FOREST PRACTICES CODE

of

BRITISH COLUMBIA

This Forest Practices Code Guidebook is presented for information only.
It is not cited in regulation. The Forest and Range Practices Act and its regulations took effect on Jan. 31, 2004. This replaced the Forest Practices Code of British Columbia Act and regulations. For further information please see the Forest and Range Practices Act.

Gully Assessment Procedure Guidebook

Fourth edition
Version 4.1

February 2001

BRITISH COLUMBIA
Ministry of Forests

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Preface

This guidebook has been prepared to help forest resource managers plan, prescribe and implement sound forest practices that comply with the Forest Practices Code.

Guidebooks are one of the four components of the Forest Practices Code. The others are the *Forest Practices Code of British Columbia Act*, the regulations, and the standards. The ***Forest Practices Code of British Columbia Act*** is the legislative umbrella authorizing the Code's other components. It enables the Code, establishes mandatory requirements for planning and forest practices, sets enforcement and penalty provisions, and specifies administrative arrangements. The **regulations** lay out the forest practices that apply province-wide. **Standards** may be established by the chief forester, where required, to expand on a regulation. Both regulations and standards are mandatory requirements under the Code.

Forest Practices Code guidebooks have been developed to support the regulations, however, only those portions of guidebooks cited in regulation are part of the legislation. The recommendations in the guidebooks are not mandatory requirements, but once a recommended practice is included in a plan, prescription or contract, it becomes legally enforceable. Except where referenced by regulation, guidebooks are not intended to provide a legal interpretation of the *Act* or regulations. In general, they describe procedures, practices and results that are consistent with the legislated requirements of the Code.

The Gully Assessment Procedure Guidebook is referenced in the Operational Planning Regulation (OPR) and the Woodlot License Forest Management Regulation (WLFMR) for the assessments required for a gully located in a cutblock where timber harvesting is proposed within the gully. A gully assessment consists of two parts:

- the first of two parts of a gully assessment is described in Part III, pages 8–24 of this guidebook;
- the second of two parts of a gully assessment is described in Part IV, pages 25–38, of this guidebook.

Completing Parts III and IV of this guidebook constitutes a gully assessment as required by OPR section 37 and WLFMR section 64 paragraph (c), Forest Practices Code of British Columbia. The two parts of the Gully Assessment Procedure Guidebook **referenced by regulation are identified by a bar along the page margin labeled with the specific regulation being referenced, as well as a change in the text typeface.**

The information provided in each guidebook is intended to help users exercise their professional judgement in developing site-specific management strategies and prescriptions designed to accommodate resource management objectives. Some guidebook recommendations provide a range of options or outcomes considered to be acceptable under varying circumstances.

Where ranges are not specified, flexibility in the application of guidebook recommendations may be required, to adequately achieve land use and resource management objectives specified in higher-level plans. A recommended practice may also be modified when an alternative could provide better results for forest resource stewardship. The examples provided in many guidebooks are not intended to be definitive and should not be interpreted as being the only acceptable options.

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Part I Introduction

Gully systems are steep headwater channels that discharge water, sediment, and woody debris onto lower valley slopes or into valley-bottom streams. Several types of hazards may be present in a gully system. Forestry operations can increase the likelihood of these hazards occurring if the operations are not done carefully. Forestry workers, the environment, and infrastructure can be at risk from these hazards. Careful planning is needed when working in gullied areas.

The gully assessment procedure (GAP) is intended to help identify the main factors that should be considered when evaluating gully systems for road crossings, cut-block layout, gully system rehabilitation, and road deactivation of the crossings. Based on those factors, the GAP provides a framework for managing gully systems during and after harvesting. Currently, the GAP is intended for sites on the Coast only.

Parts III and IV of this guidebook are considered the cited guidebook for the Forest Practices Code. The assessment procedures, management strategies, and requirements to consult with a qualified registered professional must be followed. Other parts of this guidebook give additional information to assist in the proper evaluation and management of gully hazards and risks.

The GAP has three parts:

- collection of field and air photo information
- assessment of potential hazards and resources that may be at risk
- selection of management strategies to meet the gully system management objectives.

The GAP is not geotechnically rigorous. It is intended for technical field staff and professionals not trained or experienced in geological or geomorphological processes. The GAP produces an overview assessment of the hazards and risks in a gully system. It does not replace a thorough assessment by a qualified registered professional, especially in situations where gully systems may pose a substantial hazard to downslope or downstream resources or to the safety of forest users. Where the GAP identifies situations of substantial hazard or risk, consultation with a qualified registered professional is required before planning, harvesting, deactivation, or rehabilitation activities begin. Gully assessment and recommendations by a qualified registered professional should take precedence over the results of the GAP.

This guidebook is a working draft; field testing and revisions to the guidebook continue. The GAP relies on many generalizations and simplifications, and may not always produce an effective solution. Consult with a qualified registered professional if the GAP results in unusual or illogical assessments or management strategies, or if a more detailed evaluation is warranted.

Part II Gully Systems and Hazards

Gully Systems

A gully system is usually composed of a headwall, a transport zone, and in some cases a fan. The system acts as a conduit for water, sediment, and woody debris. A typical gully system is shown in Figures 1 and 2. Common characteristics of the headwall, transport zone, and fan are described below:

- Headwall — The headwall areas are the uppermost reaches of the gully system that commonly have very steep slopes (walls). Slopes can be curved, notched into the hillside, or planar. Often there is no channel, or it is poorly defined. Groundwater seepage is sometimes present. Headwalls are susceptible to extensive landslides and erosion, and are the source area of much of the sediment and woody debris that travels down the gully system.
- Transport zone — The transport zone includes the middle reaches of the gully system that have steep sidewalls and a confined, relatively steep channel with perennial or intermittent water flow. The sidewalls and channel form a V-notched or U-notched terrain feature that is inset into the overall hillslope. Sidewalls can be stable, unstable, or potentially unstable. They are a source of much of the sediment and woody debris that is stored in the channel. Occasionally, the sediment and woody debris are removed from the channel by floods or debris flows.
- Fan — The lower reaches of the gully system are usually the deposition zones of sediment and woody debris. Fans may be gently sloping or more steeply sloping (often called cones). They may have a single channel or multiple channels. These channels can range from deeply incised to unconfined. Shifting channels and avulsions (sudden changes in channel location) are common.

The term *gully* is commonly used to refer to both the entire gully system (Figure 1), or to just the headwall and transport zones. Except for in the title, this revision of the guidebook attempts to limit the use of the term gully to the headwall and transport zones of the gully system.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a)

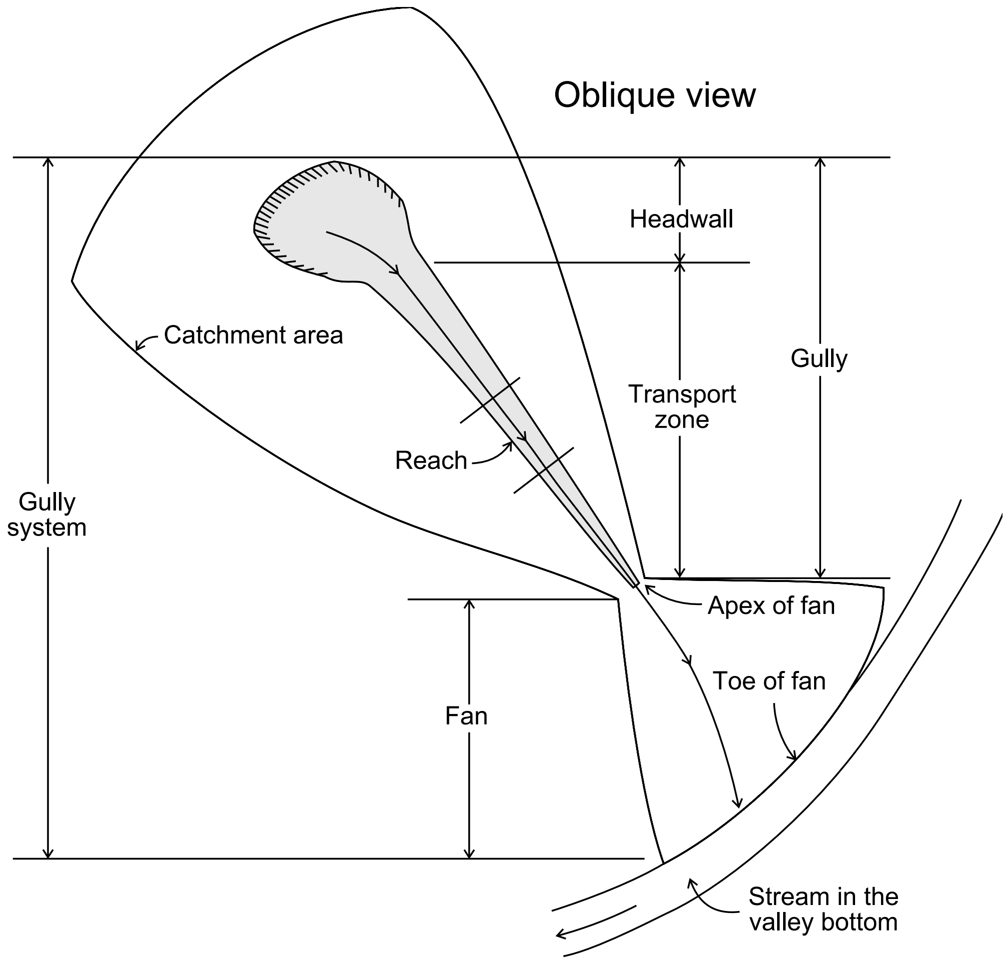

Figure 1. Sketch of oblique view of typical gully system.

The Forest Practices Code defines a gully as an area containing a stream where:

- the overall channel gradient is ≥25%, and
- from the fan apex (where the transport zone meets the fan) to the top of the headwall, at least one reach greater than 100 m in length has:
  - a channel gradient >20%
  - a sidewall >3 m
  - a sidewall slope >50%.

Methods to measure the channel gradient and sidewall slope are described in Part III. For the purposes of determining whether a channel meets the FPC definition of a sidewall greater than 3 m, stand in the bottom of the channel and draw a line perpendicular to the channel gradient that is equal distance from the two sidewalls. From the channel bottom to where this line intersects a line drawn across the tops of the two sidewalls is the sidewall height.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a)

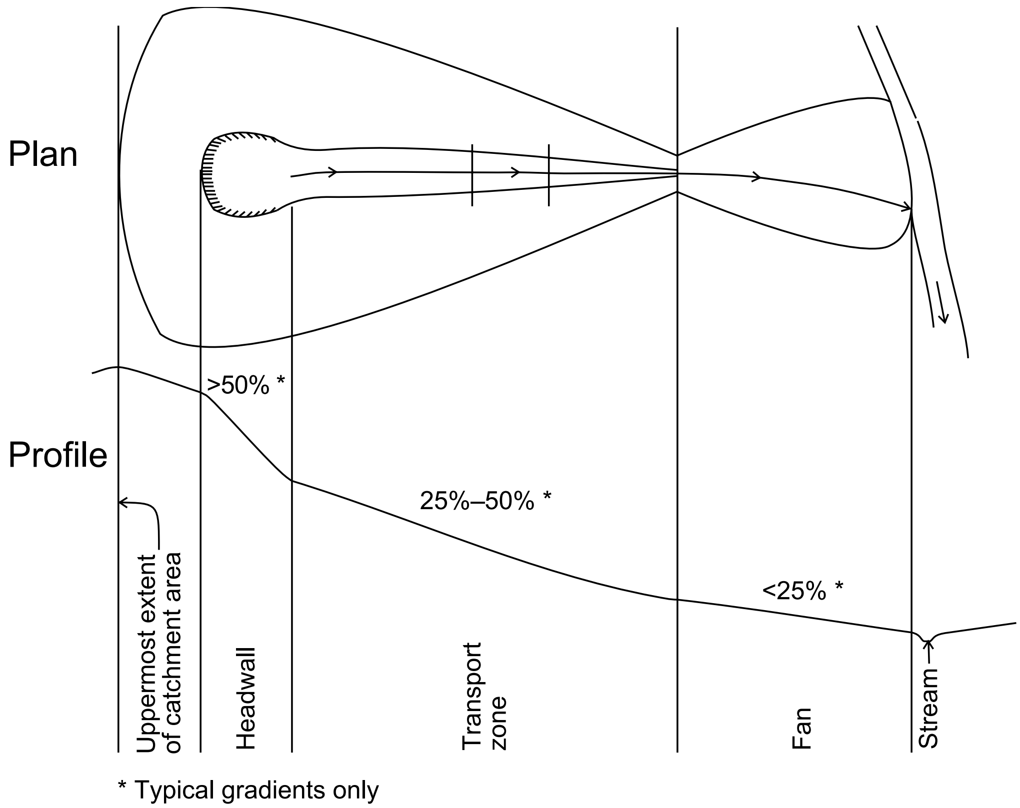

Figure 2. Sketch of plan and profile view of typical gully system.

Gully System Hazards

A number of hazards are associated with gully systems, including:

- debris slides
- debris flows
- debris floods
- water transport (water, sediment, and woody debris transport and erosion)
- fan destabilization
- snow avalanches.

Debris slides are shallow landslides that usually occur along planes of weakness between looser overlying soil, such as colluvium and weathered till, and denser underlying material, such as unweathered till or bedrock. In a gully system, debris slides often occur on the steep slopes of the headwall or sidewalls, and can begin on steep, unstable road cut-and-fill slopes. They can also occur on the open slopes of the catchment area adjacent to the gully system, and then slide or flow into the gully system. Debris slides are the main initiator of debris flows in a gully system.

