# Appendix One

## Images from helicopter flight

Image 1D1A0553  Waimanu Forest. Slash within standing pine, slash piles on flood plain, minor lower slope slipping, some movement mid slope gully.

Image 1D1A0563  Waimanu Forest, Slash in gullies, sidecasting .

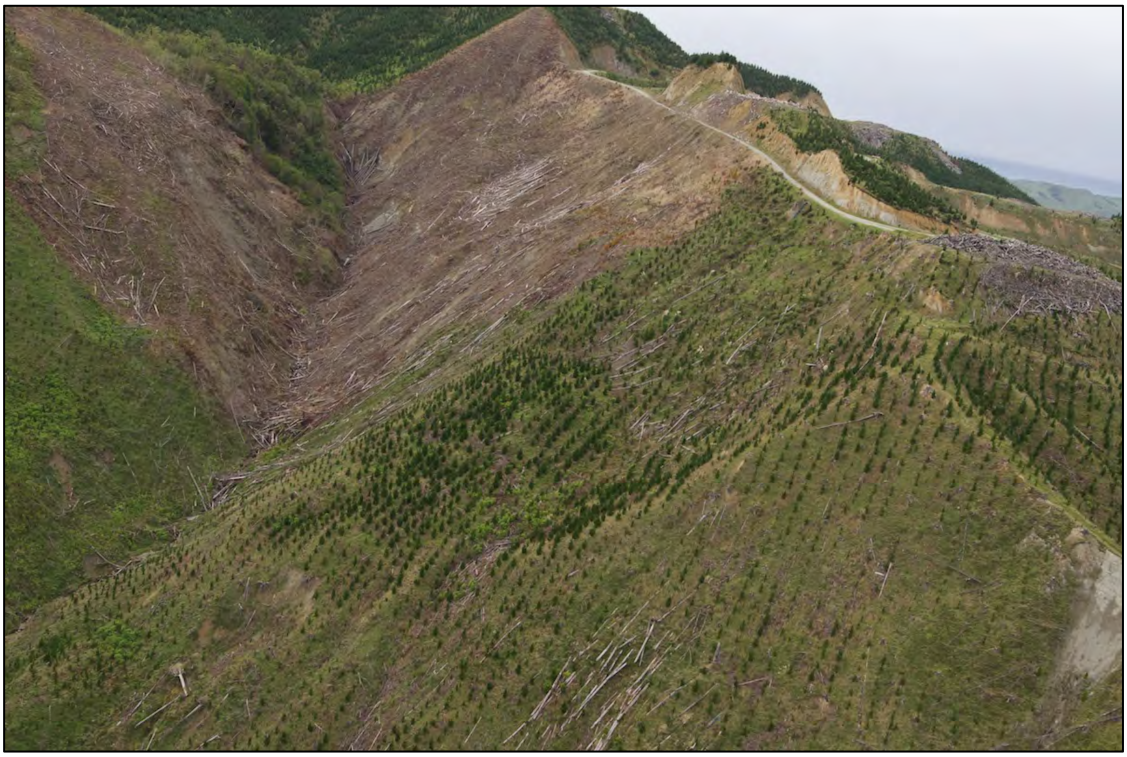

Image 1D1A0591Waimanu Forest, Slash in gullies and on unstable slopes, some mid slope failures.

Image 1D1A0599. Waimanu Forest, slash on slopes and valley floor.

Image 1D1A0612. Extensive slash in gullies.

Image 1D1A0617. Makahakaha Stream. Extensive slash in gullies and in valley floor.

Image 1D1A0657. Waimata Valley near Duncan Road. Fresh scarring on existing mid slope slips.

Image 1D1A0687. Waimata Valley north of Duncan Road. Small headwall failure in existing debris flow channel.

Image 1D1A0692. Waimata Valley Fresh headwall movement in pre-existing slip.

Image 1D1A0780. Near Tauwhareparae Road. Pre-existing headwall failure off old forestry access road to landing.

Image 1D1A0809. Doonholm Slip Tauwhareparae Road.

mage 1D1A0913. Wigan Bridge Tauwhareparae Road.

