99 Extension Note

December 2010

Landslides in Organic Soils on Forested Slopes

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Introduction

The cool, wet climate of British Columbia's Central and North Coast and northern Vancouver Island has created extensive forested landscapes with organic and organic-rich soils that have developed on moderate to steep slopes. Landslides in organic soils provide a challenge to forest operations in coastal British Columbia. Often landslides initiate at much lower slope gradients than is typical for shallow landslides; as a result, the hazards associated with organic soils are sometimes not identified. Landslides in organic soils are frequently triggered during road construction and timber harvesting activities, and therefore can pose a significant risk to worker safety.

The objectives of this Extension Note are to:

- promote awareness about landslides in organic soils on gentle through moderately steep slopes,
- provide details on site conditions associated with landslides in organic soils, and
- provide alternative management strategies to manage the risk associated with road construction and timber harvesting in areas in which organic landslides could occur.

Organic Landslide Characteristics

In this report, the identification of characteristics associated with landslides in organic soils is derived largely from input from experienced practitioners. A detailed analysis conducted by Nagle (2000) provides details of landslide characteristics in organic soils in the Prince Rupert area. Organic soils are found over a wide range of site conditions. Site indicators can be used to identify sites where organic soils occur or areas where they may exist. No one site indicator is definitive; however, several indicators in combination can indicate sites with a high likelihood to host organic soils. Excavating test pits will confirm the presence and nature of organic soils at a particular location. The presence of naturally occurring organic landslides is a strong indicator that more of these landslides may occur within the area.

Climate and Geography

Organic soils are most common in the hypermaritime and maritime variants of the Coastal Western Hemlock biogeoclimatic zone (CWHvm1, vm2, vh1, vh2). These areas are characterized by high annual precipitation rates on the order of 3000 mm (Spittlehouse et al.

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2006). Reported landslides in organic soils have been confined mainly to the Hecate Lowland and Outer Fjordland Ecosections (physiographic units, Demarchi 1996) along the Central and North Coast of British Columbia (Figure 1); however, similar conditions are found elsewhere on the mainland coast, Vancouver Island, and Haida Gwaii.

Soils, Surficial Material, and Geology

Landslide occurrence in organic soils is typically associated with the presence of Folic soils or Folisols (Soil Classification Working Group 1998). These are upland soils rather than wetland or peatland soils, and are formed through imperfect drainage resulting in periodic saturation after rainfall events or snowmelt. Organic material is typically mesic to humic in texture (moderate to advanced decomposition, respectively). Mesic sites tend to occur at higher slope positions; humic sites are more common along lower slopes. Organic soils contain greater than 30% organic matter by weight (Krzic et al. 2010). While the term "organic" soils is used throughout this report, it is meant to include both organic soils in the true sense (> 30% organic content) and organic-rich soils, which may have less organic content than this threshold. Organic soils typically form in thin veneers (10–100 cm thickness) over nutrient-poor unweathered hard bedrock and occasionally compact, impermeable till (Figure 2). Bedrock is typically competent but varies from massive to highly fractured. Competent, massive bedrock with low permeability can restrict or concentrate drainage in areas (such as concave slopes), thus creating and maintaining saturated conditions where organic soils can develop and landslides can be triggered. Highly jointed or fractured bedrock can also concentrate seepage through preferential flow pathways along joints or fractures. This may lead to organic soil development and increase localized pore-pressure (Nagle 2000). While not limited to these particular rock types, landslides in organic soils are most frequent in areas associated with the Coast Plutonic Complex including diorites, quartz diorites, granodiorites, and gneisses.

