APPENDIX 3.0-H
Terrain Stability Field Assessment 4X4 Access Road Avanti Kitsault Mines Kitsault BC

Terrain Stability Field Assessment
4X4 Access Road
Avanti Kitsault Mines
Kitsault BC

Prepared by
J.W. Schwab P.Geo., Eng.L.
Geomorphologist

Prepared for
Avanti Kitsault Mines Ltd.

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J.W. Schwab P.Geo., Eng.L. Geomorphologist	P.O. Box 2525, Smithers B.C. V0J 2N0 Tel: 1 250 847-3408 E-mail: jwschwab51@gmail.com

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General Manager Projects

Avanti Kitsault Mines Ltd.
12200 E Briarwood Ave. Suite 175
Centennial, CO 80112

Avanti Kitsault Mines Ltd.,
880-580 Hornby Street,
Vancouver BC. V6C 3BC

Introduction

Active exploration is underway at the Avanti Kitsault Mines Project located approximately 190 km by road north of Terrace BC. Road accessed is via Kitwanga and Highway 37 (Cranberry Junction) or the Nisga'a Highway via New Aiyansh, the Nass Forest Service road and the Kitsault Mine road. Plans are to develop an open pit mine at the property. Mr. Bob Jacko, General Manager Projects, Avanti Kitsault Mines Ltd., asked me to conduct a Terrain Stability Field Assessment (TSFA) along the proposed 4X4 access road alignment from the existing Kitsault Mine Road to the proposed mill site—a distance of about 4 km (Figure 1). Specifically, I was to identify terrain stability hazards and provide recommendations for construction of the proposed 4X4 access road.

Methods

The Terrain Field Stability Assessment was undertaken according to the standards for professional practice set out in the *Guidelines for Professional Services in the Forest Sector - Terrain Stability Assessments* (Association of Professional Engineers and Geoscientists of British Columbia, 2010). The terrain stability assessment follows the *Mapping and Assessing Terrain Stability Guidebook* (Ministry of Forests, 1999), the *Forest Road Engineering Guidebook* (Ministry of Forests, 2002), and Land Management Handbook 56 (Wise et al. 2004). Terminology used to describe terrain and surficial materials follows the *Terrain Classification System for British Columbia* (Howes and Kenk, 1997). *A Guide to Site Identification and Interpretation for the Prince Rupert Forest Region* is the Biogeoclimatic Ecosystem Classification used to identify and interpret ecosystems and infer soil moisture and seepage conditions (Banner et al. 1993). *A Guide for the Management of landslide-Prone Terrain in the Pacific Northwest* (Chatwin et al, 1994) provides information on terminology, procedures for recognizing and evaluating unstable terrain, and techniques for road construction.

My recommendations consider:

- slope stability and erosion hazards;
- safety for equipment operators; and,
- suggest road construction techniques to prevent or reduce the possibility of landslides caused by road construction.

Office Review

I was provided with:

- The recently completed *Reconnaissance Terrain and Terrain Stability Mapping for the Avanti Kitsault Mine Project* prepared by Knight Présold Consulting (July 8, 2011);
- The 4X4 access road plan, profile and cross sections for the road surveyed by AllNorth Consultants Ltd. (August 4, 2010), with drawings prepared by Magellan Digital Mapping (September 16, 2010);
- The location (in-field) for the re-located upper section beyond Km 3+160 undertaken by AllNorth Consultants Ltd., (August 4, 2011);
- A topographic map with the surveyed access route (August 4, 2010).

Prior to fieldwork I reviewed the Reconnaissance Terrain and Terrain Stability Mapping and Report, Engineering Plans, Profile and Cross sections; and, Google earth 3D projections of the mine site and road.

Field Assessment

My field assessment took place on August 3, 4, and 5, 2011. The assessment of the proposed 4X4 access road involved walking the road from the existing Kitsault Mine road to the proposed mill site, a distance of about 4 km. I also walked up and down slope along the proposed route to examine features of potential slope instability. Soil pits were dug in an attempt to determine materials, texture and depth. A helicopter drop (August 4) and pick up (August 5) enabled more on the ground field time. The assessment worked from the existing road toward the proposed mill site (Figure 1).

The Terrain Stability Field Assessment (TSFA) takes a geomorphologic approach to assessing terrain stability. The approach is based on the evaluation of observed terrain features, slope stability site indicators, subsurface materials uncovered in soil pits dug by hand shovel and surficial materials observed in natural exposures along stream channels and from windthrow. Hydrologic conditions are inferred by site indicator plant species, observed seepage on the soil surface and in soil pits, and observed water flow in natural channels. A detailed investigation of subsurface terrain conditions or the measurement of soil engineering properties is not undertaken.

The Terrain Stability Field Assessment is presented in Table 1. Road sections and critical sites are described. Information contained in Table1 includes: uphill-downhill slope, drainage, terrain type, observed slope instability, and recommendations to prevent or reduce the possibility of landslides caused by the 4X4 road construction. Terrain classification code and descriptions are found in Table 2 and Table 3. Examples for recommended construction benching techniques are provided in Table 4.

Physiography and Climate

The recently completed *Reconnaissance Terrain and Terrain Stability Mapping for the Avanti Kitsault Mine Project* prepared by Knight Présold Consulting (July 8, 2011) provides a general summary of the published literature within the Avanti Kitsault Mine project area. For brevity, the information is not repeated in this report. Please refer to their description of the physiography and climate and for a listing of published literature on geology and geomorphology.

Bedrock Geology

The dominant bedrock in the project area is the sedimentary rock of the Bowser Lake Group. The bedrock consists of interbedded greywacke and argillite with minor conglomerate and limestone. Individual beds vary in thickness from a few centimetres to upwards of 15 m. The sedimentary rocks within the vicinity of the mine site have undergone intense intrusive activity related to the Coast Range Crystalline Complex. Significant within the project area are flat lying to gently dipping plateau-type lava flows. The lava flows display well-developed columnar jointed cliff faces with talus blocks deposited at the cliff base.

