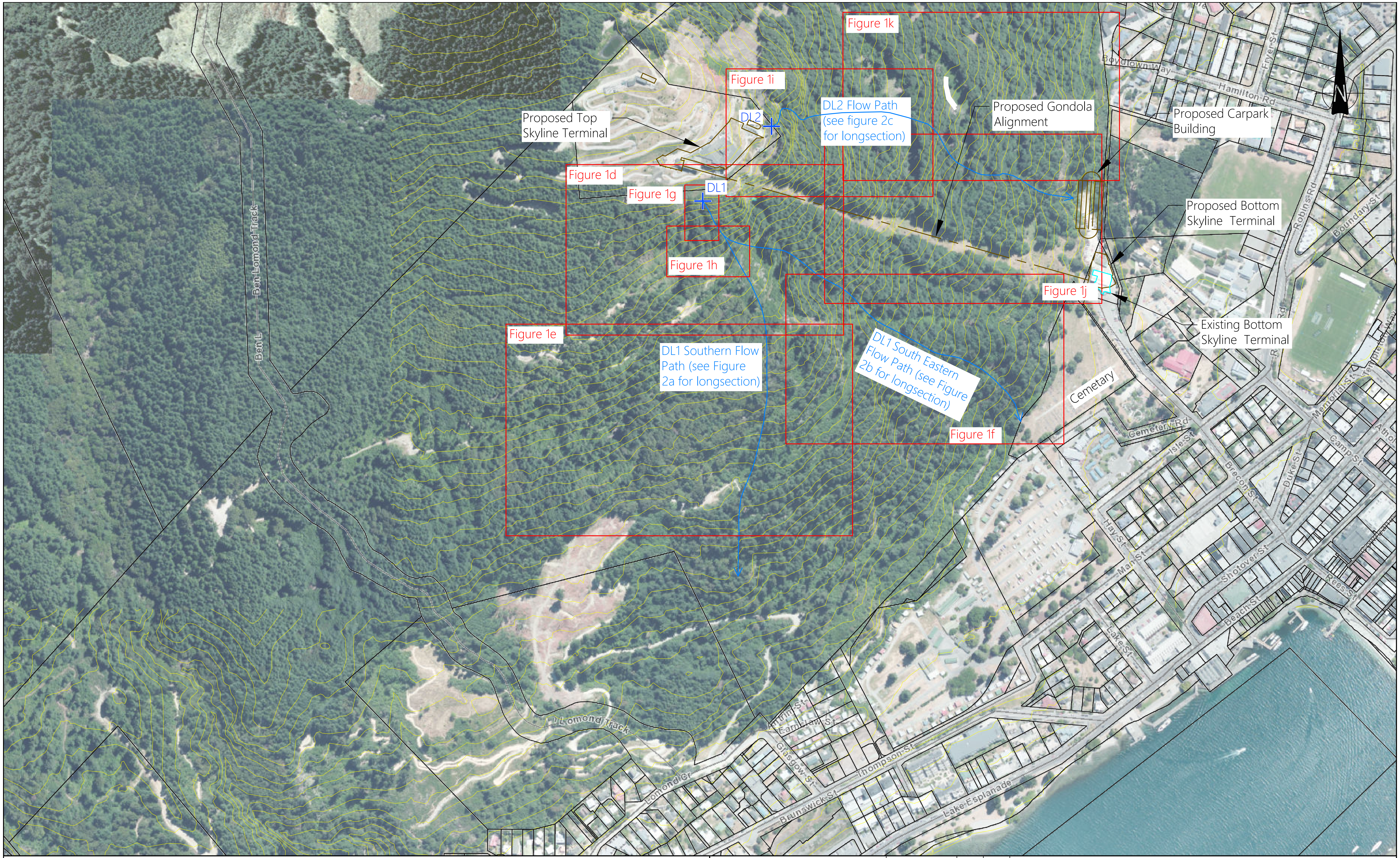

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CADFILE: 160073.02_SW.dwg

SCALES (AT A3 SIZE): AS SHOWN

PROJECT No: 160073.02

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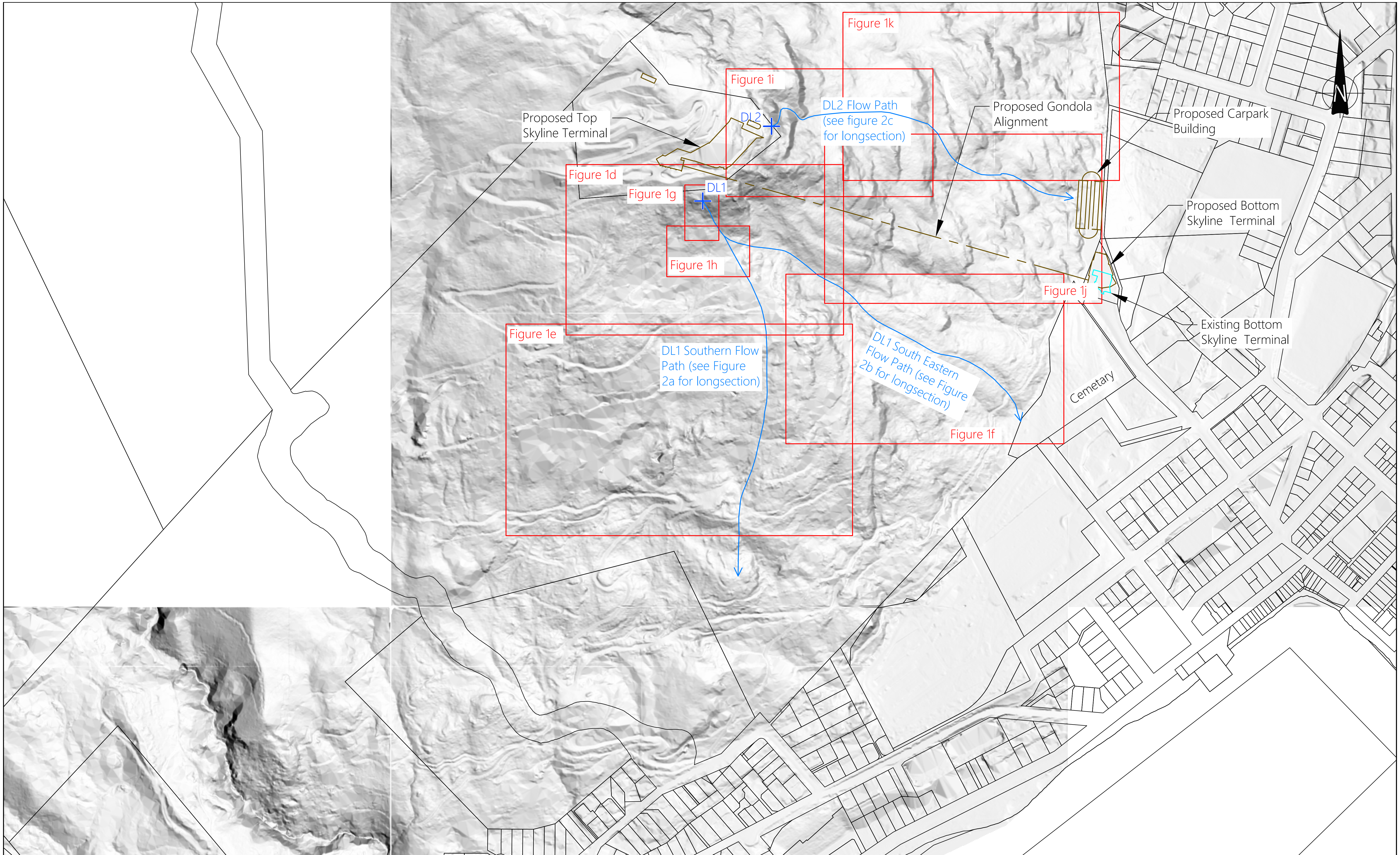
Stormwater Discharge - Detailed Hazard Assessment

Aerial Summary Plan

FIG No: Figure 1a

REV: 1



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CADFILE: 160073.02_SW.dwg

SCALES (AT A3 SIZE): AS SHOWN

PROJECT No: 160073.02

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Stormwater Discharge - Detailed Hazard Assessment

Geomorphology Summary Plan

FIG No: Figure 1b

REV. 1

Legend:

30°	Slope direction and approximate angle/fall line		Water Flow Intermittent		Sharp break 40°+
30°	Concave slope direction and approximate angle/fall line		Hypothetical debris flow path from RAMMS software		Break of Slope - Crest
	Landslide Movement Direction (Inferred)		Glacial Till		Break of Slope - Toe
20b	Photograph location and number		Bouldery Colluvium		Break of slope
13/231	Foliation		Alluvial Fan		Ridgeline
20b	Channel Cross Section		Fill		Scarp
	Boulders	TS	Topsoil		Bluff
3.0mØ	Boulder on surface with diameter in metres	==J==J==	Joint		Leaning Tree
	Organic Debris (trees, branches, etc)	==T==T==	Tension Crack		

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FILE :	160073.02_SW	
SCALE: (AT A4 SIZE) AS SHOWN		
PROJECT No. 160073.02		

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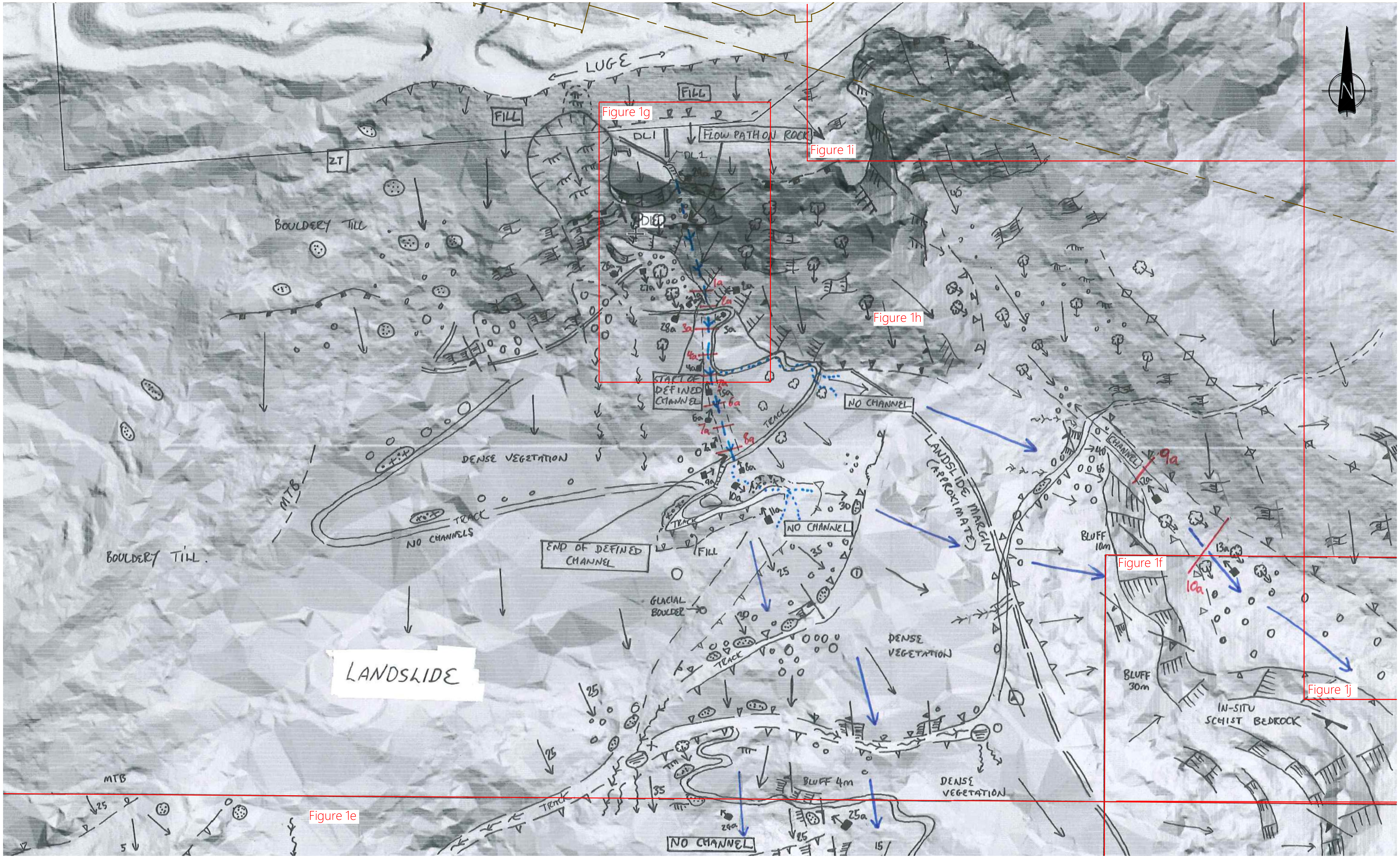
Skyline Upgrade
Stormwater Discharge - Detailed Hazard Assessment
Geomorphology Symbol Legend

FIG No. Figure 1c

Rev 0



SCALE 1:1000

0 10 20 30 40 50 (m)

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CADFILE: 160073.02_SW.dwg		
SCALES (AT A3 SIZE): AS SHOWN		
PROJECT No: 160073.02		

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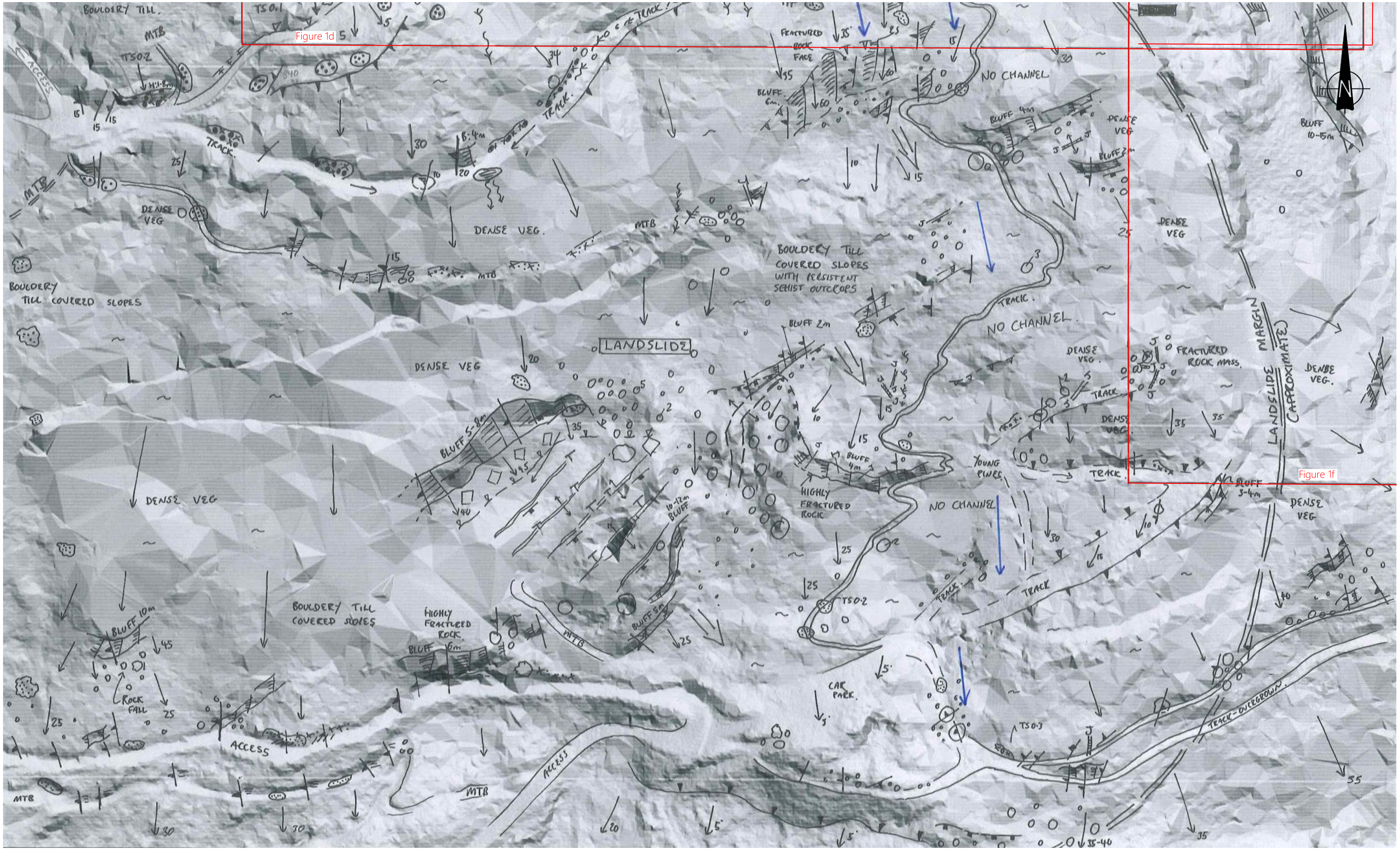
Stormwater Discharge - Detailed Hazard Assessment

Detailed Geomorphology below DL1, northern/upper zone

FIG No: Figure 1d

REV. 1



SCALE 1:1250

0 12.5 25.0 37.5 50.0 62.5 (m)

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SCALES (AT A3 SIZE): AS SHOWN

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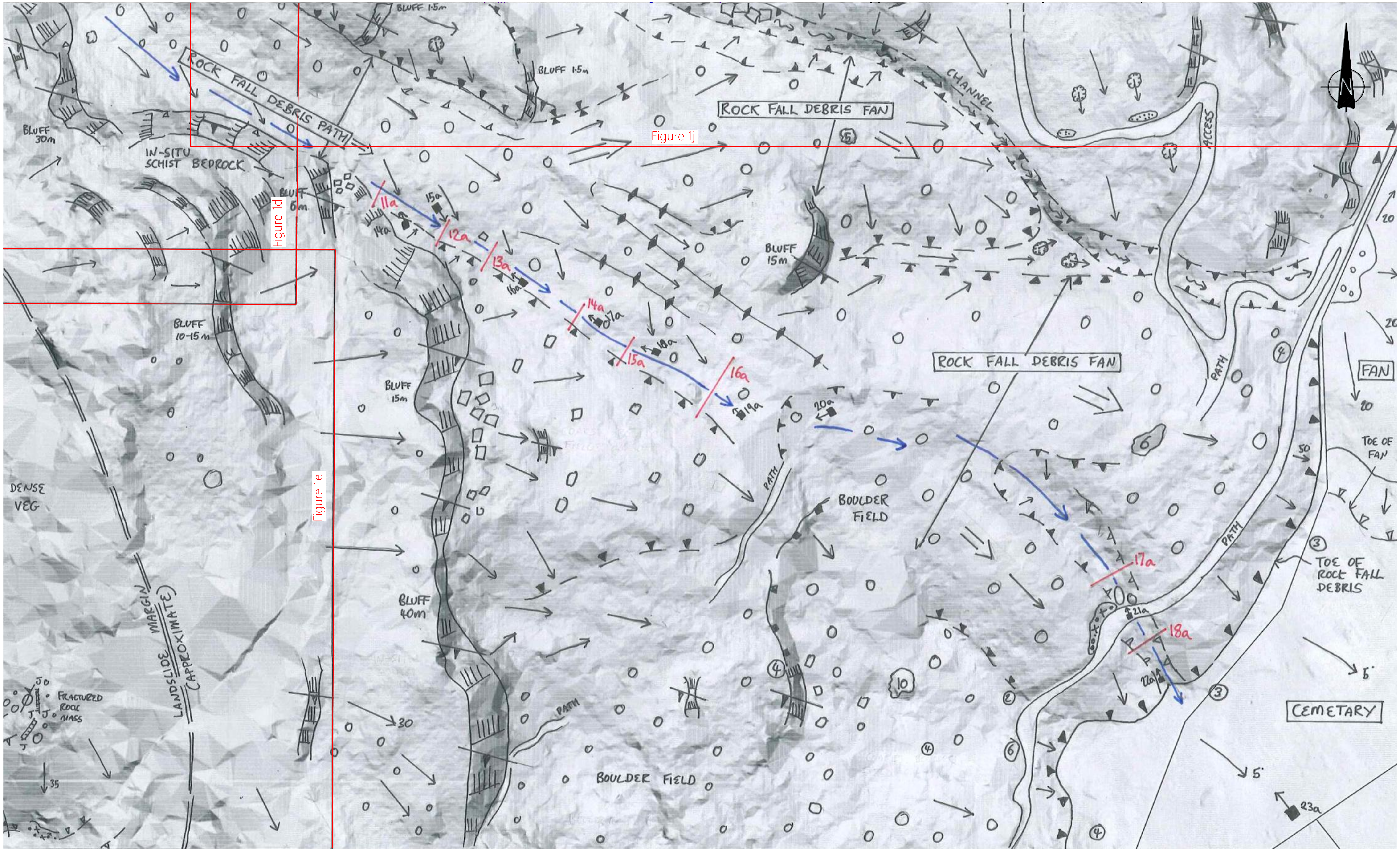
Stormwater Discharge - Detailed Hazard Assessment

Detailed Geomorphology below DL1, south western zone

FIG No: Figure 1e

REV. 1



SCALE 1:1000

0 10 20 30 40 50 (m)

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CADFILE: 160073.02_SW.dwg		
SCALES (AT A3 SIZE): AS SHOWN		
PROJECT No: 160073.02		

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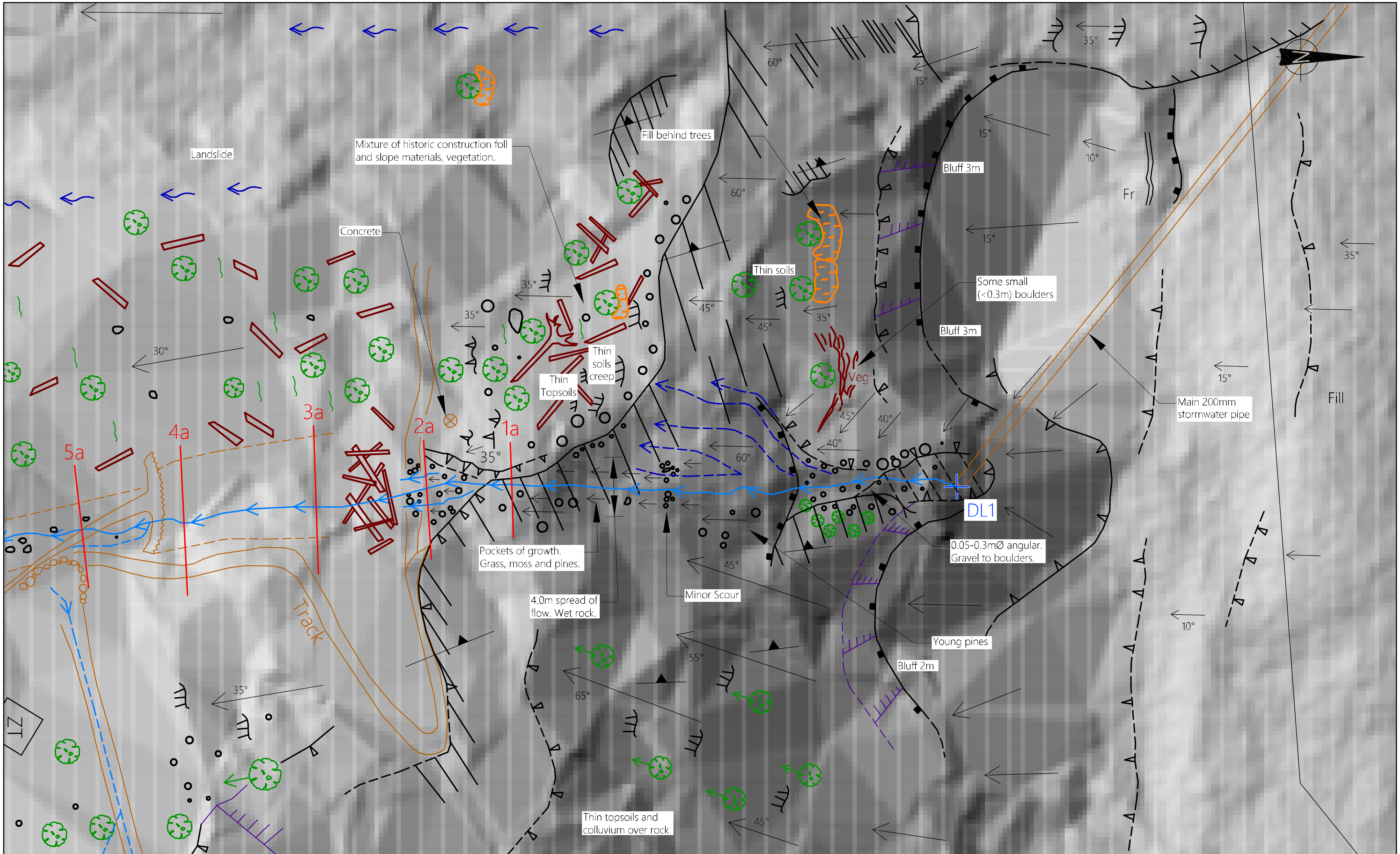
Detailed Geomorphology below DL1, south eastern zone

FIG No: Figure 1f

REV. 1



SCALE 1:200

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SCALES (AT A3 SIZE): AS SHOWN

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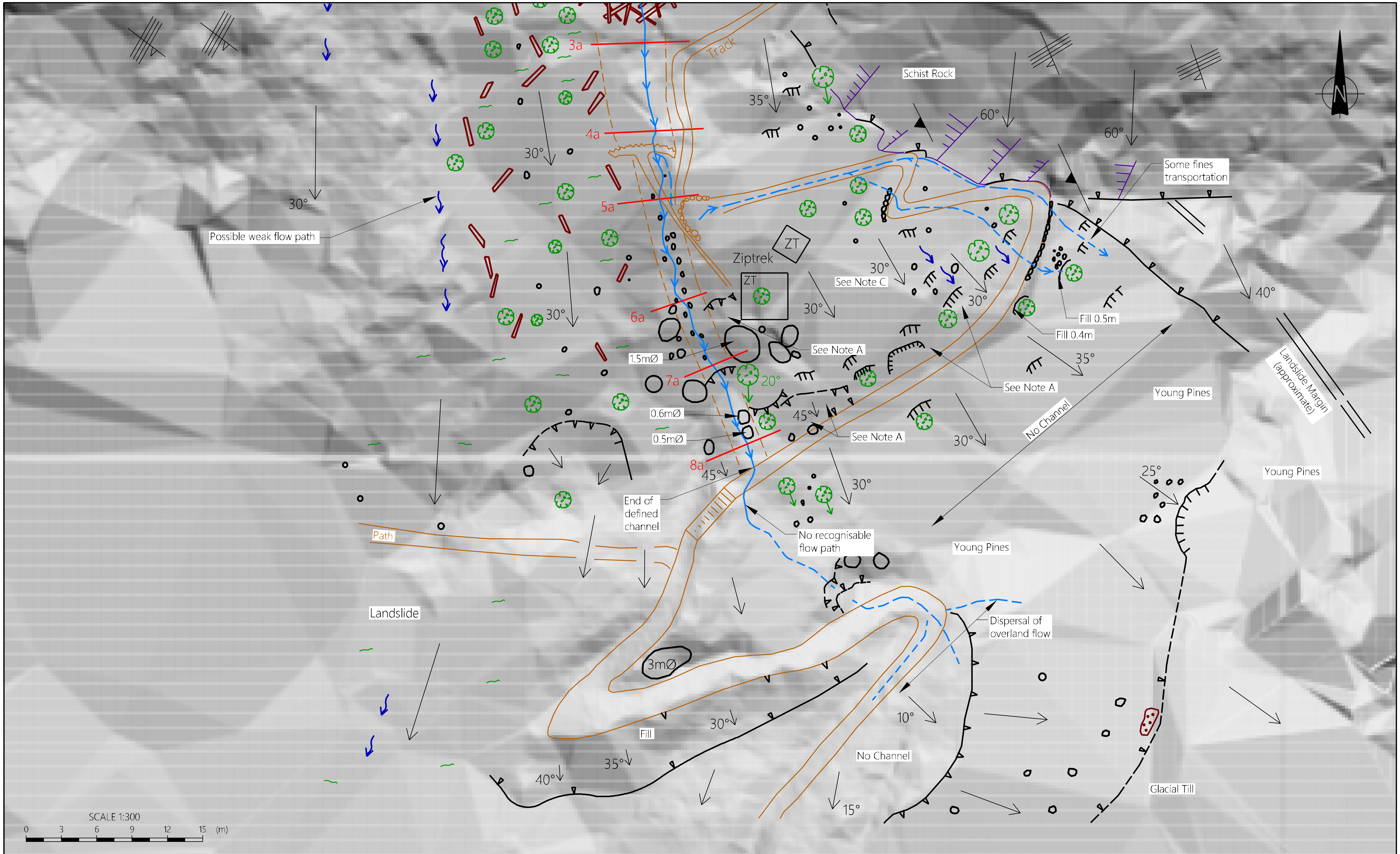
Stormwater Discharge - Detailed Hazard Assessment

Detailed Geomorphology below DL1, northern/upper zone

FIG No: Figure 1g

REV. 1



Notes from map:

A. Angular chaotic cobble and boulder deposit to 0.4m diameter. Silty sandy gravel matrix.
B. Angular cobble and boulder deposit, downslope imbrication.
C. 0.1-0.2m topsoil in most areas, some surface creep. Underlying materials are gravel, cobble, and boulders.

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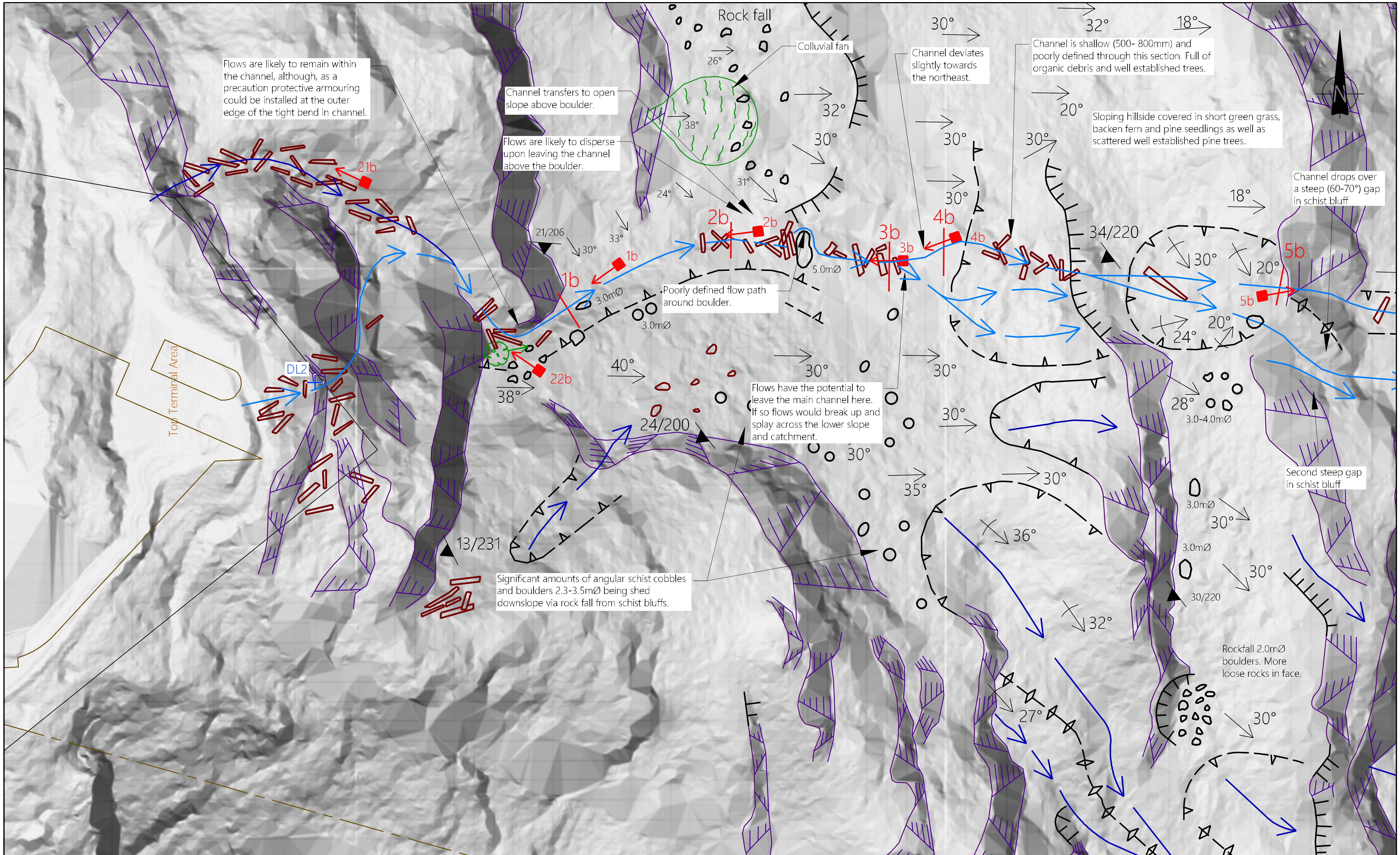
Stormwater Discharge - Detailed Hazard Assessment

Detailed Geomorphology below DL1, northern/upper zone

FIG No: Figure 1h

REV. 1



Legend:

- Scarp (Active)
- Scarp (Inactive)
- Leaning Tree
- 13/231 Slope Angle
- 20b Photograph and Direction
- Organic Debris (trees, branches, etc)
- Boulders with diameter when indicated
- Fall Line
- Hummocky Ground
- 20b Channel Cross-Section
- Cliff

SCALE 1:750

0 7.5 15.0 22.5 30.0 37.5 (m)

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SCALES (AT A3 SIZE): AS SHOWN

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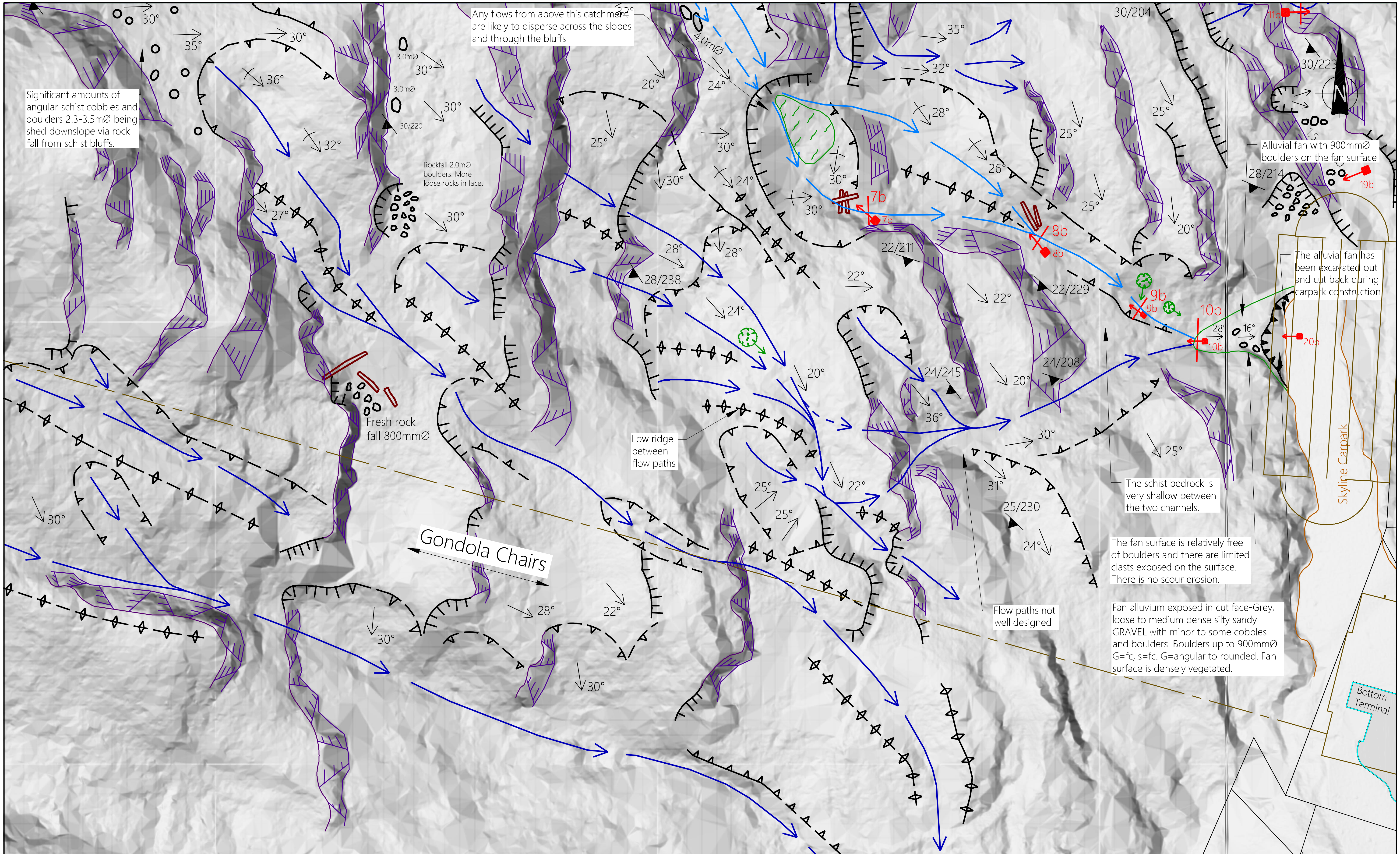
Stormwater Discharge - Detailed Hazard Assessment

Detailed Geomorphology below DL2, western zone

FIG No: Figure 1i

REV: 1



Legend:

- Scarp (Active)
- Scarp (Inactive)
- Leaning Tree
- 13/231 Slope Angle
- 20b Photograph and Direction
- Organic Debris (trees, branches, etc)
- Boulders with diameter when indicated
- Fall Line
- Hummocky Ground
- 20b Channel Cross-Section
- Cliff

SCALE 1:1000

0 10 20 30 40 50 (m)

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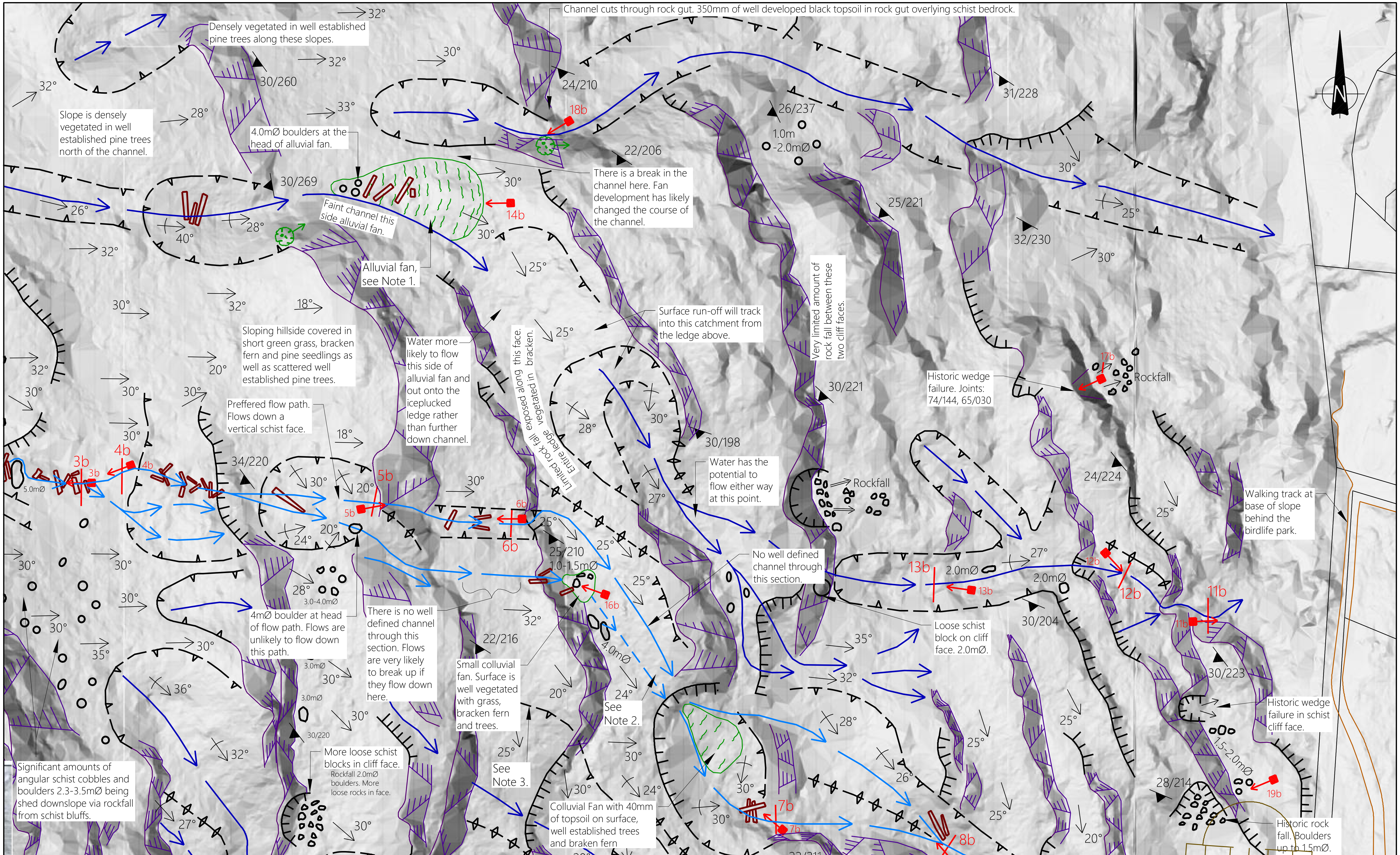
Stormwater Discharge - Detailed Hazard Assessment

Detailed Geomorphology below DL2, south eastern zone

FIG No: Figure 1j

REV. 1



Notes from map:
1. The entire fan surface is curved and lobate-historic debris flows. Fan surface is vegetated in well established trees and bracken fern. No evidence of scour erosion. 50mm of black topsoil overlying black gravelly organic SILT with trace cobbles and boulders.
2. Very faint line of channel above the cliffs. Flows are most likely to disperse across the slope upon reaching the colluvial fan, then dissipate through the bluffs.
3. 60mm of black topsoil overlying black gravelly organic SILT with some cobbles and boulders and some fine roots (Colluvial Fan).

