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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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November 18, 2016

Mr. Dan Tadic, PE
City and Borough of Sitka
100 Lincoln Street
Sitka, AK 99835

RE: GARY PAXTON INDUSTRIAL PARK DEBRIS FLOW ANALYSIS, SITKA, ALASKA

Dear Mr. Tadic:

On August 18, 2015, an intense rainstorm hit the Sitka, Alaska, area dumping 2.5 inches or more in a six-hour period. The U.S. Forest Service reported that this heavy precipitation triggered more than 50 landslides in the Sitka area. One of those landslides caused a debris flow that crossed Sawmill Creek Road (also known as the Sitka Highway) and stopped against the Administration Building at the Gary Paxton Industrial Park (GPIP) (Photograph 1). The debris flow caused architectural damage to the building, which is owned by the City and Borough of Sitka (CBS). The Vicinity Map, Figure 1, shows the location of the debris flow and the GPIP Administration Building.

The CBS requested that Shannon & Wilson, Inc. (Shannon & Wilson) evaluate potential future landslide and debris flow hazards that could affect the Administration Building, the potential for similar debris flows on the neighboring slopes, and potential remedial measures, if appropriate. Additionally, the CBS has incurred persistent issues with sediment accumulation from an unnamed creek that flows down the southeast flanks of Mount (Mt.) Verstovia, and crosses the Blue Lake Road and then the Access Road to the Sawmill Creek hydroelectric facility. For discussion purposes, we use the name West Fork Sawmill Creek in this letter. Figure 1 shows the locations of West Fork Sawmill Creek, the Blue Lake Road, and the Access Road. CBS requested that Shannon & Wilson evaluate the runout and sediment transport characteristics of debris flows in West Fork Sawmill Creek and potential remedial measures.

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Shannon & Wilson's scope of services included:

- Preparing Light Detection and Ranging (LiDAR) maps for field and office use.
- Performing a field reconnaissance on May 31 through June 2, 2016.
- Analyzing potential debris flow runout from the slopes above the Administration Building, and from West Fork Sawmill Creek.
- Developing concept-level recommendations for remedial measures.
- Preparing this letter.
- Presenting results of our findings to the CBS in a meeting.

Shannon & Wilson's scope of services was authorized by the CBS on April 26, 2016, in a Notice to Proceed from Municipal Engineer, Dan Tadic, PE.

AUGUST 18, 2015, DEBRIS FLOW

We understand the debris flow occurred in an area where previous landslides had not been reported. The initial landslide and consequent debris flow scoured a gully through forest slopes west of the Administration Building. From photographs and discussions with CBS staff, we understand the following:

- The triggering landslide and debris flow occurred in the morning on August 18, 2015. The debris flow scoured a channel down to bedrock in the slopes above Sawmill Creek Road. Deposition occurred mainly between the toe of the slope and the Administration Building. Photograph 2 shows the channel scoured above Sawmill Creek Road.
- The debris consisted of soil, riprap, and quarry spalls that had been placed on a cut-slope above Sawmill Creek Road, and trees, root wads, and bushes. Photograph 1 shows the debris against the Administration Building.
- The debris crossed Sawmill Creek Road and hit the Administration Building. Debris piled against the Administration Building to a depth of about 5 feet. Some debris flowed about 10 feet past the southwest corner of the building.
- Stormwater runoff flowed down the Blue Lake Road, onto Sawmill Creek Road, and past the south side of the Administration Building. The stormwater caused erosion along Blue Lake Road and deposited sediment on Sawmill Creek Road. Photograph 1 shows the water flowing down the Blue Lake Road in the background and past the Administration Building in the foreground.

- The debris caused architectural damage to the Administration Building, including several broken windows and broken siding. Much of the building above the debris was spattered with mud. A mailbox in front of the building was ripped from its foundations. Photograph 3 shows damage to the Administration Building.
- CBS removed about 2,050 cubic yards of debris from Sawmill Creek Road and the parking and landscape areas in front of the Administration Building.

Photograph 4 shows an overview of the slope and the debris flow channel location. Photographs 5 and 6 show views from the debris flow channel.

SITE DESCRIPTION

As shown in Figures 1 and 2, Shannon & Wilson studies addressed two slopes: (1) the slope west of the Administration Building, which is directly above Sawmill Creek Road and Blue Lake Road, and (2) West Fork Sawmill Creek. These are discussed separately below and are shown in Figures 2 and 3, respectively.

Sawmill Creek Road Slope

The slope west of the Administration Building, referred to as the Sawmill Creek Road Slope (Figure 2) hereafter, is about a 1/2-mile-long ridge that is roughly parallel to Sawmill Creek Road. Photograph 4 shows an overview of the slope, looking west from near the CBS hydroelectric facility. The slope is the east flank of a hill above Sawmill Cove and Heart Lake. Heart Lake is in a bench northeast of the hill, and south of Mt. Verstovia and West Fork Sawmill Creek. A ridge southeast and east of the Heart Lake extends from the outlet creek south to nearly above the Administration Building. There, it intersects the higher hill that rises above Heart Lake. This ridge forms the top of the Sawmill Creek Road Slope. At the toe of the Sawmill Creek Road Slope, Sawmill Creek Road is at about Elevation 30 feet. Northeast of the Administration Building, the top of the ridge is about Elevation 400 feet, and decreases to about Elevation 340 feet at the north end near the outlet of Heart Lake and to about Elevation 360 at its south end where it merges with the hill above Heart Lake.

The Sawmill Creek Road Slope has a rocky escarpment with near-vertical sections below the ridge crest at about Elevations 260 to 280 feet, as shown in the LiDAR hillshade image in the LiDAR Site Plan, Figure 2, and the Topographic Site Plan, Figure 4. The channels or chutes on the slope typically originate at or below this bedrock escarpment. Below the rocky escarpment, the slopes are mostly between 25 and 70 percent, with short segments steeper than 100 percent.

To the north of the Administration Building, the one-lane gravel, Blue Lake Road, leads uphill to the north, roughly paralleling Sawmill Creek Road. The slope is heavily vegetated with conifers, some deciduous trees, and thick undergrowth. Seepage is present in nearly all convergent slope areas.

Six small ephemeral creeks are located on Sawmill Creek Road Slope. All are unnamed; therefore, we used alphabetical designations for purposes of this letter report, as shown in Figure 4. As discussed in more detail below, many of these creeks flow in broad bowls, but the channel that failed in 2015 (Channel A) is incised into the hillside, as shown in Figure 2. Likewise, the northernmost channel on this slope that drains Heart Lake (Channel H) is deeply incised. This channel joins West Fork Sawmill Creek just below the Blue Lake Road.

West Fork Sawmill Creek

The West Fork Sawmill Creek begins in an alpine basin just east of Mt. Verstovia between about Elevations 2,200 and 2,700 feet. Photograph 7 shows the headwater area of the West Fork Sawmill Creek on the southeast flanks of Mt. Verstovia. Mt. Verstovia is part of an east- to northeast-trending ridge that is bounded by Indian River to the west and north, the Eastern Channel to the south, and Blue Lake to the east. The summit of Mt. Verstovia is the high point on the ridge (Elevation 3,300+) northwest of Heart Lake. East of the summit, the ridge turns to the northeast, and Arrow Peak is the next high point (3200+) above Sawmill Creek and east of Blue Lake. From the summit of Arrow Peak, the ridge turns north.

The West Fork Sawmill Creek descends the south side of Mt. Verstovia in a southeast direction to the Blue Lake Road, and then turns and flows generally east to its confluence with Sawmill Creek at about Elevation 20 feet. The creek channel does not descend the fall line down the slopes of Mt. Verstovia, but crosses the slope diagonally, as shown in Figure 3. The U.S. Geological Survey 7.5-minute topographic map shows a creek on the north slopes of Mt. Verstovia that is aligned with the West Fork Sawmill Creek. Therefore, we believe the creek channel is controlled by geologic structure. The 1:200,000-scale geologic map by Karl and others (2015) shows the Silver Bay Fault follows these two creeks.

The West Fork Sawmill Creek channel ranges from about 20 to 60 feet wide. It has four major tributaries along its path, including the outlet creek from Heart Lake. All but the Heart Lake outlet creek enter the West Fork Sawmill Creek on its left bank. Several of the tributary channels branch uphill into multiple channels.

The Heart Lake Trail crosses West Fork Sawmill Creek at about Elevation 300 feet, Blue Lake Road at about Elevation 140 feet (Photographs 8 and 9), and the Access Road to the Sawmill Lake hydroelectric facility at about Elevation 50 feet (Photograph 10). Between the Blue Lake Road and Sawmill Creek, the West Fork Sawmill Creek is above former clarifiers that now comprise the Fortress of the Bear and a recycling facility. The hydroelectric facility Access Road contains a buried water line in the eastern shoulder that is the primary water supply for the CBS.

EVALUATION METHODS

Existing Data and Topographic Maps

Prior to fieldwork, we prepared LiDAR hillshade and contour maps from limited LiDAR data (Alaska Division of Geological & Geophysical Surveys, 2015). Because we had limited LiDAR data, we acquired copies of the U.S. Geological Survey 7.5-minute topographic maps for the area. We used these LiDAR and topographic maps together to plan fieldwork, plot field information, and provide parameters for the debris flow analysis.

Subsequent to performing our field reconnaissance, additional LiDAR data became available (U.S. Army Cold Regions Research and Engineering Laboratory, 2016). We processed this data, and used it in our geomorphic interpretation and in our debris flow analyses.