Debris flows, also referred to as channelized debris flows (or previously as debris torrents), involve the rapid downstream movement of liquefied sediment and woody debris. They can be triggered by debris slides on the headwall and sidewalls, by landslides entering the headwall or transport zone from adjacent slopes, or, rarely, by large stream discharges. Debris slides from gully road locations often start debris flows. Debris flows usually start as relatively small events, but quickly swell in volume as they move downstream and entrain sediment, woody debris, slide debris, sidewall material, and road prism material into the flow matrix. Debris flows can travel for long distances down the transport zone to the fan, and can be very destructive. The resulting erosion often over-steepens the headwall and sidewalls, leading to further debris slides and debris flows within the gully system.

Debris floods involve the transport of large volumes of sediment and woody debris down gully systems by large volumes of water. Usually, the flowing mass associated with debris floods is less dense and moves more slowly than debris flows, but is more dense and moves more quickly than normal water transport.

Water transport not only includes the water flow in the stream channel, but depending upon the amount of water flow (such as the high water flows during a flood), the water can transport variable amounts of sediment and woody debris down the channel, and can cause erosion along the channel and the sidewalls. As with debris flows, erosion from both debris floods and water transport can oversteepen sidewalls, which can lead to further debris slides and debris flows within the gully system.

Fan destabilization occurs when high water flows and/or debris flows “jump” out of the channel or several channels on the fan. Fan destabilization can also occur when water flows are blocked by sediment and woody debris deposited in the active channel. The unconfined water, sediment, and woody debris find paths of less resistance and continue their downslope movement on the fan. Depending upon the geometry and character of the fan, the unconfined water, sediment, and woody debris often erode portions of the fan.

Snow avalanches occur in some gully systems that have headwall or source areas in steep areas with deep snowpack accumulations. Snow avalanches are not specifically addressed by the GAP; however, be aware that avalanches can pose safety hazards and road maintenance problems in some gully systems.

The occurrence of the previous hazards depends on combinations of climatic conditions and the character of the gully system, including:

- size of the catchment area
- steepness and material of the headwall and sidewalls
- channel gradient in the transport zone and on the fan
- availability and character of loose, entrainable sediment and woody debris.

Forest operations–related factors can include:

- poorly located, constructed, maintained, and/or deactivated roads and road crossings
- location of harvesting within the catchment area
- amount of ground disturbance during yarding
- volume of woody debris left in the gully system
- removal of stabilizing trees from the headwall, sidewalls, or stream channels.

Safety Considerations

Safety is always a concern in gully systems due to the potential for headwall and sidewall slope failures, debris flows, high water flows, and snow avalanches, even in unharvested gully systems. During or immediately after high-intensity or long-duration rainstorms or rain-on-snow events, avoid road layout, construction, maintenance, and deactivation, cutblock layout, falling and yarding operations, and/or rehabilitation work near a gully system. Harvesting and road building in gully systems can pose a hazard long after the harvesting is completed. In general, avoid gully systems during fall and winter storms. The stability of upslope roads should be assessed before beginning work in downslope gully areas, including the fan. Remember, most debris slides and debris flows travel faster than humans.

Part III constitutes the first of two parts of a gully assessment as specified in Operational Planning Regulation (OPR) 37(1)(c) and Woodlot License Forest Management Regulation (WLFMR) 64(2)(a).

Part III Field Assessment

Where to Carry Out the Gully Assessment Procedure

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a)

A GAP must be carried out on all gullies in proposed cutblocks. Streams that are similar to gullies should also be assessed.

For pre-harvesting, the GAP should be considered for all gullied streams that flow through proposed cutblocks, flow adjacent to proposed cutblocks, and flow across proposed road crossings, whether or not the road is in the proposed cutblock. Similarly, for post-harvest, the GAP should be considered for all streams that flow through harvested cutblocks, flow adjacent to harvested cutblocks, or are crossed by roads, whether or not the road is in the cutblock.

The GAP field assessment should extend at least 50 m upstream and at least 50 m downstream of all proposed cutblocks, proposed roads, harvested cutblocks, and built roads (Figure 3). The GAP should extend further upstream and downstream if conditions and/or downslope/downstream resources warrant.

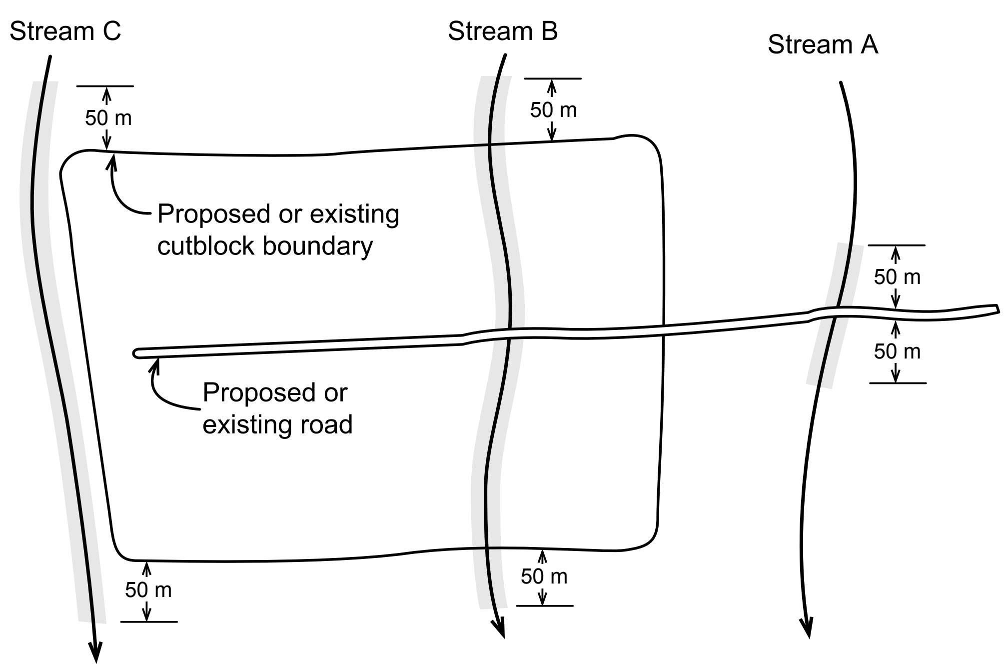

Figure 3. Sketch of where GAPs should be carried out (shaded areas).

Field Form

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

The GAP begins with the collection of information, which is recorded in the appropriate section of the GAP field form. Different parts of the field form are completed depending on whether the fan or the transport zone and headwall are being assessed, and whether it is a pre- or post-harvest situation. Most sections of the field form consist of a series of questions that leads to an assessment of the likelihood of some type of potential hazard. The assessment of potential hazards is then used to select an appropriate management strategy (refer to Part IV).

The entire gully, not just the immediate work area, needs to be considered. Hazardous sites may exist throughout the gully, and may result in severe damage to downslope resources. The field form encourages assessors to (1) look downslope/ downstream to determine what resources might be affected by gully system processes, (2) look upslope/upstream to determine what hazards may come from above, and (3) assess a specific reach of the gully system. Some of the information required can be derived from maps, aerial photographs, and other office information. Management strategies should always consider downslope/downstream and upslope/upstream conditions.

The entire field form is included as Appendix 1 and consists of seven sections (numbered Section 1 to Section 7). Section 6 has several accompanying tables.

- Section 1 — Gully system identification
- Section 2 — Downstream impact potential
- Section 3 — Upslope debris flow potential
- Section 4 — Water transport potential
- Section 5 — Fan destabilization potential
- Section 6 — Debris flow initiation potential in transport zone and headwall reach
  - Tables A1 and A2: Gully wall failure potential
  - Table B: Gully geometry potential for debris flow potential
  - Table C: Debris flow initiation hazard
- Section 7 — Post-harvest conditions

Complete Section 1 for all assessments.
For assessment of fans, complete Sections 2, 3, 4, 5 (and 7 if post-harvest).
For assessments of transport zones and headwalls, complete Sections 2, 3, 4, 6 (and 7 if post-harvest).
Enter the results in Management Strategies, Tables 2–5.

A descriptions of each section follows.
The highest-ranking answer in Sections 2, 3, 4, and 6 determines the overall ranking of the potential hazard for that section.

Section 1 Gully System Identification

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Complete this section for all assessments. Section 1 uniquely identifies the watershed, gully system, reach, cutblock (proposed or harvested), and road (proposed or existing). Each gully system within a watershed should have a unique name or number. Separate assessment and field forms are required for each reach; therefore, each reach should have a unique number. Usually, reaches are numbered upstream from the fan to the headwall.

Section 1. Gully system identification		
Watershed	Cutblock No.	Date (y/m/d)
Gully No.	Road No.	Recorded by
Reach No.	Dist. (start/end) (m)	Roll/photo No.

Fan assessments: complete Sections 2, 3, 4, 5 (and 7 if post-harvest).

Transport zone and headwall assessments: complete Sections 2, 3, 4, 6 (and 7 if post-harvest).

Enter the results in Management Strategies, Tables 2–5.

A reach of a fan, transport zone, or headwall should have relatively consistent physical and material characteristics. Physical characteristics include channel width, channel gradient, channel incision, headwall or sidewall distance, and headwall and sidewall slope. Material characteristics include types and distribution of sediment and woody debris in the channel and/or on the headwall and sidewalls. Consider assessing a road crossing as a separate reach if the road fill volume is very large. Usually, it is impractical to identify reaches shorter than about 40 m in length.

If the gully system is surveyed, the start and end distances for the reach should be recorded. Otherwise, the reach length should be recorded. In the transport zone, tributary gullies or channel slope changes often define reach breaks. On a fan, reaches should be identified by the characteristics of the main channel. A fan reach extends laterally to include all secondary channels on the fan surface.

Section 2 Downstream Impact Potential

This section, used for both fan assessments and transport and headwall assessments, addresses the downslope/downstream resources that could be affected by any gully system management activity.

Section 2. Downstream impact potential	**L**	**M**	**H**
Connection to a community watershed intake	None	Indirect	Direct
Dwellings, major installations, safety	No		Yes
Connection to fish streams or lakes or sensitive marine zones	None	Indirect	Direct

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Connection to a community watershed intake. Many gully system management activities can affect water quality. If the gully system is located in a community watershed, and the connection between the gully and the community water supply intake is direct, the downstream impact potential is considered high. Otherwise, it is considered moderate. Connection to a community watershed intake and connection to fish streams or lakes or sensitive marine zones follow.

- Direct (Figure 4) — A gully system that discharges directly into a stream reach containing a community water supply intake or into fish-bearing waters. Also includes a gully system that discharges into any stream that always maintains a gradient of >5% before entering the stream reach that contains either a community watershed intake or fish-bearing waters.
- Indirect (Figure 5) — Gully systems that discharge into a stream that has a gradient of <5% over a distance of >100 m before it enters the stream reach containing a community watershed intake or fish-bearing waters.
- No connection (Figure 6) — Gully systems that are not connected to fish streams or a community watershed intake because of a gap such as a (1) valley flat with no channel or (2) a non–fish-bearing lake or wetland that will store sediment.

Dwellings, major installations, safety. High water flows and debris flows can be both destructive and dangerous. Downstream impact potential is considered high if the safety of any development, such as dwellings or major installations, or people in these dwellings, is at risk from high water flows or debris flows. Such flows can travel long distances down a gully system. Downstream impact potential is considered low if no developments are at risk. If in doubt as to whether development is in the path of a high water flow or debris flow, consult a qualified registered professional.

Examples of major installations include logging camps, highways, pipelines, and power-line towers. For the GAP, a mainline logging road is considered a major installation, as is a logging road bridge greater than 6 m in length at risk.

Connection to fish streams or lakes or sensitive marine zones. Sediment and woody debris discharged from gully systems can have detrimental effects on fish-bearing streams depending upon the connectivity. Connection to fish streams or lakes or sensitive marine zones is defined above.