SCALE 1:1000
0 10 20 30 40 50 (m)

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PROJECT No: 160073.02

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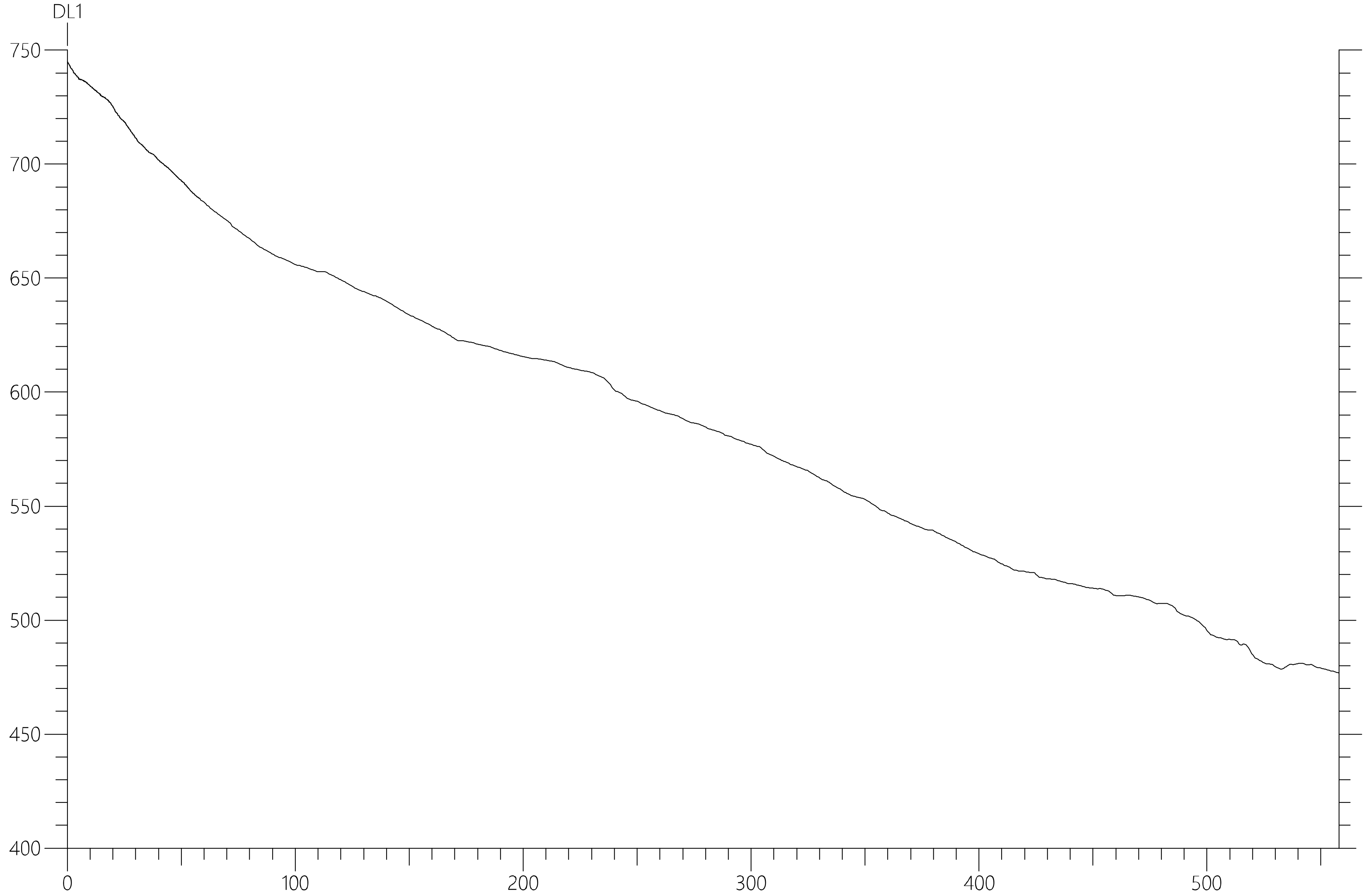
Stormwater Discharge - Detailed Hazard Assessment
Detailed Geomorphology below DL2, north eastern zone

FIG No: Figure 1k
REV. 1



SCALE 1:2500

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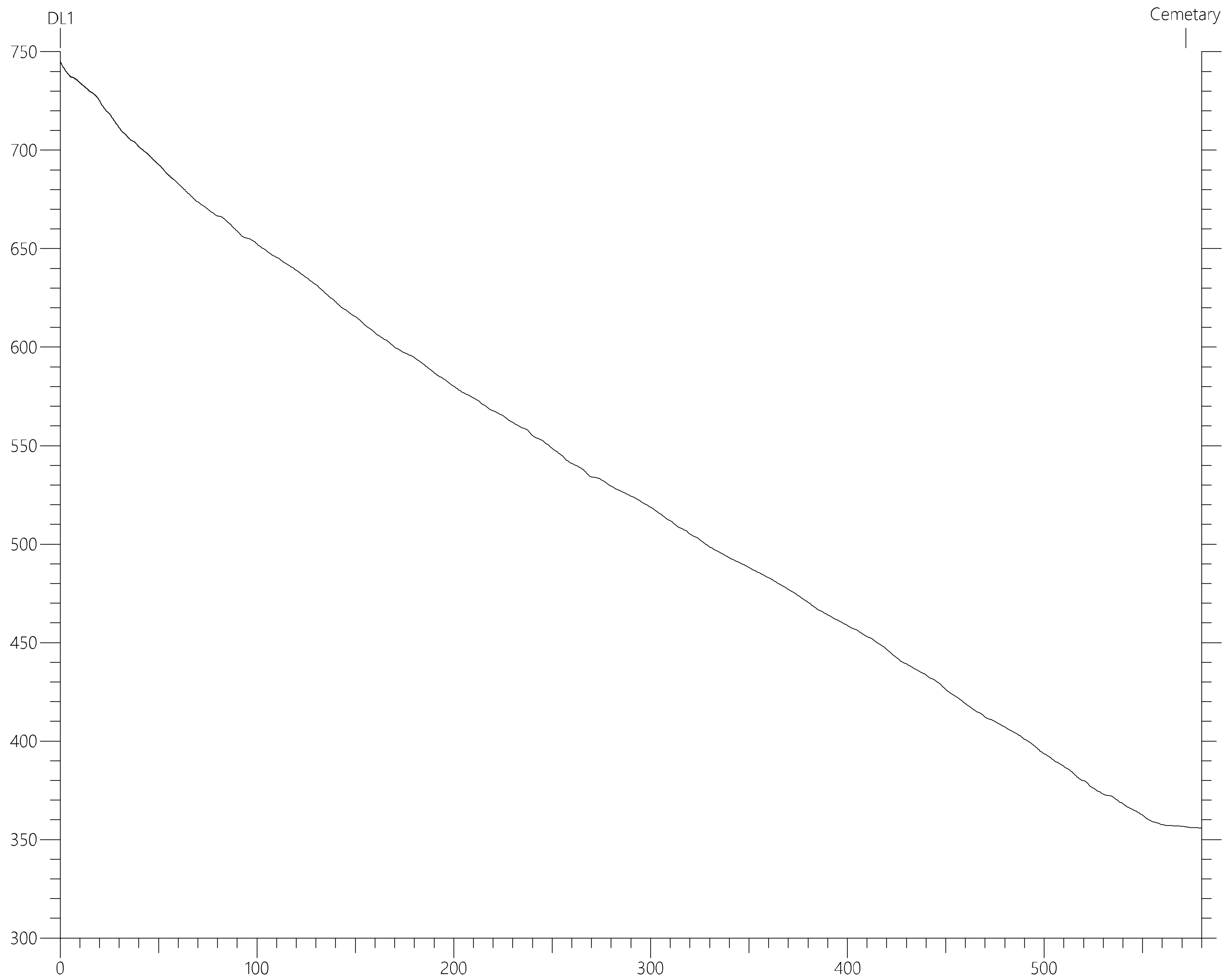
Stormwater Discharge - Detailed Hazard Assessment

DL1 Southern Flow Path Longsection

FIG No: Figure 2a

REV. 1



SCALE 1:2500

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CADFILE: 160073.02_CS.dwg

SCALES (AT A3 SIZE): AS SHOWN

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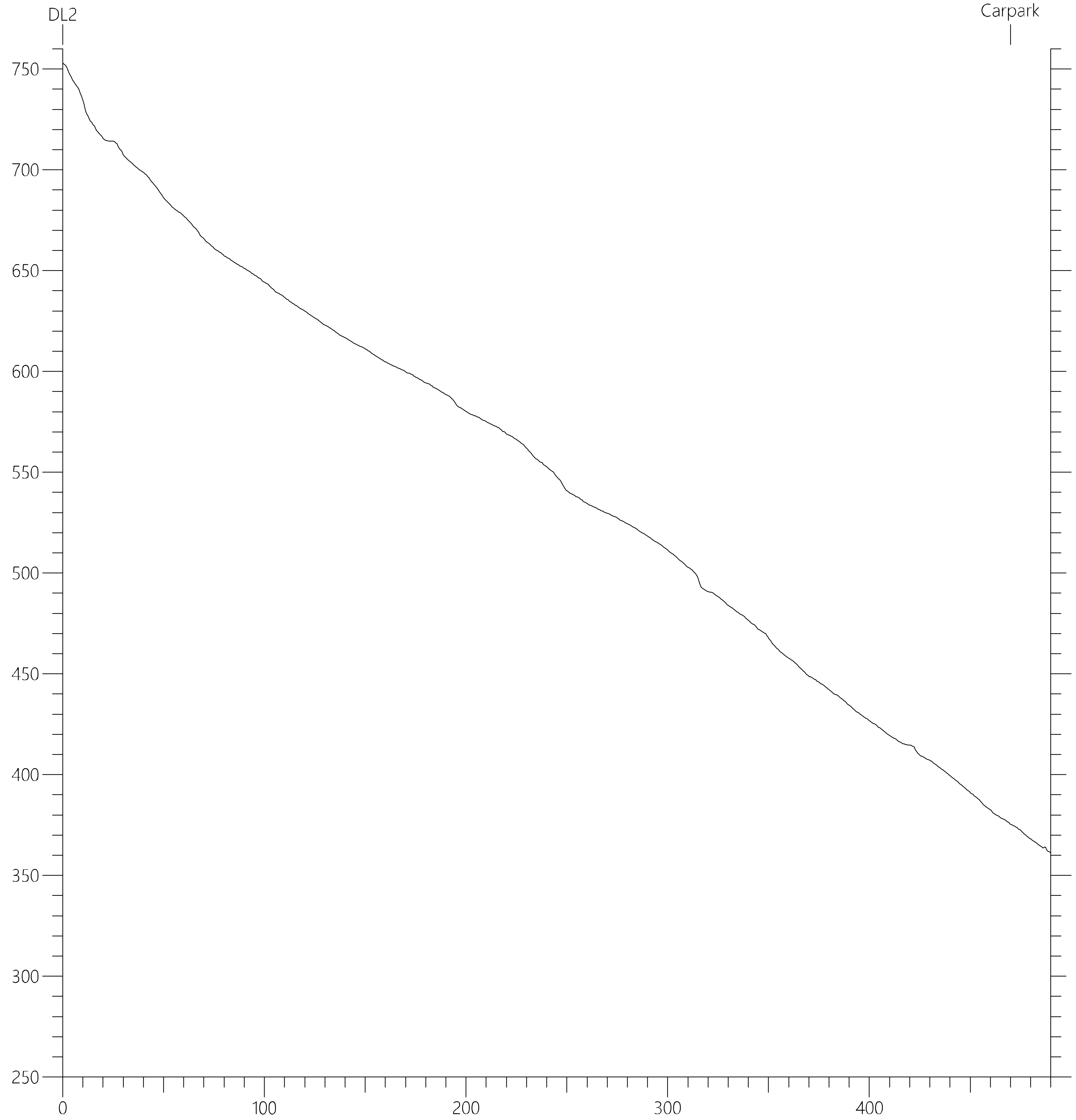
Stormwater Discharge - Detailed Hazard Assessment

DL2 South Eastern Flow Path Longsection

FIG No: Figure 2b

REV. 1



SCALE 1:2500

0 25 50 75 100 125 (m)

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Stormwater Discharge - Detailed Hazard Assessment

DL2 Flowpath Longsection

FIG No: Figure 2c

REV. 1

Appendix B: As-Built Stormwater Network

If this plan is used as the basis for any sale and purchase agreement, then it is done so on the basis that the areas and dimensions are preliminary, and may vary upon completion of the final survey.

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SKYLINE LUGE DEVELOPMENT
QUEENSTOWN
for SKYLINE ENTERPRISES LTD

SERVICES - ASBUILT PLAN - MARCH 2008
PROPOSED REDEVELOPMENT ADDED SEPT 2016

REVISION	A – Original Issue		
SURVEYED	sam 2006–2008	DATE	29 September 2016
DESIGNED		Scales	1:500 @ A1
DRAWN		A1 Original	1:1000 @ A3
CHECKED		DRAWING & ISSUE No.	
APPROVED			Q.4115.24.49B

Appendix C- Fluent Solutions Report

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Infrastructure | Experience

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Website www.fluentsolutions.co.nz

Ref: GL-16-12-06 AOP Q000318 Rev 1.Docx

By Email: bmatheson@geosolve.co.nz

16 December 2016

Blair Matheson
Geolsolve

Attention: Blair Matheson
Project Engineer

Dear Blair

Skyline Enterprises - Stormwater Effects Assessment for Proposed Development

1.0 Introduction

Fluent Solutions has been engaged by Skyline Enterprises to prepare a report on stormwater discharges and potential flood effects to be part of a broader geotechnical assessment report prepared by Geosolve. The geotechnical assessment relates to an expansion proposal for the existing Skyline Gondola terminal and restaurant building complex in Queenstown.

1.1 Background to Development Proposal

Skyline Enterprises Limited has submitted a resource consent application to the Otago Regional Council (ORC) for the addition or two roof areas to the Skyline terminal and restaurant building complex. One aspect of the application involves evaluation of the effects of increased stormwater discharges from the proposed development. In a request for additional information the ORC comments:

"It is the ORC's view an assessment by an expert in stormwater disposal in a steep mountainous environment would be appropriate. Can you please confirm if the applicant agrees to provide confirmation from an appropriately qualified person that they have assessed/reviewed the stormwater management proposal of the applicant and confirms the proposal is appropriate for the surrounding environment while avoiding adverse effects on the natural hazard issues ORC has identified. If an expert statement as described is able to be provided that supports the stormwater management proposal, this will resolve ORC's concerns."

It is proposed that the two existing roof stormwater discharge locations for the building complex would continue to be used for the proposed extensions. The question regarding stormwater raised by the ORC, relates to the potential effects of increased direct runoff from the extended building complex on the catchments below Discharge Location 1 (DL1) and Discharge Location 1 (DL2). Refer to Figure 1.1 below. The potential effects include mobilising debris slides that could affect developed urban land at the bottom of the slope.

Additionally, the Queenstown Lakes District Council (QLDC) are likely to expect comment on the effects of the discharge on urban stormwater infrastructure.

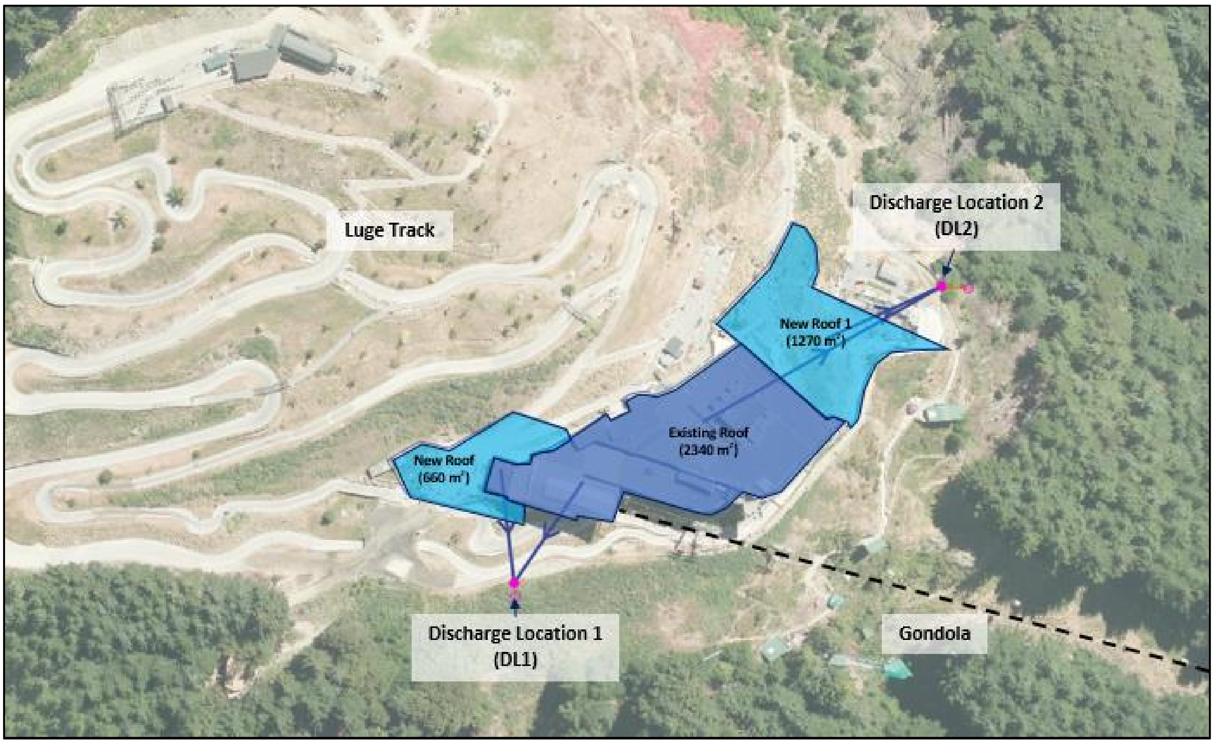


Figure 1.1: Proposed Development Layout and Stormwater Discharge Points

This report provides a preliminary assessment of the effects of discharging additional roof areas at DL1 and DL2 to support the geotechnical assessment for submission to the ORC and QLDC.

2.0 Stormwater Discharge Assessment

The ORC have used a 2D flow model to demonstrate the natural flow patterns down the slopes below the Skyline Complex using recent LiDAR data. Fluent Solutions has developed a similar 2D model using Infoworks ICM (ICM) to assess the effects of an extended roof area. The following sections describe the parameters used in the Fluent Solutions model.

The application of 2D modelling using recent LiDAR data and other parameter judgements related to the catchment areas below the Skyline complex was considered to be best available tool for this effects assessment. In the absence of recorded stormwater effects data for site specific calibration of the model results for this relatively steep catchment was not possible. The model results therefore need to be viewed as a relative assessment and is not necessarily an accurate absolute estimate of stormwater flows at a given location. In this case the relative flow assessment is appropriate given the relatively minor effects related to the building extensions. The soils and geological data is sufficient for assessing the losses in colluvium materials on the slopes in the catchment. Despite the heavy exotic coniferous tree cover, the LiDAR data appears to have accurately recorded the ground topography. The accuracy of the LiDAR data is sufficient for this relative assessment of the stormwater effects at the toe of the slopes at the boundary between the forest and the urban development areas.

2.1 Design Storm Rainfalls

A series of triangular rainfall hyetographs (rainfall depth versus time graph) were developed for a range of storm durations. The developed rainfall hyetographs were imported into the Infoworks ICM model and runoff flows were calculated. The triangular hyetograph methodology, development of storm rainfall intensities from historical rainfall events, and allowance for climate change is described below.

2.1.1 Triangular Hyetograph

The triangular hyetograph methodology adopted by the Christchurch City Council *"Advanced Analysis" method provided in the "Waterways, Wetlands and Drainage Guideline" using recorded data at the Queenstown Airport has been applied for tis effects assessment.* In the past few years, other Councils such as the Dunedin City Council have also adopted this methodology. The triangular hyetograph utilises the average rainfall intensity for a given duration as the basis for design with the peak intensity being at 2 times the average intensity and occurring at 0.7 times the duration.

An example of a typical triangular hyetograph for a 2 hour duration is shown below.

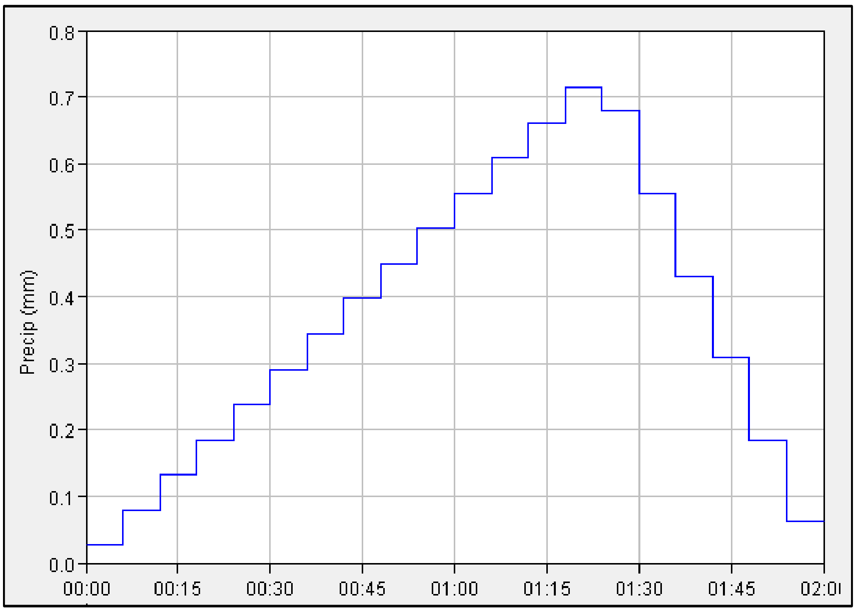


Figure 2.1: Sample 2 Hour Duration Storm Hyetograph

2.1.2 Historical Rainfall Data

To ensure that the design flow estimates are based on appropriate rainfall patterns, the design hyetographs were compared with three recent major storm rainfall events and a normalised rainfall curve derived from a set of 24 hour duration maximum rainfalls from

10 storm rainfall events at Queenstown Airport. The 24 hour data is presented in Figure 2.2. The following points are noted in regard to a 24 hour duration storm rainfalls from the data in Figure 2.2:

a. The total 24 hour rainfall depth for the three recorded storm events would have current ARI of approximately 20 years without allowance for climate change.

b. The peak rainfall intensity for the design hyetograph is greater than the maximum recorded intensity for the three highest recorded 24 hour storm events and greater than the peak of the normalised curve peak intensity using the 24 hour rainfall data including allowance for climate change.

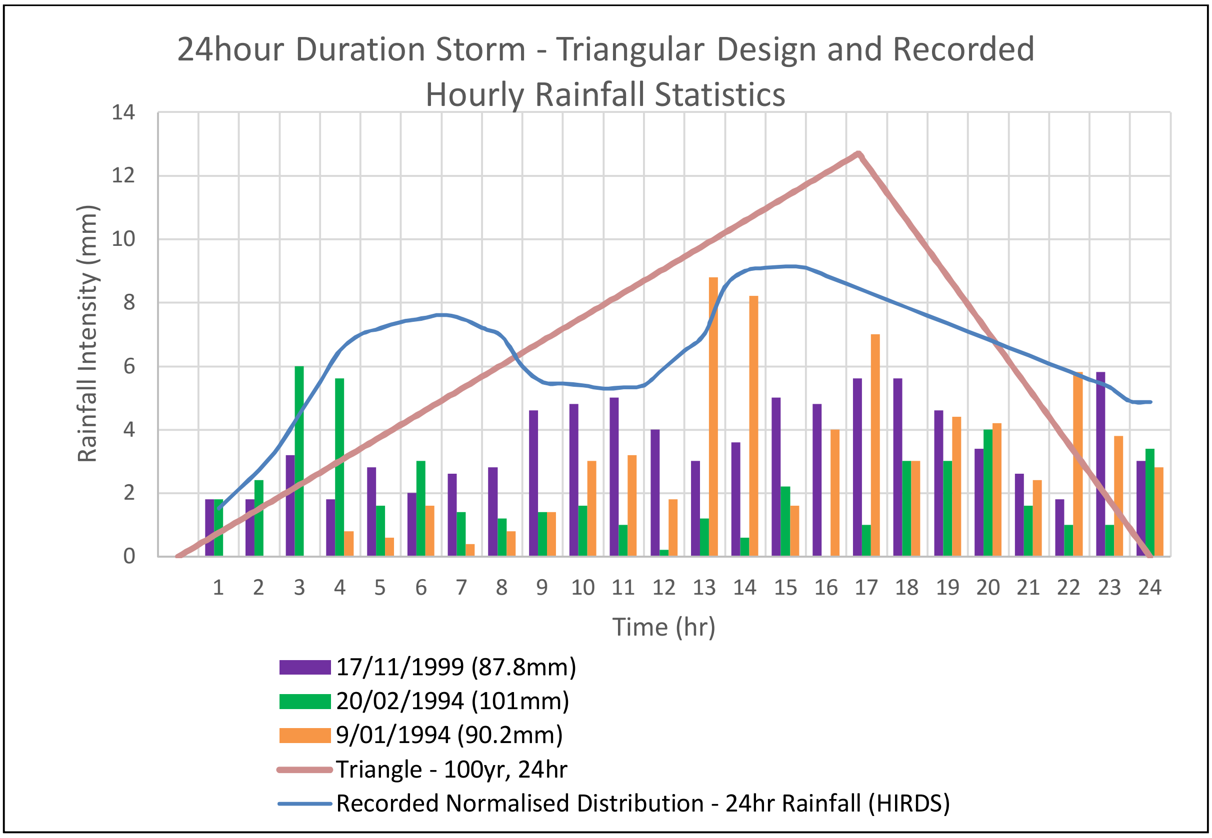


Figure 2.2: Rainfall Data Comparison

2.1.3 Climate Change

The Queenstown Lakes Code of Practice requires that climate change be a design consideration. Rainfall data from HIRDS for the 10 year and 100 year ARI storm events based on a 2ºC temperature increase, being the median projection for 2090, was used to generate the design hyetographs for a range of storm durations.

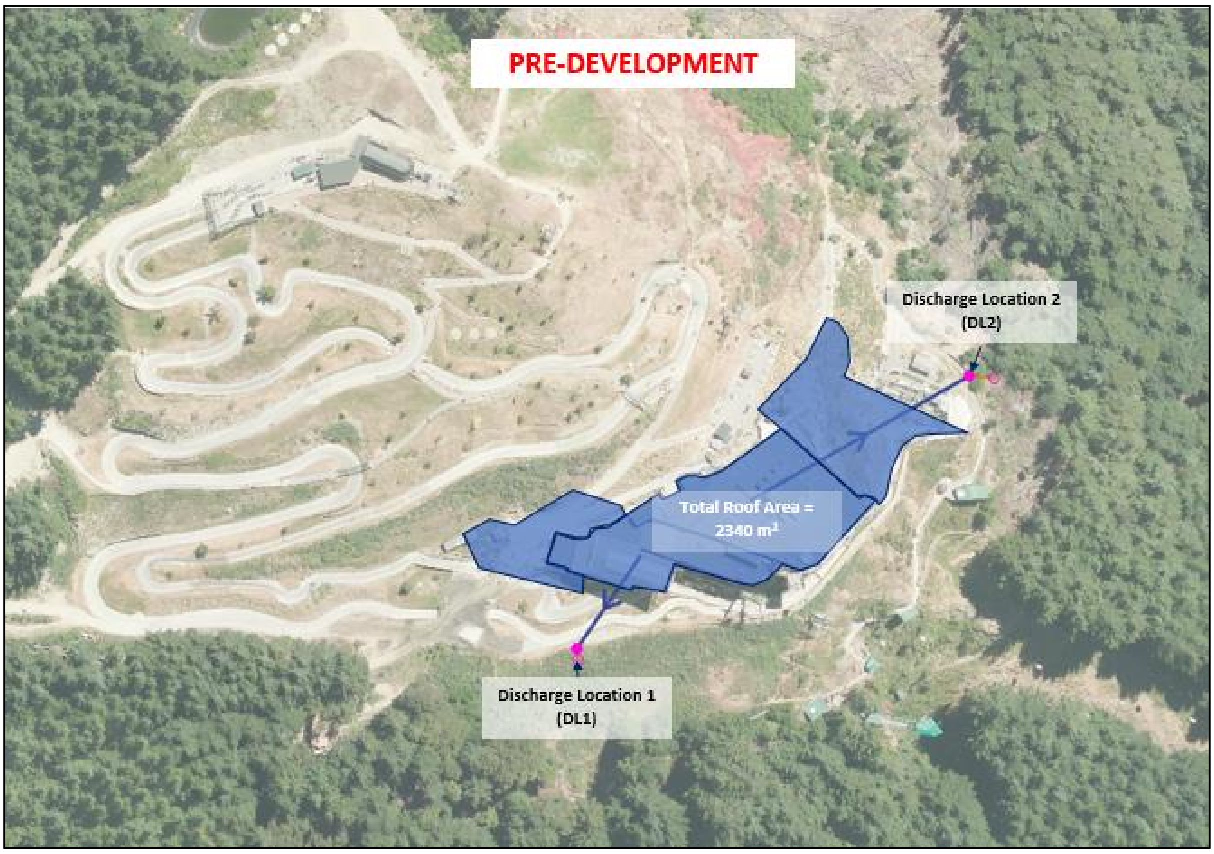
2.1.4 Storm Durations

The ICM model was used to measure the pre- and post-development runoff flows from the site. Stormwater flows were estimated for both the 10 and 100 year ARI storm events for the following durations: 0.5 hour, 1 hour, 2 hour, 4 hour, 6 hour, and 12 hour.

2.2 Catchment Conditions

2.2.1 Building Complex

Figure 2.3 shows the pre- and post-development roof layouts represented in the model. For the roof areas of the Skyline Complex (blue shading) in both the pre- and post-development scenarios, typical catchment parameters (using the ñSCSò method) have been used. When using the SCS method, the perviousness of a surface is determined by the Curve Number. Based on the *Hydrologic Modeling System HEC-HMS Technical Reference Manual, March 2000*, the curve number (CN) assumed for the roofs, being essentially impervious, was 98.



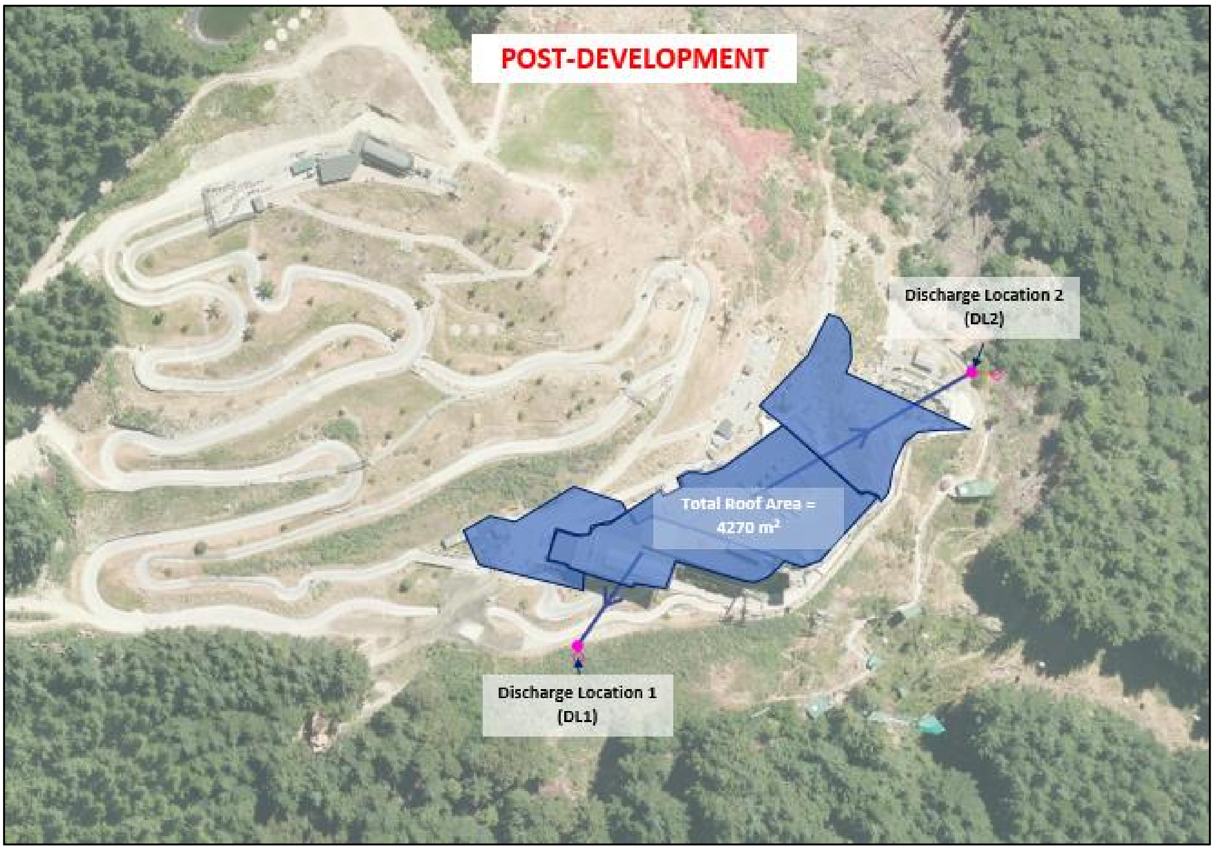


Figure 2.3: Pre and Post Development Model Representation for Roof Areas

2.2.2 Forest Catchment

The sub-catchment below DL1 is not punctuated to the same extent by bluffs as the sub-catchment below DL2 and is generally not as steep. The majority of the upper extents of the sub-catchment comprises landslide debris of the Gondola Hill Landslide. The surface soils in this area are predominantly characterised as colluvium and slope debris.

The sub-catchment below DL2 is characterised by a series of schist bluffs that punctuate the slope down to the urban area into a series of steps. Between the bluffs, the slopes that comprise the greater ground surface area, are characterised by a layer of colluvium and slope debris of the order of 1metre deep.

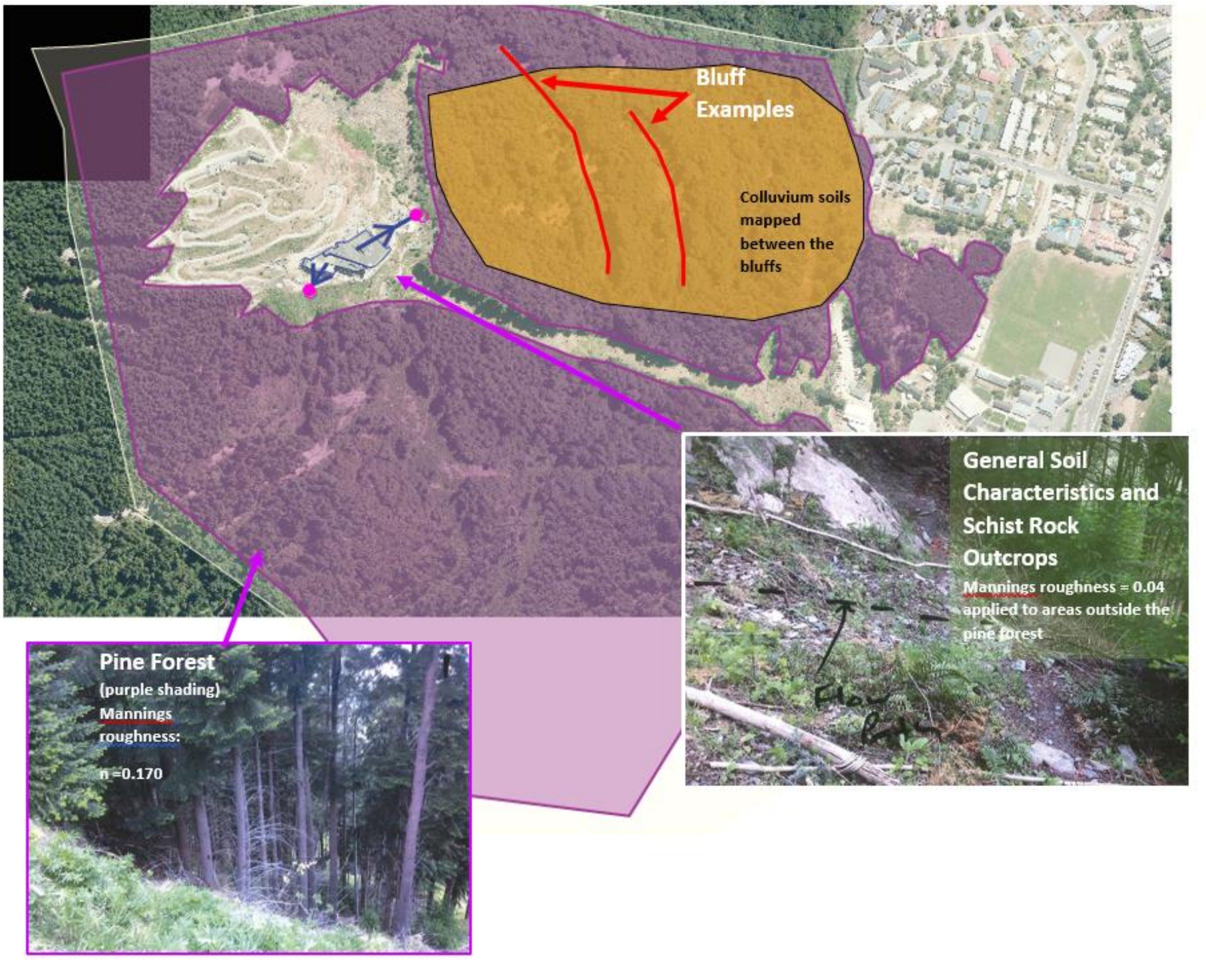


Figure 2.4: Site Characteristics Set Out in Model

2.2.3 Soil Losses

In order to represent colluvium over the site in the hydraulic model, infiltration values for the 2D surface were developed based on the Horton methodology and specific values were based on a dry loam soil with little to no vegetation (values adopted from Akan 1993). The initial infiltration (fo) was 76.2mm/hr and ultimate infiltration (fc) was 3.8mm/hr. The decay rate used was 4.1l/hr.

