Rockfall Protection Structures Maintenance Guideline

Waka Kotahi

June 2023

Version 1.0

WAKA KOTAHI
NZ TRANSPORT AGENCY

Te Kāwanatanga o Aotearoa
New Zealand Government

Rockfall Protection Structures Maintenance Guideline for Waka Kotahi Infrastructure

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June 2023

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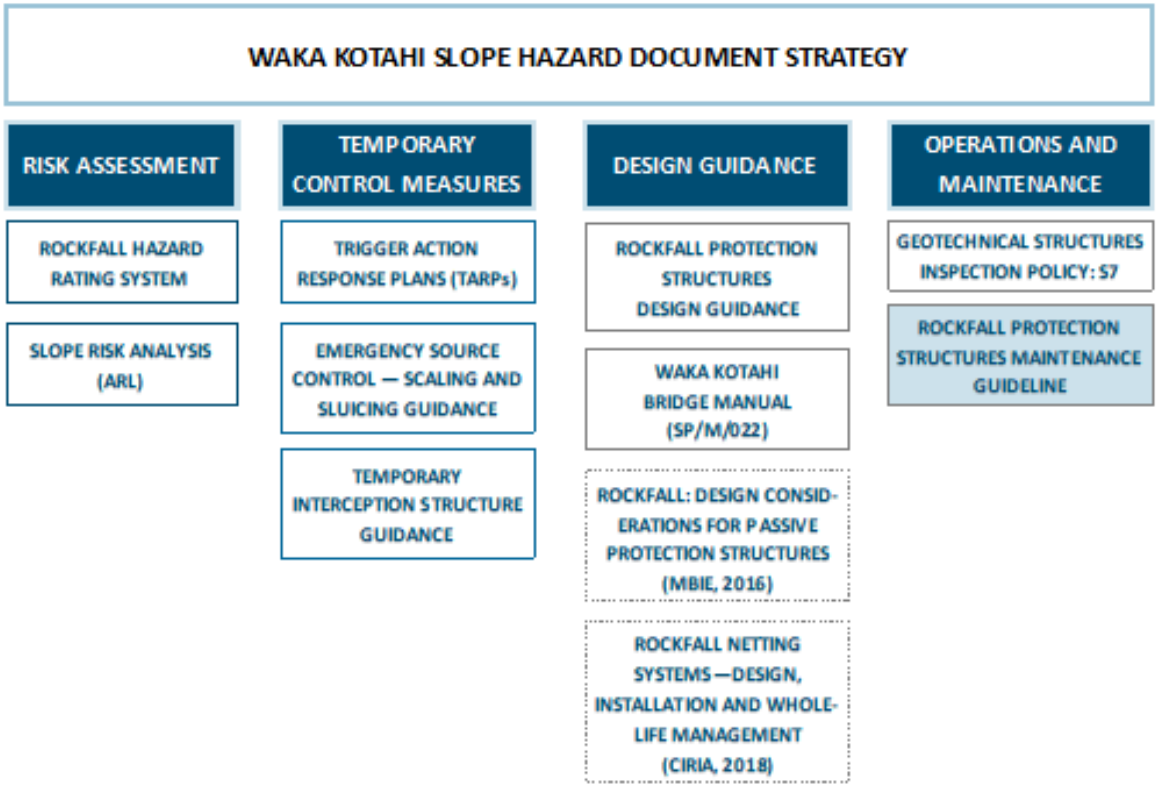
Contents

Foreword

The aim of this document is to outline considerations for the maintenance of rockfall protection structures (RPS) and provides high-level Waka Kotahi specific guidance, considerations, and references for the maintenance and repair of rockfall protections structures protecting Waka Kotahi infrastructure.

This guideline aligns with the S7: Geotechnical Structure Inspection policy and provides maintenance considerations and approaches for rockfall protection structures.

The relationship of the Waka Kotahi Rockfall Protection Structures Maintenance Guideline to other documents in the Waka Kotahi Slope Hazard document strategy is illustrated below.



1. Introduction

1.1. Purpose

The purpose of this document is to provide guidance for the maintenance of Rockfall Protection Structures (RPS) across Waka Kotahi infrastructure. This guideline provides an overarching manual relating to the common components across the various rockfall protection structures.

This guideline does not provide design guidance for rockfall protection structures as this is covered in the Waka Kotahi Rockfall Protection Structures Design Guideline.

1.2. Scope

This guideline provides an overview of maintenance inspections; considerations for the inspection of common RPS elements; and examples of when maintenance intervention would be required.

Inspection requirements are detailed in the *Waka Kotahi Geotechnical Structures Inspection Policy S7.*

Structure specific maintenance plans (SSMP), developed during design of individual structures, detail the specific requirements to maintain and operate the specific system to ensure long-term performance, an example being provided in Appendix B. Where a SSMP has been developed, it takes precedence over the guidance presented herein.

1.3. Rockfall Protection Structures

The rockfall protection structures included in this document are outlined in Table 1. If this guideline conflicts with any requirements of the Manufacturers' specific maintenance documents, the requirements of the Manufacturer's documentation takes precedence. In addition, any project and/or site-specific maintenance documentation should be reviewed in conjunction with this document.

1.4. Cultural and Environmental Management Plans

Many areas along the Waka Kotahi roading network have a high cultural significance. For maintenance works involving material clearance, the Waka Kotahi Project Manager and Contractor should review any relevant Cultural Management Plans (CMP) and Environmental Management Plans (EMP) and liaise with local stakeholders to ensure the appropriate steps are taken prior to starting clearance works.

CMPs and EMPs are commonly live documents and are typically included in the structure specific maintenance plan (SSMP) where one exists.

Environment and sustainability requirements can be found through the Waka Kotahi Highways Information Portal at https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/environment-and-sustainability-in-our-operations/ and discussed/agreed with the Waka Kotahi Project Manager.

1.5. Advanced Monitoring and Technology

There are several technologies currently in development that may be utilised to improve efficiencies and safety of ongoing maintenance of rockfall protection structures. These range from the current use of UAVs and drones to undertake the piloted or automated capture of aerial imagery, real-time monitoring of systems available from a number of manufacturers, to the developing use of InSAR and asset-based reflectors to monitor change using satellites. This document is provided as a guideline and it is anticipated that, as these technologies develop further, their uses may be applied in ways yet foreseen and therefore changes to maintenance inspection may need to be adapted.

Table 1: Rockfall Protection Structures (RPS) - Types and Definitions

Term	Definition
Active Mesh	Steel mesh secured with ground anchors and/or rock bolts, installed over a slope with surficial instability, to secure surface material from travelling downslope. This system can provide both 'active' stabilisation to improve the overall stability of slopes and/or 'passive' stabilisation for surface rockfalls (commonly referred to as 'anchored mesh').
Anchor	A mechanical rod installed and grouted into the ground to restrain or provide support for engineered slopes and other structures (include the following sub-categories - ground anchor, rock bolt.)
Assessed Risk Level (ARL)	The approach to assess risk to road users by determining the likelihood of a hazard occurring and consequences of the occurrence, using the New South Wales (NSW) Roads and Maritime Services (RMS) Assess Risk Level (ARL) risk assessment approach (and NZ Country Amendment).
Asset Owner	The controlling authority of the geotechnical structure, Waka Kotahi (NZ Transport Agency)
Attenuator	An engineered system installed on a slope to progressively reduce the energy, velocity, and bounce heights of rockfall, and direct material into a catch area or structure downslope.
Bund	An embankment that is used as a passive rockfall protection structure, can be constructed from a variety of materials including, earth/rock (sometimes reinforced), concrete blocks, gabion baskets
Catch Area / Debris Flow Basin	Areas designated for the catchment of rockfall, slope material and debris flows. May be standalone engineered ditch or incorporated into other structures such as the areas upslope of fences, barrier, and bunds where material may collect.
Designer	An engineering geologist or geotechnical engineer, who is responsible for undertaking the initial assessment, determining the suitability of the structure, and calculating the required loads and support elements for a structure. Designers' to have at least five years' experience in the design of geotechnical structures.
Design Reviewer	Responsible for the verification of design and confirmation of suitability of the structure and supporting design calculations. As a minimum a chartered member (CPEng or PEng Geol) geotechnical engineering or engineering geologist with at least 10 years of relevant experience, including rockfall protection design and infrastructure works and should be approved by the Waka Kotahi NZ Transport Agency Lead Technical Advisor - Geotechnical
Debris Flow Barrier	Proprietary systems designed to contain soil and water torrents (debris flows), often placed in natural gullies, channels, or chutes.
Drape (Draped Mesh)	Steel nets or mesh draped over a slope supported by a bearing rope system anchored to the top of the slope. The draped mesh allows for surficial slope failures to occur behind the mesh, but guides material down to the toe of the slope, restricting outward movement (commonly referred to as 'simple drapery' and 'draped netting')
Geohazard	An object, feature or activity related to the natural or engineered ground (including geotechnical structures) that has the potential to have adverse effects or undesirable consequences.

Hazard	An object, feature or activity that has the potential to have adverse effects and undesirable consequences.
Low-Energy Rockfall Fence	Non-proprietary systems intended to intercept rockfall these systems vary in construction, are generally untested or certified, and unlikely to be designed to a specific standard.
Monitoring	The recording of quantitative information to document the changes in characteristics.
Network Criticality	The attributes of the road network at a given location and time that relate to its importance.
Network Outcome Contract (NOC)	The Waka Kotahi contract to manage the operation and maintenance of the roading networks within each region.
Rigid Barrier	Non-proprietary system constructed from rigid (non-flexible) components, such as concrete blocks, steel posts or timber, intended to contain or deflect rockfall or slope material and retain within a catch area.
Rock Bolting	Rock bolts or anchors installed as a single system intended to support single blocks or boulders.
Rockfall Sheds	Reinforced concrete roof structures that are covered with an energy-absorbing material or angled such that material is deflected over the structure.
Rockfall Barrier	Proprietary rockfall protection systems designed to contain rockfall through energy dissipation that are certified to EAD 340059-00-00106 (supersedes, ETAG-027) or equivalent. Including flexible rockfall fences, shallow landslide barriers, rockfall canopies and rockfall galleries.
Rockfall Protection Structure (RPS)	An engineered system design to reduce the risk from rockfall (and in some cases shallow debris slides).
Significant Event	A natural event, such as seismic, weather, or volcanic, that is beyond the expected conditions. Thresholds for a significant event will be specific to each section of roading network.
Source	The location at which rockfall or debris material is released from the slope, often an outcrop of rock or shallow failure.
Triggers	A factor or event that causes a hazard to be realised.

2. Maintenance Inspections

The maintenance and associated inspections of the rockfall protection structures can be categorised into two distinct groups:

- Scheduled (ordinary); and
- Post-Event (extraordinary)

Scheduled structure inspections will form the most common type of periodic activity for the structures to confirm that they are operating as intended. The type, frequency, reporting requirements and responsibilities are detailed in the *Waka Kotahi Geotechnical Structures Inspection Policy S7.*

Post-Event inspections will be required following significant trigger events. These events are likely to cause a significant slope failure with the protection system possibly engaged to over 25% of its designed capacity.

For both types of inspections, the requirements for information management are similar including the capture and storage of inspection and maintenance data, being the responsibility of the Geotechnical Advisor. Further details in *Waka Kotahi Geotechnical Structures Inspection Policy S7*

For all maintenance inspections, and especially during post-event inspections due to the potential increase in risk at the rockfall protection structure following an event, it is recommended a detailed safe working methodology statement (SWMS) is developed prior to the inspection and maintenance. This SWMS should incorporate the specific Safety in Design elements identified for the site, with a focus on the geohazard particular to the site, safe access, and emergency recovery plan.

2.1. Maintenance Inspection Roles

The roles for maintenance inspection are detailed in *Waka Kotahi Geotechnical Structures Inspection Policy S7* and summarised below in Table 2.

Table 2: Maintenance Inspection Roles

Inspector	Code	Role
Network Outcomes Contract – Contract Inspector	NOC	The contractor inspection personnel, representing the Waka Kotahi contract to manage the operation and maintenance of the roading networks within each region.
Geotechnical Management Consultant	GMC	A consulting firm responsible for the operational management activities associated with the geotechnical structures.
Geotechnical Advisor	GA	A chartered member (CPEng or PEng Geol) geotechnical engineering or engineering geologist with at least 10 years of relevant experience in ground engineering and infrastructure works and approved by the Waka Kotahi NZ Transport Agency Lead Technical Advisor - Geotechnical.
Lead Geotechnical Engineer	LGE	An engineering geologist or geotechnical engineering appointed by the GA who is responsible for inspections having at least five years' experience in the design of geotechnical structures and able to interpret observations in terms of structural action.
Geotechnical Inspector	GI	A professional engineer or a person who, from extensive practical experience, is competent to judge the condition of structures. The Geotechnical Inspector with at least five years of experience in the maintenance of geotechnical structures along infrastructure networks.

2.2. Scheduled Maintenance Inspections

Scheduled maintenance inspections covering all inspection items of a rockfall protection structure, outlined in Table 3 below, are recommended in the first year of the structures design working life; generally at the end of any defects liability period. If the initial inspections result in no significant changes in the system that could otherwise impact the safety and functioning of the protection system, the inspection frequency can be extended to correspond with Table 3, below.

Table 3: Scheduled Inspection and Maintenance

Frequency of Inspection	Inspector[1]	Component	Inspection	Corresponding Maintenance
3 monthly	NOC	Catch Area	Check for any recent material within the debris catch area.	Notify the GMC once material is greater than a quarter (1/4) full at any point, or at the toe of a rigid barrier, or accumulating around the base of barrier posts.
1 year	NOC	Vegetation	Check for vegetation that may block a visual inspection and check access for inspections and maintenance is clear. Notify GMC of vegetation changes.	As determined by the GMC, reduce vegetation through removal of large trees and bushes, bush trimming where necessary.
3 years	GI	Source Area	Undertake a detailed inspection of the source area and all exposed hardware using roped access where possible and applicable.	If defects or damage is identified, replace or if minor, monitor for change.
Initial inspection or if visual inspection indicates change	GI	Wire Rope Grips / Clamps	Check to correct tightening of wire rope clamps on steel ropes.	Re-tighten to the required torque (Section 3.7)
3 years	GI	Wire Rope Grips / Clamps	Visual inspection of wire rope grips.	Only recheck torque once visual indicates a need
3 years	GI	Mesh	Check for collected debris and vegetation within mesh. Check for erosion and instability of the underlying slope.	Clear possibly by hand any debris or vegetation that may modify the behaviour of the system. Repair elements or slope affected by debris or erosion.

Frequency of Inspection	Inspector[1]	Component	Inspection	Corresponding Maintenance
3 years	GI	Barrier Height	Check rockfall barriers that the top rope is near-horizontal, and the mesh height has not drooped between posts	Notify the GMC of any droop or reduction in effective height of the mesh. If required, re-tighten system to reinstate effective height of barrier
3 years	GI	Underlying Slope	Monitor vegetation re-establishment.	Re-vegetate and hydroseed as required, additional topsoil may be needed.
3 years	GI	Corrosion Protection (inc. Denso wrap and epoxy coatings)	Check there are two applications ('wraps') of Denso Tape, and epoxy coatings are intact	Replace any missing wraps of Denso tape, and repair epoxy coatings as required (Section 3.9)
5 years	GI / LGE	Overall System	Check the overall status of the system, especially the anti-corrosion protection for all metal components.	If defects or damage is identified, replace or if minor, monitor for change. Any component with >2% visible rusting should be protected or replaced if not practicable to apply new corrosion protection.
25 year – or if anchor creep is observed	GI / LGE	Anchors	Undertake anchor acceptance testing in accordance with BS EN 1537:2013.	Replace anchors that fail acceptance testing. Consideration should be given to new anchor locations.
As determined by GMC	As determined by GMC	Defects	Monitor change of known minor defects.	Record changes and if system is compromised replace the required elements.

The range of frequencies of inspections provided in Table 3, are indicative and may be dependent on the slope activity, performance, age and specific location of each element.

It is recommended that aerial visual inspections are undertaken using a helicopter or UAV (drone) to assess the source areas and structures on slope. There should be no access behind (upslope) structures and/or into the debris catch areas without appropriate safety measure in place.

2.3. Trigger Events

Trigger events will be specific to several factors including the location of the RPS and slope failure to which they are mitigating, and details of expected trigger events should be included in the site-specific maintenance plans.

If there are no site-specific trigger events identified in the SSMP or design information, then Figure 1 and Table 4 below can be used to guide expected trigger events with a regional perspective, however these are provided for guidance only, as there will be large variability of triggering events across regions.

Specific triggering events should be determined for each structure by the GMC using local experience, analysis of High Intensity Rainfall Design System (HIRDS) data, Waka Kotahi's Bridge Manual or the GNS National Seismic Hazard model. Site specific triggers, such as snow, ice, volcanic ash, or scour should also be considered.

Figure 1: Map of Regions considered for Trigger Events

Table 4: The Regional Trigger Events for Post-Event Inspection

Region	Rainfall Duration*	Rainfall Intensity**	Earthquake*** (MMI)
Northland	48 - 72hrs	25mm/hr	V
Auckland	48 – 72 hrs	25mm/hr	VI
Waikato	72hrs +	20mm/hr	VI
Bay of Plenty	72hrs +	30mm/hr	VII
Gisborne	48 – 72 hrs	15mm/hr	VII
Hawke's Bay	48 – 72 hrs	15mm/hr	VII
Taranaki	48 – 72 hrs	25mm/hr	VI
Manawatu Wanganui	48 – 72 hrs	15mm/hr	VII
Wellington	48 – 72 hrs	15mm/hr	VII
Tasman	72hrs +	25mm/hr	VI
Nelson	48 – 72 hrs	20mm/hr	VII
Marlborough	48 – 72 hrs	10mm/hour	VII
Canterbury	48 – 72 hrs	10mm/hour	VII
West Coast	72hrs +	25mm/hr	VII
Otago	48 - 72 hrs	15mm/hr	VI
Southland	48 - 72 hrs	15mm/hr	VII

*Rainfall duration triggers are based on NIWA's general annual moisture deficient for each region and used to determine the general frequency of long period rain events.

**Rainfall Intensity is based on the data from HIRDS for a 1h intensity for a 2-yr average reoccurrence interval (ARI) for the main metropolitan centres in each region.

***Seismic triggers are based on Figure 6.2(f) from the *Bridge Manual*.

Fire within the source area and/or location of rockfall protection structure will also trigger the need for a post-event inspection.

The Post-Event assessments will require engineering input to specify the works required to maintain or reinstate the protection system to the intended design capacity. The engineering input should be as directed by the Geotechnical Advisor.

2.4. Post-Event Maintenance Inspections

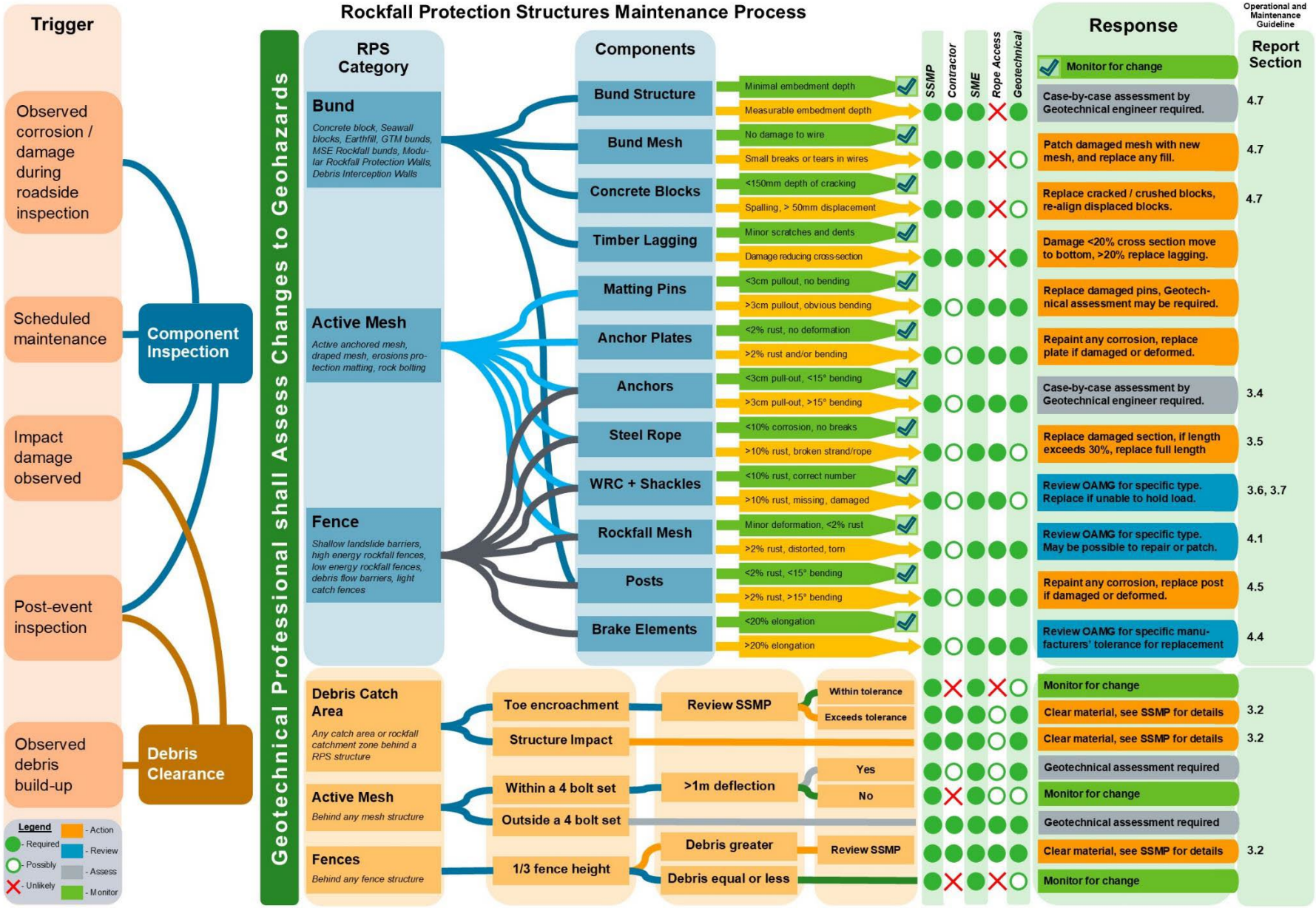
Additional inspections should be undertaken following a significant event, such as heavy rainfall, material impacting the structure or a 'strong' seismic event, as detailed in Section 2. Post-event assessments will be required to review any damage to the structures or changes to the hazard that may influence the suitability of the rockfall protection structure.

Each post-event inspection should begin with an assessment of the geohazard and whether the structure has been impacted or not. Provided the geohazard remains unchanged as a result of the event, and the structure has not been impacted by debris, a more detailed inspection is not required.