The most serious damage can potentially occur when high water flows or debris flows discharge directly into fish-bearing waters; this situation is considered to have high downstream impact potential. Indirect discharge is considered moderate downstream impact potential. No connection is considered low downstream impact potential.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

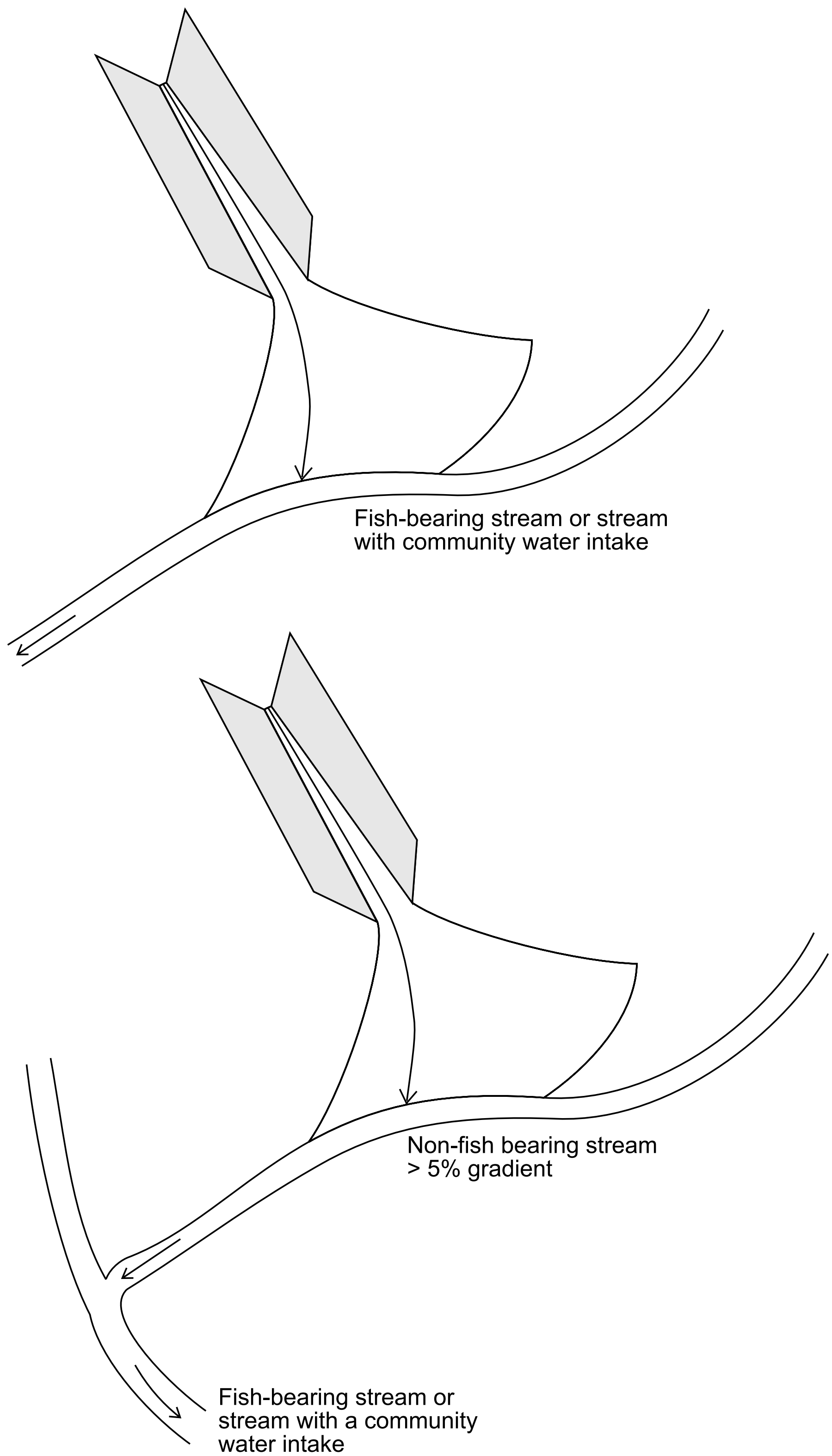

Figure 4. Sketch of direct conductivity to fish-bearing streams.

Operational Planning
Regulation 37(1)(c)
and
Woodlot License
Forest Management
Regulation 64(2)(a)
continued

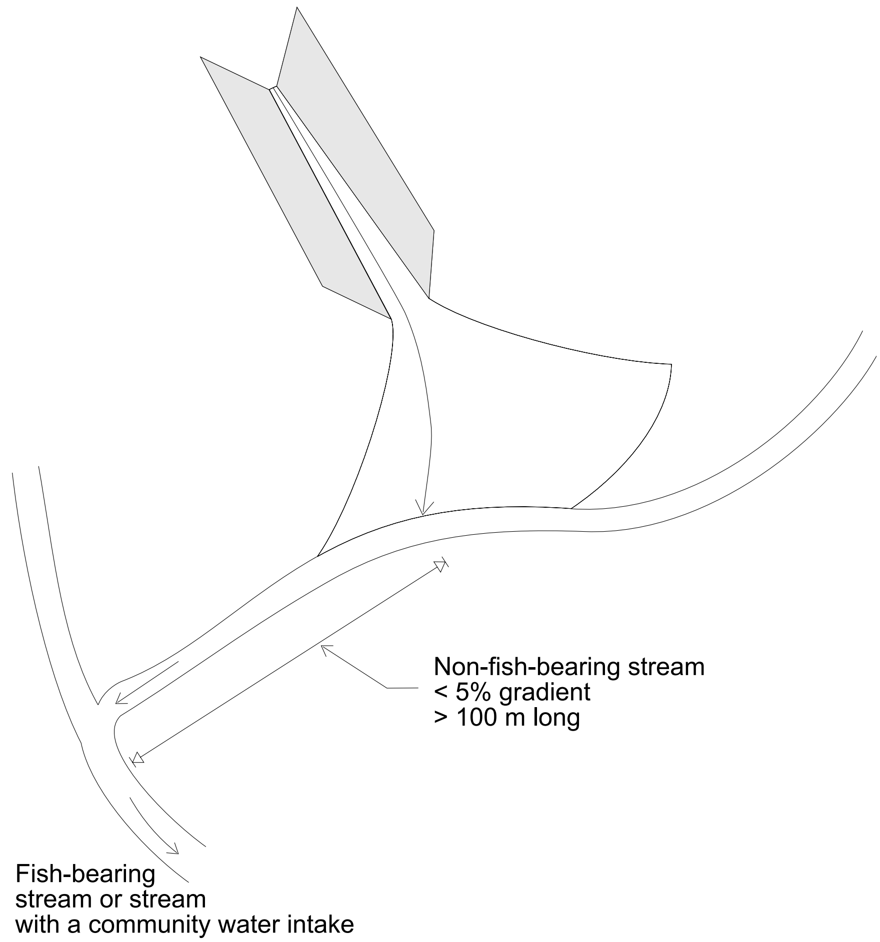

Figure 5. Sketch of indirect conductivity to fish-bearing stream.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

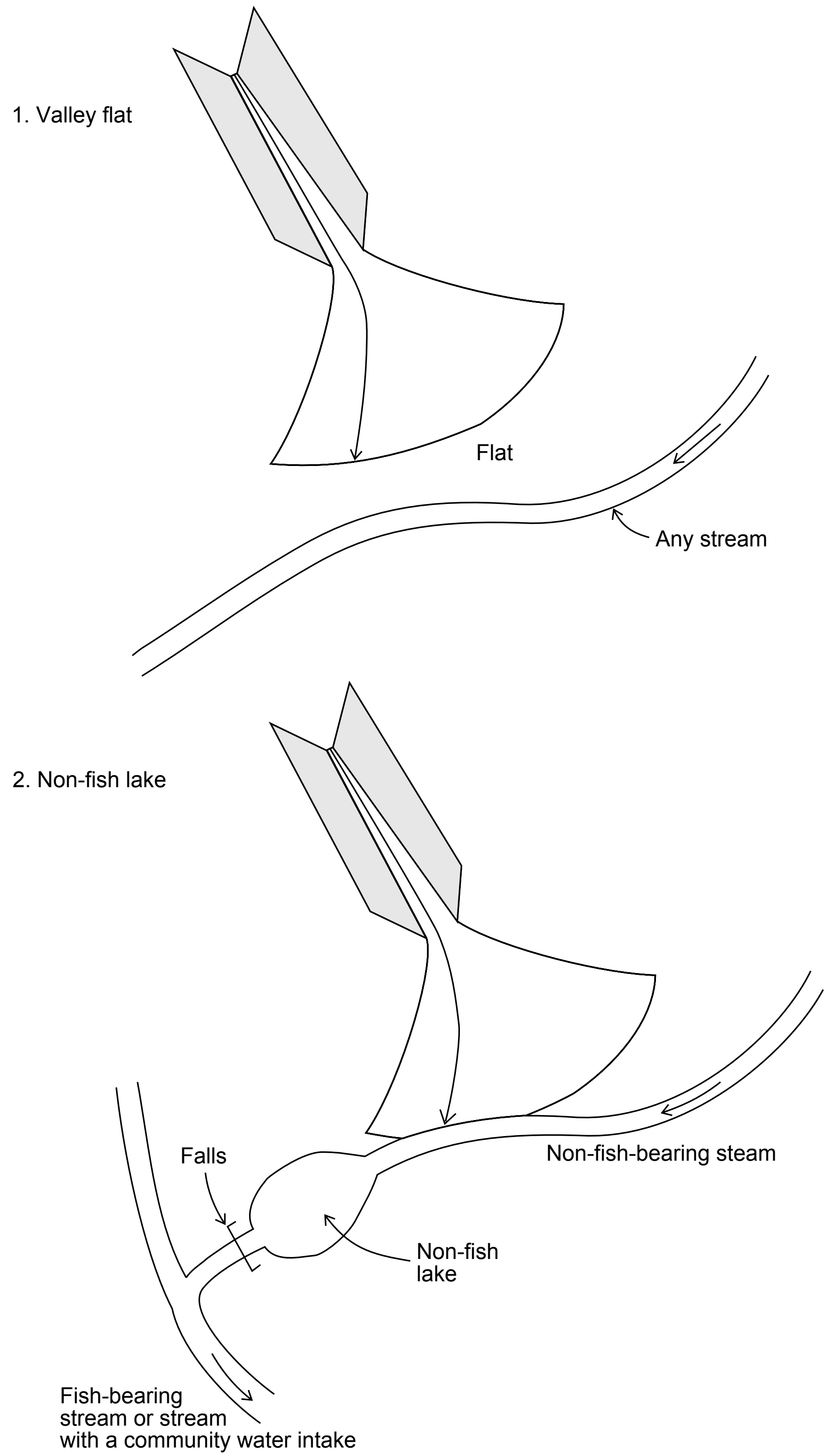

Figure 6. Sketch of no conductivity to fish-bearing streams.

Section 3 Upslope Debris Flow Potential

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

This section, used for both fan assessments and transport and headwall assessments, addresses the upslope/upstream character of a catchment area and associated gully system. If a potential hazard exists upslope or upstream, it could affect the reach being assessed.

Section 3. Upslope debris flow potential	**L**	**M**	**H**
Terrain stability class upslope (from terrain mapping)	I–III, or S	IV or P	V or U
Slope gradient upslope (if no terrain mapping)	<50%	50 – 60%	>60%
Evidence of landslides or debris flows in gully systems	N	not clear	Y

Terrain stability class upslope. Detailed terrain mapping classes I, II, and III have a low hazard of upslope debris flows. Detailed terrain mapping class IV has a moderate hazard of debris flows, and class V has a high hazard of debris flows. Reconnaissance terrain mapping class S (Stable) has a low hazard of debris flows, P (Potentially unstable) has a moderate hazard of debris flows, and U (Unstable) has a high hazard of debris flows. Higher-hazard terrain may be present in the gully system itself or on nearby open slopes that lead towards the gully system. (Refer to Chatwin et al. 1994, and the *Mapping and Assessing Terrain Stability Guidebook.*)

Slope gradient upslope (if no terrain mapping). If no detailed or reconnaissance terrain stability has been mapped, determine the steepest slope gradients in the gully system above your assessment reach. Steeper slopes have a higher hazard of debris flows.

Evidence of landslides or debris flows in gully system. Evidence of past landslides or debris flows in the gully system is a good indicator that the potential exists for further debris flow activity. Therefore, the gully system is considered to have high upslope debris flow potential. Refer to Appendix 2 for field indicators of past instability in the gully system. If no evidence is found, the potential for upslope debris flow is considered low. Past landslides from road fills that have entered the gully system should be considered as evidence. Record “not clear” if the evidence is uncertain. Landslides should have a minimum size of 25 m^2.

Section 4 Water Transport Potential

This section, used for both fan assessments and transport and headwall assessments, addresses the potential of water flowing down a gully system to transport sediment and woody debris.

The movement and storage of sediment and woody debris in gully systems is controlled in part by the amount of water flowing down the channel and in part by the presence of obstructions to water flow, such as large logs and debris jams. Therefore, gully systems with high water flows and few in-channel obstructions have much greater water power than gully systems with low flows and many obstructions. After harvest, gully systems that transport large volumes of sediment and woody debris by water flow are susceptible to erosion, downstream sedimentation, and fan destabilization. For additional information about water transport potential and the effects of logging debris in channels, see Millard (2000).

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Section 4. Water transport potential (WTP)	L	M	H
Bankfull channel width (m)	≤2	>2 – ≤3.5	>3.5
Size of water-transported woody debris	SWD	LWD	Logs or no WD
Largest sediment in storage wedges (mm)	≤100	>100 – ≤200	>200

Bankfull channel width. The ability of a stream channel to transport material can be approximated by the width of the channel when it is full of water. Wider channels can transport more, and larger, sediment and woody debris. Bankfull channel width should be measured at least three times, spaced 10 m apart. How to measure channel width is shown in Figure 7.

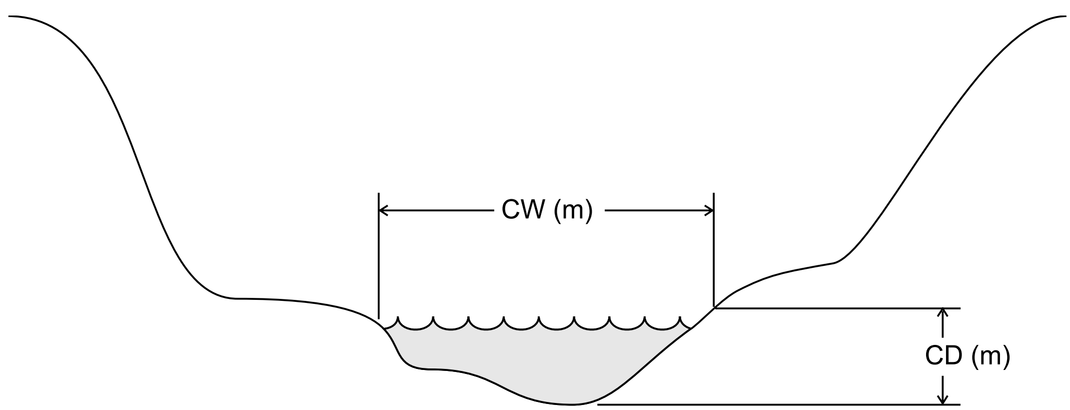

Figure 7. Measurement of channel width (CW) and channel depth (CD).