2.2.4 Surface Roughness

Mannings roughness ñò values were applied to the 2D surface in the ICM model to represent the effects of tree litter under the pine forest areas and bare ground elsewhere as illustrated in Figure 2.4. A typical Mannings roughness of 0.04 was applied to represent the shallow soils and schist rock in clear areas of ground. A roughness of 0.170 was applied to the pine forest areas.

3.0 Model Results Summary

3.1 Model Flow Result Locations

The stormwater discharges from the Skyline roof areas and the discharges to the Queenstown urban area from the DL1 and DL2 sub-catchments from the ICM model are presented for comparison below.

The discharge from DL1 and DL2 sub-catchments for the pre- and post-development scenarios were recorded using result lines from the 2D model at the base of the slope above the urban area of Queenstown. The result lines are illustrated in Figure 3.1.

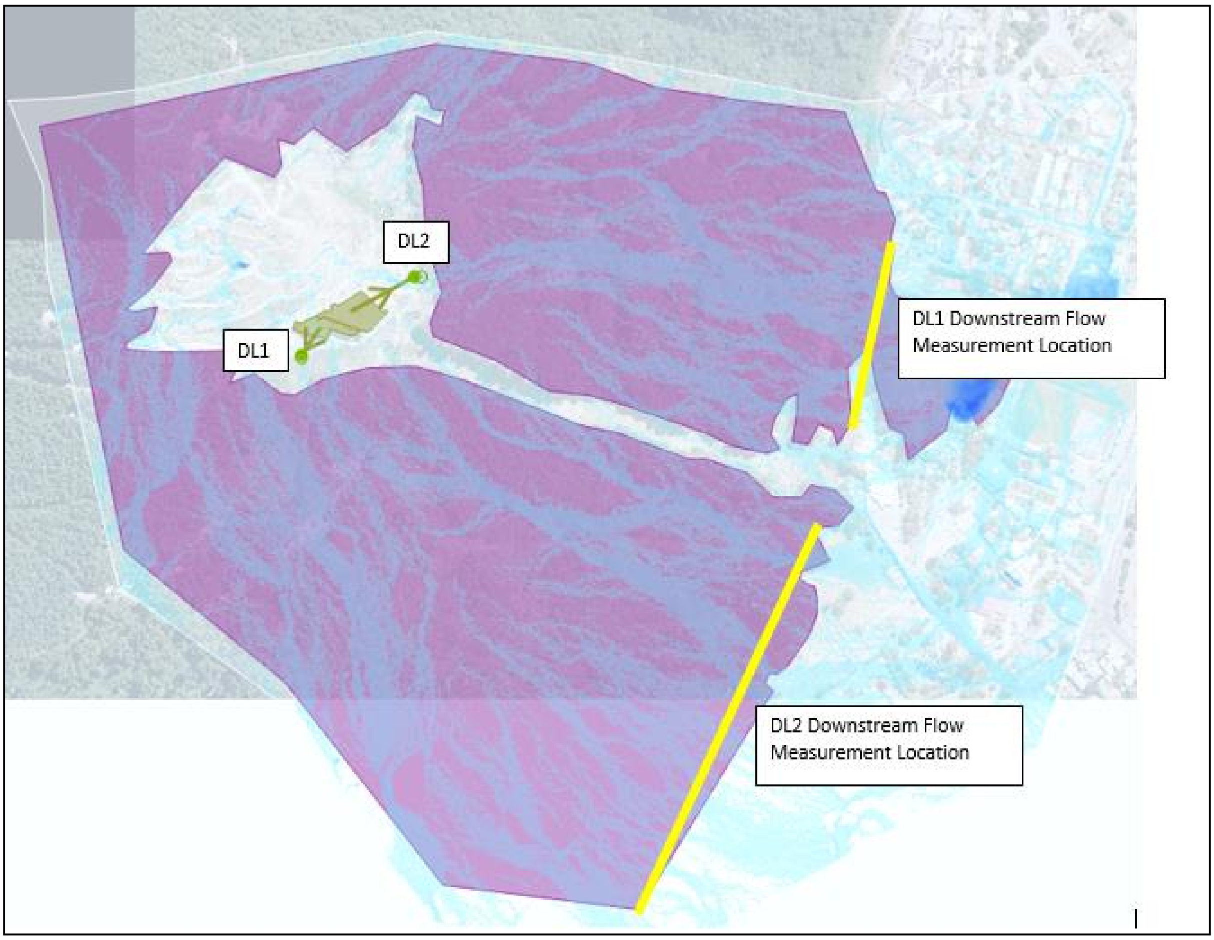


Figure 3.1: Flow Measurement Locations

3.2 Flow Results

A summary of the results for peak direct runoff from the existing and post-development proposal at the buildings and immediately upstream of the urban area of Queenstown is presented in Tables 3.1 and 3.2 below.

Table 3.1: Direct Peak Roof Runoff Flow Results

Storm Duration	DL1 Sub-catchment		DL2 Sub-catchment	
	Pre-Development DL1 Peak Flow (l/s)	Post-Development DL1 Peak Flow (l/s)	Pre-Development DL2 Peak Flow (l/s)	Post-Development DL2 Peak Flow (l/s)
10 year, 4 hr	4.3	10.8 (Increase 6.5l/s)	7.7	19.1 (Increase 11.4l/s)
100 year, 2 hr	7.7	19.2	14.1	35.4

The peak runoff flow from the DL1 and DL2 sub-catchments are set out in Table 3.2 below.

Table 3.2: Summary of Peak Flow Results for Discharge Location Sub-catchments

Storm ARI (yr) and Duration (hr)	DL1 Sub-catchment		DL2 Sub-catchment	
	Pre-Development Peak Flow (l/s)	Post-Development DL1 Peak Flow (l/s) (Difference over Pre-development Flow - %)	Pre-Development DL2 Peak Flow (l/s)	Post-Development DL2 Peak Flow (l/s) (Difference over Pre-development Flow - %)
10 year, 2hr	56	-	51	-
10 year, 4hr	**104**	**105 (1l/s = +1%)**	**95**	**98 (3l/s = +3.2%)**
10 year, 6hr	100	-	91	-
100 year, 1hr	398	-	325	-
100 year, 2hr	**454**	**456 (2l/s = +0.4%)**	**388**	**398 (1l/s = +2.6%)**
100 year, 4hr	329	-	286	-

3.3 Observations from the ICM Model Results

The observations from the results in Tables 3.1 and 3.2 are as follows:

1. The critical duration event for the 10 year ARI design storm rainfall is 4 hours.
2. The critical duration for the 100 year ARI design storm rainfall is 2 hours.
3. The magnitude of the runoff for a 100 year ARI rainfall event is approximately 4 times that for the 10 year ARI event. The % increase in peak runoff for the 100 year ARI event is less in both the DL1 and DL2 catchments.
4. The effect of the increase in building roof area on the Queenstown urban area is substantially reduced as a result of the flow down through the steep forested slopes below the Skyline buildings. For the 10 year ARI event for the DL2 sub-catchment, the increase in direct runoff of 11l/s at the buildings is reduced to 3l/s at the bottom

of the slope above the Queenstown urban area. For DL1, the increase of 6.5l/s at the building is reduced to 1l/s at the urban area.

5. The topography of the DL1 sub-catchment is more effective at reducing the increase in flow from the additional building areas.
6. The order of increase in the flow to the Queenstown urban area is likely to be relatively minor compared to the capacity of the QLDC stormwater system.
7. If there are capacity problems in the existing QLDC stormwater system, then the additional Skyline building area is unlikely to affect the QLDC system given that the peak flow in the urban area and the flow peak flow from the Skyline buildings are unlikely to coincide.
8. The increase in the volume of runoff from the Skyline buildings is likely to have a very minor effect on detention storage in the domain adjacent to Memorial Street and Horne Creek.

We have not assessed or sought information on the Queenstown stormwater system capacity. The increase in runoff due to the proposed additional Skyline building area however would be expected to have a minor adverse effect on the Queenstown urban area stormwater network.

Installing detention storage at the Skyline buildings could offset the increase in flow to the DL1 and DL2 sub-catchments. Given the schist rock catchment below the Skyline buildings, and in particular, in the DL2 sub-catchment, it is unlikely that the increase in stormwater discharge from the buildings would result in a significant increase in erosion of the watercourses below DL1 and DL2. We expect Geosolve to comment on any effects the additional stormwater may have on slope stability.

The steepness of the terrain in the DL1 and DL2 sub-catchments, the relatively shallow soils overlying rock and the topography that results in the dispersed nature of the stream flows mean that the marginal increase stormwater runoff (without detention storage) is unlikely to significantly increase the risk of, or, volume of any debris flows above the urban area.

4.0 Conclusion

The model results confirm that the effects of the increased building area on the urban area of Queenstown would be relatively minor. Virtually none of the steep land area in the DL1 and DL2 sub-catchments is suitable for urban development and therefore the damping effect of the topography on stormwater flows would not decline over time. If the extensive tree cover in the sub-catchments below the Skyline buildings were removed then the overall rate of runoff and erosion is likely to increase but the effect of the proposed additional building area as a proportion of the total flow would be expected to decrease.

If the QLDC stormwater infrastructure is under capacity, then detention storage at the Skyline site could be used to offset the increase in direct runoff from the proposed building areas.

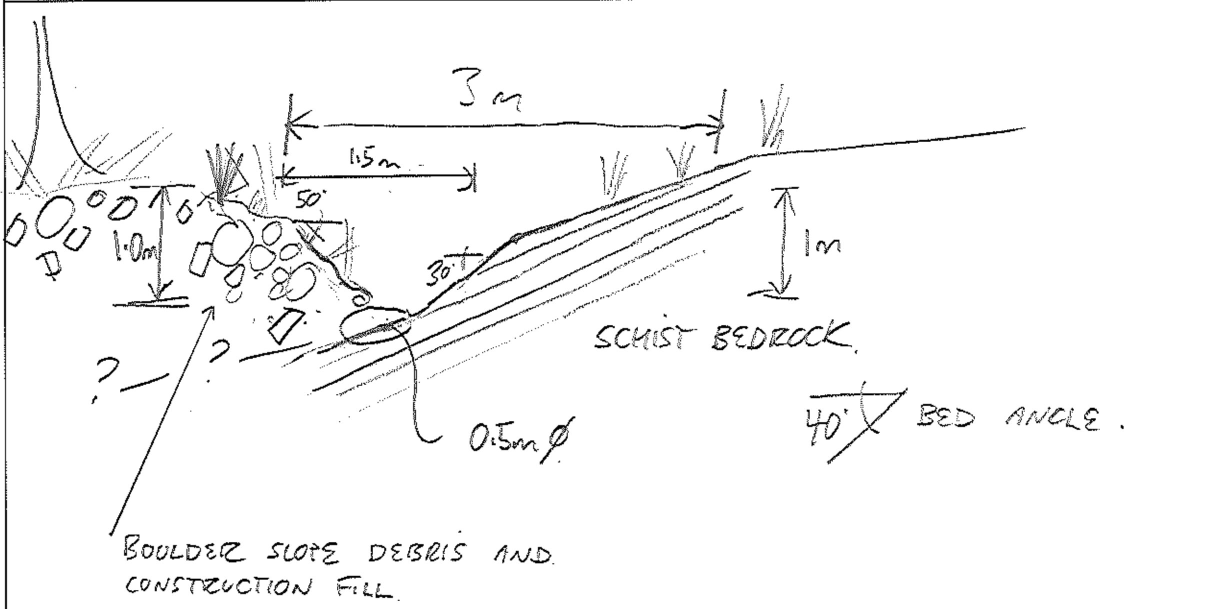
Should you have any further questions, please do not hesitate to contact us.

Yours faithfully
FLUENT INFRASTRUCTURE SOLUTIONS LTD
Per:

Gary Dent
Director / Senior Environmental Engineer

Appendix D - Photos and Field Notes

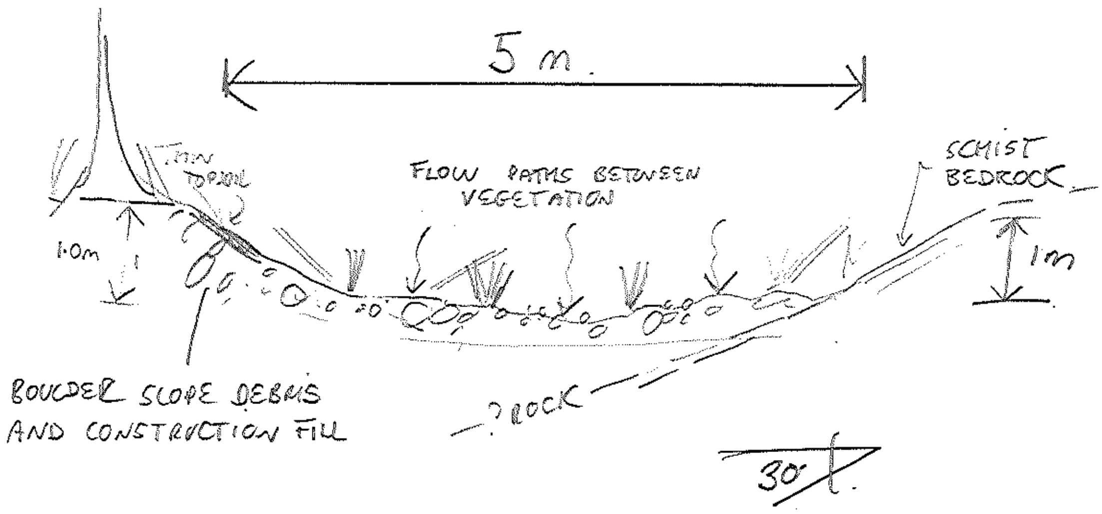
Section Number: 1a.		



angularity	Angular.		
Depth of soil	1.0m on true. right, becoming deeper.		
Average size	0.1 m+.		
Max size	0.5 m.		
Tightly interlocked or loose	Loose surface.		
Scour erosion	Minor scour on true right.		
Vegetation	Grass, shrubs, mature trees		
Depth of topsoil:	Minor, none on true left, sparse (<50mm) true right.		

Soil materials on the true right are a mixture of slope debris and fill from above, significant fallen and felled tree debris also present.

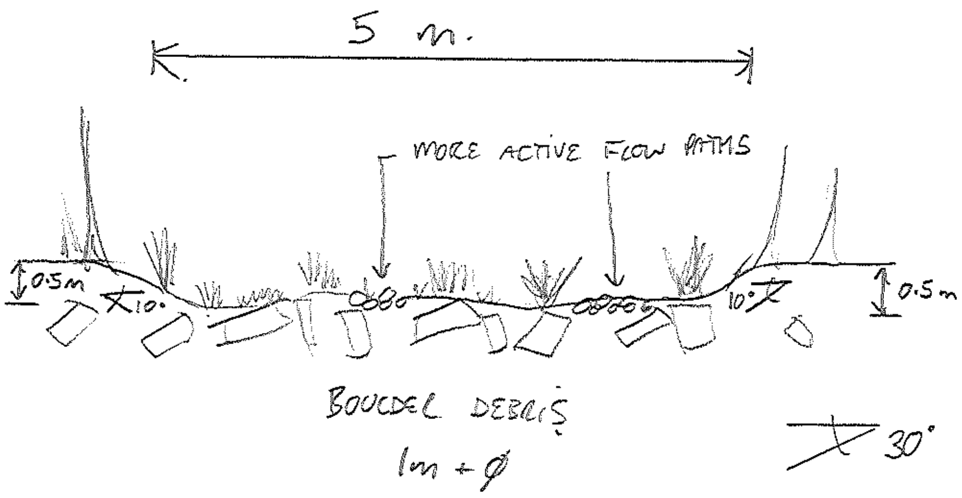
Section Number: 2a		



angularity		
Depth of soil 1m		
Average size 50 - 100mm		
Max size 0.3 m.		
Tightly interlocked or loose Loose materials on surface		
Scour erosion Some scour, transportation of gravel.		
Vegetation Sparodic grass and fern growth		
Depth of Topsoil: Sparodic cover < 50mm		

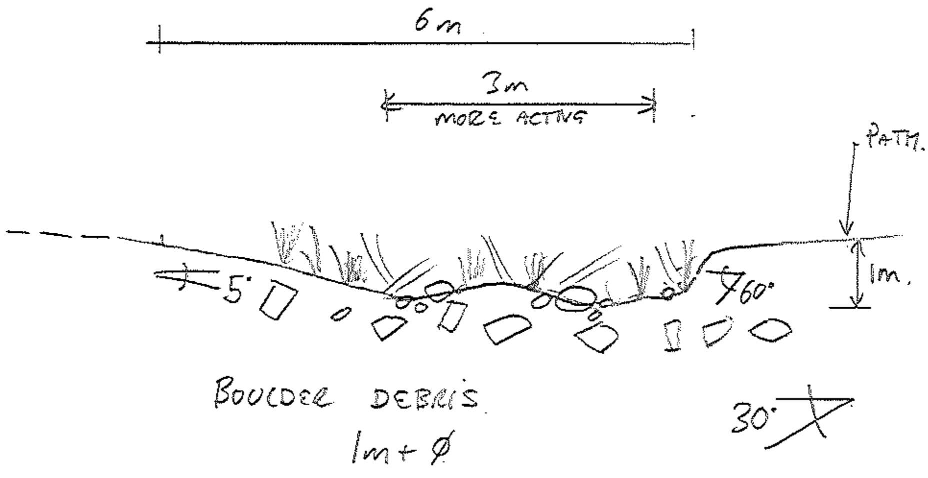
Some fallen tree debris.

Section Number: 3a.		



Angularity Angular.		
Depth of soil Unknown, estimated 2-4 m.		
Average size 50 - 100 mm		
Max size 0.3 m.		
Tightly interlocked or loose Loose gravel on surface, interlocked	boulders	beneath.
Scour erosion Some minor scour, transportation of gravel.		
Vegetation Well established grass, ferns, schrubs		
Depth of Topsoil 50 - 100 mm.		

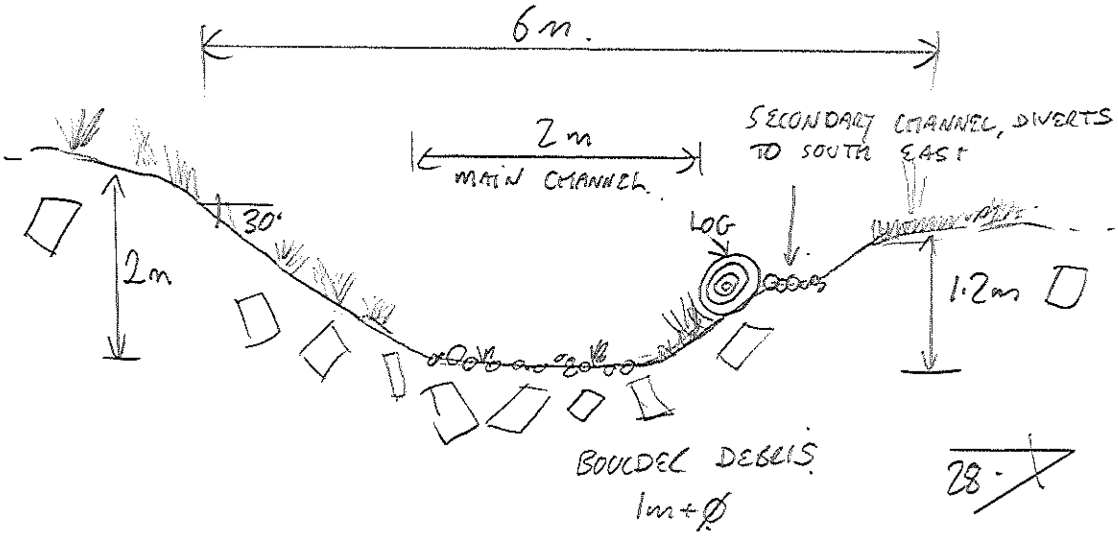
Section Number: 4a		



Angularity	Angular.		
Depth of soil	Unknown, estimated 3-6m		
Average size	50 — 100mm.		
Max size	0.3m.		
Tightly interlocked or loose	Some loose surface material, interlocked	boulder	beneath
Scour erosion	Very minor, possible transportation of gravel.		
Vegetation	Well established grass, fern, bushes.		
Depth of Topsoil	50 - 100mm.		

Significant fallen and felled tree debris.

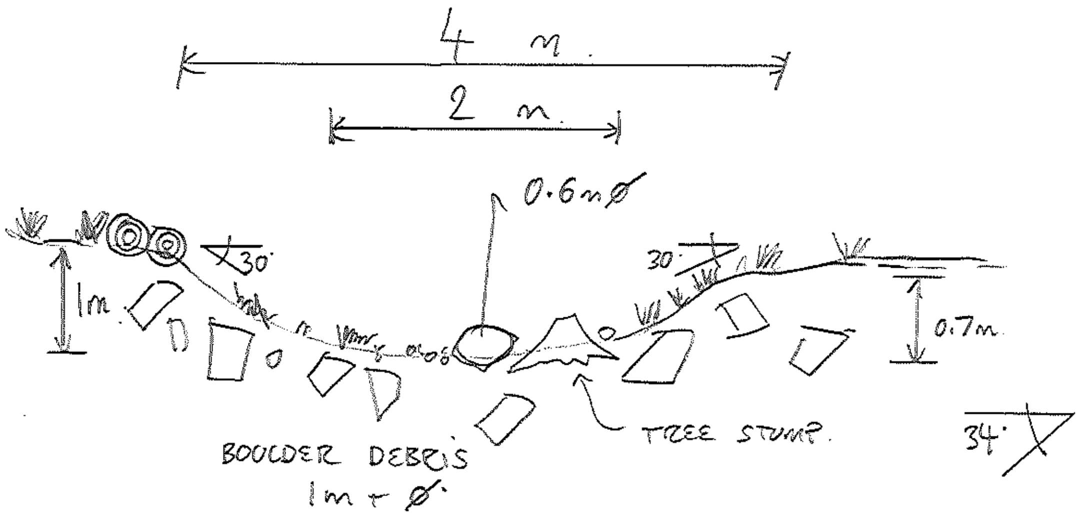
Section Number: 5a.		



Angularity	Angular.		
Depth of soil	Unknown, several metres		
Average size	50-100mm.		
Max size	0.35 m.		
Tightly interlocked or loose	Some loose material on surface, Interlocked beneath		
Scour erosion	Very minor, some transportation of gravel.		
Vegetation	Sporadic grass, ferns		
Depth of Topsoil	pockets ~ ∠50mm.		

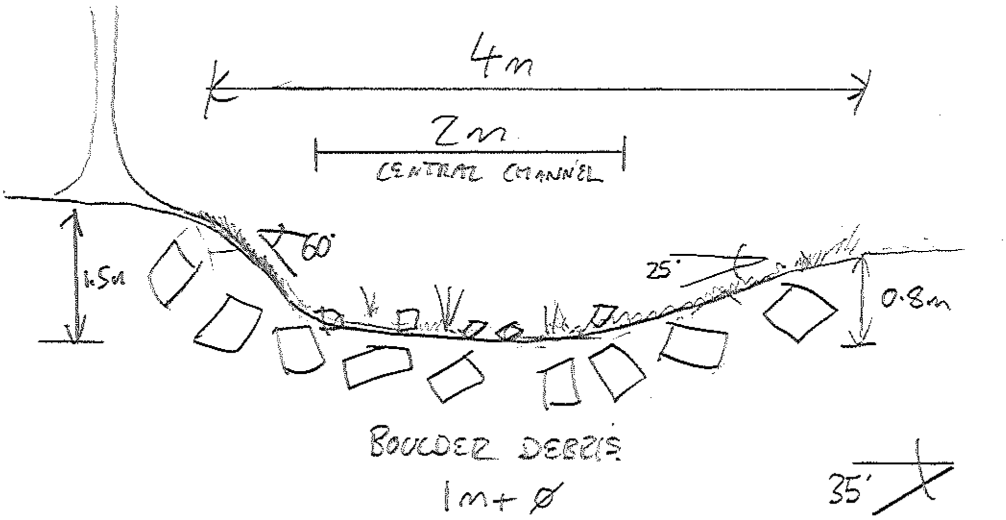
Large fallen tree in channel.

Section Number: 6a.		



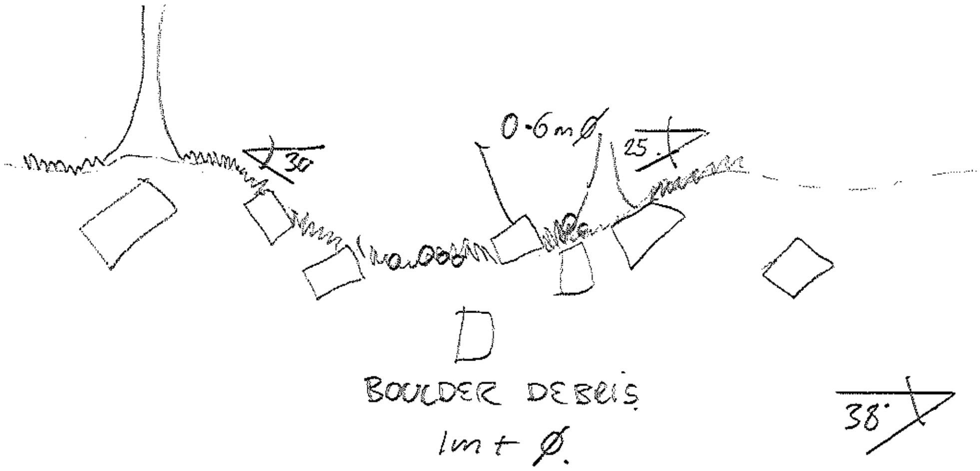
Angularity	Angular.		
Depth of soil	Unknown, several metres.		
Average size	50 – 100mm. on surface. large boulders	beneath	
Max size	0.6m. (in channel)		
Tightly interlocked or loose	Loose surface, interlocked boulders	beneath	
Scour erosion	Very minor.		
Vegetation	Pockets of grass, ferns in channel.		
Depth of Topsoil	Sparodic <50mm – 100mm.		

Section Number: 7a.		



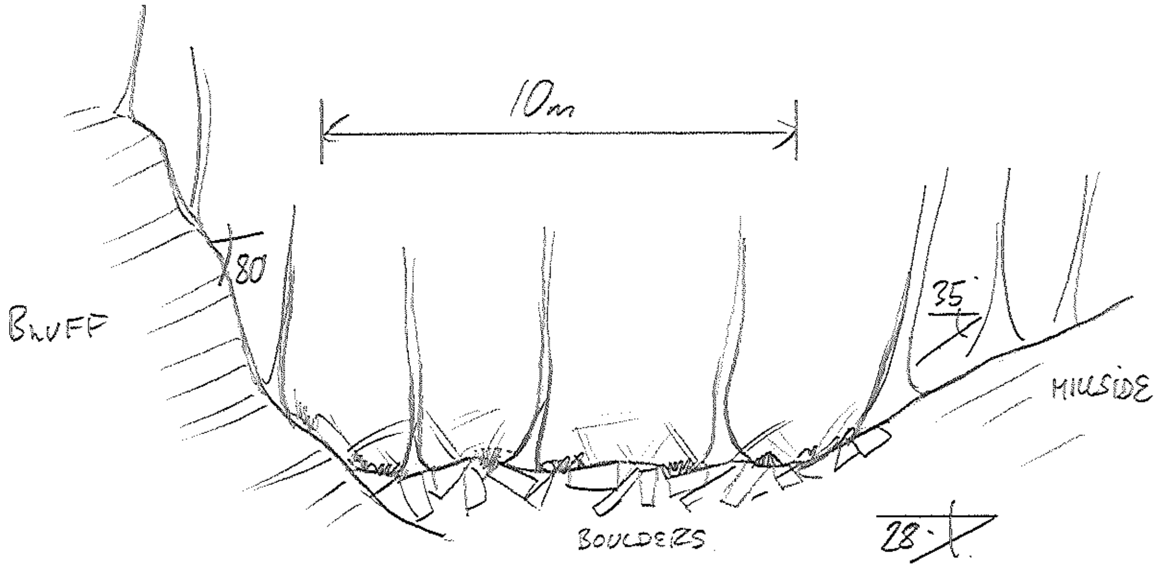
Angularity Angular		
Depth of soil Unknown, Several metres.		
Average size 50 – 100 mm.		
Max size 250mm in channel		
Tightly interlocked or loose Thin loose surface, interlocked boulders beneath.		
Scour erosion Very minor, some transportation		
Vegetation Sparodic pockets, grass shrubs.		
Depth of Topsoil Variable. coverage <50 mm – 100mm.		

Section Number: 8a		



Angularity Angular		
Depth of soil Several metres		
Average size 50 – 100 mm		
Max size 0·6m.		
Tightly interlocked or loose Thin loose soils, interlocked boulders beneath		
Scour erosion Very minor		
Vegetation Grass, shrubs, established		
Depth of Topsoil Variable ∠50mm.		

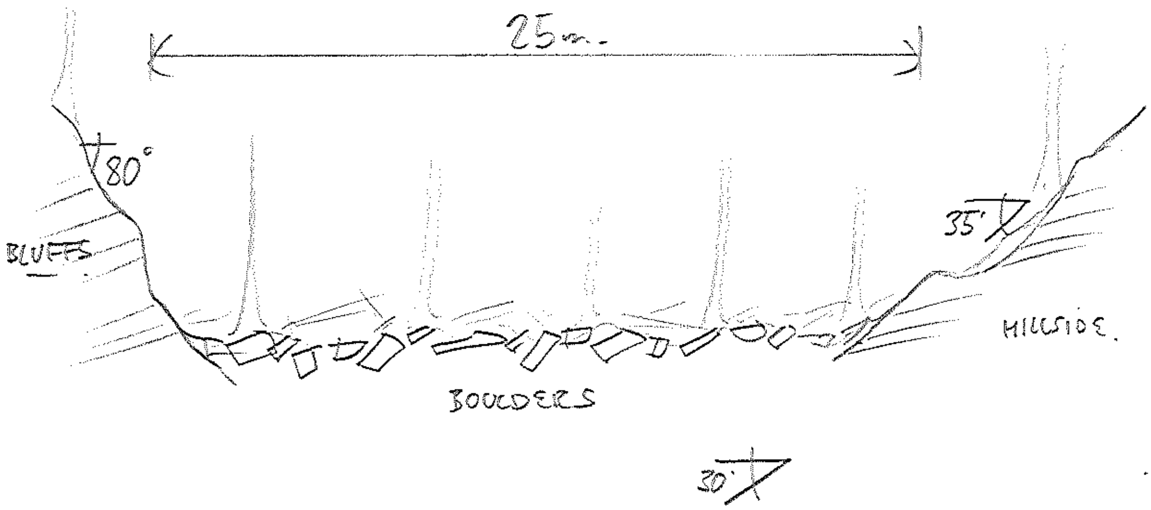
Section Number: 9a		



Angularity Angular.		
Depth of soil Unknown estimated as 1-3m.		
Average size 0.5m +		
Max size 2m		
Tightly interlocked or loose Interlocked		
Scour erosion None, no evidence of overland flow		
Vegetation Mature trees, ferns, young trees		
Depth of Topsoil 50-100mm, around boulders		

Significant fallen tree debris.

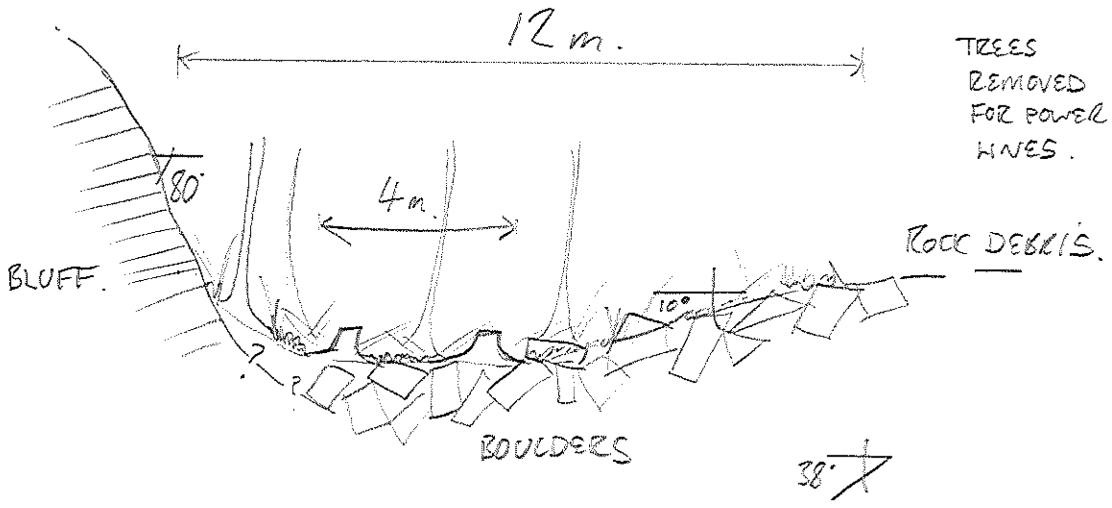
Section Number: 10a.		



Angularity	Angular.		
Depth of soil	Unknown, several metres.		
Average size	0.5 m +.		
Max size	3m.		
Tightly interlocked or loose	Interlocked.		
Scour erosion	None, no evidence of overland flow.		
Vegetation	Mature trees, ferns		
Depth of Topsoil	Established between boulders 50-100mm		

fallen tree debris.

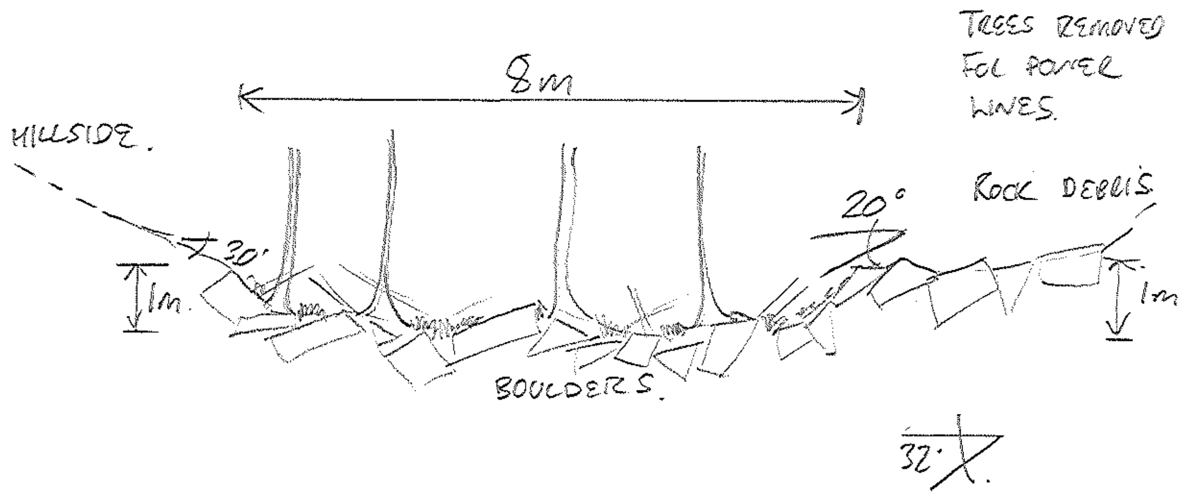
Section Number: 11a.		



Angularity Angular.		
Depth of soil Unknown, estimated 1-3m.		
Average size 0.5m+!		
Max size 1.5 m.		
Tightly interlocked or loose Interlocked		
Scour erosion None, no evidence of overland flow.		
Vegetation Well established mature trees, moss, ferns		
Depth of Topsoil Established between boulders 50-100mm.		

Significant fallen tree debris, tree trunks from felled mature trees in channel.

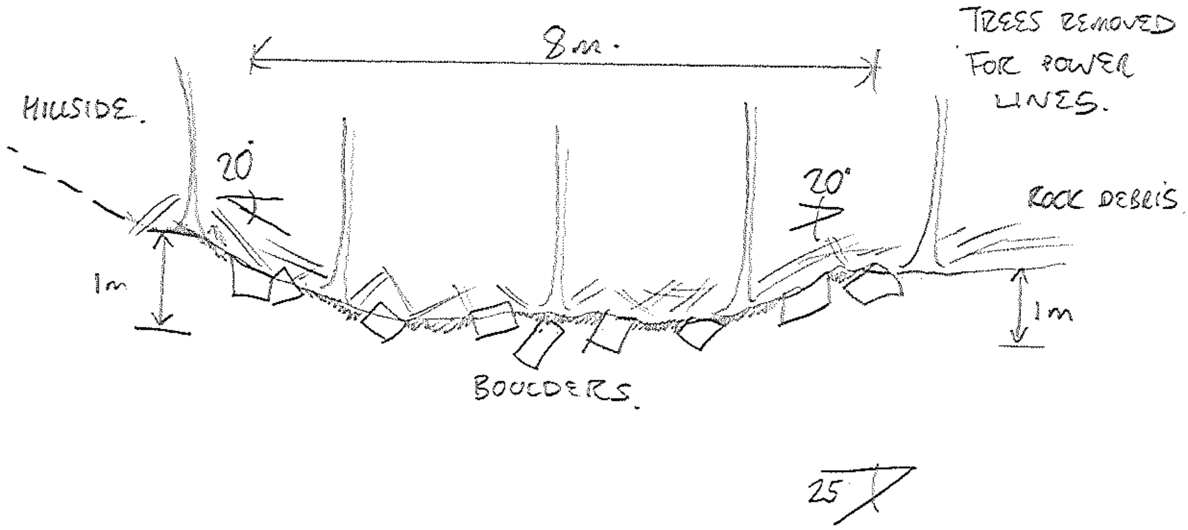
Section Number: 12a.		



Angularity	Angular.		
Depth of soil	Unknown, estimated 2–4m		
Average size	0·3m +.		
Max size	1.5m.		
Tightly interlocked or loose	Interlocked.		
Scour erosion	None, no evidence of overland flow.		
Vegetation	Mature and young trees, moss.		
Depth of Topsoil	Variable, established between boulders	50-100 mm.	

Fallen tree debris.

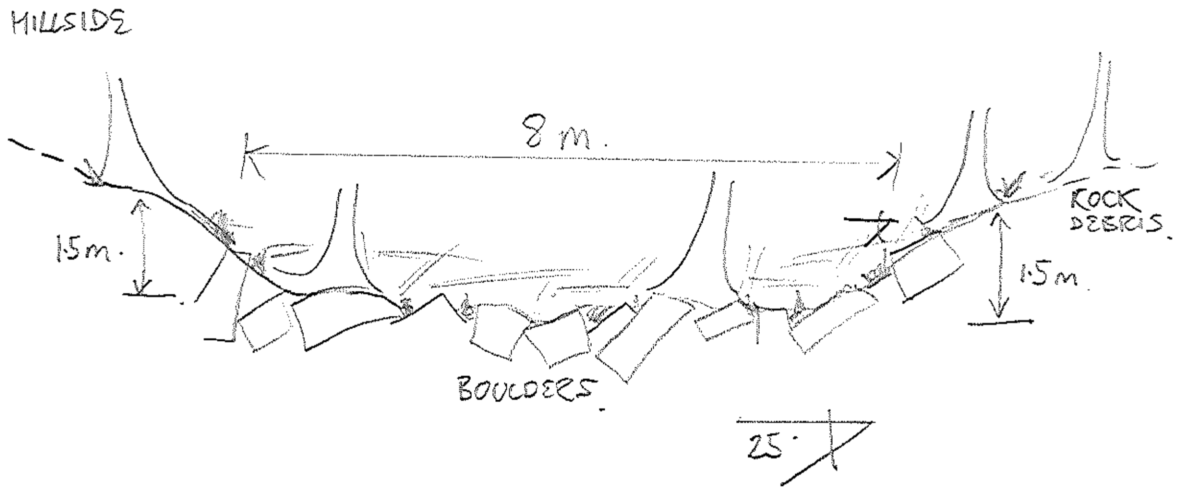
Section Number: 13a.		



Angularity Angular.		
Depth of soil Unknown, several metres.		
Average size 0.5m +		
Max size 1.5 m.		
Tightly interlocked or loose Interlocked		
Scour erosion None, no indications of overland flow.		
Vegetation Mature trees.		
Depth of Topsoil Established between boulders 50-100mm.		

Significant fallen tree debris / felled trees.