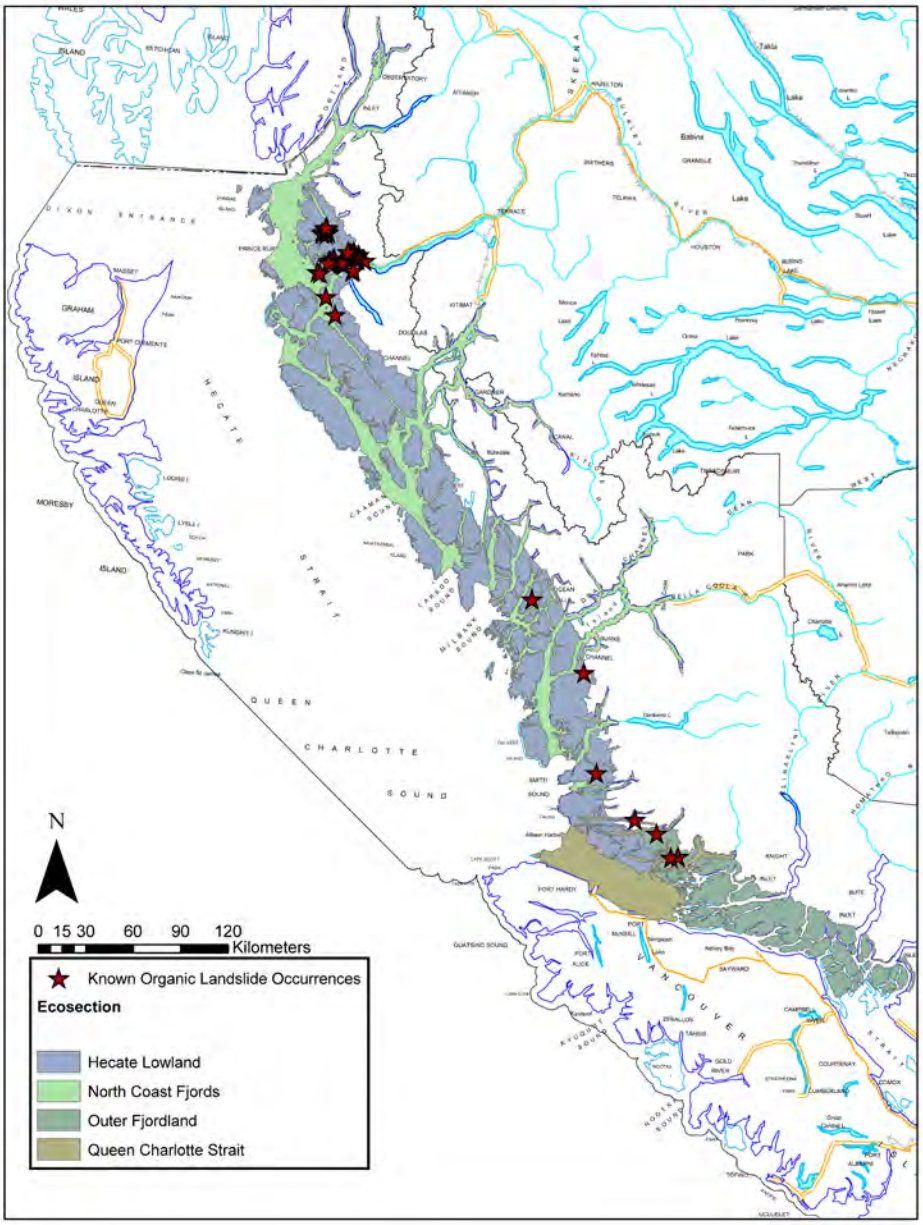

FIGURE 1 *Ecosections and known organic landslide occurrences on the Central and North Coast, British Columbia.*

Slope Morphology and Gradient

Organic soils are commonly found in isolated concave pockets or hollows where surface and/or subsurface seepage concentrates (irregular slopes, convergent slopes, depressions, and ephemeral stream channels). Thin organic soils also form across larger homogeneous areas. Organic landslides have also been associated with irregular or benched terrain. Benched,