The post-event inspections and corresponding maintenance is outlined in Table 5. There is no set inspection frequency as the timing will be dictated by the occurrence of significant events.

Table 5: Post-Event Maintenance Inspections

Inspection Item	Inspector[1]	Corresponding Maintenance
Check the geohazards within the source area associated with the protection system and reported within the Design Report and associated documents. Check the hazards have not changed from the design scenario.	GMC	An increase in the scale of the geohazards may require additional measures to reduce risk. This work should be undertaken or directed by a suitably experienced geo-professional.
Check all of the energy dissipating and attenuating devices (ropes, energy absorbers, accessories, etc.).	GMC	Replace any of the energy dissipating elements that have activated as required by the relevant manual.
Check the interception structure (mesh panels and catchment areas). Check for accumulated material or evidence of impacts or debris build up.	NOC	Replace any spans of mesh that are lacerated and/or deformed, even partially. For active mesh systems, a small degree of deformation may be acceptable, refer to manufacturer or installer's reference documentation. Clear any material deposited within debris catch area.
Check the steel cables for scratches, unexpected deformation and any breaks. Check junction elements including sleeves, wire rope clamps, loops and thimbles for scratches, deformation or sliding.	GMC	Replace any elements that are damaged or deformed even partially.
Check the exposed section of the anchors for any signs of scratches deformation or down-hole movement. Check concrete foundations and plinths for signs of cracking or any other damage.	GMC	Replace any anchors and foundations that appear damaged or deformed, even partially. Realignment of the anchors may be required to avoid drilling too close to the existing anchor location.
Check the posts and base plates for any signs of damage, aggradation of material preventing movement or deformation.	GMC	Replace or repair any posts that are deformed or damaged. If posts are undamaged, they may be able to be restored to their original geometry through tensioning or replacing upslope anchors.
Check the status of the anti-corrosion coating in case movement has resulted in abrasions or contact with an aggressive substance.	GMC	If defects or damage to the anti-corrosion is identified, replace the element or, if minor, monitor periodically – refer to Scheduled Inspections and Maintenance.
Check the underlying slope for signs of erosion or deformation.	GMC	Replace any elements that are damaged or deformed and reinstate to satisfy design requirements.


Rockfall Protection Structures Maintenance Process
Trigger
Observed corrosion / damage during roadside inspection
Scheduled maintenance
Impact damage observed
Post-event inspection
Observed debris build-up
Component Inspection
Debris Clearance
Geotechnical Professional shall Assess Changes to Geohazards
RPS Category
Bund
Concrete block, Seawall blocks, Earthfill, GTM bunds, MSE Rockfall bunds, Modular Rockfall Protection Walls, Debris Interception Walls
Active Mesh
Active anchored mesh, draped mesh, erosions protection matting, rock bolting
Fence
Shallow landslide barriers, high energy rockfall fences, low energy rockfall fences, debris flow barriers, light catch fences
Components
Bund Structure
Bund Mesh
Concrete Blocks
Timber Lagging
Matting Pins
Anchor Plates
Anchors
Steel Rope
WRC + Shackles
Rockfall Mesh
Posts
Brake Elements
Minimal embedment depth
Measurable embedment depth
No damage to wire
Small breaks or tears in wires
<150mm depth of cracking
Spalling, > 50mm displacement
Minor scratches and dents
Damage reducing cross-section
<3cm pullout, no bending
>3cm pullout, obvious bending
<2% rust, no deformation
>2% rust and/or bending
<3cm pull-out, <15° bending
>3cm pull-out, >15° bending
<10% corrosion, no breaks
>10% rust, broken strand/rope
<10% rust, correct number
>10% rust, missing, damaged
Minor deformation, <2% rust
>2% rust, distorted, torn
<2% rust, <15° bending
>2% rust, >15° bending
<20% elongation
>20% elongation
SSMP
Contractor
SME
Rope Access
Geotechnical
Response
Operational and Maintenance Guideline
Report Section
Monitor for change
Case-by-case assessment by Geotechnical engineer required.
4.7
Patch damaged mesh with new mesh, and replace any fill.
4.7
Replace cracked / crushed blocks, re-align displaced blocks.
4.7
Damage <20% cross section move to bottom, >20% replace lagging.
Replace damaged pins, Geotechnical assessment may be required.
Repaint any corrosion, replace plate if damaged or deformed.
Case-by-case assessment by Geotechnical engineer required.
3.4
Replace damaged section, if length exceeds 30%, replace full length
3.5
Review OAMG for specific type. Replace if unable to hold load.
3.6, 3.7
Review OAMG for specific type. May be possible to repair or patch.
4.1
Repaint any corrosion, replace post if damaged or deformed.
4.5
Review OAMG for specific manufacturers' tolerance for replacement
4.4
Debris Catch Area
Any catch area or rockfall catchment zone behind a RPS structure
Active Mesh
Behind any mesh structure
Fences
Behind any fence structure
Toe encroachment
Structure Impact
Within a 4 bolt set
Outside a 4 bolt set
1/3 fence height
Review SSMP
>1m deflection
Debris greater
Debris equal or less
Within tolerance
Exceeds tolerance
Yes
No
Review SSMP
Monitor for change
Clear material, see SSMP for details
3.2
Clear material, see SSMP for details
3.2
Geotechnical assessment required
Monitor for change
Geotechnical assessment required
Clear material, see SSMP for details
3.2
Monitor for change
Legend
- Required
- Possibly
- Unlikely
- Action
- Review
- Assess
- Monitor

3. Guideline for Inspection and Maintenance of Common Elements

This section outlines recommended inspection checks and maintenance for key common elements within rockfall protection structures. Assessments of these items should always be considered in relation to the overall rockfall protection structure, and the associated manufacturers documentation. Examples of components and when intervention is required due to damage can be found in Section 7.

Any access into a debris catch area or behind a RPS should not be undertaken without appropriate safety measures in place. Personnel access should be avoided, and if not possible, then additional safety measures must be in place, i.e. within a protected cabin or additional temporary protection measures installed.

3.1. Debris Catch Area

A number of systems have specified debris catch areas to provide storage of failed material. The area will require a visual inspection during scheduled and post-event assessments to assess for any new debris deposits and gauge the remaining capacity. It is recommended visual inspections are completed using UAVs (drones) or helicopter to reduce the need for personnel access into debris catch areas. No personnel should access debris catch areas without appropriate safety measures in place.

Critical items to be check include:

- Any additional debris within the catch area – notification to the Geotechnical Advisor (GA) of the GMC is required if debris build up reaches a quarter (1/4) full at any point, or material reaches the toe of a rigid barrier or bund – check the site-specific maintenance plan for clearance requirements. If the debris has occurred as an impact, the GA needs be notified regardless of volume.
- Any obvious deformation of the debris catch area/bench including the downslope side.

If the debris catch area is impacted, damaged or shows signs of failure it should be repaired to satisfy the original design, with engineering input required from the GMC.

Image 1: An example of debris accumulation behind a non-proprietary rockfall fence.

Concrete barriers (F-Shape, etc.) are sometimes used to contain low-energy debris and material within the catch area. These concrete barriers should be checked as part of the debris catch system. If damage is

observed, such as; cracking, impact marks and movement from the original location, the barriers should be realigned, repaired, or replaced. Replacement of the concrete barrier will be required if repairing cannot achieve reinstatement to the original accepted design and geometrical conditions.

A variety of measures may be necessary to remove debris from the catch areas, which in some cases are located behind rockfall protection structures. Due to the risks involved during material removal, a competent contractor with experience in rockfall protection structures should be used.

During methodology development for clearance of material the preferred method should always focus on eliminating the need for personnel entering behind the protection system, and if not possible then additional physical controls should be in place prior to access.

Solutions include, but are not limited to:

- Debris removal using a crane, with a clam-shell / dredging bucket attachment, sitting in the transport corridor.
- Debris removal using a small excavator (~5 tonne) behind the rockfall protection structure and therefore appropriate excavator cab protection is required (such as ROPs, FOPs, and or remotely operated). For some systems, conventional excavators may be able to access the bench behind a structure, while at other locations it may be necessary to crane a small excavator into place. In some cases, supporting RPS cables may need to be temporarily moved to enable access (the supporting cables will be under tension and require a tirfor winch or similar to release safely).
- Debris removal using a long reach excavator sitting in the transport corridor. Appropriate excavator cab protection is required (such as ROPs, FOPs).
- With fences, it is possible to use a remotely operated hydraulic cutter to cut the support cables (bearing in mind that the cables can be under high tension loads) to allow debris to pass over/under the fence. It may be necessary to use sluicing or excavators to assist with moving the debris downslope. A contractor with suitable experience in rockfall fences should be used and will be required to re-construct the fence to the as-built construction drawings.

Image 2: An example of a remotely operated hydraulic wire rope cutter.

- For fences and barriers located adjacent to the road corridor, the bottom rope can be released or cut to enable the mesh to be lifted, providing access to the accumulated debris. Once the bottom rope is released, the mesh can be raised and secured to the top rope. An excavator can then clear the debris. Once clearance works are completed the bottom rope should be reattached and the fence reinstated to its original condition

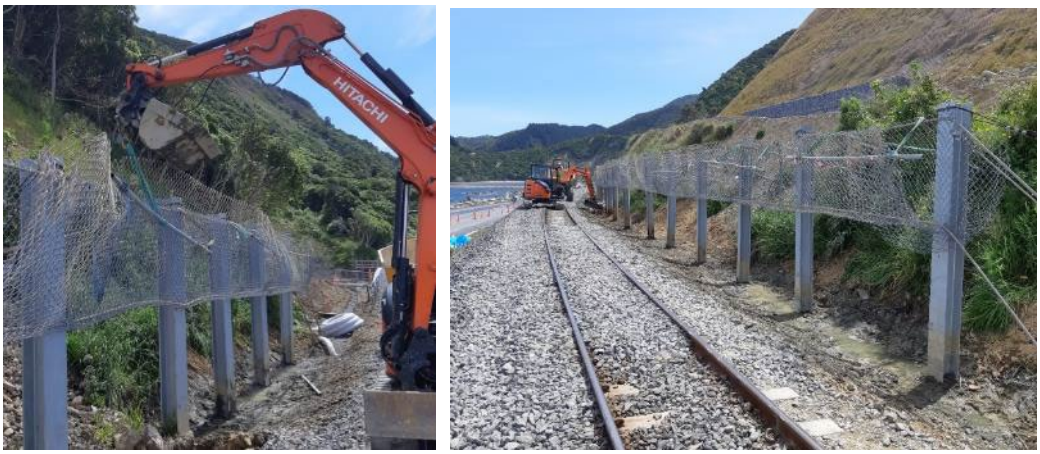


Image 3: An example of lifting the bottom rope and clearing material.

- In some cases, single blocks can be removed through drilling and epoxying in a lifting eyelet for removal by crane. If too large to lift and conditions permit, possible to remove using non-explosive expanding grout / NONEX (where appropriate).

Any works undertaken behind the structures will require assessment of the geohazards prior to commencing. This may result in work being delayed until dry weather, mechanical scaling or sluicing prior to work behind the structure, or implementing additional controls such as using a crane supported drape to protect the excavator operator.

During any works that have potential to impact a third-party property or asset (e.g., dwelling or rail), appropriate protection should be in place. For example, to avoid damage to rail, sleepers and contamination of ballast, both matting and W-beam sections have been used as shown in Image 4. The specific methodology to reduce the impact on third parties should be formally agreed in advance with the third-party including consultation with the GMC.

Image 4: An example of rail ballast contamination protection, to protect a third-party asset.

3.2. Debris Flow Basins

Debris flow basins are installed to provide storage for material brought down from identified debris flow paths. These areas require a visual inspection during scheduled and post-event assessments to monitor for any debris deposits. Due to specific consenting requirements for debris flow basins, there may be very site-specific maintenance conditions, and therefore for the maintenance of these structures, a review of the site-specific documentation is required. In summary the operation and maintenance of these structures should include;

- Assess detention basin and upstream catchment condition every three to six months, or after a significant rainfall event (See Section 2).
- Check the debris flow basin is not being scoured, outflanked or material has not accumulated beyond the allowable freeboard – this information should be provided in the site-specific maintenance plan.
- Check sediment build-up is not blocking culverts at the downstream outlet – clear as required.
- Material that requires removal should be cleared in dry weather once the stream levels have reduced to low flow (refer to regional councils and authorities, such as ECAN River Flow Data for flow rates: https://www.ecan.govt.nz/data/riverflow/).
- Material excavated from the debris flow basin will require disposal. Consideration of disposal site will be required and may vary depending on location and the environmental and cultural sensitivity of the area – consult the local Waka Kotahi Network Manager for further information.

Any work undertaken within the debris flow basins will require a specific task analysis to identify the hazards. A geotechnical assessment of the geohazards will be required prior to commencing works within or behind any debris flow structures. This may result in work being delayed until additional works can be undertaken or implementing additional physical controls such as an excavator with suitable cabin protection (ROPs and FOPs) and/or remotely operated.

3.3. Vegetation Cover

Rockfall protection structures are often installed on slopes that were either denuded by landslides or deliberate vegetation clearance to provide access for construction. In time it is likely that vegetation will grow to recover these slopes.

Vegetation regrowth within active mesh and upslope of barriers may prove to be beneficial in improving the overall slope stabilisation.

However, vegetation growth around rockfall fences, mesh drapes and hybrid fences (attenuators) is likely to inhibit the free movement of the mesh. This has the potential to reduce the effectiveness of the system and has the potential to entrap failed material within the system. It is therefore recommended that vegetation growth that causes any potential restriction in movement of the RPS is cut-back or cleared. Depending on the site and the vegetation growth that occurs, consideration could be given to regular vegetation maintenance and possibly targeted planting of preferential low-height ground cover.

Vegetation management should be carried out proactively to ensure the effectiveness of the RPS is not impacted. The maintenance works should not adversely affect the RPS system through physical damage of the mesh or ropes from mechanical cutting or through increased corrosion from spraying any chemicals (e.g., “Round-up” should not be used as it is indicated by CSP Pacific NZ to be corrosive to galvanized steel).

3.4. Rockfall Protection Structure Drainage

Where drainage systems are incorporated into slope stabilisation or rigid rockfall protection structures. In general, the drainage will take the form of rock lined channels with graded inverts to allow water flow down and off installed benches or debris catch areas. These channels are often discharged into a pipe, culvert and/or cess drain.

Limited maintenance is required for the drains under normal circumstances other than standard condition assessment, particularly as systems reach the end of their design life. The drains should be visually assessed for any scour or damage and repaired as needed. Slope installed PE drainage pipes required an inspection of the inlet and should be cleared of debris and checked for internal debris accumulation and flushed as required. The bench or debris catch area should also be checked for erosion or evidence of bypass.

Following inundation of these drainage areas with debris, the debris should be removed. Debris clearance includes clearing debris from any structures or pipes. Upon completion of the debris removal, the drainage channel and pipework should be inspected to confirm it is free of debris. Drainage material should be added to restore surface grades to those established upon completion of construction.

Subsoil drains installed as gravel filled trenches will not be able to be visually inspected. In some cases, visual inspection points may have been included in design, in which case the site-specific maintenance plans should include inspection location details. If these drains show evidence of blocking or fines contamination, the subsoil drains will need to be repaired or replaced.

3.5. Anchorages

Anchorages that provide support within dynamic rockfall barriers, installed as rock bolts or soil nails within active/draped mesh systems, or installed individually will likely be the most challenging elements to identify defects and damage during scheduled and post-event assessments as the majority of the component is below ground.

Critical items that should be checked for anchors include:

- Any obvious deformation in the anchor head, bending in the direction of failure greater than 15°.
- An anchor pull-out distance greater than 30mm, including obvious deformation of the ground surface.
- Any scratches or abrasions that may compromise the anti-corrosion protection. Additional corrosion protection may be applied depending on total area and depth of damage and influence of the system.
- Consideration should be given to additional acceptance testing of remaining anchors, in accordance with BS EN 1537, to ensure the required capacity is met. The test and design loads should be provided within the specific structures design drawings. (Note: If no information on the anchor is available, further input will be required by a geotechnical professional to determine the required working load of the anchor, and to develop a unique testing plan to test and confirm the anchor has the minimum working capacity).

If anchors are damaged and show signs of distress they should be replaced. Consideration should be given to the new anchor location to avoid influence from the damaged anchor and surrounding ground. Specialist geotechnical input will be required.

3.6. Wire Ropes

Wire ropes form an integral part of many rockfall barriers and active/draped mesh systems. Wire ropes should be checked for damage or break in the “Rope”, “Strand” and “Wire”, see Figure 2. If any “Rope” (A) or “Strand” (B) are damaged the wire rope should be replaced.

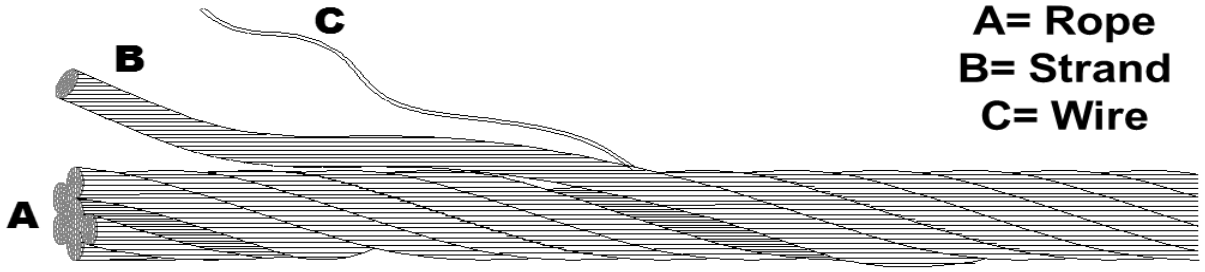


Figure 2: Steel Rope Elements

Wire ropes should be inspected for corrosion, if more than 10% of the cross-sectional area is affected the rope will require replacement.

Damaged or corroded wire ropes should be replaced as per the original design. Damaged/corroded sections of the steel rope may be removed and replaced using approved methods outlined in the manufacturers' manuals. If length of replacement exceeds 30% of the total rope length, then the full length of rope should be replaced.

3.7. Wire Rope Clamps

Wire rope clamps are used to secure wire ropes at several key locations within the rockfall protection structures. The critical aspects that require assessment include:

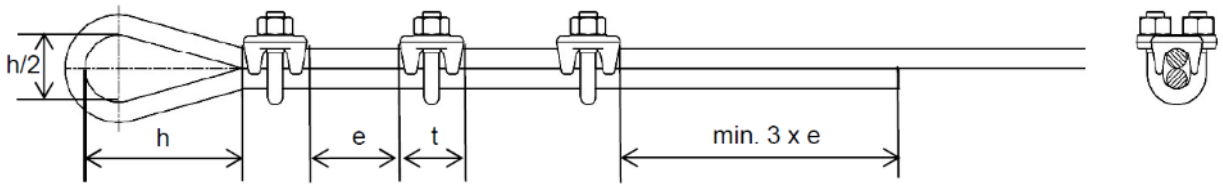
- Ensure the wire rope clamps are saddled onto the live end of the rope, see Figure 3.
- Check the torque of the wire rope clamps and re-tighten if required. Retightening values are specific to the type of wire rope clip used, for most systems an EN13411-5 type 2 (or similar) clip should be installed and the required torques are in accordance with Table 6, below. The contractor should identify the correct wire rope clip used and apply the corresponding re-torquing value.

Table 6: Wire Rope Torque Values for EN13411-5 Type 2 Clips (or similar)

Wire rope diameter (mm)	Nominal size wire rope clip	Required torque *with* lubricant (Nm)	Required torque *without* lubricant (Nm)
9 – 10	3/8"	30	75
11 – 12	7/16"	40	110
14 –15	9/16"	50	150
16	5/8"	90	170
18 – 20	3/4"	90	180
22	7/8"	150	330

Values based on Geobrugg system using FF-C-450 type 1 class 1 (similar to EN13411-5 type 2) wire rope clips.

- Check the spacing and number of the wire rope clamps correspond to the manufacturers' documentation. For example, if using FF-C-450 type 1 class 1 (similar to EN13411-5 type 2) wire rope clips refer to Figure 3.



h = 15 x rope thickness (but not be less than h/2 when unloaded)

e = 1.5 x t (at least 1 x t, but no greater than 2 x t)

t = width of the wire rope clip clamping jaws

Figure 3: Wire Rope Clamp Elements (Geobrugg Tecco Manual, 2017)

- Check for any scratches or nicks that may compromise the corrosion protection and inspect for rust that covers >2% of the total area.

If the wire rope clamps are damaged or the torque cannot be met through re-tightening, the clamps should be replaced.

If maintenance occurs and clamps are removed from the structures, refer to the manufacturers' documentation as to whether it is acceptable to re-use, as some allow whilst others indicate clamps may not be reused. This should be confirmed prior to the removal or replacement of wire rope clamps.

3.8. Shackles

Shackles are used on several systems for attaching critical components, such as mesh to mesh, see Image 5, or mesh to wire ropes. The critical aspects of the shackles that should be checked include:

- Ensuring the shackles are tight, secured with wiring (mousing) or Loctite to prevent loosening or theft, and are located as per design.
- Check the spacing and number of the shackles correspond to the design.
- Check for any scratches or deformation that may compromise the shackle including damage to the anti-corrosion coating. Surface rust is acceptable if the shackle is functional and can be opened and closed.

Image 5: Shackles used to connect two mesh panels.

If the shackles are damaged or missing, they should be replaced as per the original design.

3.9. Corrosion Protection

All corrosion protection coatings (e.g., Denso or PVC tape, galvanising and/or epoxy coatings) should be inspected as part of every inspection and repaired or replaced as necessary. Any major metal components (posts, anchor plates, etc.) showing signs of rust covering >2% of the area should be repaired or recoated in accordance with AS/NZS 2312. Depending on the element requiring recoating the following options are available, contact the GMC for guidance and confirmation on suitable approaches;

Epoxy Coating:

A remedial epoxy coating used during the NCTIR project, included the following 5-step recoating process, which was based on the recommended remedial actions for the steel pedestrian barriers:

1. Solvent clean area to be coated in accordance with Society for Protective Coatings (SSPC) SP1 (cleaning is to remove all visible oil, grease, soil, drawing and cutting compounds, and all other soluble contaminants from steel surfaces)

2. Prepare area hand sanding in accordance with SSPC-SP2 (hand sanding is to remove all loose mill scale, rust, paint and other contaminants that may be detrimental to a coating application)
3. Apply PPG Sigmazinc 109 primer or similar at 90 microns dry film thickness over bare steel area
4. Apply PPG Sigmashield 880 or similar overlapping onto the existing coatings at 300 microns dry film thickness
5. Apply PPG Sigmadur 550 or similar overlapping onto the existing coatings at 75 microns dry film thickness

Heat-shrink coating (generally only applicable for exposed bar-ends):

1. Apply a Galvanising Spray on the exposed bar end
2. Fill a heat-shrink end cap with EPCON C6 or similar and heat-shrink end cap on to bar;
3. Apply 2 layers of Denso tape over bar end.