Size of water-transported woody debris. How woody debris moves downstream is evident from the way the debris tends to pack together and pile up, or jam, at specific locations along the channel. Pay particular attention to woody debris accumulations immediately upstream of road crossings. Woody debris that does not move tends to be spread out along the channel. It is often located partly within the channel, and partly above the channel on the banks or sidewalls. Localized accumulations of woody debris indicate that the peak flows in the channel can transport debris of the size in the accumulation.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

- Logs, or no WD — Logs are considered to be >0.5 m in diameter and >3 m long, or >0.3 m in diameter and >5 m long. If evidence shows logs being transported by water, or if all the woody debris (WD) has been removed by a water flood, the water transport potential is considered high.
- LWD transport — Large woody debris (LWD) is considered to be >0.1 m in diameter and >3 m in length, or >0.2 m in diameter and >1 m in length, up to the size of logs. If evidence shows LWD, but not logs, being transported by water, the water transport potential is considered moderate.
- SWD transport — Small woody debris (SWD) includes branches, stems, and broken stems smaller than LWD. Scattered, unsorted woody debris and movement of SWD is considered evidence of low water transport potential.

Largest sediment in storage wedges. Transported sediment often accumulates behind obstructions in the channel. These storage areas develop a wedge shape, with a relatively flat top and a steep downstream front. The front is often the obstruction, either a log, a debris jam, or a cluster of boulders. The size of the largest sediment in the wedge indicates the water transport potential. If there are no storage wedges, then the size of the largest sediment that appears to have moved recently should be used. Recently transported sediment is usually fresh looking and without moss.

- Sediment >200 mm — Sediment >200 mm in storage wedges is evidence of high water transport.
- Sediment >100 mm – ≤200 mm — Sediment >100 mm and ≤200 mm in storage wedges is evidence of moderate water transport.
- Sediment ≤100 mm — Sediment ≤100 mm in storage wedges is evidence of low water transport potential.

Note: Use the intermediate axis of the sediment for measuring its size.

Section 5 Fan Destabilization Potential

This section addresses the potential for the fan portion of a gully system to become destabilized. Complete this section only if the reach you are assessing is located on a fan.

A fan is created by the deposition of sediment and woody debris at the mouth of a gully system. Because fan materials are usually relatively loose and unconsolidated, they can erode easily. Of particular concern are fans that have several poorly or shallowly incised channels. In this case, obstructions can divert water from the regular channel (an avulsion), resulting in severe erosion and downstream effects. Where a single, deeply or well-incised channel exists, the probability of channel avulsion is much lower. Channel widening and/or erosion of channel banks, however, is still a concern.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

When evaluating a fan, assess the reach breaks along the main channel. The reach extends laterally to include any secondary channels. Channel incision is evaluated on the main channel. Evaluate the fan destabilization potential in Section 5.

Section 5. Fan destabilization potential (FDP)			
Channel incision (CI)	**Number of channels (CN) (If the fan has no channels, the FDP is L, low)**		
______ (m)	**1**	**2–3**	**>3**
<0.5	H	H	H
0.5 – <1	M	H	H
1 – <2	L	M	H
≥2	L	L	M

Number of channels (CN) — Record the number of active channels. Active channels have fresh sediment and little or no vegetation, but may not have flowing water at the time of the assessment. Inactive channels are usually overgrown with vegetation and have moss-covered rocks.

Channel incision (CI) — Measure the depth of channel incision in metres vertically from the top of the bank (top of the fan surface or top of the levee) to the bottom of the main channel (Figure 8). This is measured at an average cross-section or at three locations spaced 10 m apart, then averaged.

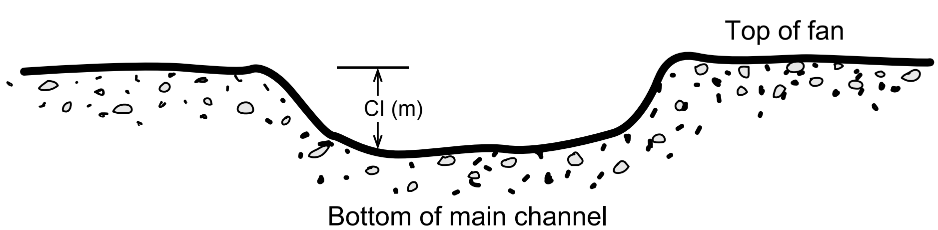

Figure 8. Measurement of channel gradient (CG).

The hazard rating for the fan destabilization index is determined from the intersection of the number of channels and the depth of channel incision in Section 5.
A fan is more likely to destabilize if there are many active channels and if those channels are shallowly incised.

Section 6 Debris Flow Initiation Potential

This section addresses the potential for debris flows to begin along the transport zone or in the headwall area of a gully system. Complete this section only if the reach you are assessing is located in a transport zone or headwall area.

Operational Planning Regulation 37(1)(c) and
Woodlot License Forest Management Regulation 64(2)(a) continued

Two factors are important in determining whether a debris flow will begin in a particular reach of a transport zone or headwall:

- the potential for sidewall or headwall slope failures to occur
- the potential of a failure to initiate a debris flow within the gully channel.

As discussed previously, events that trigger debris flows are often small headwall or sidewall slides or other slope failures. If the slide mass reaches the channel and conditions are suitable, it may continue down the channel as a debris flow (Millard 1999). Table A1 is used to determine the likelihood of a headwall slope failure. Table A2 is used to determine the likelihood of a sidewall slope failure. Table B is used to determine the likelihood of a slope failure developing into a debris flow. Table C combines the factors from Tables A and B to assess the overall debris flow initiation hazard.

Note that if the two sidewalls are different, the less stable sidewall, as determined by the less stable material, or steeper sidewall slope, or longer sidewall length, is assessed.

Table A1. Headwall failure potential (HWFP)

Headwall slope angle ______ (%)	Headwall surficial material				
	R	**C**	**M, F**	**W, L**	**FS**
>70	L	H	H	H	H
>60 – 70	L	M	H	H	H
>50 – 60	L	L	M	H	H
≤50	L	L	L	M	H

Enter the results in Table C

Table A2. Sidewall failure potential (SWFP)

Sidewall slope angle ______ (%)	Sidewall surficial material				
	R	**C**	**M, F**	**W, L**	**FS**
>70	L	H	H	H	H
>60 – 70	L	L	M	H	H
>50 – 60	L	L	L	H	H
≤50	L	L	L	M	H

Enter the results in Table C

Gully headwall or sidewall slope angle. The slope of the headwall or sidewall is one criterion that determines stability. The headwall slope angle is measured in percentage along the trend of the channel (the channel axis) (Figure 9a). The sidewall slope angle is measured in percentage along the "fall line" from the base of the sidewall to the top (Figure 9b). When standing at the top of the slope, the "fall line" is the steepest angle down the slope. In a gully system with a steeper inner gully within a less steep outer gully, the sidewall slope of the inner gully is measured. The slope of any sidecast material at road crossings is considered as the sidewall slope angle. The slope angle is recorded in the left-hand column of Table A1 or A2.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

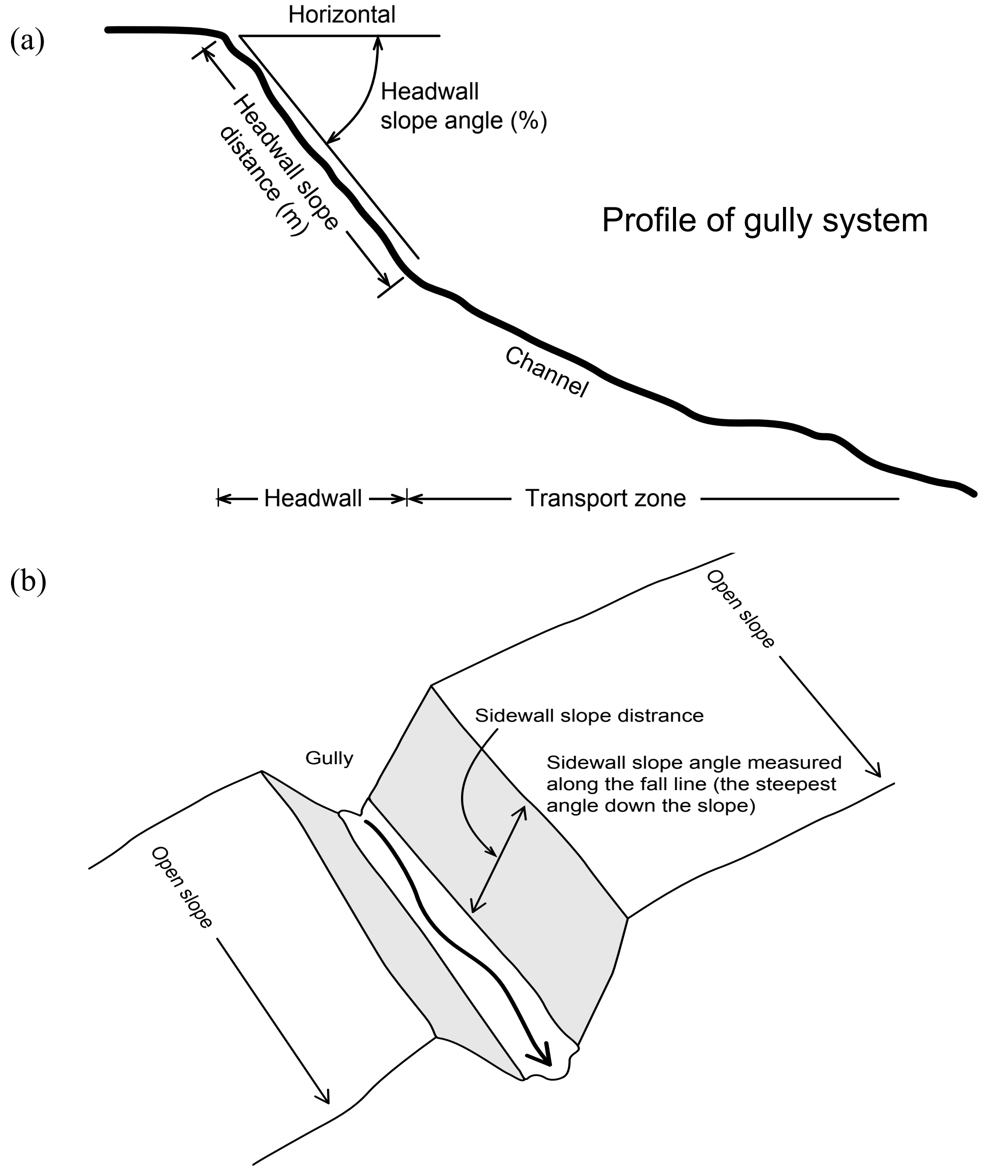

Figure 9. Measurement of headwall (a) and sidewall (b) slope angle and distance.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Surficial materials. The stability of a slope depends greatly on the type of surficial material that makes up the slope. The choices are arranged from most stable to least stable:

- R — Solid rock (R) is considered stable. If the rock is strongly sheared (broken into small pieces) or weathered, then use the colluvial classification.
- C — Colluvial (C) material is generally considered to be relatively stable soil at its angle of natural repose.
- M or F — Morainal (M, hardpan and till) and fluvial (F, sand and gravel, including glaciofluvial) materials are generally considered to be somewhat stable soils.
- W or L — Marine (W, including glaciomarine) and lacustrine (L, including glaciolacustrine) materials are generally considered to be fine-grained soils, susceptible to erosion, often oversteepened and potentially unstable.
- FS — Failure scars are present, indicating past instability and that the slope is unstable. Note that failure scars are particularly common in sidecast material at road crossing.

The surficial material is recorded along the upper row of Table A1 or A2.

Headwall or sidewall failure potential is assessed as high, moderate, or low at the intersection of the headwall or sidewall slope angle and the type of surficial material in Table A1 or A2. This assessment is transferred to the left-hand column in Table C.

Table B. Gully geometry potential for debris flow initiation

Sidewall slope distance ______ (m)	**Channel gradient ______(%)**		
	≤30	**>30 – ≤40**	**>40**
>15	L	M	H
7 – <15	L	L	M
0 – <7	L	L	L
All headwalls	M	H	H

Enter the results in Table C

Gully wall slope distance. The slope length (or distance) of a gully sidewall is a surrogate measurement for the energy a landslide will have when it reaches the channel. The sidewall slope distance is measured from the bottom of the sidewall to the top of the sidewall at the slope break, at the same location as slope angle was measured (Figures 9a and 9b). The slope distance of any sidecast material at road crossings is considered as the gully wall slope distance. The slope distance is recorded in the left-hand column in Table C. If you are assessing a headwall location, then the channel gradient is the only parameter recorded in Table C.

