Logging Impacts On Streams

Photo: Andrew Murray

NEFA BACKGROUND PAPER
Logging impacts on streams
Prepared by: Dailan Pugh, 2014

In a natural forest most water movement occurs as subsurface flows seeping through the ground. As recognised by Campbell and Doeg (1989) *"Overland flow is rare in undisturbed temperate forest because the soil strata are usually able to absorb all the precipitation reaching the ground (Pierce 1967). The destruction of protective vegetation and compaction of the soil surface that is associated with timber harvesting procedures reduces soil permeability to water increasing erosive surface runoff"*.

As noted by Cornish (1980) *"the quality of water emanating from virgin forested catchments is generally of the highest order. A reduction of quality may occur as a consequence of operations associated with logging, and this is frequently due to an increase in stream sediment concentrations and associated turbidity levels."*

In a logging operation the removal of vegetation allows an increase in rainfall volumes and the force of raindrops reaching the ground, and thus a greater mobilisation of soil particles can occur. Movement of machinery and dragging of logs causes an increase in compacted areas of soil surface and removal of topsoil, thereby reducing the permeability of the soil and increasing runoff, as well as causing channelling and creating loose soil for easy movement. In the short term the removal of the canopy also decreases transpiration, allowing water tables to rise and the soil to become saturated sooner and begin generating overland flow, particularly nearer streams.

The increased runoff also acts to increase the erosive force as doubling the depth of overland flow increases the velocity four times, resulting in the movement of particles 4096 times larger than before and an increase of 1024 times in the total mass able to be carried.

Loss of understorey vegetation and leaf litter, which slows overland flows and traps sediment, will also facilitate transport of soil for longer distances. The impacts of logging are greatly amplified by burning which removes the understorey and ground litter and/or weakens soil structure or increases soil hydrophobic properties.

As the soil becomes more disturbed or wetter it becomes more resistant to infiltration and thus overland flow is increased and mobilised soil can pass directly into streams and thus increase stream turbidity. The potential effects of logging on streams are therefore more pronounced in wetter weather and as operations get closer to streams.

As the velocity of the water begins to slow the larger soil particles begin to be deposited, causing sedimentation of stream beds and ultimately dams.

Following logging or burning, nutrients from the mineralisation of organic matter and from mineral weathering can become attached to sediments and transported along with them into streams (the ‘sorbed pathway’). Croke and Hairsine (1995) note *“It is now well established that phosphorus and many of the persistent and potentially toxic contaminants (eg heavy metals and organochlorine residues) are transported in the sorbed pathway”.*

Logging has been found to result in a variety of impacts on stream quality:

(i) significant increases in peak sediment loads (Campbell and Doeg 1989, Lake and Marchant 1991, Bonell, Gilmour and Cassells 1991, Sadek *et. al*. 1998) leading to increased sediment deposition in streams with consequent short-term and long-term impacts on invertebrates and fish (Campbell and Doeg 1989, Lake and Marchant 1991, Davies and Nelson 1994);

(ii) increased nutrient levels which can stimulate algal production in summer (Campbell and Doeg 1989, Lake and Marchant 1991, Davies and Nelson 1994), affecting both the instream community in the vicinity of logging and downstream water users and reservoirs; and,

(iii) reductions in levels of dissolved oxygen in streams as a result of oxygen demands of decomposing logging debris in streams, which becomes most apparent in periods of low flows (Campbell and Doeg 1989).

The impacts of logging on stream quality is largely related to the impacts of machinery on soils and the consequences this has for runoff and thus changes in stream turbidity, nutrients and chemistry.