Surficial Geology

Organics are the dominant surficial material within the project area – very little mineral soil development has occurred along the access route to the mill site. The organics blanket the flat lying and hummocky terrain of the lower basin and upper elevations (Figure 2 and 7). The hummocks appear to be composed of hard rock and in some instances the hummocks are covered in a shallow capping of shattered rock. Glacial till was not observed in the basin or on the upper plateau however, the topographic setting suggests that till may be exposed during excavation. Situated along the mid-elevation is a moderately steep forested slope composed of rubbly to blocky colluvium and bedrock. Folic soils have developed on forested slopes within the boulder blocky colluvium. Folic soils are also present as a thin veneer (less than 30 cm) on the steeper smooth hard bedrock. Folic soil development within the area is a reflection of very little weathering of the hard rock and a cool wet climate.

Hillslope Drainage

Scrub forests and bogs have developed on all the gently sloping relatively flat terrain within the lower basin and on the gentle upper slopes. These areas are poor to very poorly drained. Forest stands have developed only on the moderate to rapidly drained steeper slopes. Few defined streams drain the hillside and few deep gullies have been eroded into the bedrock or surficial materials. The lack of confined drainages has resulted in the development of the deep organic soils in the lower basin and at higher elevation. Pockets of deeper organics have also developed at slope breaks and along benches of the steeper slopes (Figure 3).

Slope Stability

Knight Présold Consulting (July 8, 2011) reconnaissance terrain stability mapping identified small sections of ‘potentially unstable’ terrain along the proposed mine access road between stations 1+600 and 2+000 and stations 2+500 and 3+100 as the road climbs to the lava flow plateau. No ‘unstable’ areas were identified. Their assessment is based predominantly on slope and air photo interpretation.

Landslides are not a dominant feature on the landscape. However, I found considerable evidence of present and past slope movement along the steeper road sections. The steep slopes and headwall combined with shallow folic soils, poor drainage and sloping bogs suggest that landslides will occur unless caution is exercised and appropriate road construction techniques are employed to prevent landslides.

Road Section 0+000 to 1+365

The deeper organics and hummocky terrain within the basin pose a construction challenge (Figure 2). Overland construction with the use of an engineering geotextile, covered with free draining material, will enable the floating of the road over many organic soils. No ditches are cut in the organics but cross drainage is provided at sites of surface water flow. However, overland construction is not fail safe—density and water content of the organics are critical inherent factors that must be considered. Sloping bogs are an additional problem—loading of the organics even with overland construction could result in movement of the organic mat (this comment also applies to the sloping organic bogs at road section 2+888 to 2+540 and revised section 0+546 to 0+700). Geotechnical Engineers specialized in overland construction should be consulted and possibly supervise the construction through the organic terrain, in particular, the deep wide wet bogs.

Road Section 1+366 to 1+890

The access road crosses sections of relatively steep terrain. The section generally follows and climbs effectively from bedrock bench to bedrock bench. The majority of the road can be safely constructed with a balanced cut-and-fill. A few sections will require the construction of a ¾ bench with rubbly material draped down slope. The critical portions for construction are areas of sloping thin folic soil on smooth bedrock and wet organic soils indicated by the presence of skunk cabbage (section1+487 to 1+603 and site locations 1+643 and 1+665). The wet organics will fail if loaded and must be scraped off (removed) prior to the construction of the subgrade. The stable subgrade is then constructed with free draining shot rock that permits water flow through the subgrade.

At 1+849 the road is located through a headwall. Waste material indiscriminately dumped into the headwall will likely fail. Constructing a ¾ bench to full-bench by moving the road into the slope will avoid the headwall. Large angular blocks placed into the headwall will provide sufficient support for a ¾ bench and permit free drainage through and under the fill. All organic material must be stripped prior to the placement of angular rock into the headwall.

Road Section 1+890 to 2+288

No observed active slope instability occurs within this section between 1+890 to 2+540. The terrain is not steep. Balanced cut-and-fill will provide a long-term stable road. Intermittent wet organics will pose a potential challenge for constructing a stable subgrade. Do not load the wet organics and folic soils. The organics must be stripped and fill constructed with free draining shot-rock.

Road Section 2+888 to 2+540

The road section crosses a gentle sloping very poorly drained bog of deep organics. The organics should not be disturbed or ditches constructed. Overland construction with shot-rock placed on geotextile will provide a stable road for 4X4 access.

Road Section 2+540 to 3+060 and Revised 0+000 to 0+546

This road section, approximately 1100 m in length, crosses a steep forested slope. The terrain along this road section is typical of the terrain one would expect to encounter during road construction in the BC coastal mountains. Naturally occurring slope instability occurs along this section of road (Figure 4 and 5). The most problematic sites are the headwalls located along and below the proposed centerline at about 2+580, 2+650, 3+050, and revised location 0+234, 0+249, 0+264, and 0+293. Road construction techniques required to construct a stable road vary considerably along these road sections. These techniques include: balanced cut-and-fill construction, ¾ to full bench construction with sliverfills using well drained rubble, full-bench with end-haul of waste materials or with backcasting where materials are free draining (Table 4). Construction recommendations are provided for road sections and specific site locations (Table 1). Full-bench with end-haul is required as a minimum for about 250 meters and ¾ bench with end-haul of excessive waste is required for about 200 meters. Keeping the road width to a minimum will reduce the amount of rock and excessive waste. The control of waste rock is important to prevent excessive loading of open slopes and, in particular, the identified steep unstable headwalls. Controlled blasting is important to retain blast rock on the constructed road surface for end-haul or backcasting. Controlled blasting is essential to prevent waste rock loading the headwall.

The underlying bedrock is hard and appears relatively massive. However, joints and bedding will likely be exposed in cuts, based on observation along the main Kitsault mine access road, hence; the stability of the rock cut slopes is unknown without considerably more investigation or until the rock face is exposed. Uncontrolled heavy blasting could shatter the rock face and create instability. Therefore, the rock cut slopes should be assessed on an ongoing basis during drilling and blasting.

