DIANA FALLS LANDSLIDE RECOVERY
A LAND TRANSPORT RISK MANAGEMENT CASE STUDY

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ABSTRACT

In darkness on 10 September 2013 a landslide eventually totalling 30,000m^3 was released from a slope above the closed-by-weather State Highway 6 in the Haast Pass.

Initial incident response to landslide events typically involves a rapid assessment of the slope for safety followed by re-opening the road with a focus on minimising delays to road users. This event recovery started the same way. Site feedback on hazardous conditions prompted a review of the management strategy which reinforced the implicit focus on ensuring no injuries; and communicating the road open/closed status reliably.

The New Zealand Transport Agency's processes and tools for managing project risk are well documented and readily available. The project team used a hierarchy of risk management methods, starting with a project-level risk register, then further risk assessments of functional areas or activities.

The mechanism for determining the identified escalating needs of an increasingly complex incident recovery will be considered. Successes included: integrating the project health & safety management plan – tested by a serious road accident close to the site; a communications system for the project that the Agency retained in this remote area; and a 100% positive media reporting record through a particularly trying period of construction.

INTRODUCTION

The Diana Falls landslide occurred in a remote area of New Zealand and involved potentially hazardous activities just to keep the road open before remedial works could be started. Site management was complicated by the presence of complex geology, the remoteness of the site, extreme weather conditions, no feasible detour option for a strategic State Highway route and a high energy active landslide with poor visibility between the landslide and the road.

The recovery from this landslide event to the stage of providing unimpeded two way traffic flow proved to be a substantial undertaking, wherein the initial incident response transitioned into a project managed using the Agency's formalised risk management process.

The Transport Agency's adaptation of ISO 31000: 2009 Risk Management – Principles and guidelines is well documented and readily available. When the need for formal risk management is recognised these processes and tools offer valuable support and communication mechanisms to a project manager and direction to a project team.

During the recovery phase the project team was able to safely keep the road open during a busy summer tourist season, working closely with the local community and businesses to manage and communicate the disruption caused by the need to close the road at night for safety reasons.

The project arose in a traditional network maintenance contracting structure in an area of the country with relatively low traffic volumes. While experienced in dealing with extreme weather events as part of routine network operations, the operational team were used to a predominance of repetitive and consistent maintenance activities and unaccustomed to the world of unique, high value and complex projects and the associated formalised risk management rigour. The transition to this new environment in the recovery project and the high degree of upskilling and collaboration that was achieved is a tribute to the team and was a major success of the project. This case study should be read in this context.

THE SITE

Site Location

State Highway 6 is the strategic – and only direct – road between the Southern West Coast and Central Otago. This route is on the main South Island tour bus circuit between Christchurch and Queenstown, connecting the tourist townships of Queenstown and Wanaka with the Fox and Franz Josef Glaciers. It is also an important supply route for southern West Coast farms and the fishing industry located at Jackson Bay. The alternative route from Haast to Wanaka is around 750 km longer. Traffic flows vary significantly throughout the year, peaking during the summer tourist season when more than 50 tour buses can be seen daily, along with high volumes of self-drive tourist traffic. The site in question at Diana Falls (Figure 1) is approximately 6 km north-east of the Haast Pass summit (elevation 562 metres above sea level) and 1.5 km directly south of the Gates of Haast road bridge. This site is remote (some 25 km from the nearest small settlement of

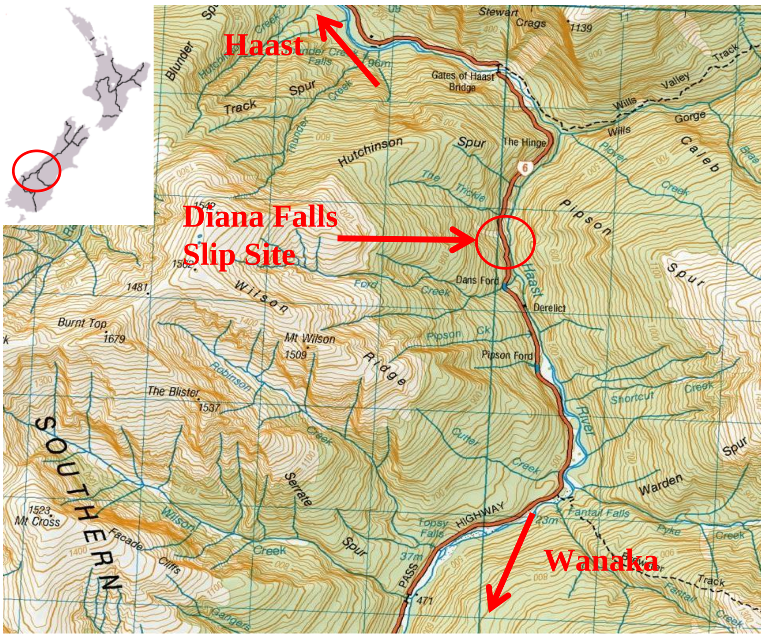

Figure 1: SH6 Diana Falls Landslide Site (New Zealand map from Wikimedia Commons)

Makarora and 90 km from Wanaka (population approx. 7,300) to the East and 50km from Haast (population approx. 280) on the West Coast.

