FOREST PRACTICES CODE

*of*

BRITISH COLUMBIA

# Mapping and Assessing Terrain Stability Guidebook

**Second Edition**

**August 1999**

FOREST SERVICE BRITISH COLUMBIA

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BC Environment

FOREST PRACTICES CODE

# Mapping and Assessing Terrain Stability Guidebook

2nd Edition

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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, but they are not 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. 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 information provided in each guidebook is intended to help users exercise their professional judgment 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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# Contents

# Introduction

A careful evaluation of the landslide hazards and risks in any proposed Forest Development Plan area is critical to good forest resource management. The recommendations in this guidebook concentrate on practical terrain stability mapping and assessment procedures, to help reduce the frequency and magnitude of landslides associated with forest development.

The mapping and assessment procedures discussed in this guidebook include reconnaissance terrain stability mapping, detailed terrain and terrain stability mapping and terrain stability field assessments.

- *Reconnaissance terrain stability maps* identify unstable or potentially unstable land areas from a broad perspective. They help identify areas where more concentrated analysis is required such as detailed terrain and terrain stability mapping and terrain stability field assessments.
- *Detailed terrain maps* present information with respect to spatial and physical attributes of the land surface, its geologic materials and processes. They provide detailed interpretive data on terrain stability conditions and soil erosion potential.
- *Detailed terrain stability maps* provide a more comprehensive assessment of terrain stability hazards. They help to more narrowly define where terrain stability field assessments are required.
- *Terrain stability field assessments* focus on specific areas of concern for a proposed cutblock or road location.

Besides outlining relevant standards and procedures for mapping and assessing terrain stability, this guidebook is intended to enlighten foresters, managers and field personnel about what to look for in mapping and assessment projects. When everyone understands the process, more effective terrain stability management and greater environmental protection is achieved.

**The *Mapping and Assessing Terrain Stability Guidebook* is cited in the Operational Planning Regulation (OPR), Forest Road Regulation (FRR) and Woodlot Licence Forest Management Regulation (WLFMR). The regulations (as indicated below) require that the following items be determined or carried out in accordance with procedures set out in this guidebook:**

- **terrain stability field assessment (OPR, FRR, WLFMR)**
- **indicators of potential slope instability (OPR, WLFMR)**
- **soil erosion potential (OPR, WLFMR)**
- **terrain stability hazard map (OPR, WLFMR)**
- **likelihood of landslides (OPR).**

# Terrain and terrain stability mapping

***Terrain mapping*** is a method to categorize, describe and delineate characteristics and attributes of surficial materials, landforms, and geological processes within the natural landscape. ***Terrain stability mapping*** is a method to delineate areas of slope stability with respect to stable, potentially unstable, and unstable terrain within a particular landscape. Terrain stability map polygons indicate areas or zones of initiation of slope failure.

Both methods are undertaken initially by stereoscopic interpretation of aerial photographs (supplemented with field-checking), and therefore require the mapper to have advanced skills in recognising and interpreting terrain and natural slope processes from both aerial photos and fieldwork. Terrain stability mapping is a derivative of terrain mapping by utilizing the terrain and map polygon attributes of the terrain mapping.

## Terrain survey intensity levels

There are five terrain survey intensity levels (TSIL) used for terrain and terrain stability mapping in British Columbia (Table 1). The survey intensity levels represent the extent of field-checking done during mapping, expressed as a scale ranging from A (most checks) to E (least checks). **Each level is a measure of the reliability of the mapping. It does not refer to a type of mapping or a map scale.**

The ranges used in Table 1 to describe the level of effort required for a given TSIL are provided to help account for the range of mapper experience, terrain complexity, and access difficulties (dense bush, severe topography, limited helicopter landing sites). For example, for TSIL C on relatively gentle plateau terrain with good road access, an experienced terrain mapper may need to ground-check only 20% of the polygons and be able to achieve a high rate of daily progress (e.g., 1200 ha/day). An inexperienced terrain mapper, however, may need to ground-check a significantly higher number of polygons (30-35%)—as well as have an experienced mapper review the results—to achieve a comparable level of accuracy. In areas of difficult or complex terrain, even an experienced mapper may need to ground-check a higher percentage of the terrain units and will have difficulty achieving a progress rate of 600-700 ha/day. Clearly, then, mapper experience, terrain complexity and access difficulties must be accounted for when work plans and budgets are being developed and reviewed for terrain and terrain stability mapping projects.

During ground checks, all terrain attributes relevant to the entire polygon being mapped must be investigated and described. Collecting detailed site data for one point in a polygon rarely qualifies as appropriate mapping procedure. Emphasis should be on walking across polygons and checking their boundaries. Vehicle traverses of existing road networks and low-level helicopter inspections can be used to supplement—not replace—information obtained from foot traverses.

**Table 1.** Terrain survey intensity levels (TSIL)[a] for terrain and terrain stability mapping

| TSIL | Preferred map scale | Estimated range of average polygon sizes (ha) | % of polygons ground-checked | Method of field-checking | Rate of field progress per crew day (ha) |
|---|---|---|---|---|---|
| A | 1:5000 to 1:10 000 | 2–5<br>5–10 | 75–100 | Ground checks by foot traverses | 20–100 |
| B | 1:10 000 to 1:20 000 | 5–10<br>10–15 | 50–75 | Ground checks by foot traverses | 100–600 |
| C | 1:20 000 to 1:50 000 | 15–20<br>50–200 | 20–50 | Ground checks by foot traverses, supported by vehicle and/or flying | 500–1200 |
| D | 1:20 000 to 1:50 000 | 20–30<br>100–400 | 1–20 | Vehicle and flying with selected ground observations | 1500–5000 |
| E | 1:20 000 to 1:100 000 | 20–40<br>200–600 | 0 | No field work, only photo interpretation | n/a |

[a] Modified from "Guidelines and Standards for Terrain Mapping in British Columbia" (Resources Inventory Committee 1995). For forestry applications, typical map scales are: TSIL A, 1:5000; TSILs B and C, 1:20 000; and TSIL D, 1:20 000 or 1:50 000. This table does not apply to terrain stability field assessments. **The field investigation and data collection requirements for terrain stability field assessments are structured differently from those for terrain and terrain stability mapping** (see section on terrain stability field assessments).

## Mapping

It is expected that the person who does the stereoscopic air-photo interpretation work will carry out the field-checking. It is not acceptable to carry out stereoscopic air-photo interpretation in the office and then send less experienced staff out to collect field data. The nature of terrain and terrain stability mapping demands that the mapper walk the ground.

***Reconnaissance and detailed mapping***

The decision whether to carry out detailed mapping or reconnaissance mapping is based on a combination of factors.

*Reconnaissance mapping* for the identification of unstable or potentially unstable terrain is most suitable for plateau areas where there are only local occurrences of potentially unstable terrain. In this case, it is not cost-effective to terrain map large areas of stable terrain. The second situation for reconnaissance is where extensive areas of steep terrain need to be mapped in a short time period and as economically as possible. In this instance, reconnaissance mapping can be used to identify areas that have potential hazards. Areas for which the consequence of landslides is high (e.g., fish streams) can also be scheduled for subsequent detailed terrain mapping.