4. Guideline for Inspection and Maintenance of Specific Elements

This section outlines the inspection checks and maintenance recommendations for some of the specific elements to each of the most common rockfall protection structures installed across the Waka Kotahi road network. Assessments of these items should be read in conjunction with the manufacturers' installation guide and latest documentation.

Examples and reference photographs for many of the maintenance interventions identified in this section are shown in Section 7, Table 10 of this guideline.

4.1. Diamond Mesh

Diamond or single twist meshes are typified by Geobrugg's TECCO / SPIDER or Trumer's SIGMA.

Image 6: Diamond Mesh, for example Geobrugg Tecco (Geobrugg, 2009)

These meshes are required to be replaced if they are compressed, heavily distorted or torn.

For small areas of mesh that have been pulled apart, a corresponding section of mesh can be laid over the damaged area and fastened to the intact mesh diamonds with shackles. Care should be taken to ensure the mesh diamonds are aligned with the intact mesh and connected on all outer diamonds.

For larger areas and where the mesh is heavily damaged the section of damaged mesh should be replaced. This is achieved by unscrewing the outermost spirals or undoing the connecting shackles of the damaged area, inserting a new mesh, and joining the new mesh to the existing system and support ropes using shackles as per the original design and manufacturer's installation manual.

During inspections (both scheduled and post-event) consideration should be given to:

- The overall condition of the steel mesh, including checking for any deformation or lacerations. Depending on the size and location of the deformation the mesh may need to be replaced. Specialist geotechnical input will be required in this event.

For active mesh areas:

- Review any erosion or slope movement that may require re-tensioning of the mesh or additional measures such as securing hollows with shotcrete, greening or emptying material and relaying the mesh.
- In some cases, slope failures behind the mesh may result in significant bulging of the mesh with material restrained by the mesh. If the mesh is compressed, heavily distorted or torn the material will need to be removed and the mesh replaced or repaired. In some scenarios the mesh may

need to be cut in order to release the material - a remote cutter (see Image 2, page 14) should be used as the mesh may be under tension, and the material may release suddenly.

- On re-vegetated slopes, vegetation should be checked to ensure the mesh is not being pushed off the surface. Periodic vegetation trimming may be required.
- Following significant slope failures or movement resulting in hollows, the detachment of mesh, emptying and re-installing should be considered.

For all mesh repairs, undertake works in accordance with the manufacturer's guidelines and provided in the structure specific Asset Owner Manual (AOM).

4.2. Double Twist Mesh

Double twist mesh, as typified by Maccaferri's DT mesh, is a hexagonal mesh with multiple twists of wire at each connection.

Image 7: Double Twist Mesh, for example Maccaferri DT Mesh

During inspections (both scheduled and post-event) consideration should be given to the overall condition of the steel mesh, including checking for any deformation or lacerations. Depending on the size and location of the deformation the mesh may need to be replaced. For repairs and replacements, specialist geotechnical input will be required.

The simplest approach to repair smaller areas of mesh within a panel that has been damaged is by fitting a correspondingly sized replacement section of mesh laid over the damaged area with a minimum overlap of 0.5m. The replacement section of mesh should be fastened to the intact mesh. Care should be taken to ensure that the mesh is aligned in the same orientation as per the intact mesh.

To undertake site repairs the contractor should refer to the manufacturers repair and installation guidelines.

For larger areas and where the mesh is heavily damaged the section of damaged mesh should be replaced. This is achieved by removing the damaged panel, and inserting a new mesh panel, and joining the new mesh to the intact mesh as per the installation guideline.

4.3. Ring Net

Steel ring-net is used as the intercepting element in a number of proprietary rockfall protection structures from various manufactures. Inspections of the ring-nets should therefore use the corresponding

manufacturers' inspection guideline. If these are not available, the ring-net can be evaluated based on Table 7, below.

A ring is determined to be damaged if any one of the wires forming the ring is broken or features plastic deformation resulting in an oval shape with less than half the width of the original ring.

Table 7: Ring-Net Inspection and Maintenance

Damage to Ring-Net	Maintenance Required
Deformation to ring-net without breaks	No maintenance or repair required.
1 – 8 rings damaged	Site repair for partial panel (see Figure 4).
>8 rings damaged	Substitute entire panel.

To undertake site repairs the contractor should refer to the specific manufacturers repair guidelines. If specific guidelines are not available, the below approach can be considered.

The simplest approach to repair a ring-net that has been damaged by 1 – 8 rings can be undertaken on site and in-situ without the need to remove the ring-net through installing a partial panel. The outline of the partial repair, as shown in Figure 4, includes:

- The removal of the damaged section of ring-net (see Figure 4, marked as the red wire).
- Replacing the damaged section with a partial section that contains the same number of rings in the same layout as those removed (see Figure 5, marked as the green wire).
- Connecting the outer rings to the adjoining ring using shackles. Each ring should have a four connection points each with a separate ring. Refer to manufacturers' installation guide for full details and requirements.
- Replace the secondary mesh behind the panel if damaged.

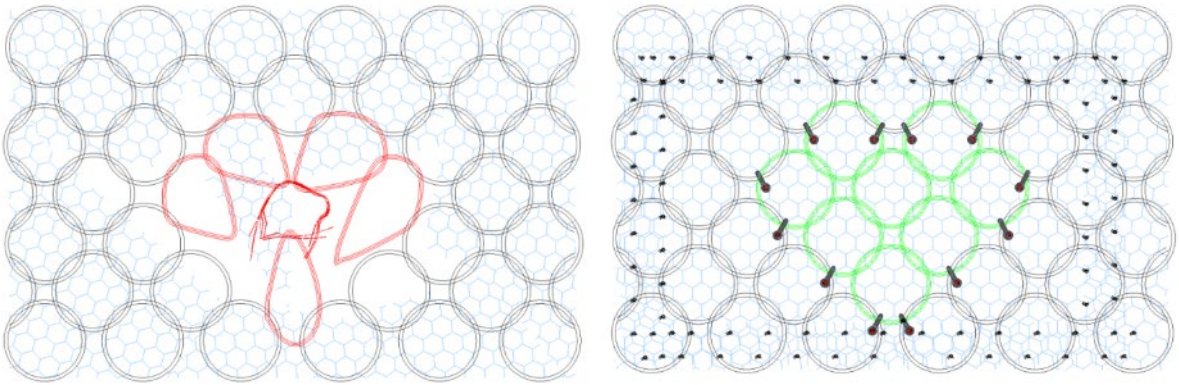


Figure 4: Repairing a damaged section within the ring-net using a partial panel (Maccaferri, 2017)

For larger areas and where the ring-net is heavily damaged the panel of damaged ring-net should be replaced. This is achieved by removing the panel of damaged rings, inserting a new curtain of ring-net, and joining the new ring-net to the corresponding locations with shackles.

For all ring-net repairs, undertake works in accordance with the manufacturer's guidelines and with the support of specialist geotechnical input.

4.4. Brake Elements

There are numerous types of brake elements used for energy dissipation on rockfall protection structures, the main two types across the various systems are ring-brakes and longitudinal brakes. Any brake replacements should be done in accordance with the manufacturer's guidelines.

4.4.1. Ring Brakes

Ring-brakes are often found on Geobrugg debris and shallow landslide barriers. Generally, once the brake element has engaged the usable height of the barrier has normally decreased.

Image 8: Ring Brake

The maintenance criteria for ring-brakes is required if the elongation of the energy dissipaters exceeds a lengthening of 40cm or has greater than 50% elongation, or the height is reduced below the required design height, the brake element should be replaced.

In the event of minor adjustments re-tightening the support ropes can be done to restore the original height.

4.4.2. Longitudinal Brakes

Longitudinal brakes are considered as braking elements that work in line with the direction of pull, and include the Geobrugg U-brakes, Maccaferri Energy Dissipators and Trumers AVT steel coils.

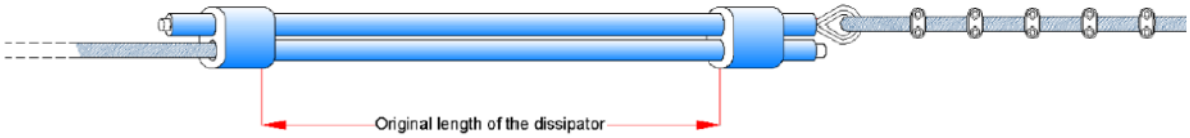


Figure 5: Example of a longitudinal energy dissipator / brake (Maccaferri, 2017)

If the elongation of the energy dissipaters exceeds the manufacturer's recommendation, the brake must be replaced. Once the braking element has engaged the usable height of the barrier has normally decreased.

The maintenance criteria for longitudinal brakes includes:

- If the elongation of the brake is greater than 20% of the original length, or the height of the structure is reduced below the required design height, the brake should be replaced.
- If the elongation of the brake is equal or less than 20% of the original length, and the height of the structure meets the required design height, no intervention is required. In this case, if the height of the structure is reduced below the required design height, re-tightening the support ropes can be done to restore to the required design height.

4.5. Posts

The steel posts form the supporting element of the rockfall barrier systems, posts generally come as fixed base posts or hinged flexible posts, see image below.

Image 9: A hinged post (left), a fixed post (right)

Inspections can be evaluated based on

- Posts that are undamaged can be realigned by retightening the support ropes to regain the usable height of the barrier.
- For hinged posts that have a slight bending of up to 15° from the design angle, replacement is not required, but increased monitoring is recommended.
- For a hinged post bent greater than 15° or a post that has signs of cracking or post damage, the post should be replaced.
- For a hinged post that has a downslope rotation or lateral rotation, within 10° of the design angles, replacement is not required, but increased monitoring is recommended. (see Figure 6)
- For a hinged post that has a downslope rotation or lateral rotation, greater than 10° of the design angles, the post should be replaced.
- The fixed posts with any slight bending or damage to welding should be notified to the GMC and inspected by a suitably experienced welding inspector.

Replacement works will vary depending on the location of the post (i.e., an edge post versus a middle post). In most cases a middle post can be replaced without removing the mesh and support ropes, while a border post may require more significant works.

For all post repairs, undertake works in accordance with the manufacturer's guidelines.

Any visible signs of corrosion / rust covering >2% of the area should be repaired or repainted in accordance with AS/NZS 2312. Localised spots of corrosion can be repainted with a suitable zinc rich epoxy paint (such as Resene ArmourZinc 120 or similar) to a thickness of 0.3mm and in accordance with suppliers' instructions and AS/NZS 2312, to provide the required corrosion protection. If corrosion is observed on more than 20% of the posts total area, replacement may be required following confirmation from the respective manufacturer.

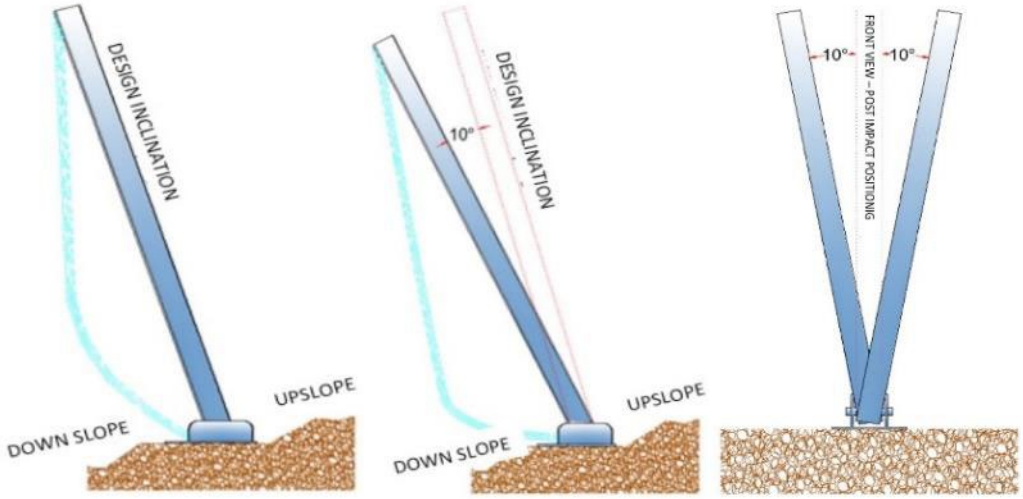


Figure 6: Rotation of the steel hinged post in relation to design angle (Maccaferri, 2017)

4.5.1. Base Plates and Foundations

Deformation of the base plate itself does not significantly impair its functionality, however if weld seams are torn the base plate should be replaced. Another key element of the base plate is the hinge bolt, which is designed as a predetermined breakpoint. If the hinge bolt is bent or broken it should be replaced.

Replacing the base plate and/or hinge bolt requires the post to be removed.

The foundation plinths should be inspected for cracking or spalling of the concrete. The surrounding ground should be inspected for deformation around the plinth. If the foundation plinth is damaged a detailed inspection will be required by a suitably experienced geotechnical engineer to determine the remaining suitability of the plinth and anchors.

In the event of a failure of the foundation plinth or anchors and a full replacement is required, it may be necessary to recreate the base plate foundation in a suitable location nearby in accordance with the product manual and anchor forces. Geotechnical guidance should be sought to provide design input into a new foundation and anchorage.

For all base plate repairs, undertake works in accordance with the manufacturer's guidelines.

4.6. Flexible Anchor Heads (FLEX Head, ICAF-44-T)

Additional to the bar anchors, head attachments are used within the high-energy rockfall barrier systems to provide connection for the support ropes to the anchorages.

Image 10: An installed flexible anchor head (left), an example of a Geobrugg FLEXHead (right)

Maintenance can be evaluated based on;

- For flexible anchor heads that have minor deformation and bending (<30°) from the direction of installation, and the steel pipe or thimble around the cable is intact, no intervention is required.

- For flexible anchor heads that have major deformation and damage resulting in damage to the steel wires, steel pipe or thimble, and/or bending greater than 30° from the design angle, the flexible anchor head should be replaced. In addition, the anchor bar should be inspected as it will likely require replacement.

Undertake anchor replacements in accordance with the manufacturer's design guidelines. Consideration should be given to the new anchor location to avoid influence from the damaged anchor and surrounding ground.

4.7. Bunds

Bunds are constructed in a range of materials, sizes and shapes and are intended to be low maintenance under normal circumstances, and relatively fast and easy to repair following impacts.

Image 11: A reinforced bund at the base of a slope

Image 12: An earth bund constructed from site won material

All repairs should reinstate the bund to the original accepted design and geometrical conditions. If this is no longer possible, a technically acceptable solution should be agreed a suitably qualified geo-professional.

The key inspection aspects for these structures include:

- An assessment of any rockfall/debris impacts. All debris should be removed from behind the bund. Small impacts (i.e., those that penetrate the bund by less than approximately 20% of the bund width and don't require the concrete blocks to be re-aligned may be repaired by replacing fill as necessary and patching the mesh if applicable. Larger impacts (particularly those that cause deflection of the front face of the bund) should be assessed on a case-by-case basis by an appropriately experienced geo-professional. In this case it is likely that some embankment material will need to be replaced. Any concrete blocks may need to be re-aligned, depending on the magnitude of displacement.
- The height of the bund should be checked. It is possible that the fill within the bund may settle over time. Should the bund height reduce by more than approximately 200 mm, the fill should be topped up with material approved by a suitably qualified geo-professional.
- Any steel mesh should be periodically checked for corrosion. Corroded areas of mesh should be patched with new mesh. Areas of mesh that have been subject to impact (either by debris, or by construction machinery during clearance of debris) may sustain damage to the corrosion protection and may need replacing/patching.
- Any concrete blocks may need to be re-aligned, depending on the magnitude of displacement. If the reinforced fill is displaced and requires re-filling, care should be taken to re-install the plastic geogrid. All repairs should be done to achieve the original design specifications.
- Any debris flow deflection bunds should be checked for overflow or impacts to the material that would compromise the bunds ability to direct future debris flows. Realignment and replacement of displaced material may be necessary.
- Modular Rockfall Protection walls comprising of concrete blocks, gabion baskets and sand filled geofabric should be inspected for damage to each component and repaired accordingly.

Key inspection requirements and repair suggestions relating to bunds are provided in Table 8.

Table 8: Guidelines for Repair of Bunds

Component	Damage Type	Indicative Description	Suggested Repairs
Gabion baskets	Minor deformation or damage	Minor penetration (<200 mm); small tears or breakages of wires over a limited area; damage to PVC coating; corrosion of gabion wires.	Patch with a section of PVC-coated double-twist mesh; if required, add gabion rockfill to reinstate gabion face to original position.
	Substantial deformation	Penetration >200 mm; significant breakage and/or deformation of gabion basket wires. Protrusion of rock fill into sand gabion baskets; damage of geofabric lining.	Remove and replace damaged rock and sand gabion baskets. Replace rock and sand fill and geofabric lining if required. A combination of gabion baskets or PVC-coated double-twist mesh may be used for patching repairs.
Concrete blocks	Cracking, spalling, crushing	Cracking, crushing or spalling that affects block edges or faces to a depth up to about 150mm.	Repairs generally not needed to maintain wall performance. May need to remove or re-fix loosened fragments on outer face if this presents a hazard to users downslope of the wall.
	Severe cracking, spalling, crushing	Cracking, crushing, or spalling resulting in a significant change in block	Replace block

Component	Damage Type	Indicative Description	Suggested Repairs
		shape or block mass; damage that extends to central ducts (note: this would be unusual for the design loads considered)	
	Minor displacement	Displacement <50mm at base of wall; includes horizontal or rotational displacement of individual blocks; rotational (overturning) displacement of wall < 2-3 deg.	Re-alignment of blocks generally not needed to maintain wall performance. This should be evaluated considering site conditions.
	Moderate displacement	Displacement between 50mm to 350mm at base of wall; rotational (overturning) displacement of wall between 3 to 5 deg.	Re-alignment of blocks may be needed, but should be assessed based on the level of damage and the site conditions
	Substantial displacement	Displacement > 350 mm at base of wall; rotational (overturning) displacement of wall in excess of 5 degrees	Re-align blocks.
Connections	Corrosion	Corrosion of steel connection elements For plates, corrosion depth >4mm (may require input from structural engineer to assess corrosion damage)	Repair corrosion with suitable epoxy paint (such as Resene ArmourZinc 120 or similar) to a thickness of 0.3mm and in accordance with suppliers' instructions and AS/NZS 2312. Replace corroded components if depth and type of corrosion is judged to compromise the integrity of the element.
	Deformed bars	Bending	Replace
	Deformed plates	Bending / dishing	Replace
	Broken or strained connection	Broken or strained lacing wire connection between concrete blocks and gabion baskets	Replace
Catch ditch	Debris build-up	Rock, soil and/or vegetation debris that fills in catch ditch	Remove debris from catch ditch

5. Safety in Maintenance

Rockfall protection structures require regular maintenance to ensure they remain operational. These activities are likely to focus around clearance of debris and the repair or replacement of damaged components.

Site-specific Safety in Design (SiD) considerations should have been completed during the design and construction phases in accordance with the Health and Safety Work Act (2014). A detailed SiD register should therefore be available for the specific RPS, attached in the corresponding documentation. If available, the SiD register should be reviewed when preparing the Safe Work Methodology Statements (SWMS) or Job Safety Analysis (JSA) required for any operational or maintenance works.

If no SiD register is available, consider the following key Safety in Maintenance (SiM) considerations for ongoing operation and maintenance of rockfall protection structures:

Slope Hazards

- The majority of operational and maintenance works over the lifetime of the structures will be undertaken in an area subjected to rockfall, landslides and/or debris flows. The nature of these slope hazards will likely change over time and should be considered at each stage of work. It will be key to identify the slope hazard areas and reduce the time that workers spend within these areas, ensuring the risks are clearly communicated to all personnel involved.
- Before any maintenance is undertaken, especially following a rainfall or seismic event, a geotechnical inspection, site monitoring, preventative scaling, placement of temporary protection and establishment of evacuation protocols should be considered within the SWMS and/or JSA prior to accessing site.
- A spotter to monitor the slope hazards should be considered during any maintenance works, and should remain outside the hazard zone, should have clear sight of the slope above the works and should be in radio communication with the construction team at all times to allow them to notify the team of any sign of movement of the slope above. Fatigue management should be carefully considered for spotters to ensure concentration levels are maintained in this critical role.

Site Specific Maintenance Plans

- Most recently constructed RPS will have a site-specific maintenance plan. These plans provide specific details of the systems and propose options to clear accumulated debris. These should be taken into account prior to any maintenance works being undertaken on site.
- Many areas in New Zealand have high cultural significance. For any works involving material clearance, the Waka Kotahi Project Manager and Contractor should review the local Cultural Management Plan (CMP) to ensure the appropriate steps are taken prior to works starting clearance works.

Access

- No access behind the structures and/or into the debris catch areas should take place without appropriate safety measures in place. Personnel access should be avoided behind the structures and/or into the debris catch areas, unless appropriate safety measures are in place. Consider using drones or helicopters to undertake remote inspections before personnel access the site.
- Sites that require rail access should comply with all KiwiRail entry requirement and permits and use a KiwiRail approved access point, contact KiwiRail for any works undertaken in proximity to rail.
- Access to some RPS may require being in close proximity to the transport corridor. An appropriate level of approved temporary traffic management will be required and include consideration for the constrained working space adjacent to rockfall areas and limited ability to stockpile material.

- For some RPS, workers will be required to work at height to access the top of the systems or higher up the slopes. A specific fall protection methodology, that does not significantly increase the time spent within the rockfall hazard zone, should be developed as part of the maintenance works.

Temporary Protection Works

- For clearance or replacement of components, enabling works that include additional temporary protection from the upslope geohazards should be considered for both the workers and road users, especially while rockfall mitigation is not in full operation (i.e., removed or lowered).

Debris Clearance

- For many sites, space will be limited for on-site debris stockpiling, consideration will be needed for the transfer to road trucks for off-site disposal. Off-site stockpile locations for removed debris will need to be identified prior to clearance works starting.

Excavation Equipment

- Clearance of debris should be undertaken by an experienced contractor and any excavation equipment accessing behind the structure and/or into the debris catch area to have suitable cabin protection (ROPs and FOPs) and/or remotely operated. When removing material from behind structures ensure emergency exit points remain clear at all times.

Designed Structures

- In some cases, high-energy structures are utilised such that multiple impacts may be arrested before debris clearance is required, reducing the frequency of maintenance. In addition, a number of fences are constructed with intermediary anchors, or as multiple structures, to reduce the length that is required to be lowered during clearance. This enables single fences, or sections, to be lowered one at a time leaving the remaining sections to provide a level of additional protection.

6. Expected Working Life of Replaceable Elements

By design, rockfall protection structures are constructed from several dynamic components that combine to create a system to attenuate rockfalls, landslides, debris flows, or debris avalanches. Many of these components are designed to function only during an impact of the structure. Due to their dynamic function each component is likely to be significantly damaged in the event of an impact, as well as having an expected working life before needing to be replaced.