Folic soils and pockets of organic soils occur at many sites along this forested section of the road (Figures 3 and 6). These soils must be removed and not loaded with waste materials or by equipment during construction—they will fail under load or vibration. Only use excavators for construction on the steeper slopes (refer to the section on landslides in folic soils).

Revised Section 0+546 to 0+700

The centerline is located along the edge of a sloping bog. Rock is likely located close to the surface on the uphill side of the centerline. A balanced cut-and-fill may help reduce the amount of overland construction with the road moved into the slope. However, overland construction is necessary to cross the bog and stream between revised stations 0+546 and 0+610.

Road Drainage Requirements

Road drainage issues cause many road associated slope failures. A constructed 4X4 access road kept to a minimum width does not require long sustained grades. Hence rolling grades (dips) will greatly reduce water channelized down grade thus reducing the probability of slope failures. Outsloping of the road surface used in conjunction with rolling grades will prevent water ponding on the inside edge of the road surface. The 4X4 road, if constructed at a higher standard with designed ditches, should ideally still use a rolling grade through the steeper hillslope sections. However, insloping and outsloping of the road prism should be designed as part of the overall water-ditch-culvert management for the road. In general, I suggest installing more culverts than are indicated on the design drawings—the area receives high rainfall during intense fall frontal storms and rain-on-snow events during the months of October and November and potential receives a high snowpack runoff. Specifically:

- Long sustained grades require frequent cross-drains;
- Switchbacks require special consideration to ensure that water does not continue to flow down the road surface;
- Sites where water could pond (seepage sites and low-lying areas) require a cross-drain to permit the free flow of water;

- The road should be insloped to a ditch when a berm is placed along the outside road edge. The berm must be broken within dips, and frequently along sustained grades to prevent water channeling down the road; and,
- Outslope the road surface in situations where a ditch cannot be maintained.

Engineering Design

My recommendations indicate that various construction techniques must be employed to prevent landslides. This information is currently not reflected in the present design profiles for the road. I suggest that the full design profile be re-run based on the information contained in Table 1. This is particularly important for specific site locations and the steeper road sections (1+366 to 1+1890, 2+540 to 3+060 and revised location 0+000 to 0+546). Table 1 and the revised full profile design should be provided to the equipment operators constructing the road.

Landslides in Folic Soils

Folic soils (shallow organic soil) are found on the forested slopes crossed by the proposed 4X4 access road. Shallow landslides in thin organic soils are frequently triggered during road construction on gentle to moderately steep terrain—a safety concern for equipment operators, hence, a brief discussion. These shallow landslides in organic soil are of particular concern because they occur at much lower slope angles than usually expected—slope angles of less than 30 %. Folic soils typically form in thin veneers (10–100 cm thick) over nutrient-poor unweathered hard bedrock. They are commonly found in isolated concave pockets or hollows where surface and/or subsurface seepage concentrates. Sometimes the thin folic soils are found on a smooth bedrock surface. Wet conditions tend to persist at these sites. The imperfectly drained nature of these soils creates an undrained loading situation. This can cause static liquefaction under situations of short-term loading during road construction that include:

- Seismic waves associated with blasting,
- Placement of subgrade fill or sidecast waste onto an over-steepened or overloaded slope,
- Vibration and weight from excavation and forwarding equipment, and
- Disruption or compaction of subsurface flow pathways.

These situations often occur during construction when workers are present—a significant safety issue. Equipment operators working on the forested slopes should be made aware of the potential for failure of the organics during construction activity. A recent publication by Campbell et al (2010) provides more detailed information on landslides triggered in Organic soil. This publication could possibly be made available to operators as part of the safety program.

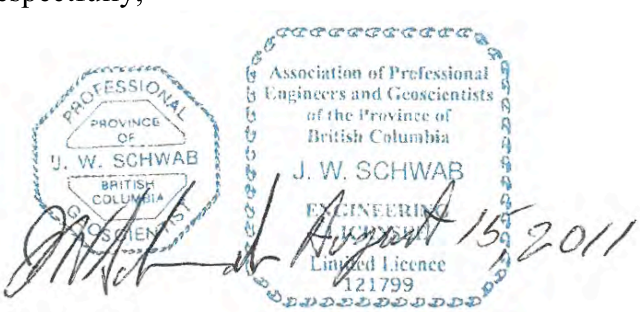
Assessment Limitations

Recommendations presented herein and in Table 1 are based on a field site inspection and terrain evaluation conducted by walking the proposed 4X4 road from the existing Kitsault road to the proposed Avanti Kitsault Mines mill site. A geomorphologic approach is undertaken for the terrain stability assessment. The approach is based on the evaluation of observed terrain features, slope stability site indicators, subsurface materials uncovered in soil pits dug by hand shovel and surficial materials observed in natural exposures along stream channels and from windthrow, and surface water flow observed in natural channels, seepage and inferred by site indicator plant species. I did **not** undertake a detailed investigation of subsurface terrain conditions or measurement of soil engineering properties to arrive at the recommendations contained in this report. If terrain conditions, unstable slopes, or slope failures occur during the excavation of materials that are not otherwise reported or that pose a safety or environmental risk, a terrain-slope stability specialist should review the encountered conditions prior to the continuation of work at a site.

This report is prepared for Avanti Kitsault Mines Ltd., and their representative that includes distribution as required. The Terrain Stability Field Assessment was carried out according to generally accepted Geoscience and Engineering practices for terrain assessments. Professional judgment is applied in developing the recommendations. No other warranty is expressed or implied to Avanti Kitsault Mines Ltd., regulatory agencies or any other third parties that may be impacted by my recommendations.

I trust the report satisfies your requirements for a Terrain Stability Field Assessment of the 4X4 access road proposed for construction from the existing Kitsault road to the proposed mill site. Should you have any questions regarding my report or if I can be of further assistance, please do not hesitate to contact me.