The CBS did not have sterographic pairs of aerial photographs. Therefore, we reviewed aerial photographs available on Google Earth. Those photographs were taken between May 2000 and September 2013. The photographs do not show evidence of historical landslides and debris flows on the Sawmill Creek Road Slope. They do show that snow avalanches and debris flows are common in the West Fork Sawmill Creek above the Blue Lake Road.

Field Reconnaissance

Bill Laprade and Chris Robertson of Shannon & Wilson Field performed a reconnaissance of the Sawmill Creek Road Slope and West Fork Sawmill Creek between May 31 and June 2, 2016. During the field reconnaissance, they took slope clinometer, channel orientations, and laser distance measurements of the slopes and channels, and recorded selected locations with a hand-held Global Positioning System unit. They recorded observations of geologic significance and factors that could affect debris flow runout, such as widths of channels and zones of deposition and scour.

Debris Flow Modelling

We used the online software UBCDFLOW (University of British Columbia Civil Engineering Department [n.d.]) to model debris flow runout in the GPIP Sawmill Creek channels. Using our field measurements and a LiDAR digital elevation model, we divided each channel into discrete reaches (i.e., segments) based on their morphology. UBCDFLOW requires the following geomorphic input parameters for each reach:

- Width
- Length
- Steepness
- Orientation (i.e., compass direction of flow)
- Flow type (confined flow, transitional flow, or unconfined flow)

We assigned flow type for each channel reach using our aerial photographic and LiDAR interpretations, field observations, and professional judgment. Factors included geomorphic indicators of debris flow scour and deposition, as well as along-channel changes in reach steepness.

We executed UBCDFLOW models using two initial debris flow volumes: 100 and 500 cubic meters. We then performed a runout sensitivity analysis by increasing and decreasing channel widths and initial debris flow volumes by 90 percent.

FIELD OBSERVATIONS

Sawmill Creek Road Slope

As described previously, six small ephemeral creeks are located on Sawmill Creek Road Slope, including the August 18, 2015, debris flow site. These creeks are unnamed; therefore, we used the alphabetical designations A though H, as shown in Figure 4 and Photograph 4. The following sections present our field observations for each creek area, including photographs showing pertinent features of the August 18, 2015, debris flow. Because of dense vegetation, features we observed in Channels B through H were not conducive to viewing in photographs.

Channel A – August 18, 2015, Debris Flow

During our field reconnaissance, we measured the debris flow channel width, slope, and other characteristics. We used these data to characterize the conditions that are conducive to landslides along the Sawmill Creek Road Slope, and in our debris flow modelling studies. The following Table 1 summarizes the debris flow channel geometry:

TABLE 1
AUGUST 18, 2015, DEBRIS FLOW CHANNEL DATA

				Cross Section Area, Equivalent Trapezoid								
				Width, ft			Depth, ft					
Slope Segment	Slope Distance	Slope, %	Elevation, ft	Left	Bottom	Right	Left	Bottom	Right	Area, SF	Segment Volume, CY	Initiation zone
Building	0	0	40									
East curb SMC Road	62	0	40									
West curb SMC Road	45	0	40									
Ditch bottom	8	-60%	36									
West side road ditch	8	60%	40									
1	30	60%	55	15	5	15	2	2	2	40	46	
2	72	40%	82	5	5	15	7	10	12	158	127	
3	63	55%	113	12	0	15	13	13	13	176	187	
4a	21	119%	129	3	10	17	8	8	8	160	296	
4b	21	84%	142	3	10	17	8	8	8	160	237	
4c	21	62%	153	3	10	17	8	8	8	160	188	
5	36	45%	168	15	5	10	12	10	8	180	162	
6	42	42%	184	9	21	10	6	7	10	224	189	
7	15	68%	193	5	30	5	3	3	3	105	133	
8	75	34%	217	4	36	5	3	4	5	163	113	I
9	18	63%	226	3	30	4	4	4	5	136	162	I
10	24	173%	247	2	12	3	4	5	5	72	159	I
11	10	270%	257	1	8	1	6	6	6	54	139	I
										Total, CY	**2,139**	
										Initiation Zone, CY	**573**	

Abbreviations: SMC = Sawmill Creek Road
ft = feet
SF = Square Feet
CY = Cubic Yards

The debris flow likely began with a landslide near the base of the rocky escarpment, which is between about Elevation 260 to 300 feet. The triggering landslide occurred mostly in volcanic ash and colluvial soil that formed below the rocky escarpment. Glacial till underlies the volcanic ash and colluvial soil. The landslide was mostly about 5 feet thick, with a maximum headscarp height of about 15 feet. We believe the triggering landslide or landslides occurred between about Elevations 220 and 260 feet. The maximum width of the landslide initiation area at its base is about 45 feet. Photograph 5 shows the triggering landslide area, which is partially obscured by downed trees in the foreground. The accompanying profile shows the slopes along the bottom of the debris flow channel. Above the landslide area shown on the profile, the slope continues up to the rocky escarpment for about 10 to 30 feet. As shown in Table 1 above, we estimate the triggering landslide volume was about 500 to 600 cubic yards.

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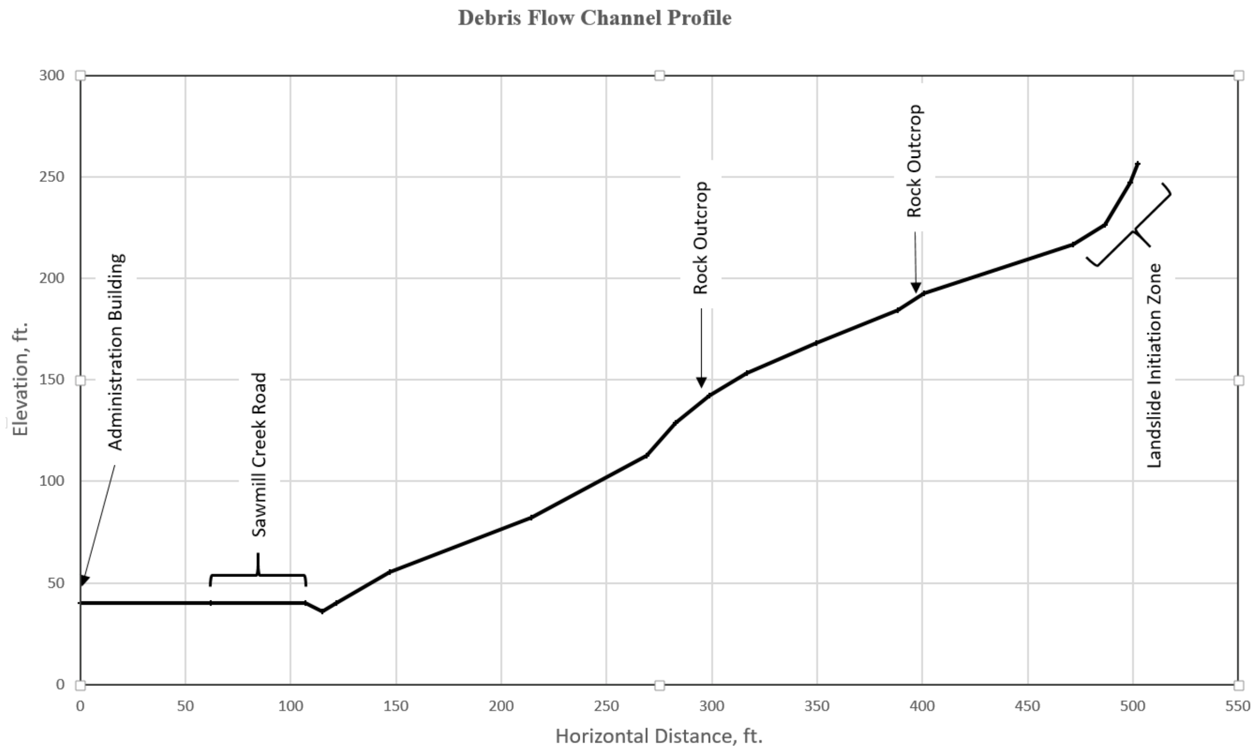


Below the triggering landslide area, the debris remolded into a soil slurry with boulders, trees, roots, and other vegetation debris. Typically, debris flows scour a channel and accumulate additional debris. Depending on the channel length and the type of soil and rock present, the total debris flow volume can be orders of magnitude larger than the triggering landslide or landslide.

Most of the channel scoured downslope from the triggering landslides contained colluvium and glacial till. In two areas, the debris flow scoured down to bedrock, as shown in the profile above. The higher bedrock area shown in the profile above is visible in the foreground of Photograph 5. The scoured channel shown in Photograph 6 is underlain by glacial till. The glacial till and bedrock are resistant to erosion, and the debris flow had a relatively short runout before reaching flat ground. Therefore, the total debris flow volume was about 2,000 cubic yards, which was on the order of four times the triggering landslide volume.

The landslide headscarp area has slopes inclined at about 1 Horizontal to 1 Vertical (1H:1V), with some sections overhanging because of tree roots. We observed some ground cracking above the headscarp. Most of the ground cracking was within about 5 feet of the headscarp. The slopes that are apparently underlain by volcanic and colluvial soil extend about 10 to 30 feet above the headscarp. Further upslope, we observed talus and rock outcrop. In our opinion, the remaining volcanic and colluvial soil between the headscarp and rocky escarpment could fail in future landslides. We discuss likely landslide potential further in the Conclusions section of this report.

