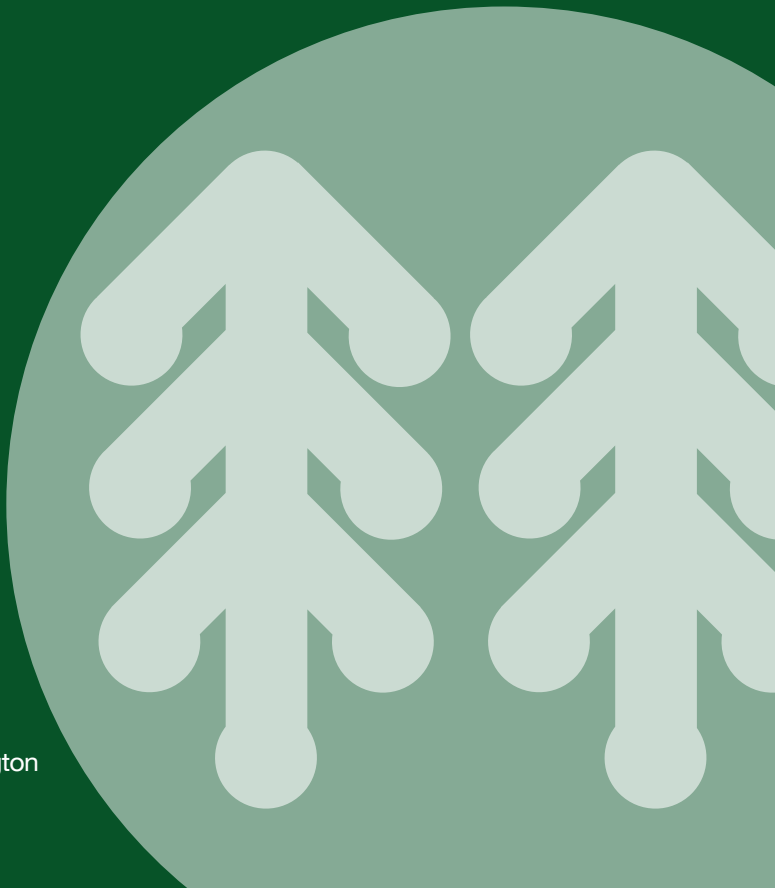
NZ Forest Road Engineering Manual

Operators Guide 2020



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NEW ZEALAND FARM FORESTRY ASSOCIATION

FOREST OWNERS ASSOCIATION

NZ Forest Road Engineering Manual

Operators Guide

The *Operators Guide* is published by the NZ Forest Owners Association and is supported by the Forest Growers Levy Trust and the NZ Farm Forestry Association

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NZ Forest Road Engineering Manual Operators Guide

The *Operators Guide* is a companion publication to the *New Zealand Forest Road Engineering Manual*. The objective of both publications is to ensure roads, water crossings and related infrastructure in New Zealand plantation forests are fit for purpose and meet high environmental standards. The Manual and the Guide may be copied or downloaded from the FOA website by those who own, manage or work in New Zealand plantation forests, and their advisers.

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OVERALL GOAL:

To assist operators, contractors and supervisors build roads and landings that meet safety, environment and performance standards.

WHAT THE GUIDE COVERS

- Construction principles
- Ways to improve construction practices
- Basic construction and maintenance methods
- Impact of poor construction methods on safety, the environment and cost

WHAT THE GUIDE DOESN'T COVER

- The Guide is not a technical manual. It does not cover engineering design or construction methods in detail
- It does not replace company guidelines or legal requirements. For example, NES-PF permitted activity or consent conditions

The Guide uses the following symbols to show good or poor practice:

Good practice

Poor practice

Risk can be to life, the environment and property. It can lead to prosecution under the Resource Management Act 1991 (RMA), the Health and Safety at Work Act 2015 (HSWA) or other legislation.

RISK

= Chance of it happening
+ Consequence if it does happen

TO MANAGE A RISK IT MUST FIRST BE KNOWN

THINGS WITHIN OUR CONTROL

- How the road or landing is constructed
- Where the road or landing is constructed
- Where fill is placed
- Where wood waste is disposed of
- Where water control is located and water is directed
- Whether earthworks meet specifications
- Whether earthworks are constructed in suitable weather conditions
- Whether disturbed sites are rehabilitated
- The quality of maintenance

THINGS THAT MUST BE CONSIDERED BUT ARE OUTSIDE OUR CONTROL

- How steep or erosion-prone the land is
- Rainfall and storms
- Who our neighbours are
- The location of protected areas
- The location of existing roads and bridges
- The potential for landslides, slumps and earth flows
- Native vegetation and fish habitat
- How sensitive the environment is downstream
- Laws and regulations. For example, RMA, HSWA

MANY RISKS COME DOWN TO HOW CLOSE YOU ARE TO SOMETHING

Think about how close you are to things like waterways, neighbours, bridges, culverts or protected sites.

RISK in road construction often comes from three things: WATER, WATER and WATER

- Where did the water come from?
- What could water do to the earthworks? Will it cross areas of fill and cause erosion? Can it be diverted safely?
- Top right: Where will the water end up going? Will it carry sediment to streams or neighbouring property?
- If there's heavy rainfall, will water control help keep the earthworks intact?
- What water control is needed to reduce the amount and speed of stormwater on uncompleted earthworks, if there is bad weather?

- Left: This debris flow started from a series of fill slope failures that picked up logging debris as it moved downslope. Once in the waterway, the soil and debris moved kilometres
- Debris can be hugely damaging and dangerous
- Sediment affects the river and its life
- The damage is often difficult or impossible to fix

STOP

AT THE END OF EACH DAY, MINIMISE RISK. IF BAD WEATHER IS LIKELY, PUT IN TEMPORARY WATER CONTROLS TO HELP PROTECT EARTHWORKS BY DIRECTING WATER AWAY

Working smart and efficiently gives the best results. A great road generally means more work for the business. Also, your job satisfaction and skill levels will go up too. What is the most efficient, safe and effective way to do the job?

Table 1: 5 steps to a top quality job
1. Plan it out, and start prepared
2. Do the job well
3. Monitor or check that things are going according to plan. If not, revise
4. Review to see if anything could be done better
5. Sign-off the job

Step 1: Plan
• Use the 'Starting the job' checklist
• Answer questions including:
- What will the end result look like?
- Where are the job's hard parts?
- What can we do to manage water?
- Which direction are the loaded trucks going to be going?
- Where to put stumps, slash, and topsoil?
Step 2: Do the job well
• Focus on things including:
- Moving the least amount of material, the least distance
- Know each machine's strengths and weaknesses
- Work machines together if their combined effort gives the best effect
- Make the best available use of materials
- Make the job fit for purpose
- Communicate and work as a team
Step 3: Continually check it's going to plan
• Keep to the plan unless there is a reason to change:
- Does some machinery need to go to another urgent job?
- Are the soils better or worse than expected?
- Is construction easier or trickier than expected?
Steps 4 & 5: Review and sign-off
• Use the job sign-off checklist
• Answer questions including:
- What was done well, or what could have been done better?
- Did everyone work well as a team?

Take pride in what you do – your job has your name on it. Everyone is responsible so everyone is accountable. Before starting the job, complete this checklist as well as any requirements of the forestry company.

Table 2: Starting the job – be prepared	
Safety	**Yes / No**
Have site safety hazards been identified and managed? Eliminate or, if not possible, minimise	
Am I using my personal protective equipment (PPE)?	
Is there a safety plan? For example, do I know my location and what to do in an emergency?	
Is the machine safe? For example, in good condition with the correct protective structures	
Is anything I do going to affect my safety or anyone else's?	
Is the correct signage in place?	
Training	
Am I trained for the job and the machine I'm about to use?	
Environment	
Have the site environmental hazards been identified and managed?	
Have the environmental requirements been provided, and do I understand these? For example, the location of fish streams, neighbour's water intake, and restricted areas	
Do I have a spill kit readily available?	
Do I know how to identify archaeological sites?	
The job	
Is there a job plan or map, and am I clear about what needs to be done?	
Do I understand the construction specs?	
Do I understand all the markings if the site has been marked out? For example, road centreline, grade, landing construction perimeter, culvert locations	
What are the NES permitted activity standards or council resource consent conditions that I must comply with? Are there copies of these on-site?	
Have I got written instructions? For example, job design (construction) standards. If so, do I understand them?	
Am I sure about the job in front of me?	
Is this the best way to do the job? Am I using the right type and size of machine for the job?	
Have I reviewed the job, plans, specs, and resource consent with my supervisor?	
If required, can I record key components of my work on phone or camera? For example, benching	

STOP

IF YOU HAVE ANSWERED 'NO', OR ARE UNSURE OF ANY OF THESE QUESTIONS, DISCUSS THEM WITH YOUR SUPERVISOR!