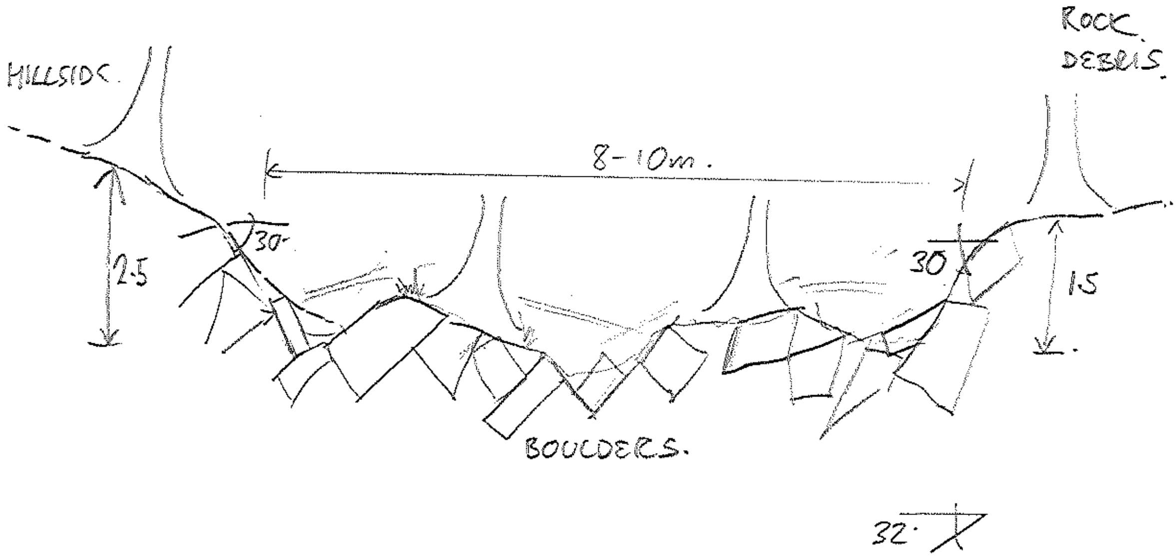
Section Number: 14a			



Angularity	Angular.		
Depth of soil	Unknown, several metres.		
Average size	0.5m +.		
Max size	1.5 m		
Tightly interlocked or loose	Interlocked.		
Scour erosion	None, no indications of overland flow.		
Vegetation	Mature trees.		
Depth of Topsoil	Established between boulders 50-100mm.		

Significant fallen tree debris / felled trees.

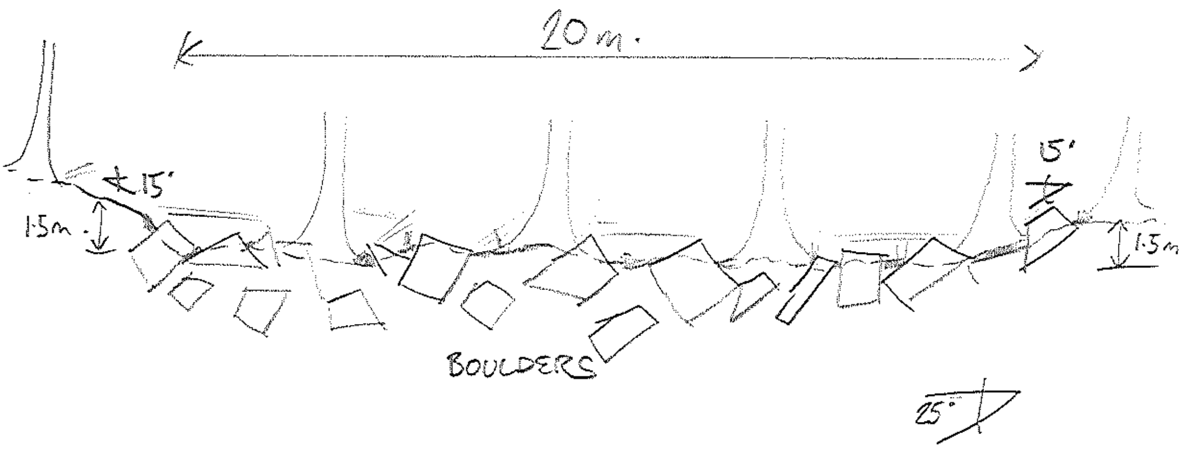
Section Number: 15a		



Angularity	Angular		
Depth of soil	Unknown, expected to be several metres.		
Average size	0.5m +		
Max size	2 m		
Tightly interlocked or loose	Interlocked.		
Scour erosion	None, no indications of overland flow.		
Vegetation	Mature trees.		
Depth of Topsoil	Established between boulders 50-100mm		

Fallen tree debris.

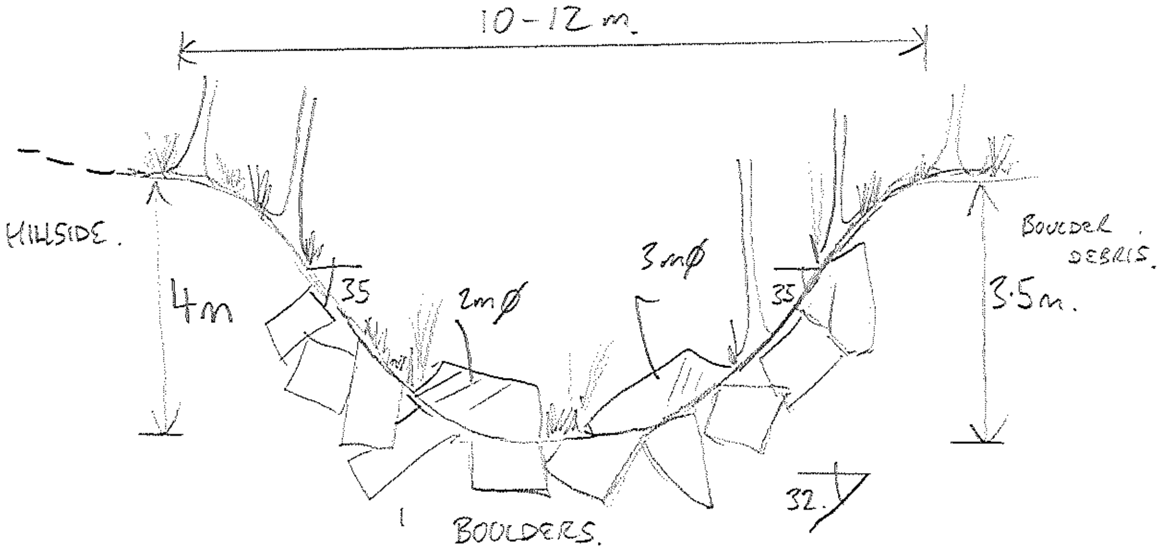
Section Number: 16a.		



Angularity Angular.		
Depth of soil Unknown, expected to be several metres.		
Average size 0.5m +.		
Max size 4m.		
Tightly interlocked or loose Interlocked, high void space.		
Scour erosion None, no indications of overland flow		
Vegetation Mature trees		
Depth of Topsoil Established between boulders 50-100mm.		

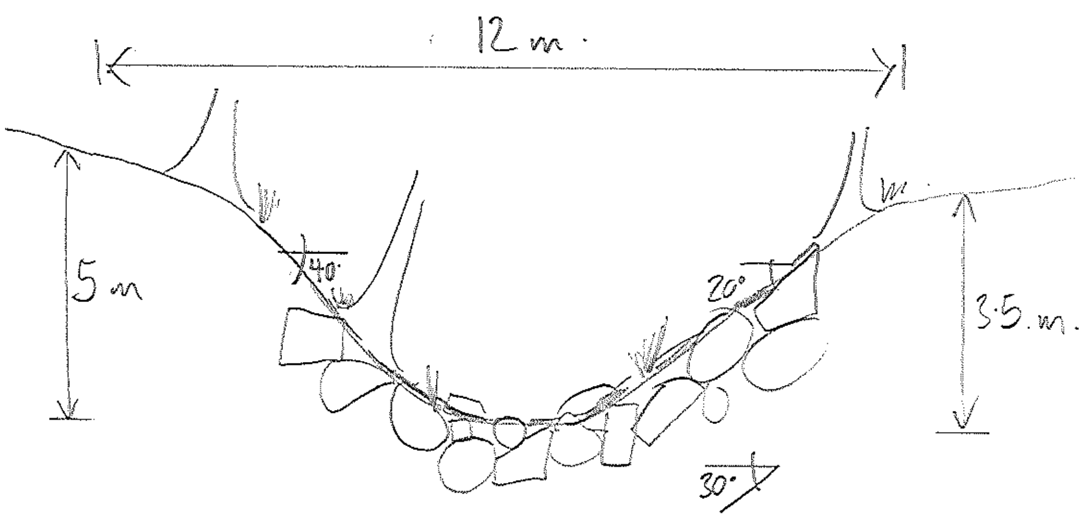
Channel is very vague, lots of bifurcation and dispersal around boulders and trees.
Very coarse boulder field, with fallen tree debris

Section Number: 17a		



Angularity	Angular.		
Depth of soil	Unknown, expected to be several metres		
Average size	0.3m +.		
Max size	3 m.		
Tightly interlocked or loose	Interlocked.		
Scour erosion	None, no indications of any overland flow.		
Vegetation	Well established, mature trees ferns, bushes.		
Depth of Topsoil	100 mm good coverage.		

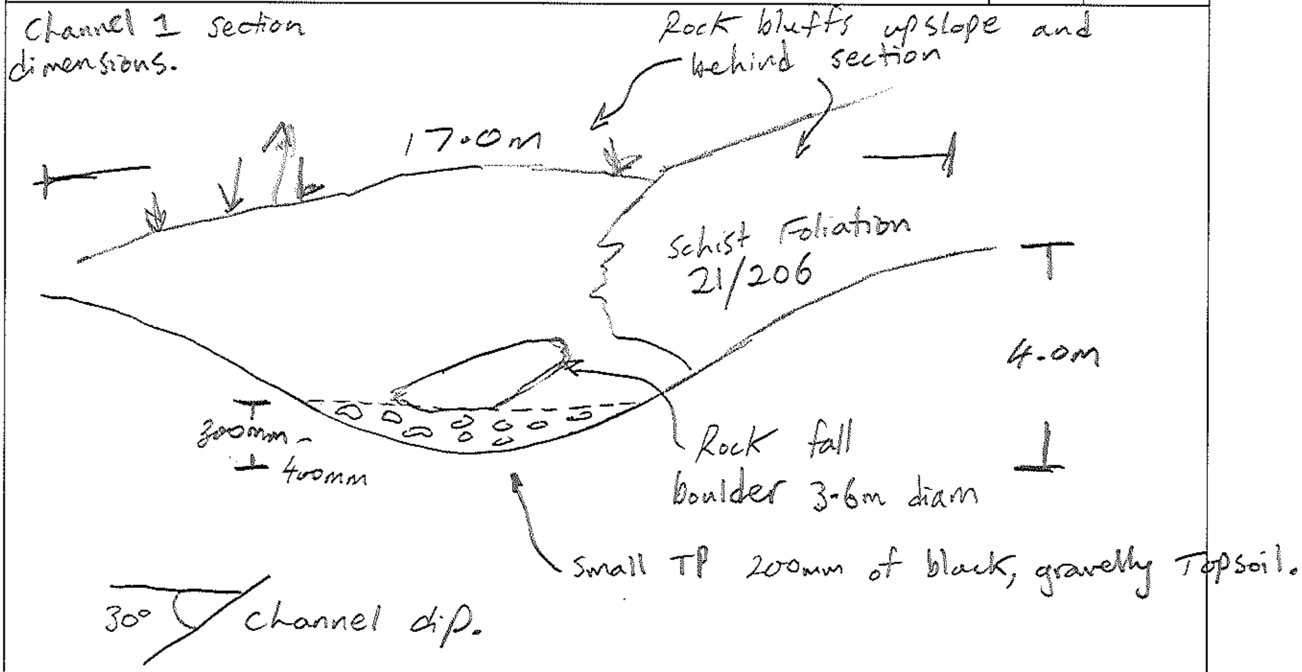
Section Number: 18a		



Angularity	Angular.		
Depth of soil	Unknown., expected to be several metres.		
Average size	Coarse boulders 300 mm +.		
Max size	1.5m.		
Tightly interlocked or loose	Interlocked		
Scour erosion	None, no indications of any overland flow.		
Vegetation	Well established, mature trees, ferns, bushes		
Depth of Topsoil	100mm, good coverage.		

MTB track above. possibly diverting flow.

Section Number: 1b		



angularity	Angular Schist clasts		
Depth of soil	300mm-400mm of erodible bedload		
Average size	100mm		
Max size	3-6m – Rock fall boulder from bluff system in channel		
Tightly interlocked or loose	Bedload soil is loose, levee material is tightly interlocked		
Scour erosion	No prominant evidence of scour erosion although evidence of sheet flow.		
Vegetation	well vegetated in short green grass and well established trees. Vegetation between trees is light and open.		

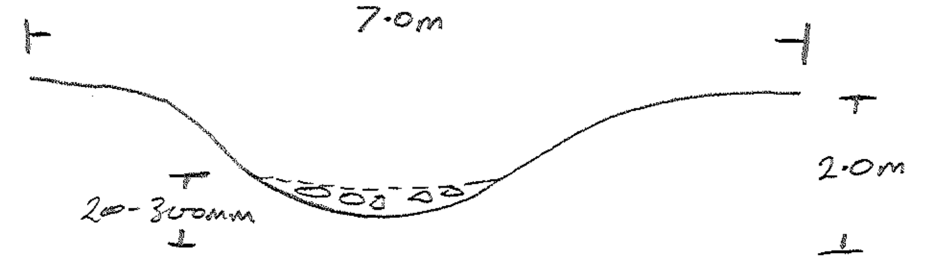
Comments: There is a steep (60-80°) rock gut which cuts through the extensive schist bluff system below where the stormwater is discharged from Skyline. Immediatly upon leaving the schist bluff system the rock gut opens up into a broad grassed channel with trees dispersed throughout the channel. Vegetation between the trees is light and open. Material within the channel is being shed from the schist bluff system via rock fall and slopewash.

Heavy rain in the storm area the previous night B4 inspection.

Note: Small TP dug with hammer into the base of channel along section line 1. 200mm of black, gravelly Topsoil ~~w~~ minor fine tree roots. clasts are grey, angular schist fragments (shed from rock fall upslope.)

Section Number: 2b		

channel ② section dimensions



34° channel dip

→ Little evidence of gravels, cobbles etc.

angularity	Angular to sub-angular schist clasts.
Depth of soil	200-300mm: Predom consits of topsoil, organic material and vegetation.
Average size	100mm
Max size	700mm – Rock fall boulder
Tightly interlocked or loose	Bedload soil is loose/soft – levee material is tightly interlocked.
Scour erosion	No evidence of scour erosion though sheet flow is evident (ground surface is smoothed over)
Vegetation	Short green grass and young braken fern with well established trees. Vegetation amongst the trees is light and open.

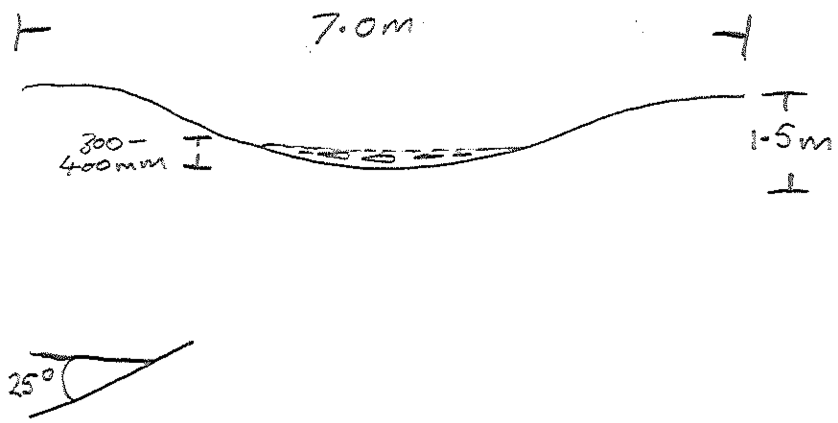
Comments: Approximately 60-70m below where the rock gut leaves the schist bluffs the single defined channel opens up and the channel becomes less distinct. The channel disperses onto an open slope. The genesis of the material is still being strongly influenced by rock fall and slope wash from the above bluff system.

Heavy overnight rain the previous night before investigations.

Note: TP dug in channel along section ② with hammer. 250mm of well developed black, Topsoil w trace of gravel. G = f-M. Below 250mm soil becomes gravelly w schist cobbles.

Section Number: 3b		
Section through bend in channel.		

Channel Section (3)

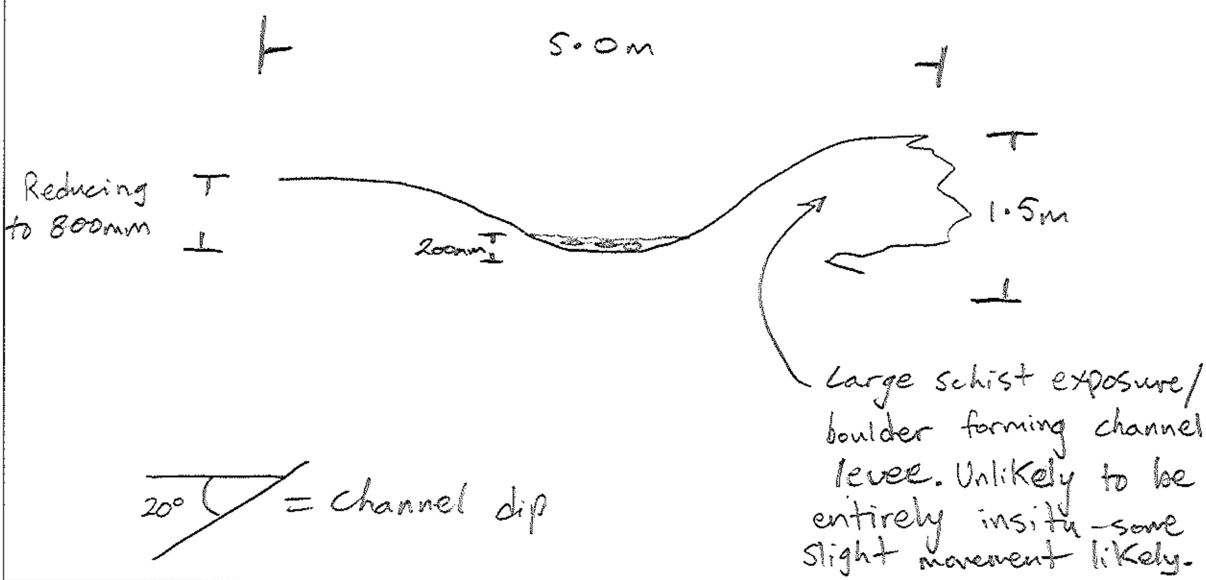


angularity Angular schist clasts (very rarely visable)		
Depth of soil 300-400mm		
Average size 100mm (There are vertually no clasts exposed in base	of channel.)	
Max size 3.0m – Exposed on channel levee		
Tightly interlocked or loose Loos/soft organic debris bedload - Tightly	interlocked levee's	
Scour erosion None whatsoever!		
Vegetation Green moss, dead leaves, well established trees within	base	
of channel.		

Comments: There is no evidence of scour erosion whatsoever! The channel is heavily choked full of dead organic debris (branches, trees etc.) There are vertually no clasts (schist) exposed in the base of the channel as the channel gravels are covered in Topsoil.

Note: TP dug in base of channel with hammer. 300mm of well developed black, Topsoil w some fine roots. Gravel clasts were only encountered at 300mm bgl.

Section Number: 4b		
Section through bend in channel.		

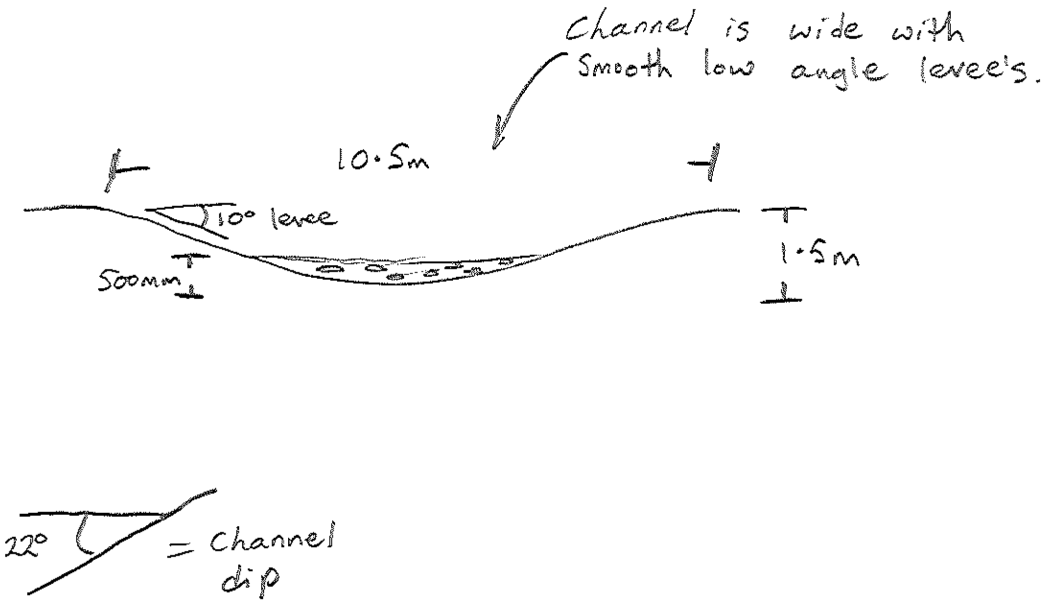


angularity Angular schist clasts		
Depth of soil 200mm		
Average size 100mm difficult to estimate as vertually no clasts exposed in channel		
Max size 1.3m angular schist boulder		
Tightly interlocked or loose Loose/soft organic debris in channel bedload		
Scour erosion None whatsoever!		
Vegetation Green moss, dead leaves, well established trees and		
dead organic debris (branches trees etc.)		

Comments: As seen further upslope there is no scour erosion in the channel bed. The channel is choked with organic debris. Vertually no gravel or cobble clasts are visable on the ground surface in the channel bed.

Note: TP dug with hammer in channel bed. 200mm of black Topsoil and decaying organic material (pine needles etc) with some fine roots. An angular schist cobble was struck at 200mm bgl.

Section Number: 5b		
Immediately above schist bluff		

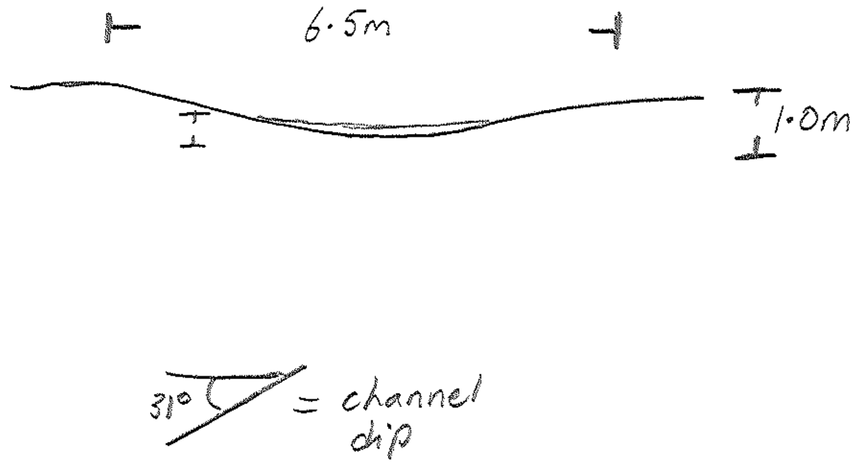


angularity Angular schist clasts		
Depth of soil 500mm		
Average size 100mm – Vertually no gravels or cobbles exposed in channel bed		
Max size 900mm angular schist boulder		
Tightly interlocked or loose Tightly interlocked levees – Loose/soft organic bedload.		
Scour erosion None whatsoever even off the bluff edge.		
Vegetation Short green grass, well established trees, dead leaves,		
organic debris including branches and dead trees.		

Comments: Immediately above the rock bluff there is a more well defined channel. Upslope of this up towards the previous bluff the channel is shallow, broad and ill-defined.

Note: dug TP with hammer. 300mm of well developed black, Topsoil with some fine roots and trace gravel. G=f-m.

Section Number: 6b		
Between to schist bluffs		



angularity Angular schist clasts		
Depth of soil 500mm		
Average size 100mm – Vertually no clasts exposed on channel bed		
Max size 2-2m angular schist boulder		
Tightly interlocked or loose Loose / Soft bedload, Tightly interlocked levee's		
Scour erosion None whatsoever!		
Vegetation Short green grass, Young bracken fern, well established pine trees.		

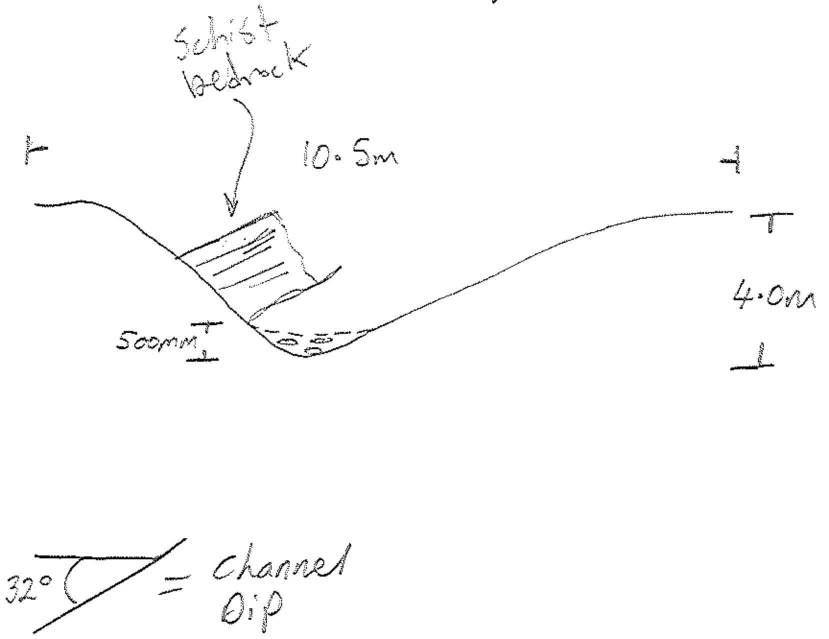
Comments: The channel between the two bluffs is shallow, broad and ill-defined. It is choked full of organic debris including branches and dead trees. The channel is better defined where it cuts over the edge of the schist bluffs. There is no evidence of scour erosion or any recent erosion. Schist clasts are being shed via rock fall/roll from the above Schist bluff. (Slope colluvium/slope debris, post glacial).

Note: Dug small TP with hammer. 150mm of black, / Dark grey. well developed Topsoil with minor fine roots. Angular schist cobbles at 150mm bgl.

Description

Section Number: 7b

Below catchment at beggining of channel

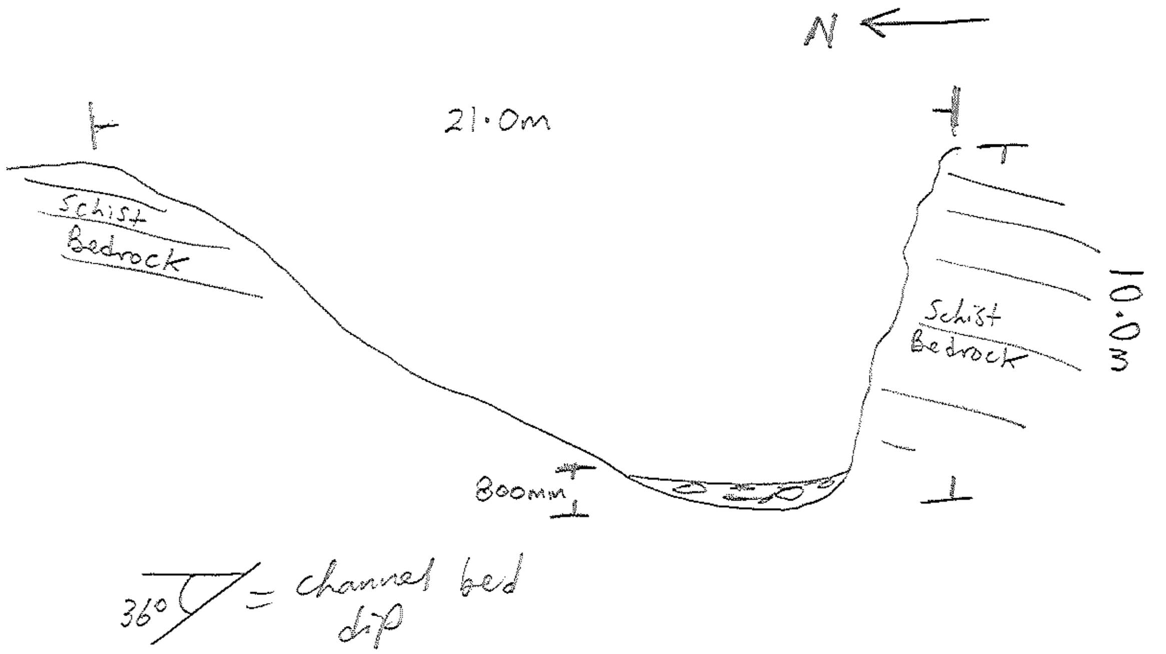


angularity Angular		
Depth of soil Approx 500mm		
Average size 50mm } There are very few clasts visable on the	ground	
Max size 600mm } surface due to topsoil & organic cover.		
Tightly interlocked or loose Soft/loose channel bed – Levees are	schist bedrock	
Scour erosion None		
Vegetation Well established trees, braken fern and short	green grass	
and dead organic debris – branchs and trees.		

Comments: Schist bedrock is exposed in the channel walls and in the channel bed immediatley upstream of the channel section. The catchment is immediatley upstream of the section.

Note: Dug TP with hammer. 60mm of black well developed Topsoil underlain by black/dark grey, gravelly organic SILT w minor sand. G=f-c, S=f. G = angular.

Section Number: 8b



Angularity: Angular Schist clasts

Depth of Soil: Approx 800mm - Schist bedrock outcrops in base of channel.

Ave size: 60mm

Max size: 900mm - angular schist boulders.

Loose/soft channel bed ✓ - Channel levee's are schist bedrock

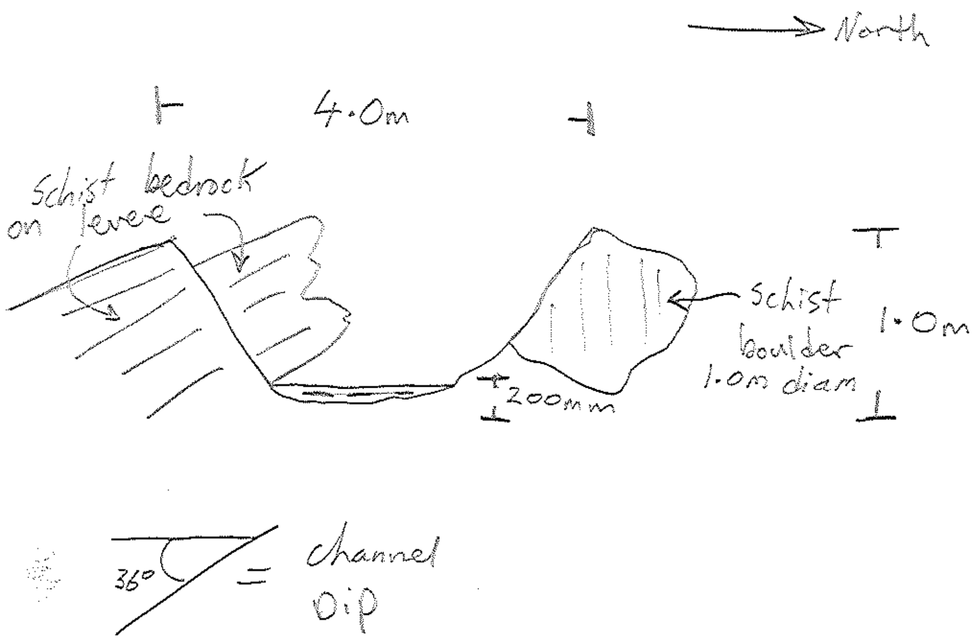
No Scour erosion

Vegetation: Braken Fern, well established trees and organic debris including dead branches & trees.

Comments: Section taken through a deep gully/channel above the carpark and above the intersection with the other channel.

Note: dug TP with hammer. 30mm of black Topsoil underlain by black gravelly organic SILT w trace cobbles. G=f-c, G=angular.

Section Number 9b		

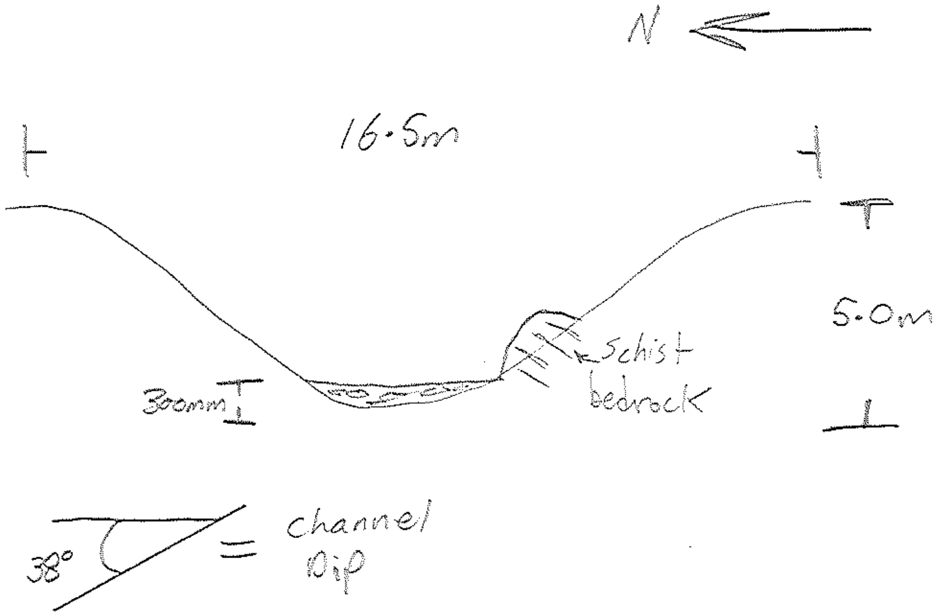


angularity – Angular schist clasts		
Depth of soil 200mm – mostly ~~topsoil~~ overlying schist bedrock		
Average size 50mm		
Max size 500mm angular schist boulder		
Tightly interlocked or loose Soft/loose bedload – schist bedrock levees		
Scour erosion None		
Vegetation Short green grass, bracken fern, well established trees		
on banks of channel – organic debris dead trees, branchs.		

Comments: Schist bedrock is exposed on the channel sides and in the base of the channel immediately upslope of this section. A thin veneer of organic SILT and organic debris covers the schist bedrock.

Note: TP dug with hammer. Black, gravelly organic SILT w minor cobbles & boulders observed to 400mm depth. G=f-c, g=angular.

Section Numbe 10b		

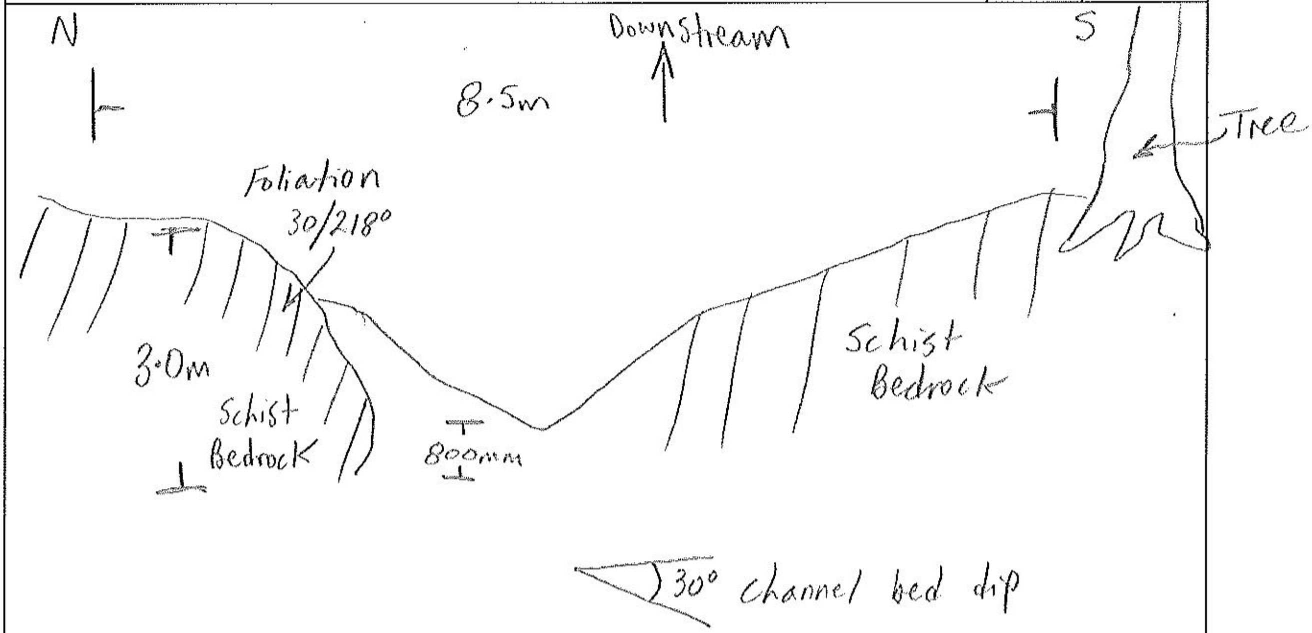


Angular schist clasts		
Ave diam: 60mm - very little exposure of clasts on channel surface		
Max diam: 600mm angular schist clasts		
Depth of soil: Approx 300mm of loose/soft organic SILT and organic debris overlying schist		
Scour Erosion: None		
Loose/soft channel bedload with schist bedrock levee's		
Vegetation: Short green grass, bracken fern, well established trees		
Channel is choked full of organic debris.		

Comments: Above the skyline carpark for the bottom terminal.

Note: Dug TP ~~w~~ hammer: 50mm black, Topsoil underlain by Organic SILT ~~w~~ some gravel & minor cobbles. G = f-c, g = angular.

Section Number: 11 b		

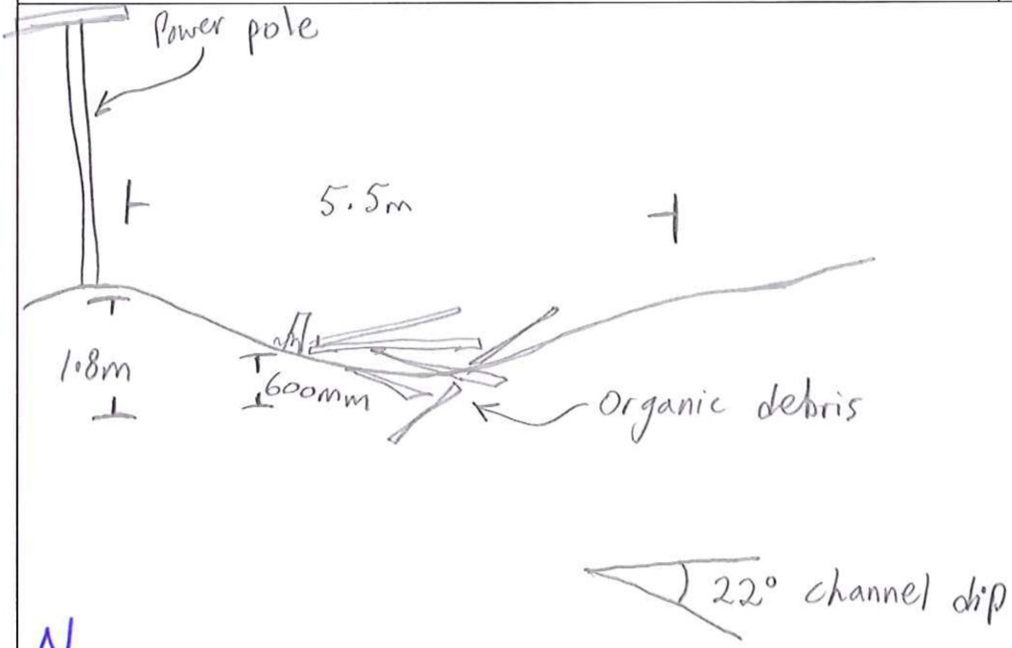


Angularity Angular		
Depth of soil 800mm + overlying schist bedrock		
Average size 40mm		
Max size 200mm		
Tightly interlocked or loose loose soil in bed / schist bedrock on levees		
Scour erosion None		
Vegetation Dead organic debris - leaves and sticks / trees		
Depth of Topsoil 60mm of poorly developed topsoil		

Hand dug test pit: 60mm, black poorly developed topsoil
400mm, light brown organic SILT and organic debris - wood fragments, rootlets, Fiberous organic material
100mm, grey/brown gravelly organic SILT angular schist clasts

Note: No loose blocks with the potential to move.