Channel gradient. The steeper the channel gradient, the higher the likelihood of a debris flow initiating. The channel gradient is measured over a minimum distance of 40 m (Figure 10). The channel gradient is recorded in the upper row in Table B.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

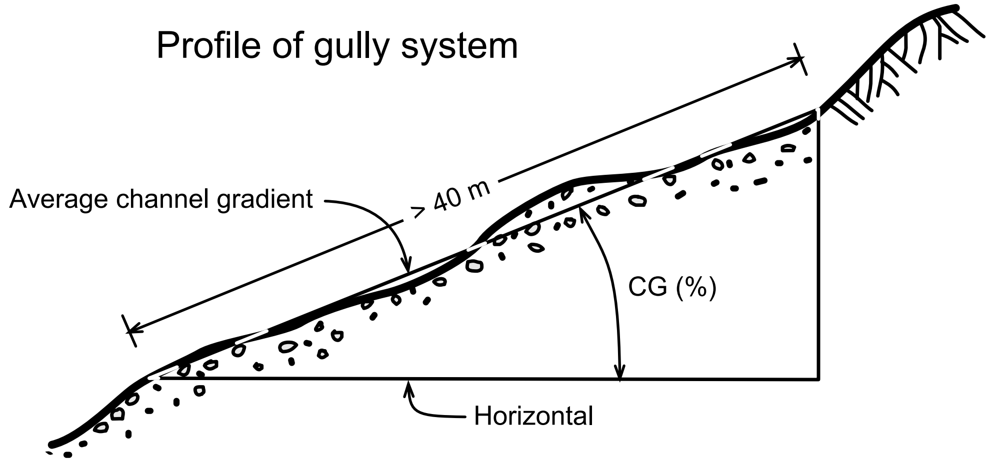

Figure 10. Measurement of channel gradient (CG).

Gully geometry for debris flow initiation is assessed as high, moderate, or low at the intersection of the headwall or sidewall slope distance and the channel gradient in Table B. This assessment is transferred to the upper row in Table C.

Table C. Debris flow initiation hazard

HWFP or SWFP (Table A1 or A2)	Gully geometry potential for debris flow initiation (Table B)		
	L	**M**	**H**
H	L	M	H
M	L	M	M
L	L	L	L

Enter the results in Section 5

Debris flow initiation hazard. This hazard is assessed as high, moderate, or low at the intersection of the headwall or sidewall failure potential (HWFP or SWFP from Table A1 or A2) and the gully geometry potential for debris flow initiation (from Table B). This assessment is transferred to Section 6.

Section 6. Debris flow initiation potential (DFIP)	L	M	H
Debris flow initiation hazard (Table C)	L	M	H
Past debris flow initiation in this reach	no	not clear	yes

Past debris flow initiation. If evidence indicates debris flows having begun within the reach, the likelihood of future debris flows initiating in that reach is high. Typical evidence of a debris flow initiating within a reach is a sidewall scar, with a channel empty of sediment and woody debris below the scar. Refer to Appendix 2 for other field indicators of past debris flows. If there is no evidence of

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

debris flows having begun within the reach, the likelihood of future debris flows initiating is considered low. If it is unclear whether a debris flow initiated in the reach, “not clear” is recorded.

Debris flow initiation potential. This is assessed as high, moderate, or low based on the highest rating from either the debris flow initiation hazard (from Table C) or past debris flow initiation.

Section 7 Post-harvest Conditions

This section is used for both fan assessments and transport zone and headwall assessments for the post-harvest situation.

Woody debris introduced by harvesting can alter natural gully system processes. This section helps to determine whether it is necessary to remove the woody debris from the gully system after harvest. Record the information in Section 7, and then consult the management strategies to determine appropriate actions to manage logging debris.

Section 7. Post-harvest conditions				
Years since harvesting	<1	2 – 5	6 –10	>10
Logging debris in channel	sparse	moderate	heavy	very heavy
Sediment stored behind logging debris	sparse	moderate	heavy	very heavy

Years since harvesting. In general, the usefulness of removing woody logging debris from a gully system decreases as the debris ages. Older woody debris becomes incorporated into the channel structure, and removing this debris may cause more sediment and woody debris to migrate downstream. The known or estimated years since harvesting are recorded as a range.

Logging debris in channel. The amount of woody logging debris in the gully system influences normal sediment transport processes, and potentially increases the volume of debris flows. However, large volumes of logging debris rarely result in the initiation of a debris flow in a gully. Pay particular attention to the accumulation of logging debris immediately upstream of road crossings. The amount of woody debris covering the channel is assessed visually. The choices are:

- Sparse — <20% of the channel is covered by scattered woody logging debris
- Moderate — 20% – 80% of the channel is covered by scattered woody logging debris, or there are two or three accumulations >1 m deep and >10 m long
- Heavy — >80% of the channel is covered by woody logging debris, or there are four or more accumulations >1 m deep and >10 m long
- Very heavy — >80% of the channel is filled with woody logging debris >1 m deep

Natural woody debris should not be included in the estimates. Natural woody debris is often more weathered and sometimes covered by moss. However, if the natural woody debris is broken up during falling and yarding operations, include it in the estimate of the amount of logging debris in the channel.

Operational Planning Regulation 37(1)(c) and
Woodlot License Forest Management Regulation 64(2)(a) continued

Sediment stored behind logging debris. Woody debris often traps sediment introduced into the channel. Streams capable of transporting sediment and woody debris often develop locations where woody debris develops jams, and sediment is stored immediately upstream of the jam. As sediment storage increases, sediment wedges or "platforms" develop. The choices are:

• Sparse	Little sediment is stored and no sediment wedges exist
• Moderate	One to five small (<1 m^3) sediment wedges exist
• Heavy	The channel has developed a stepped profile. More than five small wedges (<1 m^3), or one to five moderate-sized wedges (1 – 3 m^3), or up to three large wedges (>3 m^3) exist
• Very heavy	Several large (>3m^3) sediment wedges with extensive storage exist

Part IV constitutes the second of two parts of a gully assessment as specified in Operational Planning Regulation (OPR) 37(1)(c) and Woodlot License Forest Management Regulation (WLFMR) 64(2)(a).

Part IV Management Goals and Strategies

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a)

The GAP is designed to be used for gully system management, including: road crossings, cutblock layout, gully system rehabilitation, and post-harvest road deactivation of the crossings. Although management strategies may vary depending upon the situation, the goals of gully system management should remain the same.

Management Goals

Gully system management should:

- maintain gully wall and channel stability
- maintain natural rates of erosion and transport of sediment and woody debris.

For example, since woody debris is an important factor in channel stability, natural volumes of woody debris in the channel should be maintained. During harvesting, woody debris can be maintained in the channel by leaving standing timber, which will eventually die and fall into the channel. Where safety concerns or a potential windthrow hazard negate leaving standing timber, large woody debris can be placed across the channel. Useful large woody debris is considered to be at least twice the depth of the channel in diameter and greater than three channel-widths in length. After harvesting, woody debris can be maintained in the channel by not removing natural large woody debris, or by sometimes placing large woody debris across the channel. In both cases, the disturbance of the headwall and sidewalls, such as exposing mineral soil and displacing stumps, should be minimized.

To achieve these management goals, innovative road building, harvesting, and post-harvest strategies should be encouraged

Harvesting Strategies

Tables 1 and 2 address gully system management strategies for harvesting.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Table 1. Harvesting management strategies

Strategy	Name	Use	Typical location
Harvesting strategies			
Leave gully in natural state	NOLOG	For areas of high natural instability and high downstream impact	Unstable gullies with debris flow potential, unstable channels with high water transport, unstable fans
Leave a buffer	BUFFER	For narrow areas of high instability	Unstable gully sidewalls or unstable stream channels
Partial cutting systems	PARTIAL	To minimize fan destabilization	Fans with high destabilization potential
Clearcut, leave saplings	LS	To maintain sidewall or streambank stability	Sidewalls or streambanks with moderate instability
Clearcut	LOG	For areas of low risk	Low-hazard gullies and stable fans
Cleaning woody debris strategies			
Clean woody debris	/CTWD	To remove logging debris likely to be transported by water flows	Channels with high or moderate water transport potential
Clean large woody debris	/CLWD	To reduce the logging debris load	For gullies with high debris flow potential

The upper portion of Table 1 presents various harvesting strategies, and summarizes typical uses and locations. Figures 11 and 12 include sketches of each. The lower portion of Table 1 presents strategies for cleaning woody debris from the gully system. Cleaning is usually carried out concurrent with harvesting, or shortly thereafter. In the upper portion of the table, the strategies are listed from more restrictive (or conservative) at the top of the table to less restrictive at the bottom of the table.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

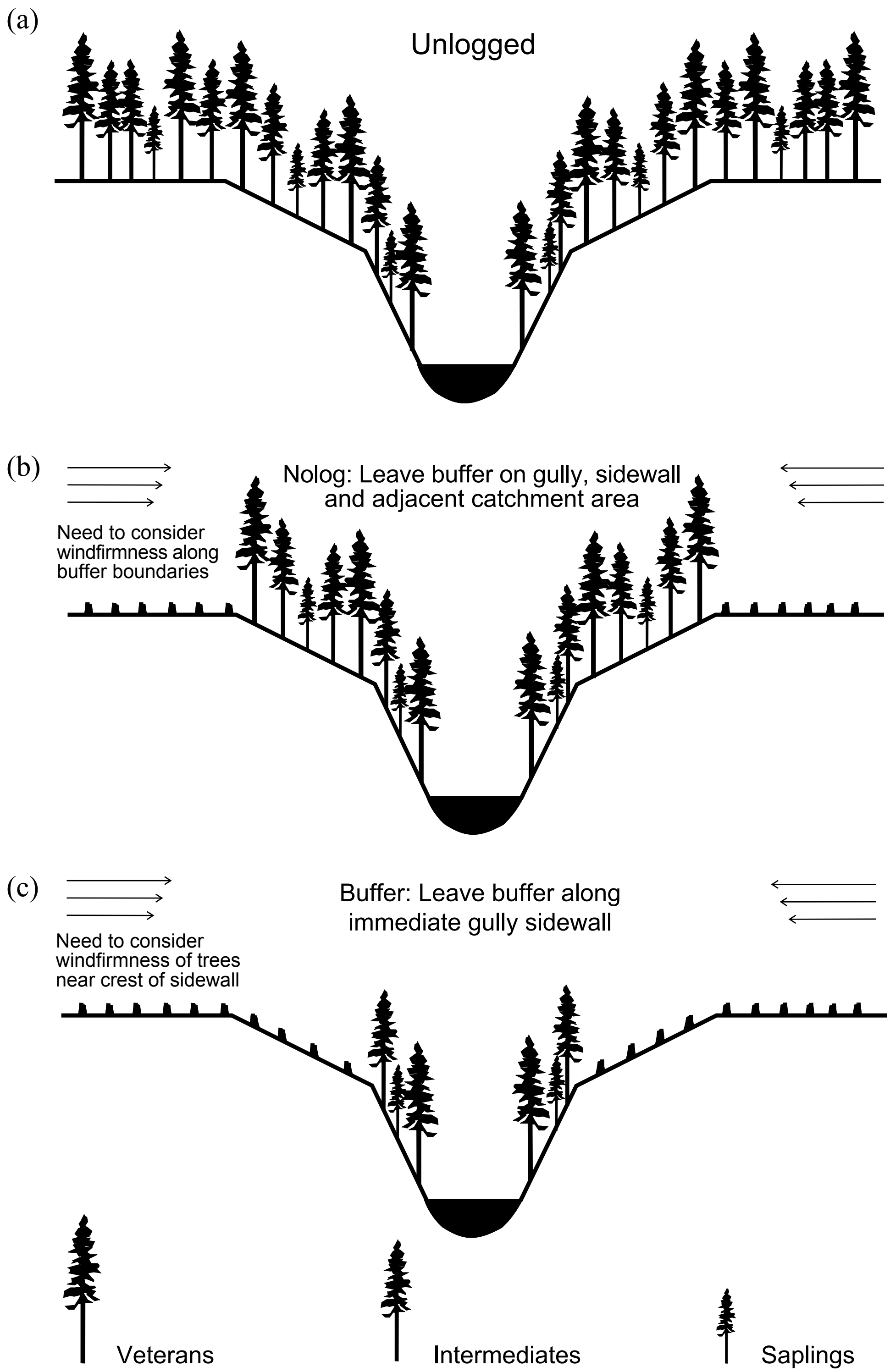

Figure 11. Sketches of logging strategies along transport zones and headwalls.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