You should leave the site proud of what you have achieved. The finished job shows your skills and care as an operator. Always do a final check.

Table 3: The job is not finished until it is signed-off	
Safety	**Yes / No**
Is the site safe? For example, free of dangerous trees, perched rocks, other hazards	
Are all markers and signage in place?	
Are there any health and safety risks left for future operations?	
Environment	
Did I comply with all the NES permitted activity standards, the resource consents or other job conditions?	
Was all the rubbish and waste taken off-site?	
Does the machinery need cleaning before moving onto the next job, to reduce the spread of noxious weeds?	
The job	
Was the plan followed? If there were plan changes, have these been agreed and documented?	
Was the preparation done correctly? For example, topsoil and stumps stripped?	
Was the subgrade formation work done correctly? For example, benched and compacted where needed. Does the road have the correct width, grade and alignment?	
Was the water control installed correctly? For example, culverts are well located and spaced, water table drains of the right depth, berms to protect fill	
Are all cut batters left in a stable and safe state – benched if over 6 m in height?	
Are fill slopes compacted and stable?	

STOP

IF YOU HAVE ANSWERED 'NO' TO ANY OF THESE QUESTIONS, DISCUSS THEM WITH YOUR SUPERVISOR!

The Operators Guide uses some of the following terms. Supervisors, planners, and engineers who visit your site are likely to use them.

Common roading terms

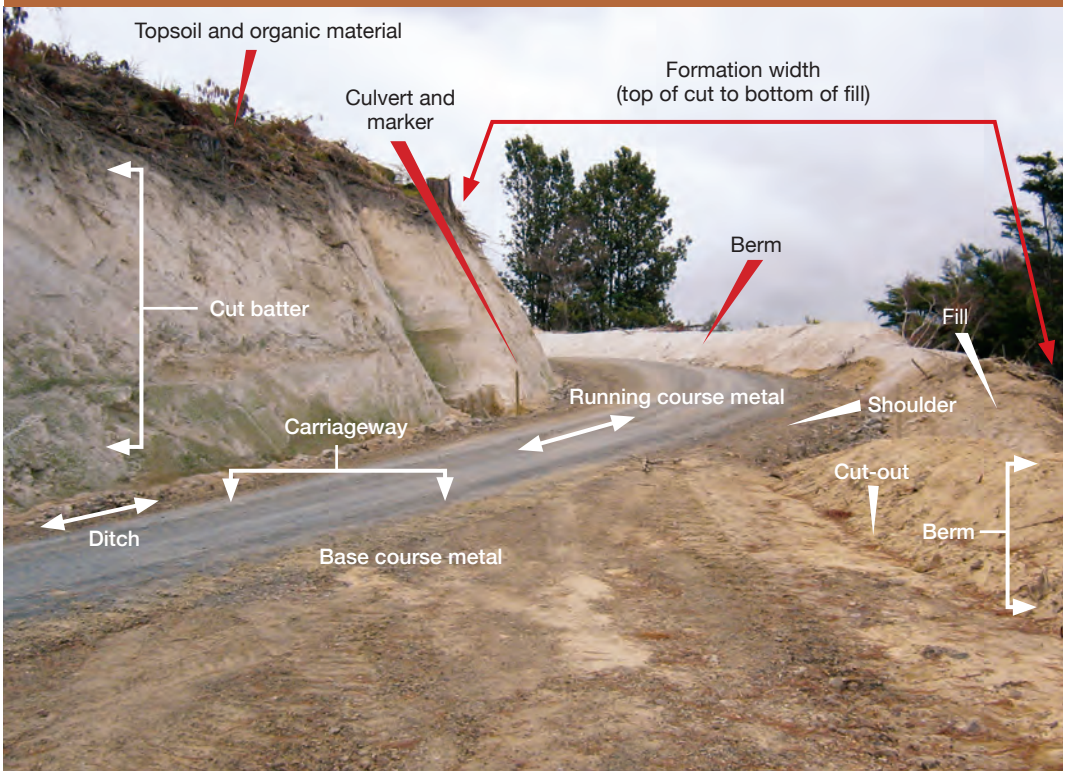


Table 4: Measuring road or slope steepness

Percent (%)	Degrees (º)	Gradient	Percent (%)	Degrees (º)	Gradient
5	3	1:20	16	9	1:6
7	4	1:14	20	11	1:5
10	6	1:10	40	22	-
12	7	1:8	60	31	-
14	8	1:7	70	35	-

Construction methods, and erosion and sediment controls, vary with the soil type. Soil types can change as you dig down, or within short distances along a road. Some can make construction very difficult.

WHAT DOES THIS SOIL MEAN TO YOU?

Black organic soil (topsoil) – has little strength and must be stripped

Pumice – water moves through it quickly. It is an erosion risk and can block culverts

Weakness area between pumice and hard white clay – water moves through pumice and then forms a slip zone on the clay

Clay – unworkable when wet. Low strength when re-worked and acts like Plasticine. It may also swell. Beware!

SOME SOILS ARE HIGHLY ERODIBLE AND CAN CAUSE SEVERE SEDIMENTATION

- Fine soil particles are slow to settle out of water. They can severely impact water quality and stream life

- Pumice can easily erode even on gentle slopes. This can create road maintenance issues and sedimentation problems

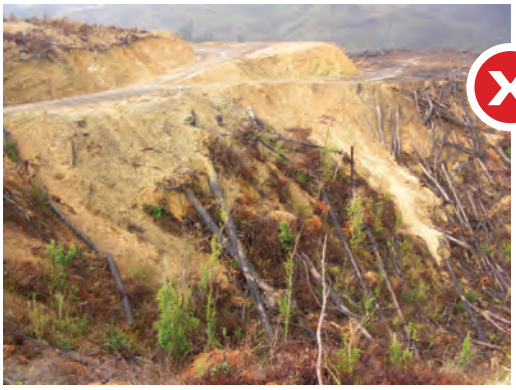
The weaker the soil, the harder it is to build a good road or landing. This is made worse on:

- Steeper ground
- Ground with poor drainage
- Soil that can easily slip off the bedrock.

- This soil is the one profiled on the previous page
- Cut banks erode even on easy to moderate country
- Water tables and culverts can easily block with sediment or pumice
- A wet location makes construction more difficult

- The grey-blue earth indicates poor drainage
- This mudstone's bedding plane angle means the soil above can easily slide off

- The soil has made construction and maintenance extremely challenging:
  - Weak soils on steep country
  - Wet weather has added to poor soil drainage
  - Mudstone bedrock is prone to soil slip



- Fine clays and silts often make poor fills
- If fills are not stable, and water control is poor, they can rapidly erode

GOOD CONSTRUCTION SOILS HAVE:

- A thin topsoil layer which makes stripping easy
- A good mix of material sizes:
  - Larger sizes, like sand and gravel, gives strength
  - Smaller sizes, like clay and silt, bind everything together
- Good drainage. Water can move down through the soil and bedrock

POOR CONSTRUCTION SOILS OFTEN HAVE:

- A lot of topsoil. This has low strength and must be stripped in almost all situations
- Just one dominant particle size, instead of a mix of rock fragments and finer soil
- Fine soils (clays, loess and silts) are hard to compact. Water erodes and weakens them
- Poor drainage. A blue or grey colour with brown spots shows the soil is often wet
- A hard bedrock layer underneath. Water doesn't drain through it, and soil can slide off

LEANING TREES – WARNING SIGN:

- Trees planted on unstable slopes often develop a lean, especially in earth flow country
- As the ground moves under the growing trees, they develop 'J' shape stems or lean uphill

STOP

THE GOAL IS TO USE SOIL TO YOUR BEST ADVANTAGE:

- **Understand the soil and where water will drain**
- **Adjust your construction methods if required**
- **Don't build when the soil is too wet. You'll make a big mess**

A WELL-CONSTRUCTED ROAD

To build a well-constructed road you need to get the basics right:

- Always think about managing water, water, water
- Make cuts and construct fills so they are stable
- Compact and shape the road so it is strong
- Make the road's width, grade and corners suitable for the traffic and terrain.