Section Number: 12 b		

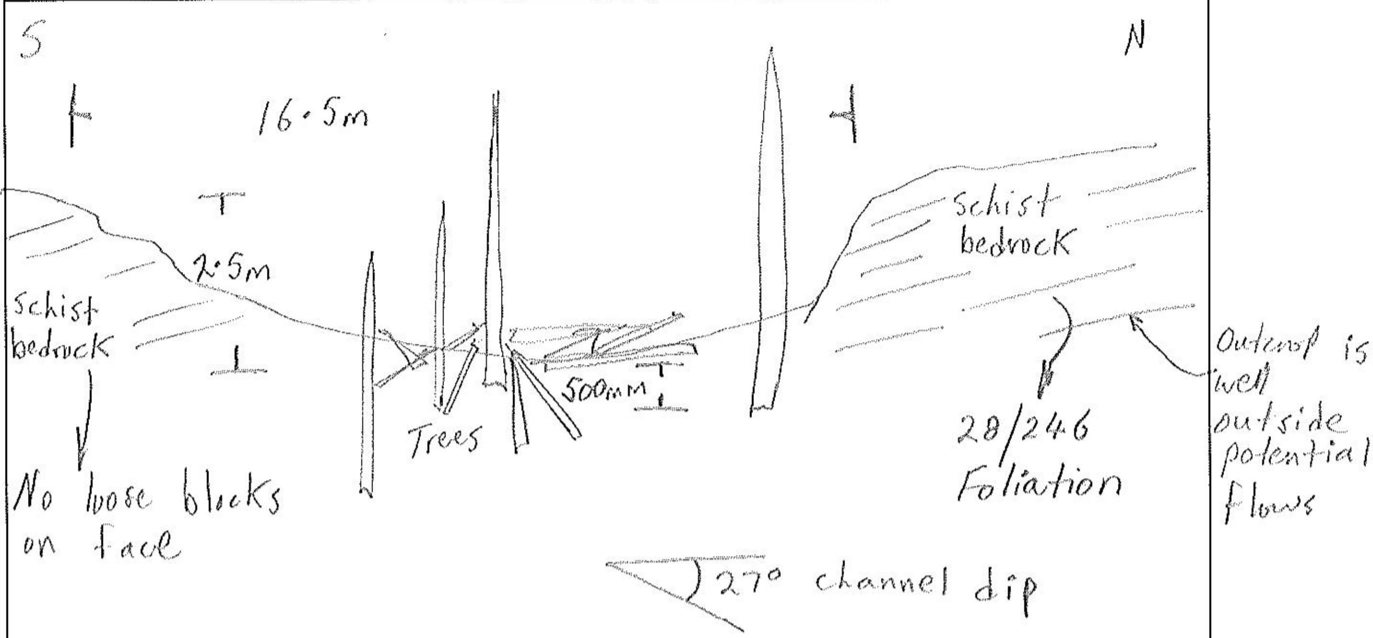


Angularity – No clasts exposed on the surface		
Depth of soil 600mm – potentially mobile		
Average size 40mm		
Max size – No clasts exposed		
Tightly interlocked or loose Loose in channel bed		
Scour erosion None		
Vegetation Bracken Fern, long green grass, broom, dead	organic	debris
Depth of Topsoil 300mm poorly developed black topsoil		

The channel bed is choked with organic debris which include dead trees and branches & tree stumps.

Hand dug TP: 300mm poorly developed black topsoil
↳ organic SILT & fiberous organic material
Overlying gravelly organic SILT w some cobbles
↳ cobbles angular to sub-rounded
↳ max size 100mm

Section Number: 13b

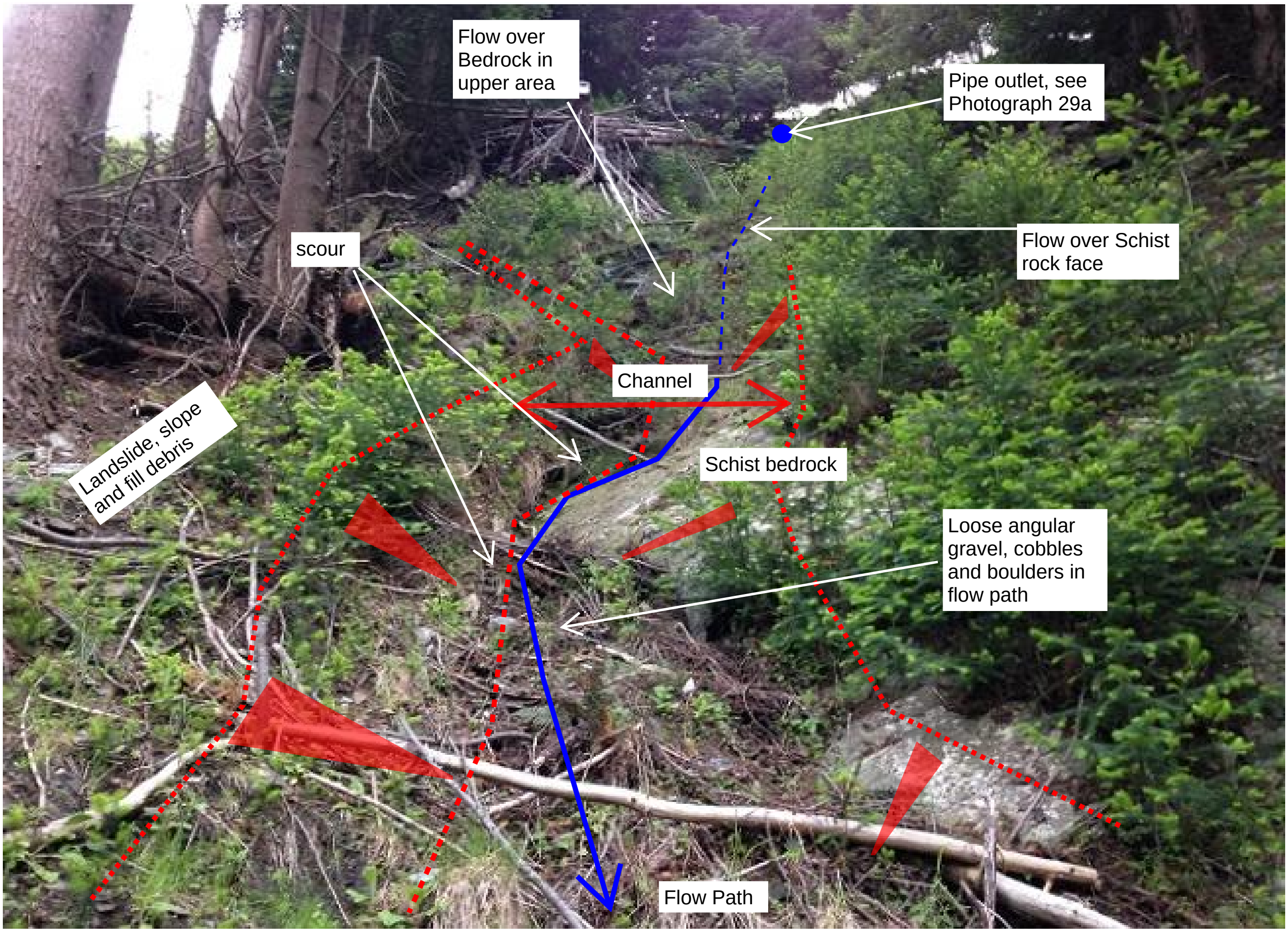


Angularity	Angular schist clasts
Depth of soil	✓ 500mm potentially ✓ mobile
Average size	50mm
Max size	1·8m - angular
Tightly interlocked or loose	✓ Loose / soft in channel bed
Scour erosion	None - organic debris appears to be heaped around trees.
Vegetation	Bracken Fern & well established trees / Dead organic debris
Depth of Topsoil	60mm well developed black topsoil

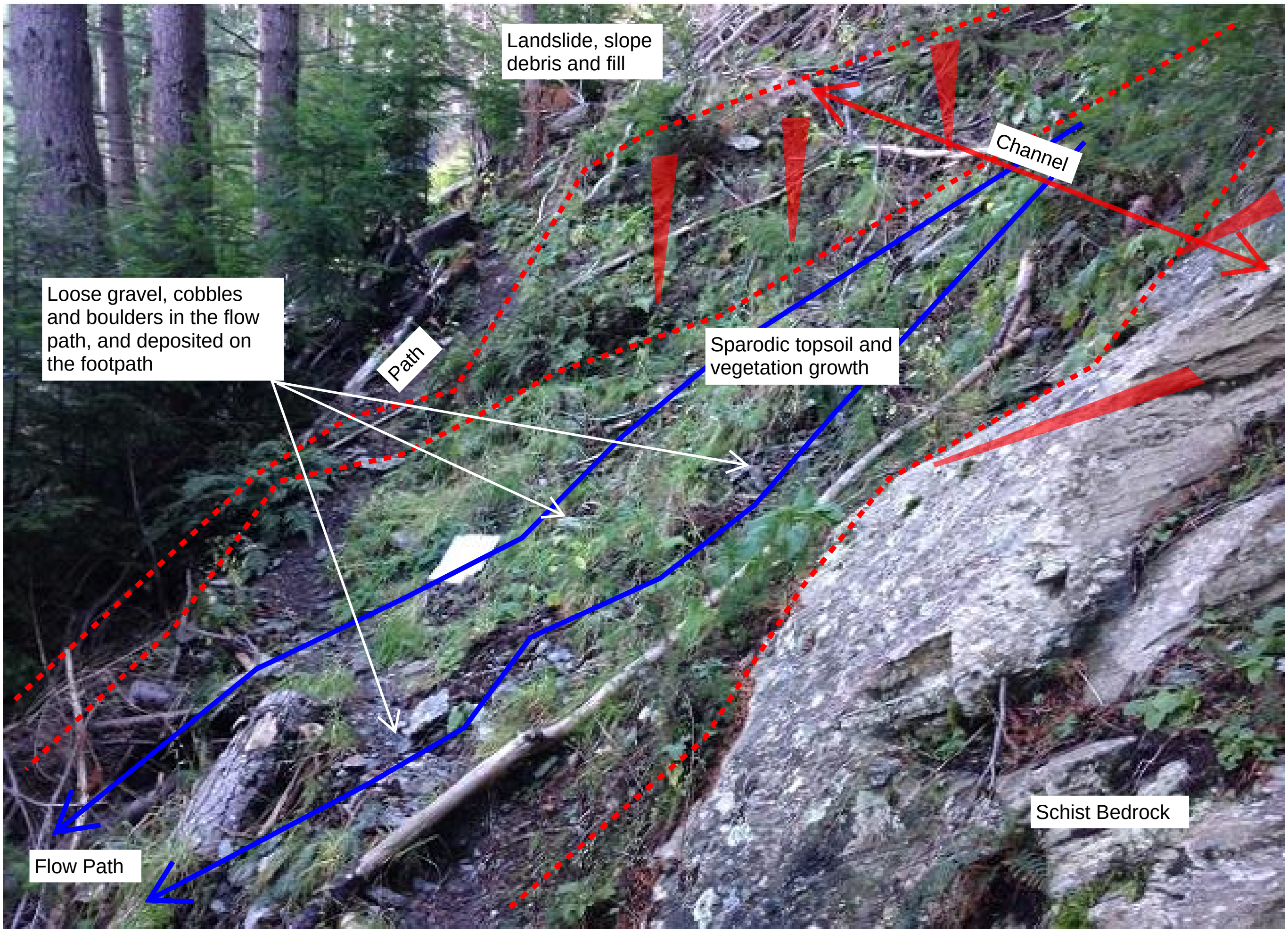
Hand dug TP: 60mm well developed black topsoil overlying 400mm+ of black gravelly organic SILT
g=angular, g=f-c
to sub-angular

DL1 - Photographs

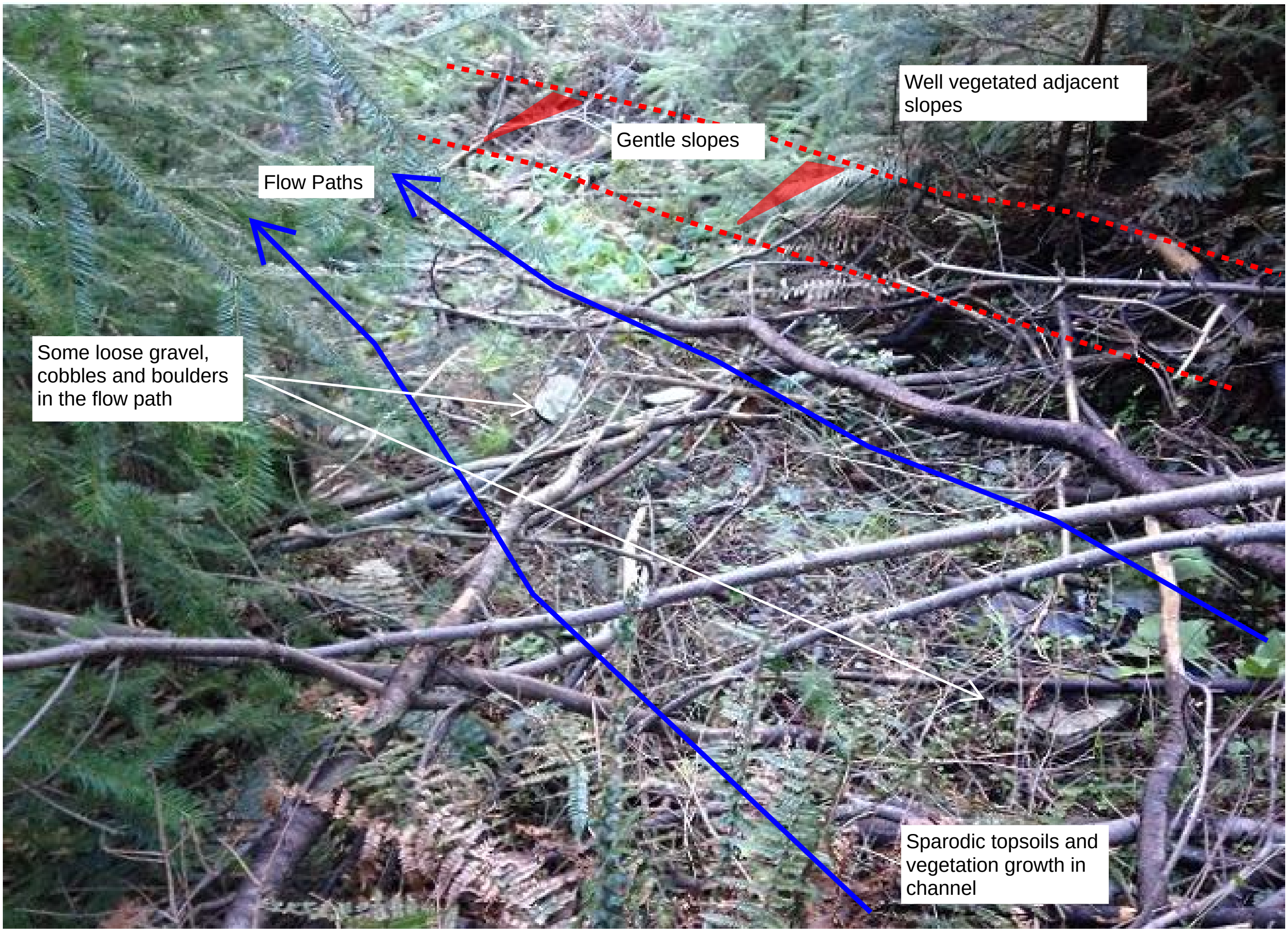
Photo A	Description
1a	Section 1a
2a	Section 2a
3a	Section 3a
4a	Section 4a
5a	Section 5a
6a	Section 6a
7a	Section 7a
8a	Section 8a Base of the Channel
9a	Path at the end of the channel top of stairs
10a	Lower areas – not channels
11a	Lower areas..
12a	Section 9a
13a	Section 10a
14a	Section 11a
15a	Section 12a
16a	Section 13a
17a	Section 14a
18a	Section 15a
19a	Section 16a
20a	No Channel area between 16a and 17a (7528)
21a	Section 17a
22a	Section 18a
23a	Base of the Channel Cemetery
24a	Southern DL1 flow path Wood slopes, topsoil and glacial till
25a	Southern Area, large schist block – translational movement
26a	GNS- top area bluff
27a	GNS -
28a	GNS concrete
29a	Top channel



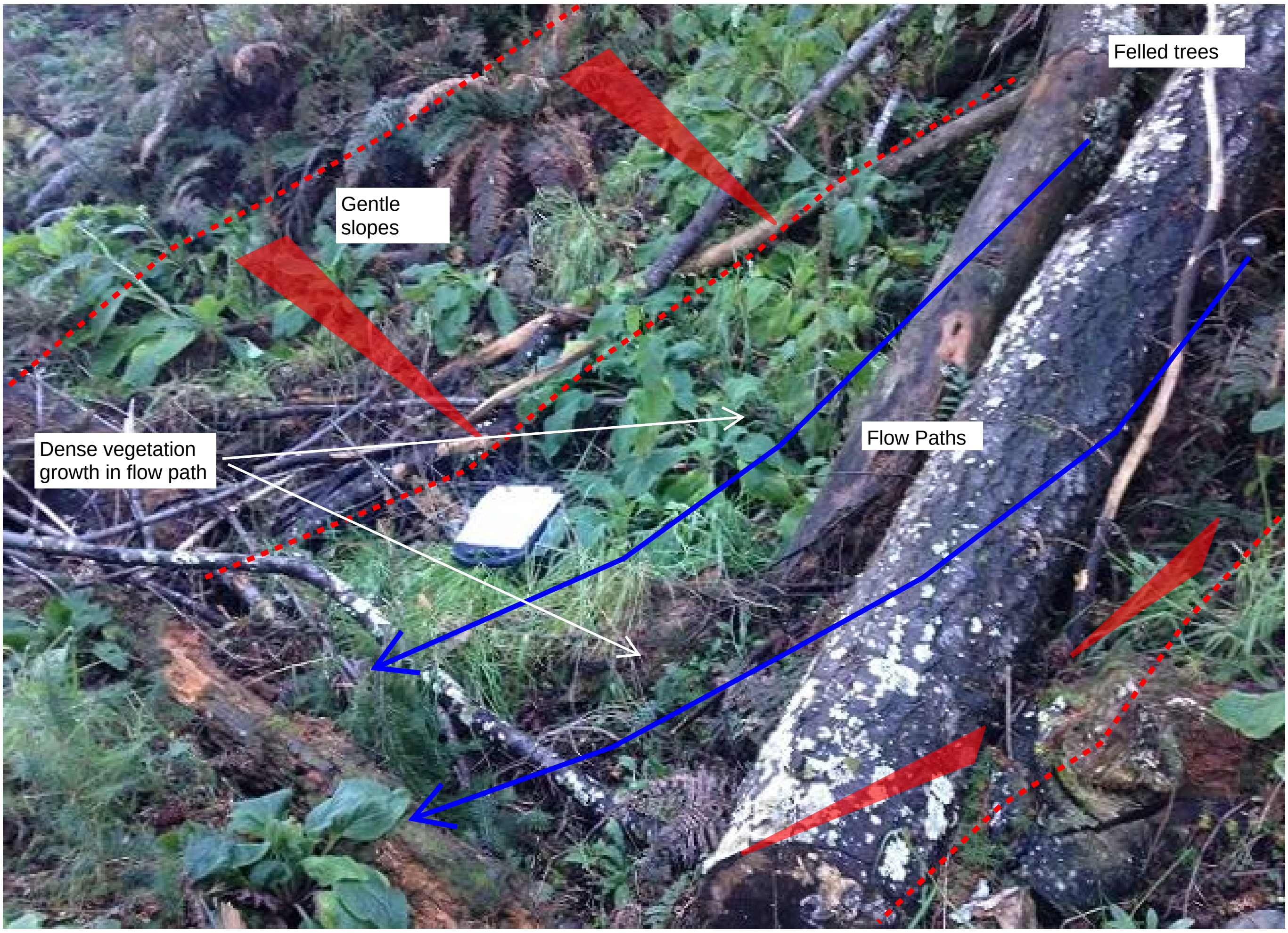
Photograph 1a. DL1 flow channel Section 1a



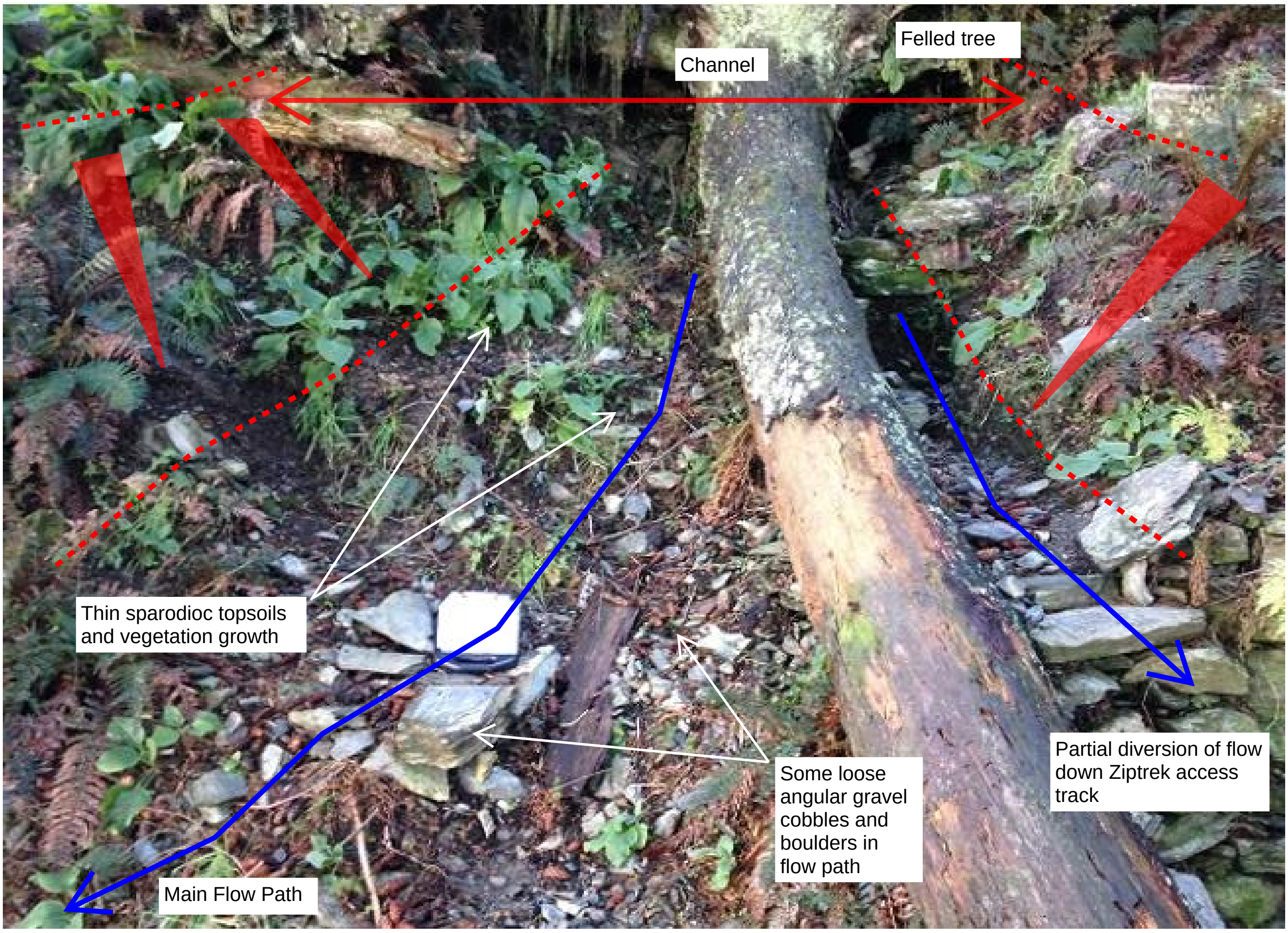
Photograph 2a. DL1 Flow Channel Section 2a.



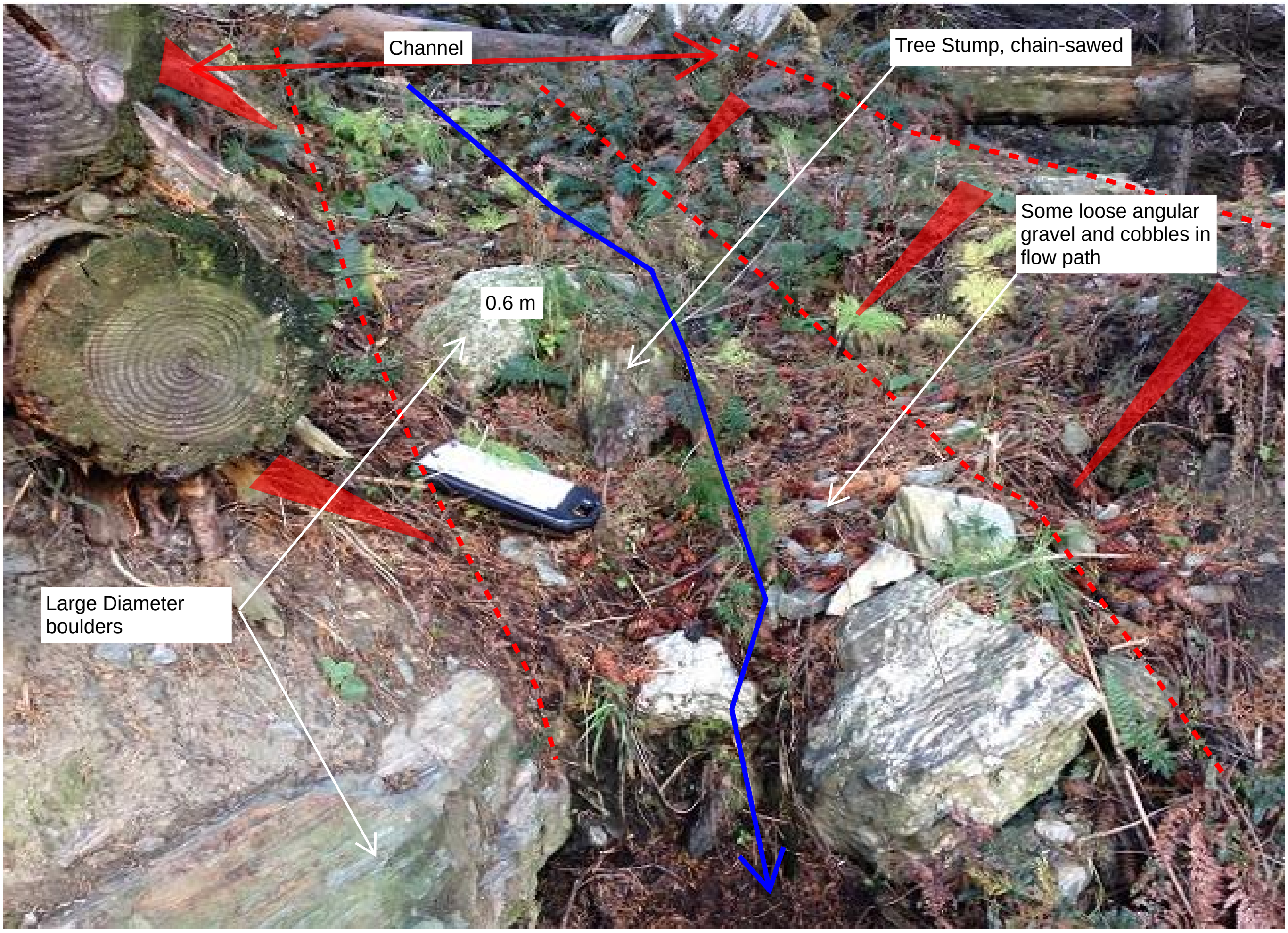
Photograph 3a. DL1 flow channel section 3a



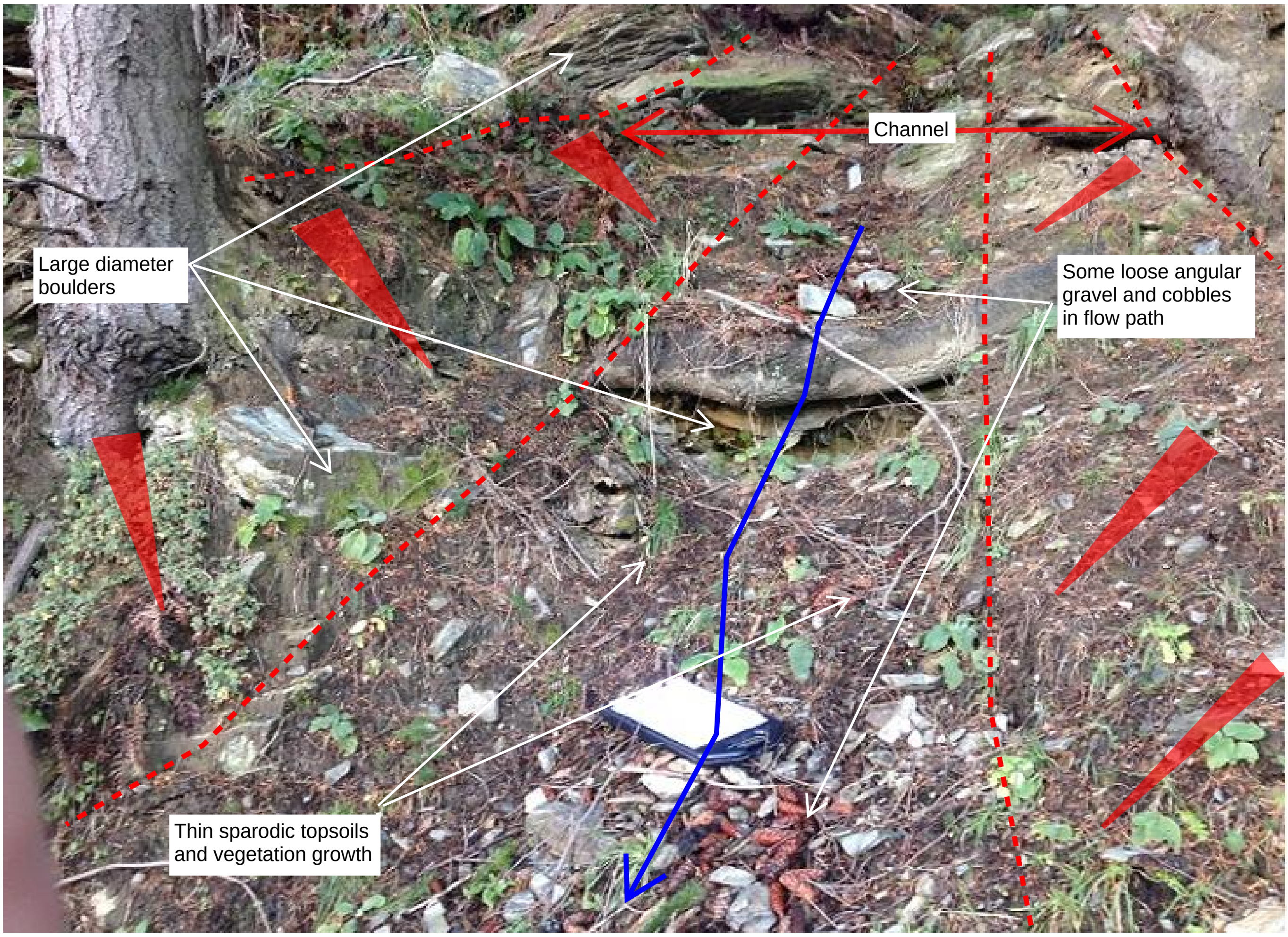
Photograph 4a. DL1 flow channel Section 4a.



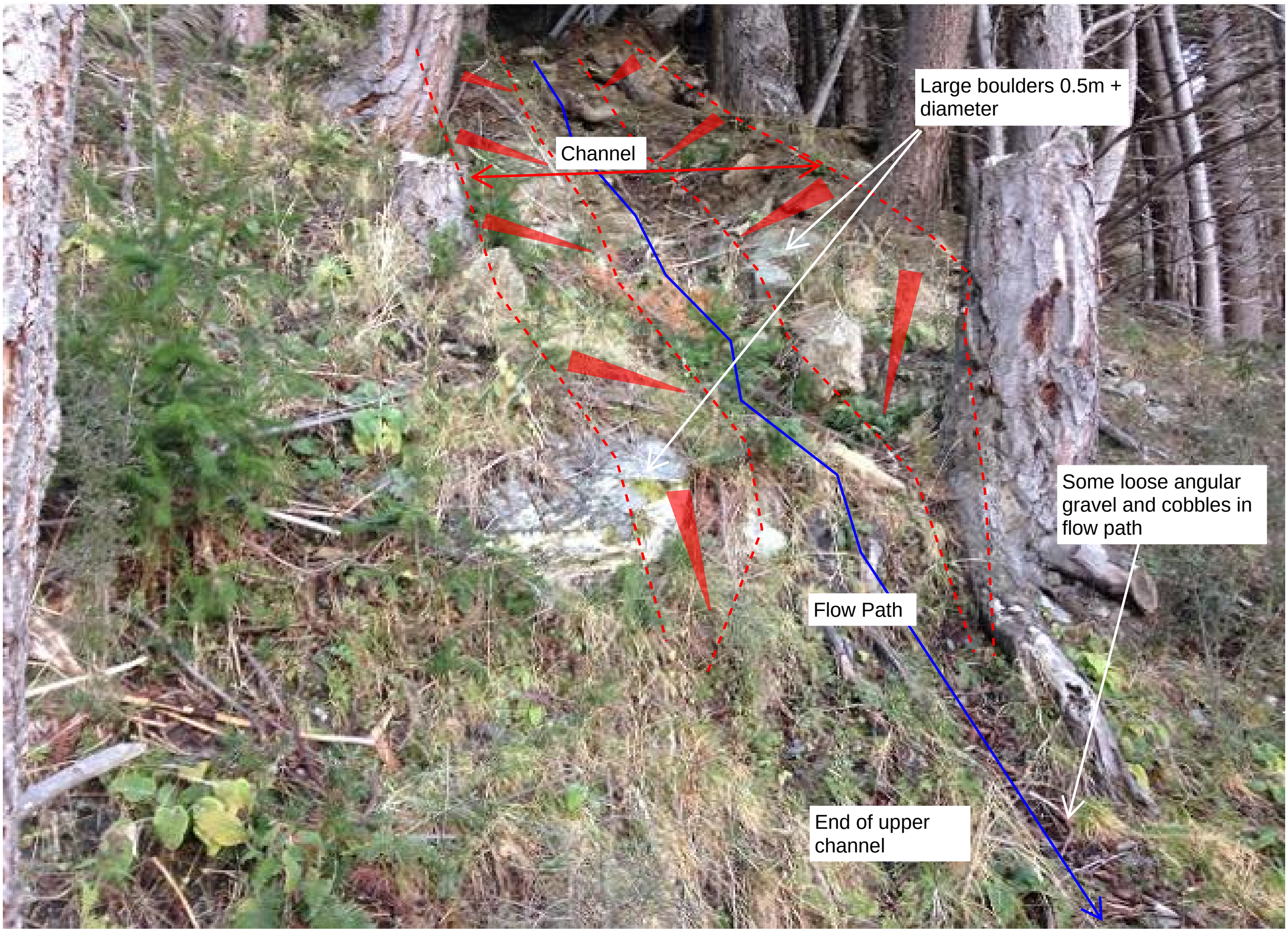
Photograph DL1 flow channel Section 5a



Photograph 6a. DL1 flow channel Section 6a



Photograph 7a. DL1 flow channel Section 7a.



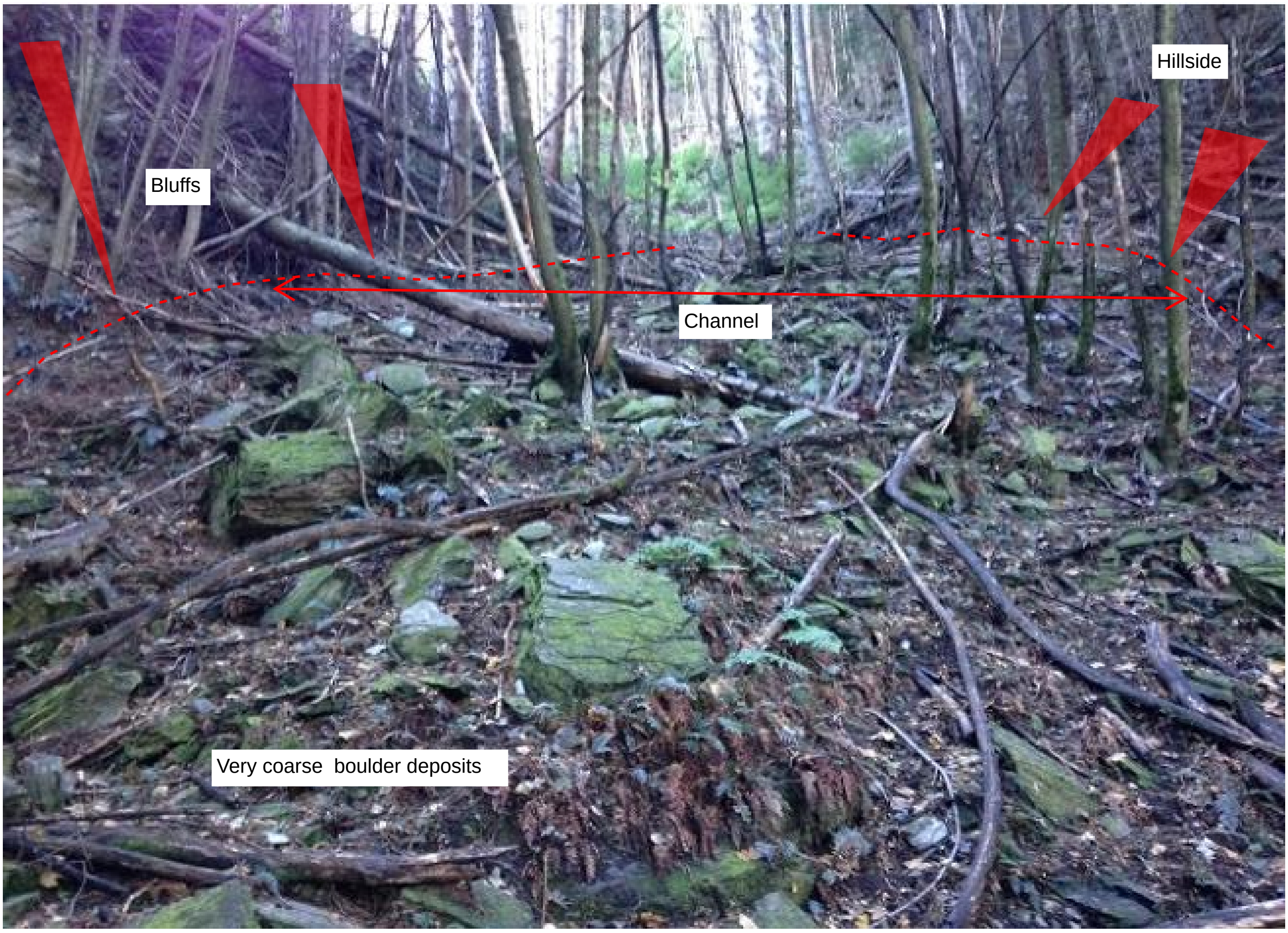
Photograph 8a. DL1 flow channel Section 8a.

Photograph 9a. End of the defined DL1 channel directly above a Ziptrek access track

Photograph 10a. Area below DL1 defined Channel, no clear flow path, dispersal/bifurcation of overland flows expected.
No existing or active channel indicating current flows don't significantly influence this area.