Respectfully,



J.W. Schwab P.Geo., Eng.L.

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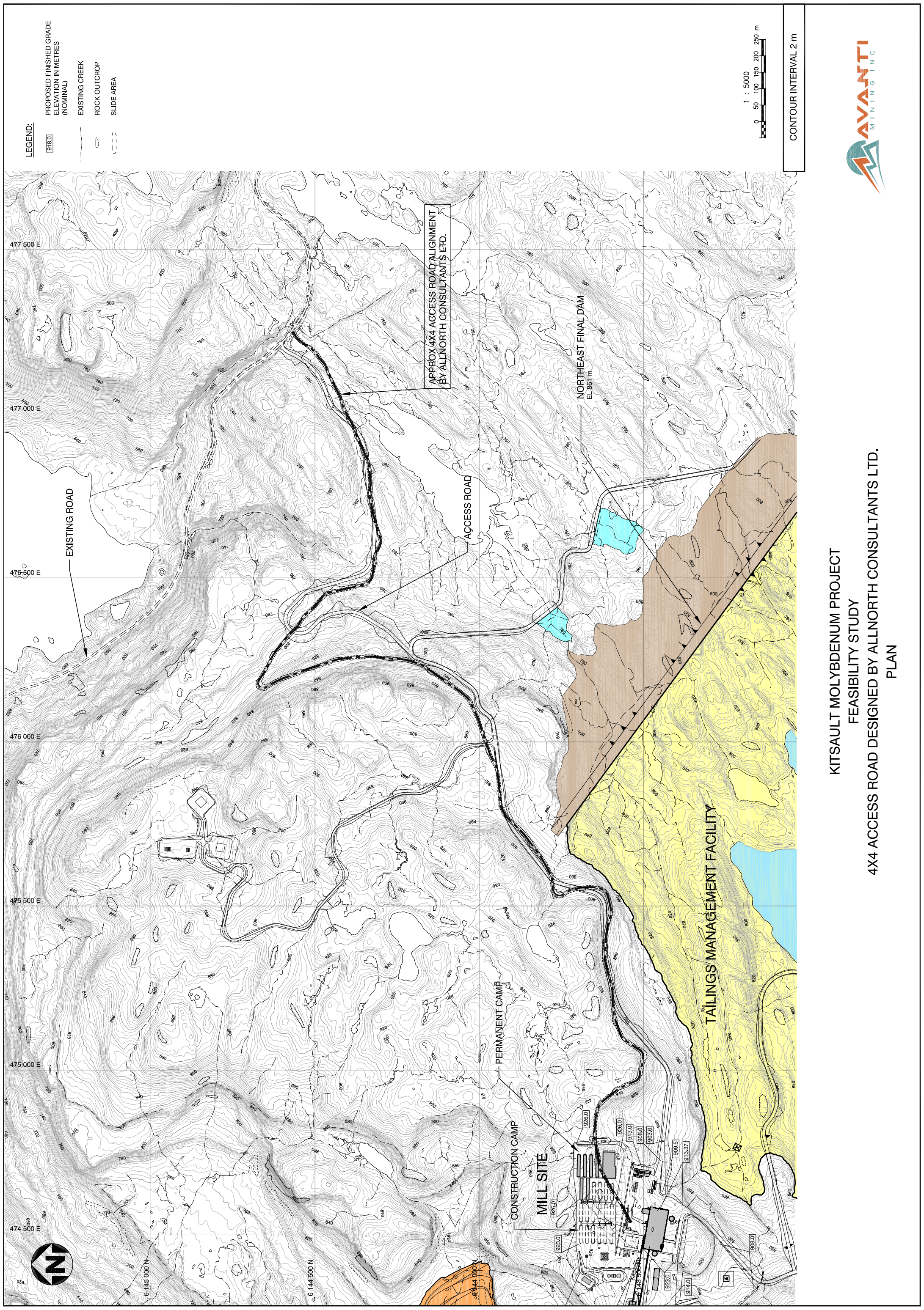


Figure 1 The approximate location of the 4X4 access road and route walked for the terrain stability field assessment. Revised road near the mill site is not delineated.

Figure 2 Hummocky terrain with deep organics in the dips between bedrock ridges.

Figure 3 Organic soils on a forested slope. Leaning trees (photo centre right) show slope movement into a depression that breaks off steeply downslope.

Figure 4 Steep forested slope with a narrow bench located above headwalls.

Figure 5 Leaning trees show active slope movement.

Figure 6 Imperfect to well drained slope with open growing forest and folic soils.

Figure 7 Bedrock appears close to the surface over much of the higher elevation plateau.

Table 1 Terrain Stability Field Assessment for 4X4 Access, Avanti Kitsault Mines

Station-section	Slope %	Drainage	Terrain-material	Description and Construction Recommendation
0+008 - 0+854	Flat-Gently rolling-Hummocks	Imperfectly to very poorly drained	Ob/Ov R//Mb Organic veneer 15-50 cm over rock. Organic blanket possibly 5-10 m deep	Scrub forest to swamp. Hummocky. Some ridges are composed of shattered rock and others of massive hard rock. Hollows are filled with organics that are very poorly drained. Overland construction is required with shot-rock placed on engineering geotextile. Some rock may be obtained from the rock hillocks but the majority will have to be quarried. Do not attempt to construct ditches. Ensure that drainage is maintained under the road at presently defined streams. A station-by-station prescription cannot be made for the section. Construction techniques could vary depending on the depth of the wet organics explored during construction, otherwise consider overland construction for all areas with organics. An engineer specialized in overland construction should be consulted.
0+719 Site location		Very poorly drained	Ob	Road turns to the northwest.
0+854-0+888	±15 %	Poorly drained	Ob	There is a potential for the organics to move if loaded. Explore depth of organics; Strip organics to a solid base and construct with shot-rock. If organics are deep, consider overland construction.