Channel B

Channel B is about 150 to 300 feet south of the August 18, 2015, debris flow. A bedrock ridge separates Channel B and the August 18, 2015, debris flow channel. The Channel B slope is heavily wooded with conifers except for deciduous trees next to Sawmill Creek Road and in areas where recent slope movement and/or erosion has occurred. The slope inclination ranges from about 40 to 75 percent.

We observed two small landslide and/or erosion areas. Photograph 11 shows a small landside near Elevation 80 feet. The landslide is 3 to 4 feet deep, up to 10 feet wide, and about 30 feet long. It is bounded by bedrock above and to the north. A small debris fan was visible below the landslide. It did not extend to the more gentle slopes next to Sawmill Creek Road.

The second landslide/erosion area is near Elevation 120 feet. The scar has a 70 percent slope, is about 70 feet long, 2 to 6 feet deep, and ranges from 10 to 30 feet wide. Near the top, the scar narrows considerably. It is bounded by bedrock to the north and to a lesser extent to the south. We did not observe a visible debris fan below the scar. Slow seepage was visible at the "headscarp". This feature may be caused by slow erosion from the groundwater seep.

We did not observe conditions that are likely conducive to a larger debris flow. Bedrock generally was closer to the surface than in the adjacent August 18, 2015, debris flow channel. The soil present consisted largely of rocky talus and colluvium. We did not observe volcanic ash deposits. In our opinion, the likelihood of landslides that could affect the Sawmill Creek Road is low.

Channel C

Channel C is located about 100 feet north of the August 18, 2015, debris flow channel. A small creek was present during our site visit, which was flowing at about 20 gallons per minute. The creek forms a 25-foot-high waterfall where it flows over the rocky escarpment. A small bedrock plunge pool is present at about Elevation 260 feet. Below the plunge pool, a small basin is densely vegetated with devils club and salmonberry, with some hemlock and cedar trees growing in mostly saturated ground. This wet slope extends down to about Elevation 210 feet. The basin is about 70 feet wide near the plunge pool and narrows to about 20 feet wide at the bottom. Below the basin the slope steepens, and the creek is mostly in bedrock and glacial till.

This small basin could have sufficient sediment to form a triggering landslide. In our opinion, the likelihood of future landslides is moderate.

Channel D

A small basin is present above the riprap apron that covers a cut-slope that is north of the intersection of the Blue Lake Road and Sawmill Creek Road. The basin is about 100 feet long measured parallel to the slope, and a bit less measured along the slope fall line. A low area is separated from the riprap slope by a "berm" that is up to 10 feet high; that is, the area up slope from the "berm" is lower. The ground is wet, with a minor drainage flowing south from the low area and then east to the road. In our opinion, this low area could represent a graben, or pull-apart feature from an old deep-seated landslide.

We did not observe other evidence of slope movement, such as leaning or bent trees. However, trees were removed from the cut-slope that is now covered with riprap. An alternative explanation could be related to the geology (e.g., a resistant geologic unit could make up the "berm.")

We did not observe conditions that are likely conducive to debris flows similar to the August 18, 2015, event. In our opinion, the likelihood of a deep-seated landslide affecting Sawmill Creek Road is low. If a deep-seated landslide did occur, we do not believe it would trigger a debris flow, and the ground movement likely would be limited to the riprap slope and possibly the Blue Lake Road.

Channel E

Channel E is a broad swale that has geomorphic features suggesting that previous debris flows have occurred in the area. We observed a swale that could have been formed by old landslide and/or debris flow movement. The swale is about 50 feet wide near Elevation 170 feet, with slopes on the order of 60 percent. The swale steepens and ends in the cliff band near Elevation 220 feet. Below Elevation 170 feet, the slopes gradually flatten to about 40 to

45 percent, except near the Blue Lake Road where they steepen. At the deepest point near Elevation 170 feet, the swale is 8 to 12 feet deep.

We observed dense vegetation, including numerous straight trees, and old growth stumps that do not show evidence of movement. In our opinion, the area likely generated prehistoric landslides and consequent debris flows. Because of the age of the trees and old growth stumps, we believe those landslides and debris flows were more than 200 years ago. We believe the potential for future debris flows is moderate.

Channel F

Channel F is a wide, colluvium-filled swale. Near Elevation 180 feet, it is about 100 feet wide and 20 feet deep. The swale has side slopes near 80 percent, with a bottom that is flat. It ends in the rock escarpment that is present above about Elevation 220 feet. The upper slopes of the swale are about 70 percent. Those slopes gradually flatten below about Elevation 180 feet to about 40 percent.

The swale is densely vegetated with devils club, salmonberry, and a mixed conifer and deciduous forest. We observed extensive wet areas on the ground, including skunk cabbage and seeps stained with iron-reducing bacteria deposits. We observed some old stumps in the basin, which indicate that previous landslides and debris flows may have occurred more than 200 years ago. We believe the potential for future debris flows is moderate.

Channel G

Channel G is a large, wide, and moderately sloping basin near the Blue Lake Road. We observed natural sediment levees consisting of gravel and cobbles that are up to 5 feet high in the basin close to the Blue Lake Road. The basin has 15 percent slopes near Blue Lake Road, and then 30 percent slopes up to about Elevation 140 feet. Near Elevation 160 feet, the basin flattens to about 15 percent. This upper portion of the basin has a mucky bottom with skunk cabbage and devils club. We observed two trees that were leaning until about 20 feet above the ground and then were straight. The trees were about 2 feet in diameter. Above about Elevation 170 feet, the slopes steepen to 30 to 35 percent and then become progressively steeper above. Between about Elevations 180 and 260 feet, the slopes are underlain by talus, are about 80 percent, and end in a 20- to 25-foot-high cliff.

We believe the conditions we observed indicate the basin has low potential for landslides and consequent debris flows. In our opinion, the bent trees likely occurred because of poor rooting in the mucky ground. The gravel and cobble levees likely were deposited by surface water runoff.

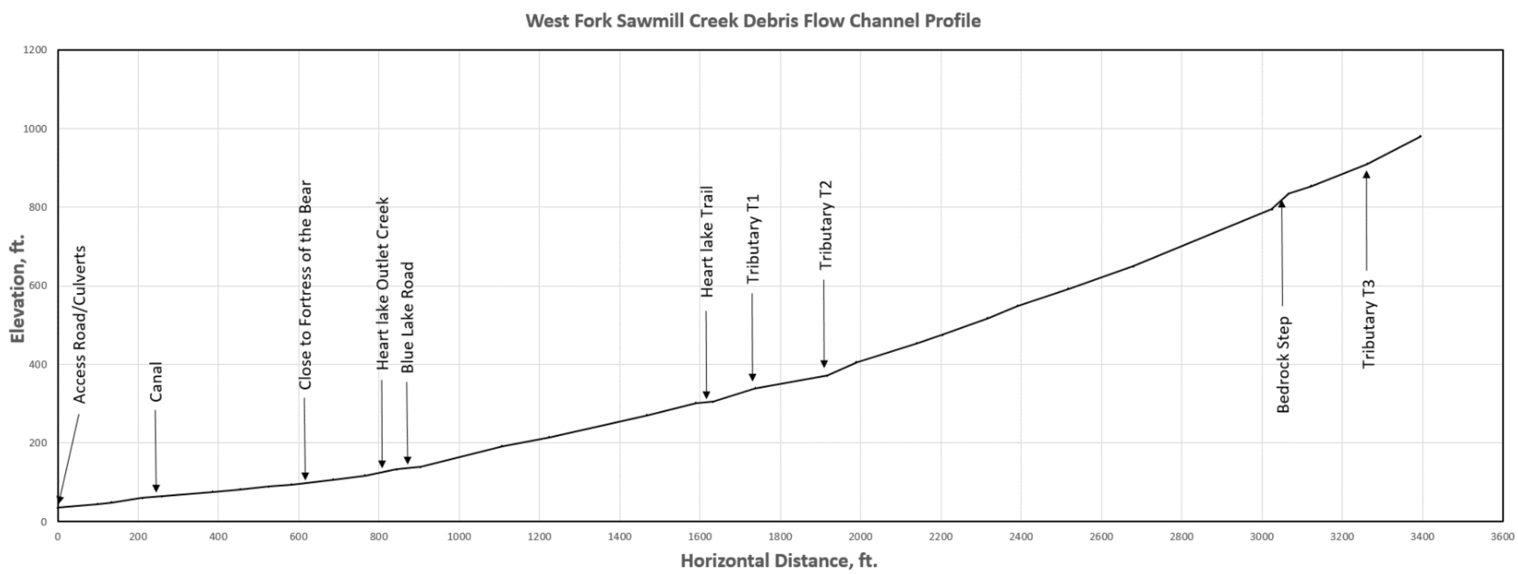
Channel H – Heart Lake Outlet Creek

The Heart Lake outlet creek is largely incised into bedrock and glacial till. We did not observe evidence of past landslides and debris flows, other than those associated with minor bank erosion.

West Fork Sawmill Creek

As described above, the West Fork Sawmill Creek begins in an alpine basin on the southeast slopes of Mt. Verstovia, descends southeast to the Blue Lake Road, and then turns and flows generally east to its confluence with Sawmill Creek. It has four major tributaries along its path, including the outlet creek from Heart Lake. In this discussion, we name the tributary creeks above the Blue Lake Road as Tributaries T1, T2, etc. Because the main creek flows diagonally across the Mt. Verstovia slopes following a geologic fault, all but the Heart Lake outlet creek enter the West Fork Sawmill Creek on its left or uphill bank. Several of the tributary channels branch uphill into multiple channels.