*Detailed mapping* is most appropriate for areas that have a large proportion of steep, landslide-susceptible terrain, as well as significant resources that might be affected by landslides. Detailed terrain mapping is required to be completed in all existing community watersheds by June 15, 2000.

## Development of criteria for terrain stability classes

The criteria used to separate terrain stability classes are usually defined in terms of slope gradient, surficial materials, material texture, material thickness, slope morphology, moisture conditions and ongoing geomorphic processes. Because of regional variations in climate, geology, soils and other factors, few specific criteria apply universally across all regions of the province.

The mapper must develop criteria for terrain stability classes specific to the map area. These criteria and the rationale used to develop them must be documented in the report or legend accompanying the terrain stability maps. The terrain stability class criteria should be applied systematically to all map polygons in a given study area. Any exceptional conditions that change assigned terrain stability classes should be noted in the list of criteria.

The criteria for terrain stability classes are typically qualitative and depend on the knowledge and experience of the terrain mapper. The criteria for terrain stability classes in reconnaissance terrain stability mapping are far less rigorous than in detailed terrain stability mapping and by necessity must be based on factors that can be determined primarily from air-photo interpretation. Polygons containing naturally occurring landslides should be categorised as reconnaissance stability class “U” (Table 2) on reconnaissance terrain stability maps and terrain stability class “V” on more detailed terrain stability maps (Table 3). An example of detailed terrain stability class criteria are provided in Appendix 1 (Table 1B).

For detailed terrain stability mapping projects, it is essential that the mapper investigate areas within the project area (or similar areas nearby) that have been logged, and areas where roads have been built. The mapper should document and report the types of terrain that typically experience landslides related to timber harvesting or road construction. Certain types of terrain will be more prone to failure than others. For example, steep, gullied terrain often experiences higher rates of post-timber harvesting landslide activity than benchy, irregular terrain. The mapper should use this information to develop criteria for ranking the different types of terrain in the map area for the expected likelihood or frequency of development-related landslide activity.

A highly systematic approach to collecting this type of data, termed a terrain attribute study, has been carried out in several areas in the province (Rollerson et al. 1997). A tentative terrain stability mapping methodology has also been developed, using extensive landslide inventory data from the Kamloops Forest Region (Pack 1994). As well, several exploratory approaches exist which use digital elevation models to derive slope and catchment characteristics for terrain stability interpretations (Pack et al. 1998). Studies of this type will be used more in the future for developing terrain stability criteria and maps.

A number of approaches for selecting qualitative or quantitative criteria for terrain stability maps have been developed in various parts of the world. These range from simple slope maps and landslide inventories to complex statistical analyses. A summary describing the most common of these approaches is included in “Terrain Stability Mapping in British Columbia” (Resource Inventory Committee, 1996b). Because terrain stability mapping is still evolving in British Columbia, the development and application of innovative and more quantitative approaches is encouraged.

A final note: The mapper must ensure that the terrain stability criteria and interpretations are not overly cautious. Such interpretations can lead to unnecessary terrain stability field assessments, increased logging and road construction costs and unnecessary prohibitions on some forest practices.

# Reconnaissance terrain stability mapping (RTSM)

## Purpose

The primary objective of reconnaissance terrain stability mapping (RTSM) is to identify all unstable or potentially unstable land areas. Reconnaissance terrain stability maps are useful for identifying land areas where more detailed mapping is required. For instance, if a reconnaissance terrain stability map shows limited, widely scattered problem areas, then additional detailed mapping of only those is warranted. On the other hand, if extensive areas with potential stability problems are identified, then detailed mapping over entire watersheds would help to identify the areas where a terrain stability field assessment is required before timber harvesting or road construction can be approved.

Since RTSM is slope hazard mapping, knowledge of specific forest development proposals or downslope/downstream elements at risk is not needed.

A *map polygon* interpreted as *unstable* typically shows evidence of natural instability. Unstable areas are expected to have a high likelihood of landslides following timber harvesting or road construction. A *map polygon* interpreted as *potentially unstable* may show no overt signs of instability under natural conditions, but have characteristics similar to unstable areas nearby. Potentially unstable areas have a moderate likelihood of landslides following timber harvesting or road construction. A *map polygon* interpreted as *stable* delineates an area that is considered to have a negligible or low likelihood of landslides following timber harvesting or road construction (Table 2).

## Recommended specifications

### Terrain survey intensity level for reconnaissance mapping

RTSM is usually conducted at TSIL D. Mapping at this level relies primarily on stereoscopic air-photo interpretation, supplemented with limited ground-checking and helicopter reconnaissance. Field-checking should concentrate on those terrain polygons that will be classified as unstable or potentially unstable.

Logistical difficulties will often restrict ground access to many unstable or potentially unstable units. Low-level helicopter verification of mapped unstable areas where tree cover is limited can be quite effective. In addition, frequent landings are recommended so that distinctive terrain features (e.g., steep rock, talus slopes, organic terrain and landslide scars) can be visually verified from stationary viewpoints with the use of field glasses. Helicopters have minimal or no utility for visual verification of terrain units in heavily forested areas. While helicopter and long-distance visual inspections are necessary to compensate for lack of ground access, representative ground checks must be made to calibrate slope gradient estimates and confirm terrain conditions in the map area.

## Map scale

All RTSM should be done on 1:15 000 to 1:40 000 scale air-photos. The scale of photos used will depend on the availability of photos with the requisite scale, density of the forest cover and the complexity and steepness of the terrain being mapped. For example, 1:15 000 to 1:20 000 scale air-photos are typically used in steep, densely forested, coastal watersheds, but 1:40 000 scale photos may be adequate for lightly forested, dry, interior valleys.

The reconnaissance terrain stability maps themselves should be at a scale of 1:20 000 to 1:50 000. Terrain Resource Information Mapping (TRIM) contour maps at a scale of 1:20 000 with 20-m contour intervals can be used as base maps. The RTSM maps must be clearly labelled as portraying reconnaissance-level information.

Minimum map polygon size should be 1 $cm^2$ irrespective of map scale. Exceptions can be made for critical terrain stability features (e.g., steep escarpments and gullies). Average polygon size will be a function of the natural variability, steepness and complexity of the terrain being mapped.

## Classification and mapping conventions

RTSM delineates map polygons for all unstable and potentially unstable terrain. It is not necessary to map the stable portions of the landscape. All areas not designated as unstable or potentially unstable are assumed to be stable. Unlike detailed terrain stability mapping, RTSM does not involve producing a terrain map first.

Map polygons should be as homogeneous as possible. Each map polygon should contain a single slope class or terrain type whenever possible. Each map polygon should be labelled with a single terrain stability class (see Table 2). In those unavoidable cases when map polygons contain more than one stability class, the entire polygon must be placed in the most hazardous category that occupies more than 10% of the unit.

Similarly, when the interpretation for a map unit is in doubt, the more hazardous class should be chosen. Because RTSM is less reliable than detailed terrain and terrain stability mapping, a reconnaissance terrain stability map may show a higher percentage of the land as hazardous than will a detailed terrain stability map.

