and trails** when the soil is not frozen, indicate the relative frequency of use for each of the water diversion options listed below by placing an "X" in the appropriate column.

Option	Frequency of use (place an X in the appropriate column for each option)*			
	Often	Moderate use	Little use	Not at all
A. Earth berm water bars				
B. Broad-based dips				
C. Slash water bars				
D. Log water bars				
E. Straw bales				
F. Open-top culverts				
G. Road crowing				
H. Road outsloping				
I. Road insloping				
J. Other (please specify)				
K. Other (please specify)				
L. Other (please specify)				

* Often - more than 70% of the time, Moderate - 41 to 70%, Little use - 1 to 40%, Not at all - 0%

6 (b). Which of the above options is the most effective on **closed (post-sale) skid roads and trails** when the soil is not frozen (circle letter)?

A B C D E F G H I J K L

7 . For each of the individual water diversion options listed below describe the operating and site conditions on active and closed **haul roads** when the option is most effective. Consider factors such as maximum degree of slope, soil type, season of activity or installation, equipment available during installation, equipment used during the timber harvest, and amount of water to be diverted.

A. Earth berm water bars

Active:

Closed:

B. Broad–based dips

Active:

Closed:

C. Slash water bars

Active:

Closed:

D. Log water bars

Active:

Closed:

E. Straw bales

Active:

Closed:

F. Open–top culverts

Active:

Closed:

7. (continued)

G. Road insloping

Active:

Closed:

H. Road outsloping

Active:

Closed:

I. Road crowning

Active:

Closed:

J. Other (please specify):

Active:

Closed:

K. Other (please specify):

Active:

Closed:

L. Other (please specify):

Active:

Closed:

8 . For each of the individual water diversion options listed below describe the operating and site conditions on active and closed **skid roads and trails** when the option is most effective. Consider factors such as maximum degree of slope, soil type, season of activity or installation, equipment available during installation, equipment used during the timber harvest, and amount of water to be diverted.

A. Earth berm water bars

Active:

Closed:

B. Broad–based dips

Active:

Closed:

C. Slash water bars

Active:

Closed:

D. Log water bars

Active:

Closed:

E. Straw bales

Active:

Closed:

F. Open–top culverts

Active:

Closed:

B. (continued)

G. Road insloping

Active:

Closed:

H. Road outsloping

Active:

Closed:

I. Road crowning

Active:

Closed:

J. Other (please specify):

Active:

Closed:

K. Other (please specify):

Active:

Closed:

L. Other (please specify):

Active:

Closed:

9. For each of the water diversion options listed below describe any special problems associated with their **installation** on either active or closed haul roads or skid roads/trails (please note which type of road and whether active or closed).

A. Earth berm water bars

B. Broad-based dips

C. Slash water bars

D. Log water bars

E. Straw bales

F. Open-top culverts

G. Road crowning

H. Road outsloping

I. Road insloping

J. Other (please specify):

K. Other (please specify):

L. Other (please specify):

10. Please describe any special problems associated with the **maintenance** of the each of the water diversion options listed below, when installed on either active or closed haul roads or skid roads/trails (please note which type of road and whether active or closed).

    A. Earth berm water bars

    B. Broad-based dips

    C. Slash water bars

    D. Log water bars

    E. Straw bales

    F. Open-top culverts

    G. Road crowning

    H. Road outsloping

    I. Road insloping

    J. Other (please specify):

    K. Other (please specify):

    L. Other (please specify):

11. Which of the water diversion options listed below are used in areas where the road or trail surface is cut lower than the surrounding landscape, making it difficult to immediately divert water off of the road? Place an "A" in front of all options which are applicable to **active** roads and a "C" in front of all options applicable to **closed** roads. Then, circle the letter(s) placed in front of the option(s) which are **most effective** in each situation. (i.e. A circled "A" would indicate that that option was the most effective on **active** roads).

_____ Earth berm water bars
_____ Broad-based dips
_____ Slash water bars
_____ Log water bars
_____ Straw bales
_____ Open-top culverts
_____ Road crowning
_____ Road outsloping
_____ Road insloping
_____ Water diversion structures in combination with a lead-off ditch
_____ Diversion structures in combination with roadside ditching
_____ Place fill to raise parts of the road surface above the surrounding landscape
_____ Other (please specify):
_____ Other (please specify):

12. Which of the water diversion options listed below are used on frozen and/or thin soils (over rock)? Place an "A" in front of all options which are applicable to **active** roads and a "C" in front of all options applicable to **closed** roads. Then, circle the letter(s) placed in front of the option(s) which are **most effective** in each situation. (i.e. A circled "A" would indicate that that option was the most effective on **active** roads).

_____ Earth berm water bars
_____ Broad-based dips
_____ Slash water bars
_____ Log water bars
_____ Straw bales
_____ Open-top culverts
_____ Road crowning
_____ Road outsloping
_____ Road insloping
_____ Other (please specify):
_____ Other (please specify):

13. If there is anything else you would like us to know about water diversion options, please write your comments here or on a separate sheet of paper.

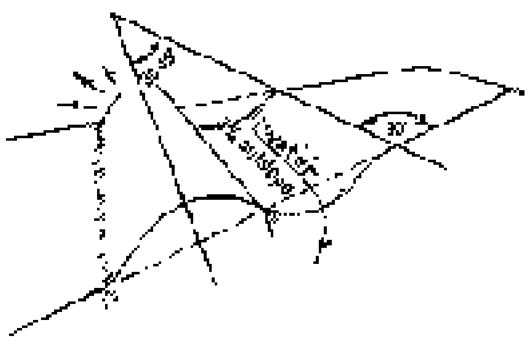
Thank you for your time and cooperation. Please return this completed survey to:

Charles Blinn
Department of Forest Resources
University of Minnesota
1530 Cleveland Avenue North
St. Paul, MN 55108

B. Definitions of Options

Options Included in the Survey

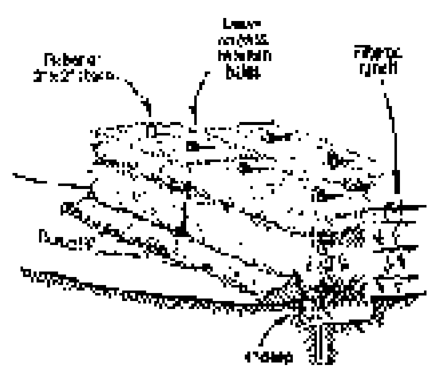
1. Earth Berm Water Bars: Narrow, earthen ridges built across roads or trails to divert water into vegetated areas at the side of the road.