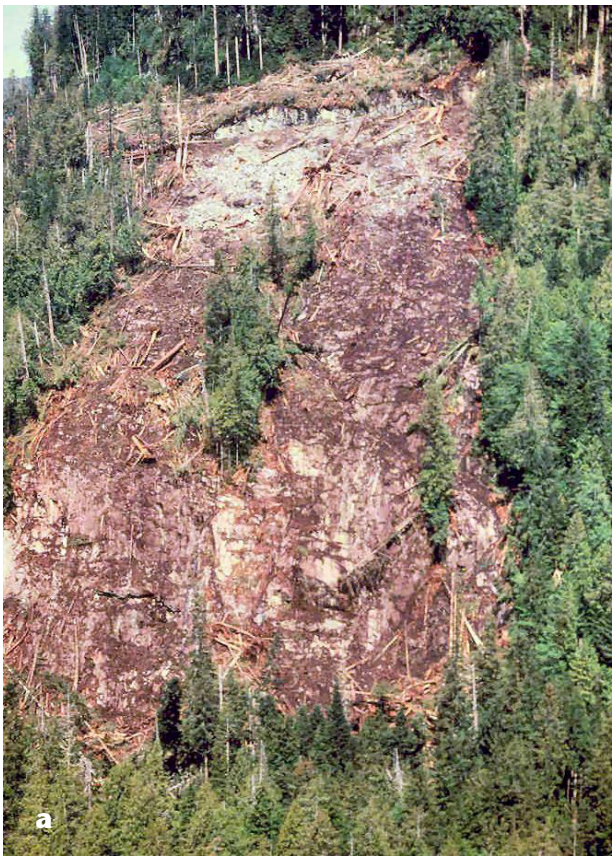

FIGURE 2 *Examples of thin organic veneer over bedrock, which is typical in organic landslides (Photos (a) and (b): Jim Schwab; Photo (c): Tim Smith).*

irregular terrain may favour the development of organic soils through the concentration of seepage in localized depressions.

Nagle (2000) found that in a sample of 30 natural landslides in organic soils around Prince Rupert, the average slope gradient at the initiation point was 93% (43°) and varied from 58% (30°) to 173% (60°); the gradients of adjacent slopes were generally much less. Typical slope gradients in the initiation zone for road construction-related landslides are in the 35–60% range. In extreme cases, landslides have occurred during road construction on slopes between 20 and 35%.

Drainage

Organic soils are most commonly associated with areas of imperfect drainage, and drainage conditions can range from moderately well to very poorly drained. Obvious sites can include poorly or very poorly drained areas where seepage or saturated conditions are visible on the surface (Figure 3a). Less obvious sites include moderately well to imperfectly drained areas dominated by subsurface seepage. Seepage zones and pervasively wet conditions promote the development of deep organic soils

FIGURE 3 *(a) Seepage zones promote pervasively wet conditions and can lead to the development of organic soils; (b) organic soil development at seepage zone (Photos: Matt Sakals).*

(Figure 3b). Concentrated subsurface flow pathways (e.g., along joints and fractures or in hollows) may also play a role in creating high pore-water pressure conditions that lead to landslide initiation. Organic materials also retain water and can produce and maintain saturated conditions that persist through time.

Vegetation Indicators

Organic soils are most common throughout the very wet hypermaritime and very wet maritime Coastal Western Hemlock biogeoclimatic subzones (CWHvm1, CWHvm2, CWHvh1, and CWHvh2). Site series include very moist and wet soil moisture regimes. Indicator shrubs and herbs include skunk cabbage (*Lysichiton americanus*), Indian hellebore (*Veratrum viride*), devil's club (*Oplopanax horridus*), spleenwort-leaved goldthread (*Coptis aspleniifolia*), deer fern (*Blenchnum spicant*), northern maiden-hair (*Adiantum aleuticum*), and salmonberry (*Rubus spectabilis*) (Figure 4a). Wet sites may also be associated with sphagnum moss (*Sphagnum* spp.). However, vegetation is not a definitive indicator of organic soils presence.

Other vegetation indicators may be associated with past or present soil movement or creep. They include leaning, split, bowed, jack-strawed, or pistol-butted trees (Figure 4b).

Landslide Trigger Mechanisms

Landslide initiation due to harvesting activities on organic soils is not necessarily related to the immediate response of the slope to heavy rainfall. Organic soils can retain moisture and remain saturated for prolonged periods. Landslides have occurred with precipitation rates of ≤ 40 mm/24 hr. The development of saturated conditions on-site in addition to other disturbance is the typical failure situation. Therefore, landslides occur in areas where wet conditions persist for long periods (days, weeks, or even seasonally). Due to moisture retention or subsurface drainage concentration, landslides may be triggered when surrounding areas (e.g., in non-organic soils) are relatively dry.

On steeper slopes (greater than 60% or 30°), landslide initiation can occur through natural processes (i.e., intense precipitation) and may be related to windthrow during storm events. The primary failure mechanism in these soils is thought to be related to a rapid increase in pore-water pressure due to short-term loading. The imperfectly drained nature of these soils creates an undrained loading situation, which can cause static liquefaction in certain circumstances. Lower gradient slopes (40–60%) may lack evidence of previous failures and appear stable.

