Control of earthflow and slump erosion

What are earthflows and slumps?

Earthflows are made up of disintegrating soil and weathered rock, which moves by inter-particle or inter-layer shear above a failure plane in underlying rock. The failure plane may be either planar or curved. The ground surface breaks into hundreds of hummocks, roughly aligned as curving ridges at right angles to the direction of flow, and separated by tension cracks which form low scarps (Figure 1).

Figure 1. Typical earthflow terrain

Earthflows can occur beneath forest, but become particularly severe after tree cover is removed from susceptible terrain. Forest clearance not only removes root reinforcement from the soil; it also alters the soil's water balance. Beneath grass cover, ground dries out earlier in summer, but becomes wetter in winter. Successive wetting and drying cycles weaken fine-grained rocks. Mechanical strength and chemical bonds are gradually lost, until the subsurface layer of disintegrating rock and clay starts to move whenever it becomes saturated with water. Movement is typically slow and protracted, amounting to no more than a few metres each winter.

Slumps are made up of several more-or-less intact blocks of soil and weathered rock, which move downslope above a curved shear surface in underlying rock. The moving mass is separated from the slope behind by a high vertical rupture or headwall. It breaks into an uneven surface of backward-tilted segments separated by lower ruptures or scarps (Figure 2). Drainage is disrupted, and swamps or ponds develop in depressions between each segment and scarp.

Slumps are initially triggered by some catastrophic event; for instance an earthquake, or a flooded stream undermining the base of a hillside; or an exceptional rainstorm. Initial collapse is rapid, followed by slower ongoing movement of the debris for several years. Eventually the hillside stabilises, is colonised by vegetation, and can even be clad by standing native forest several hundred years later. However, a thick layer of mixed-up rock and soil remains beneath. Smaller slumps or earthflows may re-activate, during heavy rainfall or wet winters.

Figure 2. Typical slump terrain

Earthflows and slumps are widespread on fine-grained rocks that weather to clay. Examples are mudstone, argillite and schist. On coarse-grained rocks such as sandstone, greywacke or volcanics, they are restricted to localities where the rock has been excessively weathered; for instance crush zones along earthquake faults, or hydrothermal alteration zones near volcanoes. Earthflows and slumps occur naturally under all types of vegetation, though at different rates.

Extent in Taranaki

30,400 hectares of land are susceptible to earthflows and slumps, or just 4% of the region. Susceptible land is dotted through the eastern hill country as pockets of rolling terrain. Slopes are typically 8 to 20 degrees. They can be anything from a few hectares, up to hundreds of hectares in extent.

Impacts of earthflow and slump erosion

If earthflows and slumps are geological phenomena, and if their extent is limited, are they worth worrying about? Can anything be done to fix them? The answer is yes to both questions.

They comprise some of the best farmland in the eastern hill country. Most pockets of rolling terrain have been cleared for farming. They have a layer of airfall ash soil (often mixed with clay and rock fragments), that grows good pasture and is in many places able to be cultivated. Fencing, tracking, water supply, and mustering are a lot easier on the rolling terrain, than on the steeper hills.

However, farming is often disrupted by renewed earthflow or slumping on parts of their surface. The impacts are:

- Damage to fences, access tracks and water supply,
- Break-up of good pasture into ridges or hummocks separated by tension cracks, depressing dry matter production,
- Seepage and ponding of soil water, which can restrict stock movement,
- Debris entering waterways, where it obstructs drainage.

Soil conservation techniques for controlling earthflows and slumps

1. Re-contouring and pasture renewal

Pasture broken-up by an earthflow or slump can lose about 40% of its dry matter production due to tension cracks, drying-out of grass on knobs, and waterlogging in hollows. Re-contouring to a smooth surface, sometimes by discing or blading, more often by bulldozing, is a pre-requisite to pasture renewal (Figure 3). Fertilisation, liming and seeding can then restore dry matter production to 90-100% of its former level.

Figure 3. Slump country following re-contouring.

As yet the Council does not have an information sheet about pasture renewal, though its Land Management Officers can supply verbal advice. Re-contouring and pasture renewal is restorative techniques only. The benefits may persist on historic slumps or earthflows that are now inactive. However where parts of an earthflow or slump surface is susceptible to re-activation, erosion gradually break up the pasture again, unless drainage is installed and trees are planted.

2. Drainage

To prevent future movement, drains must be installed to de-water the moving debris. Several different types of drain can be used:

- Graded banks: intercept runoff across the earthflow surface, diverting water into drains or streams to the side (Figure 4)

Figure 4. Graded banks across the hill slope used to intercept surface runoff.