- Good roadway salvage width
- Topsoil, slash and other substandard materials have not been used
- Stable cut and fill slopes
- Good construction technique. For example, benched, and fill compacted in layers

- Well-constructed water control
- Compacted berms direct water to either cut-outs or sediment traps
- Grass seed has been applied to stabilise fills and reduce erosion

- Adequate road width and grade. Wider is not always better. For example, in unstable areas
- Road has been metalled with good aggregate, at right depth and width
- Good crossfall
- Well-compacted road surface
- Culvert clearly marked, with water directed away from the fill
- Stable batter slopes
- Ditch is below subgrade

- The potential sediment sources have not been properly managed:
  - Little water control. The fill erosion may be due to a lack of culverts, berms or ditches
  - The fill is not contained on a bench, and has spilt up to 40 m down the slope
  - The fill has not been grassed to reduce erosion. It has no vegetation after several years

A WELL-CONSTRUCTED LANDING

A well-constructed landing is essential. It must meet operational needs. It also must be built to last and not be a major risk to the environment.

- The site is well prepared. For example, stripped and benched
- It is constructed to the right size/area specifications
- It uses the lie of the land to increase the workable area so that earthworks are reduced
- Water is directed away from the fill. The 'fall' is towards the stable ground
- Trucks can turn around, and loggers have parking close by

- The landing has a visible bench and has been compacted. The fill is stable
- It has well-constructed water control. For example, berms and water draining away from the fill
- The fill is free of stumps and woody debris

- Small landings work well if carefully planned and constructed

- Stumps and woody debris are through the fill
- The fill is too steep; slippage can already be seen at the toe of the fill (see arrow)
- Drainage is across the narrow access road
- During harvesting when the water control will be damaged, the fill could erode

Know what each machine on-site is designed to do. Understand its strengths and weaknesses. If you don't have the right gear, hire in what is needed.

- Bulldozers are designed to:
  - Push
  - Level
  - Move material short to medium distances

- Excavators are designed to:
  - Dig precisely
  - Place material accurately
  - Move material short distances

- Graders are designed to:
  - Spread
  - Level
  - Shape
  - Do the final cut

- Rollers are designed to:
  - Compact
  - Seal, depending on their type

Grass and scrub, topsoil, roots and branches must be removed because they rot or don't compact. Otherwise, water can move through this material and may cause weak and unstable fills to collapse.

- The right number of trees have been removed to build the road

- More trees should have been removed
- Standing trees should not have been buried. They will cause road stability issues when they rot, and are less safe to log
- The most valuable part of the tree is buried!

- Topsoil and wet clay are being removed
- Good use of different machines

- Stumps have been left in an unsafe position for harvesting operations

STOP

CHECK ENOUGH TREES HAVE BEEN REMOVED FOR SAFE CONSTRUCTION

- Remove vegetation, black soil, stumps and slash
- Place stumps on flat, stable ground, on a secure bench, or beyond the toe of fills
- Cart strippings to a safe disposal site if nowhere close by is suitable

- The topsoil was not properly stripped. Vegetation buried in the fill will rot and make it less stable
- The berms are too large, leading to overloaded batter slopes

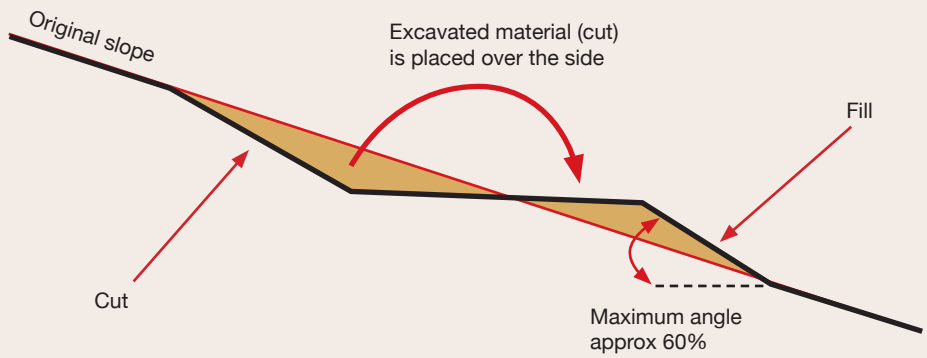
- Topsoil and slash are in a safe and stable place that will not impact on harvesting
- Material is kept away from restricted areas. For example, waterways, native bush
- Debris is placed on a bench

- This stump should have been removed
- There is no water table drainage

CUT AND SIDE CAST CONSTRUCTION METHOD

Cut and side cast construction is the simplest and cheapest construction method. Excavated material is cut and pushed into position (side cast)

Diagram 1: Cut and fill side cast construction



Use this method:

- On flat or rolling ground
- Where fill can be stabilised
- There is no risk of sediment entering a waterway
- Where side cast can be compacted to support logging traffic

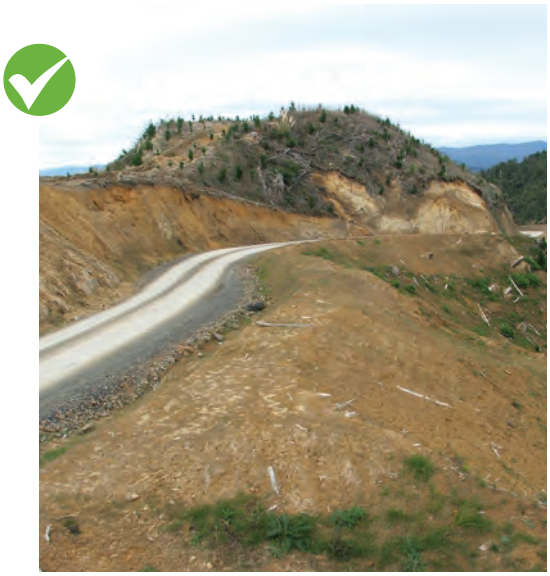
- Side cast material is contained within the roadway by slash windrow
- It has low risk of movement

- Side-cast construction should not have been used this close to a stream. End-haul construction is the correct method
- Side cast material has entered the stream. This may lead to council prosecution

HOW STEEP IS TOO STEEP FOR SIDE CASTING?

There is no rule as it depends on the site, however:

- Most non-compacted fill will not be stable if steeper than 60%. It changes depending on the material. Rockfill is the most stable
- Once the ground gets steeper than about 40% the fill is harder to contain and stabilise.



- The side cast is contained, stable and away from water
- The fill slope is less than 60%
- The fill can support logging traffic

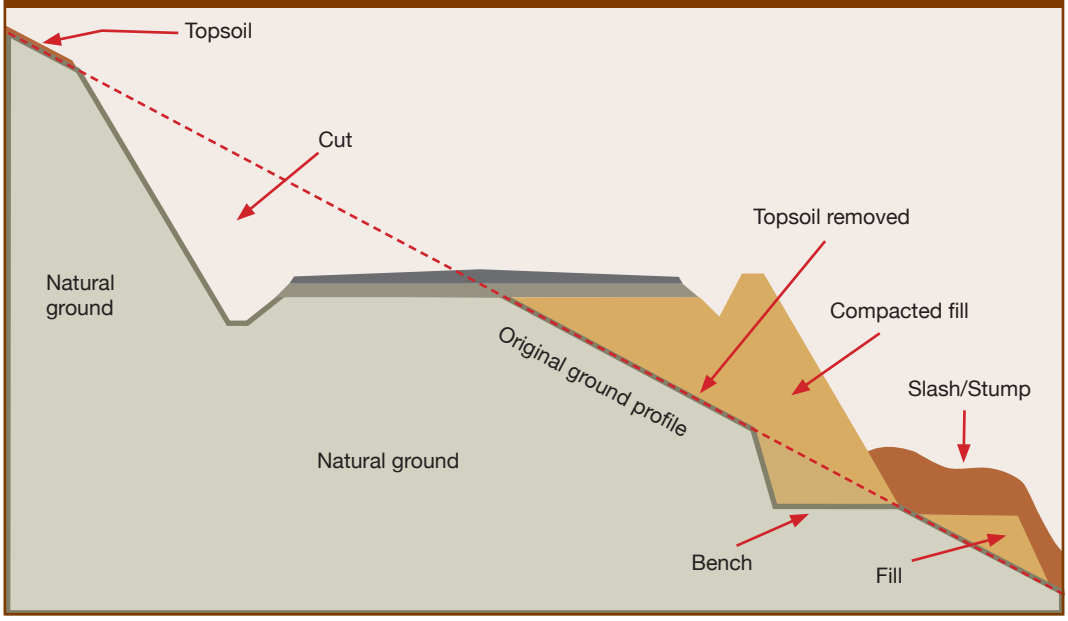
- This slope is too steep for side cast construction
- Material has gone to the gully bottom. Sediment could enter a waterway
- The fill has spilled 50 m down the slope (see the vehicle, arrowed, for scale)

STOP

ARE YOU CONCERNED THAT THE FILL MAY NOT BE STABLE OR CONTAINED? THEN USE ANOTHER CONSTRUCTION METHOD LIKE CUT AND BENCH FILL

Cut and bench fill construction is a standard method of constructing roads in moderate to steep hill country.