Image 1D1A0981. Operational landing, Mangatoitoi Stream, Tauwhareparae Road.

Image 1D1A0983. Forestry roadworks and slip clearing between Mangateao and Mangatoitoi streams, Tauwhareparae Road.

Image 1D1A1005. Tapuae Stream forestry operations

Image 1D1A1007. Tapuae Stream, slash in stream and on flood plain close to river.

Image 1D1A1008. Tapuae Stream, slash in stream and on flood plain close to river.

Image 1D1A1011. Tapuae Stream, slash in stream and on flood plain close to river.

Image 1D1A1026

Image 1D1A1030. Tapuae Stream, slash in stream and on flood plain close to river.

Image 1D1A1045.Tapuae Stream, extensive slash in stream and on flood plain close to river.

Image 1D1A1058. Tapuae Stream, extensive slash in stream and on flood plain close to river. Messy landing vulnerable to severe flooding.

Image 1D1A1069. Tapuae Stream, extensive slope scarring from forestry operations.

Image 1D1A1073. Tapuae Stream, slash in stream and on flood plain close to river.

Image 1D1A1075. Tapuae Stream, slash in stream and on flood plain close to river.

Image 1D1A1650. Mata River upstream of Whakoau Stream showing flood heights.

Image 1D1A1655. Mata River upstream of Whakoau showing buffer of trees left above steep bluffs on true right bank.

Image 1D1A1708. Whakoau stream showing recently harvested area upstream of Bremmer Bridge, landing on flood plain and slash within riverbed.

Image 1D1A1723. River crossing at Whakaou Stream showing slash inriverbed and blocking river crossing.

Image 092913 Mangatoitoi Stream cellphone image looking upstream towards operational area showing birdsnest of logs in stream and slash stowed adjacent to flood plain on both banks.

Image DJI0202. Drone image from Mangaheia River upper Tauwhareparae Road showing slash pile on river terrace, fresh slipping from edge of forestry roadway (far right) and slumping of river banks.

**Managatokerau Stream Traverse Images**

Photo of cut butt end, small dross and pine log. Base of Waterfall Creek, above road.

Cut butt end clean up area below road in Waterfall Creek.

Log pile in clean up area below road at Waterfall Creek showing cut and broken logs.

View of base of Waterfall Creek above road showing abraded end log, some dross and debris flow trim lines.

Logs on true left bank of Waterfall Creek showing height of debris flow.

Pine log at debris flow height. Waterfall Creek

Cut pine log and dross. Waterfall Creek.

Pine log with bark still on and cut marks plus dross.

View looking down Waterfall Creek showing debris flow height.

View looking down waterfall in Waterfall Creek showing pine logs and dross.

Waterfall in Waterfall Creek showing abraded pine logs.

Birds nest of logs in Waterfall Creek showing one obvious cut log.

View of damage to standing tree trunk from force of debris flow in Waterfall Creek.

Cut log (bottom left) and dross in Waterfall Creek and debris flow trim lines.

Low resolution GPS reference photo of abraded log, Waterfall Creek.

Low resolution GPS reference photo of abraded cut log, Waterfall Creek.

Low resolution GPS reference photo of abraded cut log plus dross , Waterfall Creek.

Low resolution GPS reference photo of abraded and cut logs, Waterfall Creek.

Low resolution GPS reference photo of cut log and dross , Waterfall Creek.

Abraded cut log Waterfall Creek.

Cut Log Waterfall Creek.

Low resolution GPS reference photo of abraded logs and dross , Waterfall Creek.

Collapsed fresh pine as a result of stream wall erosion during debris flow.

View of large cut log above fresh collapsed pine. Waterfall Creek.

Low resolution GPS reference photo of abraded cut logs, and abraded logs Waterfall Creek.

View of log jam caught above willow (cf Figure 94 of report) in Te Kokokahahi Stream, Mangatokerau Valley.

Mangatokerau Stream below bridge (11th July) showing failure of river bank.

Image 1D1A3417. Pine log at Mangatokerau River Bridge; 11th July.

Image 1D1A3886. Cut pine logs and dross in the Mangatoitoi stream. The flood height in this area was above road level.

