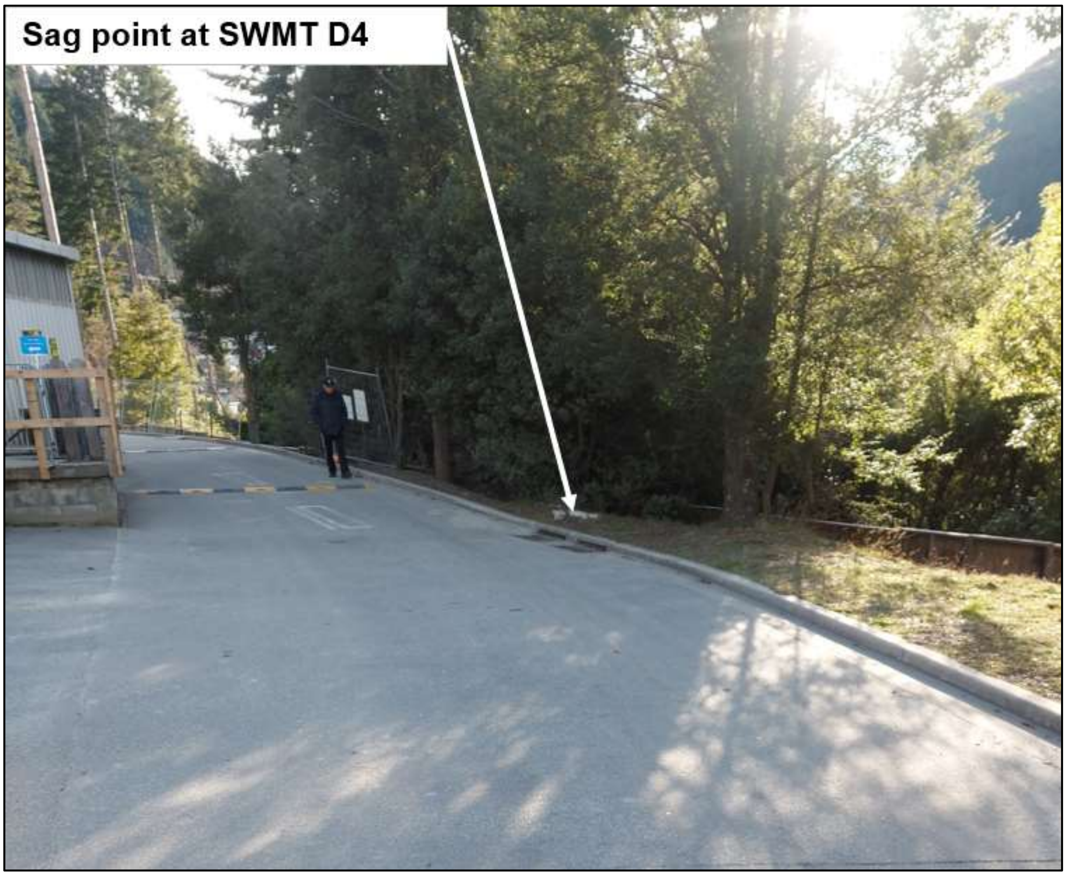


Figure 4.2: Sag Point at SWMT D4

Figure 4.3: Sag Point at SWMT C3

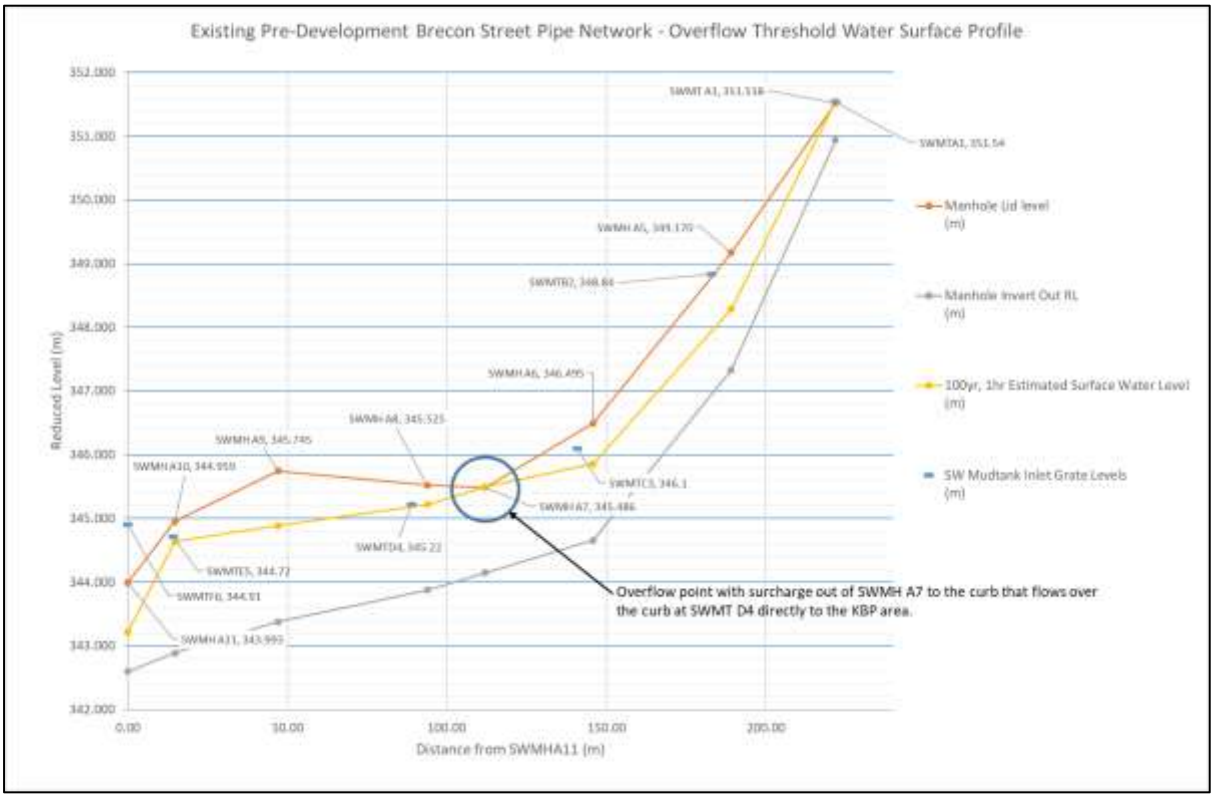


Figure 4.4: E isting Pre-development Brecon Street Stormwater System Profiles

5.0 Proposed Site Development

The proposed development plan is shown in Figure 5.1 below. The development includes the following:

- Extension of the existing Gondola Base building
- Construction of a new carparking building at the northern end of the site
- Allowance for bus parking
- Provision for additional accessways / hardstand areas to connect the existing carpark into the new carparking building

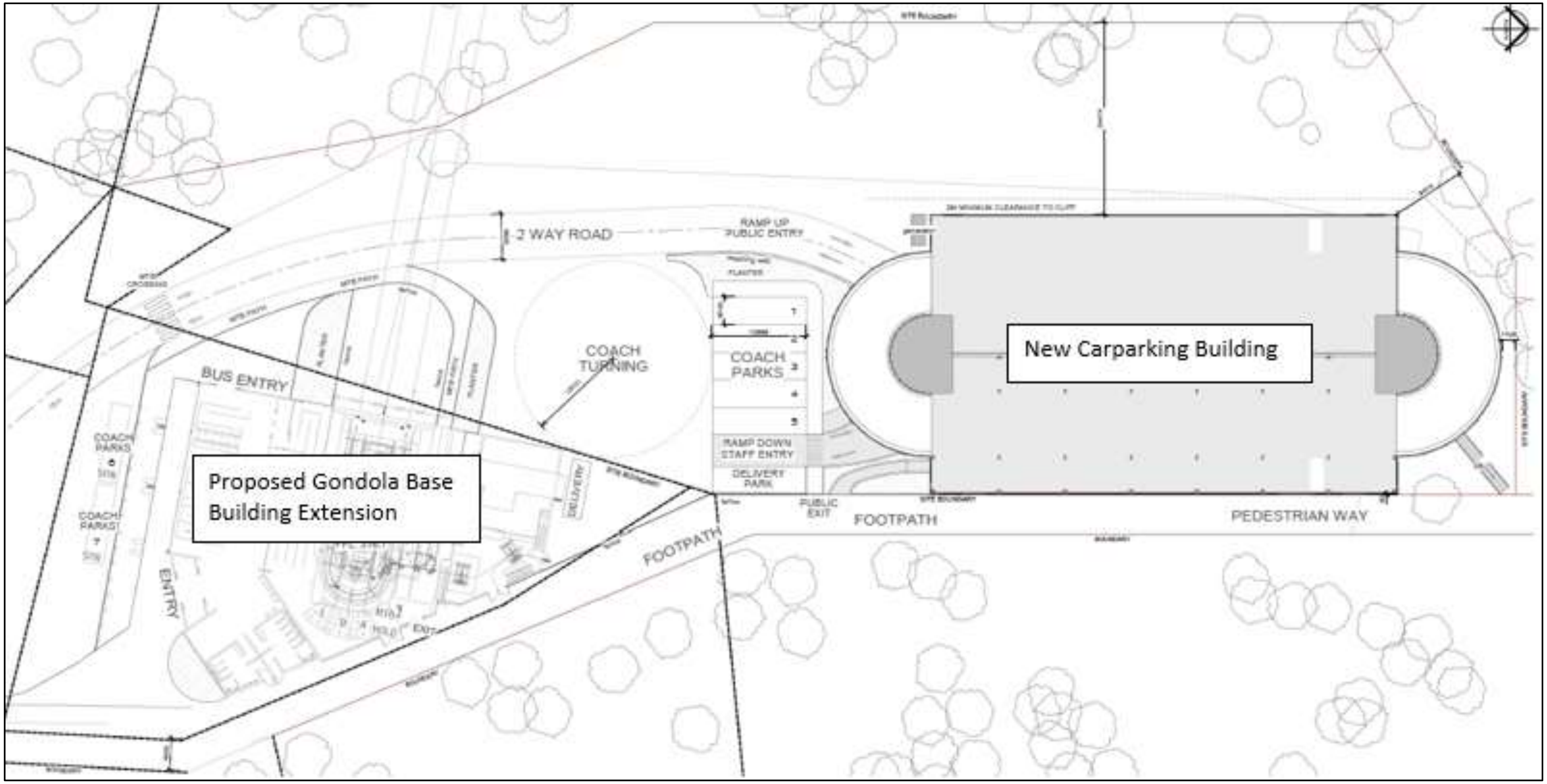


Figure 5.1: Proposed Site Development

6.0 Post-Development Stormwater Management Plan

6.1 Stormwater System Design Ob ectives

The key requirement behind the revised design is that the post-development flow conditions for the site cannot be any more adverse for downstream stakeholders than what is currently experienced for the pre-development condition.

The post-development stormwater system design has therefore been designed to replicate the existing peak stormwater discharge flows to the QLDC stormwater network in Brecon Street and provides for the discharge of overflows, above the capacity of the existing stormwater system, to proposed cycleway north east of the proposed carpark building and subsequently down the existing overland flow path passing through the KBP during major and extreme storm events as currently occurs in the pre-development case.

Replicating the stormwater flow capacity to Brecon Street preserves the reduction in the frequency of stormwater flows to the KBP Pond provided by the existing stormwater system on the Skyline site from the mountain sub-catchment above the Skyline Gondola Base (car park building and bus park). However, the inclusion of the pipe discharge to Brecon Street does not reduce overland flows entering the KBP Pond from Brecon Street (South pond sub-catchment) or overland flow from the North pond sub-catchment flow that all flow to the KBP Pond. (Section 3.7 also refers to the respective KBP Pond sub-catchment flows).

6.2 Proposed Stormwater Management Layout

A general layout for the proposed stormwater management plan for the site, including estimated flows from the above mountain catchment is provided in Figure 6.1 below. Figure 6.2 shows the difference in the amount of impermeable areas between the pre and post-development scenarios.

Drawings presented in the Appendices provide a lot more details of the proposed stormwater management design. It is noted that most of the revised stormwater management plan works proposed were included in the original application for Engineering Approval that was previously accepted in principle.

Additionally, the following sections provide further detail on the proposed works.

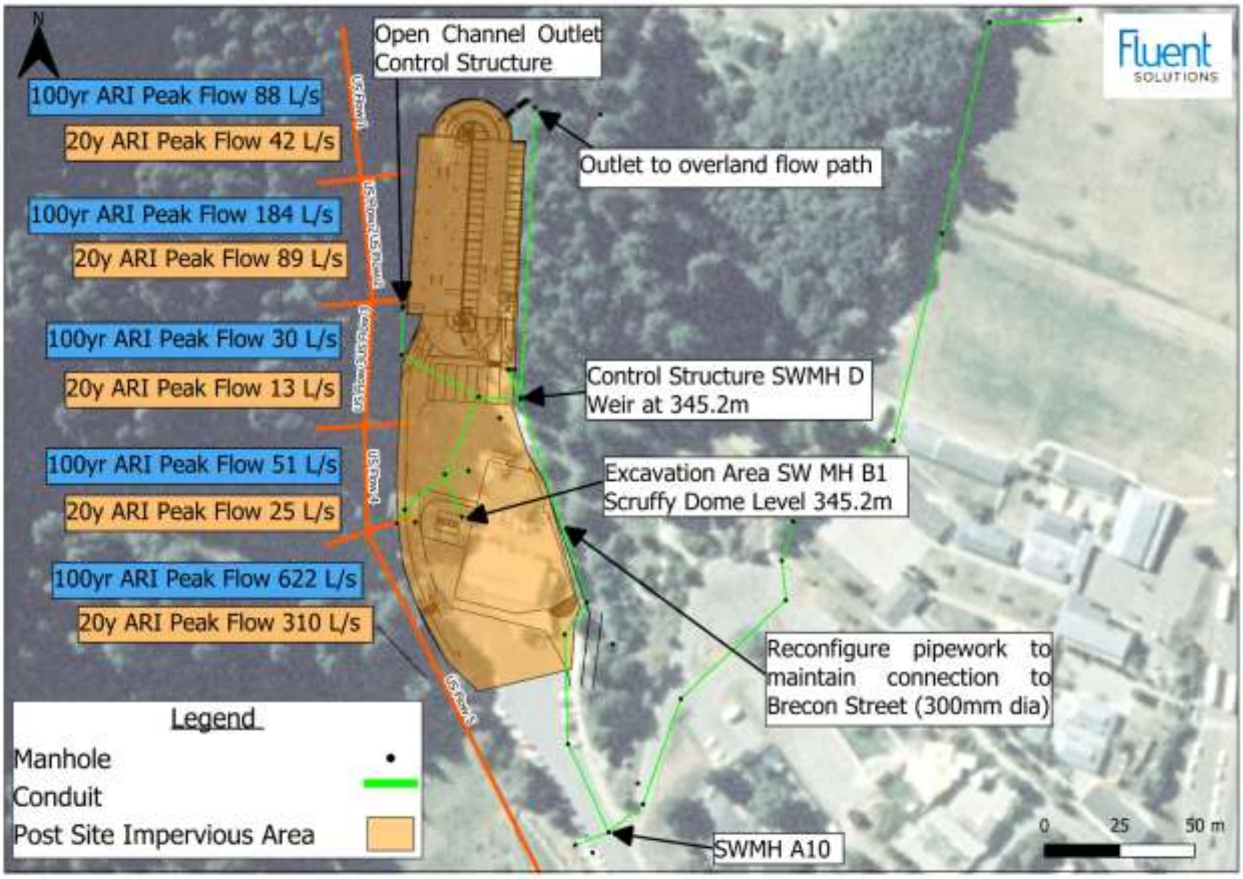


Figure 6.1: Proposed Revised Stormwater Management Plan Layout

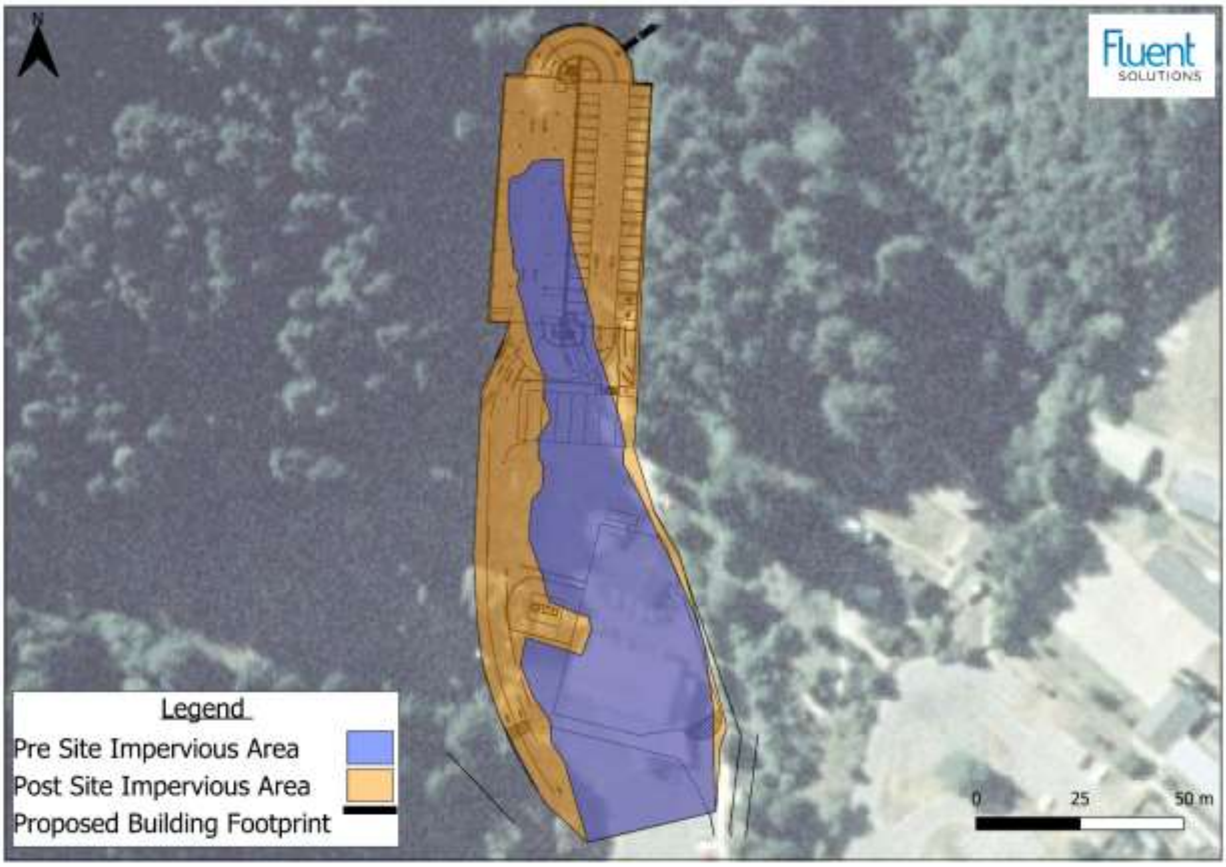


Figure 6.2: Pre vs Post-Development Impervious Area

6.3 Stormwater Management Components

6.3.1 Overview

The proposed stormwater management system shown in Figure 6.1 and the drawings in the Appendices consists of the following:

- An open collector channel that would intercept stormwater, sediment and debris from the mountain slopes above the car park building. *Included as part of the previous engineering approval application .*
- Open Channel outlet structure which provides treatment by reducing transport of debris such as pine needles from the upper hill catchment and collector channel into the pipe network system. *Included as part of the previous engineering approval application .*
- A primary stormwater collector network that conveys stormwater from the open collector channel, paving and roofs as part of the Gondola Base facilities and discharges the collected stormwater to a collector manhole (SWMH D).
- Stormwater collection from the roof of the car park building is directed to pipework and a treatment device that would then discharge to the primary stormwater collection system. The car park roof stormwater collector and treatment system is included in the services design for the car park building and therefore the detailed

design is not detailed in this report. *Included as part of the previous engineering approval application .*

- A new pipe connection from the new Skyline carparking area into the existing stormwater pipe leading to Brecon Street from SWMH D to SWMH A9. *ew component as part of this application .*
- A new stormwater control manhole (SWMH D) that includes a weir that preferentially routes stormwater flows up to approximately 100 L/s to the new Brecon Street connection via a 300mm Ø pipe. *ew component as part of this application .*
- Any stormwater that passes over the weir in SWMH D would flow to SWMH E and out to an existing overflow path where it crosses the proposed cycleway.
- Gondola Base Building excavation area features a scruffy dome manhole (New SW Manhole B1) located in the lowest point of the depression. Collected floodwater in the excavation area will be connected to SW Manhole B which directs flow to the control weir at SW Manhole D.

Each component is discussed in more detail in the following sections.

6.3.2 Mountain Catchment Collector Channel and Outlet Structure

The open collector channel intercepts flows from the mountain sub-catchment above the car park building and bus park area. Based on site observations, the runoff from above the site carries small pine cones and pine needles that blocks mud tanks. The stormwater flows from above the site can also be expected to carry sediment including rock fragments, sand and some silt.

The collector channel is nominally 1.9m to 2.0 metres (m) wide with the carpark foundation beam on the building side and a battered rock slope 7.5m to 13m high on the mountain side. The collector channel has a volume of the order of 48m^3 and, with the pipe network downstream, provides detention storage. The discharge to SWMH D downstream of the collector channel is significantly less than the peak flow from the mountain side above and hence also reduces the peak overflow flow discharge to the KBP Pond.

The Collector Channel discharges to the Outlet Structure at the southern end of the car park building that in turn discharges to the stormwater collector pipework in the bus park area. The outlet structure is designed to convey flows into the collector network with a minimum of tree debris and sediment.

The outlet structure is essentially a set of four weir sections that ponds stormwater runoff in the collector channel for the settlement of sediment. A set of four galvanised steel baffle plates before the four weir sections prevents the floating tree debris from flowing over the weir into the collector network. Should the outlet structure become partially blocked at maximum flow capacity, then any stormwater overflow can leave the channel at the northern end of the channel to the area north of and below the car park building to the KBP in a similar way to what occurs at present. In an extreme flow or blockage situation the baffle plates would also let stormwater overflow into the collector network. The design maximum stormwater level is set at the adjacent car park floor level. Under all but extreme flood conditions the stormwater level would not exceed the car park floor level.

A 25mm dia. pipe in a sump in the channel floor at the Outlet Structure drain allows the collector channel to slowly drain after a stormwater flow event (located after the treatment device in order to avoid blockage).

The details for the proposed structure are provided in the drawings presented in the Appendices.

6.3.3 Site Primary Collector Pipework

During flood events, stormwater from the mountain slopes above the car park and Gondola Base building will flow into the bus park area. "Humes Max pits" with rear overflow capacity are provided to catch the pine cone and pine needle debris during runoff events. Catch-pit inserts such as Enviropod (or similar) filtration bags, would be provided to remove grit, and vehicle contaminants for stormwater first flush wash-off during normal frequent stormwater flow events.

6.3.4 Replacement Pipe to Brecon Street and Control Structure

It is proposed that the revised stormwater design would collect stormwater from the mountain side and the Base site catchments through installation of a new stormwater pipe from SWMH D to the manhole SWMH A10 in Brecon Street. The new pipe is designed to provide the same conveyance capacity as the existing stormwater pipework between SWMH A6 to SWMH A10.

Maintaining the discharge to Brecon Street includes:

- Making the part of the existing stormwater pipe network that lies under the new car park building footprint redundant.
- Replacing part of the existing stormwater pipe network that lies under the proposed extended Base building areas; and
- Utilising part of the existing stormwater pipe network in Brecon Street to discharge stormwater to the existing QLDC stormwater network.

The sizes and provisional lengths of the new pipe are shown in the drawings in the Appendices. The proposed new pipeline would be located in the proposed pedestrian lane next to the proposed extension to the Base building, alongside, and located higher than the new foul sewer pipe.

The provisional new pipe invert and water surface profiles are indicated on the vertical profiles in Figure 6.3 and shown in the Appendices.

When the capacity of the replacement pipeline to Brecon Street is exceeded, the control weir structure (SWMH D) diverts any additional flow to the existing overland flow path that feeds through the KBP. SWMH D is designed to have a weir set at 345.2m to act as the overflow control structure.

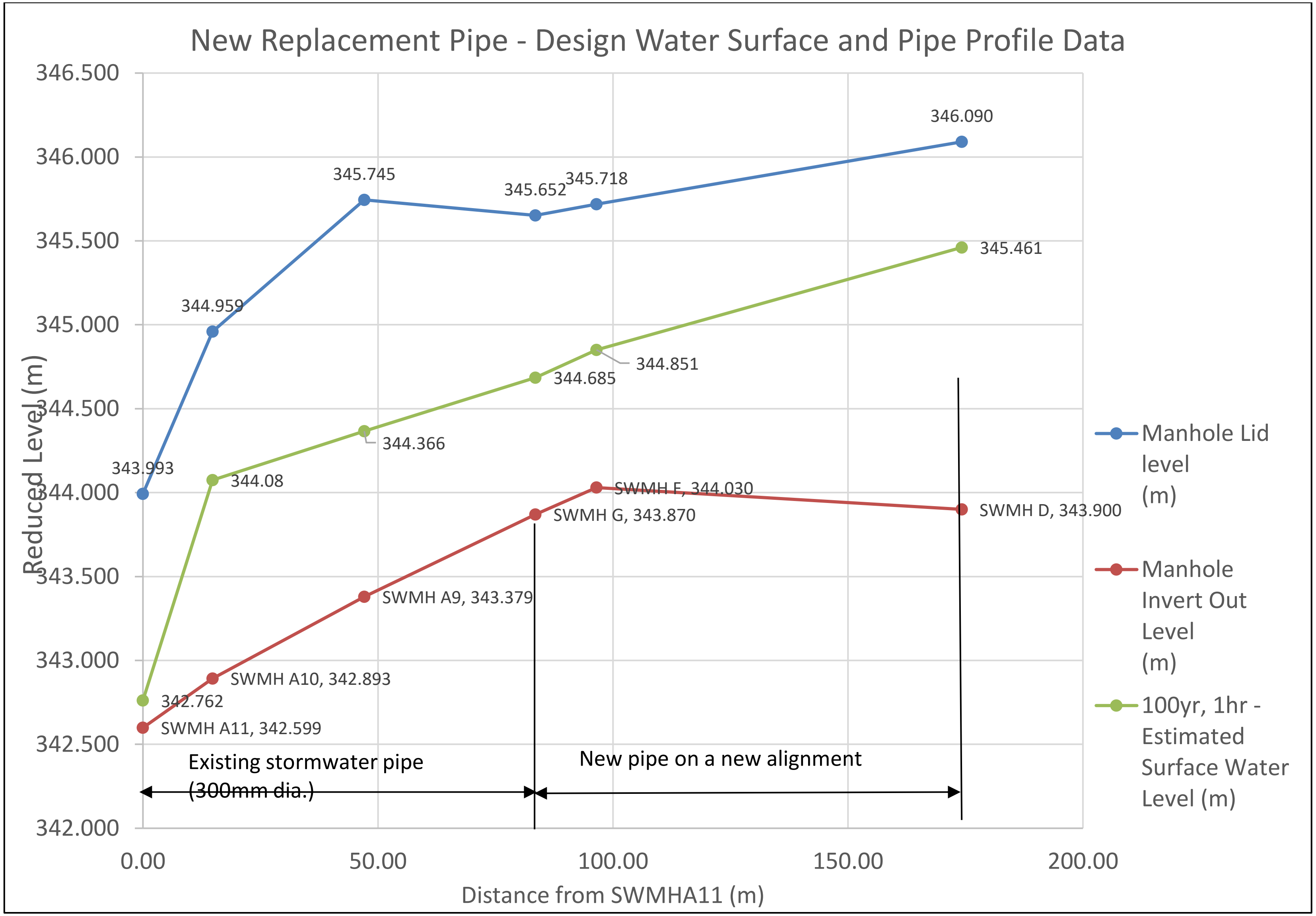


Figure 6.3: Proposed Pipeline Profiles - SWMH A11 to SWMH D

6.3.5 Overland Flow to the KBP Pond

Stormwater flows from Manhole E at the northern end of the car park building will discharge via the existing overland flow paths towards the KBP Pond.

6.3.6 Subsoil Drainage and Discharge

The location of the subsoil drainage is shown on the plans in Appendices. The primary function of the subsoil drainage system is to drain groundwater flow, which can be from surface infiltration along the batter slope via gaps within rocks or spring recharge. The subsoil drainage system would then collect and convey the excess groundwater into a manhole that would discharge into the stormwater reticulation system that drains to the KBP Pond.

6.3.7 Gondola Base Building Excavation Area

SW Manhole B1 is located in the Tower Base excavation area on the eastern side of the Gondola Base Building, as shown in Figure 6.1. The excavation is part of the final ground model designed to allow the gondola carts to swing and dip as they enter the building. The area of excavation can be prone to localised flooding for larger events as the ground is lower than the surrounding area. The Lid Level of SW MHB1, 345.2m, is based at the lowest ground level of the excavated area. Table 6.1 and Figure 6.4 presented below show the water levels determined in the modelling in the excavated area for each storm event and how they compare to the Gondola Base Building slab level as well.

Table 6.1: Water Levels in the ondola Swing one E cavated Area

Storm Event	Water Level in Gondola excavation area (mAD)	Scruffy Dome Lid Level (mAD)	Depth of Water above Scruffy Dome (m)	Gondola Recess Floor Level (mAD)	Freeboard to Gondola Recess Level of Building (m)	Gondola Ground Floor Level (mAD)	Freeboard to Gondola Ground Floor Level of Building (m)
2yr	N/A	345.2	N/A	346.15	N/A	346.7	N/A
10yr	345.31	345.2	0.11	346.15	0.84	346.7	1.39
20yr	345.46	345.2	0.26	346.15	0.69	346.7	1.24
50yr	345.66	345.2	0.46	346.15	0.49	346.7	1.04
100yr	345.79	345.2	0.59	346.15	0.36	346.7	0.91

As shown in Table 6.1, there is no flooding in the 2yr event and up to 0.59m of water in the 100yr event. The flood water in the excavated area will not pond for any significant duration, approximately a few hours.

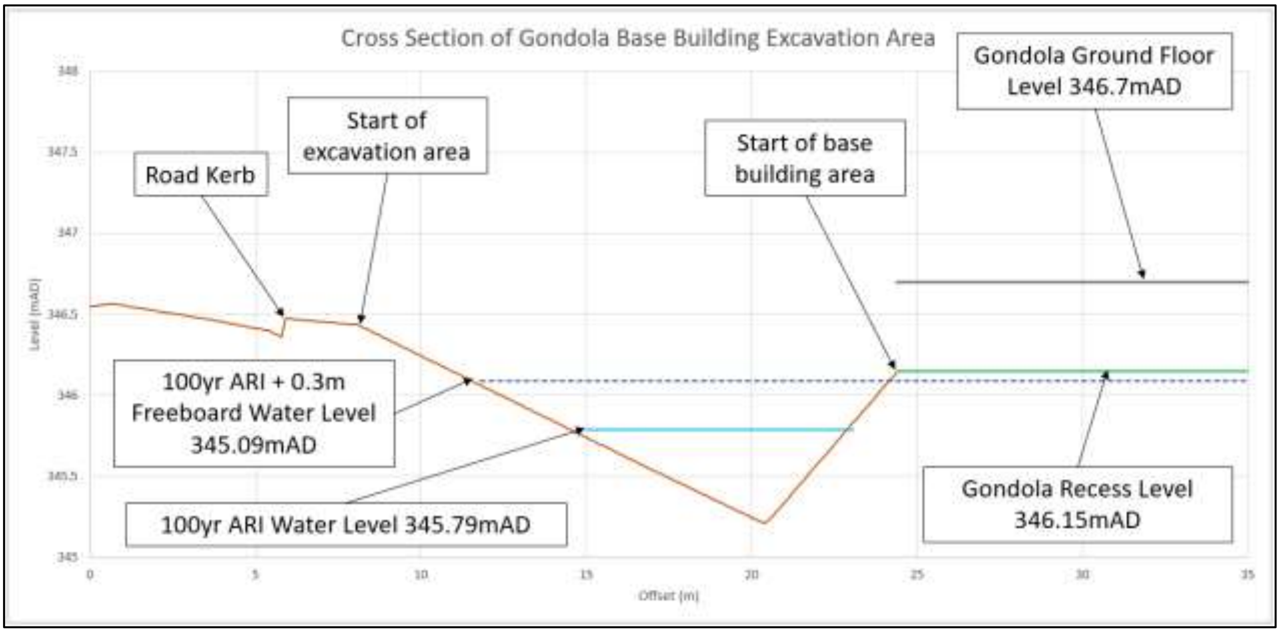


Figure 6.4: Cross Section of   ondola Base Building E cavation Area

QLDC require commercial buildings to have a minimum freeboard of 300mm in the 100yr ARI event. Figure 6.4the cross sectional profile, drawn from the road through the excavation area to the gondola base building. As displayed in 6.4, the gondola recess level and gondola ground floor are located well above the 100yr ARI +0.3m freeboard level of 345.09mAD.

7.0 Post-Development Site Discharges

As with the pre-development state, the post-development scenario was modelled to estimate the flows off the site to Brecon Street and the discharge feeding down towards KBP from the existing secondary overland flow path / new cycleway discharge point. The model results were also used for pipe sizing calculations.

Table 7.1 below shows the estimated site peak flow and volume discharges for each peak storm event.

Table .1: Pre- vs Post-Development Site Discharges

Storm Event	To Brecon Street (E isting Pipe from SWMH A9 to A10)				To BP Pond (PRE overland flow, POST pond inlet pipe discharge)			
	Peak Flow (L/s)		Total olume Discharged (m^3)		Peak Flow (L/s)		Total olume Discharged (m3)	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
2yr, 6hr	41	33	196	317	14	0	49	7
10yr, 2hr	100	97	295	403	77	48	142	36
20yr, 2hr	100	98	357	459	135	143	263	181
50yr, 2hr	101	100	417	531	228	265	475	441
100yr, 1hr	102	111	290	387	302	338	370	367

Model Result Summary

- In all cases, except for the 100yr ARI event where there is a slight increase in peak flow, the estimated flows to the Brecon Street pipeline were less than the pre-development flow.
- Note that the open channel behind the car park building provides approximately 48m^3 of storage which would be discharged slowly to the Brecon Street reticulation via a small drainage pipe. The discharge would occur over approximately 2 days following the storm event (at approximately 0.25 L/s).
- The additional peak flow in the 100yr ARI case would likely not affect the capacity of the pipeline downstream of SWMH A11 as the downstream pipe does currently not have capacity to convey the full 100yr ARI flow.
- For the 20yr, 50yr and 100yr ARI peak flow events, there is a marginal increase in peak flow to the KBP. However, in terms of volume, less overall volume is discharged to the KBP due to the inclusion of the storage in the mountain flow open collector channel and the discharge to the QLDC piped network in Brecon Street. The KBP Pond environment is sensitive to the volume of stormwater discharges rather than peak flows as increases in volume may translate to increased flood levels in the pond. The post-development flood levels in the Pond should be less now for the post development scenario than for the existing stormwater management regime.
- Higher stormwater volumes are discharged to Brecon Street at lower flow rates when the peak flows have passed through the QLDC SW network downstream of Brecon Street. The discharge via the QLDC SW network via Hone Creek to Lake Wakatipu is sensitive to increases in peak flow rate and is not as sensitive to increased stormwater volumes discharged at lower flow rates and therefore there would be no significant adverse effects downstream of Brecon Street.
- Localised stormwater will pond in the gondola “swing zone” excavated area adjacent to the Gondola Base building for larger storms. The depth of the 100yr ARI + 0.3m freeboard is still however located below the gondola recess floor and gondola base building floor slab levels. Any stormwater ponding will be short lived.

8.0 LDC Code of Practice Discharge Re uirements

8.1 Design Storms

With reference to Sections 4.3.4 and 4.3.5 of the QLDC Land Development and Subdivision (CoP) (2020), the design requirement is that, where there is no secondary flow path, the primary stormwater flow path is to be designed for the 100yr ARI event.

The primary system of channels and pipelines on the site for the conveyance of stormwater from upstream flow paths 1, 2, 3 and 4 is piped to SWMH D. From SWMH D, stormwater discharges to a new pipe that replaces a length of an existing stormwater pipe that connects to the QLDC stormwater network at Brecon Street at new SWMH F. The new replacement primary pipe is designed to have capacity equivalent to the existing pipe. As a consequence, it is concluded that the discharge restraints contained in Section 4.3.5.1 of the CoP are not applicable to the piped stormwater flow from the site since the existing pipe does not have capacity to carry the full 20yr ARI flow and instead has been designed to match the capacity of the existing pipe.

8.2 Peak Discharge and Downstream Flood Effects

The QLDC CoP outlines the mitigation requirements for management of peak discharge rates as well as overall considerations for the downstream effects of the discharge point. The relevant clauses are noted below.

Clause 4.2.4:

> "*The implications of further development on ad oining land should be on the basis of replicating the pre-development hydrological regime whereby the maximum rate of discharge and pea flood levels post-development are no greater than pre-development."*

Clause 4.2.7:

> *"Downstream impacts could include (but are not limited to) changes in flow peaks and patterns, flood water levels, contamination levels and erosion or silting effects, and effects on the existing stormwater system. Where such impacts are more than minor, mitigation measures such as pea flow attenuation, velocity control, and treatment devices will be required."*

The peak discharges from the site have been analysed for the 2yr, 10yr, 20yr, 50yr, and 100yr ARI events. Expanding the flood effect management analysis scope to include the smaller 2yr ARI storm demonstrates the effects on the overall hydrological regime.

In regard to the stormwater pipework from SWMH G to SWMH A10 in Brecon Street, there is no significant net change to the stormwater runoff entering the existing pipe at SWMH G.

Flows in excess of the capacity of the replaced stormwater pipe to Brecon Street, would discharge via SWMH E via the existing overland flow paths to the KBP. The KBP Pond discharges via an existing pipe to the QLDC stormwater network. There is no significant change to the flows and volumes discharged to the KBP Pond from the Skyline site. Additionally, the inflow from the Skyline site is very small in comparison to the inflow to the KBP Pond site from the surrounding catchment. This is discussed further in Section 9.0 below.

8.3 Stormwater uality

Clause 4.2.8 of the QLDC CoP states the following:

> *"Stormwater treatment devices may be required to avoid adverse water quality effects on receiving waters. The type of potential contaminants should be identified and then treatment devices designed to address the particular issues. The need for treatment devices should be considered for every discharge even when it is not a direct discharge to a receiving water, for instance where the discharge is to an existing networ . In this instance specific approval from the TA will be required."*

Stormwater treatment has been included as a consideration for the design through inclusion of a formal treatment device designed to provide treatment of the new carparking building (not detailed as part of this report) and the open channel outlet structure designed to limit debris in flows downstream to the QLDC network and KBP.

8.4 Construction

As required by QLDC an Environmental Management Plan that comprehensively addresses erosion and sedimentation is required prior to construction. An Erosion and Sedimentation Management Plan would be implemented together with a construction management plan to mitigate potential adverse effects.

9.0 Effects Assessment

9.1 BP Pond Stormwater Catchment

The KBP is situated in a natural flow path with flows contributing from the Skyline Base carpark site as well as multiple other overland flows from the north and overflow from Brecon Street to the south.

Historically, the stormwater flow paths from the mountain side above the proposed Skyline car park building flowed overland through the car building site and overland into the natural pond formation in the KBP area.

Later, an outlet from the pond formation to the QLDC stormwater pipe network was presumably provided to drain stormwater and spring water from the pond formation. The outlet to the QLDC network would have resulted in a permanent lowering of dry weather pond water levels and water levels in the pond during storm events provided the outlet was maintained.

With the pond formation drained, the KBP developed the pond floor and surrounding areas as a showcase for native birdlife. Survey work carried out in 2017 and 2021 confirms that development of the original pond floor is continuing. Between 2017 and 2021 the nominal pond water level at the proposed pipe outlet to the pond from the car park building area has been raised from 321.10m to 321.45m, an increase of 350mm.

9.2 Effects on the BP Pond and LDC Network

A detailed rainfall runoff assessment has been undertaken to assess the effects of runoff into the KBP and into the downstream QLDC stormwater network. Refer to Table 7.1 above and the corresponding text.

The potential change in effects on the KBP Pond are related to the differences in pre- and post-development stormwater volumes entering the pond from the Skyline Base sub-catchment.

Overall, the proposed Skyline development would have minimal, if any, adverse effects in terms of volume and runoff flow over and above the effects due to the current development on the site.

9.3 Stormwater Treatment

9.3.1 Mountain Catchment

As noted above, stormwater from the mountain side currently flows across the carpark and is either collected in the existing pipe to Brecon Street or flows overland down through the KBP area below the car park building to the KBP Pond.

During the preliminary design phase, it was noted that debris from the pine tree vegetation on the mountain side causes the inlets in the existing stormwater network to block and in response the outlet from the proposed mountain catchment stormwater collector channel behind the building is specifically designed to reduce the entrainment of debris into the stormwater network.

The risk of stormwater inlet blockage increases significantly when runoff from the mountain side begins and blockages cause overland flow to the KBP Pond. However, the risk of blockage for the proposed outlet from the collector channel is reduced compared to that for the existing stormwater network. Furthermore, an emergency overflow from the channel is provided at the northern end of the proposed car park building in the case of severe blockage.

The adverse stormwater quality effects due to debris in stormwater flows entering the QLDC network would be substantially reduced by the proposed collector channel outlet. Addressing debris blockage effects also means the risk of overland flows the magnitude of flows to the KBP Pond due to blockages would also be reduced.

9.3.2 Traffic Volume

The car park building would increase the traffic volumes to the Skyline site and therefore measures for site stormwater treatment of trafficable areas have been included in the design. Stormwater from the roof of the car park building would be treated by a proprietary device included in the services design. The access road and bus parking area would be treated using catch pit inserts in the mud tanks in the bus parking area and the traffic contaminants in the paved areas of the access road and bus turning area. Runoff from the Gondola Base station roof would not be treated.

10.0 Conclusion

The revised design includes provision for a new replacement pipe connection from the proposed Skyline Gondola Base site bus park and car park building area to the existing Queenstown Lakes District Council (QLDC) stormwater network in Brecon Street. The retention of this pipe conveyance network preserves the existing stormwater management regime in the locality. The capacity of the new pipe is equivalent to the capacity of the section of existing pipe that is being replaced.

Preservation of the stormwater management regime means that when the replacement pipe reaches its capacity, any excess stormwater flow spills over a weir that feeds down to an existing overland flow path and on into Kiwi Birdlife Park (KBP) Pond as currently occurs.

The proposed mountain catchment collector channel for flows from the mountain side of the development addresses the risk of blockages of the stormwater inlets due to debris that is inherent in the existing stormwater collection system and therefore reduces the risk of overflows to the Kiwi Birdlife Park.

With regard to the effects on the existing stormwater management regime downstream, the overall changes are minimal, and could be considered an improvement in many cases. The replacement pipe and existing stormwater connection to the QLDC pipe network in Brecon Street would discharge the same peak flow to the QLDC network as at present.

The KBP Pond environment is sensitive to the volume of stormwater discharges as increases in volume would translate to increased flood levels in the pond. Overall, the revised stormwater management system would mean that less overall volume is discharged to the KBP Pond for each of the estimated peak flow 2yr, 10yr, 20yr, 50yr, and 100yr ARI events. This means that post-development flood levels in the Pond would be less than for the existing stormwater management regime.

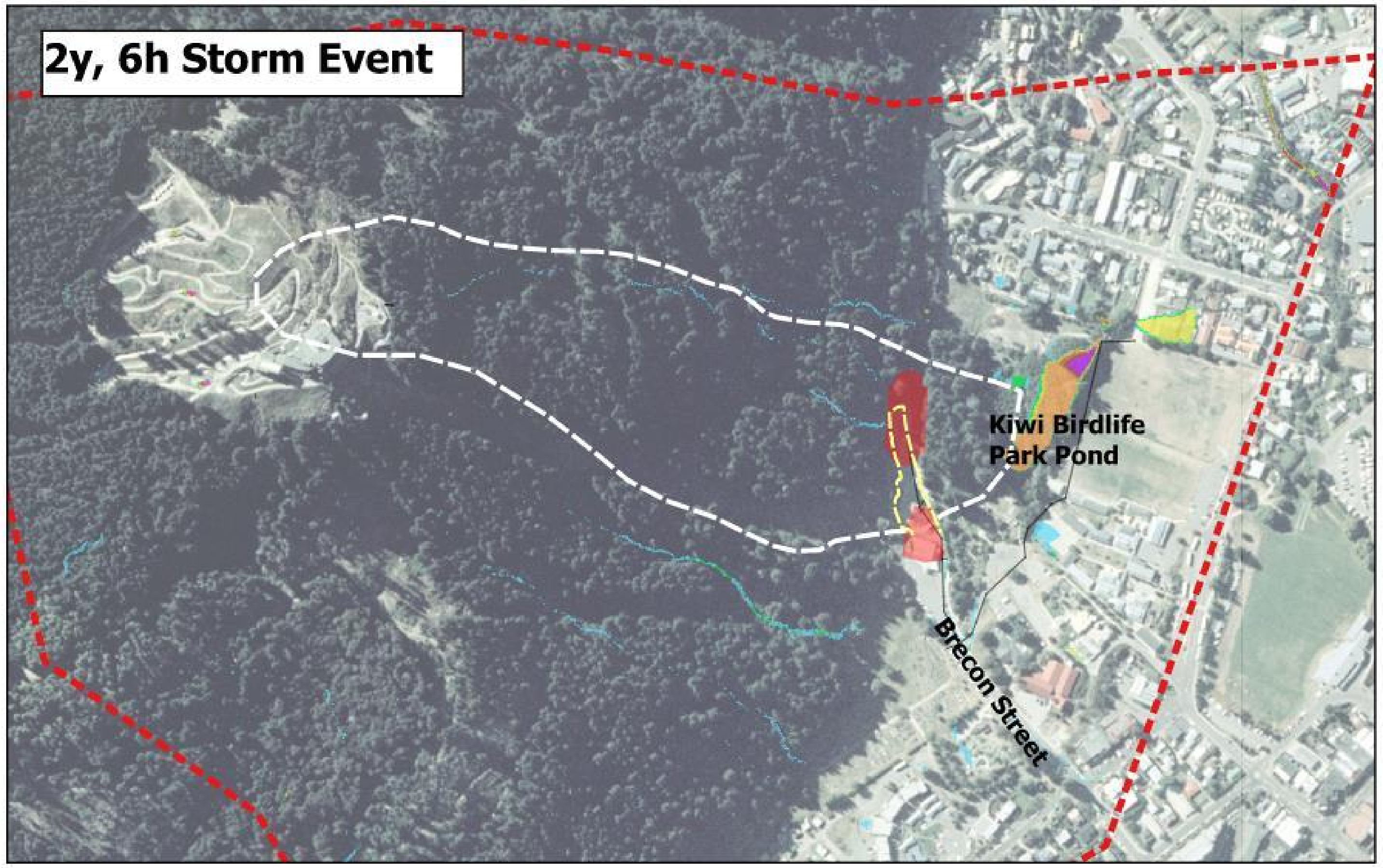
Due to the increased impervious area for the combined new bus and carparking area, the site discharges a marginally increased stormwater runoff volume. The increase in the volume of stormwater discharged is conveyed via the stormwater connection to Brecon Street, but as noted above, the peak discharge is effectively the same. The conveyance system is understood to be sensitive to peak flows rather than sensitive to volume. Therefore, any effects due to the increase in the volume of stormwater discharged to the QLDC system are considered minor.