Figure 2: Landslide after the initial event on 10 September 2013

The Landslide

The Diana Falls Slip was called 'the most complex and hazardous slip in New Zealand' by a peer reviewer[1] with 40+ years' experience. The complex geology of the site created many operational and assessment challenges. Continual modelling and observation of slip movement to understand the slope movement and failure mechanisms was carried out by geotechnical engineers. Failure was unpredictable, sometimes occurring in completely dry conditions due to the presence of groundwater on the slope. The final upper and lateral extent of the slip was, and is still not clear. What was clear was that there was a certainty that, without intervention, further large volumes of rock and soil would continue to affect the highway.

The initial event (approximately 20,000 m^3) occurred overnight on 10 September 2013 during very heavy rain (>300 mm in 24 hours[2]). It blocked the highway between Makarora and Haast, also destroying the bridge over the Diana Falls stream (see Figure 2). This slip was cleared and the highway re-opened on 20 September 2013 with full time traffic control. A large upslope extension of the slip (around 10,000 m^3) occurred on 27 September 2013, producing a long narrow slip scar, with a height of approximately 300 m and a 60 m width containing a large volume of unstable slip debris. Further numerous smaller failures continued to occur on a regular basis.

The geology of the Diana Falls Slip site comprises a 5 to 20 m deep surface layer of ancient chaotic slip debris underlain by Haast schist bedrock. The slip is an active lobe of a much larger ancient failure that stretches around 1km up the hillside, the movement of which is thought to have initially been caused by the retreat of glacial toe support after the last ice age and continued by the down cutting action of the Haast River[3]. Figure 3 shows the ancient slope failure clearly evident (red dashes) with the approximate extent of Diana Falls Slip (top of Giants Rock Garden - Figure 4) shown with orange arrow (scale is km). This figure is a NavisWorks output and was taken from a LiDAR geomorphic assessment. The whole site was originally vegetated by native Beech forest, comprising mature trees 10-15m tall on average and associated undergrowth.

The recent slip failure mechanism is considered essentially to be as follows (Figure 5).

1. Sliding initiates at the toe within a weathered zone of schist bedrock. Sliding occurs along the basal joint (172 / 27° E). This is shown in the Wanaka (south) margin of the slip through rotation observed in the schist foliation, which is typically 021 / 70° E and has rotated to lesser dips such as 010 / 36°E.

2. Dilation of the basal joint occurs and the deformation progresses at an increasing rate due to water ingress into the dilating joint. Some tension cracks and thrust ridges may be observed in the colluvium cover.

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[1] Greg Saul, Principal Geotechnical Engineer, Opus Christchurch

[2] 313mm recorded over 24 hours at Burke Flat

[3] No signs of movement of this larger landslide have been observed to date.

3. Failure eventually occurs, releasing blocks and colluvium. The schist is not homogeneous, as it contains zones of more quartz rich material that is more resistant to weathering. This causes the failure to occur in blocks ('steps' in the back face) and leaves a varying thickness of overlying colluvium debris. Each failure event results in exposure of a new less weathered surface and associated head scarp that in turn is subject to weathering and relaxation processes that will repeat the cycle in due course.

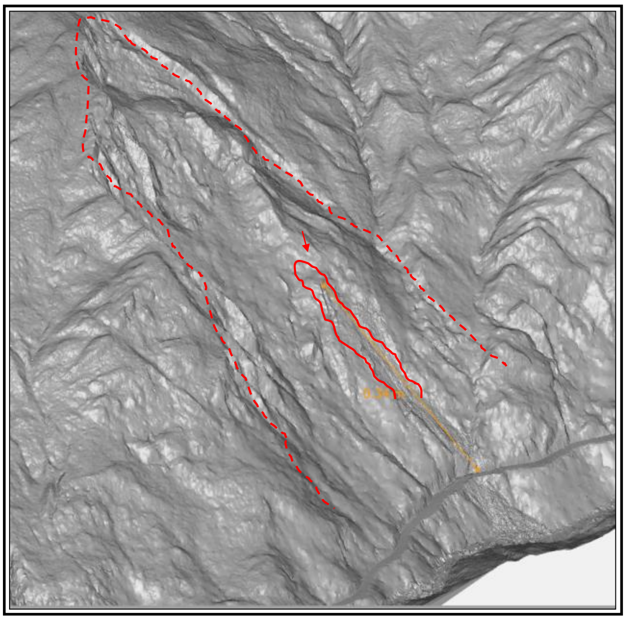

Figure 3: Initial ground surface model of lower half of slope

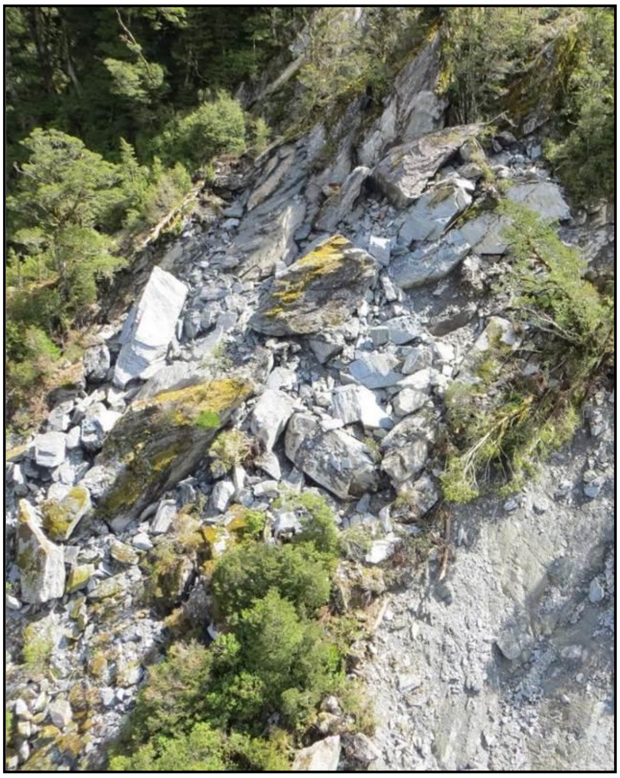

Figure 4: The Giant's Rock Garden Area October 2013

After the substantial failure at the end of September 2013, three key geological hazards were left:

1. An unstable, complex and extremely high risk head scarp area.
2. A huge volume of slip debris remaining within the slip scar itself, comprising silty gravel landslide debris with large boulders commonly 30t to 50t / 12 m^3 to 20 m^3 and up to around 300t / 125 m^3. The slip debris became extremely mobile when saturated, causing large volume debris flows and releasing huge boulders that ran over top of the debris gathering large momentum by the time they reached road level some 200 metres below.
3. The unknown risk of planar failure occurring on the lateral margins of the slip, in particular on the Wanaka side (named the 'Wanaka Chute').

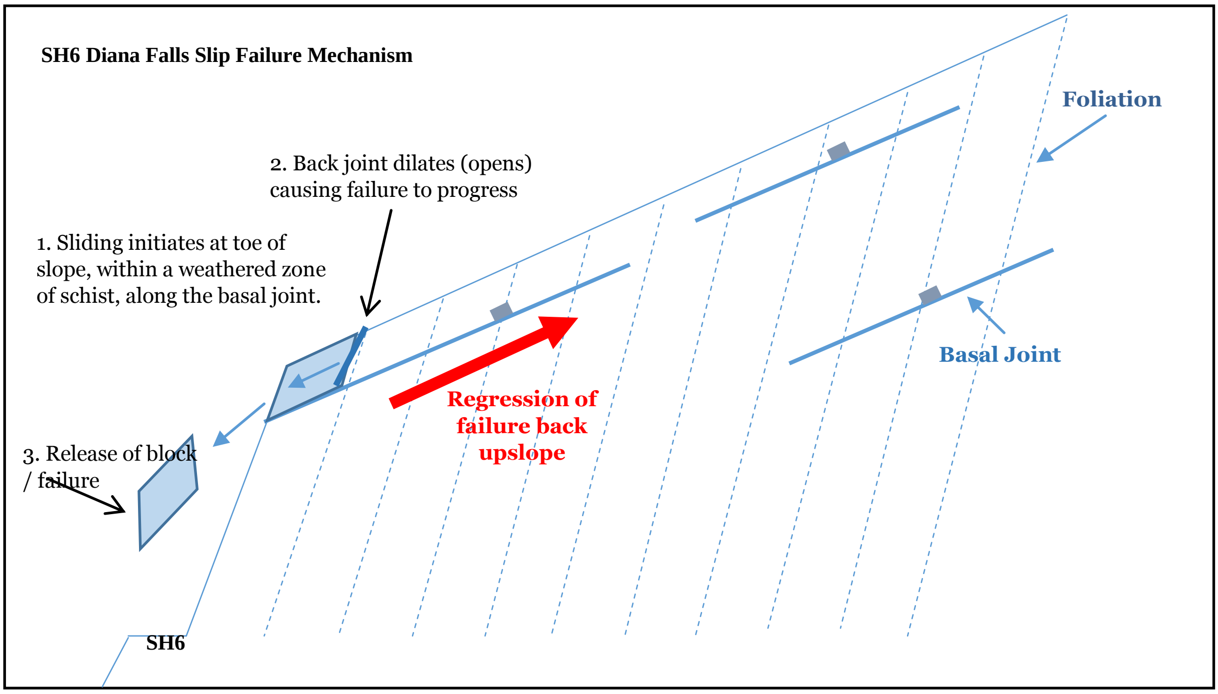

Figure 5: SH6 Diana Falls Slip Failure Mechanism (not to scale)

KEY EVENTS TO PROJECT ESTABLISHMENT

Initial Management of Road Re-Opening

On 11 September 2013, one day after the initial incident when the weather had cleared sufficiently, staff of the Agency's network management consultant (NM Consultant) and the network maintenance contractor (NM Contractor) inspected the site (one of many in the area initiated or affected by the heavy rain) and assessed the scope of work required to re-open the road. The site was considered sufficiently stable to allow clearing works to be carried out. The Agency's NM Contractor established a crew and set about clearing the landslide material to reopen the road.

Numerous geotechnical inspections were carried out and guidance given to the NM Consultant's area engineer and the NM Contractor's local supervisor. The geotechnical engineering advice was that the landslide remained active, unstable and unpredictable and recommended closing the road in the event of any rain.

The road was re-opened for public use on 20 September 2013 for single lane daylight-hours-only (8am to 6pm). During this time a continuous traffic control presence was on site, with an industrial abseil team stationed on the slope, out of sight of road level personnel, to observe and report via site-area radio telephone link on any movement of the landslide. Traffic was restricted to one vehicle crossing the landslide face at a time to minimise exposure in the event of any further material falling down to road level.

Daily helicopter inspections (weather permitting) were completed by the NM Consultant's geotechnical engineers during this period to monitor the upper sections of the landslide where significant tension cracks had been observed.

During this initial incident response phase it was recognised that the potential risk to staff on site and the travelling public due to the slip hazard was high. The NM Contractor and NM Consultant met to discuss these hazards and formulate an effective project process to assure site safety.

