Ohope Beach Landslide of 18 June 2011

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ABSTRACT

This GNS Science/GeoNet landslide investigation, made in response to a landslide which caused a fatality at Ohope Beach on Saturday 18 June 2011, is based on a site visit, interviews with those involved in the immediate response, and council, consultant and media reports. It puts the 18 June 2011 landslide into a context of regular, rain storm generated landslides that have occurred from coastal cliffs within the region since 2004.

The landslide occurred at 11.55 am from the steep, vegetated cliff slopes behind No. 55 West End Road during intense rainfall. It impacted on the ground floor rear of the two storey house, smashing through the outside wall, entering a room where it overcame and killed 17 year old Hugh Biddle, the sole occupant of the room. At the time Hugh's guardian Rob Shaw was upstairs in another part of the house. He heard the landslide impact and heard Hugh call out for him, but he was unable to open the door and enter the room, which had partially filled with saturated rock and soil landslide debris. It took emergency services some 7 hours to dig away the landslide debris and recover Hugh's body (Figures a, b & c).

Earlier in the day at 6 am on 18 June, a front bringing strong wind and heavy rain moved onto Whakatane and Ohope. Met Service forecaster Cameron Coutts reported that 76 mm of rain fell on the area from 6 am until 1 pm, with 31 mm falling between 11 am and mid-day. The landslide occurred towards the end of the hour of intense rainfall. The rain storm also caused flooding in Whakatane. It caused at least seven landslides along the Ohope - Whakatane escarpment and the Fire Service dealt with twelve related call-outs. During the emergency, Police asked some other residents close to the old cliff along West End Road to evacuate their homes.

Local rainfall and landslide records indicate that heavy rainfall, with associated flooding and landslides, has been a more than annual occurrence in the Whakatane and Ohope area in recent years. Local daily rainfall has been recorded at 21B West End Road, Ohope since 1998 by Graham Wilson (Appendix 1). The greatest rainfall on his records is 145.0 and 160.5mm which fell on 17 and 18 July 2004. This severe event caused widespread regional flooding and landslides, which also resulted in a GNS Science/GeoNet event response.

Drainage channelling and reduction of soakage above the escarpments is helpful in reducing landslide occurrence, and othe mitigation options are available for reducing the impact of landslides on properties below the escarpment. However, as landsliding from the escarpment is a cyclic process related to long-term weathering and build-up of soil and vegetation, avoidance of construction in the landslide hazard zone at both the crest and the foot of the escarpment, is considered to be the most sustainable mitigation option.

KEYWORDS

High intensity rainfall; landslides; escarpment, trees, remedial works.

1.0 INTRODUCTION

1.1 Background

The storm and landslide at West End, Ohope on 18 June 2011 received news coverage throughout NZ. For a day or two it displaced the earthquake destruction in Christchurch as a leading news item. As the landslide caused a fatality, it met the criteria for a GeoNet landslide response, and GNS Science mounted a reconnaissance. Dick Beetham, a geotechnical engineer and engineering geologist based at GNS Science, Avalon, Lower Hutt, who has a long-term interest in the Whakatane region, visited Whakatane and Ohope over 29 and 30 June, when some of the attached photographs (Figures 1 to 21) were taken. Apart from Figures a, b & c, attributed to Troy Baker of the Whakatane Beacon, and taken on the day of the landslide, the remaining non-Google Earth photographs were taken by Dick Beetham after the severe storms in late July 2004 (Figures 27 to 30, 32, 33, 36 and 38 to 40b), and mid May 2005 (Figures 41a & b), while Figures 31, 34, and 35 were taken in 2009.

For the GNS Science landslide response visit to Whakatane and Ohope, the following schedule of meetings with people involved in the response and recovery on the day of the landslide, was organised by Melissa Boswell through Diane Turner, CEO of Whakatane District Council (WDC). Being able to meet all these people for their comment and assistance was most helpful in understanding the events that occurred, and is much appreciated.

Schedule of meetings at WDC on 29 & 30 June:

Day/time	Person	Place
Wednesday 11am – 3pm	Jeff Farrell, WDC	Onsite West End. Meet at WDCouncil at 11am
Wednesday 3pm – 4pm	Kevin Hind and David Milner, Tonkin & Taylor	WDC office
Thursday 9am – 10am	Paul Smith, WDC	WDC Committee Room 2
Thursday 10am – 11am	Aelan Keeber, USAR, Shay Harrop, WDC (USAR) and Chris, Ohope Fire Brigade	WDC Committee Room 2
Thursday 2pm – 3pm	Bruce Jenkins, Police	WDC Committee Room 2

The author was not able to meet Rob Shaw, stepfather of the landslide victim.

This report presents the results of the GNS Science/GeoNet landslide investigation made in response to the landslide which caused a fatality at Ohope Beach on Saturday 18 June, 2011. The report is based on a site visit, interviews with those involved in the immediate response, and council, consultant and media reports. It puts the 18 June landslide into a context of regular, rain storm generated landslides that have occurred from coastal cliffs within the region since 2004.

The landslide occurred on 18 June 2011 at 11.55 am during intense rainfall. It slipped suddenly from the steep, vegetated cliff slopes behind No. 55 West End Road. The landslide impacted on the ground floor rear of the two storey house, smashing through the outside wall, entering a room reported to be the kitchen but more likely a bedroom, where it overcame and killed 17 year old Hugh Biddle, the sole occupant. At the time Hugh's guardian Rob Shaw was upstairs in another part of the house. He heard the landslide impact and heard Hugh call out for him, but he was unable to open the door and enter the room, which had partially filled with saturated rock and soil landslide debris. It took emergency services some 7 hours to dig away the landslide debris and recover Hugh's body (Figures a, b & c). From what can be seen in the photographs shown in Figures 1 & 4, the landslide probably entered all the rooms under the "lean to" style roof at rear of the house. The remainder of the house appears to have remained intact and undamaged. This is not the case for the house at No. 33 West End Road, where the entire house was displaced ~0.5m by its landslide impact during the same storm (Figures 13 to 20).

1.2 The landslide triggering event

The landslide was triggered by intense rainfall associated with a front bringing strong wind and heavy rain which moved onto the Whakatane – Ohope area at around 6 am on 18 June. Met Service forecaster Cameron Coutts reported that 76 mm of rain fell on the area from 6 am until 1 pm, with 31 mm falling between 11 am and mid-day. The landslide occurred at 11.55am towards the end of the hour of intense rainfall.

The rain storm also caused flooding in Peace St., McAlister St., McGarvey Rd., Apanui Rd., Hikurangi St., and Pouwhare St. in Whakatane. It caused at least seven landslides along the Ohope - Whakatane escarpment and the Fire Service dealt with twelve related call-outs. During the emergency, Police asked some other residents close to the old cliff along West End Road to evacuate their homes. Local rainfall and landslide records from WDC and Tonkin&Taylor, indicate that heavy rainfall, with associated flooding and landslides, has been a common occurrence in the Whakatane and Ohope area in recent years. Daily rainfall has been recorded at 21B West End Road, Ohope since 1998 by Graham Wilson (Appendix 1). The greatest rainfall on his records is 145.0 and 160.5mm which fell on 17 and 18 July 2004. This severe event caused widespread regional flooding and landslides, which also resulted in a GNS Science/GeoNet event response.

1.3 The landslide site

The house in which Hugh Biddle was killed is the last of three on the elongated section at No. 55 West End Road (Figures a, b, 1, 4, 7, 9 & 23). The house is tucked in close under the steep escarpment, which is an old cliff face. Here it appears that the toe of the "talus apron", the wedge of slope collapse debris accumulated at the base of the old cliff, has been at least partially excavated to form the building platform for the house (Figures 1 & 9). As the old cliff escarpment has a regular, well documented history of landsliding during severe rainfall, houses located on the talus apron are highly vulnerable to being impacted by slope failures from the cliff. Another house in a similar location on the talus apron at 33 West End Rd. was also hit by a landslide on 18 June. The house was shunted forward on its foundations by some 0.5 m (Figures 13 to 21) by the landslide impact. Although the landslide also destroyed rooms at the back of this house, the house is a holiday home and was unoccupied at the time.

1.4 Scope of the report

This report describes the specific landslide that occurred at 55 West End Road on 18 June and additionally explores the causes of the many landslides along the Ohope and similar escarpments, both in this and other rainstorm events. Reference is made to the extensive rainfall, flooding, and landslides during the severe regional storm event on 17 and 18 July 2004 and to geotechnical and mitigation work carried out by Tonkin & Taylor, Consulting Engineers to Whakatane District Council (WDC). WDC, together with the people in the Council district have faced several severe rainfall, flooding and landslide events since that in 2004. Following the 2004 storm event the WDC have completed a program of drainage mitigation works from houses on top of the escarpment at West End. These works are designed to reduce water seepage into the ground and overland flow from rainfall runoff, and thus reduce the potential for landslides to occur on the escarpment during rainstorms.

