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Monica Osuchowski and Jenna Roberts

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APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

Landslide Costs in the Wollongong Region

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by

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Executive Summary

The cost of landslide is underestimated in Australia because the impact and loss associated with these events are not readily reported or captured. There is no reliable source of data which highlights landslide cost to communities and explains who currently pays for the impacts and associated costs. The aim of this document is to investigate and analyse landslide costs within a Local Government Area (LGA) in order to highlight the varied landslide associated costs met by the local government, state traffic and rail authorities and the public. It is anticipated this may assist in developing a baseline awareness of the range of landslide costs that are experienced at a local level in Australia.

Local government authorities across Australia are required to manage and mitigate landslide hazards. The Illawarra region of New South Wales (NSW) is one example of an area in Australia continuously affected by slope failure, often resulting in damage to property or infrastructure as well as occasional injuries and fatalities. Landslide losses are described for the region of Wollongong in NSW using a series of case studies to highlight the different types of landslide cost met by different parties, the variations in the landslide types that occur and the different cost components arising from them. This approach was chosen due to variations across the quality, availability and consistency of data. Seven case studies illustrate landslides can result in considerable cumulative cost and inconvenience to the public, property owners, businesses and local council as well as state traffic and rail authorities. Initial estimates in this study indicate that cumulative costs associated with some landslide sites are well beyond the budget capacity of a local government to manage. Furthermore, unplanned remediation works can significantly disrupt the budget for planned mitigation works over a number of years. Landslide costs also continue to be absorbed directly by individual property owners as well as by infrastructure authorities and local governments. This is a marked distinction from how disaster costs which arise from other natural hazard events, such as flood, bushfire, cyclone and earthquake are absorbed at a local level.

It was found that many generic natural hazard cost models are inappropriate for determining landslide costs because of the differences in the types of landslide movement and damage. Further work is recommended to develop a cost data model suitable for capturing consistent landslide cost data. Better quantification of landslide cost is essential to allow comparisons to be made with other natural hazard events at appropriate levels. This may allow for more informed policy development and decision making across all levels.

1 Introduction

Landslides frequently damage buildings, roads, railways, vehicles, pipelines and communication lines, and can bring about adverse social consequences including death, injury, stress, inconvenience and displacement (Geoscience Australia, 2007). There had been little public recognition that landslides were a significant threat in Australia until the 1997 Thredbo landslide tragedy raised the profile of landslide hazard in Australia.

Landslide impacts in Australia are typically confined to events occurring within a regional area, across a few properties or a short stretch of road or railway (in contrast to a single event impacting an entire community simultaneously such as a tropical cyclone for example). Landslides can vary widely in their volume and rate of movement. For example, slow moving landslides may cause ongoing damage over prolonged periods of time, while debris flows may cause immediate and often destructive damage. Therefore, slope stability issues may affect communities across a broad range of severity levels[1] and pose a range of risks to properties and livelihoods.

Only a few large landslide events dominate Australia's disaster record, such as the 1872 debris flow in Hobart (TAS); the 60 000 tonne debris flow in the Dandenong Ranges in 1891 (VIC) and the 1951 debris flow in Cairns QLD). Recent high-profile events include the 1996 rock fall in Gracetown (WA) which resulted in 9 fatalities, 3 injuries and an ensuing 8-year legal battle. The 1997 Thredbo landslide (NSW) resulted in 18 fatalities, 1 injury, and approximately $25 million in remediation works alone (Figure 1).

Between 1990 and 2010, Geoscience Australia (GA) has captured approximately 963 landslide events in the Australian Landslide Database (accessed on 17 April 2010) which occurred over that twenty year period and were reported in the media. However, the cumulative impact of the less 'high profile' events has been broadly overlooked in national risk, hazard and cost analyses. This may be due to a perception the associated impact is minor and therefore the risk is considered to be more acceptable and manageable. While from a national perspective it can be argued that this is a legitimate deduction, it is important to consider these impacts in relation to who actually pays for them and their capacity to do so when considering the degree of impact.

According to data held within the Australian Landslide Database well over half of the landslides causing death or injury can be attributed either directly or indirectly to human activity (Leiba, 1999). The most common contributing factors are artificial vibration, excavation or loading of the slope or at its toe, land use change, vegetation removal and water leakages from services. This is an important consideration in measuring landslide impacts because human-induced events are often considered preventable. Therefore, the social consequences related to such events are considerably higher than for events with natural causes (Osuchowski, 2009). Human induced events tend to generate heightened feelings of anger and focus attention on attributing blame to those perceived responsible. This can significantly prolong the period of impact and slow the recovery process. Landslides are subsequently responsible for considerably greater socioeconomic losses than generally recognised (National Research Council, 2004).

[1] The severity associated with landslide events can range from insignificant to minor, medium, major and through to catastrophic damage. Insignificant damage describes limited damage to part of a structure that requires some reinstatement or stabilisation works, catastrophic damage encompasses the complete destruction of a structure as well large scale damage that requires major engineering works to stabilise a landslide site for example.

Australia may be faced with increased landslide activity in the future due to increasing population pressures to develop marginal land. Climate change influences may also impact on the rate and severity of urban landslides to some degree and these are explained further in Geoscience Australia (2007).

Figure 1: *Night works following the 1997 Thredbo landslide in NSW. Photo taken by Geoscience Australia.*

2 Classification of Cost

There are several methods of classifying losses resulting from natural disasters. The usual method is to divide losses into two categories; tangible (those with a market value) and intangible (those with no market value). Losses are further subdivided into direct and indirect losses (BTE, 2001).

Landslide costs include both direct and indirect losses that affect public and private properties. 'Direct' costs are the consequence of the initial disaster event and will be felt immediately. They are typically associated with repairs, replacements or maintenance resulting from damage to property or installations within the boundaries of the responsible landslide. All other costs are 'indirect'. Examples of indirect costs include: measures to mitigate or prevent additional landslide damage; adverse effects on water quality in streams and irrigation facilities outside the landslide; secondary physical effects such as landslide causing flooding; reduced real estate value in areas threatened by landslide; and loss of industrial, agricultural and forest productivity, and loss of tourist revenues as a result of damage to land, facilities or transportation systems.

Public costs are those which are met by government agencies with the remainder classified as private costs. The leading direct public costs are typically those attributed to disaster assistance and road and/or rail maintenance, relocation and repair. Adding to the complexities of estimating specific landslide costs are the different landslide processes. For example, costs of extremely slow-moving landslides which may commonly cause cracks or irregularities in the fabric of buildings and road surfaces, footpaths or pipelines, are typically absorbed into general maintenance and repair costs.

3 Challenges in Measuring Landslide Impact and Cost

Many economic reports on natural hazards such as BTE (2001) omit the consideration of landslide costs. This is generally because the criteria and thresholds for inclusion are not aligned with the nature of landslide impacts in Australia. For example: the cost of a single event must have exceeded $10 million for inclusion in BTE (2001). Subsequently landslides were reported as the least costly natural hazard in Australia, with the total estimated costs of landslides for the period 1967 to 1999 at $40 million (BTE, 2001). It is important to realise that this figure represents only one landslide which met the $10 million threshold, the 1997 Thredbo landslide in NSW.

Sufficient data articulating the cost of landslides to communities is not readily available. It is difficult to collect and aggregate landslide costs because a number of different parties bear the cost and these are often not reported or documented. Subsequently determining reliable estimates of the total cost of landslides across sizeable geographical entities such as an LGA is difficult, and that of several LGA's, a State or nationally, is more challenging. Landslide hazards are also excluded from insurance policies. Therefore insurance figures cannot be used as an estimate of monetary cost. Furthermore, the nature of eligibility criteria for natural disaster relief funding excludes most landslide related events and relief funding cannot be used as an indicator either.

It is important to note that these economic reports, insurance payout and relief funding figures often combine to provide an evidence base for informing natural hazard policy and priority development. However, challenges in effectively capturing and reporting on landslide impact and cost have resulted in landslides being regarded as a low cost disaster. A lack of information on the cost of landslides makes if difficult to effectively compare and contrast the cost of different hazards. The challenges in measuring landslide cost stem from a combination of sources and are further described.

3.1 LANDSLIDE DATA COLLECTION

A number of landslide inventory databases exist on the LGA level throughout Australia, although each is unique because each was established to meet a specific need. Landslide events across Australia reported in the media are captured in the Australian Landslide Database managed by GA. Accurate details about historic landslide events are important in supporting probability, cost and risk assessments. Some local councils retain a great deal of valuable and detailed information on landslides within their municipalities which may not be captured formally in a database. The level of information detailed may vary and the information may be difficult to access or discover beyond the local council. This means it is also difficult to collate and aggregate data across a state or national level because of the variation in procedures and methodology across LGA's. Furthermore, while damage may be described, cost information is not often explicitly captured in databases. It is also difficult to capture costs associated with urban landslides as home owners repair damage privately. In addition, other hazards such as severe storms may trigger landslides which can present a further challenge in isolating landslide-specific damage.

3.2 LANDSLIDE DATA WITHIN ALL HAZARD DATABASES

Emergency Management Australia (EMA) is the custodian of the primary government database containing information on natural hazard events that result in injuries, fatalities and cost. For inclusion into this database, single events must have resulted in 3+ deaths, at least 20 injuries or illnesses, and/or losses of $10 million or more. Landslide data is notably absent from this database as one event rarely produces the threshold number of injuries and fatalities required. This database has been frequently called upon for national economic natural hazard impact analyses such as BTE (2001).

3.3 COST AND IMPACT FRAMEWORKS

Often a range of cost estimates are made after a landslide event by the local council. However, these costs are seldom collated or analysed at a State level. While cost estimation frameworks for other natural disasters have been created, they are generally not specific enough to fully encapsulate landslide impacts and ongoing costs. Examples include Handmer et al. (2002), BTE (2001), OESC (in development), McKenzie et al. (2005), FEMA (2003) and ECLAC (2003). These frameworks are better suited those hazards which require a significant and coordinated multi-agency and community response, such as tropical cyclones, floods or bushfires. Handmer et al. (2005) describes a new approach towards consistent disaster loss assessment in Australia and work underway by the NSW Fire Brigades on the development of an impacts framework for natural disasters and fire emergencies may be better suited to capturing landslide costs.

3.4 LANDSLIDE INSURANCE

Insurance has an important role to play in management and recovery following a natural disaster, providing individuals with a means to protect the value of their property and assets. However, insurance coverage for landslides is categorically absent in Australia, and as such individuals must absorb private costs with little or no assistance. The absence of landslide insurance in Australia also means there is no ready source of payout data for landslides. This combined with a lack of documented indirect[2] cost and intangible[3] loss increases the challenges in understanding and measuring the cost of landslides.

Financial assistance related to natural disasters including matters surrounding insurance is further discussed in Chapter 8.

[2] For example: the cost of goods or services which as a result of a disaster are not produced or provided, and the inconvenience and stress imposed on people

[3] For example: the loss of cultural icons and personal memorabilia which affect people differently

4 Study Area: Wollongong

The regional city of Wollongong in NSW has managed landslide issues since settlement in the 1820's. Wollongong is situated on the coast approximately 80 km south south-west of Sydney (Figure 2). It is nestled in a narrow triangular coastal plain flanked to the east by the Pacific Ocean and to the west by steep slopes of the Illawarra Escarpment (Flentje and Chowdhury, 2002). The Wollongong City Council (WCC) area extends from Helensburgh and Garie Beach in the north, to Windang in the south and Macquarie Pass in the south-west in a total area of 715km^2 (Figure 3).

Figure 2: *Location of the city of Wollongong in NSW and the extent of the Wollongong LGA.*

In 2006, Wollongong's population was approaching 200,000 (ABS website, accesed 12 May 2010) as it has one of the highest population growth rates in NSW. Wollongong is also considered to be one of the first cities to run out of developable land and current development is occurring within infill subdivisions (Tobin, pers. comm. 3 September 2009). However, as population grows the demand for urbanisation along the sloping areas of the escarpment increases, leading to a subsequent increase in land instability along the escarpment area. It is understood that if town planning were to begin afresh today, urban development on escarpment slopes would not be considered appropriate.

Geomorphological and geological evidence suggest that land instability has been widespread throughout the Illawarra Escarpment long before the first record of landslide activity was documented in 1879 (Flentje, 1998). Flentje and Chowdhury (2002) state that between 1887 and 2000, a total of 31 landslides (of 478 recorded) destroyed 28 homes and caused significant damage to a further 55. The landslide database managed and provided by the University of Wollongong (UoW) for this study contained 604 landslide events at the time of analysis in 2009. In comparison, GA's national database contained only 72 events for the same spatial region which highlights the contrast between data captured locally and data captured at a national level.