During logging operations from 23% (Wronski 1984) to over 70% of the logging area can be subject to significant disturbance by machinery (Forestry Commission 1982, Rab 1994, 1996). Rab (1996) found that *“snig tracks, log landings and disturbed general logging area occupied about 19%, 3% and 66% of the coupe area, respectively.”*

Roads and tracks are the most significant sources of erosion in logging operations (Langford and O'Shaughnessy 1977, Lamb 1986, Campbell and Doeg 1989, Grayson *et. al.* 1993, Davies and Nelson 1993, State Forests 1996b, Croke *et. al.* 1997, Lacey 1998), contributing up to 95% of sediments in streams at one NSW site (Lamb 1986). Roads and tracks also alter hydrological patterns by creating new drainage lines and affecting the pattern of surface and subsurface waterflows (Bren and Leitch 1985, Lamb 1986, Bonell, Gilmour and Cassells 1991).

Croke *et. al.* (1997) found that *"For the 1:2 and 1:10 year storms, snig tracks generate approximately seven times more surface runoff per unit contributing area than the general harvesting areas on recently logged sites"*.

Croke *et. al.* (1997) assessed erosion from logged areas using simulated rainfall events and experimental plots and found that "*Snig tracks on these recently logged sites generate, on average, 20 times more sediment than the general harvesting areas for the 1:100 year* [110 mm/h] *storm intensities"*, with *"for the most recently logged sites, sediment yield is in the order of 2 to 11 t/ha for the 1:2 year and 1:100 year storms"* over a 30 minute period.

Lacey (1998) assessed sediment production on snig-tracks in Orara West and Doyles River State Forests under natural conditions and presumably best practices, finding that *"the total average amount produced on snig tracks in the first year was 29 t* ha^{-1} *at Doyles River and 31 t* ha^{-1} *at Orara West. Second year results displayed a greater difference with 9 t* ha^{-1} *at Doyles River and 4.5 t* ha^{-1} *at Orara West."*. It needs to be noted that his sediment traps did overflow and thus unquantified volumes of silt were transported further on.

The concentrated nature of runoff from roads and snig-tracks, particularly when situated on side slopes, makes it difficult to control sediments and ensure their deposition prior to reaching streams.

Where runoff becomes concentrated (i.e. outlets of road drains, cross-banks on snig tracks) it can create channels. Once water enters a channel there is very little deposition of sediment within the channel. Most channels created by roads and logging are likely to feed straight into streams. On disturbed sites and in wet weather, overland flows can overwhelm the soil's diminished infiltration capacity and also flow directly into streams. The closer that disturbances occur to streams the more likely it is that mobilised soil will reach the stream.

As noted by Croke *et. al.* (1997) *"Erosion undoubtedly occurs in forestry environments and, in particular, on disturbed areas such as snig tracks. The transportation and delivery of this material to the drainage lines depends upon a number of factors. These include the prevailing slope, topography, soil texture, and trapping efficiency of drainage structures and protection features, such as buffer strips, within the catchment."*

Lacey (1998) assessed sediment accumulation at traps located 5 m below cross bank outlets on other tracks and found it *"to be of a similar magnitude to that of the on-track traps"* at all of the Orara West sites and one of the four Doyles River sites. In other words, in the majority of cases re-direction of silt laden water over infiltration slopes had no effect. Lacey attributed this to a fire 2 months before logging at Orara West removing ground litter and vegetation and *"some ground disturbance by logging machinery"* at the Doyles River site.

Croke *et. al*. (1999) identified two principal sediment delivery pathways to streams:

- *Incised channels or gullies – where flow is concentrated, resulting in high sediment-transport capacity and runoff delivery downslope*

- *Non-channelised pathways – where water disperses or spreads across the hillslope, reducing flow depth, velocity and, consequently, the ability of the flow to transport sediment.*

Croke *et. al*. (1999) found that in their study area an additional 10 km of stream channels or gullies formed in previously un-channelled areas due to gully initiation at road-drainage outlets. These were made up of full channel linkages from road to stream (86%), partial channel linkages (11%) and direct linkages (3%). This represented a 6% increase in catchment drainage density and resulted in 31% of the natural stream network receiving and carrying runoff and associated pollutants from road-drainage outlets.

Croke et. al. (1999) found that sediment concentrations in runoff entering a gully from a road outlet showed no change with distance downslope (no net deposition or reduction of runoff). They found that about 85% of the material delivered to channelised pathways was transported downslope to the next adjoining channel. In non-channelised pathways the flows spread and move slowly downslope, giving time for infiltration to occur and sediments to be deposited. Croke *et. al*. (1999) found that *"About 10% of the material entering a non-channelised flow path was delivered to the bottom of the hillslope during an equivalent 1-in-100 year rainfall event"*.

Even with the implementation of erosion mitigation measures, significant proportions of mobilised sediments have been found to get into streams (Cornish 1980, Campbell and Doeg 1989, Davies and Nelson 1993, 1994, Grayson *et. al.* 1993, Wilson and Lynch 1998, Sadek *et. al*. 1998, Lacey 1998, Croke *et. al.* 1999). Campbell and Doeg (1989) conclude that the majority of studies indicate that *"timber harvesting operations have significant effects on stream sediment levels, water quantity, water temperature, nutrients and aquatic biota"*.

In their assessment of logging impacts on streams in steep country in northern Tasmania, Davies and Nelson (1993) found that *"fine sediment infiltration in ephemeral, first-order streams … is significantly enhanced by logging on steep slopes, by factors of two to three times the median values for unlogged streams. Infiltration by very fine organic sediment … is greatest during the 2 years immediately after logging, decreasing with time to a level similar to that for unlogged streams after 6 years."*.

In adjacent catchments in Tasmania, Wilson and Lynch (1998) found that following logging around a small intermittent stream the mean turbidity of the stream was 4.7, with a maximum of 40, compared to a nearby unlogged catchment around 10 times the size generating a mean turbidity of 1.12 with a maximum of 20. They concluded that in their study area *"logging does appear to increase turbidity in small tributary streams draining logging coups, even when these streams are protected by buffer strips."*

Even with a highly constrained and regulated logging operation Grayson *et. al.* (1993) still found that the important changes detected were a 30% increase in the median value for turbidity, 20% increase in the median value of iron and a 100% increase in the median value of suspended solids. Though they did not consider these to be a major impact.

Webb and Haywood (2005) undertook assessments of paired catchments in Middle Brother State forest and Pjurrigan National Park on the Mid North coast of NSW. The State forest was subject to a very careful and light logging resulting in only 20.7% of the tree canopy being removed. While turbidity levels in the catchments were similar before logging, despite the unusually light logging even during low-flow periods there was a 250% increase in turbidity in the logged catchment compared to the control for the first two years after logging, with elevated levels reducing but persisting 4 years after logging.

The impact of logging on turbidity is highest in storm events. Sadek et. al. (1998) found that *"the disturbed forest basin produced approximately 10 to 100 times the load per unit area during storm events compared to the undisturbed basin".*

It is not just suspended sediment that is the problem, sediments settling onto and into the substrate have the most significant and lasting consequences by smothering substrates, filling pools and infiltrating the gaps between the pebbles and rocks that are homes for numerous invertebrates. The increased turbidity following logging and burning have been found to result in massive depositions of sediment in stream channels (Good 1973, Leitch, Flinn and van de Graaff 1983, Lamb1986, Davies and Nelson 1993). While some of the yield increases may only persist for a few years after logging, others may persist for long periods, for example Davies and Nelson (1993) found that *"road crossings were associated with large increases in infiltration in adjacent riffle pairs, 30-50 years after construction".*

Once within the stream system sediments can persist for a long time. Prosser *et. al.* (2001) cite studies that have estimated that sediment yields from Australian rivers have only doubled in historical times, despite estimates of a 100-fold increase in hillslope erosion, with they attribute to *"implying that the bulk of this sediment is stored within Australia's river systems"*. Prosser *et. al.* (2001) attribute the long residence times of sediment in streams being due to sediments being stored in any reach where the supply from upstream exceeds the sediment transport capacity, noting *"that the movement of coarse material may be transport limited, whereas the rate of supply governs the export of fine sediment"*.

Sediments can also transport nutrients into streams and logging debris can affect stream oxygen levels (i.e. Campbell and Doeg 1989). Vegetation changes resultant from logging can have long-term consequences on food and shelter availability for invertebrates and fish (Campbell and Doeg 1989, Davies and Nelson 1994, Davies et. al. 2005).

Davies et. al. (2005) recognise that the secondary impacts of logging *"include declines in diversity of macroinvertebrates, fish and other vertebrates, as well as changes in community composition, growth rates, reproductive success and behaviour of aquatic biota".*

Suspended sediment alters the light regime and this affects the phytoplankton habitat and benthic biofilm production, reduces the rate of photosynthesis, decreases the abundance and diversity of macroinvertebrates, and can reduce the feeding efficiency and growth rates of fish while increasing disease (Prosser *et. al.* 2001). By smothering aquatic vegetation and streambeds, deposited sediments do have a significant impacts on aquatic invertebrates and fish. For example, sedimentation of the Richmond and Clarence Rivers (along with over-fishing) has been identified as responsible for the decline of the Eastern Freshwater Cod to the status of Endangered. Eastern Freshwater Cod have been found to lay their eggs on clean rocks in nests under boulders, rock ledges and aquatic grass root balls in slow flowing pools (Butler 2009). Sediments have covered many potential cod nesting sites, and the increased levels of free sediment may also make the maintenance of remaining sites more difficult (Butler 2009).

Effects on macroinvertebrates have been recorded in catchments where logging has been carried out with restrictive prescriptions for the protection of aquatic habitats and the impacts have been found to persist for decades (Forestry Commission of Tasmania 1991, Davies and Nelson 1993, 1994). Davies and Nelson (1994) found that in the cobble-dominated streams they studied 1-3 years after logging that significant increases in fine sediment accumulation, algal cover, water temperatures and increased loads of coarse particulate organic material due to logging were associated with declines in diversity and loss of abundance of mayflies, caddis and stoneflies (as well as fish).

The increased volumes of water delivered to streams following disturbances also initiate erosion in the stream channels. Increased water flows have been found to scour gullies and undermine streambanks (Good 1973, Leitch, Flinn and van de Graaff 1983, Davies et. al. 2005).

Changes in vegetation and stream morphology due to logging can have long lasting impacts. Davies et. al. (2005) compared environmentally similar sandy first-order forest streams in north-east Tasmania, where one group was unlogged and the other had been subject to clearfell logging fifteen years earlier. They note that *“Previously clearfelled stream channels were deeper, more uniform in internal morphology and contained more coarse sediments, exposed boulders and less fine organic material than control streams”*. They “*observed substantial differences in benthic macroinvertebrate community composition and abundance, aquatic insect emergence rates and abundance of macrophytes and algae between the two stream groups. ... Instream biological responses (changes in macroinvertebrate assemblage composition and declines in abundance) were correlated with both a measure of the intensity of the degree of historical clearfell disturbance and with the amount of fine particulate organic matter (FPOM) in the stream substrate”.*

Growns and Davis (1991) compared two sets of paired catchments south-western Western Australia 8 years after logging and found differences in the composition of the macroinvertebrate communities between the clearfelled and undisturbed streams in both catchments associated with conductivity, the amount of coarse and fine particulate organic matter, and a reduction in total nitrogen. They found 11 macroinvertebrate taxa to be associated with the separation of samples from the undisturbed and clearfelled streams.

The removal of understorey vegetation and soil degradation resultant from grazing also compounds the impacts resultant from burning or logging. Amongst other impacts, livestock cause soil compaction, reduce organic material, weaken soil structure and can cause direct degradation to stream banks and wetlands.

It also needs to be recognised that areas subject to increased rainfall intensities and/or an increased number of high intensity rainfalls as a result of global warming will be subject to an increase in the rate of soil erosion, particularly when possible ecosystem instability and changes reduce soil protection (Tegart, Sheldon and Griffiths 1990, see **North East NSW expected climate changes**).

The Battle to Protect Soils and Streams
Protecting Streams
The Need for Stream Buffers

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