Table 1 TSFA continued -- 4X4 Access, Avanti Kitsault Mines

0+888- 0+942	± 25%	Imperfectly drained	Ov/R//Mb	Side hill; Strip organic veneer; Balanced cut-and-fill construction.
0+942- 0+963	± 15%	Very poorly drained	Ob	Overland construction.
0+963 – 1+093	+ 48 % - 60 %	Moderately well drained	Ov/Cv R	No sign of slope instability; Balanced cut-and-fill. Material will spill about 25m down slope.
1+037 – 1+088	± 10%	Very poorly drained	Ov/Ob	Gentle sloping bog; Explore depth; Overland construction or strip if organics are < 30 cm.
1+088 - 1+116	± 15 %	Moderate well drained	Cv/Ov	Balance cut and fill
1+116 – 1+330	+65 % -25 to 45%	Imperfectly drained	Ov//Ob R	Forested slope; Bog situated at the base of the slope. There is a slight bow/tilt in trees from past slope movement; Caution, organics will fail if loaded. Strip organics and move road into the slope. Construct a ¾ bench road. Do not waste onto organics down slope
1+330 - 1+340	± 30%	Very poorly Drained	Ov	Skunk cabbage present; Organics will likely fail if loaded; strip organics and fill with shot-rock.
1+340 – 1+366	± 15 to 20 %	Very poorly Drained	Ob	Switch back located on a sloping bog. Overland construction required—exercise caution. The loading of the organics may result in slope movement.
1+366 – 1+487	+60 to 70 % -40 to 65 %	Well drained	rbCb/rbCv R	Forested slope. Folic soils are on and between the boulders. No signs of slope instability. Large blocks and boulders have moved onto the site from steep upslope ridges. Bedrock is close to the surface. A balanced cut-and-fill to ¾ bench required. Stack rubble to create a stable fill.

Table 1 TSFA continued -- 4X4 Access, Avanti Kitsault Mines

1+487 – 1+603	+40 to 75% -15 to 80% Bench	Moderately well to Imperfectly drained	<u>rbC/Ov</u> R	No signs of slope instability. The proposed centerline follows a bedrock-controlled bench on a forested slope. Folic soils and pockets of wet organics indicated by skunk cabbage and sites with devils club indicating water flowing close to the surface. Balanced cut-and-fill construction. Scrap off the pockets of wet organics and in-fill with shot-rock. Provide adequate subsurface drainage at sites with moving water.
1+603				Jump to the next upslope bench.
1+603 – 1+643	+ 40 % -55 % Bench	Rapidly drained	<u>Cv</u> R	Bedrock-controlled bench. Shallow soil over rock. Balanced cut-and-fill.
1 +643 Site location	+25 % -40 %	Very Poorly drained	<u>Ov</u> R	**Site centered at about 1+643.** Wet sloping organics at a gully headwall. Bowed trees are an indication of slope movement. **The organics will fail if loaded**. Strip organics; construct with shot-rock.
1+643 - 1+660	+ 40 % -55 % Bench	Moderately well drained	<u>Cv</u> R	Bedrock controlled bench. Shallow soil over rock. Balanced cut-and-fill.
1+665 Site location	-40 % +25 %	Very Poorly drained	<u>Ov</u> R	**Site centered at about 1+665.** Wet sloping organics in a dip. **The organics will fail if loaded**. Remove organics and construct with free draining shot-rock.
1+170 - 1+725	± 20 % Bench	Moderately well drained	SCv R	No signs of instability. Balanced cut-and-fill construction.
1+725 – 1+840	+70 % - 35 to 55%	Rapidly drained	<u>rbCb</u> R	No signs of slope instability. Trees that appear bent are growing on rock blocks and rubble. Balanced cut-and-fill.

Table 1 TSFA continued -- 4X4 Access, Avanti Kitsault Mines

1+849 Site location	+50 % -70%	Moderate to rapidly drained	rbCb R	**Observed slope instability;** Road is located through a headwall. Do not waste into the headwall. Waste material will likely fail and run up to 100+ meters. Construct a ¾ to full-bench road by moving the centerline into the slope. Large angular blocks placed in the headwall (locked together) will provide sufficient support for a narrow fill necessary with ¾ bench construction. This technique will provide support for the road and permit free drainage through the subgrade.
1+850 – 1+890	+70 % - 55%	Rapidly drained	rbCb R	No signs of slope instability. Trees that appear bent are growing on rock blocks and rubble. Balanced cut-and-fill.
1+890 – 2+057	+ 40 % Bench	Moderately well drained	Cv R	No signs of slope instability. Balanced cut-and-fill construction.
2+057 – 2+207	+35 to 55 % -30 to 45 %	Moderately to rapidly drained	rbCb R	No signs of slope instability. Note site location **2+147**
2+147 Site location	+35 % -45 %	Poorly drained	rCb R	Skunk cabbage and stream. Clean out mud; construct with clean draining rock, geotextile and culvert.
2+207 – 2+288	+40 % -25 %	Moderate to poorly drained	srCb/Ov	Open forest stand. Intermittent wet sites. Balanced cut-and-fill. Exercise caution with wet organics. Strip organics do not load. Construct through poorly drained areas with clean shot-rock
2+288 – 2+540	-5% Gentle slope	Very poorly drained	Ob	Overland construction with shot-rock placed on a geotextile. Do not disturb organics or construct ditches.
2+540 - 2565	+50 % -50%	Well drained	sCv/Cb	Forested slope. No signs of instability.