The design life for the rockfall protection structures will vary greatly across the network. Maintenance works to update many of the replaceable elements such as shackles, wire rope clips and wire ropes will be required during the design life of these systems. Individual posts, anchors or base plates may also require systematic replacement during the design life of the structures; however, this will be dependent on environment factors, such a local weather conditions, exposure to marine conditions, corrosion rates and frequency and magnitude of impacts.

The indicative expected working life of each replaceable element is summarised in Table 9.

Table 9: Expected Replaceable Elements Working Life

Replaceable Element	Expected Working Life* (years)
Shackles	10
Wire Rope Clips	10
Wire Ropes (inc. braking elements)	10 – 15
Mesh**	10 – 50
Posts and Base Plates***	30 – 50
Anchors (inc. FlexHeads)	50
Terramesh Bunds (Gabion Mesh)	50

*** The expected working life quoted in this Table specifically excludes damage caused by rock/debris impact to the structure.**

**** The variability in working life is dependent on the manufacturer and environment.**

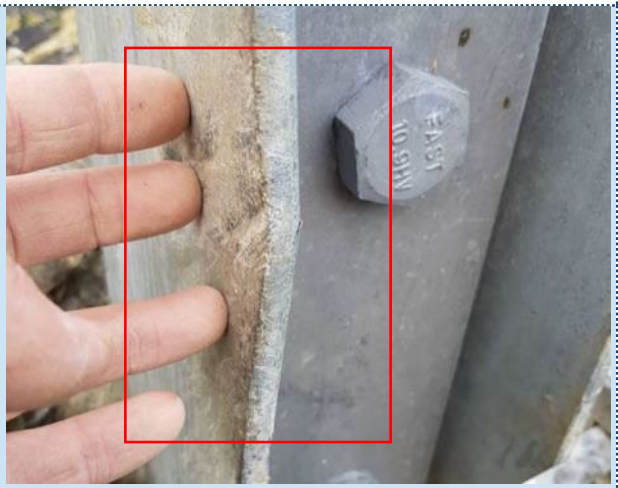
***** The life of posts may be extended by painting them with a suitable protective coating prior to the onset of corrosion as noted in regular maintenance inspections.**

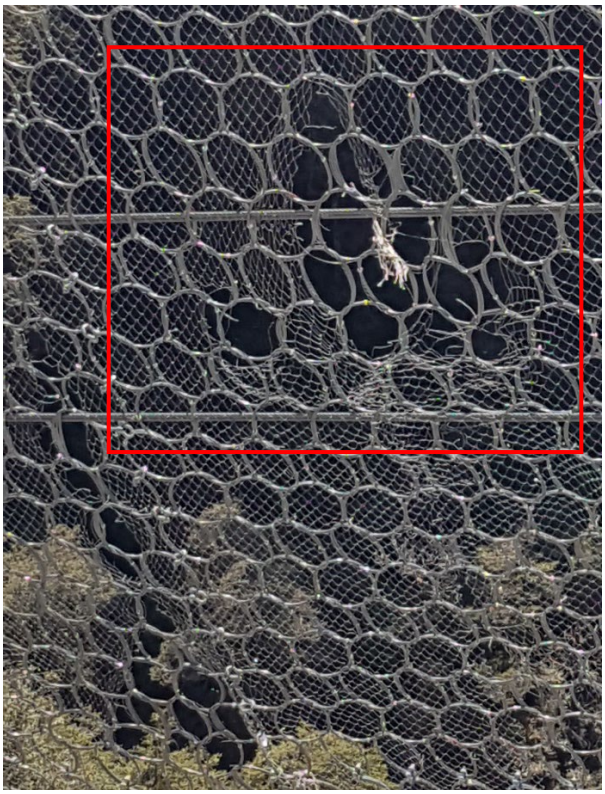
Appropriate storage of replaceable elements should be indoors and protected from the effects of corrosion. This will ensure that the expected working life of new elements begins upon installation rather than upon delivery to storage.

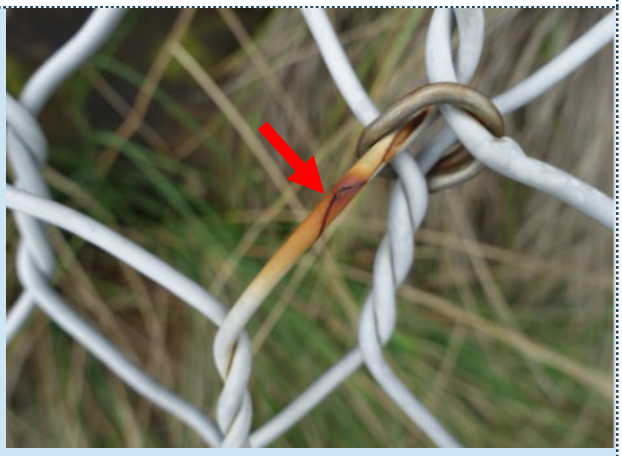
7. Examples of Maintenance Intervention

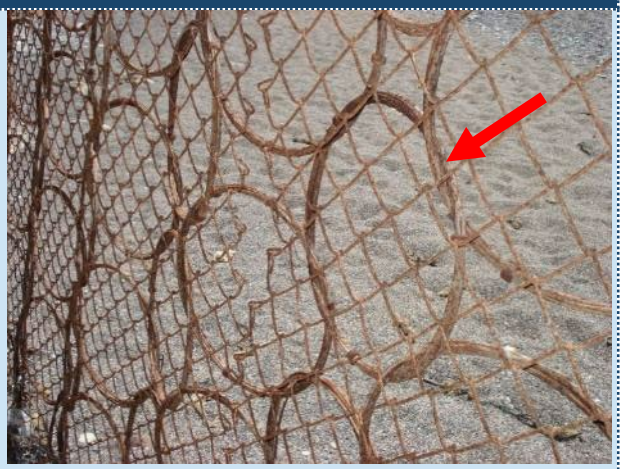
A number of different components are used across the various rockfall protection structures along the road network. Examples of intervention to repair or replace damaged components are shown in Table 10, below.

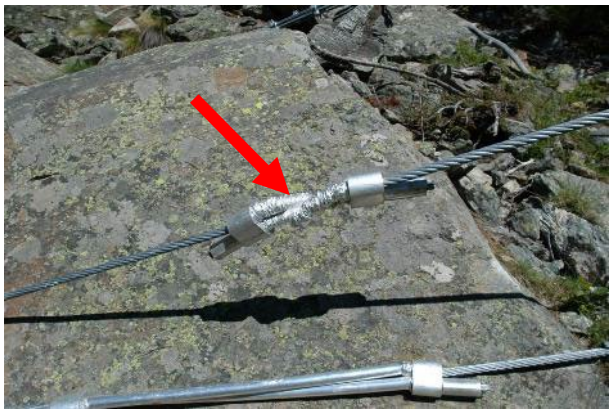
Table 10: Examples of Maintenance Intervention

Component	*Damage* / Action	Reference Photo
Anchors		
Anchor	*Obvious damage to anchor head, however bending appears less than 15°* Inspect anchor for pull-out and visible breaks in the corrosion protection. Undertake additional acceptance testing in accordance with BS EN 1537 to check load-bearing capacity is sufficient.	
Anchor	*Anchor has pulled out a distance greater than 30mm (in this case almost 1m).* Replace anchor – consideration will need to be given to the new location to avoid influence of the surrounding damaged ground. Consult geo-professional.	
Posts		
Post	*Post has been impacted by debris causing a bend in the flange of the post, and cracking of the galvanising / corrosion protection.* Bending of post is less than 15°, and damage is localised to the post flange – check with manufacturers guidance and use wire brush to remove flaked galvanising, re-paint area with zinc-epoxy anti-corrosion coating in accordance with AS/NZ 2312.	

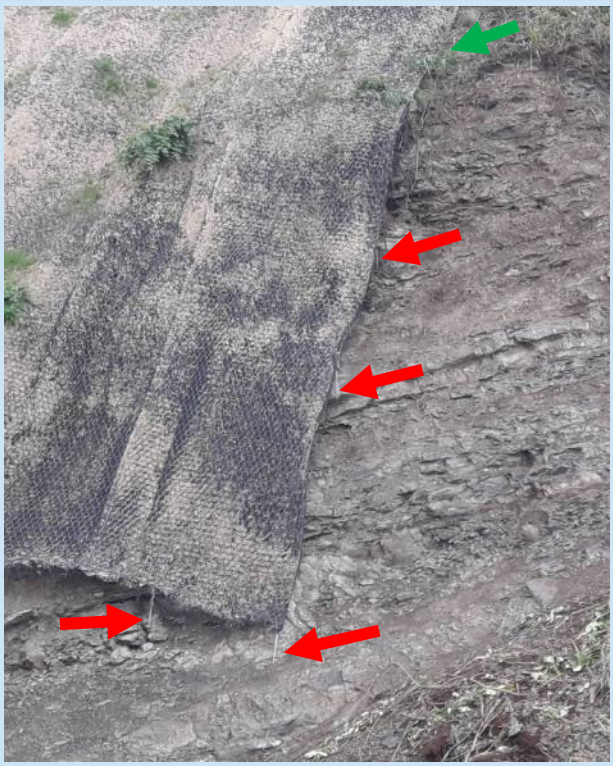
Component	*Damage* / Action	Reference Photo
Post	*Posts have been damaged following impact. Furthest left post has not sustained rotation or bending. Middle post is bent greater than 15° near the base. The right most post has lateral rotation in excess of 10°.* Replace the middle and right posts with new posts, check anchors and foundations. Check the left most post for damage to corrosion protection – re-paint/repair as required.	
Mesh		
Secondary Mesh	*Isolated sections of damage and tearing of the secondary mesh due to impact from boulders.* Sections of damage are relatively small. The areas can be patched. Secondary mesh patches can be laid over the damaged area and fastened to the mesh with steel wire ties in accordance with manufacturers guidance. Care should be taken to fasten the patch to intact mesh, ensuring it is aligned and each boundary diamond is connected.	
Diamond Mesh	*Isolated section of diamond mesh has been distorted out of shape, due to either impact or material loading.* As section of distorted mesh is relatively small, the panel can be repaired. A corresponding sized section of diamond mesh can be laid over the damaged area and fastened to the intact mesh diamonds using shackles in accordance with manufacturers guidance.	

Component	*Damage* / Action	Reference Photo
Diamond Mesh	*Corrosion observed to be developing on the diamond mesh.* As greater than 10% of the total surface area is visibly corroded, the diamond mesh will need to be replaced. As the corrosion is isolated to a single panel. Replace the single mesh panel in accordance with the manufacturers' documentation.	
Double Twist Mesh	*Corrosion observed to be developing behind the PVC coating on double twist mesh.* As less than 10% of the total surface area is visibly corroded, the mesh does not require replacement, but should be monitored for change.	
Ring-Net	*Panel of ring-net is heavily distorted by fence being fully loaded following large impact event.* Once debris is released, inspect the ring-net. If non-plastic deformation only and no breaking of rings, the panel does not need repairing. If damage to 1 – 8 rings the ring-net panel can be patched. If greater than 8 rings damaged, then the entire panel should be replaced. Note: In this case the ring-net was only distorted with no breaks – therefore it was re-used in the reinstated fence following debris removal.	

Component	*Damage* / Action	Reference Photo
Ring Net and Secondary Mesh	*Significant corrosion visible on both ring-net and secondary mesh.* Both the ring-net and secondary mesh panels will require replacement. Consideration should be given to using a higher-level of corrosion protection as the corrosive environment may be more severe than anticipated.	
Steel Rope		
Steel Rope	*Steel rope is visibly rusted and covers a significant area. Steel rope is likely to be the most prone to corrosion. In addition, the wire rope grips have been installed incorrectly.* As greater than 10% of the cross-sectional area and total surface area appears to be visibly corroded, the steel rope will need to be replaced. (Note: if the section of corrosion is very isolated <10% of the total length, it can be patched/spliced.) Repair or replace the rope in accordance with the manufacturers' documentation. Install wire rope grips in correct orientation.	
Brake Elements		
U-Brake	*The U-brake in the background has not moved. However, the U-brake in the foreground has moved and been activated roughly 300mm.* The energy dissipating U-brakes can be activated up to 600mm before requiring replacement. Therefore, no action is required other than to monitor the fence for further impacts.	

Component	*Damage* / Action	Reference Photo
Brake Ring	*Brake rings following an impact on the fence. The brake ring at the bottom of the photos has not been activated, while the brake ring at the top of the photo has been activated.* The activated brake ring exceeds the acceptable limits of 50% lengthening (~400mm elongation) and requires replacement. If the steel rope in the non-activated brake ring is undamaged it can be re-used in the reinstated fence.	
Energy Dissipater Device (EDD)	*Deformation of EDD observed, following activation due to impact of rockfall fence.* The shortening of the EDD is less than 20% of the original length, therefore no replacement is required. The EDD should be monitored for any increased corrosion due to minor deformation.	
Energy Dissipater Device (EDD)	*Deformation of EDD observed, following activation due to impact of rockfall fence.* The EDD has been completely activated with no remaining dissipater length. The EDD will need to be replaced with a new dissipater.	

Component	*Damage* / Action	Reference Photo
Accessories		
Wire Rope Clip	*Obvious visible corrosion and failure of wire rope clip.* The wire rope clip is broken and no longer holding the wire rope. The wire rope clip should be replaced. It is reasonable to assume that corrosion may have developed on other wire rope clips – spot check all other wire rope clips for visual signs of corrosion and/or damage. Consider checking the required torque is met on ~20% of the wire rope clips within the system.	
Wire Rope Clip	*Wire rope and wire rope clips are significantly corroded. Both require replacement.* In some-cases minor corrosion may be tolerated, as long as the rust is only surficial, and the wire rope clip is checked to meet the required torque. It is reasonable to assume that corrosion may have developed on other wire rope clips – spot check all other wire rope clips for visual signs of corrosion and/or damage. Consider checking the required torque is met on ~20% of the wire rope clips within the system.	
Shackles	*Visible corrosion observed on shackle.* Rust appears to be surficial, check the shackle is able to open and close, if functional then no replacement is required, but monitor for changes. If the shackle is not functional, it will need to be replaced. It is reasonable to assume that corrosion may have developed on other shackles – spot check for visual signs of corrosion on all other shackles. Check functionality of any shackles visibly corroded.	

Component	*Damage* / Action	Reference Photo
Shackles	*Significant visible corrosion observed on shackle.* The shackle is unable to open due to corrosion of the screw. The shackle should be replaced with the same size shackle in the same location connecting to the same elements. It is reasonable to assume that corrosion may have developed on other shackles – spot check for visual signs of corrosion on all other shackles. Check functionality of any shackles visibly corroded.	
Spike Plate	*The mesh and spike plate have become loose – the spike plate is no longer tight against the mesh and is not horizontally aligned.* The spike plate should be checked for damage and visible signs of corrosion. The spike plate can be re-used if corrosion covers less than 10% of the surface area (if greater than 10%, the spike plate should be replaced). Re-align the spike plate to horizontal and tighten the nut to the pre-tensioning torque as per design.	
MacMatR pins	*Several of the steel pins securing the erosion protection matting to the slope are observed hanging from the mesh and no longer connected to the slope.* As the pins have pulled out by greater than 30mm and more importantly are no longer connected to the slope they should be reinstalled. The pins should be checked for any bending or breaks. If bending is greater than 10° or obvious damaged is observed the pins will need to be replaced.	

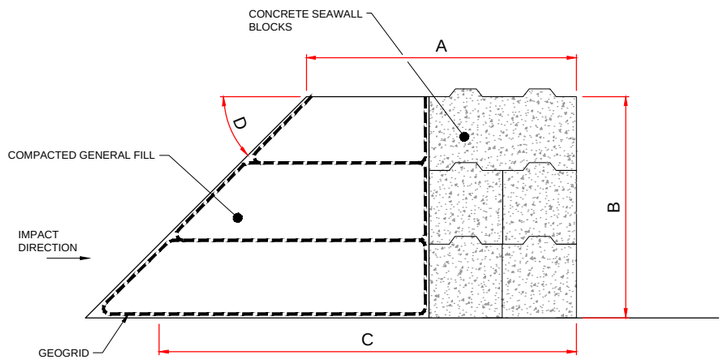
Component	*Damage* / Action	Reference Photo
Other		
Vegetation Growth	*Vegetation regrowth within active mesh may prove to be beneficial in improving the overall stabilisation.* However, vegetation in rockfall fences, drapes, and hybrid fences (attenuators) that inhibits the movement of the mesh and has the potential to entrap material upslope should be cut-back. Consideration should be given to spraying any chemicals as it may adversely affect the corrosion protection coating of the system.	
Debris Accumulation (Mesh)	*Material has accumulated beneath a mesh drape; the debris is bulging and has distorted both the mesh and bottom wire rope.* As material is distorting the mesh, and the debris catch area is more than 1/3 filled, clearance will be required. An inspection by a geotechnical engineer will be required prior to clearance and reinstatement of the system.	
Debris Accumulation (Fence)	*Material has accumulated to approximately 1/2 to 2/3 the height of the barrier. Both the SPIDER and secondary mesh are visibly distorted.* As material is greater than a 1/3 in height and the mesh is being distorted clearance is required. An inspection by a geotechnical engineer will be required prior to clearance and reinstatement of the system.	
Debris Impact (Modular Rockfall Protection Wall)	An impact into the Modular Rockfall Protection Wall has created the concrete blocks to move and the gabions to be visibly damaged. As the concrete blocks have greater than 50mm displacement, realignment of the blocks will be required – check supporting bars are not bent. There has been significant penetration >200mm with damage to the gabions and likely the sand filled	

Component	*Damage* / Action	Reference Photo
	geotextile layer – both layers will need replacing. An inspection by a geotechnical engineer will be required prior to clearance and reinstatement of the system.	 
Missing / Incorrect Components	*A TECCO T3 clip is incorrectly attaching two sections of mesh.* Missing and incorrect components should have been captured and resolved upon the completion of construction; however, some minor insufficiencies or incorrectly installed components may be found during maintenance. These should be resolved in accordance with the manufacturers' documentation.	 

Appendix A:

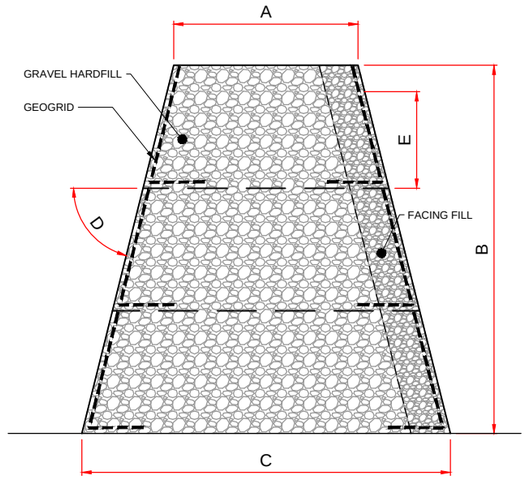
Rockfall Protection Structure Type Drawings (Examples)

KEY	ELEMENT
A	CREST WIDTH
B	BUND HEIGHT
C	BASE WIDTH
D	FACE ANGLE
E	LAYER THICKNESS (TYPICALLY 0.6m)
NOTE:	FOR SPECIFIC SYSTEM COMPONENTS, AS WELL AS TYPE AND LOCATION REFER TO THE SITE SPECIFIC MAINTENANCE SHEET AND THE MANUFACTURES MANUAL.



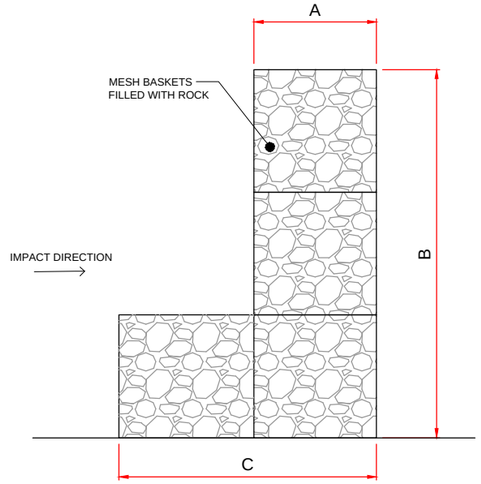
TYPICAL CONCRETE BLOCK REINFORCED FILL BUND

SCALE NTS



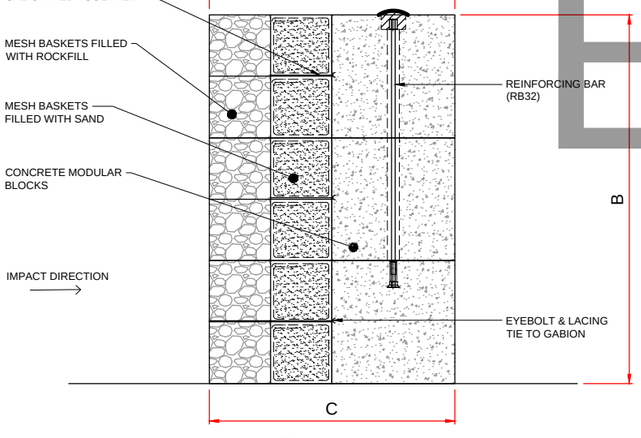
TYPICAL MSE BUND

SCALE NTS



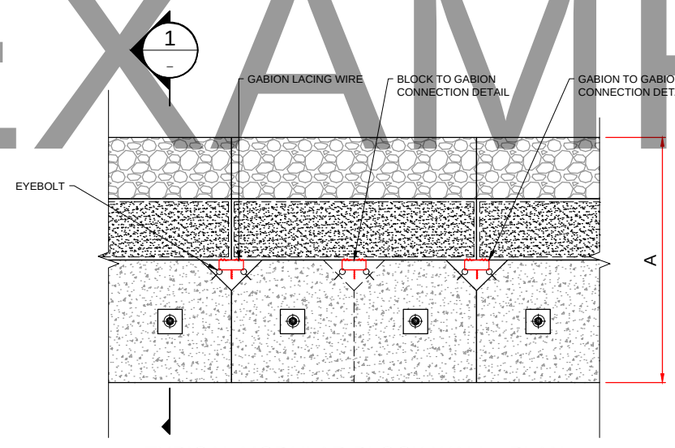
TYPICAL GABION BASKET BUND

SCALE NTS



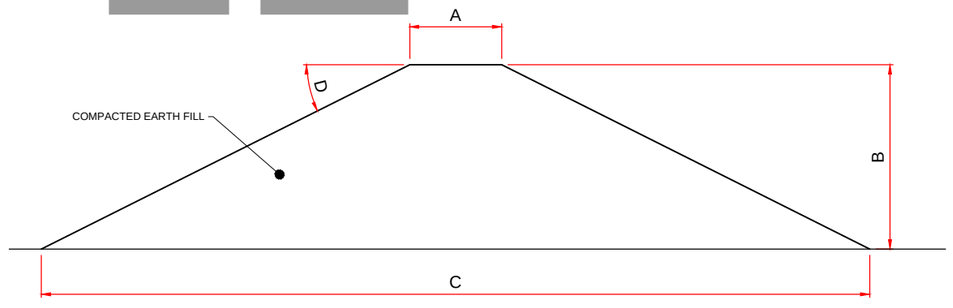
1 / - SECTION

SCALE NTS



TYPICAL MODULAR BLOCK WALL - PLAN

SCALE NTS



TYPICAL EARTH FILL BUND

SCALE NTS

ISSUED FOR MAINTENANCE

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	24/01/2019
DRAWN	T. Richards	TMR	16/01/2019
DRW. CHECK	N. Watts	NW	25/01/2019

PRINTED ON 10-Nov-20 BY rohsm

CONSULTANT FILE REF. 100001-OM-GE-DG-0025

CONSULTANT: NCTIR RECONNECTING COMMUNITIES

NZTA CHAINAGE START

KIWIRAIL CHAINAGE START

KIWIRAIL CE. NUMBER

NZTA FILE REF.