Figure a View of the landslide and tree debris from the driveway on the north side of No 55 West End Road on the afternoon of 18 June. The main emergency response, excavation and recovery was via the driveway on the south side of the house (Figures b & c below). The tree, soil and rock landslide debris seen in this photo also apparently affected the rear of the adjacent house at 56 West End Rd., to the right of this photo. *Photo by Troy Baker, Whakatane Beacon.*

Figure b An oblique aerial view of the landslide and emergency response/recovery at 55 West End Rd. on the afternoon of 18 June (photo by Troy Baker, Whakatane Beacon)

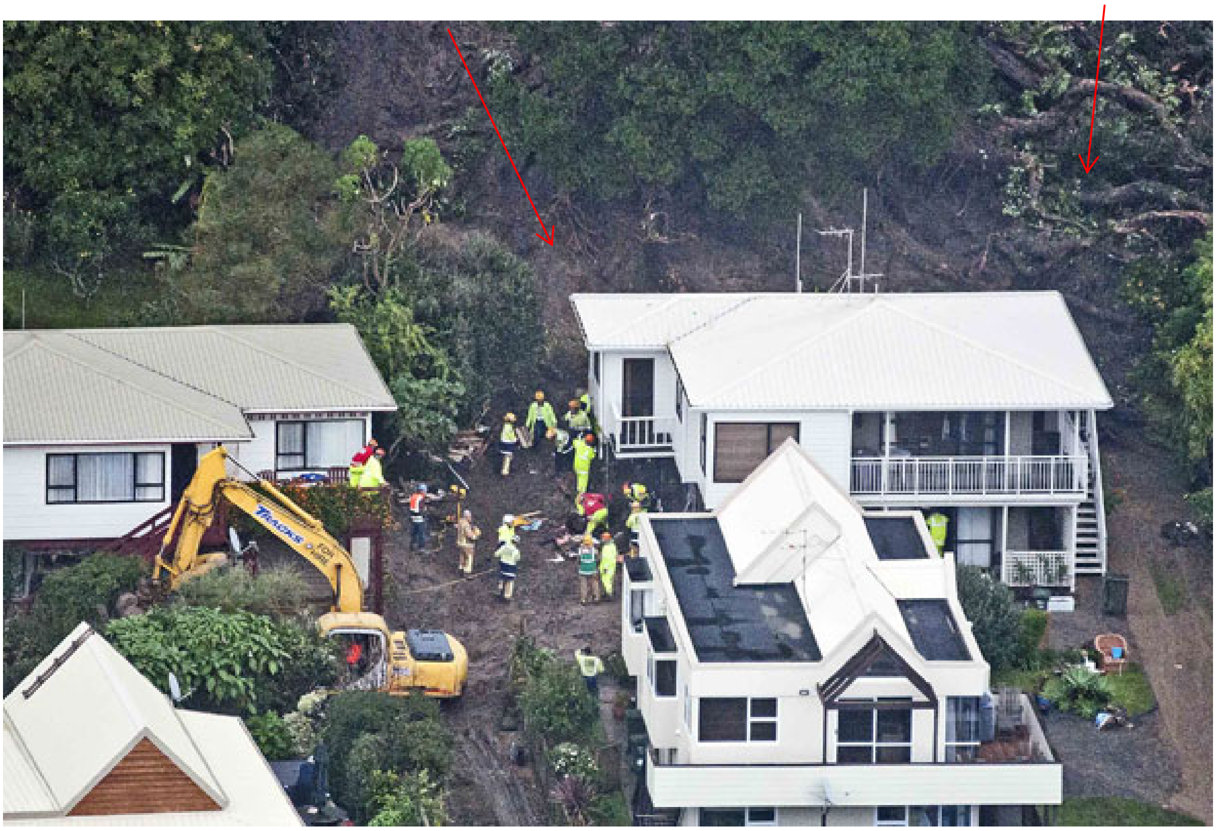


Figure c Detail of Figure (a) above showing landslide and tree debris on both sides of the pohutukawa tree directly behind the house – No. 55 West End Rd. This tree has protected the house against debris impact to some extent - (photo by Troy Baker, Whakatane Beacon).

2.0 THE LANDSLIDE OF 18 JUNE 2011

2.1 The causative storm

At 6 am on the June 18 a front bringing strong wind and heavy rain moved onto Whakatane and Ohope. Met Service forecaster Cameron Coutts reported that 76 mm of rain fell on the area from 6 am until 1 pm, with 31 mm falling between 11 am and mid-day. He is likely to have been using data from the Bay of Plenty Regional Council (BOPRC) telemetered raingauge located at Kopeopeo, several km west of Whakatane. However, his rainfall corresponds well with the 24 hour record of 88mm of rain at Ohope noted by Graeme Wilson at 21B West End Road between 8am on 18 and 8am on 19 June (Appendix 1). The landslide is reported to have occurred at 11.55 am on 18 June, towards the end of the hour of intense rainfall noted by Cameron Coutts. The heavy rain event also caused flooding in Peace St., McAlister St., McGarvey Rd., Apanui Rd., Hikurangi St., and Pouwhare St. at Whakatane. In addition it is reported to have caused at least seven landslides along the Ohope - Whakatane escarpment, and the Fire Service dealt with twelve related call-outs. During the emergency, Police asked some other residents close to the old cliff along West End Road to evacuate their homes.

2.3 The fatal landslide

As can be seen from Figures a to e, and the overview photographs - Figures 9, 10 and 11, the source of the landslide which caused the fatality on 18 June is from half to two-thirds of the height of the West End escarpment, the old cliff. The landslide is estimated to have cleared an area of cliff some 25m wide and 30m high. If the average thickness of soil and rock cleared from the cliff is half a metre (probably an over estimate), the approximate volume of the landslide is:-

$$25 \times 30 \times 0.5 = 375 \text{ m}^3$$

With estimated bulking of 20%, a debris volume of ~450 m^3 would be formed. This is regarded as a possible upper-bound estimate for the volume of debris forming the landslide. [It would be interesting to compare this estimate with the number of truckloads of material removed from the site during the emergency response and following clean-up.]

Figure d Oblique Google Earth view of the old cliff escarpment behind West End Rd. The houses at No 55 are arrowed.

The cross-section sketch shown in Figure e has been drawn using distances and elevations provided from the Google Earth image shown in the upper part of Figure e. The cross-section indicates that the landslide source area on the old cliff has an average slope angle of approximately 45º.

The landslide impacted the rear lower storey rooms of the house at about 11.55 am, near the end of an hour of high intensity rainfall said to have an intensity of 31mm per hour. According to the BOPRC web site, an hourly rainfall of 32mm is regarded as having a 2 year recurrence interval for Awakaponga and for Rangitaiki at Thornton, two rain gauge sites on the Rangitaiki Plains to the West of Whakatane. Although there can be big variations in rainfall intensity over short distances, it appears that the rainfall in the hour preceding the landslide may have been approximately a two year recurrence interval event, whereas the daily rainfall is considered by WDC to be a 5% AEP (Annual Exceedance Probability) or ~20 year recurrence event. The daily rainfall records from West End, Ohope (Appendix 1), clearly indicate that multiple events with similar or greater rainfall have occurred almost every year since 1998. If 20 year recurrence rainfall events have been occurring a few times every year since 2004, it would be timely to make a statistical re-estimate the recurrence interval (AEP's) of rainfall events in the Eastern Bay of Plenty.

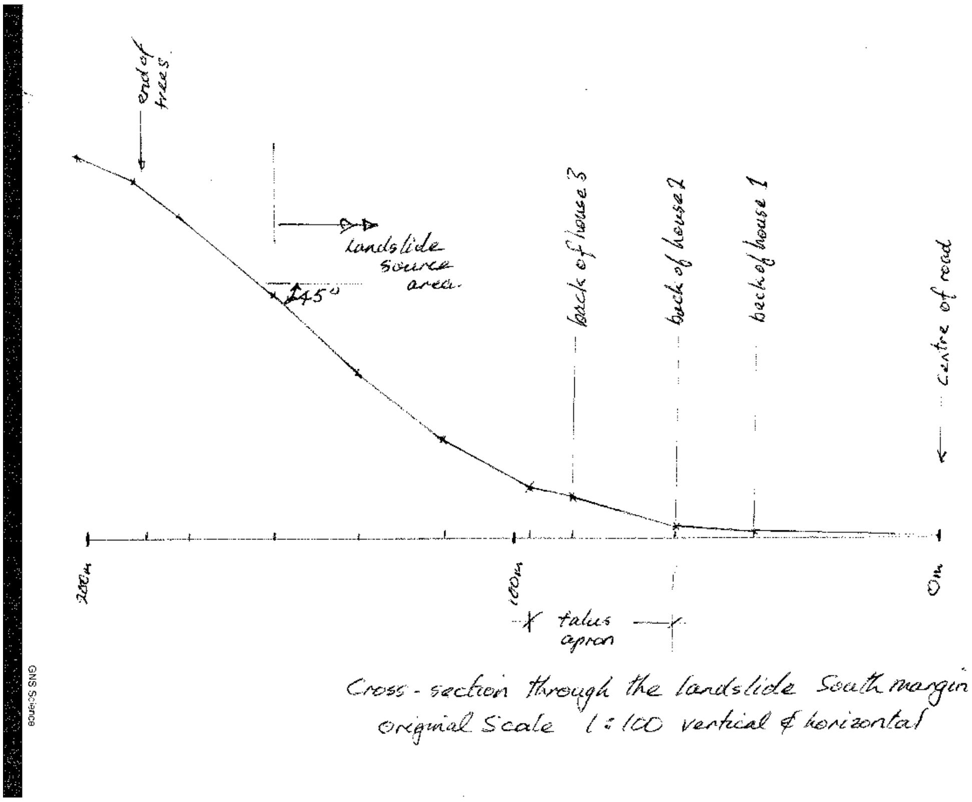


Figure e Top: Google Earth image showing the landslide source area behind No 55 West End Rd. The yellow line is the cross-section shown on the lower sketch figure from the centre of the road to the top of the cliff. The cliff slope angle is approx. 45º.

2.4 Recovery of the victim

Bruce Jenkins of Whakatane Police was off duty nearby when the landslide occurred. He was emergency paged and was able to quickly respond and be at the site of the fatal landslide by 12.15pm. At that stage it was clear that the landslide debris had overwhelmed the back of the house and had inundated the room in which Hugh Biddle was located, so he suspected that a fatality had occurred. Bruce Jenkins then, as Police representative, immediately became incident controller with the (financial) authority to call in contractors and others. He managed the recovery and emergency services until he stood down at ~8pm, about half an hour after Hugh's body had been recovered.

Initially Rob Shaw, the other occupant of the house at the time of the landslide, with assistance from neighbours, attempted to break into the landslide filled room to rescue the victim. However, their well motivated hand excavation efforts were clearly not going to succeed and by 2pm Bruce Jenkins had a large mechanical excavator and trucks operational and clearing the debris to assist the local Fire Brigade and Urban Search and Rescue personnel with recovery - (Figures b & c). The emergency services were having to exercise caution with their recovery work because of in their assessment of the "unstable nature of the ground" and the amount of runoff water flowing down the old cliff around the scene. The assessment of the on-going instability in the failure impact area is always a difficult call in a landslide emergency response. Fortunately the rainfall intensity had reduced by about mid-day and by 2pm the weather had cleared, greatly assisting the recovery efforts underway by that time. Once the intense rainfall decreased and stopped the flows down the cliff in the landslide area also reduced quickly, (Bruce Jenkins, pers. com.).