**Table 2.** Reconnaissance terrain stability classification[a]

| Reconnaissance terrain stability class | Interpretation |
|---|---|
| S<br>*does not need to be mapped* | • Stable. There is a negligible to low likelihood of landslide initiation following timber harvesting or road construction. |
| P | • Potentially unstable.<br>• Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction. |
| U | • Unstable. Natural landslide scars present.<br>• Expected to contain areas where there is a high likelihood of landslide initiation following timber harvesting or road construction. |

[a] This classification is provided to avoid confusion with older Environmentally Sensitive Areas mapping, the 5-class DTSM system and other terrain stability mapping systems used in the past.

For each polygon identified as unstable or potentially unstable, the following information should be recorded on the reconnaissance terrain stability map or on an attached table or legend:

- terrain symbol and geomorphic processes (avoid complex symbols); and
- slope, as a numerical range of slope gradients (% is recommended).

The terrain and slope information should provide some background for the terrain stability classes assigned to each polygon. This information also allows the interpretive assignments to be revised in light of new knowledge about terrain stability conditions, without the area having to be remapped. Interpretive classes alone do not provide this opportunity.

Reconnaissance terrain stability maps must show the location and type of landslides, unstable gullies and other indicators of unstable terrain that are identifiable on air-photos but too small to be mapped as separate polygons. These features can be shown on the map with appropriate symbols.

# Detailed terrain and terrain stability mapping (DTSM)

## Purpose

Detailed terrain mapping is carried out to collect and present information about the physical characteristics and properties of the land surface and its geologic materials, and to provide detailed interpretive data on terrain stability conditions and soil erosion potential.

A detailed terrain map should form the basis for the preparation of a detailed terrain stability map. Detailed terrain stability maps can be used to identify specific areas that require terrain stability field assessments. They are commonly used in conjunction with other resource information to guide forest development planning. In particular, detailed terrain stability maps help forest planners anticipate and avoid those areas where road construction, trail construction or timber harvesting could cause landslides.

Detailed terrain stability maps are *not* to be used for making site-specific prescriptions in lieu of a terrain stability field assessment. Nor are they to be used to pre-judge or overrule the conclusions or management recommendations of a qualified registered professional who has made a terrain stability field assessment of a potential problem area. Since DTSM is slope hazard mapping, knowledge of specific proposed forest development or downslope/downstream elements at risk is not needed (unless specific additional interpretations are made).

## Recommended specifications

### Terrain survey intensity levels for detailed mapping

Detailed terrain stability interpretations will normally be based on terrain mapping conducted at TSIL C, in accordance with the specifications in Table 1. In some circumstances, it may be appropriate to map at TSIL B (e.g., in watersheds or portions of watersheds with very complicated or very hazardous soil and terrain conditions). Mapping costs for TSIL B surveys will be significantly higher than for TSIL C surveys. The move from a TSIL C to a TSIL B survey is a management decision that should be based on, among other factors, consultation with experienced terrain mappers. Levels D or E may be specified for large contiguous inoperable or alpine areas within a DTSM area.

Field-checking should be concentrated in areas with complex terrain and areas of potential instability or high consequence, especially near streams. Notwithstanding this emphasis, the mapper must ensure that a representative sample of all terrain conditions present in the map area has been verified in the field.

Field-checking of detailed terrain mapping usually involves ground-checking 20-50% of the polygons on the conventionally accessible timber base, with a lower intensity of ground checks required in areas of inoperable timber. Field-checking at this intensity typically corresponds to a mapping rate (total map area per field day) of 500-1200 ha per day, depending on the access, the ratio of accessible to inaccessible timber, and the complexity of the terrain. These rates are suitable for experienced mappers. Mappers with less experience will need to spend significantly more time in the field (see Table 1).

The use of helicopters and stationary viewpoints outlined for RTSM is also applicable to DTSM. Experienced mappers often conduct local terrain verification flights at the beginning or end of each field day or will leave aerial verification until they are familiar with the geography of the map area.

The increased use of helicopters to harvest in previously inoperable timber may necessitate a higher intensity of field-checking in these areas than has occurred in the past.

## Map scale

All DTSM should be done on 1:15 000 to 1:20 000 scale air-photos. The air-photos should be the most recent available unless older air-photos have better resolution.

The most common map scale for presenting DTSM information for forest management planning is 1:20 000. Terrain and terrain stability maps should be presented at scales comparable to the photos used for the mapping (e.g., 1:20 000 scale maps for 1:15 000 to 1:20 000 scale photos). The scale of the air-photos used for the mapping must be documented on each map.

Occasionally, maps are produced at a significantly larger scale than the air-photos used for the mapping (e.g., polygon boundaries on 1:20 000 scale air-photos are plotted on 1:5 000 scale maps). This practice is not recommended. In these situations, a disclaimer outlining the limitations of the mapping must be prominently displayed on every map.

Topographic base maps should be used for map presentation when available (e.g., 1:20 000 scale TRIM maps with 20-m contour intervals, or privately produced maps at 1:20 000 or larger scale). Enlarged 1:50 000 scale contour maps should *not* be used.

Minimum map polygon size should be 1 $cm^2$ (4 ha at 1:20 000 scale) except for unusual or critical terrain features (e.g., gullies).

## Classification and mapping conventions

The *Terrain Classification System for British Columbia* (Howes and Kenk 1997) should be used for all detailed terrain mapping. The recommendations on mapping standards and procedures in the *Guidelines and Standards for Terrain Mapping in British Columbia* (Resource Inventory Committee, 1996a) are to be followed These approaches can be supplemented with innovative terrain stability mapping strategies on a trial basis where appropriate rationale is presented to, and accepted by, government staff specialists.

*Slope gradient and soil drainage labels*
Terrain polygon labels should include descriptions of slope gradient and soil drainage. Slope gradient can be derived by field measurements or from detailed large-scale contour maps if available, and should be recorded as an estimated range (or range and average) of typical slope gradients. Slopes of polygons that are not field-checked should be based on air-photo interpretation and extrapolation from similarly checked polygons. Soil drainage classes as described in the *Canadian System of Soil Classification* (Agriculture Canada 1998) should be used. The drainage class reflects both the soil permeability and site hydrology.

The recommended procedure for presenting slope information is to give a range of the maximum and minimum commonly occurring slopes in the polygon. Two ranges may be given where two disjunct slope ranges exist and the features cannot be identified as a separate polygon; e.g. a terrace face and scarp. See the *Standard for Digital Terrain Data Capture in British Columbia* (Resource Inventory Committee, 1996a) for details. Another common procedure is to give three slopes—a maximum, minimum and modal. Soil drainage classes should be given as a primary and secondary class, where a range of classes is present.

Whenever possible, polygons should delineate homogeneous terrain and slope. In certain areas of critical or complicated terrain, smaller polygons than the preferred minimum size may be necessary. For example, deep, steep-sided gullies create many forest management problems. The mapper should use specific polygons for these wherever feasible.

*Terrain stability classes*
Terrain stability classes provide a relative ranking of the likelihood of a landslide occurring after timber harvesting or road construction. They give no indication of the expected magnitude of a landslide or potential downslope/downstream damage. The 5-class terrain stability classification, a tool for forest development planning, is used for flagging potential problem areas. It should not be considered an on-site prescription tool for terrain stability field assessments.

Where sufficient data is available, the mapper can use terrain stability classes showing expected numerical frequency or likelihood of failure (e.g., 0.1 landslides/hectare) or other innovative approaches to complement the 5-class terrain stability classification.