Landslides in Wollongong occur frequently, are dangerous and costly. The primary mechanisms of slope failure are controlled by factors such as stratigraphy, geomorphology, slope inclination, geotechnical strength parameters, hydrogeology, pore pressure, rainfall and human activity (Flentje and Chowdhury, 2002). Prolonged or intense rainfall is typically the trigger for significant landslides in Wollongong. The average annual rainfall for Wollongong varies from approximately 1200 mm on the coastal plain and up to 1600 mm or more along the top of the escarpment (Flentje and Chowdhury, 2002). The types of landslides identified in the area include complex and composite slide flows, debris-slides, debris-flows and rock falls, and often range between $100m^3$ to $100\,000m^3$ (Flentje and Chowdhury, 2002). Many of the landslides in the hilly suburbs of Wollongong are latent and can be reactivated after periods of intense and prolonged rainfall. Minor movement occurs from time to time in response to heavy rainfall events and are corrected through routine maintenance. Between major rainfall events these landslides typically move extremely slowly, at a rate of approximately 16 mm per year (Flentje and Chowdhury, 2002). It is not unusual that during heavy rainfall events many of the roads out of Wollongong are closed due to landslide. Main roads include Lawrence Hargrave Drive, Bulli Pass, Mt Ousley Road and Macquarie Pass. The Princess Highway at Dunmore also closes due to flooding. Mt Kiera Pass usually remains open although is also at risk of landslides. Mt Keira Pass is strategically very important to Wollongong as the State Emergency Services rely upon it when other roads are closed.

The Illawarra region experienced a series of very wet years in the early to mid 1970s. Throughout the 1970s extensive landslide activity occurred with a prolonged series of remedial works. Houses were lost, litigation and compensation abounded, knowledge of the problem was limited and WCC needed to find a management solution to the hazard. The policy for hillside development was borne from the turmoil of the 1970's eventually referred to as AGS (2000) and AGS (2007).

5 History of Legal Difficulties and Development Policy

The WCC has experienced lengthy and costly legal problems relating to landslide management in the Illawarra region, particularly in the 1970's. Residents whose properties had been subjected to landslide action and realised they were ineligible for compensation of any kind approached the WCC for assistance or explanations, invariably culminating in numerous attempts at legal action against WCC.

One of the major problems facing WCC concerns the release of landslide information to the public, and in particular to interested buyers of land and property. Fear of liability and the significant cost associated with it, for damages to sellers, has led to WCC developing a legal policy in which they only provide general advice and do not release any specific landslide information to the public. For example, if a potential buyer approaches WCC to enquire about land stability in their area of interest, the WCC cannot release this information even if it is known that the land is subject to slip. In all cases, the practice is *caveat emptor*, as sellers have previously attempted to sue WCC for costing them a sale when landslide information has been released. WCC counsel is to seek the advice of a geotechnical professional, soils engineer or geologist. There are various forms of geotechnical advice available from consultancies ranging from a preliminary pre-purchase site assessment to a detailed project specific investigation.

Efforts to avoid complex litigation encouraged the development of a policy for hillside development, which is used by planners, building surveyors and private consultants in assessing geotechnical information. Legally, it is preferable to categorise land as 'stable and will remain so' or 'unstable'. However, from an engineering perspective this is impossible because every block of land carries some risk, even if the risk is very low. This led to the publication of the Australian Standard for Residential Slabs and Footings (Standards Australia, 1996) which containes clauses regarding risk thresholds acceptable for development. This is now used in consultant reports submitted alongside development applications to WCC and is the common guide used to consider their feasibility.

The adopted policy of withholding all information protects Council legally. However, residents of Wollongong have since expressed strong distaste for this principle. There are presently ethical dilemmas relating to WCC protecting the best interests of their community and the release of information. Further problems arise when land is purchased with the buyer unaware that it is subject to slip, because applications made to WCC to develop on such land are rejected. Owners are then left with a piece of land rendered un-developable and are still required to pay rates on the land.

During the 1970's, only the State Government had the ability to waive rates on any property, and Councils did not have the power to waive rates under the Local Government Act as it was written (Illawarra Mercury, 1978). Therefore, the WCC had no authority to underwrite landslide losses as the Local Government Act did not allow rate payers money to be used to make up the losses (Illawarra Mercury, 1976). During this time, WCC's only method of offering rate relief was to buy back such land from owners at a nominal sum (usually between $200-400) so they would be exempt from paying future rates on the property (land originally purchased by owners at approximately $4 000). However, in other cases, frustrated residents ceased making rate payments, eventually prompting the WCC to acquire the land for unpaid rates. While this relieved the burden in some way to the owner, the owner had still lost large sums of money that could not be recovered. The land then became a maintenance burden to WCC. In some cases WCC sought neighbouring property owners to purchase this land for a very low price, to either extend a backyard or re-sub-divide. There have been cases in the past in which residents have bought such land from WCC, with restrictions on development unless supporting private geotechnical advice is submitted. However, with increasing development pressure in the region and a sharp increase in property values, it became cost-effective for many owners to perform expensive remedial works so that development could occur. Therefore, the land once deemed 'undevelopable' was often then sold at a high price. This is an example of the ethical dilemmas found in landslide hazard management, in which Council may sell the acquired slip-prone land to a third party, suspecting that it will be developed. Residents of the community have an aversion to these practises, and the issue has been the topic of many media articles and public meetings. It is understood some properties were acquired during the landslides of the 1980's. However, it is believed none were acquired from the August 1998 storms.

While the relationship between the residents and WCC remains tenuous when it comes to dealing with landslides, WCC maintains that it is deeply concerned about the issue. *"In the landslide cases, I'm sympathetic for the victims, because they've got nowhere to go and they've lost everything. That's why we now have a geotechnical review of the development assessment process to try and minimise these risks; so it's not only Council's risk we're trying to minimise, but the property owners…as well"* (Tobin, pers. comm. 9 Jan 2009). While the WCC remains sympathetic and recognises that it is the regional body responsible for regional problems such as landslides, it is limited in what it can do to assist residents as the cost is simply too prohibitive until further funding assistance is available and can be obtained. The case studies aim to illustrate costs faced at a local level.

6 Case Studies

Seven landslide events were selected in consultation with WCC and UoW to explore a range of landslide costs in as much detail as possible (Figure 3). The case studies aim to highlight the different types of landslides in Wollongong and the variations in cost associated with them. They also endeavour to reveal the different parties who pay for landslide impacts and highlight tangible, intangible, direct and indirect losses that result from the hazard. The level of information available and accessible for analysis for each landslide event was also taken into consideration in selecting events.

The case studies highlight cost and loss incurred by State authorities such as RailCorp and the Roads and Traffic Authority (RTA) in NSW in addition to cost and loss incurred by WCC and the Wollongong residents. Cost and loss incurred are described and where possible quantified, relating to damage to property, temporary relocation, detours, road closures, remedial works, maintenance, monitoring, geotechnical investigation, public liaison, litigation and emergency response costs.

Data for the case studies were acquired though correspondence with RailCorp, RTA, WCC and UoW. A questionnaire was distributed (Appendix A) and a number of interviews and discussions were held with representatives of these agencies. An overview of the case studies is provided below:

1. Harry Graham Drive, Kembla Heights. This case study highlights cost to WCC and the cost effectiveness in performing mitigation actions. The study also highlights sequential landslide impacts occurring over a period of time at the same location and the flow on impact this can have on mitigating and remediating other landslide sites. Landslide issues were raised on Harry Graham Drive in the 1970’s and instability problems are continuing to impact the site in 2010. The case study highlights the difficulty in meeting requirements for accessing relief funding as a single event does not often meet the stipulated threshold. However, over time the cumulated cost of several events will exceed this threshold.

2. Lawrence Hargrave Drive, Clifton. This case study highlights a significant cost to the RTA in addition to the enormous inconvenience and loss to residents, businesses and tourism with the two year road closure. The high cost of performing adequate mitigation solutions in order to reduce public risk to a tolerable level is also described.

3. Woonona Heights, Wollongong. This case study highlights the history of a very slow moving landslide in a residential area and the difficulties in acquiring sufficient funds to undertake required remediation solutions.

4. August 1998 storms. This case study highlights the adverse impact of urban development on slope stability and the alteration of drainage systems within slopes. Rainfall intensity experienced during these storms is typical of the Wollongong climate and is expected to occur along the Illawarra escarpment approximately every 10 years.

5. Morrison Avenue, Wombarra. This case study highlights the effects of a very slow moving landslide in a semi-rural area. Landslide impacts have included destruction and subsequent abandoning of homes and disruption of the road. The challenges residents and WCC face in finding a solution are described.

6. Mt Ousley Rd, Wollongong. Instability problems have affected Mt Ousley Road since the 1970's. This case study highlights cost to the RTA and potential high cost of road closures and disruptions to traffic as well as potential impacts on import, export, tourism and trade affects should a landslide occur at this site.

7. The Coledale case study highlights cost to RailCorp following the failure of a railway embankment due to heavy rain and a blocked culvert. The impact of this event across a broad range of sites is described.

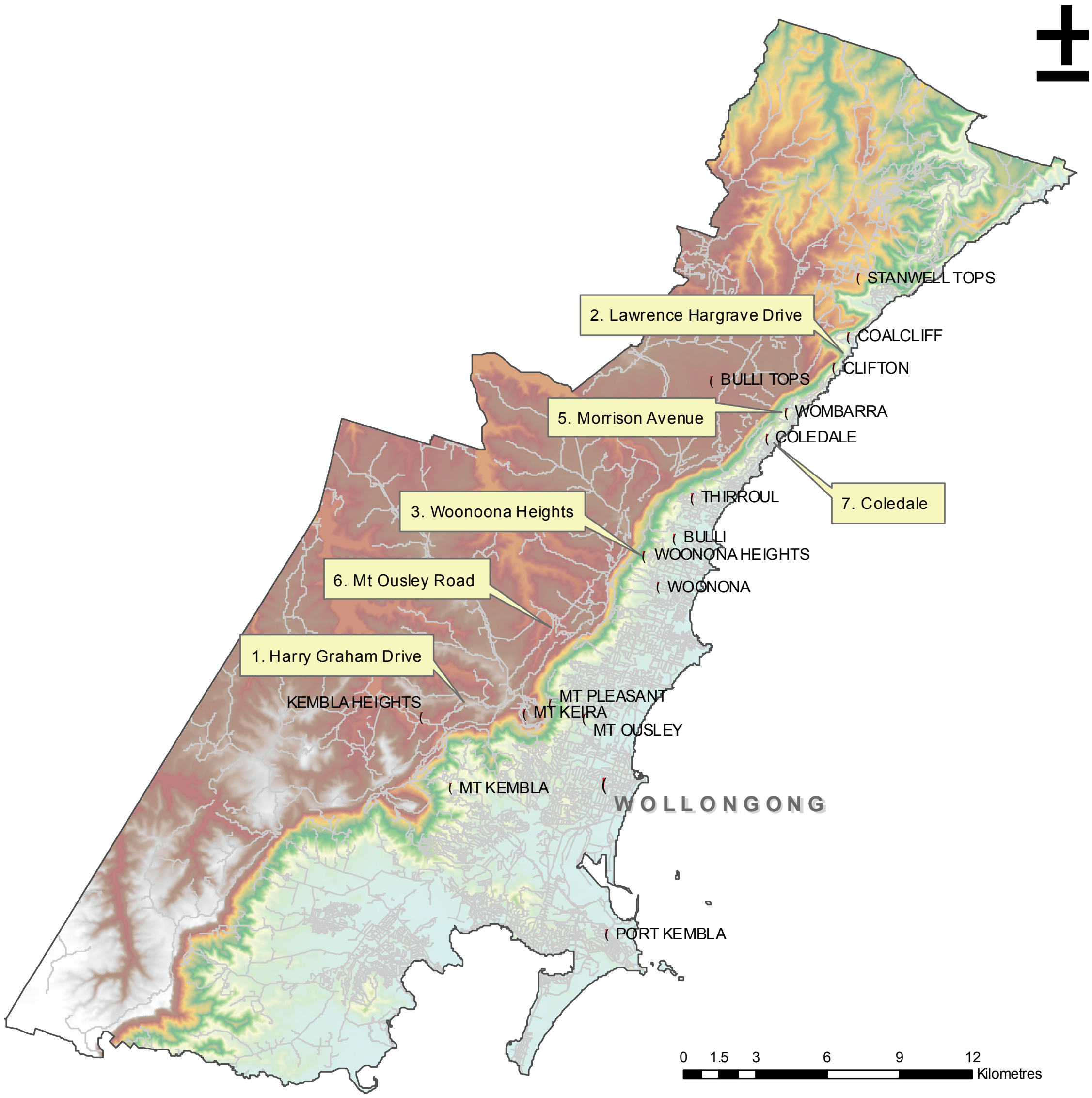

Figure 3: Case study locations within the Wollongong LGA.

6.1 HARRY GRAHAM DRIVE, KEMBLA HEIGHTS

Harry Graham Drive links Mt Keira to Mt Kembla (Figure 4). It is a local rural road of strategic importance for tourist traffic and emergency services. It is one of only two roads leading into Kembla Heights Village. The road is used by about 200 cars daily and is an important link for residents and tourists.