2.5 Geomorphology of the landslide area

As described by T&T (2011), the geomorphology varies across and along the Escarpment but can generally be divided into the following five elements:

Ohope Beach to base of cliff: This area is generally characterised by flat or gently sloping topography comprising beach sands overlying greywacke rock at variable depth.

Foot of cliff (talus apron): This area is characterised by a steepening of grade between the flat coastal zone and the cliff. The zone slopes at approximately 30° to 35° and comprises historic landslip or erosion deposits (talus) consisting typically of silt and sand overlying coastal sediments.

Cliff face: The escarpment cliffs typically standing at slopes of 45º to 60º. They are formed within Tertiary Age, soft rocks called the Ohope Beds.

Intermediate bench: A discontinuous bench is present at approximately 60 metres above sea level reflects the presence of Ohope gravel or comparably less competent beds at and above that horizon. This bench was seen behind No 55 at the top of the landslide failure area. Soil up to 2.5 m thick has been observed on this bench and it has been a major source of debris in other landslides over the last twelve months.

Cliff top: The cliff top is at an elevation of around 100 m. Some arcuate features can be seen in the topography above the cliff that may relate to old landslips. Above the West End area, these slopes appear to be stable. Any slope failure that does occur from here is likely to be low volume.

2.6 Geology

As described by T&T (2011) the Ohope Escarpment is formed of a number of geological sequences, typically including soft to dense sandstone rocks overlain by soils including pumice and ash, as summarised here.

Greywacke

The sea cliffs at the northwestern end of Ohope Beach are formed from greywacke. This rock is typically grey, slightly to moderately weathered, well indurated and moderately strong to strong with irregular, closely to very closely spaced joints. The greywacke may underlie the remainder of the Ohope Escarpment, however it cannot be observed due to the talus cover.

Ohope Beds

The greywacke rock is overlain by horizontally bedded weak sandstones and siltstones which form part of the Ohope Beds. Due to their horizontal attitude, the Ohope Beds are not particularly susceptible to failure along bedding planes. Joints have been observed in Ohope Beds at the base of the Escarpment that strike approximately parallel to the Escarpment face. These joints do not appear to be laterally continuous and may be stress relief features. They are likely to be exacerbated by weathering. They may lead to the local failure of small slabs from the face of the rock. The top surface of the sandstone is likely to be undulating (paleotopography) as a result of local erosion prior to the deposition of younger material on top.

Ohope Gravel

Terrestrial brown river gravels have been observed on the Otarawairere track. The gravel beds are impersistent and are not seen as a definite bed along the track on the eastern side of the Otarawairere Track Summit. The elevation of the gravels corresponds approximately with the bench in the eastern part of the Ohope Escarpment. Gravel deposits do not appear to be present in any of the prominent scarps observed, however there are numerous pebbles sourced from the river gravel in the debris at the base of the escarpment. It is possible that the bench at the top of the lower cliff is the location of the gravel horizon. It is known to be impersistent, which corresponds with the irregularity of the bench feature. Unlike the sandstone below it, the gravel is highly permeable and would likely act as a channel for water, with the bench being a natural site for springs. This material is typically not as stable as the sandstone below it.

Young Pumice Deposits

Above the Ohope Escarpment and overlying the Ohope Beds are pumice gravel deposits that are probably part of the Rotoiti Breccia that erupted approximately 50,000 years ago. These deposits have buried the topography that would have eroded into the top of the Ohope Beds. The thickness of the pumice gravel deposits is likely to vary in response to the paleotopography that developed on the underlying Ohope Beds. Elsewhere they have been observed up to 30 m thick. As on the bench, some material would be washed away in heavy rain, but typically not in large quantities. The uppermost Ohope sandstones will have an undulating paleotopography that will result in some overlying soils resting on a rock surface that slopes toward Ohope Beach. Landslippage on the interface between the two strata in areas of unfavourably sloping paleotopography are common.

2.7 Water

T&T (2011) consider that water flowing down the escarpment comes from three sources. The first of these are springs that emerge from the Rotoiti Breccia (pumice gravel) that overlies the Ohope Beds. This deposit would have infilled the old erosion surface on the top of the Ohope Beds. Water flowing through the pumice is likely to flow along the old infilled gullies and now emerge some 15 m vertically below the crest of the escarpment.

The second source of water is direct overland flow of water during high intensity rainfall events affecting the area. Anecdotal evidence suggests that runoff from above the cliff can form significant waterfalls down the cliff face. The locations of overland flow paths are part of a package of work currently be undertaken by T&T at the request of WDC (Jeff Farrell pers. com.), and was part of the 2011 report by T&T.

The third source of water affecting properties can emerge as springs from the river gravel layer that occurs at the approximate level of the bench on the escarpment. The locations of these springs is also part of the T&T study currently underway.

In addition to the above, a number of significant rainfall events have occurred in the last year. In particular, the months of June to August 2011 were very wet. This has caused the surface soils to remain wet and has increased their susceptibility to landsliding.

2.8 Landslide evolution on the escarpment

The weathering and landslipping processes of the Ohope escarpment described by T&T (2011) is summarised here. The natural weathering and erosion cycle of the escarpment is considered to follow a cyclical pattern which may take a few hundred years to develop and fail, and can be referred to as slope “ripenining”.

Following a landslip, a fresh face of bare rock is exposed (eg. Figure 11). Gradually small plants colonise the face as the rock weathers and soil begins to accumulate. The soil gradually thickens and larger plants and trees begin to grow. At the same time, the underlying rock weathers as it is affected by carbonic and humic acids. Larger plants also affect the rock mass as roots grow into joints and cause them to open. Eventually the slope becomes overloaded and prone to landslips.

There are likely to be extended periods of soil and vegetation build up on the slopes. Once the soil thickness and vegetation density reaches a critical level then landslides will become more frequent. Landslides will eventually remove much of the soil and the process will start again.

3.0 PREVIOUS LANDSLIDES AT WEST END, OHOPE

3.1 Web reports of previous landslides and fatalities at West End

(The information below is a Web Report filed under Auckland and NZ News, tagged Ohope; Whakatane. It has been included because it adds useful background and comment to the occurrence of the fatal landslide on 18 June 2011.)

The landslide that killed Hugh Biddle in Ohope last weekend apparently was not the first to claim a life in the area. Two other people have been killed by landslides on West End Rd, where 17-year-old Biddle perished on Saturday. Residents said there have been more landslips than before and they had spoken to the Whakatane District Council about their concerns. Landslides had demolished properties on the road and it is fortunate that more people have not been injured or killed, residents said.

Four-year-old Fiona Hogg was killed by a landslide in January 1959 when a large boulder plummeted down the cliff and crushed the tent she was sleeping in. She was staying at the property next door to Biddle's. A man was also killed by a landslip further down the road in the 1960s when he was outside feeding his chickens, West End Rd residents said.

Jack Hourigan said he had been worried about possible landslips for some time. Hourigan organised a meeting with two other residents and the council earlier this week to discuss his concerns. He said two landslips had occurred near his house in the last six weeks.
He said "We had one two doors away and one two doors the other way." Hourigan had owned property in the area since the 1990s and said there were more landslips now than there had been before. He said the slips often followed heavy rainfall and the large pohutukawa trees on top of the cliff were getting older and larger, causing more stress.
"When they slip the roots come down first and then everything else comes down."

A relative of Fiona Hogg said that landslips happened often in the area. "There's been slips constantly - it's the nature of the situation," she said. "There is now ongoing worry about the hill. It's a constant issue in the winter when it rains a lot. The hill should absorb all the water but it can't. The council needs to look at drainage." She said a large slip in 2004 caused massive damage to her property and others in the area but no-one was injured.

Her 83-year-old neighbour said she had her house built at the front of the property but if it had been further back it would have been demolished by the 2004 slip. Despite the street's record of landslips and deaths the residents who spoke said they were comfortable staying in the area - for now.

West End Rd homeowners who called an emergency meeting yesterday morning are now seeking answers from Whakatane District Council over what measures they can take to safeguard their homes. They say about 60 homes in the beachside esplanade are threatened by a steep, pohutukawa clad escarpment looming high above their properties, three of which have been red-stickered by the council due to slips in Saturday's (June 18) deluge.

Further down at another red-stickered property, Sandy Revington was "heartbroken" to find her family's shared holiday home buckled and bent forward under the weight of a large landslip that slammed through the home's washhouse and filled the kitchen with earth, debris and broken branches [No 33 West End Road]*. The front of the house, shunted on to a steep lean, was stabilised with poles and retainers that had been thrust into the front lawn. "It's a relief that no one was here, as there's people staying in the house quite often."*

Jack Hourigan, who was at the meeting, said residents were "very concerned" that another tragedy could strike. "They really don't know when the next one's going to come, or who's going to get it. There have been about 10 or 12 slips along here, but nothing to the extent of what happened on Saturday." Residents were anxious to find out what the council was doing *about the problem - and what they could do themselves. "There have been a lot of things happening, and it's getting to that stage where we have to go and ask, how do we protect ourselves? It's like having a 20-tonne bulldozer coming down and pushing earth off the banks. It's not a pleasant thought and quite a few of us are in danger of something like that happening."*

Whakatane District Council CEO Diane Turner said much of the escarpment was privately owned, but the council could facilitate work to strengthen it. A stormwater reticulation system installed by the council had reduced the amount of water flowing down the escarpment after flooding in 2004 and 2005. Without it Ms Turner believed there would have been much more damage in Saturday's storm. She said the system had significantly reduced the likelihood of slips. "The council has also worked on a one-to-one basis with many property owners in relation to tree issues and options for the minimisation of the impact of landslips," she said.

Turner was arranging a meeting with residents and landowners.

Two West End properties were red-stickered after the heavy rainfall on June 18, meaning they can't be occupied. Another West End Rd house was orange-stickered, allowing restricted access. Four other houses in Whakatane have also been orange-stickered. Elsewhere in Whakatane, two homes in Muriwai Drive were served with orange stickers, meaning their owners can live there but under short-period entry and are required to self-evacuate if there is heavy rain. Two other homes in the street already have orange stickers from a large slip that came down in August last year. "With the climate, the current weather conditions and people living there on large cliffs inherently made of unstable material, there will always be a risk," Ms Turner said. The council was examining the problem through a catchment study of Whakatane and Ohope, due to be completed in August. "We're unsure what recommendations are likely to come out of it, but we'll have to work with the community to find out what the priorities are and what needs to be funded."