During our field reconnaissance, we measured the debris flow channel width, slope and other characteristics of the main channel of the West Fork Sawmill Creek. To maximize the use of our time, our reconnaissance included making measurements in the main channel up to about Elevation 1,000 feet, and portions of Tributaries T1 through T3. We visually estimated characteristics of the main channel above Elevation 1,000, and used the LiDAR data to calculate channel slope. For our debris flow analyses we assumed the tributary channel flow characteristics would be similar to those in the main channel. Therefore, we made fewer measurements in the tributary channels. The following profile shows the slopes along the bottom of the main channel.



Debris flows in the West Fork Sawmill Creek likely begin along the main or tributary channel banks. We observed evidence for small landslides as low as the right bank below the Heart Lake Trail crossing. Landslides could initiate in numerous locations above that in the main channel or in a tributary. Further, we anticipate that late season wet snow avalanches that impact bare ground could mobilize soil and water and trigger a debris flow. The August 18, 2015, storm likely triggered a debris flow by bank erosion.

The following paragraphs summarize our channel observations:

Sawmill Creek to Blue Lake Road

The channel in this section is mostly low gradient, with slopes mostly between 8 and 14 percent. The channel is typically 15 to 30 feet wide, and is underlain by cobbly and bouldery alluvium, or bedrock. While the creek on average flows east below the Blue Lake Road, it has substantial bends, as shown in Figures 3 and 4.

The West Fork Sawmill Creek discharges into the main Sawmill Creek on its right bank, just downstream from the bridge that provides access to the hydroelectric facility and carries the water supply pipeline. It flows under the Access Road in two culverts. At the time of our site visit, the right culvert was plugged with sediment, as shown in Photograph 10. Photograph 12 shows the West Fork Sawmill Creek looking upstream from the Access Road. The photograph shows a recently excavated overflow channel to the right, which flows about 80 feet north along the road and then turns east to discharge to Sawmill Creek. At the time of our site visit, the little water flowing in the West Fork Sawmill Creek discharged through the unplugged culvert. Photograph 12 also shows riprap bank protection near the culverts and some recently placed backfill to restore erosion damage.

About 250 feet upstream from the Access Road, a drainage canal intersects the right bank for the West Fork Sawmill Creek. At the time of our site visit, the creek channel at the confluence was dry and the canal was flowing less than 1 cubic feet per second. Bedrock was exposed in the channel bottom upstream from the canal (i.e., the slow stream flow was not in pervious alluvium below the channel). We believe that during low flow, water seeps out of the channel further upstream where it is underlain by alluvium. The canal likely was constructed to control groundwater seeping onto slopes above the Fortress of the Bear and the recycle center. Bedrock is present in the channel from about 200 to 500 feet upstream from the Access Road.

A small tributary stream flows into the West Fork Sawmill Creek on its right bank about 500 feet upstream from the Access Road. At the time of our site visit, the tributary stream was flowing about 10 gallons per minute and had considerable coloration apparently from iron-reducing bacteria. We did not observe evidence closely upstream from the confluence that debris flows had occurred in this portion of the tributary stream, or that it transported substantial sediment.

About 600 feet upstream from the Access Road, a bend in the creek brings it close to the Fortress of the Bear. The active creek channel is about 20 feet away from a 1.5 H:1V Vertical slope that descends about 40 to 50 feet down to the flat ground surrounding the bear enclosures. The intervening 20 feet is about 3 to 5 feet above the channel bottom. We observed minor stream sediment on the intervening berm, but no evidence that water had overflowed down to the Fortress of the Bear.

The remaining part of the channel up to the Blue Lake Road widens upstream, and is underlain by cobbles, boulders, and woody debris. It appears that the sediment is largely reworked (i.e., deposited by the stream as opposed to more poorly sorted debris flow deposits).

Blue Lake Road to Heart Lake Trail

The channel slopes in this segment range from about 20 to 25 percent. The channel is typically 30 to 50 feet wide, and is underlain by cobbly and bouldery alluvium, debris flow deposits, and bedrock. Above the Blue Lake Road, the channel follows the Silver Bay Fault, which trends southeast. The main channel segments above the Heart Lake Trail also mostly follow this fault zone.

Considerable stream and debris flow deposition occurred just above the Blue Lake Road. Photograph 8 shows poorly sorted, recently deposited sediment that contains extensive woody debris, which is typical of debris flow deposits.

The creek has undercut a portion of right bank, leaving a nearly 1H:1V slope. The slope is mostly underlain by colluvium; however, bedrock is exposed in places. A shallow colluvial landslide along the right stream bank is about 80 feet long, 20 feet high, and 1 to 3 feet deep. We anticipate the stream will continue to erode and transport sediment in this area. A debris flow could accumulate substantial volume in this area.

Most of this channel section appears to be a transition zone where debris flow material is conveyed downstream without additional accumulation and/or some deposition occurs. Most debris flow deposition apparently occurs within about 300 feet above the Blue Lake Road (horizontal distance).

Heart Lake Trail to Tributary T2

This channel segment is similar to the Blue Lake Road to Heart Lake Trail segment in channel slope and width. Levees formed from previous debris flows are present along the active channel, which shows that some debris flow deposition occurs. On average, it appears debris flows mostly bypass this segment (i.e., deposition and erosion are about equal).

Tributary T1 intersects the main channel about 150 feet upstream from the Heart Lake Trail, as shown in the above profile and in Figure 3. The tributary channel slopes about 40 percent, is about 20 feet wide, and is underlain by bedrock. The channel is choked with vegetation and woody debris, which indicates that a debris flow has not occurred for 20 years or more. Some cobbles and boulders were present on organic debris, which suggests substantial stream discharge occurs during flood events.

Tributary T2 forms a dendritic pattern of multiple channels as shown in Figure 3. Individual channel segments typically follow: the fall line, the Silver Bay Fault trend, or a north-northeast trend. We suspect the latter has geologic control. Figure 3 shows many of the incised channels of Tributary T2 extend into the alpine slopes of Mt. Verstovia. The tributary channels are mostly underlain by bedrock. Channel slope inclinations vary considerably. Those we explored ranged in slope between about 20 and 100 percent. The main tributary T2 channel shows evidence of recent debris flow activity, including deposits along its banks near the confluence with the main channel and recently eroded stream bank at a channel bend.

Tributary T2 to Tributary T3

Above Tributary T2, the main channel slope increases to an average of about 35 percent. Locally steeper sections occur where a resistant bedrock outcrops and causes a waterfall. For example, the bedrock step shown on the profile above has an average 95 percent slope. The active channel width is mostly about 15 to 35 feet wide. While the active channel is about 5 to 10 feet deep, much of the channel is in a deeply incised gully with recently vegetated banks. The gully may be more deeply incised than other creeks in the vicinity because of the Silver Bay Fault.

Photograph 13 shows a typical channel segment that is deeply incised, with some levee deposits on the banks. Much of the channel is underlain by bedrock. Photograph 14 shows older debris flow deposits just above the confluence with Tributary T2. Note the unsorted texture and large amount of large woody debris.

The lower portions of Tributary T3 that we explored were similar to Tributary T2, but with fewer dendritic channels. Much of the channel bottom was underlain by bedrock. The T3 channel flowed over a short cliff about 50 feet upstream from its confluence with the main channel.

Above Tributary T3

The channel steepens to 40 to 55 percent within 300 feet upstream from Tributary T3. Using LiDAR data, we calculate that the slopes progressively steepen upslope. Near the top of the ridge, the channel slopes are between 70 and 85 percent. The channel appears to broaden into a talus-filled gully as shown in Photograph 15. The LiDAR shows minor gullies on the right bank of the main channel. However, these gullies are short and not as deeply incised as

Tributaries T1, T2, and T3. We believe these could cause small landslides that would trigger a debris flow if the talus deposits in the main channel were saturated.

CONCLUSIONS

The conclusions and recommendations presented in this section are based on our field reconnaissance observations, debris flow modelling, and our experience with landslide and debris flow hazard evaluation and mitigation design. The following Table 2 summarizes our conclusions for channels along the Sawmill Creek Road Slope:

TABLE 2
CHANNEL DEBRIS FLOW POTENTIAL

Channel	Likelihood	Consequences
A	High	Additional landslides could occur near the existing headscarp and trigger debris flows. We recommend assuming a debris flow would be similar to the August 18, 2015, event.
B	Low	Small landslides could occur, but debris likely would not reach Sawmill Creek Road.
C	Moderate	A landslide occurring below the rocky escarpment could trigger a debris flow of similar size to the August 18, 2015, event. Because of the channel position, a debris flow could impact the Administration Building.
D	Low	If a deep-seated landslide occurred, it likely would affect the Blue Lake Road. We do not believe it would affect the Sawmill Creek Road.
E	Moderate	A debris flow likely would deposit most debris on the Blue Lake Road. Some debris could cross the road and deposit on the slopes below and on the Sawmill Creek Road. We do not believe a debris flow would cross the Sawmill Creek Road and impact buildings.
F	Moderate	A debris flow likely would deposit most debris on the Blue Lake Road. Some debris could cross the road and deposit on the slopes below and in the flat area south of the Fortress of the Bear enclosure. We do not believe a debris flow would reach the Sawmill Creek Road or the existing Fortress of the Bear buildings. Stream reworked sediment could affect the Sawmill Creek Road.
G	Low	A debris flow likely would deposit most debris in the low gradient basins above the Blue Lake Road. Some debris could be reworked by stormwater flow, and affect the Blue Lake Road. Stormwater flow that overtops the Blue Lake Road could transport reworked sediment towards the southwestern Fortress of the Bear enclosure.
H	Low	Small landslides could deliver sediment to the Heart Lake outlet creek. This sediment could plug the culvert under the Blue Lake Road.