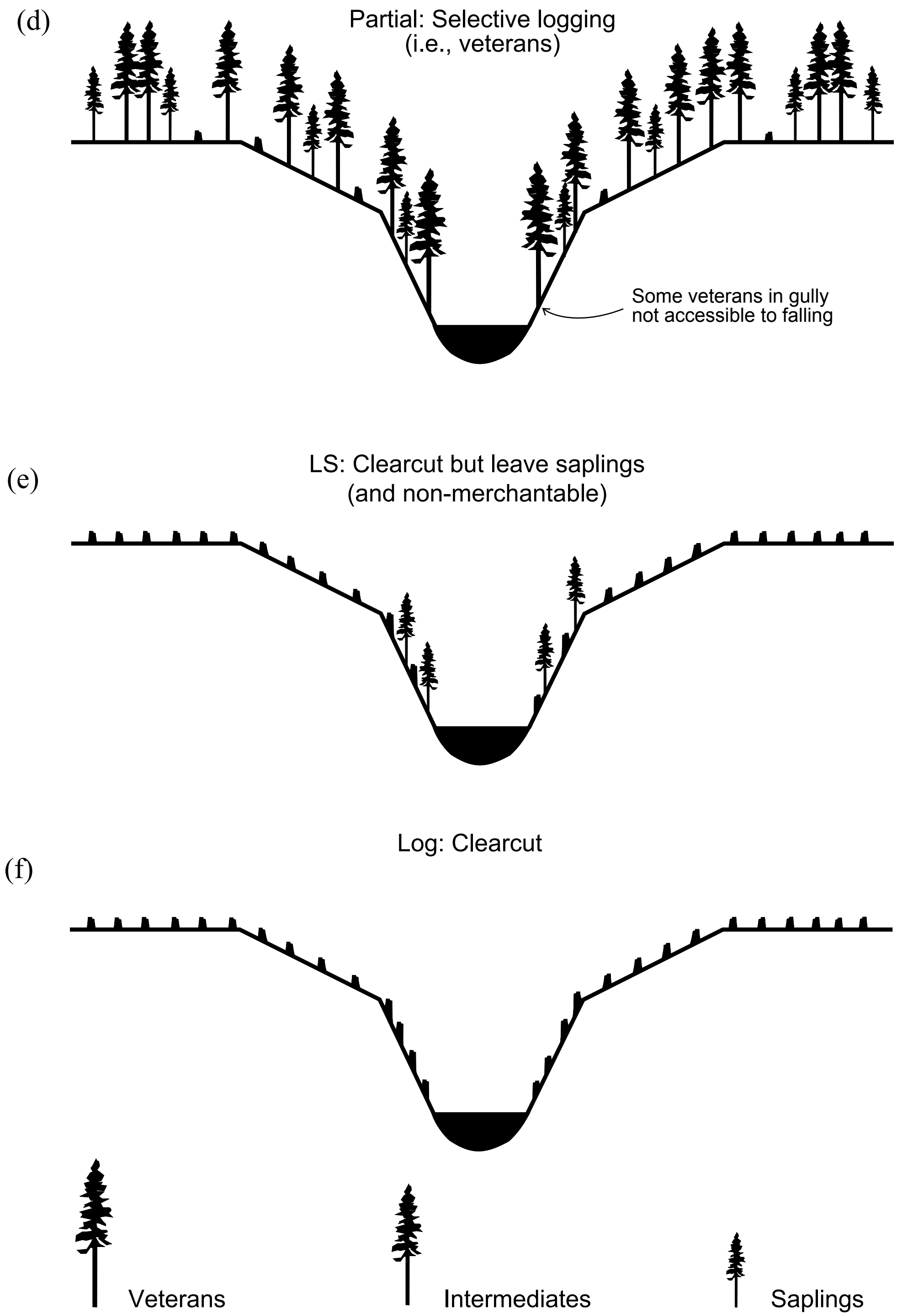

Figure 11. (continued) Sketches of logging strategies along transport zones and headwalls.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

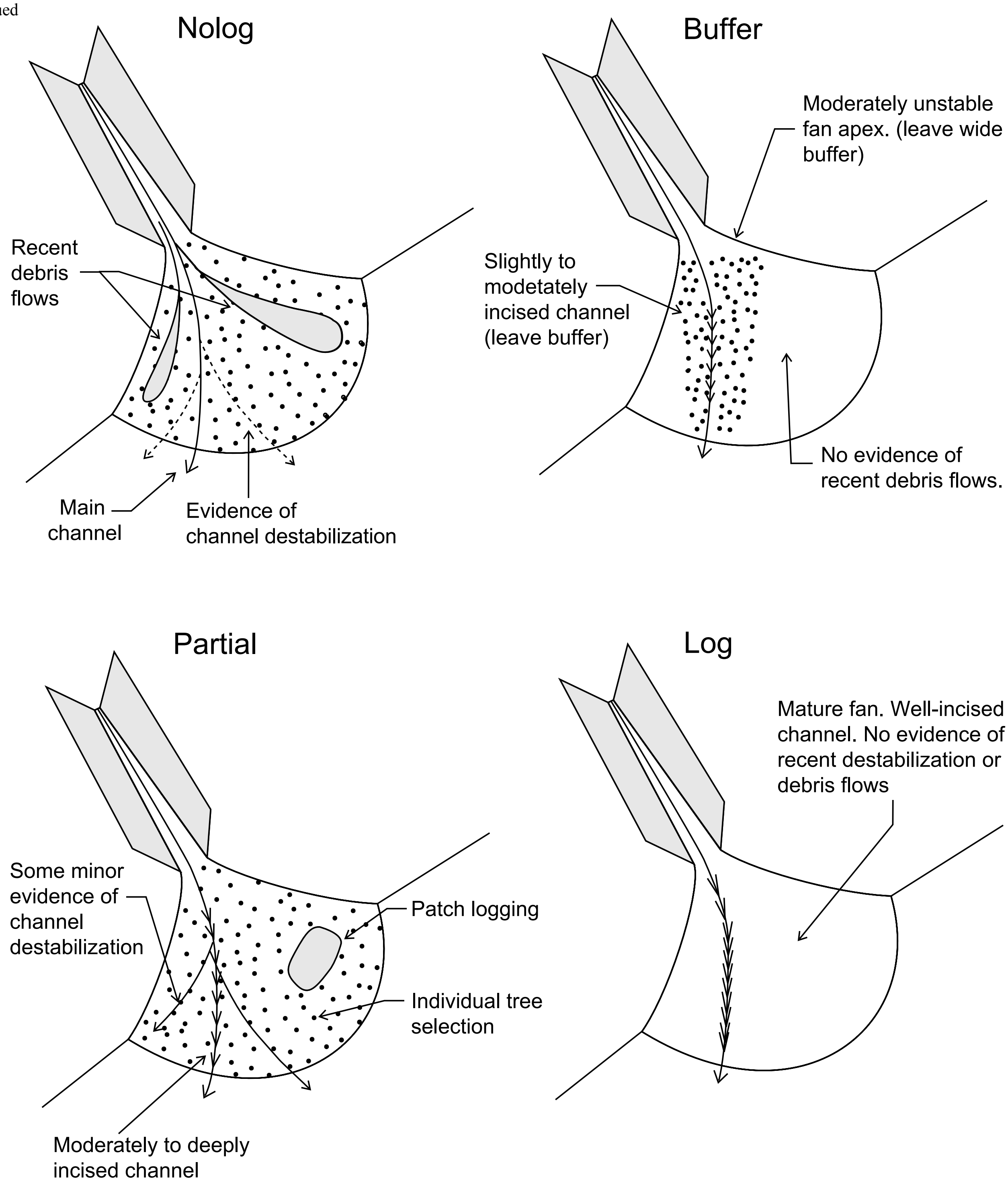

Figure 12. Sketches of logging strategies on fans

Table 2. Appropriate harvesting management strategies for forested gully systems[a]

Section 2.	Section 3.		Section 4.		Section 5.		Section 6.	
Downstream impact potential	**Upslope debris flow potential**	**Possible management strategy**	**Water transport potential**	**Possible management strategy**	**Fan desta-bilization potential**	**Possible management strategy**	**Debris flow initiation potential**	**Possible management strategy**
H	H	LOG/CLWD	H[b]	NOLOG, BUFFER	H[b]	NOLOG	H[b]	NOLOG
	M	LOG/CLWD	M	BUFFER, LS/CTWD	M[b]	BUFFER, PARTIAL	M[b]	BUFFER, PARTIAL, LS/CLWD
	L	LOG	L	LOG	L	LOG/CTWD	L	LS, LOG
M	H	LOG/CLWD	H[b]	BUFFER, LS/CTWD	H[b]	BUFFER, PARTIAL	H[b]	NOLOG, BUFFER
	M	LOG	M	BUFFER, LS/CTWD, LOG/CTWD	M	BUFFER, LOG/CTWD	M	PARTIAL, LS
	L	LOG	L	LOG	L	LOG	L	LOG
L	H	LOG/CLWD	H	LS/CTWD	H	BUFFER, PARTIAL, LOG/CTWD	H	PARTIAL, LS
	M	LOG	M	LOG/CTWD	M	LOG/CTWD	M	LS, LOG
	L	LOG	L	LOG	L	LOG	L	LOG

[a]The most limiting condition determines the management strategy.

[b]Consult with a qualified registered professional before harvesting, or if windthrow occurs and windthrow salvage is contemplated.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Table 2 relates the gully system hazards determined from the field assessment with the harvesting strategies in Table 1 and indicates under what circumstances a qualified registered professional should be consulted. More restrictive strategies are generally suggested for gully systems with higher hazard likelihoods and for those gully systems with higher-value downslope/downstream resources. If other strategies can achieve the gully system management goals better than the suggested strategies, then they should be applied.

If more than one reach is to be harvested, then if appropriate, reach-specific strategies should be considered. If one strategy is to be used for all reaches, the most restrictive strategy for the reaches should be followed.

Streams in gully systems are usually classified as either S5 or S6. The harvesting strategy selected for such streams should consider both gully system hazards and fisheries and wildlife habitat management strategies. For the latter, refer to the *Riparian Management Area Guidebook*. The more restrictive strategy should be followed.

Purposely, the suggested harvesting strategies in Tables 1 and 2 do not specify falling and yarding methods to achieve the management goals. That responsibility lies with the licensees and agencies involved with each particular cutting permit. Several basic principles, however, usually apply. For example:

- All harvesting methods should minimize the amount of woody debris entering the gully system.
- When faller safety is at risk, specific trees such as snags and heavy leaners can be felled into or across the gully. This safety measure includes trees outside the gully system margins. As a guideline, at least 1 m of vertical clearance should be left between the fallen tree and the high flow level of the stream if the log is to be left in the gully.
- Windfirm boundaries should be designed for trees left standing.

The practicality of the harvesting method should be considered for each harvesting strategy. For example, it is impractical to recommend cleaning large woody debris from a channel that cannot be reached by equipment or that presents conditions too dangerous for workers. If a method is not practical, an alternative method should be recommended to meet the goals of gully system management.

Harvesting on fans should consider the types of hazards that may exist on the fan, and the areas on the fan that may be susceptible to these hazards. For example, where the channel is deeply incised, high water transport potential or upslope debris flow potential may be adequately addressed by leaving a buffer along the channel. Where debris flows may deposit over large areas of the fan, retention of trees on the fan will help to limit the areal extent of debris flow run out. Fans are often well suited to innovative harvesting methods because the relatively gentle slopes and coarse-textured soils can allow for various harvesting methods, including ground-based methods.

Road Crossing Strategies

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Roads across gully systems can greatly increase the likelihood of all related gully system hazards.

The location and type of road crossing should be chosen carefully. The approaches to the crossing and the crossing itself should be appropriately designed, constructed, and maintained for the particular character of the gully system. For example, different types of road crossings may be appropriate for crossing a transport zone versus a fan, and different designs may be appropriate if bedrock is likely to be encountered in the road cut. Many different methods are available to construct a road across a gully system. However, they generally can be grouped into four different types of crossings:

- bridges
- fills with culverts
- cuts and fills with culverts
- fords (or Squamishes).

A separate but associated task is to determine the appropriate stream flow for the crossing. This is described in the *Forest Road Engineering Guidebook*.

After harvesting, appropriate road deactivation of the approaches and the crossing should consider the likely headwall, transport zone, and fan processes. Typical road deactivation activities near a gully crossing include:

- removing bridges, major culverts, and other drainage structures within the channel
- constructing water crossings such as fords
- pulling back and stabilizing road fill and/or stabilizing cutslopes
- re-establishing pre-harvesting channel morphology and hydrology
- armouring channel beds with erosion-resistant materials
- cleaning woody debris immediately upstream and downstream of crossing.

Tables 3 and 4 indicate under what circumstances a qualified registered professional is to be consulted to assist with the layout, design, construction, and deactivation of road crossings. Appendix 3 provides additional management information on roads across gully systems and their deactivation. This information should help to determine if it is desirable to locate a road across a gully system at a particular location, and if so, what type of crossing should be considered. It should also help to determine the appropriate deactivation procedures.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Table 3. Design and construction of roads across gully systems: when to consult a qualified registered professional[a]

Section 2. Downstream impact potential	Hazard assessment[b]	Section 3. Upslope debris flow potential	Section 4. Water transport potential	Section 5. Fan destabilization potential	Section 6. Debris flow initiation potential
H	H	N[c]	C	C	C
	M	N	N	C	C
	L	N	N	N	N
M	H	N[c]	C	C	C
	M	N	N	N	C
	L	N	N	N	N
L	H	N[c]	N	N	C
	M	N	N	N	N
	L	N	N	N	N

Table 4. Deactivation of roads across gully systems: when to consult a qualified registered professional[a]

Section 2. Downstream impact potential	Hazard assessment[b]	Section 3. Upslope debris flow potential	Section 4. Water transport potential	Section 5. Fan destabilization potential	Section 6. Debris flow initiation potential
H	H	N	N	C	C
	M	N	N	N	C
	L	N	N	N	N
M	H	N	N	C	C
	M	N	N	N	N
	L	N	N	N	N
L	H	N	N	N	C
	M	N	N	N	N
	L	N	N	N	N

[a] N = no qualified registered professional required. C = consult with a qualified registered professional experienced in road deactivation and the gully system hazards present at the location.

[b] Use the hazard assessments for upslope debris flow potential, water transport potential, fan destabilization potential (if on a fan), or debris flow initiation potential, in combination with the downstream impact potential to locate the appropriate box in the table.

[c] Although qualified registered professional consultation is not required, ensure that road crossings do not increase the hazard to downstream resources.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

In general, the location, type of road crossing, and appropriate construction, maintenance, and deactivation depend on many other factors in addition to the characteristics of the gully system. Such factors include whether the road crossing is to be permanent or temporary, the road geometrics, the value of the wood beyond the gully system versus the cost of the crossing, other road location control points, and downslope and downstream resources. In fact, because so many variables must be considered, a simple method of determining the type of crossing or type of deactivation is not practical. Each crossing should be assessed, designed, constructed, and deactivated individually.

Sometimes, a road should not cross a gully system at a particular location. Other options might include relocating elsewhere on the gully system, accessing the timber from a different direction to avoid the gully system entirely, or considering an alternative form of timber harvesting, such as long-line or helicopter. In other cases, a road can appropriately cross a gully system, but the crossing should be deactivated immediately after harvesting.