3.2 Reporting by Tonkin & Taylor

The 2011 report by Tonkin & Taylor has made a detailed study of the landslides that have occurred recently on the escarpment behind Nos. 63 to 71 West End Road. T&T have found that in this small area, 10 landslides have occurred from the escarpment since 2004. These are as follows: 2204, 1 landslide, May 2010, 2 landslides, June 2010, 1 landslide, January 2011, 2 landslides, and April 2011, 4 landslides.

T&T are currently commissioned to undertake a similar study of the escarpment behind the remainder of West End Road (Jeff Farrell, pers. com.)

4.0 WDC MITIGATION MEASURES AT WEST END

Following the 2004 and 2005 flood events which caused landslides along the Whakatane and Ohope escarpment, including at least one at West End (Figure 32), WDC commissioned the design and installation of a storm and wastewater drainage system for all houses on the escarpment above West End, Ohope. This drainage system is referred to by WDC CEO Diane Turner in her comments recorded in 3.1 above. The drainage system includes the houses at Otarawairere settlement, located on top of the old cliff beyond the north-western limit of West End Rd., as well as those accessed via Cliff and Brown Roads on top of the old cliff to the south-east (Figure f - below).

The drainage system from the cliff-top houses includes both wastewater and stormwater. It is designed to reduce infiltration (seepage) into the ground and to channel stormwater away from the old cliff, from where landslides are often triggered when the ground becomes saturated. Prior to construction of the drainage system, the houses on top of the old cliff used septic tanks for wastewater treatment and disposal. Wastewater from the septic tanks mostly soaks into the ground, keeping soil moisture levels high and leading to elevated groundwater seepage. This wet ground, combined with additional rainwater infiltration and seepage during periods of wet weather, and the effects of surface runoff during high intensity rainfall, was a recipe for potentially triggering landslides along the vulnerable old cliff faces behind West End. The cliff-top drainage works have now reduced the potential for landslides along the old cliff above West End. However, on such steep cliff faces there will always be a possibility for landslides to occur when the ground becomes saturated.

The cliff top drainage system has been designed by Tonkin & Taylor Ltd., consulting engineers to WDC. Wastewater from Otarawairere Settlement and Brown and Cliff roads is channelled via pipes in directional drillholes under the old cliff face to sewer lines along the beach front and West End Rd. The stormwater drainage is designed with a capacity of a 1% AEP (1 in 100 year recurrence stormwater flows), much greater than the normal WDC design requirement of 10% AEP (1 in 10 year recurrence interval flows). So far this 1% AEP cliff-top stormwater requirement has proved invaluable and the system has apparently coped well with the 2010 and 2011 storm events. Stormwater from Otarawairere settlement is discharged northwards via pipes and plunge pools into the stream that flows into Otarawairere Bay, while that from Brown and Cliff roads discharges south into the stream that flows into the sea where Ohope and West End Roads and Pohutukawa Ave. meet.

Design, followed by construction of the cliff top drainage scheme commenced after the 2005 floods. The scheme was completed in early 2009 at a cost of ~$2.85 million, a large sum for the relatively small communities in the cliff top and cliff bottom settlements at West End. The scheme won a Merit Award from IPENZ (the Institution of Professional Engineers NZ) in late 2009. It has been well tested by the extreme rainfall events of 2010 and 2011 and has reportedly performed very well. Stormwater from Otarawairere Road is included in the scheme. However, rainfall on the sloping grassed farmland between Otarawairere Road and the steep, bush-clad old cliff (Figure f) is not, because it would be very difficult and expensive to include. Runoff and overland flow from this farm area still flows over the old cliff during intense rainfall, as occurred behind the house at No 55 West End Rd. on 18 June.

As is noted in Section 5.0 of this report, on-going evaluation of stormwater systems in the district is being carried out by WDC, with the latest stormwater evaluation report issued in September 2011.

Figure f Aerial view from Google Earth of West End, Ohope below the bush-clad old cliff and the settlements of Otarawairere to the NW and the houses to the SE on top of the old cliff accessed from Cliff and Brown roads. Scenic Otarawairere Bay is at the centre top. It has foot access only from West End, Otarawairere settlement and Whakatane – via Kohi Point walkway.

5.0 SIMILAR RECENT STORMS

Local rainfall and landslide records (from EBoP & NIWA) indicate that heavy rainfall with associated flooding and landslides has been a common occurrence in the Whakatane and Ohope area in recent years. There have been major storms and floods recorded for most years since the 2004 floods. The following comment is from the Bay of Plenty Regional Council (BOPRC) rainfall records site for Kopeopeo:

"A major rainfall storm occurred in Whakatane on the 1 June 2010 that produced 65mm of rainfall in 1 hour at this site; the 6 hour total recorded was 121mm. The rainfall recorded at the Whakatane airport a few kilometres northwest was even higher with 161mm being recorded over a 6 hour period. The 1 hour to 6 hour duration rainfalls recorded in the area at this time rank as one of the most severe short duration storms ever recorded in New Zealand."

In addition, other extreme rainfall events have been recorded recently in the Whakatane District. As described in a WDC catchment management investigation and implementation Whakatane and Ohope report, dated November 2010 by Debbie Fransen;

"24 MAY AND 1 JUNE 2010 RAINFALL EVENTS

4.1 Rainfall analysis

An analysis of the May and June flood event was prepared for BOPRC and WDC by NIWA. The NIWA analysis showed that the storm on 24 May had a return period of between 10% and 50 % AEP, [between 10 and 2 year recurrence interval] *while the second storm on 1 June 2010 had a return period well in excess of the 1% AEP return period* [well in excess of a 1 in 100 year] *for a storm with a duration of between one and six hours.*

The 1 June 2010 storm had rainfall totals as follows :

· 1 hour total of 90mm

· 3 hour total of 139 mm

· 6 hour total of 161mm.

'These rainfall totals are large enough to rank the event as one of the most severe short duration storms ever recorded in New Zealand' (NIWA; 2010)."

However, it is noted that the 1 hour and 90 minute rainfall at the time of the Matata debris flows in May 2005, were apparently larger!

The 18 May 2005 event. *On 18 May 2005, a band of intense rain passed over the catchments behind Matata, a coastal community at the foot of old cliffs some 25km north-west of Ohope. *308mm of rainfall fell in the 20-hour period from 10pm on 17 May 2005. Approximately 106mm fell between 10pm on 17 May and 6am on the morning of 18 May 2005. After a relatively dry period until noon, a further 150mm fell between 2pm and 6pm which included:*

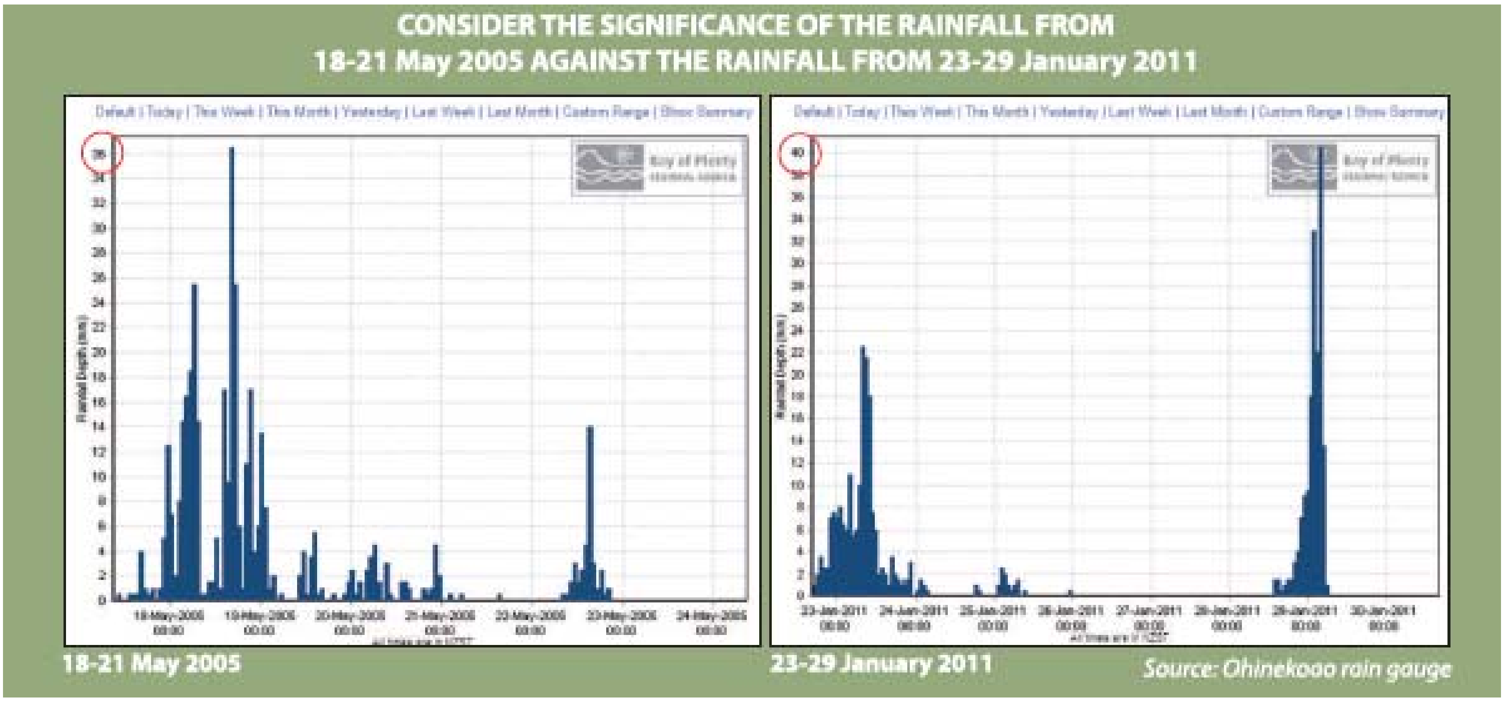
A peak one hour depth of 94.5mm (between 4.30pm and 5.30pm)

A peak 90 minute depth of 125mm (between 4pm and 5.30pm)

The above rainfall was recorded at Awakaponga, and GNS Science believes that greater elevation further inland, the rainfall in the Matata catchments may have been up to 30 per cent higher.