PROJECT TITLE: OPERATIONS AND MAINTENANCE GUIDELINES

DRAWING TITLE: VARIOUS BUNDS TYPICAL CROSS SECTIONS

NCTIR PROJECT NUMBER: 100001

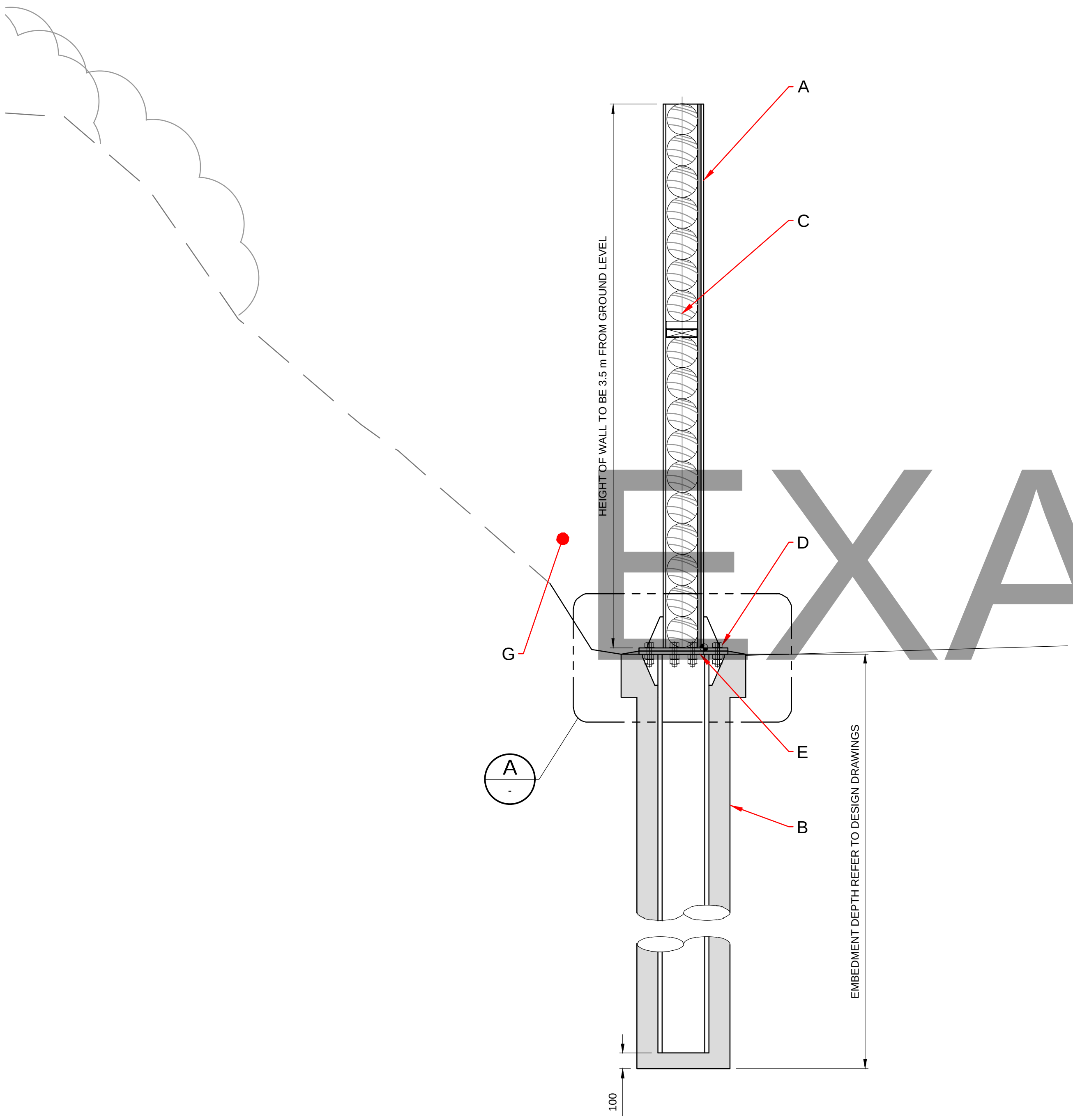
ORIGINAL SHEET SIZE: A1

SCALES: N.T.S.

DRAWING NUMBER: GE0025

REVISION: 1

KEY	ELEMENT
A	ABOVE GROUND UC POST (310UC ro 250UC DEPENDING ON SITE)
B	BELOW GROUND UC POST (310UC or 250UC DEPENDING ON SITE)
C	H5 TREATED 200mm TIMBER ROUNDS
D	M30 BOLTS
E	POST JOINT
F	MAINTENANCE WINDOW - IF DEBRIS CAN BE SEEN - CLEARANCE IF REQUIRED
G	CATCHMENT AREA



TYPICAL CROSS SECTION
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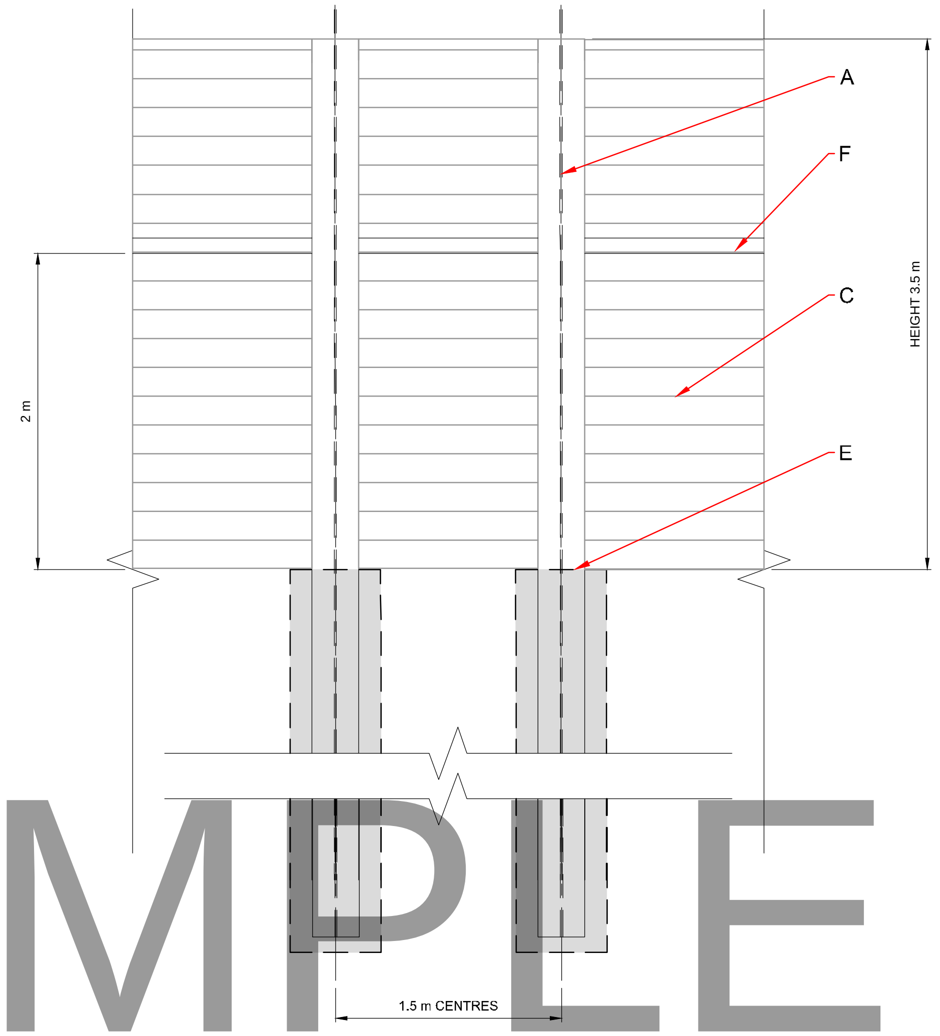
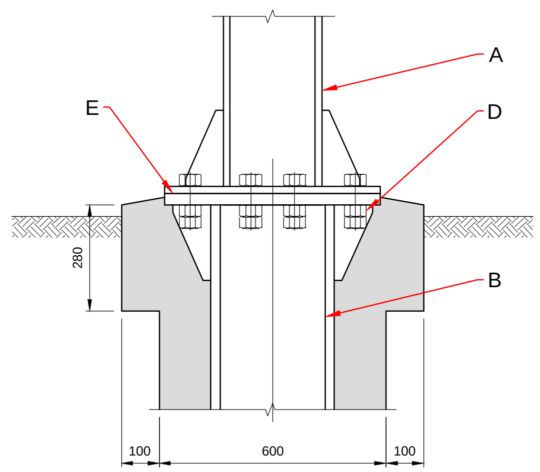


TYPICAL PLAN VIEW
SCALE NTS



A STEEL POST SPLICE DETAIL
SCALE NTS

EXAMPLE

ISSUED FOR MAINTENANCE

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	23/01/2019
DRAWN	E. Song	ES	23/01/2019
DRW. CHECK	N. Watts	NW	25/01/2019

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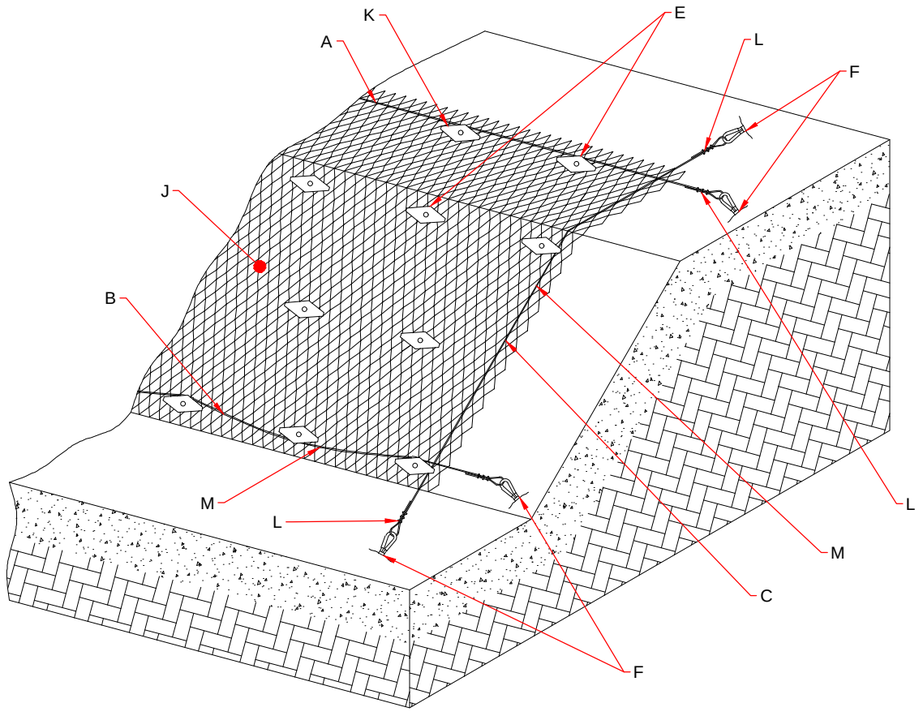
New Zealand Government
KiwiRail
NZ TRANSPORT AGENCY WAKA KOTAHI
CONSULTANT: NCTIR RECONNECTING COMMUNITIES

KIWIRAIL CE. NUMBER
NZTA FILE REF.
CONSULTANT FILE REF. 100001-OM-GE-DG-0026
NZTA CHAINAGE START
KIWIRAIL CHAINAGE START

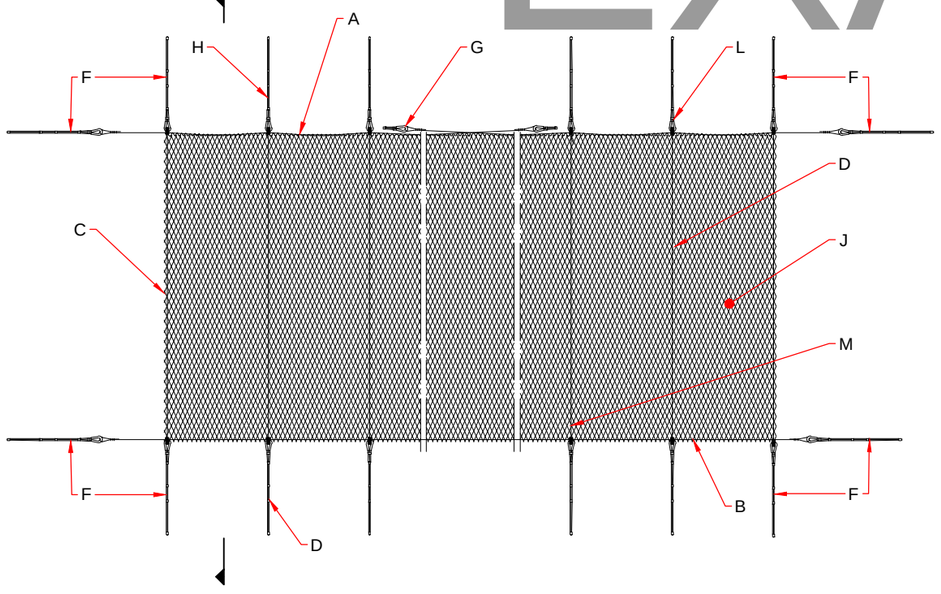
PROJECT TITLE: OPERATIONS AND MAINTENANCE GUIDELINES

DRAWING TITLE: DEBRIS INTERCEPTION WALL GENERAL ARRANGEMENT

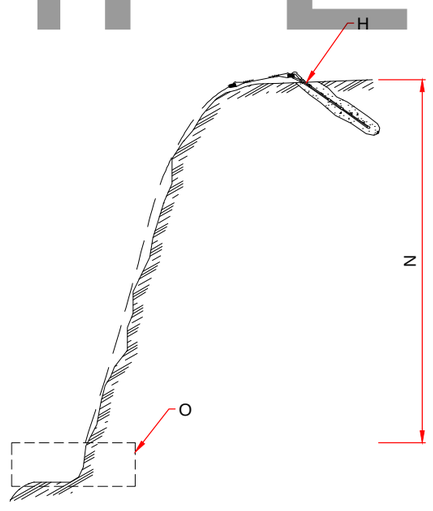
NCTIR PROJECT NUMBER: 100001
ORIGINAL SHEET SIZE: A1
SCALES: N.T.S.
DRAWING NUMBER: GE0026
REVISION: 1



TYPICAL ACTIVE MESH SYSTEM
SCALE NTS



TYPICAL MESH DRAPE SYSTEM
SCALE NTS



1 TYPICAL CROSS SECTION OF DRAPED MESH
SCALE NTS

KEY	ELEMENT
	ROPES
A	TOP BOUNDARY ROPE
	Ø14mm
	Ø18mm
B	BOTTOM BOUNDARY ROPE
	Ø18mm
C	LATERAL BOUNDARY ROPE
	Ø12mm
	Ø14mm
D	INTERMEDIATE ROPES
	Ø12mm
	Ø14mm
	ANCHORS
E	PATTERN BOLT ANCHOR
	TITAN 40/16
	RB32
	DSI DWIDAG 32
	WILLIAMS BAR 32
F	BOUNDARY ROPE ANCHOR (TITAN 40/16 OR RB32,
G	INTERMEDIATE SUPPORT ANCHORS [1] (TITAN 40/16 OR RB32, WITH
H	UPSLOPE ANCHOR [2] (TITAN 40/16 OR RB32, WITH FLEXHEAD T40)
	MESH
J	STEEL MESH
	GALMAC DT MESH (2.2/8) for MACCAFERRI
	TECCO 65/3 for GEOBRUGG
	TRUMER HPN160 for TRUMER
	OTHER
K	ANCHOR PLATE
	STEELGRID HR PLATE for MACCAFERRI
	SPIKE PLATE (P33/40 and P33/50) for GEOBRUGG
	ANCHOR CONNECTION PLATE for TRUMER
L	WIRE ROPE CLIP [3]
	7/16" (NG12)
	9/16" (NG14)
	3/4" (NG18)
	UNI-EN13411-5 (14mm)
	UNI-EN13411-5 (18mm)
M	MESH JOINING CLIPS [3]
	GEOBRUGG T2 CLIPS for TECCO MESH
	GEOBRUGG T3 CLIPS for TECCO MESH
	SPANEX FASTNERS for MACCAFERRI MESH
	2.2mm LACING WIRE for MACCAFERRI MESH
	5mm LACING WIRE for TRUMER MESH
N	DRAPE SECTION
O	CATCH AREA
Notes:	[1] REQUIRED AT 25 - 30 m INTERVALS
	[2] NOT ALWAYS INCLUDED REFER TO SITE SPECIFIC O&M SHEET
	[3] WIRE ROPE CLIPS AND MESH JOINING CLIPS ARE NOT SPECIFICALLY SHOWN. REFER TO MANUFACTURER'S PRODUCT MANUAL FOR SPECIFIC STRUCTURES
	[4] FOR SPECIFIC SYSTEM COMPONENT TYPE AND LOCATION, THE MANUFACTURERS PRODUCT MANUALS

ISSUED FOR MAINTENANCE

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

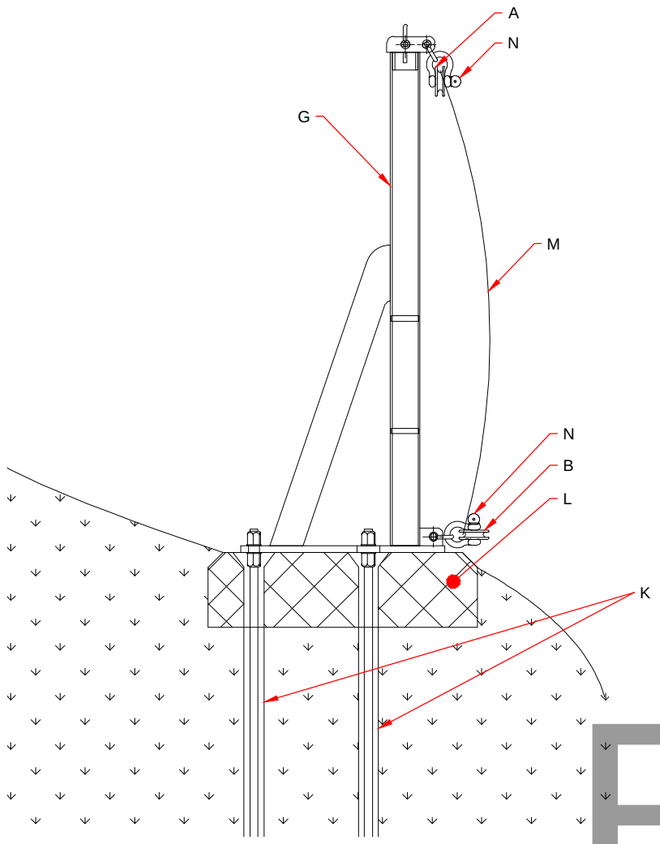
	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	23/01/2019
DRAWN	M. Rohs	MR	8/01/2019
DRW. CHECK	N. Watts	NW	25/01/2019
PRINTED ON	10-Nov-20 BY rohsm		

KIWIRAIL CE. NUMBER
NZTA FILE REF.
CONSULTANT FILE REF. 100001-OM-GE-DG-0030
CONSULTANT: NCTIR RECONNECTING COMMUNITIES
NZTA CHAINAGE START
KIWIRAIL CHAINAGE START

PROJECT TITLE: OPERATIONS AND MAINTENANCE GUIDELINES

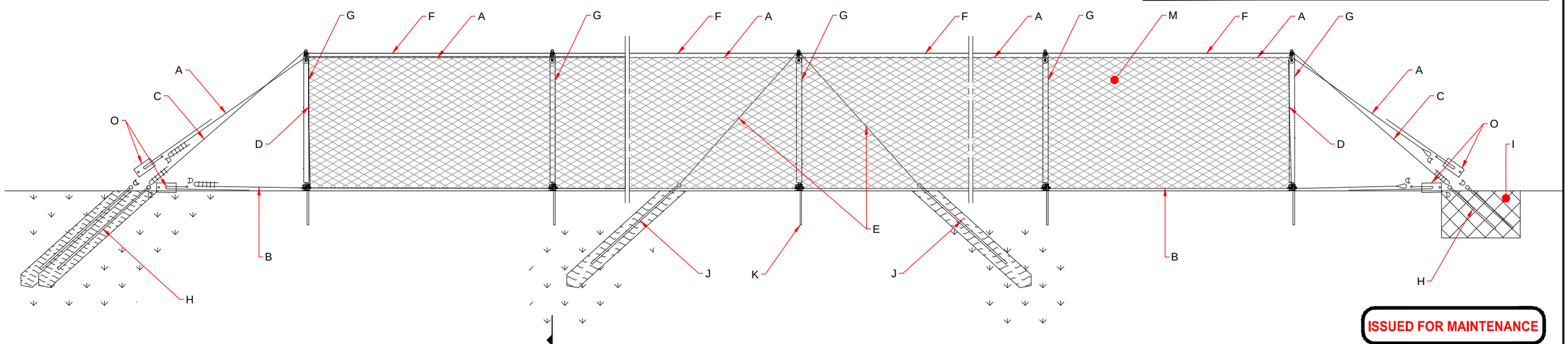
DRAWING TITLE: ACTIVE AND DRAPED MESH GENERAL ARRANGEMENT