For the derived terrain stability map, each map polygon should be labeled with a single terrain stability class (see below). In some places, highly variable terrain types are intermixed and must be mapped as composite polygons. In these cases, the entire polygon must be labeled as the more hazardous class. Similarly, when the interpretation for a map polygon is in doubt, the more hazardous class should always be chosen. This conservative approach to interpretation is necessary, given the moderate intensity of field-checking represented by a TSIL C survey. However, the mapper should not be overly conservative; the criteria used to define terrain stability classes must be justified.

The assignment and interpretation of terrain stability classes is quite subjective. The 5-class terrain stability classification system in Table 3 should be used on detailed terrain stability maps.

The IVR-class terrain stability is used only where terrain responds, with respect to slope stability, very differently to road construction than to timber harvesting. For example, steep, irregular bedrock units can have a high likelihood for road fill-slope failure, but a negligible likelihood of landslide initiation due to timber harvesting. Similarly, in areas of low rainfall, the likelihood of slope failure due to timber harvesting alone may be very low compared with the likelihood of landslides from road construction. In these situations, it is appropriate to identify the terrain stability class with IVR, indicating a low or very low likelihood of landslides initiating after timber harvesting, but a moderate or high likelihood of landslide initiation following road construction. For IVR areas, a terrain stability field assessment would be required for road construction proposed through the IVR polygon or if the proposed harvesting system included bladed or excavated trails.

**Table 3.** Terrain stability classification[a]

| Terrain stability class | Interpretation |
|---|---|
| I | • No significant stability problems exist. |
| II | • There is a very low likelihood of landslides following timber harvesting or road construction.<br>• Minor slumping is expected along road cuts, especially for 1 or 2 years following construction. |
| III | • Minor stability problems can develop.<br>• Timber harvesting should not significantly reduce terrain stability. There is a low likelihood of landslide initiation following timber harvesting.<br>• Minor slumping is expected along road cuts, especially for 1 or 2 years following construction. There is a low likelihood of landslide initiation following road construction. |
| IVR | • Expected to contain areas with a moderate likelihood of landslide initiation following road construction and a low or very low likelihood of landslide initiation following timber harvesting. |
| IV | • Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction. |
| V | • Expected to contain areas with a high likelihood of landslide initiation following timber harvesting or road construction. |

[a] Modified from: *Land Management Handbook 18* (Chatwin *et al*, 1994). The classification addresses landslides greater than 0.05 ha in size, conventional timber harvesting practices, and sidecast road construction.

On-site symbols may be used to identify features that are important for terrain stability interpretations, but too small to be mapped as distinct polygons (e.g., landslides, gullies or terrace scarps). The use of on-site symbols should not be carried to the point where they result in a cluttered or unreadable map.

Where terrain stability is influenced by bedrock geology, relevant information on bedrock geology may be included on the terrain and/or terrain stability maps (e.g., symbols for strike and dip direction, faults) or be described in the accompanying report.

## Other interpretations

### Potential for landslide debris to enter streams

The potential for landslide debris to enter a stream is an interpretation of the likelihood of bedload sized material and organic debris to colluvially enter a stream. An example classification and criteria are given in Appendix 2. This is based on a consideration of the hillslope gradient and slope morphology downslope from the polygon, evidence of landslide runout, presence or absence of a runout zone, length of the runout zone, and the presence of gullies that give direct access to the stream channel. The interpretation can be attached to the terrain stability symbol or provided on a separate map. Additional map symbols in the polygon label should be separated by hyphens (e.g. IV-2). This interpretation is made for polygons with terrain stability class IV, IVR or V.

This interpretation is best suited to site-specific assessments, for example, of short segments of road. Landslide runout estimation is sometimes difficult to apply to terrain polygons, however, many mappers have developed reasonable criteria and standardized procedures for making this interpretation. Where there is a specific need for assessing the likelihood of landslide debris entering a stream in a particular project, mappers are expected to develop and substantiate criteria relevant to their specific map area.

### Soil erosion potential

Interpretation for soil erosion potential may be required to be included in a terrain stability mapping project (e.g., in community watersheds). This interpretation can be attached to the terrain stability symbol or provided on a separate map. Additional map symbols in the polygon label should be separated by hyphens (e.g. IV-M).

Most fine sediment production from soil erosion is from surfaces exposed by roads and trails.

Classification of soil erosion potential should be based on terrain mapping. Derive a simple soil erosion potential rating from the terrain map, based on slope gradient, generic material, texture and soil drainage. Appendix 3 presents an example of classification criteria for assigning a soil erosion potential based on genetic material to terrain polygons. It is based on preliminary work done in the Nelson Forest Region, and requires modification for use in other areas. **The slope classes given are hypothetical; they have not been tested**[1].

[1] A research project in the Nelson Forest Region is being conducted to produce a final field-tested classification in late 1999.

The "soil erosion hazard key" (as described in the *Hazard Assessment Keys for Evaluating Site Sensitivity to soil Degrading Processes Guidebook*) is not recommended for use in terrain mapping.

## Risk of sediment delivery to streams

The risk of sediment delivery to streams indicates the likelihood that sediment derived from erosion sources in a specific terrain polygon will be transported or delivered to a stream. This interpretation is made for polygons that have a high or very high surface erosion potential.

This interpretation is better suited to site-specific assessments than to terrain mapping. It is difficult to apply to terrain polygons, because the risk of sediment delivery to streams often varies greatly throughout a polygon, and is highly dependent on future road alignment and gradient. Therefore, **this interpretation is not recommended for most terrain stability mapping projects**. Where there is a specific need for assessing the risk of sediment delivery in a particular project, mappers should use a classification and criteria such as the one given in Appendix 4.

# Map legends and reports for RTSM and DTSM projects

## Map legends

A legend must be attached to each terrain and terrain stability map sheet. The legend must show the date of publication, the extent and date of field-checking, and the TSIL. The legend must also summarize or define any terrain or interpretive classifications and any on-site symbols used on the map. The location of ground checks should be shown on the map. Each map sheet must show latitude and longitude, UTM grid references, and map sheet numbers and boundaries for the corresponding forest cover maps. See *Guidelines and Standards for Terrain Mapping in British Columbia* (Resource Inventory Committee, 1996a) and the *Standard for Digital Terrain Data Capture in British Columbia* (Resource Inventory Committee, 1998) for examples of map layout and other terrain mapping conventions. The professional accepting responsibility for the mapping must sign and seal each map sheet.

## Reports

A brief report should accompany all RTSM and DTSM projects. For small projects, an expanded legend or marginal notes on the map may be sufficient. The following information should be presented in the report or marginal notes:

- An introductory section outlining pertinent background information and any previous mapping or terrain stability assessment work, and a statement of the objectives of the mapping project.

- A description of the project area, including project boundaries, physiography, topography, general climatic regime, biogeoclimatic zone, general Quaternary history and bedrock geology.

- Descriptions of the landforms, surficial materials and general Quaternary stratigraphy of the area, as well as of the soil types and soil drainage conditions associated with different landforms or surficial materials.

