Rockfall Hazard Rating Procedure

(Previously SMO18 Appendix C: Rockfall Rating System)

Waka Kotahi

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Version 1

Introduction

The framework of the procedure is presented here and highlighted in boxes are useful notes which may help in implementation.

> It is important is that all parties are using the same system the same way and there is a measure of consistency nationwide. The RHRS system is intended as a proactive hazard management tool creating a quick, easy to use first cut prioritisation rather than a definitive assessment.

Inspections can be carried out by appropriately experienced staff by the network maintenance contractor. It has proved an effective method of obtaining a first cut of relative site risk to the road user that is manageable through the Waka Kotahi geo-hazard monitoring programme.

Experience has shown that although the system is relatively simple it does have certain technical aspects related to geotechnical conditions.

> It is recommended that at least 10% of all sites should be checked by an experienced geotechnical engineer. Where errors are noted, the geotechnical engineer should offer coaching to improve outcomes.

The RHR system is intended as a proactive hazard management tool rather than a complete assessment guide. Using the RHR should be seen as a first cut analysis that is useful to allow resources to be directed towards the higher risk sites for further assessment and/or physical works.

It is a semi-quantitative system that allocates points to the sites depending on,

1. Road features
2. Geological characteristics
3. Event characteristics and history

The scores for each site are then grouped into the following categories:

<275 no action needed, continue to check

>325 should be inspected in closer detail by an experienced geotechnical engineer

>500 is likely to be a serious hazard and remedial work is almost certainly required soon.

The ranges are those currently in use and may be changed by Waka Kotahi.

Waka Kotahi will direct what action is required, based upon the assessed score and internal review, which will be subject to funding.

Scores should be reviewed by the network maintenance contractor annually and Waka Kotahi advised.

Road Features

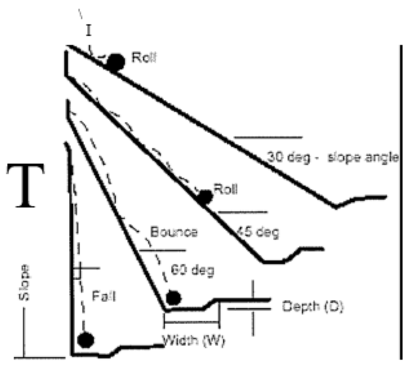
Slope Height

Rocks on higher slopes have more potential energy, so have higher risk scores. The slope height measurement should be taken to the highest point from which rockfall is expected either from within the cut or from the greater natural slope above the cut.

Estimating height can be quite difficult. A good method is to take a survey measuring staff out into the field with you and stand it up against the slope to help gauge approximate height.

Ditch Effectiveness

This is determined by the depth and size of the ditch in conjunction with the slope angle (i.e. the expected particle motion) and the expected size of the falling material.



Rock falls on slopes

Figures taken from FHWA Manual 'Rock Slopes' November 1991. USDOT Chapter 12 Page 19.

Any features on the face which will launch rocks out from the face will reduce the effectiveness of the ditches, so don't just look at the ditch width but consider its ability to actually catch rocks given the slope profile above. The figure above shows probable trajectories of falling rocks and falling rocks (i.e. from a vertical face) will need significantly smaller ditches than rapidly rolling rocks (i.e. from faces at around 45°).

More recent projects include prescribed catch-ditches, but for existing networks such 'catch areas' will be in the form of the existing verge or shoulder. Grass or gravel shoulders can be effective in absorbing energy from debris and rockfall. Be mindful that verges/shoulders that slope towards the road may result in debris falling into the road.

Average Vehicle Risk

This is a function of the speed environment of the road, the amount of traffic on the road and the length of the feature. It determines the amount of time that any vehicle is in the hazard area. It is important to ensure that only the length of the slope where rockfall is likely to occur is used to calculate AVR.

Be aware that the formula requires hourly traffic (AAHT), not just AADT which is what we are most used to using.

Use AAHT = AADT/24

Then,

AVR = AAHT (cars/hour) x slope hazard length (km) x 100%/posted speed limit (km/h)

Also note that the posted speed limit should be used.