Diagram 2: Bench cut to contain downslope fill material



- A bench or benches can help stabilise the road or landing fill slopes because they provide a more stable base for fill
- Soil from the initial bench is side cast
- Locate the bench(es) so that the earthworks cut and fill volumes are balanced

- The bench is located near the toe of the fill for the section needing benching
- The bench is level
- The bench is wide enough for safe and efficient construction
- The dozer (arrow) is stumping

- The fill is contained on the bench
- Stumps are keyed into the slope at the toe of the bench
- Slash has been used to reduce erosion

WHEN SHOULD CUT AND BENCH BE USED?

There is no rule as it depends on the site, however use benches on slopes:

- That are too steep for side cast construction
- That are between about 40 to 70% but less depending on soil type. The recommended fill slope for most soils is 65%
- Where there are known stability issues.

- A bench was built because the slope was too steep for side cast construction
- The fill was compacted in layers to increase fill strength
- The bench contains all the earthwork fill
- The edge of the bench is visible, which shows it was not over filled

- A lack of benching and poor fill compaction led to these significant failures

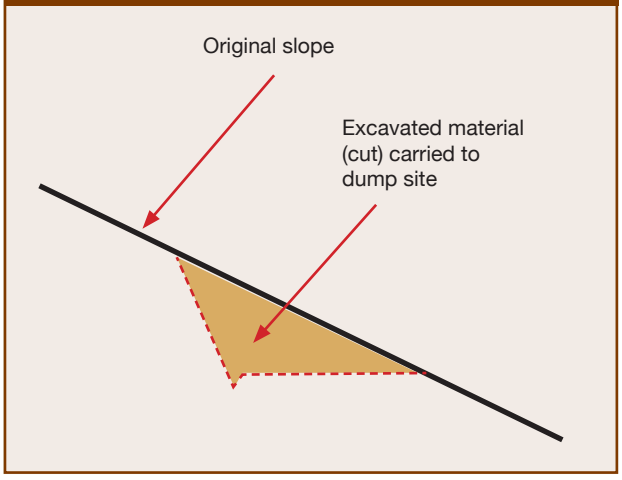
STOP

IF THE BENCH IS FULL, STOP. FIND A NEW CONTAINED AND STABLE PLACE FOR THE FILL. ALSO, IF SUBSURFACE WATER IS HIT, STOP. TALK TO YOUR SUPERVISOR ABOUT DRAINAGE

FULL BENCH CONSTRUCTION WITH END-HAUL

Full bench construction removes all the fill, so the road is built on the hard. These roads create large volumes of spoil that needs to be carted away (end-hauled).

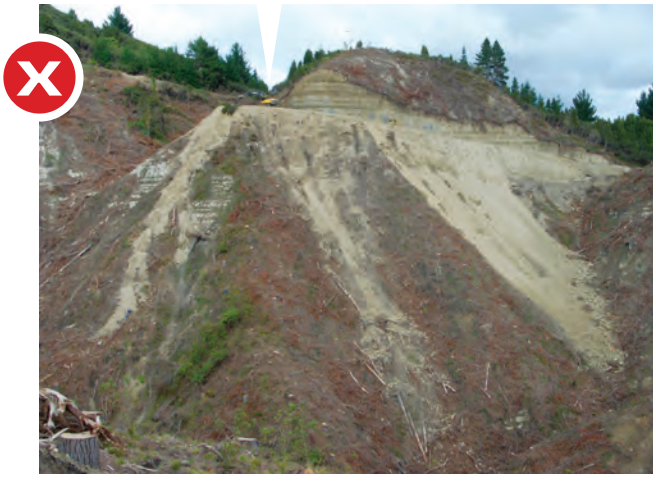
Diagram 3: End-haul (full bench) construction to eliminate fill



- End-haul is expensive. Reduce costs by having a place close by to dump spoil
- Full bench creates large cut slopes

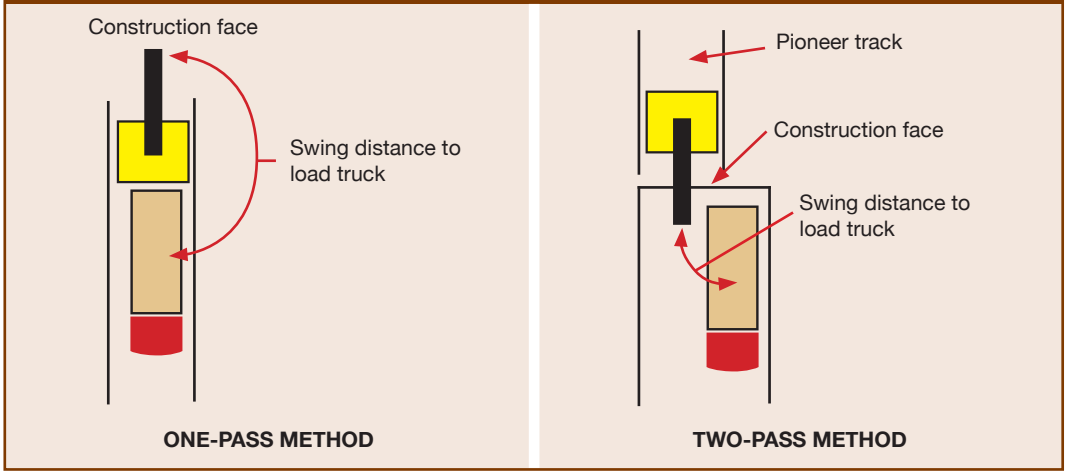
WHEN SHOULD END-HAUL BE USED?

- When slopes are too steep or unstable to place fill
- When the risk of fill failure is unacceptable. For example, when close to a stream
- Caution: Full bench can create road instability in some soil types. For example, in earth flow terrain



- Full benching would have stopped the spoil reaching the watercourse
- Side slopes were too steep to hold the fill, so it spilt to the bottom of the slope
- The arrow points to an excavator

Diagram 4: End-haul road construction methods



- Effective one pass team. A dump truck and a close spoil dumping area kept costs down

- A dump truck was used to maximise the load. Its tyres also help with compaction
- The spoil was dumped at a close and well-prepared location

STOP

CAREFULLY LOCATE SPOIL AREAS. THE SITE MAY NEED TO BE BENCHED, COMPACTED AND WATER CONTROLLED

Compaction is an important task in building a road and landing. How you compact depends on what material you are working in. All compaction needs moisture, but not too much or too little.

WHY COMPACT?

- Compaction strengthens the fill and the road. It reduces the risk of fill movement or settlement on steep or unstable slopes
  It reduces the amount of road metal needed as road subgrade is stronger
- It helps protect or 'seal off' earthworks from water penetration
  It can reduce repair and maintenance costs

WHICH COMPACTOR FOR THE JOB?

Step 1: Is the soil a clay – try to roll a worm!

- Moisten the soil and try and roll it into a thin worm 3-5 mm thick
- If the soil feels sticky and turns into a snake without cracking, you have **clay**
- A clay with sand – you will feel the sand particles

Step 2: Is the soil silty – try the tap test!

- Roll a wet soil sample into a 20 mm ball and flatten it
- Now tap the hand to see if water arises. If so, it is a **silt**

Step 3: Look at the table below

Table 5: Compactor and soil type

Heavy clay	Clayey sand	Clayey gravel	Paving gravel	Silty sand	Rock & sand
Sheep-foot					
Wedge foot					
Steel cylinder					
Vibrating smooth drum					
Vibrating sheep-foot					
Pneumatic-tyred					
Grid					

- Sheep or wedge foot rollers are the most useful in formation
- Vibrating drum rollers (smooth) are useful for sealing aggregate
- Heavy compactors work better
- Loaded metal truck wheels compact

HOW MUCH MOISTURE IS ENOUGH?