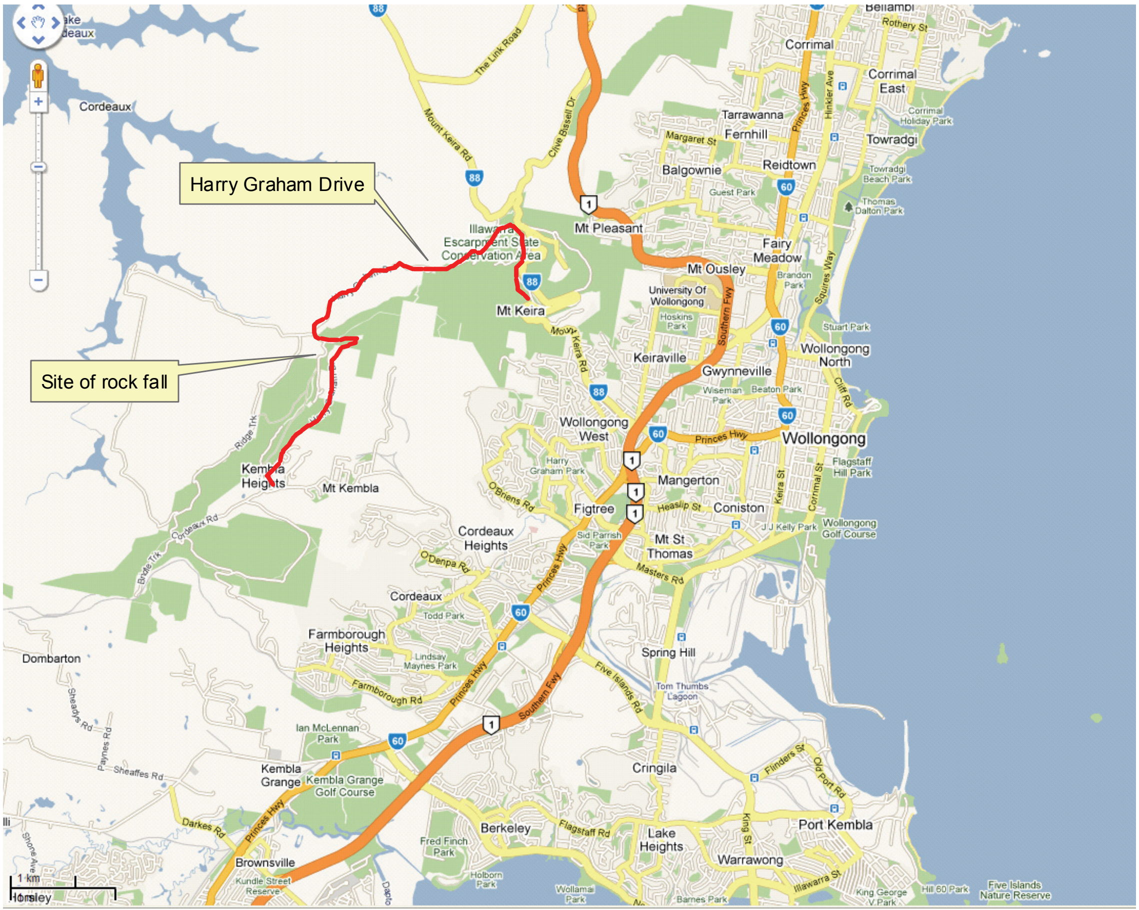

Figure 4: *Location of Harry Graham Drive(map taken from Google Maps, 24 May 2010).*

Harry Graham Drive has had a long history of landslide activity. During the 1970's uncrushed slag from the steelworks was being used free of charge as fill for the holes in Harry Graham Drive. In fact 6000 cubic yards a year were deposited on Harry Graham Drive over a four year period[4]. In August 1998, a large landslide with a debris flow over the road into the valley below occurred on the high terrace above Harry Graham Drive after a period of very heavy rainfall (Figure 5).

[4] During this time the steelworks did not have a management plan for its waste products (or by-products/co-products as known today) and access to the material was easy and free, it is likely use of this material would have continued beyond the four year period. However, a charge became associated with this product. The uncrushed slag was also frequently utilised for railway and other road repairs by local and state authorities which reduced the cost associated with acquiring fill during this time, although all other costs of remediation were still incurred by parties.

Figure 5: Landslide above Harry Graham Drive, north of Mt Kembla Village (photo by Polair and Wollongong Local Emergency Management Committee Geotechnical Team, August 1998).

While there was no significant damage to Harry Graham Drive itself at this time, a routine inspection in June 2005 raised concerns over the stability of a section of cliff above the road. There was a call for quotations from specialist rock mechanics for a risk assessment of the cliff. However, WCC faced considerable difficulty in obtaining a sufficient number of quotes. An order was raised in October 2005 for specialist consultant (URS Corp) to undertake a rock fall risk assessment. In November 2005, an in-house preliminary geotechnical assessment of Harry Graham Drive was also instigated to prioritise a program of slope remediation. Ten locations were identified where slope instability affected the road to some degree.

In December 2005 the rock fall risk assessment by URS Corp was received by the WCC. The preliminary risk assessment result of 'tolerable' was subject to further investigation. Short and long term remedial works were recommended. Part of the Stage 1 remedial works included vegetation removal and minor scaling of loose rock. This was commenced in January and was completed in February 2006 and resulted in a programmed road closure for two months. During this time WCC also successfully completed a drainage project to prevent the rate of under surface erosion, rock falls and slippages on the Kembla Village access road (WCC, 2007a).

In April 2006 tension cracks were evident in bitumen pavement and ground movement had occurred near a hairpin bend at one of the ten sites identified in November 2005. This site was approximately 350 m east of the intersection between Harry Graham Drive and O'Brien's Road and was Harry Graham Drive was described as: "The road is compromised; both lanes [are] affected. [There is] potential for [a] complete halt to traffic, [and] slip will accelerate during extreme and prolonged rainfall" (Flentje, pers. comm. 9 Dec 2008).

Minor emergency maintenance works were undertaken and the site was prioritised as part of the programmed slope remediation in Stage 2. At this time the preliminary in-house geotechnical investigation was completed by WCC although a detailed in-house geotechnical investigation was required to support the design of the remediation works.

Between July 2006 and June 2007 design of the remediation works in order to commence Stage 2 were being drafted. This work was funded as part of the 06-07 budget. By October 2006, in-house geotechnical investigation of six high priority sites on Harry Graham Drive was complete. By December 2006, Stage 1 of programmed remediation works was complete. However, following 145 mm of rain in early October 2006 and a further 80 mm rainfall over short duration in December 2006, new tension cracks were opening north of the recently completed drainage works of Stage 1.

February 2007 saw 250 mm of rainfall with no additional movement in the Stage 1 site of programmed remediation. However, given the new tension cracks opening, the programmed remediation for Stage 2 was revised. The new Stage 2 works proposed continuing remediation northward toward latest ground movement. The original Stage 2 works were deferred to Stage 3.

Wollongong received 60 mm of rain in one event during March 2007 and in April a total of 100 mm over two days. In June, a further 380 mm was received and on 22 June 2007, several hundred tonnes of boulders dislodged and fell from the cliff face and posed a serious safety threat to motorists travelling on Harry Graham Drive below (WCC, 2009). A preliminary in-house risk assessment required road to be closed. This risk assessment was subsequently confirmed by URS Corp.

Works commenced on rock fall remediation in September 2007. However, in November and December of the same year 160 mm and 130 mm of rainfall, respectively, caused delays in rock fall remediation. In early February 2008, Wollongong received an additional 300 mm of rain. At this time the rock fall remediation was 90 per cent complete. However, the rock fall impeded drainage paths that interfered with the road stability and a landslide resulted (between 8 and 11 February) within the vicinity of the rock fall, leaving the site even more unstable (Tobin, pers. comm. 9 Jan 2009). Rock fall works were suspended on 18 February and further areas of concern were closely observed. On 28 February ground movement was still occurring and major restoration works were required to reduce the residual risk to an acceptable level. The investigation was referred to a specialist consultant from URS Corp and Stage 3+ programmed remediation works were deferred indefinitely, pending completion of works required for road re-opening and future budgetary provision.

> *"The programmed management of the landslides was overtaken by unplanned events in the form of the rock fall and then the adjacent landslide activity requiring emergency response with corresponding high costs and extended inconvenience to users"*
> *(Tobin, pers. comm. 9 Jan 2009).*

As a result, the WCC closed Harry Graham Drive in mid-2007 for major upgrade works, including installation of drainage pits and further subsoil drainage to stabilise the road. At this point, only Stage One of the programmed landslide management had been completed (Tobin, pers. comm. 9 Jan 2009). The road closure was initially estimated to last approximately one month. However, geotechnical inspections of the rock fall areas indicated unstable sections of the cliff and continued road closure was necessary. Harry Graham Drive was closed in June 2007 and re-opened on 23 December 2009 one month ahead of schedule.

Costs to Harry Graham Drive

Repair expenses have been met by WCC's maintenance budget. However, the extent of the works required to stabilise the road exceeded Council's expectations, and as such the maintenance budget has been substantially surpassed. For example, $180,000 of the WCC 2007/2008 Southern Construction budget (out of a total Southern Works[5] budget in the order of $8 million) was set aside for programmed stabilisation works on Harry Graham Drive before the rock fall. The programmed stabilisation works did not commence in 2009 and became a lesser priority due to required remediation. The budget for the programmed stabilisation works was spent on the unplanned emergency works.

A total of $1.92 million of Council funds was spent on consultants, rock fall remediation (as yet incomplete) and the subsoil drainage project on Harry Graham Drive (Tobin, pers. comm. 9 Jan 2009). As an example of the proportion of WCC spending: this exceeded the entire 2007/2008 Southern Maintenance budget by 37%, and made up 24% of the entire 2007/2008 Southern Works budget. The unscheduled emergency-response works significantly disrupted following budgetary processes, and WCC is having difficulty progressing with the solution to Harry Graham Drive (Tobin, pers. comm. 9 Jan 2009). In 2009, an additional $1.05 million was awarded to complete the landslide repairs at the location of the road closure. It was expected with additional expenses, this figure would become $1.5 million. This was followed by another tender in the order of $0.5 million to complete the remediation of the rock fall area. The costs were estimated to exceed another entire Southern Works maintenance budget. The tangible and intangible costs are summarised in Tables 1 and 2.

The Illawarra Mercury reported on 23 December 2009 that more than $3.7 million was spent on stabilising the cliff and rebuilding the road during a 2 ½ year closure. With the multimillion-dollar project covering a stretch of road less than 500 m long, the project cost ratepayers about $7 400 for each metre of road. About $2.1 million came from Roads to Recovery funding. Other stability problems (Figure 6) along the remainder of Harry Graham Drive have yet to be addressed (Tobin, pers. comm. 9 Jan 2009).

[5] The WCC has three works districts (North, Central and South) and Harry Graham Drive is in the Southern Works District.

Figure 6: *Slow moving landslide rear main scarp intersects the Mount Keira fire trail. Displacement approximately 30cm. Photo taken by Phil Flentje on 28 August 1998, accessed from UoW website, 29 January 2009.*

Social consequences

The WCC ensured the broader public were informed and updated on the status of progress and new developments through media releases. The WCC also consulted and involved residents in the process through community meetings, and negotiated road closures and access with local residents in an endeavour to reduce the level of inconvenience. The closure of the road caused significant unrest amongst the local community. The only alternative route to Mt Kembla, Mt Kembla Village, Kembla Heights and Windy Gully was Cordeaux Road. Mt Kiera road was recommended for access to Mt Keira, Picton Road and Clive Bissell Drive (WCC, 2007b).

Newer residents to the area have had difficulty coming to terms with the inconvenience that the closure has caused and understanding the lengthy delays. Longer-term residents, whilst generally more aware and accepting of landslide issues in the area, were also greatly inconvenienced as all residents are facing significantly higher transport costs with the need to take alternative, much longer routes (Tobin, pers. comm. 9 Jan 2009). Residents were reportedly frustrated at the inconvenience to attend festivals and other cultural events, and were concerned about increased delays in receiving emergency services, particularly during the bushfire season.

Table 1: Tangible costs incurred on Harry Graham Drive

COST TYPE	AMOUNT	PAID BY
DIRECT		
Stabilisation, improvement project	$200 000	WCC
Consultants, rockfall remediation, subsoil drainage project (Stage 1)	$1 920 000	WCC
Stage 2 (to commence in 2009). Subsoil drainage project completion; final consultant reports, landslide stabilisation works	$1 500 000	WCC
Stage 3 (to commence following completion of Stage 2 works) Completion of rock fall remediation	$500 000	WCC
INDIRECT:		
Increased transport costs	Unknown	Residents, freight companies.