Forestry activities that can cause short-term loading include:

- seismic waves associated with blasting activities during road building
- placement of subgrade fill or sidecast material during road building activities that over-steepen or overload slopes (Figure 5)
- vibration and weight from excavation and hoe forwarding equipment during road building, harvesting, and site preparation activities
- impact of large trees hitting the ground during timber falling

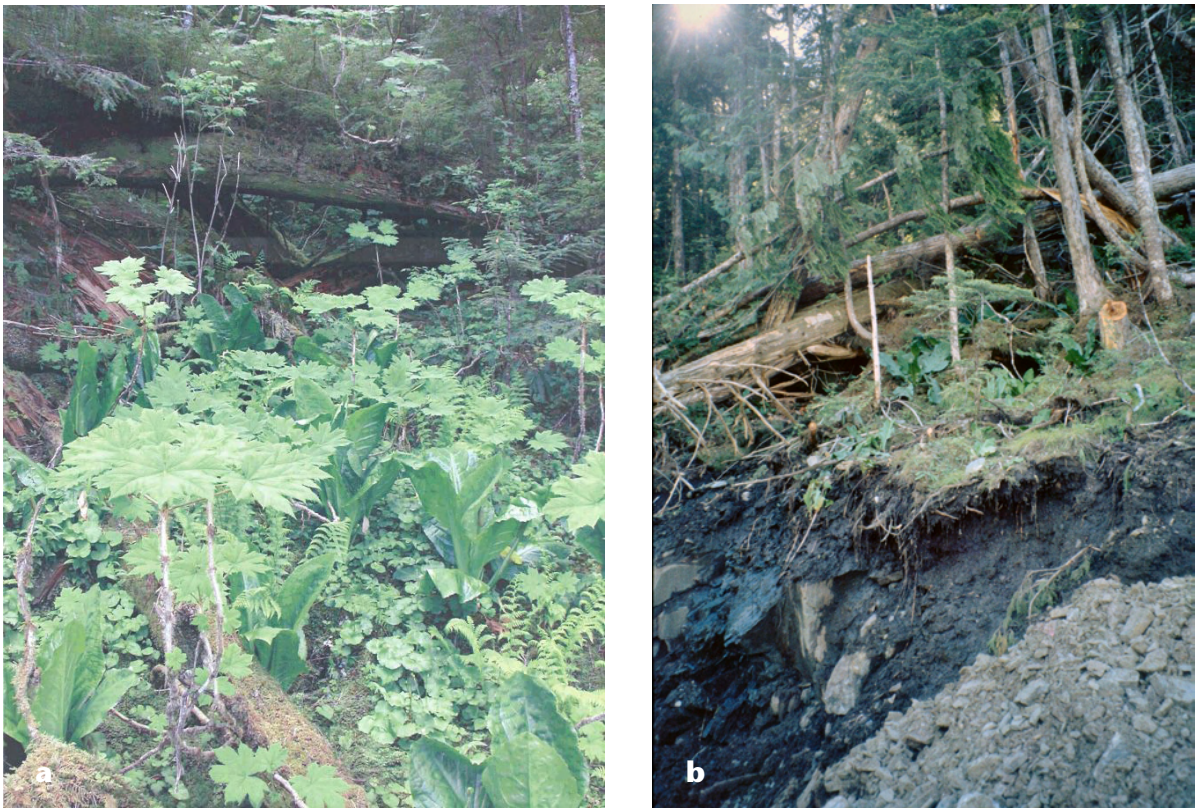

FIGURE 4 *Site vegetation indicators include (a) devil's club, skunk cabbage, and Indian hellabore, and (b) leaning and pistol-butted trees (Photos: Jim Schwab).*

- stress induced on backspars during yarding
- log impact to standing timber during yarding or helicopter logging operations
- windthrow along falling boundary edges following harvesting
- disruption or compaction of subsurface flow pathways

Many of these situations occur when workers are present, which creates a significant safety issue.

Landslide Characteristics

Landslides that occur in thin organic soils are typically either debris slides or debris avalanches. Organic landslide paths often have a triangular shape: narrow at the initiation zone and widening through the transport and deposition zone (Figure 2c). This characteristic reflects the typical unconfined surface of relatively smooth underlying bedrock. Runout zones can extend to lower gradients and can travel farther distances than "typical" non-organic landslides of similar magnitude (Figure 6).

Potentially unstable organic soils may also undergo periodic natural soil creep, slumping, or small-scale failures. Signs of slope movement include relic head scarps, scalloped shaped hollows, tension cracks, single-tree slumps, or signs of soil creep (bowed trees and split trees). Natural occurrences of organic landslides are a strong indicator of potentially similar conditions in the area.

