LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

A PRELIMINARY DESCRIPTION OF LOGGING ROAD CONSTRUCTION PRACTISES FOR UNSTABLE SOILS USED IN THE U.S. NORTHWEST

P.R. 31 1987

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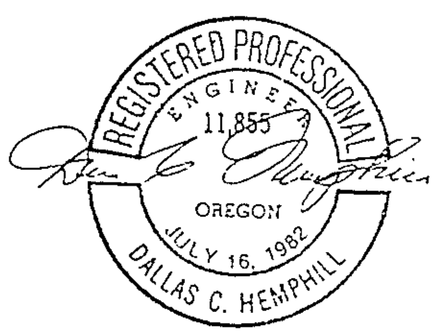
Prepared By :



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JANUARY, 1987

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SUMMARY AND CONCLUSIONS

1. New Zealand forest enterprises would find it highly profitable to improve reconnaissance engineering skills and to concentrate on avoiding stability problems rather than trying to cure them.

2. A radical review of present road standards represents a major economic opportunity for some organisations in New Zealand, as many roads are presently being built to grossly conservative standards.

3. It is worthwhile to use geological and geotechnical expertise to assist in forest road design on unstable terrain.

4. Technically qualified supervision of construction is critical.

5. Outsloped roads are worth considering as a minimum-impact road for cohesive soils, although they have certain operational limitations.

6. Excavator road construction work methods and attachments are still developing in the U.S. The selection of a specific method depends on site and timber conditions. Substantial cost differentials exist between methods. Combination excavator-bulldozer methods are very common.

7. Various methods are in use for endhauling waste material, with substantial cost differentials between techniques.

8. Sidecast pullback is a much cheaper alternative to conventional endhaul, that has potential for New Zealand logging roads.

9. Hog fuel is finding increased use on Northwest logging roads as a lightweight fill material, and it should be tested also in New Zealand.

10. Geotextiles of widely varying properties find extensive use for many forest road applications such as filtration in drainage systems, separation of aggregate from the subgrade, and fill reinforcement. Geogrids are also used, although less extensively, for slope reinforcement and fill reinforcement.

11. Exploration drilling is regarded as an important first step preceding subsurface drainage design. Vertical drains and horizontal drains find use in dewatering slide and flow areas, with flexible PVC culvert pipe widely used to carry the flow to a disposal location.

12. Intercepting ditches are a relatively cheap method used to intercept shallow flows.

13. Rock blankets are used to dewater fills on some American logging roads.

14. New prefabricated drainage products show good promise for an economical alternative to a conventional French drain. They can be used with a deeper trench and require no rock. These products should be installed on a trial basis.

15. Rock buttresses are quite widely used on Northwest logging roads, mainly to retain cuts in flow or slumping material. An alternative of probable interest for many parts of New Zealand is the compacted soil buttress.

16. Various types of walls are used on U.S. forest roads, but they probably have limited potential for New Zealand.

17. Pedological maps have been found adaptable to the purpose of aggregate depth determination.

18. The concept of building temporary roads,deliberately deconstructed after logging to a self-maintaining state, deserves consideration for specific sites in New Zealand.

19. American companies give priority to good location for avoiding stability problems, with a second preference for simple solutions such as compaction and drainage. Complex solutions are the least preferred.

INTRODUCTION

In this report is presented a preliminary description of road construction practises used by the forest industry on the West Coast of the United States for certain unstable soils, that may also be considered for application in problem areas in New Zealand. Techniques that primarily address the problems of unstable fine-grained soils on the East Coast of the North Island and in the Nelson-Marlborough region are the main focus of the report. As well as construction techniques, a discussion of planning aspects is also presented, as they represent a major opportunity for New Zealand forest owners.

Many of the construction methods described have already been used in New Zealand, although not necessarily in the timber industry. Some techniques are sufficiently costly that they can only be justified for mainline roads.

The techniques examined primarily address mass movement failures and subgrade failures in fine-grained soils. Practices used for culvert installation, the prevention of surface scouring, rock excavation, and pavement stabilisation are addressed only incidentially, or not at all, as they are beyond the scope of the present report.

While some of the techniques reported on are specific in their application, most of the construction methods and also the planning approaches documented are applicable or adaptable to quite a wide range of soil types with similar stability problems.

This report is preliminary in nature, intended to scope the state-of-the-art on the U.S. West Coast and to provide possible research direction for the future in New Zealand.

CHARACTERISTICS OF CERTAIN PROBLEM AREAS IN NEW ZEALAND

Nelson-Marlborough

Problems were observed to have occurred in recent road construction in a field inspection undertaken in January 1986 and from past experience, in a variety of soils with a high clay content, including schistose soils in the Wairau catchment and Opouri and Kenepuru steepland soils. While these soils are generally competent for subgrade construction, they are subject to shallow rotational slides and slumps, mostly not large in size. Debris chutes, in which there has been a rapid flow of soil, rock, and vegetative debris down a gully, are much less common on undisturbed slopes than the slump type of failure. Faulting occurs widely, with associated zones of incompetent rock.

Particularly within active or past slide zones, road cut slopes commonly fail by raveling, scouring, and minor slumping, interfering with drainage and consequently causing maintenance problems that have sometimes resulted in fill failures. Cut slopes were seen to be unstable where dip slopes paralleled the ground surface (figure 1).

Figure 1 : Cut slope failure where rock foliations parallel slope

Debris slides have been initiated or reactivated by road construction, particularly where fill or waste material has been sidecast onto steep slopes over 70% (figure 2), where the rock foliations parallel the ground surface, and where fill has failed through the decay of buried slash. In some cases debris slides originating from the sidecasting of waste material on steep slopes have resulted in downstream damage to agricultural properties. The potential political consequences of such activity appear to be seriously underestimated by some in the New Zealand forest industry.

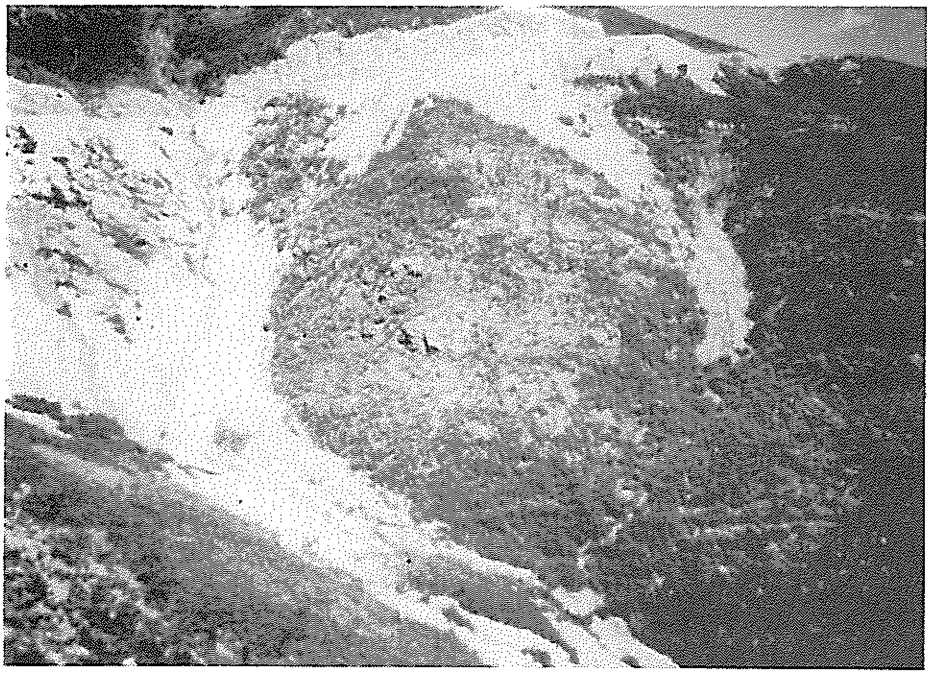


Figure 2 : Debris slides originating from sidecast waste

Fill failures were observed to occur where the natural ground surface was too steep and/or insufficiently prepared to catch a fill (figure 3), where cut slope failures had routed water onto fills, and where buried slash had decayed.

East Coast

In a field inspection taken in the Wairarapa in January 1986 and during earlier experience further north in Hawkes Bay, problems were observed in the fine-grained clay soils derived from sedimentary deposits and, in the north at least, an ash mantle. Much of the clay is expansive in nature. The terrain is characterised by large, sometimes spectacular earthflows, with a depth typically of 10 m or more. Slumping, both active and ancient, is widespread. Gully erosion is a common natural process along live streams.

Slumping failures of road cut slopes are quite common in this material. Cut slope failures are sometimes large enough to block the road (Figure 5).

Roads built across large active earthflows of course move with the surface soil layers, at a non-uniform rate up to 5 m per year. If the road is not destroyed in the process, at least it rapidly loses any semblance of the original alignment.

Figure 3 : Sidecast soil beginning to fail on steep slope

Figure 4 : This road dropped about 5 m elevation when the slope slumped

Subgrade failures through slumping are also to be seen (Figure 4), related; to the natural movement of the underlying unstable materials and subsurface water, to the diversion of water onto fill material through drainage failure, and to the incompetence of fill material that either became saturated or had been placed on too steep of a slope.

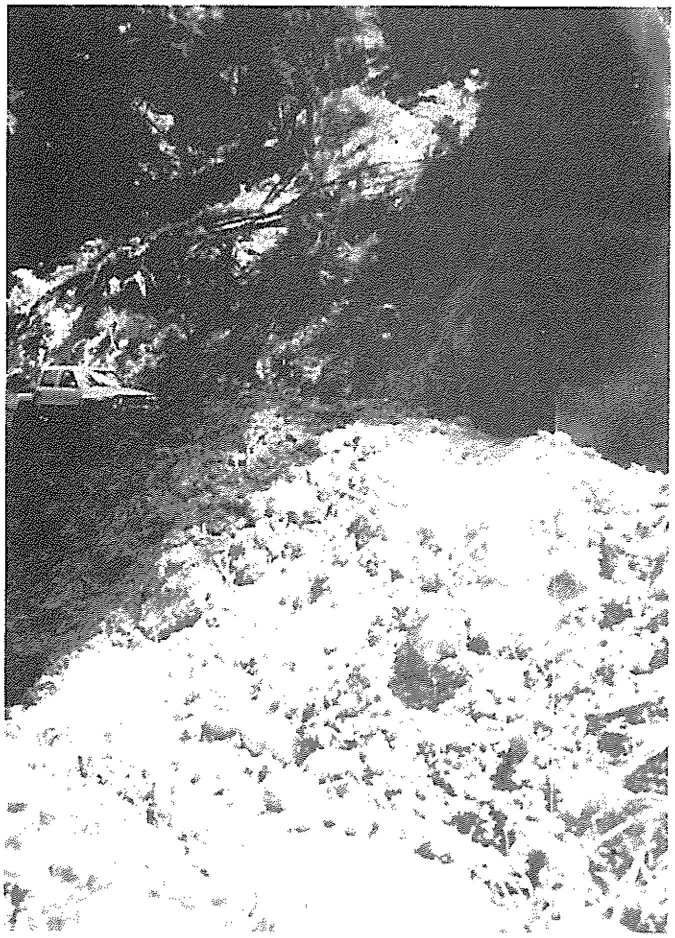


Figure 5 : Cut slope failure had to be cleared to re-open road

AMERICAN LOGGING ROAD CONSTRUCTION PRACTISES

Many mitigation measures used by the U.S. West Coast timber industry have potential application in New Zealand. Some have application to a variety of soil types, while others are more specific. In particular it should be noted that American experience in montmorillonite clays has been greatest in the gentle topography of the Gulf States in the South. Northwest logging operators have much more limited experience in expansive clays. There is considerable experience, however, on the U.S. West Coast with measures appropriate to slump and flow terrain that is directly applicable to the New Zealand scene. The various American mitigation measures are described below according to the class of practice used.

PLANNING ASPECTS

It must be emphasised that by far the most cost-effective stability hazard mitigation in logging road construction is done long before any machine reaches the road location - at the planning stage. The following brief description will serve only to highlight some aspects of planning that are important to maximising road and slope stability.

Reconnaissance and Location

In all American steepland logging operations, reconnaissance to obtain the most favourable road location is regarded as by far the most effective means of limiting road problems. Extensive use is made of aerial photos, topographical and geological maps where available, and ground reconnaissance to identify unstable features, such as landslides, slumps, debris chutes, swamps, etc that exert control on road location. Sometimes the critical geomorphological features are plotted photogrammetrically to enhance the value of paper planning, enabling the subsequent field work to go much faster. Planning on a drainage-by-drainage basis, with a complete layout of all roads, settings, and landings, is practised by those landowners who have the greatest success with road and slope stability.

In difficult terrain, those companies with the fewest road failures have their field reconnaissance done by people with extensive logging, construction, and engineering experience, having also had formal training in geology and soil mechanics. They also employ specialist geotechnical help in some cases.

The primary logic in road location is to avoid the problem areas, while reaching the necessary landings to permit low-cost logging as far as possible. The emphasis is on avoidance of the unstable ground (figures 6, 7). Where unstable ground must be crossed in order to reach a landing, the reconnaissance engineer makes an evaluation of the surface indicators and decides on the best construction technique to mitigate the problem.

There is a definite need in New Zealand for improved reconnaissance engineering skills. Many of the problems now being encountered in construction could have been avoided by

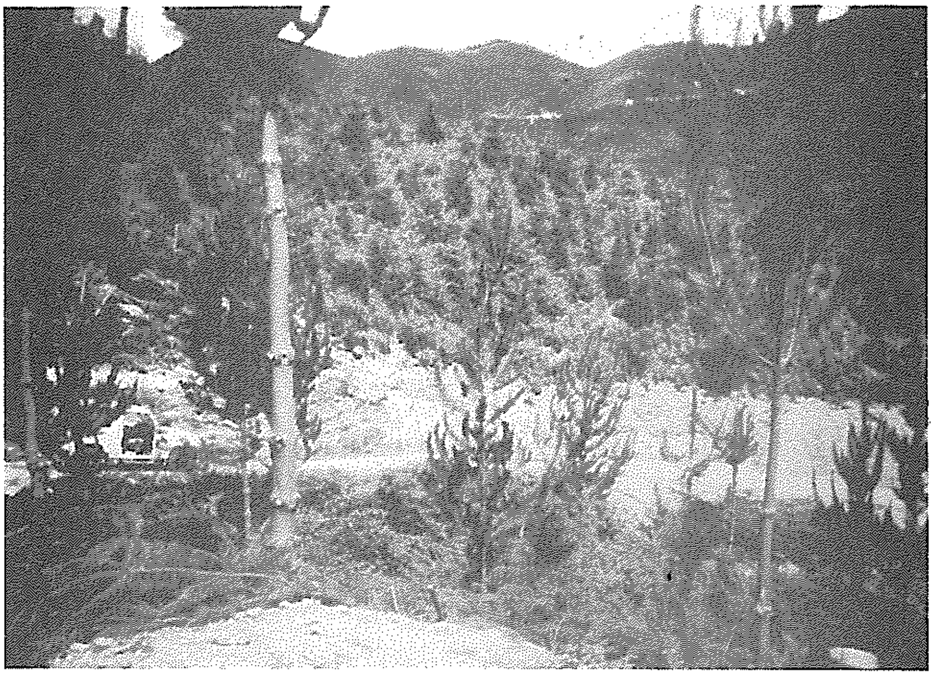


Figure 6 : Example of good location. An 18% grade is used on this planting road to avoid an unstable area.

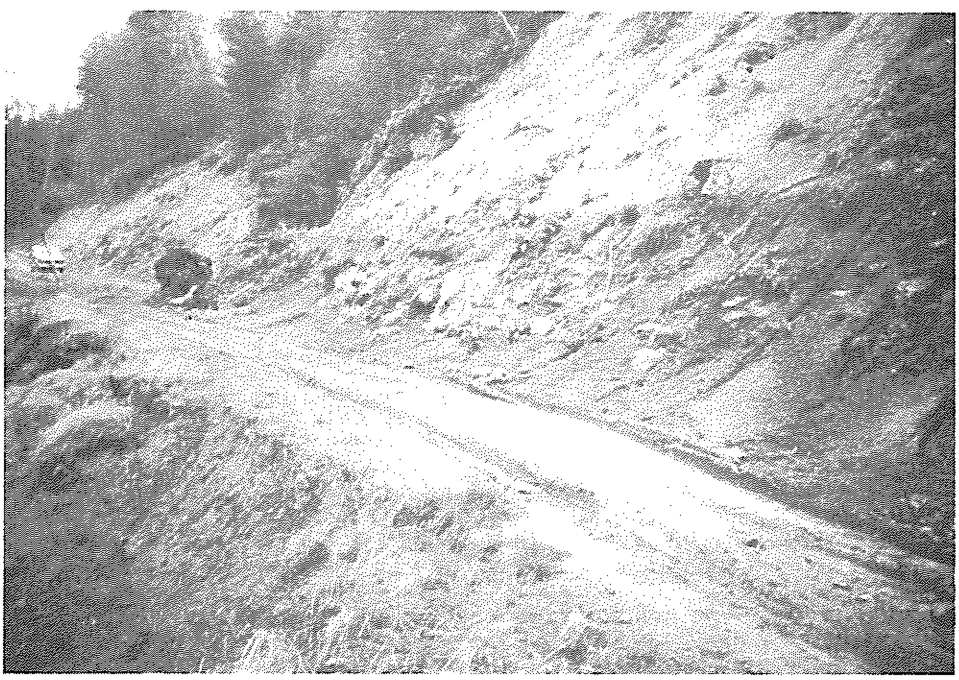


Figure 7 : Example of incorrect location. The 3% grade used undercut a chronic slide problem. An 18% grade could have been used instead to avoid most of the problem.

better location of the road. Improved reconnaissance and location practices represent a major economic and environmental opportunity for many New Zealand logging companies, with an excellent return-on-investment.

Road Standards

Hand-in-hand with the strategy of avoiding unstable zones is the American philosophy toward logging road standards on difficult terrain. U.S. companies lower their road standards as far as necessary within safety limitations to make it possible to access landings for the most productive systems. Extracts from typical standards for roads of a class accessing up to a couple or few hundred hectares in ground with substantial stability problems are as follows :

Preferred maximum grade	18% fav., 16% adv.
Absolute maximum grade, unassisted	20% fav., 18% adv.

(Steeper grades are rarely used, normally with a tractor assist.)
Width : Subgrade 4 - 6 m, plus ditch 0 - 1 m.
Minimum curve radius 15 - 20 m.

These roads are being built for trucks and equipment very similar to those used in New Zealand, and accessing timber volumes per hectare that are comparable to New Zealand. Maximum grades are of course generally lower in non-cohesive soils prone to surface scouring, where surfacing is not proposed.

Many timber concerns in New Zealand would find it highly profitable to adopt low geometric standards in tough terrain. Not only are construction costs and environmental risks reduced greatly with such an approach, but lower logging costs are achieved through accessing more landings that permit productive logging. The increase in trucking and maintenance costs will normally be small by comparison. In the case of planting (as opposed to logging) roads, a high percentage of grades approaching the maximum could be economically justified. The selection of maximum grades should of course be tempered by the surface scouring characteristics of specific soils and the need for surfacing.

Another policy successfully applied in the Northwest is to vary road standards when conditions warrant, e.g. varying normal grade or width limits in order to successfully traverse unstable terrain.

While many U.S. logging roads are built to what would be regarded as a low standard in New Zealand, they are often relatively highly engineered. On difficult terrain, it is not unusual for even spur roads to be designed and slope-staked. Proper design can significantly improve the cost and performance of a road in tough terrain. The standard of design varies greatly in the Northwest, depending on the difficulty of the terrain, skill of the engineer, and the standard of road.

A radical review of road standards is strongly recommended to New Zealand forest concerns operating on unstable terrain. For some, it represents a major opportunity.

Road Use

One approach used by American companies on certain pieces of unstable terrain is to accept that it would be uneconomic to build a permanent, stable road, and instead to build a cheap road of very low standard with a design life of only one or two seasons. The road is decommissioned after use in a manner that permits it to be self-maintaining, although not passable to vehicles. The loss of access for forest management is a serious consideration, and therefore this approach is mainly used on spur roads. It merits consideration for specific difficult sites in New Zealand, possibly even with a modification of the silvicultural regime if higher access costs would seriously impact stand treatment costs.

The temporary road concept has of course seen wide use in New Zealand, but it has normally been by default, rather than by the deliberate deconstruction of a road to permit it to self-maintain without further degradation.

American operators typically carefully schedule road use for seasons when road use is feasible or when road damage by vehicles will be minimised (e.g. when the soil is dry or frozen). This approach is of course already applied in New Zealand, and it can be expected to find extensive application in clay country.

American forest owners sometimes prevent off-season access by gates and/or dirt barriers. Recreational four-wheel drive use is a much greater problem than in New Zealand.

Geotechnical Exploration

The U.S. Forest Service employs geotechnical engineers and engineering geologists to evaluate stability problems, perform subsurface explorations, and develop designs for specific problem areas. Most companies, which typically have a smaller proportion of unstable terrain, do not employ such specialists, although they are sometimes retained from the outside to advise on specific sites. Industry appears to have more road stability problems than the government in spite of having generally easier ground. This is mainly due to the much more cautious environmental approach of the Forest Service, but is also partly due to the more intensive geological investigation done. It is critical, however, that the geologist have good local experience and an appreciation of logging road practicalities.

For specific problem sites where conventional construction is considered likely to fail, U.S. Forest Service geotechnical engineers first map the site for surface indicators of soil structure. They then do test borings, using both portable drills that reach 9 m and larger drills to reach deeper. On slumps, they typically drill four or five holes along a strip that extends about 100 m above the proposed centerline and to about 30 m below it. Soil samples are subjected to shear tests. In some cases they also insert water monitors in drill holes over at least one rainy season to determine the depth of the water table. Design is done according to conventional slope stability analysis. Economic comparisons are made between alternative designs, always keeping in mind that it might eventually prove most economic to build no road at all or only a temporary road.

Construction itself is regarded as a further subsurface exploration opportunity, with the design being modified if necessary in the light of fresh information.

Supervision

It is considered critical to have well-qualified supervision of road construction. In unstable terrain, supervisors should have the necessary technical training to undertake tasks such as compaction tests and to evaluate soil characteristics.

SLIDE ANCHORING

There have been some attempts in the U.S. on forest roads to physically pin an entire rotational slide to a competent stratum below, using concrete or epoxy poured into holes drilled throughout the slide. These attempts were unsuccessful as the "pins" sheared, although the method was attempted on small slides only.

American operators regard the destruction over time of any road built on an active slide or earthflow as inevitable, except where the unstable feature is small. If they have to cross an active feature of any size, they treat the road as a temporary structure.

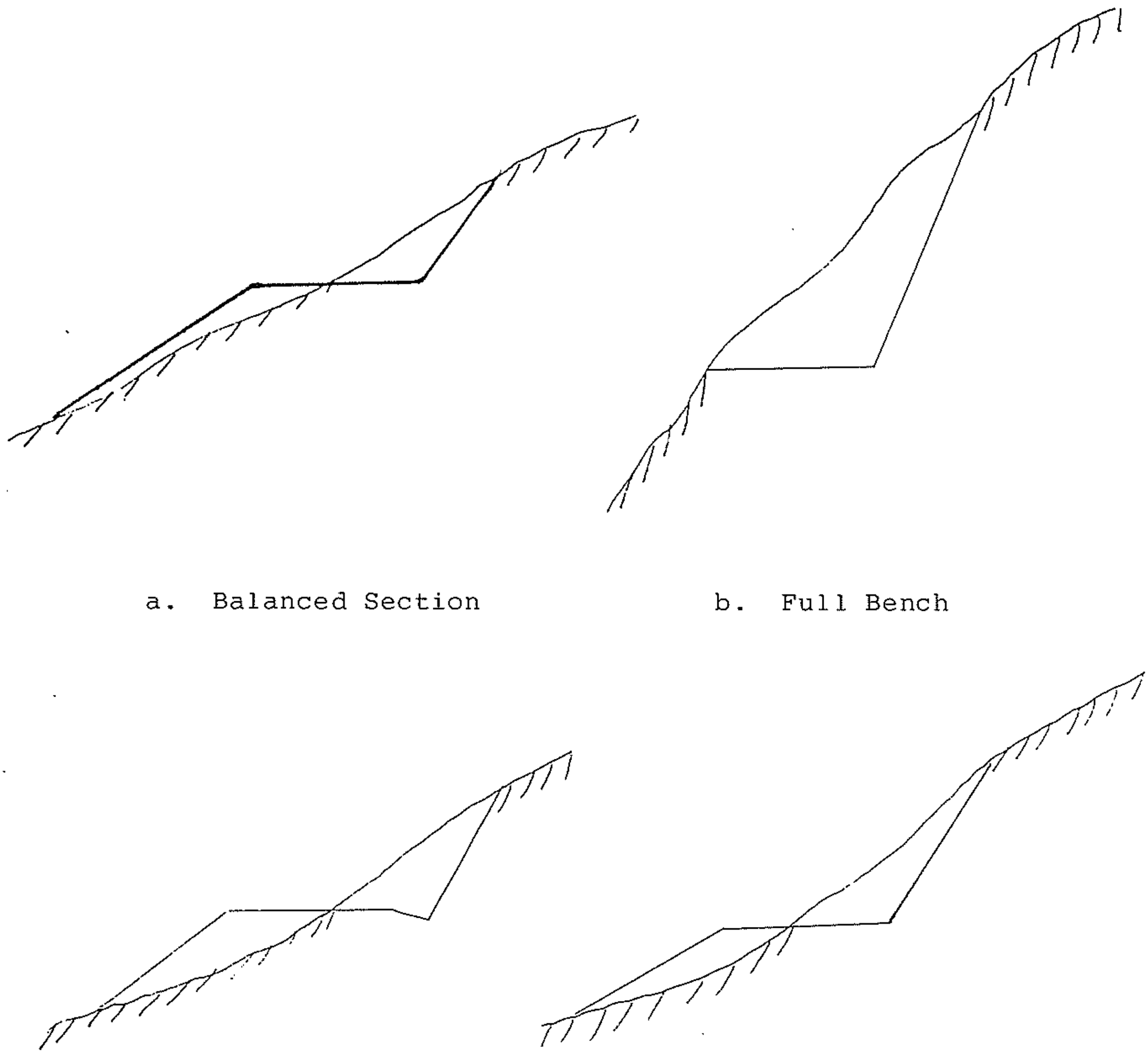
SELECTION OF ROAD CROSS SECTION

Balanced Section vs Full Bench

Most operators in the U.S. Northwest design for a fill slope of 1.5:1, although fills will typically stand at 1.33:1. Depending on the soil characteristics and the environmental emphasis of the landowner, construction on ground over 50% to 65% is usually therefore full bench. Full bench construction is also specified on flatter sideslopes than this where the competence of the material for fill is suspect. However, where the competence of the fill is overshadowed by the height of cut slope that can stand in unstable areas, a compromise is sometimes made by specifying a "minimum cut - minimum fill" section. This is a common choice for flow areas and could be quite widely applicable in New Zealand clay soils.

A balanced section is sometimes specified on slopes too steep to hold a fill, where flatter ground below, within say 20 m or so, will catch the fill.

Maximum fill heights are sometimes specified for clay soils.



a. Balanced Section

b. Full Bench

c. Ditch Inslope

c. Outsloped

Figure 8 : Typical cross-sections of Northwest U.S. logging roads

<u>Cut Slopes</u>

The slopes and maximum desirable height of cut slopes for each locality are determined from experience. Naturally they can vary quite widely depending on soils. It is not unusual to specify a limit of 2 or 3 m for cut heights in flow areas.

It has been observed in the U.S., as in New Zealand, that the smoother cut slope made by an excavator is less prone to sloughing that that made by a bulldozer. Opinions vary as to whether this is because the smoother surface left by the excavator makes the particles less apt to detach, or because the surface layers of soil are disturbed less by the excavator. It is sometimes required to round the top of the cut slope to further reduce failures.

Cut slopes are sometimes laid back at slopes of 1.5:1 or flatter where continuing failure is a problem. This can be a successful means of preventing cut slope failures in flow material, but it often involves large volumes of earthmoving and tends to be avoided because of the expense.

Benches

On slopes over about 35%, it is common to require that a pioneer road be built slightly above the toe of the fill prior to construction, to catch the fill and improve stability. Additional benches are occasionally specified, e.g. in filling through steep gullies.

Ditch

Conventional industry practice is to provide a 0.6 to 1 m width ditch on the inside edge of the road, draining through relief culverts, as is also the usual case in New Zealand.

On public ownerships in some areas of the western U.S., there has been a strong trend in recent years to the elimination of the ditch and the outsloping of the road at a cross-slope of 4 to 6% to drain the water directly across the road. In some cases rock-lined water dips (not water bars) are provided for cross-road drainage.

Outsloping in this fashion has the obvious advantages of reducing the requirement for culverts and the quantity of excavation. For a 4 m subgrade, the earthmoving volume on 50% ground is typically reduced by 33% through elimination of the inslope ditch.

Outsloping has the disadvantages that the road can quickly scour in non-cohesive soils; that the cut slope ravels directly onto the road, reducing road width, requiring maintenance, and contaminating the ballast (figure 9); and that on steep grades it poses a danger to the movement of heavy equipment, especially in wet weather. An additional width of road may need to be cut on the outsides of sharp curves in order to move towers, compared to the road with an inslope ditch. Another concern that is more valid in the U.S. than in New Zealand is that landing width is reduced by not having the extra metre of ditch width available.

In the U.S., outsloped roads appear to be a successful option where the soils are cohesive, grades are not excessive, and dry weather predominates in the logging season. They are reported to have been used successfully in expansive clays in southwest Oregon, where the logging season is largely dry. Outsloped roads merit consideration for cohesive soils not prone to scouring in New Zealand, particularly for planting roads and where cut slope sloughing is manageable. For some of the problem hill country soils, cut bank failures are not manageable and outsloped roads would not be an appropriate choice.

Figure 9 : Outsloped road inappropriately used where soil tends to ravel from cut slope.

CLEARING AND GRUBBING

Clearing and grubbing practices used by Northwest operators in industry are the same as those used in good New Zealand practice - removing all organic material from under the road prism and placing it on the lower side.

Reference may be seen in the literature to extremely expensive clearing methods required on U.S. Forest Service road projects. Clearing and grubbing is sometimes the most expensive phase of a Forest Service project. In nearly all cases the extravagant practices are unjustified and they do not represent any opportunity for New Zealand.

In temporary road construction it is common to permit the inclusion of slash in a fill that is going to be removed later.

EXCAVATION MACHINES

The main earthmoving machines in the Pacific Northwest logging industry are the same as in New Zealand - the bulldozer, with the D-8 size (200 kW) machine found to be the most economic where the road is not narrower than a blade width, and the hydraulic backhoe, with Cat 225 - 235 size (100 - 145 kW) machines being the most common.

Bulldozer excavation methods are very familiar to New Zealanders and are not discussed here. Excavator techniques are still developing in the U.S., and some may not be familiar to the New Zealand forest industry, so a brief discussion ensues.

Hydraulic Excavators

Backhoe construction continues to grow in popularity for Northwest logging roads, with some now being built entirely by backhoe from log salvage to final subgrade grading ready for ballasting (figure 10).

Figure 10 : Entire subgrade construction performed by excavator

Depending on the site, timber, and type of equipment available, the economics can be found by American logging companies to favour either method. In fact, the most common method is often a combination of both machine types. Some examples of combination methods are :

1. **Tractor :** Pioneer and log road line, final subgrade grading
   Excavator : Bench, clear and grub, excavate rough subgrade

2. **Tractor :** Pioneer and log road line, clear and grub, bench, final subgrade grading
   Excavator : Excavate rough subgrade

3. **Tractor :** Pioneer, final subgrade grading
   Excavator : Clear and grub, deck logs, excavate rough subgrade

4. **Tractor :** Pioneer and log road line
   Excavator : Clear and grub, excavate subgrade

The excavator has an advantage compared to the bulldozer for wet conditions, and where downhill dozing is not feasible. In unstable terrain it has the advantage of being able to undertake selective placement in a superior manner, wasting unsuitable materials and using suitable material for fill, matching the fill to the microtopography. However the economics of drifting material even a short distance are very poor compared to the bulldozer. Especially on steep ground, the excavator can have a substantial economic advantage for clearing and grubbing.

American companies have found that, for soils comparable to many hill country soils in New Zealand, in the dry season per-m3 excavation costs are typically cheapest with a bulldozer, for straight sidecast construction. The advantage of the bulldozer seems to be greatest on the simplest type of construction - sidecast.

The excavator is found to be most economic in the more complex projects requiring, for example, selective placement and/or endhaul, extensive installation of culverts or other structures, the excavation of swampy areas, and so on.

A significant advantage for the excavator in some areas is that, by virtue of its ability to work on wetter soils, it has a longer operating season than a bulldozer. However this advantage may be minimised if other equipment essential to construction - e.g. the dump trucks in an end-haul project - have a shorter season than the excavator. The excavator also has the advantage that it can perform many functions that the bulldozer is less suited to (e.g. cut slope smoothing, loading trucks, placing spalls), especially with the range of auxiliary attachments that continues to grow.

While the larger 150 kW excavators are more productive in m3 per hour than the small 100 kW machines, operators often prefer the smaller excavator because it can swing on a narrower road, therefore moving less soil and actually being more productive in terms of lineal m per hour.

The continuing refinement in work methods and attachments is allowing for concomitant cost improvements.

Substantial cost differences can exist between work methods.

WASTE DISPOSAL

The following options are used in the Northwest for disposing of waste generated by throughcuts and full bench construction :

- Sidecast
- Endhaul
- Sidecast and pullback

Sidecast

Sidecast waste disposal was once widely applied in the U.S. Northwest, accepting large sliver fills and some consequent slope failures as a result. Increasingly, landowners are finding it politically inconvenient to shove their waste material over the side. Additionally, excessive sidecast material causes an increase in stump height downslope.

Endhaul

In response to laws making it illegal to allow waste material to enter streams, the Northwest forest industry began endhauling waste to a stable disposal site. The Forest Service, with its more cautious environmental approach, requires endhauling on most slopes over 50% to 60%, while industry tends to endhaul mainly where material is likely to enter the stream, or a sliver fill would create slope instability or major aesthetic problems highly visible to the public. Sometimes the topography suits a cheap endhaul technique such as slot dozing (figure 11) or the use of a scraper, but most often it is necessary to excavate the material and load it with a backhoe into trucks or a scraper for hauling. Sometimes, for instance in excavating a landing, there is sufficient room to load with a small traxcavator (figure 11), but the backhoe is by far the most common.

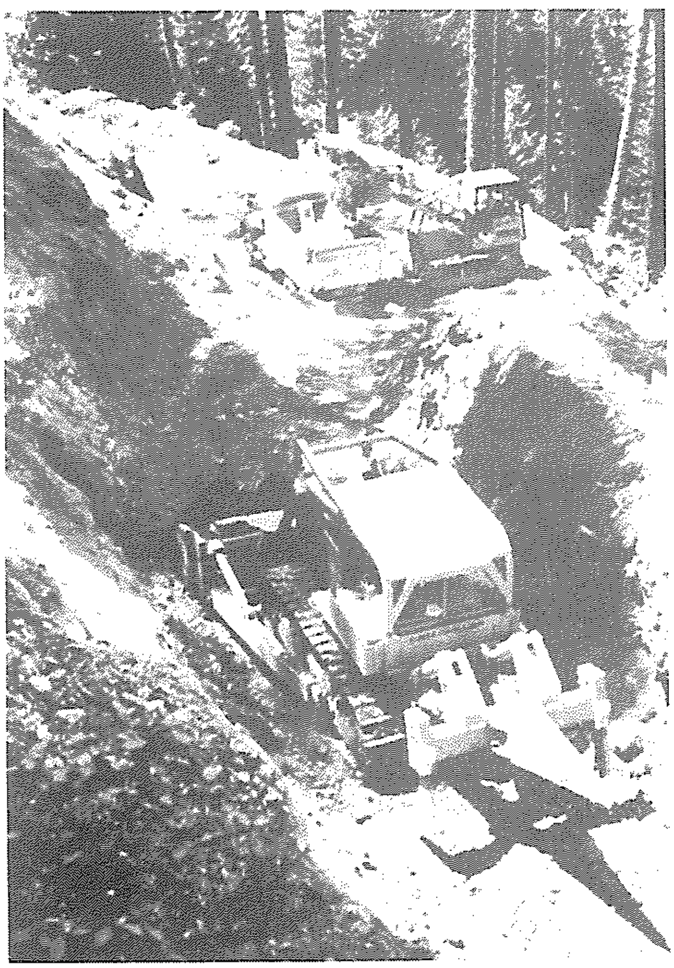


Figure 11 : Slot dozing, to loading point where traxcavator loads trucks for endhaul

Backhoe or excavator operation for endhaul on logging roads is currently undergoing considerable refinement. Depending on the terrain and road specifications, several modes of operation can be considered, as follows :

1. **One-pass method :** The excavator clears and grubs, piles logs, and excavates and loads soil into trucks in one pass along a road. (A dozer is normally used for final grading.)

2. **Bench-loading method :** The excavator builds a pioneer road close to the top of the cut, and clears and grubs and piles logs. Then, operating from the pioneer road, it excavates to grade, loading trucks on final grade as it goes.

3. **Two-pass method :** A bulldozer is used for the recovery of logs, and clearing and grubbing and pioneering. An excavator does the bulk of the earthwork, then the bulldozer returns to do the final grading.

Several variations on the above methods are practised by individual operators, in response to site conditions and equipment capabilities.

Operation of the dump trucks in an optimal manner is important for cost control. Balancing the number of trucks with excavator capacity and providing turnouts as close as possible to the excavator are important. Most operators use 7.5 m3 trucks, some enlarging the bodies to 10 m3 for off-highway use. Larger 15 m3 belly-dumpers can be economic alternatives where there is room to turn them, for long haul distances. Normal haul distances are usually 500 to 1500 m.

Endhaul is not attractive economically. Typically the per-cu.m excavation plus endhaul cost runs at about 5 times the excavation cost for simple sidecast construction. It may therefore double the cost of the completed road, compared to sidecasting the waste.

<u>Sidecast Pullback</u>

Apparently in response to the difficult economic situation in the early 1980's and in some cases to prevent the failure of previously sidecast waste, the industry began "sidecast pullback" as a cheaper alternative to endhaul. In this method, waste material is sidecast, later recovering as much of it as can be reached with an excavator to load it for endhaul. Pullback is frequently performed as soon as logging is completed on a spur, using the freshly-abandoned landing as a disposal site.

Sidecast pullback cuts costs in three ways. Firstly, it is estimated that about half of the material sidecast is allowed to remain on the slope below the road. This is frequently enough to minimise the chances of a slope failure. Secondly, pullback is a more productive operation than normal excavation, because of the optimum digging position. Thirdly, cheap road construction by conventional sidecast methods can be used.

It is considered critical to have good control over equipment operators to get acceptable results with sidecast pullback, and to get the material pulled back before the wet season. Obviously careful scheduling is necessary.

On the U.S. West Coast it appears that in future sidecast pullback will be practised on spur roads and/or where the slope stability risks are not extreme. Where the risks are greater and/or sidecast would reach a stream, endhaul is expected to continue as a waste disposal method.

In New Zealand the usual practice for waste disposal on forest roads is of course sidecast. It is likely that this will become increasingly unacceptable politically, and the industry will find it necessary to dispose of waste in some other way. Much of the present waste sidecasting can be eliminated simply by more emphasis on proper road location and adapting road standards to the terrain. Where waste disposal is necessary, however, sidecast pullback should be seriously considered wherever it is a viable alternative to endhaul.

FILL PREPARATION

The primary methods of fill preparation used on U.S. logging roads are :

- Non-selective placement, i.e. end dump
- Selective placement
- Layer placement
- Substitution
- Reinforcement
- Compaction
- Drainage

Non-selective placement (e.g. many bulldozed fills) and layer placement and compaction by the prime mover in layers of specified depth, e.g. 30 cm) are well known techniques in New Zealand and will not be described here. Selective placement, which is a characteristic advantage with excavator construction since materials can be selected and placed where the microtopography best suits, is also assumed to be familiar in New Zealand forest roading and is not discussed here. Drainage measures are of course all-important and they are discussed under a separate category below.

Compaction

American forest road compaction uses basically the standard highway techniques. For New Zealand logging roads, it would be most appropriate to borrow from local highway compaction experience in the exact same soils. Compaction equipment is therefore not addressed here.

In Northwest logging road practice, those roads that are not full benched by virtue of the steepness of the terrain are mostly sidecast balanced construction. Large through-fills are not especially common.

Compaction practice varies between industry and government ownership.

In industry, compaction is mainly achieved by earthmoving equipment. Roller compaction and testing are used only on the largest through-fills. Compaction is probably sub-optimal in many cases.

On Forest Service roads, compaction is more closely monitored. At one time density measurements were common but budgetary restrictions have led to their replacement to a large extent by visual methods. The Forest Service uses the following compaction measures :

1. Side cast and end dump - generally on slopes uder 33%.

2. Layer placement, compacted in the process of placement by earthmoving equipment.

3. Layer placement with roller compaction, with compaction considered to be achieved when either (a) there is no visible deflection under the equipment, or (b), in the case of a sheepsfoot roller, the roller walks out of the material. At least three complete passes are required.

4. Controlled compaction of layers to 5% of AASHTO T-99, Method C or D. This requires frequent density measurements.

5. Controlled compaction with a control strip is similar to 4., but it also requires that a 300 sq. m control strip be constructed at the beginning of work on each type of material. When maximum compaction has been reached on the control strip, nuclear density tests are taken, and the results used to determine the target density of the rest of the fill.

6. Special project controlled compaction is to 90% of AASHTO T-180 Method C or D.

The selection of one of the above compaction methods is made according to the nature of the material, the ground slope, the importance of the road, and the risks entailed in a failure.

It goes without saying that industry excavation costs are a fraction of those experienced on Forest Service roads. The Industry standard that material is suitable for logging traffic once it doesn't deflect under a loaded 10-yard dump truck seems to be a good direct measure of roadway strength for many situations that can be widely applied.

Substitution

The technique of removing incompetent materials, and substituting other competent soils or rock, is already well known in New Zealand. However a variation on this method that is rapidly finding favour on U.S. logging roads may not be used in New

Zealand yet. That is the use of waste forest products for lightweight fill. Sawdust and pulp chips have been used, but the most common material is hog fuel. Most fills of this type have been used on temporary roads, but some are incorporated in permanent roads. The oldest such fill is thought to be about 15 years, but it is known that much older sawdust piles consist of sound material under the surface. On roads planned to last more than a couple of years it is usual to seal the fill surface with asphalt. The fill is often underlaid with filter fabric.

There is no experience in the U.S. with radiata pine hog fuel; Douglas fir waste products are the most common used in fills. It would be worthwhile to construct a trial fill of sawdust, chips, or hog fuel (or all three) in an area where fill mass is critical, to test the stability of radiata pine for this method.

There is already experience in New Zealand with the use of mill slabs as a raft for temporary roads.

Polystyrene has been considered as a lightweight fill material but it is regarded as prohibitively expensive.

Fill Reinforcement

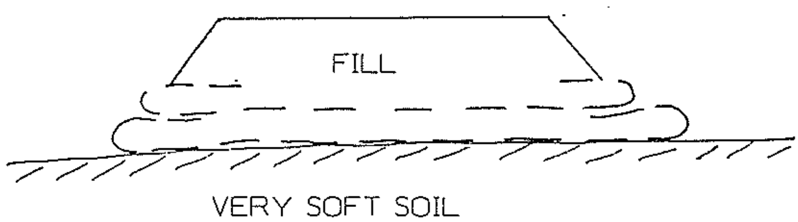


Figure 12 : Fill reinforcement with geotextile

Apart from the reinforcement of fills with substituted material such as rock, there has been some experience on U.S. logging roads with the use of fabric for fill reinforcement. It is used in the nature of a raft to place a fill over incompetent material, in much the same way as filter fabric is used under aggregate as a separation layer. In fabric reinforcement, it is usual to fold the outside edges of the fabric over to enclose about a 30 - 60 cm thickness of fill, then add a second and if necessary more reinforcing layers of fabric before completing the fill.

An alternative to fabric for fill reinforcement is the geogrid, the most common brand used being "Tensar". Tensar is a plastic grid material that is rolled out and covered with a layer of fill, in much the same way as fabric. Tensar has been used on forest roads in a variety of soils, although apparently it has found only limited application in clay. No logging road experience in expansive clays is known to have occurred with Tensar, although there is likely to be highway experience. For fill reinforcement, it is often found that fabric is more economical to use, because of its lower cost, although more layers are likely to be required than if Tensar were used instead.

The biggest application of Tensar on logging roads is for slope reinforcement. Horizontal layers of Tensar are incorporated in the outer edge of a fill to enable it to be built at a steeper slope than usual, say 1:1.

FABRICS

Fabrics are widely used on Northwest logging roads for a variety of applications, which generally fall into one or more of the following categories :

Filtration : remove the water, retain the soil, typically in drainage.
Separation : prevent mixing of materials, typically preventing fines from contaminating desired soil or basecourse.
Subgrade restraint : restrain soils by confinement with the fabric.
Earth reinforcement : strengthen soil.
Erosion control : prevent surface soil movement.
Water proofing : hold asphalt in a waterproof layer.
Pavement reinforcement : strengthen pavement and reduce required thickness.

Forest industry experience in the Northwest with the latter two applications is very limited and they are not discussed here.

With the large number of products available, it is necessary to select the right type of fabric for each application. No one fabric is suitable for all applications.

Filtration

Typical filtration applications are discussed in the section below headed "Drainage".

Fabrics are regarded as more reliable means of filtration than graded filters, given that the latter require a gradation designed to provide the right balance of permeability (which requires large pore spaces) and piping (which requires small pore spaces (to trap soil particles)). For the average forest road application, however, the difference is not great in practical terms.

U.S. Forest Service experience has been that conventional graded aggregate filter drains have failed about 50% of the time, whereas the failure rate with woven filter fabric is believed to be less than 5%.

It is usual to select a fabric for filtration that has approximately the same permeability as the soil. It is usual to install woven filter fabrics of 70 to 100 EOS (Equivalent Opening Size, a measure of permeability) for most projects, with 30 to 70 EOS fabrics used only in coarse sands and gravels of high permeability. Non-woven fabrics, with their more variable and less easily measured permeability, are not recommended for high-risk filtration applications. Non-woven fabrics are acceptable, however, for most forest road drainage applications.

Fabrics are strong and are very rarely damaged by the placement of rock.

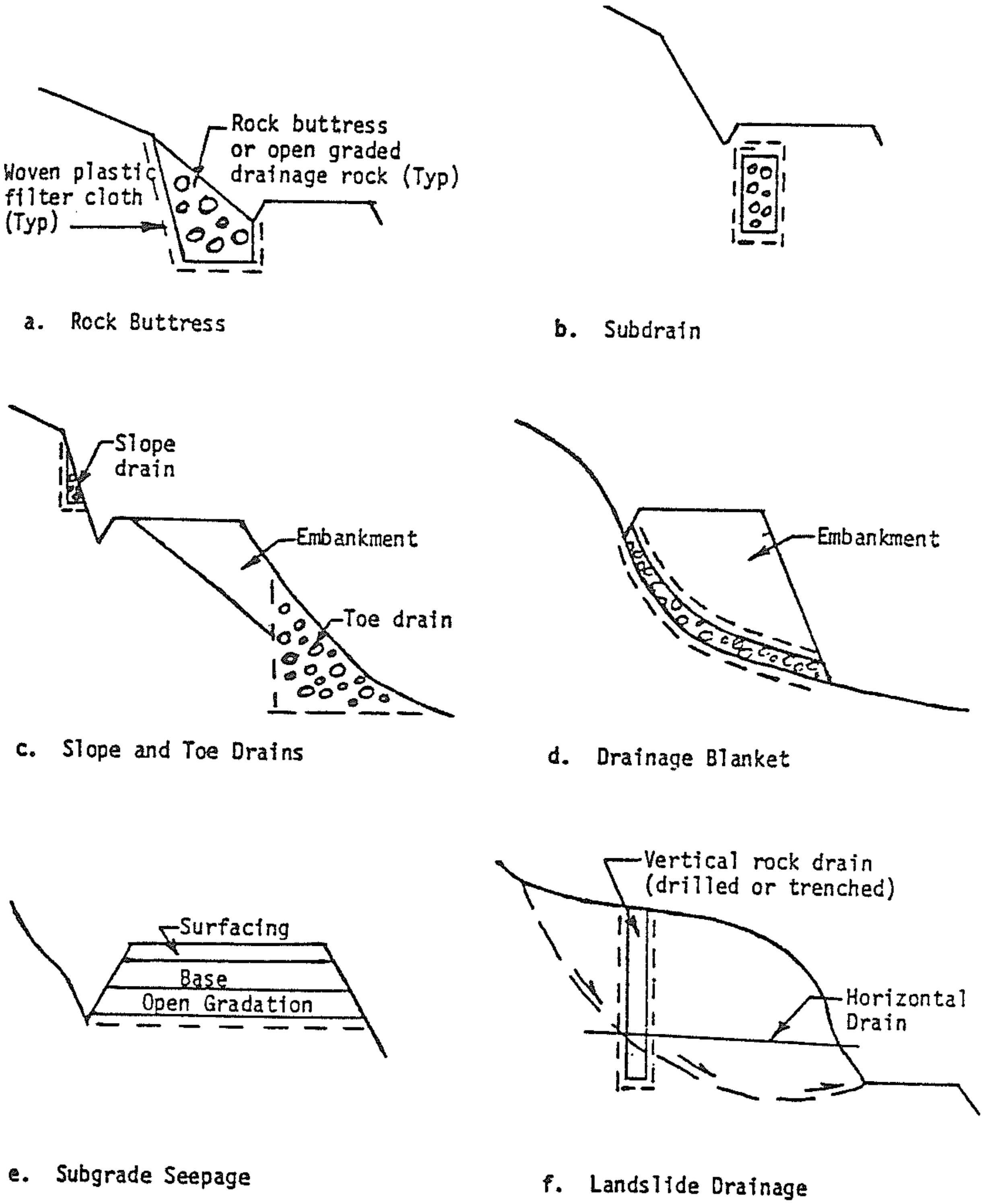


Figure 13 : Typical drainage applications for filter fabric

Drain rock used with filter fabric can be pea gravel to spall size, although with spalls it is prudent to provide a layer of smaller material to protect the fabric.

Separation

The most extensive use of geotextiles on Northwest logging roads is for separation, which normally means laying fabric over the subgrade before spreading rock, to reduce contamination of the rock with fines. One rule of thumb is that the fabric will save 7 to 15 cm of rock through the reduction of contamination. If necessary, an economic analysis can be conducted to determine the desirability of using fabric on a particular project, by comparing (a) the CBR and therefore thickness required of the aggregate with normal contamination from the subgrade, and with (b) the CBR and therefore thickness required of the aggregate with a reduced level of contamination (25% is a common number) through using fabric. In practice the decision to use fabric is normally made on experience.

Non-woven and some slit-film woven fabrics have been the most successful for separation.

Subgrade Restraint

The economics of using fabrics for restraint will control only for subgrades with a CBR of less than 2 or 3. Where the subgrade CBR is greater than 2 or 3, the separation function will normally control. The use of fabric in the subgrade restraint application is most favoured economically on low standard roads where large deflections and 10 to 15 cm ruts can be tolerated. It is thought that aggregate thickness can be reduced up to 1/3 less than without the fabric, but the thickness should be adjusted by trial during construction to limit the depth of ruts to, if possible, 5 cm.

It is claimed that this technique has been successful in forest road construction over soils with a CBR of less than 0.1.

The heavier non-woven fabrics are the most suitable for subgrade restraint.

Earth Restraint

Earth reinforcement with fabrics on forest roads has been used to make retaining walls. For the reasons given below under the heading "Retaining and Buttressing", fabric walls are not considered likely to find wide application in New Zealand and are therefore not discussed here.

The other application of earth reinforcement with fabrics on Northwest forest roads, supporting fills on soft soil, is described above under the heading "Fill Reinforcement". Non-woven fabrics are the most suitable for this application.

Erosion Control

Fabric has been used on Northwest forest roads as culvert aprons, as silt fences erected at the toes of fills, as silt barriers draped over piles of brush at the toes of fills, as scour protection under rock in channels, and as a protection for entire fill slopes.

CHEMICAL STABILISATION

Expansive clays have been successfully stabilised by lime and by cement on some West Coast forest roads. The best U.S. experience with chemical stabilisation is in the Gulf States of the South, where montmorillonite clays are the most common. While there is a large amount of highway experience in the South with expansive clays, the terrain is very subdued and slope stability problems are not nearly as common as in New Zealand.

The practices used in lime and cement stabilisation on American forest roads have followed standard highway techniques.

Reynolds Road Packer, a product used in New Zealand, was heavily promoted in the U.S. forest industry at one time also. It is now regarded as "snake oil", but its disrepute appears to be based at least in large part on ill-advised application in unsuitable soils. It is now difficult to obtain reliable data on the performance of roads that may or may not have been correctly and/or appropriately treated with the product.

DRAINAGE

Drainage is regarded as the primary method of subgrade stabilisation in flow and slump areas. The drainage methods in use on logging roads are :

Road surface drainage - either with an inslope ditch or across an outsloped road, as discussed above in the section "Selection of Cross Section".
Vertical or French subsurface drains (figure 14).
Horizontal subsurface drains.
Rock blankets.
Surface intercepting ditches.
Prefabricated drainage products.

Note that with all types of subsurface drains, American engineers regard prior exploratory drilling as essential if the large investment in drainage is not to be partly or wholly wasted. One case has been quoted where $150,000 in additional construction costs was incurred through the failure to spend $1000 or so on some simple exploration.

Vertical or French Drains

Where it is necessary to lower the water table in a subgrade, vertical filter drains are used. The graded aggregate (sand or gravel) filters of the past have largely been replaced with rock spalls protected by a filter fabric enclosure from contamination by fines. If necessary, a perforated pipe is placed at the bottom of the trench, connecting to horizontal drainage under the fill for disposal on the downhill side. Extensive use is made of flexible corrugated polythene culvert pipe for drainage under and beyond the road. Its flexibility and lightness are advantageous in installation, and its flexibility is especially important where there may be soil movement that would cause the failure of other pipe materials.

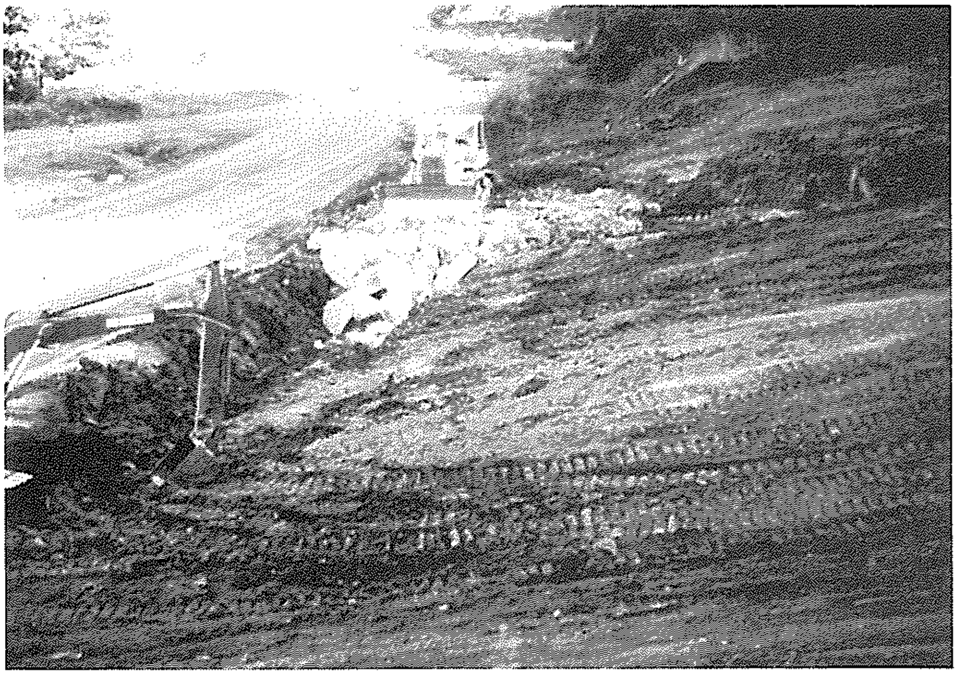


Figure 14 : Crude French drain under construction to arrest earthflow. Cure also included laying back cut slope to 5:1.

The maximum depth of a French drain is frequently constrained by the depth that a trench can be excavated without the risk of collapse. For many soils in the Northwest, this has meant a practical depth limit of about 3 to 3.5 m, and it is felt that in many cases this did not lower the water table sufficiently. It is often considered economic to drill first to determine the depth required.

Vertical drains would be a likely dewatering method for many wet areas on New Zealand logging roads. However, they are expensive, and difficult to justify economically except on mainlines or for short lengths. This is the case in the U.S. Northwest, where good rock is usually more readily available than in the unstable areas of New Zealand. Vertical drains are found to be effective for dewatering a subgrade, to increase its strength, but generally do an insufficient job in solving slope stability problems.

Horizontal Drains

In addition to the conventionally-installed horizontal drains noted above, drilled horizontal drains are also installed to drain seepage. These are used fairly widely in slumps and flow areas to dewater the contact plane of the slide and stabilise the subgrade. For this application, it is considered economic to first drill exploratory holes to locate the water table and/or contact plane.

Two types of drilled horizontal drain have been used on forest roads. One is a metal pipe that is augered into the ground, and the other is a PVC pipe inserted inside the drillpipe after the hole is drilled. It is important not to drill too far past the slip plane, as then if the slide continues to move it may shear the drain and actually aggravate the condition.

Horizontal drains are usually installed above the top of a cut to intercept water that would otherwise saturate the subgrade. They are sometimes also inserted from the toe of the fill if additional dewatering is required. It is frequently found that the largest volumes of water are actually intercepted not directly above the natural seepage outlet, but laterally one direction or the other. The money spent on horizontal drains may therefore be wasted unless adequate drilling is done to locate the flow. Successful use has been made of dyes to determine the path of flow.

Water trapped by the horizontal drain can either be allowed to flow out of the outlet to the ground, in which case adequate scouring protection must be provided, or else fittings are attached to the outlets (figure 15) to enable collection of the water and discharge to a stable location (figure 16). Flexible corrugated PVC culvert pipe is successfully used where water must be carried some distance across unstable ground (figure 17). It is not damaged by slope movements where other pipe materials probably would be.

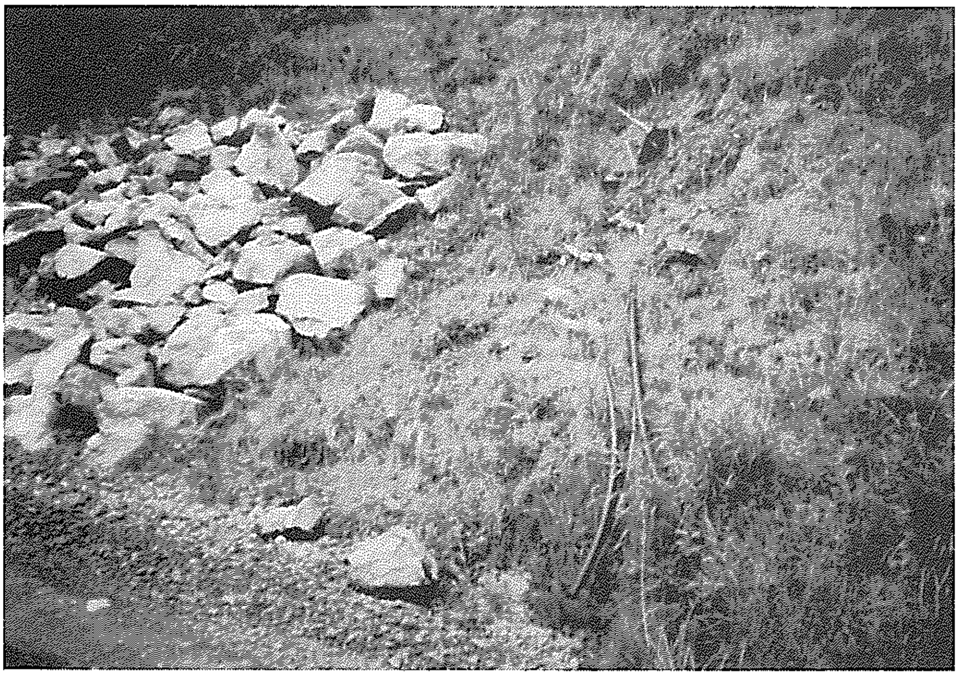


Figure 15 : Pipes carry flow from horizontal drains to stable outlet

Horizontal drains have been used both to reduce slope instability and for subgrade dewatering. It is claimed that one slide of 2 ha has been largely arrested by this method.

Horizontal drains are expensive and are difficult to justify on roads other than mainlines. Presumably there is New Zealand highway experience with this method of stabilisation, that could be adapted to logging roads.

Figure 16 : Collection point for several horizontal drains

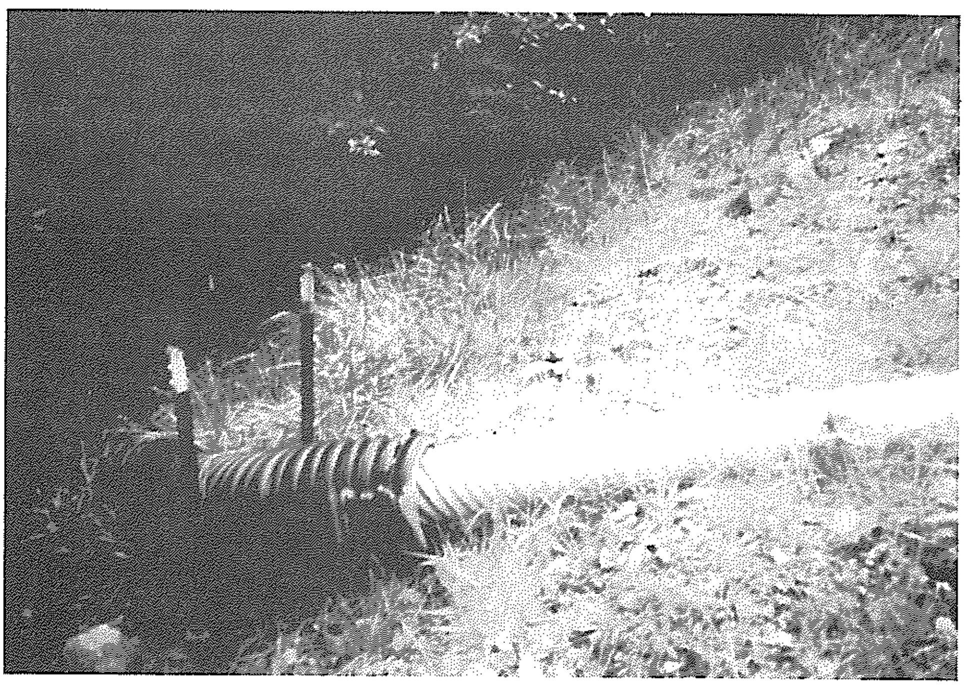


Figure 17 : Flexible PVC pipe is not damaged by slope movement

Rock Blankets

A technique used on American logging roads and on highways in New Zealand is the rock blanket. Rock is placed in a layer of about 1 m under a fill, with fabric above and below to prevent contamination. As well as dewatering the fill above, a rock blanket may also be used to drain water from a French drain on the uphill side. It may also sometimes serve a combined buttressing function.

Intercepting Ditches

Intercepting ditches installed above the cut can sometimes be a "cheap fix" for unstable areas on forest roads, particularly on shallow slumps with a slip plane close to the surface. One such installation consisted of a channel lined with rock and a fabric filter, that intercepted surface flow 60 m above a road. This approach could also be combined with intercepting vertical drains in locations accessible to trenching equipment.

Of course the opportunity to drain sag ponds that have developed in slump terrain is always taken advantage of, usually by making an intercepting ditch with a bulldozer or excavator.

Prefabricated Drainage Products

Recent entries to the road construction business are Prefabricated Drains, of which Miradrain and Enkadrain (information appended) are representative.

Prefabricated drains of the type of most interest for forest roads consist of a 1 to 2 cm thick panel of plastic baffles or plastic mesh, sandwiched between outside surfaces of filter fabric. The sheet is used as a substitute for a vertical aggregate or rock plus fabric French drain. The fabric prevents soil migration into the panel, the space between the baffles provides drainage for water that enters through the fabric, and the baffles or mesh serve to prevent collapse of the structure.

A trench of about 90 cm width is typically dug, and it is found practical to dig deeper than with a rock drain - frequently 4 m, and possibly 6 m. The trench is backfilled with native material, eliminating the need for rock. It is common to place a perforated pipe at the bottom of the trench, connecting to cross-road drainage.

It is necessary to select a product that uses a covering fabric with a sufficient modulus for the specific application, so that it will not deflect into the drainage passage.

At this time, prefabricated drainage is regarded as a product that is not fully proven but which has generated considerable enthusiasm from widespread test installations. Its two advantages are that it eliminates the need for rock or aggregate for a vertical drain, and that a deeper drain is feasible. It has potential for New Zealand and certainly deserves some trial installations.

It has not apparently yet been tested as a substitute for a rock blanket. It is not known whether the plastic would slowly deform over time under a fill, causing drainage to fail. Lateral pressures in a vertical installation are not considered a problem.

RETAINING AND BUTTRESSING

Walls and buttresses are used to support cuts and fills.

Rock Buttresses

Cut slopes are fairly commonly buttressed with rock in unstable areas in the U.S. West, particularly on mainline roads (figure 18). The smaller buttresses are rarely designed, but built from local experience. They are often built on existing roads in response to a chronic cut failure through slumping or flow. Typically they consist of a 1 to 2 m thick layer of spalls up to 3 m high for the control of flow material in a road cut. For common small cut slope failures it is usual to use 30 to 50 cm of rock on filter fabric. For areas of major instability, rock buttresses are designed and may have a size up to 6 m thick and 12 m high. They are effective in retaining slumps, but of course an ample supply of good rock is necessary. It is important that the added mass does not overload the fill, and for a large buttress a stability analysis is required to avoid this.

Figure 18 : Rock buttress used to retain chronic flow on a mainline road

Rock buttresses are rarely seen on fill slopes of forest roads as the quantity of rock required to provide stability tends to make it uncompetitive with other methods.

On some logging roads, rock buttresses have been used to support an unstable natural slope beneath a fill.

Rock buttresses are already used on New Zealand highways and it would be redundant to provide a further description here.

Compacted Soil Buttresses

Small compacted soil buttresses have been successfully used to control cut failures at the toe of a flow (figure 19). One observed at the base of a slide deposit consisted of about 1.5 m of compacted native soil over a 30 - 60 cm rock blanket with a fabric filter beneath. This technique would have application on some New Zealand forest roads, and presumably there is already some local highway experience with the method.

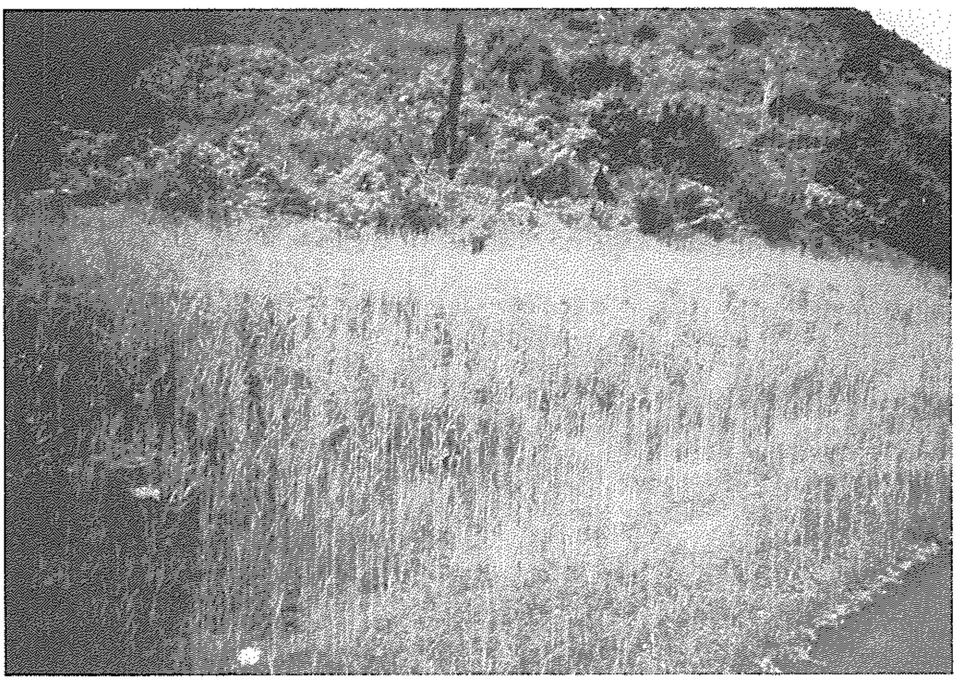


Figure 19 : Compacted soil buttress used to retain earthflow on forest road

Retaining Walls

Retaining walls are used on American logging roads to retain fills where they can be economically justified by a large tributary timber volume. The following types have been used :

- H-pile and lagging
- Fabric encased
- Bin walls
- Crib walls
- Chain link netting
- Hilfiker wire wall
- Gabions

Walls probably have limited application on New Zealand forest roads. Most types are intended to allow fill construction to proceed across ground steeper than the angle of repose of the fill material, and for most New Zealand situations it is cheaper instead to full bench the road. In the U.S., walls are primarily used on logging roads in areas where the topography is very uneven and an acceptable alignment could not be obtained for a full bench road without extremely large cuts. The main exception is the H-pile, which is used to cross slide zones, but which is expensive. American logging road practise with walls is therefore treated only cursorily in this report.

H-pile Walls

These are expensive structures used to stabilise fills across slide zones, and are justifiable only for main haul routes. The piles are driven down into competent material below the slip plane, and tied back to a deadman pile driven into competent material upslope. Timber lagging is used to complete the wall between the piles. It is assumed that the method is already well known in New Zealand highway practise and it is therefore not described further here. Similarly, bin, cement bag, and crib walls are believed to be established New Zealand highway techniques and are not discussed here. They find occasional use on American logging roads.

Fabric Walls

Walls constructed by filling in 60 - 100 cm layers over sheets of filter fabric, folding the sides of the fabric up to support the fill in a nearly vertical wall, have never become popular on West Coast logging roads. To prevent photodegradtion of the fabric, it is sealed with asphalt, which of course seals in the water, a problem in impermeable soils. The fabric also is prone to accidental damage and vandalism.

Chain Link Netting Walls

Chain link walls are constructed by placing a layer of fill on a layer of netting, then folding the netting up over the edge to contain the fill in a nearly vertical wall. They require considerable skill for successful installation.

The Hilfiker product is a welded wire mesh that is used as a substitute for the chain link wall. It is more expensive than the chain link material, but is less labour intensive in its installation. Americans find that the chain link is typically a cheaper wall up to 6 m height, above which height the Hilfiker is cheaper.

Gabions

Gabions are wire netting cages filled with rock spalls. They are used for small walls and also for buttresses and river bank protection. It is assumed that their use is well known in New Zealand.

PAVEMENT STABILISATION

Brief mention is made here of a couple of pavement stabilisation ideas from the U.S. that would find application in New Zealand.

1. Where it may be economically justifiable in theory to seal a mainline road, American experience in unstable terrain has been that cracks develop as fill settles, that are not acceptable in a paved road. Maintaining the road as a sealed road then becomes expensive. A gravel road would actually have been a better choice in many cases, since the crack can be graded more or less smooth.

2. Some forest owners have relatively good soils maps, in which the soils are delineated on a pedological rather than a geotechnical basis. By sampling these soils for clay content and plastic index, an R Value is derived for each soil series. ("R Value" is a bearing ratio that may be correlated with CBR.) The tabulation of R Values is combined with the expected number of traffic passes over the road to produce a recommended aggregate depth. This has been found to produce fairly good results in terms of surfacing economy and pavement stability, for a much lower cost than could have been achieved by testing soils from each road project individually. A similar approach would be applicable in New Zealand where soils have been mapped in detail.

3. Various chemicals have been used in the U.S. for the forest road pavement stabilisation, including dust abatement, that may not have been considered in New Zealand. Their use could be appropriate in some of the rock-poor post-war planting areas.

ROAD DECOMMISSIONING

It is regarded as critical in the U.S. timber industry that temporary roads be abandoned in an ordered manner that will allow them to be self-maintaining (in a state that is generally not suitable for vehicles) until such time as they may be needed in the future, and without a risk of environmental impact through road failure. This is done through the removal of all culverts in live streams and fills over about 1 or 2 m height, water bars that are spaced appropriately for the local soil and road grade, pullback of oversteepened sidecast material, grass seeding, and any other measures necessary to control the movement of water on the road.

Most of these techniques are already well known in New Zealand forests. The philosophy of treating certain roads as temporary structures that can be self maintaining between times of use, however, does merit consideration for the New Zealand case, as discussed previously.

PRIORITIES

In Northwest practice it has been found that the best way to maximise stability is to put the greatest emphasis on good location and the use of road standards appropriate to the terrain. Where mitigation measures are found to be necessary, the simpler fixes are also the most effective - compaction and drainage. More complex geotechnical solutions such as walls are used where nothing else will work. The same philosophy should also apply in New Zealand forests.

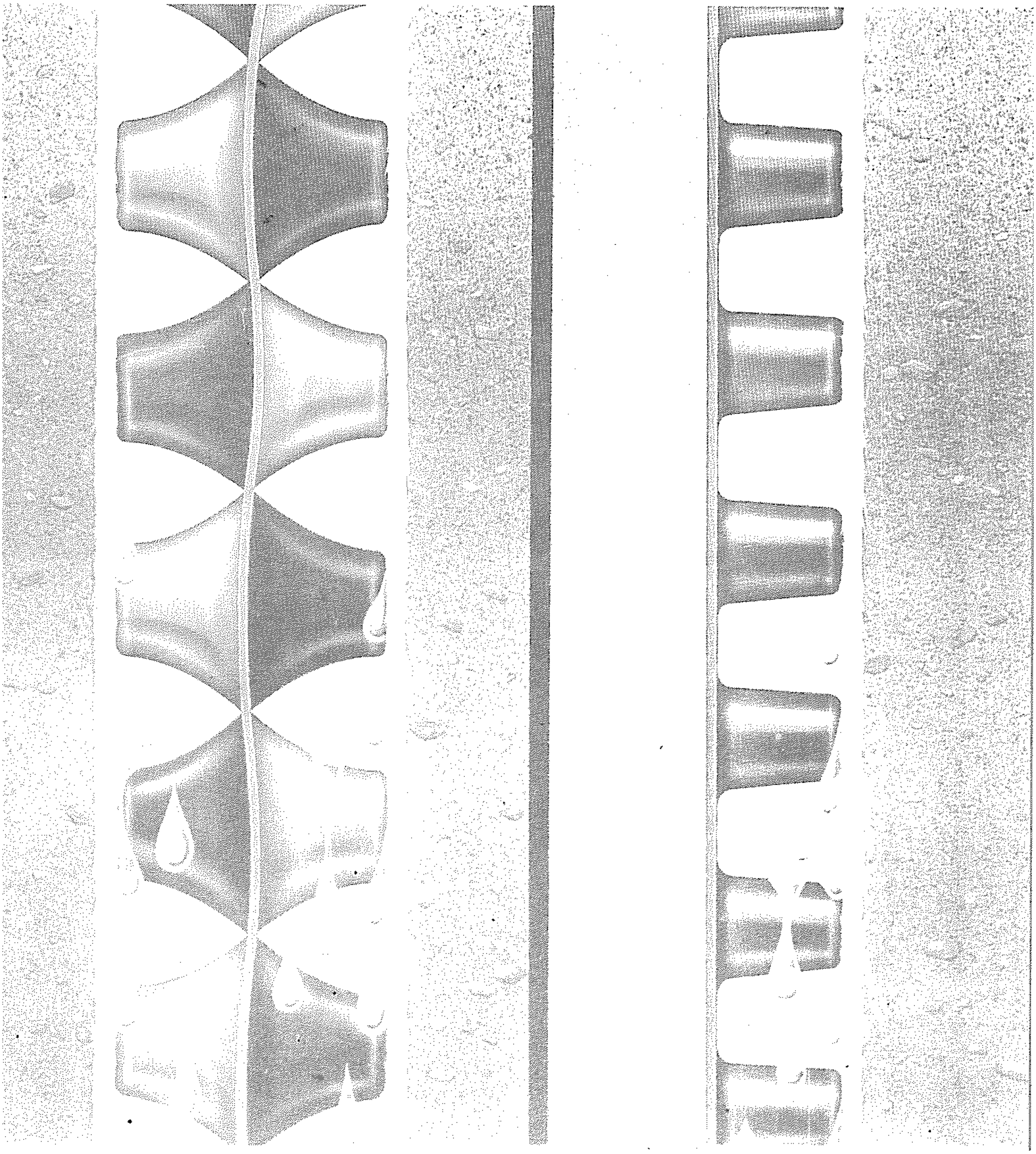
A PRODUCT OF MIRAFI INNOVATION

APPENDIX

MIRADRAIN™

PREFABRICATED DRAINAGE STRUCTURES

The proven alternative to aggregate drains



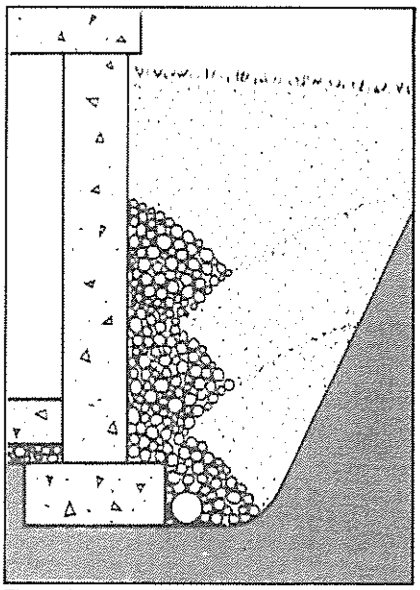


Fig. 1–Aggregate Drain System

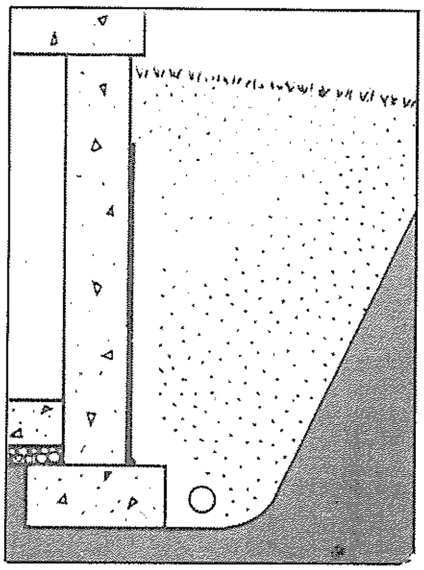
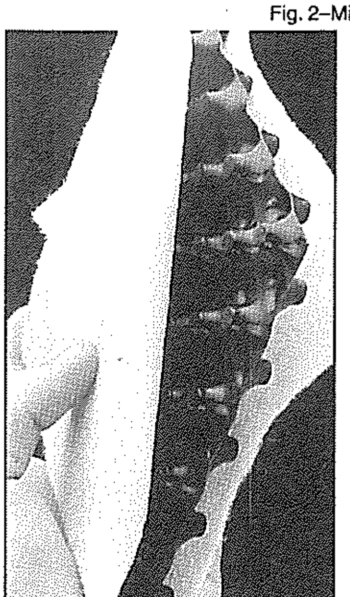
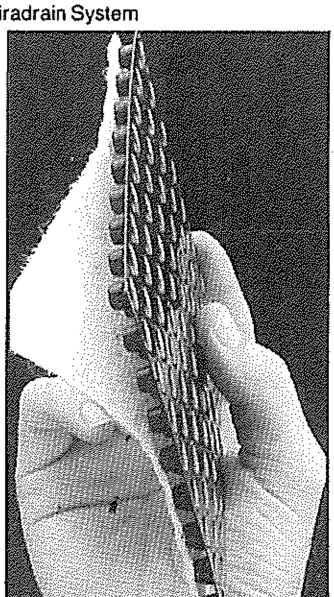


Fig. 2–Miradrain System



Miradrain 4000



Miradrain 6000

THE IMPORTANCE OF EFFECTIVE DRAINAGE

Drainage plays a critical role in the design and construction of subterranean walls. Without proper drainage, ground water seepage may cause hydrostatic pressure which can result in severe structural damage.

Effective drainage is essential. Yet, the costly and time-consuming installation of conventional aggregate drainage systems (Fig. 1) often compels builders and designers to compromise on drainage. In too many cases, drainage systems are not given proper attention; the resulting maintenance costs of weakened or leaking walls far outweigh the initial cost of installing an effective drainage system.

MIRADRAIN

Recognizing the importance of effective drainage, Mirafi has conducted extensive research into cost-effective drainage systems for more than a decade. In addition, Mirafi has gained considerable field experience in numerous subsurface drainage applications throughout the United States and Canada. The result of this research and experience is Miradrain, a line of patented* prefabricated drainage systems engineered to replace costly, conventional aggregate drains.

Miradrain systems (Fig. 2) effectively reduce hydrostatic pressure against below-grade structures and aid in dewatering saturated soil by collecting and conveying ground water to a drainpipe for discharge.

The Miradrain concept consists of a lightweight, 3-dimensional, high-impact polymeric core and a Mirafi filter fabric. The Mirafi filter fabric is bonded to the dimples of the polymeric core to maintain a rigid surface. This bonding prevents the backfill from pushing the fabric into the flow channels and reducing water flow. The filter fabric allows water to pass freely into the molded drain core where gravity draws the water through the flow channels to the discharge system. The Mirafi filter fabric also prevents soil particles from entering and clogging the core structure and discharge pipe, and significantly increases the effectiveness and service life of the drain system.

ADVANTAGES

Miradrain's predictable and reliable performance is the result of careful engineering and product design.

- Multi-directional core channels provide sufficient flow capacity for most drainage applications.
- Compressive strengths are engineered to withstand a wide range of installation and earth stresses.
- Interlocking assembly ensures continuous flow channels between adjacent panels.
- Filter fabric is bonded to the molded core dimples to prevent the fabric and soil from blocking the water flow channels during backfilling.
- Uniform product quality ensures consistent in-place performance characteristics.
- Miradrain enhances waterproofing by conveying ground water away from the waterproofing system.
- Miradrain eliminates hydrostatic pressure build-up against subterranean structures.

CONSTRUCTION BENEFITS

- **Increased jobsite productivity.** Because the panels are lightweight and flexible, installation is easy and fast, requiring only unskilled labor. Skilled labor and heavy

*U.S. Patent Nos. 3,563,038 and 3,654,765.

equipment are released for more demanding tasks.

- **Cost savings.** Rapid assembly combined with low labor and equipment requirements result in project cost savings.
- **Local availability.** Miradrain systems are available at over 300 locations throughout the U.S. and Canada.
- **Technical support.** Qualified Mirafi engineers and technical representatives are available to assist with design and construction considerations.

MIRADRAIN 4000

DESCRIPTION

Miradrain 4000 (Fig. 3) is a lightweight, high-impact polymeric drain core with flow channels on both sides. A Mirafi filter fabric is bonded to the tops of the molded dimples on one or both sides.

APPLICATIONS: TWO-SIDED DRAINAGE

With filter fabric on both sides, Miradrain 4000 is designed to promote soil stability by intercepting and removing ground water in a variety of two-sided drainage applications:

- Slopes
- Embankments
- Pavements
- Earth Dams
- Pavement Edge Drains

MIRADRAIN 6000

DESCRIPTION

Miradrain 6000 (Fig. 4) is a lightweight, high-impact polymeric drain core with flow channels on one side with a Mirafi filter fabric bonded directly to the molded dimples. This prefabricated drainage structure is specifically designed for applications where drainage is needed only on one side. Since the molded flow channels are on one side, the flat back side of the core will fit directly against wall surfaces to provide maximum compatibility with a wide variety of waterproofing systems.

APPLICATIONS: ONE-SIDED DRAINAGE

Miradrain 6000 can be applied as a continuous drainage system or as a series of intermittent chimney drains in the following applications:

- Foundation walls
- Retaining walls
- Bridge abutments
- Box culverts

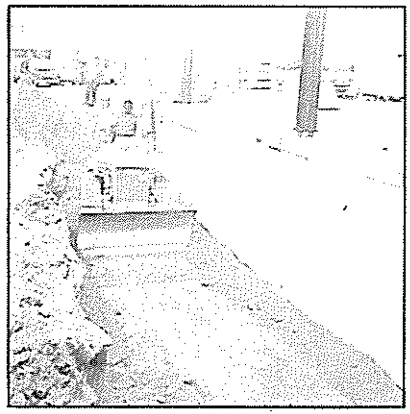
Finished wall surfaces: Since the back of Miradrain 6000 is flat, it is especially suited for installation adjacent to finished walls made of block, poured-in-place concrete and precast concrete.

Shoring systems: Because Miradrain 6000 installs easily against lagging, caisson, and other applications where concrete forms are required on one side, it is a highly effective alternative to aggregate drains. Particularly since concrete, Gunite or Shotcrete can be applied directly to the drain core.

OTHER MIRADRAIN APPLICATIONS

Miradrain prefabricated drainage structures can also provide effective drainage in other applications such as planter boxes, leachate collection systems, and tunnels.

Mirafi engineers are available and prepared to help evaluate specific site conditions and determine the Miradrain configuration best suited for the drainage application under consideration.



Miradrain adjacent to finished foundation wall

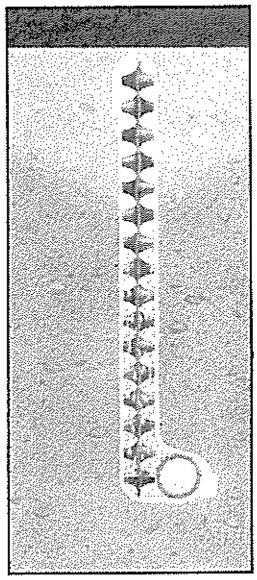
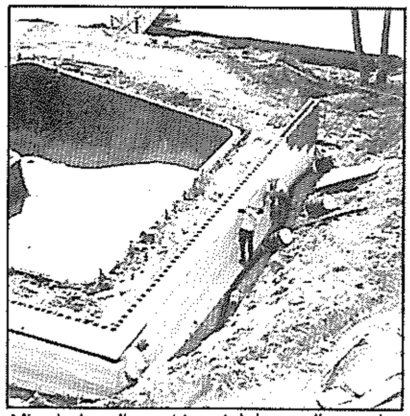


Fig. 3–Miradrain 4000



Miradrain adjacent to retaining wall

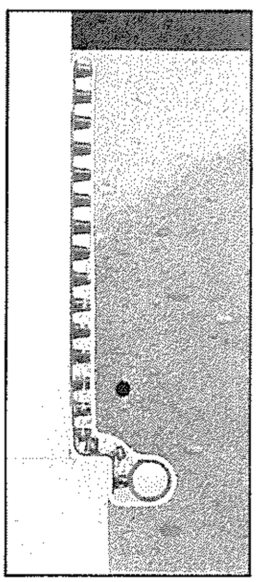
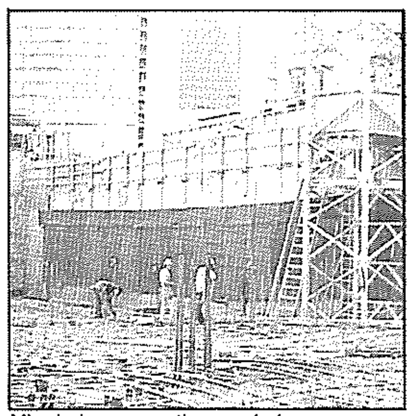
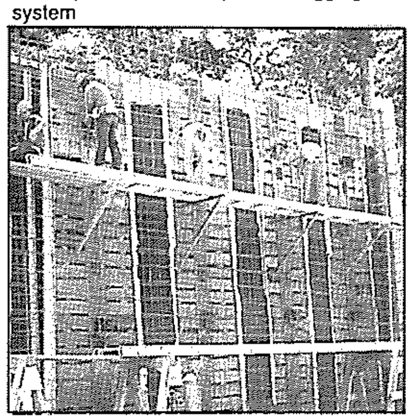


Fig. 4–Miradrain 6000



Miradrain as a continuous drainage structure adjacent to soldier pile and lagging system



Miradrain as a chimney drain adjacent to lagging system.

MIRADRAIN INSTALLATION GUIDELINES

ONE-SIDED VERTICAL WALL DRAINAGE

ADJACENT TO FINISHED WALLS

(1) MIRADRAIN ATTACHMENT

Attach the Miradrain panels using the following materials depending upon the type of substrate:
Concrete Substrate: Drive nails through washers or wood lathing strips. Power or pneumatic actuated fastening devices can increase the rate of installation.
Insulation/Protection Board Substrate: Miradrain is often specified as a dual purpose replacement for the protection board. If insulation is required, metal stick clips (1⅝" long) with self-locking speed washers are fast and most effective for insulation and protection board substrates. Mastic adhesives should be used according to the recommendation of the insulation manufacturer. Drive nails at a downward angle in extruded or expanded polystyrene boards.
Waterproofing Substrate: Metal stick clips are excellent for attaching Miradrain to waterproofing materials. Soft membranes such as rubberized asphalts should be installed according to the manufacturer's recommendation with a protective layer placed prior to Miradrain attachment. For bentonite systems, Miradrain can be supplied with a confinement membrane on the side opposite the filter fabric. If recommended by the bentonite manufacturer, Miradrain may be nailed to the bentonite and concrete wall.

(2) SECTION CONNECTIONS

Peel or trim the fabric off the attached section (Panel 1) to expose 3" of core. Overlap core of the second section (Panel 2) by 2" and interlock. Cover the joint with the fabric flap (Fig. 5). Repeat to cover the wall surface. Shingle each course overlapping the upper and lower sections in the direction of water flow.

(3) DISCHARGE SYSTEM CONNECTION

Drain Pipe: Peel back the bottom fabric flap. Place the pipe next to the core. Wrap the fabric around the pipe and tuck it behind the core (Figs. 6 & 7).
Weep Hole: Cut off or drill the core tips on the side opposite the fabric at weep hole positions. The fabric should also be cut at the weep hole to prevent blocking the discharge flow. (Fig. 8).

(4) ENCLOSE TERMINAL ENDS

Cover all terminal edges with the fabric flap by tucking it behind the core.

(5) BACKFILLING

Place fill within 7 days or as specified by the engineer. Place and compact the fill material 6" above the top edge of Miradrain. Avoid damaging Miradrain with compactor exhaust or tamper foot. Replace any damaged fabric.

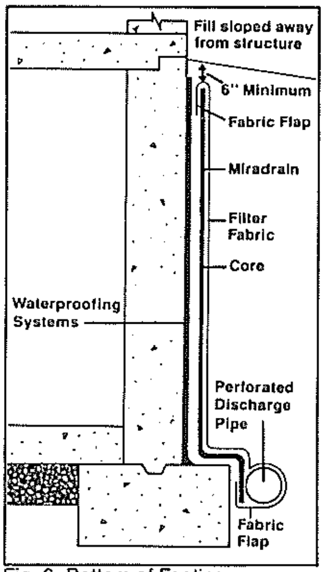


Fig. 6–Bottom of Footing Discharge Option

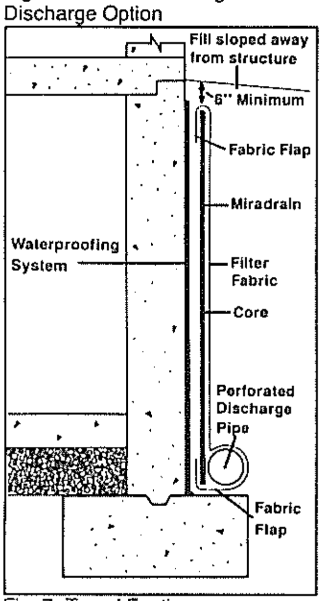


Fig. 7–Top of Footing Discharge Option

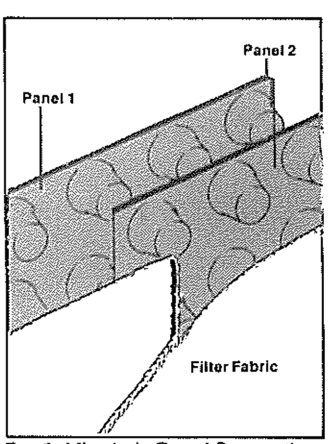


Fig. 5–Miradrain Panel Connection

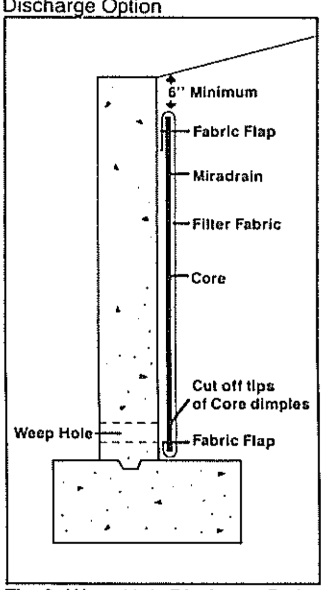


Fig. 8–Weep Hole Discharge Option

ADJACENT TO SHORING SYSTEMS

(1) **PANEL ATTACHMENT**

Attach the panels (Panel 1) using the following materials depending upon the substrate material:
Wood Substrate: Roofing nails.
Earth Substrate: 4" to 8" anchor pins (3/16" diameter) with washers. Before fastening, smooth the earth face to insure that the fabric lies flat against the excavation.
Concrete Substrate: Concrete nails driven through washers or wood lathing.

(2) **PANEL CONNECTIONS**

Fold or trim the fabric flap on one edge of the second section (Panel 2) to expose 3" of core. Overlap 2" of the attached section and interlock the cores (Fig. 11). Fasten the remaining fabric flaps to the substrate. Repeat this procedure for each course. Shingle each course by overlapping upper and lower sections. When installing Miradrain with poured-in-place concrete, overlap should be in the direction of the pour to prevent panel separation.

(3) **TIEBACK FITTINGS**

Cut openings in the panel with a knife to fit around fittings and other protrusions in the substrate surface. Overcut the core opening by 1" (Fig. 10). Tie bolts can be driven through Miradrain.

(4) **DISCHARGE SYSTEM CONNECTION**

Collection Reservoir: Before installing Miradrain, remove lagging to excavate cavity for perforated pipe. Drape a section of the filter fabric in the cavity. Attach the fabric to the upper and lower lagging (Fig. 9). Place stone, drainpipe and "T-section" in fabric-wrapped cavity. If a perforated drainpipe is used, place perforations toward the lagging. Fill any voids and cover the cavity with perforated treated wood or metal plate.

(5) **ENCLOSE TERMINAL EDGES**

Fold all terminal fabric flaps over the core edge and fasten to the core and/or substrate. This prevents concrete intrusion along terminal edges.

(6) **WALL CONSTRUCTION**

Concrete Placement: Follow the current American Concrete Institute standards for concrete wall construction. High drop heights are not recommended. Use proper concrete chuting techniques and pour carefully around panel joints.
Gunite/Shotcrete: After Miradrain is secured to the shoring or excavated earth area, Gunite and Shotcrete can be applied directly to the backside of the Miradrain core to form the wall.

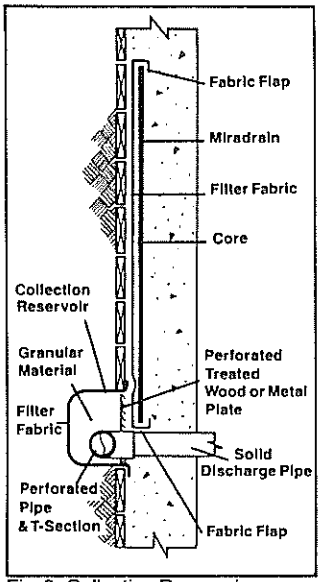


Fig. 9–Collection Reservoir Discharge Option

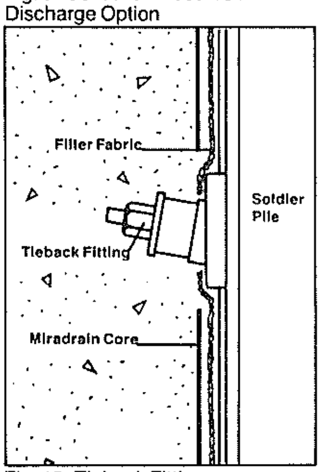


Fig. 10–Tieback Fitting

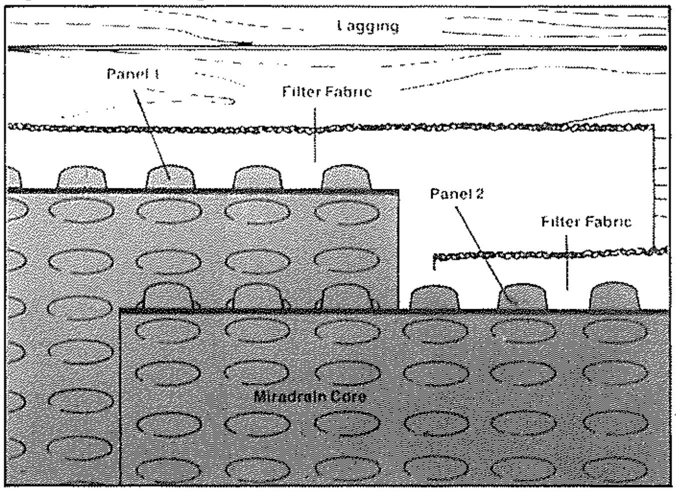


Fig. 11–Panel Connection against Lagging

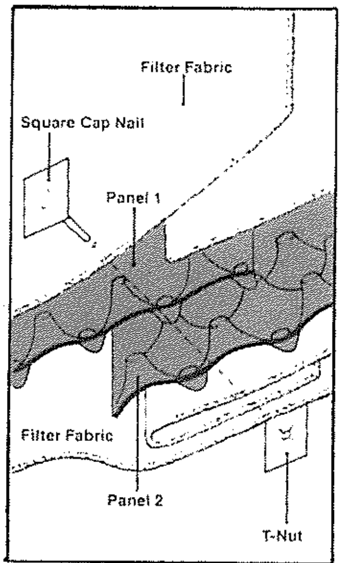


Fig. 12–Cap Nail & T-Nut

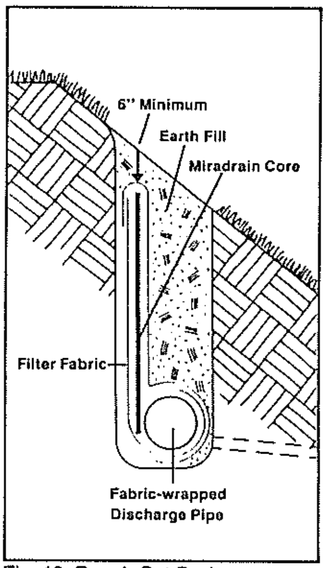


Fig. 13–Bench Cut Drain Installation

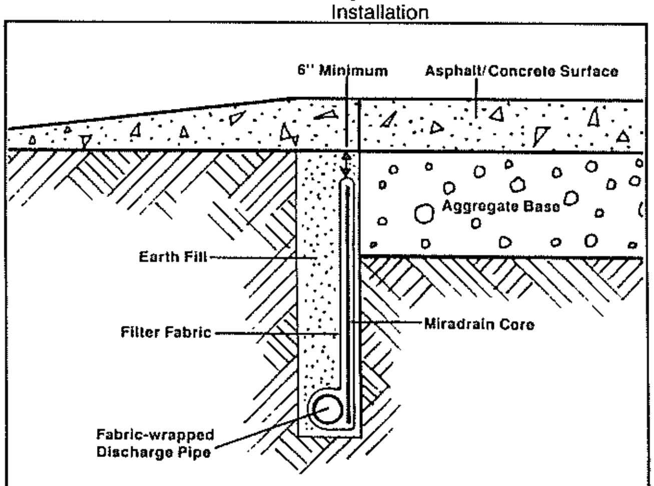


Fig. 14–Highway Edge Drain Installation

TWO-SIDED VERTICAL DRAINAGE

CUT-OFF DRAINS AND HIGHWAY EDGE DRAINS

(1) PANEL CONNECTIONS

Lay the panels on the ground. Peel back or trim the top fabric of one core (Panel 1) to uncover 3" of core on the joining edge. Peel back 3" of fabric at the bottom of the adjacent core (Panel 2) and overlap the core 2." Interlock the cores. Fold the fabric flaps over the joint and fasten every 2 feet using square cap nails and T-nuts (Fig. 12). For bench cut installations (Fig. 13), panel connections are made as the panels are attached to the earth wall.

(2) PIPE ATTACHMENT

Position the discharge pipe between the two fabric flaps and fold the flaps to enclose the pipe on one side of the core. Fasten the fold with tape or staples.

(3) PANEL ATTACHMENT

Miradrain panels may be secured to the side of the excavation using 4"-8" anchor pins (3/16" diameter) with washers. For bench cut installations, follow the procedure described for Miradrain adjacent to finished wall surfaces. In highway edge drain installations (Fig. 14), panels should be held in place until backfilling is completed.

(4) ENCLOSE TERMINAL EDGES

Tuck both fabric flaps behind the panels and secure to the wall to prevent intrusion of soil.

(5) BACKFILLING

Fill all voids behind the attached panels to insure that the fabric conforms with excavation sides. Backfill and compact immediately covering the top edge of the panels with 6" of fill.

PRODUCT HANDLING

Miradrain should be installed according to the guidelines provided by Mirafi Inc. Prior to backfilling, all Miradrain panels and rolls should be inspected to ensure that all Miradrain core and drainpipe are enclosed by the filter fabric to prevent any soil intrusion. Any panels or rolls damaged during installation should be replaced by the installer.

Miradrain should be protected from sunlight during transport and storage. Also, to limit fabric exposure to ultraviolet radiation, backfilling should occur within seven days of installation.

Miradrain is resistant to chemicals in normal soil environments. However, some chemicals may affect its performance. Mirafi representatives should be consulted concerning the suitability of Miradrain in unusual soil environments.

TECHNICAL SERVICE

Experienced engineers and manufacturers' representatives are available to provide assistance with the design and construction of any drainage project. Contact Mirafi Inc.

MIRADRAIN SPECIFICATIONS

PRODUCT DESCRIPTION

Miradrain is a composite structure consisting of: 1) a 3-dimensional, high-impact resistant, polymeric sheet, and 2) Mirafi 140N filter fabric.* The filter fabric is securely bonded to the dimples of the molded polymeric sheet to maintain a rigid surface, thus preventing intrusion of the fabric into the flow channels when backfilled. The filter fabric extends beyond the edges of the polymeric sheet (3" minimum) to provide overlap with adjacent panels and discharge pipe.

PHYSICAL PROPERTIES

Miradrain conforms to the property values listed in the following table.

PROPERTY	TEST METHOD	UNIT	TYPICAL VALUES MIRADRAIN 4000	TYPICAL VALUES MIRADRAIN 6000
Color			Black	Black
Weight	ASTM D-3776	oz/ft^2	2.9	2.9
Thickness	ASTM D-1777	in.	.75	.377
Compressive Strength	ASTM D-1621	psf	4320	10,800
Flow, Q		gpm/ft. width		
@ 1400 psf			5	
@ 3600 psf				15
Filter Fabric				
Equivalent Opening Size	COE CW02215	U.S. Standard	100	100
Flow	CFMC GET-2	gpm/ft^2	285	285
Grab Strength	ASTM D-1682	lb	100	100
Weight	ASTM D-3776	oz/yd^2	4.0	4.0

PACKAGING

Miradrain 4000 and 6000 prefabricated drainage systems are available in panel and roll form. Custom sizes are available to meet specific job requirements. Consult your local Mirafi representative.

*Specific site conditions may require a filter fabric other than the standard Mirafi 140N. For further information regarding selection of a Mirafi filter fabric, consult your local Mirafi representative.