On 27 September, a second heavy rainfall event occurred (51 mm recorded in 24 hours). This brought down a further 10,000 m^3 of landslide material, completely blocking SH6 and again closing it to the travelling public.

Development of Formalised Operational Procedures

The NM Consultant & NM Contractor sought a Site Safety Plan from the industrial abseil company responsible for monitoring the upper section of the slip not visible from the road. This plan identified the need to work with other parties and to be inducted by and work to the NM Contractor's overall site management processes.

On 19 September 2013 the NM Consultant's Operations Manager identified the threat of ongoing landsliding in an Operation Plan provided to the Agency. The plan included the intention to open the road during daylight hours only, and emphasised aspects such as managing traffic, observing slope movement, clearing debris and re-opening the road expediently. The plan included a proposal to close the road if the NM Contractor's site supervisor felt this was warranted. Communication was issued by the Agency to the travelling public that the road may be closed at short notice for extended periods.

On 2 October 2013 a set of Operational Procedures, initiated and prepared by the project geotechnical engineer, was promulgated by the NM Consultant. This document identified the site as a project and formalised the various parties associated with the management and operation of work associated with the project. The document described roles and responsibilities – including identifying the NM Consultant site manager (area engineer) as the person to make the final decision on road opening times as well as coordinating all operations on site. The document set out business as usual road opening and closing procedures as well as a procedure for closing the road in an emergency.

On 8 October 2013 the NM Consultant produced a site-specific Health & Safety Management Plan (HSMP) for their geotechnical inspection operations. Prior to this point the work had considered to be covered by the Generic HSMP for work on the highway as part of the Network Maintenance Contract. This document recognised that other parties (the NM Contractor and the industrial abseilers) contribute to implementation of the NM Consultant's HSMP.

All documents at this stage of the project emphasised the importance of working collaboratively.

Further Development of the Recovery Strategy

Refocussing and Documenting the Landslide Recovery Strategy

The Agency, NM Consultant, and NM Contractor together agreed that the recovery objectives should be documented, promulgated and the project guided by (i) ensuring no injuries to anyone; and (ii) reliably communicating to the public the road open/closed status. With this subtle but important change in focus the landslide recovery project was formally transitioned from its incident response phase to the recovery phase – with all of the associated rigour required of management such as health & safety, communication, resourcing, cost, time, and risk.

Health & Safety Management Plan Risk Assessment

The NM Contractor developed a HSMP which incorporated relevant aspects from other parties HSMPs, including the NM Consultant, industrial abseil crew, and the helicopter company used for aerial inspections and sluicing the unstable face. This made for a robust and complete whole-of-project HSMP. On 27 November 2013 representatives from the Agency, the NM Consultant, the NM Contractor and the industrial abseil company met to review the HSMP in a risk assessment workshop. The HSMP was used as an input for the options workshop on the following day (see below) and was subsequently updated and issued under the control of the NM Contractor.

Options Workshop

On 28 November 2013 a facilitated options workshop was held between representatives of the Agency, the NM Consultant including geotechnical engineers, the NM Contractor, and the industrial abseil company manager. This workshop canvassed knowledge of the site, objectives of any solution, and provided an opportunity for all to brainstorm remedial options and issues around each in the context of the various site health & safety risks and their management. A collaborative conclusion was then reached on the best way forward. This was documented and issued to all attendees, including high level risk treatment plans.

MANAGING RISK ON THE PROJECT

The Transport Agency's System

The Agency has developed a suite of documents and processes that underpin risk management for the organisation. The Agency guide the scaling of project-specific consequences and provide tools to allow a project team to rank and manage risks in line with the Agency's risk appetite to achieve the optimal project outcome.

Managing by Focussing on Risk

Establishing the Objectives

The first essential task with formally managing risk is to identify what level of risk is acceptable in what circumstances. This was the first task of the project manager when implementing the management strategy. Collaborative workshops combined with documenting the strategy gave everyone associated with the project the confidence to plan and execute their work and to speak up if they saw anything that threatened to deviate the project activities away from achieving the collective objectives.

After establishing the objectives the recovery could be planned and staged. This technical planning exercise was led by the project geotechnical engineers and proposed a staged decrease in site presence and reduction in management effort over time as temporary remedial solutions were implemented, knowledge of the landslide was improved and the slope was made more secure until a permanent solution could be implemented.

Risk Assessments as a Project Management Tool

A risk assessment focusses people on doing the right thing for the activity being considered. The process also ensures there is a platform for raising concerns and for assessing detailed work proposals. A group of people with different perspectives sitting in a room and talking about what they see in a plan or a design promotes honest discussion and challenge of wider considerations than individuals working in isolation. Once risks and treatments are identified then there is a greater ability for the project team to manage appropriately to implement the agreed treatments.

To help the project team achieve the objectives and to allow testing of various elements of the solution development, a range of key stages were identified at which a risk assessment should be carried out to challenge proposals. Risk assessments were identified for (i) developing the project risk register (essential for comparing the overall design options and for managing operations and construction works on site), (ii) testing the health & safety management plan and emergency response procedures, (iii) testing constructability of the eventual design solution, and (iv) planning for commissioning of the completed works before full re-opening of the road.

Preparing for, facilitating, and extracting useable information from a risk assessment requires considerable effort. It is important to establish a clear briefing document for the risk assessment and the Transport Agency Z/44 guideline provides the means to do this.