- A description of the active geomorphic processes, particularly the type, magnitude and frequency of landslides present in the map area, and the landforms or portions of landforms or terrain units typically associated with landslide activity (in terms of the initiation, transport and deposition or runout zones of landslides).

- An inset map showing the location of all helicopter traverses and foot traverses, as well as:
  - brief descriptions of the mapping methods, the percentage of polygons ground-checked, and the reliability of the map data, and
  - a description (with delineation on a map, if necessary) of the areas of high-intensity versus low-intensity field-checking.

- The criteria and rationale used to develop terrain stability classes and other interpretations.
  - If background data have been collected on areas of previous timber harvesting, summary tables or summary statistics should also be provided. The report should describe the limitations of the interpretations.

- A concise summary that discusses any specific recommendations or concerns with regard to terrain stability and forest management practices in the project area.

The professional accepting responsibility for the report must sign and seal it.

**Additional Tips for RTSM and DTSM:**

**Do...**
- Ensure mapping contractors have appropriate qualifications, competence and experience.
- Ensure that an experienced reviewer with extensive terrain and terrain stability mapping experience in forested and mountainous terrain in British Columbia is included in the project, to guide, supervise and correct the work of less experienced mappers.
- Allocate adequate time for field-checking and data collection. Inexperienced mappers will require more time than experienced mappers.
- Ensure air-photo typing is as precise as possible. Carefully position boundaries that follow obvious slope breaks and other discontinuities in the landscape that are clearly visible on the air-photos.
- Avoid messy symbols, sloppy linework, thick lines, etc. These create an impression of haphazard, inaccurate and unreliable mapping.
- Box the air-photos and ensure that terrain polygon boundaries are never on more than one air photo. Duplicate linework, especially lines that vary in location, waste time, create the impression of inaccurate mapping, and may cause errors during line transfer.
- Ensure that the final air-photos have complete polygon labels and finalize mapping on the air-photos, as well as on the maps.
- Make neat, systematic and comprehensive field notes. Where less experienced mappers are employed, field notes should be sufficiently detailed to allow an experienced mapper/reviewer to evaluate mapping quality and the accuracy of terrain/surficial material designations.

- Develop local criteria for interpretations and provide a supporting rationale.
- Ensure that interpretations are consistent and are linked to terrain attributes described for the terrain polygons mapped.
- Ensure that the terrain polygons mapped are consistent with known geomorphic history and that landforms are identified correctly.
- Ensure that the conventions for terrain polygon descriptors, on-site symbols, map polygon boundaries, etc., presented in the "Terrain Classification System for British Columbia" (Howes and Kenk, 1997) and other supporting documents are applied correctly.
- Update or modify terrain stability map class criteria and/or interpretations if new studies show that the current criteria and/or the interpretations are no longer valid. For example, TSFAs for cutblocks and road locations can serve as part of the field-checking requirement for terrain mapping and terrain stability mapping if the two activities are carried out concurrently. The results of a single TSFA, however, should not be used to modify a pre-existing reconnaissance or detailed terrain stability map. If TSFAs repeatedly indicate that the existing RSTM or DTSM for a forest development plan area is overly conservative or unreliable, then consideration should be given to revising the mapping.

**Do not...**

- Map large generalized polygons that have substantive internal slope breaks or terrain boundaries.
- Use photocopies for stereoscopic air-photo interpretation or line transfer to digital files. Photocopies are not dimensionally accurate, and they lack the resolution of the original air photos.
- Assume that terrain polygons mapped for purposes of terrain stability equate to terrain polygons outlined for terrestrial ecosystem mapping and vice versa. There can be differences.

# Terrain stability field assessments (TSFAs)

A terrain stability field assessment (TSFA) is an on-site assessment of the potential impact of timber harvesting, road construction, or the construction of excavated or bladed trails on terrain stability. The purpose of a TSFA is to: describe the terrain conditions within a proposed cutblock or along a proposed section of road; evaluate the likely effect of timber harvesting or road construction on terrain stability; and recommend site-specific actions to reduce the likelihood of post-harvesting or road-related landslides including a recommendation not to locate or construct trails on areas where the likelihood of a landslide will be significantly increased or there is a moderate or high likelihood of landslide debris entering fish streams or streams in community watersheds, or cause damage to private property or public utilities. These actions may involve modification of the cutblock layout, harvesting technique, road location, trail location, construction techniques, or rehabilitation techniques.

A TSFA should not be considered mapping, because only areas of immediate concern within a forest development plan (e.g., a cutblock or a road location) are assessed. With few exceptions, TSFAs are based on inspections on the ground, not on stereoscopic air-photo interpretation, although air-photos are often used for background information. They require knowledge of the surficial geology and terrain stability of the area, as well as of the proposed forest development, including the proposed timber harvesting and road or trail construction and rehabilitation methods.

Field assessments may involve several stages, depending on the nature of the terrain or soil problems present, and the state of development planning. Sometimes a recommendation will be that a further assessment or prescription is needed by a different specialist.

Wherever possible, field assessments should be done with the forestry, logging or engineering staff of the licensee or the forest district. Often, useful information that is not in the written plan can be supplied by these people. As well, agreement on prescriptions or changes to the plan on the site can often be reached, which would not be possible if the assessor did the assessment in isolation. Generally, the best results are achieved if a terrain specialist works as part of a planning team, providing advice when needed.
The resulting TSFA reports for cutblocks and road locations may be used and reviewed by a wide range of individuals:

- Forest operations staff;
- Regulatory agencies making land management decisions;
- Other professionals; and
- Public interest groups and other organizations.

Professionals carrying out TSFAs must ensure that prepared reports provide sufficient technical information to support their interpretations and judgment, and that they are written concisely and in a language that is understandable to a wide readership.

## Conducting TSFAs

TSFAs can take several forms:

- a pre-layout field assessment of an area to identify potential landslide/ sedimentation hazards before cutblock boundaries or road locations have been selected;
- a post-layout assessment of cutblocks or road locations; and
- assessments of specific sites or road sections where the rest of the cutblock/ road has either been assessed previously or does not require assessment.

Pre-layout assessments, especially if done with the layout personnel, can often produce more cost-effective layout and environmental protection. Post-layout reviews ensure that falling boundaries and roads are optimally located, and avoid potential problem areas.

The level of field effort and the information provided in the report will depend on what type of assessment is being done. The most detailed level for a terrain stability assessment is generally a post-layout field assessment of a proposed cutblock or proposed road locations.

In areas where there is no terrain mapping but slopes are greater than 60% and previous studies have shown a low likelihood for landslides, a qualified registered professional who is familiar with the forest development plan area may carry out low-level aerial reconnaissance and stereoscopic air-photo interpretation of the area. If, on the basis of this air-photo interpretation, the professional can describe the terrain and confirm in writing and with supporting logic that certain cutblock areas will have a low likelihood of post-harvesting failure, then a report by the professional may be considered an adequate substitute for an on-the-ground TSFA. Examples of such terrain for which this approach may be adequate include steep, irregular bedrock bluffs and blocky talus slopes. This approach is only suitable for areas where no roads will be built, or harvesting will be by cable or aerial systems and excavated trails will not be constructed.

A TSFA may be combined with other assessments such as those for soil erosion hazard, risk of sediment delivery to streams, gully assessments, windthrow hazards, snow avalanche hazards and stream channel stability. Considerable efficiency can be gained by combining more than one type of assessment and teaming with one or more professionals or specialists to carry out the work.