Table 2: Intangible costs incurred on Harry Graham Drive

LOSS TYPE	IMPACT
Delays in emergency services	General feeling of unease and fear amongst local community (especially in bushfire season). Increased stress, affecting lifestyle of locals and concerns accessing emergency services if required.
Damaged relationship between WCC and Wollongong residents	Increased difficulty for WCC carrying out future work in the community; general mistrust and aggression from residents toward WCC role.

6.2 LAWRENCE HARGRAVE DRIVE, CLIFTON

Lawrence Hargrave Drive is a popular coastal road extending between Stanwell Park and Thirroul (Figure 7). The 1350 m section of road between Coalcliff and Clifton was initially constructed in the 1860's near the base of the 330 m high coastal Illawarra escarpment. The escarpment comprises a series of near-vertical cliffs separated by steep slopes above road level. The uppermost soil layers are characteristically stony with a low water-holding capacity, and despite the low erodibility of the soil material, over time the escarpment was over-steepened by aggressive marine erosion of the coastal platform (Wilson et al, 2008; RTA, 2008).

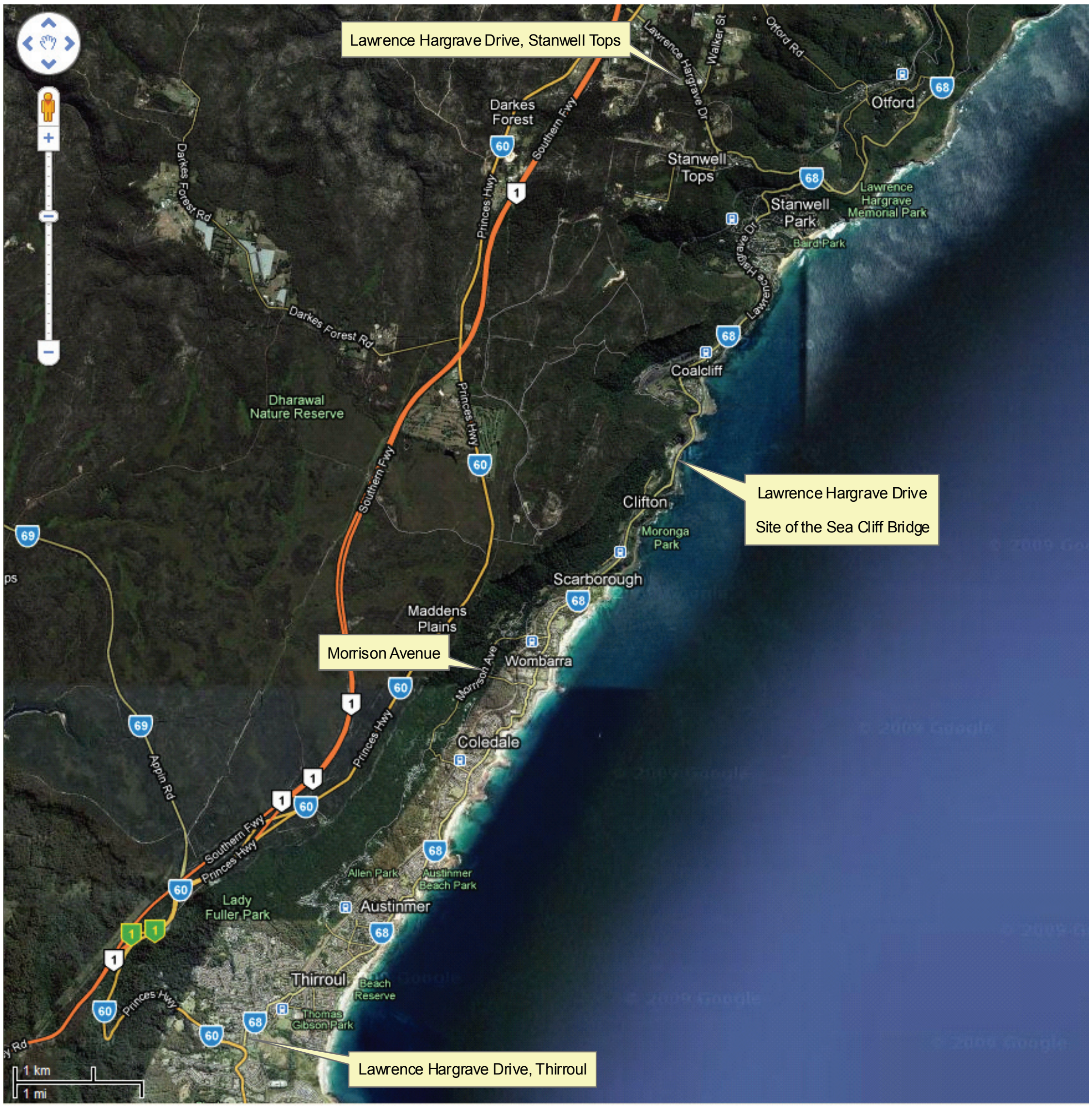

Figure 7: Aerial view of Lawrence Hargrave Drive extending from Stanwell Tops along the coast to Thirroul. Residents north of the road closure and site of the Sea Cliff Bridge faced significant delays and challenges in accessing Clifton, and the southern suburbs (map taken from Google Maps, 24 May 2010).

The road has had a long history of substantial geotechnical instability for intermittent landslides, rock fall and debris flow between Clifton and Coalcliff since 1879, frequently resulting in road closures sometimes for months at a time (Figure 8). In fact, the coast road from Coalcliff to Clifton was rated the most dangerous in NSW due to ongoing rock falls, landslides and slippages (RTA, 2008). It is believed Queen Elizabeth intended to drive along the road during a visit to Wollongong in 1954, but was persuaded to catch the train instead due to the risk of a rock fall (ABC, 2005). Annual daily traffic observed between 1986-2000 (excluding periods of road closure due to works) ranged between 2 200 and 3 400 vehicles per day, and the annual daily traffic in 2008 was reported at 4 000 per day (Wilson et al, 2008).

Figure 8: *Debris slump on Lawrence Hargrave Drive (UoW website, photo: Flentje)*

The NSW RTA is responsible for the road and ongoing monitoring was managed by the RTA at a cost of approximately $200 000 per annum prior to construction of the Sea Cliff bridge (Figure 9). A series of stabilisation works was performed by the RTA throughout 1988-89, 1998-99 and 2002-3 totalling approximately $28 million during this time. Clean-up costs are unknown. Many of the rock falls have been in the order of 100 – 600 tonnes of displaced rock and debris and road closures have typically ranged from days to several months (RTA, 2008).

In 2002 a study showed the risk of rock falls on Lawrence Hargrave Drive increased after heavy rain. In response, the RTA introduced a program of temporary road closures following 35 mm of rain (RTA, 2004). Early in 2003 further research concluded the risk to the public posed by the road was ‘intolerable’. Many attempts were made to maintain the road in an open condition, none with long term success. In June 2003, a widening crack approaching 1 m in diameter was discovered and on 11 July 2003, approximately 15 cubic metres of rock fell on to the roadway. These events further highlighted the dangers of the road and need for repairs (RTA, 2004). A maintenance resolution was not possible, and the road was considered an intolerable or unacceptable risk to public safety.

Therefore, on 29 August 2003 the NSW Minister for Roads closed a 900 m section of Lawrence Hargrave Drive in order enable a more permanent solution to be constructed and re-open a new road two and a half years later. The curved 455 m-long 'Sea Cliff Bridge' was opened two years later in December 2005.

Eighteen months prior to the bridge solution Lawrence Hargrave Drive was closed for 15% of the time (RTA 2008). The bridge was built 45 m east of the existing road (Figure 9) in order to bypass the unstable cliff line and associated rock falls (RTA 2008). RTA quoted geotechnical investigations as costing approximately $1.7 million, and the construction of the bridge itself as up to $50 million. The relocation of power (communications) cost approximately $325,000, and legal costs throughout the following three months cost approximately $1.09 million. A summary of tangible and intangible costs collected are shown in Tables 3 and 4.

Social consequences

There were significant losses faced by the local community over the two and half year period. The closure of Lawrence Hargrave Drive involuntarily split the community in half. Individuals were separated from their schools, friends, sporting activities and recreational interests (ABC, 2003). Alternative routes from Lawrence Hargrave Drive were lengthy, and smaller roads were not equipped to deal with such heavy traffic. Detours could add up to half and hour or more to travel time (Tobin, pers. comm. 9 Jan 2009). This was a considerable inconvenience to school students and professionals in the region and some students were required to change schools (ABC, 2003). Individuals required to use public transport often relied on trains to arrive every two hours (ABC, 2003).

Tourist-based businesses faced substantial losses in trade, with some businesses closing down due to almost complete loss of tourism (RTA, pers. comm. Dec 2008). For example, a popular community establishment known as the Clifton Pub was permanently closed, and the Scarborough Pub, a popular heritage-listed bar and bistro, reduced their trading hours substantially during the closure and was renamed 'The Poverty Bistro' by locals (The Illawarra Mercury, 2003). However, other businesses reported an increase in demand for their services (ABC, 2003). It is also likely that following the construction of the Sea Cliff bridge property values increased in the area.

While, in principle, it is the responsibility of the RTA to liaise with the public on matters surrounding road closure, thorough public consultation and guidance was not carried out prior to and throughout the closure of the road (Tobin, pers. comm. 9 Jan 2009). It is believed the wider community were not fully aware of the impact aggressive marine erosion had underneath the road and did not realise the high risk to life posed by rock fall hazard above the road, and became increasingly frustrated at the long road closure. This resulted in a series of public protests and heated public meetings, as well as persistent complaints to the (then) NSW Minister for Roads. The RTA commented the landslide problems on Lawrence Hargrave Drive, associated road closures and major public unrest were a 'catastrophic' episode (RTA, pers. comm. Dec 2008).

The RTA completed an oral history project capturing the stories of Lawrence Hargrave Drive (ABC, 2005). A selection of local residents, government roads staff and technicians were interviewed to highlight the impact the closure of Lawrence Hargrave Drive had on the lives of locals.

Figure 9: *The $49 million Sea Cliff Bridge opened late 2005 (photo: Bob Pearce, The Sydney Morning Herald, 2005).*

Table 3: Tangible costs incurred on Lawrence Hargrave Drive

COST TYPE	AMOUNT	PAID BY
DIRECT:		
Stabilisation works prior to road closure	$28 000 000	RTA
INDIRECT:		
Ongoing monitoring prior to road closure (1950's – 2003, in 2000 dollars)	$200 000 p/a	RTA
Geotechnical investigations	$1 700 000	RTA
Construction of 'Sea Cliff Bridge'	$50 000 000	RTA
Relocation of power/communication lines	$325 000	RTA
Legal Costs (over two months)	$1 090 000	RTA
Increased travel time for residents (approx. ½ hour additional)	Unknown	Residents, freight companies
Loss of trade and tourism	Unknown	Local businesses

Table 4: Intangible costs incurred on Lawrence Hargrave Drive

LOSS TYPE	IMPACT
Community outrage at lengthy closures	Increased stress and tension within the community. General feeling of unease and unhappiness. Damaging for the wellbeing of the community as a whole.
Loss of trust by residents towards the RTA	Residents likely to be suspicious and mistrusting of future RTA projects requiring community co-operation or understanding.
Damaged relationship between NSW Minister for Roads and Wollongong residents	Community anger towards management of issue impacting on Minister popularity; increase of hostility and mistrust for future projects, in turn affecting Ministerial future roles and career.
Recreational activities, personal relationships	Increased travel time, segregation of community activities, difficulties maintaining friendships and sporting activities, adaptation resulted in lifestyle changes (i.e. school, work and after school/work commitments).

6.3 WOONONA HEIGHTS, WOLLONGONG

Woonona Heights is a northern hillside suburb of Wollongong that has been significantly affected by an episodically active extremely slow moving landslide. The 225 000 m3 landslide is comprised of gravelly and sandy clay colluvium that includes several coal seams, sliding over residual bedrock. The entire landslide is located within a densely developed urban area. The area of interest extends from the T-junction within Joanne Street, downslope in a south-south-east direction to the south end of June Parade and Joseph Street and also includes Stephen Drive (Figure 10).

Figure 10: Residential area of Woonona heights depicting area affected by landslide (map taken from Google Maps, 24 May 2010).

Progressive slip and drainage failure has occurred since 1972, with another peak in movement occurring in the early 1990's corresponding to periods of increased rainfall. In these instances, utilities such as water mains, sewer mains and power poles were affected, although these were addressed promptly and costs were met by the responsible companies (Sydney Water and Integral Energy). Up to 29 residential houses situated within the landslide and another 10 immediately adjacent to its margins, and it is believed up to 70 homes are currently in motion due to mobile soils (Tobin, pers. comm. 9 Jan 2009). One house has been destroyed by slip movement, many of the houses on Joseph Street were required to be rebuilt, and at least 19 others have required major repairs. It is understood that rigourous construction practices were not enforced during the 1960's when the subdivision was developed. Road works on Joanne Street in 1979 cost $12 000, and reconstruction of Joseph St in 1979 cost $32 000 (only to be rebuilt again in the early 1990's at an undocumented cost). Reconstruction of Stephen Drive was also undertaken in the early 1970's at an undocumented cost. It is also believed there were substantial legal costs in the 1970's due to threatened legal action by residents on WCC although the cost figures are unknown (Tobin, pers. comm. 9 Jan 2009). Utility services were also affected from time to time.