Step 1: Do the squeeze test

- Squeeze some material in your hand, then take off the pressure
- If it just holds together, and the content doesn't stick to your fingers, the moisture is about right
- More granular materials are less likely to hold too much water

Step 2: Plan your next steps

Table 6: Earthworks compaction

Just right	All good to go
Too dry	Add water with a water cart
Too wet	Wait until it dries out

HOW THICK CAN A LAYER BE COMPACTED?

Limit layer thickness, so compaction goes the full depth of each layer.

Table 7: Earthworks compaction

Material size	Maximum compaction layer thickness
Up to 100 mm	200 mm
100 – 200 mm	Between 250 – 350 mm, thicker if larger size
Over 200 mm	Decide on site

- The correct compactor – a vibrating sheep-foot – has been used
- The right moisture content ensured good compaction
- Compaction had been done in the right layer thickness for the material
- The material has not been over-compacted

- Dozers and excavators are not compactors
- Wide tracked machines apply low ground pressure even though they are heavy
- Track rolling only gives minor compaction, however, it tightens the fill by breaking down larger material

- The metal is being compacted with the correct compactor – a vibrating steel drum
- The aggregate is compacted in layers less than 150 mm

- Excessive vibrating rolling has brought moisture to the surface and hasn't improved the result
- Do not try to compact wet or very dry materials, as these may become liquid

- Penetrometers are useful for identifying subgrade weaknesses
- They also show that the subgrade has met compaction standards

- Lack of compaction, or too much moisture in the fill, led to this major road failure
- Water will enter the tension cracks and make the fill even less stable

STOP

COMPACTION MUST BE DONE RIGHT. CHECK THE SOIL TYPE, MOISTURE CONTENT, AND THE THICKNESS BEING COMPACTED

Landings often require large amounts of earthworks. Poor construction can cause significant environmental impacts if something goes wrong.

- Stumps have been moved to a safe location and put in a trench at what will be the toe of the benched fill
- Rotting stumps and roots will not cause fill problems in the future

- Serious tension cracks – the result of poor benching and compaction
- Water going into the tension cracks will make the fill heavier and more likely to collapse and erode

- The landing formation was benched
- Benches are visible. They have not been covered over with fill
- Substandard material and vegetation were removed
- Fill has been compacted in layers

- Major landing failure caused by poor water control and lack of compaction
- Slash on the fill made the problem worse
- Material triggered a debris flow which went onto the neighbour's land
- This is a serious environmental incident

- Landing design was worked into the 'lie of the land', while meeting operational requirements
- Stumps and debris were put in a safe location that will not affect harvesting operations

- Bird's nest has failed. There was no accessible and stable area for loggers to put the slash
- No pocket (slash) bench was constructed to put slash onto
- Expensive rehabilitation can only partly solve the problem, because not all material can be reached by the excavator. The remaining option is to burn the bird's nest

- Drainage is directed away from the fill slopes
- The landing has fall to control water and reduce ponding
- The landing surface was track rolled to help shed water. Roller compaction would have a better result

- Water was not directed away from the fill
- Water has severely scoured the landing edge
- Sediment has gone into the river

- The fill is compacted. The horizontal ridges will help reduce erosion
- The fill is over-sown

- Water is draining through the middle of the skid
- This will cause operational problems during logging

- The slash bench was built as part of the planned construction
- It is in a good, safe location
- Stumps and slash are located on the bench
- Water from the road should not have been directed onto the bench
- The bench does not have drainage to stop ponding and saturating the fill

- Poor water control has caused heavy scouring at the front of the skid
- Water should be directed away from large fills
- Water volume and speed will erode earthworks

- Construction includes space for truck turning and vehicle parking
- A two-stage pad was built to improve logging and to create extra space to process the logs

- Poor construction and ongoing maintenance of water control contributed to this failure many years after construction
- The visual impact will last for years
- Slip sites grow poor trees

- The landing was built with good access for ground-based harvesting

- A failed landing subgrade caused by a too shallow and narrow ditch at the back of the landing, plus poor contractor maintenance
- Log corduroy was needed to make the landing accessible to trucks

Poorly constructed corners and in-bends can often cause road access or safety issues.

- The grade on the corner has been reduced to improve truck traction. On roads steeper than 12%, it is good practice to reduce grade on corners and intersections
- The corner is wider to accommodate heavy vehicle off-tracking
- The road has zero or negative superelevation on steep sections

- This steep, narrow corner caused trucking issues
- The corner is too tight for some trucks, causing them to cut the corner (see arrow)
- Build switchbacks with a minimum curve radius of 14 m; 16 m is preferred
- Extend pavement width to cater for trailers (about 4.5 m extra width)

- The inside of the road is benched to improve sight distance to address safety concerns

STOP

REDUCE ROAD GRADE BEFORE, THROUGH AND AFTER STEEP CORNERS AND SWITCH BACKS. IF BUILT INCORRECTLY, THEY ARE HARD TO FIX

FINAL GRADING BEFORE METALLING

Getting the final touches right before metalling makes a big difference. The road will be better for traffic, and metalling and maintenance costs can be reduced.

- The road has a good shape for shedding water
- Depressions and holes are removed
- Deep ditches will allow water to drain from both the surface and under the road

- The formation is not shaped to the final road shape
- Metal will need to be used to fill in the hollow
- Metal is expensive and can be in short supply

- Shaping was done with a grader or tilt bucket
- Culverts were installed before metalling – the culvert markers are visible

- Poor formation shape and shallow water tables led to this steep road section failing
- The failure stopped cartage and caused operational disruption
- Corduroy with logs or slash is a temporary fix

Unstable cut and fill leads to high maintenance costs, environmental incidents and road closures.

BUILD IT RIGHT FIRST TIME

- Construct cut and fill angles correctly
- Bench and compact fills
- Construct good water control
- Use slash, mulch and grass to protect soil from rain erosion

- A slash bund at bottom of the fill helps reduce sediment movement
- The fill is contained and stable
- The fill has been compacted to reduce the risk of failure on steep, unstable slopes
- The grass will help protect the fill and reduce erosion

- Poor water control and no fill compaction at the top of the fill has led to rill erosion
- The fill is not protected and erosion will likely get worse
- Water control and hydroseeding or grassing would help

WHAT IS A GOOD FILL SLOPE ANGLE?

Use the table below as a guide. Also drive around existing roads with similar material and see what angle provides the most stability.

Table 8: Fill batter slopes

Material type	Maximum fill slope
Sand	2.0 horizontal to 1.0 vertical (50%)
Pumice	1.5 horizontal to 1.0 vertical (67%)
Clay	1.5 horizontal to 1.0 vertical (67%)
Rock, dumped	1.25 horizontal to 1.0 vertical (80%)

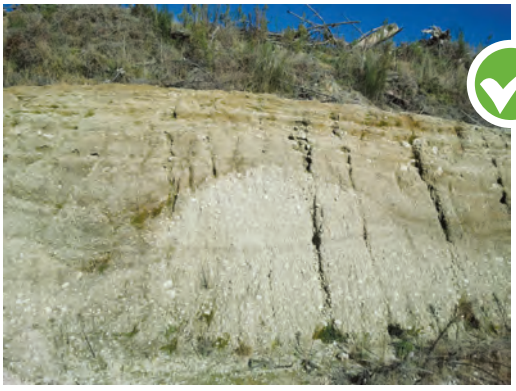
WHAT IS A GOOD CUT SLOPE ANGLE?