*Method*

The following is intended as a guide to professionals carrying out TSFAs. Each professional must exercise their professional judgment in selecting the methodology that best suits the site conditions, the goals of the assignment and the client's needs.

Before conducting a TSFA, the following background information, where available, should be obtained and reviewed:

- Air-photos. These are an essential component of a TSFA. If they were not available for review, the report should state this as a limitation. In some cases, different ages of photography may be used to investigate the landslide history of an area.
- Topographic maps of appropriate scale
- Forest cover maps (timber harvesting/wildfire history of adjacent areas)
- Local knowledge of terrain conditions and post-harvesting behaviour
- Previous reports in the area (e.g., terrain reports, windthrow assessments, landslide assessments)
- Bedrock, surficial geology and/or terrain stability maps
- Road profiles and cross-sections
- Deflection lines
- Gully assessment reports
- Watershed and/or channel assessment reports
- Stream classification maps or reports
- Results from terrain attribute studies
- Other research data applicable to the area

A TSFA should assess the existing and potential terrain stability hazards of all critical areas within and adjacent to the cutblock and road location such as: unstable areas, moderate to steeply sloping areas, potentially unstable areas, and steep gully headwalls. As well as ground traverses, helicopter overviews can be useful. Areas of highly erodible soils should be assessed in locations where soil erosion or stream sedimentation is a concern.

Traverses along falling boundaries should describe and evaluate the terrain inside and immediately outside the falling boundary. Traverses along road alignments should describe and evaluate the terrain immediately upslope and downslope of the centerline. These assessments should identify stability hazards that could affect the road or cutblock (such as snow avalanche tracks, debris flows, rockfalls upslope of the road, etc.). For small cutblocks, traverses of the falling boundaries and road locations may suffice. In large cutblocks or in complex terrain, additional traverses within the cutblock area may be necessary to fully describe and evaluate terrain conditions. For areas with no topographic mapping or for which the only available mapping does not have adequate resolution (e.g., TRIM), it is best to record geographic features that can be easily identified (e.g., bedrock bluffs, talus slopes, windthrow patches, tall snags).

Traverses of the hillside and valley floor below a cutblock or road location may be necessary for a full assessment of the areas that could be adversely affected by road drainage, potential landslide runout zones and geomorphic consequences of landslide activity.

The assessment should cover the potential on-site and off-site effects of harvesting and road construction, including possible downslope consequences of post-timber harvesting and road construction landslide activity. It should also cover the potential stability hazards to workers carrying out harvesting or road construction, including stability hazards (natural, harvesting and road related) that may originate upslope of the subject area.

Sufficient field time must be allowed to adequately traverse all areas of concern. Complex or difficult terrain may require several days of field investigation. Return trips to pick up missing information are very costly, especially for remote sites or sites requiring helicopter access.  TSFAs must be carried out when the area is not covered with snow.

## Reports

### Contents

A TSFA report should normally include the following. The order and headings shown are to assist the author; they are not meant to establish a report template. Not all information is necessarily relevant in all cases.

*Assignment information*
- Client name
- Site location/name (general geographic location)
- Purpose or objectives of the assessment
- Type of assessment (pre or post-layout, road layout)
- Scope of the assessment (i.e., the areas/sections investigated and how the assessment was carried out)
- Type of harvesting method proposed (e.g., helicopter, cable-based, ground-based)

*Field assessment*
- Sources of information used for the assessment
- Traverse description or traverse map
- Date of field assessment
- Personnel on site during field assessment
- Time spent on field assessment
- Length of road (km) or size of cutblock area (ha) assessed
- Weather conditions at the time of assessment

- Limiting factors (e.g., snow cover, weather, heavy groundcover or windthrow)
- Any critical or non-critical areas not traversed, with an explanation of why they were not visited

*Background*
- General geographic location/setting
- General terrain and terrain conditions in the vicinity of the cutblock or road examined
- Distribution and geomorphic consequences (size, runout length, adverse geomorphic effects on downslope resources) of natural landslides or post-harvesting landslides and associated terrain conditions in adjacent areas
- Windthrow/wildfire history of the general area relevant to the stability assessment

*Site information*
Site descriptions for in-block harvesting, road locations and adjacent areas should be sufficiently complete, clear and concise to support the conclusions and recommendations. It is not sufficient to describe areas using terrain mapping and/or 5-class terrain stability mapping nomenclature or labels. Ensure descriptions of the following are provided:
- Bedrock type and condition
- Soil and/or surficial material types, textures, stratigraphy and depths
- Slope morphology
- Soil drainage
- Numerical slope gradients (range and mean) and point slope gradients, where helpful.
- Elevation and aspect relevant to a discussion of terrain behavior
- Vegetative indicators for high soil moisture or slope movement
- Soil creep, seepage, gully channel conditions and snow avalanches
- Indicators of potential slope instability (see Table 5)
- Natural landslide activity:
    - presence or absence
    - distribution, age, approximate area, magnitude and effects
    - location of initiation zones, runout zones and deposition zones
- Windthrow/wildfire history relevant to terrain stability or erosion/ sedimentation

**Table 4.** Example field indicators of potential slope instability[a]

| Field indicators | Potential landslide type |
|---|---|
| • recent landslide scars<br>• revegetated landslide scars | high likelihood of landslides of the same type and size |
| • partially revegetated strips (may also be snow avalanche tracks)<br>• jack-strawed trees (trees tilted in various directions)<br>• linear strips of even-aged timber<br>• landslide debris piled on lower slopes<br>• soil and rocks piled on the upslope side of trees<br>• curved or sweeping trees (may also indicate snow creep)<br>• mixed or buried soil profiles<br>• poorly developed soils relative to other comparable slopes<br>• tension fractures<br>• poorly drained or gullied*, fine-textured materials <3 m deep on slopes >50%<br>• poorly drained or gullied* coarse-textured materials on slopes >50%<br>• wet site vegetation on slopes >50%<br>• shallow, linear depressions<br>• shallow, wet, organic soils on slopes >40% | • debris avalanches<br>• debris flows<br>• debris slides |
| • recently scoured gullies*<br>• exposed soil on gully sides*<br>• debris piles at the mouths of gullies*<br>• vegetation in gully much younger than the adjacent forest<br>• poorly developed soils on gully sides relative to adjacent slopes (repeated shallow failures continually remove the developed soil profile) | • debris flows<br>• debris slides |
| • tension fractures<br>• curved depressions<br>• numerous springs at toe of slope, sag ponds<br>• step-like benches or small scarps<br>• bulges in road<br>• displaced stream channels<br>• jack-strawed trees (trees tilted in various directions), split trees<br>• poorly drained medium- to fine-textured materials (e.g., till, lacustrine, marine and some glaciofluvial deposits) >3 m deep<br>• mixed or buried soil profiles<br>• ridged marine deposits | • slumps<br>• earthflows |
| • talus or scattered boulders at base of slope<br>• rock faces with freshly exposed rock<br>• steeply dipping, bedrock discontinuities (bedding planes, joints or fracture surfaces, faults) that parallel the slope<br>• bedrock joint or fracture surface intersections that dip steeply out of the slope | rock slides or rock fall (can be induced by excavation and blasting for roads) |

*Apply the Gully Assessment Procedure Guidebook to any gullied areas on the Coast.