Table 1 **TSFA continued -- 4X4 Access, Avanti Kitsault Mines**

2+565 - 2590	+55 % -55%	Moderately well drained	Cv/Cb	**Observed slope instability;** Headwall located about 10 meters down slope of the centre line. The headwalls drop off steeply down slope. Move road into the slope and **construct a ¾ bench to full bench** with **end-haul**: no sidecast or waste placed into the headwall.
2+590 - 2+620	+50 % - 55 %	Moderately to rapidly drained	Cv/Cb	No signs of instability. Construct ¾ bench with sliverfill.
2+620 Site location	+50 % - 55 %	Moderately well to poorly drained	Ov	Drainage, culvert required. Skunk cabbage site. Do not load organics. Strip organics/mud construct with clean shot-rock.
2+620 – 2+644	+50 % - 55 %	Moderately well drained	Cv/Cb	No signs of instability. Construct ¾ bench with sliverfill.
2+644 – 2+660	+ 55 % - 60 %	Moderately well drained	Cv/Cb	**Observed slope instability;** Headwalls situated down slope of road location are unstable; drops off steeply. The headwalls are located about 10-15 meters down slope of the centre line. Construct a ¾ bench to full-bench road with no sidecast or waste spilled into the headwall; End-haul waste or back-cast.
2+660 – 2+720	+ 55 % - 40 to 55%	Moderately well to rapidly drained	Cv/Cb/R	No signs of instability on the proposed road. However, the slope drops off rapidly about 20 meters below the centre line. Construct ¾ bench with sliverfill but do not waste into drop off.
2+720 – 2+725 Site location	+50 % - 50 %	Moderately well to poorly drained	Cv/R	Wet seepage area below the centerline; devils club and skunk cabbage are present. Do not load organics. Scrape out the organics; expose the seepage zone; deal with the water (culvert); construct with free draining shot-rock.

Table 1 **TSFA continued -- 4X4 Access, Avanti Kitsault Mines**

2+725 – 2+850	+50 % -50 to 35 %	Moderately well drained	R/Cv//Cb	No instability observed. Materials range from rock to shallow colluvium. Stream is located within 25 m down slope. Balanced cut-and-fill. Do not waste material into stream.
2+850	+10 % -15 %	Flowing Stream	sMb//Cb	Stream crossing; 1.5m stream bank; possible Till.
2+850 – 2+873	+35 % -13 %	Moderately well to poorly drained	Ov/Ob	**Observed slope instability;** Jackstraw trees on the uphill side of the centre line; a possible indication of movement in the organics. Strip organics to a competent base; balanced cut-and-fill construction.
2+873 – 3+000	± 20 to 30 %	Moderately to poorly drained	Ov Cb	Strip organics to a competent base; balanced cut-and-fill construction.
3+000 – 3+038	+40 to 70 % -45 to 55 %	Moderately Well to rapidly drained	srCv/R	No observed slope instability. Balanced cut-and-fill.
3+038 - 3+060	+60 % -65 %	Moderately Well to rapidly drained	Cv R	**Observed slope instability**; Headwall located below centre line—a historic landslide headscarp. Construct ¾ to full-bench road with sliverfill. Do not waste material into headwall area.
3+060 – 3+160	+ 45 % - 60 %	Moderately well to rapidly drained	Cv/ R R	No observed natural instability. Bedrock controlled. Construct ¾ bench road with sliverfill.

Table 1 **TSFA continued -- 4X4 Access, Avanti Kitsault Mines**

Start Revised Location 0+000 – 0+160	+65 to 85 % -55 to 100 %	Moderately well drained	Cv/R R//Cv	**Observed slope instability,** site is **unstable**. Bowed and leaning trees at station 0+080 and landslide headwalls at 0+118, 0+129, and 0+143. Fill or waste material placed in the headwalls will cause a landslide. **Full-bench with end-haul construction.** B**ack-cast if practical** to reduce the end-haul requirement.
Revised Location 0+160 – 0+200	+ 20 to 50 % - 45 to 80 %	Moderately well to poorly drained	Cb	No observed slope instability. Generally wet slope. Construct ¾ bench with sliver fill. Do not waste excess material down slope onto wet soils. If practical back-cast coarse materials onto subgrade.
Revised 0+200 – 0+205	+35 % -45 %	Poorly drained	Cb	**Observed slope instability**; headwall of an old landslide. The slope is not steep but the old headwall in wet soil suggests a high probability for a slope failure if the headwall is in-filled or loaded. **Full-bench with end-haul construction**.
Revised 0+205 – 0+230	± 45 to 55 %	Moderately well drained	Cv//Cb	No signs of slope instability. Construct balanced cut-and-fill.
Revised 0+230 - 0+295	+30 to 55 % -45 to75 %	Moderate to poorly drained	Cv/R Ov/R	**Observed slope instability**; wet headwalls located at about 0+234, 0+249, 0+264 (20 m wide) and 0+293. These headwalls are located down slope from the proposed centerline. There is a high probability for slope failure if the headwalls are loaded with waste or fill. Construct ¾ **bench to full-bench** with the **end-haul of waste materials to prevent slope failure.** Do not waste material into the headwalls.

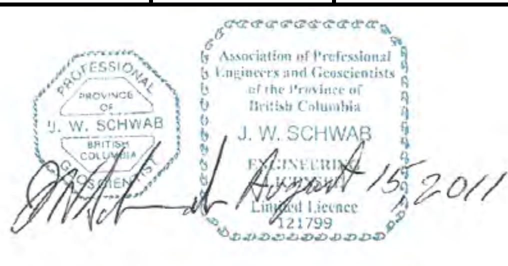
Table 1 **TSFA continued -- 4X4 Access, Avanti Kitsault Mines**

Revised 0+234 Site location	+ 45 % - 60 %	Moderately well to poorly drained	Cv	**Headwall** located 10 m below centerline. Construct ¾ bench to full bench. **Do not waste material into the headwall**.
Revised 0+249 Site location	+55 % - 60 %	Moderate to poorly drained	Cv	**Headwall** located directly below centerline. Slope drops off steeply at about 40 meters. Construct ¾ bench to full bench. **Do not waste material into the headwall**.