Table 9: Cut batter slopes

Material types	Maximum cut slope
Sand	1.5-2.0 horizontal to 1.0 vertical (67% to 50%)
Pumice	1.0-0.25 horizontal to 1.0 vertical (100% to 400%) Depending on cementation
Ash	0.5-0.25 horizontal to 1.0 vertical (200% to 400%) Some slumping accepted
Clay, loose gravel, topsoil	0.75 horizontal to 1.0 vertical v (133%)
Compacted gravelly, clay boulder and earth mix	0.75 horizontal to 1.0 vertical (133%)
Tight cemented gravels, papa, mudstone	0.5 horizontal to 1.0 vertical (200%)
Average rock	0.25 horizontal to 1.0 vertical (400%)
Solid rock	Vertical

For example, an average rock cut slope is steep. A 4 metre high cut bank only needs to be offset 1 metre horizontally

- Steep cut angles of about 2 metres vertical to 1 metre horizontal were appropriately used for papa, so the batters are more likely to be stable



- Pumice batters can be near vertical to reduce rill erosion

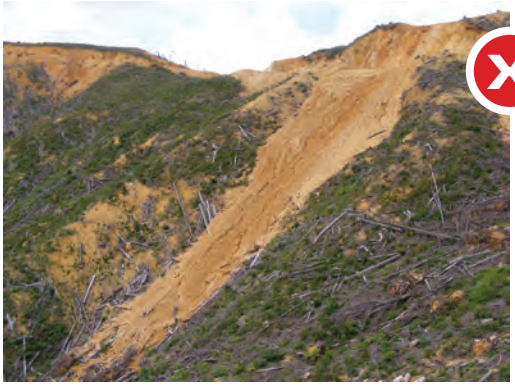
STOP

MAKE SURE CUT AND FILL SLOPES ARE AT THE RIGHT ANGLES. LOOK AT OLDER ROADS IN SIMILAR SOILS TO SEE WHAT HAS WORKED

- Slash spread on the logging track has reduced surface erosion and sediment
- The fill is protected from rain directly hitting and eroding it
- The slash filters sediment and slows the speed of the runoff
- Slash helps grass and vegetation grow by providing cover

- Radiata logs should not be used as a permanent retaining structure as they will rapidly rot and leave the road section unstable
- Some water is still running onto the fill
- The fill is too steep to be stable and will continue to cause issues
- It is difficult to fix something after a failure
- A temporary structure, like radiata logs, should be removed after use

- Cuts and fill require regular maintenance until fully stabilised



- The slope is too steep to hold the fill and it has spilt 60 m down the hill
- The fill is eroding, and sediment is in the gully
- Water will flow in the gully in heavy rainfall. This will affect water quality and stream life

Establishing vegetation is an excellent way to help prevent erosion and to reduce sedimentation.

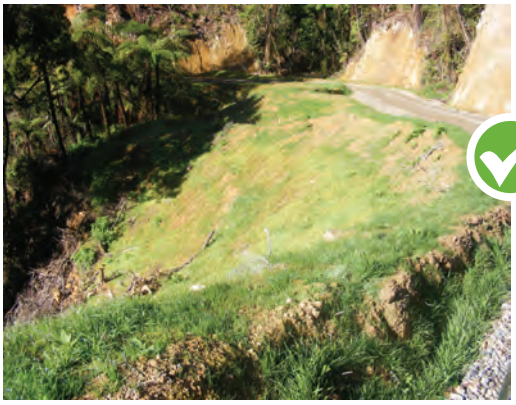
Table 10: Types of vegetation stabilisation available

Vegetative method	Effectiveness	Cost	Challenges
Slash	Good	Free	Machinery able to place material correctly
Hay	Fair	Moderately expensive	Wind, short life span, and grazing animals
Grassing	Fair	Cheap	Can have low strike and die off on steep or hard sites. Can wash away after rain, and have poor growth on low fertility fill or hard sites. Grazing animals can be a problem
Hydroseed	Good	Expensive	Needs specialist equipment. Can strike then die, or peel off cut slopes
Hydromulch	Good	Expensive	Needs specialist equipment. Can strike then die, or peel off

Grassing

- Is easy to do by hand or with a handheld seed spreader
- Autumn and spring are the best times for sowing grass
- Grass prefers warm and moist conditions; summer drought or winter frost kills germinating seed

- The fill slope has been protected from erosion
- Water is directed off the fill by a sock
- Hay is being used to assist revegetation



- Grassing the berm and the fill slope has been effective
- The cut bank is impracticable to grass due to the soil material

Good drainage and sediment control are essential. They help protect roads and landings, and reduce the amount of sediment that gets into waterways. Ongoing sediment harms stream life.

- Drainage is onto stable ground
- Water is cut off as often as possible, to avoid directing lots of water into one place – where it would scour
- Culverts on the top and lower sections of the road are lined up to minimise the amount of water forced into the lower road's ditch

- Poor water control can quickly cause a lot of damage and erosion
- This leads to expensive road maintenance work
- It also generates fine sediment, which can severely damage stream life

- Drainage is directed away from the fill
- The fill is contained by slash and stabilised by hydroseeding
- Water and sediment control were installed to reduce sediment going into waterways

- Large amounts of fine sediment are in the stream
- If this was the result of poor practice, it could lead to prosecution

Ditches protect the road by directing water off it. They also strengthen the road by keeping the subgrade drier.

- The ditch is deep, so helps drain the subgrade

- The ditch has been rock armoured to reduce erosion on a steep road section in a known problem area

- The road has enough crossfall (camber) to direct water into the drains
- The ditch can easily catch groundwater flow from the cut bank
- Water volume and speed have been reduced by regular cut-outs to help prevent erosion and sediment loss

- The ditch has scoured out because it was forced to handle too much water that was flowing too fast
- The spacing between culverts was too far apart
- Too much water on a steep road can quickly cause road failure

Road drainage culverts (cross road culverts) are essential for draining water across a road. They often have sediment traps at their inlet, and could also have other sediment controls at the outlet like flumes, rock, slash or sediment traps. Note regulations apply when people are working in a trench deeper than 1.5 m, and deeper than it is wide at the top.

HOW DO YOU SPACE, LOCATE AND SIZE A CULVERT?

Step 1: Use the table at right for approximate spacing

- Identify the soil risk for the steepness of the road section. Steeper roads on highly erodible soils need closely spaced culverts

Table 11: Recommended maximum culvert spacing (metres) for non-ridge top roading

Grade	Soil or rock erodibility			
	High	Moderate	Low	Non-erosive rock
18% (1 in 6)	40	80	120	200
14% (1 in 7)	50	90	140	220
12% (1 in 8)	55	100	160	240
11% (1 in 9)	60	115	180	260
10% (1 in 10)	65	130	210	300
8% (1 in 12)	80	165	250	350

Step 2: Consider other site factors which may affect location, spacing and size

Table 12: Site factors which may affect culvert location, spacing and size

Site factor	Options
Are cut banks big or could they slump?	Put closer or install a larger culvert?
Does an area above the road drain into the ditch?	
Do frequent storms hit the area?	
Are there other risks of ditches blocking?	
Is it ridge top roading?	Make them further apart?
Do ditches seldom flow due to porous ground?	
Is it a low rainfall and storm intensity area?	

Look around the road and factor in these considerations. Ideally, locate outlets:

- On solid ground, where possible
- Away from large fills unless flumed
- Where trucks or logging equipment will not damage them

Step 3: Sizing the culvert

- The NES-PF regulations require installing minimum sized drainage culverts
- Oversize or add more if other factors identified in Step 2 show increased risk

Table 13: Sizing the culvert

Size	NES-PF erosion susceptibility classification
325 mm internal diameter	Green, yellow and orange less than 25 degrees
375 mm internal diameter	Orange more than 25 degrees, and red zone

- The solid bund at the culvert entrance helps ensure that water does not bypass the culvert
- The culvert mouth is easy to clean with an excavator
- The culvert has a marker peg and is GPS located

- The culvert inlet is easily blocked
- The culvert is hard to keep clean
- The culvert will be bypassed in heavy rain. This will damage the road and cause erosion

STOP

MAKE SURE YOU USE ENOUGH CULVERTS. THEY NEED TO BE CORRECTLY SIZED, SPACED AND LOCATED

- Install during road construction, not after metalling
- Set at a minimum of 20 degrees across the road and downslope to reduce blockage

- A good culvert inlet was constructed
- The inlet can be cleaned easily with an excavator bucket without damaging the culvert mouth

- The culvert has sufficient fall so water drains from the pipe and doesn't block easily
- The culvert bed was compacted
- Pipe sections are joined in the trench
- No sharp rocks or objects are in the backfill
- Care is taken to compact soil around the pipe

- The ground around the pipe was compacted
- The trench is flat and to a depth recommended by the manufacturer

- The culvert outlet is armoured by rock to reduce sedimentation

- Two non-marked culverts in a row were destroyed
- The culverts were not marked, so damage was more likely
- Water has bypassed the culverts and heavily scoured the road

- The culvert should not drain straight into the stream if there is no sediment control above the inlet
- The road should not be built so close to the stream, unless there are no other feasible alternatives
- Roads close to streams require council approval

BERMS AND CUT-OUTS

Berms are small banks on the outside edge of roads and landings. They direct stormwater away from erosion-prone fills and slip faces to more stable ground. Water then goes to cut-outs, and possibly flumes and sediment traps.