[a]Modified from Land Management Handbook 18 (Chatwin *et al*, 1994). Consult LMH 18 for background information.

*Results and recommendations*

The results and recommendations should be clearly stated in plain language so that forestry personnel fully understand the planning/management implications. Included should be:

- Expected outcomes of timber harvesting for individual boundary segments and landforms within and adjacent to the cutblock:
  - likelihood and/or expected frequency of landslide activity.
  - expected landslide runout zone/size and relative geomorphic consequences
  - potential for soil erosion/stream sedimentation
  - expected outcomes of road construction for individual road sections as outlined above for the cutblock
  - downslope/downstream terrain stability concerns related to road or logging trail drainage
  - potential effects of windthrow on terrain stability on adjacent slopes
  - safety: potential terrain hazards originating both within and upslope of the subject area and which present an undue risk to workers, and an assessment of whether this risk is similar or greater than adjacent areas. The client and professional conducting the assessment should ensure that current Workers' Compensation Board requirements and concerns are addressed.
  - downslope/downstream elements at risk and possible consequences

The results and recommendations must also state whether proposals for clearcutting and construction of excavated or bladed trails will be in compliance with the Timber Harvesting Practices Regulation. For example:

- In a community watershed, on areas with a moderate likelihood of landslides and a high risk of landslide debris entering directly into streams, the recommendations must state whether there are reasonable grounds to believe that clearcutting will not significantly increase the risk of a landslide.
- Outside of a community watershed, on areas with a high likelihood of landslides, the recommendations must state whether there are reasonable grounds to believe that clearcutting will not significantly increase the risk of a landslide and that there is a low likelihood of landslide debris:
  - entering into a fish stream or perennial stream that is a direct tributary to a fish stream; or
  - damaging private property or public utilities.
- Inside or outside of a community watershed, on areas with a moderate likelihood of landslides, the recommendations must state whether there are reasonable grounds to believe that an excavated or bladed trail can be located, constructed and rehabilitated in a manner that will not significantly increase the risk of a landslide, and there is a low likelihood of landslide debris:
  - entering into a perennial stream in a community watershed, a fish stream or a perennial stream that is a direct tributary to a fish stream; or
  - damaging private property or public utilities.

*Documentation of any inherent limitations of the TSFA*
The recommendations must be clearly written so that forestry personnel fully understand what needs to be done. They should address by segments/areas along the falling boundary, reserve areas and interior of the cutblock or road sections:
- harvesting issues (e.g., falling boundary relocation, alternative harvesting methods, in-block reserves, gully/stream management)
- windthrow relevant to stability in and around a cutblock (e.g., in-block reserves, falling boundary relocation, feathering, crown modification)
- roads and stream crossings (e.g. relocation, sidecast limitations, ditchwater control, cutslope control, designed fills, gully crossing advice, endhaul sections, spoil site locations, deactivation considerations)

As well, they should identify any additional investigations or other expertise that is needed (e.g., windthrow assessment, geotechnical engineering design of specific sites, snow avalanche assessments, hydraulic design or rock slope assessments).

The results and recommendations should be supported by a rationale, including:
- Geomorphic, hydrologic, geotechnical, geological or pedologic inferences
- Past response of comparable natural or logged areas nearby (the effects of timber harvesting may mimic the response of specific terrain units to natural wildfire or extensive windthrow)
- Local knowledge/history of terrain performance
- Applicable research data/knowledge where available
- Applicable models if any, or new information
- Other rationales

The report should indicate whether a professional or a designate need be on site during road construction or deactivation. Typically an on-site specialist is required if:
- the design and design changes are dependent on actual conditions and materials encountered during construction;
- the design is complex or non-standard and the specialist needs to explain it and consult with on-site forest operations personnel to ensure that it is correctly built; or
- there are significant downslope/downstream elements at risk.

## Methods of describing cutblocks, gullies, streams, roads, and adjacent areas in TSFA reports

*Cutblocks*
- linearly, by falling boundary section (delineated by falling corners or other geographic references), supplemented with map polygons, points, groups of points or spatial descriptions, as necessary, to clearly describe the interior of the block or adjacent areas. This is the preferred and more common approach.

- by map areas (polygon), with an appropriate detailed description for each unit delineated. These descriptions must be accompanied by linear traverse notes that clearly document the extent of field investigation carried out to define the polygons. The use of map polygons as a descriptive tool does not satisfy the requirement for complete foot traverses of all critical areas within, adjacent and above the block. Descriptions based on single point observations or incomplete foot traverses of critical areas are not acceptable. Map area (polygon) boundaries and descriptions must be accurate and must not mislead readers as to the extent, variability or character of the terrain included in each polygon.

*Gullies and streams*
- linearly, by reach for critical harvesting areas; and by point descriptions at road crossings.

*Roads*
- linearly, by homogenous road design section (delineated by station numbers), or on a map that shows traverse routes.

## Terminology

Accepted standard terminology should be used in TSFA reports to avoid confusion or misinterpretation. The following are the conventions in common use for this type of work in the forest sector:
- Forest soils: *Canadian System of Soil Classification* (Agriculture Canada 1998)
- Terrain and surficial materials: *Terrain Classification System for British Columbia* (Howes and Kent 1997)
- Engineering design: *Unified Soil Classification System* (1953); *The Use of the Unified Soil Classification System by the Bureau of Reclamation* (Wagner 1957)
- Gully and stream descriptions: use the current versions of the following Forest Practices Code guidebooks: *Channel Assessment Procedure Guidebook; Fish-stream Identification Guidebook; Gully Assessment Procedure Guidebook; Riparian Management Area Guidebook*. Some habitat information is still in the form of the Coastal Fisheries Forestry Guidelines conventions, and is acceptable for use provided it is properly referenced.

(If the author chooses to use another convention, he or she should state what convention that is.)

Maps should use the cartographic conventions specified by the *Terrain Classification System for British Columbia* and the *Guidelines and Standards for Terrain Mapping in British Columbia* to indicate map reliability.

## Appendices and attachments

Presentation of information will depend to some extent on the specific requirements of the client (e.g. format requirements) and the manner in which the TSFA report is submitted. For example, if the report is submitted along with the forest development plan documents, other information relevant to the assessment may already be in the forest development plan (e.g., stream classifications, terrain classification/stability mapping, 1:20 000 location maps, etc.). On the other hand, if the TSFA is a stand-alone document, or is being forwarded for review or other information purposes, it may be helpful to attach some of these other documents in full or in part.

Typical attachments include the following:
- 1:5000/1:10 000 maps showing topography, obvious and critical terrain features, cutblock boundaries and road locations, traverse routes and stability hazard areas
- additional sketches to delineate relatively homogenous areas or segments of the cutblock or road location, identify specific terrain hazards, or illustrate recommendations
- 1:20 000 (or in some cases 1:50 000) location map of the cutblock and roads
- photos, where feasible and useful
- summaries of gully assessment data or stream classifications, where relevant
- where measures to maintain terrain stability or water quality are required, any sketches or plans necessary to describe the measures to forest operations personnel

## Reports in low hazard areas

A TSFA report can be abbreviated where an on-the-ground inspection (required for road and cutblock location) determines that, for selected road location, the assessed terrain has a likelihood of landslide initiation no more severe than low. A report rationale must be included to explain why an area is determined to have a low likelihood of landslides. Sufficient attachments, such as maps at 1:5000 to 1:10 000 and other items as listed above, must be included to clearly identify the areas traversed.