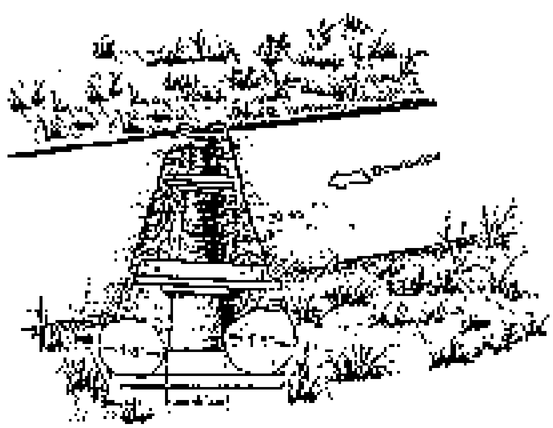
2. Broad-Based Dips: Gentle waves in the surface of forest roads. Water flows into the bottom of the dip and drains into vegetated areas at the side of the road.

3. Slash/Log Water Bars: Strips of piled logging debris placed across road surfaces to divert water into vegetated areas at the side of the road. The distinction is in the size of material used, with logs being larger-diameter material.

4. Straw Bales: Tightly packed, staked bales of straw used to filter runoff and to divert water into vegetated areas at the side of the road.



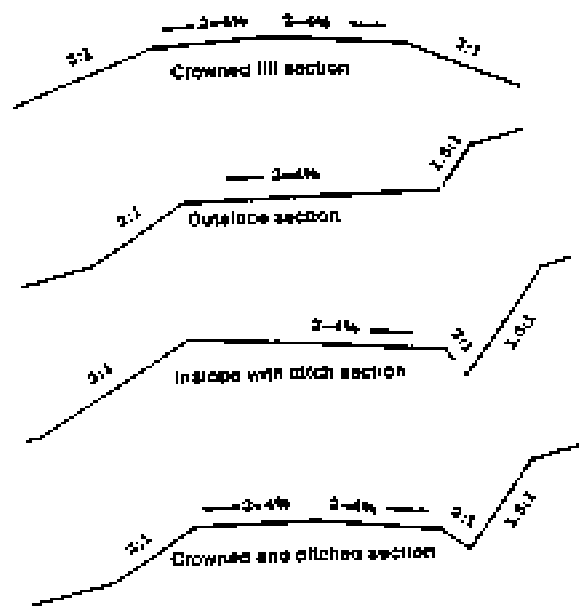
5. Open-Top Culvert: A drainage channel built to permit water movement across temporary roads and to divert water into vegetated areas at the side of the road. The channel is reinforced with two parallel logs connected with lumber to allow traffic movement. *Source: MN DNR 1995*[1].



6. Road Shaping: Shaping road surfaces so that water runs off the road and into vegetated areas at the side of the road.

- Crowning: sloped from the center to the outside.
- Insloping: sloped out to the downhill side.
- Outsloping: sloped into the uphill side

Source: MN DNR 1995[1].

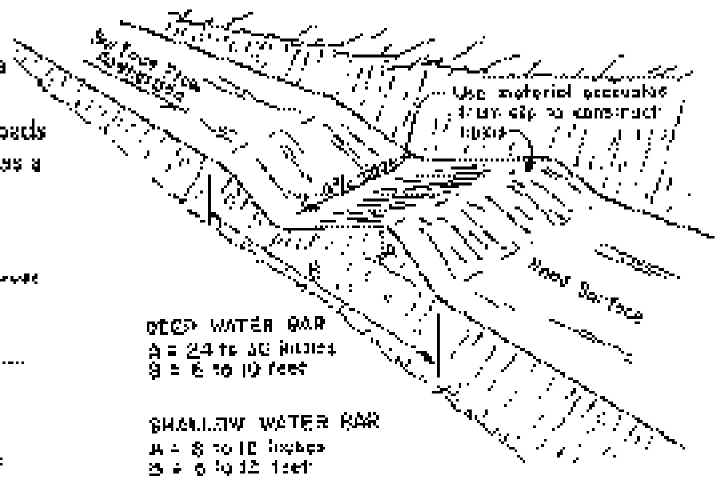


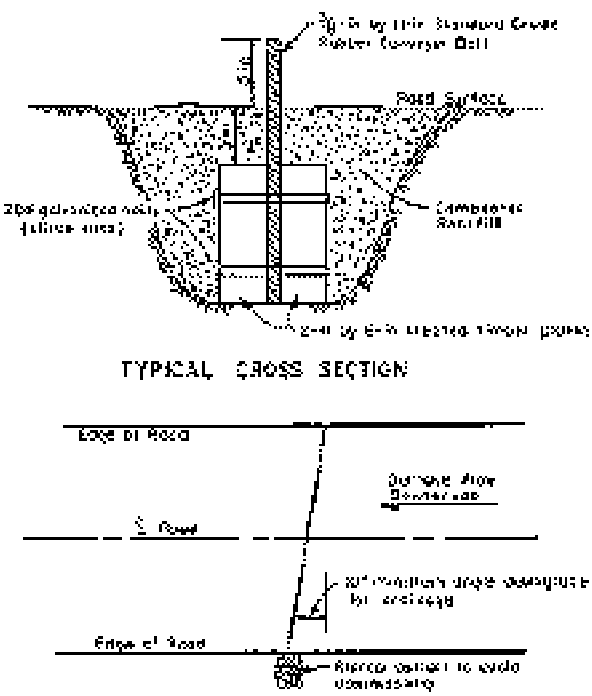
Additional Options

Berm directs water across contoured land, slowing flow and keeping water away from stream.