Wide angle panorama of Mangatoitoi Stream showing slash stowed at vulnerable height on edge of the flood plain (Images 1D1A3888 to 1D1A3896).

Image_0116. Mangatoitoi forestry road showing silt deposition from flooding and scattered logs.

Image_0107. View of flood trim line and slash pile at Magatoitoi forestry road.

Low resolution GPS reference photo of cut logs on edge of Mangatoitoi forestry road.

Image_0089 Slash pile above Wigan bridge prior to deconstruction showing cut logs and muddy debris. It was not possible to accurately determine overall proportion of woody debris types without pulling the pile apart.

Image 1D1A3424. Lower slash pile Wigan Bridge post deconstruction.

Poorly configured silt fence installed at Wigan Bridge.

Image 1D1A4315. View of mix of willow and pine woody debris caught up on banks of Tapuae Stream downstream of Paroa Road bridge.

New slash catcher installed at Whakoau Stream showing new logs including cut logs caught against catcher

**Mata River   Ihungia Bridge Traverse upstream October 21st**

Image 1D1A4221. View of pine and dross woody debris caught up in old bridge pile Ihungia.

Image 1D1A4225. Windthrow pine logs caught up against Ihungia Bridge.

Image 1D1A4236. Scattered small pine logs on riverbed, Mata River.

Image 1D1A4242.  Pine log, Mata River.

Image 1D1A4243. Abraded pine log and dross Mata River. Note flood height at top of bank.

# Appendix Two

## Tolaga Beach Slash Identification guide

**Windthrow Log** Has root structure or a rounded ball shape at one end. Can be willow or pine. Pine will be straight and willow may be irregular shaped or branched.

**Cut Log.** Log may look fresh or weathered. Shows signs of cuts and the cut colour looks the same as the rest of the log. Log in foreground is a cut log. Logs in background are irregular and branched and so are willow.

**Long resident log.** Will be weathered but with rounded, cone shaped or flat ends. Log may show Wharratah marks

**Long resident log with fresh cut (firewood)**. Log looks weathered but has a fresh cut

**Poplar.** Poplar has a distinctly different bark to pine. Willow can be distinguished from pine by its irregular shape and may have multiple branches.

# Appendix Three
## What is a Debris Flow?

### Debris Flow Definition

A debris flow is a moving mass of loose mud, sand, soil, rock, water and air that travels down a slope under the influence of gravity. To be considered a debris flow, the moving material must be loose and capable of "flow," and at least 50% of the material must be sand-size particles or larger (*Figure One*).

Some debris flows are very fast – these are the ones that attract attention. In areas of very steep slopes they can reach speeds of over 160 km per hour. However, many debris flows are very slow, creeping down slopes by slow internal movements at speeds of just 30 to 60 centimeters per year.