Photograph 11a. Slope area immediately below the defined DL1 channel. Vegetated slopes no clear scour/erosion or active down slope movement of materials. Very dense vegetation comprising young pines on the left of the photograph.

Photograph 12a. Flow Channel Section 9a.



Photograph 13a. Flow channel Section 10a.

Photograph 14a. Flow channel Section 11a.

Photograph 15a. Flow channel Section 12a

Photograph 16a. Flow channel Section 13a

Photograph 17a. Flow channel section 14a.

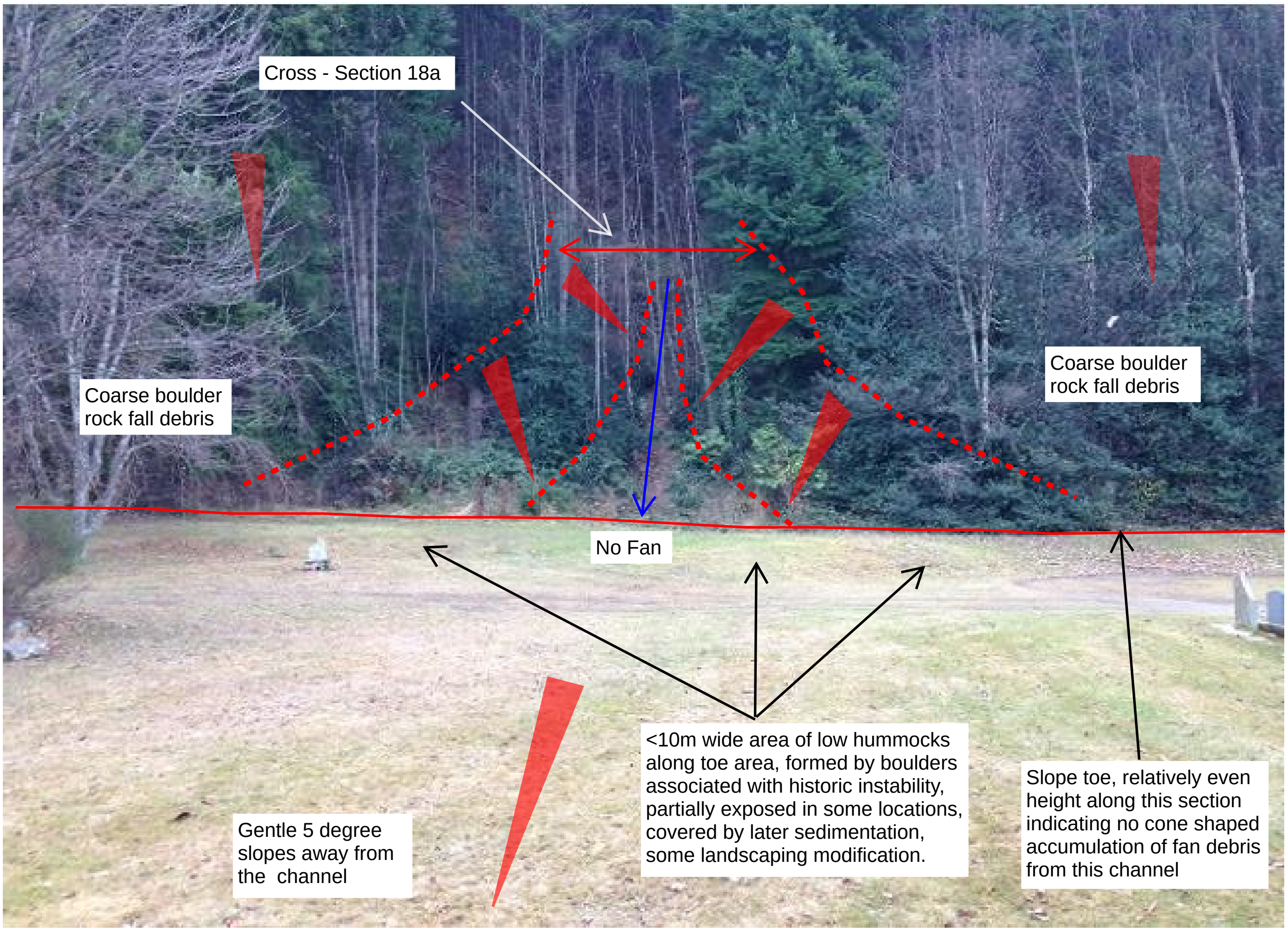
Photograph 18a. Flow channel Section 15a.

Photograph 19a. Flow channel Section 16a.

Photograph 20a. Area with no clear channel. Very rough, coarse boulder surface with dispersal and bifurcation of overland flows expected.

Photograph 21a. Flow channel Section 17a.

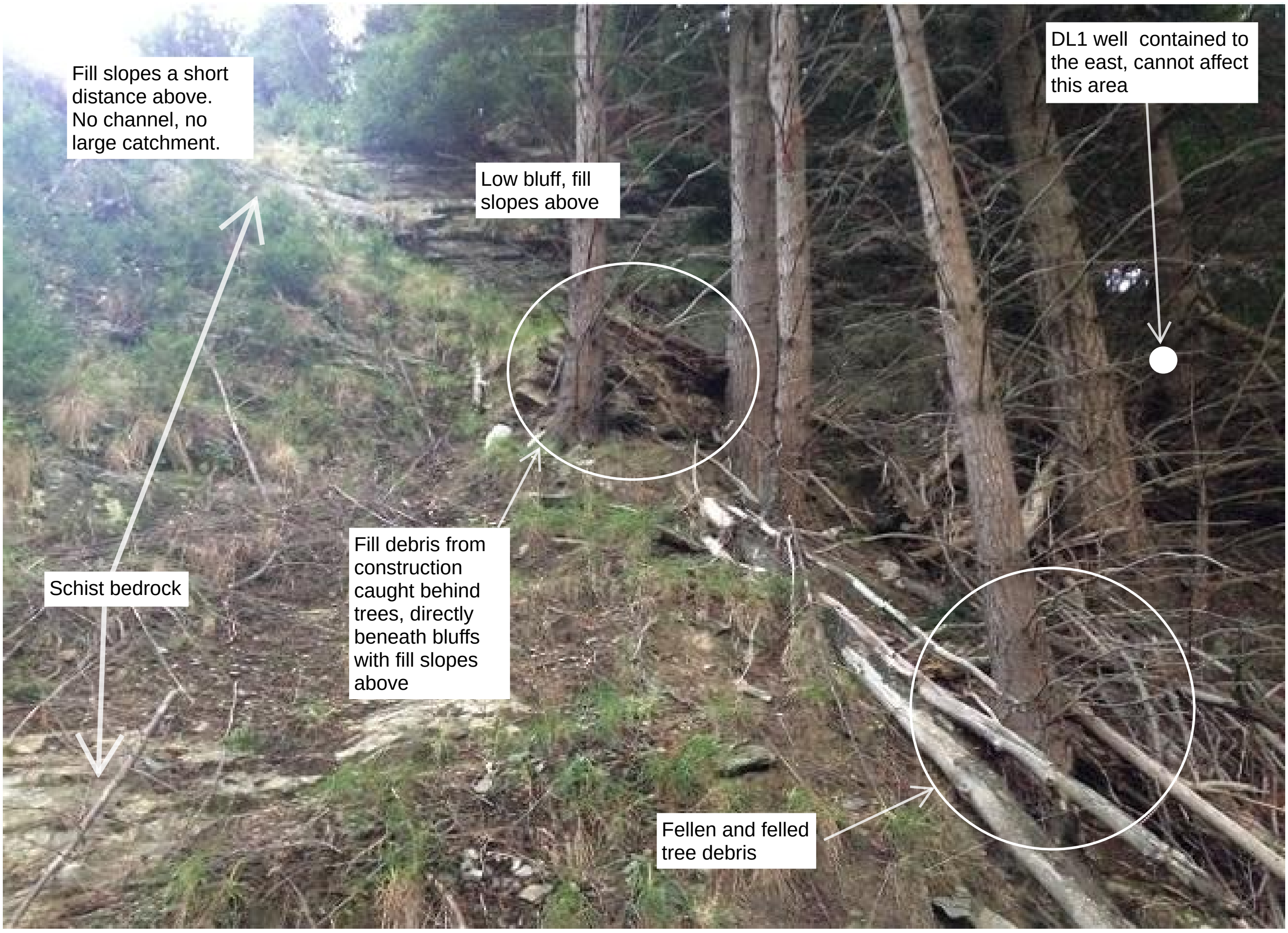
Photograph 22a. Flow channel Section 18a.



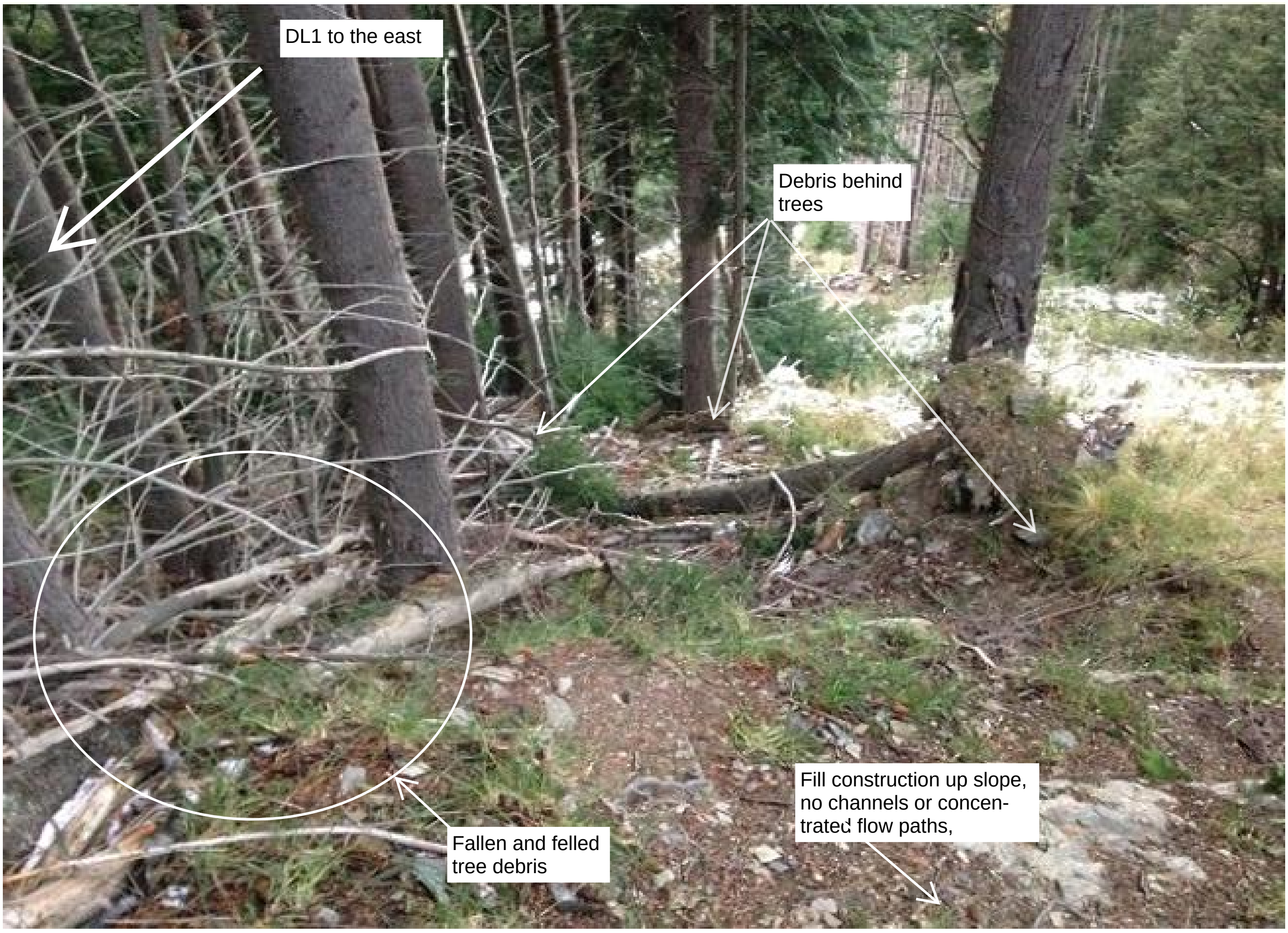
Photograph 23a. Base of the channel, slope toe area in Queenstown Cemetery

Photograph 24a. Typical forested slope beneath DL1, western areas. Forest cover, topsoil, colluvium and glacial till soils. No well defined channels

Photograph 25a. Large schist exposure typical of the landslide below DL1, southern areas. Consistent foliation orientation indicating translational movement of large schist blocks.

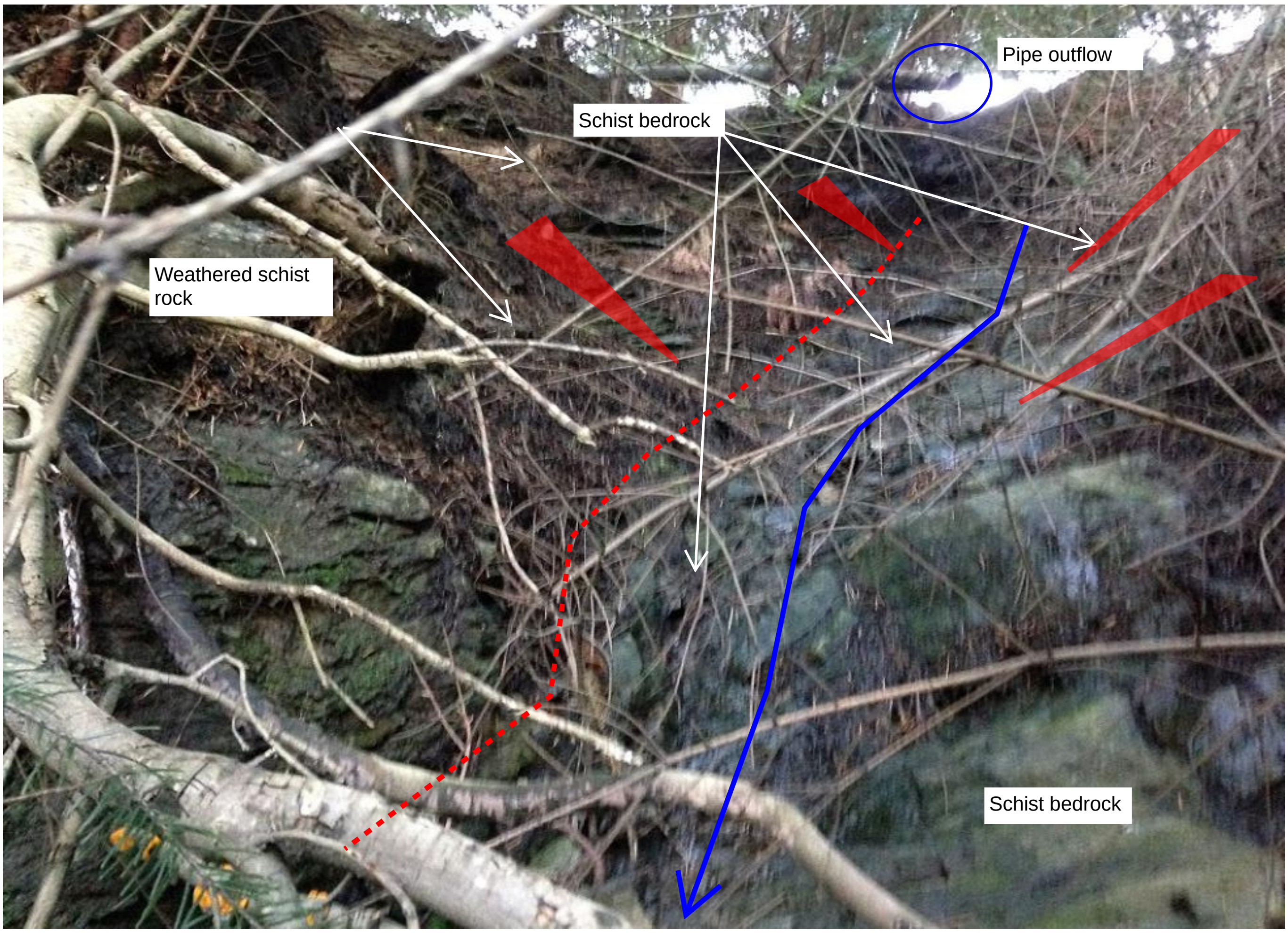


Photograph 26a. Debris behind trees a short distance below the skyline complex.



Photograph 27a. Soil and vegetion debris behind trees a short distance below the Skyline complex.

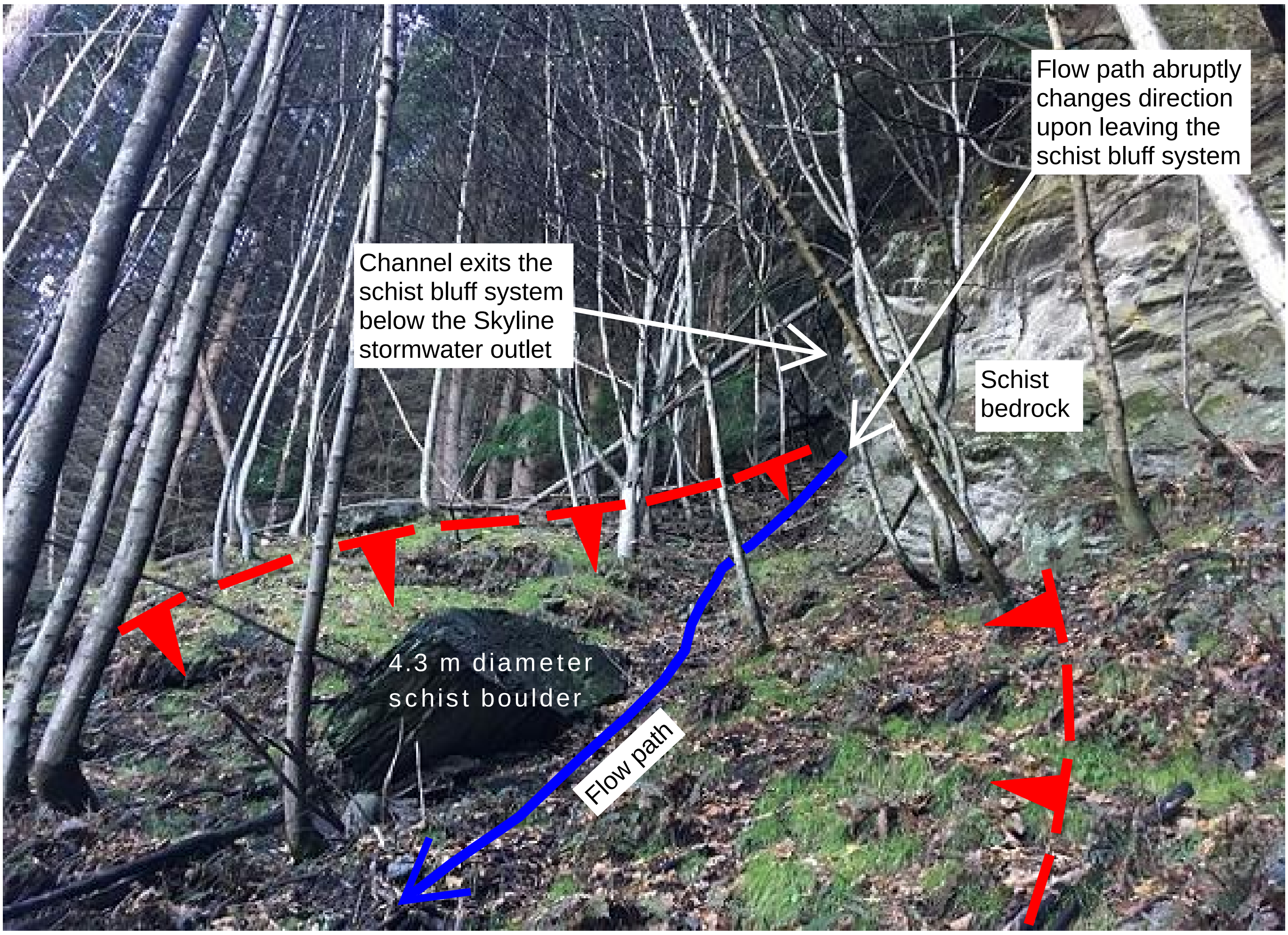
Photograph 28a. Concrete indicating the presence of fill materials



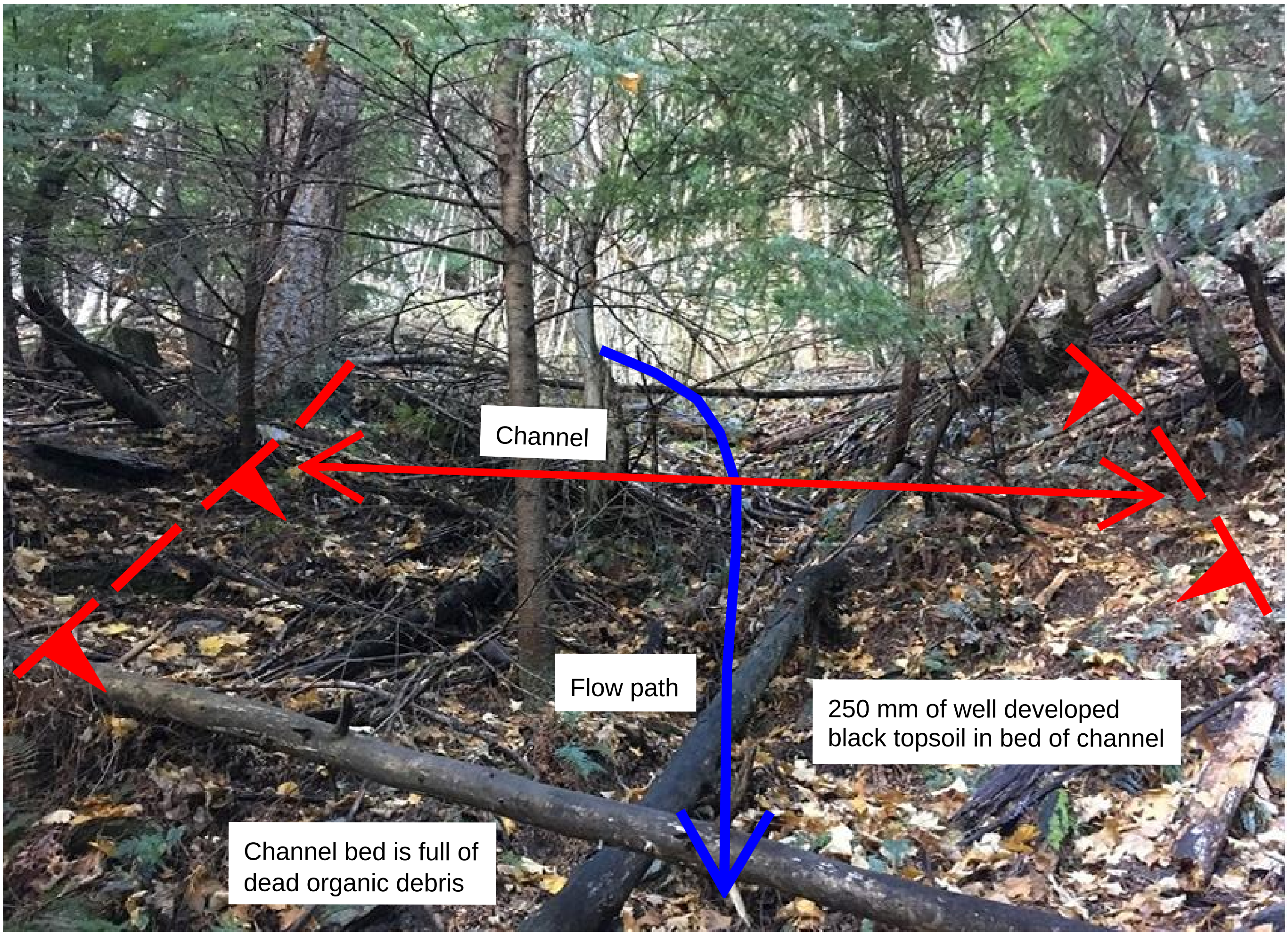
Photograph 29a. DL1 outflow onto rock at the top of the slope

DL2 - Photographs

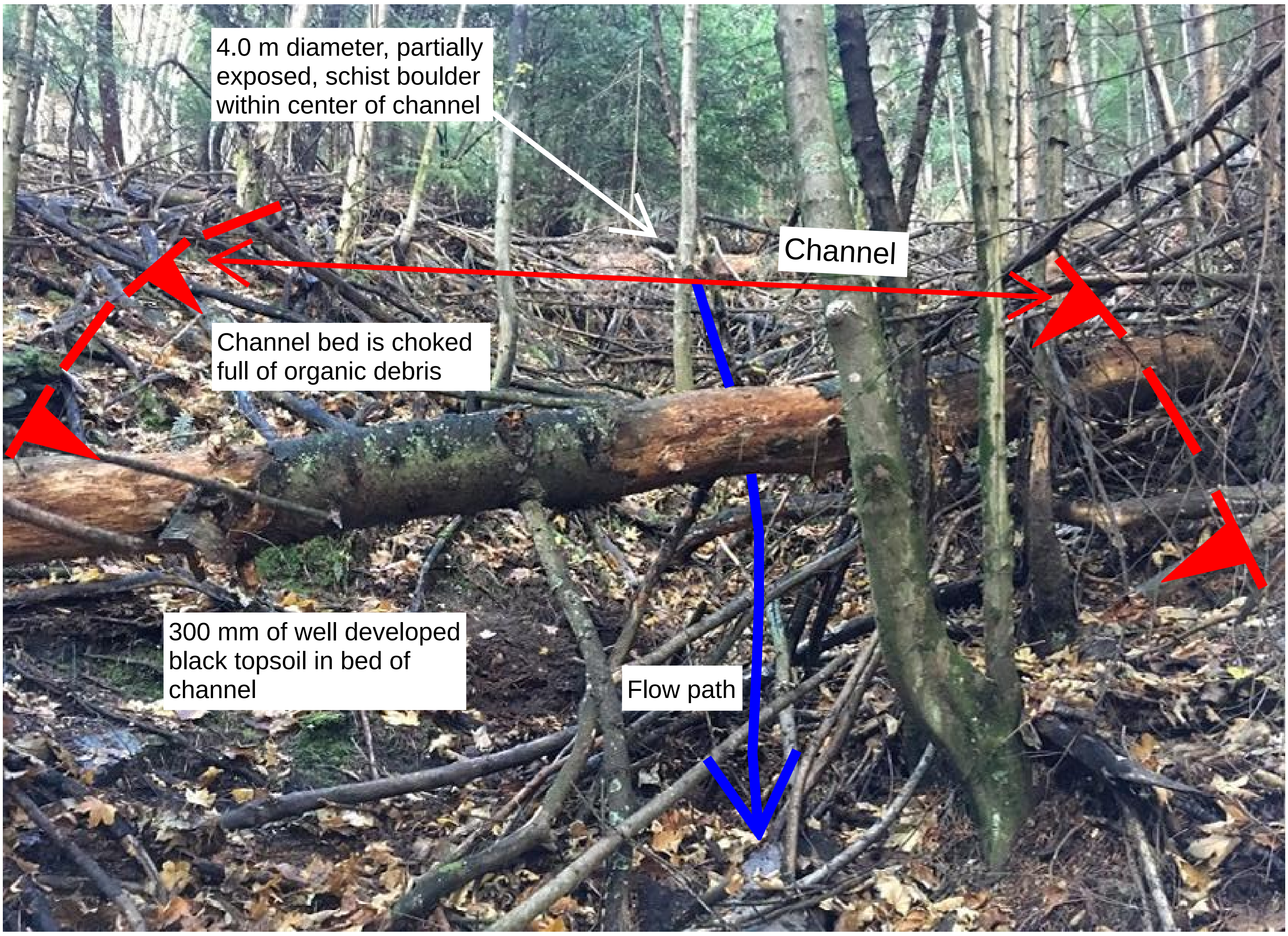
Photo A	Description
1b	Section 1b
2b	Section 2b
3b	Section 3b
4b	Section 4b
5b	Section 5b
6b	Section 6b
7b	Section 7b
8b	Section 8b
9b	Section 9b
10b	Section 10b
11b	Section 11b
12b	Section 12b
13b	Section 13b
14b	General photograph, see site plan for location
15b	General photograph, see site plan for location
16b	General photograph, see site plan for location
17b	General photograph, see site plan for location
18b	General photograph, see site plan for location
19b	General photograph, see site plan for location
20b	General photograph, see site plan for location
21b	General photograph, see site plan for location
22b	General photograph, see site plan for location



Photograph 1b. DL2 flow channel Section 1b. Flows discharge from the Skyline stormwater outlet above the schist bluff system.

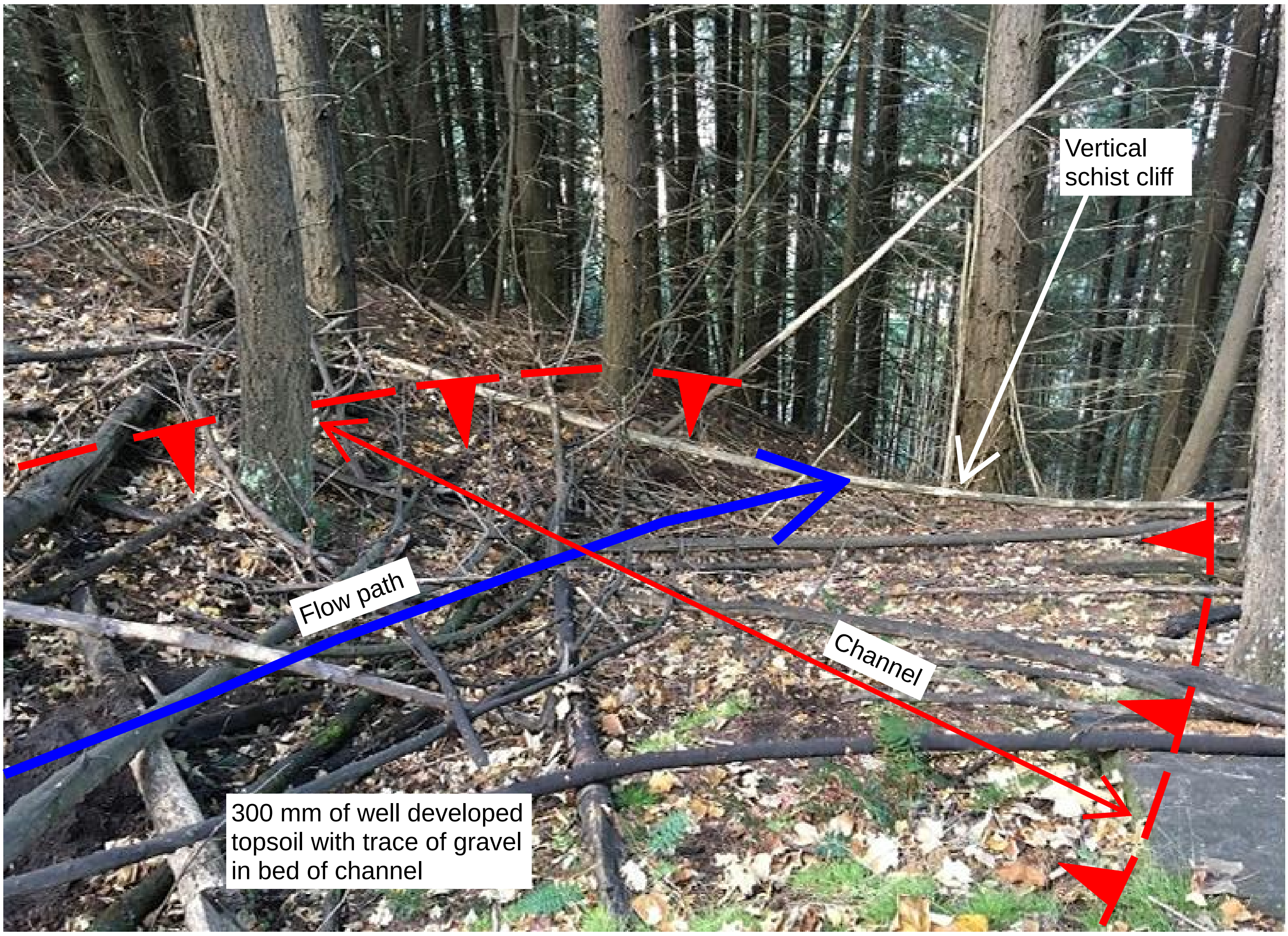


Photograph 2b. DL2 flow channel Section 2b. Immediately below Section 2b there is no clear flow path. Dispersal/bifurcation of overland flows is expected above a large, partly exposed, boulder blocking the channel.

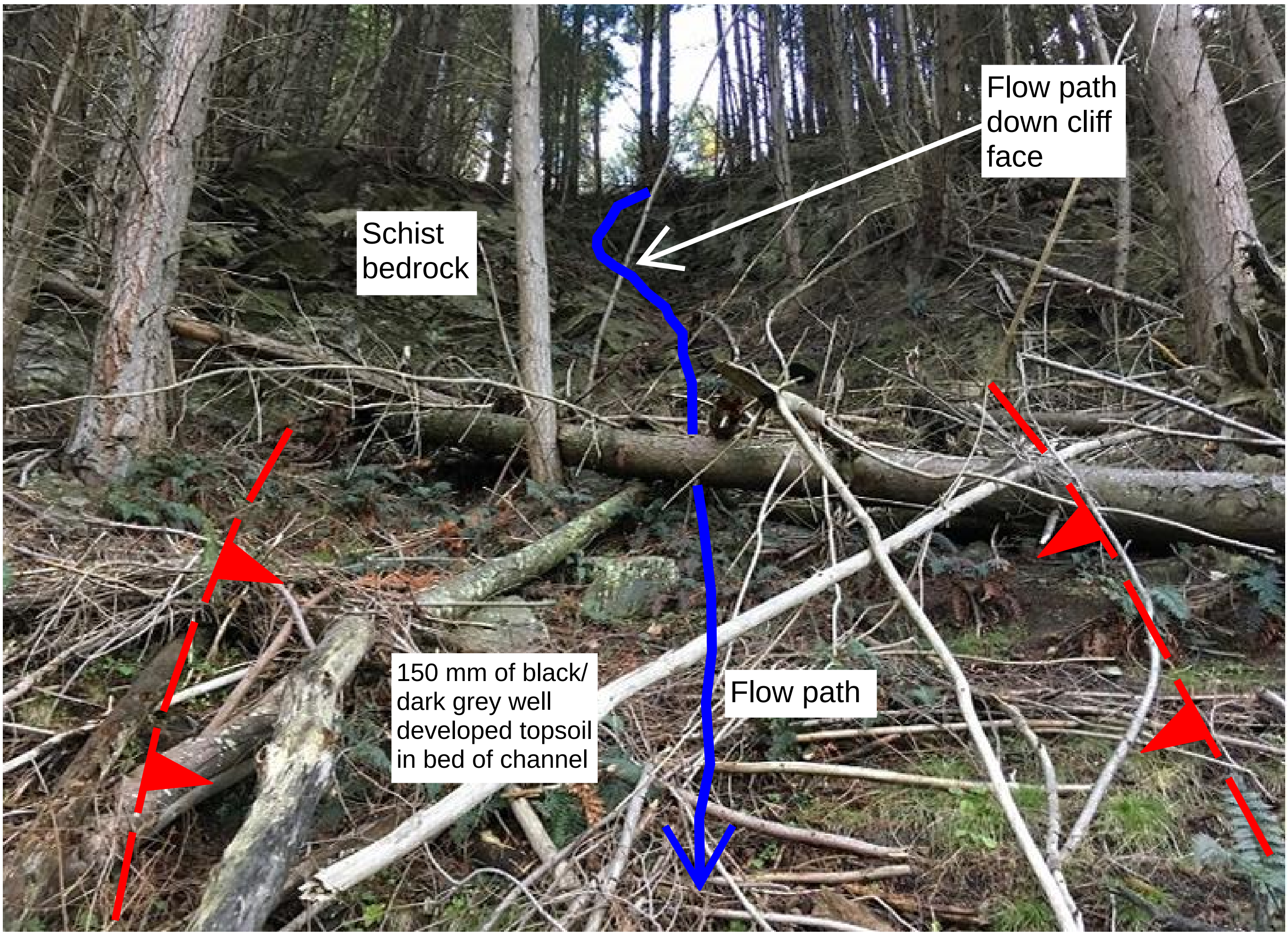


Photograph 3b. DL2 flow channel Section 3b, downstream of a schist boulder within the center of the channel. Poorly defined flow paths around either side of the boulder are visible. Channel bed is full of dead organic debris.

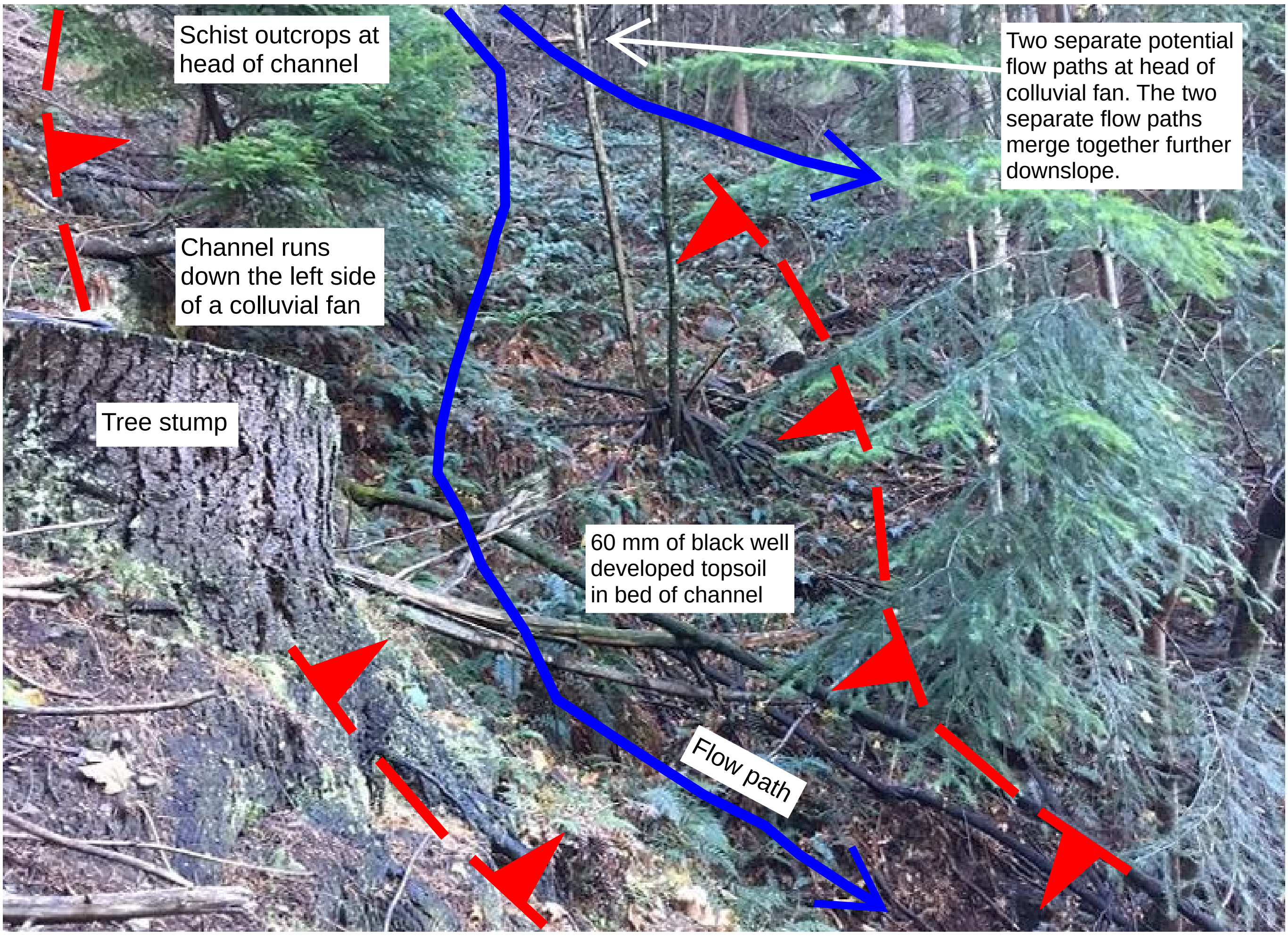
Photograph 4b. DL2 flow channel Section 4b. Heavy flows are likely to leave the channel and disperse/bifurcate across the downstream slope.