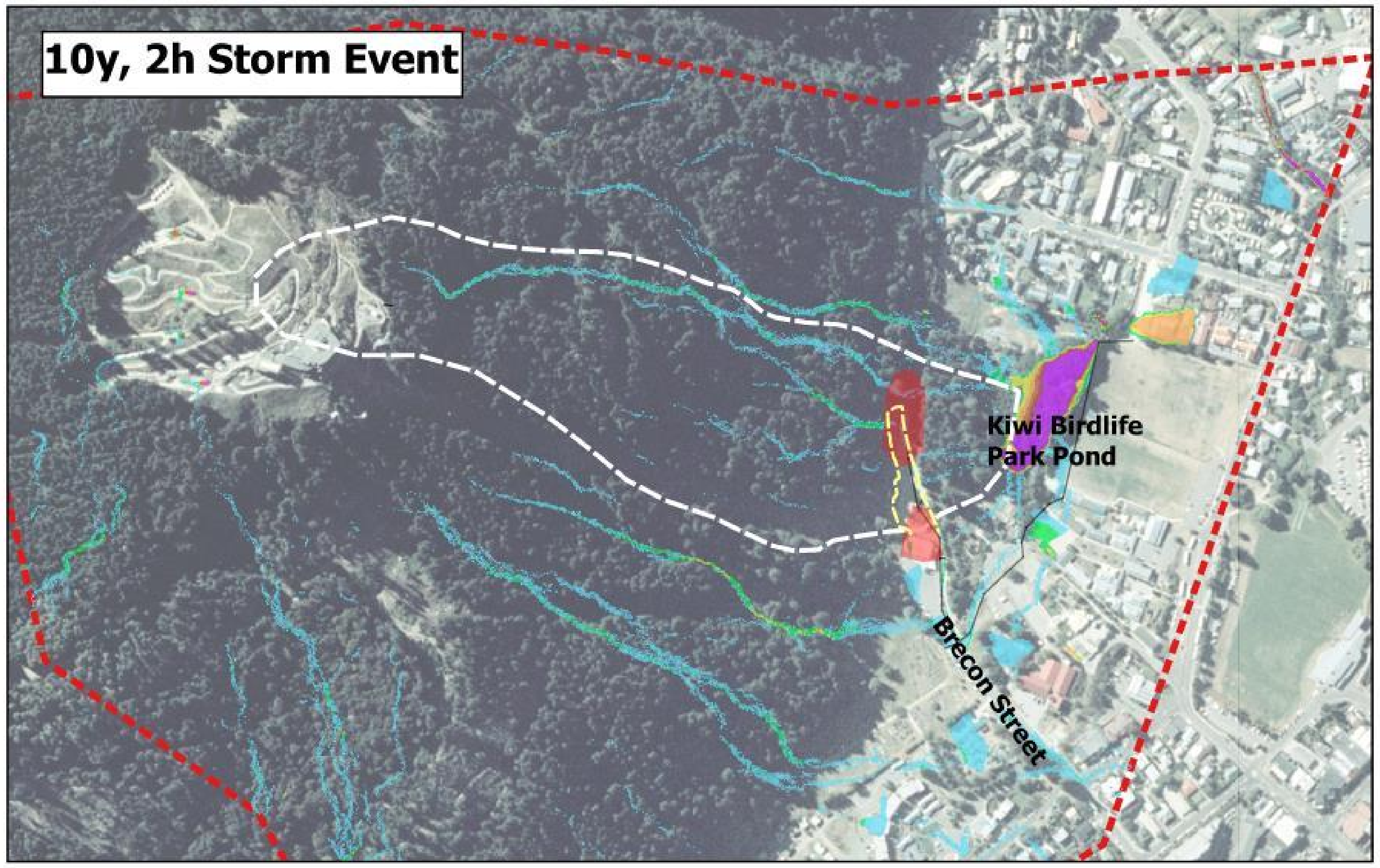
APPENDI   A

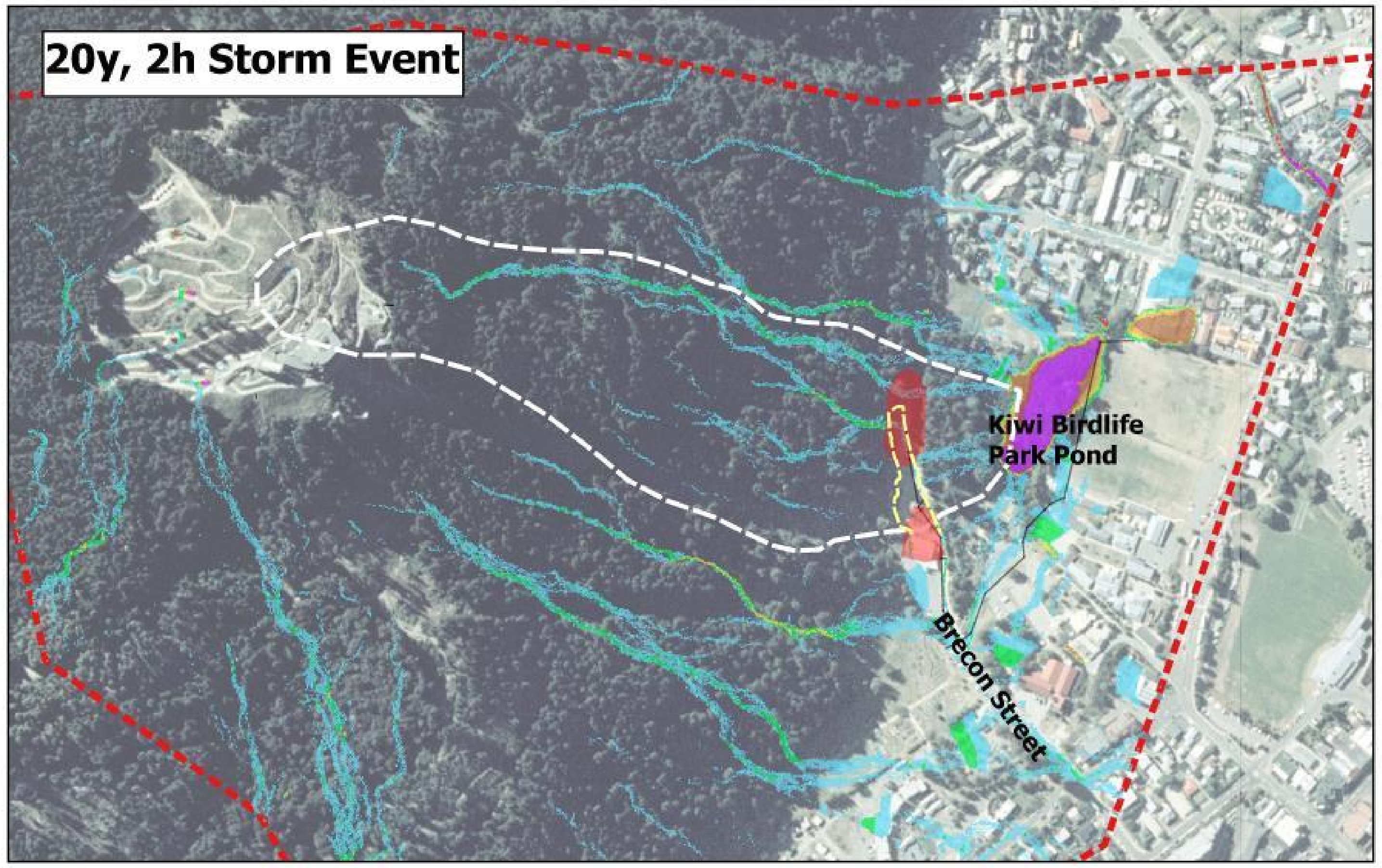
Flood Flow Diagrams - Pre-development -
2yr, 10yr, 20yr, 50yr, and 100yr ARI Peak Storms

Preliminary Flood Flow Paths - Hillside Mountain Catchment
Includes Allowance for RCP8.5 (2081-2100) Climate Change Factor
Presented 9 August 2021

Full Extent



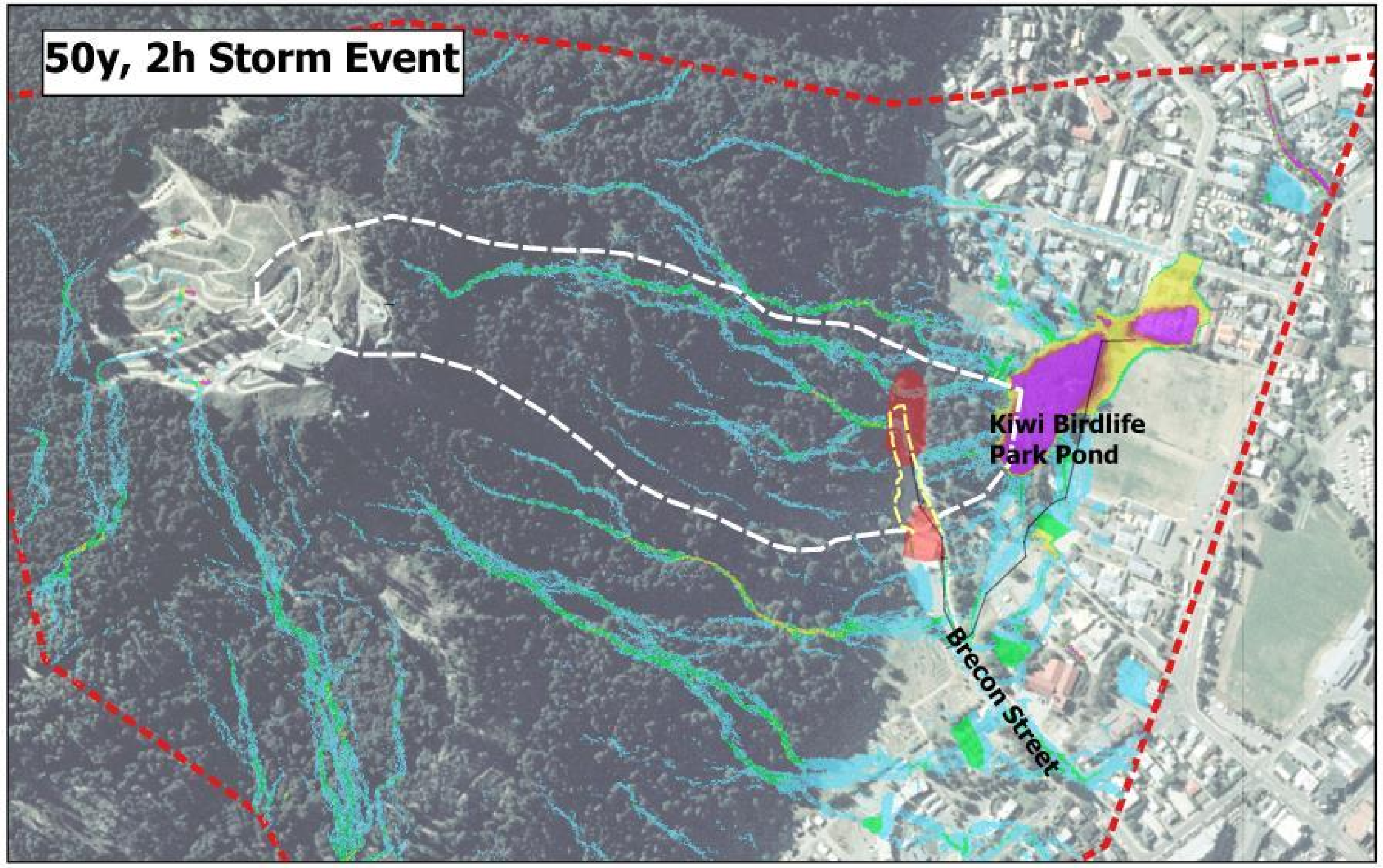


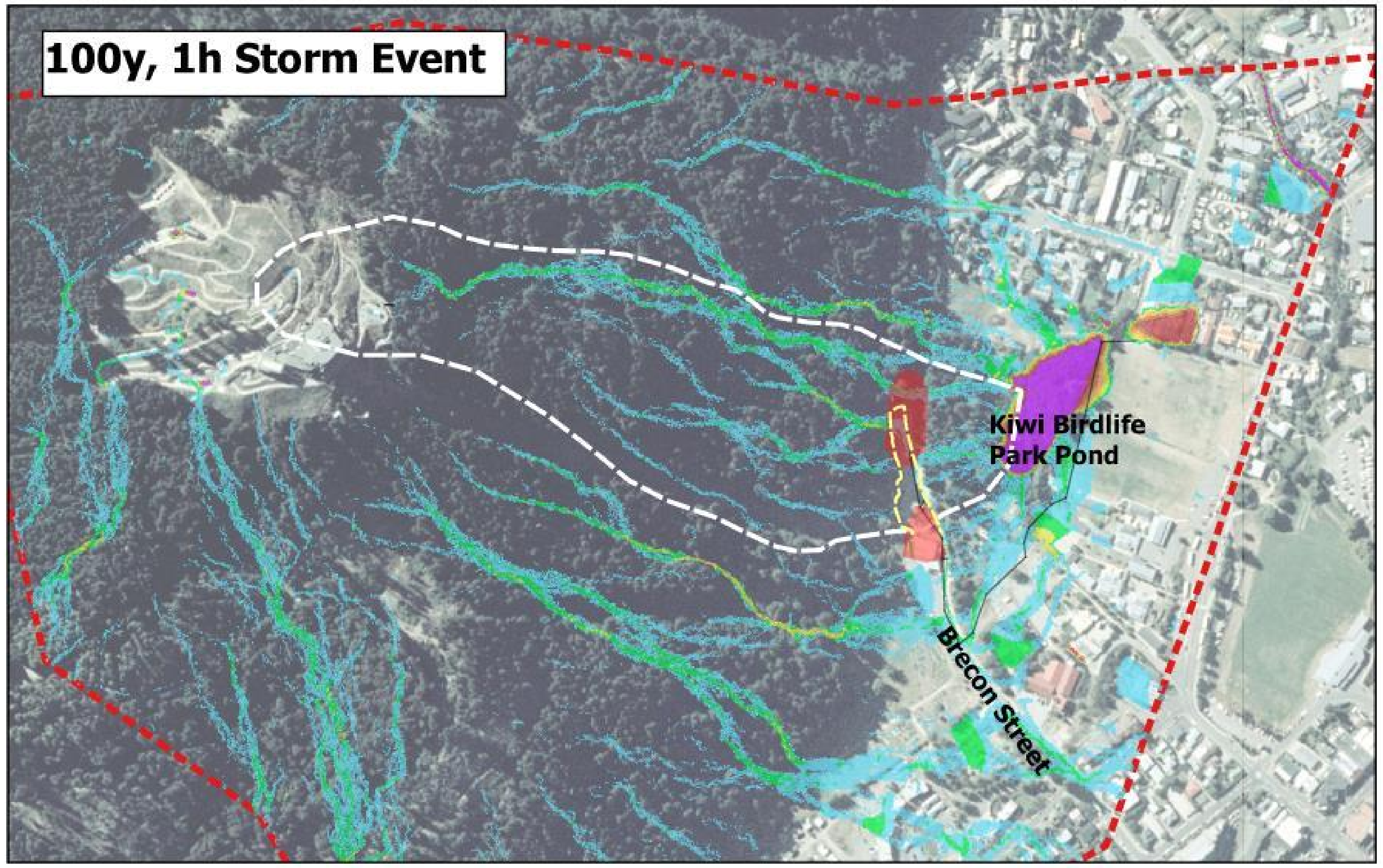


Flood Depths (m)
- 0.025 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- >0.5
- Modelled Extent
- Reference Proposed Building Footprints
- Estimated Skyline Catchment
- Existing Carpark Extent

Preliminary Flood Flow Paths - Hillside Mountain Catchment
Includes Allowance for RCP8.5 (2081-2100) Climate Change Factor
Presented 8 August 2021

Full Extent

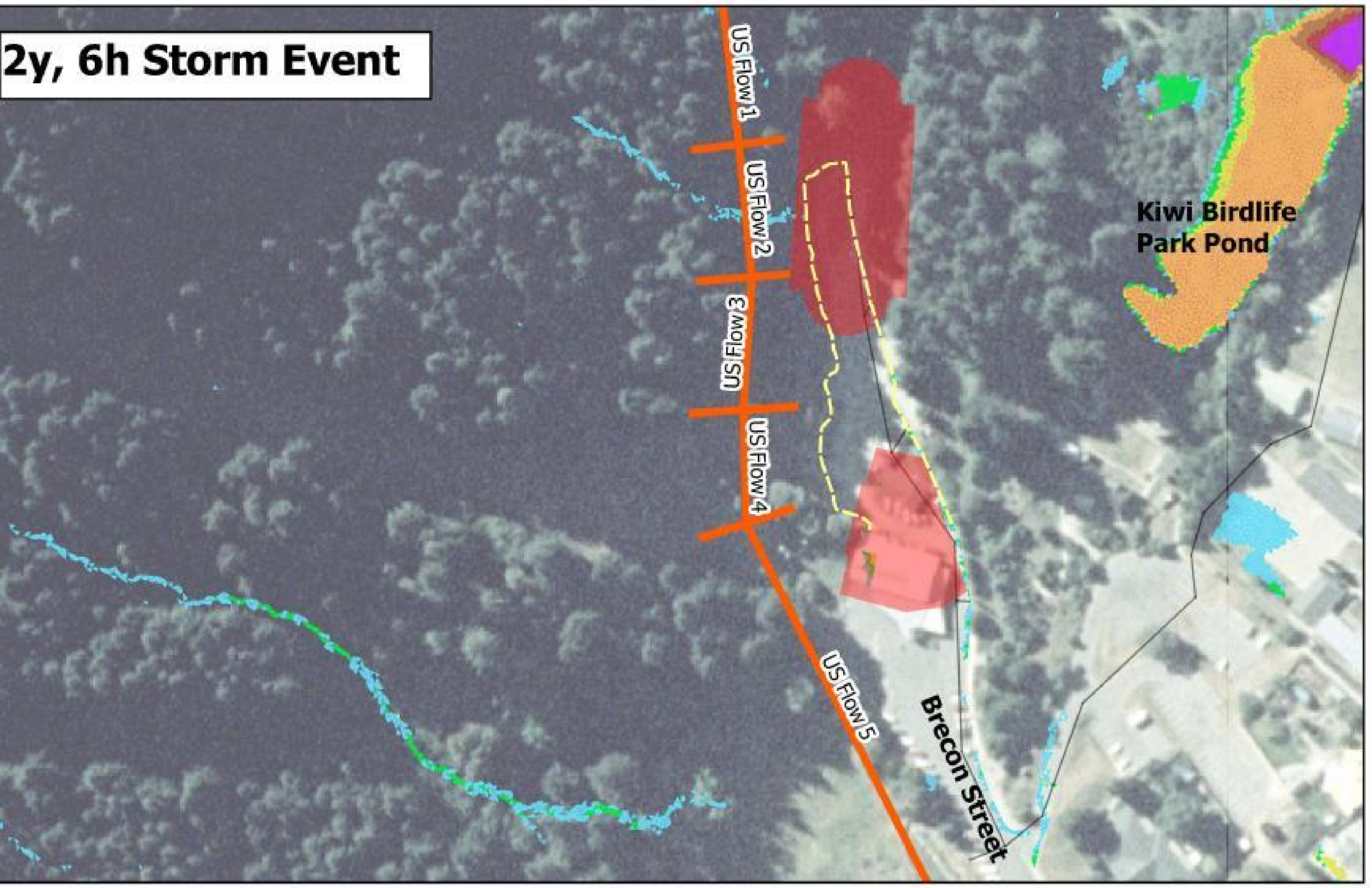


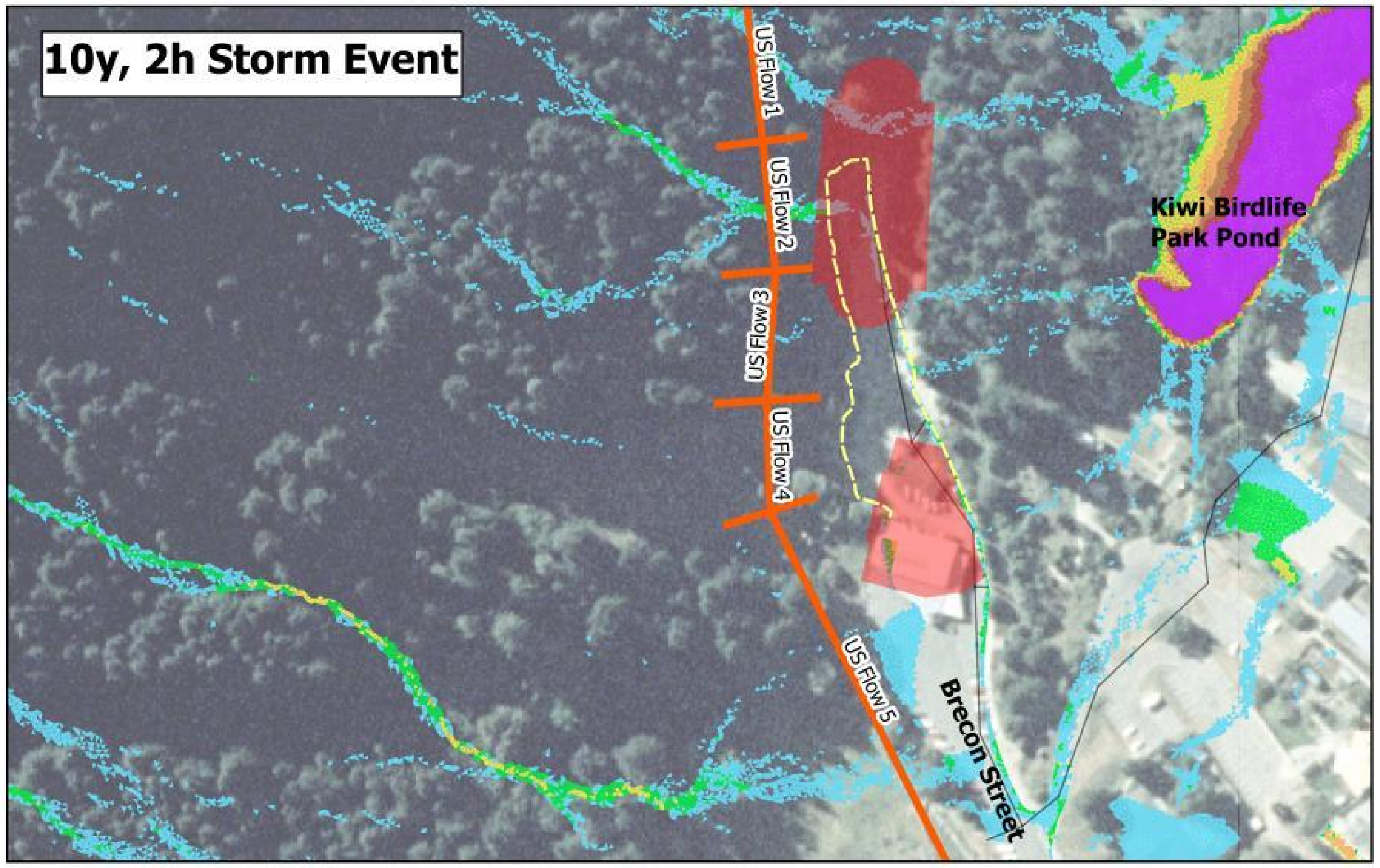


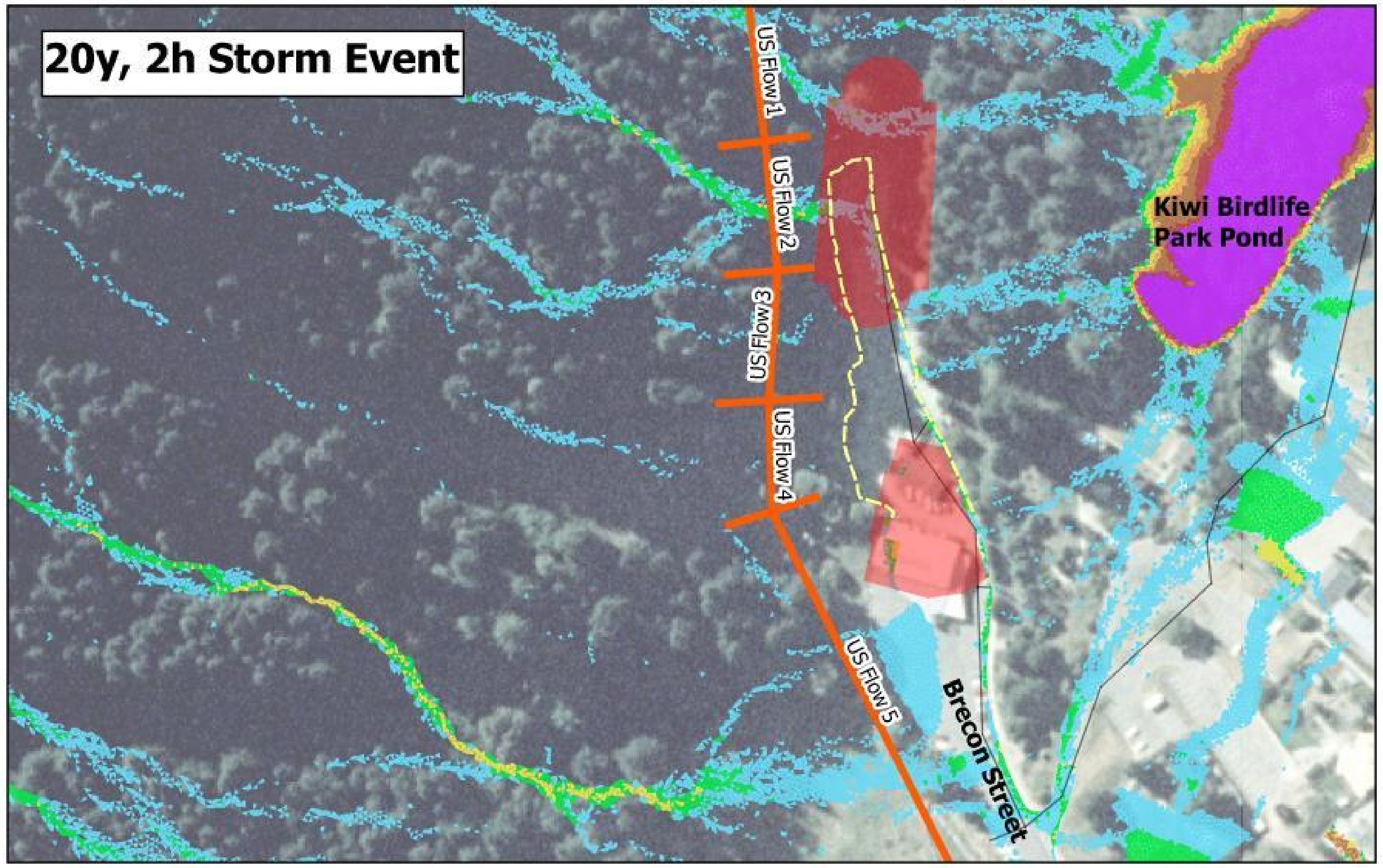
Flood Depths (m)
- 0.025 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- >0.5
- Modelled Extent
- Reference Proposed Building Footprints
- Estimated Skyline Catchment
- Existing Carpark Extent

Preliminary Flood Flow Paths - Hillside Mountain Catchment
Includes Allowance for RCP8.5 (2081-2100) Climate Change Factor
Presented 9 August 2021

Local Extent







Flood Depths (m)
- 0.025 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
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- Modelled Extent
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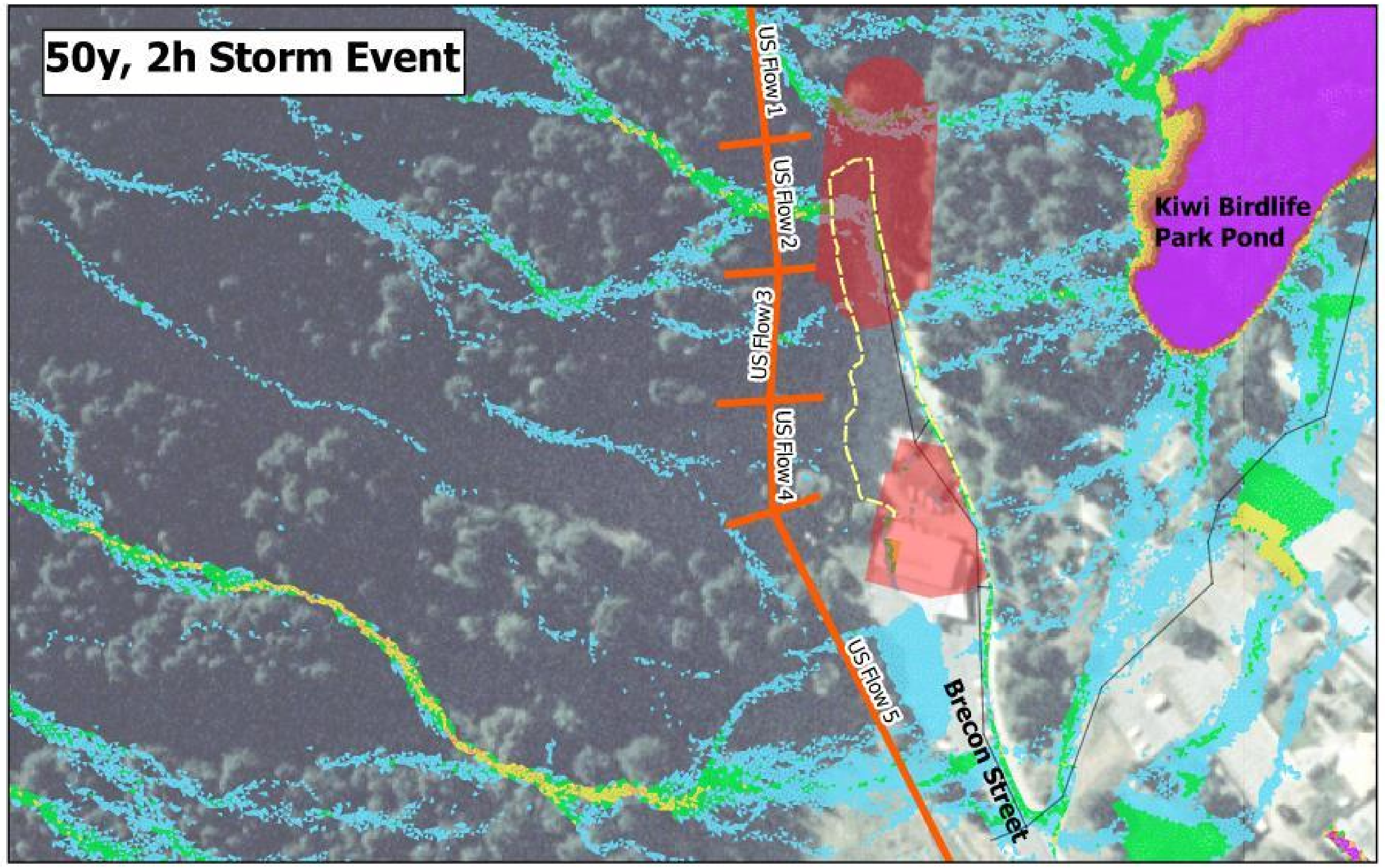
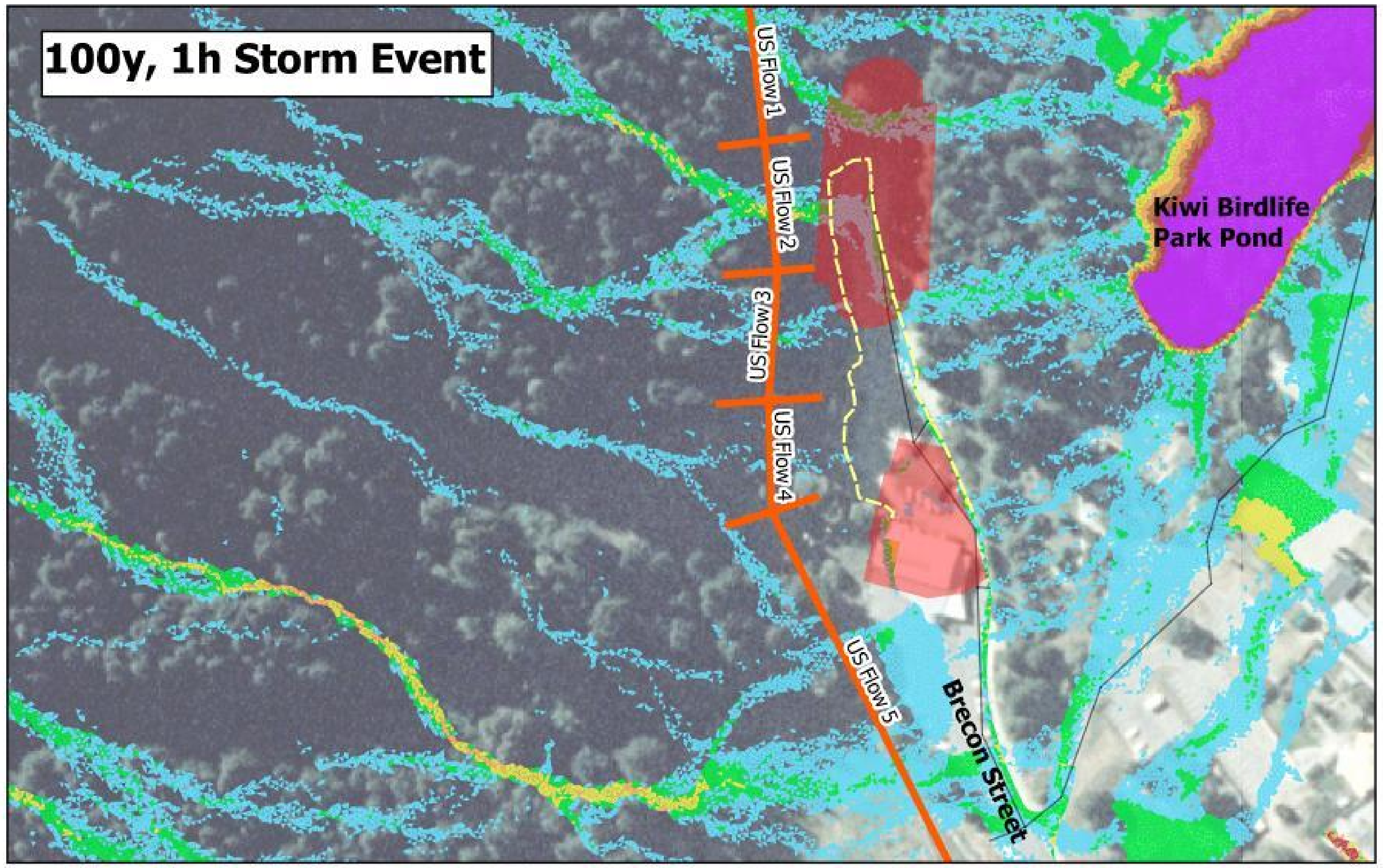
Preliminary Flood Flow Paths - Hillside Mountain Catchment
Includes Allowance for RCP8.5 (2081-2100) Climate Change Factor
Presented 8 August 2021

Local Extent

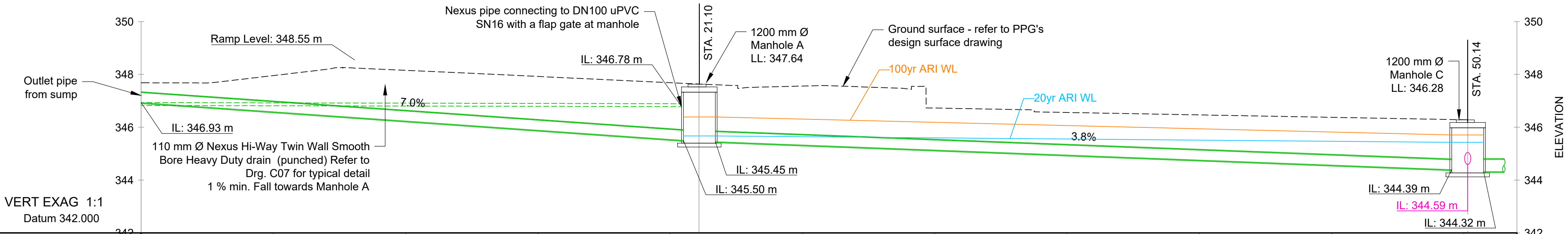




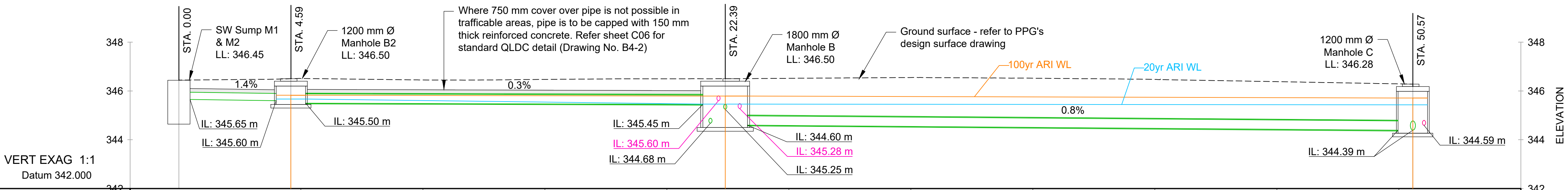
Flood Depths (m)
- 0.025 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- >0.5
- Modelled Extent
- Reference Proposed Building Footprints
- Existing Carpark Extent

APPENDI B

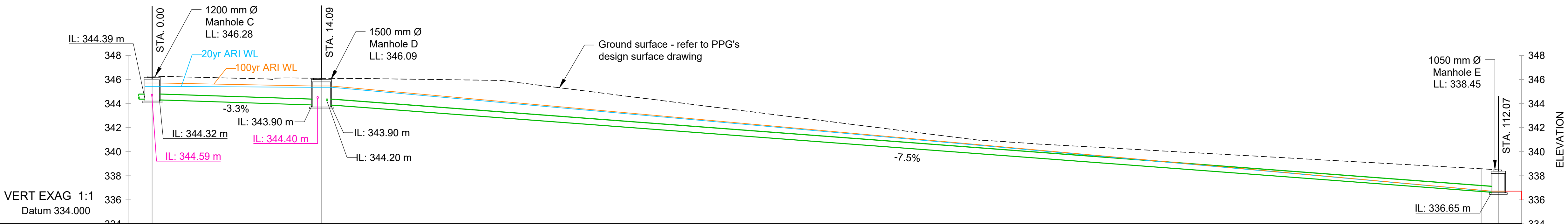
Hydraulic Profiles for 20y and 100yr ARI Peak Storms



STATION (m)	0	5	10	15	20	25	30	35	40	45	50	52
GROUND LEVEL (m)	347.68	348.15	348.50	347.92	347.68	347.56	347.10	346.56	346.47	346.38	346.28	
PIPE TYPE	375 Ø RCRRJ Class 3 Pipe 20.61 m Length					375 Ø RCRRJ Class 3 Pipe 27.87 m Length						



STATION (m)	-2	5	10	15	20	25	30	35	40	45	50	55
GROUND LEVEL (m)		346.51	346.45	346.47	346.50	346.52	346.55	346.52	346.47	346.41	346.29	
PIPE TYPE	DN 300 Ø uPVC SN16 Pipe ~3.6 m Length	DN 375 RCRRJ Class 3 Pipe 16.26 m Length				DN 375 RCRRJ Class 3 Pipe 26.67 m Length						



STATION (m)	-2	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	114
GROUND LEVEL (m)		346.28	346.16	346.01	346.09	346.05	345.98	345.80	345.18	344.56	343.93	343.31	342.68	342.06	341.43	340.90	340.57	340.29	340.01	339.74	339.46	339.18	338.90	338.62	
PIPE TYPE	450 Ø RCRRJ Class 3 Pipe 12.72 m Length				DN 475 Ø uPVC SN16 Pipe 96.69 m Length - Cement stabilised bedding to trench where grading > 5%																				

NOTE:

1. In trafficable areas: Pipe cover to be 1 m minimum.
2. In Non -trafficable areas: Pipe cover to be 600 mm minimum
3. 110 mm Ø Nexus Hi-Way Twin Smooth Bore Heavy-Duty drain (punched with filter sock) installed at invert level along full length of SW pipe. - Refer to typical trench detail on Drg. C06
4. Concrete bulkhead to be installed (as drawn) a min. of 1.5 m upstream of manhole structures

Revision		App	Date
A	For Approval	05/04/22	A.S.

Surveyed	-	-
Designed	H.M.	Apr '22
Drawn	E.G	Apr '22
Reviewed	-	-
Approved	A.S.	Apr '22

Fluent SOLUTIONS
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Client: Skyline Enterprises

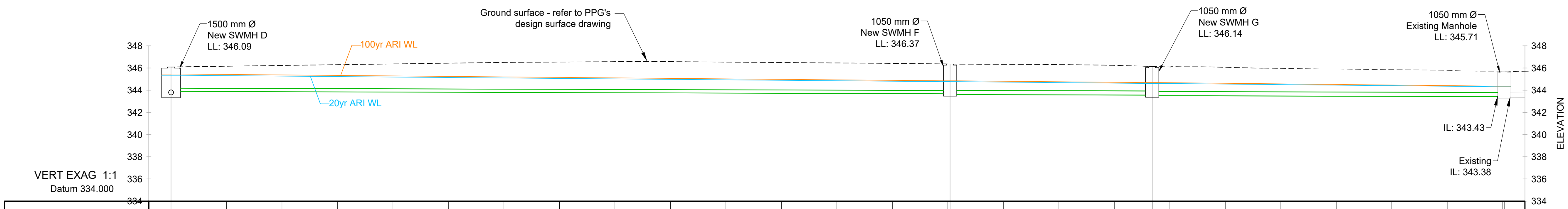
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Hydraulic Grade Lines 1 of 2

Scale (A1 Original): 1:200 m

Issue: For Approval

Project No: Q000507 | Sheet: SK01 | Revision: A



STATION (m)	GROUND LEVEL (m)	INVERT LEVEL
-2		
0		343.90
5	346.16	
10	346.23	
15	346.30	
20	346.37	
25	346.44	
30	346.51	
35	346.54	
40	346.57	
45	346.57	
50	346.53	
55	346.50	
60	346.46	
65	346.42	
70	346.37	343.69 / 343.62
75	346.33	
80	346.31	
85	346.24	
88		343.57 / 343.52
90	346.10	
95	346.06	
100		
105		
110		
115		
120		343.43
122		

GRADE %	PIPE DETAILS (CL to CL LENGTHS)
0.3%	DN 300 UPVC SN16 Length: 70.20 m
0.3%	DN 375 UPVC SN16 Length: 18.21 m
0.3%	DN 375 UPVC SN16 Length: 31.73 m

BRECON STREET CONNECTION LONG SECTION

Rev	Description	App	Date
A	For Approval	05/04/22	A.S.

Revision | App | Date

Surveyed	-	-
Designed	H.M.	Apr '22
Drawn	E.G	Apr '22
Reviewed	-	-
Approved	A.S.	Apr '22

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Client: Skyline Enterprises

Project Title
Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title
Hydraulic Grade Lines
2 of 2

Scale (A1 Original)	Issue	Project No	Sheet	Revision
1:200 m	For Approval	Q000507	SK02	A

APPENDI C

Fluent Solutions Stormwater Management Drawings dated April 2022

SKYLINE
STORMWATER MANAGEMENT PLAN

CIVIL ENGINEERING DRAWINGS

Project No. Q000507

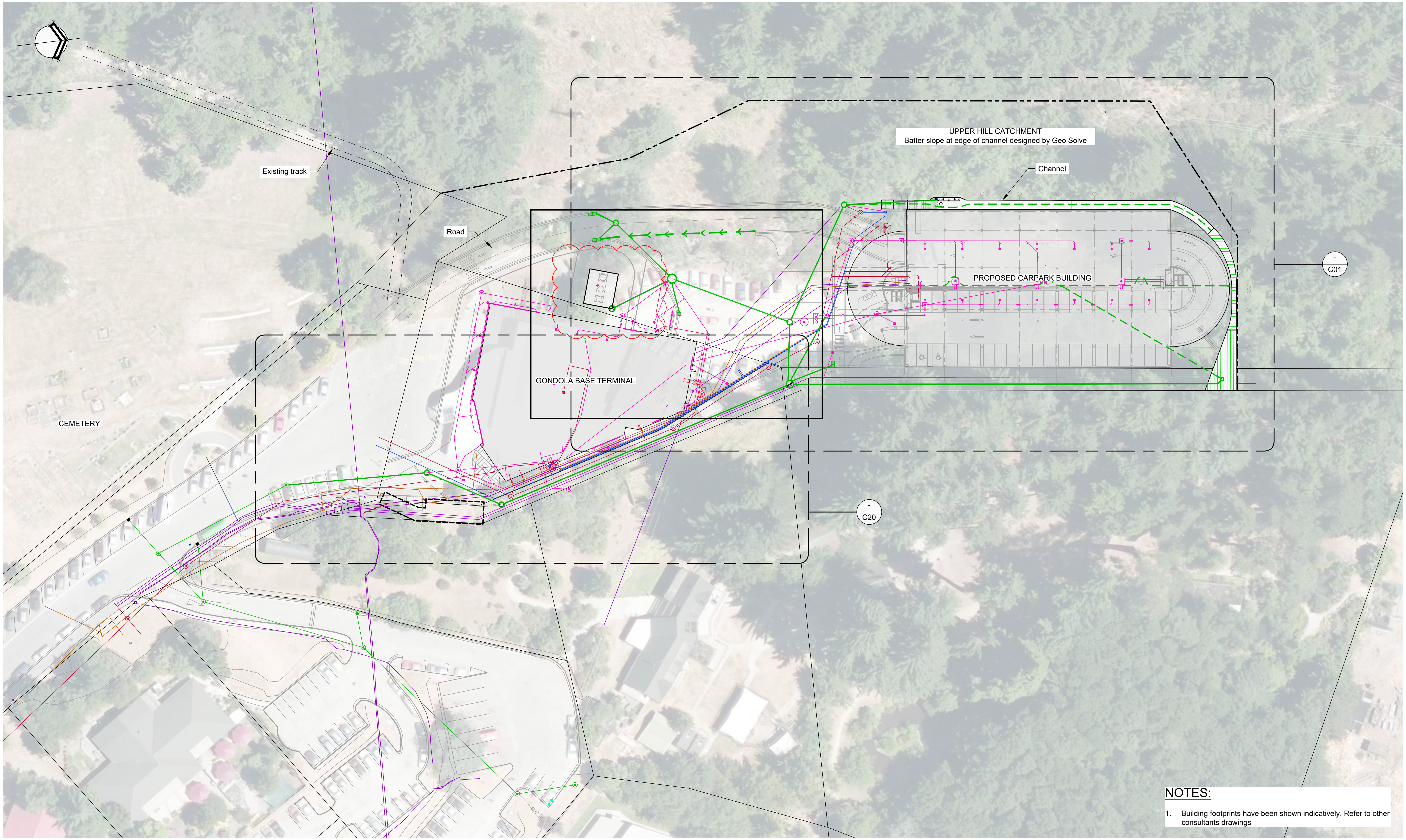
Fluent SOLUTIONS

www.fluentsolutions.co.nz

Sheet Index

Sheet Number	Sheet Title	Rev
C00	Overall Site Layout Plan	1
C01	Site Layout 1 Plan	2
C02	Stormwater Channel Plan	1
C03	Pipe Longsections	2
~~C04~~	~~Site Layout 2 Plan & Longsection~~	~~0~~
C05	Outlet Structure Details	1
C06	Channel Drainage & Pipe Connection Details	1
C07	Outlet Structure Details 2	1
~~C08~~	~~Discharge to Pond Details~~	~~0~~
C09	Typical Manhole Details	1
C10	Scruffy Dome & Secondary Overflow Details	1
C11	Typical Sump Details	1
C20	Brecon St Connection Layout Plan	1

ISSUED FOR APPROVAL
21/12/21



NOTES:

1. Building footprints have been shown indicatively. Refer to other consultants drawings

OVERALL SITE PLAN

1:400 at A1
1:800 at A3

Revision		App	Date
2	Swale removed	A.S.	05/04/22
1	Updated SW Network	A.S	21/12/21
0	For Construction	P.D	26/03/21

Surveyed	P.P.G	-
Designed	Z.S	Apr '19
Drawn	J.P	Apr '19
Reviewed	G.D	Apr '19
Approved	G.D & T.C	Apr '19

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Client: Skyline Enterprises

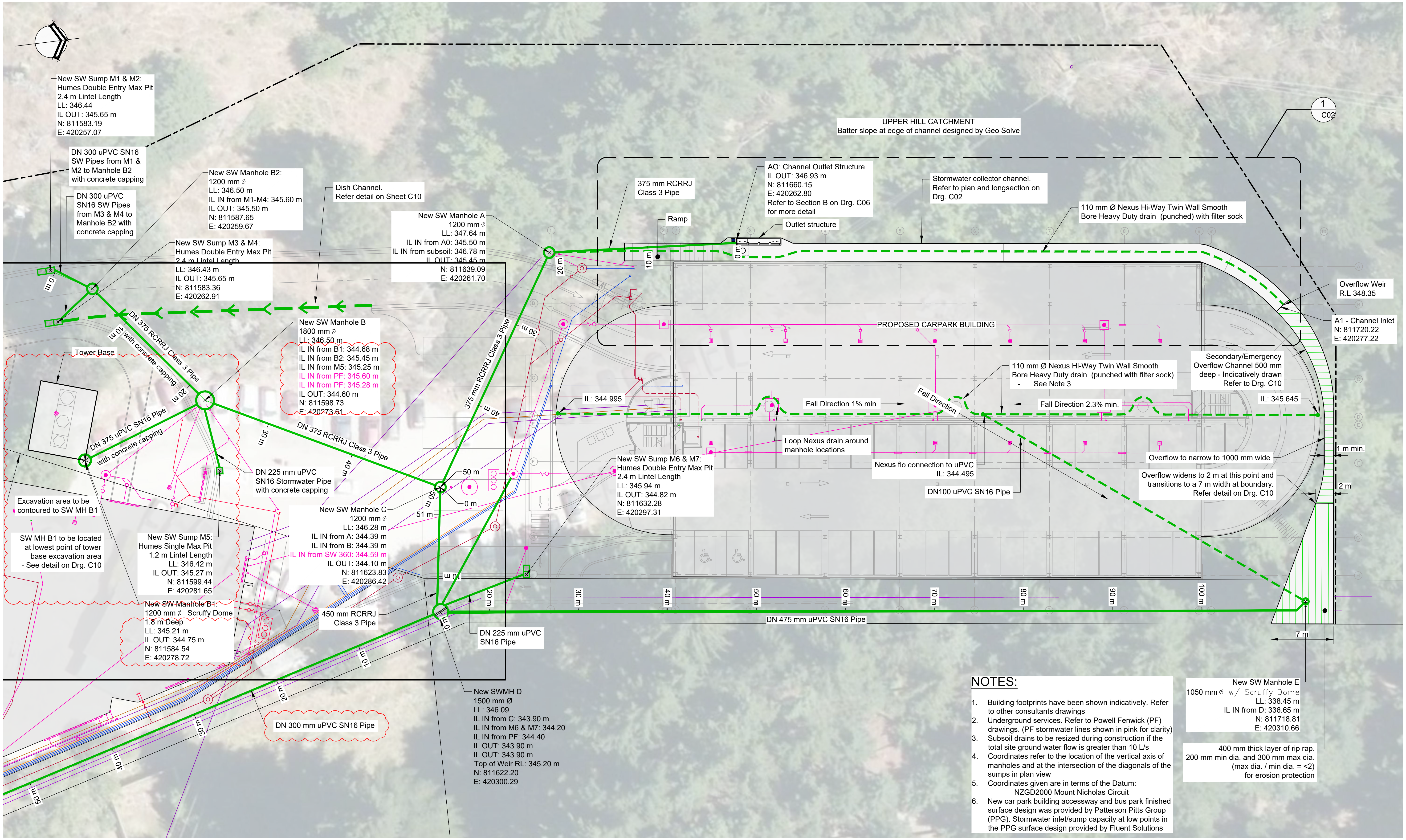
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Overall Site Plan

Scale (A1 Original): 1:400 m

Issue: For Approval

Project No	Sheet	Revision
Q000507	C00	2



NOTES:

1. Building footprints have been shown indicatively. Refer to other consultants drawings
2. Underground services. Refer to Powell Fenwick (PF) drawings. (PF stormwater lines shown in pink for clarity)
3. Subsoil drains to be resized during construction if the total site ground water flow is greater than 10 L/s
4. Coordinates refer to the location of the vertical axis of manholes and at the intersection of the diagonals of the sumps in plan view
5. Coordinates given are in terms of the Datum: NZGD2000 Mount Nicholas Circuit
6. New car park building accessway and bus park finished surface design was provided by Patterson Pitts Group (PPG). Stormwater inlet/sump capacity at low points in the PPG surface design provided by Fluent Solutions

SITE LAYOUT 1 PLAN

1:200 at A1
1:400 at A3

Revision		App	Date
3	Updated SW Network	A.S.	05/04/22
2	ILs Amended SWMH D	A.S	18/01/22
1	Updated SW Network	A.S	21/12/21
0	For Construction	P.D	26/03/21

Surveyed	P.P.G	-
Designed	Z.S	Apr '19
Drawn	J.P	Apr '19
Reviewed	G.D	Apr '19
Approved	G.D & T.C	Apr '19

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Client: Skyline Enterprises

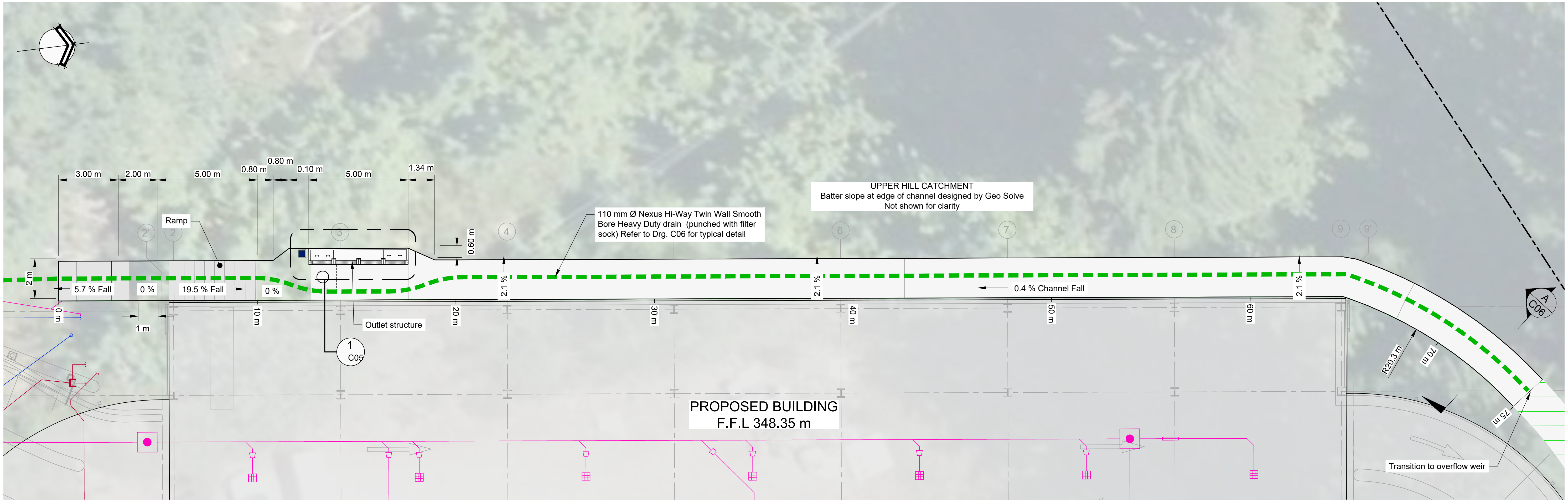
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Site Layout 1 Plan