7. Lead-off Ditches: These ditches avoid draining water that is diverted from the road directly into lakes, streams or open-water wetlands. Instead, water is guided into a filter strip or vegetated area. Lead-off ditches may also be called spreader ditches or diversion ditches. *Source: MN DNR 1995*[1].

8. Types of Earth Berm Water Bars: On closed roads the "deep" water bar is typically constructed, while on active roads the "shallow" variant (also referred to as a rolling dip or Utah dip) may be used. *Source: Wiest 1998*[7].

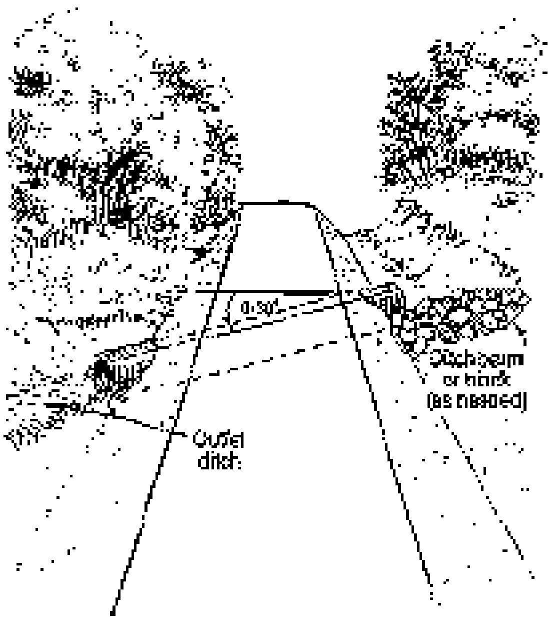




TYPICAL CROSS SECTION

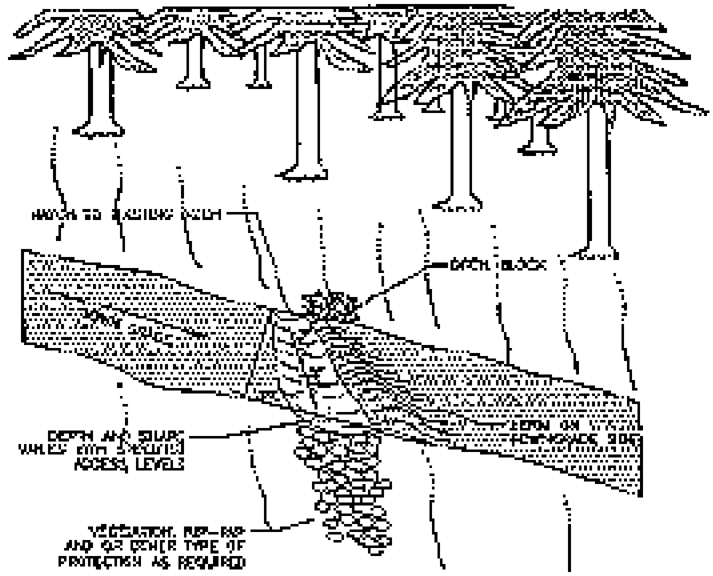
TYPICAL PLAN VIEW

9. Conveyor belt water bars: Also referred to as deflectors or "flappers", these are a low-cost, low maintenance method to deflect surface water off a roadway. The deflector is simply a piece of rubber belting fastened between treated timbers, with about 3 in of rubber exposed above the road surface. They can be used on grades over 10%. *Source: Wiest 1998*[7].



Angle of culvert placement for low-velocity flows may be less than 30°.

10. **Cross-Drainage Culverts:** Culverts should be installed at grades 2% more than ditch grade and angled at least 30 degrees from perpendicular to the flow of the water, with armored inlets and outlets. *Source: MN DNR, 1995*[1].



11. **Cross-Ditches:** Ditches are excavated across a road at an angle and with sufficient depth to divert both road surface water and ditch water off or across the road. They may be used to replace cross-drainage culverts on road closure. The ditches should be skewed by 3 degrees from the road centerline and provided with a ditch block on the downslope side. *Source: BC MOF, 1997*[4].

Notes

[1] Minnesota Department of Natural Resources, Division of Forestry. 1995. Protecting Water Quality and Wetlands in Forest Management: Best Management Practices in Minnesota.

[2] University of Minnesota Extension Service. 1998. Using logging debris or logs to build water bars. *Forest Management Practices Fact Sheet. Managing Water Series #4.*

[3] Wiest, R.L. 1998. A Landowner's Guide to Building Forest Access Roads. Technical Publication NA-TP-06-98. USDA Forest Service, Northeastern Area State and Private Forestry. 45 p.

[4] Province of British Columbia Ministry of Forests. Kamloops Forest Region. 1997. Typical Road Deactivation Prescriptions Drawing No. 012094-00-05-2.

C. Survey Tabulation

Q. 1. Overall frequency of use of water diversion options.

Table C.1: Relative use frequencies of water diversions: actual number of responses for each category by region.