NCTIR PROJECT NUMBER: 100001
ORIGINAL SHEET SIZE: A1
SCALES: N.T.S.
DRAWING NUMBER: GE0031
REVISION: 1



TYPICAL CROSS SECTION
AT POST LOCATION
SCALE NTS

KEY	ELEMENT
	ROPES
A	BOTTOM SUPPORT ROPE (4x WIRE ROPE CLIPS AT TERMINATION POINT)
	Ø18mm for GBE-500
	Ø20mm for GBE-1000
B	TOP SUPPORT ROPE (4x WIRE ROPE CLIPS AT TERMINATION POINT)
	Ø18mm for GBE-500
	Ø20mm for GBE-1000
C	LATERAL ANCHOR ROPE (Ø18mm)
D	VERTICAL ROPE
	Ø18mm for GBE-500
	Ø20mm for GBE-1000
E	INTERMEDIATE SUSPENSION (Ø14mm)
F	POST HEAD ROPE (Ø14mm)
	POSTS
G	POST
	RXE/GBE HEA 120 for GBE-500-A
	GBE HEA 180 for GBE-1000-A-R
	ANCHORS
H	LATERAL ANCHOR (TITAN 40/16 OR RB32 WITH FLEXHEAD T40)
I	LATERAL SUPPORT FOUNDATION PLINTH (IF APPLICABLE)
J	INTERMEDIATE SUSPENSION ANCHORS
K	BASE PLATE ANCHORS (TITAN 40/16 OR RB32)
L	BASE PLATE FOUNDATION PLINTH
	MESH
M	TECCO 80/4
	OTHER
N	CLEVIS WHEEL
O	U-BRAKE (TYPE U-300-R20)
-	SHACKLE [1]
	3/8" 9mm
	1/2" 12mm
	5/8" 16mm
	3/4"' 18mm
	1" 25mm
-	WIRE ROPE CLIPS [1]
	9/16" NG14
	5/8" NG16
	3/4" NG18
	7/8" NG22
-	GEOBRUGG ROUND CLIPS (T4) [1]
Notes:	[1] SHACKLES, WIRE ROPE CLIPS, AND T4 CLIPS NOT SPECIFICALLY SHOWN. REFER TO MANUFACTURER'S PRODUCT MANUAL FOR GBE-500A, AND 1000A-R
	[2] FOR SPECIFIC SYSTEM COMPONENT TYPE AND LOCATION MANUFACTURER'S PRODUCT MANUAL FOR GBE-500A-, AND 1000-A-R SHALL BE USED IN CONJUNCTION WITH THIS TABLE



ELEVATION OF ANCHOR POINTS
SCALE NTS

ISSUED FOR MAINTENANCE

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	24/01/2019
DRAWN	M. Rohs	MR	8/01/2019
DRW. CHECK	N. Watts	NW	25/01/2019

PRINTED ON 10-Nov-20 BY rohsm

CONSULTANT: NCTIR RECONNECTING COMMUNITIES

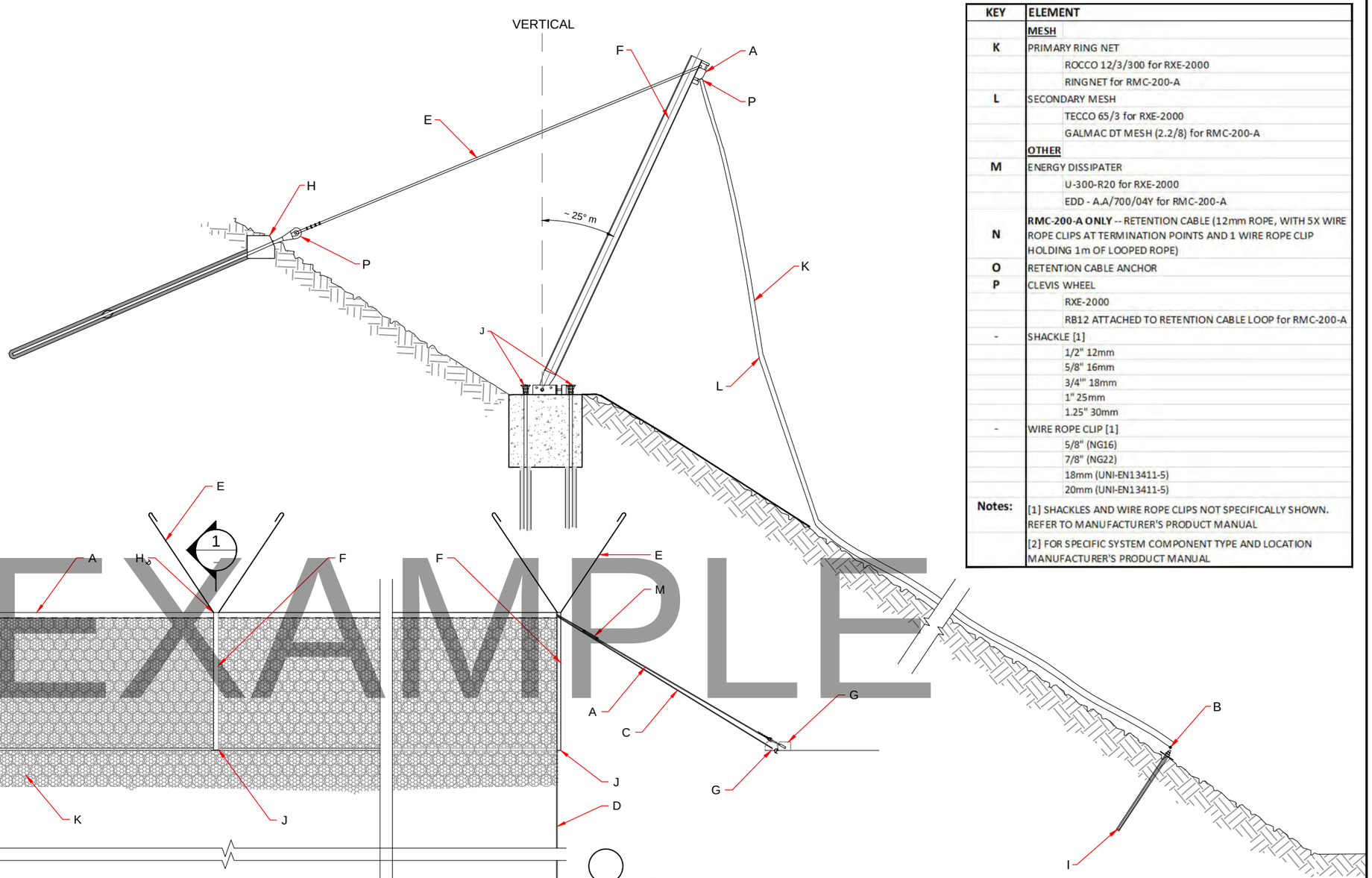
PROJECT TITLE: OPERATIONS AND MAINTENANCE GUIDELINES

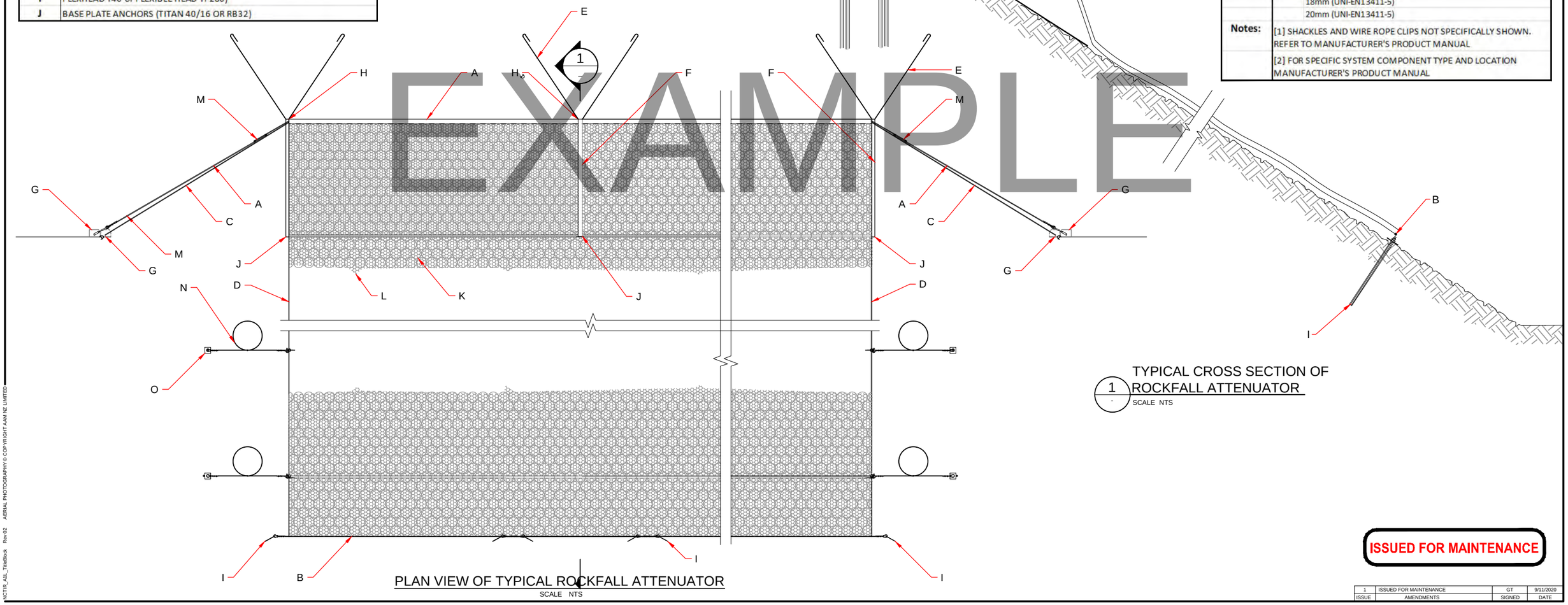
DRAWING TITLE: GEOBRUGG GBE-1000A-R & 500A ROCKFALL BARRIER GENERAL ARRANGEMENT

NCTIR PROJECT NUMBER	ORIGINAL SHEET SIZE	SCALES
100001	A1	N.T.S.
DRAWING NUMBER		REVISION
GE0032		1

KIWIRAIL CE. NUMBER | NZTA FILE REF. | CONSULTANT FILE REF. 100001-OM-GE-DG-0030 | NZTA CHAINAGE START | KIWIRAIL CHAINAGE START

KEY	ELEMENT
	ROPES
A	BOTTOM SUPPORT ROPE (5X WIRE ROPE CLIPS AT TERMINATION POINTS)
	Ø18mm for RMC-200-A
	Ø22mm for RXE-2000
B	2X TOP SUPPORT ROPE (5X WIRE ROPE CLIPS AT TERMINATION POINTS)
	Ø18mm for RMC-200-A
	Ø22mm for RXE-2000
C	LATERAL ANCHOR ROPE (5X WIRE ROPE CLIPS AT TERMINATION POINTS)
	Ø18mm for RMC-200-A
	Ø22mm for RXE-2000
D	VERTICAL RETENTION ROPE (5X WIRE ROPE CLIPS AT TERMINATION POINTS)
	Ø18mm for RMC-200-A
	Ø22mm for RXE-2000
E	UPSLOPE SUPPORT ROPE (5X WIRE ROPE CLIPS AT TERMINATION POINTS)
	Ø18mm for RMC-200-A
	Ø22mm for RXE-2000
	POSTS
F	POST
	RXE/GBE HEA 200 with Groundplate Typ 2 440/330/90 for RXE
	Post (W6x20) HEA-160 with Baseplate 400/550/15 for RMC
	ANCHORS
G	LATERAL ANCHOR (TITAN 40/16 OR RB32 WITH FLEXHEAD T40 or FLEXIBLE HEAD TF280)
H	UPLSOPE ANCHOR (TITAN 40/16 OR RB32 WITH FLEXHEAD T40 or FLEXIBLE HEAD TF280)
I	BOTTOM ROPE SUPPORT ANCHOR (TITAN 40/16 OR RB32 WITH FLEXHEAD T40 or FLEXIBLE HEAD TF280)
J	BASE PLATE ANCHORS (TITAN 40/16 OR RB32)





PLAN VIEW OF TYPICAL ROCKFALL ATTENUATOR
SCALE NTS

TYPICAL CROSS SECTION OF ROCKFALL ATTENUATOR
1 / -
SCALE NTS

KEY	ELEMENT
	MESH
K	PRIMARY RING NET
	ROCCO 12/3/300 for RXE-2000
	RINGNET for RMC-200-A
L	SECONDARY MESH
	TECCO 65/3 for RXE-2000
	GALMAC DT MESH (2.2/8) for RMC-200-A
	OTHER
M	ENERGY DISSIPATER
	U-300-R20 for RXE-2000
	EDD - A.A/700/04Y for RMC-200-A
N	**RMC-200-A ONLY** -- RETENTION CABLE (12mm ROPE, WITH 5X WIRE ROPE CLIPS AT TERMINATION POINTS AND 1 WIRE ROPE CLIP HOLDING 1m OF LOOPED ROPE)
O	RETENTION CABLE ANCHOR
P	CLEVIS WHEEL
	RXE-2000
	RB12 ATTACHED TO RETENTION CABLE LOOP for RMC-200-A
-	SHACKLE [1]
	1/2" 12mm
	5/8" 16mm
	3/4"' 18mm
	1" 25mm
	1.25" 30mm
-	WIRE ROPE CLIP [1]
	5/8" (NG16)
	7/8" (NG22)
	18mm (UNI-EN13411-5)
	20mm (UNI-EN13411-5)
Notes:	[1] SHACKLES AND WIRE ROPE CLIPS NOT SPECIFICALLY SHOWN. REFER TO MANUFACTURER'S PRODUCT MANUAL
	[2] FOR SPECIFIC SYSTEM COMPONENT TYPE AND LOCATION MANUFACTURER'S PRODUCT MANUAL

ISSUED FOR MAINTENANCE

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	24/01/2019
DRAWN	H. Nash	HN	17/01/2019
DRW. CHECK	N. Watts	NW	25/01/2019

PRINTED ON 10-Nov-20 BY rohsm

CONSULTANT: NCTIR RECONNECTING COMMUNITIES

PROJECT TITLE: OPERATIONS AND MAINTENANCE GUIDELINES

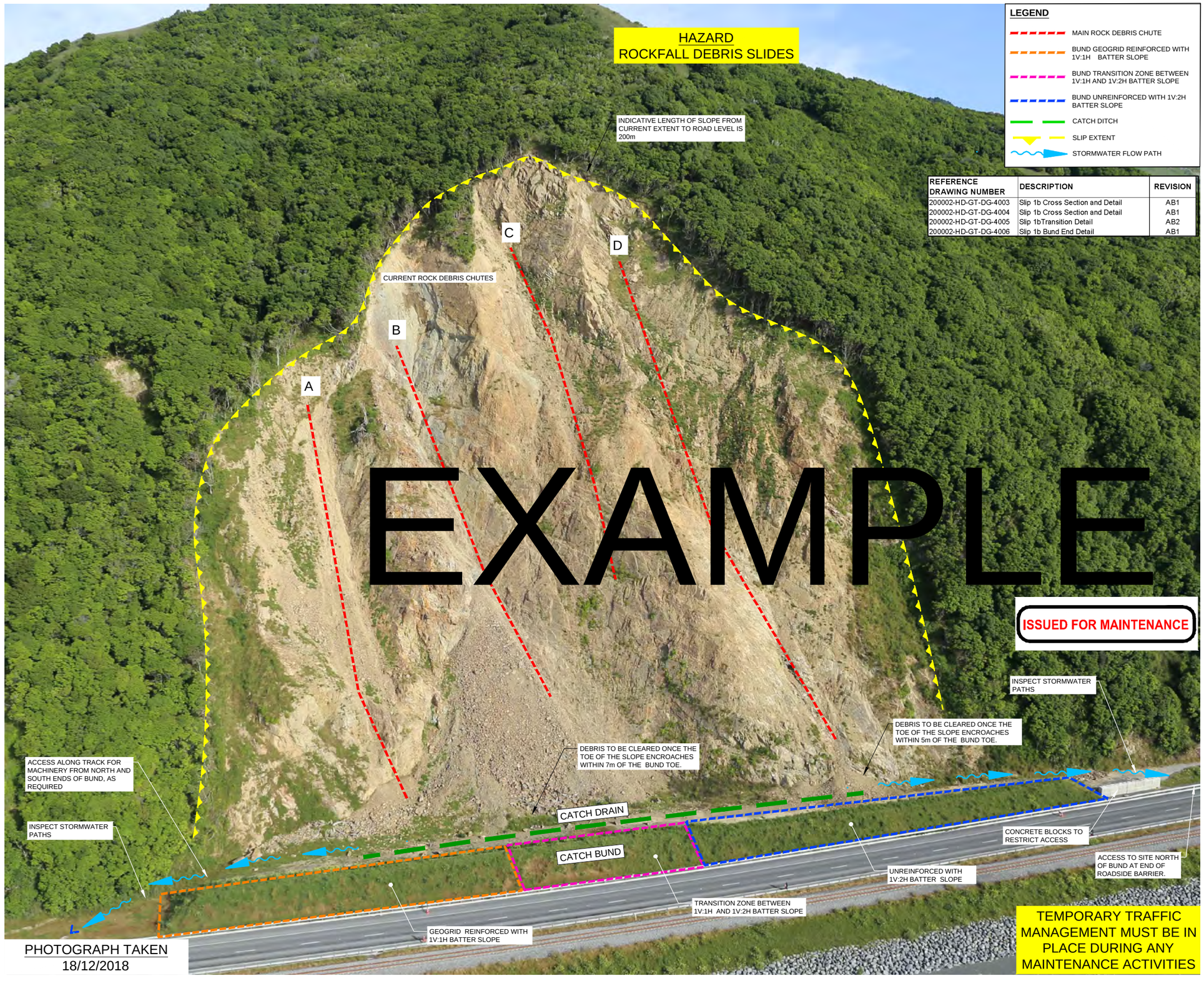
DRAWING TITLE: ROCKFALL ATTENUATOR/ HYBRID FENCE GENERAL ARRANGEMENT

KIWIRAIL CE. NUMBER	
NZTA FILE REF.	
CONSULTANT FILE REF.	100001-OM-GE-DG-0030
NZTA CHAINAGE START	
KIWIRAIL CHAINAGE START	
NCTIR PROJECT NUMBER	100001
ORIGINAL SHEET SIZE	A1
SCALES	N.T.S.
DRAWING NUMBER	GE0033
REVISION	1

FILE LOCATION D:\1305\prep\10\Geotechnical_13\01\General\Operational and Maintenance\00_Drawings

Appendix B:

Examples of Site-Specific Maintenance Plans



PHOTOGRAPH TAKEN
18/12/2018

LEGEND

- MAIN ROCK DEBRIS CHUTE
- BUND GEOGRID REINFORCED WITH 1V:1H BATTER SLOPE
- BUND TRANSITION ZONE BETWEEN 1V:1H AND 1V:2H BATTER SLOPE
- BUND UNREINFORCED WITH 1V:2H BATTER SLOPE
- CATCH DITCH
- SLIP EXTENT
- STORMWATER FLOW PATH

REFERENCE DRAWING NUMBER	DESCRIPTION	REVISION
200002-HD-GT-DG-4003	Slip 1b Cross Section and Detail	AB1
200002-HD-GT-DG-4004	Slip 1b Cross Section and Detail	AB1
200002-HD-GT-DG-4005	Slip 1bTransition Detail	AB2
200002-HD-GT-DG-4006	Slip 1b Bund End Detail	AB1

VIEW LOOKING SOUTH ALONG SH1
(1V:2H SECTION)

GENERAL NOTES:

1. AERIAL VISUAL INSPECTIONS USING HELICOPTER OR DRONE SHALL BE UNDERTAKEN TO ASSESS THE SOURCE AREA AND THE STRUCTURE FOLLOWING RAINFALL EVENTS GREATER THAN 1 in 5 YEAR ARI (~120 mm IN 24 hr) OR AN EARTHQUAKE GREATER THAN MODERATE (>MM7 OR PGA >0.2 g). SCEHDULED MAINTENANCE INSPECTIONS WILL BE REQUIRED IN ACCORDANCE WITH THE OPERATION MAINTENANCE GUIDELINE SECTION 2.1. THE VISUAL INSPECTION SHALL INSPECT ALL COMPONENTS AND RECORD THE HEIGHT OF THE ACCUMULATED DEBRIS.
2. A DETAILED INSPECTION OF THE SOURCE AREA AND ALL EXPOSED HARDWARE USING ROPED ACCESS IS REQUIRED OF ANY FEATURES OF CONCERN IMMEDIATELY AND DURING SCHEDULED MAINTENANCE AS OULINED IN THE OPERATION AND MAINTENANCE GUIDELINE.
3. ALL MAINTENANCE AND INSPECTIONS SHALL BE DONE IN ACCORDANCE WITH THE OPERATIONS AND MAINTENANCE GUIDELINE AND MANUFACTURERS DOCUMENTATION.
4. NO ACCESS BEHIND THE STRUCTURE AND/OR INTO THE DEBRIS CATCH AREA WITHOUT APPROPRIATE SAFETY MEASURES IN PLACE. PERSONNEL ACCESS SHALL BE AVOIDED BEHIND THE STRUCTURE AND/OR INTO THE DEBRIS CATCH AREA, UNLESS APPROPRIATE SAFETY MEASURES ARE IN PLACE (I.E. WITHIN A PROTECTED CABIN OR ADDITIONAL TEMPORARY MEASURES INSTALLED).
5. THIS SITE AND THE MANY OTHER ACROSS THE KAIKOURA COAST AND SURROUNDING AREAS, HAVE A HIGH CULTURAL SIGNIFICANCE. FOR ANY WORKS INVOLVING MATERIAL CLEARANCE, THE NZTA/KIWIRAIL MAINTENANCE AGREEMENT PROJECT MANAGER AND CONTRACTOR MUST REVIEW THE KAIKOURA COASTAL TRANSPORT CORRIDOR CULTURAL MANAGEMENT PLAN (CMP) TO ENSURE THE APPROPRIATE STEPS ARE TAKEN PRIOR TO WORKS STARTING CLEARANCE WORKS. THE CMP IS AVAILABLE FROM THE TE RUNANGA O KAIKOURA (Takahanga.Office@ngaitahu.iwi.nz, PHONE 03 3196523).