Post-harvest Strategies

After harvesting, the gully system is assessed to determine whether the harvesting activities have achieved the management goals. If the goals have not been achieved, or if harvesting was carried out several years ago before the introduction of the GAP, it is necessary to determine what strategy is required to meet the goals.

Post-harvest management strategies can be broadly divided in two.

- Preventive measures that prevent or minimize disturbances resulting from future debris slides, debris flows, water transport, or fan destabilization. Management of logging debris is the primary preventive measure, and riparian planting of fast-growing hardwood species may help to maintain channel stability.
- Rehabilitative measures attempt to mitigate conditions if the gully system has already been affected by one or more of the associated hazards. Revegetation of disturbed areas is the primary rehabilitation activity.

Preventive measures. The amount of logging debris in a gully system may greatly influence the rates of erosion and sediment transport and, as a result, channel stability. Gullies with high or moderate water transport potential will transport woody debris and sediment, resulting in increased scour of sidewalls, storage of sediment and woody debris in jams, and frequently greater amounts of sediment and woody debris delivered to downstream channels. If a harvested gully with large amounts of logging debris has a debris flow, the result will be a larger debris flow and greater damage. If logging debris is left in a gully for several years, then the wood often becomes partially buried in sediment and incorporated into the channel structure. Removal of buried woody debris generally results in more harm than good; therefore, it is important to remove logging debris shortly after its introduction to the channel.

The decision as to whether logging debris should be removed depends on the hazards within the gully, the downslope/downstream resources, the amount of logging debris in the channel, and the relative amounts of sediment stored behind the debris. If a gully is cleaned, subsequent movement of small woody debris into ditches and culverts may require regular work to maintain water passage. Use the following objectives to assess whether to clean logging debris from gully

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

channels. Each cleaning objective should be evaluated separately, but the appropriate cleaning method may need to achieve more than one objective.

- *Cleaning objective for water transport potential:* Clean all logging debris that can be transported by peak flows. The size of logging debris pieces cleaned should increase as channel size increases. Pieces of natural woody debris that are broken up into small pieces of woody debris during falling and yarding operations should also be cleaned.
- *Cleaning objective for debris flow initiation or upslope debris flow potential:* Clean almost all logging debris to reduce total volume of woody debris that could be incorporated into a debris flow.
- *Cleaning objectives for fans:* Clean almost all logging debris to prevent a channel avulsion (change in channel location). Channel avulsions that are affected by the presence of logging debris are primarily due to water transport. The deposition of debris flows is unlikely to be significantly affected by logging debris within a fan channel.

Table 5 provides cleaning strategies for gully and fan channels. Consider cleaning strategies for water transport potential in all channels. Consider cleaning strategies for debris flows in headwall and transport zone channels. Finally, consider cleaning strategies for fans in fan channels. When deciding whether to clean channels several years after harvesting, consider the cleaning principles listed in Table 5.

Table 5. Post-harvest management strategies for removing logging debris from gully and fan channels

Table 5a: Cleaning strategies for water transport potential

Section 2. Downstream impact potential	Section 4. Water transport potential	Action
H or M	H or M	Clean all logging debris likely to move during peak flow events if the debris load is moderate or greater
L	H	Clean all logging debris likely to move during peak flow events if the debris load is moderate or greater
H or M	L	Do not clean
L	M or L	Do not clean

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Table 5b: Cleaning strategies for debris flows		
Section 2. **Downstream impact potential**	**Section 3. Upslope debris flow potential *or*** **Section 6. Debris flow initiation potential**	**Action**
H or M	H	Clean almost all logging debris if the debris load is heavy or very heavy
H	M	Clean almost all logging debris if the debris load is very heavy
H	L	Do not clean
M	M	Clean almost all logging debris if the debris load is very heavy
M	L	Do not clean
L	H, M, L	Do not clean

Table 5c: Cleaning strategies for channels on fans			
Section 2. **Downstream impact potential**	**Section 4.** **Water transport potential**	**Section 5.** **Fan destabilization potential**	**Action**
	H or M	H or M	Clean all logging debris if the debris load is moderate or greater
H or M	H or M	L	Follow WTP cleaning recommendations
	L	H, M, L	Do not clean
	H	H	Clean all logging debris if the debris load is moderate or greater
L	M	M	Clean all LD if LD load is heavy or greater
	M	M	Do not clean
	L	L	Do not clean

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Several basic principles usually apply when cleaning woody debris. For example:

- Do not remove or cut natural large woody debris. Removing natural woody debris may destabilize channel banks and may result in significant amounts of sediment and woody debris being transported downstream.
- Do not remove logging debris with no capability to affect the potential for debris build-up or to significantly increase the volume of a debris flow.
- Do not remove logging debris that is potentially unsafe to move.
- For channels logged 2 or more years ago, cleaning logging debris is often not useful. Generally, leave logging debris that is buried in sediment. Remove woody debris that is mobile and will be transported downstream.
- Remove logging debris that is trapping sediment and additional woody debris. This may require cutting pieces of wood to leave the portion of the log that is buried in sediment, and to remove the portion that will trap more debris and sediment.
- If a channel shows no sign of logging debris movement several years after harvesting, it may not be worth removing the debris, except to reduce potential debris flow volume.
- Always leave some large woody debris in the channel. Such debris should be greater than two channel-depths in diameter and greater than three channel-widths in length.
- Place all removed woody debris well beyond the limits of peak water flow and on stable ground. If woody debris cleaning is done to reduce potential debris flow volume, place all woody debris outside of the gully.
- Do not burn slash accumulations within the channel.

If sediment loads are moderate, heavy, or very heavy, and if removing the woody debris could cause a rapid release of sediment that could have significant downstream consequences, it may be prudent to leave the channel untouched. In this case, options may include the construction of sedimentation basins or debris flow control structures.

Woody debris jams may result from either debris flows or high water flows. Generally, removal of woody debris from jams should be considered only when the wood is not yet storing sediment. Recent debris flow jams that appear to be unstable may need to be removed. Consult with a qualified registered professional before removing woody debris jams.

Where there are high downstream resources, or the risk is high, a qualified registered professional should be consulted.

Gully system rehabilitation. After disturbances to the gully system have occurred, several activities can be carried out to rehabilitate scoured headwall and transport zones and destabilized fans.

Scoured headwall and transport zones:

- hydroseed with a grass/legume mixture combined with fertilizer
- plant conifers, hardwoods, and/or shrubs.

Operational Planning Regulation 37(1)(c) and Woodlot License Forest Management Regulation 64(2)(a) continued

Destabilized fans:

- plant fast-growing hardwoods along the channel margins, if no streamside buffer is in place or the buffer is very narrow.

In addition to rehabilitation in these areas, re-establishing a commercial crop may be possible.

In addition to revegetation, other activities can include:

- excavate excessive sediment and debris accumulations
- install riprap to prevent undercutting of sidewalls or scour of channel beds, to provide bank support, and/or to address retrogression of nick points in the channel
- construct check dams, log retaining structures, or other in-channel structures.

These activities require the input of a qualified registered professional.

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Forest Practices Code Guidebooks

Forest Road Engineering Guidebook
Mapping and Assessing Terrain Stability Guidebook
Riparian Management Area Guidebook

Appendix 1 Field form for gully assessment

Section 1. Gully system identification		
Watershed	Cutblock No.	Date (y/m/d)
Gully No.	Road No.	Recorded by
Reach No.	Dist. (start/end) (m)	Roll/photo No.

Fan assessments: complete Sections 2, 3, 4, 5 (and 7 if post-harvest).

Transport zone and headwall assessments: complete Sections 2, 3, 4, 6 (and 7 if post-harvest).

Enter the results in Management Strategies, Tables 2–5.

Section 2. Downstream impact potential	L	M	H
Connection to a community watershed intake	None	Indirect	Direct
Dwellings, major installations, safety	No		Yes
Connection to fish streams or lakes or sensitive marine zones	None	Indirect	Direct

Section 3. Upslope debris flow potential	L	M	H
Terrain stability class upslope (from terrain mapping)	I–III, or S	IV or P	V or U
Slope gradient upslope (if no terrain mapping)	<50%	50 – 60%	>60%
Evidence of landslides or debris flows in gully systems	N	not clear	Y

Section 4. Water transport potential (WTP)	L	M	H
Channel width (m)	≤2	>2 – ≤3.5	>3.5
Size of water-transported woody debris	SWD	LWD	Logs or no WD
Largest sediment in storage wedges (mm)	≤100	>100 – ≤200	>200

Section 5. Fan destabilization potential (FDP)			
Channel incision (CI) ______ (m)	Number of channels (CN) (If the fan has no channels, the FDP is L, low)		
	1	2–3	>3
<0.5	H	H	H
0.5 – <1	M	H	H
1 – <2	L	M	H
≥2	L	L	M

Table A1. Headwall failure potential (HWFP)

Headwall slope angle ______ (%)	Headwall surficial material				
	R	**C**	**M, F**	**W, L**	**FS**
>70	L	H	H	H	H
>60 – 70	L	M	H	H	H
>50 – 60	L	L	M	H	H
≤50	L	L	L	M	H

Enter the results in Table C

Table A2. Sidewall failure potential (SWFP)

Sidewall slope angle ______ (%)	Sidewall surficial material				
	R	**C**	**M, F**	**W, L**	**FS**
>70	L	H	H	H	H
>60 – 70	L	L	M	H	H
>50 – 60	L	L	L	H	H
≤50	L	L	L	M	H

Enter the results in Table C

Table B. Gully geometry potential for debris flow initiation

Sidewall slope distance ______ (m)	Channel gradient ______(%)		
	≤30	**>30 – ≤40**	**>40**
>15	L	M	H
7 – <15	L	L	M
0 – <7	L	L	L
All headwalls	M	H	H

Enter the results in Table C

Table C. Debris flow initiation hazard

HWFP or SWFP (Table A1 or A2)	Gully geometry potential for debris flow initiation (Table B)		
	L	**M**	**H**
H	L	M	H
M	L	M	M
L	L	L	L

Enter the results in Section 6

Section 6. Debris flow initiation potential (DFIP)	**L**	**M**	**H**
Debris flow initiation hazard (Table C)	L	M	H
Past debris flow initiation in this reach	no	not clear	yes

Section 7. Post-harvest conditions				
Years since harvesting	<1	2 – 5	6 –10	>10
Logging debris in channel	sparse	moderate	heavy	very heavy
Sediment stored behind logging debris	sparse	moderate	heavy	very heavy

Appendix 2 Field indicators of gully system instability

Headwall and transport zones

Sidewall and headwall instability

- Small, fresh, or revegetated debris slide scars on the gully walls.
- Frequent pistol-butt (bowed) trees or leaning trees along the gully walls.
- Young, shallow soils (result of repeated failure over time) compared with adjacent slopes when gullies are developed in deep tills or glaciofluvial materials.
- Stepped scarps, tension cracks, and soil creep.

Evidence of debris flow movement down the transport zone

- Channel floor scoured clean of sediment and woody debris.
- U-shaped channel cross-section.
- Trim lines or younger vegetation and trees, along the floor and lower sides of the channel.

Fan zones

Indicators of past debris flow activity

- Surface slopes on fans created by debris flows typically range from 10 to 30%, while fans formed solely by stream action generally have gradients <5%.
- Piles, lobes, and levees of debris are composed of large woody debris and coarse sediment.
- Multiple stream channels.
- Bands of different-aged trees that run from the top towards the bottom of the fan.

Appendix 3 Strategies for roads across gully systems

Introduction

Tables 3 and 4 in the body of the guidebook give some guidance about when to consult an appropriately qualified registered professional about the design and construction, and deactivation of roads across gully systems. In addition, the Forest Road Regulations require the input of a qualified registered professional in certain situations.

This appendix provides additional information to non-professional field personnel to help with the location, design, construction, maintenance, and deactivation of roads across gully systems. It should help determine if a particular location along a gully system is suitable for a road crossing, and if so what type of crossing should be considered. It should also help determine appropriate deactivation strategies. If in doubt, consult a qualified registered professional.

In general, the location, type of road crossing, and appropriate construction, maintenance, and deactivation depend on many factors, in addition to those associated with the gully system. Such factors include:

- permanency of the road crossing (i.e., permanent or temporary)
- road geometrics
- value of the wood beyond the gully system versus the cost of the crossing
- other road location control points
- downslope/downstream resources.

In fact, so many variables are involved that a simple table of gully system characteristics versus type of road crossing or type of road deactivation is not practical. Each road crossing must be assessed, designed, constructed, and deactivated site-specifically.

In some cases, a road should not cross a gully system at a particular location. Other options might include:

- relocating the road crossing to a different location, either upstream or downstream along the gully system
- accessing the timber from a different direction to avoid the gully system entirely
- considering an alternative harvesting system, such as long-line or helicopter.

In other cases, it may be appropriate for a road to cross the gully system, if the crossing is removed as soon as harvesting has been completed.

The following sections review the terrain characteristics and road requirements that should be considered before a crossing location and the type of crossing are selected. Then, the typical types of road crossings with potential advantages and disadvantages of each, and some road and gully system interactions, are reviewed.

Terrain characteristics and roads

A gully system usually consists of a headwall, a transport zone, and a fan. Different factors must be considered for each of these components when designing road crossings of gully systems.

Headwall. For road crossings, curved and notched headwalls can be considered similar to the transport zone (discussed below), while a planar headwall can be considered similar to a very steep, open slope. Important considerations include slope gradient, underlying geology, stability of the natural slopes, and active geomorphic processes, such as creep, gullying, and groundwater seepage.