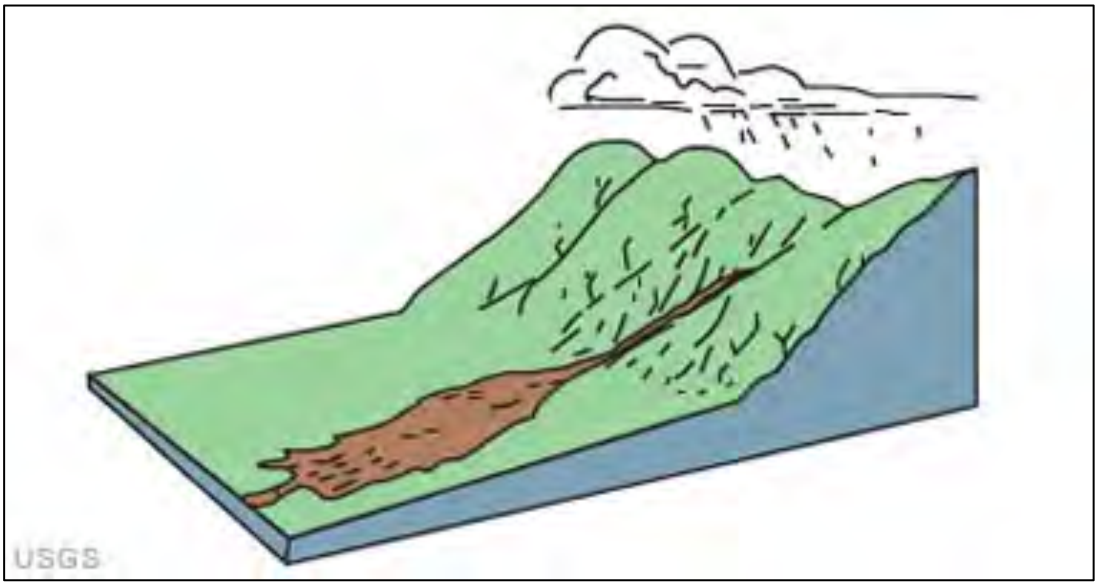


*Figure One. Debris-flow source areas are often associated with steep gullies, and debris-flow deposits are usually indicated by the presence of debris fans at the mouths of gullies. Image and caption by the United States Geological Survey.*

### The Debris Flow Hazard

The speed and volume of debris flows make them very dangerous. Every year, worldwide, many people are killed by debris flows. This hazard can be reduced by identifying areas that can potentially produce debris flows, educating people who live in those areas and govern them, limiting development in debris flow hazard areas, and developing a debris flow mitigation plan.

### Conditions Required to Produce a Debris Flow

The source area of a debris flow must have:
1) a very steep slope,
2) an abundant supply of loose debris,
3) a source of abundant moisture, and
4) sparse vegetation.

Identifying areas where debris flows have happened in the past (*Figure Two*) or where these conditions are present is the first step towards developing a debris flow mitigation plan.

*Figure Two. Venezuela debris flow. Material deposited by a prehistoric debris flow in northern Venezuela and exposed for view by stream erosion. Note the person for scale. The deposit consists of large sub-angular gneissic boulders supported by a sandy matrix.*

## Is It a Debris Flow, a Mud Flow, or a Landslide?

Debris flows differ from slides because they are made up of "loose" particles that move independently within the flow (*Figure Two*). A slide is a coherent block of material that "slides" over a failure surface (*Figure Three*).

A mud flow is composed of mud and water. Debris flows typically have larger particles – at least 50% of a debris flow is made up of sand-size or larger particles but this depends on source material.

## What Causes Debris Flows?

Debris flows can be triggered by many different situations. Here are a few examples:

**Addition of Moisture:** A sudden flow of water from heavy rain, or rapid snowmelt, can be channeled over a steep valley filled with debris that is loose enough to be mobilized. The water soaks down into the debris, lubricates the material, adds weight, and triggers a flow.

**Removal of Support:** Streams often erode materials along their banks. This erosion can cut into thick deposits of saturated materials stacked high up the valley walls.

This erosion removes support from the base of the slope and can trigger a sudden flow of debris.

*Figure Three. View of the Wallis Road Landslide, Kaiti Hill. Note that the material has remained coherent and is sliding downslope.*

*Figure Four. Debris flow apron at the north end of Kaiti Beach.*

**Failure of Ancient Landslide Deposits:** Some debris flows originate from older landslides. These older landslides can be unstable masses perched up on a steep slope. A flow of water over the top of the old landslide can lubricate the slide material, or erosion at the base can remove support. Either of these can trigger a debris flow.

**Wildfires or Timbering:** Some debris flows occur after wildfires have burned the vegetation from a steep slope or after logging operations have removed vegetation. Before the fire or logging, the vegetation's roots anchored the soil on the slope and removed water from the soil. The loss of support and accumulation of moisture can result in a catastrophic failure. Rainfall that was previously absorbed by vegetation now runs off immediately. A moderate amount of rain on a burn scar can trigger a large debris flow.

## Debris Flow Early-Warning Systems

Debris flows can be very dangerous. They can move at high speeds, travel long distances, and fill stream valleys up to 100 meters deep with debris. Signage is being used in areas where debris flow risk is especially high, For example North Kaiti Beach. One method uses sensitive seismographs to detect debris flows that have already started moving. Another uses radar precipitation estimates and established rainfall intensity-duration threshold values to determine when meteorological conditions are right for flows to occur.