Type of Road	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
US Mountain States (n=33)					
Active Haul	21	9	3	0	0
Closed Haul	27	5	1	0	0
Active Skid	10	7	13	3	0
Closed Skid	23	5	5	0	0
US West Coast (n=19)					
Active Haul	14	1	4	0	0
Closed Haul	18	0	1	0	0
Active Skid	10	2	6	1	0
Closed Skid	17	2	0	0	0
Southern US (n=17)					
Active Haul	12	1	4	0	0
Closed Haul	12	3	1	1	0
Active Skid	9	2	6	0	0
Closed Skid	11	1	5	0	0
Eastern US (n=40)					
Active Haul	9	17	12	2	0
Closed Haul	14	11	14	1	0
Active Skid	2	11	25	2	0
Closed Skid	11	10	18	1	0
East/Central Canada (n=20)					
Active Haul	8	4	4	4	0
Closed Haul	5	0	8	7	0
Active Skid	0	5	6	7	2
Closed Skid	0	1	7	10	2
Western Canada (n=12)					
Active Haul	5	3	2	2	0
Closed Haul	11	1	0	0	0
Active Skid	2	3	4	2	1
Closed Skid	5	4	1	1	1

Q2. Most frequently cited reasons for non-use of water diversion options.

The following are the reasons listed in the survey for non-use of water diversion options.

A. Landowner or forester lack of awareness of the need to install water diversions.
B. Logger lack of awareness of the need to install water diversions.
C. Limited awareness of the water diversion options available.
D. Landowner or forester does not require installation of water diversion devices.
E. Disregard for the need to install water diversion devices.
F. Concern about the cost of installation of water diversion devices (real or imagined).
G. Site conditions prevent the installation of water diversion devices.
H. Concern about liability exposure from recreational users of roads or trails.
I. Lack of knowledge about how to install option.
J. Other (please specify).

Table C.2: Reasons most frequently cited for not using water diversion structures on roads or trails. A rating of 1 means that reason was the most frequently cited according to the indicated number of respondents in each reason, while a rating of 10 indicates that the reason was the least frequently cited.

	FREQUENCY RATING											
Reason	1	2	3	4	5	6	7	8	9	10	Unrated	Blank
US Mountain States (n=23)												
A	1	1	1	0	2	2	1	1	0	6	0	8
B	2	2	1	4	1	0	1	3	0	3	0	6
C	0	1	2	1	3	1	2	1	1	4	0	7
D	6	0	3	1	0	1	1	1	1	2	1	6
E	2	3	2	1	1	2	1	1	0	4	1	6
F	2	1	2	2	3	0	1	2	0	3	0	7
G	6	3	3	1	0	0	2	2	0	1	0	5
H	0	0	0	1	1	0	0	2	7	6	0	6
I	1	1	2	1	1	2	2	0	2	5	0	6
J	6	2	0	0	0	1	0	0	0	3	4	7
US West Coast (n=14)												
A	0	0	0	1	0	1	0	0	0	2	0	10
B	1	1	0	0	1	0	0	0	0	2	0	9
C	0	0	0	2	1	1	0	0	0	1	1	8
D	0	0	1	0	0	0	1	0	1	2	1	8
E	0	1	0	0	1	0	0	0	0	2	2	8
F	1	0	0	0	1	0	1	0	0	1	2	8
G	1	1	0	0	0	0	0	4	0	0	2	6
H	0	0	0	0	0	0	0	1	2	1	1	9
I	0	1	2	0	0	0	0	0	0	2	0	9
J	1	0	0	0	0	0	0	0	1	0	2	10

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Table 2, continued

	FREQUENCY RATING										
Reason	1	2	3	4	5	6	7	8	9	10	Unrated	Blank
US Mountain States												
Southern US (n=12)												
A	0	2	1	0	0	2	1	0	0	0	0	6
B	2	2	0	0	2	0	0	0	0	0	0	6
C	0	0	1	1	1	0	2	0	0	0	0	7
D	2	0	0	3	0	0	0	1	0	0	1	5
E	3	0	2	0	0	0	1	0	0	0	0	6
F	0	1	2	0	2	1	0	0	0	0	0	6
G	0	1	0	1	0	0	0	3	0	0	0	7
H	0	0	0	0	0	0	0	1	4	0	0	7
I	0	2	1	0	0	2	1	0	1	0	0	4
J	3	0	1	0	0	0	0	0	0	0	2	6
Eastern US (n=34)												
A	1	2	2	2	5	1	4	3	2	3	0	9
B	4	5	2	2	2	3	2	1	1	3	0	9
C	2	1	4	2	2	4	3	2	0	4	0	10
D	6	6	3	372	0	1	2	0	2	0	9	
E	5	2	1	1	3	0	3	3	3	6	0	9
F	2	2	4	2	1	3	2	3	3	3	0	0
G	4	3	1	1	1	3	1	3	5	3	1	8
H	8	0	1	0	1	0	1	4	5	8	0	12
I	0	3	3	4	2	0	1	3	3	5	0	10
J	14	1	0	0	2	0	0	2	0	2	1	12
East/Central Canada (n=23)												
A	2	1	2	0	2	4	1	1	0	0	0	4
B	3	2	2	3	2	0	2	0	0	0	0	3
C	1	2	3	1	2	0	0	3	0	1	0	4
D	2	3	0	1	2	1	0	3	2	0	0	4
E	5	2	0	1	3	0	1	1	0	1	0	3
F	3	0	3	1	3	1	1	2	1	0	0	2
G	0	3	0	0	0	2	3	1	3	3	0	2
H	2	0	2	2	2	0	1	1	3	0	0	4
I	1	3	0	1	3	1	1	1	0	2	0	4
J	4	1	2	0	0	0	0	0	0	1	3	7
Western Canada (n=10)												
A	1	0	0	2	0	1	2	0	0	0	0	4
B	3	0	1	1	0	0	1	0	0	0	1	3
C	0	1	1	1	0	0	1	1	0	0	1	4
D	1	1	2	2	0	0	0	0	0	0	1	3
E	0	2	1	0	2	0	0	0	0	0	1	4
F	0	2	1	0	1	1	1	0	0	0	1	3

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Table 2, continued

	FREQUENCY RATING											
Reason	1	2	3	4	5	6	7	8	9	10	Unrated	Blank
US Mountain States												
G	1	0	0	0	0	2	0	1	0	0	0	6
H	0	0	0	1	1	0	0	2	1	0	0	5
I	0	0	0	0	0	1	0	0	3	1	1	4
J	2	0	0	0	0	0	0	0	0	0	2	6

Q. 3(a). Relative frequencies with which water diversion options are used on active haul roads.

The following are the water diversion options listed in the survey:

EWB Earth berm water bars.
BBD Broad-based dips.
SWB Slash water bars.
LWB Log water bars.
SB Straw bales.
OTC Open-top culverts.
RC Road crowning.
RO Road outsloping.
RI Road insloping.
Other Unlisted options.