Management Strategies

The following strategies can help reduce the risk of organic landslides to worker safety or the environment:

- Organic soils within cutblocks and along road alignments should be identified during layout. Vegetation indicators can help identify potential organic soils sites, and the presence of organic soils can be confirmed by digging soil pits. These areas should be marked on road design and harvesting documents, and the workers should be made aware of the potential risks of working in these areas. Naturally occurring landslides are prevalent on unlogged slopes that are draped with organic soils. If naturally occurring landslides in organic soils are present in the area of a proposed cutblock or road, the design crew should anticipate the presence of these soils and seek guidance from a terrain stability professional.

- Where organic soils are present, slopes as gentle as 30%, or even less, should be assessed reviewed by terrain stability professionals. Terrain stability professionals who are completing terrain mapping or Terrain Stability Assessments should be aware of the landslide potential associated with road construction and forest harvesting activities on slopes draped with organic soils. When assessing the downslope risk, the terrain stability professional should be aware of the longer runout characteristics of these landslides so that appropriate management strategies can be implemented.
- Where the landslide risk to workers or downslope resources is high, terrain with organic soils should be avoided if possible.
- Forest professionals and harvesting and road building contractors who are working in areas with organic soils should be aware of their presence, the potential for landslide initiation, and the risks associated with this hazard. Operators should stay alert to ground conditions, including the presence of organic soils, soil saturation, or signs of seepage.
- Trees that are rooted in organic soils and are used as backspars may not have sufficient strength to resist yarding stresses. Similarly, yarding that impacts stumps in organic soils may cause stresses that exceed soil strength, which can lead to landslide initiation.
- Sidecast road construction on slopes as gentle as 40% can trigger landslides on terrain draped with organic soils. Full bench and end-haul with no sidecast construction is often the only option for crossing these slopes.
- Road construction should stop when organic soil conditions are encountered, but these conditions are not described in a Terrain Stability Assessment report. Guidance from a terrain stability professional should be sought as soon as possible. Operators should be made aware of any site-specific recommendations made by terrain professionals.
- Workers must not work downslope of road construction or harvesting activities.
- Construction activities should be conducted during dry summer months and dry conditions where possible. Wet soil conditions in organic soils persist for extended periods, days, or weeks after snow-melt or winter storms.
- Wet weather shutdown criteria should be more restrictive to reflect the possible initiation of landslides in organic soils under relatively low-intensity precipitation events. Due to localized high soil moisture, landslide hazard in organic soils can remain high despite otherwise dry conditions. Rainfall shutdown guidelines should be reviewed against known landslide initiation for the area and amended where possible. Rain gauges should be operated and maintained in areas of active falling (including heli-logging activities) and road building. Wet weather shutdown guidelines should be strictly adhered to.

FIGURE 5 *Failure of an organic soil loaded with sidecast material, Security Bay (Photo: Jim Schwab).*

Summary

Organic soils are relatively common in the lowlands and fjords of the Central and North Coast of British Columbia, and they pose a challenge to forestry activities, particularly during road construction activities. In general, organic soils develop under wet conditions. Landslide hazards can exist on organic soils overlying impervious substrates. Due to the sensitive nature of these soils, landslides can occur on

FIGURE 6 *Landslide triggered in shallow organic soil during road construction, Kennedy Island. Landslide debris struck a crew truck parked on the switchback. Timber felling occurred post-landslide (Photo: Jim Schwab).*

much gentler gradients (35–60%) than would be expected in terrain without organic soils. Landslide hazard on these slopes can be exacerbated by the weight and vibrations of logging and road construction machinery, blasting during road construction, tree disturbance, yarding, windthrow, or slopes overloaded with waste or sidecast materials. Identification of organic soils is critical to understanding potential landslide risks and developing appropriate strategies to mitigate those risks.

Acknowledgements

Many thanks to Tim Smith and Del Ferguson who shared their wealth of operational experience with organic landslides and provided much constructive feedback. Hardy Bartle, Terry Chow, Jim Dunkley, and Scott Weston also provided useful discussion on slide occurrences and characteristics. Thank you to Tim Smith and Matt Sakals for thorough reviews of this report.

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Citation

Campbell, D., B. Roberts, J. Schwab, and T. Millard. 2010. Landslides in organic soils on forested slopes. B.C. Min. For. Range, For. Sci. Prog., Victoria, B.C. Exten. Note 99. www.for.gov.bc.ca/hfd/pubs/Docs/En/En99.htm