Local daily rainfall has been recorded at 21B West End Road, Ohope since 1998 by Graham Wilson (Appendix 1). The greatest daily rainfalls on his records are 145.0 and 160.5mm which fell on 17 and 18 July 2004. In his 24 hour records, the rainfall for 1 June 2010 was 125mm at West End. However on his records in 2010 there was 122.5mm on 20 January, 116.5mm on 17 May, 139mm on 24 May and 88.5mm on 14 August. The winter of 2010 was indeed wet! Then in 2011 he records 83 and 81.5mm on 22 and 23 January, 107 and 62mm on 25 and 26 April, followed by the 88mm on 18 June (Appendix 1). Although the 24 hour rainfall of 88mm at West End on 18 June 2011 was relatively modest compared to several other events listed above, it was severe enough to cause flooding in Whakatane, landslides along the escarpment and emergency service call-outs. It appears that the very wet antecedent conditions, the rainfalls during 2010 and 2011, may well have affected the amount of landsliding which occurred on 18 June.

5.1 The May 2005 rainfall compared to that of January 2011



The newly available "*Stormwater Catchment Management Investigation and Implementation* ***Whakatane and Ohope*** – Mitigation Options" by Debbie Fransen, dated Sptember 2011, makes the following comments:

4.0 RAINFALL AND CLIMATE CHANGE

The Whakatane District experienced a very wet period from May 2010 to June 2011 due to the persistent La Nina conditions. Storm events in this period that affected the study area included:

24 May 2010 approx 5% AEP

1 June 2010 greater than 1% AEP

29 January 2011 approx 5% AEP

26 April 2011

18 June 2011 – approx 5% AEP (probability of occurring in any 1 year)

It can be seen by this review of events that the method of referring to a flood by a return period in years can be misleading as the study area has experienced 4 events with a return period of 5% (20 years or greater) within a period of a little over 1 year.

6.11 Ohope Escarpment Runoff

It is understood that only minor flooding of land has occurred due to runoff from the Ohope escarpments from West End to Maraetotara Road. It is acknowledged that erosion of this escarpment and the Whakatane escarpment also poses a significant hazard however that cannot be eliminated through stormwater controls. This site has not been considered in detail within the scope of this project.

6.0 EXAMPLES OF LANDSLIDES IN OTHER REGIONAL STORMS

Landslides from coastal escarpments, bush-clad areas and farmed hills have occurred often in the Whakatane District and Eastern Bay of Plenty during high intensity rainfall events. Some examples of these landslides are included in this report as they help explain and provide evidence of what may be happening on the escarpment at West End, and what may be feasible in the way of mitigation options. The author and other GNS Science staff have attended the 2004 regional storm and flood and the 2005 Matata debris flow events. The 2005 high intensity rainfall storm affected Tauranga before it passed along the coastal escarpment south, before causing the debris flows at Matata, where it then faded away.

The landslide examples included are at Bryans Beach 2004, also a fatal landslide involving a pohutukawa tree, (Figures 27 to 31), Ohiwa in 2004 (Figures 33 to 35), Waiotahi Beach Road 2004 (Figures 36 to 37d), Waiotahi Valley 2004 (Figure 38) and Ohiwa harbour Road 2004 (Figures 39 to 40b), and Matata in 2005, (Figures 41a & b), which coalesced in confined catchment area streams to form the highly destructive debris flows at and near Matata.

Google Earth often provides a series of past aerial photo images which can be referred to and compared with more recent images. These are valuable for comparing changes to the landscape with time, as has been done for West End Ohope with Figures 22a (Feb 2011 image), 22b (Nov. 2009), 22c (March 2003) and 22d (Sept. 2002). An enlargement of the latest of these aerial photos (15 Feb. 2011) is shown in Figure 24. In Figure 24 three landslides can be seen which have affected houses on the talus apron at the foot of the cliff. These landslides occurred at the northern end of West End in January 2011 and in May and June 2010 (T&T 2011) and affected houses at No.'s 70, 68, 67 and 65D West End Rd. The building at No 65D is multi-level apartments built high on the talus apron under the old cliff. However, these multi-level apartments are more strongly built than a house and have not been significantly damaged by the landslides (June 2010 and Jan. 2011) from the cliff directly behind, although there is apparently an overhanging pohutukawa tree on the cliff which is raising concern (Kevin Hind, T&T, pers. com.).

Similarly Figures 37a, b and c are Google Earth images of the pohutukawa clad cliffs at SH2/Waiotahi Beach Road taken in Dec. 2002, Feb. 2007 and Dec. 2010. The development of landslides on the cliff since 2002 is well illustrated by the Google Earth images. The landslides from these cliffs were photographed by the author in 2004 (Figure 36). It is clear that there have been new landslides from the cliffs since 2004 and that the 2004 landslide areas are revegetating by Dec. 2010.

7.0 DISCUSSION AND CONCLUSIONS

7.1 Summary & Discussion

1. Records show that high intensity rainfall events have occurred nearly every year in the Eastern Bay of Plenty, causing extensive damage due to flooding and landslides in 2004, the Matata debris flows in 2005 and flooding and landslides in Whakatane District most years since 2005.

2. The daily rainfall of 88mm at Ohope which caused the 18 June 2011 landslide is regarded as approximately a 1 in 20 year recurrence event, while the intensity of rainfall in the hour preceding the landslide (31mm) is regarded as approximately a 1 in 2 year event. Up until the end of June during 2011 there were 4 rainfall events (storms) with daily rainfall greater than 80mm. In 2010 there were 5 events with daily rainfall greater than 80mm; in 2009 there were 3 events, etc (Appendix 1).

3. On 16 and 17 July 2004, over those 2 consecutive days, the rainfall was 145mm and 160.5mm respectively. This quantity of rainfall caused widespread landslides even on moderate slopes. However, steep escarpment slopes, such as the old cliffs behind West End, Ohope and in many other parts of Eastern Bay of Plenty, are particularly vulnerable to landsliding during wet periods, high intensity rainfall, and in strong earthquakes such as the 1987 Edgecumbe Earthquake. These escarpment slopes are often vegetated with large pohutukawa trees and are an iconic part of the New Zealand landscape, especially at Christmas when the pohutukawa display their crimson flowers.

4. The geology and geomorphic evolution of the old cliff escarpment slopes are described well by Tonkin and Taylor (2011). As the old cliffs are often no longer being actively eroded at their base by the sea, they are fronted by gently sloping accumulated beach sands and dunes, as is the case at West End. However, the old cliffs are still steep with angles of 45 to 60º that will regrade to more gentle and more stable slopes over time by shedding material from the steepest parts of the old cliffs onto an accumulating debris apron at the toe. The upper debris apron has an angle of approximately 30º, the angle of repose of the debris shed from the cliff face. The debris or talus apron is an area at very high risk from landslides falling from the "old cliff face" escarpment directly above.

5. The old cliff faces go through a cyclic process of "ripening" and failure, which judging from the size of the pohutukawa trees in places, may take up to a hundred years or more. After a landslide has cleared off a slope, the "ripening" process occurs as the bare exposed face gradually re-vegetates and weathers to form a soil profile of variable thickness. The developing soil is weaker than the bare "rock" face, but is held in place by intertwined vegetation and tree roots. Pohutukawa are hardy trees which can have long, expansive tree roots that are well adapted to colonising and clinging to steep, rocky, cliff faces, and they can grow to a large size in these places.

6. The fatality at Snells Beach in 2004 (Figures 27 to 30) and the damage to the house at 33 West End Road on June 18, 2011 (Figures 13 to 21), were caused by large, solo pohutukawa trees no long able to hang on in the saturated, upper debris apron materials in which they are growing. In both these cases the tree, together with its entire root clump - including soil, has let go and slid down the ~30º, sodden, debris apron slope. In other cases, such as the fatal landslide at 55 West End Road on 18 June 2011 (Figures

1 to 11), the landslide at the back of 34 West End Road in 2004 (Figure 32), the landslide on the cliff at Ohiwa in 2004 (Figures 33 & 34) and the landslides from the cliff at SH2/Waiotahi Beach Road also in 2004, all included clusters or groups of mature pohutukawa trees falling from steep cliff slopes.

7. Trimming mature pohutukawa trees may be an effective mitigation option as it undoubtedly removes some of the tree ‘superstructure” weight, and may delay slope failure due to “ripening” for some time. However, on steep, high, old cliff faces, trimming the trees is a very difficult, hazardous, and costly operation, especially when there are houses located close by below. As well the tree stump, together with roots and soil, represents a large proportion of the tree weight, and that remains in place. Following the slope ripening process, it will eventually collapse onto the talus apron as part of the inevitable cyclic evolution of the cliff slope.

8. Thus although trimming the trees may delay landslide occurrence from the old cliffs, it will not prevent the landslides from occurring. As well, the trimmed stump and root mass is bulky and forms a large percentage of the weight of the original tree. It also remains a hazard as in the cyclic landslide process, the trimmed stump and root mass will eventually form part of a landslide.

9. Other mitigation options include debris barriers of various types. Where there is space at the bottom of the cliff to install them, a debris barrier may be effective. However, thet should be well designed and installed by appropriately qualified people.

10. It is recognised that the coastal land, such as the properties along the beach at West End, Ohope are beautiful places to live, enhanced by the pohutukawa clad cliff backdrop. Because of this, land values are high and residents are keen to utilise as much of the land as possible, including building high on the debris apron, close to the cliff face where the elevation enhances the sea-scape views. Houses in this situation, such as those at 33 and 54 West End Road, are exposed to a very high and unacceptable risk from cliff face landslides. Generally our society recognises that a natural hazard with a recurrence interval less than 50 years requires mitigation. The occurrence of landslides from the escarpment behind West End Road is far more frequent than this.

7.2 Conclusions

- It is concluded from the above discussion that landslides from the cliffs present an unacceptable risk to houses constructed on the debris apron at the toe, and that effective mitigation measures may not always be a viable option. In this case the construction of dwellings on the debris apron at the toe of a steep cliff should not be given a building consent and the local territorial authority should consider zoning the debris apron areas as non-residential, scenic reserves, as is currently being done in areas with rock-fall hazard in the Port Hills of Christchurch.