## Limitations of TSFAs

### Limitations

A TSFA depends on surface features and natural exposures observed during the field visit, supplemented by air photo interpretation and evaluation of topographic maps and other available information. This type of assessment does not include subsurface investigation or measurement of the engineering properties of materials. It is, by nature, a qualitative assessment based on the professional's training, observational skills and experience in similar terrain. Prediction of terrain stability is based on an understanding of past and present geomorphic processes and the extent to which they are influenced by forestry operations. Terrain stability predictions are more accurate for some types of terrain and certain types of instability than for others.

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# Appendix 1. Terrain stability mapping systems and criteria

**Table 1A**. Comparison of various terrain stability mapping systems used in BC.

| Terrain stability class | Reconnaissance stability class | ESA soil sensitivity class |
|---|---|---|
| **I** | S | unclassified |
| **II** | S | unclassified |
| **III** | S | unclassified |
| **IV** | P | Es2 |
| **V** | U | Es1 |

**Table 1B**. An example of terrain stability class criteria

| Terrain stability class | Sample criteria |
|---|---|
| **I** | • floodplains and level to undulating coastal plain areas<br>• most terrain with slopes <20%. Exceptions are noted in higher classes |
| **II** | • most gently sloping (20-40%), poorly to well-drained lower slope landforms. Exceptions are noted in higher classes<br>• moderately sloping (40-60%), well-to rapidly drained surficial deposits |
| **III** | • moderately sloping (40-60%), imperfectly to poorly drained surficial deposits that are not glaciomarine or glaciolacustrine<br>• level to gently sloping (0-40%), imperfectly to poorly drained deep glaciomarine clays and glaciolacustrine deposits<br>• moderately sloping, deeply gullied surficial deposits that are not glaciomarine or glaciolacustrine |
| **IV** | • steeply sloping (>60%), well drained, deeply gullied surficial deposits<br>• steeply sloping, poorly drained surficial deposits<br>• moderately sloping, deeply gullied or imperfectly to poorly drained glaciolacustrine or glaciomarine deposits |
| **V** | • any areas where natural landslide scars are visible on air-photographs or in the field<br>• very steeply sloping (>70%), imperfectly to poorly drained, deeply gullied surficial deposits |

*Caution: These criteria are hypothetical. They do not necessarily represent any particular area in the province. They should not be used as default criteria for terrain stability mapping.* ***Mappers must develop criteria specific to each mapping project based on the historical response of the terrain to timber harvesting and road construction in their map area or similar areas nearby.***

# Appendix 2. Example classification and related criteria for assessing the likelihood of landslide debris entering streams[a]

| Class | Interpretation | Example criteria |
|---|---|---|
| 1 | • Low likelihood that a landslide originating in the polygon will enter a stream. | • The hillslope below the polygon is uniform and the toe of the slope is >100 m from the stream edge.<br>• Gully channels within and below the polygon terminate on fans that do not impinge on the stream channel.<br>• There is no air-photo or field evidence of landslides entering the stream. |
| 2 | • Moderate likelihood that a landslide originating in the polygon will enter a stream. | • The hillslope below the polygon is uniform and the toe of the slope is 50-100 m from the stream edge.<br>• Gully channels within and below the polygon terminate on fans that impinge on or are partially truncated by the stream channel.<br>• There is air-photo or field evidence of limited landslide debris entering the stream. |
| 3 | • High likelihood that a landslide originating in the polygon will enter a stream. | • The hillslope below the polygon is uniform and the toe of the slope is <50 m from the stream edge.<br>• Gully channels within and below the polygon terminate at the stream channel (there is no fan present).<br>• There is clear air-photo or field evidence of landslides entering the stream. |

[a]*This is an example classification developed from experience on Vancouver Island and the Queen Charlotte Islands. Modifications to suit other areas will be necessary. The reader is referred to Benda and Cundy (1990), Church (1983), Hungr et al. (1984), and VanDine (1985 and 1996) for additional background information on landslide runout lengths, deposition zone characteristics and debris yield predictions.*

# Appendix 3. Example classification: Soil erosion potential

| Class | Rating | Example criteria | Management implications |
|---|---|---|---|
| VL | Very low | • Blocky colluvial deposits<br>• Terrain dominated by competent bedrock | No or only very minor surface erosion. |
| L | Low | • Morainal veneers; most rubbly colluvial deposits with high coarse fragment content | Expect minor erosion of fines in ditch lines and disturbed soils. |
| M | Moderate | • Morainal blankets (depends on texture and coarse fragment content; varies across the province)<br>• Glaciofluvial gravels<br>• Soft, friable bedrock | Expect moderate erosion when water is channeled down road surfaces or ditches. |
| H | High | • Some morainal blankets steeper than 60%, or steeper than 30% if gullied or poorly drained (depends on texture and coarse fragment content; varies across the province)<br>• Fine textured lacustrine (silts & clays), glaciolacustrine, glaciomarine, glaciofluvial or aeolian silts, slopes less than 15%<br>• Glaciofluvial or fluvial sands with low bulk density, slopes less than 30%<br>• Colluvial deposits derived from the above materials with the same slope or moisture criteria<br>• Colluvium derived from soft, friable rock (e.g., soft phyllites, some pyroclastics), steeper than 60% or steeper than 30% if gullied | Significant erosion problems can be created when water is channeled onto or over exposed soil on these sites. |
| VH | Very high | • Fine textured lacustrine (silts & clays), glaciolacustrine, glaciomarine, glaciofluvial or aeolian silts, slopes steeper than 15%, or gullied or poorly drained<br>• Glaciofluvial or fluvial sands with low bulk density, steeper than 30% or gullied or poorly drained<br>• Peat, organic soils or tufa on sloping ground<br>• Colluvial deposits derived from the above materials with the same slope or moisture criteria | Severe surface and gully erosion problems can be created when water is channeled onto or over these sites. |

[a]This is an example classification only. Modifications will be necessary to suit local conditions.

# Appendix 4. Example classification and criteria for assessing the risk of sediment delivery to streams

| Risk of sediment delivery to streams | Proximity of stream channel to polygon | | |
|---|---|---|---|
| | No stream channel in or adjacent to polygon | Minor stream* channel in or adjacent to polygon | Major stream** channel in or adjacent to polygon |
| Very Low | Gentle to Steep slope | | |
| Low | | Gentle slope | |
| Moderate | | Moderate slope | Gentle slope |
| High | | Steep slope | Moderate slope |
| Very High | | | Steep slope |
| | Slope steepness downslope from polygon to stream channel | | |

* Minor streams are those perennial streams with channel widths that are less than or equal to 1.5m, or any ephemeral stream.

** Major streams are perennial streams with channel widths that are greater than 1.5m.

Note: Perennial streams are defined in this guidebook as any stream where it is reasonably likely that the stream flows after July 15 (during the summer period) in most years.