- Spring-taps: collect groundwater springs on a flow's or slump's surface and divert it away to adjacent drains or streams.
- Shallow surface drains: drop the water table slightly; often enough to stabilise the top metre of soil but do not stop movement deeper in sub-soil (Figure 5).

Figure 5. A shallow surface drain installed to remove excessive water away from the slip plane.

- Deep surface drains: an open drain 2 to 3 metres deep above the head of an earthflow or slump can divert shallow groundwater sideways, so that it doesn't lubricate the moving debris.
- Sub-surface drains: a drain up to 5 to 6 metres deep, with a pipe surrounded by gravel at the bottom, backfilled with soil on top. May be needed to divert groundwater from the head of a deep-seated flow or slump.

- Horizontal bores: a perforated PVC pipe drilled from the toe of a flow or slump, upward at a slight angle. Used to intercept groundwater rising beneath a deep-seated failure. Installed in quantity, they are able to drop soil pore water pressure throughout the moving mass (Figures 6 and 7).

Figure 6. The drilling of a horizontal bore.

Figure 7. A pipe inserted into a horizontal bore for draining the slip plane.

- Wells: a vertical shaft sunk through the moving mass. Horizontal bores can be drilled outwards from the well. Groundwater seeps out, collects in the bottom, and is led away by a drainage pipe.

3. Spaced planting of trees in pasture

This is a good preventive technique on earthflow or slump terrain that is currently inactive or just starting to move (Figure 8); as well as on active terrain that has just been re-contoured. The lateral roots of fast-growing trees meet up throughout the top metre of soil. On flows or slumps up to 5-6 metres deep, they form a resistant layer - like a membrane - against outward or upward movement of the subsoil. Where the failure plane is 5 to 10 metres deep, the mass of moving subsoil is greater so tree-planting alone is unlikely to suffice; it must be supplemented by drainage.

Figure 8. Shallow earthflow stabilised by space-planted poplars and willows in pasture

Spaced planting, supplemented by drainage where needed:

- Does not totally prevent future movement, but reduces its area by 50 to 80% compared to an unplanted paddock,
- Has minimal impact on dry matter production, because any lost through canopy shading (about 20% beneath the trees) is more than compensated by avoiding the dry matter loss (around 40%) on areas that would have moved in the trees' absence.

Poplars or willows are normally used, because they are fast growing, have extensive lateral roots, and the least canopy density.

4. Close planting of trees on land retired from grazing

Where earthflows or slumps cannot be stabilised in pasture by a combination of the three techniques listed above, close planting with trees is another option (Figure 8). Poplars or willows may be used; alternatively pines or other conifers such as redwoods. The root network of a close planting is much denser than that of a spaced planting, so is able to arrest a greater mass of moving subsoil. The de-watering effect of a dense coniferous planting may also help - a greater percentage of rainfall is intercepted by and evaporated from the tree canopy without ever reaching ground level. Surveys have demonstrated that blanket afforestation:

- Does not totally prevent future movement, but reduces its area by 90% or more compared to an unplanted paddock.

This technique has the disadvantage that grazing is lost. However, close-planting a small area of particularly severe earthflow or slump, will prevent it from eating back into other parts of the rolling terrain that is normally preferred for stock management on a farm. If conifers are planted, there is the prospect of future income; though they should be promptly re-planted after harvest so that a new root network can develop as the old one decays.

Figure 9: Deep-seated earthflow stabilised by close-planted pines on surface with poplars up gullies.

5. Streambank and gully stabilisation

Old slump terrain is often reactivated by a stream eroding its toe or by a gully eating back through the debris. In these circumstances, pasture renewal, drainage and spaced planting has no chance of stabilising the slump itself, unless the streambank and / or gully are also stabilised. Options for doing this are:

- Close planting of the streambank or gully,
- Retirement and reversion to bush or scrub cover,
- Small-scale engineering works e.g. debris dams, drop structures.

Further information

Earthflows and slumps are not widespread in Taranaki, but they affect some of the best farmland in the hill country. There will always be some re-activation of existing failures because of their geology. On rare occasions, completely new failures will occur through earthquakes or undermining by streams. In both situations, a raft of techniques is available to repair damage and restore production. Some are simple, low-cost, and can be undertaken by farmers themselves. Others entail engineering design, outside contractors, and substantial expense. Inspection is usually needed, to work out an appropriate mix for each site.

For further advice and assistance, contact:

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