Revised 0+264 Site location	+30 % - 50 %	Moderate to poorly drained	Ov R	**Observed slope instability along centerline** (wet area 20 m wide, bowed trees). Construct across wet area by: **scraping off and removing the organics**; and **replace with free draining shot-rock** to construct the subgrade.
Revised 0+293 Site location	+55 % -45 to 75%	Moderate to poorly drained	Ov	**Headwall** located 10 m down slope from centerline. Slope drops off steeply below headwall. Construct ¾ bench to full bench. **Do not waste material into the headwall**.
Revised 0+295 – 0+350	± 65%	Moderately well drained	Cv/R	No observed instability. Open Hemlock forest. Balanced cut-and-fill construction.
0+350 – 0+400	+ 25 to 55 % - 25 to 50 %	Moderately well drained	Cb	No observed instability. Open Hemlock forest. Balanced cut-and-fill construction.
0+400 – 0+450	+20 to 35 % -10 t0 20 %	Moderate to poorly drained	Ov/Cv//Cb	No observed instability. Open scrub forest and along the upper edge of bog. Strip organics. Construct a balance cut-and-fill.
0+450 – 0+546	+30 to 40 % -20 %	Moderate to poorly drained	Cv/Ov	No observed instability. Strip organics. Construct a balance cut-and-fill.

Table 1. TSFA continued -- 4X4 Access, Avanti Kitsault Mines

0+546				Edge of bog
0+546 – 0+610 (Stations as flagged are possibly not correct)	0 to 30 %	Moderately well to very poorly drained	Ob/Ov	Sloping bog. Centerline is located along the edge of the bog. Overland construction. Construct with shot-rock placed on geotextile. **Caution** sloping organics may move when loaded. Possibly shift road into sloping terrain if material beneath is colluvium (not observed).
0+553 Site location	± 15 %	Very poorly drained	Ov	Stream crossing. Some boulders found in stream suggest bedrock or possibly Till is located within one meter of the surface.
0+610 – 0+700 (Station flags possibly incorrect)	0 to 30 %	Moderately well to very poorly drained	Ov/Ob Mb-R	Road centerline is located along the edge of the sloping bog. Sloping terrain is moderately well drained and the bog very poorly drained. Possibly move road into slope if material beneath is Till or rock (not observed). Otherwise overland construction is required with shot-rock placed on geotextile.



J.W. Schwab P.Geo., Eng.L

Table 2. Terrain Classification Terminology and Symbols[1]

TERRAIN SYMBOL

Example **sgCb-R**

Texture **sg**
surficial material **C**
surface expression **b**
geomorphological process **-R**

COMPOSITE SYMBOL

. components on either side of the symbol are of approximately equal proportion
/ the component in front of the symbol is more extensive than the one that follows
// the component in front of the symbol is considerably more extensive than the one that follows
_ the component in front of the symbol overlays the one that follows

TEXTURE

a blocks (>256 mm; angular)
b boulders (>256 mm; round)
k cobbles (64-256 mm, rounded)
p pebbles (2-64 mm, rounded)
g gravel (rounded particles, >2mm)
s sand (0.63-2 mm)
z silt (0.002-0.63 mm)
c clay (<0.002 mm)
d mixed particles (angular and rounded)
x angular fragments
g gravel
c rubble (angular)
m mud (silt and /or clay)
y shells
e fibric organics
u mesic organics
h humic organics

SURFICIAL MATERIALS

A anthropogenic material
C colluvium
D weathered bedrock
E aolian sediments
F fluvial sediments
$\mathbf{F}^G$ glaciofluvial sediments
I ice
L lacustrine sediments
$\mathbf{L}^G$ glacial lake sediments
M till
R bedrock
U undifferentiated materials
V volcanic sediments
W Marine material
$\mathbf{W}^G$ Glaciomarine material

SURFACE EXPRESSION

a moderate slope(s) (27-49%)
b blanket
c cone
d depression
f fan
h hummocky topography
j gentle slope(s) (6-26%)
k moderately steep slope(s) (50-70%)
m rolling topography w mantle of variable thickness
p plain (0-5%)
r ridge topography
s steep slope(s) (>70%)
t terraced
u undulating topography
v veneer
w mantle of variable thickness
x thin veneer

GEOMORPHOLOGICAL PROCESSES

Erosional Processes	**D** deflated (wind) **K** karst **P** Piping **V** gully erosion **W** washing (water)
Fluvial Processes	**B** braided channel **I** irregularly sinuous channel **J** anstomosing channel **M** meander channel
Mass movement Processes	**A** snow avalanches **F** slow mass movement **R** rapid mass movement
Deglacial Processes	**E** glacial meltwater channels **H** kettled
Periglacial Processes	**C** cryoturbation **N** nivation **S** solifluction **X** permafrost processes **Z** general periglacial processes
Hydrologic Processes	**U** inundated **L** Surface seepage
Superscripts:	**A** = active, **I** = inactive

GEOMORPHOLOGICAL PROCESSES: SUBCLASSES AND SUBTYPES

F" slow mass movement, initiation zone
Fc soil creep
Fk tension cracks
Fr slow rockslide(s)
Rb rockfall(s)
Fe slow earthflow(s)
Fg rock creep
Fs slow debris slide(s)
R" rapid mass movement, initiation zone
Rd debris flow(s)
Rr rapid rockslide(s)
Rs rapid debris slide(s)
Ra rock avalanche
Rt debris torrent(s)

[1] Terrain Classification System for British Columbia (Version 2) 1997.

Table 3. Soil Drainage Classes

Very rapidly drained (vr) Water is removed from the soil very rapidly in relation to supply. There may be very rapid subsurface flow during heavy rainfall provided there is a steep gradient. Soils are usually coarse textured, or shallow or both. Water source is precipitation.

Rapidly drained (r)
Water is removed from the soil rapidly in relation to supply. Subsurface flow may occur on steep gradients during heavy rainfall. Soils are usually coarse textured, or shallow, or both. Water source is precipitation.

Well drained (w)
Water is removed from the soil readily but not rapidly. Soils are generally intermediate in texture and depth. Water source is precipitation. On slopes subsurface flow may occur for short durations.

Moderately well drained (m)
Water is removed from the soil somewhat slowly in relation to supply due to shallow water table, lack of gradient, or some combination of these. Soils are usually medium to fine textured. Precipitation is the dominant water source in medium to fine textured soils; precipitation and significant additions by subsurface water are necessary in coarse textured soils.

lmperfectly drained (i)
Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Soils have a wide range in available water supply, texture, and depth, and are gleyed phases of well drained subgroups.

