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1983/12. The erosion of granite-derived soils in eastern and north-eastern Tasmania, with reference to forestry operations. Part 2: Investigation of erosion at forestry coupe EL1, Chain of Lagoons

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Abstract

Observations at Forestry Commission coupe EL1 at Chain of Lagoons show that gully erosion has occurred due to a two year time lag between clear-felling and the implementation of erosion control measures.

Gullying is the most obvious form of erosion and has become established along drains, snig tracks, and wheel ruts. Erosion control measures have been only partially successful in some areas because of the difficulty of applying control procedures to previously existing gullies.

Logging trash is not favoured as a sole method of diverting runoff from snig tracks, but is useful in conjunction with the construction of 'grips' which must be placed in order that the runoff diverted does not contribute to damage elsewhere. 'Scoops' are favoured as both an erosion control measure and as a method of monitoring sediment runoff, acting as settling ponds.

Erosion control procedures must be implemented during and immediately after logging ceases, in accordance with the Forestry Commission Guidelines (1981).

INTRODUCTION

Forestry coupe EL1 is an area of approximately 2.5 km^2 at Chain of Lagoons (fig. 1) at the foot of Elephant Pass [EP070875]. The coupe was clear-felled during 1977. The area is underlain by adamellite and granodiorite, and there were some erosion problems in the two years immediately after clear-felling. Erosion and stream sediment control measures were implemented at this time.

The area was carefully examined in order to investigate erosion problems and to determine the adequacy of the Forestry Commission's 'Guidelines for the planning and control of logging in native State Forests' (1981), for other proposed operations in the far north-east region, an area underlain by similar, highly erodable granite soils. Investigations were also conducted in an attempt at correlation with the results of extensive long-term studies conducted elsewhere (Sloane, 1983), the observations being made prior to a literature search in an attempt to avoid bias.

Forestry coupe EL1 was considered to be a suitable type-study as the area has granite soils, had been clear-felled some five years ago, has varying relief, moderate rainfall with short periods of high intensity rain, and has been clear-felled up to maximum slope angles that can be worked by the logging machinery used.

Samples of granite soils were taken for comparison with those from areas north of St Helens to determine any differences in their grain size distribution and consequent differences of the erosion potential of the different granite types.

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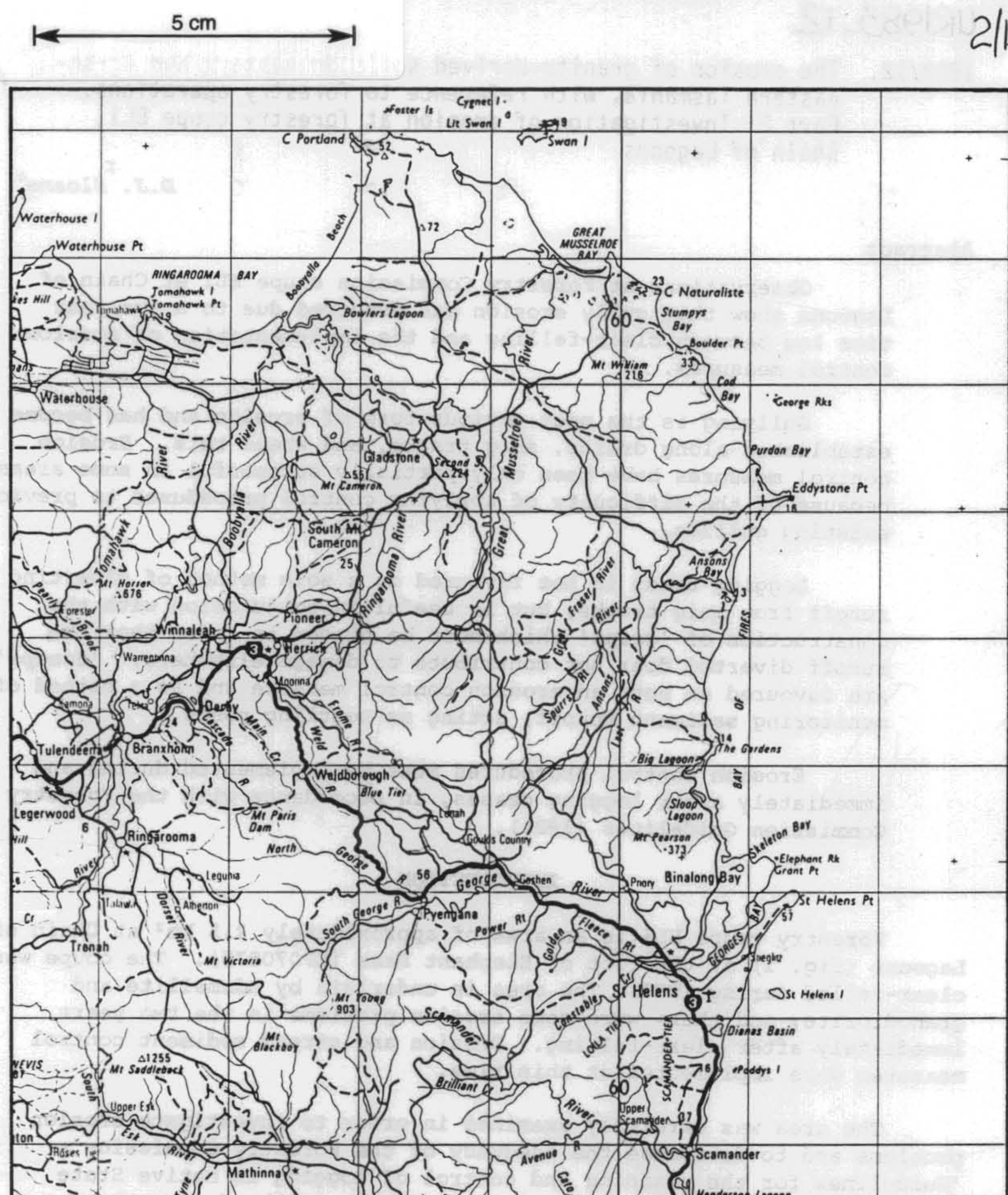


Figure 1. *Location of coupe EL 1.*

INVESTIGATIONS

This section of the report contains documentation of observation and comments on erosion control.

Forestry coupe EL1 at Chain of Lagoons (fig. 1) covers an area of approximately 2.5 km^2 and is underlain by biotite hornblende adamellite and granodiorite. Basically the topography of the area is composed of a flat coastal plain backed by steep slopes to the west (fig. 2). These steeper slopes are up to 28°, but the lower slope of the coastal plain ranges between 5° and 10°. Steep slopes occur adjacent to Lower Marsh Creek which forms the southern boundary of the area.

One of the most obvious areas of denudation is located at a small quarry situated towards the rear of the coastal plain. The quarry has been used to provide weathered granite material for road construction, and excavation has occurred to a depth of between three and four metres. The organically enriched sandy topsoil, with a depth of approximately 0.3 m, can be observed in the sides of the quarry.

Erosion of the main quarry face has occurred, resulting in rilling and gullying and a fan of eroded debris at its base (Plate 1). A fill slope up to four metres high has been made at the eastern margin of the quarry where material has been pushed to produce a flat quarry floor. The face of this fill slope has been eroded, and rilling and gullying has resulted in the transport of loose sediment for distances of up to 100 m on the regional 8° slopes below the quarry. A major drain, excavated across the floor of the quarry has formed a gully approximately two metres deep where it crosses the fill slope. A logging rubbish barrier placed in the drain at the base of the fill slope has largely succeeded in retaining sediment eroded from the gravel pit.

Despite the construction of log barriers, sediment originating from the quarry can be seen at distances of up to 100 m downslope. Once the sediment leaves the main quarry drain the disposal pattern becomes very braided due to interception of the drainage flow by vegetation and surface litter.

Quarry and gravel pit areas are large areas of disturbance and erosion that provide a major source of sediment. Often the sediment can be contained within the gravel pit, but where drains originate in a gravel pit attention must be given to the provision of sediment traps in an attempt to contain the sediment close to its source.

Some pertinent observations of the effects of drainage can be made along the main access roads. Roadside drainage is usually either directed away from the road into bulldozed 'scoops' or, where a larger section of road is drained, culverts are constructed under the road and straight ditches or drains direct the water away downslope. These methods can display two very different effects, irrespective of the length of road drained. The scoops are, in effect, small dams which act as settling ponds and sediment traps (Plate 2). The velocity of drainage water is drastically reduced upon reaching the scoop, resulting in virtually all of the sediment load being deposited. Water does overflow the scoops but unless they are completely full of sediment there is little evidence of deposition beyond them. Once a scoop is full of sediment, overflow occurs and sediment can be observed below the scoop. The culvert and straight drain type of construction can result in sediment being distributed considerable distances from the road. Examples observed show sediment

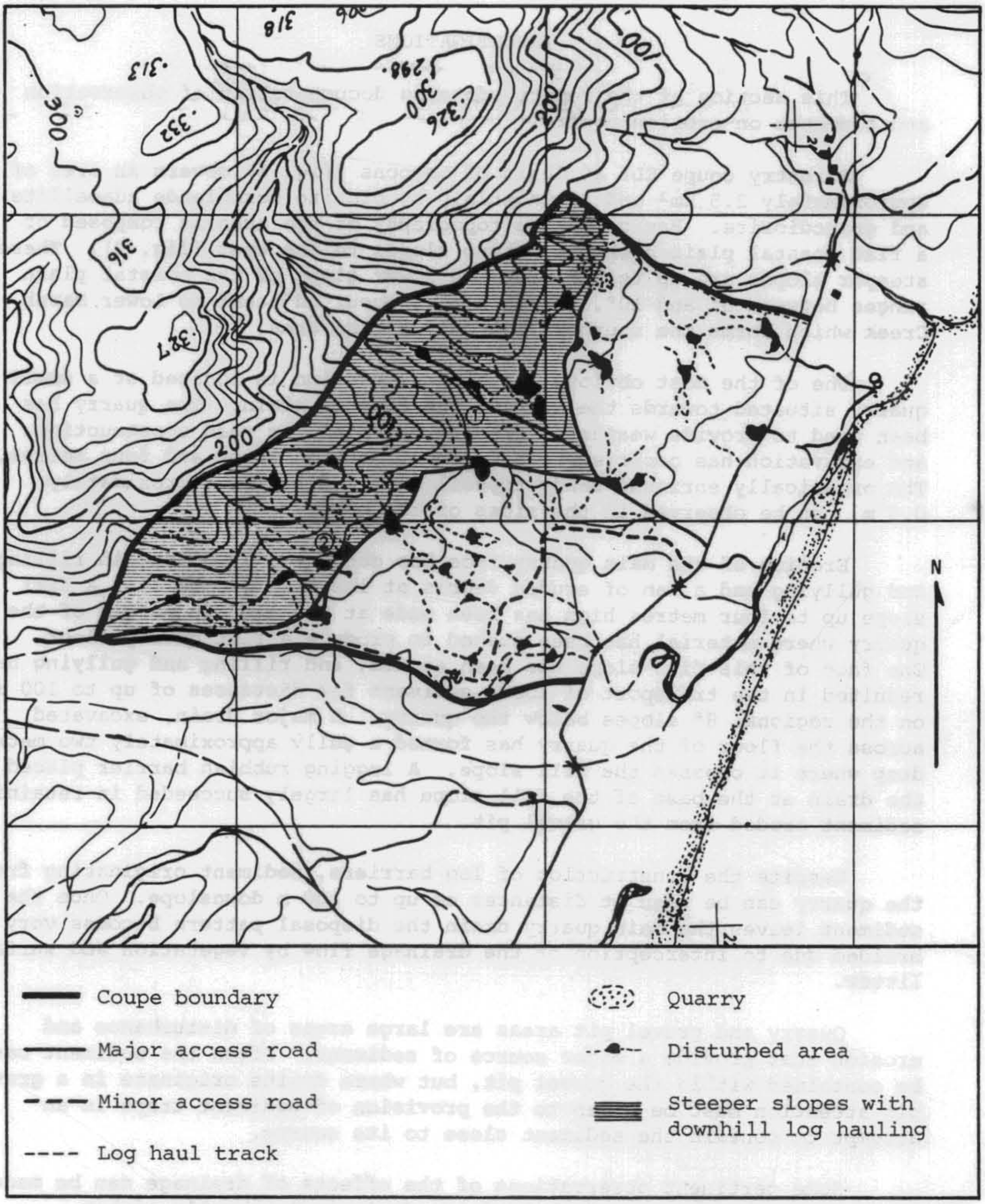
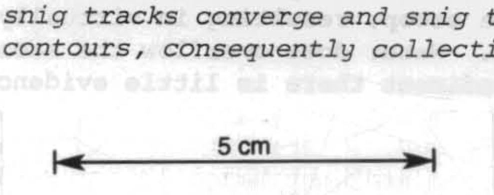


Figure 2. *Map at EL1 forestry coupe showing snig tracks and major access roads. Good location of major tracks along the foot of the steeper slopes. Major snig tracks generally follow ridges. Gullying generally occurs where snig tracks depart from this pattern, e.g. along road (1) and on slopes above. Gullying also evident in area (2) where major snig tracks converge and snig tracks close to large landings follow contours, consequently collecting runoff from large areas upslope.*



deposited up to 100 m from the main access road. Due to the reduction of drainage water velocity, coarser material is deposited close to the road and there is a reduction in sediment grain size as distance from the road increases.

The main access roads are surfaced with weathered granite gravel. Due to compaction causing a consequent low permeability, this material provides a large source of loose sand and gravel-sized material which is readily removed by rainfall runoff. Roadside culverts are also excavated in weathered granite and provide an additional source of sediment for runoff water. Such culvert lengths should therefore be kept to a minimum by means of frequent side drains, because as the velocity and volume of water flow increases with the downslope length of the drain there is a consequent increase in the erosive and sediment carrying capacity of the water.

Minor examples of gullying due to improperly constructed culverts have been observed where side drainage has been omitted over long distances. Side drains have, in some places, been directly drained into the adjacent stream, where moderately steep slopes occur between access roads and streams. This is unintentional and often due to a sparse vegetation filter strip or water finding a natural path to follow. In such situations scoops and logging debris barriers should be provided to prevent sediment being directly discharged into streams.

Another source of erosion and sediment can frequently be found adjacent to roads where small excavations have been left after providing fill for road surfaces (Plate 3). These, together with road embankments, are frequently rilled and gullied in the head and side scarps. Topsoil is absent in such areas and re-vegetation is slow or non-existent.

Road drainage has occasionally been directed into streams. An example of this can be seen along the Chain of Lagoons road where a small sediment fan has formed from the discharge of roadside drains into Hughes Creek. This situation is adequately covered by the 'Guidelines' (1981), where the road drainage is required to be directed into the surrounding vegetation some 40 m from a stream. The vegetation again acts as a sediment trap and reduces the velocity of runoff water by dispersion, retention, and increase of flow path lengths. At EL1 this guideline has been followed in most cases and sediment has thus been prevented from discharging directly into streams.

SUMMARY AND RECOMMENDATIONS FOR ROADS

The above observations on the effects of road drainage must be considered in relation to the variables involved. Factors to be considered include road distance drained, road slope, runoff from surrounding areas due to the type of area drained, slope of the ground, and nature of vegetation cover. The extent of sediment deposition at the end of drains not only depends on such factors but also on the slope and vegetation cover of the area onto which the drain discharges. Additionally the effect of any sediment control structures such as scoops and logging debris barriers must be considered.

An exhaustive study, taking into account all variables, would take considerable time. Despite this some useful conclusions can be reached. As discussed in Sloane (1983) the most important consideration is the prevention of the concentration of runoff into channels where large volumes travel long distances on steep slopes. Side drains on road culverts should be placed at frequent intervals to prevent the occurrence of such conditions. As a rule of thumb, the same spacing as that used for draining snig tracks sould be used (p.14 of the 'Guidelines', 1981).

The construction of bulldozer scoops (Plate 2) at the end of short side drains is desirable. These scoops trap and retain sediment close to the source and prevent distribution in a broad fan. Scoops appear to be easy to construct and inexpensive, being formed by the bulldozer operator dropping the blade to produce a small dam, the walls of which are formed by the debris pushed in front of the blade. Logging debris can also be used in conjunction with the scoops, so that any overflow will be intercepted by the debris. Two or three such scoops may be constructed to provide a drainage succession where there is a large area contributing runoff and sediment.

Several examples of the use of logging rubbish, with varying results, have been observed. The debris provides a good sediment trap only when each log is in close contact with the ground surface, acting as a water barrier, reducing velocity, increasing flow path length, and consequently causing the deposition of transported sediment. Once sediment reaches the top of the barrier water flows over the top of the log and begins to erode a small plunge pool where it strikes the ground (fig. 3). This plunge pool erodes back underneath the log until the trapped sediment washes down. The result is that the water then flows underneath the log, removing most of the previously trapped sediment, and the log ceases to function as a sediment and water barrier. Unless logs or branches are carefully placed in contact with the ground surface, their effect can be minimal.

Initially tree heads provide good barriers, the leafy fronds providing a good sediment trap, but once the leaves dry out and fall off, or burning occurs, many of the remaining stems and branches are generally not in contact with the ground. Additional examples of failed barriers occur where logging debris has been placed in small gullies in an attempt to prevent further erosion. In many cases such barriers have not worked and gullying has continued, as it is difficult to place the logging debris in close contact with the base of the gully to provide a continuous barrier. This case will be mentioned later when snig track drainage is discussed. Logging debris barriers are therefore not favoured unless they are used as a supplement to other methods.

As they are prone to erosion, roads, culverts, embankments, and roadside excavations act as major sediment sources. Embankments and roadside excavations for road fill and surfacing material should be kept to a minimum and attention must be paid to the drainage and restoration of such features. Embankments in granite areas can be constructed quite steeply, as the material is relatively stable with regard to landslipping and slumping, whilst steep embankment batters reduce the area of weathered granite exposed. Restoration of embankments, gravel pits *etc.* is desirable, but limited by cost. Replacing topsoil or mulching, together with seeding and tree planting, not only reduces sources of sediment and erosion, but also reduces the cost of maintenance of culverts and drains. This type of restoration is often cost effective and the seeding of roads reduces the general maintenance drastically and preserves the access and drains for further use, little work being required when the area is to be reharvested (Haupt and Kidd, 1965; Kochenderfer, 1970).

Strict adherence to the 'Guidelines' is essential at road stream crossings to prevent roadside culvert water from discharging directly into streams. The drainage must be directed into a vegetation filter

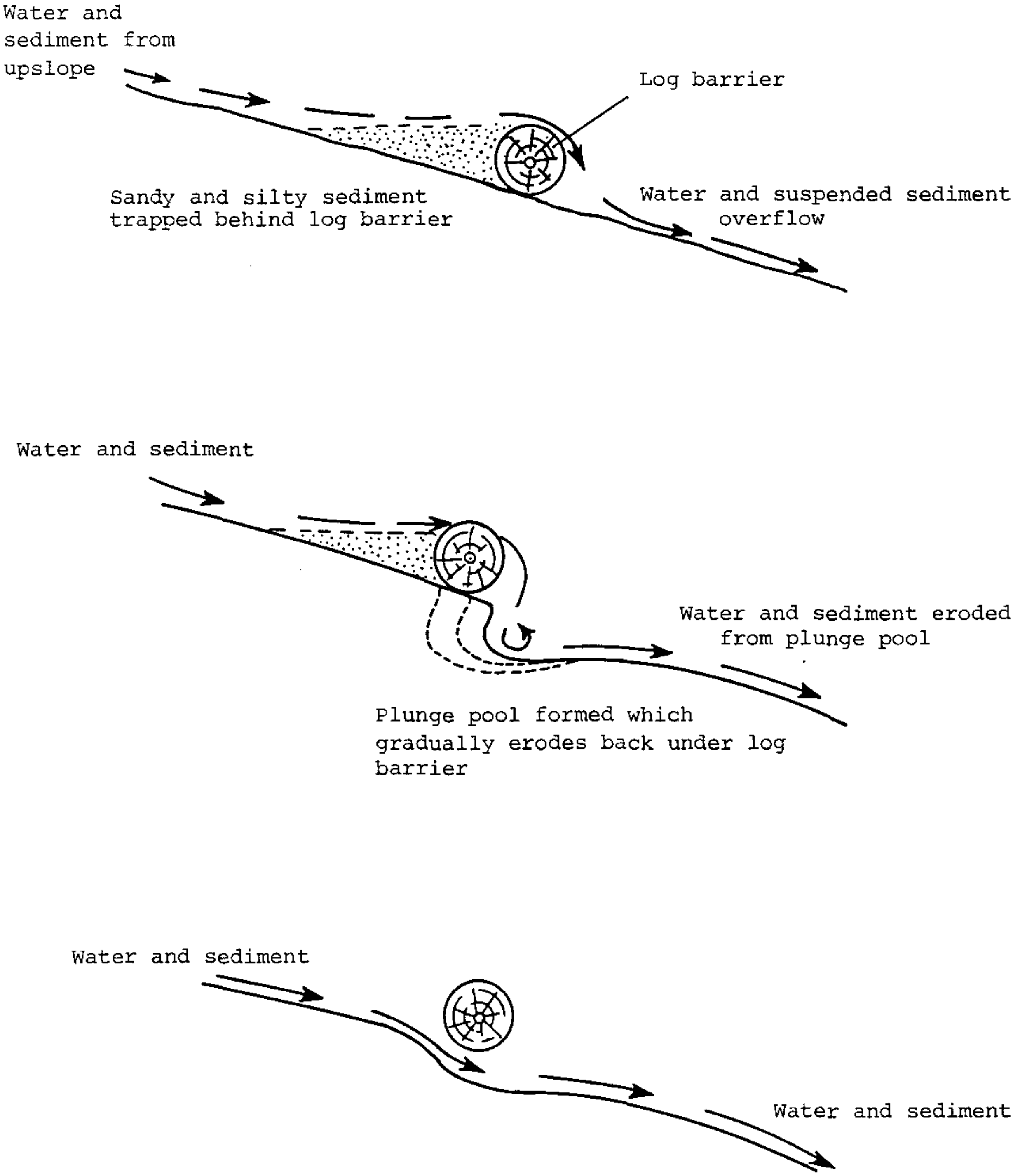


Figure 3. *Cross-sectional diagram showing stages of the effectiveness of a log sediment barrier.*

5 cm

strip to reduce sediment entry and the consequent effect on water quality.

EFFECTS OF GROUND DISTURBANCE DURING CLEAR-FELLING

Other observations at EL1 were based on the effects of the disturbance associated with the clear-fell operation. This area is one of the few where clear-felling has been conducted on an area underlain by granite soils. The area was clear-felled during 1977 and some two years later it was found that some remedial erosion control measures were required due to the development of gullying. The western limit of clear-felling has been defined by the maximum slope on which current machinery can operate (about 25°, but locally up to 28°). Logs have been snigged downhill, major snig tracks largely being located on ridges in the steeply sloping area to the west. Landings have been located adjacent to the main access roads at the foot of the steeper slopes.

Gullying is the main observable evidence of erosion at EL1. Virtually all gullying is confined to snig tracks or machinery ruts on the middle to lower slopes (Plate 4). 'Grips' or cross drains have been constructed across the snig tracks and gullies to divert water and prevent a downslope increase of water flow and velocity which is responsible for the lower slope gullying. Few of these cross drains work efficiently. In some cases the cross drains or grips merely divert the water to an adjacent snig track or machinery rut, allowing unobstructed downhill flow of water. At one location, parallel machinery ruts following a small depression on the lower slopes have resulted in gullying up to two metres in depth.

The ridge location of major snig tracks appears to work well, as little catchment is available to contribute runoff to the tracks. Snig tracks located on the sides of small drainage valleys, or close to the base of these areas, are prone to erosion due to their contributory catchment areas, and to the difficulty of diverting water away from the snigs due to the natural drainage of the region. These areas at EL1 are all located on the steeper slopes uphill from the main access roads and show that despite locating most major snig tracks on ridges, gullying has occurred in the few cases where such tracks or machinery ruts follow depressions, or where cross tracks have linked several snig tracks and thereby collected runoff into a single rut.

Uphill snigging has largely been used on the lower side of the main access roads, where slopes are about 10° or less. Few problems have occurred in this area, any areas of sediment deposition being contained close to their sources.

Landings in the area do not appear to have eroded to any great extent (Plate 5). Landings are generally located on flat areas and on ridge crests, with drainage being diverted away. Landings do provide a large area of ground disturbance but the main problems appear to be associated with the difficulty of revegetation due to the loss of topsoil.

The pattern of logging operations at EL1 highlights the importance of road drainage. All drainage from the steeper slopes is intercepted by the roads which are located at the base. Most drainage and sediment from the areas of gully erosion and landings is diverted by the roads. Careful road drainage is important, especially in relation to the discharge of water towards streams.

Attempts have been made to repair erosion and to drain snig tracks, especially those adjacent to Marsh Creek and Lower Marsh Creek where the slopes are moderately steep and underlain by deeply weathered granite. One method involves the use of logging debris barriers. As discussed previously, this method is not favoured as a sole means of erosion control as in most cases it is difficult to place timber in close contact with the base of the gully. The other method used is to construct grips or side cuts across the gullies and snig track ruts (fig. 4). Most grips appear to work well, only small fans of sediment being evident at their discharge points. Those grips that have not worked have not been constructed carefully enough, with the excavated grip not being cut down to the base of the gully or snig track and with fill placed at the base to form a barrier. The fill is generally loose sandy gravel that is easily eroded and soon breached by the water flowing in the gully, rendering the grip ineffective. This problem is caused by the initiation of gullying before the construction of the grip, and indicates the necessity of implementing erosion control measures immediately after logging operations cease. Grip spacing at EL1 ranges between 25 m to 30 m on a 20° slope, and 40 m to 45 m on a 15° to 10° slope.

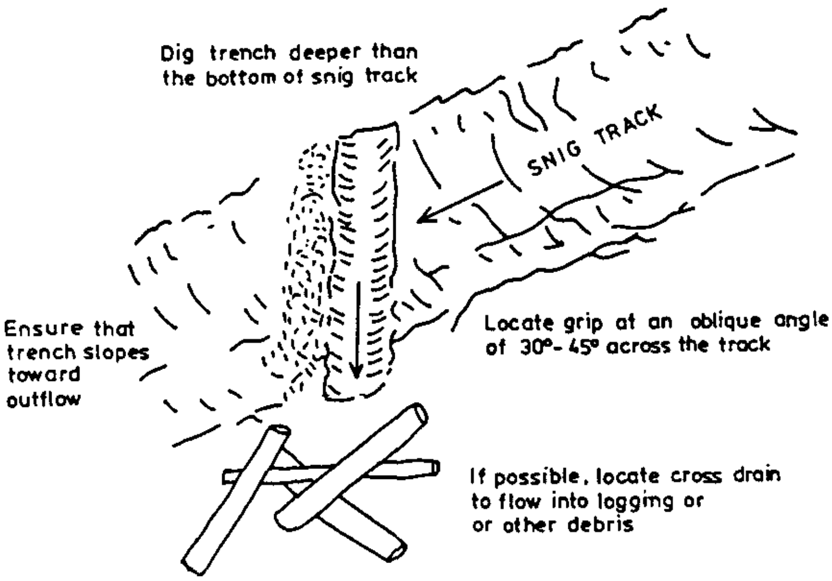
The construction of effective drainage grips is a major problem on snig tracks which converge downhill to a landing. In some cases the grips are constructed without due regard to the effects of their discharge, and they occasionally drain directly into an adjacent snig. The problem tends to become compounded where the snig tracks converge towards the landing. The construction of grips in these areas is generally ineffective.

SUMMARY AND RECOMMENDATIONS CONCERNING GROUND DISTURBANCE DURING LOGGING OPERATIONS

The pattern of log snigging should, perhaps, be the main consideration of logging operations on granite soils. Theoretical considerations can lead to a system whereby erosion is minimal, but the main constraints are practical ones related to the capability of logging machinery. The most undesirable effect of snigging downhill to a landing is that runoff is collected by the ruts and concentrated to a common point at the landing. Unless intercepting drains are constructed, the volume and velocity, and hence the erosive capacity of intercepted runoff water increases as the tracks approach the downslope landing. On an area of uniform slope, each snig track collects runoff from larger areas towards the snigs uphill end, resulting in a potential for large volumes of water to be carried over the majority of the track length. The incremental collection increase lessens as the area between the tracks decreases towards the collection point at the landing.

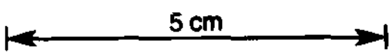
Uphill snigging has a divergent downslope pattern of tracks which also collects runoff from the segments between tracks, but the larger contributing areas occur towards the downhill end of each track and thus generally lower volumes and velocities occur per unit length of track. The pattern is also distributory in nature. It is considered that uphill snigging methods are preferable, purely from surface hydrologic conditions. However, this method is probably only practical on slopes of 12° or less, due to machinery limitations.

From discussions with operators and Forestry Commission personnel, it seems that on steep slopes downhill snigging is largely unavoidable, due to wheel and track spin causing more disturbance to the soil surface than is desirable when attempting uphill snigging. However the system can be modified by locating major snig tracks along ridges and angling secondary snig tracks up and across contours to the ridge tracks. The location of major snig tracks along small drainage depressions should be



From Forestry Commission Guidelines, 1981

Figure 4. *Diagram showing proper grip construction. Logs placed in the snig track are generally not sufficient to provide a water and sediment barrier.*



avoided; logs can be snigged from these areas as described above. This system approaches the contour snigging method, which is largely impractical in this case due to the limited capabilities of machinery, but which is probably the most desirable system in that interception and retention of runoff occurs in a way similar to that in which contour ploughing and strip cropping are used in agriculture to prevent erosion. The ridge track system indicated above will be a good practice, as intercepted runoff will mostly be directed away from drainage depressions.

The general location of major access roads at the base of steeply sloping areas can also be used to prevent runoff containing sediment from entering streams, because this type of road system intercepts the runoff from the steeper slopes. In this respect road drainage and careful attention to the 'Guidelines' is highly important.

At EL1 the uphill snigging system on the lower slopes below the major access roads distributes any runoff and sediment, the result being that little sediment is discharged from the coupe area. Main access roads should be located in this manner and mid-slope roading is not advised (Fredriksen, 1970), as these tend to initiate gullying.

Landings should be located on high ground or ridges and attention to landing drainage is important. At EL1 landings are properly sited and little runoff and sediment dispersal is evident. This is due to the choice of location and the fact that the area is 'randomly' disturbed. In consequence it has a high retention storage with few major ruts available for uninterrupted water flow. Problems can occur on poor sites and landings may provide large amounts of sediment, especially as re-vegetation of these areas is slow or difficult (Plate 5).

The construction of grips is essential on all snig tracks and large machinery ruts, especially in areas of downhill snigging. The spacing of these grips as indicated in the 'Guidelines' (1981) appears adequate, provided they are carefully constructed as per the diagram (see fig. 4). Perhaps the important feature is to dig the grip deeper than the bottom of the snig track. Logging debris is not favoured as the sole means of providing a water and sediment barrier for reasons previously discussed, but debris can be used as an adjunct to grip construction, and is considered to be very effective when used in conjunction with other drainage methods. Due consideration must be given to the direction of discharge of grip drainage, as there is little benefit if runoff is directed into an adjacent track. Scoops could also be constructed where practical, especially near the discharge points of major snig tracks.

CONCLUSIONS

Despite the specific criticisms and observations resulting from a detailed inspection of erosion problems at forestry coupe EL1, there appears to have been little sediment movement out of the coupe area. This should be a major aim of the soil erosion and stream sedimentation control methods used in any area of clear-felling.

The basic planning of the operations as regards access roading, landing location, and snigging patterns has been well planned and, with hindsight, few improvements could be suggested. The erosion problems that have occurred are largely a result of late implementation of erosion and sediment control measures as detailed in the 'Guidelines'. This is probably related to a lack of understanding of the behaviour of the highly erodable granite soils. The 'Guidelines' appear adequate, cover virtually all eventualities, and must be strictly adhered to in areas of granite soil.

The planning of road and snig track locations and patterns is highly important. These features are the main source of sediment and erosion within an area and are thus the major factors which may result in water quality deterioration, and high bedload and suspended sediment yield to adjacent streams and rivers. Erosion and stream sedimentation methods must be implemented during logging operations and immediately after these cease.

The effective drainage of major areas of disturbance during logging operations, that is snig tracks and landings, is highly important. The area under investigation is subject to periods of high intensity rainfall and it is during these periods that damaging erosion may be initiated, either during or soon after logging. Restoration becomes more difficult and expensive once erosion has initiated gullying, as machinery and personnel must be returned to an area. The purpose of the 'Guidelines' is to prevent and reduce erosion and sediment-carrying runoff, thus preventing a deterioration in regional water quality as a result of the logging operations. Not only will these purposes be served by careful attention to detail in such sensitive areas, but maintenance costs will be reduced and access and soil fertility will be preserved for the next cycle of operations.

The main conclusion regarding the geological considerations of the region is that soils are generally thin on the steeper slopes, especially towards the ridge crests where rock crops out. Soil thickness and depths of weathered granite bedrock are greatest on the lower footslope at the rear of the coastal plain. Some of this material has no doubt been derived from the steeper slopes and forms a thicker wedge of easily erodable material at the slope base. It should be noted, with reference to runoff models (Sloane, 1983) that it is often in this area that erosion initiates. No distinct patterns are observable in relation to effects of jointing and slope aspect on the depth of granite weathering.

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[30 March 1983]

Plate 1. *Gullying in weathered granite at the main quarry.*

Plate 2. *'Scoop' or roadside push-off area (Central Highlands) in an area of easily eroded windblown sand. 'Scoop' acts as settling pond providing a good sediment trap.*

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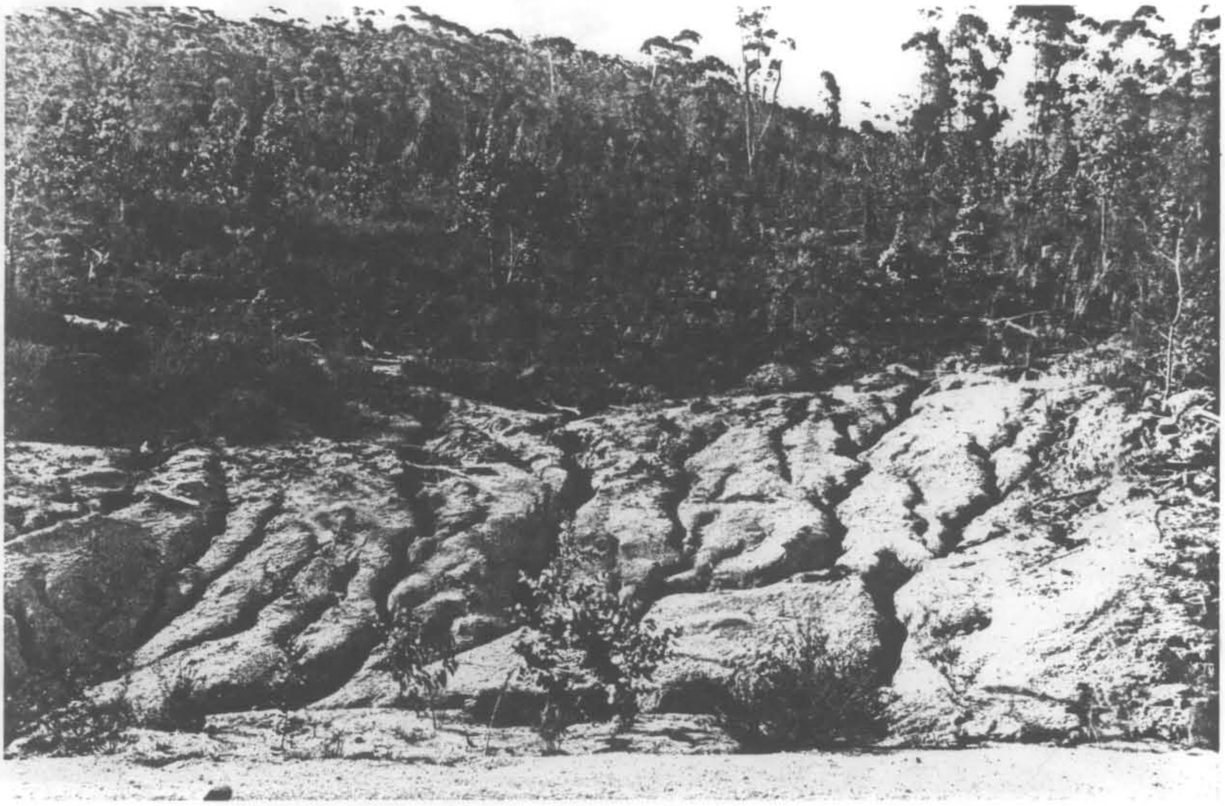

Plate 3. *Gullying on embankment excavated for road fill and surfacing.*

Plate 4. *Gullying initiated along wheel and track ruts.*

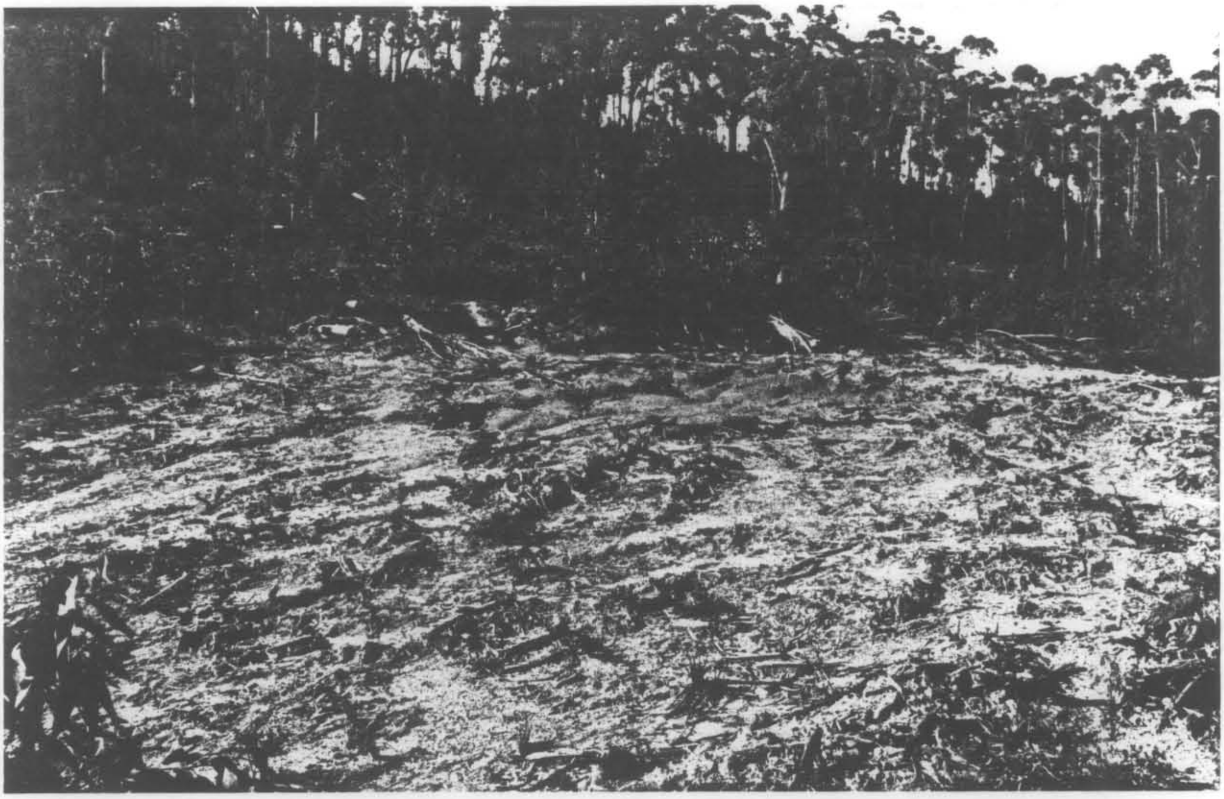

Plate 5. *Large area of disturbance around log landing with little revegetation. A major source of sediment runoff if drainage and location is inadequate.*