Developing a Project Risk Register

A risk register is an important tool for recording and agreeing on threats and on controls as well as to guide and support management through the project life cycle. On the Diana Falls project the team used a hierarchy of risk assessments, starting with building an overall project-level risk register, then drilling down and doing further risk assessments of specific functional areas (e.g.

health & safety), processes and solutions (e.g. day-to-day site operational management and movement of people and vehicles, or the detailed design and its buildability), and activities (e.g. designing and installing a slope based high pressure water sluicing system to remove high risk areas of the landslide, or site planning of specific tasks).

For Diana Falls the project risk register was regularly revisited to ensure it remained current. The project risk register served to remind team members about why controls were established after time has passed and amid project pressures. The register allowed the project management team to consider new suggestions and either accept them or reject them on the basis of the risks posed by changes proposed. The recorded risks were also used as a benchmark against which to compare and assess proposed new work plans, methodologies, resources, processes, etc.

Critical Risks and Their Management

The Diana Falls landslide recovery project team identified a number of critical risks through several workshops. Some of these risks were being managed before instigation of the formal risk management process after the initial incident response. The full risk assessment built on the initial management measures and provided a formal mechanism for their prioritised implementation. The most significant amongst the risks formally identified and collaboratively ranked by the project team have been reframed from the negative risk description below to represent treatments. These were the following:

Risk 1: Accountability and Collective Responsibility

All members of the site team are to be clear on what their responsibilities are, and to adhere to these and their role description. Site safety of workers and the travelling public is always the top priority. Work should be programmed to ensure that the disruption to the travelling public is minimised, but consistent with safe operation.

Risk 2: Constantly Evolving Slip Site & Changing Strategic Objectives

Due to the complex slip geology, the geotechnical engineers identified early on that this project would not be a typical incident response ‘clean up and re-open’ slip event. Constant re-evaluation of the evolving slip and modification of the approach on site was needed. Good communication and trust needed to be built between the various parties responsible for different areas on site, as well as acceptance of a constantly changing work environment and working through of innovative project solutions.

Risk 3: Health & Safety Management

The NM Contractor was assigned by the project team to lead development of an integrated HSMP for all parties involved in the project. This document and its processes, procedures and protocols were then tested by a collective review. A great deal of effort by the management team went in to planning for various emergency response scenarios and contingencies. This was emphasised because of the remote nature of the site and associated poor communications available. There was no mobile phone coverage within an hour of the site, satellite phone reception was sporadic and only reliable for two or so hours a day due to the narrow valley, and – for similar reasons – an activated emergency position indicating radio beacon (EPIRB) was expected to take upwards of 15 minutes to be picked up by the New Zealand Rescue Coordination Centre (NZRCC). Given the nature of the site any incident was expected to be serious so these notification times were considered unacceptable.

Emergency response planning included notifying emergency services and providing them with site details and likely rescue helicopter response needs, as well as extensive training of site personnel on implementation of an emergency response. Involving emergency services personnel or people who are familiar with how they operate and what they expect or require when preparing for and responding to an incident led to addressing matters often not considered.

Risk 4: Rockfall Striking Person or Vehicle

Treatment of this risk required the road to be opened only when there was full visibility on the slope. Not allowing personnel or the public under the face when the slope could not be seen included night time and in fog or rain, and drove the project team's ability to manage road closures while placing great effort on communicating well with the public. Also crucial to planning and carrying out works at road level was the overlay (see Figure 6) of "No Access" (Red or "Hot"), "Limited Access" (Orange or "Warm"), and "Full Public Access" (Green or "Cold") zones across the site, developed by the project manager in association with rockfall analysis by the geotechnical engineers. This resulted in the traffic controller station at the south end of the site being relocated for safety.

Early in the incident response phase the team had set up a robust site presence with an industrial abseil crew observing the upper face and reporting via radio telephones to road level traffic management personnel. One vehicle at a time was directed through the direct rockfall hazard area (the Red Zone in Figure 6). Travel time through the direct hazard zone was about five seconds. The maximum notification time from the slope of a rock moving from the top of the slope (300m above) until the rock reached road level was about 10 to 15 seconds. The minimum time (from the base of the slope – 50m above road level) was around 3 to 5 seconds.

Due to the relatively short warning time from rocks moving lower in the slope compared to vehicle traversing time, combined with a lack of visibility of the slope hazard from road level, a proactive warning system was essential. A simple but effective system was established to pass information about rocks rolling from the slip back face to the staff controlling traffic on the road below. Three observational abseilers were located at the top, middle and bottom of the slip. A local radio telephone call stating either 'rocks rolling' or 'green for go', meaning that vehicles could pass through the bottom of the slip on SH6 safely one at a time, as well as ensuring the safety of the staff on site. Each vehicle was advised by traffic management to drive straight through the site with no stopping and staff were stationed at each end of the Red Zone to proactively signal vehicles through with hand movements.