Table C.3: Relative frequency of use of water diversion options on active haul roads that are not frozen. Data are the actual number of responses marked in each category (N=138).

Option	USE FREQUENCY				
	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
US Mountain States (n=32)					
EWB	6	7	11	7	1
BBD	15	11	3	3	0
SWB	0	1	4	24	3
LWB	0	0	6	23	3
SB	0	1	6	23	2
OTC	2	3	10	16	1
RC	7	11	6	5	3
RO	13	15	3	1	0
RI	8	14	9	0	1
Other	2	3	3	0	24
US West Coast (n=19)					
EWB	3	2	7	6	1
BBD	6	6	5	2	0
SWB	1	0	1	15	2
LWB	0	0	1	16	2
SB	2	1	2	12	2
OTC	1	0	3	13	2
RC	11	3	3	2	0
RO	13	4	2	0	0
RI	10	4	4	0	1

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Table C.3, continued

Option	USE FREQUENCY Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
Other	2	0	1	0	16
Southern US (n=17)					
EWB	7	1	9	0	0
BBD	0	3	5	0	0
SWB	1	1	1	13	1
LWB	1	0	3	12	1
SB	1	4	8	4	1
OTC	1	0	6	9	1
RC	9	4	3	1	0
RO	8	3	5	0	1
RI	5	1	7	1	3
Other	1	0	2	0	14
Eastern US (n=39)					
EWB	2	5	18	12	2
BBD	4	5	22	6	2
SWB	2	4	8	24	1
LWB	2	1	8	26	2
SB	0	0	14	23	2
OTC	0	0	10	26	3
RC	21	11	7	0	0
RO	11	16	10	2	0
RI	8	18	11	2	0
Other	5	5	5	0	24
East/Central Canada (n=19)					
EWB	1	0	5	12	1
BBD	2	1	0	14	2
SWB	0	3	5	10	2
LWB	1	2	5	10	1
SB	0	2	6	10	1
OTC	0	1	4	13	1
RC	14	1	1	2	1
RO	4	3	5	6	1
RI	3	3	5	6	2
Other	6	1	0	0	12
Western Canada (n=12)					
EWB	1	2	2	4	3
BBD	1	2	5	1	3
SWB	0	1	1	7	3
LWB	0	1	0	8	3
SB	0	1	3	5	3

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Table C.3, continued

Option	USE FREQUENCY				
	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
OTC	0	1	4	4	3
RC	4	4	2	0	2
RO	3	4	4	0	1
RI	4	4	3	0	1
Other	5	1	0	0	6

Q. 3(b). Which of the options in 3(a) is most effective on active haul roads?

Table C.4: Frequency with which options were rated most effective for active haul roads (N=135).

Region	Option									
	EWB	BBD	SWB	LWB	SB	OTC	RC	RO	RI	Other
US Mountain States	4	21	1	0	0	1	5	8	7	2
US West Coast	1	10	0	0	0	0	8	7	6	1
Southern US	2	14	0	0	0	1	1	2	1	3
Eastern US	2	7	0	0	0	0	27	8	5	8
East/Central Canada	1	0	0	0	0	0	10	1	1	9
Western Canada	0	1	0	0	0	0	4	3	2	4

Q. 4(a). Relative frequencies with which water diversion options are used on active skid trails.

The following are the water diversion options listed in the survey:

EWB Earth berm water bars.
BBD Broad-based dips.
SWB Slash water bars.
LWB Log water bars.
SB Straw bales.
OTC Open-top culverts.
RC Road crowning.
RO Road outsloping.
RI Road insloping.
Other Unlisted options.

Table C.5: Relative frequency of use of water diversion options on active skid trails that are not frozen. Data are the actual number of responses marked for each category (N=138).

Option	USE FREQUENCY				
	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
US Mountain States (n=33)					
EWB	9	7	9	6	2
BBD	5	3	12	12	1
SWB	2	10	6	13	2
LWB	0	2	12	16	3
SB	0	1	4	24	4
OTC	0	1	5	23	4
RC	0	3	2	24	4
RO	3	9	6	13	2
RI	0	3	8	18	4
Other	1	2	1	0	29
US West Coast (n=18)					
EWB	6	2	3	6	1
BBD	2	4	5	6	1
SWB	1	1	3	12	1
LWB	0	2	3	12	1
SB	1	1	3	12	1
OTC	0	0	2	13	3
RC	1	0	3	12	2
RO	2	2	8	4	2
RI	1	0	6	9	2