Coffey Partners' geotechnical investigations into rehabilitation of unstable slopes in the area cost WCC $58 700 in 1990 (2008 dollars), $98 000 in 1992 (2008 dollars) and $4 500 in 1994. In 1992, $15 800 was spent on legal investigations, in which WCC examined legal options to recover some of these costs. Regional remediation works proposed include a permanent gravity dewatering system with deep bores connected to a near-horizontal drainage drive. In 1994 the cost of these works were estimated to be in the order of $1.5 million. However, such a system is currently well beyond the capacity of WCC and residents. Subsequently "no remedial works [have been] installed or [are] likely in the near future. [The] slip will continue to move, at increased rates during increased rainfall. [The] magnitude of damage will increase" (Flentje, 2008). Some of the collected costs are shown in Tables 5 and 6.

In 1992 a proposal was presented, where WCC costs could be recovered via a special local rate imposed on affected property and asset owners in Woonona Heights. Therefore, the cost would need to be apportioned amongst affected asset owners and met by individuals (as the WCC did not have the funds required for repair). However, such a cost was beyond the means of these residents to meet and efforts to raise the amount of money required became 'too hard'. This was politically and publicly unpopular, and the idea was abandoned. However, over the last fifteen years very few repairs have been made as there has been very little landslide activity due to conditions being relatively dry. Therefore, periodic repair is performed by WCC as required as it is more cost effective to repair the road as needed than to remediate the landslide (Tobin, pers. comm. 9 Jan 2009). The area is also infrequently monitored by UoW.

The residents of Woonona Heights kept a high media profile, organising protests and writing to Council as well as various Ministers during this period. It is understood that there is not a high turnover in property ownership and it is believed many of the property owners feel trapped because they would not get enough from the sale of their property to purchase elsewhere. In addition, it is believed moving away from the mountains would be viewed as a step backwards by many residents.

Table 5: Tangible costs within the Woonoona Heights region.

COST TYPE	AMOUNT	PAID BY
DIRECT:		
Remedial works (1970s)	$50 000	WCC
Major property repair (minimum of 19)	Unknown	Private land/ property owners
INDIRECT:		
Coffey Partners' investigations (1990, 1992 and 1994: rehabilitation options – unstable slopes)	$161 200	WCC
Legal investigation, 1992 (options to recover cost)	$15 800	WCC
FUTURE DIRECT COST ESTIMATIONS		
Gravity de-watering system installation	$1 500 000	WCC and residents
Maintenance of de-watering system	Not specified	WCC and residents

Table 6: Intangible costs within the Woonoona Heights region.

LOSS TYPE	IMPACT
Increased stress, frustration and concern for property owners	Increased stress and tension within the community, feeling of fear and unease about future damage.
Damaged relationship between Wollongong residents and Council	Increased difficulty for WCC carrying out future work in the community; general mistrust and hostility from residents toward WCC role.
Property value	Reduction in property values.

6.4 AUGUST STORMS IN 1998

A series of intense rainfall events occurred in the Wollongong region in August 1998 resulting in one drowning fatality and approximately 148 landslides (Figure 11). The RTA has rated landslide activity associated with these storms as 'catastrophic' (RTA, pers. comm. Jan 2009). Debris or hyperconcentrated flows originating from anthropogenic and natural sediment sources caused significant damage to urban areas (Reinfelds and Nanson, 2001). Access to the city was cut by landslides and floodwaters for up to 24 hours. It is estimated that up to $100 million dollars damage resulted (Geoscience Australia, 2003) including $500 000 dollars damage to vehicles.

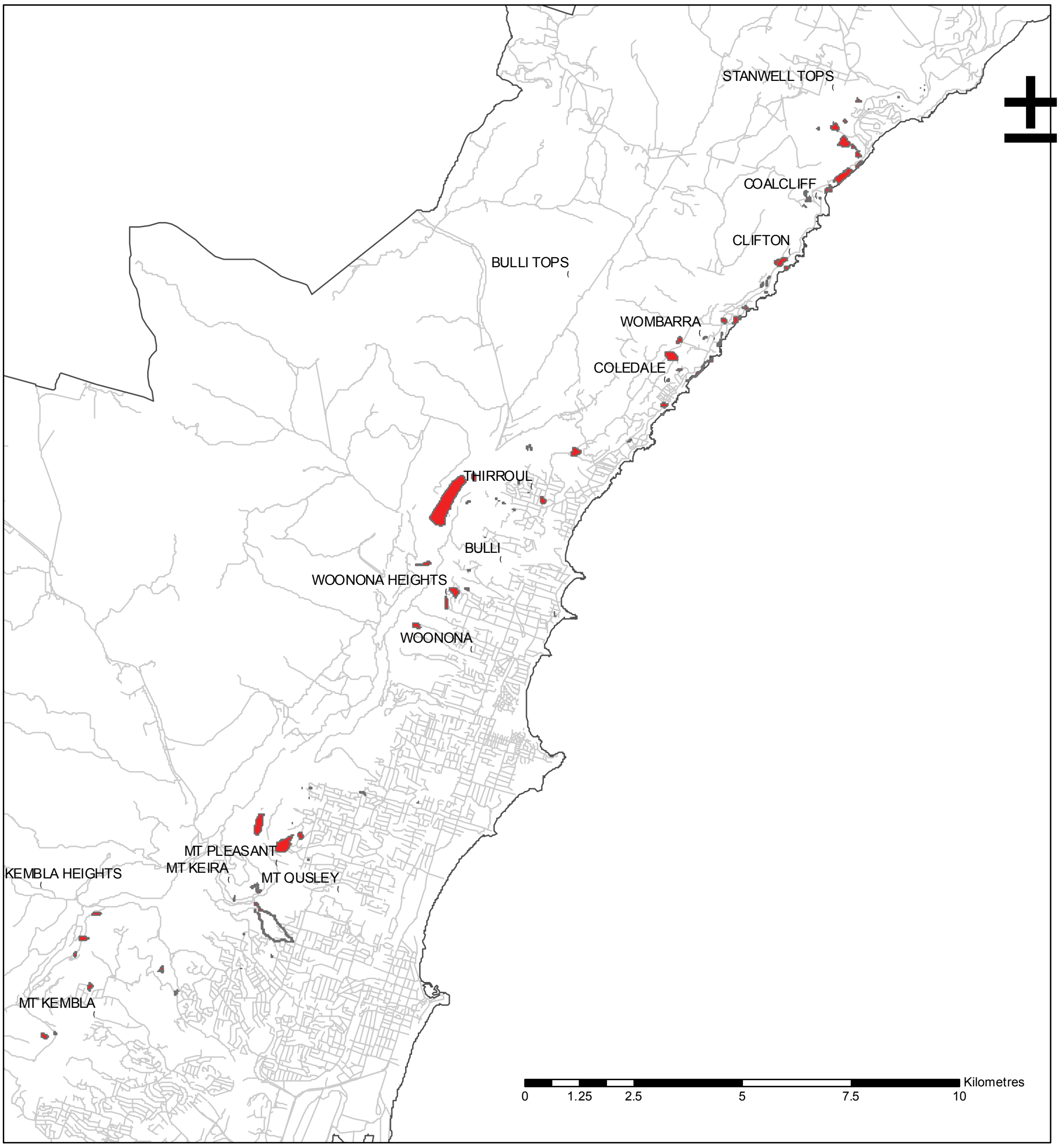

Figure 11: *Distribution of landslides following the August 1998 storms in Wollongong.*

Many of these sites where debris flows originated had no prior history of instability (Tobin, pers. comm. 9 Jan 2009). On 17 August two debris flows inundated the suburb of Keiraville damaging several houses in their paths (Flentje and Chowdhury, 2002). On 20 August another debris flow resulted in a 12 hour evacuation of a portion of the Mt Kembla village including 50 houses and 130 residents during the night (Flentje and Chowdhury, 2002). Another debris flow inundated and blocked a road for 24 hours. A main road referred to as the 'Bulli Pass' was closed due to debris for several days, and several vehicles were badly damaged (Figure 12).

Figure 12: *Bulli Pass in the early morning on 18 August 1998. Photo courtesy NSW SES on UoW website, accessed 24 May 2010.*

As the debris flows lost momentum they formed fan deposits up to two meters deep filling a public reserve, backyards, garages and swimming pools (Reinfelds and Nanson, 2001). One house was later demolished it was so badly damaged from the fan deposit. Other damage was sustained to fences and drainage. During these storms, widespread erosion occurred particularly where urban development had encroached on natural water courses (Reinfelds and Nanson, 2001). Erosion of channel banks undermined many homes leaving them perilously close to the edge of streams (Reinfelds and Nanson, 2001). The alteration of drainage systems within slopes is considered to be one of the most critical factors in stability determination and the damage to drainage catchments during the storm increased vulnerability of urban areas to land slippage.

Cost information for this event is difficult to assess, as the distinction between costs exclusive to landslides and costs related to other storm damage is unclear in WCC records. In most cases property owners were faced with the full cost of repairing damage to their individual properties and assets[6]. In very few cases, where legal and insurance definitions of 'storm damage' permitted, successful applications by insured parties were made for compensation for landslide damage.

[6] as landslide insurance is not available unless it is directly related to a storm event and occurs within a specific period

However, this was a lengthy process (≥1 year), and there were a number cases of class action taken against certain insurance companies deemed overly-reluctant to offer compensation, thus further delaying individuals' recovery.

The community raised money to assist individuals who had lost everything. There was no government response that benefited individuals suffering significant damage or destruction to their homes, although WCC received funds under the NSW State Emergency Services to restore public assets (Tobin, pers. comm. 9 Jan 2009). However, the restoration of public assets did not include fixing such assets. RTA incurred costs of approximately $500 000 (2008) to clear and repair Bulli Pass (Figure 12). In addition, RTA incurred costs of approximately $300 000 for geotechnical investigations into the Mt Ousley culvert and $3 million to replace the culvert and an additional $1 million to maintain it until 2008. The culvert was reconstructed at night to reduce traffic disruption. RTA also estimated that "disruption costs for Bulli Pass…were in the vicinity of $1 million a week during the full time closure" (RTA, pers. comm. 23 Dec 2008). Some of the tangible and intangible costs are listed in Tables 7 and 8.

The road closures resulting from the August 1998 storms temporarily isolated Wollongong. It is estimated approximately 15 000 commute to Sydney each day for work, whether by road or rail. Individuals could not get to work and their movements were restricted. Residents were co-operative with any measures that needed to be taken though, such as closing roads and performed clean-up operations around their properties. Frustrations in the community for this event were found to lie with insurance companies and expectation that the government would provide greater assistance to those affected.

Although not typical for the month of August, this rainfall intensity is typical of the Wollongong climate and is expected to occur along the Illawarra escarpment approximately every 10 years. Combining cyclic heavy rainfall episodes with ongoing alterations to the ground profile and drainage (resulting from deforestation, excavation, filling and construction) increases the risk of land slippage dramatically (Figure 14). In terms of mitigation works, hazard reduction works and clarity of legal responsibilities, it is believed that neither WCC or residents are any more prepared for a recurrence of this type of weather than in 1998, and are likely to be faced with similar issues of property damage, road closures and compensation difficulties in future (Tobin, pers. comm. 9 Jan 2009).

Figure 13: *Head scarp area of large slide which moved during the August 1998 storms. Photo taken by Phil Flentje on 25 October 2004, accessed from UoW website on 20 January 2009.*

Table 7: Tangible costs incurred following the 1998 August storms.

COST TYPE	AMOUNT	PAID BY
DIRECT:		
Repairs to Bulli Pass (closed due to debris)	$500 000	RTA
Replacement of Mt Ousley culvert	$3 000 000	RTA
Repairs to damaged properties	Unknown	Private land/ property owners
Evacuation of 50 houses and 130 residents during the night	Unknown	Emergency Services
INDIRECT:		
Investigations into Mt Ousley culvert (prior to replacement)	$300 000	RTA
Increased transport costs (for duration of closure of Bulli Pass)	Unknown	Residents, freight companies
FUTURE COST ESTIMATIONS		
Maintenance to 2008 of culvert	$1 000 000	RTA

Table 8: Intangible costs incurred following the 1998 August storms.

LOSS TYPE	IMPACT
Increased stress, frustration and concern for property owners	Increased stress and tension within the community in general – general feeling of fear and unease about future damage during periods of heavy rainfall. Detrimental to the wellbeing of the community as a whole.
Damaged relationship between insurance companies and their clients, and the general public	General mistrust for insurance companies as a beneficial and accommodating body; potential decrease in client base due to poor publicity.