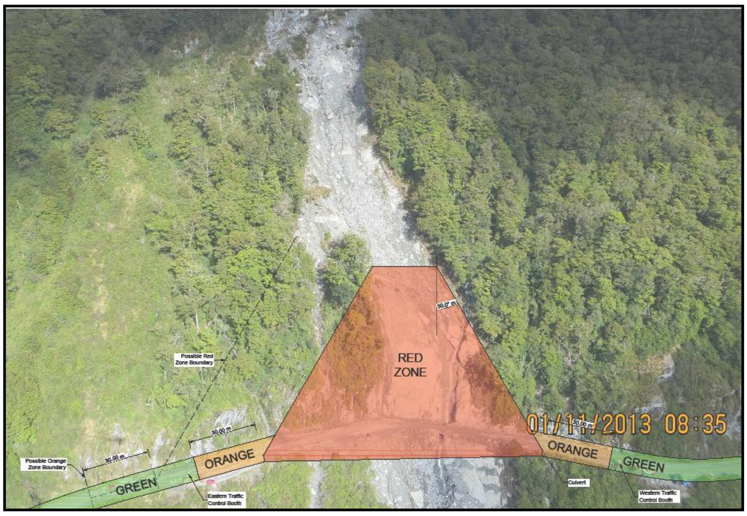

Figure 6: Site Road Level Access and Occupancy Zones

Needless to say, trust and a strong collaborative working relationship was needed between the ground traffic management crew, and the abseil slope hazard crew. To achieve this, each staff member's role was clearly defined and adhered to (with no interference) and daily site meetings were held at the start of each day to discuss the day's planned work and solve issues.

Later in the project, a new road level construction methodology proposed night work. Without an ability to see rocks moving and with no other suitable control having been established to treat this particular risk the proposal was declined.

Risk 5: Communication to the Public

When an incident such as this landslide and associated road closure occurs, the initial reaction by local and regional stakeholders is perhaps one of panic and concern about the impact of the road closure on their business. In the initial stages when the technical experts are determining the extent of risk and likely project duration, and when site processes are being established, it can be difficult to reliably communicate to the satisfaction of all involved. As the site is in a gorge in a remote area that often experiences adverse weather, communication out from site was also challenging.

The Agency held public meetings in Hokitika, Fox Glacier, Franz Josef Glacier, Haast, Makarora and Wanaka early on in the project to assure the communities, business and tourism interests that there was a recovery plan and the timing of the recovery as well as explaining the need for night time closures. This helped to restore public confidence as well as ensuring that the Agency had a comprehensive communications strategy that allowed stakeholders to be regularly updated on progress and news from the site. Public feedback was extremely positive about the communications produced, as the following quotes show:

> *"I have to compliment the Agency for your impeccable communication through this process, under very changeable circumstances. It really does help us immensely in our decision making to read the absolute honesty in the statements - whether we like them or not! Thank you very much, keep it coming! Thoughts with the guys on the ground too…"*

> *"Our thanks to the team working down there. We try to explain the situation to our guests and your updates are very helpful in this. Photos are really good, especially shots of machinery working to give a sense of scale to the size of the slip and the material it produces"*

Due to the low number of vehicle movements along this section of road, queue lengths were typically three to four vehicles during normal working operations (post initial incident response period) and hence vehicle wait time at the site was not a commonly perceived issue. While queue lengths did increase at times to around 20 vehicles each way these were uncommon events, occurring during rock rolling events or helicopter operations. Site delays were therefore in the order of 0 to 5 minutes and up to 30 minutes. Road users were generally pleased to be able to use the route, rather than needing to turn back or detour through Christchurch. The site location was also somewhat fortunate as many road users were tourists and therefore usually happy to stop in this scenic location and view operations as part of their travel experience. The main users who were averse to any delay were tour bus operators and freight transporters. Traffic management personnel were briefed to allow these vehicles through the site without delay if possible and safe. This was received positively by operators.

A detailed communications plan was developed for the Diana Falls site by the NM Consultant. This analysed the needs of the various road user groups and the project team (the Agency, NM Consultant and NM Contractor) and the available methods for communication. It set out strategies and detailed procedures for effective internal and external communications, so it was clear to all who was responsible for which aspects and how incidents and events would be dealt with. This document proved to be invaluable for the project.

It eventually helped in the Agency to achieve a 100% positive media reporting record through a particularly trying period of construction between October and December 2014 when the road was closed more than normal. This nationally unprecedented 100% positive media reporting record was ascribed to the public being communicated with in a timely manner and able to plan their journey with more certainty. This goal is in line with the Agency's (then-new) Journey Manager role, which had not yet been initiated for Canterbury/Westland at the start of the project.

SUCCESSES AND LEARNINGS

Clear Statement of and Working to Objectives

Development of the key project objectives helped to focus the team and provided support to drive actions within the project to achieve these objectives. The key success factor was the ability to refocus the previously assumed objective into a more clearly thought out one that involved managing expectations and communicating effectively with stakeholders.

The Agency's decision to back the agreed collaborative approach and hence fund the works, knowing the temporary nature of the proposed solution, was integral to project success. The Agency's project manager was a very responsive and engaged contributor in the team which enabled rapid decision-making and support.

Rigorous Options Assessment and Technically Robust Staged Recovery Plan

In every way, the Diana Falls Slip was an unconventional slip clean-up and remediation. The unique, complex and challenging geological and environmental setting meant there were many uncertainties. Site operation and predicted construction risks, stakeholder and programme pressure meant that innovation had to be constantly employed at every stage of the project, from incident response to design to construction of the remedial option.

The refocussing of the project objectives and the collaborative approach to identifying risks and their management during construction and maintenance drove the innovation in the engineering solution installed on the Diana Falls project. This was not only in the use of three high energy rockfall attenuators in a highly challenging construction environment but in their use together as a complete rock debris control system. This is unique in the Southern Hemisphere. The attenuators were designed and placed at strategic positions in the slip back face so as to absorb 50 to 70% of the energy from the rock debris and 'feed' it through in a controlled manner to continue its descent down the slope to the next attenuator in the system. At the base of the landslide, an impressive spider mesh drape was connected to the tail of the third attenuator for the full height of the 60 m high rock bluff so that rock debris could fall in a controlled manner to a catch pit at road level. The system can then easily be cleared by the Highway Maintenance Contractor as part of their routine maintenance activities.

The choice of the steel post and wire attenuators over other potential remedial options also showed innovation in finding the best solution for the design constraints. The key aim of the remediation project was to, as quickly and economically as possible, restore 24 hour, two lane SH6 access at the site with no active observational controls from abseilers or traffic management.

Options such as a concrete rock shelter or moving the road away from the base of the bluff were assessed to be extremely high cost and with a substantial delay (at least 12 months) before these options could be designed and construction started. As it was also not clear how the slip would develop, the effectiveness of these options was not definitively known. The relatively cheap and easily constructed temporary attenuator system was decided upon as the best option.

The working relationship between the many parties on site was positive and the risk assessment process ingrained into the team's planning and activities. This allowed innovative procedures to be applied to ensure the right option and construction methodology was selected.

Construction work began at the start of April 2014, with Geovert Ltd employed as the specialist slope protection installation and rope access sub-contractor. The road was reopened to 24 hour traffic on 5 November 2014, and construction work was completed on 20 December 2014, which met the earlier established programme deadline of two lane road re-opening by Christmas 2014.

After 20 December 2014, the site transitioned to the post-work stage consisting of uninterrupted public use of the road; regular inspection and monitoring of the site; and periodic maintenance activities.

Integrated HSMP and Emergency Response Procedures

No one party involved in a project should be made wholly responsible for managing health & safety. It is a joint project team approach, with all team members accountable and being heard, that results in the best outcome. All parties view a proposal differently and all can - and should - contribute to robust planning.

Developing an integrated Health & Safety Management Plan for the whole project gave focus to all of the personnel working at the site and ensured that everyone had the same information. The process and subsequent document as it evolved collectively and was communicated encouraged all parties to acknowledge they had a part to play in managing H&S on the project. This helped build a strong site culture of looking out for each other. This process was also in line with the then-unknown requirements of the Health & Safety at Work Act.

The poor communication links to places remote from site led to the installation for the project of a radio over internet link between the site and Greymouth. This system required installation of two radio mast repeater stations on mountaintops and installation of computerised translation stations at both the NM Consultant and NM Contractor offices in Greymouth. The Transport Agency have subsequently decided to leave this system in place as a permanent installation to improve their ability to manage this remote area safely.

The subset of the HSMP around emergency response procedures was developed carefully and thoroughly, and was tested at site initially by drills and trial evacuations. Subsequently on 27 January 2014 the preparation of site personnel was put to the test when a tourist cyclist was seriously injured in a fall about one kilometre from the construction site, suffering head injuries, fractures, and contusions in a high speed crash. Advanced first aid personnel and support traffic controllers along with the site manager responded to the scene. Rescue helicopter crew (*pers. comm.* Stuart Drake chief crewman) feedback was:

> *"…*
>
> *The crew working on the slip were involved in providing first aid to the cyclist. They also contacted emergency services and then managed traffic and provided a safe landing area for the Greymouth based New Zealand Coal and Carbon (NZCC) Rescue Helicopter when we arrived on the scene.*
>
> *I was impressed by the actions of the crew and the way in which their emergency plan was applied on the day. Without their presence the injured woman's treatment and transport to hospital would have been considerably delayed with a possible detrimental impact on her recovery.*
>
> *…"*

The Health & Safety at Work Act places clear obligations on clients, designers, and contractors as Persons in Control of a Business or Undertaking (PCBU) to be actively involved, to identify and manage risk, to collaborate with other PCBUs, and supports more effective whole team engagement and participation. This is appropriate and will lead to more robust and integrated planning and execution of works. The risk management processes used at Diana Falls, with collaborative risk identification, challenging of proposals, and collective risk treatment decision-making was innovative at the time and is consistent with the new H&S management legislation.

A Suite of Key Risk Assessments and Actions

Development of the project risk register against the background of the refocussed landslide recovery objectives provided clear direction to the project team as well as a valuable communication tool with and for the Agency.

As the incident response phase transitioned into the recovery phase, geotechnical engineers led a workshop to assess options for staged recovery. All options were considered against the project risk register and the project HSMP. Real highlights of this project experience were the high physical H&S risks that had to be dealt with from the particular geotechnical hazard, and the refocussing on managing expectations / communications and how this influenced the stated project objectives.

As management of the site moved from immediate incident response to a holding pattern while design was finalised and construction started, a ground-based water cannon sluicing system was developed to remove loose and unstable areas of the face and hence improve road level safety. The development and installation of this sluicing system was robustly planned. The process included preparation of a design report and peer review, construction methodology documentation, a commissioning plan, a construction and commissioning risk assessment, operational procedures, then commissioning and validation.

A Safety in Design and constructability review with the Agency, the NM Consultant and geotechnical engineers, the NM Contractor, and the specialist slope protection installation subcontractor provided the forum for construction issues to be discussed and solved prior to establishment on site.