- The berm was constructed at the same time as the road
- The berm has protected the fill
- Grass helps stabilise the berm
- Berms don't need to be this wide

- The berm is already starting to collapse because it has overloaded the fill
- Berms should not be used to dispose of extra fill, because they get too big
- The berm is not keyed into compacted fill
- The fill is not stable

- Berms protect the large fill
- The road is shaped so runoff is directed away from the fill via berms to flumed cut-outs
- The berm has been compacted and keyed into the fill

- Ponding and scour will likely cause road failure
- Water should have been cut out before the fill, and not allowed to pool in the middle and scour out and saturate the fill
- The low point of the road should not be in the middle of the crossing. If unavoidable, use a through-berm flumed culvert to remove water

Flumes channel water over fill and onto more stable ground. They can also be used to direct water into sediment controls, like sediment traps or slash.

- The flume has a well-constructed inlet
- The inlet is at least twice the pipe diameter
- Water will not bypass the entrance

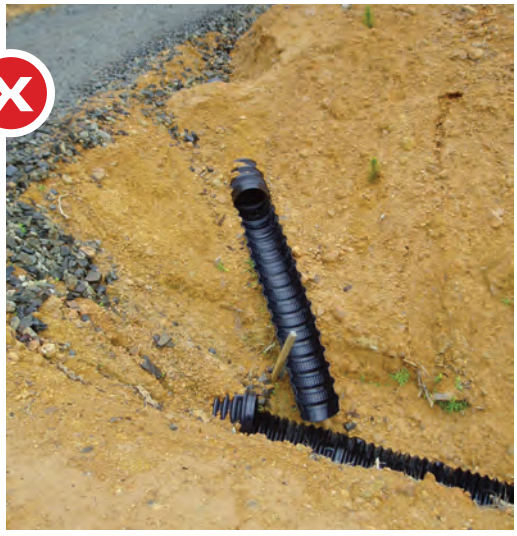
- The flume entranceway was bypassed when the fill eroded around it during a storm

- The flume has good fall to reduce silting within it
- The flume follows the ground shape
- The flume exit has slash to armour the outlet and help stop erosion
- The flume is firmly secured with pegs
- Flumes with internal ribs help slow the speed of water

- The flume outlet has failed
- The outlet was not armoured, and erosion has led to the undermined pipe

- The flume sits on the ground so the water's weight is supported
- The flume is firmly fixed with pegs
- The water runs onto more stable ground

- No fluming caused the fill slope to fail
- The fill will continue to erode and sediment will enter the nearby stream



- Both flumes have too few pegs
- The top flume inlet is likely to be bypassed in a storm
- The bottom flume is expected to fill with debris, because the slope above it has loose material that can spill into it

- Corrugated iron should not be used
- Flumes that do not follow the ground often fail
- Corrugated plastic flumes are better. They slow the water's speed, and joints seal between flume sections. These are less likely to move once secured

- Culvert sock flumes are an option to direct water over long and unstable fill
- The sock is well pegged
- Inspect socks regularly, as they are prone to blocking

- Poorly pegged and maintained socks are prone to rolling and moving in wind gusts
- Once blocked they often fail
- Consider using flexible full round corrugated pipes for very windy conditions
- May be better than half pipes or socks

SILT TRAPS AND SOAK HOLES

Silt traps and soak holes help to reduce sediment entering water bodies. They allow heavier sediment to settle, then the water either discharges (silt trap) or drains away (soak hole). Care must be taken to ensure they are not a vehicle safety hazard.

- Constructed large enough to slow the water so that the coarse sediment can settle on the bottom
- Made deep, as they can fill in rapidly
- Located close to the source of the sediment
- Built on solid ground as otherwise water may drain into the fill and increase the risk of a fill failure
- The outlet is broad and level to reduce scouring

- A large sediment trap built too close to the road.
- This is an unnecessary safety hazard because it could be constructed further away from the road. Safety cones should not be needed
- It is unsafe to build these on road corners

- A small silt trap built well
- A small excavator bucket can easily clean it out

- The silt trap is too small, and the culvert mouth is too close to the road edge
- The silt trap has stopped working

- A silt trap and fence were used to reduce sediment entering a stream
- Silt traps and sediment fences are effective when used together

- Fine slash like branches and needles can effectively trap sediment
- These can be used in many situations like at culvert outlets

- The silt trap was built in a safe location
- It is located where an excavator can easily clean it out
- It has been built away from a watercourse or stream

- This silt trap failed when the water drained through the fill
- Do not build on fill as it will increase the risk of bank failure
- The trap needs maintenance to remove sediment

SILT FENCES

Silt fences can reduce sediment movement across the ground into sensitive areas. The fence fabric helps trap coarse sediment. Locate silt fences carefully. They are only a short-term solution until the site stabilises.

- The fence is in a good location below a cut-out but before the stream
- The fence cloth traps most sediment
- Hand-seeded grass is becoming established

- Good fence location below the fill but not in the gully
- Can be cleaned if required
- Wings have been built to stop sediment going around the sides

- The fence is working well, capturing most of the coarse sediment
- Shade cloth traps are less prone to blowout or overfilling because they only trap coarse sediment

- Do not build in places where there is too much water. For example, in a riverbed or ditch
- Fences rapidly fill then fail

SINGLE CULVERT RIVER CROSSINGS

Culvert crossings are used to cross small to medium sized rivers where there is low gravel movement that could fill the culvert. They need careful installation. Follow the installation requirements within the resource consent or NES-PF permitted activity rules.

- The culvert is being installed in suitable weather and low stream flows
- Disturbance has been limited to the immediate work site
- The stream is diverted temporarily
- The trench is at the correct depth and grade, so the culvert's inlet and outlet are 20% below the streambed level
- The trench width is adequate to compact the backfill
- Construction occurred outside the fish spawning season

- A crushed culvert failed because of poor fill compaction, damage from equipment, or not enough fill depth above it
- Failure can lead to a significant safety or environmental incident
- This will be an expensive fix

- The pipe is being carefully backfilled with clean fill, and compacted in layers
- It has been bedded on a firm base to prevent water flowing under it

- Poor compaction and lack of a headwall has led to water bypassing the culvert

- The headwall helps prevent inlet damage from floods
- The bagged concrete headwall should last
- The pipe is of the correct size and length
- New rules require 20% of the culvert to be below stream level

- The headwall is ineffective (arrow)
- The pipe is too short because the over-steep fill is already slumping
- Unstable fill above the culvert entrance could block it
- This structure could fail in a heavy rain

- The pipe is long enough so that culvert batter slopes are no steeper than normal fill slopes
- The fill has topsoil placed to help with grass growth
- The culvert is marked

- Lots of problems! No headwall, the culvert is too short, and the road width is unsafe
- Untreated radiata logs will quickly rot, making the problem worse
- The culvert mouth is so far back it can't be seen in the photo

- The culvert exit is armoured with concrete wing walls so is unlikely to scour
- The culvert is set correctly in the streambed
- The fill slope is not too steep
- The fill was stabilised

- Poor culvert installation has led to the outlet scouring
- The culvert is above the streambed and the lip is perched out from the bank. This prevents fish moving upstream
- This is in breach of regulations

- The crossing was designed with an armoured spillway to reduce the risk of culvert 'blowout'
- Overflows began at the road's low point, which is rock armoured to reduce damage

- No armoured headwall was installed
- The culvert was too small
- The fill above the culvert was the weakest point in the installation
- A storm spillway was not built. It could have easily been done in this location
- An expensive rebuild is now needed

- Concrete is effective at armouring culvert outfalls
- Take care when pouring concrete that it doesn't enter the water, as cement kills fish and stream life
- Rip rap is an effective fish ladder

- The culvert outlet is not at streambed grade
- The culvert does not provide fish passage
- One correctly sized pipe is better than two small pipes that will be prone to blocking

- This culvert looks doomed to fail
- The pipe is small (arrow) and can easily block with debris immediately upstream
- The culvert is not long enough, and the fill has been supported by a few poorly anchored boards

- On vulnerable sites, install a debris barrier upstream if possible
- This one uses railway irons and wire rope anchored by deadmen
- Railway irons in stream beds require resource consent
- Ensure debris barriers can be maintained, and debris removed
- The size of the catchment will influence the design of the debris barrier

- The culvert does not interrupt the fish passage
- The bottom of the culvert is about 20% below streambed level so fish can go through the culvert

- Fish ladders help fish move up and through culverts

FORD CROSSINGS

Ford crossings can be natural riverbeds or ones with a concrete pad. Fords are generally used on low volume roads to cross broad, shallow rivers and where alternative river crossings are not feasible. Fords can create much more sediment than other types of river crossings. Fords are the least preferred river crossing.