- Where there are existing buildings located on the talus apron toe under steep cliff faces, the emerging practice of evacuating these houses when there is a local heavy rain warning, is a pragmatic and effective solution to a complex problem, which would help prevent fatalities due to landslides. If an evacuation call had been given to vulnerable properties when the June 18, 2011 storm was forecast earlier in the day, the tragic accident at 55 West End Road could have been avoided.

8.0 ACKNOWLEDGEMENTS

This landslide reconnaissance could not have been completed without the generous assistance of many people, most of whom are acknowledged in the report. Diane Turner, Jeff Farrell and others at Whakatane District Council, Bruce Jenkins from the Police, Kevin Hind and David Milner from Tonkin & Taylor, and many others, were most helpful.

Penny Murray is thanked for her work formatting the report, and Graham Hancox and Alex Moore, all of GNS Science for their thorough reviews of the report.

9.0 REFERENCES

M J McSaveney, R D Beetham & G S Leonard 2005. The 18 May 2005 debris flow disaster at Matata: Causes and mitigation suggestions. *GNS Client Report 2005/7, June 2005.*

Tonkin & Taylor 2011: Ohope Escarpment Condition Survey, No's 63 to 71 West End Road, Ohope. Draft report to Whakatane District Council, June 2011. David Milner & Kevin Hind authors.

FIGURES

Figure 1 View looking NE to the back of the damaged house, No. 55 West End Road. The area in which the fatality occurred is arrowed. The landslide debris have been cleared away.

Figure 2 The old cliff source area of the fatal landslide behind the house. The trunk base, root mass and broken branches of a large pohutukawa tree can be seen in place at the centre of the photo (arrowed) and a displace one in the right-hand corner.

Figure 3 Looking obliquely across the cliff source area of the fatal landslide.

Figure 4 Looking at the damaged house from the toe of the cliff in the southern neighbours' property.

Figure 5 View directly across the cliff source area of the fatal landslide from its southern margin. Note the remnant pohutukawa tree hanging onto the slope in the middle of the photo.

Figure 6 Looking down the path of the fatal landslide from its southern margin. Note the root masses of 2 large and 1 smaller pohutukawa tree (red arrows) caught up behind and on the live pohutukawa tree (green arrow)

Figure 7 A similar but wider view to Figure 6. The landslide at the north end of Ohope Beach, as seen in Figure 12, is arrowed red.

Figure 8 The top and south margin of the fatal landslide source area.

Figure 9 View up the path and cliff source of the fatal landslide. The landslide debris (cleared away here) entered and partially demolished a room (now removed) on the house at the red arrow. The pohutukawa tree which prevented large slipped trees, as shown in Figure 6, from impacting the back of the house, is arrowed green.

Figure 10 View of the cliff source of the fatal landslide looking SW. The scrub and pungas to the right of the landslide scar are regrowth on the scar of an earlier landslide.

Figure 11 A closer view of the fatal landslide scar in Figure 10.

Figure 12 A landslide several hundred metres away at the north end of Ohope Beach which, according to T&T, occurred during a high intensity rainfall storm in April 2011. The West End rainfall records show 107 and 62mm on 25 & 26 April (Appendix 1). This landslide, also seen in Figure 7, has occurred from the cliff face, removing trees and scrub, and leaving a clean scar. The landslide has taken out the walking track to Otarawairere Bay and Kohi Point. Note the debris on the beach at the toe of the landslide. Ancient greywacke rock is found below the arrow, and young Ohope beds above.

Figure 13 This house at No. 33 West End Road has also been impacted by a landslide from the slope behind.

Figure 14 A large pohutukawa tree with root mass & soil dislodged from the lower slope and slid into the house shunting is forward ~half a metre. The back of the adjacent house (red arrow), No. 34, was affected by a landslide in 2004 (Figure 32).

Figure 15 The front of the house propped to prevent further forward tilting.

Figure 16 Tree and soil landslide debris at the back of the house.

Figure 17 Large pohutukawa trees on the boundary of 33 and 34 West End Road. These trees are growing in the tallus fan at the foot of the old cliff where the slope angle is ~20º. They can provide protection from landslide debris falling from the old cliff above.

Figure 18 The source of the slipped pohutukawa tree, from near the top of the talus fan and not rock, where the slope angle is steeper, about 25 to 30º.

Figure 19 This block wall has been tilted forward with the movement of the house caused by the impact of the pohutukawa tree and associated landslide at the back.

Figure 20 View along the back wall of the house showing tree and soil landslide debris. The main impact appears to have been from the large pohutukawa tree.

Figure 21 The inferred source (arrowed) and sliding path of the pohutukawa tree that impacted the house.

Figure 22a A 15 February 2011 Google Earth aerial photo of West End, Ohope Beach. For comparison, the following images 22a, b, c & d are all of the same area at the same scale.

Figure 22b A 27 November 2009 Google Earth aerial photo of West End, Ohope Beach.

Figure 22c A 01 March 2003 Google Earth aerial photo of West End, Ohope Beach.

Figure 22d A 21 September 2002 Google Earth aerial photo of West End, Ohope

Figure 23 Detail of the source area of the fatal landslide from the 15 February 2011 Google Earth image.

Figure 24 Landslides at the northern part of West End seen on the Feb. 2011 Google Earth image. From top to bottom the landslides indicated by red arrows occurred in January 2011 (top), May 2010 (middle), and June 2010 (bottom) according to the T&T (2011) draft report.

Figure 25 A small landslide can be seen amongst the trees on the northern cliff at West End in the Feb. 2011 Google Earth image. This appears to have expanded in April 2011 to form the much bigger landslide seen in Figure 12.

Figure 26 A 2011 Google Earth image of No. 33 West End Road, taken just a month before the landslide which wrecked the house.

2004 STORM PHOTOS

Figure 27 Bryans Beach fatality site in 2004 – front of the house

Figure 28 Back of house which was impacted by the displaced pohutukawa tree, which slid down and caused the fatality - a lady who was outside clearing drains.

Figure 29 Source area of the pohutukawa tree which caused the fatality in the 2004 heavy rainstorm. The slope angle in the source area is ~35º.

Figure 30 Detail of the debris and tree behind the wrecked house at Bryans Beach.

Figure 31 A 2009 photo of the new house built on the site at Bryans Beach. The landslide scar behind the house is revegetating.

Figure 32 A landslide involving large trees from the ~80m high cliff at West End in 2004 impacted a "batch" at the back of No 34 West End Road.

Figure 33 A landslide involving mature pohutukawa trees on a ~20m high cliff below houses at Ohiwa. The slope angle is 30º to 40º.

Figure 34 Remedial works, as seen in 2009. Note the revegetation since 2004.

Figure 35 Detail of retaining wall remedial works seen in 2009.

Figure 36 2004 Failures involving large pohutukawa trees from the ~60m high cliffs along SH2/Waiotahi Beach Road where the slope angle is ~40º.

Figure 37a A 12 December 2002 Google Earth image of Waiotahi Beach Road/SH2 when much of the cliff is intact. For comparison the following Google Earth images 37b & 37c are of the same area at the same scale. They illustrate how different parts of the cliff have shed landslides and trees between Dec. 2002 and Dec. 2010.

Figure 37b In this 14 February 2007 Google Earth image the landslide areas from 2004 are revegetating.

Figure 37c Many new landslide areas have appeared on this 22 December 2010 Google Earth image.

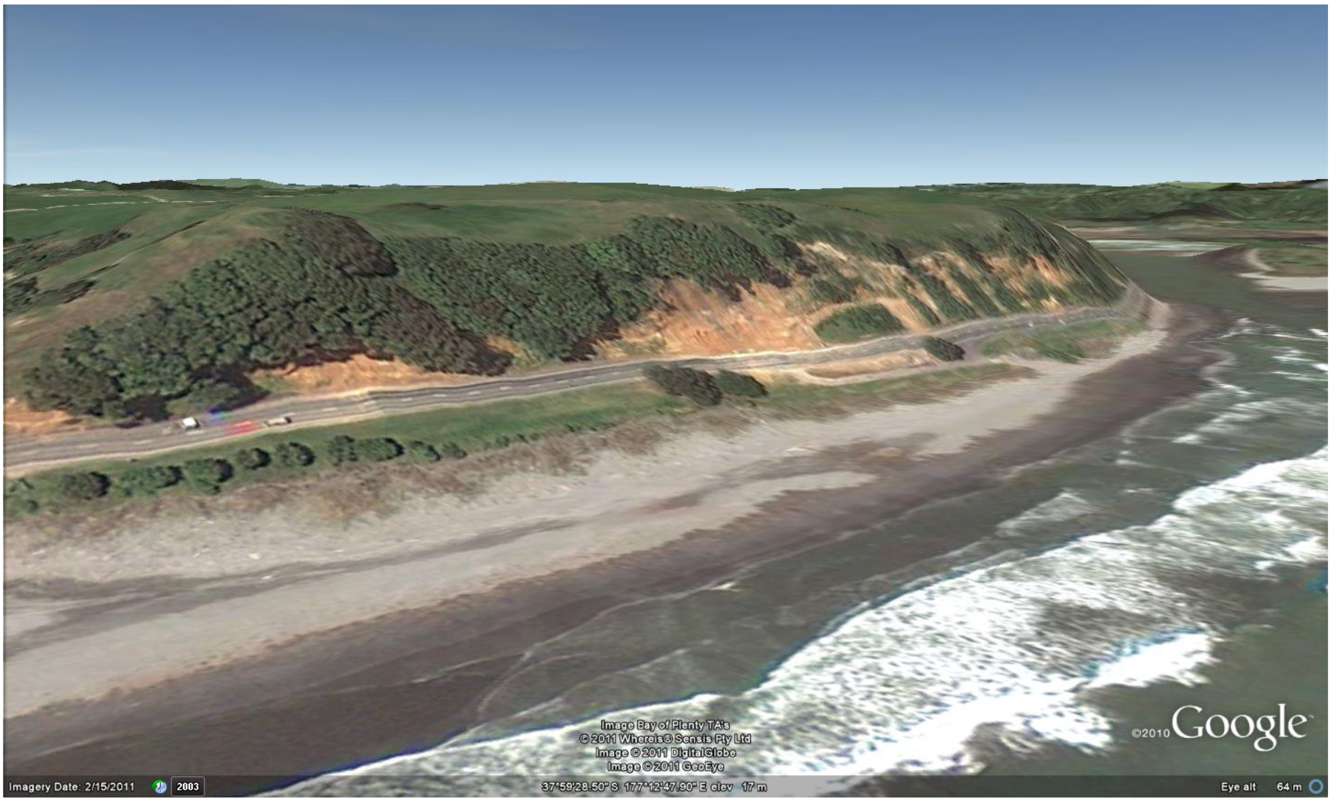


Figure 37d The 22 Dec. 2010 image seen in Figure 37c above has been rotated in Google Earth to form this oblique view of the ~60m high cliff.