From early in the recovery phase the project cost forecast was assessed considering the impact of uncertainty on achieving each cost build up line item. Cost forecast for the project incorporating uncertainty (risk) in February 2014 had a range from $7.5 M to $12.5 M with a most likely cost of $10 M. The outturn projection was progressively tracked through the project (see Figure 7) to the final cost of $10.4M upon completion in January 2015. Early upward revisions in the project cost forecast arose from outcomes of the Options Assessment workshop in November 2013, refinement of the project scope which grew to include a replacement road bridge, and as greater definition could be drawn around the slope-based landslide remedial works.

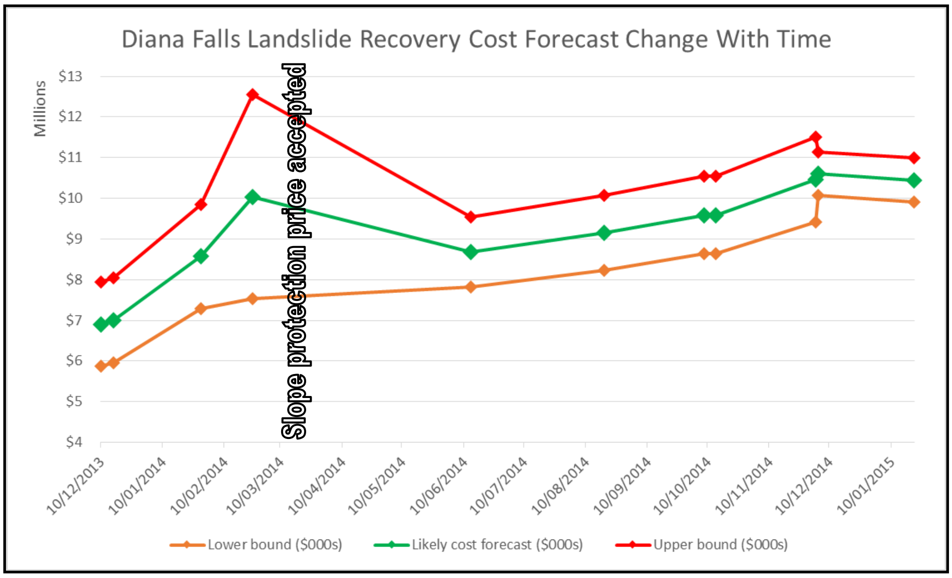

Figure 7: Cost Forecast Range Through Time

Focussed and Appropriate Public and Stakeholder Communication

The project team prepared targeted information sheets which were issued at key stages to the local communities immediately affected by the works. The NM Contractor staffed kiosks at each settlement either side of the site with staff who were specifically tasked to inform travellers of travel times, including providing handouts in five different languages for tourists.

Considering Establishing a Project Early in Recovery

Learnings from the project included observations around some coarse considerations for deciding early in the incident response phase whether the recovery could be treated as a simple maintenance activity or if it should be framed into a discrete project with the associated escalated management effort and tools.

Broadly speaking incident response can be separated into Routine; Moderately Complex; and Unique and Complex. This may (as examples) be defined as follows:

> *Routine* – Road Traffic Crash without complications, or small and contained environmental spill;
>
> *Moderately Complex* – Moderate scale landslide or river erosion/washout on a route with readily available detour, snow clearing which is well-predicted and with robust operational plans in place, or a chemical spill with some hazards;
>
> *Unique and Complex* – Large scale landslide with poor knowledge of features, road closures of expected extended duration (weeks to months) and no or highly undesirable detour route.

It is also important that the assessment of the incident response phase into which an event falls should always be carried out by a suitably qualified professional. If the event is a landslide, a quick initial assessment should be carried out by a geotechnical engineer or engineering geologist to confirm there is a manageable risk of a larger failure. An error in assessment of the correct category could result in the consequences of a failure becoming worse. For example a simple clearing methodology (e.g. toe clearing) wrongly applied to a complex landslide could cause catastrophic failure and prolonged loss of service that could be avoided.

Factors that contribute to assignment into one or other category include:

1. Expected duration of closure and recovery time;
2. Technical complexity or level of knowledge of the hazard;
3. Knowledge or confidence in systems established to remedy the incident;
4. Competing demands (economic imperatives for recovery versus worker and traffic safety);
5. Strategic importance of the route and detour options (including adverse publicity, and refer also to 1 and 3);
6. Active effort required to keep the road open (spotters on the face, traffic controllers, reduced lanes, restricted opening hours, sluicing or other mechanisms to move material on or from the face);
7. Potential for life-changing injury or death of recovery workers or the public;
8. Vulnerability of the site/route (lanes, exposure to hazards beside road);
9. Confidence in the risk treatments or existing controls for work activities including specific hazardous works.

CONCLUSIONS

The risk management process worked effectively at the Diana Falls Slip event and remediation, from September 2013 until February 2015.

Determine and agree key success factors by asking "What will success look like?" at the outset. Ensure all parties are actively involved in key project decisions and change points – collaborative workshops are recommended.

Establish organisational risk appetite, project context and objectives at the outset. These will allow the project team to focus the project set up and implementation and will enable alignment of the project team.

Clear operational guidelines should be established early in the project.

Introduce and embed risk assessments into all elements of the project. If this meets resistance then rename the risk assessment as a review or discussion. The essential value to be extracted is using collective knowledge and experience to rigorously and methodically consider a whole proposal before starting.

Road users appear generally less concerned about a road being closed than they are about not knowing whether they can plan a journey with confidence.

Rigorous planning and communication combined with realistic levels of confidence around outcome-type project elements of time and cost give the client confidence in your management ability as well as allowing flexibility in balancing the broader aspects of project management.

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