Percent of decision sight distance

This determines the likelihood of a vehicle hitting a rock that has already fallen onto the road. The measured sight distance is the distance from which a 150mm object on the edge of the road can be seen with an eye level 1.3m above the roadway. The decision sight distance is the average distance that is needed for a driver to react to a hazard and stop their vehicle.

Percent of decision sight distance= Actual site distance x 100%/Decision site distance

Posted Speed Limit (km/h)	Decision Sight Distance (m}
50	135
60	180
80	230
100	300

Roadway Width

This influences the risk at a site because it affects the likelihood of a vehicle impacting a fallen rock. On a wide roadway there will be space for a vehicle to avoid a rock without risking a collision with oncoming traffic. Narrow roadways will reduce the chance of a vehicle being able to avoid a fallen rock.

Geological Characteristics

There are two cases within the geological characteristics of the rockfall, either defect or erosion driven events.

Case 1: Events that are defect driven

For the defect dominated sites, the presence and orientation of defects and the friction available to resist sliding are the two controlling factors on failure. The following two tables show the point values associated with different conditions.

Do **NOT** interpolate between the point values: adopt one of the values shown.

Defect Presence and Orientation

3 points	*Discontinuous joints, Favourable Orientation* Jointed rock with no adversely oriented joints, bedding planes, etc.
9 points	*Discontinuous joints, Random Orientation* Rock slopes with randomly oriented joints creating a three-dimensional pattern. This type of pattern is likely to have some scattered blocks with adversely oriented joints but no dominant adverse joint pattern is present.
27 points	*Discontinuous joints, Adverse Orientation* Rock slope exhibits a prominent joint pattern, bedding plane, or other discontinuity, with an adverse orientation. These features have less than 3m of continuous length,
81 points	*Continuous joints, Adverse Orientation* Rock slope exhibits a dominant joint pattern, bedding plane, or other discontinuity, with an adverse orientation and a persistency greater than 3m.

Continuous joints are defined as being greater than 3m long.

Friction Available to resist sliding.

3 points	*Rough, Irregular* The surface of the joints is rough and the joint planes are irregular enough to cause interlocking. This macro and micro roughness provides an optimal friction situation
9 points	*Undulating* Also macro and micro rough but without the interlocking ability.
27 points	*Planar* Macro smooth and micro rough joint surfaces. Surface contains no undulations. Friction is derived strictly from the roughness of the rock surface.

81 points	*Clay Infilling or Slickensided* Low friction materials, such as clay and weathered rock, separate the rock surfaces negating any micro or macro roughness of the joint planes. These infilling materials have much lower friction angles than a rock on rock contact. Slickensided joints also have a very low friction angle and belong in this category.

Case 2: Events that are erosion driven or are over steepened slopes

Erosion dominated sites are scored in two categories, the presence of erosion features, and the difference in erosion rates. The presence of erosion features scores 3 points for few, minor differential erosion features and 81 points for major erosion features, including overhangs or severely over steepened talus slopes. The difference in erosion rates is the other category and covers the rate at which new erosion features develop. A small difference in erosion rates (i.e. a slope that is near equilibrium) scores 3 points, while a slope with erosion features developing rapidly (multiple times per year) scores 81 points.

Climate and presence of water on slope

The hydrological characteristics of the area are also important causal factors in rockfalls, so the presence of water, ice jacking and freeze thaw activity is given points. 3 points are assigned for sites with no freezing periods, no water flows, and little precipitation. 27 points are assigned for slopes with either a high precipitation, long freezing periods or water on the slope. 81 points are scored when the site has long periods of freezing and either continual water on the slope or high precipitation.

Rainfall within brackets reflect mountainous areas (high rainfall, >1250mm/yr) and very dry areas such as Central Otago (<450mm/yr).

Event Characteristics and History

Block Size

The maximum block size expected in an event is included in the hazard rating. Large rocks do more damage than multiple small ones, so carry a higher risk rating.

Quantity of Rockfall per event

The size of the event also affects the severity of the event.