Figure 38 An example of soil flow landslides on moderate to steep grassed slopes in the Waiotahi Valley after the high intensity rainfall in 2004.

Figure 39 Landslides along Ohiwa Harbour Road at the Waiotahi Valley end in 2004.

Figure 40a Landslides on a new subdivision at the junction of Ohiwa Beach and Ohiwa harbour Roads.

Figure 40b Detail of the landslides on a new subdivision at the junction of Ohiwa Beach and Ohiwa harbour Roads in 2004.

Figure 41a Landslides from the coastal (old cliff) escarpment just north of Matata in May 2005 have been cleared form the roadway, which is on the talus apron.

Figure 41b Numerous landslides such as these in the Awatarariki Stream catchment coalesced to form the destructive Matata Debris flows in May 2005.

APPENDIX 1 DAILY RAINFALL RECORDS COLLECTED BY GRAHAM WILSON AT 21B WEST END ROAD

2011

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1												
2				4.0								
3					44.0							
4			11.0	38.0	12.0							
5	2.5			40.0		28.5						
6	1.0		5.5	2.5								
7	2.5		33.5		22.5	7.5						
8			8.0		18.5							
9												
10						13.0						
11						46.5						
12		20.0			16.0	10.0						
13					21.0	~~13.0~~						
14					4.0							
15	5.0											
16					3.0							
17				32.0	~~[illegible]~~							
18	11.0					9.5						
19	23.0		3.5	3.0	SLIP @ 55 →	88.0						
20												
21			6.5			8.0						
22			42.5									
23	83.0	2.5		29.0	6.0	2.0						
24	81.5	1.0				26.0						
25		30.0		19.0		25.0						
26				107.0	12.0							
27		17.5	36.5	62.0	52.0							
28			35.0		2.5							
29	119.0					4.0						
30												
31												
	328.5	71.0	182.0	336.5	213.5	270.0						

(← 1401.5 →)

2010 1897.5

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1		24.0			4.5					8.0		2.0
2			5.5		2.0	125.0		35.5				
3			9.0			2.0		11.0	2.0		←	
4						^		41.0			4.5	
5	2.0							32.5			3.0	
6							13.5				6.5	
7				35.0				1.5	9.5			
8								24.0	3.5	^		5.0
9								7.5	4.5			6.5
10									52.0			7.0
11	7.5										^	
12									35.5	15.0		
13	5.0	5.5		^	17.0			1.5	16.5			
14		1.0			16.5			31.5		18.0		
15					22.5			58.5	8.5	13.5		
16		6.5			31.0							3.5
17	16.0	4.0			5.5				12.5			17.0
18	1.5				116.5			9.0	8.5	10.5		8.5
19				13.0				2.0	1.5			40.5
20												62.0
21	19.5				12.0	122.5		3.0	2.0	6.5		4.0
22	21.0				1.5				14.0			
23	38.0	1.5					53.5				30.0	
24	19.5				31.0						10.0	
25	6.0		21.5		139.0	22.5					1.5	
26		8.0			8.0	13.0		36.5				
27				2.0				3.0				
28				11.5	18.0					3.0		
29					14.5	20.0		1.0				8.0
30								13.0			8.5	
31	28.0							5.0				
	164.0	50.5	36.0	61.5	439.5	305.0	67.00	317.00	160.5	74.5	64.0	158.0

744.5

Margin notes: June (8–20): GIRLS TO AWAY; April (13–18): EVANS B/DAY; July (14–22): B/DAY FENCE, AMBERS SARAH; Oct (8–12): SUSAN GIRLS BACK; Nov (12–22): SUSAN CARBS HILLS SARAH; right margin (row 3): NEW SPOUTING

2009

Sheet1

1569.5

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1			86.0									
2												3.0
3					3.0		9.0	4.0		7.0		37.5
4	20.0											
5							19.0			34.0	1.0	
6		2.5	3.5							24.0	2.5	14.0
7			51.0				2.5					
8			14.0	5.0			7.5					
9					6.0							
10		2.5		2.0	8.5	12.0				24.0		
11		3.0			22.0	109.0						
12		11.0		H/S →	47.0	3.0	25.0				1.0	
13		14.0			3.5	74.0			7.0			
14						20.5						
15							13.5	46.0		3.5		6.5
16					1.0		↑	13.0		32.5		1.0
17			14.5					6.5				
18		15.5			5.0	↑			9.0	3.0		
19	11.0	57.0	8.0		3.5			1.0	2.0		10.0	
20		46.5		7.5				11.5	1.0			
21	2.0	1.5		11.5						17.0		
22			6.0								2.0	
23												
24						Away @ Sarahs	Away @ Sarahs					
25		3.5			13.5				100.0	7.0		
26				3.0				10.5				
27								1.5	13.0	2.0		
28									~~100.0~~	17.0		
29	20.0			1.5		↓			11.5		2.0	3.0
30				2.0		100.0	↓		160		[illegible]	12.0
31					14.5		79.0	21.0			1.5	
	53.0	157.0	183.0	32.5	127.5	318.5	155.5	115.0	303.5	171.0	20.0	77.0
									159.5			

2008

1412.5

Sheet1

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1			1.5	10.0				6.0	1st WISTERIA			
2			47.0	3.0	2.0	HENRY & GIRLS		12.5	7.5			3.0
3									4.0			
4			1.5				5.5		3.0			
5		8.5			28.5		2.0				10.0	
6					14.5							
7										21.5		
8			12.0					31.0		3.5		
9					RAE'S	12.0		6.5	16.5			8.0
10					95.5				1.5			21.5
11		6.5							9.0			
12								10.0				
13							12.5	12.0	5.5			
14			5.5					7.5		8.0		
15				20.0		2.0		4.0				~~20.5~~ 20.0
16				87.0								20.0
17		3.0		71.0								
18				2.0		29.5	22.0		4.0	33.5	4.5	
19							4.5					
20		3.0					46.5	[illegible]				
21							5.5				2.0	4.5
22	28.5											
23	2.5					35.5	21.0					
24												
25		40.5								28.5	24.5	
26		7.5				14.0				2.0		15.0
27				11.0		4.0	31.5				2.0	
28			1.5	9.0			2.5	94.5				
29						17.0						
30				41.0			38.5					36.0
31	3.0						56.0					1.0
	34.0	69.0	69.0	254.0	140.5	114.0	248.0	184.0	51.0	97.0	43.0	109.0

2007

1099·6

Sheet1

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	15·0				35·0					10·5		
2	12·5						17·0					
3	7·0				11·5	2·0	1·0			4·0		
4		12·0	29·5									
5							13·0	27·0	20·0		7·0	
6							1·0		8·5			19·0
7							15·0	8·0				35·5
8		3·5	3·0									
9										2·0		5·5
10	52·5								8·0	2·0		2·0
11						9·5				19·0		
12	22·0		22·0			1·5						
13				15·0								
14			·1					12·0	7·0	18·0		
15			4·5									3·0
16	27·0									3·0		
17							5·0	22·5	18·5			
18	1·0									18·5		14·0
19								7·5				24·0
20							33·0		10·5			11·5
21						13·5						
22					4·0		17·0					
23					5·5							
24					13·5			away	9·0	3·5	4·0	
25							1st [illegible]					
26									7·5			3·5
27												
28				14·5								
29				27·0				17·5				
30			76·0	6·0		64·5	82·0					
31			10·0									
	137·0	15·5	147·1	62·5	69·5	91·0	184·0	94·5	89·0	80·5	11·0	118·0

2006

1688.5

Sheet1

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1								15.5				
2		44.0						15.0				
3				36.0	64.5					48.5		
4								2.0				
5	3.0					21.0				3.0		5.0
6		4.0			10.5		39.0		52.5			
7	9.5							139.0				
8			21.5	19.0				7.0			27.0	
9		39.0										4.0
10		52.5			15.5				60.0	5.0	8.0	
11		145.5										
12												
13			6.0			19.5	6.0					
14							14.0					
15					12.0		7.5				4.0	
16												
17												
18												
19				39.0							13.0	17.0
20		35.5				14.0	33.0					52.0
21			12.0				4.0					3.0
22						3.0		3.5				12.5
23					12.0							
24					9.5					17.5		
25	52.0			20.0	3.5			22.0		3.0		
26	22.0			22.0								
27	10.0		47.5									
28			21.5	4.0								
29			10.5	37.5								
30				27.0	24.5					14.0	13.5	
31	3.0											
	99.5	320.5		204.5	152.0	57.5	103.5	204.0	112.5	91.0	65.5	93.5
			119.0									

2005 1405.00

Sheet1

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1						12.0					7.0	
2						1.0		19.5				
3					14.5					21.0		
4		19.0			75.0							
5		6.0			1.5					5.5		
6	2.5									2.0		
7		8.0								11.0		21.0
8							71.5	30.5			[illegible]	2.5
9												
10												
11										23.0		
12		23.5		9.5			39.5	15.0		30.5	BLACK	
13										.5		17.5
14									WISTERIA FULL FLOW			
15							13.5		12.0			
16												
17					37.5					10.5	ALL	17.5
18			28.0		55.0				20.0			5.0
19		MATATA FLOOD →			62.0		22.0					
20					10.0	[illegible]			7.5			6.5
21					10.0					54.0		
22										40.0	AWAY	6.5
23					38.5				4.5			15.0
24									4.5			
25		37.0	13.5					15.0				
26			31.5									
27				3.5	2.0	110.0						
28			15.0		34.0		14.5					
29							14.0					22.0
30			30.0		6.0			WISTERIA 1st colour			72.5	
31										14.5		
	2.5	93.5	118.0	13.0	346.0	123.0	175.0	80.0	48.5	212.5	79.5	113.5