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Table C.5, continued

Option	USE FREQUENCY Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
Other	3	3	0	0	12
Southern US (n=17)					
EWB	9	3	4	1	0
BBD	1	3	8	2	3
SWB	1	4	4	7	1
LWB	1	0	3	11	2
SB	0	2	7	7	1
OTC	0	0	1	13	3
RC	0	0	6	8	3
RO	3	2	6	5	1
RI	0	1	5	6	5
Other	0	0	1	0	16
Eastern US (n=39)					
EWB	3	6	18	10	2
BBD	1	7	16	12	3
SWB	4	5	19	11	0
LWB	1	2	13	20	3
SB	0	0	9	28	2
OTC	0	0	9	28	2
RC	0	2	10	24	3
RO	3	7	10	17	2
RI	1	4	14	17	3
Other	2	3	3	0	31
East/Central Canada (n=19)					
EWB	0	2	2	11	2
BBD	0	2	2	13	2
SWB	0	4	4	9	2
LWB	0	4	4	9	2
SB	0	2	2	13	2
OTC	0	1	3	13	2
RC	0	0	1	15	3
RO	0	0	1	15	2
RI	0	0	1	15	3
Other	2	2	0	0	15
Western Canada (n=12)					
EWB	2	0	7	2	1
BBD	1	3	3	2	3
SWB	0	1	3	5	3
LWB	0	1	3	5	3
SB	0	0	2	6	4

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Table C.5, continued

Option	USE FREQUENCY				
	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
OTC	0	1	2	6	3
RC	0	1	3	6	2
RO	2	2	2	5	1
RI	0	2	3	5	2
Other	1	0	0	0	11

Q. 4(b). Which of the options in 4(a) is most effective on active skid trails?

Table C.6: Frequency with which options were rated most effective for active skid trails (N=119).

Region	Option									
	EWB	BBD	SWB	LWB	SB	OTC	RC	RO	RI	Other
US Mountain States	12	9	5	1	0	0	0	8	1	3
US West Coast	7	2	3	0	1	0	1	3	1	4
Southern US	12	3	0	0	1	0	0	1	0	1
Eastern US	11	6	15	4	0	1	1	5	0	6
East/Central Canada	2	0	5	0	0	0	0	1	1	1
Western Canada	2	3	0	1	0	1	1	5	2	0

Q. 5(a). Relative frequencies with which water diversion options are used on closed haul roads.

The following are the water diversion options listed in the survey:

EWB Earth berm water bars.
BBD Broad-based dips.
SWB Slash water bars.
LWB Log water bars.
SB Straw bales.
OTC Open-top culverts.
RC Road crowning.
RO Road outsloping.
RI Road insloping.
Other Unlisted options.

Table C.7: Relative frequency of use of water diversion options on closed haul roads that are not frozen. Data are the actual number of responses marked for each category (N=136).

Option	USE FREQUENCY				
	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
US Mountain States (n=33)					
EWB	17	9	4	2	1
BBD	9	16	4	2	2
SWB	2	6	6	16	3
LWB	2	0	7	20	4
SB	0	0	5	23	5
OTC	0	3	6	20	4
RC	3	7	8	9	6
RO	11	13	6	3	0
RI	6	9	10	4	4
Other	10	4	1	0	18
US West Coast (n=19)					
EWB	18	0	1	0	0
BBD	5	10	3	1	0
SWB	0	0	1	15	3
LWB	0	0	2	14	3
SB	2	0	3	12	2
OTC	1	0	0	15	3
RC	5	3	6	3	2
RO	10	6	2	0	1
RI	5	6	4	2	2

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Table C.7, continued

Option	USE FREQUENCY Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
Other	5	1	1	0	12
Southern US (n=16)					
EWB	9	3	4	0	0
BBD	4	5	4	1	2
SWB	1	2	3	8	2
LWB	0	1	4	8	3
SB	0	2	5	6	3
OTC	0	0	5	8	3
RC	3	3	5	2	3
RO	5	2	6	1	2
RI	3	1	5	4	3
Other	1	0	1	0	14
Eastern US (n=39)					
EWB	13	9	12	3	2
BBD	6	5	16	10	2
SWB	0	13	9	16	1
LWB	1	5	14	17	2
SB	1	1	15	20	2
OTC	0	1	9	27	2
RC	12	14	7	5	1
RO	7	14	12	5	1
RI	4	17	12	5	1
Other	9	4	6	0	20
East/Central Canada (n=17)					
EWB	2	0	3	10	2
BBD	2	2	0	12	2
SWB	2	1	2	10	2
LWB	1	1	3	10	2
SB	1	1	3	10	2
OTC	0	0	0	15	2
RC	2	1	3	9	2
RO	1	0	3	11	2
RI	1	1	2	11	2
Other	3	0	0	0	14
Western Canada (n=12)					
EWB	9	3	0	0	0
BBD	4	3	4	0	1
SWB	1	0	1	7	3
LWB	0	0	2	7	3
SB	0	1	2	6	3

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Table C.7, continued

Option	USE FREQUENCY Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
OTC	2	4	4	1	1
RC	2	6	3	0	1
RO	2	5	4	0	1
RI	4	0	2	0	6
Other	2	0	0	0	10

Q. 5(b). Which of the options in 5(a) is most effective on closed haul roads?

Table C.8: Frequency with which options were rated most effective for closed haul roads (N=126).

Region	Option EWB	BBD	SWB	LWB	SB	OTC	RC	RO	RI	Other
US Mountain States	14	7	2	1	0	1	4	6	4	7
US West Coast	16	5	0	0	1	0	4	5	3	4
Southern US	13	3	0	0	0	0	0	2	0	1
Eastern US	20	7	5	1	0	0	11	3	1	10
East/Central Canada	2	1	0	0	2	0	4	0	1	3
Western Canada	6	2	0	0	0	0	1	2	0	4

Q. 6(a). Relative frequencies with which water diversion options are used on closed skid trails.

The following are the water diversion options listed in the survey:

EWB Earth berm water bars.
BBD Broad-based dips.
SWB Slash water bars.
LWB Log water bars.
SB Straw bales.
OTC Open-top culverts.
RC Road crowning.
RO Road outsloping.
RI Road insloping.
Other Unlisted options.

Table C.9: Relative frequency of use of water diversion options on closed skid trails that are not frozen. Data are the actual number of responses marked for each category (N=137).