We conclude debris flows will be common in the West Fork Sawmill Creek channel and its tributaries that are above the Blue Lake Road. Most debris flows will deposit cobbly and boulder sediment mostly between the Blue Lake Road and the Heart Lake Trail. In that area, most deposition likely will be within a few hundred feet upslope from the Blue Lake Road. The debris flow sediment could block the culverts under the Blue Lake Road. If larger or multiple debris flows occur, some sediment could be deposited on or overtop the Blue Lake Road. Downstream from the Blue Lake Road, we do not expect direct debris flow deposits. However, we expect sediment from the debris flow deposits will be reworked by stormwater flow, and transported downstream. Facilities downstream from the Blue Lake Road that could be affected:

- West Fork Sawmill Creek comes within about 20 feet of the slope down to the Fortress of the Bear. Sediment deposition in the channel near this slope could cause the channel to aggrade, which could lead to channel avulsion resulting in the creek flowing down the slope to the Fortress of the Bear.
- We understand sediment accumulation at the Access Road has affected operations. Potential damage from a large sediment load caused by reworked debris flow material includes: sediment filling the culverts under the road, flood overtopping and consequent erosion of the Access Road, and potential for damage to the buried water supply line in the Access Road.

Figure 4 shows our interpretation of the risk zones associated with the potential Sawmill Creek Road slope debris flow channels described in Table 2 and the paragraphs above for the West Fork Sawmill Creek. Our interpretation of the risk zones is based on runout analyses geologic judgment and experience. We relied heavily in our geomorphic interpretation of the LiDAR hillshade images presented in Figures 2 and 3. They show the corridors of erosion/incision and deposition, and relative ages of the related landforms, factors of particular importance in informing land use decisions.

RECOMMENDATIONS

Based on the foregoing, we recommend considering mitigation alternatives for Channels A and C along the Sawmill Creek Road Slope. For potential debris flows in the West Fork Sawmill Creek, we recommend considering mitigation alternatives at the Blue Lake Road, above the Fortress of the Bear, and at the Access Road.

Channel A Hazard Mitigation

We believe that future debris flows from the Channel A are likely in a storm with similar or greater rainfall intensity. Future debris flows likely will be smaller because less soil is available for triggering landslides, and less soil would be accumulated along the existing channel. Because the channel now has less soil and debris, it will have less resistance to flow. Therefore, we anticipate a smaller debris flow likely would still impact the GPIP Administration Building. We estimate future debris flows in Channel A could have a total volume between 500 and 1,000 cubic yards.

In our opinion, stabilizing the slopes in the debris flow initiation zone would not be practical. Therefore, remedial alternatives are limited to containing or redirecting a debris flow at or near the bottom of the slope. Because of the steepness of the roadway cut-slope and limited area, we do not recommend a berm to redirect a debris flow so it would flow onto and approximately parallel to the Sawmill Creek Road. Alternatives to arrest and contain a debris flow could be achieved by constructing a barrier. Because of the limited space, berms and other rigid barriers likely would not be practical. Therefore, we recommend considering a flexible debris flow barrier.

A flexible debris flow barrier consists of high-tensile steel wire netting and mesh that are supported by a steel cable on top. The top cable can be anchored to sides of a channel or supported on steel posts. The steel posts typically have anchor cables or bars to resist impact forces. Because the system is flexible, large deformation during debris flow impact and energy absorbing elements in the ropes substantially reduce peak loads during impact. Photographs 16 and 17 show a typical debris flow barrier, which was constructed on a slope along the Beartooth Highway near Red Lodge, Montana.

Flexible debris flow barriers have been constructed at numerous sites around the world, and have been successful in containing debris flows. We discussed the possibility of constructing a debris catchment fence with Tim Shevlin of Geobrugg North America, LLC (Geobrugg). Geobrugg is a primary manufacturer of debris catchment fences, has considerable experience worldwide, and is capable of providing catchment fence material.

Flexible debris flow barriers are commonly constructed across debris flow channels so the debris flow is contained in the channel upslope from the fence. Effective catchment requires an understanding of total debris flow volume, flow velocity, and peak discharge. The catchment area must be capable of storing the total debris flow. Once a debris flow occurs, the debris should be removed to provide catchment volume for subsequent debris flows. Therefore, the barrier should be constructed at a location where construction equipment and personnel can access to perform maintenance.

We recommend considering three flexible debris flow barrier alternatives at the locations shown on Figure 4:

- **Location 1:** A barrier at the base of the slope and next to the road would prevent coarse sediment from flowing onto the road and would protect the Administration Building. Because flexible debris flow barriers are made of wire rope, water, mud, and fine sediment can pass through the barrier. Therefore, the road would still receive mud and fine sediment.
- **Location 2:** A barrier could be constructed per Location 1, but with excavation to create additional storage at the bottom of the channel. This would require making a cut-slope that is steeper than the existing roadway cut-slopes. We anticipate excavated slopes could be as steep as 1.25H:1V if underlain by glacial till and 1H:1V if underlain by rock. Where practical, the channel bottom should be excavated so it has a gentle slope near the roadway and fence. The gentle slope would promote deposition, reduce impact loads on the catchment fence and facilitate maintenance.
- **Location 3:** A barrier between Sawmill Creek Road and the Administration Building parking lot. In our opinion, a flexible debris flow barrier at this location would protect the Administration Building from impact by logs and coarse sediment. A ditch or other water diversion measures may be needed to protect the building from mud and fine sediment that could pass through the barrier.

We made preliminary calculations to estimate the size of a flexible debris flow barrier that would be required to capture future debris flows. For a barrier at the bottom of the slope, we calculated the dimensions assuming likely total debris flow volume that would need to be retained and the slope geometry. When calculating barrier dimensions, at the base of the slope, we assumed that a future debris flow would come to rest with an angle of repose of 5H:1V parallel to the slope fall line, and 3H:1V perpendicular to the slope fall line. For a barrier between the road and parking lot, we estimated the debris thickness from photographs provided by CBS of the August 18, 2015, debris flow. Our preliminary conclusions:

- **Location 1:** Because of the steep cut-slope above the roadway, a flexible barrier has limited capacity to retain sediment. We estimate a 100-foot-long barrier would need to be 18 feet high to retain 1,000 cubic yards, and about 12 feet high to retain 500 cubic yards. We estimate a 120-foot-long barrier would be needed.

- **Location 2:** The required barrier height would depend on the amount of storage excavated. For example, steepening the existing slope to 1.25H:1V over a height of 30 feet and 60-foot width would create about 250 cubic yards of storage. With this additional storage, a 15-foot-high barrier could retain about 1,000 cubic yards. We estimate a 120-foot-long barrier would be needed.
- **Location 3:** A barrier about 10 feet high, such as the Geobrugg shallow landslide SL-150 with a spiral rope net should be effective stopping debris between Sawmill Creek Road and the Administration Building parking lot. A minimum 200-foot-long barrier would be needed.

The following Table 3 summarizes advantages and disadvantages for each site.

TABLE 3
MITIGATION MEASURE ADVANTAGES AND DISADVANTAGES

Location	Advantages	Disadvantages
1	▪ Prevents most debris from impacting Sawmill Creek Road. ▪ Barrier away from other infrastructure.	▪ Less effective storage because of steep slopes. ▪ Moderate access for maintenance. ▪ May require special excavation equipment and drilling equipment. ▪ Moderate access for construction. ▪ Higher cost barrier.
2	▪ Same as Location 1. ▪ Lower height barrier than Location 1. ▪ Lower cost barrier than Location 1. ▪ A wider flat storage area behind the barrier would facilitate maintenance.	▪ Moderate storage because of steep slopes. ▪ May require subsurface explorations to design steeper road cut. ▪ Excavation costs. ▪ Higher cost barrier.
3	▪ Lowest cost barrier. ▪ Good access for construction. ▪ Good access for maintenance.	▪ Would limit access to the Administration Building to the ends of the barrier. ▪ The barrier could be considered unsightly. That could be mitigated with landscaping. ▪ The barrier will require about a 10-foot width to accommodate anchorage ropes or bars.

We discussed the probable construction cost of flexible barriers with Tim Shevlin at GeoBrugg. We recommend considering two types of flexible barriers:

- Geobrugg SL-150 is described as a flexible shallow landslide barrier. It is suitable for moderate energy landslides and debris flows. The typical installation has a maximum height of 3.5 meters (11.5 feet). Higher flexible barriers of this type can be custom fabricated.
- Geobrugg UX-180 is intended to resist rapidly moving debris flows or mudflows. The UX flexible barriers are designed specifically for each application. They have a maximum height of 6 meters (20 feet).

Tim Shevlin provided the following information typical material cost information:

- SL-150 120 feet long, 11.5 feet high – $425 per lineal foot
- SL-150 120 feet long, 20 feet high – $750 per lineal foot (very rough estimate)
- UX-180 – 130 feet long, 20 feet high – $1,150 per lineal foot

Based on Geobrugg experience with typical construction costs, we recommend using the following estimates presented in Table 4 below to compare alternatives. We do not recommend using these concept-level opinions of probable construction cost to develop project budgets. Additional design and developing opinions of probable construction cost should be performed first.