Scale (A1 Original): 1:200 m

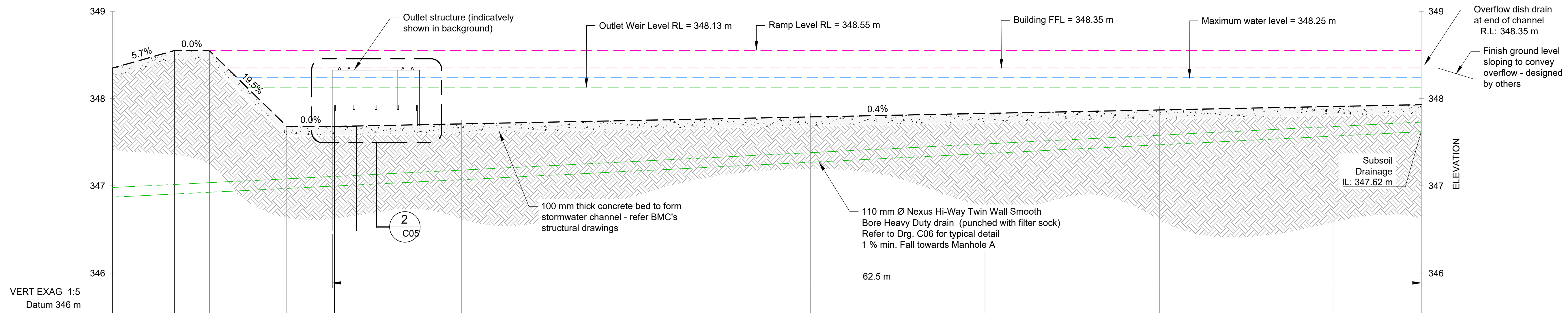
Issue: For Approval

Project No: Q000507 | Sheet: C01 | Revision: 3



1 C01 STORMWATER CHANNEL PLAN

1:100 at A1
1:200 at A3



DESIGN LEVELS (m) SSL @ Batter Slope	348.35	348.55	348.55	347.68	347.68	347.71	347.75	347.79	347.83	347.87	347.91	347.93
DESIGN LEVELS (m) SSL @ Building	348.35	348.55	348.55	347.72	347.72	347.75	347.79	347.83	347.87	347.91	347.95	347.97
STATION (m)	0.00	3.55	5.55	10.00	12.73	20.00	30.00	40.00	50.00	60.00	70.00	75.00

STORMWATER CHANNEL LONGSECTION

1:125 (h) 1:25 (v) at A1
1:250 (h) 1:50 (v) at A3

Revision		App	Date
1	For Approval	A.S	21/12/21
0	For Construction	P.D	26/03/21

Surveyed	P.P.G	-
Designed	Z.S	Apr '19
Drawn	J.P	Apr '19
Reviewed	G.D	Apr '19
Approved	G.D & T.C	Apr '19

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Client
Skyline Enterprises

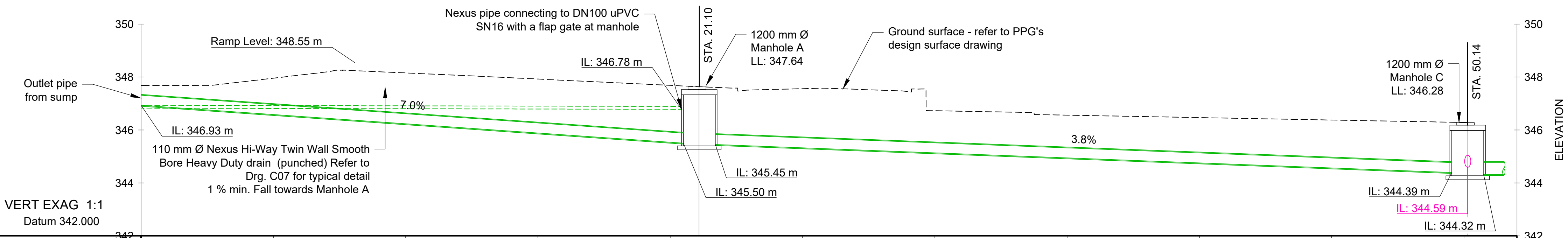
Project Title
Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title
Stormwater Channel Plan & Longsection

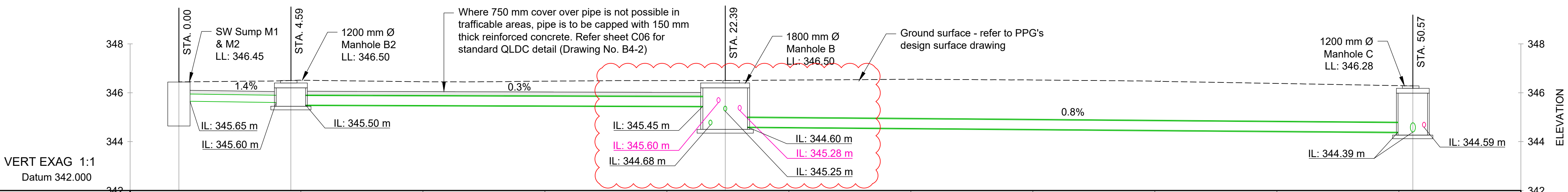
Scale (A1 Original) As Shown

Issue For Approval

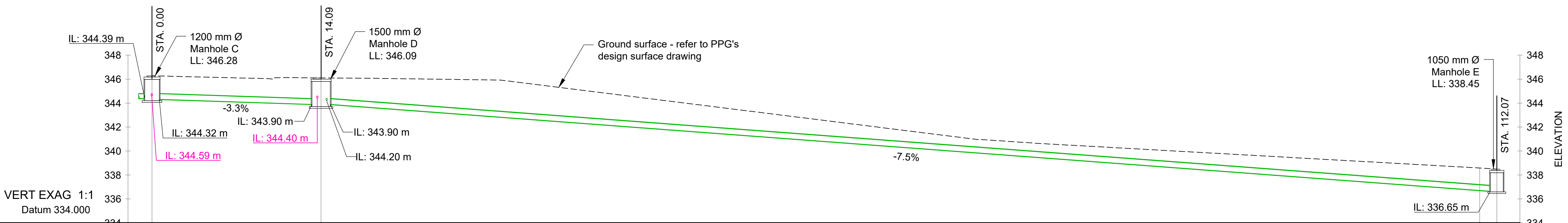
Project No	Sheet	Revision
Q000507	C02	1



STATION (m)	0	5	10	15	20	25	30	35	40	45	50	52
GROUND LEVEL (m)	347.68	348.15	348.50	347.92	347.68	347.56	347.10	346.56	346.47	346.38	346.28	
PIPE TYPE	375 Ø RCRRJ Class 3 Pipe 20.61 m Length					375 Ø RCRRJ Class 3 Pipe 27.87 m Length						



STATION (m)	-2	5	10	15	20	25	30	35	40	45	50	55
GROUND LEVEL (m)		346.51	346.45	346.47	346.50	346.52	346.55	346.52	346.47	346.41	346.29	
PIPE TYPE	DN 300 Ø uPVC SN16 Pipe ~3.6 m Length	DN 375 RCRRJ Class 3 Pipe 16.26 m Length				DN 375 RCRRJ Class 3 Pipe 26.67 m Length						



STATION (m)	-2	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	114
GROUND LEVEL (m)		346.28	346.16	346.01	346.09	346.05	345.98	345.80	345.18	344.56	343.93	343.31	342.68	342.06	341.43	340.90	340.57	340.29	340.01	339.74	339.46	339.18	338.90	338.62	
PIPE TYPE	450 Ø RCRRJ Class 3 Pipe 12.72 m Length				DN 475 Ø uPVC SN16 Pipe 96.69 m Length - Cement stabilised bedding to trench where grading > 5%																				

NOTE:

1. In trafficable areas: Pipe cover to be 1 m minimum.
2. In Non -trafficable areas: Pipe cover to be 600 mm minimum
3. 110 mm Ø Nexus Hi-Way Twin Smooth Bore Heavy-Duty drain (punched with filter sock) installed at invert level along full length of SW pipe. - Refer to typical trench detail on Drg. C06
4. Concrete bulkhead to be installed (as drawn) a min. of 1.5 m upstream of manhole structures

Revision		App	Date
3	Updated SW Network	A.S.	05/04/22
2	ILs Amended SWMH D	A.S	18/01/22
1	Updated SW Network	A.S	21/12/21
0	For Construction	P.D	26/03/21

Surveyed	P.P.G	-
Designed	Z.S	Apr '19
Drawn	J.P	Apr '19
Reviewed	G.D	Apr '19
Approved	G.D & T.C	Apr '19

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Client: Skyline Enterprises

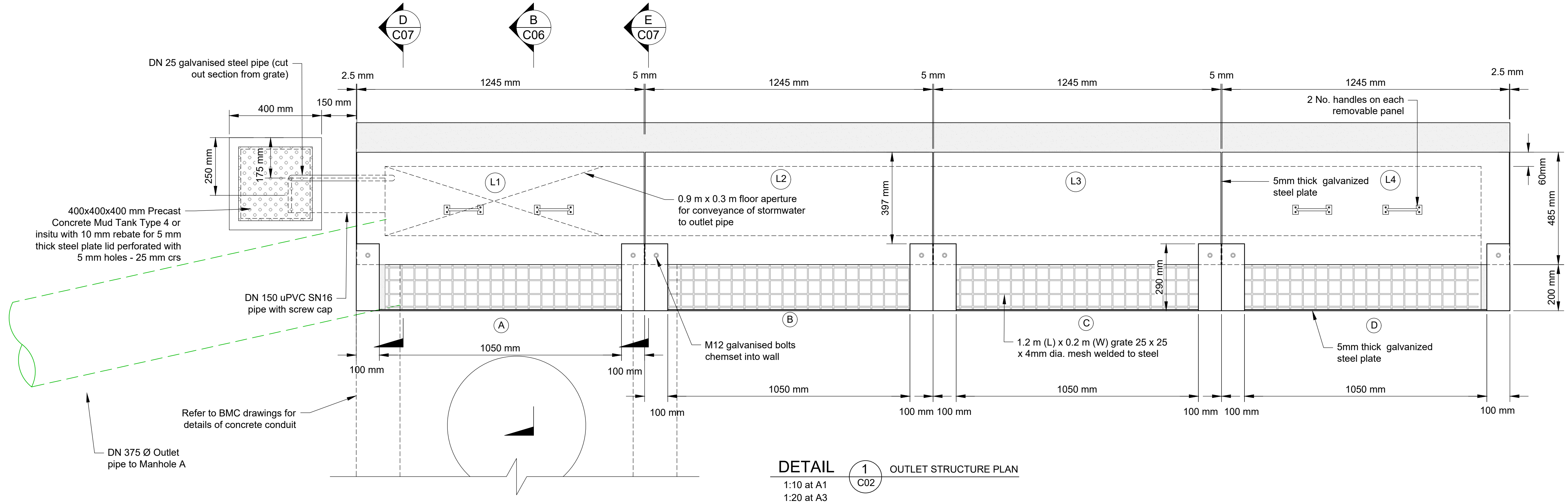
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Pipe Longsections

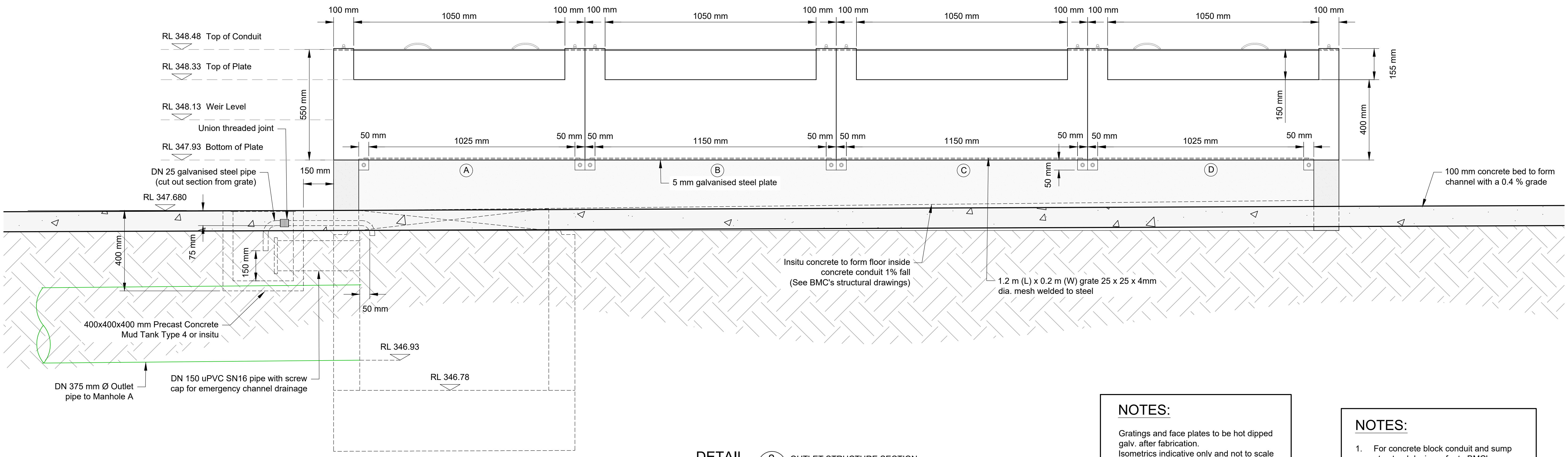
Scale (A1 Original): 1:200 m

Issue: For Approval

Project No: Q000507 | Sheet: C03 | Revision: 3



DETAIL 1 OUTLET STRUCTURE PLAN C02
1:10 at A1
1:20 at A3



DETAIL 2 OUTLET STRUCTURE SECTION C02
1:10 at A1
1:20 at A3

NOTES:

Gratings and face plates to be hot dipped galv. after fabrication.
Isometrics indicative only and not to scale

Shop drawings for steelwork shall be submitted to the engineer for approval prior to fabrication

NOTES:

1. For concrete block conduit and sump structural design refer to BMC's drawings
2. 110 mm Ø Nexus drain not shown for clarity

Revision		App	Date
1	For Approval	A.S	21/12/21
0	For Construction	P.D	26/03/21

Surveyed	P.P.G	-
Designed	Z.S	Apr '19
Drawn	J.P	Apr '19
Reviewed	G.D	Apr '19
Approved	G.D & T.C	Apr '19

Fluent SOLUTIONS

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E: office@fluentsolutions.co.nz

Client: Skyline Enterprises

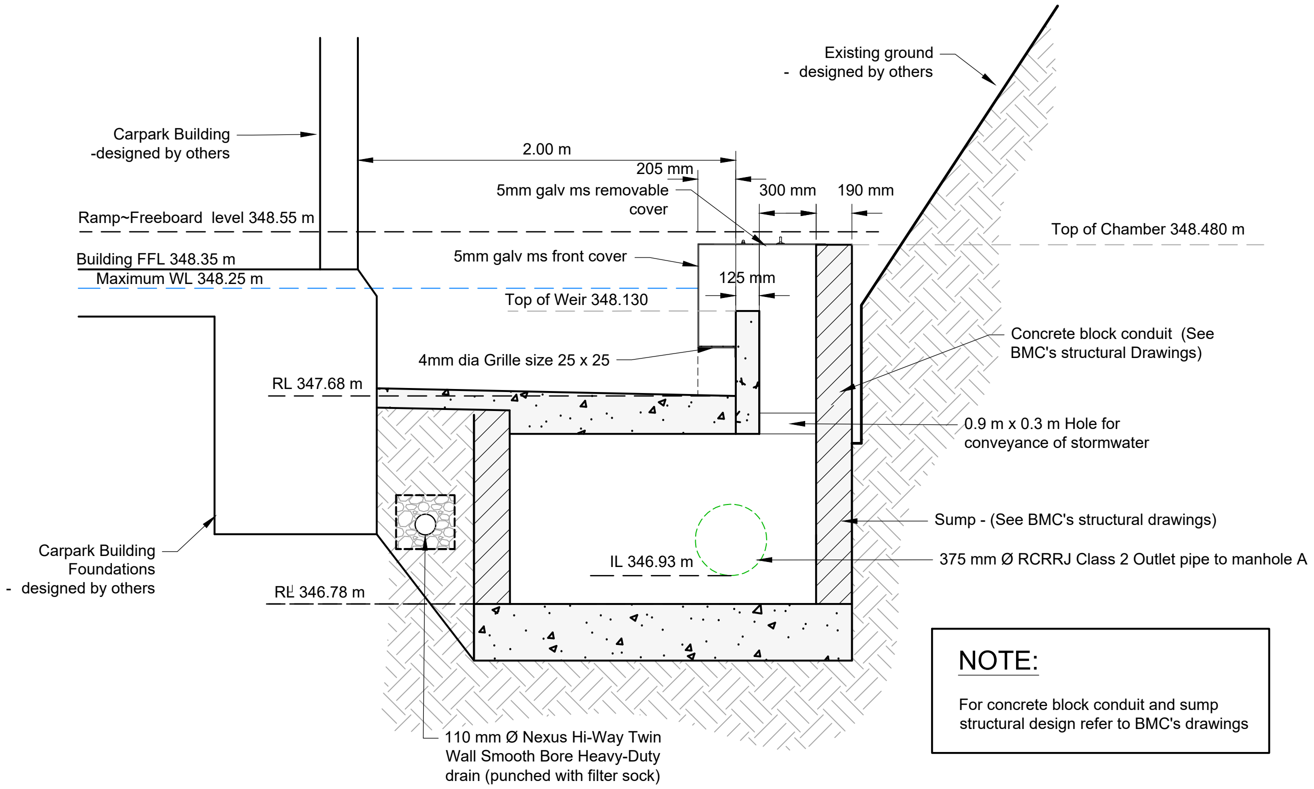
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Outlet Structure Details

Scale (A1 Original): 1:10_4 m

Issue: For Approval

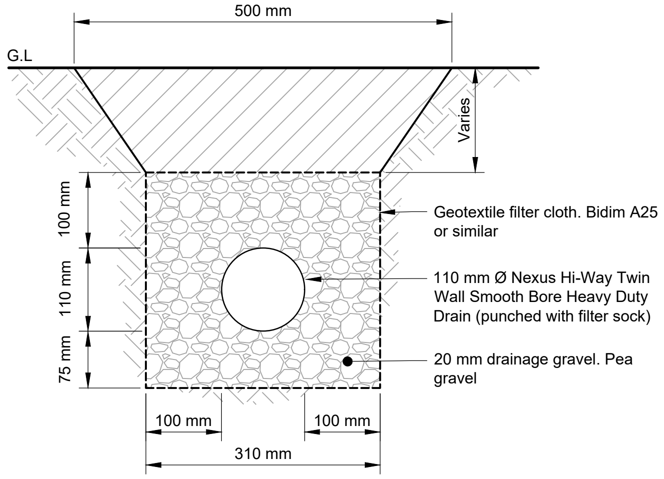
Project No	Sheet	Revision
Q000507	C05	1



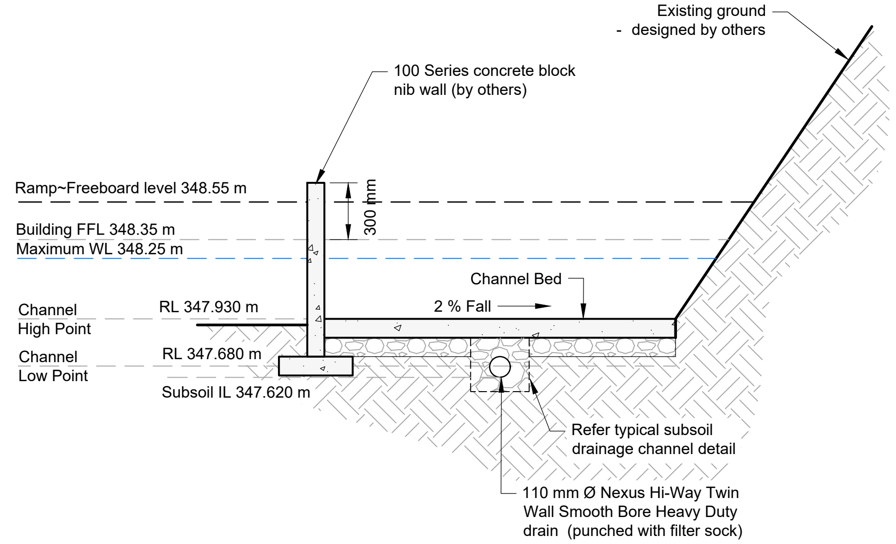
NOTE:

For concrete block conduit and sump structural design refer to BMC's drawings

SECTION B C05 OUTLET STRUCTURE CROSS-SECTION
1:20 at A1
1:40 at A3



DETAIL A C06 TYPICAL SUBSOIL DRAIN
1:5 at A1
1:10 at A3



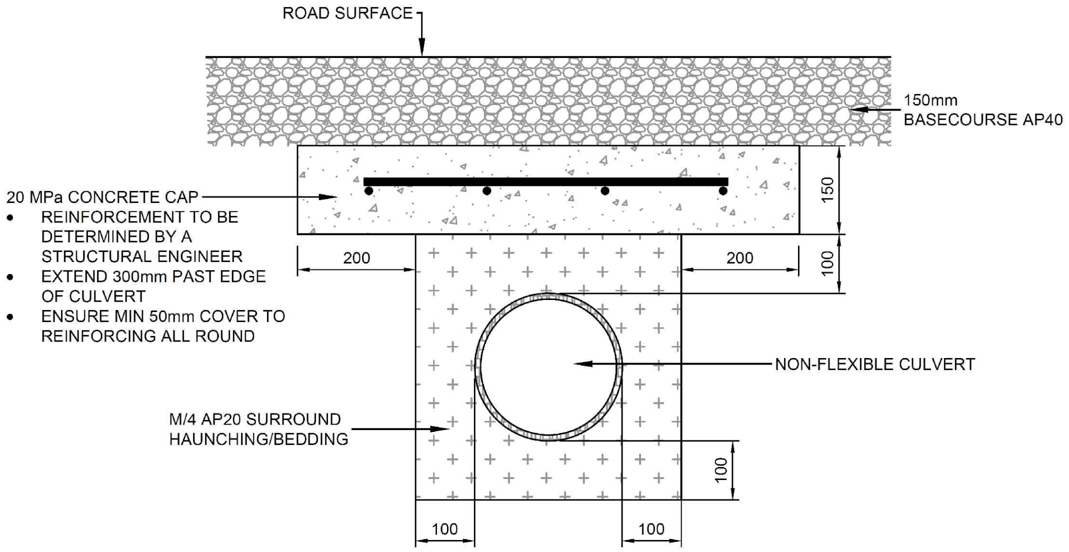
SECTION A C02 TYPICAL CROSS-SECTION OF STORMWATER CHANNEL
1:20 at A1
1:40 at A3

TRENCH DIMENSIONS:

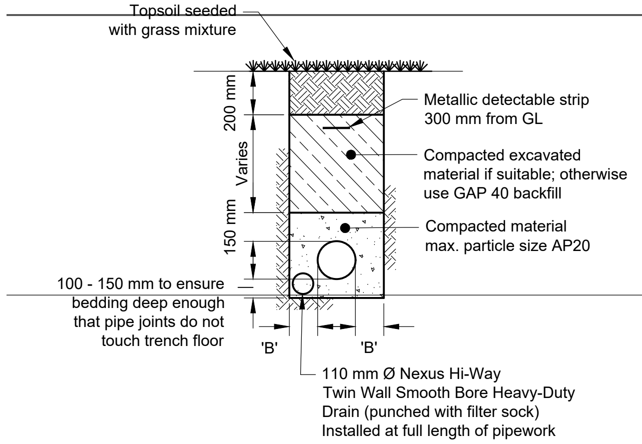
Pipe Sizes < DN375 Ø	B = 150 mm
Pipe Sizes > DN375 Ø	B = 225 mm

NOTES:

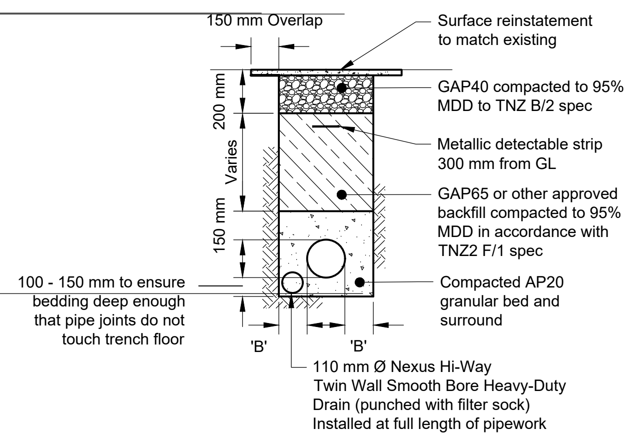
Where pipe grades are >5 %, add 2 % cement to trench bedding



CONCRETE CAPPING DETAIL



TYPICAL TRENCH DETAIL - UNSEALED
NTS



TYPICAL TRENCH DETAIL - SEALED CARRIAGEWAYS
NTS

Revision		App	Date			
1	Updated SW Network	A.S	21/12/21	Surveyed	P.P.G	-
0	For Construction	P.D	26/03/21	Designed	Z.S	Apr '19
				Drawn	J.P	Apr '19
				Reviewed	G.D	Apr '19
				Approved	G.D & T.C	Apr '19

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Client: Skyline Enterprises

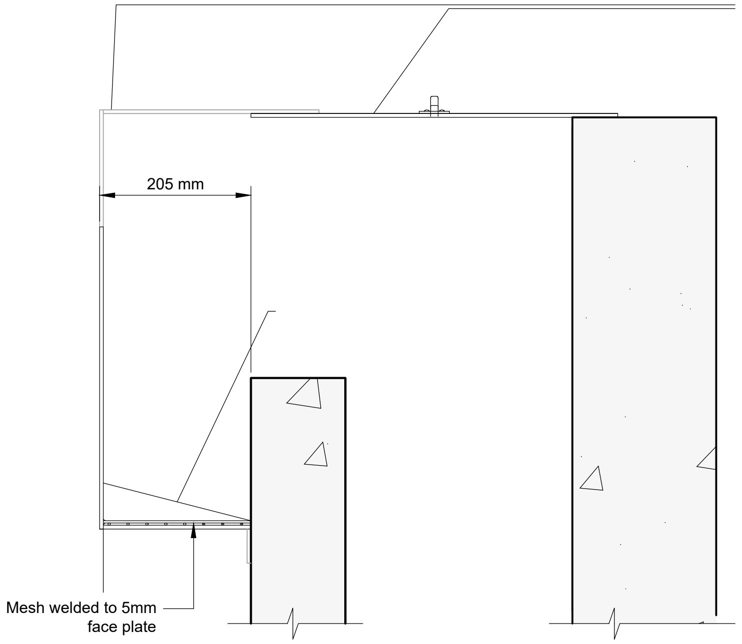
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Channel Drainage & Pipe Connection Details

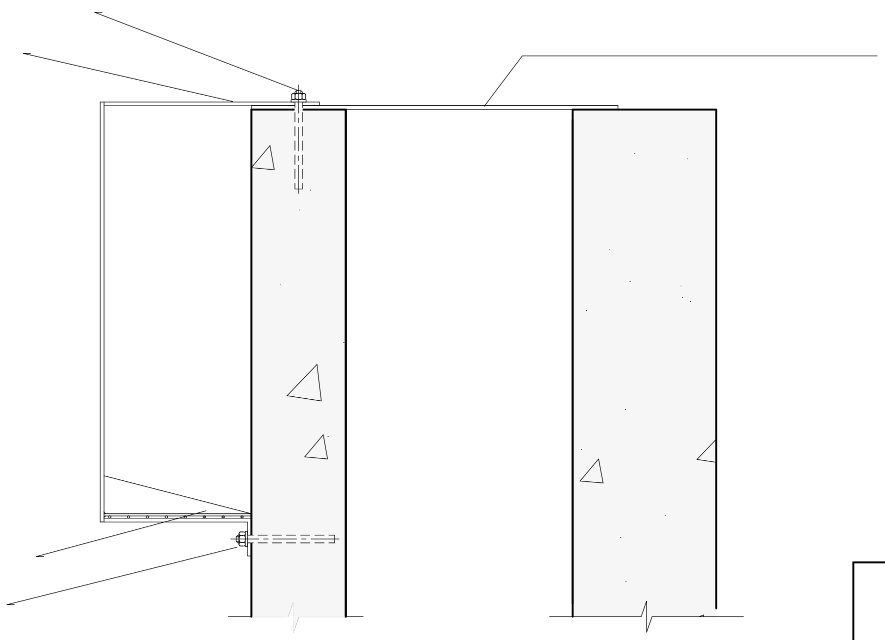
Scale (A1 Original): As Shown

Issue: For Approval

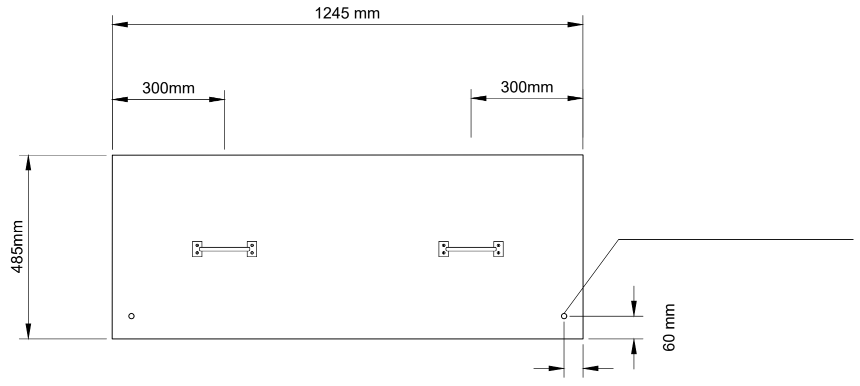
Project No	Sheet	Revision
Q000507	C06	1



SECTION D C05 OUTLET STRUCTURE CROSS-SECTION
1:5 at A1
1:10 at A3



SECTION E C05 OUTLET STRUCTURE CROSS-SECTION
1:5 at A1
1:10 at A3

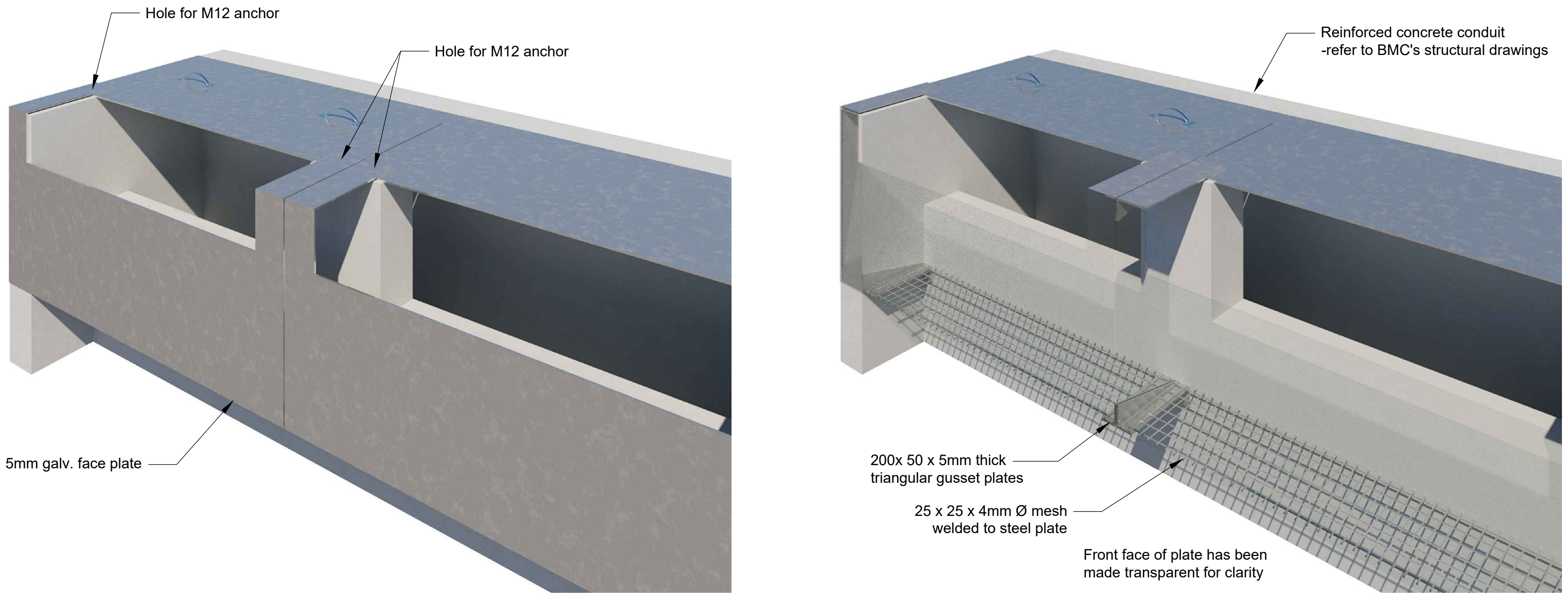


LID DIMENSIONS
1:10 at A1
1:20 at A3

NOTES:

Gratings and face plates to be hot dipped galv. after fabrication.
Isometrics indicative only and not to scale

Shop drawings for steelwork shall be submitted to the engineer for approval prior to fabrication



OUTLET STRUCTURE 3D REPRESENTATION
N.T.S

Revision		App	Date
1	For Approval	A.S	21/12/21
0	For Construction	P.D	26/03/21

Surveyed	P.P.G	-
Designed	Z.S.	July '19
Drawn	D.R. & J.P	July '19
Reviewed	G.D	July '19
Approved	G.D & T.C	July '19

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Client: Skyline Enterprises

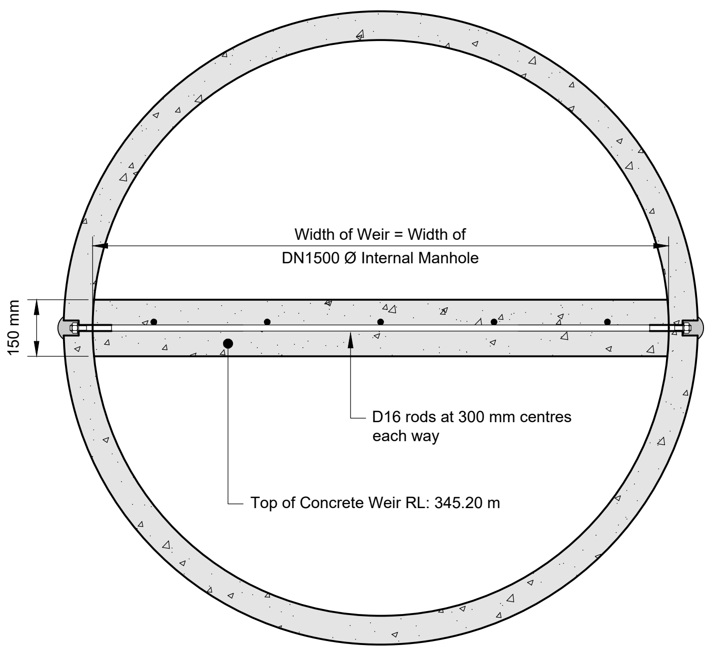
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Outlet Structure Details 2

Scale (A1 Original): As Shown

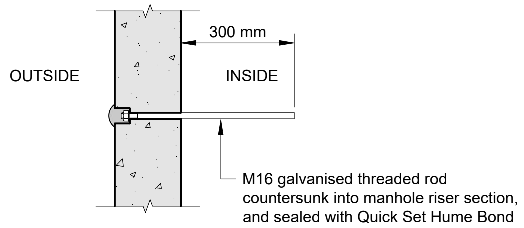
Issue: For Approval

Project No	Sheet	Revision
Q000507	C07	1



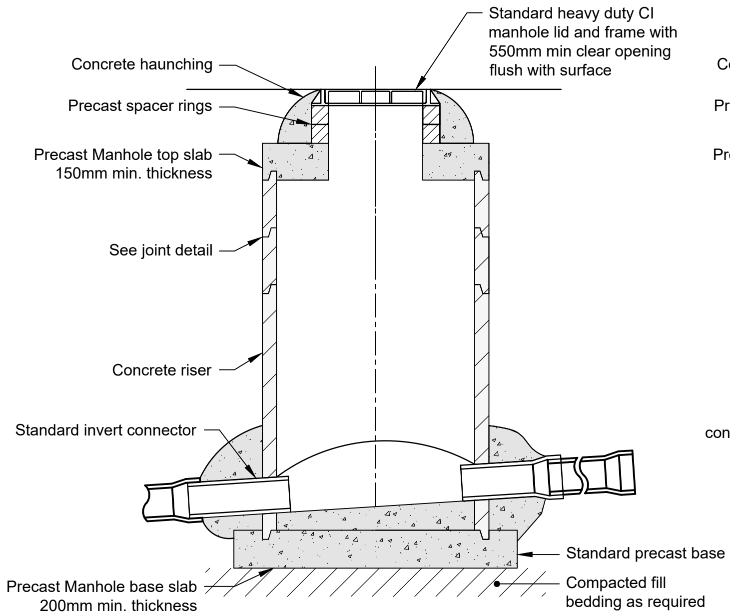
SW MANHOLE D WEIR DETAIL

1:10 at A1
1:20 at A3

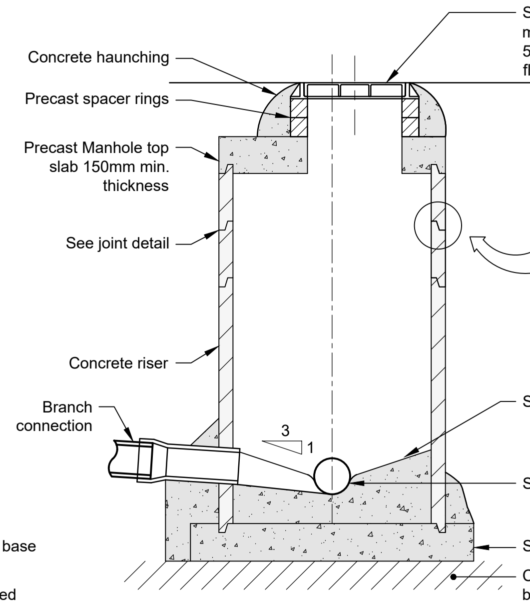


RISER / WEIR STARTER DETAIL

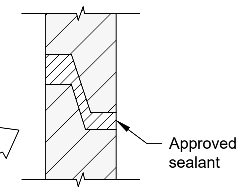
1:10 at A1
1:20 at A3



SECTIONAL ELEVATION

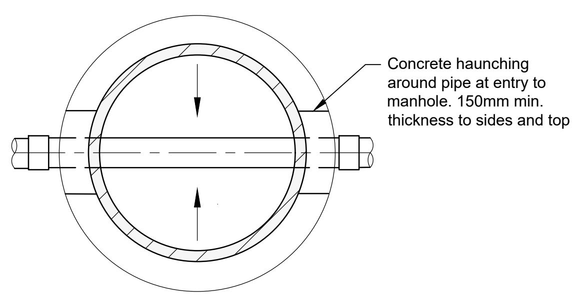


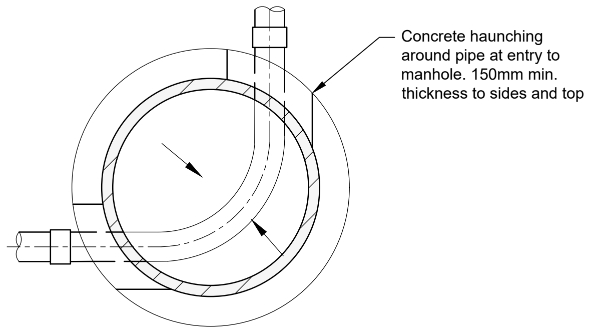
SECTIONAL ELEVATION

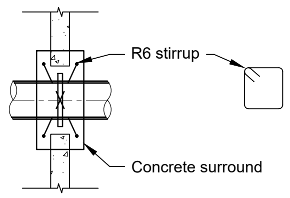


TYPICAL JOINT DETAIL

Suitable for insitu and precast MH

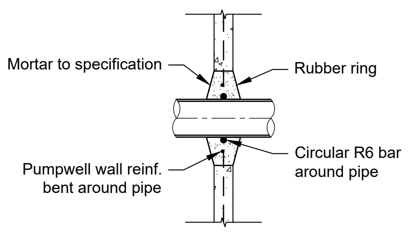






INLET JOINT DETAIL

1:20 at A1
1:40 at A3



TYPICAL MORTAR JOINT DETAIL

1:20 at A1
1:40 at A3

NOTE: Detail applies to all pump well penetrations except for rising main and inlet pipe

PLAN

TYPICAL STRAIGHT

1:20 at A1
1:40 at A3

PLAN

TYPICAL ANGLE

1:20 at A1
1:40 at A3

1	Updated SW Network	A.S	21/12/21	Surveyed	P.P.G	-	
0	For Construction	P.D	26/03/21	Designed	Z.S	Apr '19	
Revision		App	Date	Drawn	J.P	Apr '19	
				Reviewed	G.D	Apr '19	
				Approved	G.D	Apr '19	

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Client: Skyline Enterprises

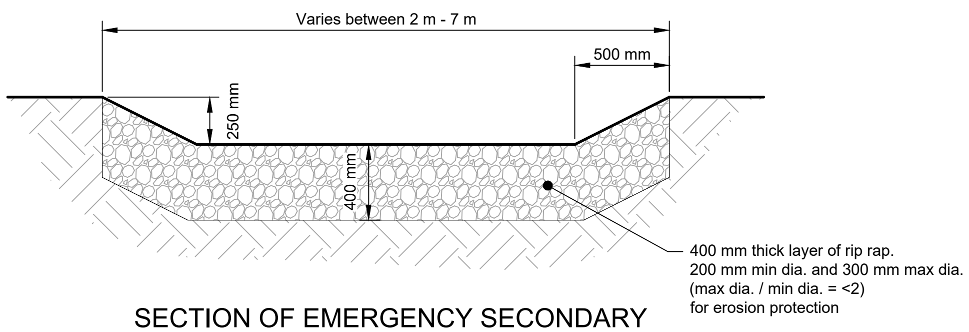
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Typical Manhole Details

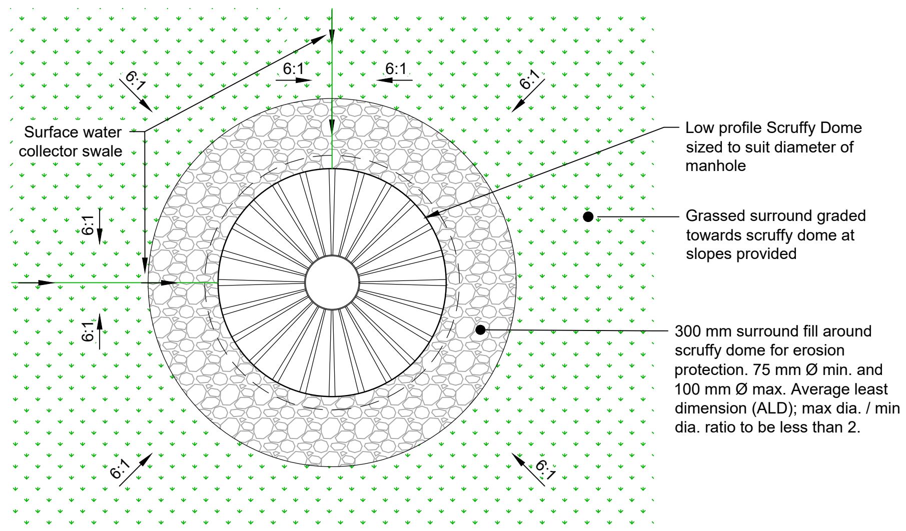
Scale (A1 Original): 1:20 m

Issue: For Approval

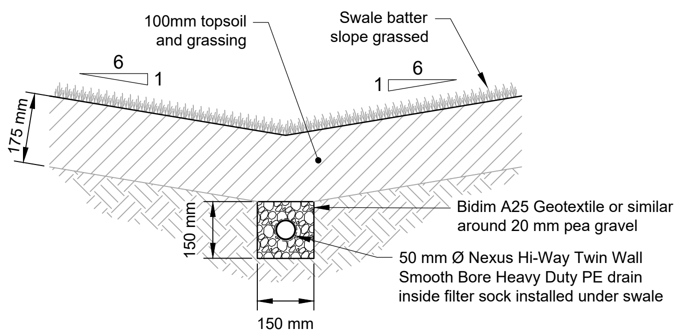
Project No	Sheet	Revision
Q000507	C09	1



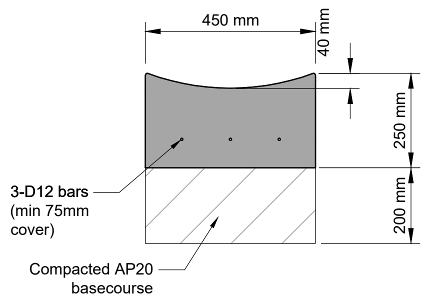
SECTION OF EMERGENCY SECONDARY OVERFLOW CHANNEL
1:20 at A1
1:40 at A3



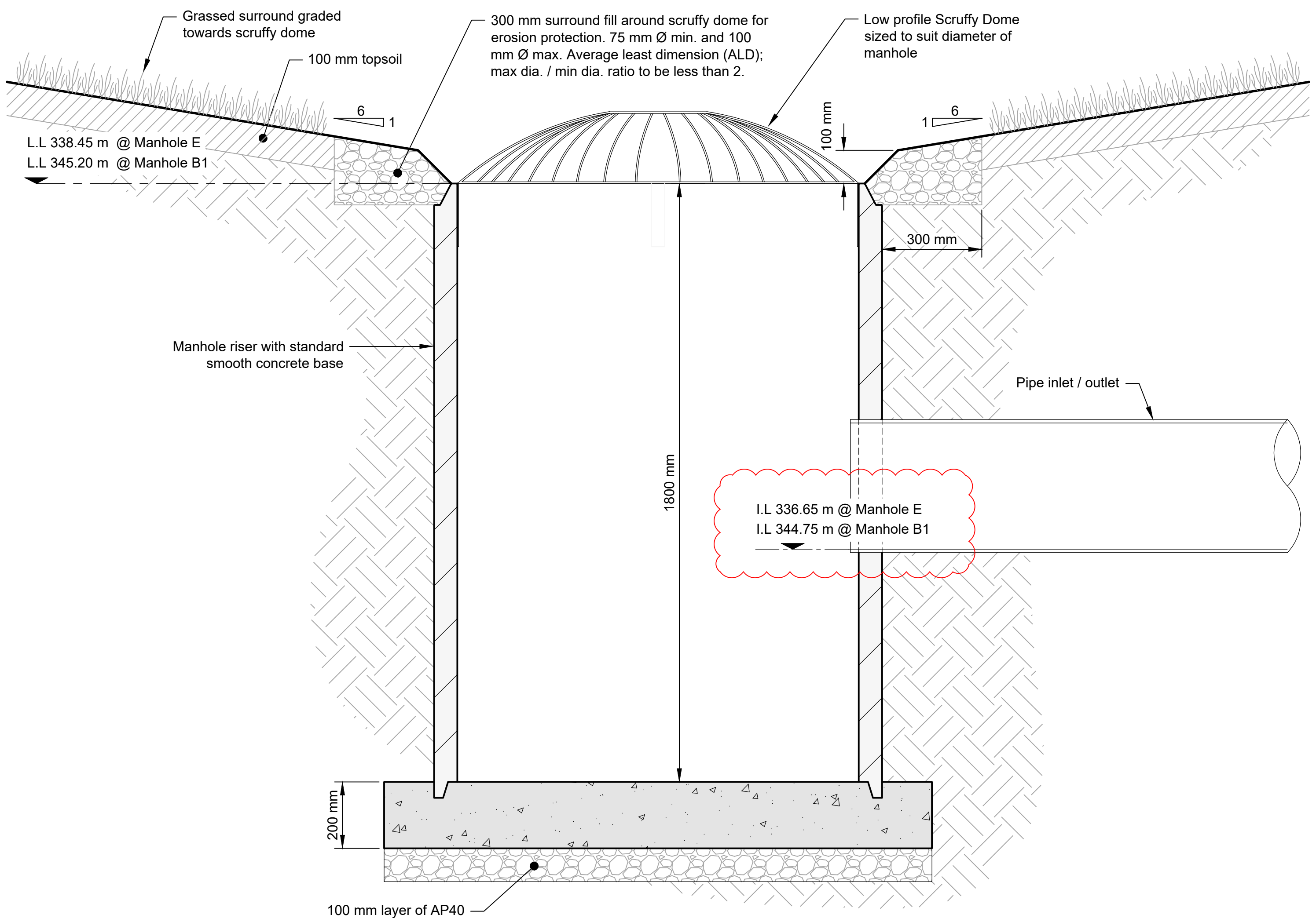
TYPICAL PLAN OF SCRUFFY DOME
1:20 at A1
1:40 at A3



TYPICAL SECTION OF SWALE IN AROUND TOWER BASE
1:10 at A1
1:20 at A3



DISH CHANNEL WITH REINFORCEMENT
1:10 at A1
1:20 at A3



SECTION OF SCRUFFY DOME
1:10 at A1
1:20 at A3

Revision		App	Date
2	Scruffy Dome Updated	A.S.	05/04/22
1	For Approval	A.S	21/12/21
0	For Construction	P.D	26/03/21

Surveyed	P.P.G	-
Designed	Z.S	Apr '19
Drawn	J.P	Apr '19
Reviewed	G.D	Apr '19
Approved	G.D	Apr '19

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Client: Skyline Enterprises

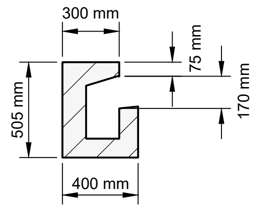
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Scruffy Dome & Secondary Overflow Details