Option	USE FREQUENCY				
	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
US Mountain States (n=33)					
EWB	26	3	3	1	0
BBD	4	7	9	11	2
SWB	7	12	3	10	1
LWB	2	1	11	15	4
SB	0	1	6	22	4
OTC	0	0	5	23	5
RC	0	2	5	21	5
RO	7	6	8	12	0
RI	3	1	9	16	4
Other	9	5	1	0	18
US West Coast (n=19)					
EWB	18	1	0	0	0
BBD	2	5	5	6	1
SWB	2	3	3	10	1
LWB	0	3	4	10	2
SB	1	0	3	13	2
OTC	0	0	0	16	3
RC	1	0	0	15	3
RO	4	6	1	6	2
RI	0	3	3	10	3

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Table C.9, continued

Option	USE FREQUENCY				
	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
Other	4	0	2	0	13
Southern US (n=16)					
EWB	13	0	3	0	0
BBD	0	5	4	3	4
SWB	1	4	3	6	2
LWB	0	2	3	8	3
SB	0	1	7	5	3
OTC	0	0	1	12	3
RC	1	3	3	7	2
RO	3	2	5	4	2
RI	0	1	4	7	4
Other	1	0	0	0	15
Eastern US (n=39)					
EWB	10	6	20	2	1
BBD	2	5	18	12	2
SWB	7	10	13	9	0
LWB	2	3	19	13	2
SB	1	0	16	20	2
OTC	0	0	10	26	3
RC	0	3	11	21	4
RO	1	5	11	18	4
RI	1	1	15	18	4
Other	3	2	5	0	29
East/Central Canada (n=18)					
EWB	0	2	0	14	2
BBD	0	2	0	14	2
SWB	1	2	3	10	2
LWB	1	3	1	11	2
SB	1	2	2	11	2
OTC	0	0	0	16	2
RC	0	0	1	15	2
RO	0	0	0	16	2
RI	0	0	1	15	2
Other	1	0	0	0	17
Western Canada (n=12)					
EWB	5	5	0	2	0
BBD	0	3	2	4	3
SWB	0	2	2	5	3
LWB	0	1	1	7	3
SB	0	0	1	8	3

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Table C.9, continued

Option	USE FREQUENCY				
	Often (over 70%)	Moderate (41–70%)	Little (1–40%)	Never (0%)	Blank
OTC	0	0	2	7	3
RC	0	0	3	6	3
RO	2	2	5	2	1
RI	0	0	5	4	3
Other	4	1	0	0	7

Q. 6(b). Which of the options in 6(a) is most effective on closed skid trails?

Table C.10: Frequency with which options were rated most effective for closed skid trails (N=114).

Region	Option									
	EWB	BBD	SWB	LWB	SB	OTC	RC	RO	RI	Other
US Mountain States	20	2	6	1	0	0	1	6	2	10
US West Coast	15	1	1	0	0	0	1	3	1	3
Southern US	15	0	1	0	0	0	0	2	0	1
Eastern US	20	3	13	1	0	0	1	2	0	5
East/Central Canada	0	0	4	0	2	0	0	0	0	2
Western Canada	6	0	1	0	0	0	0	1	0	3

Q. 11. Which diversion options are used where the road or trail is below grade?

The first nine options were identical to those in questions 3–6, while the last three represent the combined options listed for Question 11. An "Other" option was also provided for this question, however, in all cases where the "Other" option was indicated it was not assigned to a specific road or trail category. Therefore the 28 instances in which "Other" options are described are summarized in Chapter 2 but not included in the tabular summary.

- EWB Earth berm water bars.
- BBD Broad-based dips.
- SWB Slash water bars.
- LWB Log water bars.
- SB Straw bales.
- OTC Open-top culverts.
- RC Road crowning.
- RO Road outsloping.
- RI Road insloping.
- DLD Diversion structures with lead-off ditch.
- DRD Diversion structures with roadside ditching.
- FILL Placement of fill to raise the road surface.

Table C.11: Frequency with which the listed option was indicated for given road or trail conditions. Data are the actual numbers of responses in each category. (N=117).

Option	Type of Road/Trail Used On			Type of Road/Trail *Best* On			Blank
	Closed	Active	Both	Closed	Active	Both	
US Mountain States (n=28)							
EWB	6	0	3	4	0	1	14
BBD	1	4	4	0	3	0	17
SWB	6	0	0	1	0	0	21
LWB	4	0	0	0	0	0	24
SB	3	1	1	0	0	0	23
OTC	0	3	1	0	1	0	23
RC	0	3	6	0	0	0	19
RO	0	2	5	0	1	0	20
RI	0	4	4	0	1	0	19
DLD	3	2	7	1	3	6	6
DRD	2	7	5	0	3	4	7
FILL	0	6	3	0	4	0	15
US West Coast (n=17)							
EWB	8	0	3	3	0	0	4
BBD	0	2	2	0	2	1	1
SWB	0	0	0	0	0	0	17

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Table C.11, continued

Option	Type of road/trail used on			Type of road/trail *best* on			Blank
	Closed	Active	Both	Closed	Active	Both	
LWB	2	0	1	0	0	0	14
SB	1	0	1	0	0	0	15
OTC	1	1	1	0	0	0	14
RC	0	2	6	0	2	0	8
RO	0	1	4	0	0	1	11
RI	0	4	4	0	0	1	8
DLD	2	2	6	1	3	1	3
DRD	1	5	3	3	2	1	3
FILL	0	2	1	1	1	1	12
Southern US (n=15)							
EWB	5	0	1	2	0	2	5
BBD	0	3	0	0	3	1	8
SWB	2	0	1	0	0	0	12
LWB	2	0	0	0	0	0	13
SB	2	0	0	0	1	0	12
OTC	0	0	0	0	0	0	15
RC	0	3	1	0	1	1	9
RO	0	2	1	0	1	1	10
RI	0	1	1	0	0	1	12
DLD	1	3	2	0	1	1	7
DRD	0	4	2	1	3	0	5
FILL	1	1	1	0	0	1	11
Eastern US (n=33)							
EWB	8	0	5	4	1	0	15
BBD	2	6	5	0	0	0	20
SWB	6	1	6	3	0	0	17
LWB	8	0	1	0	0	0	24
SB	9	1	2	0	0	0	21
OTC	3	1	4	0	0	0	25
RC	0	8	7	1	3	2	12
RO	1	8	6	0	0	0	18
RI	0	8	6	0	0	0	19
DLD	0	1	9	3	4	5	11
DRD	2	7	10	0	0	6	8
FILL	0	9	4	1	2	2	15
East/Central Canada (n=14)							
EWB	0	0	0	1	0	0	13
BBD	0	1	1	1	0	0	11
SWB	2	0	0	1	0	0	11
LWB	2	1	0	0	0	0	11
SB	2	1	0	1	0	0	10

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Table C.11, continued

Option	Type of road/trail used on			Type of road/trail *best* on			Blank
	Closed	Active	Both	Closed	Active	Both	
OTC	0	0	0	0	0	0	14
RC	0	6	1	0	5	1	1
RO	0	3	1	0	0	0	10
RI	0	3	1	0	0	0	10
DLD	0	2	0	0	4	1	7
DRD	1	5	1	0	1	2	4
FILL	0	2	1	0	2	0	9
Western Canada (n=10)							
EWB	1	1	0	0	0	0	8
BBD	0	0	0	0	0	0	10
SWB	0	0	0	0	0	0	10
LWB	0	0	0	0	0	0	10
SB	0	0	0	0	0	0	10
OTC	0	0	0	0	0	0	10
RC	0	3	3	0	1	0	4
RO	0	0	2	0	0	0	8
RI	0	0	2	0	0	0	8
DLD	1	2	3	1	0	1	3
DRD	0	3	2	0	2	0	3
FILL	0	2	1	0	1	0	6

Q. 12. Which diversion options are used on roads or trails in frozen or thin soils or over rock?

A total of 25 respondents described alternative options for this question, which are summarized in Chapter 2. The options list for this question included the following:

EWB Earth berm water bars.
BBD Broad-based dips.
SWB Slash water bars.
LWB Log water bars.
SB Straw bales.
OTC Open-top culverts.
RC Road crowning.
RO Road outsloping.
RI Road insloping.
Other Unlisted options.

Table C.12: Frequency with which the listed option was indicated for given road or trail conditions on frozen or thin soils or over rock. Data are the actual numbers of responses in each category. (N=102).

Option	Type of Road/Trail Used On			Type of Road/Trail *Best* On			Blank
	Closed	Active	Both	Closed	Active	Both	
US Mountain States (n=29)							
EWB	4	1	3	2	1	1	17
BBD	0	1	2	0	4	3	19
SWB	2	0	0	4	1	1	21
LWB	2	0	0	0	0	1	26
SB	3	0	0	0	0	0	26
OTC	0	4	0	0	0	0	25
RC	0	5	4	0	0	1	19
RO	2	3	7	0	5	3	9
RI	0	5	6	0	1	1	16
Other	3	0	1	0	1	0	24
US West Coast (n=15)							
EWB	5	0	2	3	0	0	5
BBD	0	6	0	0	0	2	7
SWB	2	0	0	0	0	1	12
LWB	2	0	0	0	0	0	13
SB	1	0	2	1	0	1	10
OTC	0	3	0	0	0	0	12
RC	0	3	2	0	3	1	6
RO	1	2	3	1	2	2	4
RI	0	4	2	0	0	1	8

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Table C.12, continued

Option	Type of road/trail used on			Type of road/trail *best* on			Blank
	Closed	Active	Both	Closed	Active	Both	
Other	0	0	2	0	0	0	13
Southern US (n=10)							
EWB	2	0	1	3	0	0	4
BBD	0	3	1	0	2	0	4
SWB	3	0	1	0	0	0	6
LWB	3	0	0	0	0	0	7
SB	4	0	0	0	0	0	6
OTC	0	2	0	0	0	0	8
RC	0	2	1	0	1	0	6
RO	1	3	0	0	0	1	5
RI	1	2	0	0	0	0	7
Other	1	0	0	0	0	0	9
Eastern US (n=25)							
EWB	2	0	2	3	0	0	18
BBD	1	0	3	0	1	0	20
SWB	5	2	1	5	0	2	10
LWB	6	0	4	1	0	0	14
SB	7	0	0	3	0	0	15
OTC	1	0	0	1	0	0	23
RC	1	1	1	0	4	3	15
RO	1	3	4	0	1	1	15
RI	1	3	3	0	0	0	18
Other	1	2	1	0	0	0	21
East/Central Canada (n=12)							
EWB	1	0	0	1	0	0	10
BBD	0	0	0	0	0	1	11
SWB	2	0	0	1	0	0	6
LWB	2	1	0	0	0	0	9
SB	1	1	0	1	0	0	9
OTC	0	1	0	0	0	0	11
RC	0	3	1	0	6	1	1
RO	0	2	1	0	0	0	9
RI	0	2	1	0	0	0	9
Other	0	0	0	0	2	0	10
Western Canada (n=11)							
EWB	2	1	1	1	0	0	6
BBD	0	0	1	0	0	0	10
SWB	0	0	0	0	0	0	11
LWB	1	0	0	0	0	0	10
SB	0	0	0	0	0	0	11
OTC	0	0	0	1	0	0	10

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Table C.12, continued

Option	Type of road/trail used on			Type of road/trail *best* on			Blank
	Closed	Active	Both	Closed	Active	Both	
RC	0	2	2	0	0	1	6
RO	0	1	4	0	1	0	5
RI	0	2	2	0	0	1	6
Other	1	2	1	1	1	0	5