(696.00)

1405.00

2004 1695.5

Sheet1

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1												
2		8.5			33.0				15.5		31.0	
3		16.0	1.5									
4					10.0							
5		34.0						32.0		17.0		50.0
6					7.0		10.5	24.0				
7		6.0					13.0					
8										21.5		
9										31.5		
10												
11												
12										4.5	12.0	
13					74.0							
14	3.5	29.0	7.5		5.0							
15	1.5										33.0	
16												5.0
17		7.0					145.0	17.0	27.0		5.0	
18			18.0				160.5			9.0		
19						95.0	8.5					
20	16.0	11.5										10.0
21	6.0						2.0			4.5		
22						4.5						14.0
23												
24					44.0						14.0	
25										17.5		
26									48.5			
27										3.0		
28				20.0								
29		81.5		62.0	30.5		30.5		3.5			
30				55.0		65.0						
31	33.0				2.0		7.0					81.0
	60.0	193.5	27.0	137.0	205.5	164.5	377.0	73.0	94.5	108.5	95.0	160.0

High Sea/STORM
Cyclone IVY

Page 1

17/18 JULY
FLOODS
E/Q4

1395.0 2003

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1			14.0									
2				12.5								
3			36.0	18.0	27.0				21.5			
4									1.0	72.5	24.5	
5						11.0			19.0			
6												
7				73.5								19.5
8							12.0		13.0			
9	18.5					59.5						6.0
10	73.0		6.0			10.0						33.5
11									2.5	21.5		4.0
12			19.5									
13										98.0		
14					4.0				25.5		7.5	
15									7.0			
16								54.0				
17						44.5			16.0			4.0
18		2.0	7.5			4.5						
19					2.5	30.0						
20		2.0										
21					40.0			12.0	17.0			
22				12.5	15.5							14.5
23												
24		25.5				20.0						
25	6.0	10.0				4.5						
26		1.5			11.5			18.0			29.0	8.5
27		19.5	23.0								3.0	
28		4.5						14.5		24.0		
29			11.0						20.0	12.5		
30			3.5			34.5						30.0
31								6.0				
	97.5	65.0	120.5	116.5	100.5	218.5	12.0	104.5	142.5	228.5	64.0	125.0

1022·5 2002

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1												
2							19.5				5.0	
3			54.5						14.0			
4											18.5	16.0
5							10.0	↑				
6	2.0							39.0			2.0	
7		6.5		17.0			11.5	9.0			1.0	
8												22.0
9								13.0				
10	26.0					23.0						
11												
12	36.0	15.5							19.5			
13	16.5	8.5								4.0		4.0
14												
15							18.5	14.0				
16			6.5									
17										12.0		
18											19.0	
19			6.5			39.0						
20	26.0								21.5		5.5	
21					9.0							
22					30.0	40.5						25.0
23					5.0							
24							59.5					
25								12.0				
26	15.5								6.5			
27				87.5								
28				2.0	16.5							
29					2.0					24.0		
30						84.0			11.5			
31			10.0									
	122.0	30.5	77.5	106.5	62.5	186.5	119.0	87.0	73.0	40.0	51.0	67.0

1910.0 mm   2001

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1		23.0										
2									6.0			9.0
3				108.0	43.5							
4			80.0	2.0								
5											17.5	
6					53.0				56.5			
7		12.5			2.0					33.5		
8									39.5			47.5
9												55.0
10			40.5							77.5		
11						13.0				2.5		
12		↑			125.0			↑				
13		100.0		66.0								14.0
14								68.5			12.0	
15	12.5										2.5	
16							44.0		50.0	11.0		17.5
17		102.0				11.0						
18		57.0										23.5
19												23.0
20		2.0	6.5		7.5							17.5
21				19.0						24.0		4.5
22											5.0	
23								29.0			40.5	17.0
24											10.5	
25		31.0				38.0						
26					15.5			8.5				
27												
28												45.0
29	7.0		9.0			6.5				47.5		3.5
30												3.0
31					22.5		28.5					
	19.5	327.5	136.0	195.0	269.0	68.5	72.5	106.0	152.0	196.0	88.0	280.0

678.0

1298.5 mm 2000

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1				5.5		12.5						
2			45.5			31.0						
3			46.0				7.0			20.0		
4						14.5						17.0
5				13.0								
6				28.0							32.5	
7				2.0		3.0			2.0			2.0
8					20.5						13.5	
9	36.0		50.0	19.5								
10				24.0					28.0			38.0
11												
12								18.5		20.0		21.5
13				3.0	53.0							
14					12.5				14.5		29.0	
15			8.0									
16					1.0							
17		12.5								3.0		3.5
18								43.0				
19				17.0								
20	6.0			17.5			21.5	18.0				
21				11.0								
22			4.5	6.5			34.0					
23											10.0	4.5
24				28.5								
25				19.5								
26	12.5					10.5			17.5			
27		9.0				2.0		47.5				
28											8.0	
29	40.0					12.5					21.5	
30	28.5		4.0			5.5				13.5	6.5	
31					38.0		20.0	27.5				21.5
	123.0	21.5	158.0	195.0	125.0	91.5	82.5	154.5	62.0	56.5	121.0	108.0

1393.5 1999

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1												
2					33.0							
3					1.0							
4							50.0				↑	
5			2.0			30.0						
6						25.0						
7			35.0									
8			6.0						47.0		63.0	
9				38.5						90.0		
10		3.0	11.0	5.5								
11											70.5	
12								92.5			14.0	
13						^				3.5		12.0
14	↑					45.5			750			12.0
15	40.0				13.5	8.5					9.5	3.0
16	11.0			10.0		25.0		42.0				
17	45.5		8.0		10.5	6.0	↑					
18				9.0			56.0	26.5			3.0	
19										6.0		
20							1.0		5.0			65.0
21										3.0	17.5	
22							9.5			22.5		18.0
23	70											
24			4.0									
25												
26												6.0
27		15.5	1.5						4.5			
28					5.5						61.5	
29			4.0							8.0		
30											9.0	
31	7.5		6.5		12.0			1.5				
	111.0	18.5	78.0	63.0	75.5	140.0	116.5	162.5	131.5	133.0	248.0	116.0

1422.5

1998
Rainfall

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1								8.0				
2							38.5				8.0	
3					65		4.0					
4											37.0	28.5
5				1.5						3.0		13.0
6			5.0									
7			1.0						6.0			
8					2"	20.5						
9				24.0		8.0				9.0	14.0	
10			2.0	180	2.0	30.0	77.5					
11			10.5		6.0		2."	54				
12			36.5				1"			23.5		
13			21.0									
14			2.0			19.0		58.0		10.0		
15			9.0			52.0	56.5	50		12.0		
16			1.0									
17									33.5			
18							23.5		4.5			
19				4.0		36.0		11.0				42.5
20	5.0											
21	22.0		4.5							10.5		
22							410					
23											15.5	
24	14.5			11.0	9.0		23.0					
25	12.0					5.0	20.0					
26						19.0					2.5	
27				5.0		9.0	4.0					
28				35				30.0				
29			2.0	1.0						48.5		
30			3.0								67.0	
31												
	53.50		97.50	68.0	73.50	198.50	332.00	211.0	44.0	116.5	144.0	84.0

APPENDIX 2 SUMMARY OF THE 2005 DEBRIS FLOW EVENTS

*On 18 May 2005, a band of intense rain passed over the catchments behind Matata. *308mm of rainfall fell in the 20-hour period from 10pm on 17 May 2005. Approximately 106mm fell between 10pm on 17 May and 6am on the morning of 18 May 2005. After a relatively dry period until noon, a further 150mm fell between 2pm and 6pm which included:*

- *A peak one hour depth of 94.5mm (between 4.30pm and 5.30pm)*
- *A peak 90 minute depth of 125mm (between 4pm and 5.30pm)*
- **Rainfall was recorded at Awakaponga, therefore GNS believes the rainfall in the Matata catchments may have been up to 30 per cent higher.*
- *The rain triggered many landslips, and several large debris flows, which with their associated flooding, destroyed 27 homes and damaged a further 87 properties in Matata and caused extensive damage to Herepuru Road and farmland at either ends of the township.*
- *A debris flow caused the extensive damage in the vicinity of the Awatarariki and Waitepuru Streams, moving boulders up to 7 meters across!*
- *A debris flood, a direct consequence of a debris flow, damaged homes and property adjacent to the Awakaponga Stream.*
- *Properties were damaged and State Highway 2 and the railway were closed for many days due to a debris flow in the vicinity of the Ohinekoao Stream.*
- *Landslides directly from the hillsides above Matata and beside SH2 to the west, were debris avalanches. These are similar to debris flows, but lack a confining channel.*
- *There is evidence that equally as large, and larger debris flows have occurred many times during the previous 7000 years, which built the land beneath Matata.*
- *Historical records indicate that three smaller debris flows have likely occurred since 1860.*
- *Experts classify debris flows as a type of landslide. They are dense fluid mixtures of all manner of rock, soil, organic debris and water, which move rapidly, and are capable of carrying immense boulders.*
- *Debris flows are usually accompanied by debris floods, which did occur in Matata, causing damage that extended beyond the debris flows.*
- *IGNS states that the boulders carried by the debris flows were mostly buried in the streambeds and banks, having fallen from the bluffs above the stream in the past. Most of the harder boulders are derived from strongly welded ignimbrite of the Matahina formation.*

STATISTICS

Damage

- *27 Homes destroyed*
- *87 Homes and properties damaged*
- *Evacuation of 538 people*
- *Extensive damage to local roads*
- *Destruction of railway bridge and significant damage to railway line*
- *Closure of SH2 to the west and east of Matata*
- *Flooding of rural land*
- *Flooding in Edgecumbe*
- *Disruption and damage to water and electricity supplies*
- *Damage to stormwater and septic tank sewerage disposal systems*
- *Estimated 700,000m3 debris of all kinds in and around Matata*
- *Locals report 9 caravans swept out to sea*
- *Locals report 27 vehicles in the Te Awa o Te Atua Lagoon*

Debris Volumes

- *Awatarariki Catchment approximately 250,000m3*
- *Waitepuru approximately 100,000m3*

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