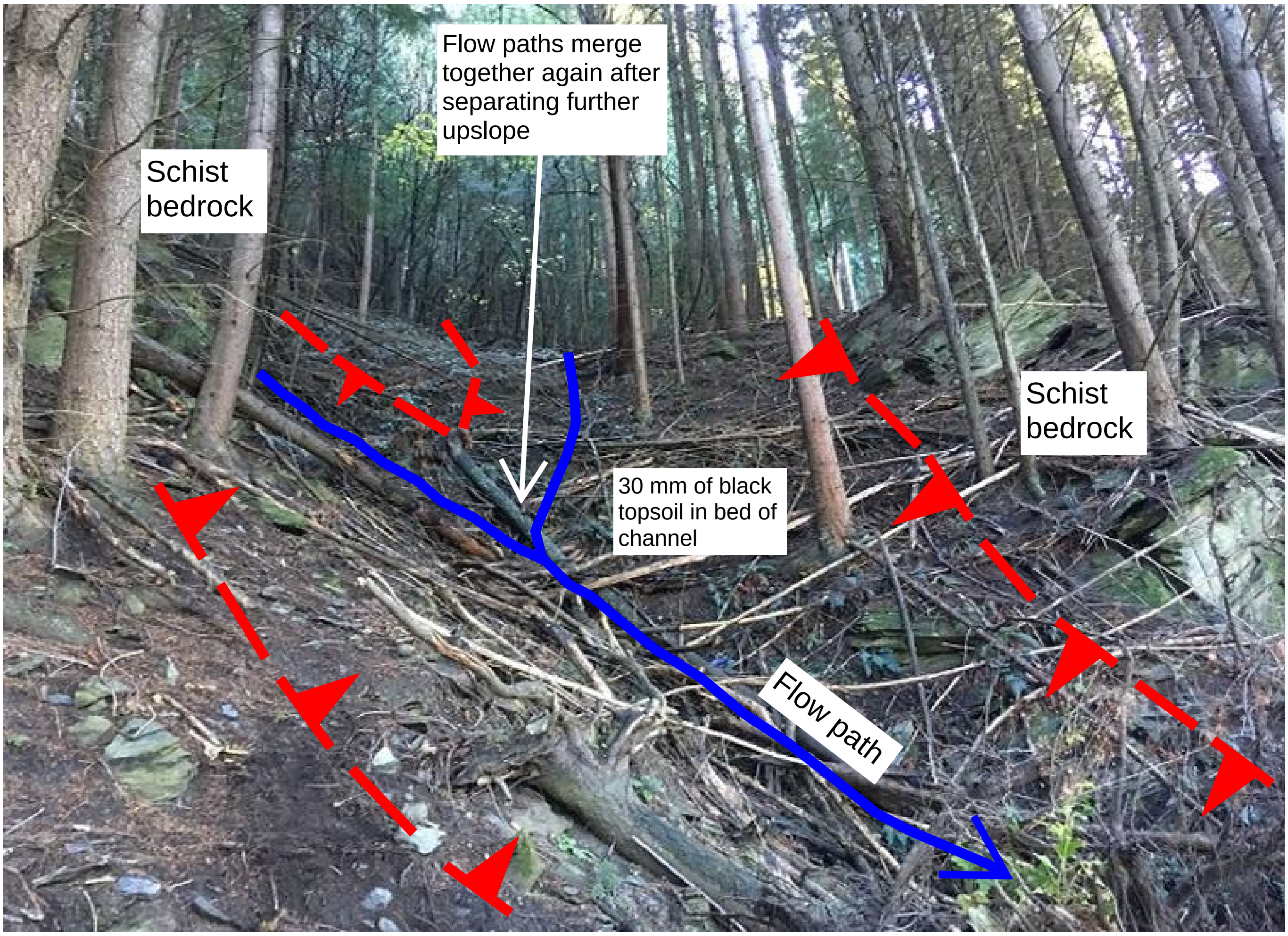
Photograph 5b. DL2 flow channel Section 5b. Flows drop down a 10 m high vertical schist bluff.



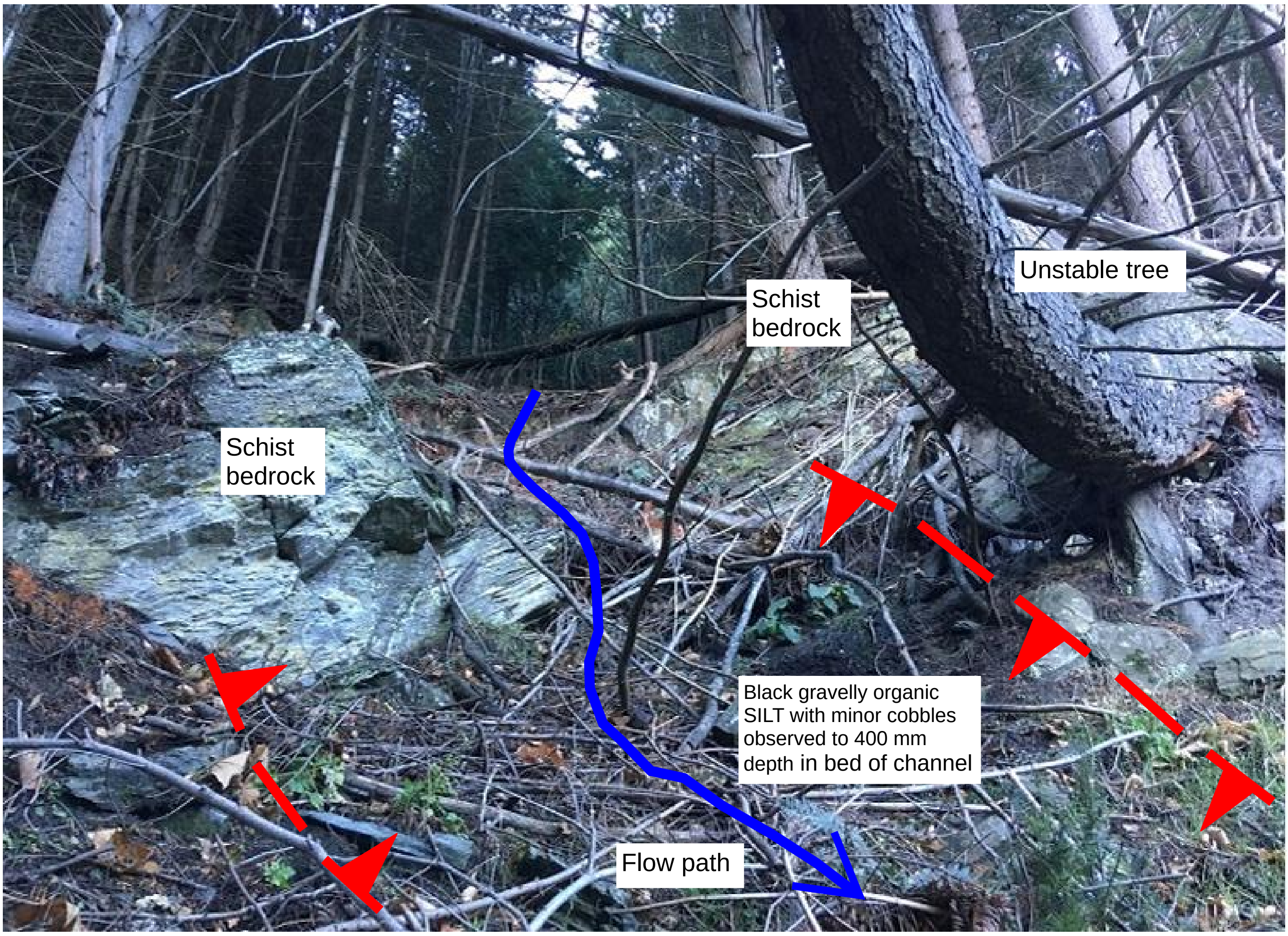
Photograph 6b. DL2 flow channel Section 6b.



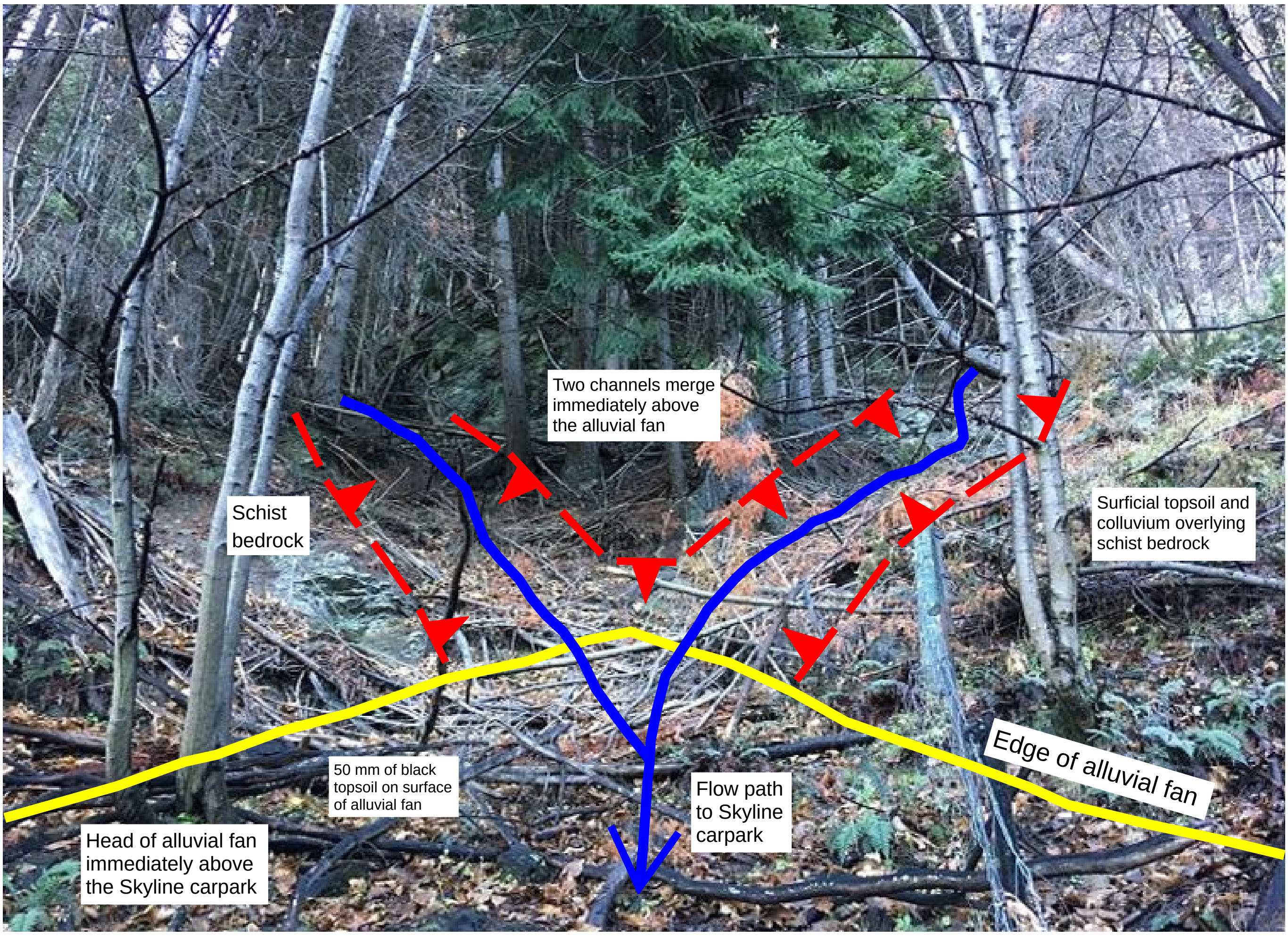
Photograph 7b. DL2 flow channel Section 7b. Flows coming down the bank from above have the potential to flow down one of channels which merge together again further downslope.



Photograph 8b. DL2 flow channel Section 8b. The two flow paths now merge back together again after separating further upslope above channel Section 7b.

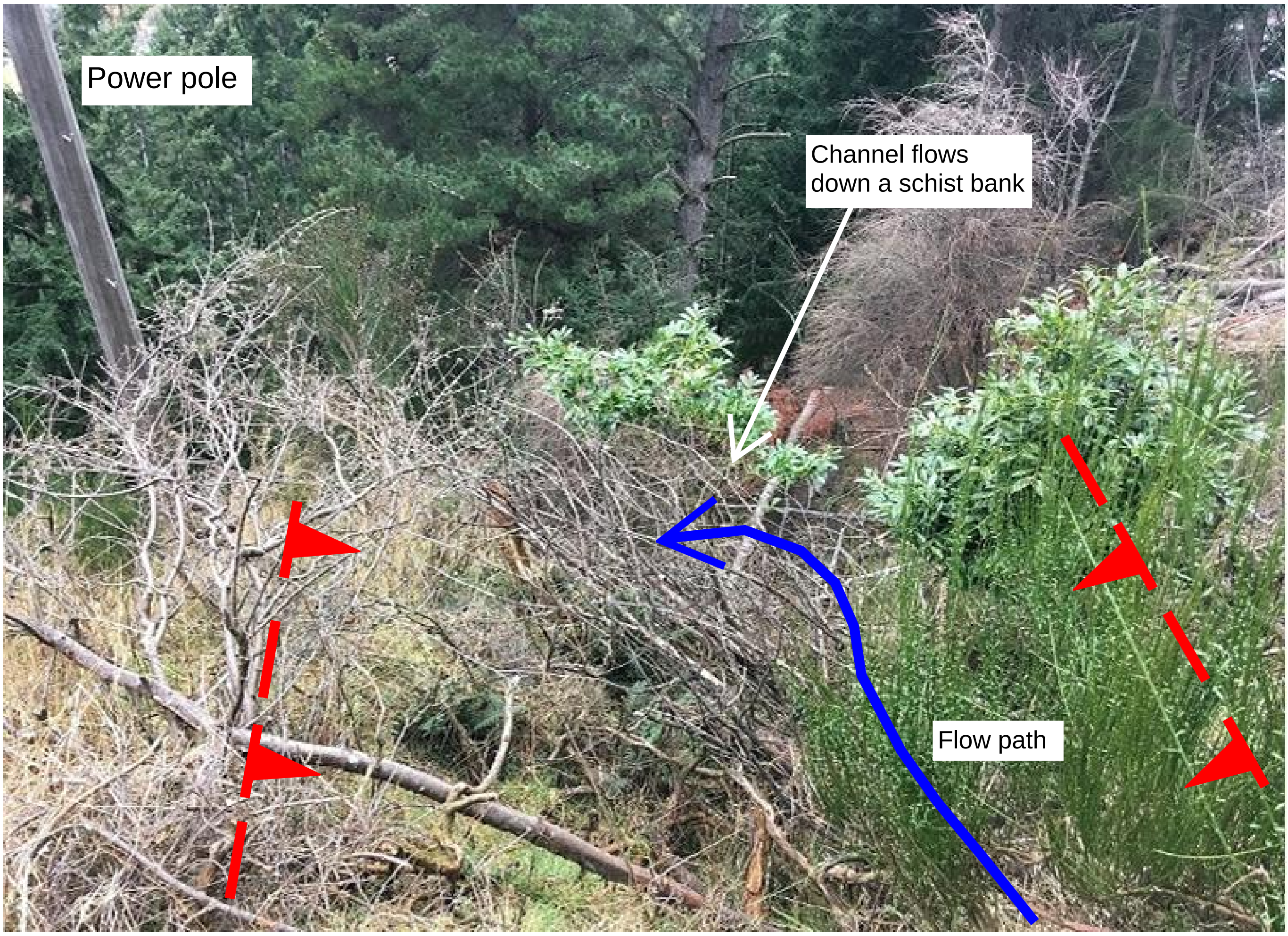


Photograph 9b. DL2 flow channel Section 9b.

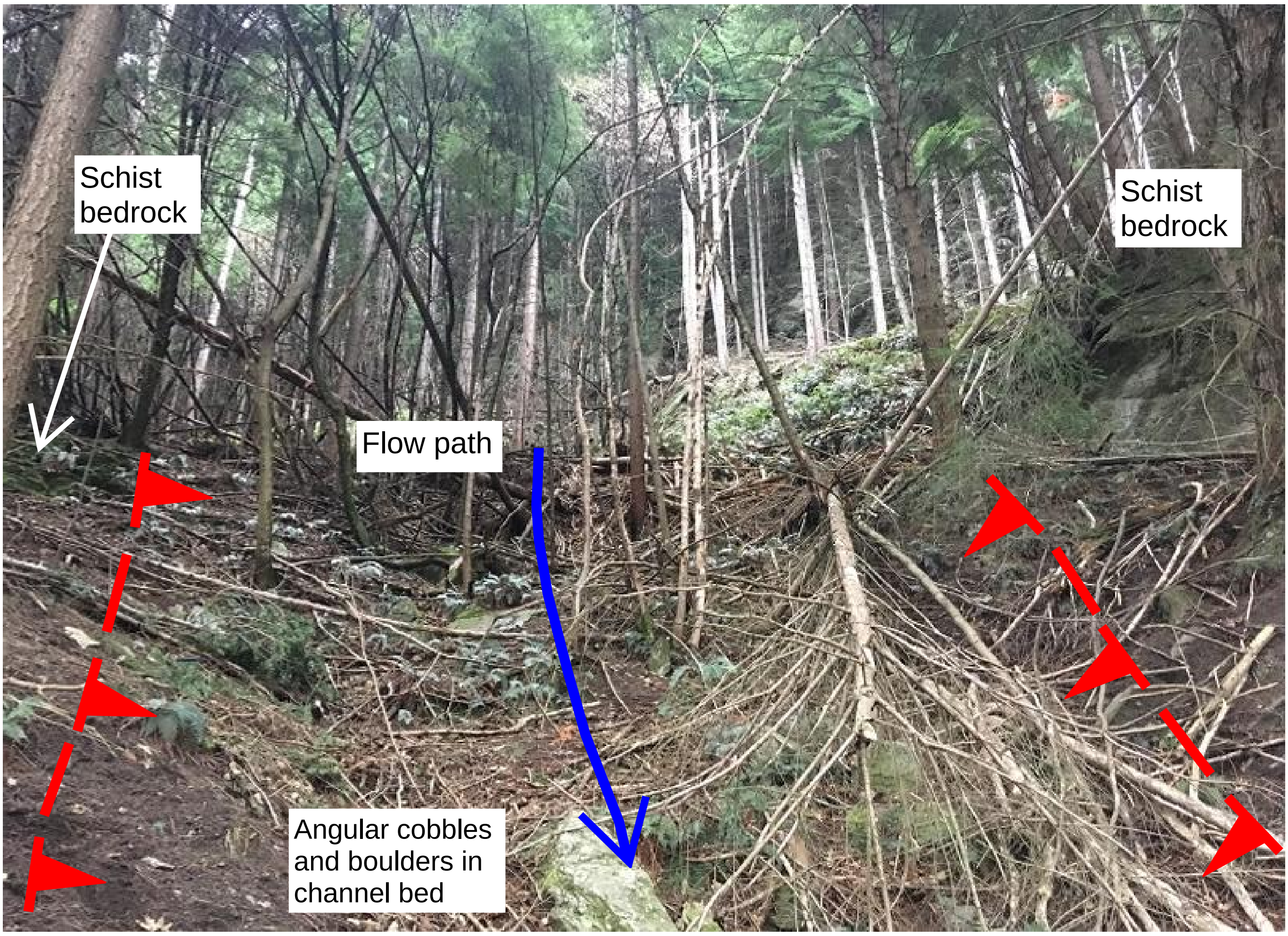


Photograph 10b. DL2 flow channel Section 10b. Two separate flow channels merge immediately upstream of an alluvial fan. The alluvial fan is positioned immediately above the existing Skyline carpark.

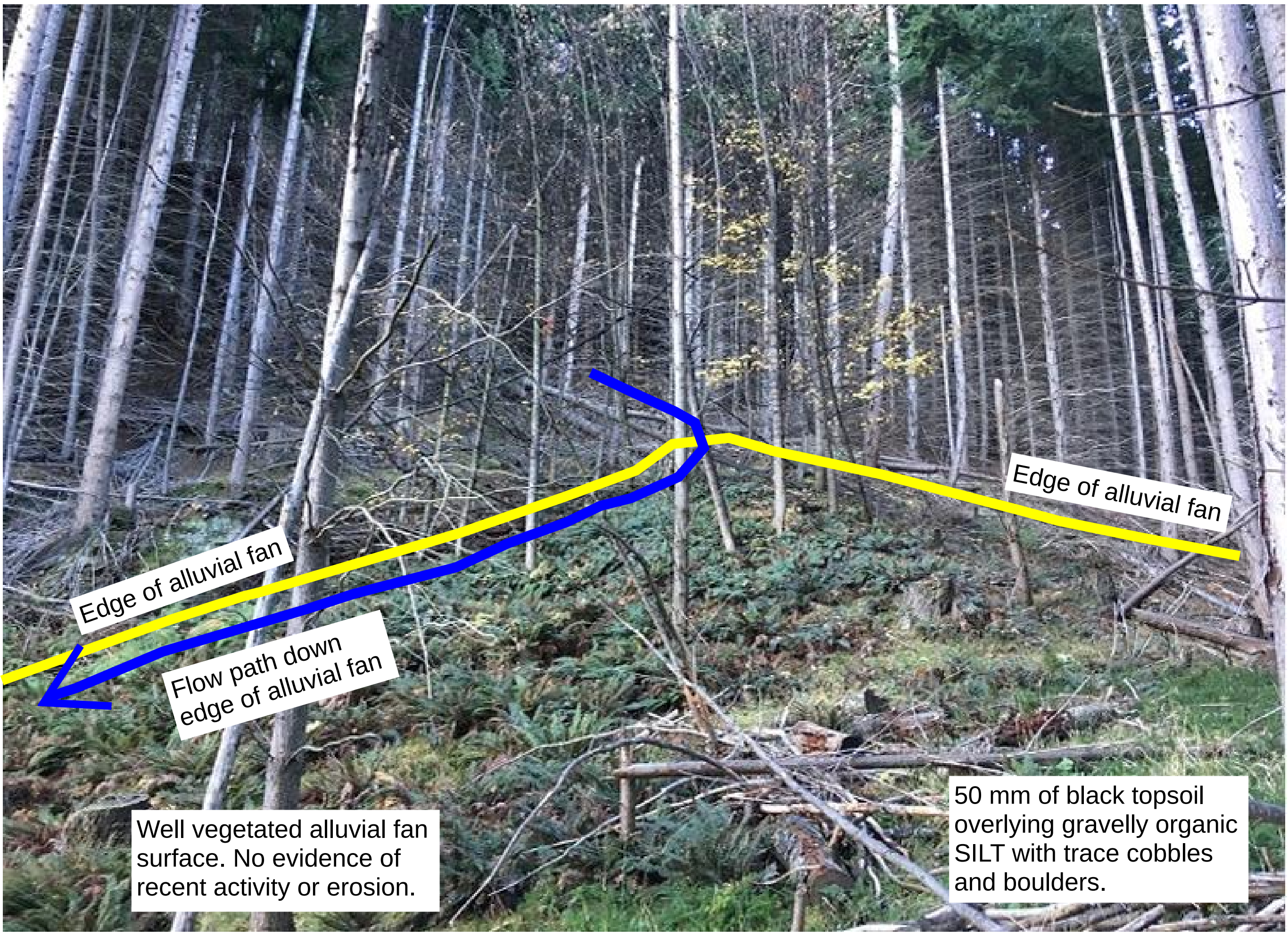
Photograph 11b. DL2 flow channel Section 11b. No evidence of recent scour erosion.



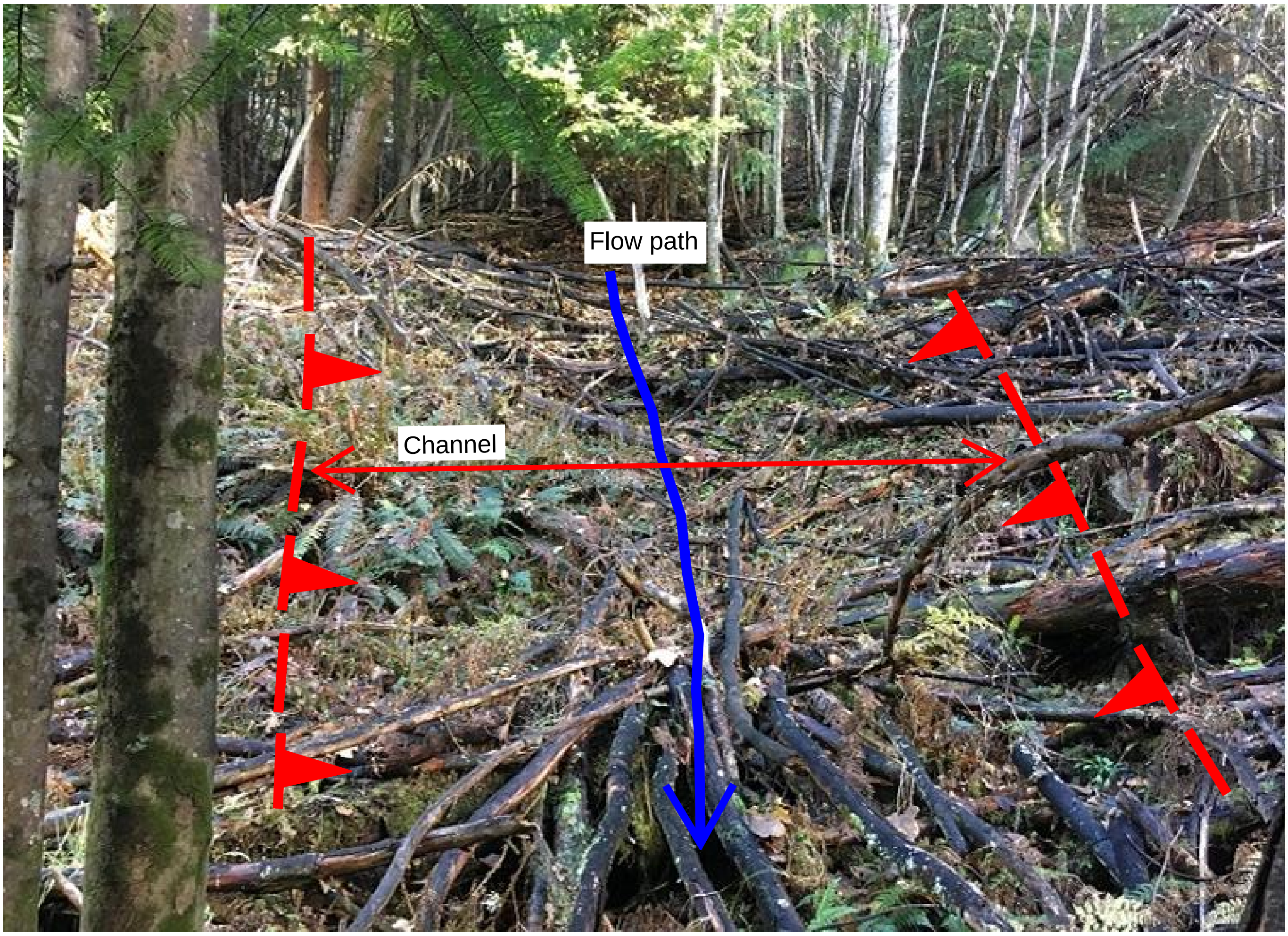
Photograph 12b. DL2 flow channel Section 12b. Channel bed is heavily vegetated in grass, fern and broom scrub.



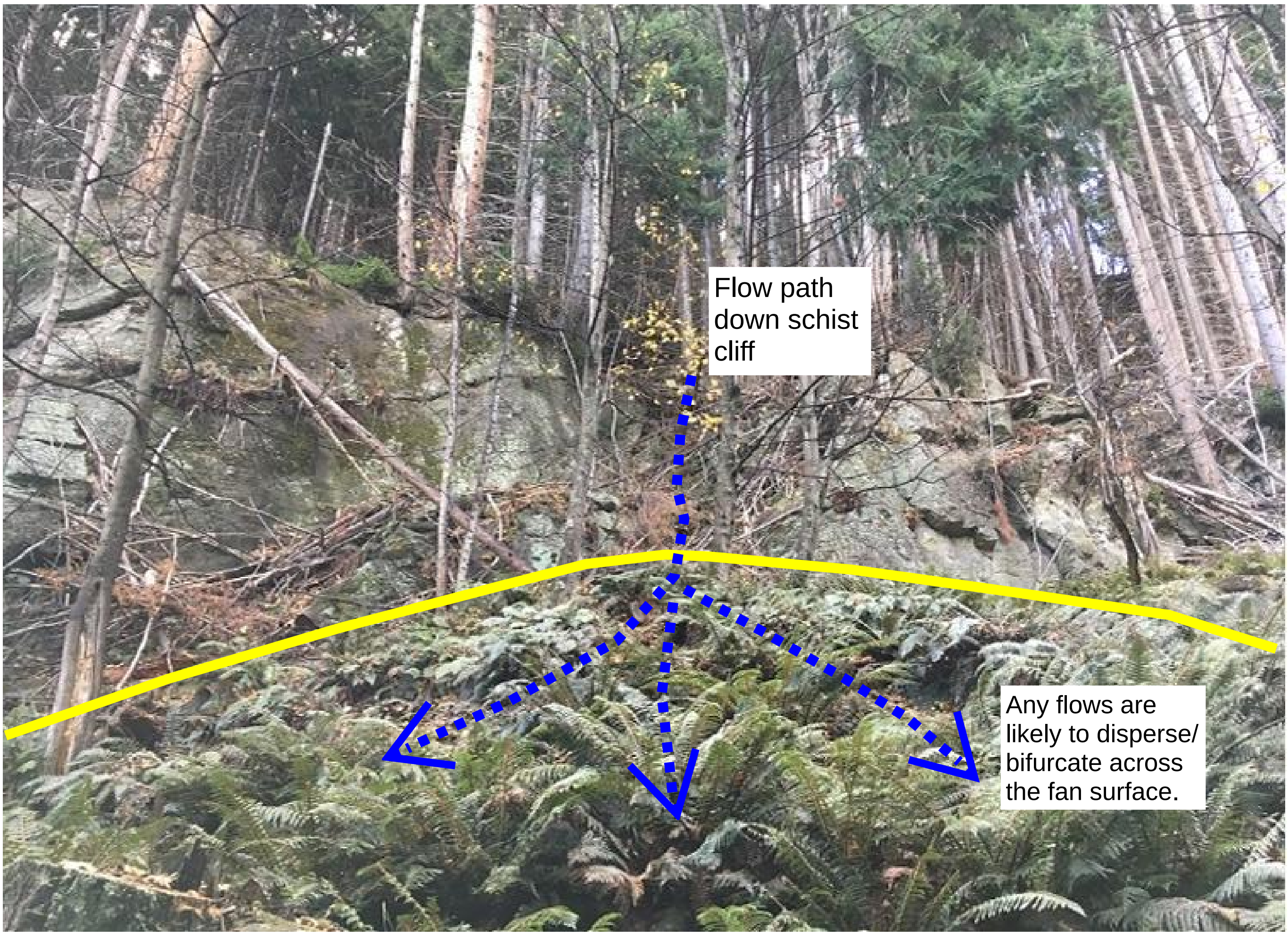
Photograph 13b. DL2 flow channel Section 13b.



Photograph 14b. DL2 map area general photograph. Alluvial fan at the base of a schist bluff on the northern edge of the DL2 map area. The entire fan surface is curved and lobate indicating possible historic debris flows. Stormwater discharge from Skyline will not be fed into this flow path nor does it have the potential to make it into this catchment area.

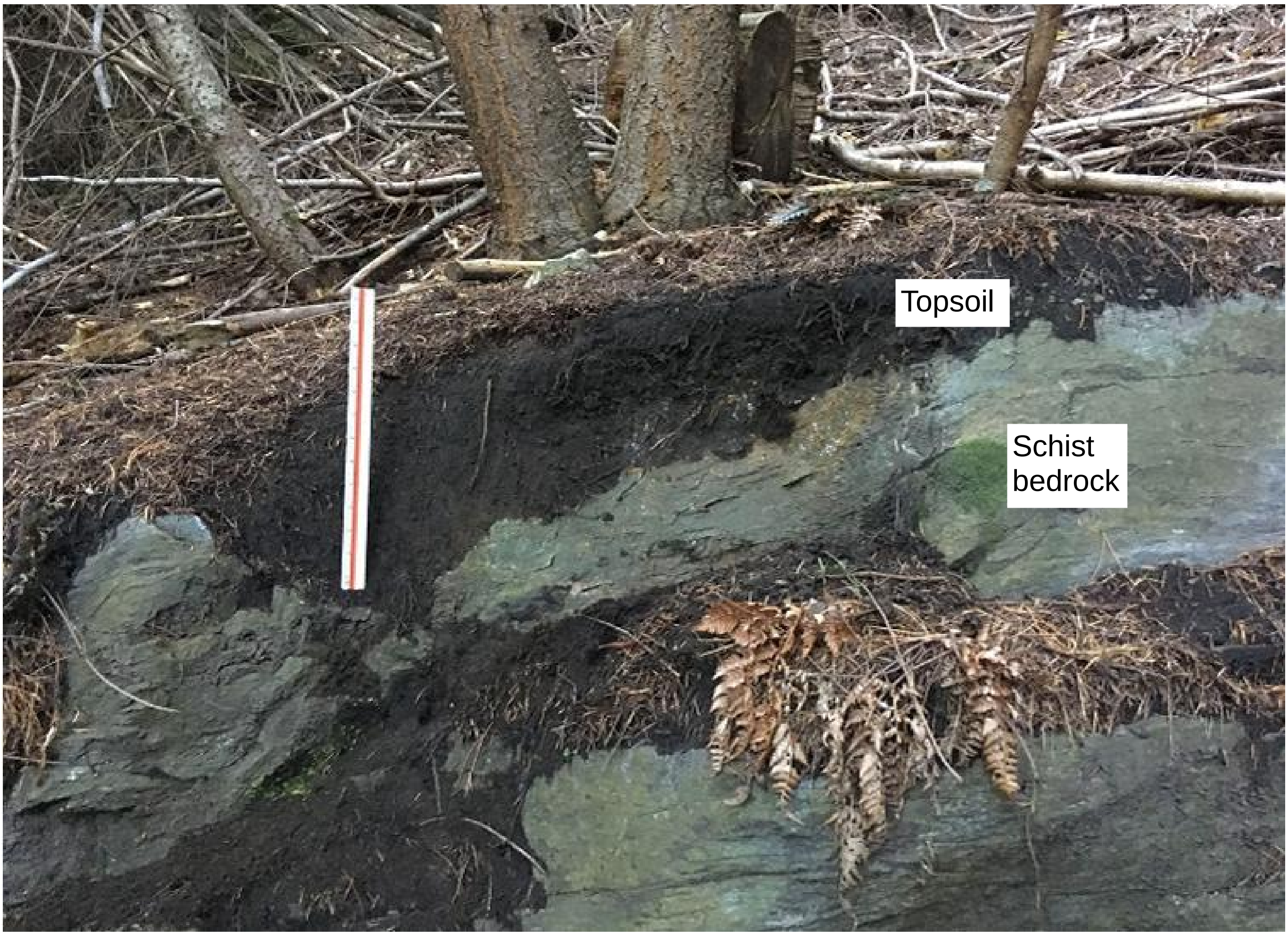


Photograph 15b. DL2 map area general photograph. Channel bed choked full of dead organic debris downslope of channel Section 4b.

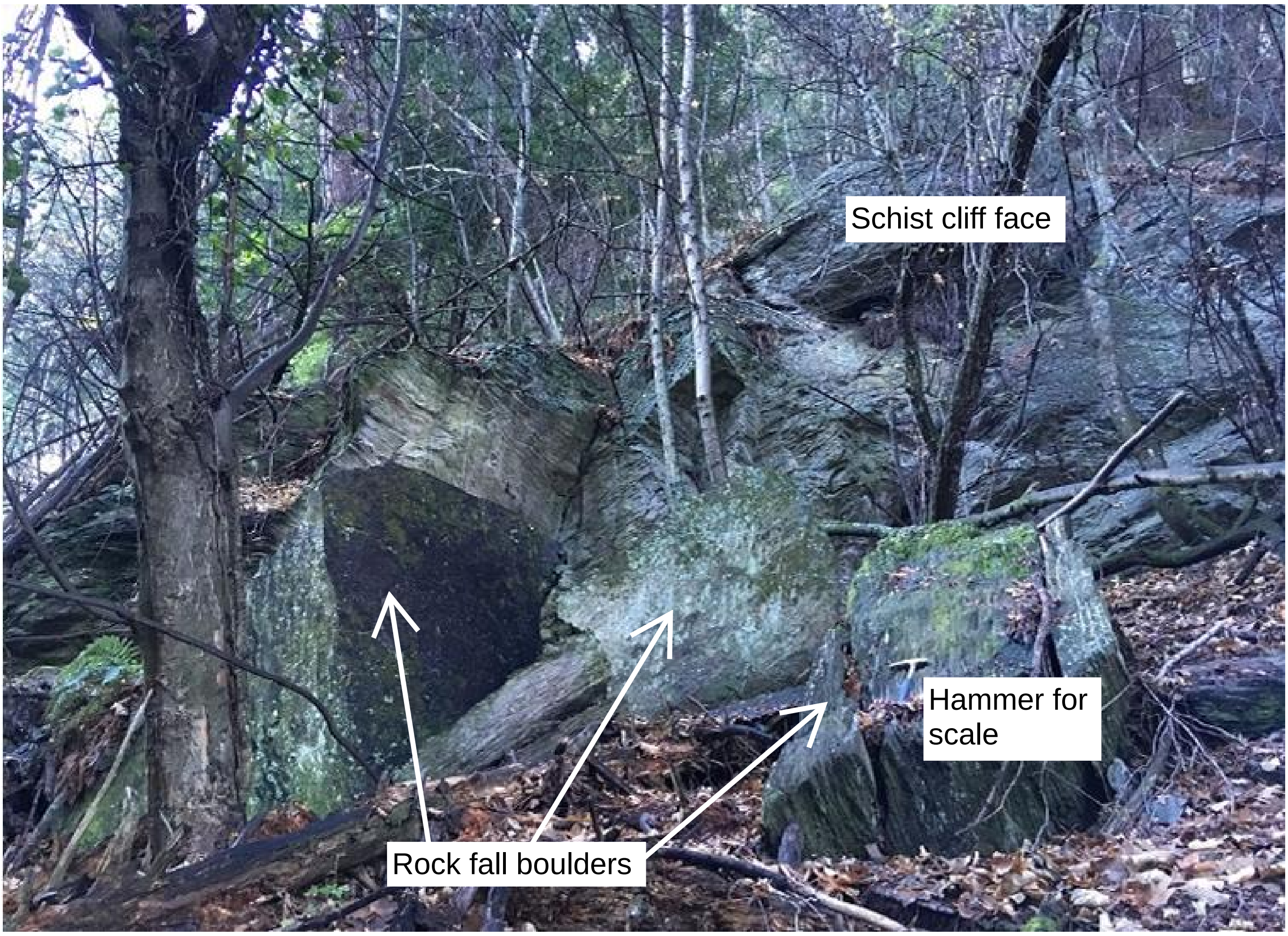


Photograph 16b. DL2 map area general photograph. Colluvial fan at the base of a schist bluff. The fan surface is densely vegetated in fern and there is no evidence of recent activity or erosion. Any flows coming down the cliff face at the head of the fan are likely to disperse/bifurcate across the fan surface. There is no defined channel.

Photograph 17b. DL2 map area general photograph. Historic post glacial wedge failure in schist bluff.