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TABLE 4
POTENTIAL CONSTRUCTION COSTS

Barrier Model	Length	Materials Cost Per LF[4]	Materials and Installation[5] Cost Per LF	Total[6]
Location 3, SL-150 – 11.5 feet high	200 feet	$425	$1,488	**$300,000**
Location 3, SL-150 – 11.5 feet high	300 feet	$425	$1,488	**$450,000**
Locations 1 and 2,[1] Custom SL-150 – 20 feet high[2]	120 feet	$750	$2,625	**$315,000**
Locations 1 and 2, Custom UX-180 – 20 feet high[3]	120 feet	$1,150	$4,025	**$485,000**

Notes:
1. Does not include excavation cost at Location 2.
2. Very rough estimate.
3. Cost based on a recent Geobrugg North America, LLC project in Canada.
4. LF = lineal foot
5. Cost for lower 48 states typically three times the material cost. Assume cost for Alaska is three and a half times the material cost.
6. Rounded

Channel C Hazard Mitigation

We believe that Channel C has moderate potential to cause a future debris flow. We anticipate it would be similar in size to the August 18, 2015, debris flow that occurred in Channel A. Therefore, we recommend assuming it would have a total volume on the order of 2,000 cubic yards. In our opinion, it would not be practical to use a flexible debris flow barrier to retain that volume at the base of the slope and next to the road. If CBS elects to construct protection measures for possible debris flows emanating from Channel C, we recommend constructing a barrier at Location 3. In our opinion, the flexible barrier recommended for Channel A could be lengthened to about 300 feet to provide protection for Channels A and C. The discussion above and concept level of probable costs discussed for Channel A apply.

Channels B, D, E, F, G, and H

In our opinion, debris flows from these channels are not likely to impact buildings. Therefore, we do not recommend hazard mitigation measures. We believe the CBS maintenance practices for the Blue Lake Road would be an effective strategy for dealing with debris flows that might rarely affect the road.

West Fork Sawmill Creek

As described above, we recommend considering mitigation alternatives for sediment accumulation and culvert blockage at the Blue Lake Road and at the Access Road, and for possible channel avulsion above the Fortress of the Bear.

Blue Lake Road

In our opinion, most debris flows in the West Fork Sawmill Creek deposit upstream from the Blue Lake Road. Sediment transport below the Blue Lake Road is primarily by fluvial sediment transport. However, substantial debris flow deposits upstream from the Blue Lake Road can block culverts, overtop the roadway causing fluvial erosion and deposition, and provide a ready source for sediment transport downstream. We understand CBS excavated substantial debris flow deposits from the West Fork Sawmill Creek channel at and just above the Blue Lake Road to restore the roadway surface, unplug culverts, and provide sediment storage for future debris flow events.

We recommend considering several alternatives to protect the Blue Lake Road and to facilitate maintenance:

1. Excavate additional storage upstream from the Blue Lake Road. Our modelling indicates debris flow volumes deposited within about 300 feet upstream from Blue Lake Road could be on the order of 1,000 to 3,000 cubic yards.

   Limited potential exists for excavating additional sediment storage upstream from the Blue Lake Road. Photograph 9 shows that the CBS excavations made on August were limited because of bedrock. Additional storage could be created by excavating further upstream and to the banks on either side of the river. We visually estimate that the total storage with additional excavation could be on the order of 1,000 cubic yards.

2. Raise Blue Lake Road to increase sediment storage potential, and to reduce the potential for the creek overtopping and eroding the roadway.

   Additional sediment storage could be created by raising Blue Lake Road at the West Fork Sawmill Creek crossing. Assuming sediment accumulates for about 200 feet upstream and the average channel width is 60 feet, each foot of additional height would provide about 450 cubic yards of sediment storage. Assuming excavations of sediment in the existing channel would be on the order of 1,000 cubic yards, the roadway would need to be raised 4 to 5 feet to provide a total 3,000 cubic yards of sediment storage. Excavated material in the channel could be used to increase the height of the road.

3. Replace the culverts with a vented ford with a removable deck to facilitate cleaning and that provides an armored high-water crossing.

   Photographs 18 through 23 show concrete box vented fords with culverts that have removable steel or concrete decks. The roadway has a dip that is designed to pass the creek flow if the culvert becomes plugged or if the discharge exceeds the culvert capacity. Photographs 18 through 21 show low water crossings where the dip is armored with concrete to prevent erosion. Photographs 22 and 23 show a low water crossing armored with articulated concrete panels and riprap. The culvert can be sized for fish passage and other environmental considerations. We recommend constructing a trash rack at the inlet to reduce potential for large sediment entering the culvert to reduce cleaning.

Creek Bank Above Fortress of the Bear

During our field reconnaissance, we observed that a portion the natural creek bank above a portion of the slope down to the Fortress of the Bear enclosures is low and narrow. We observed some recent sediment on the top of the creek bank, suggesting that the creek flow was close to overtopping during the August 18, 2015, storm. If the stream is aggrading because of rapid sediment accumulation, this potential could be worsening.

Evaluating potential stream avulsion is not part of our scope of services or in our area of expertise. We recommend that a fluvial geomorphologist and/or a hydraulic engineer evaluate the potential for stream avulsion.

Access Road

The culverts under the Access Road appear vulnerable to plugging, and are difficult to clean. The overflow channel CBS constructed should alleviate flooding and associated erosion potential, provided it is maintained. For example, small floods that do not impair the culverts could deposit sediment in the overflow channel and reduce its effectiveness in a subsequent larger flood.

An alternative to reduce future maintenance could include constructing a vented ford as described above. The vented ford should include a removable deck to facilitate cleaning, a trash rack to prevent large sediment from entering the culvert, and a culvert section that promotes sediment transport.

ADDITIONAL SERVICES

This letter report provides concept-level and preliminary design recommendations for debris flow hazard mitigation measures. It is intended to provide information for CBS to select hazard mitigation measures it may implement. Additional design should be performed before mitigation measures are budgeted and constructed. Additional services that may be required include:

Flexible Debris Flow Barrier Design

Flexible debris flow barriers typically are designed by the supplier. The contract documents should specify the maximum debris flow height, volume, and velocity. They should also specify the flexible barrier location, including the starting and ending elevation of each barrier segment. Survey data should be provided that is accurate to +/- 6 inches. The survey data can be based on a local datum. Therefore, we recommend surveying the area where a flexible barrier will be constructed. The survey should extend upslope if excavation will be performed to increase the sediment storage.

Foundation design for posts and anchors can be performed by the owner's team or by the contractor. If the contractor performs the design, the owner typically provides allowable bearing capacity for the post foundations and soil and/or rock bond stress for anchor design.

Blue Lake Road and Access Road

We recommend surveying the Blue Lake Road at the West Fork Sawmill Creek crossing to provide sufficient accurate data to design excavations and or raising the roadway to increase sediment storage. A survey will be needed if a vented ford will be designed and constructed. A hydraulic and civil engineer should be retained to size a vented ford, including the culvert and high-water crossing. Because the work would be constructed in a creek and could affect nearby wetlands, environmental permits likely would be needed.

Creek Bank Above Fortress of the Bear

As described above, we recommend that a fluvial geomorphologist and/or a hydraulic engineer evaluate the potential for stream avulsion. Additional surveying likely will be needed.

CLOSING REMARKS

The analyses, conclusions, and recommendations contained in this letter report are based on site conditions as they presently exist, and further assume that our interpretations from our field reconnaissance are representative. This letter report should not be used for final design. It is intended to provide information to select mitigation alternatives. Additional design should be performed to develop construction documents, and for cost estimates suitable for budgeting purposes. If there is a substantial lapse of time between the submission of this letter report and final design or if conditions have changed because of natural forces or construction operations at or adjacent to the site, we recommend that we review our letter report to determine the applicability of the conclusions and recommendations.

Within the limitations of scope, schedule, and budget, the analyses, conclusions, and recommendations presented in this letter report were prepared in accordance with generally accepted professional geotechnical engineering principles and practice in this area at the time this letter report was prepared. We make no other warranty, either express or implied. These conclusions and recommendations were based on our understanding of the project as described in this letter report and the site conditions, as observed at the time of our reconnaissance.

This letter report was prepared for the exclusive use of CBS to select debris flow hazard mitigation measures. The data and letter report could be provided to contractors for their information, but our letter report, conclusions, and interpretations should not be construed as a warranty of subsurface conditions included in this letter report.

The scope of our services did not include environmental assessments or evaluations regarding the presence or absence of wetlands or hazardous or toxic substances in the soil, surface water, groundwater, or air on or below or around this site, or for the evaluation or disposal of contaminated soils or groundwater, should any be encountered.

Shannon & Wilson has prepared and enclosed an “Important Information About Your Geotechnical/Environmental Report” to assist you and others in understanding the use and limitations of our reports.

SHANNON & WILSON, INC.

We appreciate this opportunity to be of service. If you have any questions, please contact Bill Laprade at (206) 695-6891 or Chris Robertson at (206) 695-6763.

Sincerely,

SHANNON & WILSON, INC.