Scale (A1 Original): As Shown

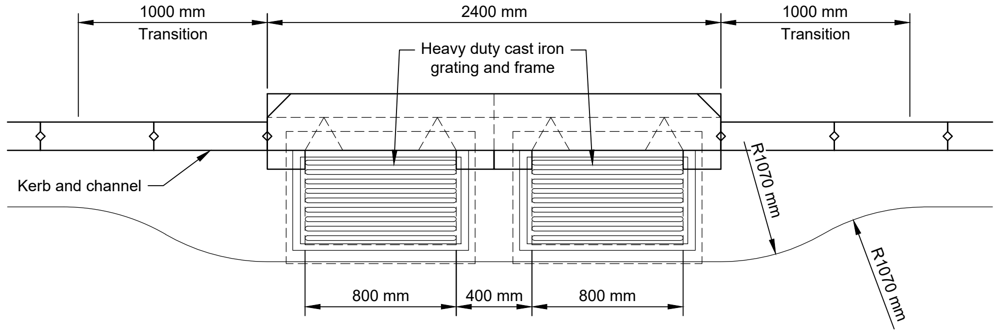
Issue: For Approval

Project No	Sheet	Revision
Q000507	C10	2

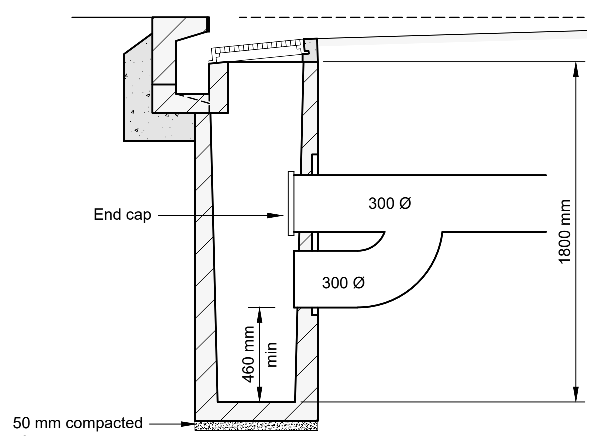


NOTE:

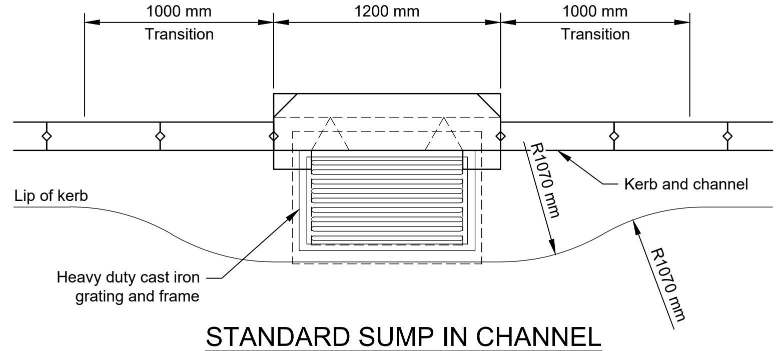
Details referenced from Humes Max Pit sump details.
Refer manufacturer specifications and installation instructions



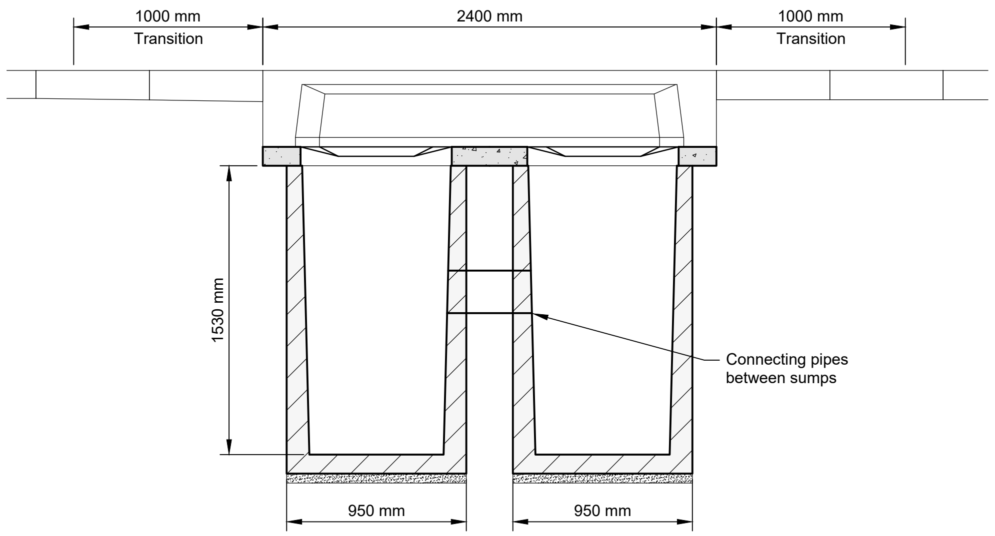
STANDARD DOUBLE SUMP IN CHANNEL
1:20 at A1
1:40 at A3



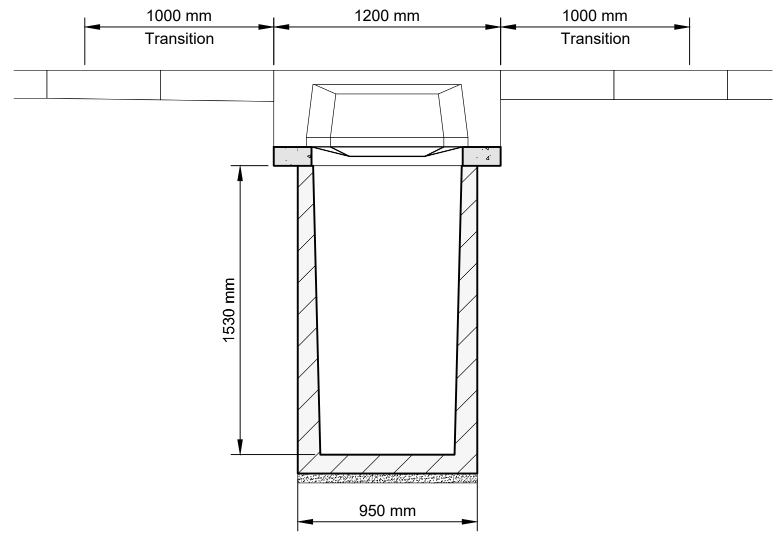
STANDARD BACK ENTRY SUMP - SECTION
1:20 at A1
1:40 at A3



STANDARD SUMP IN CHANNEL
1:20 at A1
1:40 at A3



STANDARD DOUBLE SUMP IN CHANNEL SECTION
1:20 at A1
1:40 at A3



STANDARD SUMP IN CHANNEL SECTION
1:20 at A1
1:40 at A3

Revision		App	Date
1	For Approval	A.S	21/12/21
0	For Construction	P.D	26/03/21

Surveyed	P.P.G	-
Designed	Z.S	Apr '19
Drawn	J.P	Apr '19
Reviewed	G.D	Apr '19
Approved	G.D	Apr '19

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Client: Skyline Enterprises

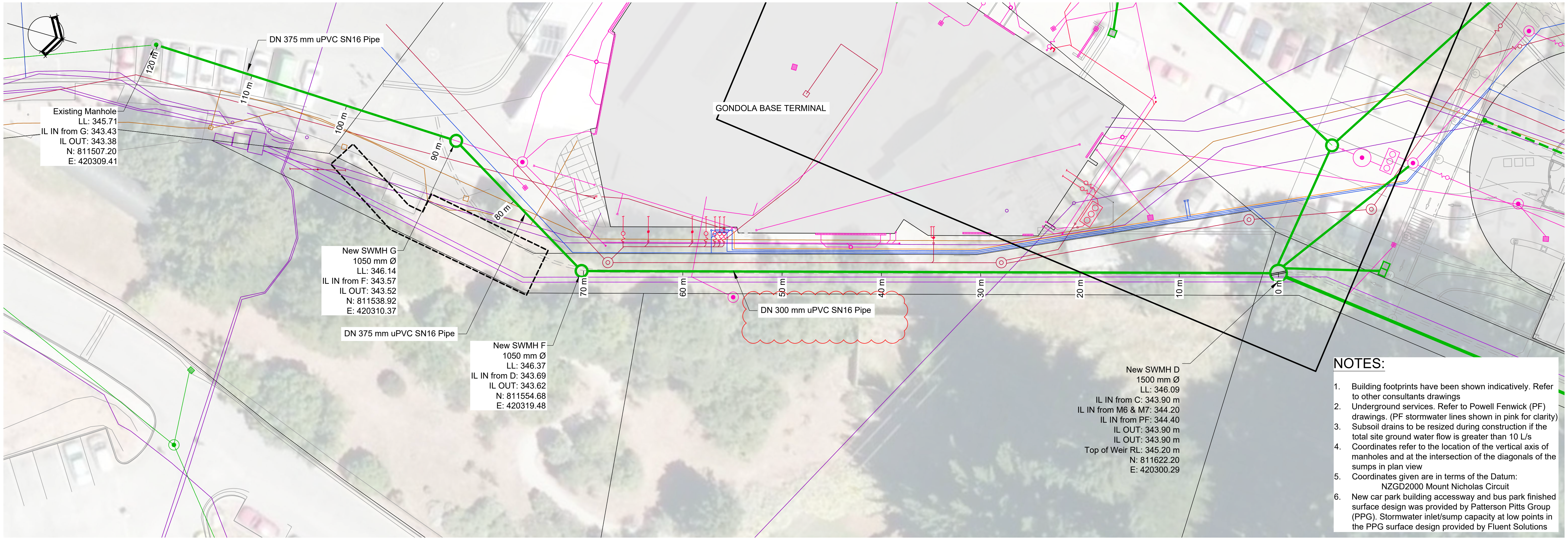
Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Typical Sump Details

Scale (A1 Original): As Shown

Issue: For Approval

Project No	Sheet	Revision
Q000507	C11	1

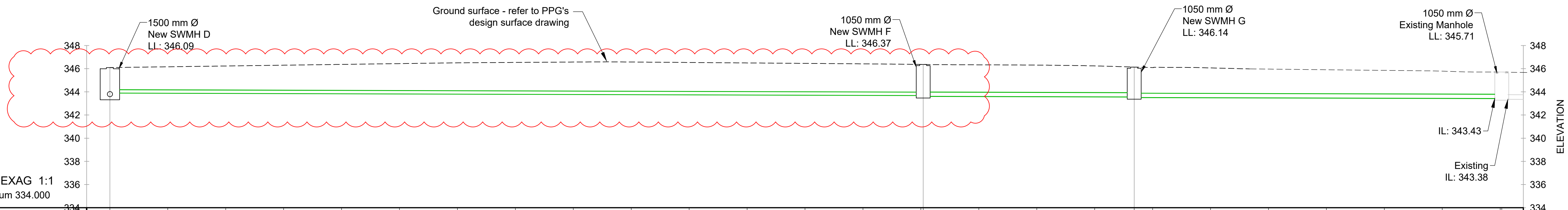


NOTES:

1. Building footprints have been shown indicatively. Refer to other consultants drawings
2. Underground services. Refer to Powell Fenwick (PF) drawings. (PF stormwater lines shown in pink for clarity)
3. Subsoil drains to be resized during construction if the total site ground water flow is greater than 10 L/s
4. Coordinates refer to the location of the vertical axis of manholes and at the intersection of the diagonals of the sumps in plan view
5. Coordinates given are in terms of the Datum: NZGD2000 Mount Nicholas Circuit
6. New car park building accessway and bus park finished surface design was provided by Patterson Pitts Group (PPG). Stormwater inlet/sump capacity at low points in the PPG surface design provided by Fluent Solutions

BRECON STREET CONNECTION SITE LAYOUT PLAN

1:200 at A1
1:400 at A3



STATION (m)	GROUND LEVEL (m)	INVERT LEVEL
-2		
0		343.90
5	346.16	
10	346.23	
15	346.30	
20	346.37	
25	346.44	
30	346.51	
35	346.54	
40	346.57	
45	346.57	
50	346.53	
55	346.50	
60	346.46	
65	346.42	
70	346.37	343.69 / 343.62
75	346.33	
80	346.31	
85	346.24	
88		343.57 / 343.52
90	346.10	
95	346.06	
100		
105		
110		
115		
120		343.43
122		

	0 – 70	70 – 88	88 – 120
GRADE %	0.3%	0.3%	0.3%
PIPE DETAILS (CL to CL LENGTHS)	DN 300 UPVC SN16 Length: 70.20 m	DN 375 UPVC SN16 Length: 18.21 m	DN 375 UPVC SN16 Length: 31.73 m

BRECON STREET CONNECTION LONG SECTION

Revision		App	Date
2	Updated SW Network	A.S.	05/04/22
1	SWMH F Location	A.S.	18/01/22
0	New Sheet	A.S	21/12/21

Surveyed	P.P.G	-
Designed	A.P	Dec '21
Drawn	J.P	Dec '21
Reviewed	A.S	Dec '21
Approved	A.S	Dec '21

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Client: Skyline Enterprises

Project Title: Base Terminal & Carpark Building - Stormwater Management Plan

Sheet Title: Connection to Brecon St Site Layout Plan

Scale (A1 Original): 1:200 m

Issue: For Approval

Project No: Q000507 | Sheet: C20 | Revision: 2

From: Melanie Stevenson <melanie@fluentsolutions.co.nz>
Sent: Wednesday, September 20, 2023 5:02 PM
To: Nigel Lloyd <nigel@hadleys.co.nz>; James Hadley <james@hadleys.co.nz>
Cc: Paul Embleton-Muir <Paul.Embletonmuir@skyline.co.nz>; Sean Dent <sean@southernplanning.co.nz>; Anthony Steel <anthony@fluentsolutions.co.nz>
Subject: RE: 233824 - Skyline Stormwater Review - Initial Design Review Sheet

Hi team

Please find attached a summary of the information from the new catchment modelling.

Background:
A new survey was flown in August 2023. We have brought this new surface into our 2D model to check flow paths and catchment areas. We also modified parameters to be more conservative as proposed in our recent design review. The total flow through the site with the more conservative parameters is 439L/sec.

Key findings are:

- The new 2D modelling with the new surface model reduces the catchment boundary feeding into the carpark development by 0.67Ha – about 8% reduction
- The reduction in catchment area was related to the line up the gondola pathway where the trees have been cleared
- The new surface survey showed that some flow from the catchment is diverted down the main track about halfway up the gondola. This is diverted away from the new carpark development. This is in the order of 10% of flows 51L/sec.
- The new 2d modelling was completing using more conservative parameters, as proposed in the design review. The increase in flow to the carpark development is around 24% for the 100 year event, and 40% when considering total flow off the catchment face (11% being diverted away)
- The flow paths entering the site have not changed significantly with the new survey data, however the flow rates have changed somewhat (likely to be due to a more accurate surface model and the formation of tracks). An example of this is flows through US Flow 4 were 14% of flows and now it constitutes 32% of the flow from the hillside. This would result in more flows to the gondola base building and away from the debris channel. We would need to run the model with these new inputs to determine if this was an issue. Options to address this (change in flow pathways due to the track formation) is, fill in the track to reinstate, or divert added flow away from site towards Brecon St. This could potentially be a simple cutoff drain above the retaining wall and direct towards Cemetery/Brecon St.

Please be in touch if you have any queries. Otherwise we are happy for you to share results with the QLDC.

Regards
Melanie

Melanie Stevenson
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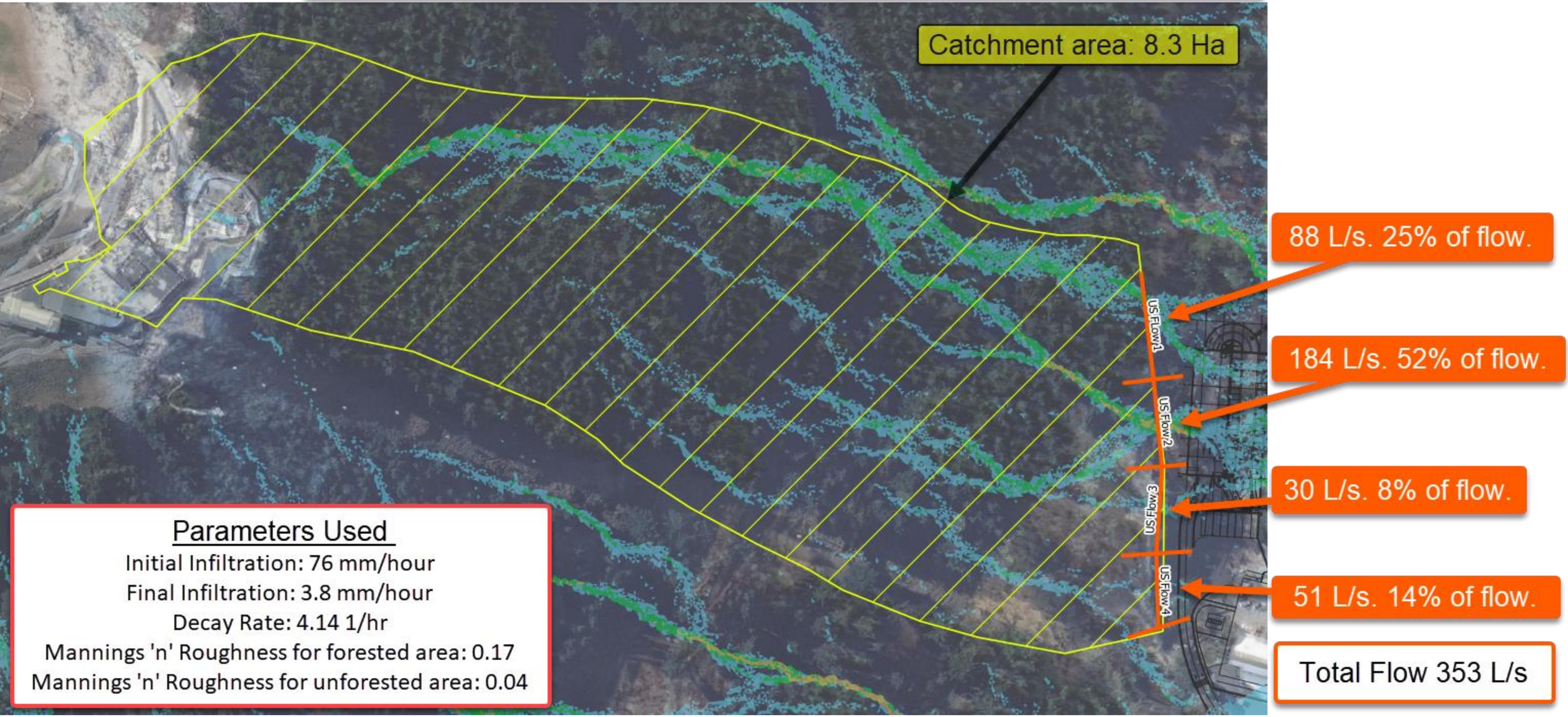
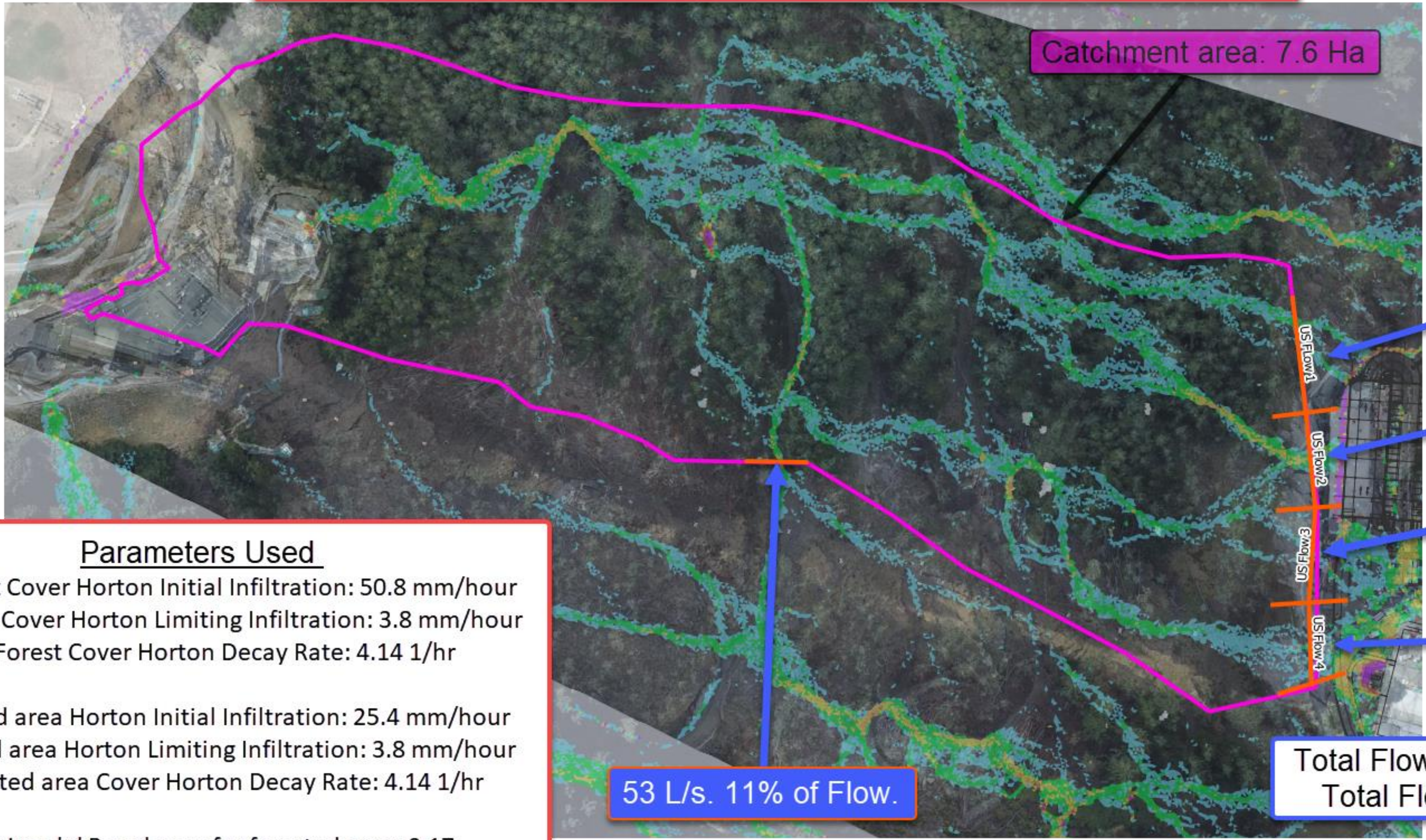
100yr 1hr RCP8.5 Hillside Catchment Flow modelled using 2016 LiDAR



2023 Updated Sensitivity 100yr 1hr RCP8.5 Hillside Catchment Flow modelled using new August 2023 LiDAR



Parameters Used

Pine Forest Cover Horton Initial Infiltration: 50.8 mm/hour
Pine Forest Cover Horton Limiting Infiltration: 3.8 mm/hour
Pine Forest Cover Horton Decay Rate: 4.14 1/hr

Unforested area Horton Initial Infiltration: 25.4 mm/hour
Unforested area Horton Limiting Infiltration: 3.8 mm/hour
Unforested area Cover Horton Decay Rate: 4.14 1/hr

Mannings 'n' Roughness for forested area: 0.17
Mannings 'n' Roughness for unforested area: 0.04

Appendix F: Concept Debris Flow Barrier

DEBRIS FLOW BARRIER: UEENSTOWN

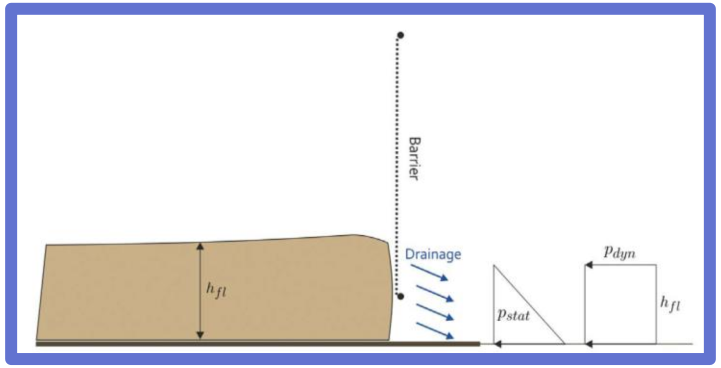
Feiger Nadine

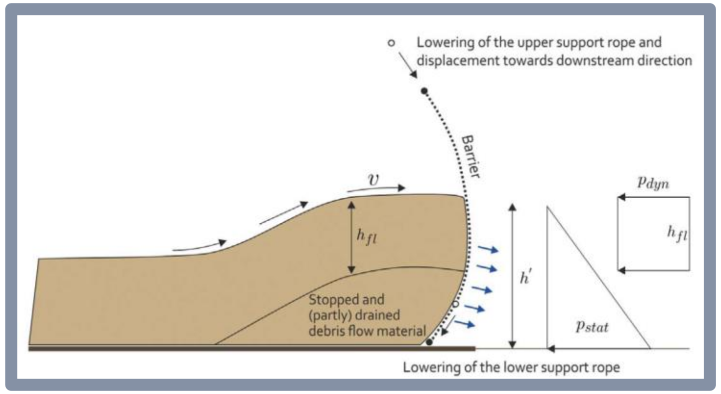
BRUGG Geobrugg

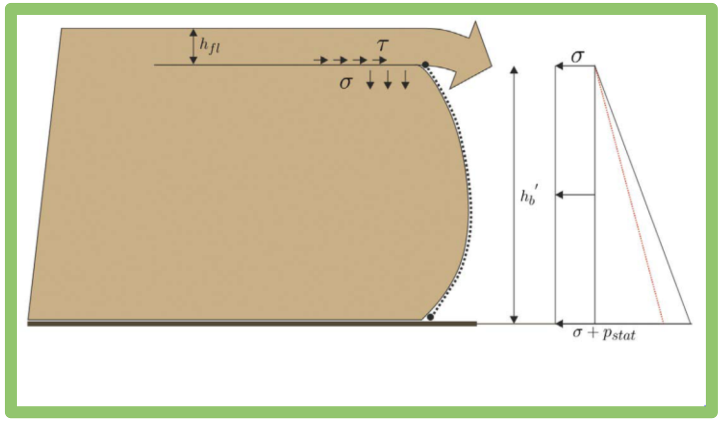
Safety is our nature

Debris flow barrier - ueenstown

Design approach for flexible debris flow barriers







Load Case	Main influence factor
Stopping → Pressure surge	Impact + Increasing debris pressure
Filling	Debris pressure + drainage under hydrostatic pressure
Overflowing	Debris pressure + overtopping

Debris flow barrier - ueenstown

Load case I:

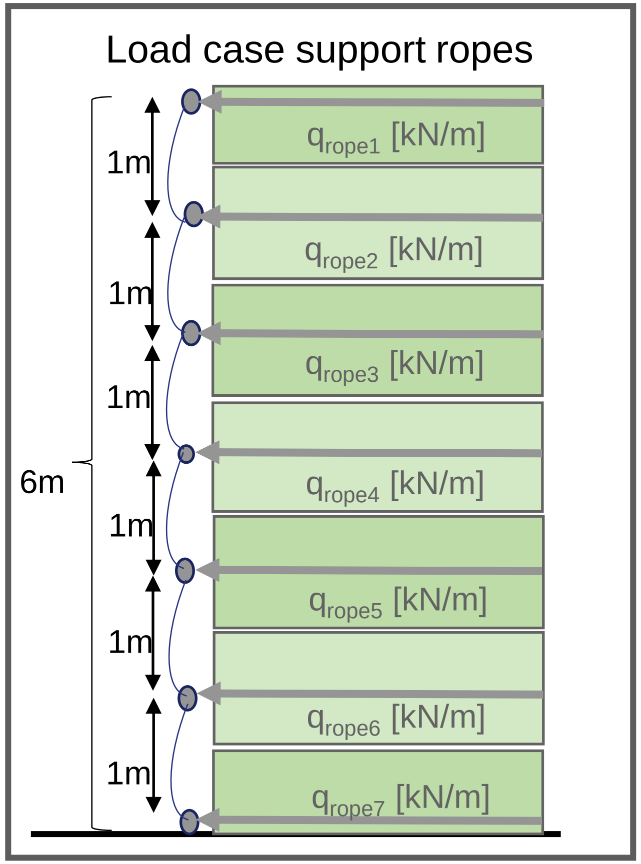
System height: 6m
System length: 60m
Post spacing: 8m/7m/6m/6m/6m/6m/6m/7m/8m

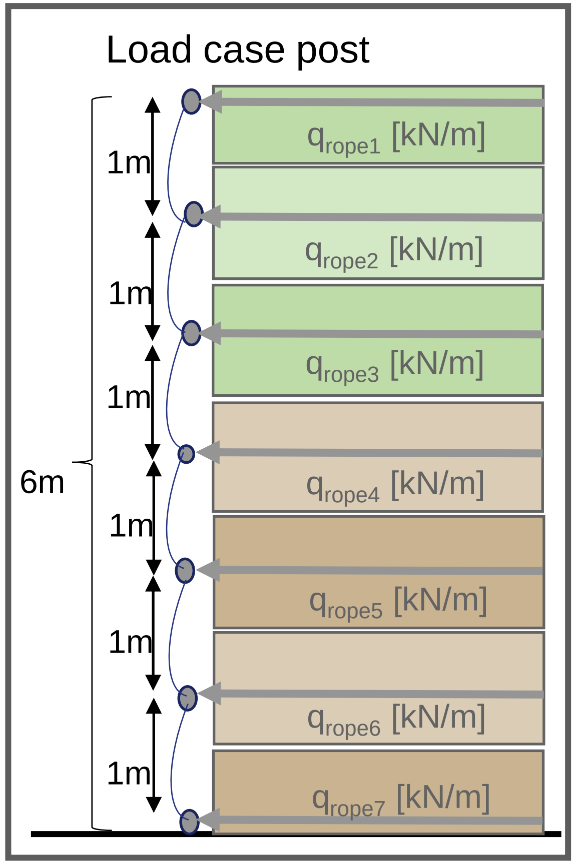
Design parameter:

- v = 7 m/s
- ρ = 1600 kg/m^3
- h_{fl} = 0.8 m
- c_d = 0.8

Impact over entire barrier length

Impact support ropes: dynamic (greenish color)
Impact post: dynamic on the upper part, static impact lower part (brownish color)

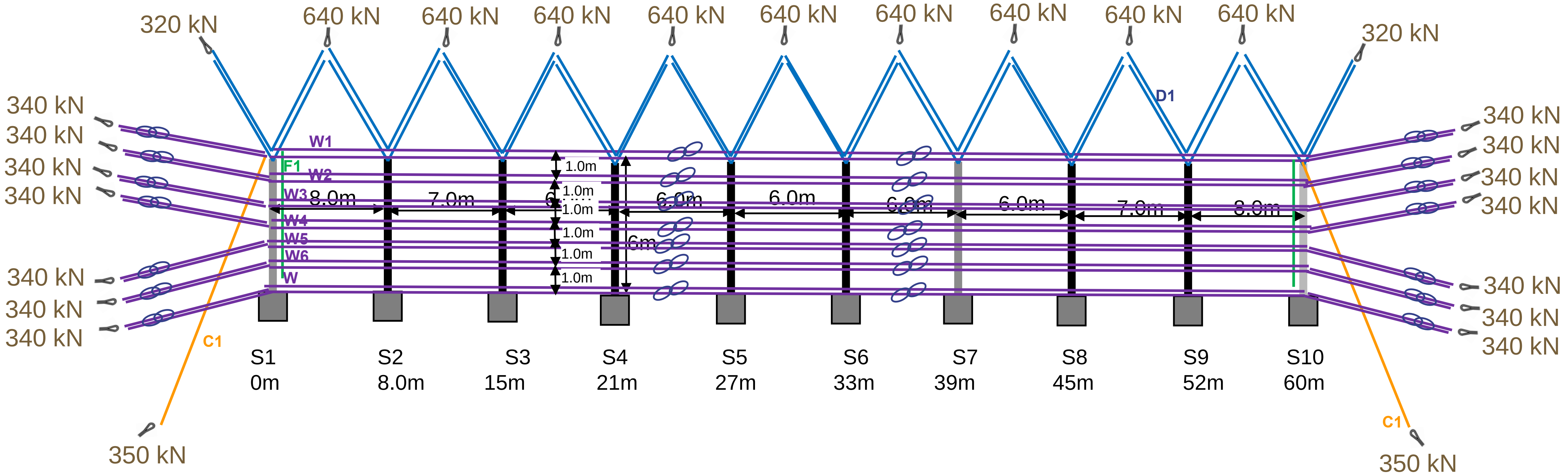




Debris flow barrier - ueenstown – Design Load case I

BRUGG Geobrugg

Special U -H6 L=60.0m Post spacing=6.0m



Legende:

W1-W : Support rope Ø 22 mm Geobinex with 4x GN-9017

C1: Lateral rope Ø 22 mm Geobinex

D1: Upslope rope Ø 22 mm Geobinex with 1x GN-9017

F1: Vertical rope Ø 22 mm Geobinex

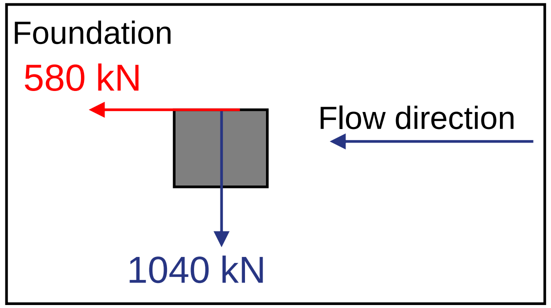
S1,S10: Border post UC1310x310x158 Steel 300

S2-S9: Middle post UC1310x310x158 Steel 300

WRA: 22.5mm

ROCCO 12/3/350 with secondary mesh

Abrasion protection



* All forces are characteristic forces

Debris flow barrier -   ueenstown

Load case II:

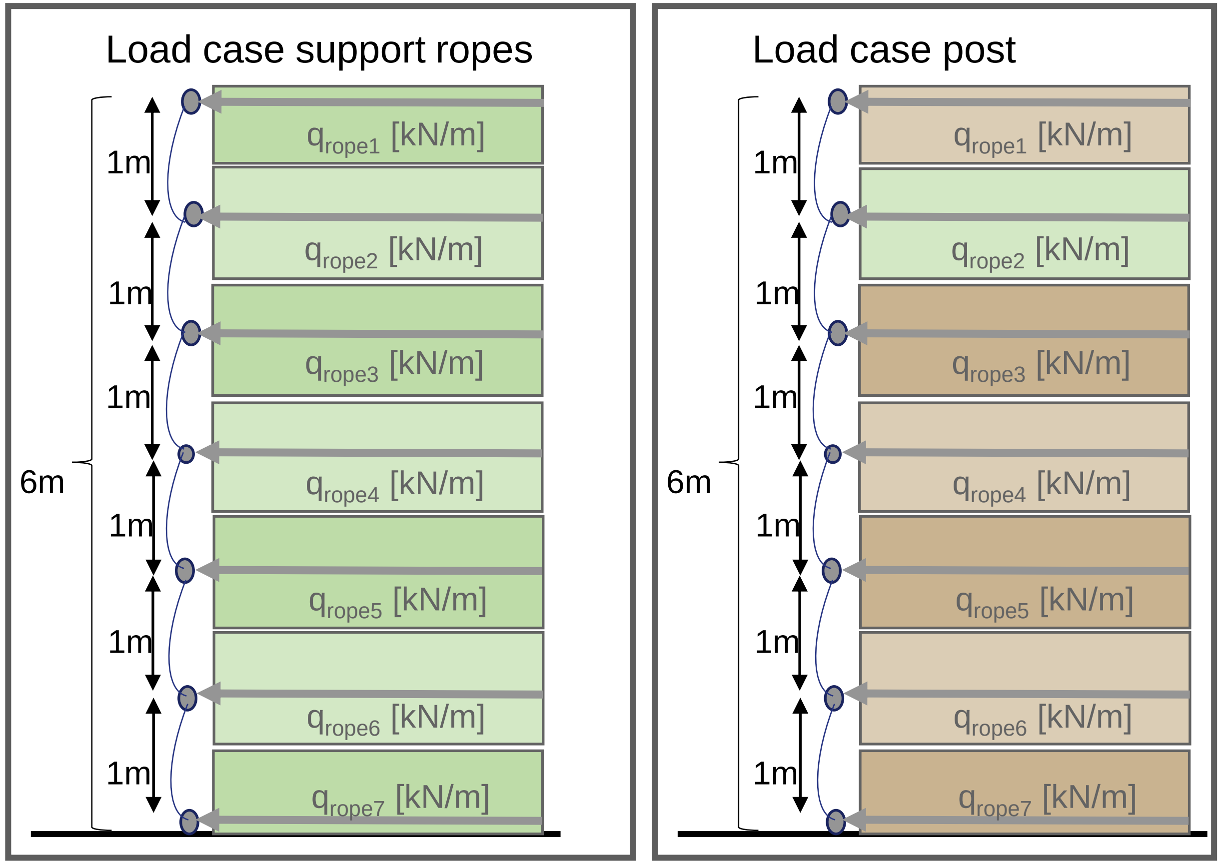
System height: 6m
System length: 60m
Post spacing: 8m/7m/6m/6m/6m/6m/6m/7m/8m

Design parameter:

- $v = 9$ m/s
- $\rho = 1600$ kg/m^3
- $h_{fl} = 1.0$ m
- $c_d = 0.8$

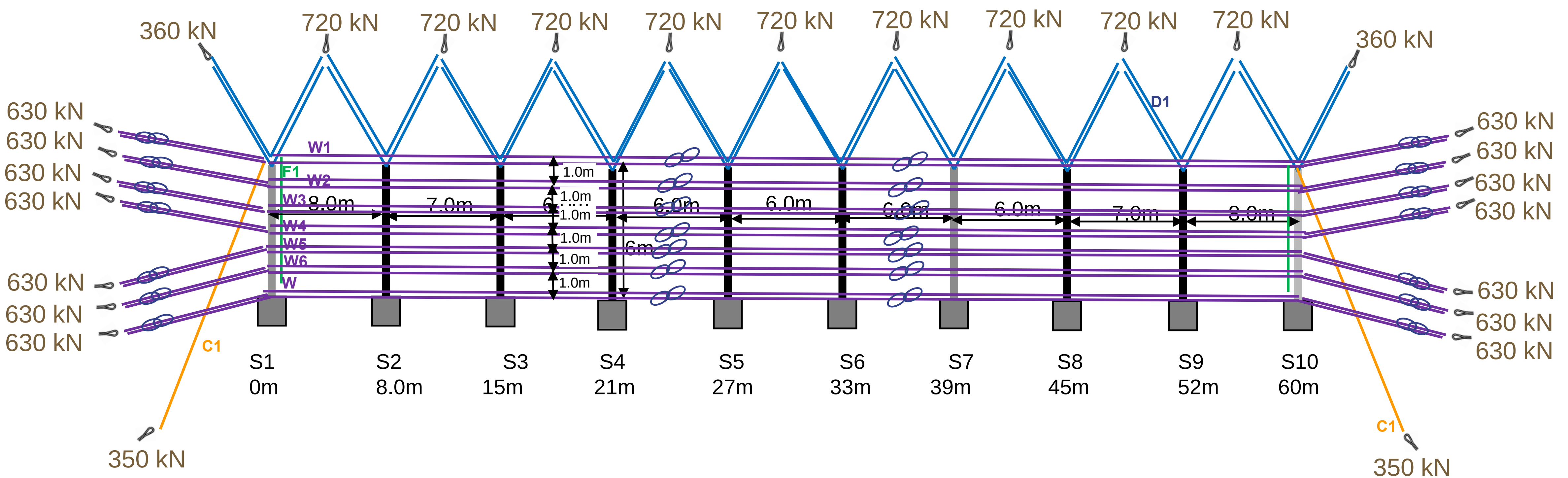
Impact over entire barrier length

Impact support ropes: dynamic (greenish color)
Impact post: dynamic on the upper part, static impact lower part (brownish color)

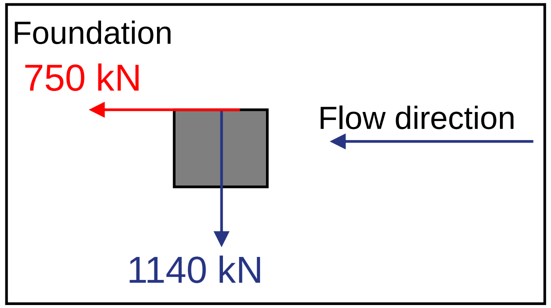


Debris flow barrier - ueenstown – Design Load case II

Special U -H6 L=60.0m Post spacing=6.0m



Legende:
W1-W : Support rope Ø 22 mm Geobinex with 4x GN-9017
C1: Lateral rope Ø 22 mm Geobinex
D1: Upslope rope Ø 22 mm Geobinex with 1x GN-9017
F1: Vertical rope Ø 22 mm Geobinex
S1,S10: Border post UC1310x310x158 Steel 300
S2-S9: Middle post UC1310x310x158 Steel 300
WRA: 22.5mm
ROCCO 12/3/350 with secondary mesh
Abrasion protection



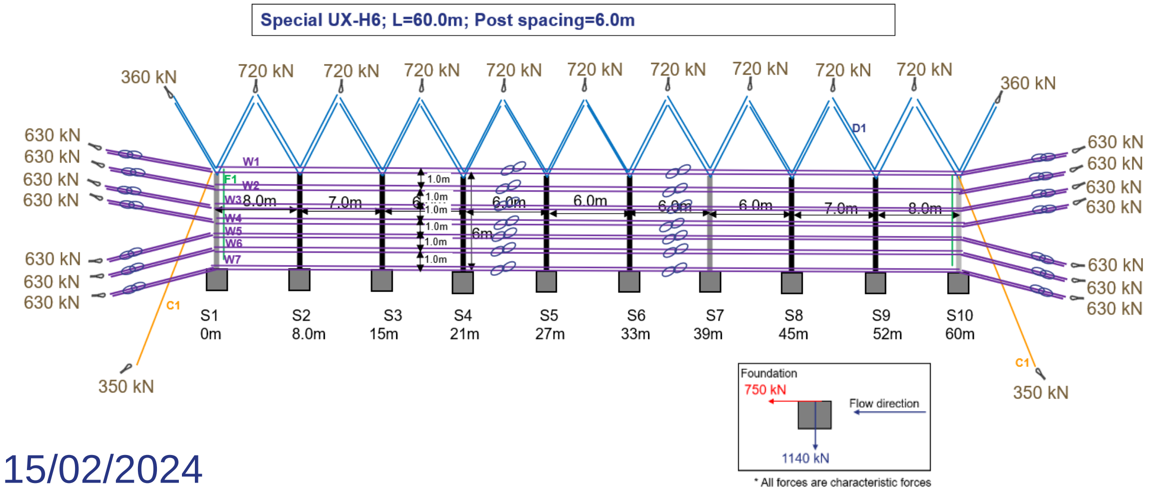
* All forces are characteristic forces

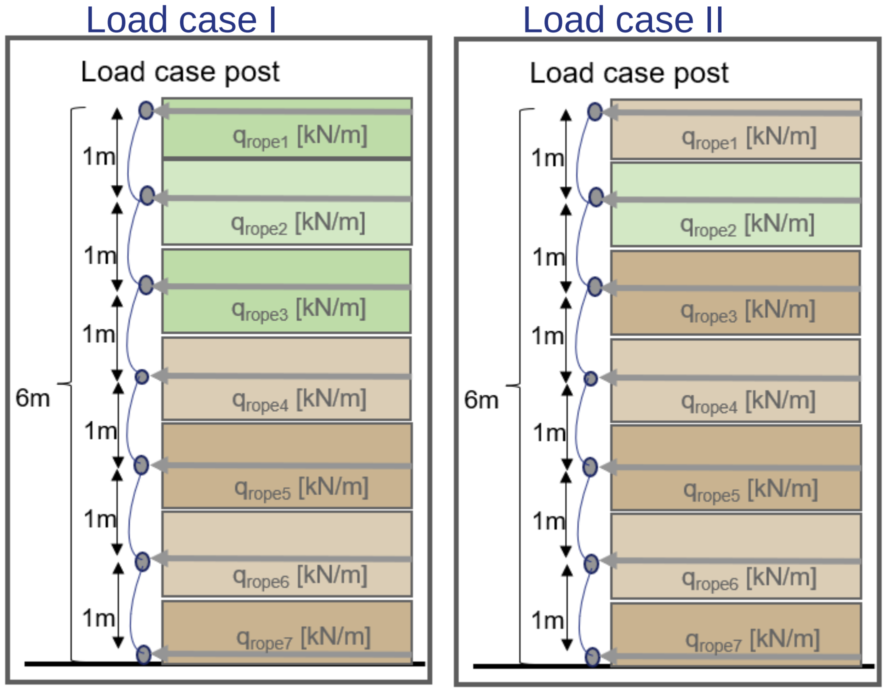
Debris flow barrier - ueenstown – Final design and summary

Two different load cases are applied for the debris flow barrier with 6m height and 60m length.
To withstand the dynamic impact on different flow height, all rope layers are dimensioned with the load of the dynamic impact. The applied load distribution on the post differences between the two load cases. The dynamic load on the post was applied on the most unfavorable case. In load case II the dynamic impact is assumed to be over 1m and acts on an already filled barrier with 4.5m static load. In load case I the dynamic impact is applied over 2.5m on the top 3 rope layers.

All loads are applied over the entire barrier length.
→ Load case II is decisive for the design

To cover different kind of impact scenarios it is suggested to use the design for load case II.





Dimensioning Debris Flow Barrier
Queenstown I, New Zealand

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Date:
15.02.2024

CONTENT

1. Introduction

The following report explains the concept of dimensioning a debris flow barrier which is placed on an open hill slope in Queenstown, New Zealand. The cross-section is 60m (Fig. 1).
The design is based on assumed input parameters which have not been verified by Geobrugg, since no parameters were provided by the client.
Chapter 2 describes the design parameters, action and analytical verifications.

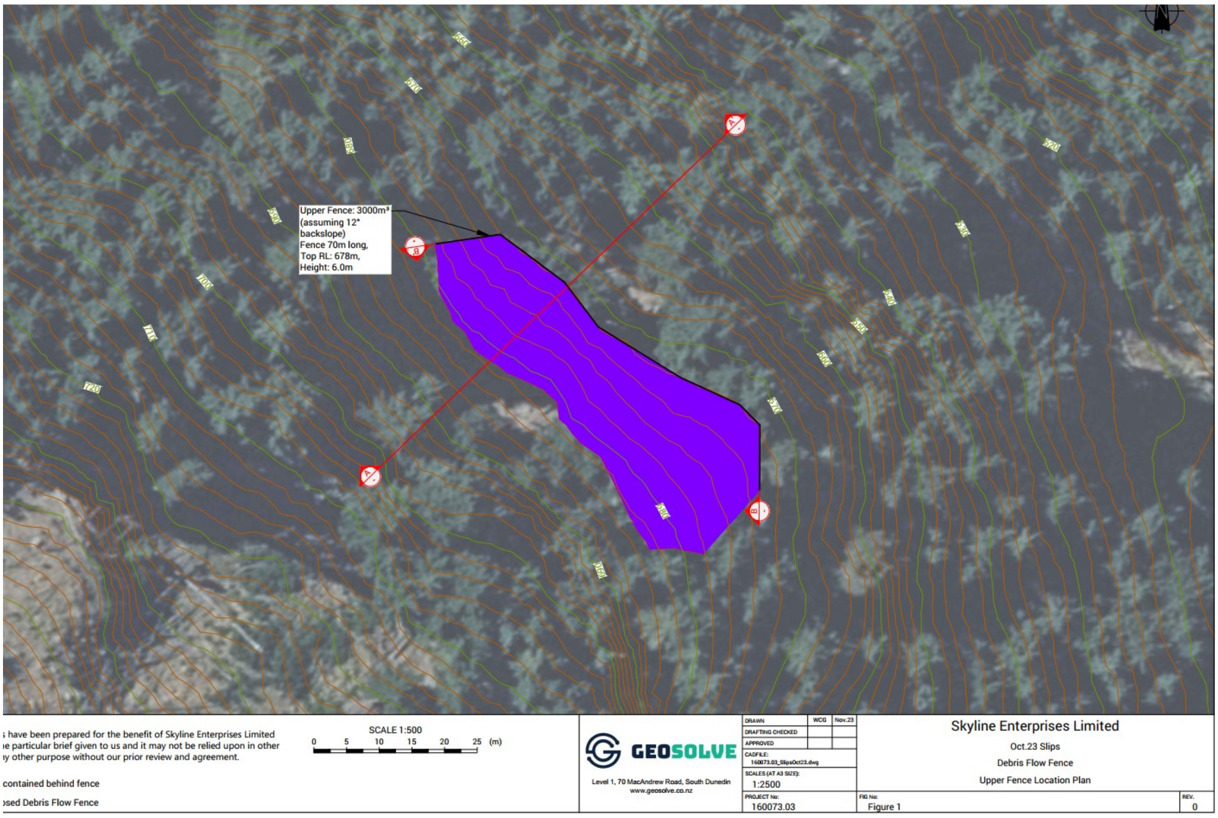

Fig. 1: Overview debris flow barrier location (drawn by the client)

2. Dimensioning debris flow barrier

The design of Geobruggs' debris flow barrier is based on the worldwide accepted load model by Wendeler (2008). The model takes into account the load case of the dynamic first impact, the filling process and the overflow (Fig. 3-5).

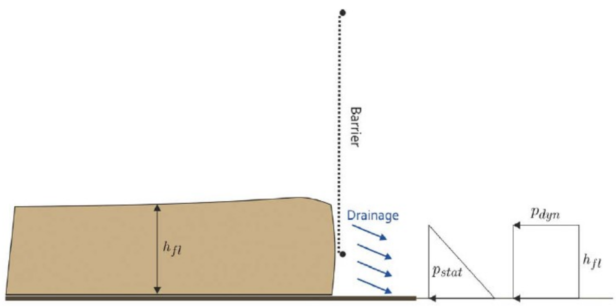

Fig. 3: Pressure surge as first impact on the barrier (WSL, Practical guide for debris flow and hillslope debris flow protection net)

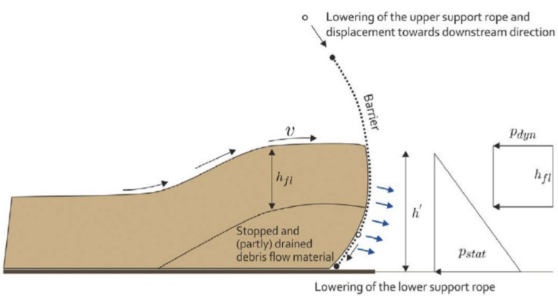

Fig. 4: Filling up the barrier by followed surges (WSL, Practical guide for debris flow and hillslope debris flow protection net)

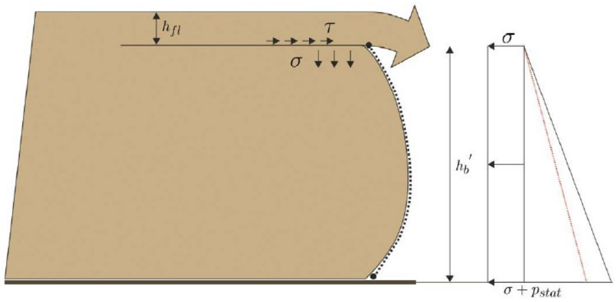

Fig. 5: Filled barrier under overflow condition (WSL, Practical guide for debris flow and hillslope debris flow protection net)

2.1 System requirements

Partial safety factor impact:	$\gamma_Q := 1.0$
Partial safety factor material:	$\gamma_M := 1.05$

2.1.1 Geometry

Barrier height:	$H := 6\ m$		
Barrier width bottom:	$b_u := 60\ m$	*Total cross-section*	
Barrier width top:	$b_o := 60\ m$	*Total cross-section*	
Average width:	$b_m := \frac{(b_o + b_u)}{2}$		$b_m = 60\ m$
Height filled barrier:	$H_0 := H \cdot 0.75$		$H_0 = 4.5\ m$
Top rope width:	$b_1 := 60\ m$		$b_1 = 60\ m$
2nd top rope width:	$b_2 := 60\ m$		$b_2 = 60\ m$
3th top rope width:	$b_3 := 60\ m$		$b_3 = 60\ m$
4th top rope width:	$b_4 := 60\ m$		$b_4 = 60\ m$
5th top rope width:	$b_5 := 60\ m$		$b_5 = 60\ m$
6th top rope width:	$b_6 := 60\ m$		$b_6 = 60\ m$
Bottom rope width:	$b_7 := 60\ m$		$b_7 = 60\ m$
Basal opening:	$h_d := 0\ m$		$h_d = 0\ m$
Post spacing:	$b_{post} := 6\ m$		$b_{post} = 6\ m$

2.1.2 Debris flow parameter

The following values are used to calculate the impact forces on the barrier. All values are assumend and have not been verified.