6.5 MORRISON AVENUE, WOMBARRA

Morrison Avenue is a semi-rural road with a long history of landslide activity. The area of interest is located south of Denmark Street, Wombarra (Figure 7). The upper sections of this site slope steeply at 15-20° at the base of the main escarpment, whilst the lower sections have shallower, irregularly contoured slopes of approximately 10° (Flentje, 2008). The landslide activity has resulted in the destruction of properties with homes being subsequently abandoned or demolished. Major failures occurred on Morrison Avenue in 1974 which resulted in at least three houses being destroyed. Disruptions to the road have also been significant with the road totally destroyed and rebuilt in 1970, 1974 and 1990-91 (Figure 15). Approximately ten minor instances of failure were also reported between 1974 and 1984 (Flentje, 2008).

Figure 14: *Damage to the pavement of Morrison Ave, in April 1990. Photo taken by Phil Flentje and accessed from UoW website on 20 January 2009.*

Residents of destroyed or significantly damaged homes during landslide activity in the 1970's were unsuccessful in seeking compensation for their loss, and as such had to bear the full impact of losing their home (Figure 15, Figure 16). WCC land rates were based on land value prior to the landslide activity and these were still required to be paid following the landslides. However, many residents refused to continue payment after losing their homes. In the 1970's, WCC acquired six properties for unpaid rates, which have since been available for purchase from WCC at a very low price and heavy restrictions on development (Tobin, pers. comm. 9 Jan 2009). WCC also incurred costs for legal proceedings related to Morrison Avenue although the details are not known.

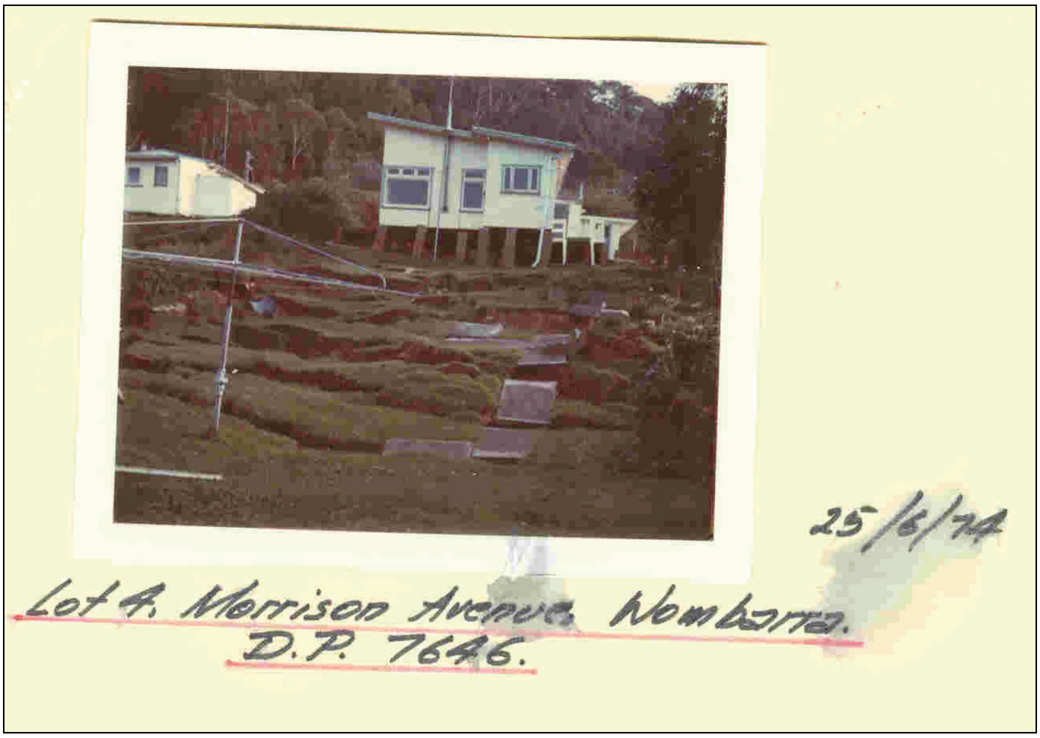

Figure 15: *Landslide at Morrison Avenue in 1974, Wombarra. Photo courtesy of Wollongong City Council.*

Figure 16: *Major structural damage to house on Morrison Avenue during 1974. Damage resulted from house straddling landslide margin. Photo by Ann Young, accessed from UoW website on 20 January 2009.*

It is important to realise the closure of Morrison Avenue poses a considerable inconvenience to residents, as while traffic flow on this road may be light, it is the only alternative route to Lawrence Hargrave Drive[7] and is therefore strategically important. In addition to road repairs and road closures, water mains, power poles and communication lines have been damaged and services interrupted on numerous occasions during ground movement, which have generally been restored relatively quickly by the responsible companies such as Sydney Water and Integral Energy.

The area of landslide risk surrounding and including Morrison Avenue was fully investigated in 1991 (at a cost of approximately $300 000).

Remediation works were designed and options were proposed including:

- Do nothing, perform periodic repair as required;
- abandon road;
- slot drainage to reduce movement ($1.2 million in 1991);
- eductor system ($0.3 million in 1991 and ongoing high cost); or,
- pier wall system ($3.5 million in 1991).

The remediation solutions are currently too costly to implement and as the majority of the area affected is on private property, the cost would need to be proportioned amongst the various property owners. Due to the high cost of remediation, the site is maintained as required. The frequency of maintenance works is weather-dependent. Similar to the landslide at Woonona Heights, over the last fifteen year limited works have been conducted. However, there is evidence of tension cracks opening up again and with the continued poor drainage the area will become more mobile if rainfall levels increase. The long-term residents of Morrison Avenue expect and understand landslide problems will occur from time to time, while the newer residents find the problems more difficult to come to terms with.

The WCC rated this landslide activity as ‘catastrophic’ due to the significant financial losses faced by homeowners, and the enormous cost to WCC to remediate the landslide (Tobin, pers. comm. 9 Jan 2009). Some of the tangible and intangible costs are shown in Tables 9 and 10.

[7] Lawrence Hargrave Drive is also often closed for significant periods due to landslide.

Table 9: Tangible costs incurred on Morrison Avenue.

COST TYPE	AMOUNT	PAID BY
DIRECT:		
Drainage works, repairs, purchase of lots, legal costs between 1972 – 1981.	$77 547 (2008)	WCC
Ongoing destruction and damage to private properties	Unknown	Private land/ property owners
Frequent utility repairs (water mains, power poles)	Unknown	Sydney Water, Integral Energy
Ongoing road repairs	Unknown	WCC
Geotechincal investigation	$300 000	WCC
FUTURE COST ESTIMATIONS		
Remediation options (Longmac, 1991):		Private land/property owners and WCC
-Eductor system installation	$460 000	
-Slot drainage installation to reduce movement	$1 840 000	
-Pier wall system installation	$5 370 000	
INDIRECT:		
Longmac Investigation (private consultants) 1991 - remediation options	Unknown	WCC
Increased transport costs (extensive traffic delays or alternative routes)	Unknown	WCC
Legal costs	Unknown	WCC, residents
Decreased property values	Unknown	Private property owners, lessors and sellers

Table 10: Intangible costs incurred on Morrison Avenue.

LOSS TYPE	IMPACT
Inconvenience to residents	Frustration and hostility about continued problems.
Damaged relationship between residents and WCC	Increased difficulty for WCC carrying out future work in the community; general mistrust and hostility from residents toward Council role.
Increased stress and concern for property owners	Increased stress and tension in community, feelings of fear and unease about future damage.

6.6 MT OUSLEY ROAD, WOLLONGONG

Mt Ousley Road is a major road forming the link between the north and south sections of the F6 Southern Freeway to Sydney (Figure 17). It serves as the primary route up and down the Illawarra Escarpment and is the major entrance to Wollongong. A landslide on this road could cause total closure of a major arterial road and the risk of closure is unacceptable. This road is frequently closed during heavy rainfall events and the number of lanes open are often restricted (Figure 18). Typical problems relate to boulders blocking pipes and pipes exploding, culverts needing to be rebuilt because of damage done and creeks being blocked with debris forcing the drainage onto Mt Ousley Road.

Figure 17: Mt Ousley Road in Wollongong, part of the Southern Freeway (map taken from Google Maps, 24 May 2010).

There was extensive damage to private property adjacent to Mt Ousley Road in the mid 1970's. The RTA financed restoration works that included drainage words through to Brokers Road. The area failed 'in a spectacular fashion and it was only a miracle there were no fatalities (Tobin, pers. comm. 23 Jan 2009). In 1988, a 200 m wide, 60 m long landslide was detected by RTA on Mt Ousely Road, when field observations showed cracking and subsidence of Mt Ousley pavement (Flentje, 2008). The large-scale soil slope instability in the escarpment has affected all six lanes of the F6, in what has been documented as the largest landslide in Wollongong (Flentje, 2008). During 1988, a series of vertical eductor wells were installed into the site in an attempt to de-water and stabilise the landslide area in order to inhibit rises in pore pressure. The effectiveness and performance of the eductor system is still being assessed. While some movement is still occurring it is believed the eductor system is likely to have significantly slowed motion (Flentje, 2008). Road closures over time have severely affected traffic flow for several months at a time during slip reconstruction and after heavy rain. After the August 1998 storms five lanes were closed during culvert repair (RTA, pers. comm. Dec 2008; Tobin, pers. comm. 9 Jan 2009).

Figure 18: *Mt Ousley Road descending the Illawarra escarpment (Ozroads website, accessed 20 January 2009).*

The RTA has incurred substantial costs as a result of this landslide activity. For example, approximately $2 million (2008) has been spent on geotechnical investigations, approximately $20 million on slip reconstruction, and ongoing surveying and real-time monitoring has been estimated in excess of $100 000 per year. $1.5 million was spent in the 1970's on restoration works and drainage installations in the area to prevent further damage to private properties near the road. Future works have been predicted as costing approximately at least $15 million to reduce risk (RTA, pers. comm. Dec 2008). Some of the tangible and intangible costs are summarised in Tables 11 and 12.

Tourism and trade in Wollongong have been significantly affected as a result of frequent road closures and disruptions to traffic. The impact is predicted to increase dramatically if the road must be completely closed for extended periods. Furthermore, with the growth of the Port Kembla port, the Mt Ousley Road is being increasingly heavily utilised and often struggles to manage the level of traffic (RTA, pers. comm. Dec 2008; Tobin, pers. comm. 9 Jan 2009). The increased freight load along Mt Ousley Road leaves the ground material vulnerable to soil liquefaction and ground movement. The RTA has cited the impact of landslide activity on Mt Ousley Road as major.

The community is aware and understand the landslide risk on this road and they can see the problems. It is understood the community is therefore more accepting of the road closures and while closures are an inconvenience they understand that it is a risk. It is believed that if landslide activity closes Mt Ousley Road again, it is likely that alternate routes would also be closed at the same time due to the same problem, such as Harry Graham Drive and Mt Kiera Pass (Figure 17).

Table 11: Tangible costs on Mt Ousely Road

COST TYPE	AMOUNT	PAID BY
DIRECT:		
Slip reconstruction	$20 000 000	RTA
Residential property damage and clean up	$1 500 000	Unknown
INDIRECT:		
Geotechnical Investigations	$2 000 000	RTA
Ongoing monitoring (surveying, real-time monitoring from 1950's – 2003, in 2000 dollars)	$100 000 p/a	RTA
Restoration works and drainage installations (preventing further damage to private properties adjacent to Mt Ousley Rd)	$1 500 000	RTA
Increased transport costs (due to extensive traffic delays or alternative routes)	Unknown	Wollongong/Syd residents, freight companies
Loss of trade and tourism	Unknown	Local businesses
FUTURE COST ESTIMATIONS		
Risk reduction works and stabilisation	$15 000 000+	RTA

Table 12: Intangible costs on Mt Ousely Road

LOSS TYPE	IMPACT
Commuter frustration	Increased stress/tension for drivers, heavy vehicles on other roads.

6.7 COLEDALE RAILWAY EMBANKMENT FAILURE

Coledale is a small mining town close to Wollongong that experienced a fatal landslide on 30 April 1988. Two weeks of heavy rainfall combined with a blocked culvert caused a 17 m high railway embankment to collapse. This was due to severe under-mining and subsidence from saturation of earth and rock ballast that was used to fill an old mine dam. The slip surface first developed in the natural slope bank below the embankment, and the catastrophic failure was caused by blocked drainage uphill and high pore water pressures in a layer of ash forming part of the embankment (Flentje and Chowdhury, 2002). An extremely rapid, very wet debris flow collided with a house on Rawson Street at 4 am, first turning it 60° before completely demolishing it (Figure 19). A young mother and her infant son inside the house were tragically killed, while two children and their father managed to escape.