William T. Laprade, LEG
Senior Vice President

11/18/2016

Christopher A. Robertson, PE
Vice President

CAR:WTL/car

Enc: References
Figure 1 – Vicinity Map
Figure 2 – Sawmill Creek Road Slopes LiDAR Site Plan
Figure 3 – West Fork Sawmill Creek LiDAR Site Plan
Figure 4 – Topographic Site Plan and Debris Flow Risk
Photographs 1 through 23
Important Information About Your Geotechnical/Environmental Report

REFERENCES

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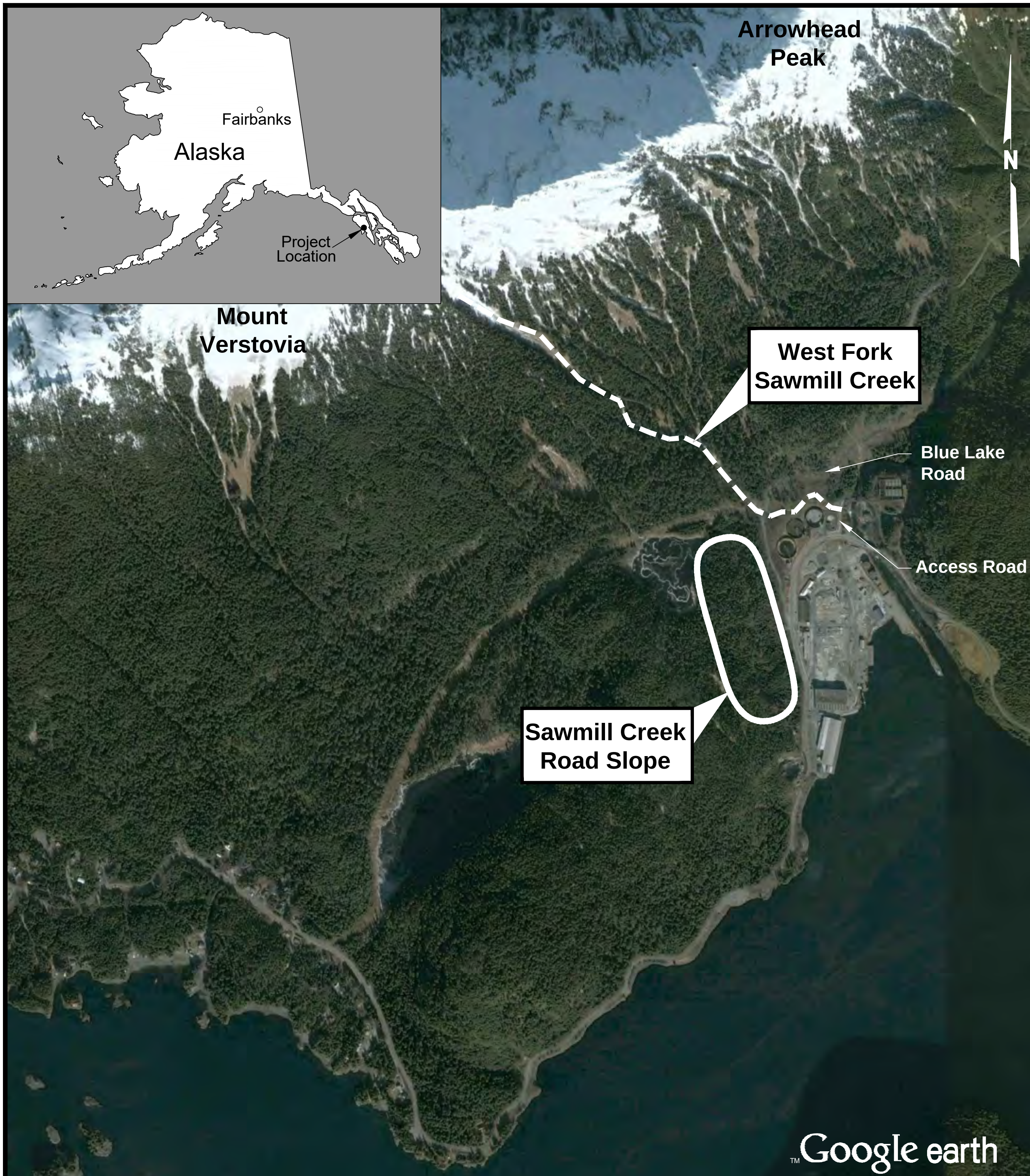
University of British Columbia Civil Engineering Department, [n.d.], UBCDFLOW: Available: http://dflow.civil.ubc.ca/index.php.



NOTE

Map adapted from aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

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Debris Flow Analysis
City and Borough of Sitka, Alaska

VICINITY MAP

November 2016 21-1-22168-002

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FIG. 1

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Gary Paxton Industrial Park
Debris Flow Analysis
City and Borough of Sitka, AK

SAWMILL ROAD CREEK SLOPE LIDAR SITE PLAN

November 2016

21-1-22168-002

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FIG. 2

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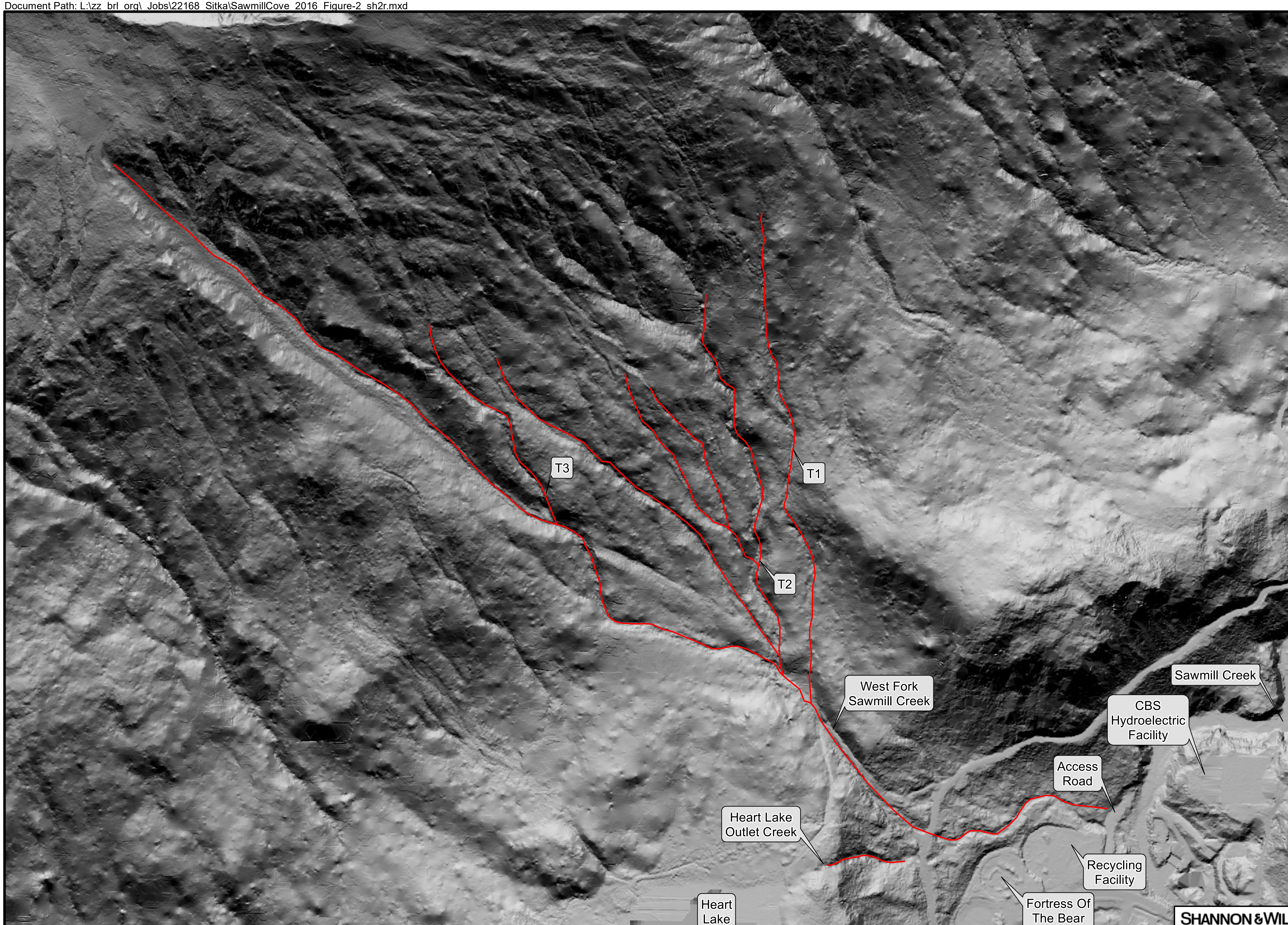