Type of debris flow:	Muddy flow
Debris flow density:	$\rho := 1600\ \frac{kg}{m^3}$
Velocity:	$v := 7\ \frac{m}{s}$

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Discharge: $Q := 350 \ \frac{m^3}{s}$

The flow height is calculated by the continuity equation: Q= v*A. Velocity and discharge are given as well as the bottom width of the cross-section.

Flow height: $h_{fl} := \frac{Q}{(v \cdot b_u)}$ $\qquad h_{fl} = 0.83 \ m$

2.2 Analytical Proof: Impact

In the following, pressure surge, filling process, and overflow are determined for the respective area load acting on the support ropes. Based on these forces, the decisive load is determined and used for dimensioning of the support ropes.

Load cases:
1. First pressure surge
$F_{pressure\_surge}$ = hydrostatic pressure + hydrodynamic pressure
First pressure surge is used to dimension bottom support rope when force is decisive.

2. Impact on support ropes filling process
q= hydrostatic pressure + hydrodynamic pressure

3. Filled barrier/ overflow
Earth pressure is additionally added instead of the hydrodynamic pressure.
$F_{overflow}$ = additional weight + hydrostatic pressure

4. Identify decisive load case

2.2.1 Pressure surge

Pressure surge is made up as follows: F= hydrostatic pressure + hydrodynamic pressure. Hydrodynamic coefficient depends on the density of the debris flow material and can be defined as: $c_d = 2.0 \ granular$ and $c_d = 0.8 \ mudflow$.
Based on the density $\rho = 1600 \ \frac{kg}{m^3}$ a hydrodynamic coefficient of $c_d := 0.8$ is applied.
With a basal opening equal or smaller than the flow height, the initial impact is completely absorbed by the lower support rope. In the presented case for Queenstown with a basal opening of $h_d = 0 \ m$, a flow height $h_{fl} = 0.83 \ m$, and a support rope spacing $h_{spacing} := 1 \ m$ the initial impact will be distributed on the lowest layer of ropes from the bottom up.
Hydrostatic and hydrodynamic pressure for the initial impact (characteristic) is calculated as followed:

Flow height assumption: $h_{fl} := 0.8 \ m$

Hydrostatic pressure: $P_{hyd} := \frac{1}{2} \cdot \rho \cdot g \cdot h_{fl}$ $\qquad P_{hyd} = 6.28 \ \frac{kN}{m^2}$

Hydrodynamic pressure: $P_{dyn} := c_d \cdot \rho \cdot v^2$ $\qquad P_{dyn} = 62.72 \ \frac{kN}{m^2}$

Total load pressure surge: $F_{pressure\_surge} := P_{hyd} + P_{dyn}$ $F_{pressure\_surge} = 69\ \frac{kN}{m^2}$

$f_{pressure\_surge} := \frac{1}{2} \cdot \rho \cdot g \cdot h_{fl}^2 + c_d \cdot \rho \cdot v^2 \cdot h_{fl}$ $f_{pressure\_surge} = 55.197\ \frac{kN}{m}$

2.2.2 Filling process

The area load on the support ropes during the filling process is made up as follows: q= hydrostatic pressure + hydrodynamic pressure. Below an example:

Top support rope: $q_1 := 52.14\ \frac{kN}{m}$

2th top rope: $q_2 := 58.02\ \frac{kN}{m}$

3th top rope: $q_3 := 58.02\ \frac{kN}{m}$

4th top rope: $q_4 := 58.02\ \frac{kN}{m}$

5th top rope: $q_5 := 58.02\ \frac{kN}{m}$

6th top rope: $q_6 := 58.02\ \frac{kN}{m}$

Bottom support rope: $q_7 := 52.14\ \frac{kN}{m}$

2.2.3 Overflow

In the case of a filled barrier or during overflow, the effect is composed of q= hydrostatic pressure + additional weight. Below an example:

Additional weight: $\sigma := \rho \cdot h_{fl} \cdot g$ $\sigma = 12.55\ \frac{kN}{m^2}$

Hydrostatic pressure: $P_{hyd} := \rho \cdot g \cdot H_0$ $P_{hyd} = 70.61\ \frac{kN}{m^2}$

Total impact overflow: $F_{overflow} := \sigma + P_{hyd}$ $F_{overflow} = 83.16\ \frac{kN}{m^2}$

Top support rope: $q_{1\_2} := 6.99\ \frac{kN}{m}$

2th top rope: $q_{2\_2} := 20.59\ \frac{kN}{m}$

3th top rope: $q_{3\_2} := 29.42\ \frac{kN}{m}$

4th top rope: $q_{4\_2} := 38.25\ \frac{kN}{m}$

5th top rope: $q_{5\_2} := 47.07\ \frac{kN}{m}$

6th top rope: $q_{6\_2} := 55.9\ \frac{kN}{m}$

Bottom support rope: $q_{7\_2} := 31.26 \frac{kN}{m}$

2.2.4 Decisive load

In a next step the decisive load case of each rope layer (Fig. 6) has to be identified. The values above show that the dynamic impact is decisive for determining the number of top ropes till the 5th top rope. Decisive for the 6th top rope and bottom support ropes is the overflow condition.

Top rope: $q_{rope1} := \max\left(q_1, q_{1\_2}\right) = 52.14 \frac{kN}{m}$

2nd top rope: $q_{rope2} := \max\left(q_2, q_{2\_2}\right) = 58.02 \frac{kN}{m}$

3th top rope: $q_{rope3} := \max\left(q_3, q_{3\_2}\right) = 58.02 \frac{kN}{m}$

4th top rope: $q_{rope4} := \max\left(q_4, q_{4\_2}\right) = 58.02 \frac{kN}{m}$

5th top rope: $q_{rope5} := \max\left(q_5, q_{5\_2}\right) = 58.02 \frac{kN}{m}$

6th top rope: $q_{rope6} := \max\left(q_6, q_{6\_2}\right) = 58.02 \frac{kN}{m}$

Bottom rope: $q_{rope7} := \max\left(q_7, q_{7\_2}\right) = 52.14 \frac{kN}{m}$

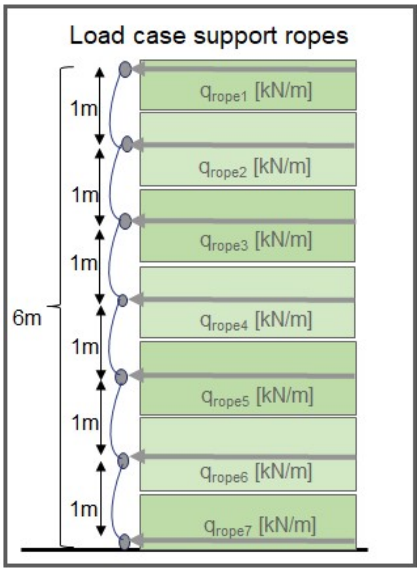

Fig. 6: Load case support ropes

2.3 Proof: ROCCO Net

ROCCO 12/3/350 is required to withstand the load.

Impact: $F_{Ed;Netz} := 53.52 \frac{kN}{m}$

Resistance: $F_{Rd;Netz} := 238.1 \frac{kN}{m}$

Proof: $F_{Ed;Netz} \le F_{Rd;Netz}$

$\text{if}\left(F_{Ed;Netz} \le F_{Rd;Netz}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Safety factor SF: $SF := \frac{F_{Rd;Netz}}{F_{Ed;Netz}} = 4.45$

$\text{if}\left(SF \ge 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

2.4 Proof: Support ropes

The determined impact on each rope layer is then used in the multiple field rope equation (Palkowski 1991) to identify the amount of needed ropes. Figure 7 shows a system with 4 posts as supports with three fields on which the load q1-q3 acts. For debris flow barriers the impact force on each field is the same for each rope layer. In other words q1=q2=q3=qn.

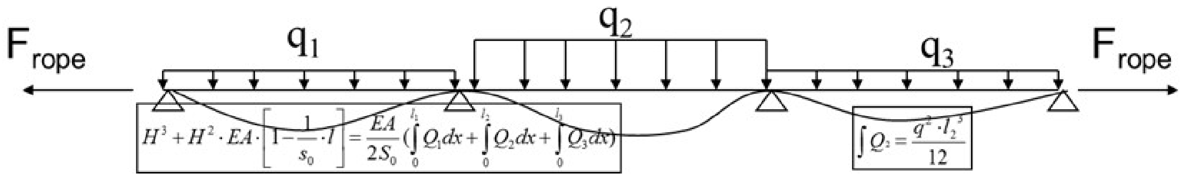

Fig. 7: Multiple field rope equation

Top support rope:	2x 22mm Geobinex mit 4x GN-9017
2nd top support rope:	2x 22mm Geobinex mit 4x GN-9017
3th top support rope:	2x 22mm Geobinex mit 4x GN-9017
4th top support rope:	2x 22mm Geobinex mit 4x GN-9017
5th top support rope:	2x 22mm Geobinex mit 4x GN-9017
6th top support rope:	2x 22mm Geobinex mit 4x GN-9017
Bottom support rope:	2x 22mm Geobinex mit 4x GN-9017

Top support rope:

Impact: $q_{rope1} = 52.14 \; \frac{kN}{m}$

Rope length: $b_1 = 60 \; m$

Rope force: $F_{rope1} := 302.87 \; kN$

Number of ropes: $n1 := 2$

Force per rope: $F_{pro\_Seil1} := \frac{F_{rope1}}{n1}$ $\quad F_{pro\_Seil1} = 151.44 \; kN$

Impact: $F_{Ed;Seil} := F_{rope1} \cdot \gamma_Q$ $\quad F_{Ed;Seil} = 302.87 \; kN$

Resistance: $F_{Rd;Seil} := \frac{(n1 \cdot 400 \; kN)}{\gamma_M}$ $\quad F_{Rd;Seil} = 761.9 \; kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

$\text{if}\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.52$

$\text{if}\left(SF \ge 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil1} \cdot \gamma_Q$ $\quad F_{Ed;bremse} = 151.44 \; kN$

$F_{Rd;bremse} := \frac{330 \; kN}{\gamma_M}$ $\quad F_{Rd;bremse} = 314.29 \; kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

2nd top support rope:

Impact: $q_{rope2} = 58.02 \; \frac{kN}{m}$

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Rope length: $b_2 = 60\ m$
Rope force: $F_{rope2} := 335.61\ kN$
Number of ropes: $n2 := 2$

Force per rope: $F_{pro\_Seil2} := \frac{F_{rope2}}{n2}$ $F_{pro\_Seil2} = 167.81\ kN$

Impact: $F_{Ed;Seil} := F_{rope2} \cdot \gamma_Q$ $F_{Ed;Seil} = 335.61\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n2 \cdot 400\ kN)}{\gamma_M}$ $F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

if $\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.27$

if $\left(SF \ge 1.0, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil2} \cdot \gamma_Q$ $F_{Ed;bremse} = 167.81\ kN$

$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$ $F_{Rd;bremse} = 314.29\ kN$

if $\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

3th top support rope:

Impact: $q_{rope3} = 58.02\ \frac{kN}{m}$
Rope length: $b_3 = 60\ m$
Rope force: $F_{rope3} := 335.61\ kN$
Number of ropes: $n3 := 2$

Force per rope: $F_{pro\_Seil3} := \frac{F_{rope3}}{n3}$ $F_{pro\_Seil3} = 167.81\ kN$

Impact: $F_{Ed;Seil} := F_{rope3} \cdot \gamma_Q$ $F_{Ed;Seil} = 335.61\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n2 \cdot 400\ kN)}{\gamma_M}$ $F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

if $\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.27$

if $\left(SF \ge 1.0, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil3} \cdot \gamma_Q$ $F_{Ed;bremse} = 167.81\ kN$

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$$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M} \qquad F_{Rd;bremse} = 314.29\ kN$$

if $(F_{Ed;bremse} < F_{Rd;bremse}, \text{"Fulfilled"}, \text{"Not fulfilled"}) = \text{"Fulfilled"}$

4th top support rope:

Impact:	$q_{rope4} = 58.02\ \frac{kN}{m}$
Rope length:	$b_4 = 60\ m$
Rope force:	$F_{rope4} := 335.61\ kN$
Number of ropes:	$n4 := 2$

Force per rope: $F_{pro\_Seil4} := \frac{F_{rope4}}{n4}$ $\qquad F_{pro\_Seil4} = 167.81\ kN$

Impact: $F_{Ed;Seil} := F_{rope4} \cdot \gamma_Q$ $\qquad F_{Ed;Seil} = 335.61\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n4 \cdot 400\ kN)}{\gamma_M}$ $\qquad F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

if $(F_{Ed;Seil} \le F_{Rd;Seil}, \text{"Fulfilled"}, \text{"Not fulfilled"}) = \text{"Fulfilled"}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.27$

if $(SF \ge 1.0, \text{"Fulfilled"}, \text{"Not fulfilled"}) = \text{"Fulfilled"}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil4} \cdot \gamma_Q$ $\qquad F_{Ed;bremse} = 167.81\ kN$

$$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M} \qquad F_{Rd;bremse} = 314.29\ kN$$

if $(F_{Ed;bremse} < F_{Rd;bremse}, \text{"Fulfilled"}, \text{"Not fulfilled"}) = \text{"Fulfilled"}$

5th top support rope:

Impact:	$q_{rope5} = 58.02\ \frac{kN}{m}$
Rope length:	$b_5 = 60\ m$
Rope force:	$F_{rope5} := 335.61\ kN$
Number of ropes:	$n5 := 2$

Force per rope: $F_{pro\_Seil5} := \frac{F_{rope5}}{n5}$ $\qquad F_{pro\_Seil5} = 167.81\ kN$

Impact: $F_{Ed;Seil} := F_{rope5} \cdot \gamma_Q$ $\qquad F_{Ed;Seil} = 335.61\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n5 \cdot 400\ kN)}{\gamma_M}$ $\qquad F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

if $(F_{Ed;Seil} \le F_{Rd;Seil}, \text{"Fulfilled"}, \text{"Not fulfilled"}) = \text{"Fulfilled"}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.27$

$\text{if}\left(SF \geq 1.0, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil5} \cdot \gamma_Q$ $\quad F_{Ed;bremse} = 167.81\ kN$

$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$ $\quad F_{Rd;bremse} = 314.29\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

6th top support rope:

Impact: $q_{rope6} = 58.02\ \frac{kN}{m}$

Rope length: $b_6 = 60\ m$

Rope force: $F_{rope6} := 335.61\ kN$

Number of ropes: $n6 := 2$

Force per rope: $F_{pro\_Seil6} := \frac{F_{rope6}}{n6}$ $\quad F_{pro\_Seil6} = 167.81\ kN$

Impact: $F_{Ed;Seil} := F_{rope6} \cdot \gamma_Q$ $\quad F_{Ed;Seil} = 335.61\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n6 \cdot 400\ kN)}{\gamma_M}$ $\quad F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \leq F_{Rd;Seil}$

$\text{if}\left(F_{Ed;Seil} \leq F_{Rd;Seil}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.27$

$\text{if}\left(SF \geq 1.0, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil6} \cdot \gamma_Q$ $\quad F_{Ed;bremse} = 167.81\ kN$

$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$ $\quad F_{Rd;bremse} = 314.29\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Bottom support rope:

Impact: $q_{rope7} = 52.14\ \frac{kN}{m}$

Rope length: $b_7 = 60\ m$

Rope force: $F_{rope7} := 302.87\ kN$

Number of ropes: $n7 := 2$

Force per rope: $F_{pro\_Seil7} := \frac{F_{rope7}}{n7}$ $\quad F_{pro\_Seil7} = 151.44\ kN$

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Impact: $F_{Ed;Seil} := F_{rope7} \cdot \gamma_Q$ $F_{Ed;Seil} = 302.87\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n7 \cdot 400\ kN)}{\gamma_M}$ $F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

if $(F_{Ed;Seil} \le F_{Rd;Seil}$, "Fulfilled", "Not fulfilled"$)$ = "Fulfilled"

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.52$

if $(SF \ge 1.0$, "Fulfilled", "Not fulfilled"$)$ = "Fulfilled"

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil7} \cdot \gamma_Q$ $F_{Ed;bremse} = 151.44\ kN$

$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$ $F_{Rd;bremse} = 314.29\ kN$

if $(F_{Ed;bremse} < F_{Rd;bremse}$, "Fulfilled", "Not fulfilled"$)$ = "Fulfilled"

Retaining rope:

Impact: $q_{retaining} := 635.09\ kN$

Number of ropes: $n_{retaining} := 4$

Force per rope: $F_{retaining} := \frac{q_{retaining}}{n_{retaining}}$ $F_{retaining} = 158.77\ kN$

Impact: $F_{Ed;Seil} := q_{retaining} \cdot \gamma_Q$ $F_{Ed;Seil} = 635.09\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n_{retaining} \cdot 400\ kN)}{\gamma_M}$ $F_{Rd;Seil} = 1523.81\ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

if $(F_{Ed;Seil} \le F_{Rd;Seil}$, "Fulfilled", "Not fulfilled"$)$ = "Fulfilled"

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.4$

if $(SF \ge 1.0$, "Fulfilled", "Not fulfilled"$)$ = "Fulfilled"

Breaking load brake: $F_{Ed;bremse} := F_{retaining} \cdot \gamma_Q$ $F_{Ed;bremse} = 158.77\ kN$

$F_{Rd;bremse} := \frac{350\ kN}{\gamma_M}$ $F_{Rd;bremse} = 333.33\ kN$

if $(F_{Ed;bremse} < F_{Rd;bremse}$, "Fulfilled", "Not fulfilled"$)$ = "Fulfilled"

Vertical rope:

Impact: $q_{lat} := 53.52\ \frac{kN}{m}$

Rope length: $b_{lat} := 6\ m$

Rope force: $F_{lat} := 232.24\ kN$

Number of ropes:	$n_{lat} := 1$	
Force per rope:	$F_{pro\_lat} := \dfrac{F_{lat}}{n_{lat}}$	$F_{pro\_lat} = 232.24\ kN$
Impact:	$F_{Ed;Seil} := F_{lat} \cdot \gamma_Q$	$F_{Ed;Seil} = 232.24\ kN$
Resistance:	$F_{Rd;Seil} := \dfrac{\left(n_{lat} \cdot 400\ kN\right)}{\gamma_M}$	$F_{Rd;Seil} = 380.95\ kN$
Proof:	$F_{Ed;Seil} \leq F_{Rd;Seil}$	

$$\text{if}\left(F_{Ed;Seil} \leq F_{Rd;Seil}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$$

Safety factor SF: $SF := \dfrac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.64$

$$\text{if}\left(SF \geq 1.1, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$$

2.5 Proof: Post

The acting force on the barrier is transferred over the horizontal support ropes into the anchors on the side flank. In case of narrow cross-sections the acting force can directly be transferred over the ropes into the side. Statically speaking, we have on the right and left a support and a beam in our case a rope that takes up the load and transferres it. In case of larger cross-sections a support on the left and right is not enough that the beam respectively rope is capable of taking the load up. Therefore, more supports are needed. For a debris flow barrier that means posts are needed.
Due to the wide span of the cross-section horizontal ropes have to be guided on the post. On each of the support (guided rope on post) is not only a horizontal force but also a vertical force that has to be taken up by the post.
Each post has to take up acting forces from the retaining rope, top rope, 1th to the 5th top rope.
The post stability proof is verified with the static software Rstab according to Eurocode 3.
The post beam is a standard beam used in Europe so-called HEM or UC (Fig. 7). The HEM/ UC beam is the heaviest and widest (wide flange) of the H beams. It is used for particularly high requirements on the ultimate load. Wide flange beams offer the great advantage of a very high buckling resistance. This is due to their large average area.

According to the Eurocode 3 (EC3) stability proof - bending and compression was executed according to 6.3.3 (Uniform members in bending and axial compression), equation 6.61 and 6.62.

2.5.1 Buckling resistance of members according to Eurocode 3 (EC3)

According to EC3 Chapter 6.3.3 for uniform members in bending and axial compression which are subjected to bending and axial compression should satisfy the following equations:

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$$\frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y;Ed} + \Delta M_{y;Ed}}{\chi_{LT} \cdot \frac{M_{y;Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z;Ed} + \Delta M_{z;Ed}}{\frac{M_{z;Rk}}{\gamma_{M1}}} \leq 1.0 \qquad \text{(Equation 6.61)}$$

$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y;Ed} + \Delta M_{y;Ed}}{\chi_{LT} \cdot \frac{M_{y;Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z;Ed} + \Delta M_{z;Ed}}{\frac{M_{z;Rd}}{\gamma_{M1}}} \leq 1.0 \qquad \text{(Equation 6.62)}$$

N_{Ed}, $M_{y;Ed}$, $M_{z;Ed}$: design values, compression force and maximum moments about y-y and z-z axis
$\Delta M_{y;Ed}$, $\Delta M_{z;Ed}$: are the moments due to the shift of the centroidal axis for class 4 sections
χ_y, χ_z: are the reduction factors due to flexural buckling
χ_{LT}: is the reduction factor due to lateral torsional buckling
k_{yy}, k_{yz}, k_{zy}, k_{zz}: are the interaction factors

Acting force on post:
The model in Rstab are single bars with spacing 1m. The horizontal load, vertical load and the moment are applied at the nodes, see values below. The applied load case for the post is assumed to be on the top with a dynamic impact that are transferred from the ropes into the post and on the lower part with the static force from the filled/settled material in the barrier (Fig. 8).

Top support rope:
Horizontal/Vertical load: $276.42\ kN$ $387.78\ kN$
Moment at node: no moment

2nd support rope:
Horizontal/Vertical load: $194.82\ kN$ $229.57\ kN$
Moment at node: $44.42\ kN \cdot m$

3th support rope:
Horizontal/Vertical load: $194.82\ kN$ $229.57\ kN$
Moment at node: $44.42\ kN \cdot m$

4th support rope:
Horizontal/Vertical load: $127.95\ kN$ $153.59\ kN$
Moment at node: $29.72\ kN \cdot m$

5th support rope:
Horizontal/Vertical load: $157.74\ kN$ $187.75\ kN$
Moment at node: $36.33\ kN \cdot m$

6th support rope:
Horizontal/Vertical load: $187.62\ kN$ $221.51\ kN$
Moment at node: $42.86\ kN \cdot m$

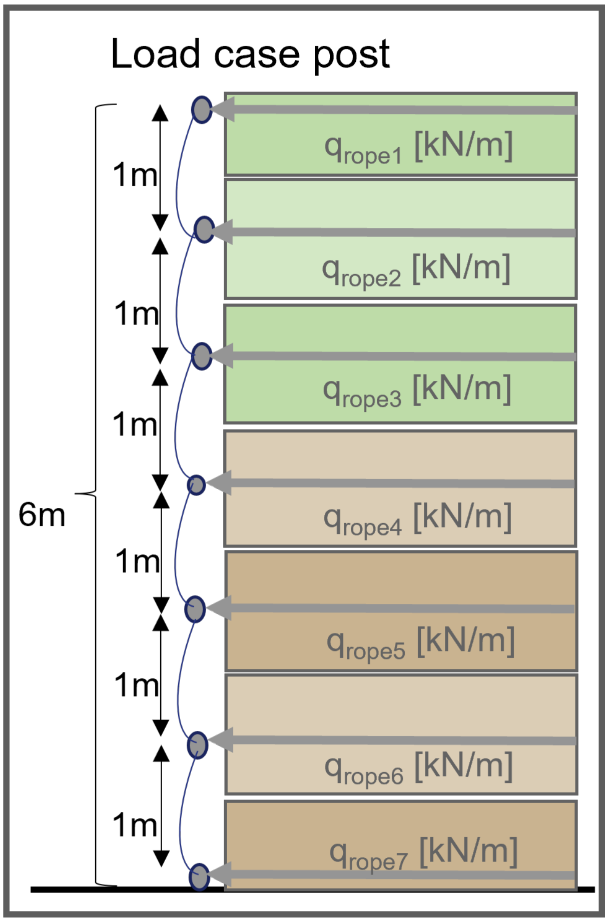

Fig. 8: Load case post

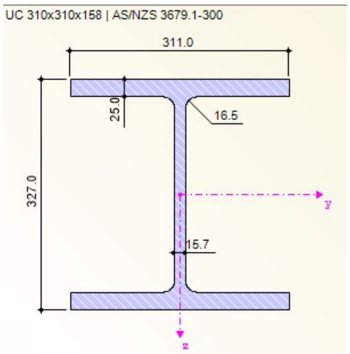

Fig. 9: UC 310x310x158

Material and Cross-section:
Steel S300 AS/NZS 4600:2005
UC 310x310x158 (Fig. 9)

Section class:
Section class 1 according to $c/t \le 72\ \varepsilon$ with:

$c := 277\ mm$

$t := 15.7\ mm$ $\qquad c/t \le 72\ \varepsilon$

$\varepsilon := 0.81$ $\qquad 17.6 \le 58.32$

Design dimensions: (see Fig. 10-13)

Normal force:	$N_{Ed} := 1000.51\ kN$	no partial safety factor added: $\gamma_Q := 1.0$
Moment:	$M_{y;Ed} := 716.02\ kN \cdot m$	
Moment:	$M_{z;Ed} := 0.0\ kN \cdot m$	
Moment:	$\Delta M_{y;Ed} := 0\ kN \cdot m$	only for section class 4 needed
Moment:	$\Delta M_{z;Ed} := 0\ kN \cdot m$	only for section class 4 needed

Proof:

Partial safety factor: $\gamma_{M1} := 1.1$

Compressive strength: $N_{Rk} := 6891.68\ kN$
Moment resistance: $M_{y;Rk} := 914.46\ kN \cdot m$
Moment resistance: $M_{z;Rk} := 417.98\ kN \cdot m$

Reduction factor: $\chi_y := 1.0$
Reduction factor: $\chi_z := 1.0$
Reduction factor: $\chi_{LT} := 1.0$

Interaction factor: $k_{yy} := 0.959$
Interaction factor: $k_{yz} := 0.345$
Interaction factor: $k_{zy} := 0.767$
Interaction factor: $k_{zz} := 0.575$

Proof y-y axis:
(Eq: 6.61)

$$\frac{N_{Ed}}{\dfrac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y;Ed} + \Delta M_{y;Ed}}{\chi_{LT} \cdot \dfrac{M_{y;Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z;Ed} + \Delta M_{z;Ed}}{\dfrac{M_{z;Rk}}{\gamma_{M1}}} = 0.99 \ (0.73 \le 1)$$

Proof z-z axis:
(Eq: 6.62)

$$\frac{N_{Ed}}{\dfrac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y;Ed} + \Delta M_{y;Ed}}{\chi_{LT} \cdot \dfrac{M_{y;Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z;Ed} + \Delta M_{z;Ed}}{\dfrac{M_{z;Rk}}{\gamma_{M1}}} = 0.82 \ (0.60 \le 1)$$

Stability proof according EC3, equation 6.61 and 6.62 is given for both axis with 0.99<1.0 and 0.82 < 1.0.

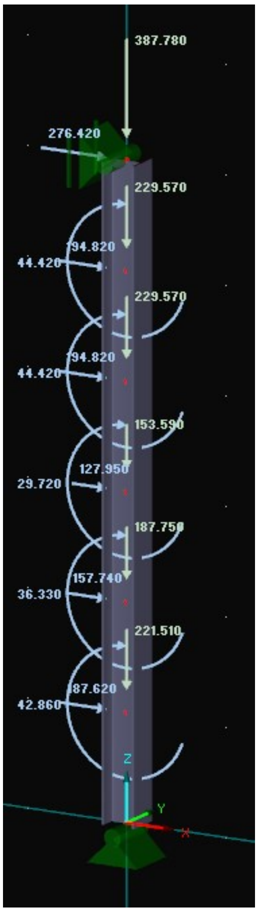

Fig. 10: Impact on post

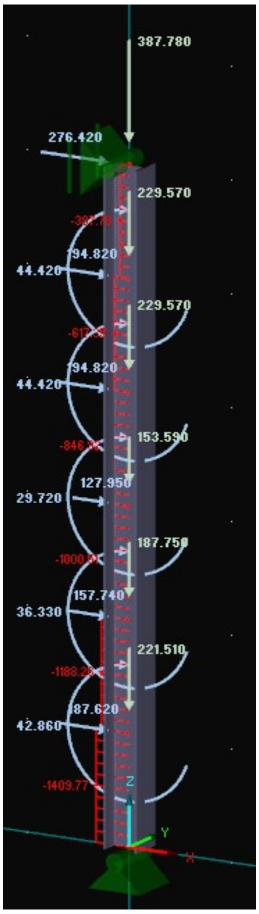

Fig. 11: Normal force

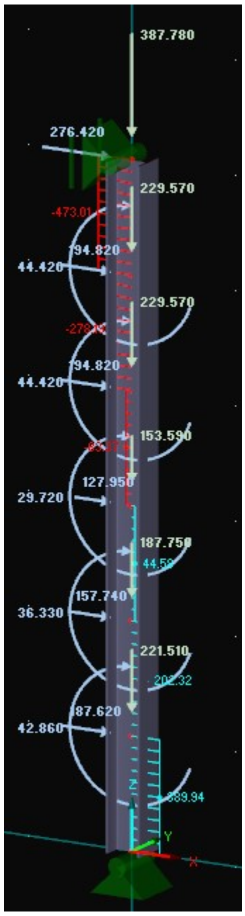

Fig. 12: Shear force

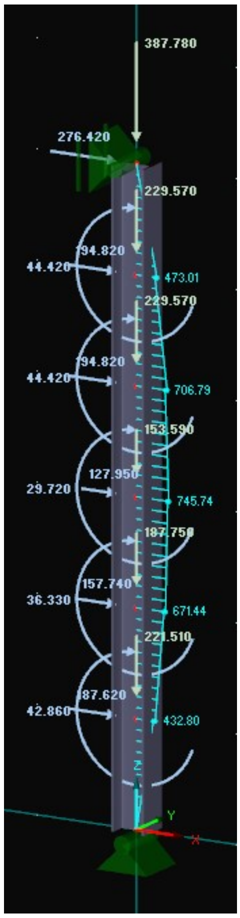

Fig. 13: Moment

2.6 Anchorage forces

In principle, all ropes are anchored with at least the breaking load of the respective rope incl. braking element. This guarantees a failure of the ropes and not of the anchors in case of overload. For each support rope a anchorage force of 350kN is recommended.
Foundation forces is once the vertical/normal force from the post and the shear force.
Characteristic anchor forces for the ropes are shown below:

Lateral rope:	$350\ kN$
Each retaining rope:	$160\ kN$
Each support rope:	$170\ kN$

Pressure force post: $F_{vertical} := 1040\ kN$
Horizontal force post: $F_{horizontal} := 580\ kN$

3. Summary

	Amount of ropes:	Width:	
$q_{rope1}=52.14\ \frac{kN}{m}$	$n1=2$	$b_1=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope2}=58.02\ \frac{kN}{m}$	$n2=2$	$b_2=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope3}=58.02\ \frac{kN}{m}$	$n3=2$	$b_3=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope4}=58.02\ \frac{kN}{m}$	$n4=2$	$b_4=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope5}=58.02\ \frac{kN}{m}$	$n5=2$	$b_5=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope6}=58.02\ \frac{kN}{m}$	$n6=2$	$b_6=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope7}=52.14\ \frac{kN}{m}$	$n7=2$	$b_7=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*

Total amount of ropes: $n_{tot}:=n1+n2+n3+n4+n5+n6+n7=14$

Number of posts: $n_{post}:=10$ *UC 310x310x158 Steel 300*
Base plate: $n_{baseplate}:=n_{post}=10$ *Special plate 1x1m*
Retaining ropes per post: $n_{retainingpost}:=4$ *x 22mm Geobinex with 1x GN-9055*
Total retaining ropes: $n_{retaining}:=n_{retainingpost}\cdot n_{post}=40$
WRA 22.5mm: $n_{flexhead}:=n_{tot}+\frac{n_{retaining}}{2}+2=36$

Net: ROCCO 12/3/350
Post height: $H=6\ m$
Post spacing: $b_{post}=6\ m$
Rope spacing: $h_{spacing}=1\ m$
Basal opening: $h_d=0\ m$
Abrasion protection yes
Secondary mesh: yes

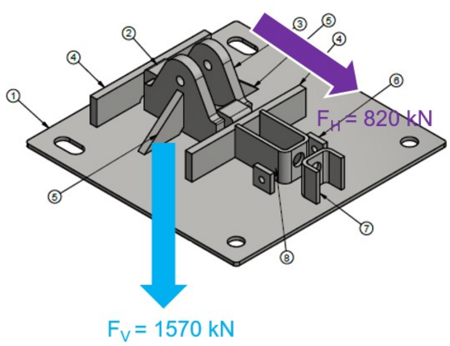

Fig. 14: Baseplate example

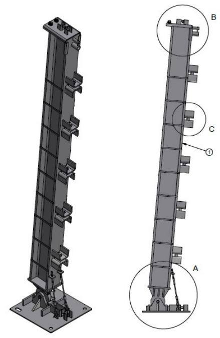

Fig. 15: HEM Post example

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Dimensioning Debris Flow Barrier
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15.02.2024

CONTENT

1. Introduction

The following report explains the concept of dimensioning a debris flow barrier which is placed on an open hill slope in Queenstown, New Zealand. The cross-section is 60m (Fig. 1).
The design is based on assumed input parameters which have not been verified by Geobrugg, since no parameters were provided by the client.
Chapter 2 describes the design parameters, action and analytical verifications.

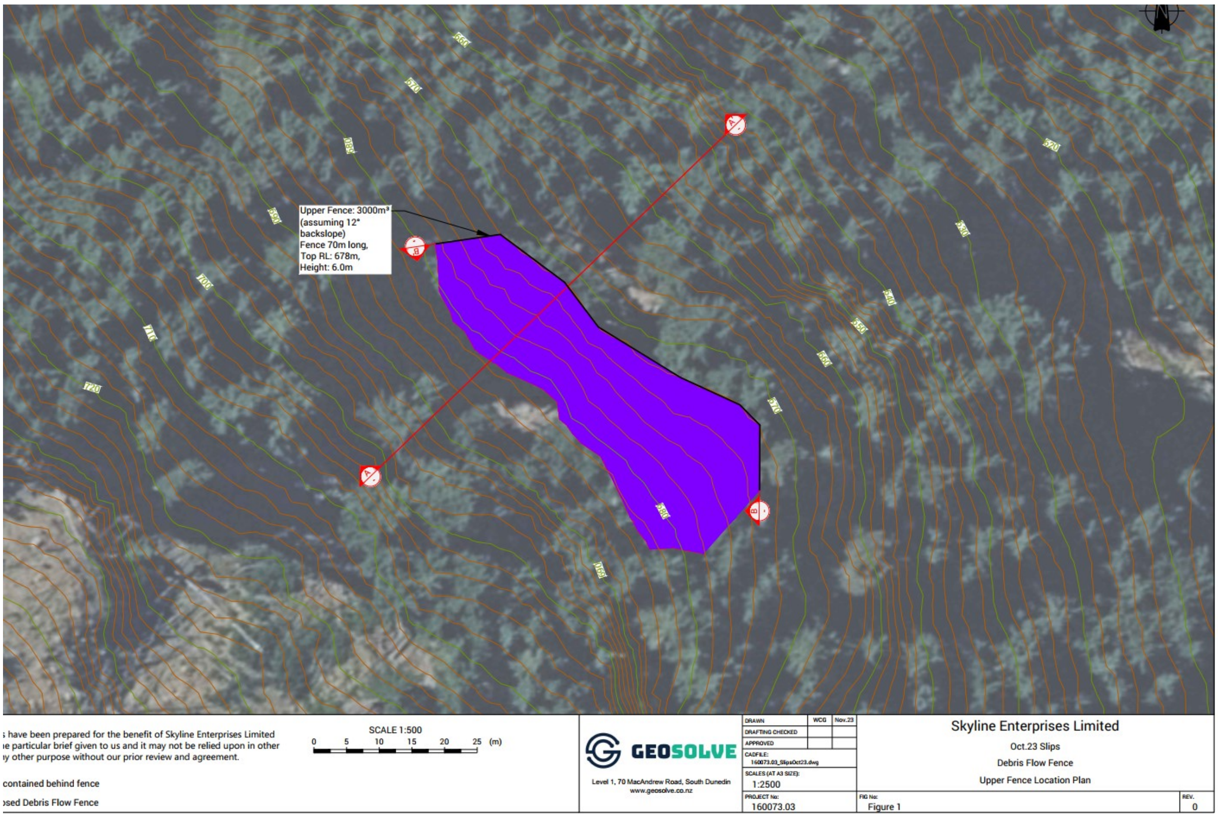

Fig. 1: Overview debris flow barrier location (drawn by the client)

2. Dimensioning debris flow barrier

The design of Geobruggs' debris flow barrier is based on the worldwide accepted load model by Wendeler (2008). The model takes into account the load case of the dynamic first impact, the filling process and the overflow (Fig. 3-5).

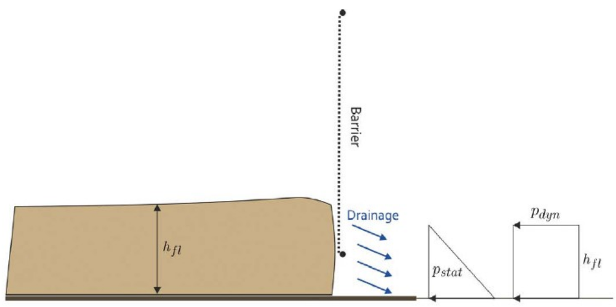

Fig. 3: Pressure surge as first impact on the barrier (WSL, Practical guide for debris flow and hillslope debris flow protection net)

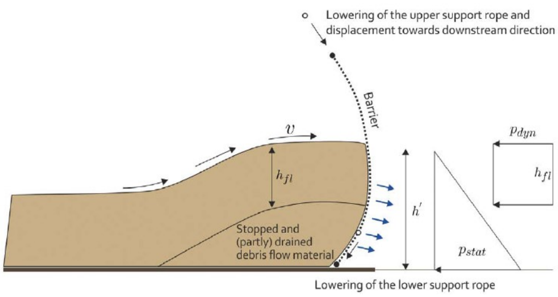

Fig. 4: Filling up the barrier by followed surges (WSL, Practical guide for debris flow and hillslope debris flow protection net)

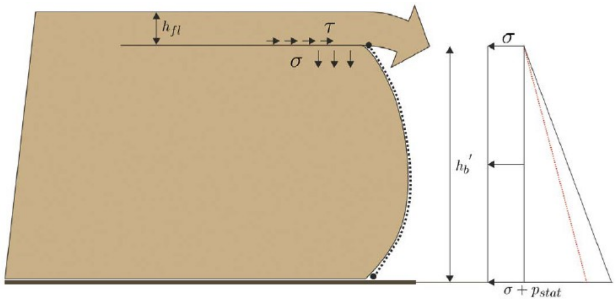

Fig. 5: Filled barrier under overflow condition (WSL, Practical guide for debris flow and hillslope debris flow protection net)

2.1 System requirements

Partial safety factor impact: $\gamma_Q := 1.0$
Partial safety factor material: $\gamma_M := 1.05$

2.1.1 Geometry

Barrier height:	$H := 6\ m$		
Barrier width bottom:	$b_u := 60\ m$	*Total cross-section*	
Barrier width top:	$b_o := 60\ m$	*Total cross-section*	
Average width:	$b_m := \frac{(b_o + b_u)}{2}$		$b_m = 60\ m$
Height filled barrier:	$H_0 := H \cdot 0.75$		$H_0 = 4.5\ m$
Top rope width:	$b_1 := 60\ m$		$b_1 = 60\ m$
2nd top rope width:	$b_2 := 60\ m$		$b_2 = 60\ m$
3th top rope width:	$b_3 := 60\ m$		$b_3 = 60\ m$
4th top rope width:	$b_4 := 60\ m$		$b_4 = 60\ m$
5th top rope width:	$b_5 := 60\ m$		$b_5 = 60\ m$
6th top rope width:	$b_6 := 60\ m$		$b_6 = 60\ m$
Bottom rope width:	$b_7 := 60\ m$		$b_7 = 60\ m$
Basal opening:	$h_d := 0\ m$		$h_d = 0\ m$
Post spacing:	$b_{post} := 6\ m$		$b_{post} = 6\ m$

2.1.2 Debris flow parameter

The following values are used to calculate the impact forces on the barrier. All values are assumend and have not been verified.

Type of debris flow: Muddy flow

Debris flow density: $\rho := 1600\ \frac{kg}{m^3}$

Velocity: $v := 9\ \frac{m}{s}$

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Discharge: $Q := 540 \ \frac{m^3}{s}$

The flow height is calculated by the continuity equation: Q= v*A. Velocity and discharge are given as well as the bottom width of the cross-section.

Flow height: $h_{fl} := \frac{Q}{(v \cdot b_u)}$ $\qquad h_{fl} = 1 \ m$

2.2 Analytical Proof: Impact

In the following, pressure surge, filling process, and overflow are determined for the respective area load acting on the support ropes. Based on these forces, the decisive load is determined and used for dimensioning of the support ropes.

Load cases:
1. First pressure surge
$F_{pressure\_surge}$ = hydrostatic pressure + hydrodynamic pressure
First pressure surge is used to dimension bottom support rope when force is decisive.

2. Impact on support ropes filling process
q= hydrostatic pressure + hydrodynamic pressure

3. Filled barrier/ overflow
Earth pressure is additionally added instead of the hydrodynamic pressure.
$F_{overflow}$ = additional weight + hydrostatic pressure

4. Identify decisive load case

2.2.1 Pressure surge

Pressure surge is made up as follows: F= hydrostatic pressure + hydrodynamic pressure. Hydrodynamic coefficient depends on the density of the debris flow material and can be defined as: $c_d = 2.0 \ granular$ and $c_d = 0.8 \ mudflow$.

Based on the density $\rho = 1600 \ \frac{kg}{m^3}$ a hydrodynamic coefficient of $c_d := 0.8$ is applied.

With a basal opening equal or smaller than the flow height, the initial impact is completely absorbed by the lower support rope. In the presented case for Queenstown with a basal opening of $h_d = 0 \ m$, a flow height $h_{fl} = 1 \ m$, and a support rope spacing $h_{spacing} := 1 \ m$ the initial impact will be distributed on the lowest layer of ropes from the bottom up.
Hydrostatic and hydrodynamic pressure for the initial impact (characteristic) is calculated as followed:

Flow height assumption: $h_{fl} := 1.0 \ m$

Hydrostatic pressure: $P_{hyd} := \frac{1}{2} \cdot \rho \cdot g \cdot h_{fl}$ $\qquad P_{hyd} = 7.85 \ \frac{kN}{m^2}$

Hydrodynamic pressure: $P_{dyn} := c_d \cdot \rho \cdot v^2$ $\qquad P_{dyn} = 103.68 \ \frac{kN}{m^2}$

Total load pressure surge: $F_{pressure\_surge} := P_{hyd} + P_{dyn}$ $F_{pressure\_surge} = 111.53 \ \frac{kN}{m^2}$

$f_{pressure\_surge} := \frac{1}{2} \cdot \rho \cdot g \cdot h_{fl}^2 + c_d \cdot \rho \cdot v^2 \cdot h_{fl}$ $f_{pressure\_surge} = 111.525 \ \frac{kN}{m}$

2.2.2 Filling process

The area load on the support ropes during the filling process is made up as follows: q= hydrostatic pressure + hydrodynamic pressure. Below an example:

Top support rope: $q_1 := 105.64 \ \frac{kN}{m}$

2th top rope: $q_2 := 111.53 \ \frac{kN}{m}$

3th top rope: $q_3 := 111.53 \ \frac{kN}{m}$

4th top rope: $q_4 := 111.53 \ \frac{kN}{m}$

5th top rope: $q_5 := 111.53 \ \frac{kN}{m}$

6th top rope: $q_6 := 111.53 \ \frac{kN}{m}$

Bottom support rope: $q_7 := 105.64 \ \frac{kN}{m}$

2.2.3 Overflow

In the case of a filled barrier or during overflow, the effect is composed of q= hydrostatic pressure + additional weight. Below an example:

Additional weight: $\sigma := \rho \cdot h_{fl} \cdot g$ $\sigma = 15.69 \ \frac{kN}{m^2}$

Hydrostatic pressure: $P_{hyd} := \rho \cdot g \cdot H_0$ $P_{hyd} = 70.61 \ \frac{kN}{m^2}$

Total impact overflow: $F_{overflow} := \sigma + P_{hyd}$ $F_{overflow} = 86.3 \ \frac{kN}{m^2}$

Top support rope: $q_{1\_2} := 6.99 \ \frac{kN}{m}$

2th top rope: $q_{2\_2} := 20.59 \ \frac{kN}{m}$

3th top rope: $q_{3\_2} := 29.42 \ \frac{kN}{m}$

4th top rope: $q_{4\_2} := 38.25 \ \frac{kN}{m}$

5th top rope: $q_{5\_2} := 47.07 \ \frac{kN}{m}$

6th top rope: $q_{6\_2} := 55.9 \ \frac{kN}{m}$

Bottom support rope: $q_{7\_2} := 31.26 \frac{kN}{m}$

2.2.4 Decisive load

In a next step the decisive load case of each rope layer (Fig. 6) has to be identified. The values above show that the dynamic impact is decisive for determining the number of top ropes till the 5th top rope. Decisive for the 6th top rope and bottom support ropes is the overflow condition.

Top rope: $q_{rope1} := \max\left(q_1, q_{1\_2}\right) = 105.64 \frac{kN}{m}$

2nd top rope: $q_{rope2} := \max\left(q_2, q_{2\_2}\right) = 111.53 \frac{kN}{m}$

3th top rope: $q_{rope3} := \max\left(q_3, q_{3\_2}\right) = 111.53 \frac{kN}{m}$

4th top rope: $q_{rope4} := \max\left(q_4, q_{4\_2}\right) = 111.53 \frac{kN}{m}$

5th top rope: $q_{rope5} := \max\left(q_5, q_{5\_2}\right) = 111.53 \frac{kN}{m}$

6th top rope: $q_{rope6} := \max\left(q_6, q_{6\_2}\right) = 111.53 \frac{kN}{m}$

Bottom rope: $q_{rope7} := \max\left(q_7, q_{7\_2}\right) = 105.64 \frac{kN}{m}$

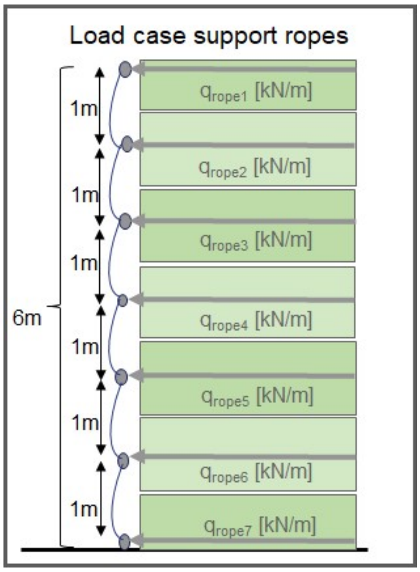

Fig. 6: Load case support ropes

2.3 Proof: ROCCO Net

ROCCO 12/3/350 is required to withstand the load.

Impact: $F_{Ed;Netz} := 60.61 \frac{kN}{m}$

Resistance: $F_{Rd;Netz} := 238.1 \frac{kN}{m}$

Proof: $F_{Ed;Netz} \le F_{Rd;Netz}$

$\text{if}\left(F_{Ed;Netz} \le F_{Rd;Netz}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Safety factor SF: $SF := \frac{F_{Rd;Netz}}{F_{Ed;Netz}} = 3.93$

$\text{if}\left(SF \ge 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

2.4 Proof: Support ropes

The determined impact on each rope layer is then used in the multiple field rope equation (Palkowski 1991) to identify the amount of needed ropes. Figure 7 shows a system with 4 posts as supports with three fields on which the load q1-q3 acts. For debris flow barriers the impact force on each field is the same for each rope layer. In other words q1=q2=q3=qn.

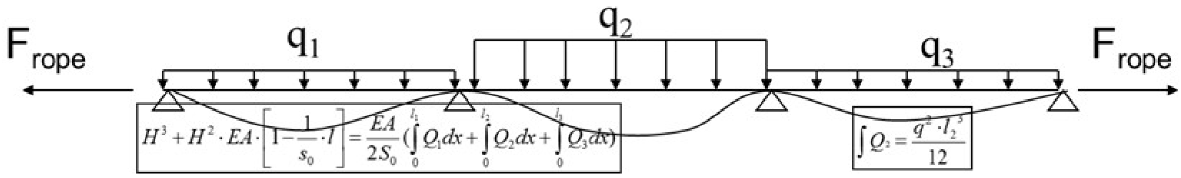

Fig. 7: Multiple field rope equation

Top support rope:	2x 22mm Geobinex mit 4x GN-9017
2nd top support rope:	2x 22mm Geobinex mit 4x GN-9017
3th top support rope:	2x 22mm Geobinex mit 4x GN-9017
4th top support rope:	2x 22mm Geobinex mit 4x GN-9017
5th top support rope:	2x 22mm Geobinex mit 4x GN-9017
6th top support rope:	2x 22mm Geobinex mit 4x GN-9017
Bottom support rope:	2x 22mm Geobinex mit 4x GN-9017

Top support rope:

Impact: $q_{rope1} = 105.64 \ \frac{kN}{m}$

Rope length: $b_1 = 60 \ m$

Rope force: $F_{rope1} := 592.31 \ kN$

Number of ropes: $n1 := 2$

Force per rope: $F_{pro\_Seil1} := \frac{F_{rope1}}{n1}$ $\qquad F_{pro\_Seil1} = 296.16 \ kN$

Impact: $F_{Ed;Seil} := F_{rope1} \cdot \gamma_Q$ $\qquad F_{Ed;Seil} = 592.31 \ kN$

Resistance: $F_{Rd;Seil} := \frac{(n1 \cdot 400 \ kN)}{\gamma_M}$ $\qquad F_{Rd;Seil} = 761.9 \ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

$\text{if}\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.29$

$\text{if}\left(SF \ge 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil1} \cdot \gamma_Q$ $\qquad F_{Ed;bremse} = 296.16 \ kN$

$F_{Rd;bremse} := \frac{330 \ kN}{\gamma_M}$ $\qquad F_{Rd;bremse} = 314.29 \ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

2nd top support rope:

Impact: $q_{rope2} = 111.53 \ \frac{kN}{m}$

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Rope length:	$b_2 = 60\ m$	
Rope force:	$F_{rope2} := 623.13\ kN$	
Number of ropes:	$n2 := 2$	
Force per rope:	$F_{pro\_Seil2} := \dfrac{F_{rope2}}{n2}$	$F_{pro\_Seil2} = 311.57\ kN$
Impact:	$F_{Ed;Seil} := F_{rope2} \cdot \gamma_Q$	$F_{Ed;Seil} = 623.13\ kN$
Resistance:	$F_{Rd;Seil} := \dfrac{(n2 \cdot 400\ kN)}{\gamma_M}$	$F_{Rd;Seil} = 761.9\ kN$
Proof:	$F_{Ed;Seil} \leq F_{Rd;Seil}$	

$\text{if}\left(F_{Ed;Seil} \leq F_{Rd;Seil}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Safety factor SF: $SF := \dfrac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.22$

$\text{if}\left(SF \geq 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Breaking load brake:	$F_{Ed;bremse} := F_{pro\_Seil2} \cdot \gamma_Q$	$F_{Ed;bremse} = 311.57\ kN$
	$F_{Rd;bremse} := \dfrac{330\ kN}{\gamma_M}$	$F_{Rd;bremse} = 314.29\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

3th top support rope:

Impact:	$q_{rope3} = 111.53\ \dfrac{kN}{m}$	
Rope length:	$b_3 = 60\ m$	
Rope force:	$F_{rope3} := 623.13\ kN$	
Number of ropes:	$n3 := 2$	
Force per rope:	$F_{pro\_Seil3} := \dfrac{F_{rope3}}{n3}$	$F_{pro\_Seil3} = 311.57\ kN$
Impact:	$F_{Ed;Seil} := F_{rope3} \cdot \gamma_Q$	$F_{Ed;Seil} = 623.13\ kN$
Resistance:	$F_{Rd;Seil} := \dfrac{(n2 \cdot 400\ kN)}{\gamma_M}$	$F_{Rd;Seil} = 761.9\ kN$
Proof:	$F_{Ed;Seil} \leq F_{Rd;Seil}$	

$\text{if}\left(F_{Ed;Seil} \leq F_{Rd;Seil}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Safety factor SF: $SF := \dfrac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.22$

$\text{if}\left(SF \geq 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Breaking load brake:	$F_{Ed;bremse} := F_{pro\_Seil3} \cdot \gamma_Q$	$F_{Ed;bremse} = 311.57\ kN$

$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$ $F_{Rd;bremse} = 314.29\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

4th top support rope:

Impact: $q_{rope4} = 111.53\ \frac{kN}{m}$

Rope length: $b_4 = 60\ m$

Rope force: $F_{rope4} := 623.13\ kN$

Number of ropes: $n4 := 2$

Force per rope: $F_{pro\_Seil4} := \frac{F_{rope4}}{n4}$ $F_{pro\_Seil4} = 311.57\ kN$

Impact: $F_{Ed;Seil} := F_{rope4} \cdot \gamma_Q$ $F_{Ed;Seil} = 623.13\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n4 \cdot 400\ kN)}{\gamma_M}$ $F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

$\text{if}\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.22$

$\text{if}\left(SF \ge 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil4} \cdot \gamma_Q$ $F_{Ed;bremse} = 311.57\ kN$

$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$ $F_{Rd;bremse} = 314.29\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

5th top support rope:

Impact: $q_{rope5} = 111.53\ \frac{kN}{m}$

Rope length: $b_5 = 60\ m$

Rope force: $F_{rope5} := 623.13\ kN$

Number of ropes: $n5 := 2$

Force per rope: $F_{pro\_Seil5} := \frac{F_{rope5}}{n5}$ $F_{pro\_Seil5} = 311.57\ kN$

Impact: $F_{Ed;Seil} := F_{rope5} \cdot \gamma_Q$ $F_{Ed;Seil} = 623.13\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n5 \cdot 400\ kN)}{\gamma_M}$ $F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \le F_{Rd;Seil}$

$\text{if}\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

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Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.22$

$\text{if}\left(SF \geq 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil5} \cdot \gamma_Q$ $\quad F_{Ed;bremse} = 311.57\ kN$

$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$ $\quad F_{Rd;bremse} = 314.29\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

6th top support rope:
Impact: $q_{rope6} = 111.53\ \frac{kN}{m}$
Rope length: $b_6 = 60\ m$
Rope force: $F_{rope6} := 623.13\ kN$
Number of ropes: $n6 := 2$

Force per rope: $F_{pro\_Seil6} := \frac{F_{rope6}}{n6}$ $\quad F_{pro\_Seil6} = 311.57\ kN$

Impact: $F_{Ed;Seil} := F_{rope6} \cdot \gamma_Q$ $\quad F_{Ed;Seil} = 623.13\ kN$

Resistance: $F_{Rd;Seil} := \frac{(n6 \cdot 400\ kN)}{\gamma_M}$ $\quad F_{Rd;Seil} = 761.9\ kN$

Proof: $F_{Ed;Seil} \leq F_{Rd;Seil}$

$\text{if}\left(F_{Ed;Seil} \leq F_{Rd;Seil}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.22$

$\text{if}\left(SF \geq 1.0, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Breaking load brake: $F_{Ed;bremse} := F_{pro\_Seil6} \cdot \gamma_Q$ $\quad F_{Ed;bremse} = 311.57\ kN$

$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$ $\quad F_{Rd;bremse} = 314.29\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{“Fulfilled”}, \text{“Not fulfilled”}\right) = \text{“Fulfilled”}$

Bottom support rope:
Impact: $q_{rope7} = 105.64\ \frac{kN}{m}$
Rope length: $b_7 = 60\ m$
Rope force: $F_{rope7} := 592.31\ kN$
Number of ropes: $n7 := 2$

Force per rope: $F_{pro\_Seil7} := \frac{F_{rope7}}{n7}$ $\quad F_{pro\_Seil7} = 296.16\ kN$

Impact:	$F_{Ed;Seil} := F_{rope7} \cdot \gamma_Q$	$F_{Ed;Seil} = 592.31\ kN$
Resistance:	$F_{Rd;Seil} := \frac{(n7 \cdot 400\ kN)}{\gamma_M}$	$F_{Rd;Seil} = 761.9\ kN$
Proof:	$F_{Ed;Seil} \le F_{Rd;Seil}$	

$\text{if}\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.29$

$\text{if}\left(SF \ge 1.0, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Breaking load brake:	$F_{Ed;bremse} := F_{pro\_Seil7} \cdot \gamma_Q$	$F_{Ed;bremse} = 296.16\ kN$
	$F_{Rd;bremse} := \frac{330\ kN}{\gamma_M}$	$F_{Rd;bremse} = 314.29\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Retaining rope:

Impact:	$q_{retaining} := 704.37\ kN$	
Number of ropes:	$n_{retaining} := 4$	
Force per rope:	$F_{retaining} := \frac{q_{retaining}}{n_{retaining}}$	$F_{retaining} = 176.09\ kN$
Impact:	$F_{Ed;Seil} := q_{retaining} \cdot \gamma_Q$	$F_{Ed;Seil} = 704.37\ kN$
Resistance:	$F_{Rd;Seil} := \frac{(n_{retaining} \cdot 400\ kN)}{\gamma_M}$	$F_{Rd;Seil} = 1523.81\ kN$
Proof:	$F_{Ed;Seil} \le F_{Rd;Seil}$	

$\text{if}\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 2.16$

$\text{if}\left(SF \ge 1.0, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Breaking load brake:	$F_{Ed;bremse} := F_{retaining} \cdot \gamma_Q$	$F_{Ed;bremse} = 176.09\ kN$
	$F_{Rd;bremse} := \frac{350\ kN}{\gamma_M}$	$F_{Rd;bremse} = 333.33\ kN$

$\text{if}\left(F_{Ed;bremse} < F_{Rd;bremse}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Vertical rope:

Impact:	$q_{lat} := 60.61\ \frac{kN}{m}$
Rope length:	$b_{lat} := 6\ m$
Rope force:	$F_{lat} := 248.43\ kN$

Number of ropes:	$n_{lat} := 1$	
Force per rope:	$F_{pro\_lat} := \frac{F_{lat}}{n_{lat}}$	$F_{pro\_lat} = 248.43\ kN$
Impact:	$F_{Ed;Seil} := F_{lat} \cdot \gamma_Q$	$F_{Ed;Seil} = 248.43\ kN$
Resistance:	$F_{Rd;Seil} := \frac{(n_{lat} \cdot 400\ kN)}{\gamma_M}$	$F_{Rd;Seil} = 380.95\ kN$
Proof:	$F_{Ed;Seil} \le F_{Rd;Seil}$	

$\text{if}\left(F_{Ed;Seil} \le F_{Rd;Seil}, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

Safety factor SF: $SF := \frac{F_{Rd;Seil}}{F_{Ed;Seil}} = 1.53$

$\text{if}\left(SF \ge 1.1, \text{"Fulfilled"}, \text{"Not fulfilled"}\right) = \text{"Fulfilled"}$

2.5 Proof: Post

The acting force on the barrier is transferred over the horizontal support ropes into the anchors on the side flank. In case of narrow cross-sections the acting force can directly be transferred over the ropes into the side. Statically speaking, we have on the right and left a support and a beam in our case a rope that takes up the load and transferres it. In case of larger cross-sections a support on the left and right is not enough that the beam respectively rope is capable of taking the load up. Therefore, more supports are needed. For a debris flow barrier that means posts are needed.
Due to the wide span of the cross-section horizontal ropes have to be guided on the post. On each of the support (guided rope on post) is not only a horizontal force but also a vertical force that has to be taken up by the post.
Each post has to take up acting forces from the retaining rope, top rope, 1th to the 5th top rope.
The post stability proof is verified with the static software Rstab according to Eurocode 3.
The post beam is a standard beam used in Europe so-called HEM or UC (Fig. 7). The HEM/ UC beam is the heaviest and widest (wide flange) of the H beams. It is used for particularly high requirements on the ultimate load. Wide flange beams offer the great advantage of a very high buckling resistance. This is due to their large average area.

According to the Eurocode 3 (EC3) stability proof - bending and compression was executed according to 6.3.3 (Uniform members in bending and axial compression), equation 6.61 and 6.62.

2.5.1 Buckling resistance of members according to Eurocode 3 (EC3)

According to EC3 Chapter 6.3.3 for uniform members in bending and axial compression which are subjected to bending and axial compression should satisfy the following equations:

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$$\frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y;Ed} + \Delta M_{y;Ed}}{\chi_{LT} \cdot \frac{M_{y;Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z;Ed} + \Delta M_{z;Ed}}{\frac{M_{z;Rk}}{\gamma_{M1}}} \leq 1.0 \qquad \text{(Equation 6.61)}$$

$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y;Ed} + \Delta M_{y;Ed}}{\chi_{LT} \cdot \frac{M_{y;Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z;Ed} + \Delta M_{z;Ed}}{\frac{M_{z;Rd}}{\gamma_{M1}}} \leq 1.0 \qquad \text{(Equation 6.62)}$$

N_{Ed}, $M_{y;Ed}$, $M_{z;Ed}$: design values, compression force and maximum moments about y-y and z-z axis
$\Delta M_{y;Ed}$, $\Delta M_{z;Ed}$: are the moments due to the shift of the centroidal axis for class 4 sections
χ_y, χ_z: are the reduction factors due to flexural buckling
χ_{LT}: is the reduction factor due to lateral torsional buckling
k_{yy}, k_{yz}, k_{zy}, k_{zz}: are the interaction factors

Acting force on post:
The model in Rstab are single bars with spacing 1m. The horizontal load, vertical load and the moment are applied at the nodes, see values below. The applied load case for the post is assumed to be on the top with a dynamic impact that are transferred from the ropes into the post and on the lower part with the static force from the filled/settled material in the barrier (Fig. 8).

Top support rope:
Horizontal/Vertical load: $38.51\ kN$ $53.02\ kN$
Moment at node: no moment

2nd support rope:
Horizontal/Vertical load: $377.92\ kN$ $426.25\ kN$
Moment at node: $82.48\ kN \cdot m$

3th support rope:
Horizontal/Vertical load: $101.94\ kN$ $104.49\ kN$
Moment at node: $20.22\ kN \cdot m$

4th support rope:
Horizontal/Vertical load: $129.47\ kN$ $146.72\ kN$
Moment at node: $28.39\ kN \cdot m$

5th support rope:
Horizontal/Vertical load: $157.74\ kN$ $187.75\ kN$
Moment at node: $36.33\ kN \cdot m$

6th support rope:
Horizontal/Vertical load: $187.62\ kN$ $221.51\ kN$
Moment at node: $42.86\ kN \cdot m$

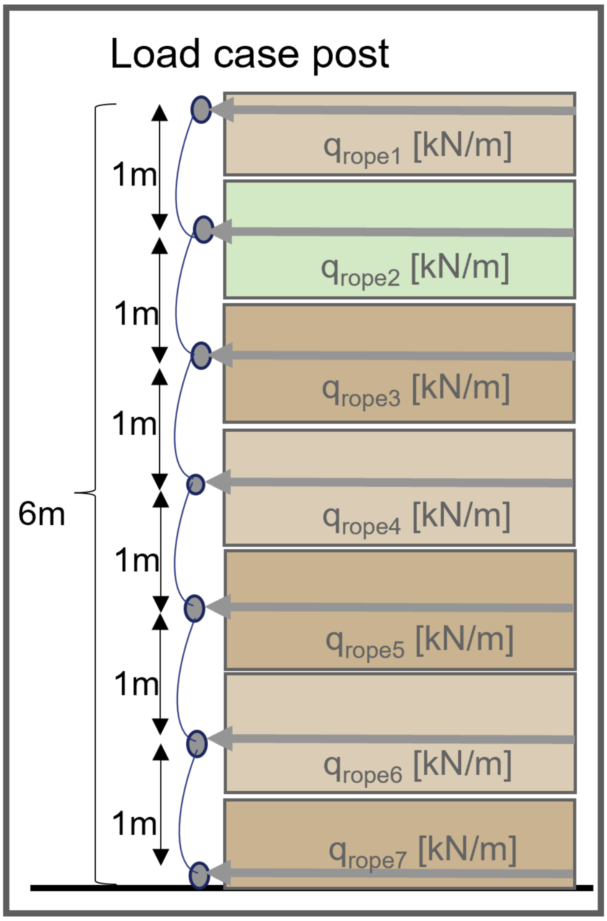

Fig. 8: Load case post

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Material and Cross-section:
Steel S300 AS/NZS 4600:2005
UC 310x310x158 (Fig. 9)

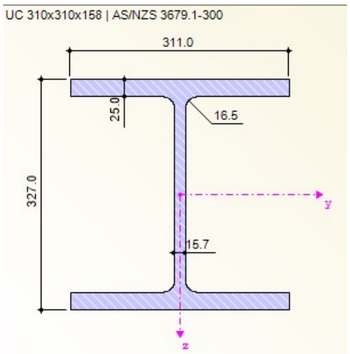

Fig. 9: UC 310x310x158

Section class:
Section class 1 according to $c/t \le 72\ \varepsilon$ with:

$c := 277\ mm$

$t := 15.7\ mm$ $\quad c/t \le 72\ \varepsilon$

$\varepsilon := 0.81$ $\quad 17.6 \le 58.32$

Design dimensions: (see Fig. 10-13)

Normal force:	$N_{Ed} := 730.48\ kN$	no partial safety factor added: $\gamma_Q := 1.0$
Moment:	$M_{y;Ed} := 710.95\ kN \cdot m$	
Moment:	$M_{z;Ed} := 0.0\ kN \cdot m$	
Moment:	$\Delta M_{y;Ed} := 0\ kN \cdot m$	only for section class 4 needed
Moment:	$\Delta M_{z;Ed} := 0\ kN \cdot m$	only for section class 4 needed

Proof:

Partial safety factor:	$\gamma_{M1} := 1.1$
Compressive strength:	$N_{Rk} := 6891.68\ kN$
Moment resistance:	$M_{y;Rk} := 914.46\ kN \cdot m$
Moment resistance:	$M_{z;Rk} := 417.98\ kN \cdot m$
Reduction factor:	$\chi_y := 1.0$
Reduction factor:	$\chi_z := 1.0$
Reduction factor:	$\chi_{LT} := 1.0$
Interaction factor:	$k_{yy} := 0.964$
Interaction factor:	$k_{yz} := 0.349$
Interaction factor:	$k_{zy} := 0.767$
Interaction factor:	$k_{zz} := 0.581$

Proof y-y axis:
(Eq: 6.61)

$$\frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y;Ed} + \Delta M_{y;Ed}}{\chi_{LT} \cdot \frac{M_{y;Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z;Ed} + \Delta M_{z;Ed}}{\frac{M_{z;Rk}}{\gamma_{M1}}} = 0.94\ (0.73 \le 1)$$

Proof z-z axis:
(Eq: 6.62)

$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y;Ed} + \Delta M_{y;Ed}}{\chi_{LT} \cdot \frac{M_{y;Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z;Ed} + \Delta M_{z;Ed}}{\frac{M_{z;Rk}}{\gamma_{M1}}} = 0.77\ (0.60 \le 1)$$

Stability proof according EC3, equation 6.61 and 6.62 is given for both axis with 0.94<1.0 and 0.77 < 1.0.

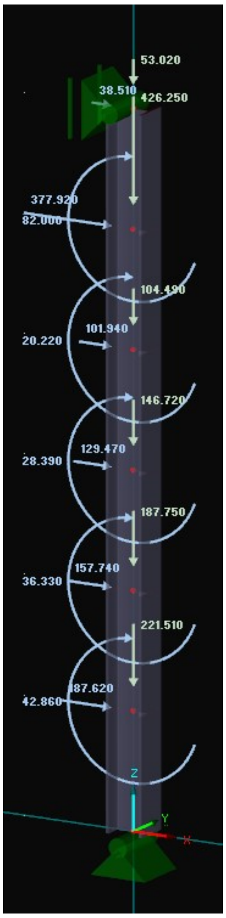

Fig. 10: Impact on post

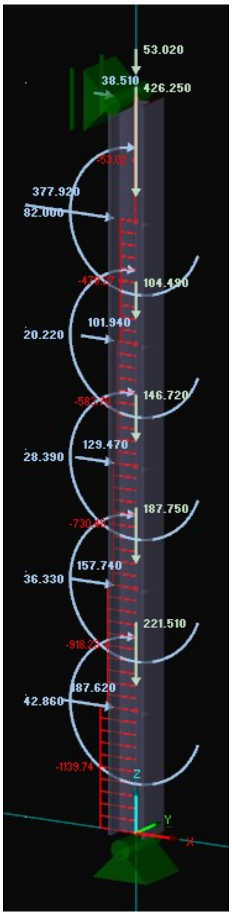

Fig. 11: Normal force

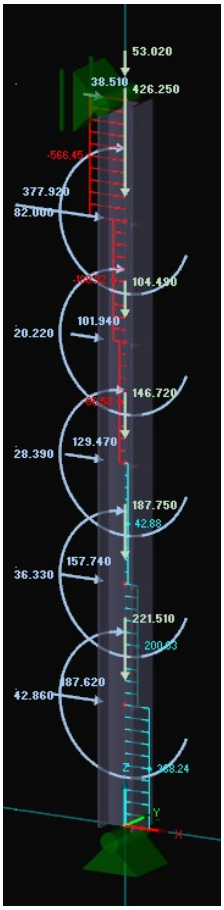

Fig. 12: Shear force

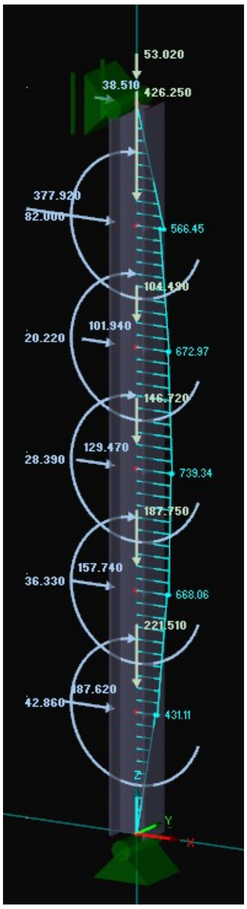

Fig. 13: Moment

2.6 Anchorage forces

In principle, all ropes are anchored with at least the breaking load of the respective rope incl. braking element. This guarantees a failure of the ropes and not of the anchors in case of overload. For each support rope a anchorage force of 350kN is recommended.
Foundation forces is once the vertical/normal force from the post and the shear force.
Characteristic anchor forces for the ropes are shown below:

Lateral rope: $235\ kN$
Each retaining rope: $180\ kN$
Each support rope: $315\ kN$

Pressure force post: $F_{vertical} := 1140\ kN$
Horizontal force post: $F_{horizontal} := 750\ kN$

3. Summary

	Amount of ropes:	Width:	
$q_{rope1}=105.64\ \frac{kN}{m}$	$n1=2$	$b_1=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope2}=111.53\ \frac{kN}{m}$	$n2=2$	$b_2=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope3}=111.53\ \frac{kN}{m}$	$n3=2$	$b_3=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope4}=111.53\ \frac{kN}{m}$	$n4=2$	$b_4=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope5}=111.53\ \frac{kN}{m}$	$n5=2$	$b_5=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope6}=111.53\ \frac{kN}{m}$	$n6=2$	$b_6=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*
$q_{rope7}=105.64\ \frac{kN}{m}$	$n7=2$	$b_7=60\ m$	*x 4 brake ring GN-9017 per 22mm Geobinex support rope*

Total amount of ropes: $n_{tot}:=n1+n2+n3+n4+n5+n6+n7=14$

Number of posts:	$n_{post}:=10$	*UC 310x310x158 Steel 300*
Base plate:	$n_{baseplate}:=n_{post}=10$	*Special plate 1x1m*
Retaining ropes per post:	$n_{retainingpost}:=4$	*x 22mm Geobinex with 1x GN-9055*
Total retaining ropes:	$n_{retaining}:=n_{retainingpost}\cdot n_{post}=40$	
WRA 22.5mm:	$n_{flexhead}:=n_{tot}+\frac{n_{retaining}}{2}+2=36$	

Net:	ROCCO 12/3/350
Post height:	$H=6\ m$
Post spacing:	$b_{post}=6\ m$
Rope spacing:	$h_{spacing}=1\ m$
Basal opening:	$h_d=0\ m$
Abrasion protection	yes
Secondary mesh:	yes

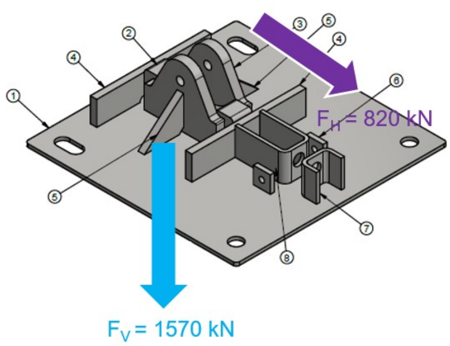

Fig. 14: Baseplate example

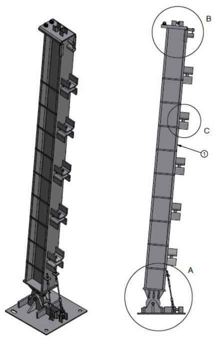

Fig. 15: HEM Post example

Appendix G: Environmental Management Plan and Catchment Analysis

Environmental Management Plan (Rev E)

Skyline – Reavers Slip Repair Works

July 2024

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Document Control	
Title	Skyline – Reavers slip repair - Environmental Management Plan
Address	53 Brecon Street, Queenstown 9300
Consent Number	TBC
Client	Skyline Enterprises Limited
Our Reference	24007
Prepared by and	**Quinn McIntyre** (MSc, CEnvP) Principal Environmental Consultant **Tom Grandiek** (BAppSc, CEnvP) Senior Environmental Consultant

Document Control			
Revision	Revision Date	Revision Details	Prepared by
A	8/03/2024	For client review	QM
B	18/04/2024	ESCP update to reflect revised earthworks plans	QM
C	22/04/2024	For council	QM
D	9/05/2024	ESCP update after May Monthly Environmental Inspection	QM
E	18/07/2024	EMP update following work progress	TG

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Appendix 7	Complaints Register
Appendix 8	Environmental Non-Conformance Register
Appendix 9	Water Quality Monitoring Results Form
Appendix 10	Archaeological Discovery Protocol

Disclaimer

Enviroscope has exercised due skill, care, and attention in preparing this EMP on the basis of their understanding of the subject site through their own site visits as well as information provided by the client and its consultants. Enviroscope has no control over the physical actions, detailed design, equipment, services, and methodologies undertaken by the client or other third parties tasked with implementing Enviroscope's instructions or recommendations. Enviroscope does not accept any responsibility for any environmental incidents or other defects of control measures if there is any departure or variance from the measures detailed in this EMP and any supporting documentation. This document does not attempt to provide hazard or ground stability management and it is recommended that specialist geotechnical and hydrological advice is sought.

Emergency Contacts

Contact made with any of the following shall be undertaken with due consultation of the Environmental Representative or Project Manager.

Table 1: Emergency Contacts

Element	Emergency Contact	Details
Pollution incident	Otago Regional Council (ORC) Spill Hotline	0800 800 033 compliance@orc.govt.nz
Environmental complaint	Environmental Representative	Warren McGregor Beaver Contracting 027 200 9808
Discovery of contaminated land	Environmental Representative	
Unexpected heritage finds	Environmental Representative	
Human remains	New Zealand Police	111
Fire including bushfire	Fire and Emergency New Zealand (FENZ)	111
Public utilities	Queenstown Lakes District Council (QLDC)	(03) 441 0499 rcmonitoring@qldc.govt.nz
Internal contacts	Project Manager	Paul Embleton-Muir Skyline 021 630 403 Sean Donohoe Verve Projects 021 2616 514
Internal contacts	Environmental Consultant	Tom Grandiek Enviroscope 027 2633 113

1.0 INTRODUCTION

1.1 Purpose and Scope

On behalf of Skyline Enterprises Limited, Enviroscope has prepared this Environmental Management Plan (EMP) for debris removal and remedial works for the Reavers Catchment at Skyline. This EMP aims to reduce the effects of the project's construction activities on the environment and sensitive receptors.

This EMP is prepared according to the Queenstown Lakes District Council (QLDC) *QLDC Guidelines for Environmental Management Plans*, *June 2019* (EMP Guidelines). It is considered to have a 'High' environmental risk level as per the risk categories outlined in the EMP Guidelines.

The erosion and sediment controls associated with the access track have been designed in accordance with the New Zealand Forest Owners Forestry Association's (NZFOA) *New Zealand Forest Road Engineering Manual, 2020* (Forestry Manual). Where conflicts arise between the EMP Guidelines and the Forestry Manual, the guidance of the Forestry Manual shall prevail in accordance with the letter received from QLDC's Parks Team on 14 February 2024 outlining their expectations for the works.

The purpose of this EMP is to be an effective and practical reference manual for construction personnel that applies to all project activities during the construction phase and includes the following:

- Strategies to manage environmental aspects and risks, based on associated best practice.
- Provides for contingency planning.
- Provides a framework for monitoring, reporting, review and continual improvement.
- Defines roles and responsibilities.
- Procedures to investigate and resolve environmental non-conformances and initiate corrective and preventative actions.

An overview of the project and sequencing can be found in the construction methodology at **Section 2.0**.

1.2 Site Overview

The works for this proposed activity involve the removal of debris from a landslip that occurred in the rain event of 22nd September 2023 downslope of the upper Skyline building. The topography of the site is considered steep to very steep with slope gradients approximately 40 – 45 degrees with numerous bluffs within the site. The site is part of the upper catchment of Reavers Creek, with evident flow paths within the slip debris and crossing access tracks. Debris is present down the length of Reavers Creek from the slip location to the existing stormwater intake at Reavers Lane.

The general vegetation onsite is dominated by a canopy of mature Douglas Fir trees.

The slip is accessed by existing forestry haul routes, of which, 3,000 m of temporary access tracks are to be installed in order to access the slip. The surrounding land uses are forestry, recreational use of Skyline's facilities, the gondola passing overhead to the west and residential dwellings to the east of the downslope portion of the site adjacent Reavers Lane.

This is depicted in **Figure 1** below.

Figure 1: General location of the slip in yellow (Source: QLDC GIS)

1.2.1 Soils and Geotechnical Summary

A geotechnical report has been prepared by Geosolve (dated March 2024) which details site investigations and reports on the geotechnical conditions. The report details the general geological stratigraphy which can be summarised as:

- **Localised uncontrolled fill** (where deposited and overlying), containing the debris bulb which mostly comprises schist rock scalpings broken into well graded granular material primarily comprising gravel, cobble and boulder sizes with a minor sand and silt fraction. The mid and lower overland flow paths of the catchment beneath the debris bulb comprises finer grained excavated schist rock that has mobilised from the debris bulb. This is described by Geosolve as being shallow in depth (< 1.0 m).
- **Colluvium** (overlying), variable in composition, comprising a mixture of loose sand, gravel and cobbles or soft silt. Geosolve notes that this may be underlain by glacial till in some locations;
- **Glacial till** (overlying) observed in localised pockets comprising light brown sandy silt or silt sand with variable fractions of gravel and cobbles;

- **Schist bedrock** underlies the areas of interest at shallow to moderate depth and is exposed in many locations.

Geosolve also expect that perched ground water conditions are expected to be present at the schist/colluvium contact and in some locations through fracturing in the rock mass. They note that localised groundwater flows may develop as seeps or ephemeral streams following periods of extended rainfall.

1.2.2 Summary of Earthworks

A total of approximately 2,500 m^3 of slip material will be removed from the debris bulb at the upper portion of the Reavers Catchment (Zone A depicted in **Figure 2**). A further 500 – 750 m^3 of soil will be removed from the Reavers Channel and the slopes between the top source area and Reavers Creek Culvert (Zone B depicted in **Figure 2**).

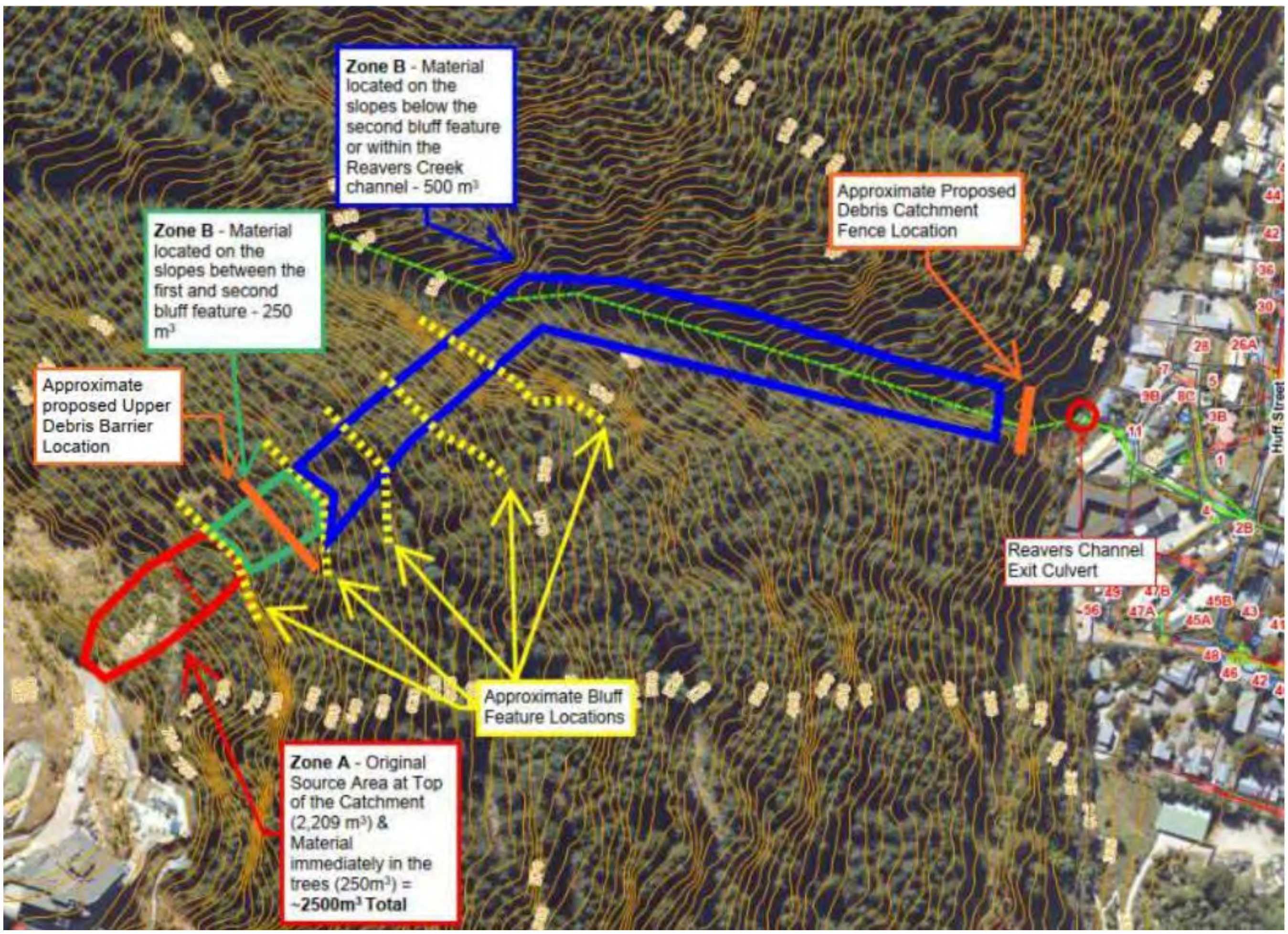


Figure 2: Slip material to be removed (Source: Geosolve Report, March 2024)

Furthermore, existing haulage tracks and new tracks will need to be temporarily installed to allow site access for haulage trucks to remove the slip material. Once the slip material is removed, the temporary tracks will be removed/reinstated to restore the natural ground contours and overland flow paths.

Some minor localised earthworks (benching and drilling) will also be required to install the debris fence and associated anchor points.

1.3 Suitably Qualified and Experienced Professional

This EMP has been prepared by Quinn McIntyre of Enviroscope Limited. Quinn is a Certified Environmental Practitioner (CEnvP) and holds a Master of Science. Quinn has worked in various environmental roles on a range of construction projects, including bulk earthworks in New Zealand and Australia. Quinn has extensive experience in the preparation and monitoring of EMPs and ESCPs.

This EMP has also been prepared by Tom Grandiek of Enviroscope Limited. Tom is a certified Environmental Professional (CEnvP) and holds a Bachelor of Applied Sciences degree, majoring in Environmental Management. He spent five years working in RMA compliance with local government. Tom has extensive experience in the preparation and monitoring of EMPs and ESCPs.

Quinn and Tom meet the criteria of a Suitably Qualified and Experienced Professional (SQEP) for the purposes of preparing this EMP and overseeing the environmental aspects of this project.

2.0 CONSTRUCTION METHODOLOGY

2.1 Sequencing of Works

The following sequencing will ensure the earthworks are undertaken efficiently while ensuring good environmental outcomes. This is a preliminary staging methodology and may be subject to change based on site conditions encountered during construction.

The methodology below is focused on timing and inputs for erosion and sediment control installation and general environmental management measures. It is adopted from and therefore shall be read in conjunction with the *Upper Debris Removal Methodology* prepared by Skyline and the Erosion and Sediment Control Plan (ESCP) attached as **Appendix 1**.

Preliminary works and site establishment (prior to as-built confirmation)

- Ensure the current EMP is available onsite.
- Complete site induction with Environmental Consultant.
- Establish site laydown area.

Stage 1 – Enablement – establishment of access to debris field

In order to access the site to facilitate debris removal, the existing Andrews Haulage Track (AHT) needs to be restored/upgraded and an additional 3,000 m of new temporary access tracks are to be constructed. The construction and restoration of these haul roads is to be completed as follows as it relates to erosion and sediment control:

- Remove trees and forestry slash from the path of the access tracks and dispose of appropriately.
- Remove loose material from the upslope side of the track and bench to accommodate wider track (minimum 4.0 m). Excess material is to be removed from site utilising 4x4 dumpers.
- As the access tracks are constructed, the surface shall be graded into the slope to divert any surface water flows into a ditch, which is to be constructed in accordance with schematics provided in ESCP-006. This channel will convey any surface water flows from the upslope catchment and track surface to culverts which will be installed at regular intervals, in accordance with the NZFOA, to ensure that water remains in its natural catchment.
- Install rock ballast on the portion of the access track surrounding the existing 450 mm culverts (Culvert A on ESCP) associated with the Breacon Street Catchment gully.
- Install sediment traps as per ESCP-002- ESCP-005 and line the ditch with aggregate or similar to reduce in-channel flow velocity and prevent scouring.
- Culvert flume socks are to be attached to the outlet of the pipe to convey water over fill areas to be discharged below the works extent to prevent erosion.
- The outlet of the culverts or culvert sock flumes are to be stabilised effectively as per engineering design in accordance with the schematic provided in ESCP-011.
- Rock breaking and removal may be required in order to accommodate a four-metre-wide track. If this is not possible, temporary retaining may be required to provide the required track width. If required, retaining structures are to be installed in accordance with engineering design and geotechnical advice.

Culvert installation

The proposed access tracks are to be constructed to have a minimum width of four metres with gradients of 1:6 or better if possible. A series of culverts are to be installed along these tracks to ensure that water stays within its natural catchment. As per the guidelines provided by the New Zealand Forest Owners Forestry Association's (NZFOA) *New Zealand Forest Road Engineering Manual, 2020* (Forestry Manual), at least one 325 mm diameter culvert is to be installed every 65 m along the new access tracks. Additional culverts are to be installed as per ESCP-001, **Appendix 1** to ensure that water remains in its natural catchment. Culverts are to be installed in accordance with the following methodology:

- Ensure there is a minimum 3% crossfall to prevent sediment accumulation and blockages.
- If possible, the culverts should be installed on hard ground, not fill material. Culvert locations may require amendment by the Environmental Consultant if this is not possible.
- Undertake backfill of the trench in progressive layers, compacting appropriately with each layer to ensure structural integrity of the pipe is maintained.
- Where a culvert outlet is positioned to discharge flows onto an area of fill, socks are to be clamped to the outlet of the culvert and extended over the fill area to discharge flows beyond the toe of the works extent. Culvert sock flumes may also be utilised to divert the discharge location of culverts to ensure that water remains in its natural catchment. These culvert socks are to be secured in place by anchoring the sock eyelet and attaching it to the ground over the entire length, this will prevent twisting and displacement of the sock.

Stage 2 – Debris fence installation

- Prior to debris fence installation, the location of anchor points are to be confirmed by the Geotech and surveyor.
- Establish designated concrete washout pit as per ESCP.
- Install silt fence on the benched area immediately downslope of the proposed location of the debris fence prior to any works commencing. This fence must be keyed at least 200 mm into the ground in order to operate effectively, if this cannot be achieved, alternative solutions are to be discussed with the Environmental Consultant.
- Establish water take line from the Skyline Luge bottom station.
- Install anchor points utilising drill rig and grout. Excess grout is to be removed from the rockface immediately and disposed of in designated waste bins.
- Install debris fence as per geotechnical engineer design.

Stage 3 – Debris removal

- Works to remove debris is only to be undertaken in fine weather. Ensure that vehicle movement is limited after rain events to reduce erosion and sediment transport.
- Remove any trees within the toe of the debris field. Remove trees from the debris site and place them in identified safe locations.
- Remove MacMat from the upper slip area and set aside for reinstallation after debris has been removed. Remove existing drains as encountered by excavator when removing debris.
- Remove debris utilising spider excavator to push debris downslope to the debris fence. Ensure that debris does not overtop the fence and damage the downslope silt fence. From here the debris is to be removed from the debris field and transported off site utilising 4x4 dumpers.
- Install silt fence downslope of the stockpile area at Skyline access road.
- Removed material is to be transported to the designated stockpile at Skyline access road, from here the material is to be loaded into standard 6-wheel trucks and transported to an approved site.
- Slip material downslope of the tracks and in Reavers Creek to be manually removed by placing sediment into impermeable bags for extraction by helicopter.

Stage 4 – Decommission of track

- When debris material has been removed and the batter slope has been constructed to 35 – 40 degrees, the slope can be stabilised.
- Apply grass seed to surfaces upslope of the debris fence when all debris has been removed. Grass seed species shall include a suitable mix of quickly establishing perennial ryegrass, and deeper rooting brown top and fescues. Other erosion matting may be required as per geotechnical engineer advice.
- When the upslope catchment has reached 80% stability and the debris fence, and all associated infrastructure, has been removed and transported from site the silt fence can be decommissioned.
- Utilise excess fill to return the tracks to the original contour. Apply approved grass seed to stabilise finalised surfaces.
- Once works are completed, the temporary tracks shall be filled in and associated devices to be removed to restore site to natural contours. These areas are to be immediately topsoiled and seeded. Additional controls such as silt fences and water bars may be required. This will be undertaken in consultation with the Environmental Consultant.

2.2 Hours of Operation

Construction activities and the associated hours of operation shall comply with *NZS 6803:1999 Acoustics - Construction Noise Guidelines*. Site works may be undertaken between 0730 and 1800 hours, Monday to Saturday. No works are to be undertaken on Sundays or Public Holidays. However, this does not preclude any emergency works or works required for incident investigation or response. Additional detail relating to noise-producing activities are to be undertaken in accordance with Section 7.0 of this EMP.

3.0 EMP IMPLEMENTATION

3.1 Environmental Roles and Responsibilities

3.1.1 Project Manager

The Project Manager is responsible for the effective implementation of the EMP and has overall responsibility for the environmental performance of the project. Duties include:

- Ensuring adequate resources are in place to implement the EMP.
- Ensuring all staff and sub-contractors operate within the guidelines of the EMP.
- Ensuring that an EMP is prepared and that environmental standards, processes and procedures meet relevant resource consent conditions.
- Overseeing the successful implementation, monitoring and review of the EMP.
- Ensuring that inspections are carried out in accordance with the relevant EMP.
- Restricting or stopping any activity that has the potential to or has caused adverse environmental effects.
- Providing notification and reporting of Environmental Incidents to Council and other environmental reports as required by The Guidelines.
- Delegating authority of the above responsibilities.

3.1.2 Environmental Representative

The Environmental Representative supports the Project Manager in the day-to-day implementation of the EMP. Duties include:

- Ensuring the installation of environmental controls as per the EMP.
- Undertaking environmental site inspections.
- Undertake water quality sampling during rainfall events.
- Overseeing the maintenance and improvement of defective environmental controls.
- Providing environmental inductions to all staff and sub-contractors.
- Assisting the project leadership in attending to Environmental Incidents and Complaints.

The Environmental Representative shall be familiar with environmental risks associated with the project, the EMP and best practice erosion and sediment control principles and practices.

3.1.3 Environmental Consultant

The Environmental Consultant (SQEP) will provide technical environmental management advice as required. Key tasks include delivering the Site Environmental Induction to core staff and providing as-built confirmation of erosion and sediment controls to Council. The Environmental Consultant shall undertake monthly monitoring of the site and submit Monthly Environmental Reports to QLDC.

3.1.4 All Staff and Sub-Contractors

All staff and sub-contractors have a responsibility to undertake all activities in accordance with the requirements of this EMP. This includes reporting any activity that has the potential to or has resulted in an Environmental Incident to the Project Manager or Environmental Representative.

3.2 Site Environmental Induction

All staff and subcontractors shall attend an Environmental Induction to ensure they are aware of the project's environmental risks as well as their responsibilities to help manage these risks. Prior to ground-disturbing activities, the Environmental Consultant will deliver the induction to core staff. During the project, the Environmental Representative will induct sub-contractors and new staff.

The site induction handout is attached as **Appendix 3** and all persons inducted will be recorded on the Induction Register attached as **Appendix 4**.

3.3 Environmental Inspections

Table 2 outlines the regular environmental inspections to be undertaken.

Table 2: Environmental inspections

Environmental Inspection	Timing	Purpose
Weekly Inspection	Every seven days following the last round of rain event monitoring.	A comprehensive environmental inspection will: • Confirm that all environmental controls are present, functional, and adequate. • Identify any activities that may cause an environmental incident or actual or potential environmental effects. • Identify maintenance requirements for implemented management measures. All weekly inspections shall be recorded on the Weekly Site Inspection form attached as **Appendix 5**.

Environmental Inspection	Timing	Purpose
Pre-Event Inspection	Prior to a significant rain event[1]	To ensure that erosion and sediment controls are present, functional, and adequate for forecast rain event. This inspection will inform any preventative work required and may result in the Rapid Response Procedure being implemented (see Section 4.6).
Rain Event Monitoring (where safe to do so)	During a significant rain event	To ensure that: • Erosion and sediment control devices continue to function correctly and inform any necessary emergency responses. • Ditches, sediment traps and culverts are functioning effectively and have capacity available. • No 'conspicuous change in colour or visual clarity' in receiving waters below the activity area[2]. Observations and remediation measures taken will be recorded in a daily job diary.
Post-Event Inspection	Immediately following a significant rain event	Any observations and corrective actions should be recorded in a daily job diary.

3.4 Monthly Environmental Inspection and Reporting by SQEP

The Environmental Consultant (SQEP) will monitor the site monthly to ensure that the EMP is correctly implemented, identify any unforeseen issues arising and advise on alternative environmental solutions.

The Environmental Consultant (SQEP) will also submit a Monthly Environmental Report to QLDC within five working days of the end of each month. The report will include the following information:

- Updates to the EMP and the Erosion and Sediment Control Plan (ESCP) during the month.
- Number of weekly and pre and post-rain event site inspections completed.
- Summary of corrective actions undertaken.
- Positive environmental outcomes achieved and opportunities.

[1] A significant rain event is defined as any forecast/actual rain event of 10 mm within a 12-hour period or a rain event that can generate overland flow, noting that this varies seasonally.

[2] As per the New Zealand Forest Road Engineering Manual, 2020.

3.5 Environmental Incident Management

Environmental incidents shall be responded to as soon as the project team becomes aware of them occurring. The response will generally involve oversight by the Environmental Consultant and will involve:

- Immediate cessation of the activity that caused the incident.
- Investigation into the cause of the incident.
- Initial response to bring the incident under control.
- Implement any remediation works.

The Project Manager shall notify QLDC of the details of any Environmental Incident within 12 hours of becoming aware of the incident. Notification will be through a phone call to Council monitoring staff (see Emergency Contacts on Page 4).

The Project Team shall provide an Environmental Incident Report within ten working days of the incident occurring. The Incident Report form is attached as **Appendix 6**.

3.6 Complaints Procedure

Any complaint received will be recorded and an investigation will be carried out. The complainant will be provided with a response acknowledging receipt of the complaint and outlining corrective actions to be implemented. After the investigation, any necessary corrective actions will be carried out and a follow-up of the original complaint is to be conducted to ensure the actions implemented have been effective.

All complaints will be recorded on the Complaints Register attached as **Appendix 7**.

3.7 EMP Non-Conformance and Corrective Actions

EMP non-conformances found during site inspections, monitoring or as a result of environmental incidents or complaints shall be recorded in the EMP Non-Conformance Register. The non-conformance register attached as **Appendix 8** will detail when corrective actions are due, how they are to be carried out and the close out date.

The non-conformance register ensures that issues do not escalate or are missed, as well as, providing a clear record of evidence that can be used to defend any potential complaint or formal enforcement action.

3.8 Records and Registers

The records listed below will be collated onsite. If a request is made by a QLDC official, the records shall be made available to the official within 24 hours of the request being made.

- Environmental Induction Register - **Appendix 4**.
- Weekly Environmental Inspection Form - **Appendix 5**.
- Environmental Incident Reports - **Appendix 6**.
- Complaints Register - **Appendix 7**.
- EMP Non-Conformance Register - **Appendix 8**.
- Water Quality Monitoring Results - **Appendix 9**.
- Rain event inspection observations.

3.9 EMP Updates

The EMP will be regularly reviewed throughout the project to ensure the document remains fit for purpose and to drive continual improvement. This may be initiated by:

- Significant changes to the construction methodology.
- Improvements identified as a result of an Environmental Incident or Corrective Action.
- Where directed by QLDC's Monitoring and Enforcement team.

All EMP updates will be managed through the document control table on page one and shall be submitted to QLDC and ORC for acceptance.

4.0 EROSION AND SEDIMENT CONTROL MEASURES

4.1 Performance Criteria

Design, install and maintain erosion and sediment controls in accordance with industry best practices. Generally*, Erosion and Sediment Control Guidelines for Land Disturbing Activities in the Auckland Region 2016* (Auckland Council Guideline Document GD2016/005).

- Queenstown Lakes District Council's (QLDC) *QLDC Guidelines for Environmental Management Plans, June 2019 (The Guidelines).*
- New Zealand Forest Owners Association's (NZFOA) *New Zealand Forest Road Engineering Manual (2020)*

4.2 Erosion and Sediment Control Principles

Erosion and sediment control ('ESC') devices shall be installed, maintained and decommissioned in accordance with the following principles:

- Erosion and sediment controls are integrated with construction planning.
- Construction is staged to minimise the duration and area of exposed soil open at any one time.
- A 'treatment train' approach so that the sediment retention devices operate as efficiently and effectively as possible.
- The extent and duration of soil exposure is minimised.
- Controls are always maintained in proper working order.
- Progressively stabilise and revegetate disturbed or completed areas.
- The site is monitored, and erosion and sediment control practices are adjusted to maintain the required performance standard.
- Soil erosion is minimised as far as reasonable and practical.
- Avoidance of sediment discharge off-site and protection of receiving environments.

4.3 Guidance on Erosion and Sediment Control Devices

The effective control of surface water shall be achieved through the utilisation of carefully selected erosion and sediment control devices to achieve a specific purpose. These guidelines for the devices employed on this project shall be read in conjunction with the ESCP attached as **Appendix 1** of this document.

4.3.1 Site Definition

At the commencement of the project, the following components onsite will be clearly defined as detailed in **Table 3**.

Table 3: Site definition specifications

Site component	Method of Demarcation
Site boundaries	Temporary fencing or hoardings

Internal ‘no-go’ areas (protected or sensitive areas)	Bunting or flagging tape with waratahs

4.3.2 Stabilised Entranceway

An existing stabilised entrance is located off Lomond Crescent. This stabilised access services the wider skyline road and forestry tracks. This stabilised access is considered appropriate for the scope of these works and will be monitored regularly to ensure it is operating effectively to minimise sediment tracking onto Lomond Crescent.

4.3.3 Ditches

The haul roads and access tracks are to be installed with a roadside ditch. This ditch is to act as a dirty water diversion channel to divert any water from the road surface and upper contributing catchment to regularly spaced culverts. The ditches are to be lined with rock or geofabric in steeper sections to reduce erosive potential. Check dams are to be utilised within the ditches at regular intervals between the sediment traps to slow in-channel flow velocity. These ditches are to be constructed accordance with the schematic diagram in ESCP-006, **Appendix 1.**

Ditches designed in accordance with NZFOA specifications have a width of 600 mm and depth of 300-500 mm. In order to construct ditches in accordance with these specifications, the excavations and therefore the area of exposed soil required would increase significantly in order to accommodate the extra width. The volume provided by these ditches is significantly larger than required for this site, recording a buffer of 5,961 % for the ditch for the largest contributing catchment (being combined Catchment 1).

Therefore, due to space constraints on site and excessive buffer provided by NZFOA design specifications, for this site ditches have been designed to cater up to a 5% AEP event (as a minimum) in accordance with GDO5 specifications (complete guidelines on pages 43-46 of GD05). It is considered appropriate to utilise channel design as per GDO5 specifications as the channel design accommodates much less space and still records a conservative buffer of 884 % for the largest contributing catchments (1). Full calculations for both GDO5 and NZFOA are included in **Appendix 2**.

4.3.4 Check Dams

Rock check dams will be deployed primarily to reduce the velocity of concentrated flows in the ditches. They will also act to capture some coarse sediment. Check dams are to be constructed from 100 mm to 300 mm mix rock and installed at regular intervals along the entire track network in accordance with the table provided in ESCP-008. The check dams will be constructed in accordance with the schematic diagram in ESCP-008, **Appendix 1** (complete guidelines on page 127 of NZFOA).

4.3.5 Sediment Traps

Sediment traps will be used within the ditches to allow the heavier coarse sediments to drop out, preventing them from entering the culverts and reducing loads on these devices. Placements and locations of sediment traps depicted on ESCP-002 to ESCP-005 are indicative only. Sediment trap spacings will vary throughout the site in accordance with the table provided in ESCP-007. Generally, the sediment traps are to be constructed every 10-20 m as a conservative approach. The sediment traps will be constructed in accordance with the image reference in ESCP-007, **Appendix 1** (complete guidelines on pages 135-136 of NZFOA).

4.3.6 Temporary Culverts

Culverts shall be used onsite to transport water from one side of the haul road alignment to the other. Culverts shall consist of a PVC, farm-grade, plastic drainage coil. A variation of pipe diameter will be utilised around the site to accommodate differing contributing catchments as depicted in calculations provided in **Appendix 1**. However, as per NZFOA, at least one 325 mm culvert is to be installed every 65 m of the track.

Where the culvert outlets onto an area of fill, a culvert sock is to be clamped on the outlet of the pipe to convey water over the fill area to be discharged below the works extent and onto natural ground. Energy dissipation pads constructed from rock will need to be placed at the outlet to prevent scouring of the natural surface by the concentrated flow. This will minimise any erosion of the fill area whilst it progresses towards stabilisation. The energy dissipation pads shall be constructed in accordance with the schematic diagram in ESCP-011, **Appendix 1**.

Calculations are provided in **Appendix 2** to demonstrate the culverts can accommodate the upslope run-on water. Culverts shall be constructed in accordance with the schematic diagram in ESCP-007, **Appendix 1**.

4.3.7 Culvert socks

Culvert socks shall be used to transport water from outlet of the culvert to an appropriate location below the works extent without causing erosion. This is the most suitable measure for these locations as the slope steepness is greater than 3:1. These culvert sock flumes are to be secured in place by anchoring the sock eyelet and attaching it to the ground over the entire length, this will prevent twisting and displacement of the sock. As per above, the outlet of the sock is to be stabilised effectively with rock armouring to prevent erosion. The sock will be installed in accordance with the schematic diagram in ESCP-009, **Appendix 1** (complete guidelines on pages 133-135 of NZFOA).

4.3.8 Silt Fences

A silt fence will be used to capture potential sheet flows from the debris field below the debris fence. It is important that the silt fence is installed along a contour to prevent any concentrated flow accessing the fence or pooling water upslope of the fence. The silt fence will be installed in accordance with the schematic diagram in ESCP-010, **Appendix 1** (complete guidelines on pages 120-125 of GD05).

4.3.9 Temporary Stockpiles

Stockpiles may be formed as part of earthworks. It is recognised that the location of stockpiles will change with the progress of the earthworks. Stockpiles shall be constructed in accordance with the schematic diagram in ESCP-012, **Appendix 1.**

4.3.10 Progressive Rehabilitation

Progressive stabilisation of earthworks is to occur promptly as areas are finished to minimise the area of exposed soil and thus the generation of sediment-laden water. Prior to final landscaping, this can comprise temporary grassing, turfing or clean aggregate.

4.3.11 Removal of Sediment from Mid/Lower Reavers Catchment and Creek

As no machinery will be able to track far from the lower Reavers Catchment track, any removal of sediment will be undertaken manually (by shovels) and placed into impermeable bags to be lifted out by helicopter. This will have the added benefit of causing no further disturbance to the natural surface.

During any manual works in the creek, care will need to be taken to ensure that disturbance to the natural bed is avoided. This will in turn minimise disturbance and suspension of sediment from the creek bed. It is noted that some suspension of sediment is unavoidable given the constrained nature of the creek and rocky substrate of the gully making it impossible to install temporary measures such as silt curtains.

During works within Reavers Creek, the creek will be regularly monitored 50 m downstream to ensure that there is no conspicuous change in colour or visual clarity of the creek. If this cannot be achieved, contingency measures such as sandbags to capture coarser sediments can be installed. This shall be undertaken in consultation with the Environmental Consultant.

4.4 As-Built Verification

The Environmental Consultant will provide the Council with as-built confirmation to verify that the erosion and sediment controls have been installed in accordance with the approved ESCP.

4.5 Maintenance of Erosion and Sediment Control Devices

Ongoing maintenance of the site shall be undertaken as follows:

- Clean out sediment of erosion and sediment controls as soon as 20% capacity has been reached.
- Any mucked-out sediment shall be stockpiled, dried and reused as planting media for revegetation.
- Brush down sediment stains on silt fencing material.
- Monitor the outlet of culverts and culvert socks to ensure no erosion is occurring.

4.6 Rapid Response Procedure for Significant Rain Events

The Environmental Representative will stay vigilant of weather forecasts. If a significant rain event is imminent, all works will cease in sufficient time for staff to inspect and maintain erosion and sediment control devices and undertake any stabilisation required. Observations will continue through the rain event to ensure the functioning of erosion and sediment control devices.

4.7 Decommissioning and Removal

Erosion and sediment control devices will remain in place until ‘stabilisation’ of the site has been achieved. This is generally defined as 80% vegetative cover as depicted in **Figure 2**.

It is noted that the removal of controls may result in minor soil exposure. Any soils exposed during decommissioning will be stabilised with either grass, mulch or other appropriate erosion control.

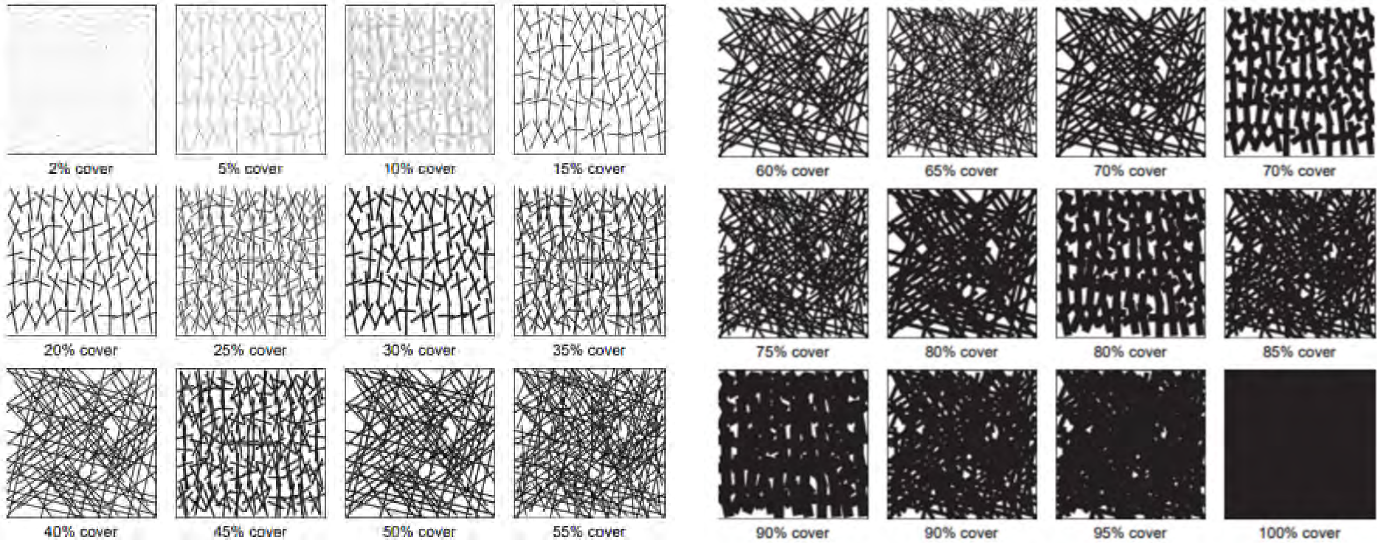


Figure 2: Visual cover estimation (Source: Catchments and Creeks Pty Ltd)

4.8 Inspections and Monitoring

Details of inspections and monitoring are stated in Section 3.3.

4.9 Contingency Measures

The following contingency measures in **Table 4** shall be deployed as required.

Table 4: Erosion and sediment control contingency measures

Issue	Contingency Measure
Sediment-laden stormwater flowing across the site boundary	Undertake measures to stop the flow immediately. Ensure controls are installed according to the ESCP. Contact the Environmental Consultant (SQEP) who will initiate the incident response.
Controls do not appear to be working as intended	Contact Environmental Consultant (SQEP) to inspect, advise and revise ESCP as required.
The site is inappropriately exposed prior to imminent rain event	Cease works and shift effort to checking erosion and sediment controls and stabilisation via the Rapid Response Procedure outlined in Section 4.6.
Abatement notice issued by Council	Contact the Environmental Consultant (SQEP) immediately to advise on methods to meeting abatement notice requirements within the time stated by the abatement notice.

4.10 Erosion and Sediment Control Incident

An erosion or sediment control incident is considered to have occurred where performance criteria outlined in Section 4.1 is not met. The incident procedures outlined in Section 3.5 shall commence.

5.0 WATER QUALITY MANAGEMENT

5.1 Receiving Waterbodies

The slip has occurred within the upper catchment of Reavers Creek. The debris has been deposited within the creek bed and on adjacent slopes, thus works will be required to be undertaken within close proximity of the creek to remove/stabilise debris. The upper catchment of Reavers Creek is characterised by steep slopes, numerous bluffs and mature Douglas fir pine trees. The creek is fed by numerous flow paths that convey water in high flow events. These flow paths intersect the access roads that are to be constructed as part of this development.

Reavers Creek runs into a formalised intake connected to QLDC's stormwater network and eventually to Lake Wakātipu. The site is situated 780 m from Lake Wakātipu from the outlet of Reavers Creek.

The southern end of the access tracks to be upgraded are located in the Brecon Street Catchment. Overland flows here will flow down to Brecon Street and the Queenstown Cemetery.

Figure 3: Waterways within and in proximity to the site

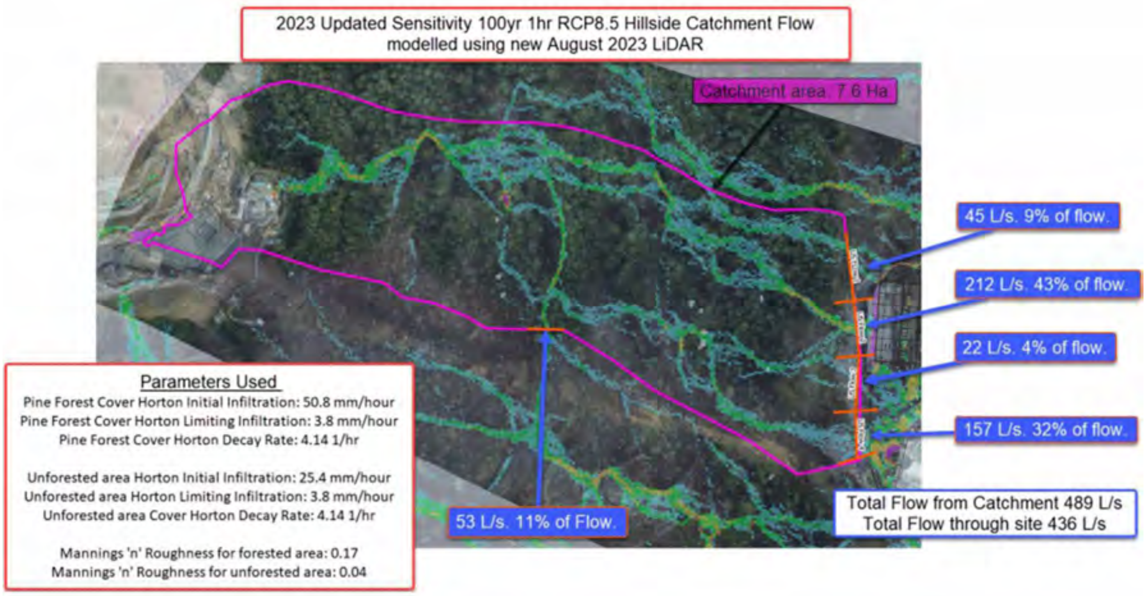


Figure 4: Hydraulic modelling results focusing on the Brecon Street catchment (Fluent Report, 2023)

5.2 Performance Criteria

Any waters flowing across the site boundaries will meet the criteria in **Table 5**.

Table 5: Water quality discharge criteria

Parameter	Discharge Criteria
Clarity of receiving waters	No 'conspicuous change in colour or visual clarity' in receiving waters below the activity area [3]
pH[4]	5.5 – 8.5
Hydrocarbons or tannins	No visible trace
Waste	No waste or litter is visible

[3] Turbidity can be instantly measured using a nephelometer. This is considered desirable as opposed to testing TSS which requires laboratory testing and can take several days. Turbidity can be inferred from the relationship with TSS via linear regression. If the specified turbidity value is not met, a water sample will be collected and sent for TSS laboratory testing.

[4] pH to be tested only when chemical treatment is undertaken.

5.3 Management Measures

The following measures will be deployed to ensure the protection of water quality:

- Erosion and sediment controls will be implemented and maintained in accordance with the Erosion and Sediment Control Measures in Section 4.0.
- Refuelling, servicing and storage of hydrocarbons will be in accordance with the relevant procedures in the Chemicals and Fuels Management in Section 10.0.
- All plant and equipment onsite will be inspected regularly to ensure they are of an acceptable standard.
- Stockpiling of any organic, erodible or hazardous material onsite is not to be placed within close proximity of a watercourse/major drainage line, unless appropriate controls are in place.

5.4 Monitoring

Water quality will be monitored in accordance with **Table 6**.

Table 6: Water quality monitoring measures

Sampling Scope	
Objective	To confirm that all controlled and uncontrolled water flowing from the site meets the Discharge Criteria referred to in Section 5.2.
Responsibility	On site water quality sampling is to be completed by the nominated Environmental Representative. Note: The Environmental Consultant is available to provide training and guidance regarding on site sampling and can provide sampling services as required.
Spatial boundaries	All water that enters and exits the site from rainfall or overland flow.
Frequency	Immediately following 20 mm of rain in a 12-hour period or when water is flowing across the boundary of the site. Where a Significant Rain Event occurs through the night, monitoring shall be undertaken as soon as practically possible, the following morning. Regularly during manual removal of sediment from Reavers Creek.
Sampling Design	
Water Quality Criteria	As outlined in the Discharge Criteria referred to in Section 5.2.
Sampling Locations	Reavers Creek 50 m below the lowest discharge point from the overland flow path.

Sampling Method	• Water clarity – visual observations • pH – pH meter – only if utilising chemical treatment • Gross pollutants – visual observations • Tannins – visual observations (any unusual darkening of waters?) • Hydrocarbons – visual observations (is there any oily film[5] on surface or smell?)
Quality Control	Any water quality meter will be calibrated according to manufacturer instructions. All observations will be recorded and analysed.
Recording	
Recording Results	All results will be entered into a spreadsheet and kept onsite (form attached as **Appendix 9**).
Actions	
Non-conformances	Any exceedances observed will be reported to the Project Manager/ Environmental Consultant who will investigate and ensure appropriate corrective actions are implemented immediately.

5.5 Contingency Measures

The following contingency measures in **Table 7** shall be adopted if required.

Table 7: Water quality contingency measures

Issue	Contingency Measure
Exceedance of water quality criteria	• Contact the Project Manager and Environmental Consultant (SQEP) immediately. • Works will cease or be modified to remove further risk of contamination. • QLDC will be verbally notified. • The Environmental Incident procedure will commence. • Remedial measures will be implemented and the Environmental Incident will be closed out by the Environmental Consultant (SQEP), with a copy of an Environmental Incident report to the Project Manager, QLDC.

5.6 Water Quality Incidents

A water quality incident is considered to have occurred where the water quality performance criteria outlined in Section 5.2 is breached. The incident procedures outlined at Section 3.5 shall commence.

[5] Some bacteria produce a naturally occurring film on the water surface. Bacteria films breaks apart in angular shapes when disturbed whereas hydrocarbon film separates as globules.

6.0 DUST MANAGEMENT

Dust from construction activities, vehicle movements and stockpiles can contribute to sediment runoff and create a nuisance to the public, neighbouring properties, adjoining roads and service infrastructure. The key risks associated with dust occur during the bulk earthworks phase of the project.

There are a range of activities that may produce dust onsite including but not limited to:

- General disturbance of soil (particularly during drier months).
- Vehicle movements along haul roads.
- Slow or ineffective revegetation procedures.

It is noted that the dense forest of mature, evergreen Douglas fir will provide opportunities for dust screening across much of the work site. However, this should not be fully relied upon. There will be an element of adaptive management to control dust.

6.1 Sensitive Receptors

Key sensitive receptors to protect from the effects of dust include visitors and recreational users of Ziptrek and Skyline facilities, mountain bike trails and Tiki Trail. The prevailing wind conducive to dust generation during the summer months, is generally from the north-west. Being located above Lake Wakātipu, wind direction and speed can be highly variable. Contractors shall remain vigilant for variations in wind conditions.

It should be noted that the exposure of the forementioned sensitive receptors to the effects of dust are temporary in nature, therefore the effects of dust anticipated to be less than minor.

6.2 Performance Criteria

The project must ensure that reasonable and practical measures are taken to avoid dust moving across the boundaries of the site at all times.

6.3 Management Measures

The following measures will be deployed to ensure dust generation onsite is minimised:

- Stage works where possible to minimise soil exposure extents and timeframes.
- Progressive application of aggregate to tracks.
- Revegetate batters/disturbed areas progressively throughout construction.
- Dust suppression of exposed areas by water trucks or other methods approved by Environmental Representative.[6]
- If dust activities cannot be controlled during high winds, works will cease until favourable conditions return.

[6] Ensure a consented water take permit is approved by the local authority. If taking water from lakes and or rivers, ensure that the permitted volume of water is taken.

- Only designated access points and haul routes are to be used.
- A maximum speed limit will be posted as 15 km/hr, unless deemed otherwise by the Project Manager.
- To avoid spillage risks, trucks will not be overloaded.
- All trucks must have tail gates up and swept or cleaned prior to exiting to external roads.
- Stockpile heights are to be minimised where possible (< three metres) unless they are covered (e.g. an erosion blanket, chemical sealant, temporary cover crop or mulched).
- Long-standing stockpiles (greater than four weeks) shall be appropriately stabilised.
- Within two weeks of completion, all earth worked areas will be sown out with grass, landscaped or otherwise stabilised by an appropriate erosion control.

6.4 Monitoring

Site staff will maintain continual vigilance for any increases in wind to ensure measures are deployed prior to dust crossing site boundaries. Weekly Environmental Inspections and the Monthly SQEP Environmental Inspections will also ensure that the management measures described above are sufficient and performing effectively.

6.5 Contingency Measures

The contingency measures in **Table 8** shall be adopted if required.

Table 8: Dust contingency measures

Issue	Contingency Measure
Excessive dust creation from soil disturbance	• Spray down excavation areas and activities where excavator bucket is operating. • Cease excavation during high winds, particularly if wind direction is likely to impact sensitive receivers.
Excessive dust creation from hauling operations	• Reduce truck speeds. • Cover or spray down loads causing dust impacts. • Apply new skim of aggregate over the haul road surface.
Excessive dust creation from stockpiles	• Spray stockpiles with water or apply a temporary polymer. • Hydro-mulch, seed or stabilise stockpiles, cover stockpiles with geofabric. • Locate stockpiles further away from sensitive receptors.
Abatement notice issued by Council	Contact the Environmental Consultant (SQEP) immediately to advise on methods to meeting abatement notice requirements within the time stated by the abatement notice.

6.6 Dust Incident

A dust incident is considered to have occurred where:

- Dust is observed crossing the boundary into sensitive receptors or,
- A justified complaint is received regarding dust emissions across the boundary of the site.

The incident procedures outlined at Section 3.5 shall commence.

7.0 NOISE AND VIBRATION MANAGEMENT

Noise and vibration generated during construction has the potential to impact sensitive receivers by reducing comfort, impeding communication, causing cosmetic damage to structures and damaging household possessions.

The following assessment and management measures are intended for standard construction equipment that is not expected to induce noise or vibration beyond the maximum limits in the QLDC District Plan. Where upper noise and vibration levels of district plans will be breached, an Acoustic Specialist may need to be engaged to assist with the management of these nuisance effects.

Potential noise and/or vibration effects may be generated by the following:

- Excavation and earth moving plant
- Ancillary plant and equipment
- Piling equipment
- Rock breaking

7.1 Sensitive Receptors

Nearby sensitive receptors include residential dwellings at the outlet of Reavers Creek, and visitors and recreational users of Skyline and Ziptrek facilities. Geosolve note in their March 2024 report that given the distance from the site to neighbouring properties, the risk of vibration issues for third parties is low.

7.2 Performance Criteria

1. Construction activities shall meet relevant noise limits specified under Rule 36.5.13 of the Queenstown Lakes Proposed District Plan. This rule requires Construction sound at any point within the site must comply with the limits specified in Tables 2 and 3 of *NZS 6803:1999 Acoustics - Construction Noise*, when measured and assessed in accordance with that standard (see **Table 9** below).
2. Construction activities shall meet relevant vibration limits specified under Rule 36.5.10 of the Queenstown Lakes Proposed District Plan. This rule requires vibration from any activity must not exceed the guideline values given in *DIN 4150-3:1999 Effects of vibration on structures* on any structures or buildings on any other site.
3. Construction activities shall be undertaken in accordance with the permitted hours of operation outlined at Section 2.2 above.

Table 9: Upper limits in dB(A) for construction work noise in residential areas for more than 20 weeks

Time of Week	Time Period	$L_{Aeq(t)}$	L_{Afmax}
Weekdays	0630 – 0730	55 dB	75 dB
	0730 – 1800	70 dB	85 dB

	1800 – 2000	65 dB	80 dB
Saturdays	0630 – 0730	45 dB	75 dB
	0730 – 1800	70 dB	85 dB

Table 10: Vibration Thresholds for Structural Damage (PPV mm/s)

	Short Term				Long-Term
	At Foundation			Uppermost Floor	Uppermost Floor
Types of Structures	0 to 10 HZ	10 to 50 Hz	50 to 100 HZ	All Frequencies	All Frequencies
Commercial/Industrial	20	20 to 40	40 to 50	40	10
Residential	5	5 to 15	15 to 20	15	5
Sensitive/Historic	3	3 to 8	8 to 10	8	2.5

Note: When a range of velocities is given, the limit increases linearly over the frequency range.

7.3 Management Measures

The following measures will be deployed to ensure noise and/or vibration associated with the project are appropriately mitigated:

- Notify surrounding sensitive receptors prior to commencing particularly noisy or vibration inducing activities.
- Where practicable, select lower noise producing equipment or use lower noise generating alternatives.
- Regularly service equipment to ensure plant is running optimally.
- Plant and equipment to be fitted with noise control/attenuation devices as appropriate and maintained and operated in accordance with manufacturer's specifications.
- Revving of engines will be limited. All plant and vehicles will be turned off when not in use and if safe to do so.
- The use of audible alarms on mobile equipment will be limited, and two-way communication will be used.
- Undertake activities that may lead to noise or vibration effects, during reasonable and practical hours.

7.4 Monitoring

All earthworks activity will be closely monitored by the operator to ensure that noise and vibration remains within the required limits. If monitoring finds the activity cannot comply with performance criteria, an Acoustic Specialist may need to be engaged to assess the project and provide appropriate mitigation measures and monitoring. Weekly Environmental Inspections and Monthly SQEP Environmental Inspections shall include an assessment of the site to determine the effectiveness of noise and vibration management controls.

7.5 Contingency Measures

The following contingency measures in **Table 11** shall be adopted if required.

Table 11: Noise and vibration contingency measures

Issue	Contingency Measure
Noise and/or vibration complaint received	Manage the complaint in accordance with the Environmental Complaints procedure in Section 3.6.
Exceedance of performance requirement criteria	The Environmental Consultant (SQEP), in consultation with the Environmental Representative, will investigate and implement actions to reduce noise and/or vibration levels to below criteria levels.
Ongoing noise and/or vibration issues	Where noise or vibration emissions consistently exceed the performance criteria despite the site staff's best efforts, an Acoustic Specialist will be engaged to assist.
Abatement notice issued by Council	Contact the Environmental Consultant (SQEP) immediately to advise on methods to meeting abatement notice requirements within the time stated by the abatement notice.

7.6 Noise and Vibration Incident

A noise or vibration incident is considered to have occurred when a justified complaint is received and on investigation is found to exceed the performance criteria. The environmental incident procedures outlined in Section 3.5 shall commence.

8.0 CULTURAL HERITAGE MANAGEMENT

The loss or damage of cultural heritage items could be caused by construction activities. The damage or loss of artefacts can lead to the loss of culturally or historically significant items and information.
Examples of cultural heritage items include:

- Koiwi tangata (human skeletal remains).
- Waahi taoka (resources of importance).
- Waahi tapu (places or features of special significance).
- Māori artefact material.
- A feature or archaeological material predating 1900.
- Unidentified archaeological or heritage site.

8.1 Location of Known Cultural Heritage Significance

A search of QLDC's database indicates the extent of works does not directly intersect any known areas of historic heritage features.

Skyline is located within the Te Taumata o Hakitekura, Ben Lomond, under the Heritage Protection Order. Its values are listed as Wāhi taoka, wāhi tapu. It's recognised threats are listed as; Exotic species including wilding pines, buildings and structures, utilities, new roads or additions/alterations to existing roads, vehicle tracks and driveways and activities affecting the ridgeline and upper slopes. However, due to the scope of the works being temporary and remedial in nature, it is not anticipated to conflict with these matters. **Figure 5** describes the identified areas of cultural significance.

Figure 5: Locations of areas with cultural significance (Source: QLDC Maps)

8.2 Performance Criteria

- The protection of cultural heritage artefacts and places in accordance with the *Heritage New Zealand Pouhere Taonga Act, 2014*.
- Strict adherence to Heritage New Zealand's *Archaeological Discovery Protocol* (attached as **Appendix 10**) in the case of unexpected finds.

8.3 Management Measures

All works on this project will be undertaken in accordance with the obligations of the *Heritage New Zealand Pouhere Taonga Act*, 2014.

8.4 Monitoring

Weekly inspections shall include a visual assessment of the site to ensure that no new significant artefacts have been encountered. However, operators must remain vigilant for such encounters as they occur.

8.5 Accidental Finds

If any unknown artefacts are uncovered, the project will work to Heritage New Zealand's *Archaeological Discovery Protocol* (attached as **Appendix 10**).

9.0 VEGETATION MANAGEMENT

The site is predominantly covered in mature Douglas Fir pine trees. Some forestry has occurred within the area to remove some trees for thinning purposes and to generate a fire break around the Skyline infrastructure. However, the vegetation cover around the area of the slip is predominantly pine trees.

9.1 Sensitive Receptors

There is no identified protected vegetation within proximity of the site, therefore, there are no other specific protections or management measures. However, any existing indigenous vegetation discovered during works will be demarcated as 'no-go zones'.

9.2 Performance Criteria

- Avoid the clearance of indigenous or protected vegetation where possible during excavation works.
- Avoid the spread of noxious weeds onsite or to other sites.

9.3 Management Measures

The following measures will be deployed to manage vegetation:

- Demarcate any discovered protected vegetation areas as no go zones.
- Treating weeds prior to disturbance of the natural surface.
- Maintain existing indigenous and or any protected vegetation.

9.4 Monitoring

Weekly Environmental Inspections and Monthly SQEP Environmental Inspections shall include a visual assessment of the site to determine the effectiveness of vegetation management controls.

9.5 Vegetation Incident

A vegetation incident is considered to have occurred where:

- Protected vegetation is damaged or removed.
- A no-go zone is breached.

The environmental incident procedures outlined at Section 3.5 shall commence.

10.0 CHEMICALS AND FUELS MANAGEMENT

Hazardous substances can endanger both human health and the environment. Used incorrectly they can cause catastrophic accidents, such as fires and explosions, and serious harm to people who are exposed to them.

10.1 Sensitive Receptors

Key sensitive environmental receptors include staff members working on the site, neighbouring properties and users of Skyline's facilities.

10.2 Performance Criteria

- Chemicals and fuels are stored and used in a manner that avoids contamination of site and surrounding environment.
- All spills are cleaned up immediately and the contaminated soils/waters disposed of appropriately.

10.3 Management Measures

The following measures will be deployed to ensure chemicals and fuels associated with the project are appropriately managed.

- All hazardous substances to be stored, transported and used according to the safety data sheet requirements.
- Storage of chemicals and fuels shall be located as far as practicably possible from waterways and concentrated flows.
- Refuelling of vehicles and plant onsite will occur in the designated refuelling bay as shown in ESCP-013, **Appendix 1**.
- All concrete washing is to be undertaken in the designated concrete wash-out pit as per the design specifications in ESCP-013, **Appendix 1**.
- One 240 L Oil and Hydrocarbon spill kit and one 240 L Chemical spill kit will be located in close proximity to the location of liquid hazardous materials storage and refuelling areas.
- The volumes of the hazardous substances listed in **Table 12** will not be exceeded.

Table 12: Maximum volumes of chemicals and fuels

Chemicals and Fuels	Maximum Volume	Storage Location
Diesel	1,000 L	Fuel tank or Jerry cans in lockable container
Unleaded Fuel	100 L	Jerry cans in lockable container
Oil	10 L	Packaging in lockable container
Lubricant (WD40 or similar)	Six Cans	Packaging in lockable container
Grease	5 L	Packaging in lockable container

Chemicals and Fuels	Maximum Volume	Storage Location
Spot marking paint	2 L	Packaging in lockable container

10.4 Monitoring

Weekly Environmental Inspections and Monthly SQEP Environmental Inspections shall include a visual assessment of the site to determine the effectiveness of chemicals and fuels management.

10.5 Contingency Measures

The following contingency measures in **Table 13** shall be adopted if required.

Table 13: Chemicals and fuels contingency measures

Issue	Contingency Measure
Spills response	• Stop works in proximity to the spill and assess the safety of all personnel. • Take immediate action to contain the spill to prevent discharge into stormwater drains or natural waterways. • Use spill kits to contain and treat the spill. • Notify Environmental Consultant to advise on next steps. • If necessary, notify the Regional Council spill response unit. • Remove contaminated material to a suitable contained location for remediation/disposal (require any necessary approvals/permits from ORC). • The spill kits shall be replaced by an approved supplier.
Inappropriate storage	• Upgrade facility. • Clean-up of storage area. • Notify and train staff.
Inappropriate handling/transport	• Notify and train staff through toolbox meetings on the appropriate handling and transport methods.
Inadequate spill kit materials	• Order more materials. • Investigate types of chemicals onsite and consult a supplier for advice on appropriate equipment. • Develop or revise spill material monitoring and ordering system.
Inappropriate disposal of chemicals or fuels	• Provide appropriate disposal facilities or service providers. • Notify and train staff.

Issue	Contingency Measure
Inaccurate or insufficient records	• Advise staff and update records. • Monitor through inspections.

10.6 Chemicals and Fuels Incident

A chemicals and fuels incident is considered to have occurred where:

- A spill more than five litres has occurred.
- A situation is discovered where a spill of more than five litres would likely have occurred before it happens where the management measures listed above have not been followed.

The environmental incident procedures outlined at Section 3.5 shall commence.

11.0 WASTE MANAGEMENT

Waste from construction activities can create a nuisance to the public, neighbouring properties, and adversely affect flora and fauna.

11.1 Sensitive Receptors

Key sensitive environmental receptors include staff members working on the site, neighbouring properties and users of Skylines facilities.

11.2 Performance Criteria

- Non-recyclable waste generation is minimised, and the site and surrounds are kept free from waste at all times.
- Wastes shall be stored safely and in an organised manner until recycling, reuse, or disposal.

11.3 Management Measures

The following measures will be deployed to ensure waste management associated with the project is appropriately mitigated:

- The Waste Management Hierarchy philosophy will be implemented, as illustrated in **Figure 6**.

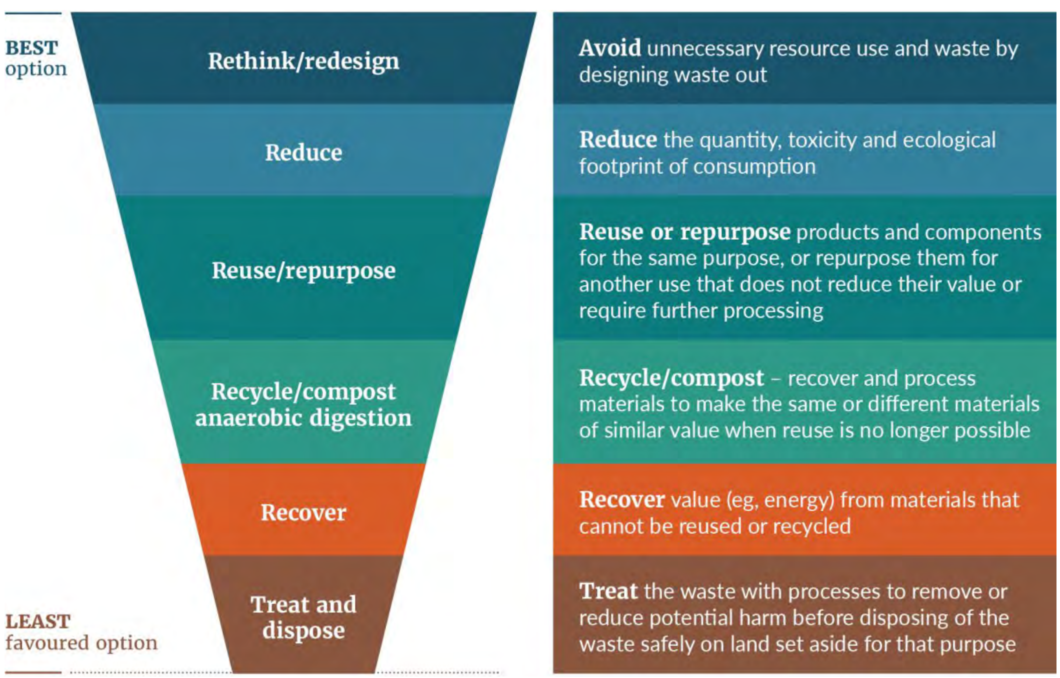


Figure 6: The Waste Hierarchy (Source: Ministry for the Environment).

- Measures will be implemented to ensure the site is maintained in a safe, clean and tidy state.

- Where possible, waste shall be segregated into labelled bins with lids: General, Hazardous and Recyclables.
- Wastes onsite shall be suitably contained and prevented from migrating offsite.
- The waste is to be contained so it doesn't contaminate soil, surface or ground water, create unpleasant odours or attract vermin.
- Any material dropped in or adjacent to open drains shall be recovered immediately after it occurs.
- Waste storage is not permitted in or near drainage paths.
- The burning of waste is strictly prohibited.
- No wastes shall be disposed of onsite.
- Wastes shall be removed from site regularly and at completion of works.

11.4 Monitoring

Site staff will be briefed on waste processes prior to works commencing and shall maintain continual vigilance for excess waste around the site and following appropriate disposal procedures. Weekly Environmental Inspections and Monthly SQEP Environmental Inspections shall include a visual assessment of the site to determine the effectiveness of waste management controls.

11.5 Contingency Measures

If waste items are accumulating or are stockpiled, the following contingency measures will be adopted:

- Arrange for collection by approved licensed contractor.
- Provide additional bins with lids if available.
- Remove waste offsite as soon as possible.

11.6 Waste Incident

A waste incident is considered to have occurred where:

- Waste from the site is found within a sensitive environment or where it may reasonably migrate to a sensitive environment,
- A complaint is received regarding inappropriate management of waste and on investigation is warranted.

The environmental incident procedures outlined at Section 3.5 shall commence.

12.0 CONTAMINATED SITE MANAGEMENT

A search of Council records has not provided any indication of the site being used in the past for a HAIL activity.

12.1 Sensitive Receptors

Key sensitive environmental receptors include staff members working on the site, neighbouring properties and users of Skylines facilities.

12.2 Performance Criteria

- Effectively identify and manage any sites where contaminants are found and ensure they do not contaminate beyond the location they are found (including offsite) or present a risk to human health.

12.3 Management Measures

The following measures will be deployed to ensure contaminated soil associated with the project is appropriately mitigated:

- If any evidence of contamination is noticed in the field, the personnel noting the contamination shall immediately notify the Environmental Representative.
- Any known contaminated soil to be removed must be undertaken wearing appropriate PPE.
- Many of the controls required to manage potential for effects associated with low level contaminated soil is based on best practice erosion and sediment control and dust management techniques. These are outlined in Section 4.3 (erosion and sediment controls) and Section 6.4 (dust controls). Both sections cover management of stockpiles.
- All surplus fill material requiring removal shall meet the Ministry for Environment definition of clean fill, as specified in Section 2.2 of the report "A Guide to the Management of Cleanfills", prepared by *Beca Carter Hollings & Ferner Ltd for the Ministry for the Environment and dated January 2002.*
- Trucks removing or transporting any soil from the site will be covered or sealed to prevent dust, leakage or loss of materials during transport.

12.4 Monitoring

Unless any higher-level contamination is accidentally found during earthworks, no specific monitoring of soil, groundwater or water quality will occur (other than what is detailed in the water quality criteria outlined at Section 5). If material is found it is expected that monitoring may be required but this shall be at the direction of the soil contamination expert.

12.5 Contingency Measures

It is not expected that contaminated material will be encountered, however this cannot be ruled out. If a potential contaminated site is identified (e.g., by landfilled waste, odour) during construction works, the following contingency measures will be undertaken:

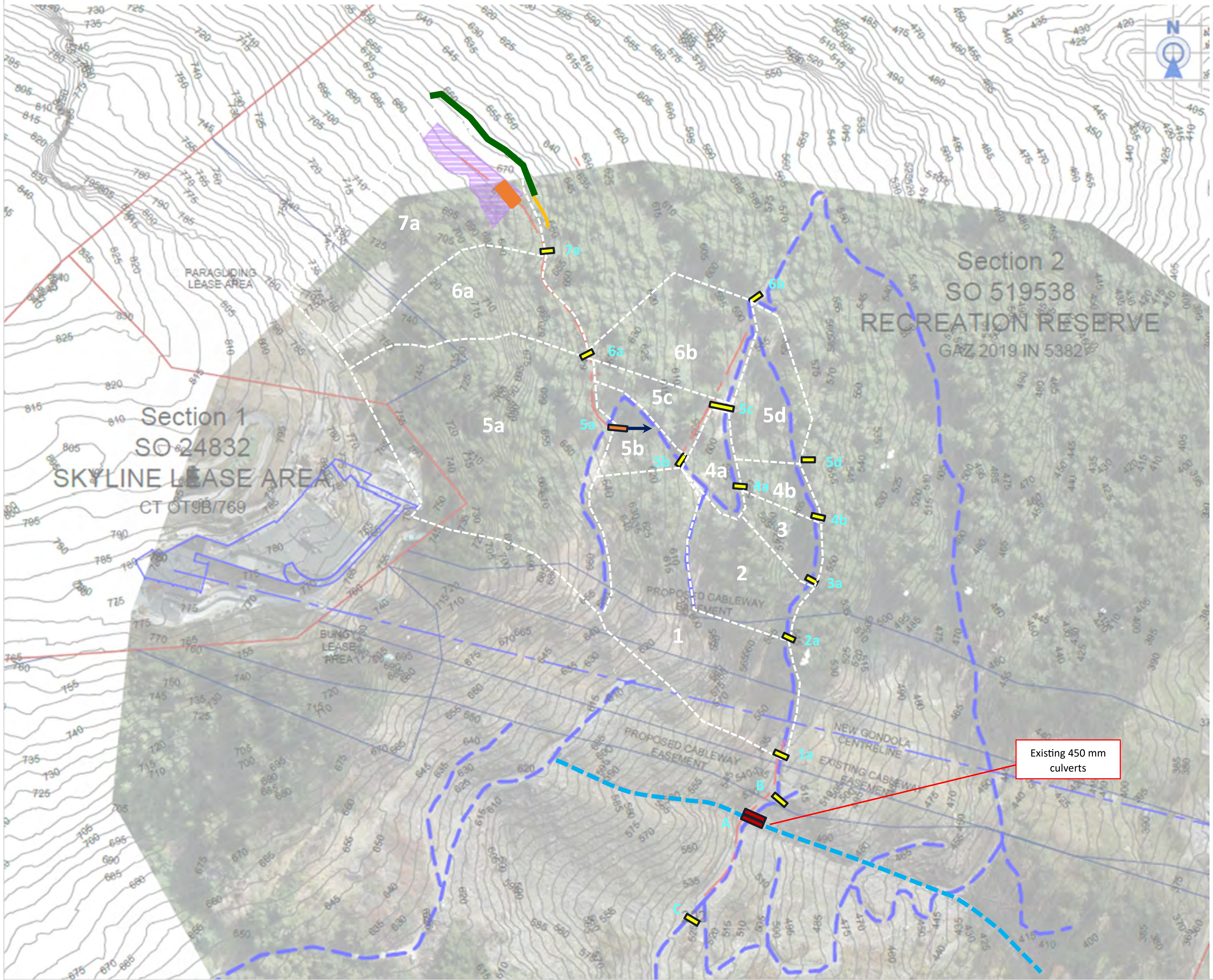
- Immediately notify the Project Manager.
- Prevent spread of contamination by installation of silt fencing, covering material with plastic or geofabric material. This will be done wearing appropriate PPE as outlined in the Health and Safety Management Plan.
- Engage the Environmental Consultant who will advise on the engagement of a Contaminated Soil expert.
- EMP to be amended to manage any new contaminated soil encountered in coordination with the contaminated soil expert (if engaged).

12.6 Contamination Incident

An environmental incident is considered to have occurred where inspection finds that excavation or other work continues within contaminated soil without report or remedial action.

The environmental incident procedures outlined in Section 3.5 shall be followed.

APPENDIX 1 Erosion and Sediment Control Plan Drawing



Legend

	Ephemeral waterway
	Silt fence
	Temporary culvert (325 mm minimum)
	Temporary culvert (150 mm minimum)
	Permanent culvert
	Existing haul road
	New access tracks
	Catchment boundaries
	Laydown area
	Earth bund

Notes

- This plan is to be read in conjunction with the Environmental Management Plan document prepared by Enviroscope.
- All locations of erosion and sediment control (ESC) devices are indicative and exact placement to be confirmed onsite.
- ESC devices to be installed and maintained in accordance with the New Zealand Forest Owners Forestry Association's (NZFOA) *New Zealand Forest Road Engineering Manual, 2020* and manufacturer's instructions where relevant.
- All devices are to be inspected daily and pre and post-rain event to ensure they are fully functional.
- Ditches on slopes greater than 10% are to be stabilised by installing rock armouring. For ditches with gradients less than 10%, check dams are to be installed in accordance with the table in ESCP-008 as per NZFOA.

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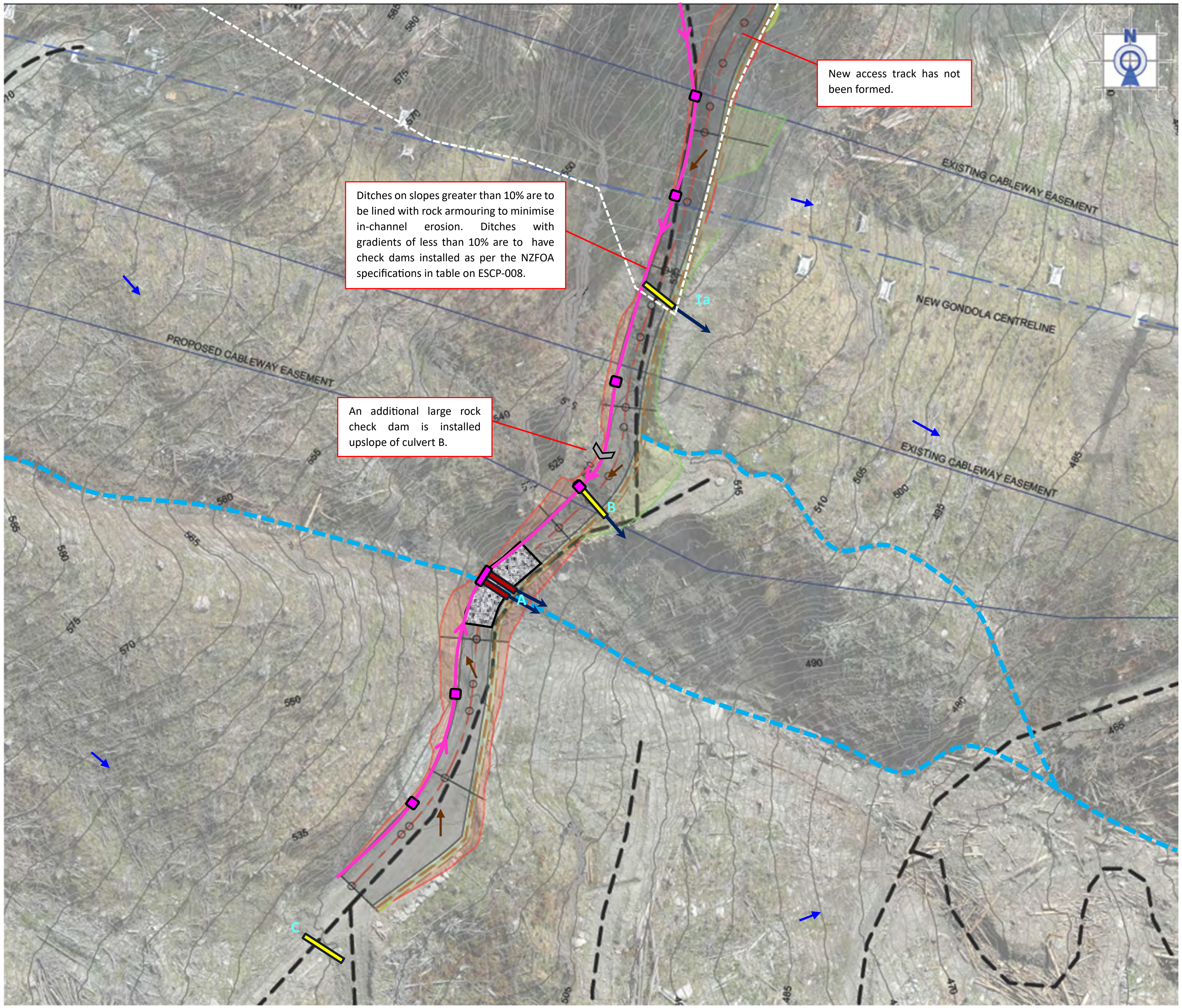
Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan Drawing – Sub-Catchment Overview

Drawn	Approved	Date	Drawing No.	Revision
TG	TG	18/07/2024	ESCP - 001	E



Legend

	Clean water overland flow
	Dirty water overland flow
	Ditch
	Ephemeral Waterway
	Silt fence
	Temporary culvert (325 mm minimum)
	Temporary culvert (150 mm minimum)
	Permanent culvert
	Culvert flume sock
	Existing haul road
	New access tracks
	Catchment boundaries
	Sediment traps
	Check dam (Additional to NZFOA requirements)
	Cut
	Fill
	Rock Ballast
	Laydown area
	Earth bund

Notes

- This plan is to be read in conjunction with the Environmental Management Plan document prepared by Enviroscope.
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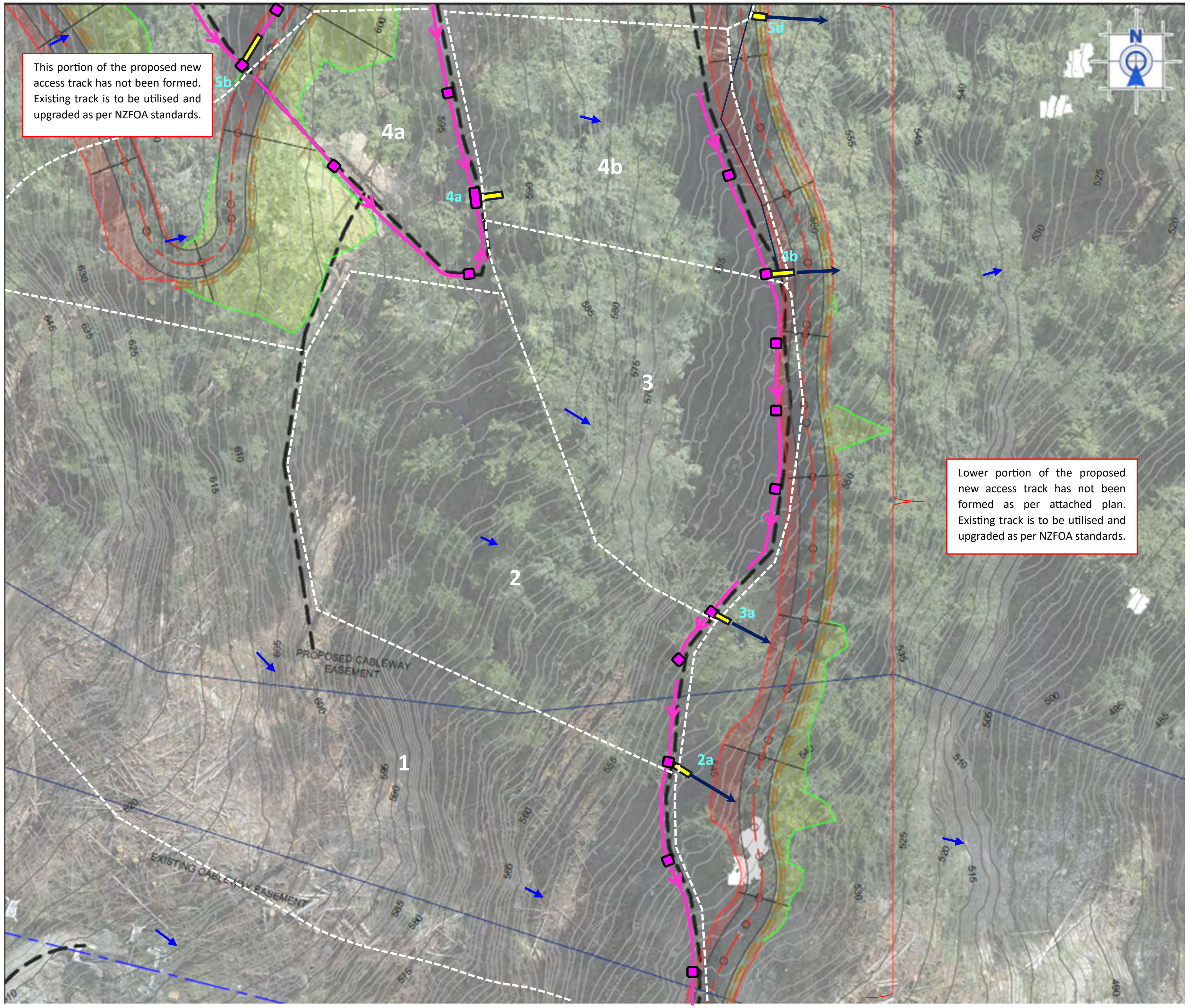
- Ditches on slopes greater than 10% are to be stabilised by installing rock armouring. For ditches with gradients less than 10%, check dams are to be installed in accordance with the table in ESCP-008 as per NZFOA.

Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan Drawing

Drawn	Approved	Date	Drawing No.	Revision
TG	TG	18/07/2024	ESCP - 002	E



Legend

	Clean water overland flow
	Dirty water overland flow
	Ditch
	Ephemeral Waterway
	Silt fence
	Temporary culvert (325 mm minimum)
	Temporary culvert (150 mm minimum)
	Permanent culvert
	Culvert flume sock
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	Check dam (Additional to NZFOA requirements)
	Cut
	Fill
	Rock Ballast
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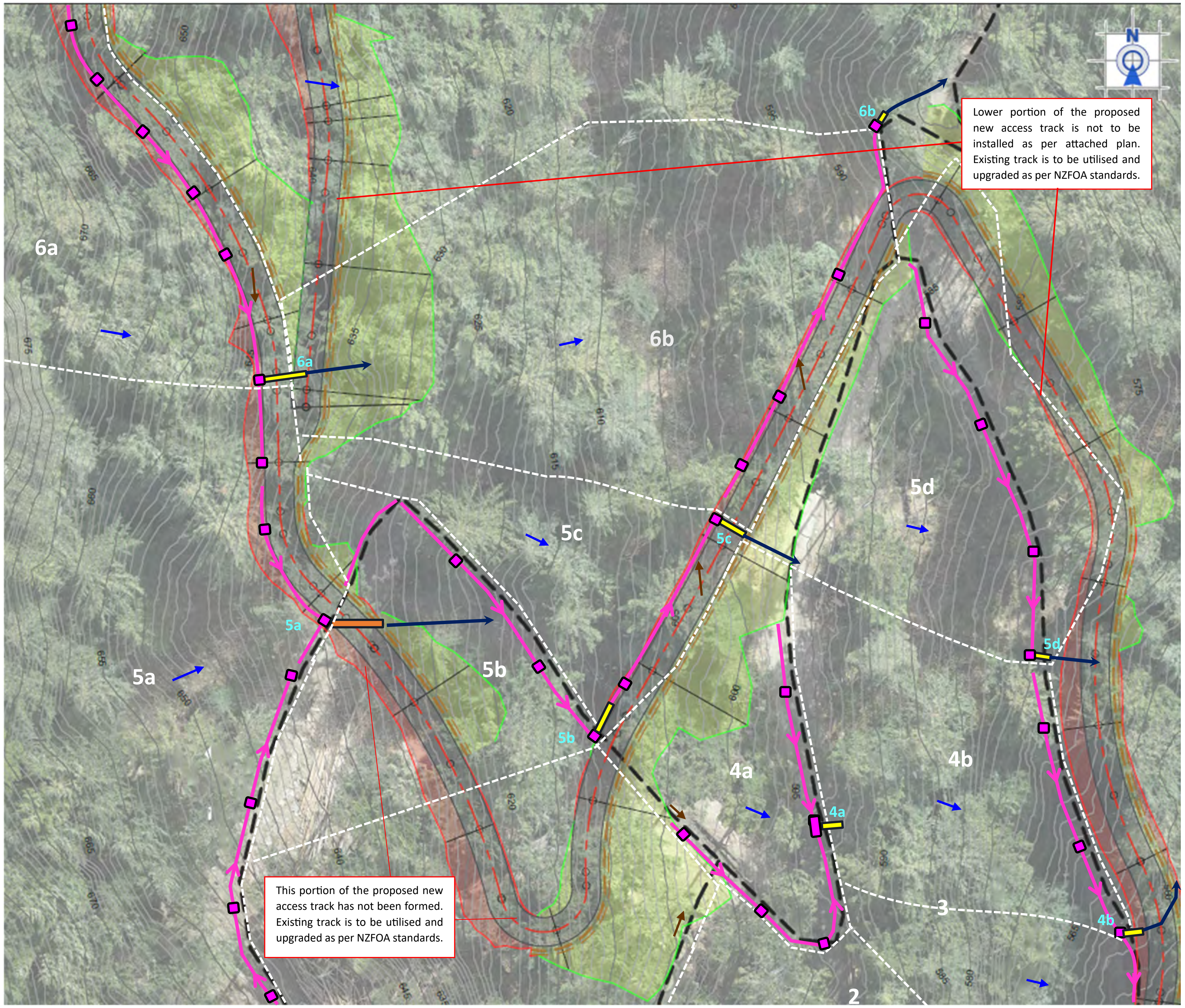
- All devices are to be inspected daily and pre and post-rain event to ensure they are fully functional.
- Ditches on slopes greater than 10% are to be stabilised by installing rock armouring. For ditches with gradients less than 10%, check dams are to be installed in accordance with the table in ESCP-008 as per NZFOA.

enviroscope

Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan Drawing

Drawn	Approved	Date	Drawing No.	Revision
TG	TG	18/07/2024	ESCP - 003	E



Legend

	Clean water overland flow
	Dirty water overland flow
	Ditch
	Ephemeral Waterway
	Silt fence
	Temporary culvert (325 mm minimum)
	Temporary culvert (150 mm minimum)
	Permanent culvert
	Culvert flume sock
	Existing haul road
	New access tracks
	Catchment boundaries
	Sediment traps
	Check dam (Additional to NZFOA requirements)
	Cut
	Fill
	Rock Ballast
	Laydown area
	Earth bund

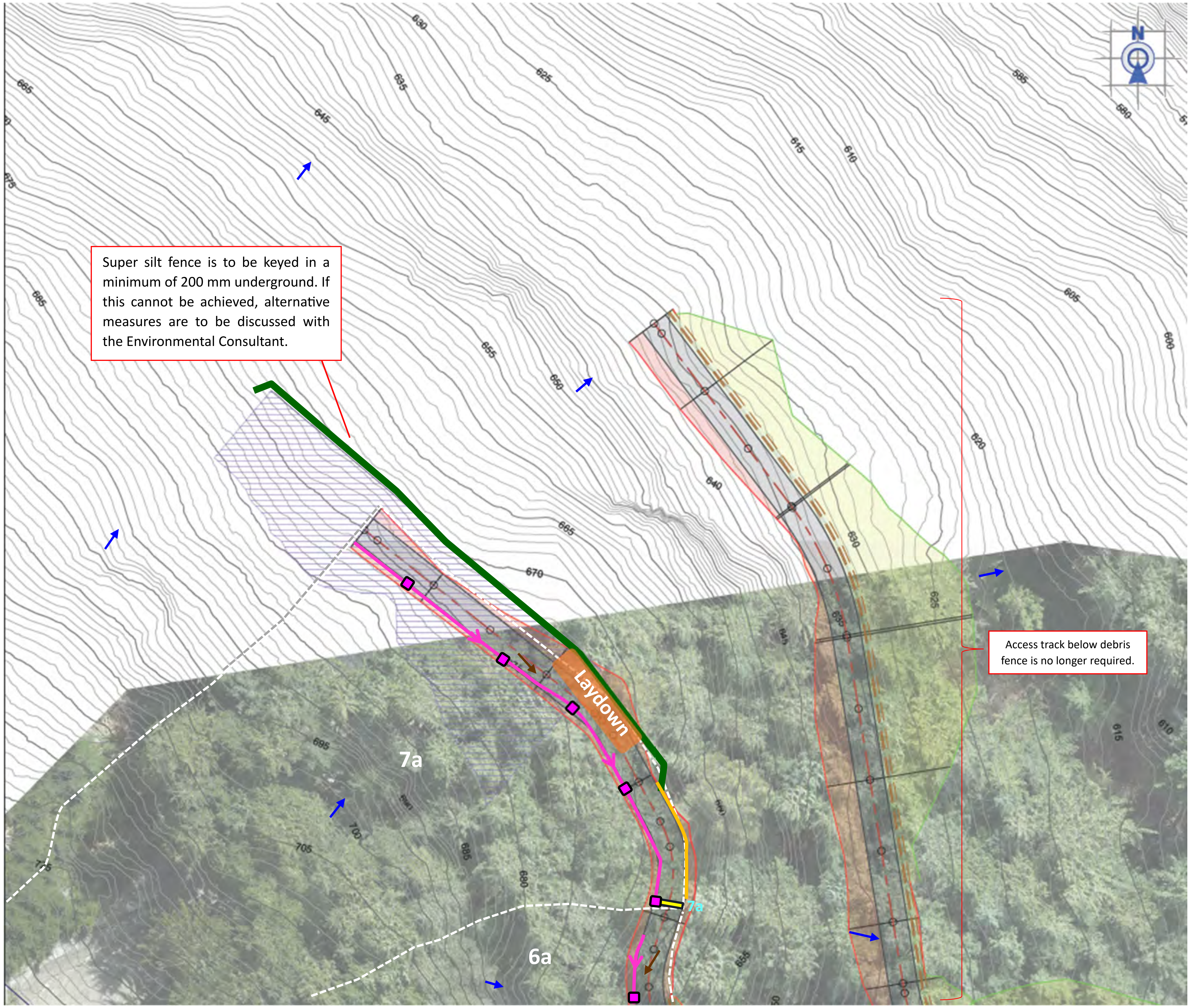
Notes

- This plan is to be read in conjunction with the Environmental Management Plan document prepared by Enviroscope.
- All locations of erosion and sediment control (ESC) devices are indicative and exact placement to be confirmed onsite.
- ESC devices to be installed and maintained in accordance with the New Zealand Forest Owners Forestry Association's (NZFOA) *New Zealand Forest Road Engineering Manual, 2020* and manufacturer's instructions where relevant.
- All devices are to be inspected daily and pre and post-rain event to ensure they are fully functional.
- Ditches on slopes greater than 10% are to be stabilised by installing rock armouring. For ditches with gradients less than 10%, check dams are to be installed in accordance with the table in ESCP-008 as per NZFOA.

Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan Drawing

Drawn	Approved	Date	Drawing No.	Revision
TG	TG	18/07/2024	ESCP - 004	E



Legend

	Clean water overland flow
	Dirty water overland flow
	Ditch
	Ephemeral Waterway
	Silt fence
	Temporary culvert (325 mm minimum)
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Notes

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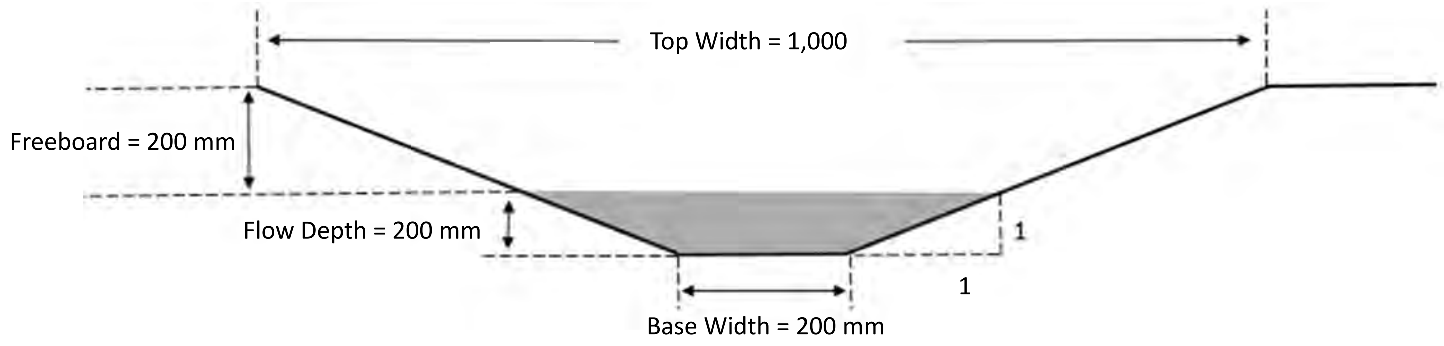
Project: Skyline – Reavers Slip Repair

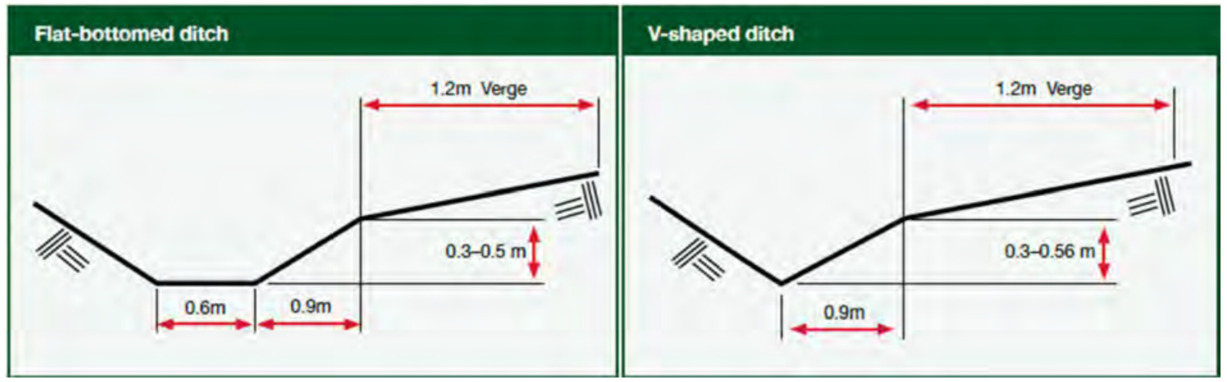
Description: Erosion and Sediment Control Plan Drawing

Drawn	Approved	Date	Drawing No.	Revision
TG	TG	18/07/2024	ESCP - 005	E

DITCH

(Pages 124-127 from NZFOA)





Base Width	Top Width	Flow Depth	Freeboard Height	Batter ratio	Channel slope	Buffer
200	800	200	200	1:1	25	869 %

Base Width	Top Width	Flow Depth	Freeboard Height	Batter ratio	Channel slope	Buffer
600	1500	300	200	1:1.5	25	5,867 %

- This has been designed to comfortably carry a 5% AEP design event.
- Check dams required.
- Rock armouring required.
- Flat bottomed shape as per schematic provided.
- Note ditches have been designed as per GDO5 specifications as per the schematic above. This deviates from the ditch design specifications recommended by the New Zealand Forest Owners Association as shown in the schematic to the right.
- Full calculations for both GDO5 dirty water diversion channel and NZFOA ditch are included in **Appendix 2**.

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Project: Skyline – Reavers Slip Repair				
Description: Erosion and Sediment Control Plan - Schematics				
Drawn	**Approved**	**Date**	**Drawing Number**	**Revision**
TG	TG	18/07/2024	ESCP - 006	E

SEDIMENT TRAPS

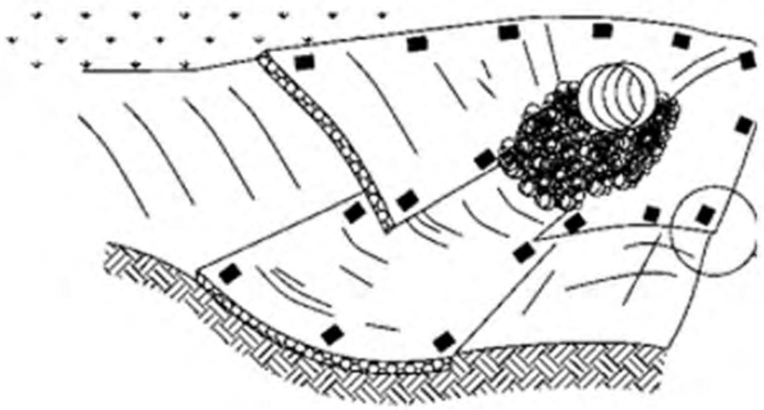
Pages 135 and 136 from NZFOA

- Sediment traps should be 1 m deep by 1.5 m long. A good length to width ratio is 3:1.
- Spacings of Sediment traps will vary throughout the site with differing gradients. However, generally the sediment traps are placed every 10-20 m.
- As a contingency measure, sediment traps can be increased in size and lined to prevent any scour of the pit.

Soak hole spacing guide	
Site slope	Soak hole spacing
Less than 12%	40m
More than 12%	30m down to 10m

TEMPORARY DRAINAGE CULVERT

Pages 130 – 132 of NZFOA



- The culvert diameters will vary throughout the site, with at least one 325 mm culvert placed every 65 m as per the table below.
- Geofabric and rock or slash should be placed at the outlet to prevent scour from the higher velocity water exiting the culvert. This is also applicable to the outlet of culvert sock flumes.
- Full calculations are included in **Appendix 2**.

Recommended maximum spacing (m) for road drainage culverts located on roads traversing mid and lower slopes

Grade	Soil or rock erodibility and distance spacing guide (m)			
	High	Moderate	Low	Non-erosive rock
18% (1 in 6)	40	80	120	200
14% (1 in 7)	50	90	140	220
12% (1 in 8)	55	100	160	240
11% (1 in 9)	60	115	180	260
10% (1 in 10)	65	130	210	300
8% (1 in 12)	80	165	250	350

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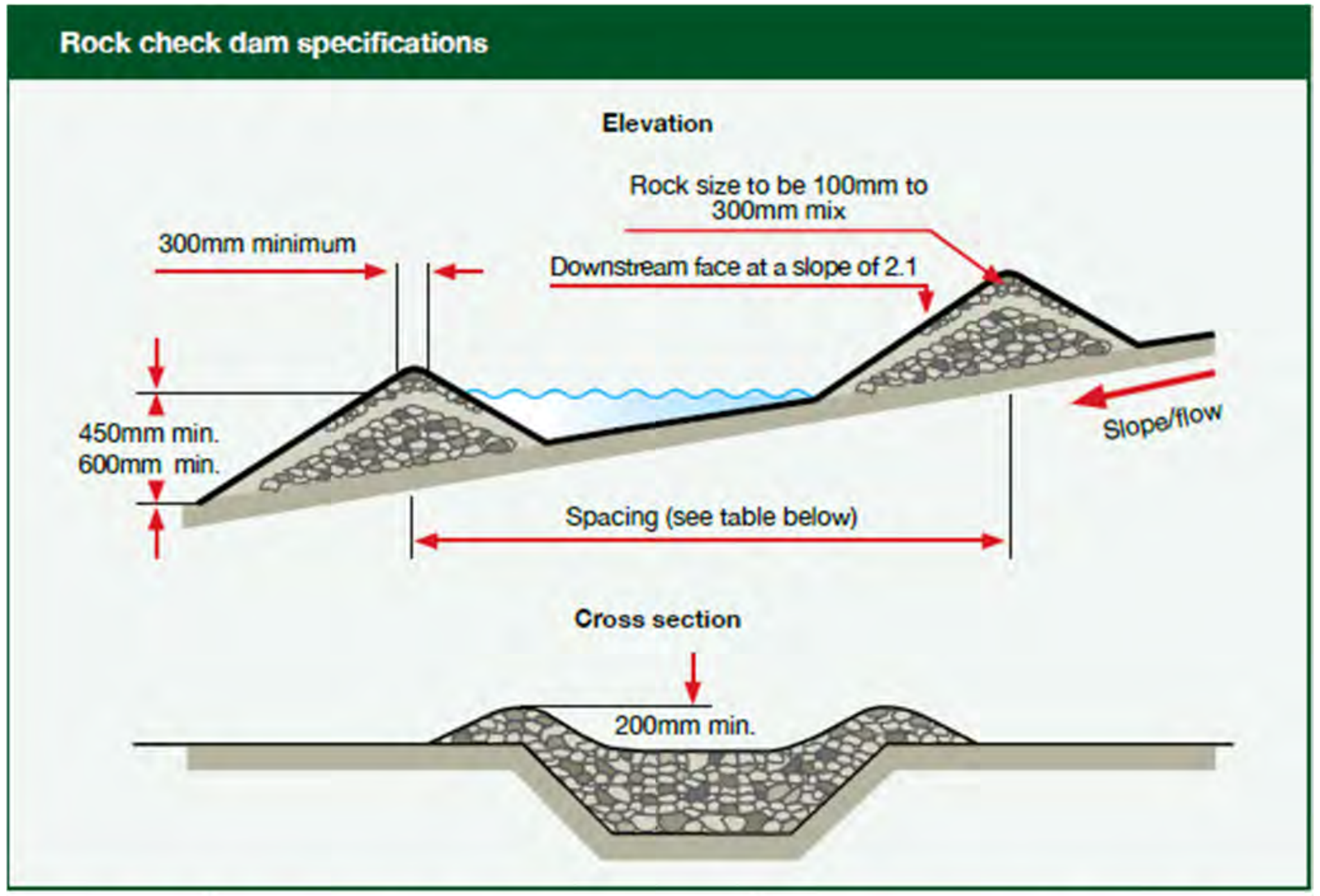
Project: Skyline – Reavers Slip Repair				
Description: Erosion and Sediment Control Plan - Schematics				
Drawn	**Approved**	**Date**	**Drawing Number**	**Revision**
TG	TG	18/07/2024	ESCP - 007	E

CHECK DAMS

(Page 127 from NZFOA)



Slope	Spacing (m) between dams (450mm centre height)	Spacing (m) between dams (600mm centre height)
2% or less	24	30
2% to 4%	12	15
4% to 7%	8	11
7% to 10%	5	6
over 10%	Use stabilised channel	Use stabilised channel

- Check dams will be constructed out of 100 – 300 mm mix rock or sandbags.
- Check dam spacing will vary throughout the site dependant on the track gradient. Spacings shall be determined according to the table above.

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Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan - Schematics

Drawn	Approved	Date	Drawing Number	Revision
TG	TG	18/07/2024	ESCP - 008	E

SOCKS

Pages 133-135 from NZFOA

- Culvert socks are to be installed on the outlet of culverts to protect earthworks from erosion, particularly areas of fill.
- Culvert socks will also be utilised to manipulate the culvert discharge location to reduce erosion of sensitive areas and keep flows within the same natural catchment as required.
- Culvert socks are to be clamped to the outlet of the culvert and secured to the approved location by anchoring the sock eyelets to the ground.
- Ensure the sock is installed on a slope with a minimum gradient of 5%.

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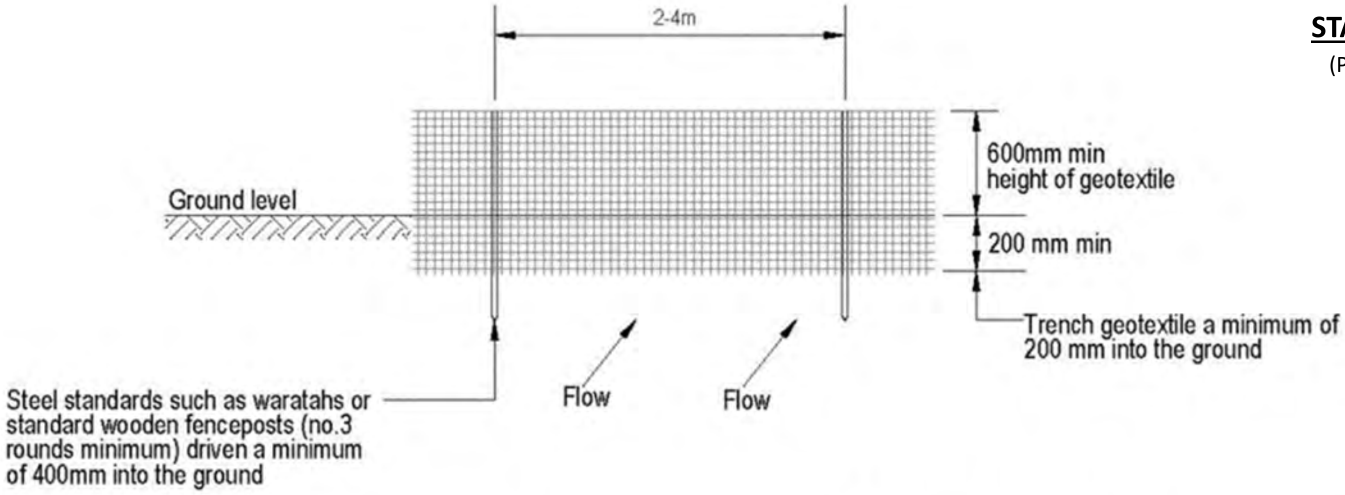
Project: Skyline – Reavers Slip Repair

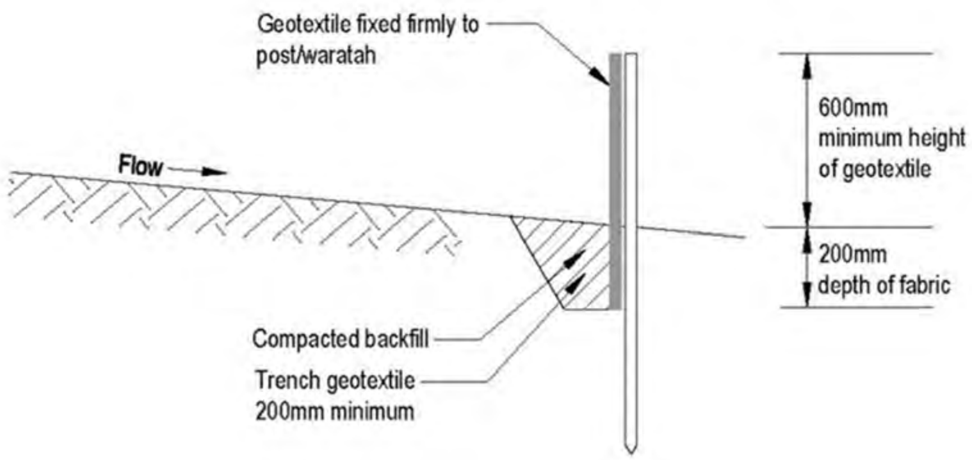
Description: Erosion and Sediment Control Plan - Schematics

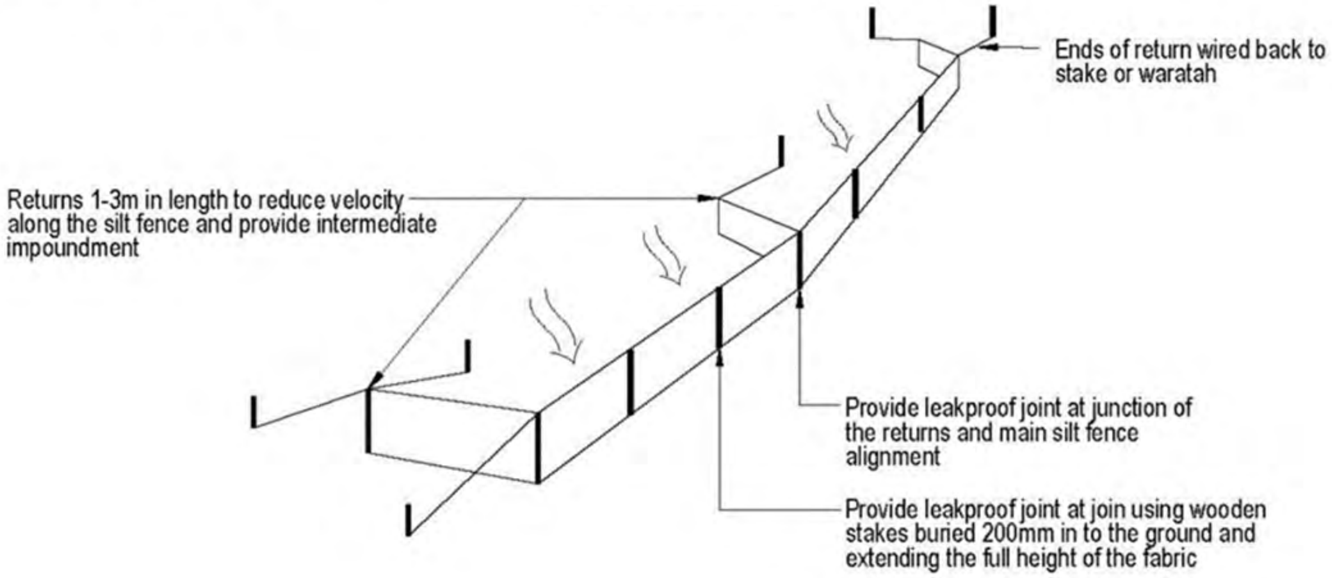
Drawn	Approved	Date	Drawing Number	Revision
TG	TG	18/07/2024	ESCP - 009	E

STANDARD SILT FENCE

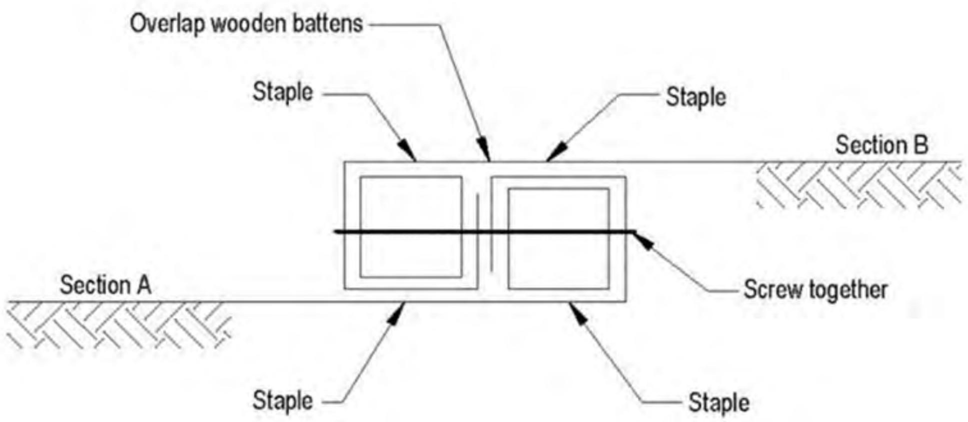
(Page 112-119 from GD05)







Slope steepness (%)	Slope length (m) (maximum)	Spacing of returns (m)	Silt fence length (m) (maximum)
Less than 2%	Unlimited	N/A	Unlimited
2- 10%	40	60	300
10- 20%	30	50	230
20- 33%	20	40	150
33- 50%	15	30	75
Greater than 50%	6	20	40



- Ensure the silt fence is ‘keyed’ into the ground to form a good seal at ground level to capture water and avoid undermining.
- Silt fences should be 600 mm above ground level and 200 mm below ground level.
- Supporting waratahs should be placed at 2-4 m intervals.
- Returns should be formed at either end facing upslope to contain flows.
- It is also important that silt fences are installed along the contour of the slope to prevent ponding of water in a concentrated area of the fence.
- To be mucked out once 20% capacity reached.

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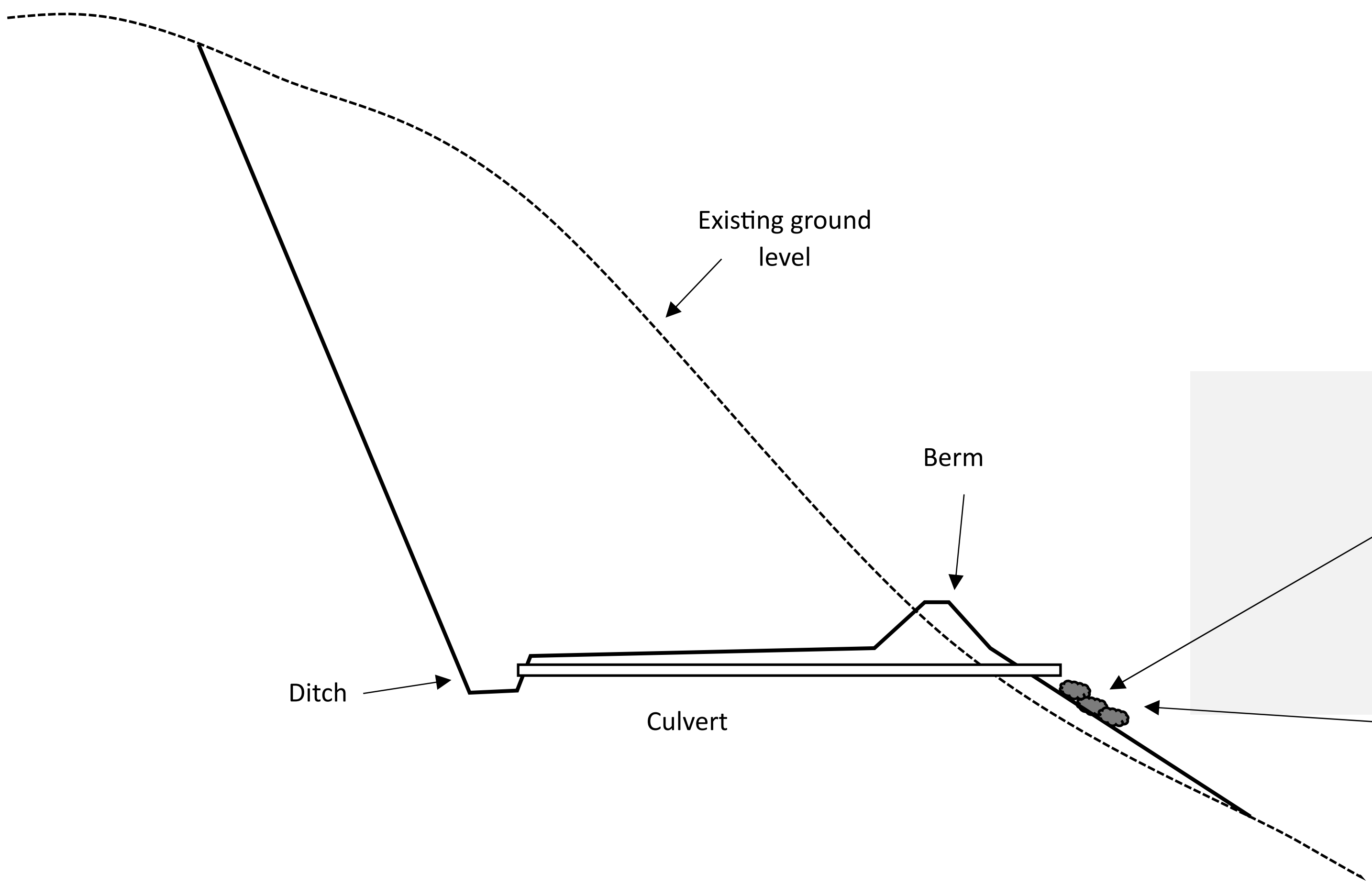
Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan - Schematics

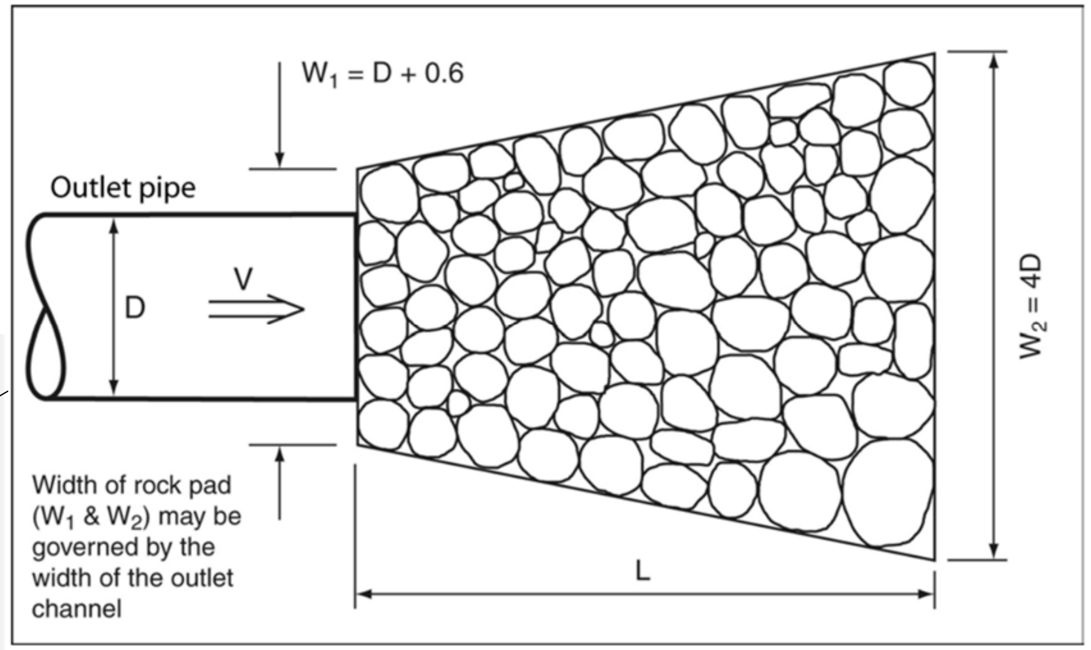
Drawn	Approved	Date	Drawing Number	Revision
TG	TG	18/07/2024	ESCP - 010	E

ACCESS TRACK CONSTRUCTION



ROCK ARMOURING CULVERT OUTLET

Page 38 of *Erosion and Sediment Control: A Field Guide for Construction Site Managers*. Catchments & Creeks Pty Limited. Witheridge, G. (2010).



Rock armouring is to be constructed in accordance with engineering design.

Schematic sourced from: Witheridge, G. (2010). *Erosion and Sediment Control: A Field Guide for Construction Site Managers*. Catchments & Creeks Pty Limited.

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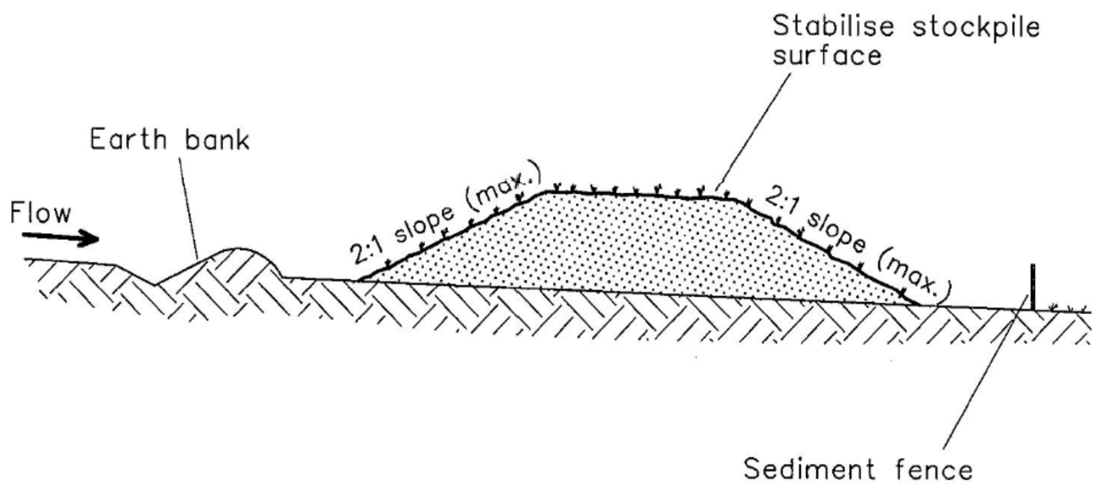
Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan - Schematics

Drawn	Approved	Date	Drawing Number	Revision
TG	TG	18/07/2024	ESCP - 011	E

TEMPORARY STOCKPILES



- Temporary stockpiles should be a maximum height of two metres to mitigate wind effects and to preserve the quality of the topsoil as future planting media for revegetation.
- If the stockpile is to be left insitu for a period of 12 weeks or more it shall be seeded with grass or erosion control matting to provide erosion and dust protection.
- A silt fence should be installed on the downslope of the stockpile.

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Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan - Schematics

Drawn	Approved	Date	Drawing Number	Revision
TG	TG	18/07/2024	ESCP - 012	E

REFUELING BAY

- Where possible construct a hardstand as far as practicably possible from waterways and concentrated flows.
- Ensure spill kit is located nearby.

CONCRETE WASHOUT PIT

- The concrete wash out pit consists of a plastic-lined bunded pit constructed with fill or straw bales.
- After concrete washout any water shall be left to evaporate.
- Cured concrete is to be disposed of within the plastic sheet to a licensed facility.

SPILL KITS

- One 240 L Oil and Hydrocarbon spill kit and one 240 L Chemical spill kit will be located in close proximity to the location of liquid hazardous materials storage and refuelling areas.

WASTE

- Where possible, waste shall be segregated into labelled bins.
- Wastes on site will be suitably contained and prevented from escaping off site. This may include covering skip bins during high winds.
- Waste storage is not permitted in or near drainage paths.
- Wastes will be removed from site when bin is full.

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Project: Skyline – Reavers Slip Repair

Description: Erosion and Sediment Control Plan - Schematics

Drawn	Approved	Date	Drawing Number	Revision
TG	TG	18/07/2024	ESCP - 013	E

APPENDIX 2 Calculations for Erosion and Sediment Controls

CATCHMENT AND CULVERT CALCULATIONS - REAVERS SLIP REPAIR

Catchment	Individual CatchmentApprox Area (m2)	Individual Qp L/sec	Combined Catchment Area (m2)	Combined Qp L/sec	Minimum Culvert Diameter Recommended (mm)*	% Buffer on recommended culvert
1	6,800	37.1	6,800	37.1	325	834
2	2,200	12	2,200	12	325	2,786
3	600	3.3	600	3.3	325	10,482
4a	550	3	550	3	325	11,444
4b	525	2.9	1,075	5.9	325	5,860
5a	12,400	67.6	12,400	67.6	325	412
5b	600	3.3	13,000	70.9	325	388
5c	750	4.1	13,750	75	325	362
5d	1,400	7.6	15,150	82.6	325	320
6a	6,000	32.7	6,000	32.7	325	958
6b	3,300	18	9,300	50.7	325	583
7	5,850	31.9	5,850	31.9	325	985
Total	40,975					

CATCHMENT- SKYLINE - REAVERS SLIP REPAIR

Specifications	Value 1	Value 2	Value 3	Value 4	Value 5	Units	Reference/Notes
Site Details							
Contributing catchment					1.5	ha	Worst case - largest contributing catchment
Design rainfall event					0.05	AEP	
Time of Concentration							
Overland sheet flow path length (L)					135	m	
Hortons roughness value (n)					0.2		Very steep, heavily forested catchment
Slope of surface (S)					77.4	%	
Time of Concentration (Tc)					5.7	minutes	
Rounded Tc to align with HIRDS					10	minutes	10 minute minimum required if Tc <10
Rational Method: Q = (C*I*A)/360							
Area ground cover	Grass	Concrete	Forest	Shrubs	Bare soil		
Proportion of catchment	0	0	0.85	0	0.15		
Runoff coefficient (C)	0.4	1	0.4	0.5	0.9		Manning's Roughness Coefficient (n)
Rainfall intensity (I)	41.3	41.3	41.3	41.3	41.3	mm	
Catchment Area (A)	0.00	0.00	1.28	0.00	0.23	ha	
Qp (Peak runoff flow)	0.0000	0.0000	0.0585	0.0000	0.0232	m3/s	Rational Method: Q = CIA
Total Qp (Peak runoff flow)					0.0817		

CULVERT SIZING - SKYLINE - REAVERS SLIP REPAIR

Specifications	1	2	3	4	Value	Units	Reference/Notes
Pipe diameter					325	mm	
Pipe material					Drainage coil		
Pipe length					6	m	
Drop					0.2	m	
Flow velocity					4.17	m/s	
Flow discharge					0.346	m3/s	Provides necessary capacity for worse case scenario
Flow discharge in L/s					346	L/s	
Buffer					323	%	

DITCH CALCULATIONS - SKYLINE- REAVERS SLIP REPAIR

Specifications			Units	Reference/Notes
Site Details				
Contributing catchment		1.5	ha	
Design rainfall event		0.05	AEP	5% AEP as required by GD05
Time of Concentration				
Overland sheet flow path length (L)		65	m	
Hortons roughness value (n)		0.2		
Slope of surface (S)		60.0	%	
Time of Concentration (Tc)		4.7	minutes	
Rounded Tc to align with HIRDS		10	minutes	10 minute minimum required if Tc <10
Rational Method: Q = (C*I*A)/360				
Area ground cover	Bare soil	Forest		
Proportion of catchment	0.2	0.8		
Runoff coefficient (C)	0.6	0.3		Manning's Roughness Coefficient (n)
Rainfall intensity (I)	31.7	31.7	mm	NIWA HIRDS, 10 min (Tc), 5% AEP
Catchment Area (A)	0.30	1.20	ha	
Qp (Peak runoff flow)	0.0159	0.0264	m3/s	Rational Method: Q = CIA
Total Qp (Peak runoff flow)		0.0423		
Channel Design - NZFOA				Manning's Formula Uniform Trapezoidal Channel Flow
Bottom Width		600	mm	
Batter ratio= 1 to		2	ratio	
Manning's roughness coefficient of channel (n)		0.025		Gravelly earth channel
Channel slope		25	%	
Flow depth		300	mm	
Channel depth		500	mm	
Flow (Q)		2.1859	m3/s	
Buffer		5072	%	
Top width		1500	mm	
Channel Design - GDO5				Manning's Formula Uniform Trapezoidal Channel Flow
Bottom Width		200	mm	
Batter ratio= 1 to		1	ratio	
Manning's roughness coefficient of channel (n)		0.025		Gravelly earth channel
Channel slope		25	%	
Flow depth		200	mm	
Channel depth		400	mm	200 mm freeboard selected rather than 300 mm as per GD05 to reflect the significantly less intensive rain in Central Otago (approx. 50% as intense as Auckland)
Flow (Q)		0.3549	m3/s	
Buffer		740	%	
Top width		800	mm	

APPENDIX 3 Environmental Site Induction Handout

ENVIRONMENTAL SITE INDUCTION HANDOUT

Key Roles and Responsibilities

Role	Responsibilities
Project Manager	The Project Manager is responsible for the effective implementation of the EMP and has overall responsibility for the environmental performance of the project. Duties include: • Ensuring adequate resources are in place to implement the EMP. • Ensuring all staff and sub-contractors operate within the guidelines of the EMP. • Ensuring that an EMP is prepared and that environmental standards, processes and procedures meet relevant resource consent conditions. • Overseeing the successful implementation, monitoring and review of the EMP. • Ensuring that inspections are carried out in accordance with the relevant EMP. • Restricting or stopping any activity that has the potential to or has caused adverse environmental effects. • Providing notification and reporting of Environmental Incidents to Council and other environmental reports as required by The Guidelines. • Delegating authority of the above responsibilities.
Environmental Representative	The Environmental Representative supports the Project Manager in the day-to-day implementation of the EMP. Duties include: • Ensuring the installation of environmental controls as per the EMP. • Undertaking environmental site inspections. • Overseeing the maintenance and improvement of defective environmental controls. • Providing environmental inductions to all staff and sub-contractors. • Assisting the project leadership in attending to Environmental Incidents and Complaints. The Environmental Representative shall be familiar with environmental risks associated with the project, the EMP and best practice erosion and sediment control principles and practices.
All staff and sub-contractors	All staff and sub-contractors have a responsibility to undertake all activities in accordance with the requirements of this EMP. This includes reporting any activity that has the potential to or has resulted in an Environmental Incident to the Project Manager or Environmental Representative.

Key Environmental Locations

Environmentally sensitive receptors: Reavers Creek, nearby residential dwellings at the outlet of Reavers Creek, recreational users of Skylines Luging facilities, mountain bike trails and Tiki Trail.

Key Resource Consent Conditions

All resource consent conditions are important to comply with in order to avoid or mitigate adverse environmental effects.

The site EMP has been prepared in response to all environmental-related conditions of consent and therefore provides direction for how compliance with these conditions will be achieved. Provided that the EMP is followed, the project will at the same time comply with all conditions of consent.

Limits of Clearing

The sequencing of works is a key component to ensure that environmental effects of construction are appropriately managed. It is imperative that the sequencing outlined in Section 2.1 of the EMP is followed so that the site is stabilised in the most efficient manner.

All staff should be familiar with this sequence. Any potential changes to that sequence need to be approved by the Project Manager which will be discussed first with the Environmental Consultant.

Key Environmental Management Measures in EMP

Erosion and Sediment Control (Section 4 of EMP)

- Direction provided in Erosion and Sediment Control Plan (ESCP) in Appendix 1 of EMP.
- Separation of clean and dirty water is the most important principle to ensure that the contributing catchment of dirty water that needs to be treated is as small as possible.
- Progressive stabilisation (revegetation) of disturbed areas will ensure that the extent and duration of exposed soil is minimised. Keep it covered!
- All controls to be checked immediately before storm events to ensure they are in good-working order.
- Erosion and sediment control devices to remain in place until site is stabilised (defined as 80% vegetative cover).

Any works that disturb the controls outlined on the ESCP must be reinstated before moving to the next task.

Water Quality Management (Section 5 of EMP)

- Any water caught in the sediment devices to be re-used in dust suppression where possible and if required.
- Any observations of dirty water running offsite to be reported directly to the Project Manager.

Dust Management (Section 6 of EMP)

- Dust suppression should occur on any exposed soil on unsealed roads, this can be done using the water caught in the retention basin.
- Avoid all unnecessary vegetation clearing that exposes soil and work should be conducted in stages as this can increase the impact from dust in the event of strong winds.
- During high wind events and dust suppression is becoming difficult works must cease until more favourable weather conditions.
- Constant vigilance should be maintained onsite to ensure that dust is appropriately managed and weekly monitoring should be completed to ensure that management measures are effective.

Noise and Vibration Management (Section 7 of EMP)

- Noise producing works only be undertaken during the hours of 0730-1800 from Monday-Saturday and no works to be completed on Sundays or public holidays.
- Particularly noisy work should be completed during the middle of the day during business hours.
- Noise dampening should occur when possible.
- Weekly site inspections should be undertaken by the Environmental Representative to ensure the strategies in place are effective.

Historic Heritage Management (Section 8 of EMP)

- If any artefacts are found works must stop within 20 meters of the discovery and the site manager notified immediately.
- The site manager must then secure the area and notify the Heritage New Zealand Regional Archaeologist, who will advise when works can begin again.

Vegetation Management (Section 9 of EMP)

- Maintain vegetated surfaces as far as reasonably possible.
- Maintain protected or indigenous vegetation.
- Complete all landscaping and or ecological restoration in accordance with approved plans.

Chemicals and Fuel Management (Section 10 of EMP)

- Chemicals and fuels are stored and used so not to cause contamination of works areas and surrounding environment.

Waste Management (Section 11 of EMP)

- Waste management on site will ensure wastes are stored safely and in an organised manner until recycling, reuse or disposal.

Contaminated Land Management (Section 12 of EMP)

- Prevent spread of contamination.
- Engage the Environmental Consultant (SQEP) to ensure that the site can be managed in accordance with statuary requirements (i.e., National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health).

Environmental Incidents

The procedure for managing environmental incidents is outlined in Section 3.5 of the EMP, however these can be summarised as follows:

- Environmental incidents must be reported as soon as they occur, and the Project team must respond immediately to mitigate further environmental impacts.
- Investigation into the cause of the incident should be completed and a solution should be constructed to remediate the Environmental damage.
- The Project Manager must then notify the QLDC and/or the ORC of the details of the incident within

12 hours of being made aware of the incident.

Rapid Response for Storm Events

The procedure for rapid response to storm events is outlined in Section 4.6 of the EMP, however these can be summarised as follows:

- The Project Manager will observe and understand the **weather forecast** throughout the project to ensure appropriate preparation onsite.
- If a **significant storm** event is forecast all works should stop within an appropriate amount of time to inspect ESC devices and undertake any maintenance or site stabilisation required.
- The sediment controls should be in operating condition and fully functional.
- During the storm event the site should be monitored to sure the functioning of the ESC devices and maintained if required.

When storms are forecast it is crucial that tools are downed in time for the rapid response procedure to be implemented. This will help avoid environmental incidents, potential enforcement action and site shutdown.

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APPENDIX 4 Environmental Site Induction Register