Figure 19: *Vertical view of Coledale Station area, days after the 1988. Photo taken on 30 April 1998, accessed from UoW website on 20 January 2009.*

One track of the dual railway line was closed for an unknown extended period. Following this disaster, RailCorp has spent many millions of dollars on geotechnical investigations and remedial works (Flentje, 1998). For example, drainage amplification works at the site to limit flooding potential is thought to have cost approximately $5.2 million for installation (Flentje, 2008), and spin-off RailCorp projects completed over the following 20 years are thought to run into the hundreds of millions of dollars (Mackney, pers. comm. 2008). It is estimated that between 1989 and 1996 the cost of landsliding to railway infrastructure alone in Wollongong was $25 million annually.

Difficult legal proceedings following the fatalities on Rawson Street ran for many months, and the cost is thought to have run into tens of millions of dollars. Due to these legal proceedings, RailCorp is unable to release any information regarding the costs associated with the Coledale disaster.

7 Landslide Impacts in Wollongong

In Wollongong, there are four primary parties bearing the cost of landslides. These include the WCC, RTA, RailCorp and private property owners. It was difficult to separate out landslide costs for these case studies because repairs resulting from landslide damage are often absorbed into general maintenance budgets. Maintenance being performed as a result of landslide is not often recorded or tagged as such, and the cost is therefore difficult to extract.

The reported costs in this study, while preliminary and approximate, demonstrate clearly that the financial and social cost of landslides in the Wollongong region are high and ongoing. Both direct and indirect costs resulting from landslides in Wollongong are significant. The largest direct public cost can be attributed to the repair or relocation of transport facilities. The main costs incurred by WCC and RTA include mitigation works, remedial works, maintenance, monitoring, geotechnical investigation and reporting, emergency response costs, litigation and clean up costs. The only case study which considered the cost to State Rail Authorities was the Coledale landslide. RailCorp estimated that over a seven year period until 1996, the cost of landslides to railway infrastructure alone in Wollongong was $25 million annually.

State vs local road repair

While landslides affect the community as a whole, management and remediation varies according to the asset or property owner. For example, landslide damage on a state road is the responsibility of the state authority, and damage to local assets or roads is the responsibility of the local council. The maintenance of several main roads in Wollongong is the responsibility of the RTA, for example Lawrence Hargrave Drive and Mt Ousely Road. The WCC has responsibility for the maintenance of local roads such as Harry Graham Drive, Morrison Avenue and those in Woonona Heights.

There is a distinction between the level of resources allocated and available to the repair of state roads versus local roads, and subsequently how rapidly state-owned asset damage is addressed compared to local-owned asset damage. The case studies show that while repairs to state roads, such as Lawrence Hargrave Drive, are enormously expensive, they have been prioritised and carried out as quickly as practically possible with the best solution possible. The roads repaired by State authorities have performed very well over time, with no movement reported on those repaired roads in the storms of August 1998. Local authorities such as the WCC are required to find a solution that is within their budget to manage. Subsequently, due to the high number of sites that require mitigation in Wollongong; many of these sites remain unaddressed as a result of prohibitive cost. This also leads to a prioritised process of repair and increased frustration levels by residents in the time taken to mitigate hazards. Difficulties also arise in performing long term mitigation solutions when disruptions to the budget occur from response-oriented repairs.

For example, it was shown that the cost of repair to just a portion of Harry Graham Drive was approximately $4 million and resulted in road closures of 2 ½ years. It was reported this project cost ratepayers about $7 400 for each metre of road, and additional landslide sites along Harry Graham Drive are yet to be remediated. The landslide repairs at just one of the identified sites along Harry Graham Drive exceeded the WCC maintenance budget and consequently impacted WCC future budget for landslide remediation and mitigation works. Subsequently, sufficient funds are not available to remediate other known landslide sites in Wollongong (such as Woonona Heights estimated at $1.3 million). Property owners have been made aware they need to finance their own regional stabilisation of landslide sites (such as in Woonona Heights and Morrison Avenue). This highlights ongoing problems local councils face with effectively managing a hazard that can be beyond their budgetary capacity to mitigate and the need for access to funding to assist.

Cost benefit in mitigation vs response

The cost-benefit in performing mitigation works has been loosely demonstrated through the series of events occurring on Harry Graham Drive. WCC set aside $180,000 to undertake programmed stabilisation works on Harry Graham Drive before the rock fall, and it can be assumed similar funds would have been allocated in subsequent years to complete works. However, emergency response works to one of the sites on Harry Graham Drive resulted in a cost of $4 million. It is difficult to ascertain whether if stabilisation works had been completed, as to whether the rock fall and secondary landslide would have occurred and to what extent. However, the risk of failure would have been reduced. A cost-benefit relationship can be seen in comparing the rock fall at Harry Graham Drive to a potential hazard on Mount Kiera Pass. The rock fall at Harry Graham Drive occurred in a similar geology to a rock fall hazard on Mount Kiera Pass. The WCC were able to mitigate the rock fall hazard estimated to be the same size as the one on Harry Graham Drive on Mount Kiera Pass before a rock fall occurred at a cost of approximately $150 000 to $200 000, further highlighting the difference between proactive and reactive costs.

Hardship to residents

A landslide event can result in financial ruin for property owners, often because they cannot acquire money they need to re-establish due to ‘bad debt’ as their investment is destroyed. Property owners impacted by landslide damage often could not afford to demolish their home, in some instances newspaper articles reported that this was believed to have placed homes down slope at higher risk. In addition to the social consequences described throughout the case studies, some residents believed a number of Wollongong lending institutions had placed blanket bans on landslip prone mountain areas and were refusing to finance home buyers (even in areas consultant engineers and geologists claimed to be quite stable). This forced some home owners to wait up to two years or longer before they could sell due to a lack of finance (Illawarra Mercury, date unknown). A collection of newspaper articles published by the Illawarra Mercury indicate that many residents in Wollongong live in fear of heavy rain fall events.

Wollongong residents and property owners have suffered significant hardship as a result of landslides[8]. This hardship includes stress, psychological trauma, loss of homes, loss of savings, loss in trade of tourist based businesses (with almost a total loss of tourism damaging some businesses), increased commuter time, cost and inconvenience associated with temporary relocation, loss in social and recreational activities, litigation costs, reduced real estate values in areas at risk of landslides, loss of tax revenues on properties devalued as a result of landslides, loss of tourist revenues as a result of damage to land or facilities or interruption of transportation systems in addition to private costs of measures to prevent or mitigate landslide activity.

These hardships are often greater for landslides than other natural hazards because the community are more accepting of a hazard beyond their control such as cyclones or earthquakes (National Research Council, 2004). However, because many landslides may be considered human induced events (due to loading, construction, altered drainage) there are greater expectations that such hazards can be avoided or mitigated. Often affected parties therefore seek or attribute blame to those responsible and litigation processes prolong the recovery time.

[8] This section draws on correspondence with WCC geotechnical representatives, media articles published in the Illawarra Mercury (1970’s-present), and information held in the WCC archives.

Role of Public Relations

During the repair of local roads (for example Harry Graham Drive) WCC engaged residents and kept them updated and informed through media releases and community meetings. However, it is believed there was no formal public liaison role during the remediation of Lawrence Hargrave Drive by RTA. The public did not understand how high the risks were to loss of life and were in denial as to the rock fall hazard. The prolonged closure of the road and the consequences of this resulted in extreme public outrage that culminated in the Minister for Roads at the time being ambushed.

The public have been significantly affected by landslide related issues and have actively and vocally expressed their frustration via media, public demonstrations and letters to WCC. Many cases of public unrest have resulted from the public being unaware of the extent of the damage, danger and risk before ‘drastic’ action is taken such as closing a road. While dealing with and consulting the wider public on landslide issues is clearly important, it does not have a designated role within WCC. In most cases, the person responsible for public liaison is the Manager for Infrastructure, or their designated Project Manager. However, these parties do not have the technical landslide knowledge necessary to be able to discuss and explain the issue fully to residents, and the geotechnical specialists within WCC are rarely employed as public relations officers. There have been proven occasions where geotechnical specialists have had contact with the public and a chance to fully explain the problem, and residents have become very supportive of WCC work (Tobin, pers. comm. 9 Jan 2009). Therefore, there is clearly a benefit in ensuring the public is consulted and kept informed of landslide related issues, and that their expectations are managed accordingly.

8 State and Federal Government Assistance

While landslides might be considered the least costly natural hazard in reports such as BTE (2001), it is important to consider this in the context of who pays. From an Australian Government and State Government perspective, landslides are the least costly natural disaster because most landslides in Australia are not eligible to receive relief assistance as they do not often require a ‘significant and coordinated multi-agency and community response’. However from a Local Government perspective, such as WCC, landslides are a significant and costly natural disaster hazard for council and the community.

The last time Wollongong had a very wet year was in 1974 and 1975. During this time landslides were seen as the WCC’s biggest problem and challenge. Furthermore, Reinfelds and Nanson (2001) state that intense storms causing extensive flooding and damage to urban and rural areas in Wollongong have occurred with a historical frequency of about one in eight years (with the most recent damaging storm occurring on 17 August 1998). It is likely that landslides will continue to impact on the Illawarra region in a similar fashion in the future.

The City of Wollongong, through the State Emergency Service, identifies landslide and mudslide hazards as one of the top five major sources of risk which could have the most serious impact within the City. Landslides have been given a risk rating of high/moderate with moderate consequences, noting the general threat along the escarpment particularly at the urban interface (WLEMC, 2006). Landslide is a key subcommittee of the Wollongong Local Emergency Committee, because it is seen as such a significant hazard and a ‘Landslide Action Plan’ has been developed as a sub-plan to the City of Wollongong Local Disaster Plan (WCC, 1999).

Access to funding support for landslide hazard

An issue that causes grief and frustration to residents and WCC alike is the perceived lack of access to funding to assist with managing landslides, particularly due to insurance not being available. Over the past 40 years, a series of applications were made to State and Federal Members of Parliament seeking to access relief funding, research assistance and community-disability grants to help alleviate the high landslide costs being incurred. The applications were rejected and continued efforts by residents and WCC on this matter eventually ceased. In the past, frequent responses to requests for financial assistance from the NSW State Government for the management of landslides in Wollongong confirmed that landslide hazard was considered the council’s responsibility to finance and the State Government was not prepared to approve of a State grant being made towards the cost of such matters.

In 1974 the Federal Government did not provide financial assistance to individuals suffering hardships as a result of natural disasters. This was due to the arrangements determined through consultations with States and the Federal Government regarding financial assistance. The Federal Government recognised the need for investigation into natural disaster insurance and investigated this option with representatives of insurance companies. On 5 June 1979 it was announced that the Federal Government decided not to proceed with a natural disaster protection scheme (Illawarra Mercury, 1979). This meant that any loss from landslip would fall on property owners, even if they had no previous knowledge of the potential hazard prior to purchasing that property. WCC spent considerable effort urging the State and Federal Government to have landslip declared a natural disaster, in order to qualify property owners of financial help. The Federal Government stated it would not introduce a disaster protection scheme *“because Government authorities should seek to avoid intervention in matters that can be left to the private sector”* (Illawarra Mercury, 1979). Private insurance companies continue to refuse to cover certain types of natural disasters such as landslip.

Currently, the Natural Disaster Relief and Recovery Arrangements (NDRRA) administered through the Attorney-General's Department provides a mechanism of assistance in the event of natural disasters. However, the definition of a natural disaster in the context of NDRRA is one that 'means a serious disruption[9] to a community or region caused by the impact of a naturally occurring rapid onset event that threatens or causes death, injury or damage to property or the environment and which requires significant and coordinated multi-agency and community response'. Events where human activity is a significant contributing cause (for example, poor environmental planning, commercial development, personal intervention (other than arson), or accident) are not considered natural disasters. This definition excludes the majority of landslides as they occur in Australia. Local Councils and property owners must continue to locate their own funds in order to manage the hazard.

The Australian Government also provides disability allowances or grants that are provided to Councils across Australia on the basis of specific constraints in their area which put an overburden on those Councils resources. About thirty-three percent of Wollongong's urban environment is hillside development that is prone to ground movement, and the problems are a big cost burden on WCC just to maintain roads and watercourses (Tobin, pers. comm. 9 Jan 2009). The disability grants cover a broad range of categories such as libraries and surf lifesaving. However, disabilities due to geology and geomorphology are not supported under the criteria (Tobin, pers. comm. 9 Jan 2009).

Benefits of regional landslide studies

It is believed the only regional studies done were in the late 60's by the NSW Geological Survey and that this report is still the benchmark as far as the Illawarra Region is concerned, including a review completed of this study in 1983 (Tobin, pers. comm. 9 Jan 2009). The WCC has been sponsoring landslide research and database maintenance through the UoW over the last 15 years ($35 000 per annum) because information required is not otherwise affordable, is not viewed as a priority, or is not seen as an appropriate expenditure (Tobin, pers. comm. 29 Jan 2009).