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LIDAR SITE PLAN

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21-1-22168-002

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FIG. 3

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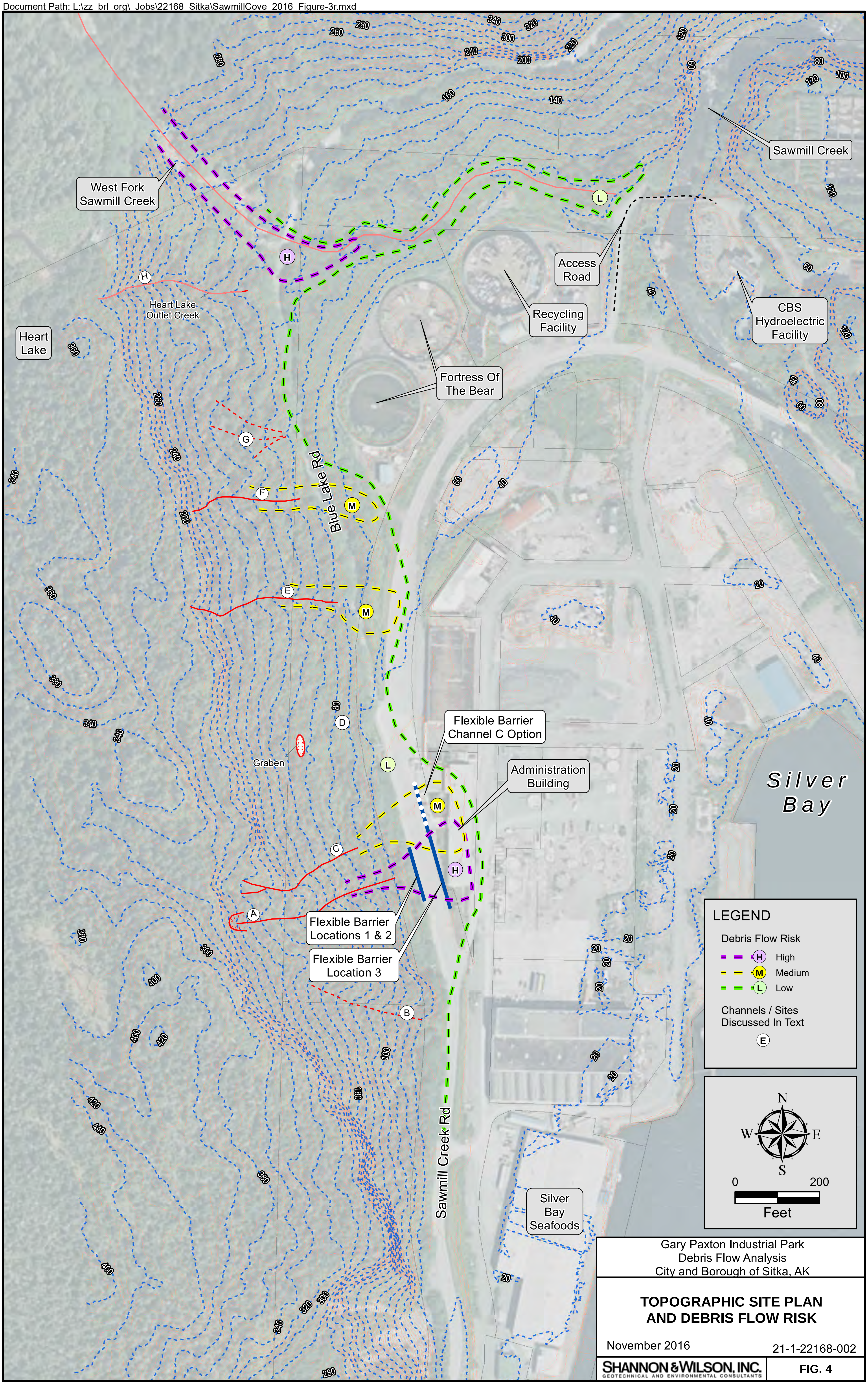

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TOPOGRAPHIC SITE PLAN AND DEBRIS FLOW RISK

November 2016

21-1-22168-002

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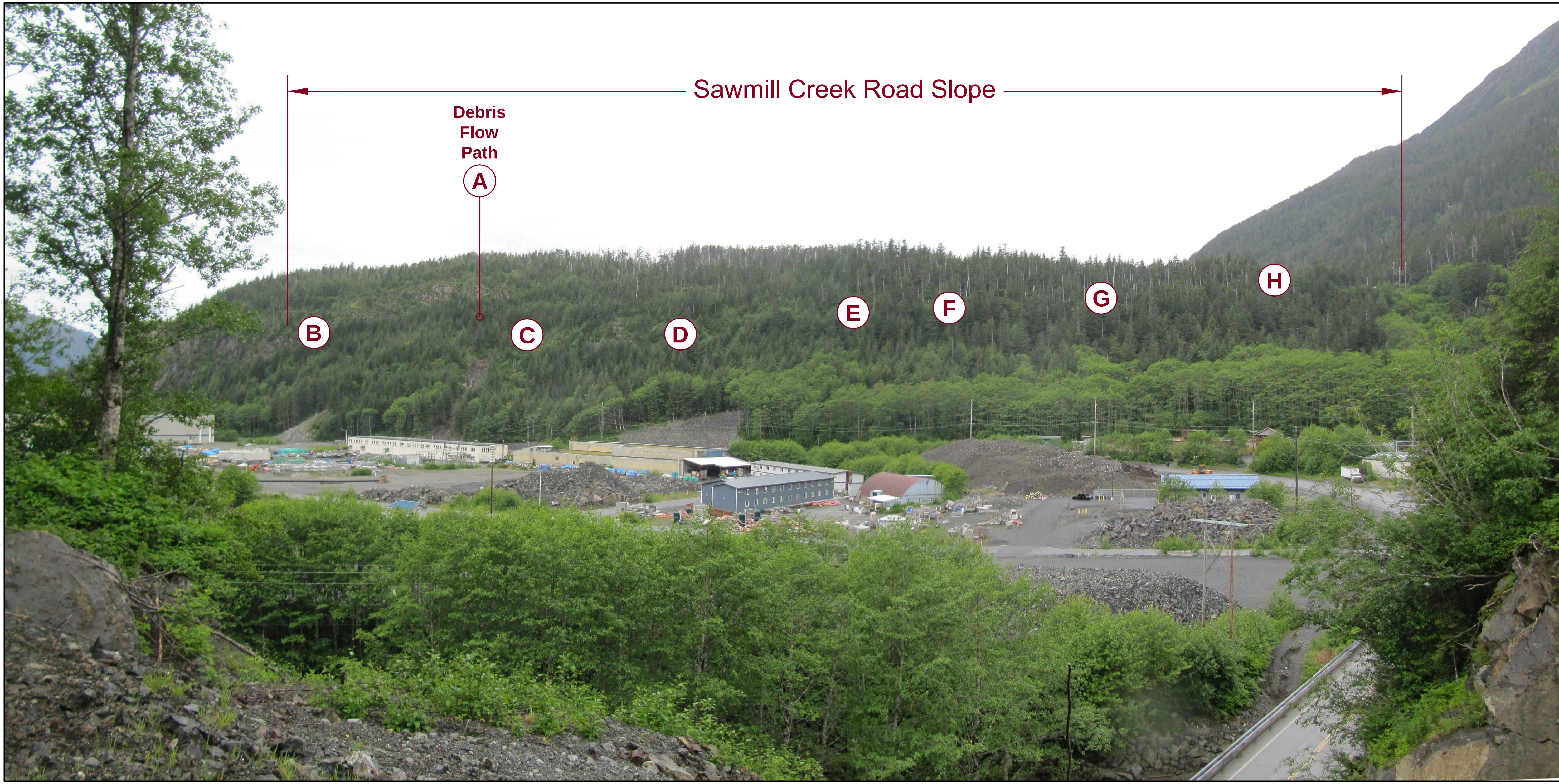
FIG. 4

Photograph 1. Debris against administration building on August 18, 2015. Photograph provided by CBS

Photograph 2. Sawmill Creek Road debris flow on August 21, 2015. Photograph provided by CBS

Photograph 3. Damage to Administration Building from Sawmill Creek Road debris flow. Photograph provided by CBS



Photograph 4. Sawmill Creek Road view looking west.

Photograph 5. Sawmill Creek Road debris flow initiation area.
Photograph taken May 31, 2016

Photograph 6. Sawmill Creek Road debris flow path, looking east.
Photograph taken May 31, 2016

Photograph 7.
Head of West Fork Sawmill Creek debris flow channel.

Photograph 8. West Fork Sawmill Creek channel, upstream from Blue Lake Road on August 19, 2015. Photograph provided by CBS

Photograph 9. West Fork Sawmill Creek channel, upstream of Blue Creek Road crossing on June 2, 2016. Note rock outcrop in creek channel.

Photograph 10. West Fork Sawmill Creek twin culvert beneath hydroelectric facility access road. Note right culvert is filled with debris. Photograph taken May 31, 2016.

Photograph 11. Small landslide at the top of channel B. Note bedrock above and to the right of the landslide scar. Photograph taken June 1, 2016.

Photograph 12. West Fork Sawmill Creek, looking upstream from hydro electric facility access road. Overflow channel is to the right.

Photograph 13.
West Fork Sawmill Creek below bedrock step. Note steep side, recent vegetation and mostly bedrock outcrop in channel bottom.

Photograph 14. West Fork Sawmill Creek just upstream from confluence with Tributary 2. Note large wood in previous unsorted debris flow deposits.

Photograph 15.
Upper, steep segments of West Fork Sawmill Creek.

Photograph 16. Typical flexible debris flow barrier that was installed along the Beartooth Highway, MT, in 2005.

Photograph 17. Typical flexible debris flow barrier profile view. Beartooth Highway, 2005.

Photograph 18. Vented ford with steel grate cover over box culvert. Note concrete armor for flood flow.

Photograph 19. Vented ford: close up of steel grate cover and trash rock.

Photograph 20. Vented ford with removable concrete cover over box culvert.

Photograph 21. Vented ford looking downstream through box culvert.

Photograph 22. Vented ford looking downstream through box culvert. Note articulated concrete mat and riprap erosion protection.

Photograph 23. Close up of vented ford in Photograph 22 showing removable metal grate over box culvert and articulated concrete mat.

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Attachment to and part of Report 21-1-22168-002

Date: November 18, 2016
To: Mr. Dan Tadic, PE
City and Borough of Sitka, Alaska

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports, and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland