Report on exotic forest debris management related to storm events in the Bay of Plenty

Bay of Plenty Regional Council
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July 2011

5 Quay Street
P O Box 364
Whakatane
NEW ZEALAND

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Executive Summary

In late 2010 and early 2011, the eastern Bay of Plenty was affected by a series of extreme storm events. These resulted in severe debris flows of woody material from plantation forests adversely impacting on waterways and properties downstream.

Two plantation forests, at Taneatua and Omataroa, have been used as case studies to consider options for forest management practices to reduce the risk of potential problems from wood debris in the future.

A joint working group comprising Council staff and representatives of the Bay of Plenty forest industry and Scion has developed a series of recommendations covering forest management practices and identification of high risk land in the Bay of Plenty region.

In addition, Council staff members have identified further work required on clarification of critical storm thresholds, and internal consents and compliance procedures to minimise the adverse effects of debris flows from plantation forests as a result of severe storm events in the future.

Part 1: Project outline

1.1 Objective

To recommend best management practice guidelines to minimise the potential for exotic forest slash movement downslope and entering waterways, particularly during extreme storm events when ground conditions are saturated. The recommendations should consider forest management practices, identification of high risk land, consents and compliance processes, and clarification of what constitutes critical storm events.

For the purposes of this report forest debris is waste wood and forest slash, which is a by-product of harvesting operations and remains on hill slopes following the harvest of trees. It does not relate to wood waste (such as off cuts or stumps), which is generated at a landing or during road formation operations.

1.2 Outputs

1. Provide summary of how two Eastern Bay of Plenty exotic forests were affected by an extreme rainfall event in January 2011 as a case study. This will provide a level of base information to assist in making recommendations for high risk areas, and management options to reduce the risk of debris flows from exotic forest in future extreme storm events.

2. Review literature which deals with storm events which have similar characteristics and affected other exotic forest estates in this way.

3. Provide a spatial analysis with regard to the Bay of Plenty forest estate which will show the high risk areas. The critical elements associated with high risk areas include steep slopes (slopes over 25 degrees), and particular lithology's that are more prone to soil slip and gully erosion under extreme storm events, or prolonged conditions of soil saturation.

1.3 Linkages

A number of parties have been used for feedback and comment in the preparation of this report:

Brenda Baillie – Freshwater scientist Scion
Robin Black – Hancock Forest Management (NZ) Ltd
Sally Strang – Hancock Forest Management (NZ) Ltd
Kit Richards – PF Olsen Ltd
Kelvin Meredith – Rayonier NZ
Norm Ngapo – Waiora Soil Conservation Ltd

Part 2: Summary of the 2010 and 2011 storm events – Eastern Bay of Plenty

2.1 The storm events

In the latter part of 2010 and in January 2011 three storm events bringing significant rainfall occurred in the Bay of Plenty. The rainfall was Bay of Plenty wide with significant concentrations occurring in the eastern areas of the region around Whakatāne.

Photo 1: Typical mid slope failure in the lower Whakatane catchment which has light volcanic soils known as Kaharoa ash over lapilli.

Bay of Plenty Regional Council rainfall recorders at Kopeopeo, Awakaponga and Ohinekoao recorded measurements of 250 mm over a 24 hour period with intensities of over 50 mm per hour. HIRDS (1.5b) equates this 24 hour rainfall as being in excess of a 100 year storm event.

Other unsubstantiated rainfall recorders measured intensities of up to 60 mm per hour with 180 mm measured in three hours in the above vicinities. HIRDS (1.5b) equates this three hourly rainfall as being in excess of a 100 year storm event.

The direction of the storms were from the north east and were associated with downgraded tropical cyclones which when they reach New Zealand shores are described as an intense low with heavy rain.

2.2 Forest areas affected by the rainfall

The storms affected the Whakatāne River, Ōhiwa and Nukuhou, Waimana, and Ōpōtiki area river catchments. Where harvesting of *Pinus radiata* had occurred within the last five years, the upper catchment areas were the most affected. The majority of the catchments had been replanted, with very steep slopes >36 degrees left to revert to indigenous cover. The Land Use Capability Classes for these areas were Land Use Capability Classes 6e and 7e. All the forested areas had been confirmed as being monitored for resource consent compliance.

Photo 2 The upper catchment of the Taneatua forest with logging debris washed down from steep slopes into flowing waterways

The rainfall events which occurred in the latter part of January were a week apart. The first event deposited 240 mm evenly over a 24 hour period. The second rainfall event delivered 260 mm over a 24 period but the intensities were greater with measurements of up to 60 mm per hour over a three hour period - see Figure 1.

The previously unaffected upper catchments were still saturated from the earlier event when the second event arrived. It is considered that the high intensity rainfall combined with saturated catchments were pre disposing factors triggering the erosion problems.

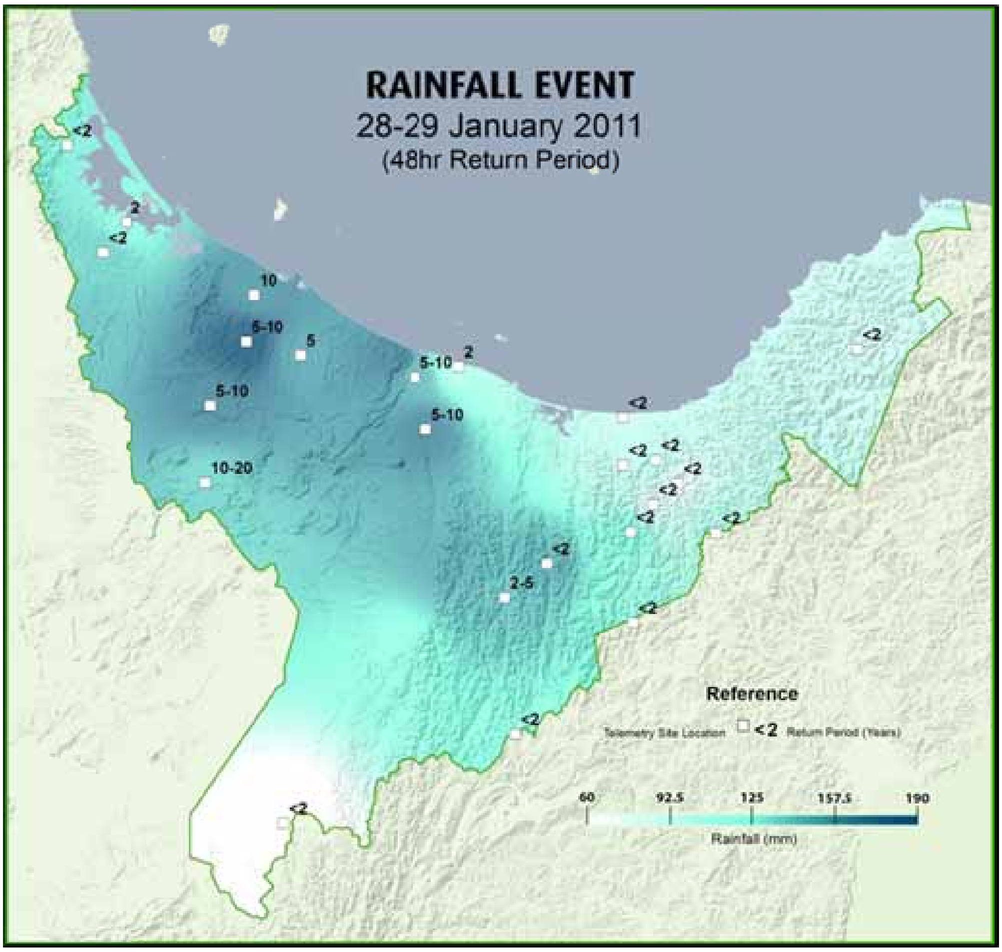

Figure 1 Storm event recorded rainfall (mm) for Bay of Plenty region.

2.3 Erosion types within forest areas

There are four main erosion types which have occurred

Sheet and soil slip erosion – Occurred on slopes between 25 and 36 degrees and was located in the upper hill slopes.

Gully headward erosion – Occurred below the sheet erosion areas and were located in incised areas with a hard geological base such as greywacke.

Debris avalanche – This occurred on very steep hillslopes over 36 degrees with well-established tree cover of both indigenous and exotic.

Streambank erosion – An accumulation of the previously named these erosion types found their way into permanently flowing water bodies with all the woody material which had accumulated. The result was severe stream bank erosion along with deposition of woody material in stream. Much of this material now sits in streams which are inaccessible by a machine which could remove it. Habitats have been severely affected with all streamside vegetation ripped out along with significant soil loss.

The four erosion types above have culminated in debris flows of forest slash and forest debris, which has been washed downstream and deposited in stream channels and flood plains where the grade flattens out.

The percentage forest area eroded was relatively small with approximately five per cent of forest area directly affected. The storm front which passed through and impacted the forest area was very localised and appeared to cut a path approximately 3 km wide.

The two areas most affected by the storm event were both located in the lower reaches of the Whakatāne River. The catchment to the east was in Omataroa forest and the other was to the west and was in the steeper areas of the Taneatua forest - see Figure 2.

Figure 2 *Forest areas affected by the January 2011 event Taneatua and Omataroa.*

2.4 Forest estate land cover types commonly affected in the Bay of Plenty region

Recently harvested (<2 years) – these sites were the areas which suffered the greatest erosion which lead to the accumulation of woody debris in streams.

Recently replanted (<5 years) – sites with trees up to five years old were other areas to suffer erosion. However, the erosion was not as severe as recently harvested areas.

Established forest and indigenous bush (>5 years) – these areas were least affected but there were areas which were significant enough to record the erosion due to the extreme nature of the storm.

In addition, pastoral catchments bounding these forests were also affected with similar erosion types and severity. The big difference is that only soil and water were carried down to the flowing waterways from the pastoral land. Where forested land was affected, the erosion type resulted in debris flows carrying a substantial amount of forest debris.

Part 3: Basic forest management statistics for the Bay of Plenty region

The managed exotic forests cover in the Bay of Plenty region is approximately 270,000 ha.

The at risk area within the forest estate with slopes greater than 25 degrees is 25,700 ha which is approximately 9% of the Bay of Plenty forest estate.

The recent events showed that approximately 5% of the forest area identified as at risk was seriously affected. This was largely due to the path which the rainfall took and also due to the soils which overlaid the underlying geology which will be discussed in the next section.

A map which shows the locality of these high risk areas will assist forest managers with their identification for future management - see Figure 3.

3.1 District analysis of the potential problem

The forests now being harvested are located on Māori owned land with trusts who were forced to convert from farming to forestry some 30 years ago, as farming was uneconomic. Other forest plantation areas were converted from native forest to plantation forest under Government afforestation incentives at that time. For the 30 years or so that these forests have been growing they have also provided major soil and water benefits below them. In cases where the land was converted from farming to plantation forestry, they have controlled erosion problems which occurred while being farmed.

Regional economic assessments show forestry's financial contribution as approximately 10% of the regional GDP ($1billion dollars).

The potential effects of erosion problems on steep forested country as a result of extreme storm events is going to be more prevalent in the eastern part of the region. This is due to the predominantly steep topography which the forests are located on. There is also strong evidence to suggest that the rainfall patterns which are required to begin, this erosion process are more likely in the coastal areas of the region. When they were established, there was little attention paid to the potential environmental effects which would result pre and post-harvest.

The Ōpōtiki district has several forests which have the steep topography, soft geology and weather patterns which place them in a high risk category for woody debris mobilisation. Some of those forests include but are not restricted to Waiotahi, Houpoto, Tōrere, Orete, Wairata, Waikawa and Ōmaio. All forests are located on very steep country with a coastal rainfall influence which has tended to be high intensity short duration rainstorms originating from downgraded tropical cyclones.

The Whakatāne area forests which exhibit high risk traits are Tāneatua, Kiwinui, Omataroa, Tūhoe, Te Manawa o Tūhoe, Sisams and Ngāti Manawa. The underlying recent unconsolidated volcanic geology coupled with steep geology and heavy rain can and has led to the mobilisation of woody debris.

Although forestry is located throughout the Bay of Plenty region the risks in other districts is less likely on the scale recently witnessed in the Eastern Bay of Plenty areas.

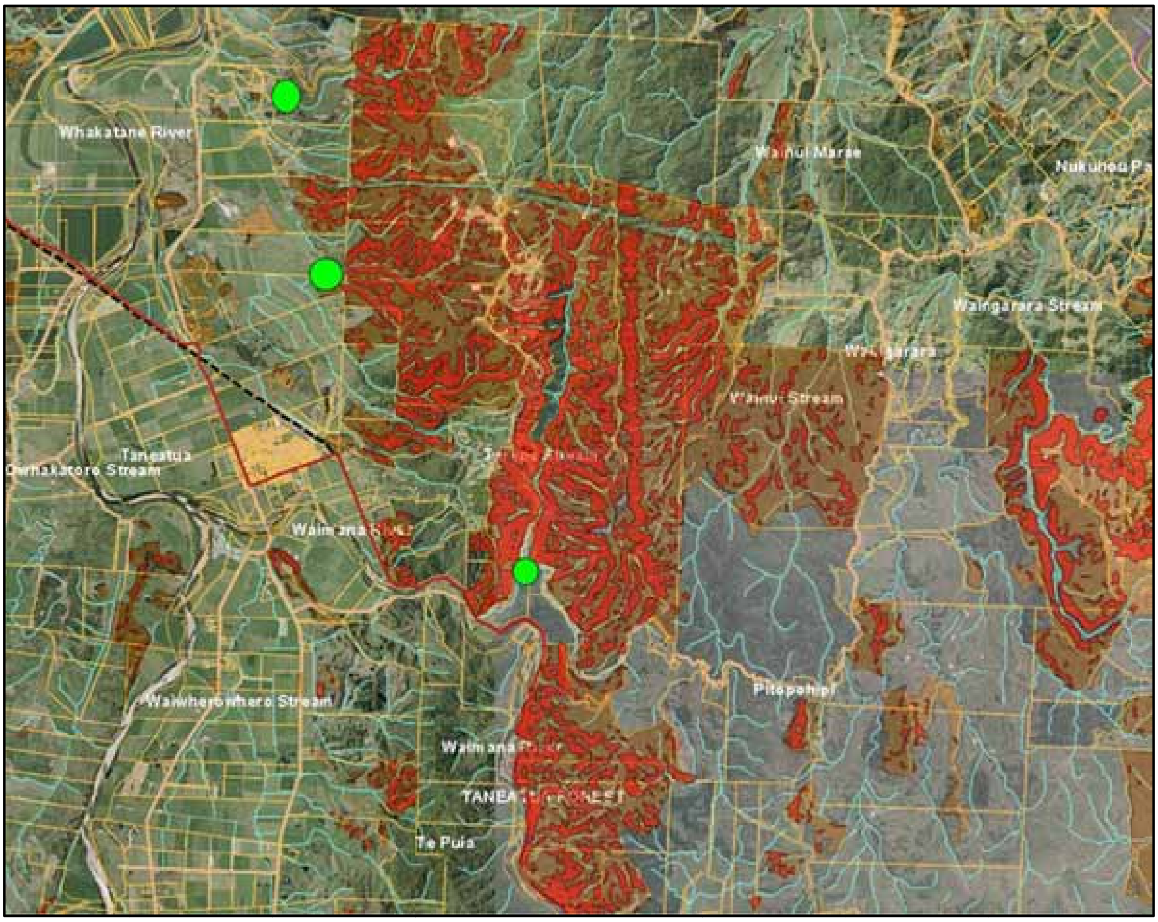

Figure 3 *An example of Taneatua forest with slopes in excess of 25 degrees shown in red .Green circles are where debris flows have occurred.*

3.2 Types of damage resulting from the woody debris build-up

The first noticeable damage which occurred was at the point where the debris had been deposited and or was eventually halted. The material was generally backed up against bridges, culverts, farm fences, heavily wooded native bush or deposited in streams and their floodplains.

There was significant debris deposited on paddocks, tracks, roadways, in estuaries and on beaches. Capital works and structures have been affected with significant damage due to woody debris build-up but this has been largely within forest estates. Recent examples of significant capital works damage occurred in the Ōmaio area, Ōpōtiki. This was caused by woody debris, but this catchment was exclusively indigenous and the woody debris was indigenous. The potential risk to from exotic woody debris to infrastructure still remains as much of the woody debris is now trapped in inaccessible areas which need another event to re-mobilise it.

The natural loss of the soil from the slopes as a result of erosion has affected many aquatic ecosystems through deposition into once pristine ecological areas. It must be noted however that this mid slope failure has been attributed to extremely heavy rainfall and similar soil loss was more serious in adjoining pastoral areas with similar soil types and slopes where extreme rainfall events had occurred – see Photo 5.

A comparative study of a pastoral versus forested area in the Pakaurutahi catchment, in the Hawkes bay, showed that the soil loss from pastoral areas was higher over a 30 year period, than the soil loss from a forested catchment despite soil loss peaks during the harvesting and re-establishment phases of the forest operation.

Photo 3 Significant erosion which carried logging slash downstream in the Waiotahi area.

3.3 Forest owners response

The forestry companies have been assisting with the clean-up on farm properties affected by accumulated debris. Bay of Plenty Regional Council staff have also been asked to assist with advice by both forest owners and landowners.

The forest industry, regional council staff and other technical experts have been discussing the future practices which will reduce or eliminate the mobilisation of woody debris. Considerable consultation with forest managers has taken place to date. Much of this has been in the field along with numerous helicopter inspections to assess the scope of the problem.

The woody slash/debris is normally used as part of the rehabilitation process of harvested sites. This is because it provides organic material and can reduce some aspects which lead to erosion such as rainfall impact on bare soils. Forest material used to be burned as a part of the replanting process. This was replaced by herbicide desiccation due to the many complexities and consent requirements for burning to commence.

This is a new issue for many forest managers and they are responding by planning harvest operations to minimise the likelihood of this problem occurring. There is also going to be more collaborative approach to come up with ideas which could reduce or minimise the problems. This will involve using a range of technical and mapping information to help identify high risk areas. Working collaboratively with regional council, research providers and technical experts to research the issue with a view to finding solutions is also necessary.

Photo 4 Gully erosion which carried logging slash downstream.

The Bay of Plenty Regional Council will review resource consent conditions to see if the current conditions are adequately dealing with the problem. The forest industry is very concerned with this problem and it will be discussed at the next Bay of Plenty Forestry Forum meeting.

Photo 5 Pasture adjacent to forests also suffered significant erosion.

3.4 Research and literature review

There is little research on how slash becomes mobilised and the physical processes involved on slopes. Most research has concentrated on the effect mobilised woody debris has had from a stream bank erosion perspective. The following research covers high intensity storm events on hill country and harvested forest areas. Most research looks at sedimentation from erosion, although there is also some work covering failure of log landings. The following four are brief examples of relevant research.

1 Selby MJ 1976

Slope erosion due to extreme rainfall a case study from New Zealand. Selby M.J. 1976. Department of Earth Sciences University of Waikato, Hamilton.

ABSTRACT*. The characteristics of three high intensity rainstorms, and the landslides they induced, in the greywacke ranges of the South Auckland district, New Zealand, are described. The return period of storms of such magnitude that they cause land sliding in grassland areas is about 30 years, and similar erosion in forested catchments is caused by storms with a return period of about 100 years. The landslides are in deeply weathered sandstones and siltstones. Most landslides are of the debris avalanche type. Landslides occur preferentially on upper slope segments and as a result slope evolution produces an upper slope convexity.*

The relevance of this is due to the similar scenarios which exist after forest has been harvested from steep slopes are similar to that which has a pasture cover.

2 Fahey & Marden 2008

A report titled Forestry Effects on Sediment Yield and Erosion Hawkes Bay by Barry Fahey and Mike Marden was completed in 2008.

This study compares sediment yield from the Pakuratahi catchment (3.45 km^2) in mature forest, that was subsequently harvested and replanted, with that monitored over the same period in the adjacent Tamingimingi catchment (7.95 km^2) left in pasture. The broader question of whether land in pasture or forestry can be expected to generate more sediment in the longer term, is also considered. In addition, the relative contribution of the various sediment generating processes to sediment yield are assessed, together with the degree of site disturbance, and subsequent vegetation recovery.

3 **Pearce & Hodgkiss 1987**

Erosion and sediment yield from a landing failure after a moderate rainstorm, Tairua Forest. Pearce A.J. & Hodgkiss P.D., 1987.

A 1.5 to two year return period rainfall event caused substantial erosion of a recently formed log landing in Tairua Forest, Coromandel Peninsula. Sediment yield from the catchment affected was 3000 times larger than from an adjacent catchment during the storm. Steep slopes leading directly into streams are particularly hazardous because fill failures are likely to create debris slides or failures which will transport large volumes of sediment into streams.

4 **Phillips, Marden & Rowan 2005**

Sediment yield following plantation forest harvesting, Coromandel Peninsula North Island New Zealand. Phillips C, Marden, Rowan D 2005.

This study looked at Sediment sources and delivery following plantation harvesting in a weathered volcanic terrain. The sediment yield from two storms with annual to two year return periods was measured. The two storms contributed to 37% of the total sediment yield off the harvested area.

3.5 Measuring flood events and storm events

There is a difference between **flood events** and **storm events**.

A **flood event** is the discharge (volume of storm water flowing per second) measured at a specific point in a catchment. A 50 year flood event for a catchment must be qualified by noting where the flood is measured. For instance, a 50 year flood at a culvert in a particular stream can be used to specify a flood event.

A **storm event** is a measurement of depth of rainfall over a specific time period. Therefore a 50 year rainfall event must be qualified by noting the storm duration. For instance, a 50 year 10 minute storm has a different rainfall depth to a 50 year 24 hour storm. Another complicating factor is that a 50 year 10 minute storm in one part of the catchment is likely to be different to a 50 year storm event in another part of the catchment. This is because rainfall patterns change according to locality. This variability in rainfall is addressed by using programmes such as HIRDS (High Intensity Rainfall Design System), where you enter the location of the site and the programme gives you a full range of rainfall depths, based on different duration and return periods. For more details on probability see Appendix 1.

3.6 Discussion

Using probability analysis, you can calculate the risk of a critical storm (5, 10, 20, 50 or 100 year storm) that may occur during a harvest period. This can then be used to decide whether to spread the risk over a number of years by harvesting a smaller area each year, or to harvest the whole area in one year, and carry the risk over the whole area for a shorter period. Generally speaking, if the risk is high, then it would be better to spread the risk over a number of years so that the area likely to be affected is smaller than if the whole area was exposed at once.

Similarly, you can calculate the risk of having a storm of (say) five year return period while undertaking earthworks over a short period (say two months). As you increase the length of time over which the works are undertaken, you increase the risk that you will get a five year storm event.

Choosing an appropriate storm duration may require some consideration. For earthworks, appropriate storm durations could be relatively short (30 minutes to 1 hour), as short duration/high intensity storms tend to cause problems with earthworks. Another factor to be considered is that over the late summer/autumn period, there is a higher likelihood of the intense cyclonic storms from the east and north-east. However, for slip or earthflow erosion, longer duration storms such as 24, 48 or 72 hour storms are often the ones that cause problems because the ground saturated over the longer time period, and this increases the likelihood of slip or earthflow erosion.

Regional council staff should consider what storm events should be used as the critical storms for harvesting operations. This will very likely be different depending on the receiving environments. The risk is increased if the post-harvest regime is pastoral rather than forest.

The Bay of Plenty Regional Council already takes risks into account for earthworks operations through the Winter Earthworks Policy. As long as forestry earthworks follow Best Management Practices, and are undertaken over the summer earthworks period, (15 September through to 30 April), the regional council accepts that the risk of a storm adversely affecting the earthworks is provided for. There will be times when excessive sized storms destroy earthworks. However, as long as the works are undertaken in accordance with the Winter Earthworks Policy, then the Council has accepted that the operations have been undertaken in accordance with good engineering practice and in line with acceptable risk management.

Part 4: High risk land in the Bay of Plenty region

4.1 Introduction

In 1995, as a precursor to developing a framework for monitoring sustainable land management in the Bay of Plenty region, a Regional Council project team identified eight At-Risk land areas classes in the Bay of Plenty.

4.2 Background

The eight At-Risk land areas were identified as being particularly susceptible to erosion, and were derived from Land Management Suites based on the New Zealand Land Resource Inventory (NZLRI) data. The NZLRI uses land use capability assessment to classify land according to its suitability for long term sustainable productive use after taking into account the physical limitations of the land.

4.3 High risk land based on land management suites

The following land types were identified as being high risk from underlying geological erosion during extreme rainfall events – see table 1.

Table 1 High risk land types analysis for the Bay of Plenty.

Land types	Erosion type	Forest estate location
Sand Country	Wind	Matakana Island. Wind erosion
Kaharoa Ash (deep)	Slip, sheet, gully, streambank	Rotoehu, Pongakawa
Kaharoa Ash over lapilli	Sheet, slip, gully, streambank	Tāneatua, Ōmataroa,slip and sheet erosion, Matata
Recent tephras (Tarawera Ash, non-arable)	Gully, streambank	Tarawera forest
Recent tephras (Rotomahana mud, non-arable)	Slip, gully, streambank	Highlands forest, Whakarewarewa,
Taupo Pumice – Flow Tephra (arable)	Severe gully, slip, sheet, streambank	Kāingaroa,
Taupo Pumice – Flow Tephra Taupo Pumice – Waimihia Lapilli (non-arable)	Severe gully, slip, sheet, streambank	Minginui, Tūhoe, Waimihia
Mudstone / Argillite	Sheet, gully, streambank	Tōrere, Orete, Houpoto

These eight high risk classes of land have been identified using a robust system of land classification that is based primarily on land use capability assessment. While the eight classes of land were identified as having an inherent high risk of erosion, their identification is seen as a first step in identifying land that may be at risk from establishment into plantation forest – see Figure 3.

Other factors that should be considered include steepness and risk of sediment or debris affecting watercourses. This will mean that steep slopes and proximity to watercourses are predisposing factors that need to be taken into account when identifying high risk land.

Where there are compounding factors such as steep land overlain by Kaharoa Ash or recent tephra's, then the combination of these predisposing factors carry an inherently higher risk of erosion problems.

Recently harvested plantation forest slopes over 25 degrees are considered to have a high risk of debris movement under extreme storm events or when soils are saturated. Slopes of over 30 degrees are considered to have a severe risk. Where these high risk slopes (over 25 degrees) are in close proximity to perennial watercourses, then the risk is considered to be severe.

It is noted that the erosion characteristics associated with these severe storm events are for mass movement erosion and gully erosion, rather than surface erosion. This indicates that saturation by prolonged rainfall is often a predisposing factor that needs to be taken into account. While the extreme high intensity rainfall events are capable of causing debris flow events, it is often more likely that the prolonged rainfall events and/or saturated soil conditions are likely to be common triggers.

Part 5: Recommendations

The following five recommendations were developed from the project working party.

5.1 Mapping areas with slopes greater than 26 degrees within the forest estate

In all instances steep slopes have been one of the main factors which has led to the mobilisation of woody debris. The slope angle which started this process was greater than 26 degrees.

Using spatial mapping, slopes greater than 26 degrees within the forest estate can be shown. This will begin to help forest managers identify areas which have a high likelihood of eroding due to steepness, thereby depositing transporting slash into gullies and eventually into water bodies if this slash remains following harvest. This identification has been carried out by Bay of Plenty Regional Council and has been overlaid on the Bay of Plenty forest estate map.

5.2 Identify the underlying geology and soils associated with these areas

Using spatial mapping, a map layer has been created showing the soils which indicate a high risk of eroding during extreme rainfall events. A table naming the soils, their erosion risk types and general forest location has been created as a guide to assist forest managers – see Table 1 and Figure 3.

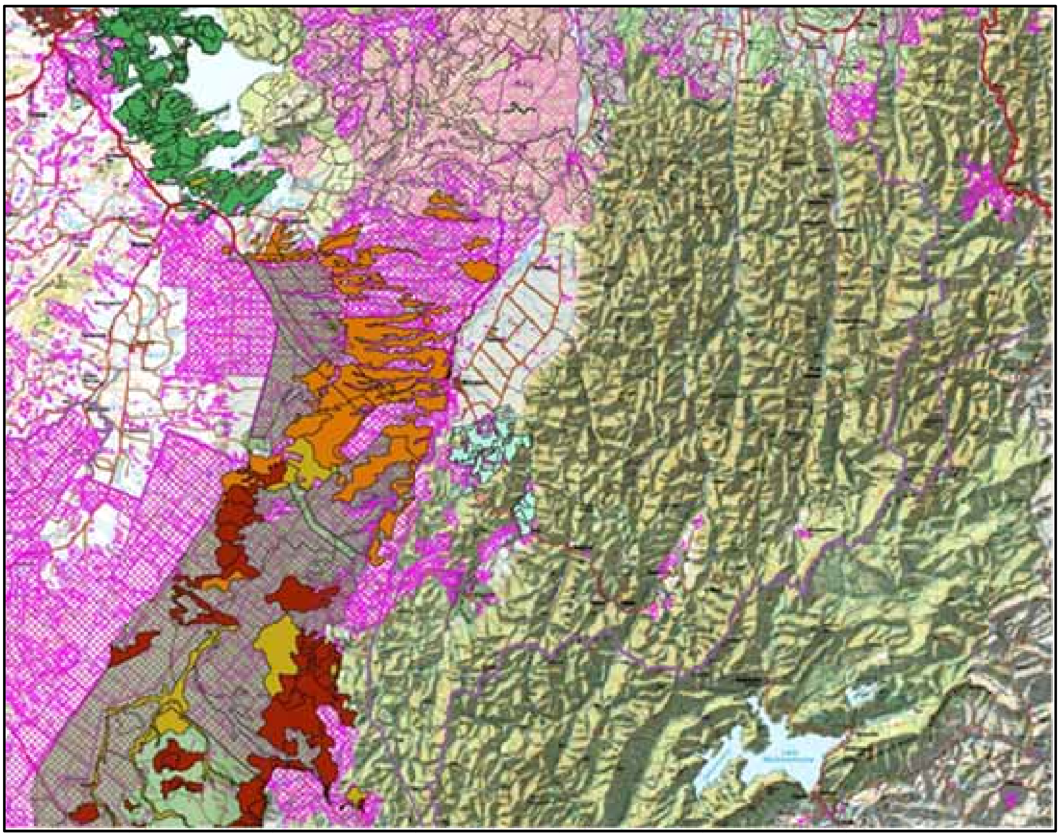

Figure 4 A spatial example showing high risk soils within the Kaingaroa forest.

The example shown above will need some in forest assessment carried out to see what specific sites within it are susceptible to underlying geological failure based on the factors previously discussed.

5.3 Implementation of the following operational practices where appropriate

5.3.1 Slash removal

Physically remove slash from the at-risk harvest site. This particularly applies to large diameter material such as logs longer than four metres with an S.E.D of 30 cm, large slovens and intact tree heads. The pushing of slash from skid sites into areas with a high likelihood of underlying failure on very steep slopes should not be carried out. If there is a requirement to dispose of slash in this way, it should have as much organic material removed from it. The slash should also be placed on a stable excavated bench which should not be overloaded by ensuring that it is visible.

5.3.2 Burning

Eliminate logging slash from steeply incised gullies identified as above, by burning at these particular sites. It is not ideal, but where there are no other methods for slash removal this will have to be considered as a mitigation tool. Where recently established trees (up to 5 years old) exist and a threat has been identified it will be difficult to carry out so may have to be dealt with at the eventual discharge point.

5.3.3 Poison standing trees

Trees which have little chance of being recovered during harvesting should not be felled to waste if they are to remain within the steep highly erodible areas. They should be poisoned standing and left to break down slowly. This can be done by drilling the stem and applying a herbicide such as Glysophate into the stem. This will also allow suitable regrowth to establish between the poisoned stems as the canopy dies off

5.3.4 Interception of woody debris below vulnerable sites

Slash racks located on alluvial fans where the problem is likely to occur is another mitigation option. These will require heavy machine access so that the slash racks can be easily cleared when build-up of slash occurs. The slash racks are usually constructed using railway irons and wire rope driven into a floodway area where slash can accumulate. The slash racks should not be placed across gullies or in streams.

Standing managed forest trees on alluvial fans can also be used to contain woody debris during extreme rainfall events. A structure would have to be constructed in the floodway to guide the woody debris into the trees when the stream was in full flood.

Photo 6: An alluvial fan which would be suitable for the construction of a slash rack.

Partial harvesting of a highly erodible area so that the part of the vegetative cover remains intact until it is safe to harvest the balance. This would a high degree of planning to implement, but where the risk is so great that any of the above cannot be considered this will become a viable option.

5.4 Education and information transfer

Discuss the BMP recommendations with the forestry forum .This is a forest manager's forum who deal with operational matters affecting forest practices in the Bay of Plenty region The Bay of Plenty Forestry forum is to meet to discuss the findings and begin to develop identification processes and practices to minimise the threat which has occurred.

Finalise the BMP recommendations. The Geospatial information should be made available to forest managers and training carried out where required to ensure that the information supplied is fully understood. This can be done through field days both in a classroom situation and application of that information to a field scenario. It can be included in the overall environmental risk analysis when considering harvest operations.

5.5 Consent drafting alterations

Consent staff are considering what consent conditions will need to be reviewed in light of the recent events. This is being carried out as part of an operational review of the Bay of Plenty Earthworks and Sediment Guidelines for Forestry.

Woody debris has been regarded as one of the rehabilitation tools which assist with the stabilisation of steep hill slopes by protecting bare hills slopes from rainfall impact and holding seeds applied for re grassing on site. In the vast majority of cases this woody material will carry out that function without causing any real problems. The conditions which exist at present which allow it to remain where it lies are largely that the area is not a flowing water body. At present there are no rules which can be used to enforce the removal of that woody material.

5.6 Conclusion

Critical storm sizes should be used to assist in the planning of harvest operations.

In general terms, earthworks are reasonably well catered for through the Winter Exclusion Policy. Also, if earthworks are undertaken over a very short time period (less than three months) and stabilised on completion, then the likelihood of being affected by a small to moderate sized storm (up to 10 year storm) would be minimal.

However, when planning to harvest large areas of forest, particularly on steep erosion prone country and/or in proximity to streams, critical storm events should be used as a basis to help manage risk for the duration of the time when the harvested area is susceptible to adverse storm events. The risk management is likely to be for a number of years until the ground cover/forest establishment is able to achieve effective stabilisation.

Appendix 1 – Probability concepts using frequency analysis

Hydrologic design is often based on frequency and often described in probabilistic terms. Probability can be equated to Risk.

Probability basics:

Tossing a coin Probability (heads) = 0.5
Probability (tails) = 0.5

The 100 year storm:

The probability of a 100 year storm occurring in any one year has a 1% chance of occurring.
P = 0.01 = 1%

The average return period (recurrence interval) is defined as T = 1/P = 1/0.01 = 100 years.

The probability that an event will occur in any year is P = 1/T.

The probability that an event will not occur in any one year is P = 1–1/T.

The probability that an event will not occur for n successive years is:
P1 * P2 * ....* Pn = Pn = (1 – 1/T)

The probability (risk) that an event will occur at least once in n successive years is:
R = 1 – (1 – 1/T)n

Probability examples:

(a) What is the chance of a 100 year storm (the 1% Annual Exceedence Probability [AEP] storm) occurring in a 50 year period?

$R = 1 - (1-1/T)^n$
$R = 1- (1-1/100)^{50}$
$= 0.395$
$= 39.5\%$

(b) What is the probability of the 100 year storm occurring in 100 years?

$R = 1 - (1-1/T)^n$
$R = 1- (1-1/100)^{100}$
$= 0.63396$
$= 63.4\%$

(c) What is the probability of a five year storm occurring in a two month period?

$R = 1 - (1 - 1/T)^n$
$R = 1- (1 - 1/5)^{1/6}$
$R = 1- (0.8)^{0.1666}$
$= 0.0365$
$= 3.65\%$

From the information above, we can show that the shorter time period that it takes to undertake earthworks, the lower the risk of getting a severe storm over the period. If we undertake earthworks over a two month period and stabilise the area immediately on completion, the chance of a five year or larger storm event occurring over that time is only 3.65%.

(d) What is the probability of a fifty year storm occurring in a five year period?

$R = 1 - (1 - 1/T)^n$
$R = 1 - (1 - 1/50)^5$
$R = 1 - (0..98)^5$
$= 1 - 0.90$
$= 10\%$

If we assume that it takes up to six years for a harvested forest to have reasonably full canopy cover to protect it from a severe storm event (20 year return period) but not a severe storm event (50 year return period or greater), then there is a 10% chance that a 50 year storm or greater will occur over a five year period until reasonably full canopy cover is achieved at age six. Using the same formula, there is a 15% chance that a 50 year storm or greater will occur over an 8 year period until full canopy cover is achieved at age nine.