Transport zone. The sidewalls of large gullies are often the road approaches to the actual stream crossing. Sidewalls are often planar and can be considered similar to steep to very steep, open slopes. As with headwalls, important considerations for roads across sidewalls include slope gradient, underlying geology, stability of the natural slopes, and active geomorphic processes, such as creep, gullying, and groundwater seepage.

Other important considerations for road crossings of headwalls and transport zones include channel gradient, water discharge, passage of sediment and woody debris, and construction of stable abutments. The possibility of debris flows and snow avalanches down the gully system should also be weighed. Generally, fish passage is not an issue for steeply inclined transport zones.

Fan. Important considerations for fan crossings include water discharge, variability of the location, size, and number of channels, the possibility of flooding and/or an avulsion, deposition of sediment and woody debris, debris flows and snow avalanches, and the passage of fish.

Road requirements

Many factors go into road layout, design, construction, maintenance, and deactivation. The crossing of gully systems is just one of many. Others are outlined in the *Forest Road Engineering Guidebook* and summarized as follows:

- intended use of the road (e.g., vehicle size, loading and volume of traffic, mainline vs. spur)

- intended season(s) of use (e.g., winter, summer, vs. all seasons)
- climate (e.g., rainfall, snowfall, freezing conditions)
- intended life expectancy (e.g., one season, <3 years, >3 years)
- user safety (e.g., industrial and public, travel speeds, appropriate traffic control)
- resource impacts (e.g., forestry, fisheries, wildlife habitat, visual, downslope/downstream)
- economics (e.g., construction, maintenance, and deactivation, cost-benefit ratios)
- road alignment (e.g., horizontal and vertical geometry, stopping and sight distances)
- road width (e.g., single or double lanes, turnouts, and widening)
- soil and rock types (e.g., stable fill and cutslope angles, excavation and blasting requirements)
- construction materials available (e.g., location and suitability of soil, rock, timber)
- borrow areas; slash and end-haul spoil areas (e.g., location, size, environmental constraints)
- construction methods (e.g., balancing of cuts and fills, full bench and end haul)
- surface drainage (e.g., crowning, inslope, outslope), ditches, French drains
- stream crossings (e.g., size and type, upstream protection)
- construction problems (e.g., rock, steep terrain, erodible soils, soft subgrade)
- future deactivation requirements.

Refer to the *Forest Road Engineering Guidebook* for further information about each of the previous requirements. Most of these requirements, however, should be considered during road layout, design, construction, maintenance, and deactivation across gully systems.

Typical types of road crossings

The many different methods to construct a road across a gully system can generally be grouped into four different types of crossings.

- bridges
- fills with culverts
- cuts and fills with culverts
- fords (or Squamishes).

Each of the four types, along with some advantages and disadvantages, are briefly described. Some complex road crossings can be considered to be combinations of more than one of the above four types. For most crossing types (except high bridges), the road grade should dip into the crossing and climb out of the crossing. This approach will keep water from the gully stream in the gully, even if the road drainage structure is blocked. The decision not to cross a gully system for valid reasons should also be considered as an option. Refer to the Forest Road Regulation and the *Forest Road Engineering Guidebook* for further design requirements.

Bridges. Under the right circumstances, bridges can be used to span the entire headwall or the sidewalls and channel. For very large gullies, bridges will span only the channel, and conventional approaches will still be required. On fans, bridges can be isolated by shifting channels or can unnaturally constrict flow. Bridges have several advantages and disadvantages, as shown below.

Potential advantages of bridges	Potential disadvantages of bridges
• in some circumstances can avoid unstable headwall and sidewall approaches • maintain horizontal and vertical alignments • provide adequate cross-sectional area for design water discharge • provide opening for sediment and woody debris • give clearance for debris flows to pass • provide for fish passage • can be constructed from local materials • require less maintenance than culverts • can be relatively easy to deactivate • recycle or reclaim some structures	• require professional design for spans >6 m • can be relatively costly • require lead time for design and procuring materials • require strong foundations, or possibly retaining structures, for abutments • may require realignment of the road • may be subject to shifting stream channels on fans

Fills with culverts can be used for crossings only on relatively small gully systems and/or on relatively gentle slopes. Steeper slopes generally require cuts and fills. Therefore, fills with culverts are often suitable for crossing fans or carefully chosen low-gradient reaches. The actual stream crossing can be either a corrugated metal pipe culvert (CMP) or a wooden box culvert (WBC).

Potential advantages of fills with culverts	Potential disadvantages of fills with culverts
• often are suitable for crossing fans • can be relatively inexpensive • can be constructed from local materials • can use conventional construction methods • usually do not require extensive cuts and fills for approaches • the crossing of the channel can be relatively inexpensive • do not require professional design, except for major culverts • can possibly stop a relatively small debris flow • are relatively easy to deactivate	• are useful only on relatively small gully systems and on relatively gentle gradients • generally are not suitable for crossing headwalls and gullies with deep sidewalls • can be plugged, overtopped, eroded, and/or destroyed unless specially designed • require specific design considerations for passage of woody debris, debris flows, and fish

Cuts and fills with culverts can be used for crossing all sizes of gully systems on relatively steep slopes. Because of the relatively steep slopes, sections of the road across the headwall or the approaches across the gully sidewalls can be difficult to construct, maintain, and deactivate. The actual crossing of the channel can be relatively straightforward and can be either a corrugated metal pipe culvert (CMP) or a wooden box culvert (WBC).

Potential advantages of cuts and fills with culverts	Potential disadvantages of cuts and fills with culverts
• are often suitable for crossing headwalls and gully sidewalls • can be constructed from local materials • are suitable for temporary roads • the crossing of the channel can be relatively inexpensive	• are generally not applicable on fans • very steep headwalls and/or very steep sidewalls require considerable attention to design (possibly retaining structures), construction, and maintenance • can potentially result in unstable cuts and fills • prone to triggering debris slides and/or debris flows • cuts and fills may require design by appropriately qualified professional • often require abrupt changes in horizontal alignment • can be plugged, overtopped, eroded, and/or destroyed unless specially designed • can require specific design considerations for passage of woody debris, debris flows, and fish • cuts and fills may be difficult to deactivate

Fords (or Squamishes) are a suitable alternative crossing method under certain conditions only. These conditions usually include relatively gentle gradients, coarse-textured or bedrock substrate, relatively low traffic volumes, seasonal use, relatively narrow channels, and non-fish streams. Because the water flows over the top of the road, no bridge or culvert is required.

Potential advantages of fords	Potential disadvantages of fords
• often are suitable for crossing fans • require no bridge or culvert • water floods, debris flows, and snow avalanches can pass over road, without damaging or removing fills or culvert • are relatively inexpensive to construct • are relatively easy to construct, but require specific design requirements • require relatively little maintenance • are useful crossing for deactivated roads	• suitable only on non-fish streams • suitable only on low-use roads • suitable only on streams with relatively low or seasonal discharge • require coarse-textured or bedrock substrate, or imported materials • often require abrupt changes in horizontal and vertical alignment • require Ministry of Environment, Lands and Parks approval

Road and gully system interactions

Debris slides upslope/upstream of a road crossing can directly affect the road crossing or can initiate a debris flow that can affect the road crossing. The likelihood of upslope/upstream debris slides should be considered as part of locating a road across a gully system.

A road across a very steep headwall, or the approaches of a road crossing steep to very steep sidewalls, can lead to conditions favourable for initiating debris slides. Both cutslope and fillslope failures can lead to the initiation of a debris flow within the gully system downstream of the road.

Conventional cut-and-fill road construction, and/or poor construction, maintenance, or deactivation practices across the very steep terrain of a headwall or sidewalls can result in cutslope failures on the oversteepened upslope side of the road or fillslope failures on the oversteepened downslope side of the road. Typical road maintenance practices include blading material that has sloughed off the cutslope over the edge of the fillslope. This often results in an over-steepened and overloaded fillslope, which later fails. Roads should be located to avoid very steep and/or unstable headwalls and sidewalls. If such terrain must be crossed, special cutslope and fillslope designs may be required such as engineered retaining structures, narrow road width, no ditch, constructing a temporary road instead of a permanent structure, and special blasting or construction procedures. Rock fills are often preferable because they are less susceptible to saturation, less erodible, and more permeable, and can be constructed at steeper slope angles, thus minimizing the volume of the fill.

Road deactivation should consider the likelihood of upslope/upstream debris slides occurring, and the potential impact forces from the slide, the effect of added weight of slide debris on the road structure, and the potential disruption to the flow of surface water. For the deactivation of roads across steep headwalls and sidewalls, pulling back any oversteepened, potentially unstable fillslopes that might fail into the gully system, and using that material to help buttress any oversteepened, potentially unstable cutslopes should be considered.

Debris flows. Most debris flows begin in the upper portion of the gully system, travel the length of the gully system, and come to rest in the valley bottom, often on the fan. Debris flows that start upstream of a road crossing can plug, overtop, erode, and sometimes remove the road crossing. In some cases, road crossings, whether or not specifically designed for such, can stop a debris flow.

Several methods can be used to build a road across a transport zone that has a moderate or high debris flow hazard. These include constructing a bridge with sufficient clearance or constructing a ford that can be overtopped.

Roads that use fills to cross the gully system are most at risk from debris flows. Such debris flows can be extremely powerful, and can erode everything in the channel. Road fills are commonly incorporated into a debris flow, but unless a large road fill is involved or the road crosses the same gully system many times, the increased volume from the road fill is not significant to the downstream consequences. If there is little risk of environmental damage, safety concerns, or needing to maintain access, sacrificial cut-and-fill crossings may be appropriate.

When a debris flow is small or slow moving, or when the road fill is large and stable, the road fill can sometimes stop or slow down a debris flow. Because of the consequences if a debris flow is not stopped, road crossings to stop or slow down a debris flow should be designed only by a qualified registered professional.

When deactivating a road, the simplest solution to minimize downstream consequences from future debris flow hazards is to remove the crossing and ensure that all remaining cut-and-fill slopes associated with the approaches are stable. During road deactivation, any unwanted logging debris should be removed from the channel upstream and downstream of the crossing. After removing the crossing, the channel bed should be armoured to minimize erosion. If road access is required, a ford is a viable alternative because future debris flows can pass over the crossing with relative ease, and without incorporating road fill material into the debris flow.

Water transport of sediment and debris. Road crossings must be designed to accommodate the Q_{100} water flow (refer to the *Forest Road Engineering Guidebook*). An undersized road culvert can result in the plugging, overtopping, and ultimate erosion of a road crossing. These can all lead to debris slides and/or initiate debris flows downstream. In some cases, when water starts to flow over a road, it will follow the road grade downslope, which can erode the road surface, alter the natural flow path, and artificially increase the catchment area of the gully system. All of these problems may also result from poor construction, maintenance, or deactivation practices.

Culverts and bridges should be designed to be able to pass the sediment and woody debris likely to be transported in the channel. Often grizzlies (large grates constructed of logs or metal) are used to prevent blockage, but a poorly designed grizzly can sometimes be more harmful. Maintenance of culverts, grizzlies, and bridges is essential.

Erosion of the channel bed by water flows is common, and sometimes results in significant changes to the channel. Road crossings can change the channel profile, which can result in nickpoint erosion where a local increase in channel gradient leads to progressive upstream erosion. Road cuts in channels should be armoured if easily eroded materials are exposed.

As with debris flows, the simplest solution to minimize downstream consequences from future water transport hazards is to remove the crossing and ensure that all remaining cut-and-fill slopes associated with the approaches are stable. After removing the crossing, the channel bed and any pulled-back fill should be armoured to minimize erosion. If road access is required, a ford crossing is a suitable alternative.

Fan destabilization. Roads across fans are subject to shifting channels, avulsions, aggrading streambeds, and the deposition of debris flows. Since stream channels on fans are often fish habitat, roads across fans deserve particular attention. Although in some instances road crossings, whether or not specifically designed for such, can help to stabilize a fan, more often improperly located and/or constructed, maintained, and deactivated roads across fans can lead to increased fan destabilization.

Roads can increase the likelihood of channel avulsions when culverts or bridges are blocked by sediment, woody debris, and/or debris flows. The new channel location is often influenced by the road location and geometry, as water and/or debris can flow down the road for some distance before re-establishing itself. Fans often have numerous secondary channels, which only flow during certain times of the year, or possibly less frequently. The secondary channels may require their own road crossings to ensure sufficient drainage. For all of these reasons, under the right conditions, well-designed and constructed fords are often appropriate road crossings on fans.

If access is required during road deactivation, replacing the bridge or culvert with a ford is the simplest solution. After removing the crossing, the channel bed and any pulled-back fill should be armoured to minimize erosion. Because fish-bearing streams are common on fans, provision for protection, and possibly enhancing, fish habitat should be considered. Depending upon how active the channels on the fan are, it may be necessary to remove the fill between the crossings so that future water flows down the fan are unobstructed and can find their natural channels.

Appendix 4 Photographs

Photo 1. Medium-sized mid-slope gully systems, showing (A) headwall, (B) transport zone, and (C) fan.

Photo 2. Small debris slide on sidewall of transport zone.

Photo 3. Small debris flow (in channel) with debris slide (on sidewall) in background.

Photo 4. Water-transported sediment and woody debris.

Photo 5. Fan destabilization.

Photo 6. Active channel on a fan.

Photo 7. Sparse logging debris in channel.

Photo 8. Moderate logging debris in channel.

Photo 9. Heavy logging debris in foreground.

Photo 10. BUFFER management strategy along transport zone.

Photo 11. Clearcut, leave saplings, LS management strategy.