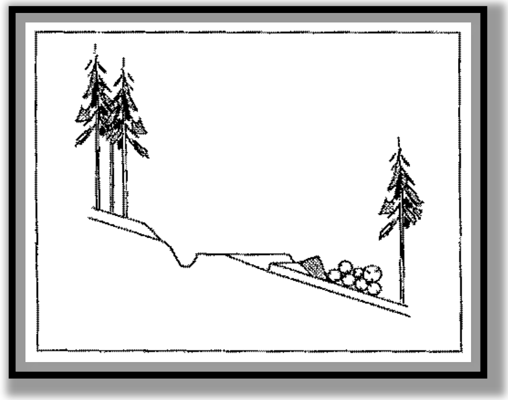
Poorly drained (p)
Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soils not frozen. Subsurface flow or groundwater now, in addition to precipitation are the main water sources, with precipitation exceeding evapotranspiration. Soils have a wide range in available water storage capacity, texture, and depth, and are gleyed subgroups, Gleysols and Organic soils.

Very poorly drained (vp)
Water is removed from the soil so slowly that the water table is near or at the surface tor the greater part of the time the soil is not frozen. Groundwater flow and subsurface flow are the major water sources. Precipitation is less important. Soils have a wide range in available water storage capacity, texture, and depth, and are either Gleysolic or Organic.

Table 4 Road Benching Techniques.

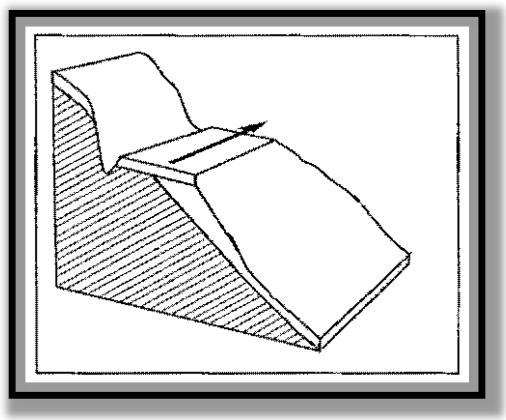
Balanced cut-and–fill

- Three passes excavator construction.
- Log and stump removal (pioneer track).
- Overburden removal.
- Bearing surface is constructed with unweathered native material.



Sliverfills

- Three-quarters to full bench road constructed through rock or coarse colluvium.
- Material is placed or draped down the slope by the backhoe.
- Broken rock is ideal material.
- Use only in rock or coarse colluvium, shattered rock is ideal.
- Do not use in silts or clays.
- Do not place material on to organic soils, slash, logs or brush.



Backcasting

- Excavated material is back-cast onto the constructed bench behind the excavator.
- Back-cast material forms the subgrade.
- Materials must be medium to coarse texture and well drained (shot-rock).
- Culverts and ditch are completed after the back-cast material settles.

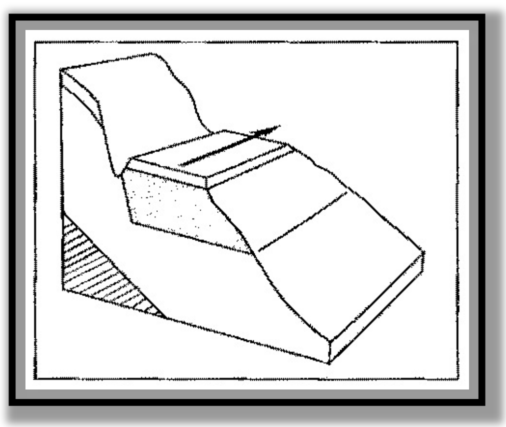
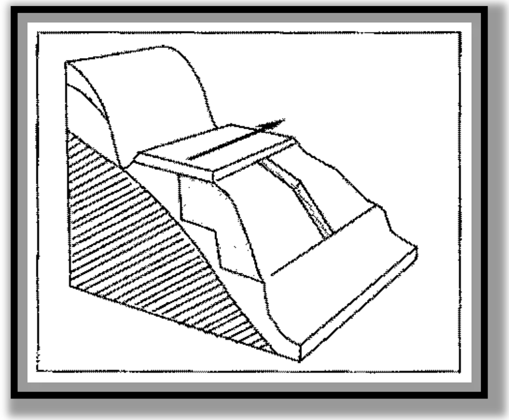


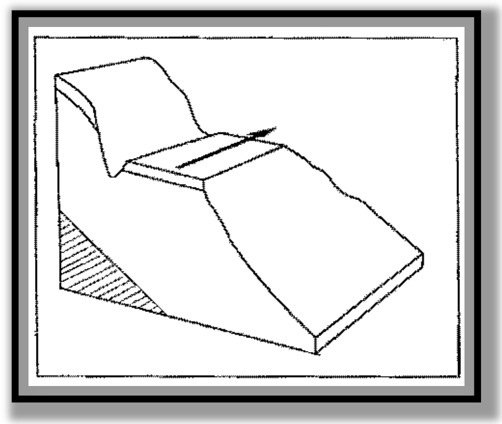
Table 4 Road Benching Techniques (continued).

Multi-benching



- Seldom used but an effective technique to provide a stable footing for fill material.
- Construct a small bench directly below grade; sidecast or end-haul material.
- Second and higher benches are constructed with sidecast material supported by lower benches.
- Multi-benching results in a fill-slope keyed into the hillslope on three or more benches.
- Sidecast and the need to end-haul material is reduced.
- Drainage must be carried over the fill.

Full-bench and end-haul



- The most common technique used to construct through unstable terrain
- Full bench construction must only be used in stable rock and not be in soft soils.
- Bench is cut equal to the road width.
- No fill construction.
- Excavated material is end-hauled (trucked away) to a stable site or used as ballast rock for road surfacing.