Rockfall History

This can be obtained from available records although in some cases there may not be any history of rockfall events, such as new slopes or in areas where rockfalls have been cleared up without any reporting being carried out. If there are no records, the maintenance costs for rock clearing in the area in general may give an indication of the rockfall history.

The table below shows the points assigned for the different categories within rockfall history.

3 points	*Few Falls* Rockfalls have occurred several times according to historical information but it is not a persistent problem. If rockfall only occurs a few times a year or less, or only during severe storms this category should be used. This category is also used if no rockfall history data is available.
9 points	*Occasional Falls* Rockfall occurs regularly. Rockfall can be expected several times per year and during most storms
27 points	*Many Falls* Typically rockfall occurs frequently during a certain season, such as the winter or spring wet period, or the winter freeze-thaw, etc. This category is for sites where frequent rockfalls occur during a certain season and is not a significant problem during the rest of the year. This category may also be used where severe rockfall events have occurred.
81 points	*Constant Falls* Rockfalls occur frequently throughout the year. This category is also for sites where severe rockfall events are common.

ROCKFALL RATING FIELDSHEET

Rockfall Hazard Rating Fieldsheet				
SH:	**RP:**	**Area:**	**RHS/LHS**	**Length**
Category	**Rating Criteria and Score**			
	Points 3	**Points 9**	**Points 27**	**Points 81**
Slope Height	7.6m	15.2m	22.9m	30.5m
Ditch effectiveness	Good catchment: all or nearly all of falling rocks are retained in the catch ditch	Moderate catchment: falling blocks occasionally reach the roadway	Limited catchment: falling rocks frequently reach the roadway	No catchment: no ditch or ditch totally ineffective
Average vehicle risk	25%	50%	75%	100%
% of decision sight distance	Adequate sight distance, 100% of low design value	Moderate sight distance, 80% of low design value	Limited sight distance, 60% of low design value	Very limited sight distance, 40% of low design value
Roadway width including paved shoulders	13.4m	11.0 m	8.5m	6.1m
Geological Character – **Case 1**	CASE 1: for slopes where discontinuities are the dominant structural feature			
Structural condition	Discontinuous joints, favourable orientation	Discontinuous joints, random orientation	Discontinuous joints, adverse orientation	Continuous joints (joint persistency >3m), adverse orientation
Rock Friction	Rough, irregular	Undulating	Planar	Clay infilling, slickensided or low friction mineral coating
Geological Character – **Case 2**	CASE 2: for slopes where differential erosion or over steepened slopes is the dominant condition that controls rockfall. Common slopes that are susceptible to this condition are: layered units containing easily weathered rock that erodes undermining more durable rock.			
Structural Condition	Few differential erosion features	Occasional erosion features	Many erosion features	Major erosion features
Difference in Erosion Rates	Small difference; erosion features develop over many years	Moderate difference; erosion features develop over a few years	Many erosion features; erosion features develop annually	Major erosion features; erosion features develop rapidly
Block size	300mm	600mm	900mm	1500 mm
Quantity of rockfall/event	1 m^3	1.5 m^3	2.5 m^3	3.0 m^3 or greater
Climate and presence of water on slope (adjusted for NZ conditions)	Low to moderate precipitation eg<450mm /year; no freezing, no water on slope	Moderate precipitation 450-2m/yr or short freezing (<1 week) periods or intermittent water on slope (seasonal or in response to rainfall)	High precipitation >2m/yr or long freezing periods (>1 week frozen) or continual water on slope	High precipitation >2m/year and long freezing periods or continual water on slope and long freezing periods (>1week frozen)
Rockfall history	Few falls; rockfall only occurs a few times a year or less	Occasional falls; rockfall can be expected several times a year	Many falls; frequent rockfalls during a certain season, e.g. winter freeze-thaw	Constant rockfalls; rockfalls occur frequently throughout the year
AAHT = AADT/Z4	**Posted Speed Limit (km/h)**	**Measured Sight Distance m**	**Decision Sight Distance m**	**Total Score**