SITE SPECIFIC MAINTENANCE METHODOLOGY:

1. REGULAR ROADSIDE VISUAL INSPECTIONS BY NOC CONTRACTOR OF THE STRUCTURE TO BE UNDERTAKEN TO DETERMINE ANY OBVIOUS DAMAGE OR DEBRIS ACCUMULATION REQUIRING MAINTENANCE OR FURTHER DETAILED INSPECTION.
2. BEFORE ANY MAINTENANCE OR INSPECTIONS ARE UNDERTAKEN A GEOTECHNICAL PROFESSIONAL MUST ASSESS THE SLOPE HAZARDS.
3. A RISK ASSESSMENT AND SPECIFIC SAFE WORKING METHODOLOGY STATEMENT (SWMS) MUST BE COMPLETED. THIS SHALL INCLUDE A REVIEW OF THE SAFETY IN DESIGN REGISTER INCLUDED IN THE DESIGN DOCUMENTATION.
4. ANY SPOTTERS REQUIRED FOR GEOTECHNICAL HAZARD MONITORING NEED TO BE POSTIONED WITH GOOD LINES OF SIGHT, CLEAR OF GEOHAZARDS AND COMMUNICATION WITH OPERATORS.
5. ANY EXCAVATION EQUIPMENT ACCESSING BEHIND THE STRUCTURE AND/OR INTO THE DEBRIS CATCH AREA TO HAVE SUITABLE CABIN PROTECTION (ROP'S AND FOP'S) AND/OR REMOTLEY OPERATED. WHEN REMOVING MATERIAL FROM BEHIND THE STRUCTURE ENSURE EMERGENCY EXIT POINTS REMAIN CLEAR AT ALL TIMES. STORAGE OF MATERIAL ON SITE IS LIMITED.
6. ENSURE TEMPORARY TRAFFIC MANAGEMENT MEASURES ARE IN PLACE PRIOR TO ACCESS TO SITE.
7. FOR SCHEDULED MAINTENANCE AND REMOVAL OF DEBRIS FROM BEHIND THE BUND ACCESS IS POSSIBLE VIA BOTH THE SOUTHERN AND NORTHERN ENDS OF THE BUND.
8. DEBRIS ACCUMULATING AT THE BASE OF DEBRIS FLOW CHUTES A, B, AND C SHOULD BE CLEARED ONCE THE TOE OF THE SLOPE ENCROACHES WITHIN 7 M OF THE BUND TOE.
9. DEBRIS ACCUMULATING AT THE BASE OF DEBRIS FLOW CHUTE D SHOULD BE CLEARED ONCE THE TOE OF THE DEBRIS SLOPE ENCROACHES WITHIN 5 m OF THE BUND TOE.
10. DEBRIS ACCUMULATION MARKERS CAN BE INSTALLED AND MAINTAINED BY THE NOC CONTRACTOR OF THE STRUCTURE.
11. DEBRIS REMOVAL SHOULD TARGET LARGE (>1 m) ROCK BLOCKS FROM THE SURFACE OF THE DEBRIS FAN IN THE LOWER 15 m OF THE SLOPE. DEBRIS REMOVAL TO REINSTATE THE CATCH AREA SHALL ENSURE THE REMAINING SLOPE IS 1:5:1 OR SHALLOWER. THIS WORK SHOULD BE COMPLETED BY A LARGE (>20T) EXCAVATOR.
12. ENSURE SPOTTER FOR CHANGING GEOTECHNICAL HAZARDS IS IN A SAFE LOCATION WITH GOOD LINES OF SITE.
13. TRACKED EXCAVATOR/BOBCAT OR SIMILAR TO HAVE FULL CABIN PROTECTION (ROPS AND FOPS) AND/OR REMOTELY OPERATED.
14. CHECK FOR LARGE OR DENSE VEGETATION THAT MAY BLOCK A VISUAL INSPECTION OF THE BUND OR PREVENT ACCESS BEHIND THE BUND. LIGHT VEGETATION COVER (GRASS / SCRUB <0.5 m HIGH) OF THE BUND IS ACCEPTABLE
15. STORMWATER PATHS TO BE MAINTAINED AND CLEARED OF DEBRIS TO PROVIDE UNIMPAIRED OVERLAND FLOW.

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	15/02/2019
DRAWN	N. Watts	NW	27/02/2019
DRW. CHECK	N. Watts	NW	27/02/2019

PRINTED ON 9-Nov-20 BY rohsm

CONSULTANT: NCTIR RECONNECTING COMMUNITIES

PROJECT TITLE: OPERATIONS AND MAINTENANCE GUIDELINES - SITE SPECIFIC MAINTENANCE PLANS

DRAWING TITLE: P1B BUND

KIWIRAIL CE. NUMBER:

NZTA FILE REF.: .

CONSULTANT FILE REF.: 200002-OM-GE-DG-0001

NZTA CHAINAGE START: 01S-0138/483

KIWIRAIL CHAINAGE START: MNL/205.680

NCTIR PROJECT NUMBER: 200002

ORIGINAL SHEET SIZE: A1

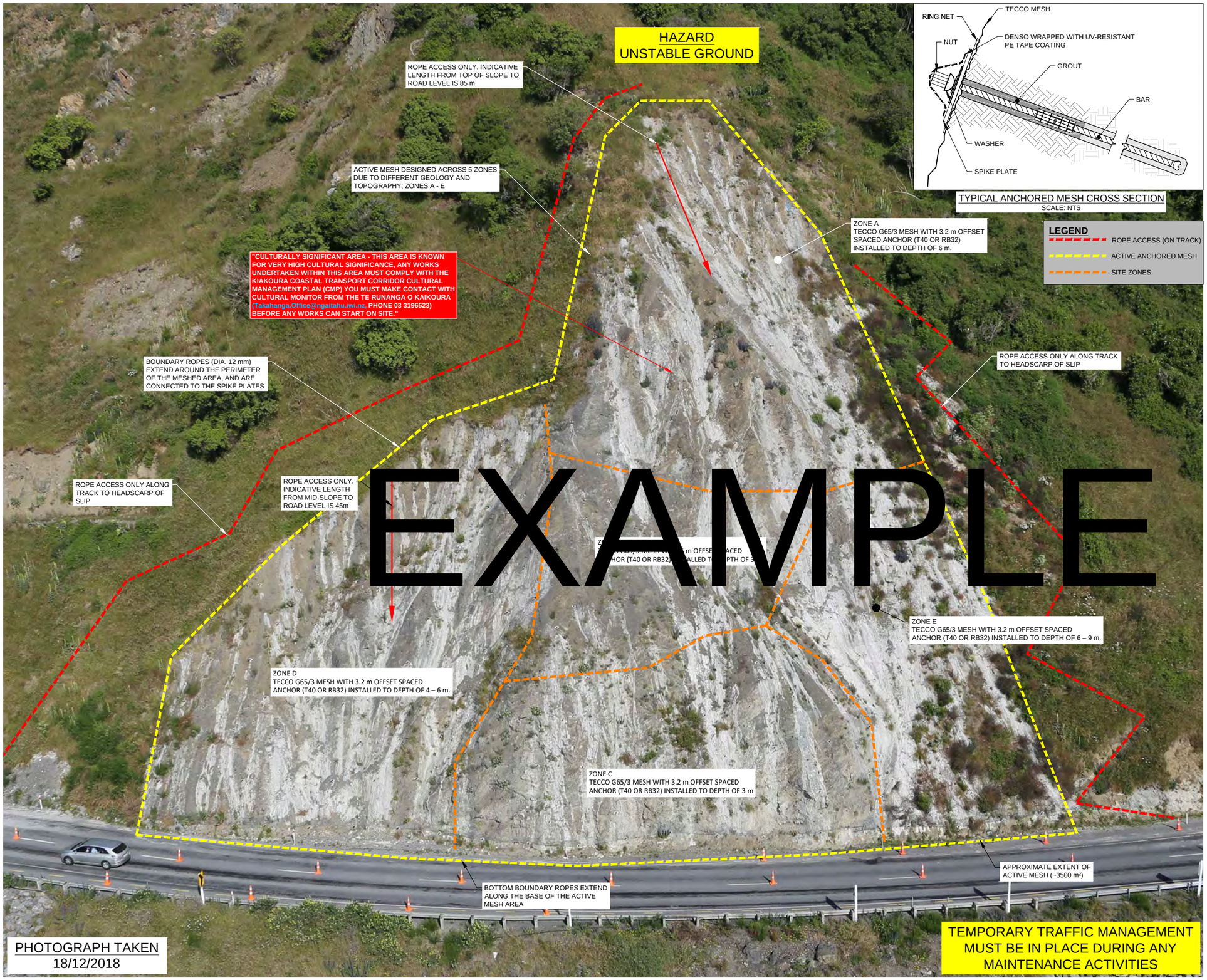
SCALES: N.T.S.

DRAWING NUMBER: GE0001

REVISION: 1

NCTIR_A1L_TitleBlock Rev:02

FILELOCATION D:\13\Synergy\10\Geotechnical_1\81\General\Operational and Maintenance\00_Drawings



TYPICAL ANCHORED MESH CROSS SECTION
SCALE: NTS

LEGEND
- ROPE ACCESS (ON TRACK)
- ACTIVE ANCHORED MESH
- SITE ZONES

GENERAL NOTES:

1. AERIAL VISUAL INSPECTIONS USING HELICOPTER OR DRONE SHALL BE UNDERTAKEN TO ASSESS ALL EXPOSED HARDWARE AND UNDERLYING ROCKFACE FOLLOWING RAINFALL EVENTS GREATER THAN 1 in 5 YEAR ARI (~120 mm IN 24 hr) OR AN EARTHQUAKE GREATER THAN MODERATE (>MM7 OR PGA >0.2 g). SCHEDULED MAINTENANCE INSPECTIONS WILL BE REQUIRED IN ACCORDANCE WITH THE OPERATION MAINTENANCE GUIDELINE SECTION 2.1. THE VISUAL INSPECTION SHALL INSPECT ALL COMPONENTS AND RECORD ANY ACCUMULATED DEBRIS.
2. A DETAILED INSPECTION OF THE UNDERLYING ROCKFACE AND ALL EXPOSED HARDWARE USING ROPED ACCESS IS REQUIRED OF ANY FEATURES OF CONCERN IMMEDIATELY AND DURING SCHEDULED MAINTENANCE AS OULINED IN THE OPERATION AND MAINTENANCE GUIDELINE.
3. ALL MAINTENANCE AND INSPECTIONS SHALL BE DONE IN ACCORDANCE WITH THE OPERATIONS AND MAINTENANCE GUIDELINE AND MANUFACTURERS DOCUMENTATION.
4. NO ACCESS INTO THE DEBRIS CATCH AREA WITHOUT APPROPRIATE SAFETY MEASURES IN PLACE. PERSONNEL ACCESS SHALL BE AVOIDED INTO THE DEBRIS CATCH AREA, UNLESS APPROPRIATE SAFETY MEASURES ARE IN PLACE (I.E. WITHIN A PROTECTED CABIN OR ADDITIONAL TEMPORARY MEASURES INSTALLED).
5. THIS SITE AND THE MANY OTHER ACROSS THE KAIKOURA COAST AND SURROUNDING AREAS, HAVE A HIGH CULTURAL SIGNIFICANCE. FOR ANY WORKS INVOLVING MATERIAL CLEARANCE, THE NZTA/KIWIRAIL MAINTENANCE AGREEMENT PROJECT MANAGER AND CONTRACTOR MUST REVIEW THE KAIKOURA COASTAL TRANSPORT CORRIDOR CULTURAL MANAGEMENT PLAN (CMP) TO ENSURE THE APPROPRIATE STEPS ARE TAKEN PRIOR TO WORKS STARTING CLEARANCE WORKS. THE CMP IS AVAILABLE FROM THE TE RUNANGA O KAIKOURA (Takahanga.Office@ngaitahu.iwi.nz, PHONE 03 3196523).

SITE SPECIFIC MAINTENANCE METHODOLOGY:

1. REGULAR ROADSIDE VISUAL INSPECTIONS BY NOC CONTRACTOR OF THE STRUCTURE TO BE UNDERTAKEN TO DETERMINE ANY OBVIOUS DAMAGE OR DEBRIS ACCUMULATION REQUIRING MAINTENANCE OR FURTHER DETAILED INSPECTION.
2. BEFORE ANY MAINTENANCE OR INSPECTIONS ARE UNDERTAKEN A GEOTECHNICAL PROFESSIONAL MUST ASSESS THE SLOPE HAZARDS.
3. A RISK ASSESSMENT AND SPECIFIC SAFE WORKING METHODOLOGY STATEMENT (SWMS) MUST BE COMPLETED. THIS SHALL INCLUDE A REVIEW OF THE SAFETY IN DESIGN REGISTER INCLUDED IN THE DESIGN DOCUMENTATION.
5. ANY SPOTTERS REQUIRED FOR GEOTECHNICAL HAZARD MONITORING NEED TO BE POSTIONED WITH GOOD LINES OF SIGHT, CLEAR OF GEOHAZARDS AND COMMUNICATION WITH OPERATORS.
6. ANY EXCAVATION EQUIPMENT ACCESSING BEHIND THE STRUCTURE AND/OR INTO THE DEBRIS CATCH AREA TO HAVE SUITABLE CABIN PROTECTION (ROP'S AND FOP'S) AND/OR REMOTLEY OPERATED. WHEN REMOVING MATERIAL FROM BEHIND THE STRUCTURE ENSURE EMERGENCY EXIT POINTS REMAIN CLEAR AT ALL TIMES. STORAGE OF MATERIAL ON SITE IS LIMITED.
7. ROPE ACCESS ONLY TRACK PROVIDES ACCESS TO THE TOP OF THE SITE AND MAY REQUIRE PERIODIC MAINTENANCE TO REMAIN ACCESSIBLE. LAND ACCESS IS WITHIN THE ROAD CORRIDOR.
8. COMPONENTS ARE TECCO G65/3 MESH SYSTEM WITH VARYING ANCHOR BOLT SPACING, SEE ZONE DETAILS. ANCHORS ARE TITAN 40N (T40) OR RB32 SOLID BARS INSTALLED TO VARYING DEPTHS BASED ON THE ZONE. T40 BARS INSTALLED WITH DRILL DIAMETER OF 90 mm AND RB32 SOLID BARS INSTALLED WITH DRILL DIAMETER OR 100 mm.
9. DAMAGED MESH SHALL BE REPAIRED/PATCHED OR SECTION REPLACED AS PER THE OPERATIONS AND MAINTENANCE GUIDELINE.
9. ACCUMULATED MATERIAL ISOLATED WITHIN A SINGLE SET OF ANCHOR BOLTS (4) IS ACCEPTABLE. ANY MATERIAL/DEBRIS EXTENDING BEYOND A SINGLE SET REQUIRES FURTHER INSPECTION AND POTENTIAL REMOVAL. A SPECIFIC MAINTENANCE PLAN FOR REMOVAL OF MATERIAL WILL BE REQUIRED BASED ON THE LOCATION WITHIN THE MESH. IN SOME CASES, THE MESH MAY NEED TO BE REMOTELY CUT IN ORDER TO RELEASE THE MATERIAL FOLLOWED BY A MESH REPAIR.
10. DISLODGED OR ACCUMULATED MATERIAL WILL REQUIRE REMOVAL AND WILL REQUIRE A SPECIFIC MAINTENANCE PLAN BASED ON LOCATION WITHIN THE MESH. IN SOME CASES, THE MESH/RING NET MAY NEED TO BE REMOTELY CUT IN ORDER TO RELEASE THE MATERIAL FOLLOWED BY A MESH REPAIR.
11. ALL REMOVAL OF MATERIAL AND ADDITIONAL SCALING WORKS SHALL BE UNDERTAKEN USING A TOP DOWN APPROACH.
12. BOUNDARY ROPES SHALL BE INSPECTED FOR DAMAGE OR CORROSION, IF A ROPE REQUIRES REPLACEMENT THE NEW ROPE SHALL BE LAID FIRST AND CONNECTED TO THE ANCHORS AND MESH, FOLLOWED BY THE REMOVAL OF THE DAMAGED ROPE.
13. ANCHOR PULL TESTING IN ACCORDANCE WITH BS EN 1537 WILL BE REQUIRED ON 10% OF THE THE ANCHORS WITHIN THE ACTIVE MESH AND BOUNDARY SUPPORT EVERY 25 YRS. REPLACE ANCHORS THAT FAIL THIS TESTING, CONSIDERATION SHALL BE GIVEN TO THE NEW ANCHOR LOCATIONS.
14. BOLTS WILL REQUIRE REPLACEMENT OF DENSO TAPE AND PET TAPE WRAPPING OR SIMILAR ON EXPOSED HARDWARE, WHEN DENSO HAS DRIED OUT OR PET TAPE UNWRAPS.
15. REVEGETATION OF THE SLOPE SHOULD BE MONITORED. IF VEGETATION LIFTS OR PULLS ON THE MESH IT MAY NEED TO BE REMOVED OR MAINTAINED.

REFERENCE DRAWING NUMBER	DESCRIPTION	REVISION
200015-HD-GE-DG-0001	Cover Sheet SR3 & 4	AB1
200015-HD-GT-DG-1401	Site SR3 & 4 General Arrangement	AB1
200015-HD-GT-DG-3401	SR3 Typical Cross Sections	AB1
200015-HD-GT-DG-4401	SR3 Tecco Mesh Details	AB1
200015-HD-GT-DG-4402	SR3 Self-Drilling Anchor Details	AB1

ISSUED FOR MAINTENANCE

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	15/02/2019
DRAWN	N. Watts	NW	27/02/2019
DRW. CHECK	N. Watts	NW	27/02/2019

PRINTED ON 9-Nov-20 BY rohsm

CONSULTANT: NCTIR RECONNECTING COMMUNITIES

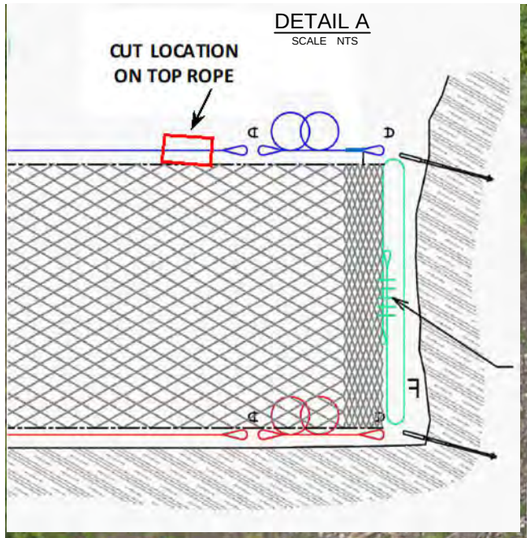
PROJECT TITLE: OPERATIONS AND MAINTENANCE GUIDELINES - SITE SPECIFIC MAINTENANCE PLANS

DRAWING TITLE: SR3-ACTIVE MESH

NCTIR PROJECT NUMBER: 200015
ORIGINAL SHEET SIZE: A1
SCALES: N.T.S.
DRAWING NUMBER: GE0001
REVISION: 1

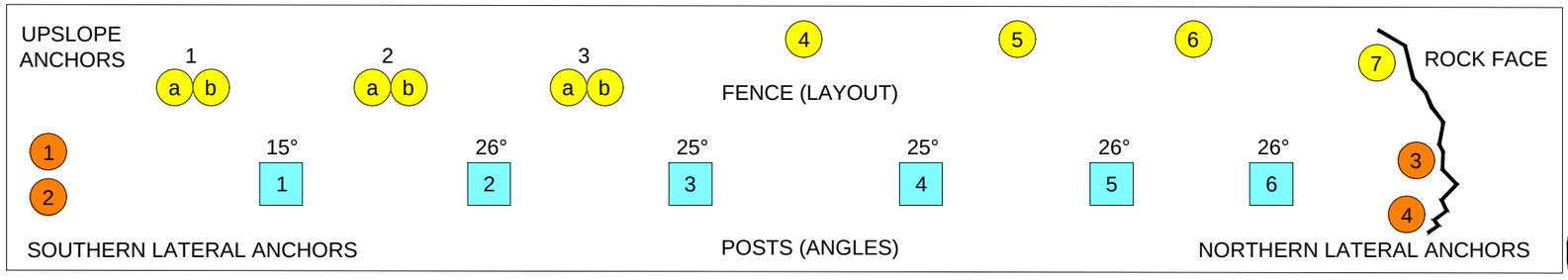
KIWIRAIL CE. NUMBER:
NZTA FILE REF.: .
CONSULTANT FILE REF.: 200015-OM-GE-DG-0001
NZTA CHAINAGE START: 01S-0163/4425
KIWIRAIL CHAINAGE START: MNL/179.380

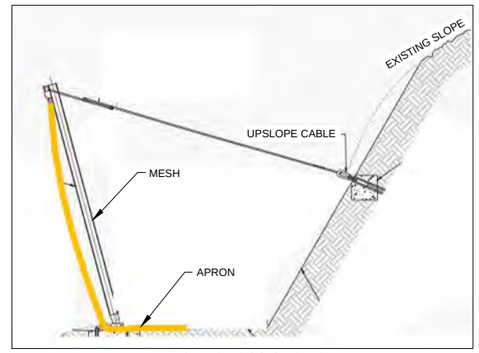
REFERENCE DRAWING NUMBER	DESCRIPTION	REVISION
200022-HD-GE-DG-0001	Cover Sheet	AB2
200022-HD-GT-DG-1101	SR11, 12 & 13 General Arrangement	AB1
200022-HD-GT-DG-4101	Anchor Details	AB1
200022-HD-GT-DG-4102	Post Baseplate & Cable Anchor Head Foundation Details	AB1
200022-HD-GT-DG-4103	Barrier Layout Details	AB1
200022-HD-GT-DG-4104	Cross Section & Adjusting Border Post Detail	AB1
200022-HD-GT-DG-4105	Geobrugg Rockface Connection Detail	AB1
200022-HD-GT-DG-4106	Geobrugg SL-150 with Anchor Forces	AB1



PHTOGRAPH TAKEN
18/12/2019

TEMPORARY TRAFFIC MANAGEMENT
MUST BE IN PLACE DURING ANY MAINTENANCE ACTIVITIES





TYPICAL CROSS SECTION
SCALE: NTS

GENERAL NOTES:

1. AERIAL VISUAL INSPECTIONS USING HELICOPTER OR DRONE SHALL BE UNDERTAKEN TO ASSESS THE SOURCE AREA AND THE STRUCTURE FOLLOWING RAINFALL EVENTS GREATER THAN 1 in 5 YEAR ARI (~120 mm IN 24 hr) OR AN EARTHQUAKE GREATER THAN MODERATE (>MM7 OR PGA >0.2 g). SCEHDULED MAINTENANCE INSPECTIONS WILL BE REQUIRED IN ACCORDANCE WITH THE OPERATION MAINTENANCE GUIDELINE SECTION 2.1. THE VISUAL INSPECTION SHALL INSPECT ALL COMPONENTS AND RECORD THE HEIGHT OF THE ACCUMULATED DEBRIS.
2. A DETAILED INSPECTION OF THE SOURCE AREA AND ALL EXPOSED HARDWARE USING ROPED ACCESS IS REQUIRED OF ANY FEATURES OF CONCERN IMMEDIATELY AND DURING SCHEDULED MAINTENANCE AS OULINED IN THE OPERATION AND MAINTENANCE GUIDELINE.
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5. THIS SITE AND THE MANY OTHER ACROSS THE KAIKOURA COAST AND SURROUNDING AREAS, HAVE A HIGH CULTURAL SIGNIFICANCE. FOR ANY WORKS INVOLVING MATERIAL CLEARANCE, THE NZTA/KIWIRAIL MAINTENANCE AGREEMENT PROJECT MANAGER AND CONTRACTOR MUST REVIEW THE KAIKOURA COASTAL TRANSPORT CORRIDOR CULTURAL MANAGEMENT PLAN (CMP) TO ENSURE THE APPROPRIATE STEPS ARE TAKEN PRIOR TO WORKS STARTING CLEARANCE WORKS. THE CMP IS AVAILABLE FROM THE TE RUNANGA O KAIKOURA (Takahanga.Office@ngaitahu.iwi.nz, PHONE 03 3196523).