A regional approach to mapping landslides allows for a chronological approach to landscape evolution to be adopted. It encompasses a more diverse range of environments and leads to more robust datasets for geomorphology. The expertise and level of effort required in creating geomorphology datasets also lends itself better to the task being undertaken on a regional scale as opposed to several times on a local scale. For example, in Tasmania aerial photo interpretation at a 1:5 000 scale was found to be ideal for regional mapping of landslide as interpretation from 1:10 000 and beyond presented difficulties in distinguishing landslide features (Osuchowski, unpublished).

[9] Such serious disruption can be caused by any one, or a combination, of the following natural hazards: bushfire; earthquake; flood; storm; cyclone; storm surge; landslide; tsunami; meteorite strike; or tornado

9 Cost Models

As the pressure of expanding populations cause the built environment to expand into more unstable hillside areas, the socio economic losses from landslide impacts are increasing. While the losses attributed to most individual landslides are small, they can be devastating and catastrophic to individual property owners. However, because damage costs are borne mostly by individuals and transport authorities, with only some involvement of Australian and State Government relief and recovery programs, the magnitude of cumulated landslide effects to communities has not been adequately reported and the financial risk posed by landslides has not been calculated.

The current financial and social thresholds for inclusion into EMA's national disaster database are not appropriate for landslides. A methodology is needed to provide an accurate assessment of the full cost and loss due to landslide. For example, the indirect costs commonly exceed the direct costs for the landslides included in this report. However, indirect costs are not incorporated into many hazard databases, and subsequently their assessments. Landslides are regarded as a low-cost disasters based on direct costs. It is difficult to ascertain whether one disaster is more or less expensive than another, which is a direct function of the framework used to measure cost. It is important to understand who bears the loss and what the type of loss is.

Cost and impact models for natural disasters generally do not fully capture the effects on the local community and its governing bodies. This is especially true for landslides, where the effects can be unique, variable, ongoing and widespread. For example, a landslide may reactivate a number of times over a period of years, or a number of different events may occur along the same stretch of road. This report has already highlighted some of the social costs associated with landslides and the need to take into account impacts at a local-community level when considering the full impact of natural disasters, as they can bear strongly on the well-being and recovery of the local community.

10 Discussion

The case studies highlight that landslide issues affecting local assets as well as property can place significant strain on a local council as well as the local community. Ongoing road closures, continued movement of landslides in residential areas and the failure to implement engineering solutions due to insufficient resources demonstrates that mitigation and remedial action is often too costly for WCC and its community, and that the legal and social burden on WCC is great.

The primary cost of landslide impact in Wollongong is related to the mitigation and remediation of road and rail assets. While for landslides, the local government bears this responsibility for local assets, similar costs for similar road assets arising from other natural disasters are frequently funded on a cost share basis through Natural Disaster Relief and Recovery Arrangements (NDRRA). For example a report on the public cost of natural disasters in QLD (Geoscience Australia, 2005) found that 90-95% of the annual State and Local claims on NDRRA were spent on road restoration due to recurrent flooding. This is in addition to funding provided through the Regional Flood Mitigation Program (RFMP) available at the time, and also the Natural Disaster Mitigation Program (NDMP). Personal hardship and distress payments (PHD) were also typically provided to individuals who were uninsured or were within low income groups.

An analysis of NDMP funding for NSW between 03-04 and 06-07 found that a total of $11 210 933 was spent on flood mitigation through the NDMP. A further $13 703 334 was spent on flood mitigation works through RFMP. In contrast, the amount spent in NSW for landslide over the same period of time totals $687 000 for research and data collection, with an additional $165 000 for structural works at one locality (as an exceptional circumstances waiver). The amount and type of NDRRA claims for NSW was not investigated. These figures may highlight either that landslide hazard is not viewed as a priority area for funding by the State Government because applications made are not successful or that applications are not received for consideration. Further analysis on these relationships would be beneficial.

The impact of a home that is destroyed by a slow moving landslide or a debris flow to a family or individual is no less devastating than a home destroyed by a tropical cyclone or flood. However, funding assistance is often available to support victims of disasters such as floods, bushfires and tropical cyclones. It is also important to note that in most cases in Wollongong, the land was considered stable upon purchase by an individual prior to development, and the landslide hazard has been presented some time later. While development can occur safely in landslide prone areas subject to correct engineering solutions, these factors can preclude access to disaster relief and recovery funding. However, development is often permitted in knowingly bushfire prone areas, and, following a bushfire disaster government financial aid is available (even in the case the bushfire was caused by arson).

11 Conclusion

Primary responsibility for the management of landslide hazard in Australia has been delegated to the Local Government and is subsequently considered a local problem to manage. Each local government develops their own strategies for managing the hazard with the private sector providing technical support. The effectiveness of these strategies is dependent on the ability and determination of local government officials to apply the mitigation techniques available to them, to oversee major works and limit or guide growth in hazard-prone areas.

However, the combined, cumulative cost of several landslides across an LGA in Australia can be significant, particularly to the affected local government. These costs are absorbed directly by individual property owners as well as by infrastructure authorities and local governments. Landslides can result in financial ruin to property owners. Harry Graham Drive indicates that landslide hazards can be beyond the budget capacity of a local government to manage, and that an unexpected event can have a significant impact on future budgets and mitigation plans.

Initial estimates in this study place the cumulative cost of many Wollongong landslides events above thresholds used in BTE (2001) regardless of who pays for the remediation. Better quantification of accurate landslide costs is imperative in order to understand the full impact of landslides compared with that of other natural hazard events, and to also facilitate measuring the cost effectiveness of mitigation and policy decisions. However, existing cost and loss models are not suited to effectively capturing the nature of short and long term landslide impacts. Further work is needed to develop a cost data model for the appropriate capture of cost information across hazards.

12 Recommendations

National

Undertake similar studies in other landslide-prone areas of Australia, such as northern Queensland or Tasmania to gain a greater insight into landslide costs across a range of stakeholders and local government areas. This will allow for comparisons to be drawn more appropriately across landslide hazards.

Effort into standardising estimation techniques for compiling loss data in order to measure cost consistently across all hazards. Recommend that an agency be responsible for compiling comprehensive cost/loss database such as Emergency Management Australia, including indirect cost data and working with State Government or LGA's to collect data. A National Emergency Management Project currently managed by the NSW Fire Brigades work may assist in this process. Inclusion of landslide data may require adjustments to impact thresholds for events in the EMA disaster database to more accurately reflect unique costs and impacts for individual hazards.

State

Support the regional mapping of landslides at a local scale in priority areas. This would be a cost effective approach to consistent hazard mapping.

Consider more broadly, a state-wide landslide management plan (similar to those available for bushfire and flood) removing legal liabilities of individual councils, ensuring that landslide information is accessible to the general public and council can address the issue openly without concern for litigation.

Encourage the adoption of a systematic process of capturing and recording cost information across all and incorporate cost and impact data to ensure a strong evidence-base for applications of funding and assistance from the state and federal government.

Local (in partnership with State or national bodies)

A more detailed survey performed in the Wollongong region would capture indirect and intangible losses suffered as a result of landslide-related damage and more accurately quantify direct costs.

This may include the following tasks:

- Document challenges in acquiring costs (e.g. extraction of maintenance costs from transport budgets, litigation concerns, etc.)
- Comparative analysis of rapid onset landslides with slow ongoing landslide events.
- Compare the cost benefit of mitigation works and emergency response works, and implications for future budgets (eg. Harry Graham Drive).
- Investigate the costs of litigation to council.
- Develop pro-forma for detailed surveys of community members and local business owners to quantify and promote awareness of financial losses faced by those parties (compare public versus private costs). This could include a directory of questions for local government and council use;
- More extensive consultation with WCC, RTA, RailCorp and consultant groups to accurately enumerate costs;
- economic modelling to better quantify some of the direct and indirect costs;
- Develop tools to assist LGA's in the capture of landslide costs and impacts.
- Develop tools or resources to assist LGA's in public liaison and consultation roles regarding landslide issues prior to, or concurrent with, Council action (i.e. closure of a road).

13 Acknowledgements

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15 Appendix A

INSTRUCTIONS

Thankyou for your assistance with landslide cost / loss estimations in the Wollongong area. The questionnaire is divided by landslide event into separate worksheets. The components of the questionnaire are grouped by overall themes of impact, cost, and indirect cost / loss. As well as targeting these themes, please include any points of interest, comments, thoughts or additional information you may have on each event, no matter how insignificant they may seem. A description of each field is provided below (with the required 'value' of each field), which may be useful to reference whilst breaking down cost information.

If there are any queries or difficulties, please do not hesitate to contact Jenna Roberts on (02) 6249 9391

IMPACT

SEVERITY	DESCRIPTION	Indicate with an X
None	Feature inspected for damage but no damage observed	
Insignificant	Little damage	
Minor	Limited damage to part of structure of site requiring some reinstatement or stabilisaiton works	
Medium	Moderate damage to some of sturcutre or significant part of site requiring large stabilisation works	
Major	Extensive damage to most of structure or extending beyond site requiring significant stabilisation	
Catastrophic	Stucture completely destroyed or large scale damage requiring major engineering works to stabilise	
Unknown	Unknown damage severity	

COST AND LOSS

1) SITE

LOSS	DESCRIPTION	REQUIRED VALUE
Remedial / repair work	Total cost - specify type of repairs / remedial work, time spent on-site, materials and labour costs	Dollars, comment
Cleanup costs	Total cost - specify labour costs, materials, length of time taken to reach pre-slip / acceptable condition	Dollars, comment
Geotechnical Investigations	Type / classification, labour cost, length of time taken for assessment	Dollars, comment
Ongoing monitoring:	Cost of continued and expected future works:	
	Yearly slope maintenance / stabilisation	Dollars
	Rehabilitation of unstable slopes	Dollars
	Future works	Dollar estimate

2) ROADS, TRAFFIC & TRANSPORT

LOSS	DESCRIPTION	REQUIRED VALUE
Repairs	Type of repairs, length of time taken to reach pre-slip / acceptable condition, labour and material costs	Dollars, comment
Road closures	Number of hours / days / weeks / months road unavailable	Estimate, comment
Traffic flow	Extent of delays, efforts to redirect, alternative route expediency	Comment
New structures	Number and cost of bridges, gantries, new roads, pedestrian paths, bicycle paths or other (please specify)	Type, number, dollars
Cuttings per year	Number of new cuttings, cost and type of stabilisation / slide prevention (nets, shock-crete, pegs or other-please specify)	Number, type, dollars

3) UTILITIES

LOSS	DESCRIPTION	REQUIRED VALUE
Gas	Hours / days / weeks service disrupted; area affected	Comment
Power	Hours / days / weeks service disrupted; area affected	Comment
Water	Hours / days / weeks service disrupted; area affected	Comment
Communications	Hours / days / weeks service disrupted; area affected	Comment
Repair cost:	Cost of repairs:	
	Gas	Dollars
	Power	Dollars
	Water	Dollars
	Communications	Dollars

4) PROPERTY

LOSS	DESCRIPTION	REQUIRED VALUE
Residential:		
Extent of structural damage	Number damaged / destroyed, extent / degree of damage, contents damage (mild, moderate, severe)	Comment
Repair cost	Cost to return to pre-slip condition	Dollars
Future cost (if applicable)	Degree of expected future damage, time period in which damage is expected to occur, cost of future repairs	Dollar estimate
Council:		
Extent of structural damage	Number damaged / destroyed, extent / degree of damage, contents damage (mild, moderate, severe)	Comment
Repair cost	Cost to return to pre-slip condition	Dollars
Future cost (if applicable)	Degree of expected future damage, time period in which damage is expected to occur, cost of future repairs	Dollar estimate

INDIRECT LOSS

1) ENVIRONMENTAL

EFFECT	DESCRIPTION	REQUIRED VALUE
Agricultral	Fences, equipment, crops and pastures, livestock	Comment
Other adverse effects	Increased erosion, blockage of drainage, siltation of streams and reservoirs	Comment
Time taken to reach pre-slip condition	Number of weeks / months / years for envirnment to return to pre-slide health	Estimate, comment

2) LITIGATION

EFFECT	REQUIRED VALUE	ASSESSMENT
Time taken for legal proceedings	Estimate, comment	
Total cost	Dollar estimate	

3) COMMUNITY

EFFECT	DESCRIPTION	REQUIRED VALUE
Inconvenience	Road / footpath / bicycle track closure, interrupted or redirected traffic flow, increased fuel consumption,affected services.	Comment and rate 1 - 10: 1 = minimal inconvenience, 5 = moderate inconvenience, 10 = extreme public inconvenience.
Public outrage	Complaints to council, media reports, overall community sentiment.	Comment and rate 1 - 10: 1 = minimal outcry, 5 = moderate outcry, 10 = extreme public outrage.
Tourism	Effects on tourism to area due to inaccessibility of roads, public concern for safety, limited services.	Comment
Property Values	Decreased value due to damages (past and recurrent), regional landslide risk, public concern.	Comment