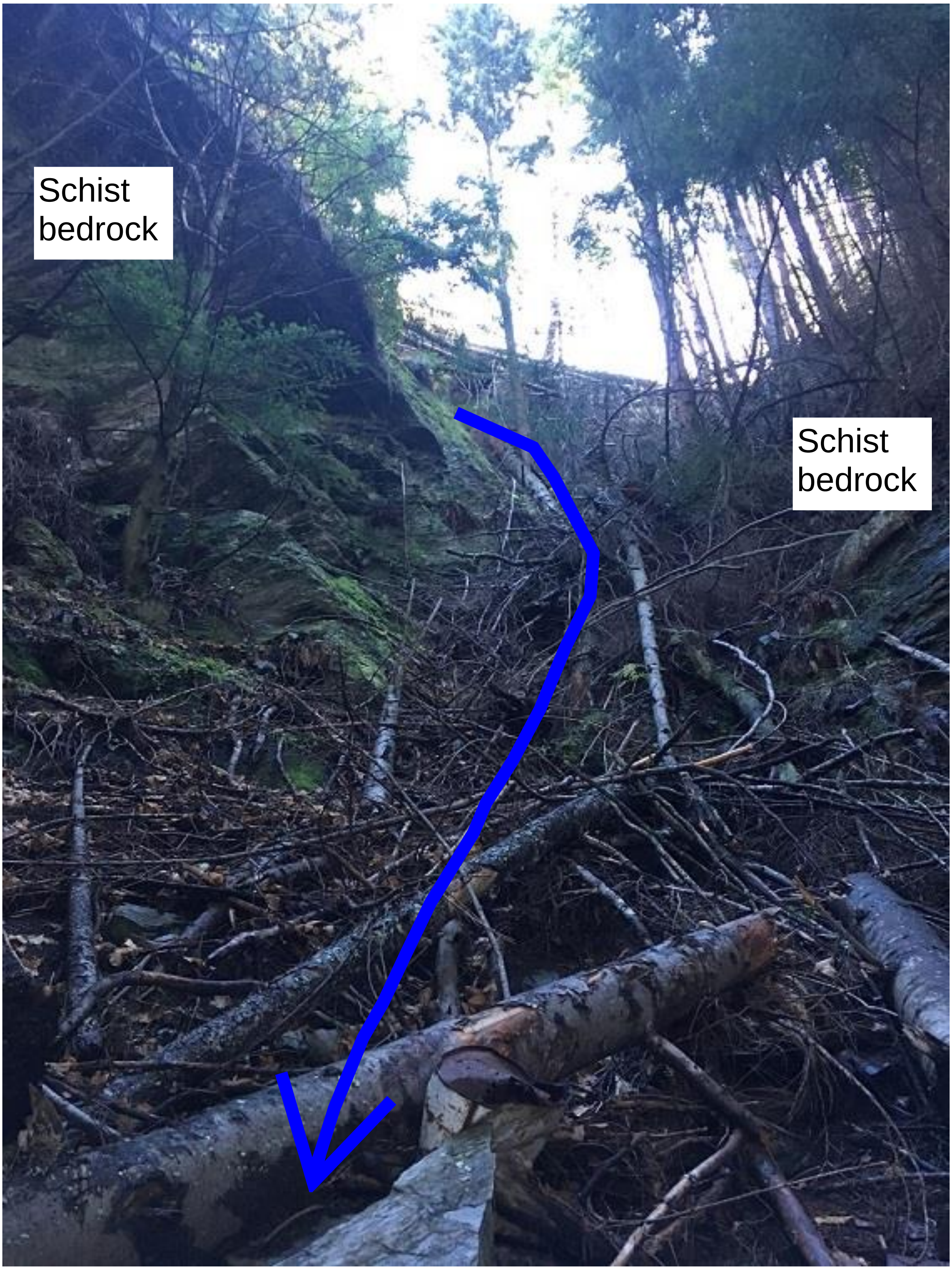


Photograph 18b. DL2 map area general photograph. 350 mm thick well developed black topsoil layer overlying schist bedrock exposed in channel bed on the northern edge of the DL2 map area. 30 cm ruler for scale.

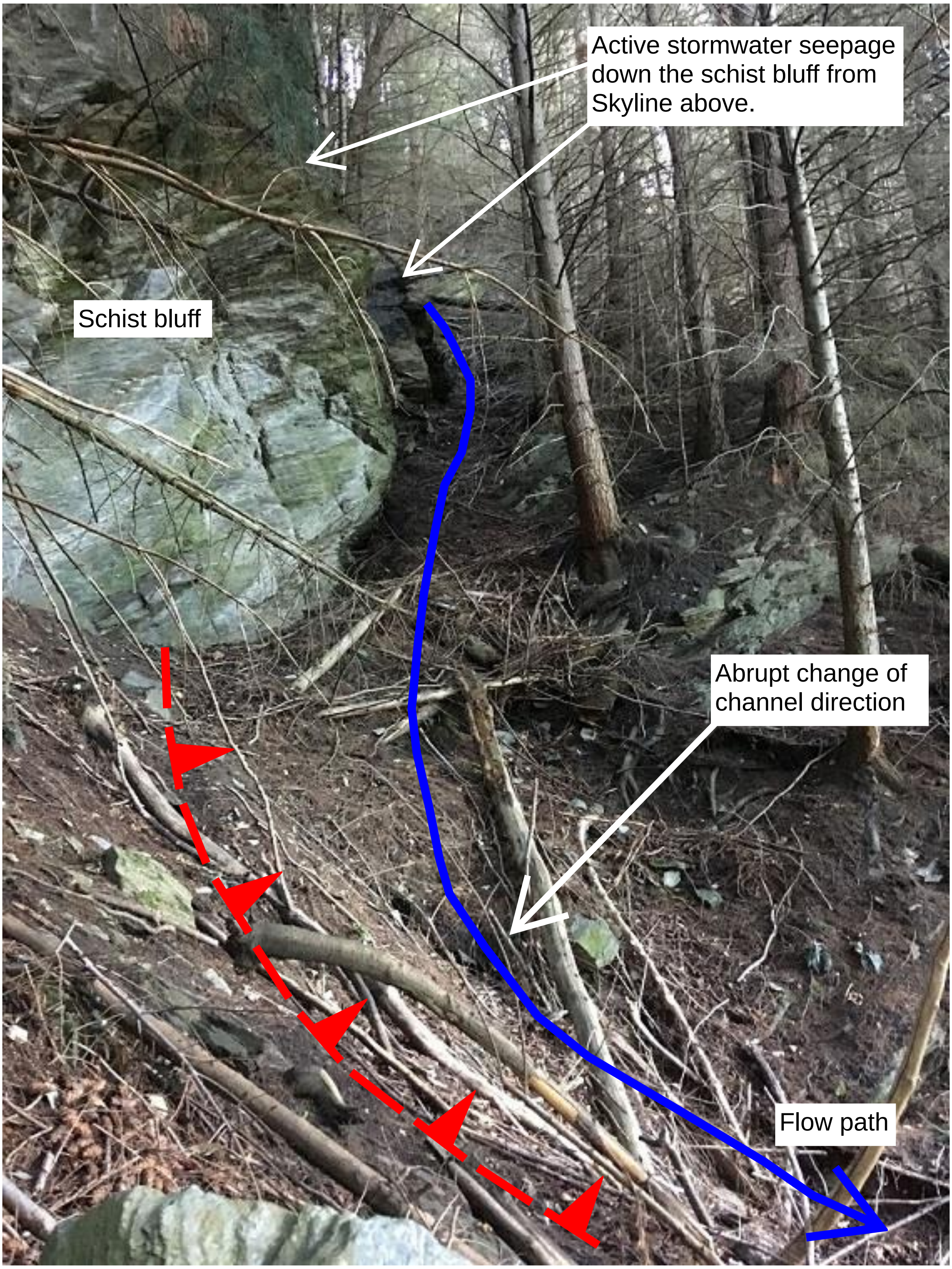


Photograph 19b. DL2 map area general photograph. Historic rock fall north of the existing Skyline carpark.

Photograph 20b. DL2 map area general photograph. Alluvial fan sediment exposed in excavated batter cuts above the existing Skyline carpark. Hammer for scale. Soils comprise silty sandy GRAVEL with minor to some cobbles and boulders.



Photograph 21b. DL2 map area general photograph. Channel bed within the schist bluff system immediately below the Skyline stormwater outlet. Active stormwater seepage could be observed seeping down the cliff face to the left of image.



Photograph 22b. DL2 map area general photograph. Channel leaves the schist bluff system immediately below the Skyline stormwater outlet.

Appendix E: Previous Catchment Analysis

Skyline Enterprises Limited

Queenstown Gondola Base and
Carpark Building Development
Stormwater Management
Revised Design Report

April 2022

Fluent SOLUTIONS

www.fluentsolutions.co.nz

Fluent SOLUTIONS

Skyline Enterprises Limited

ueenstown ondola Base and Carpark Building Development
Stormwater Management - Revised Design Report

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Job No.: Q000507
Date: 5 April 2022
Reference: RP-22-04-05-HM-Q000507-SW.Docx

Skyline Enterprises Limited

ueenstown ondola Base and Carpark Building Development
Stormwater Management - Revised Design Report

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APPENDI A
Flood Flow Diagrams - Pre-development - 2yr, 10yr, 20yr, 50yr, and 100yr ARI Peak Storms

APPENDI B
Hydraulic Profiles for 20y and 100yr ARI Peak Storms

APPENDI C
Fluent Solutions Stormwater Management Drawings dated April 2022

1.0 Introduction

Fluent Solutions (Fluent) was engaged by Skyline Enterprises Limited (Skyline) to provide a stormwater management plan and detailed design for the primary stormwater collection system for the proposed Gondola Base building extension and new carpark building development at 53 Brecon Street, Queenstown.

Previously, a stormwater management design was submitted to and accepted in principle by Queenstown Lakes District Council (QLDC). Since acceptance/submission additional conversations between Skyline, Fluent, QLDC, and the Kiwi Birdlife Park (KBP) were held during early 2022 and focused around the magnitude and frequency of stormwater discharges to the KBP Pond.

The developed and detailed stormwater management plan presented in this report takes into account the original design concept as well as additional commentary received from QLDC and the KBP as noted above.

Overall, the updated stormwater management plan is based on the previously accepted design, but now includes a connection to the QLDC stormwater network in Brecon Street. Furthermore, any flows over and above the capacity if the Brecon Street pipeline are now proposed to discharge to an existing pre-development overland flow path north east of the proposed new carpark building.

This report has been prepared to provide further information regarding:

- Updated site overland flow path assessment
- Collation and review of as-built data for the existing stormwater network in Brecon Street
- Pipeline capacity assessments
- Climate change considerations including the use of design rainfall data based on the RCP8.5 (2081-2100) climate change projection scenario
- Presentation of the updated stormwater management design as described above.

This report has been prepared for the purpose of obtaining approval in principle to allow the proposed works to proceed.

It is understood QLDC has planned stormwater works for Brecon Street including additional stormwater inlets and a new pipeline starting adjacent to the existing Skyline connection to the QLDC stormwater network. This report does not address the effects of the proposed QLDC works on the existing Skyline piped stormwater system or on the stormwater pipe replacement proposed in this report.

2.0 Background

2.1 ondola Site Location

The location of the Gondola Base site is at the northern, upper end of Brecon Street in Queenstown. The proposed stormwater management plan for the site provides for an extended Gondola Base building and the new carpark building to the north of the Base building. Features relevant to this report are identified in Figure 2.1 below.

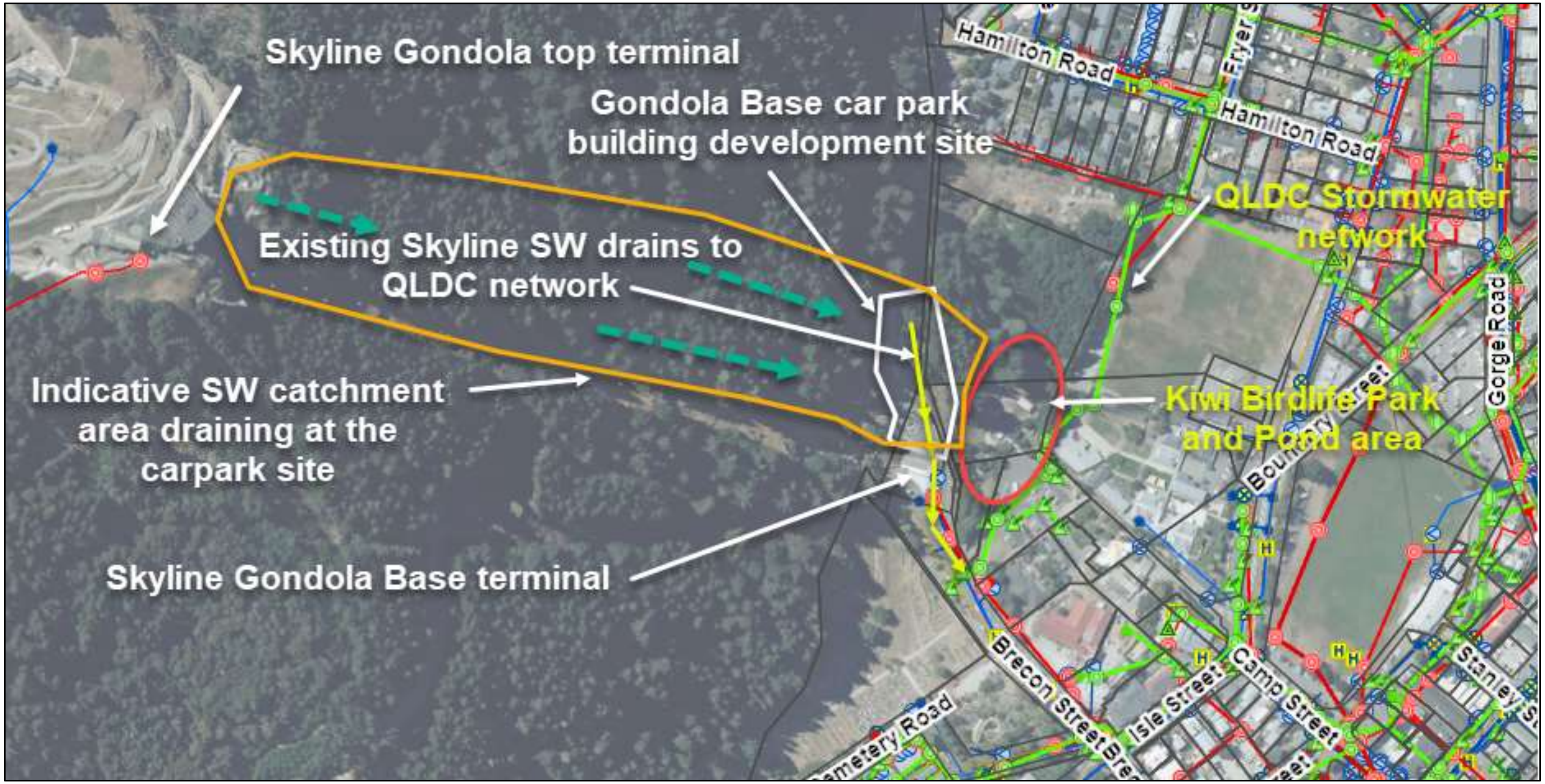

Figure 2.1: Site Locality Plan

Unless otherwise indicated the "North" direction on maps is up the page.

2.2 Previous Reporting

2.2.1 Land Use Consent

An options report entitled “Queenstown Gondola Base Carpark Building Development - Stormwater Management Plan Options - Draft” (dated 25 May 2017) was prepared by Fluent Solutions and identified four stormwater collection and disposal options for consideration by Skyline Enterprises for the proposed car park building development. “Option 3” was selected by Skyline Enterprises and was developed further and presented in the Fluent Solutions report entitled “Skyline Enterprises Limited - Queenstown Gondola Base Carpark Building Development - Stormwater Management Plan” (dated 14 August 2017). “Option 3” formed the basis of the land use consent approvals for the Base building extensions and new car park building and is referred to in the consent conditions.

“Option 3” included for the use of a stormwater collector pipe network within the Skyline Gondola Base site for the discharge of all stormwater flows into the KBP Pond via a pipe and did not allow for a stormwater connection to Brecon Street.

2.2.2 Engineering Approval

Subsequently, “Option 3” was developed to the final design stage and Engineering Approval was granted (in principle) by the QLDC based on the report prepared by Fluent Solutions entitled “Queenstown Gondola Base and Carpark Building Development - Stormwater Management Design Report” - Rev. 1 (dated 20 August 2019).

2.2.3 Further Consultation

Further consultation with the downstream affected parties (QLDC and KBP) were held during early 2021. From these discussions, it was decided to incorporate the use of an additional stormwater pipeline to connect into the existing stormwater network in Brecon Street for the disposal of smaller, more frequent, and moderate rainfall event stormwater flows as occurs currently. Any additional flows from major and extreme storm events would be diverted to an existing pre-development overland flow path to the northeast of the proposed car park building.

The proposed revised design is described further as part of this report.

3.0 Upper Catchment Flow Assessment

As a first step, it was important to understand the upstream mountainous catchment and the corresponding runoff to estimate the inflows to the site area. The methodology to derive these flows and the flow estimates is described below.

3.1 Analysis Methodology

The hydraulic and hydrological modelling software Infoworks ICM (ICM) was used to estimate flood flows from the mountain catchment above the Gondola Base site and stormwater flows within and downstream of the site.

The model utilises a 2D surface based on 3D LiDAR information combined with SCS hydrological calculations to estimate runoff flows from buildings and surrounding land.

3.2 Soil and Land Characteristics

The sections below set out the assumptions for the soil and land use characteristics.

3.2.1 Mountain Catchment

Flows from the mountain catchment areas were modelled using a 2D surface based on 3D LiDAR information. The Horton methodology was used for estimating infiltration losses to the soil applied to a "rain on grid" surface created from 3D LiDAR data (flown in 2016). The specific infiltration values were based on a dry, loam soil with little to no vegetation due to the steepness of the catchment and the rock bluffs characterised throughout (values adopted from Akan 1993). The initial infiltration (fo) adopted was 76.2mm/hr and ultimate infiltration (fc) was assumed to be 3.8mm/hr. The decay rate used was 4.1 hr^{-1}.

Additional to the soil characteristics, the roughness characteristics of the surface were analysed. A Manning's roughness (n) of 0.17 was estimated to represent the dense tree areas and 0.04 for the remainder areas.

3.2.2 Carpark

In both the pre- and post-development scenarios, the Gondola Base carpark was modelled using a 2D surface using a combination of design surface data and LiDAR data. No infiltration to ground was allowed for in these areas and a Manning's roughness of 0.0125 was used to represent this surface.

3.2.3 Buildings

Stormwater runoff from buildings was estimated using curve number values for the soil loss and the SCS routing method. For these areas, a curve number of 98 has been assumed.

3.3 Rainfall Hyetographs

A series of triangular rainfall hyetographs (rainfall depth versus time graph) were developed for a range of storm durations and used in the model. The triangular hyetograph methodology adopted by the Christchurch City Council *"Advanced Analysis" method provided in the "Waterways, Wetlands and Drainage* Guideline" using recorded data at the Queenstown Airport has been applied for this assessment. This approach has been used in multiple applications to QLDC over the past few years. Other Councils such as the Dunedin City Council have also adopted this methodology. The triangular hyetograph utilises the average rainfall intensity for a given duration as the basis for design with the peak intensity being at 2 times the average intensity and occurring at 0.7 times the duration.

To ensure that the design flow estimates are based on appropriate rainfall patterns, the design triangular hyetographs were compared with three recent major storm rainfall events and a normalised rainfall curve derived from a set of 24 hour duration maximum rainfalls from 10 storm rainfall events recorded at Queenstown Airport. The 24 hour recorded rainfall data is presented in Figure 3.1. The following points are noted in regard to the shape of the actual storm rainfall patterns compared to the assumed triangular hyetograph shape for the 24 hour duration storm rainfalls presented in Figure 3.1:

a. The total 24 hour rainfall depth for the three recorded storm events would have a current ARI of approximately 20 years without allowance for climate change.

a. The peak rainfall intensity for the design hyetograph is greater than the maximum recorded intensity for the three highest recorded 24 hour storm events and greater than the peak of the normalised curve peak intensity using the 24 hour rainfall data including allowance for climate change.

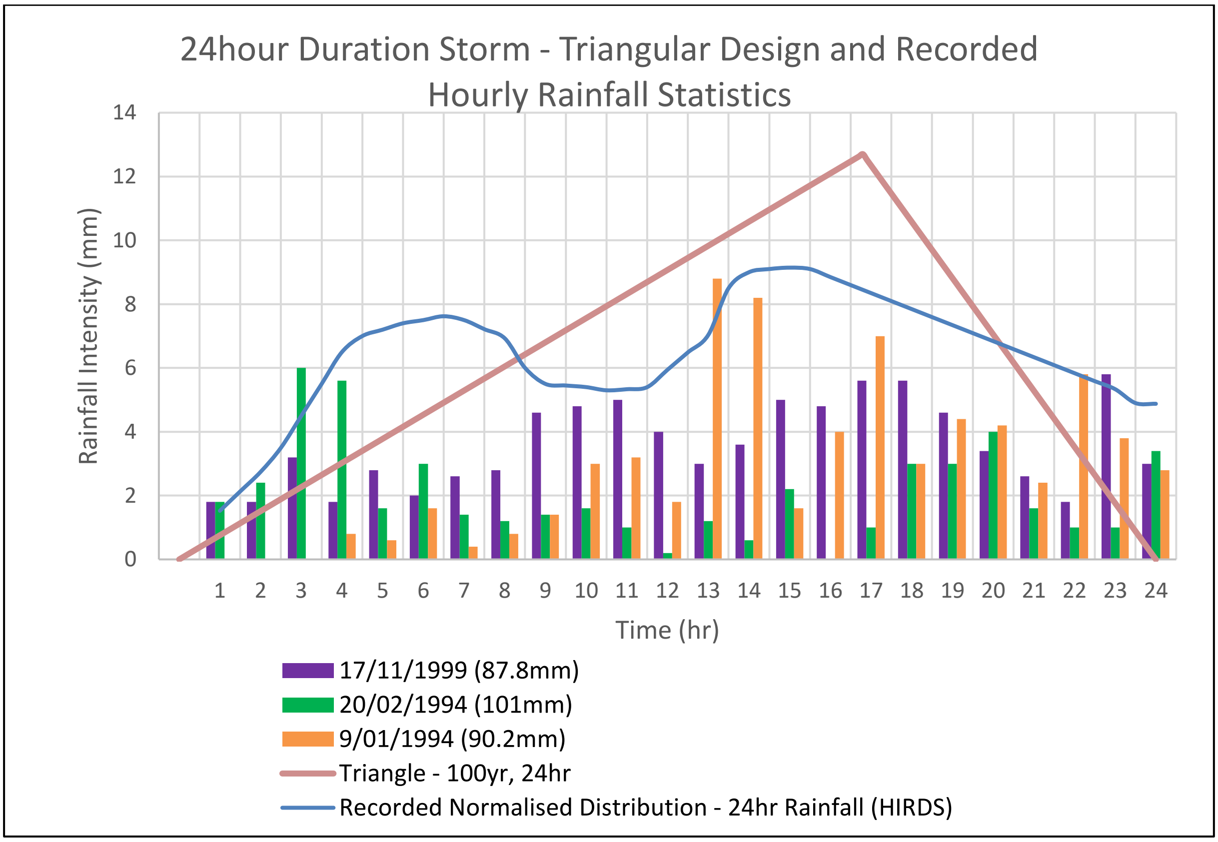

Figure 3.1: Rainfall Data Comparison

3.4 Climate Change

The 2020 QLDC Code of Practice requires that climate change be included as a design consideration. The design approach used as part of the updated design included in this report is based on HIRDS Version 4 RCP8.5 (2081-2100) rainfall data as a conservative estimate. It is noted that the usage of this climate change allowance is greater than the 2.1° Celsius temperature allowance used in Fluent Solutions earlier reporting.

3.5 Storm Events

Flow estimates have been calculated for the pre-development and post-development scenarios for the 2year (yr),10yr, 20yr, 50yr and 100yr Average Recurrence Interval (ARI) rainfall events. The model was used to identify the critical storm rainfall duration stormwater runoff flow and volume effects. Design rainfall hyetographs for durations from 0.5 hours to 24 hours for the ARI rainfall events were therefore run in the model to identify the critical rainfall duration flows.

3.6 Critical Storm Durations

As a result of the modelling work, the critical duration storms (peak flow) were assessed to be the 6hr duration storm for the 2yr ARI rainfall event, 2hr storm for the 10yr, 20yr, and 50yr ARI events, and the 1hr duration for the 100yr ARI. The difference in durations is related to the volume of rainfall during the storm and the characteristics of the soils in the catchment.

3. Flow Path Runoff Results

The mountain side catchment area and flow paths that drain to, and through, the Skyline site and to the KBP are illustrated in Figure 3.2 and Figure 3.3. Note that Figure 3.1 shows the peak 100yr ARI runoff flows (1hr duration) and Figure 3.3 shows the peak 20yr ARI runoff flows (2hr duration). Flow paths for other storm ARIs are presented in the Appendices.

Note that the figures show the proposed revised Gondola Base building (south) and the proposed new carpark building (north) for reference in red. The proposed buildings and overall site layout are discussed further in Section 5 below. The extent of the existing carpark is shown as a yellow dotted line. The Skyline sub-catchment is shown as a white dotted line.

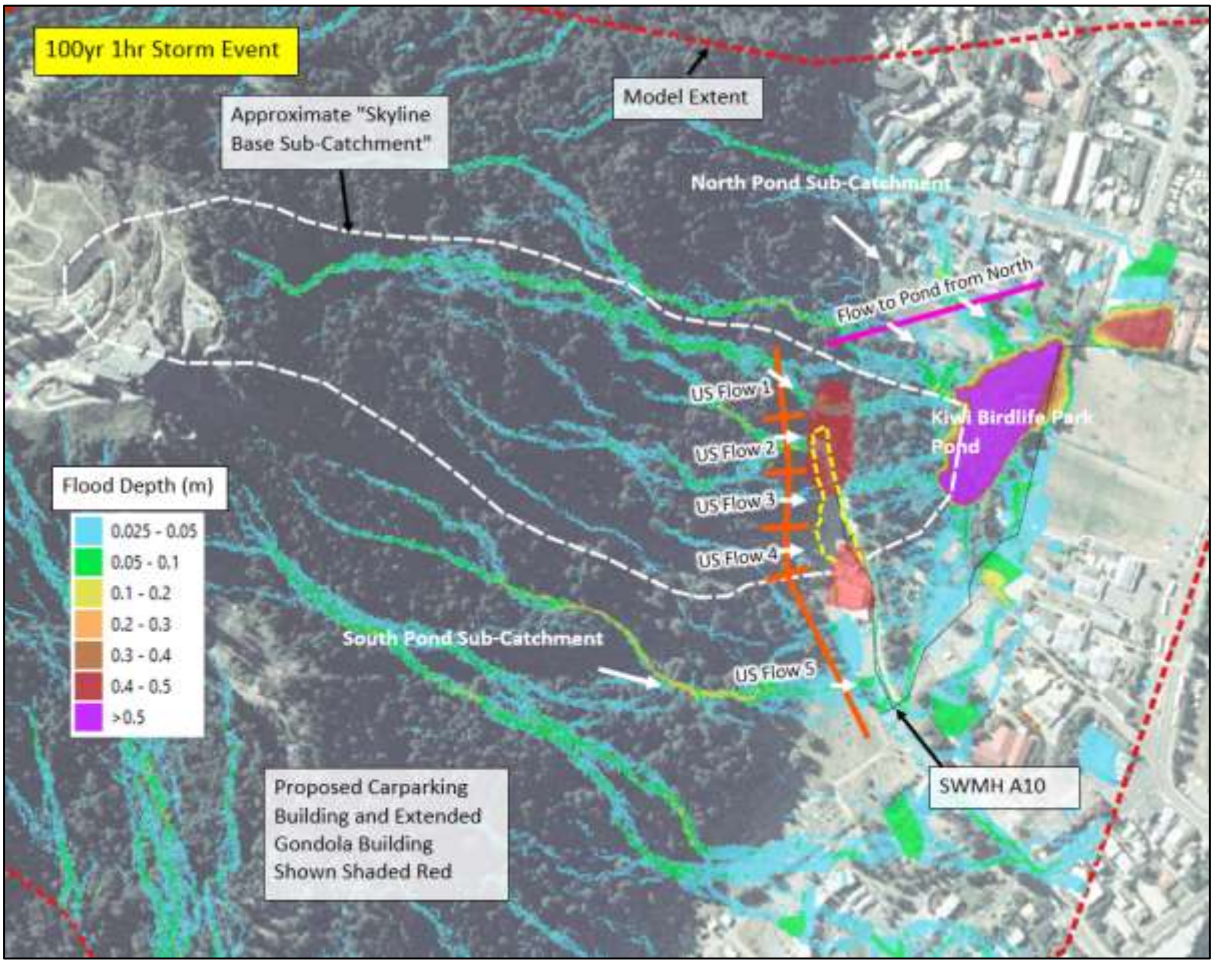

Figure 3.2: Mountain Catchment Flow Paths - 100yr 1hr Storm Event

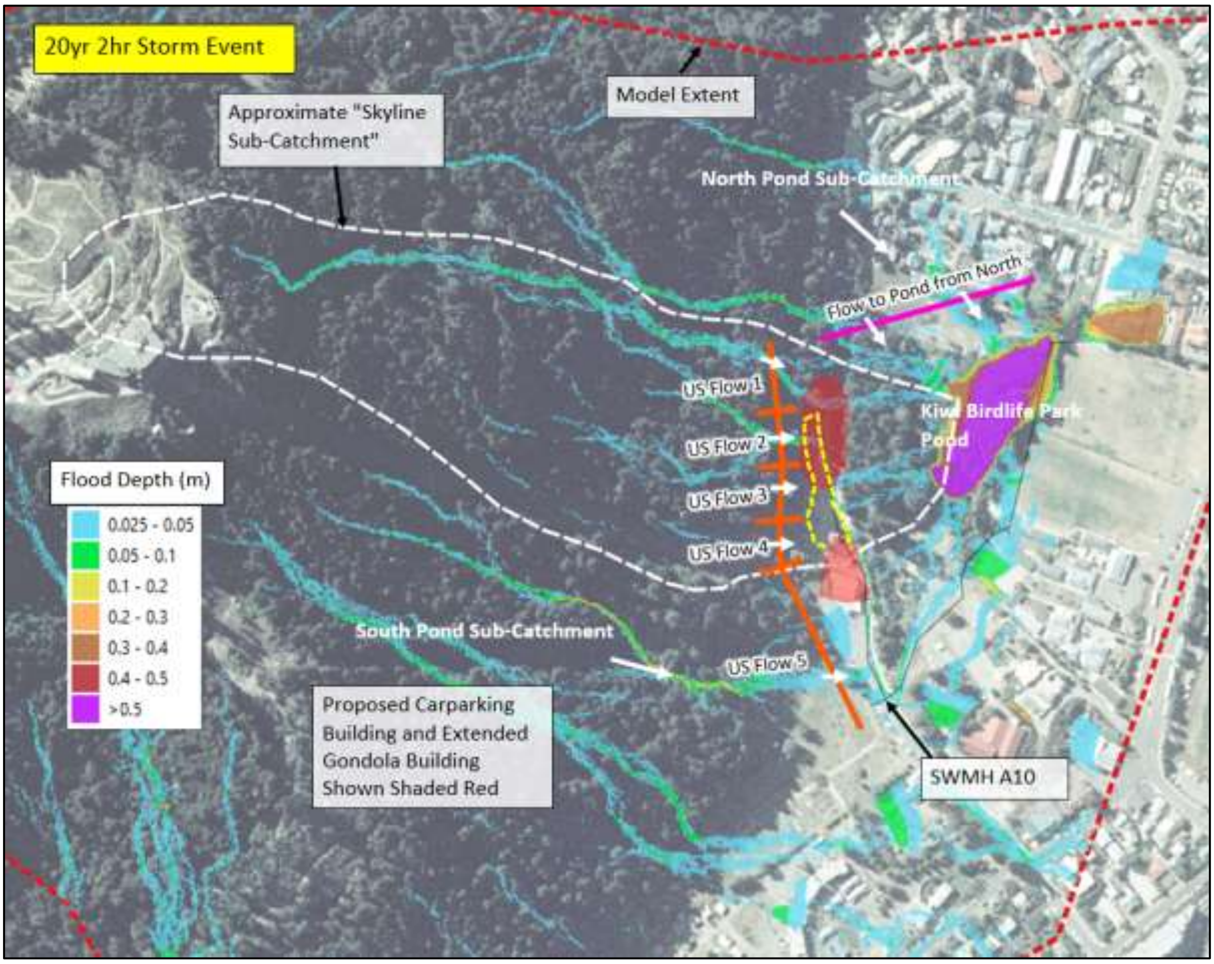

Figure 3.3: Mountain Catchment Flow Paths - 20yr 2hr Storm Event

Figure 3.2 and Figure 3.3 show the five sub-catchment area flow paths that have been identified as discharging through the Skyline site and the upper part of Brecon Street.

One upstream flow path (US Flow 1) flows to the north of the existing car park and discharges directly to the KBP Pond. However, as part of the proposed works, this flow would be caught by the stormwater works for the new car park building. Three flow paths (US Flows 2, 3 and 4) are intercepted by the existing car park area and discharge via the existing stormwater network to SWMH A10 or overflow to the KBP area when the pipe capacity is exceeded. The fifth flow path (US Flow 5) with the largest flow discharges onto Brecon Street between the Base building and SWMH A10.

Table 3.1 below shows the estimated peak runoff flows and volumes for the various flow paths.

Table 3.1: Estimated Mountain Catchment Peak Runoff Flows

	Storm Event				
	2yr, 6hr	10yr, 2hr	20yr, 2hr	50yr, 2hr	100yr, 1hr
Measure Location	L/s	L/s	L/s	L/s	L/s
US Flow 1	4	25	42	60	88
US Flow 2	9	54	89	140	184
US Flow 3	1	8	13	21	30
US Flow 4	2	15	25	38	51
US Flow 5	33	188	310	481	622

Figure 3.2 and Figure 3.3 also show the estimated catchment area draining through the Skyline Base carpark site as compared to the full hillside catchment.

It is noted that the KBP is situated in a natural flow path with flows from the Skyline Base carpark site sub-catchment and two other sub-catchments (see Figure 3.3). Overland flows also enter the KBP from the north pond sub-catchment and from the south pond sub-catchment via overflow from Brecon Street. For example, in a 100yr ARI event the overland flow from the north pond sub-catchment area to the north of the KBP Pond contributes 671 L/s compared to 353 L/s total from the Skyline Base sub-catchment (Flow lines 1-4). A similar pattern is displayed in the 20yr ARI event with 334 L/s from the northern pond sub-catchment and 169 L/s contribution from the Skyline sub-catchment.

Furthermore, it is noted that the KBP has also modified the existing flow path by construction/modification of the pond and park enclosures.

4.0 Predevelopment Stormwater Network Capacity Assessment

4.1 As-built Information

As described above, the existing piped stormwater system collects stormwater from the existing Gondola Base building carpark and discharges it into the QLDC stormwater network in Brecon Street. Refer to Figure 4.1 below.

Note that stormwater manholes and mud tanks, as illustrated in Figure 4.1 below, are given the abbreviations SWMH and SWMT respectively with a reference, for example A10 is referenced as SWMH A10.

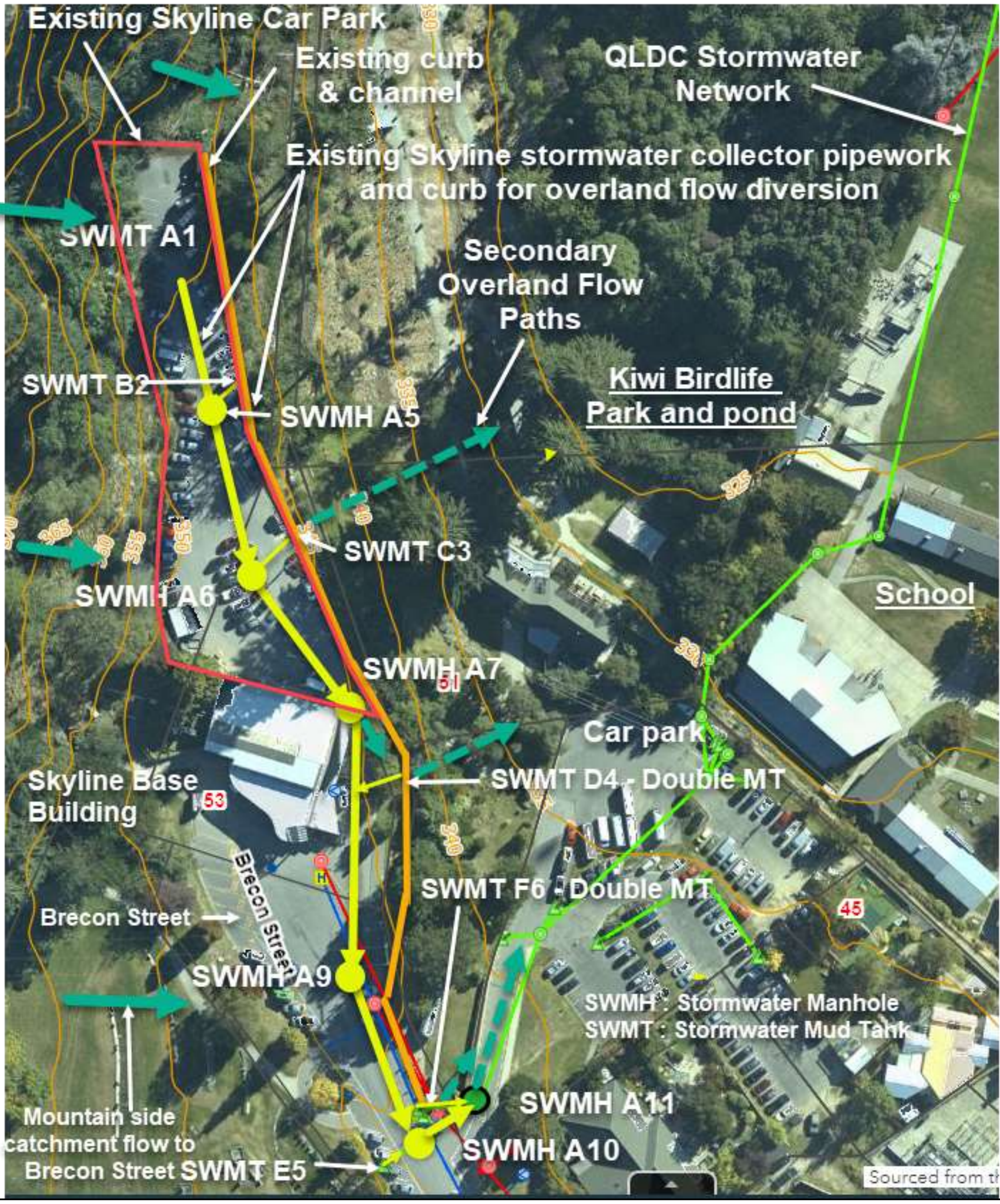

Figure 4.1: E isting Skyline / Brecon Street Stormwater Infrastructure Plan

The existing Skyline carpark stormwater system was constructed between 2012 and 2014. The manhole positions, lid levels, and pipe invert levels in Brecon Street and through the school were resurveyed to check the as-built levels. The updated survey data has been used to estimate the capacity of the existing 300mm diameter (dia.) stormwater system to discharge from the car park building and bus park area to the stormwater network in Brecon Street.

4.2 Capacity Assessment Approach

The pre-development discharge capacity of the existing stormwater system upstream of SWMH A10 was estimated using a hydraulic model as well as a supplementary hand calculation check. It was found that when the stormwater pipe network upstream of SWMH A10 is operating at capacity it subsequently starts to overflow at SWMH A7 and SWMT D4 and results in overland flows into the KBP.

Photos below in Figure 4.2 and Figure 4.3 of SWMT D4 and SWMT C3 illustrate the sag points where stormwater would overflow from the existing stormwater pipe network into the KBP. The water surface flow profile for the flow in the existing pipe network when overflows would begin at SWMH A7 is illustrated in Figure 4.4.

The capacity of the existing network is estimated to be as follows:

a. The overflow at SWMH A7 is estimated to occur when the flow from SWMH A6 exceeds approximately 100 L/s. This flow continues down the network through SWMH A9 to SWMH A10.

b. When the pipe entering SWMH A10 is at capacity then the flow from the mountainside onto Brecon Street is also high and exceeds the capacity of the existing SWMTs E5 and F6 and SWMH A11 causing overflows downstream.