MAINTENANCE METHODOLOGY:

1. REGULAR ROADSIDE VISUAL INSPECTIONS BY NOC CONTRACTOR OF THE STRUCTURE TO BE UNDERTAKEN TO DETERMINE ANY OBVIOUS DAMAGE OR DEBRIS ACCUMULATION REQUIRING MAINTENANCE OR FURTHER DETAILED INSPECTION.
2. BEFORE ANY MAINTENANCE OR INSPECTIONS ARE UNDERTAKEN A GEOTECHNICAL PROFESSIONAL MUST ASSESS THE SLOPE HAZARDS.
3. A RISK ASSESSMENT AND SPECIFIC SAFE WORKING METHODOLOGY STATEMENT (SWMS) MUST BE COMPLETED. THIS SHALL INCLUDE A REVIEW OF THE SAFETY IN DESIGN REGISTER INCLUDED IN THE DESIGN DOCUMENTATION.
4. ANY SPOTTERS REQUIRED FOR GEOTECHNICAL HAZARD MONITORING NEED TO BE POSTIONED WITH GOOD LINES OF SIGHT, CLEAR OF GEOHAZARDS AND COMMUNICATION WITH OPERATORS.
5. ANY EXCAVATION EQUIPMENT ACCESSING BEHIND THE STRUCTURE AND/OR INTO THE DEBRIS CATCH AREA TO HAVE SUITABLE CABIN PROTECTION (ROP'S AND FOP'S) AND/OR REMOTLEY OPERATED. WHEN REMOVING MATERIAL FROM BEHIND THE STRUCTURE ENSURE EMERGENCY EXIT POINTS REMAIN CLEAR AT ALL TIMES. STORAGE OF MATERIAL ON SITE IS LIMITED.
6. ADDITIONAL PROTECTION FROM THE UPSLOPE GEOHAZARDS SHOULD BE CONSIDERED FOR THE CONTRACTOR AND ROAD/RAIL USERS IF THE FENCE IS LOWERED.
7. ANCHOR PULL TESTS IN ACCORDANCE WITH BS EN 1537 WILL BE REQUIRED ON 10% OF THE ANCHORS EVERY 25 YEARS. REPLACE ANCHORS THAT FAIL THIS TESTING, CONSIDERATION SHALL BE GIVEN TO NEW ANCHOR LOCATIONS.
8. BOLTS WILL REQUIRE REPLACEMENT OF DENSO TAPE AND PET TAPE WRAPPING OR SIMILAR ON EXPOSED HARDWARE, WHEN DENSO HAS DRIED OUT OR PET TAPE UNWRAPS.
9. DAMAGED OR CORRODED COMPONENTS SHALL BE REPAIRED OR REPLACED AS PER THE OPERATIONS AND MAINTENANCE GUIDELINE
10. FOR SCHEDULED MAINTENANCE AND REMOVAL OF DEBRIS FROM BEHIND THE FENCE, ACCESS IS VIA THE SOUTHERN END. MATERIAL SHOULD BE CLEARED FROM SOUTH TO NORTH.
11. ENSURE TEMPORARY TRAFFIC MEASUREMENT MEASURES ARE IN PLACE PRIOR TO ACCESS TO SITE.
12. FOR REMOVAL OF MATERIAL FROM BEHIND THE FENCE, A LONG REACH EXCAVATOR AT ROAD LEVEL MAY BE ABLE TO REACH OVER THE MESH IN CERTAIN SCENARIOS. IF NOT POSSIBLE THEN A SMALL EXCAVATOR OR BOBCAT (~2 m TRACK WIDTH) CAN ACCESS BEHIND THE FENCE – SOME UPSLOPE SUPPORT CABLES MAY NEED TO BE TEMPORARILY REMOVED FOR ACCESS. CARE SHALL BE TAKEN WHEN TRACKING OVER THE MESH APRON AT THE BASE OF THE FENCE - SEE TYPICAL CROSS SECTION.
13. APPROPRIATE CABIN PROTECTION OR REMOTE CONTROL ABILITIES WILL BE NEEDED FOR MACHINERY ACCESSING BEHIND THE FENCE.
14. ENTER THE SITE THROUGH THE W-BEAM AND TRI-BEAM ROAD BARRIERS. MACHINERY CAN TRACK AROUND TO THE SOUTHERN LATERAL ANCHORS [1,2] AND UPSLOPE SUPPORT ANCHORS [1,2,3] – TAKE CARE NOT TO DAMAGE CONCRETE PLINTHS AND BE AWARE OF APRON OF MESH, SEE CROSS-SECTION.
15. REMOVE MATERIAL FROM A SOUTH TO NORTH DIRECTION – ENSURE EMERGENCY EXITS POINTS ARE KEPT CLEAR AT ALL TIMES. STORAGE OF MATERIAL IS LIMITED. TRUCKS CAN BE TEMPORARILY PARKED AT SOUTHERN GATE FOR LOADING. IN THE EVENT OF A SIGNIFICANT AMOUNT OF DEBRIS – RELEASE OF FENCE MAY BE REQUIRED.
16. IF MATERIAL CANNOT BE EFFECTIVELY CLEARED FROM BEHIND THE FENCE, THE TOP ROPE MAY NEED TO BE RELEASED TO ACCESS MATERIAL FROM ROAD LEVEL. TO RELEASE FENCE THE TOP ROPE CABLE WILL NEED TO BE CUT AT THE NORTHERN LATERAL ANCHOR, SEE DETAIL A. USE A REMOTELY OPERATED CUTTER TO CUT THE TOP ROPE DIRECTLY SOUTH OF THE 1" SHACKLE CONNECTING THE TOP ROPE TO BRAKE RINGS AT LATERAL ANCHOR [3].
17. ONCE THE TOP ROPE IS CUT AND THE FENCE IS ON THE GROUND, MATERIAL CAN BE REMOVED USING EXCAVATOR ON ROAD CORRIDOR - A LANE CLOSURE WILL LIKELY BE REQUIRED - CONSULT WITH STMS.
18. ONCE MATERIAL IS REMOVED – RELEASE EXCESS TOP ROPE COILED AT THE SOUTHERN END AND RE-TENSION TO THE TOP ROPE, CONNECTING BACK TO THE BRAKE RINGS IN THE NORTH.
19. IF ANCHORS ARE DAMAGED AND REQUIRE REPLACEMENT CONSIDERATION WILL BE NEEDED TO NEW LOCATION AND DESIGN INPUT WILL BE REQUIRED TO ENSURE AVOIDANCE OF IMPACTING THE TUNNEL 12.

ISSUED FOR MAINTENANCE

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	15/05/2019
DRAWN	H. Nash	HN	12/02/2019
DRW. CHECK	M. Rohs	MR	22/05/2019

PRINTED ON 10-Nov-20 BY rohsm

New Zealand Government
KiwiRail
KIWIRAIL CE. NUMBER

NZ TRANSPORT AGENCY WAKA KOTAHI
NZTA FILE REF. .

CONSULTANT FILE REF. 200022-OM-GE-DG-0002

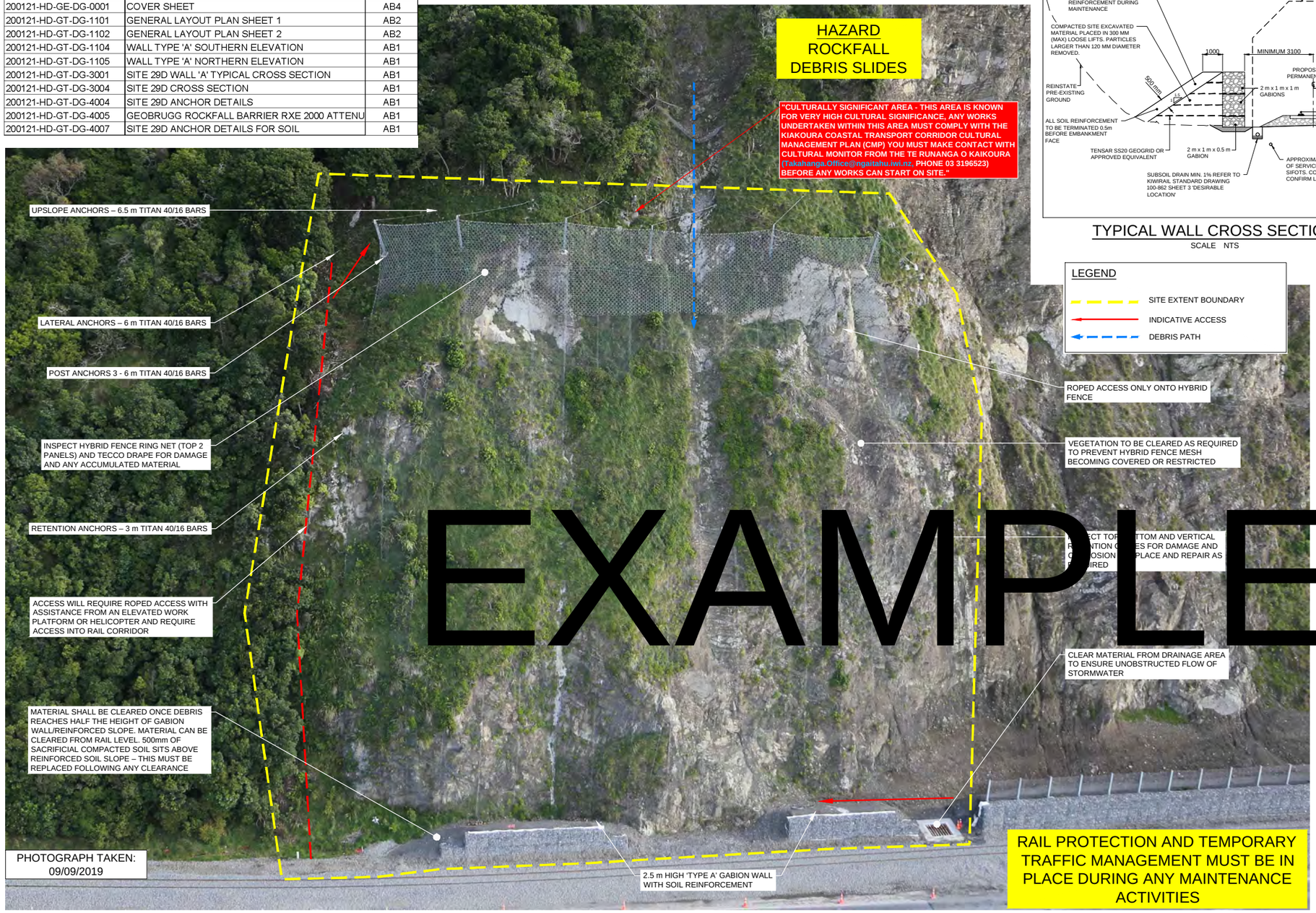
CONSULTANT NCTIR RECONNECTING COMMUNITIES
NZTA CHAINAGE START 01S-0163/5440
KIWIRAIL CHAINAGE START

PROJECT TITLE
OPERATIONS AND MAINTENANCE GUIDELINES - SITE SPECIFIC MAINTENANCE PLANS

DRAWING TITLE
SR11 - SL-150 SHALLOW LANDSLIDE BARRIER

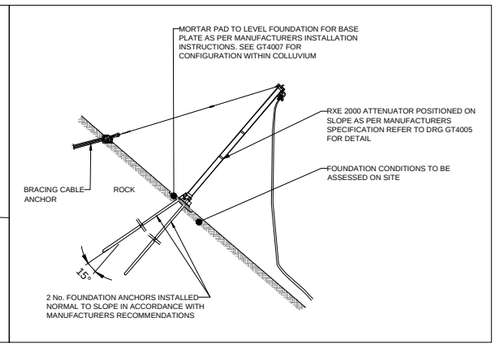
NCTIR PROJECT NUMBER 200022
ORIGINAL SHEET SIZE A1
SCALES N.T.S.
DRAWING NUMBER GE0002
REVISION 1

REFERENCE DRAWING NUMBER	DESCRIPTION	REVISION
200121-HD-GE-DG-0001	COVER SHEET	AB4
200121-HD-GT-DG-1101	GENERAL LAYOUT PLAN SHEET 1	AB2
200121-HD-GT-DG-1102	GENERAL LAYOUT PLAN SHEET 2	AB2
200121-HD-GT-DG-1104	WALL TYPE 'A' SOUTHERN ELEVATION	AB1
200121-HD-GT-DG-1105	WALL TYPE 'A' NORTHERN ELEVATION	AB1
200121-HD-GT-DG-3001	SITE 29D WALL 'A' TYPICAL CROSS SECTION	AB1
200121-HD-GT-DG-3004	SITE 29D CROSS SECTION	AB1
200121-HD-GT-DG-4004	SITE 29D ANCHOR DETAILS	AB1
200121-HD-GT-DG-4005	GEOBRUGG ROCKFALL BARRIER RXE 2000 ATTENU	AB1
200121-HD-GT-DG-4007	SITE 29D ANCHOR DETAILS FOR SOIL	AB1



TYPICAL WALL CROSS SECTION

SCALE NTS

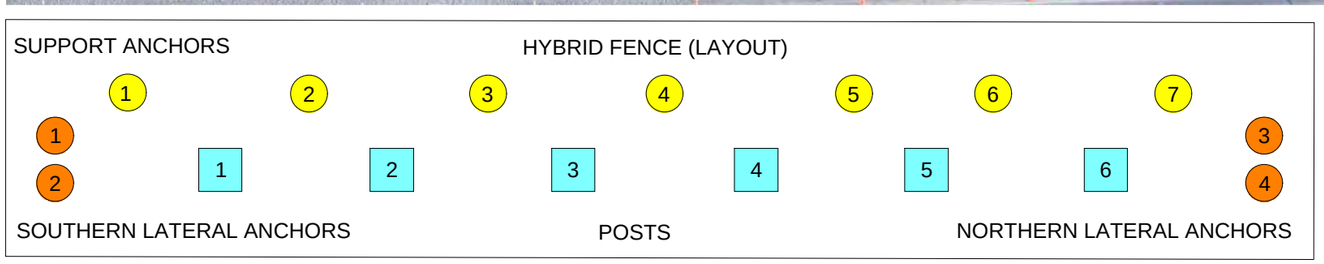


TYPICAL ANCHOR CROSS SECTION

SCALE NTS

LEGEND

- SITE EXTENT BOUNDARY
- INDICATIVE ACCESS
- DEBRIS PATH



GENERAL NOTES:

1. AERIAL VISUAL INSPECTIONS USING HELICOPTER OR DRONE SHALL BE UNDERTAKEN TO ASSESS THE SOURCE AREA AND THE STRUCTURE FOLLOWING RAINFALL EVENTS GREATER THAN 1 in 5 YEAR ARI (~120 mm IN 24 hr) OR AN EARTHQUAKE GREATER THAN MODERATE (>MM7 OR PGA >0.2 g). SCEHDULED MAINTENANCE INSPECTIONS WILL BE REQUIRED IN ACCORDANCE WITH THE OPERATION MAINTENANCE GUIDELINE SECTION 2.1. THE VISUAL INSPECTION SHALL INSPECT ALL COMPONENTS AND RECORD THE HEIGHT OF THE ACCUMULATED DEBRIS.
2. A DETAILED INSPECTION OF THE SOURCE AREA AND ALL EXPOSED HARDWARE USING ROPED ACCESS IS REQUIRED OF ANY FEATURES OF CONCERN IMMEDIATELY AND DURING SCHEDULED MAINTENANCE AS OULINED IN THE OPERATION AND MAINTENANCE GUIDELINE.
3. ALL MAINTENANCE AND INSPECTIONS SHALL BE DONE IN ACCORDANCE WITH THE OPERATIONS AND MAINTENANCE GUIDELINE AND MANUFACTURERS DOCUMENTATION.
4. NO ACCESS BEHIND THE STRUCTURE AND/OR INTO THE DEBRIS CATCH AREA WITHOUT APPROPRIATE SAFETY MEASURES IN PLACE. PERSONNEL ACCESS SHALL BE AVOIDED BEHIND THE STRUCTURE AND/OR INTO THE DEBRIS CATCH AREA, UNLESS APPROPRIATE SAFETY MEASURES ARE IN PLACE (I.E. WITHIN A PROTECTED CABIN OR ADDITIONAL TEMPORARY MEASURES INSTALLED).
5. THIS SITE AND THE MANY OTHER ACROSS THE KAIKOURA COAST AND SURROUNDING AREAS, HAVE A HIGH CULTURAL SIGNIFICANCE. FOR ANY WORKS INVOLVING MATERIAL CLEARANCE, THE NZTA/KIWIRAIL MAINTENANCE AGREEMENT PROJECT MANAGER AND CONTRACTOR MUST REVIEW THE KAIKOURA COASTAL TRANSPORT CORRIDOR CULTURAL MANAGEMENT PLAN (CMP) TO ENSURE THE APPROPRIATE STEPS ARE TAKEN PRIOR TO WORKS STARTING CLEARANCE WORKS. THE CMP IS AVAILABLE FROM THE TE RUNANGA O KAIKOURA (Takahanga.Office@ngaitahu.iwi.nz, PHONE 03 3196523).

MAINTENANCE METHODOLOGY (CONT'D):

5. ANY EXCAVATION EQUIPMENT ACCESSING BEHIND THE STRUCTURE AND/OR INTO THE DEBRIS CATCH AREA TO HAVE SUITABLE CABIN PROTECTION (ROP'S AND FOP'S) AND/OR REMOTELY OPERATED. WHEN REMOVING MATERIAL FROM BEHIND THE STRUCTURE ENSURE EMERGENCY EXIT POINTS REMAIN CLEAR AT ALL TIMES. STORAGE OF MATERIAL ON SITE IS LIMITED.
6. ACCESS TO SITE MUST USE KIWIRAIL APPROVED ACCESS POINTS, CONTACT NZTA/KIWIRAIL MAINTENANCE AGREEMENT PROJECT MANAGER FOR NEAREST KIWIRAIL APPROVED CROSSING LOCATION AND ENSURE A SUITABLE LEVEL OF RAIL PROTECTION IS IN PLACE PRIOR TO ACCESSING SITE. INCLUDING MANAGING THE RISK TO RAIL USERS WHILE ROCKFALL MITIGATION IS NOT IN FULL OPERATION.
7. DURING WORKS THAT HAVE POTENTIAL TO IMPACT RAIL, PLACE PROTECTION OVER RAIL, SLEEPERS AND BALLAST TO AVOID CONTAMINATION OF BALLAST AND DAMAGE TO RAIL AND SLEEPERS. THE METHODOLOGY SHOULD BE AGREED IN ADVANCE WITH KIWIRAIL AND APPROVED BY NZTA/KIWIRAIL MAINTENANCE AGREEMENT PROJECT MANAGER.
8. ADDITIONAL PROTECTION FROM THE UPSLOPE GEOHAZARDS SHOULD BE CONSIDERED FOR THE CONTRACTOR AND ROAD/RAIL USERS IF THE FENCE IS LOWERED.
9. ANCHOR PULL TESTS IN ACCORDANCE WITH BS EN 1537 WILL BE REQUIRED ON 10% OF THE ANCHORS EVERY 25 YEARS. REPLACE ANCHORS THAT FAIL THIS TESTING, CONSIDERATION SHALL BE GIVEN TO NEW ANCHOR LOCATIONS.
10. BOLTS WILL REQUIRE REPLACEMENT OF DENSO TAPE AND PET TAPE WRAPPING OR SIMILAR ON EXPOSED HARDWARE, WHEN DENSO HAS DRIED OUT OR PET TAPE UNWRAPS.
11. ACCESS TO THE BASE OF THE HYBRID FENCE CAN BE ACHIEVED VIA EITHER END.
12. RAIL PROTECTION MEASURES MUST BE IN PLACE PRIOR TO ACCESSING SITE.
13. DAMAGED OR CORRODED COMPONENTS SHALL BE REPAIRED OR REPLACED AS PER THE OPERATIONS AND MAINTENANCE GUIDELINE.
14. ACCUMULATED MATERIAL WITHIN THE HYBRID FENCE WILL REQUIRE REMOVAL AND WILL REQUIRE A SPECIFIC TASK ANALYSIS BASED ON LOCATION WITHIN THE RING NET OR MESH. IN SOME CASES, THE RING NET OR MESH MAY NEED TO BE LIFTED BY A CRANE OR LONG-REACH EXCAVATOR IN ORDER TO RELEASE THE MATERIAL.
15. ALL REMOVAL OF MATERIAL SHALL BE UNDERTAKEN USING A TOP DOWN APPROACH.
16. BOUNDARY ROPES SHALL BE INSPECTED FOR DAMAGE OR CORROSION, IF A ROPE REQUIRES REPLACEMENT THE NEW ROPE SHALL BE LAID FIRST AND CONNECTED TO THE POSTS, ANCHORS AND MESH, FOLLOWED BY THE REMOVAL OF THE DAMAGED ROPE.
17. FOR REMOVAL OF MATERIAL FROM THE BASE OF THE HYBRID FENCE AND BEHIND THE BUNDS, AN EXCAVATOR CAN BE TRACKED AROUND THE BUNDS TO CLEAR MATERIAL.
18. ONCE MATERIAL IS REMOVED – REINSTATE AND ENSURE THE GABION BUND IS RE-CONSTRUCTED AS PER DESIGN DOCUMENTATION.

MAINTENANCE METHODOLOGY:

1. REGULAR ROADSIDE VISUAL INSPECTIONS BY NOC CONTRACTOR OF THE STRUCTURE TO BE UNDERTAKEN TO DETERMINE ANY OBVIOUS DAMAGE OR DEBRIS ACCUMULATION REQUIRING MAINTENANCE OR FURTHER DETAILED INSPECTION.
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ISSUED FOR MAINTENANCE

ISSUE	AMENDMENTS	SIGNED	DATE
1	ISSUED FOR MAINTENANCE	GT	9/11/2020

	NAME	SIGNED	DATE
SITE ENG.	T. Revell	TR	30/10/2019
DRAWN	H. Nash	HN	29/10/2019
DRW. CHECK	M. Rohs	MR	27/11/2019

PRINTED ON 12-Nov-20 BY rohsm

CONSULTANT: NCTIR RECONNECTING COMMUNITIES

PROJECT TITLE: OPERATIONS AND MAINTENANCE GUIDELINES - SITE SPECIFIC MAINTENANCE PLANS

DRAWING TITLE: SR29D - HYBRID FENCE AND GABION BUND

KIWIRAIL CE. NUMBER	NZTA FILE REF.	CONSULTANT FILE REF.	NZTA CHAINAGE START	KIWIRAIL CHAINAGE START
	.	200121-OM-GE-DG-0002	01S-0163/8154	MNL/176.050

NCTIR PROJECT NUMBER	ORIGINAL SHEET SIZE	SCALES
200121	A1	N.T.S.
DRAWING NUMBER		REVISION
GE0002		1