- A natural ford with low vehicle use
- The riverbed is hard and stable
- Clean rock fill was added to strengthen the riverbed
- Fish passage is not affected

- Concrete pad ford built on a stable low gradient site
- The concrete pad extends to medium river flow
- Crossing meets fish passage rules

- Natural crossings generate more sediment than concrete pads
- Sediment comes from tyres in the river and water washing up the road
- Steep approaches create ongoing sediment problems

- The pad has concrete aprons
- There are cut-outs and sediment control on ford approaches
- Fish passage may not be met when the river is low, as water is spread thinly across the concrete, which is also too smooth for fish to swim across

Bridges are a good alternative to culverts, especially in environmentally sensitive situations. They need careful planning and installation to prevent failure, and often require a building consent.

- This bridge is a single deck steel structure
- The right equipment was used for the job
- The bridge location is good

- This bridge is a twin deck concrete structure
- It is constructed by trained and skilled operators
- All building and resource consent requirements were met

- The bridge is located square on to the stream

- Rock armour protects the bridge abutments
- The bridge width is the width of the stream

APPLYING AGGREGATE (METALLING)

Aggregate or metal strengthens the road by spreading wheel weight. It also protects and seals the earthworks and gives traction to vehicles so they can climb and brake. Metalling can be very expensive.

- The unmetalled section of the road has good shape and strength. Truck wheels have not deformed it
- Consistent thickness of metal was applied because of well-constructed subgrade

- Heavy rainfall has rilled the subgrade
- Earthworks should not be too far ahead of metalling, especially in ‘high risk’ areas

- Metal is being spread to the right depth
- The subgrade is not deformed or wheel rutted

- An excavator is an effective way to spread dumped metal
- Metal needs to be put down thicker than its final depth because it compacts down. See the thickness in front of, and behind the excavator

- Quality angular metal was applied
- There is a good mix of the aggregate size that provides strength and binds together well
- The metal can be graded, which is important for road maintenance

- Metalling is an expensive way to solve poor formation
- Huge volumes of metal were used to build up this corner. The arrow shows the size of a pinecone

- Metal was applied soon after completion of formation work
- Metal was applied to specification
- Metalling was done when the earthworks and weather were ok
- Metal was kept to the roadway and is not in the water tables
- A light roll at the right moisture helped tighten and seal the surface

- Some aggregate was wasted
- Metal is an expensive resource. It needs to be applied to the roadway, not the water tables or fill

- A grader was used to make the final shape before drum rolling
- The metal was at a good moisture content
- When using a grader, ensure that there are enough fines so that the metal can bind
- Grading can easily move larger stone to the outside of the road. This changes the aggregate size in the road pavement

- Do not use weed-infested metal stockpiles unless the area to be metalled already has those weeds
- Weeds are expensive and difficult to control once established
- Kill weeds in stockpiles before they get large enough to seed, not after they have seeded as in this photo

Ongoing repairs and maintenance (R&M) are an essential part of keeping a road, landing and other infrastructure like river crossings and drainage culverts up to standard. It prolongs life and reduces the risk to safety and the environment.

Build roads and landings properly in the first place. This helps reduce maintenance costs.

- Maintained culverts are less likely to block and cause road damage
- Remove vegetation from culvert mouths and outlets
- A shovel is one of the most effective maintenance tools!

- The fill became saturated, weakened, and slipped off papa (blue mudstone) bedrock
- Several things led to this failure, including there was no bench for the fill, and the poorly located and non-flumed culvert saturated the fill

STOP

TELL SOMEONE IF YOU SEE A 'HIGH RISK' MAINTENANCE ISSUE!

Timely maintenance is key. The repairs and maintenance section will briefly explain common maintenance issues, what causes them and the necessary steps to fix them.

- The correct road shape is critical
- Roads need 3-5% crossfall (the sun rays show this)
- Flat road surfaces will not shed water. Water quickly weakens the road surface and formation

- Grading is an essential part of road maintenance
- Grading helps restore the road to its correct shape

- Lack of rip rap downstream of the ford led to the scouring
- After heavy rain, always check culverts, crossings and other water control

- Poor road surface drainage causes potholes
- Water lies in puddles and seeps into the pavement, weakening it
- The centre of the road must be higher than its edges to create crossfall
- Grass growing onto the road has stopped water going to the ditches
- Fix the potholes by restoring the shape of the road by grading and removing grass on the road shoulders, so that water goes into the ditches

R&M is often needed on new construction, especially after storms and before vegetation has grown. Work includes fixing bank collapse, and cleaning out ditches, drainage culvert inlets and outlets, and sediment control structures.

- Newly cut banks can fail especially after heavy rain
- Clean up slips quickly before more damage occurs

- Sediment traps need to be maintained
- Check new construction regularly until it stabilises, and especially after heavy rain
- Clean out if they have lost 1/3 of their storage

- Silt fences are short-term solutions. They are difficult to maintain as they can fill rapidly and are hard to clean out

- Culvert mouths are vulnerable to bank collapse and infilling
- Check culverts regularly, especially on new roads
- After clearing the bulk with the excavator, use a shovel to clear around the culvert mouth
- Be sure stormwater will go down the culvert!

- Water tables on new roads need to be inspected after every storm
- They can scour and block culverts
- Additional culverts may need to be added after construction

- Drainage socks need to have regular maintenance, as they can easily twist or roll
- This sock was poorly anchored

- Fill slopes need to be inspected
- Water has drained across a fill leading to a slump
- A berm would have helped direct water off the road at a more suitable location

- Steep roads in wet areas often need more maintenance than other roads
- Make sure the maintenance programme identifies high-risk steep roads

Weak or failed subgrade needs fixing

- The soft spot was dug out to 0.5 m below the finished road surface and will be backfilled with good material
- The soft spot can now drain into the ditch

- The soft spot was not dug deep enough
- The new metal cannot drain into the ditch, which may create another soft spot!
- Deepening the ditch drain may also improve the fix

- The new material that replaced the soft spot was compacted to improve strength and help seal the surface
- Aggregate with broken or angular faces are best as they lock together. Smooth stones don't

- Straight river run gravel laid over a weak formation caused this failure
- River run gravel needs to be applied in a thicker layer. If it isn't, the formation must be strengthened by compaction, geotextile, or other methods

- Corduroy was laid after the road failed
- The corduroy forms a layer to separate the subgrade from the metal. Corduroy also spreads vehicle weight across the subgrade
- This rapid and guaranteed fix was essential because the road was needed for logging

- This soft spot will continue to fail and allow water into the subgrade
- The fix is to fill in the potholes and create road shape to shed water
- If conditions allow, grading will improve the road. Grading in poor conditions may make the problem worse by opening the road up to water

STOP

FORMATION FAILS FOR A REASON. DON'T DO A HALF JOB OF FIXING THEM. YOU MAY BE BACK THERE AGAIN OTHERWISE!

Increasing the strength of the subgrade.

- These photos show hydrated lime used to stabilise a road:
  - The lime is spread from a truck
  - It is ripped into the surface with the grader
  - A water truck is used to achieve optimum moisture before compacting
- Good drainage, crossfall and compaction is essential
- Use the road only when the lime has fully cured
- Do not use lime in cool conditions as it doesn't cure
- Do not use agricultural lime as it won't work

- Geotextile strengthens a road by separating the weak subgrade from the metal
- Separation stops the aggregate being worked down into the subgrade

- Geogrids work by increasing the strength of the metal
- The plastic grid helps lock the metal together; this increases its strength

Harvesting can be tough on infrastructure. R&M can be very expensive and challenging, especially on new and poorly constructed roads, in wet weather, and where there is a lot of traffic.

- Corrugations are normally created on steep road segments from uphill traffic
- Corrugations get worse if they are not fixed
- A short-term fix is to grade to the depth of the corrugation, re-shape, spread metal, water and roll to compact
- A long-term solution is to use a clay binder, lime stabiliser or tarsealing

- Check water control during and after harvest
- Loggers often damage water controls. These include culverts, drainage culvert mouths, sediment traps, berms and flumes

- Wet weather, the steep grade and poor road shape have led to surface rutting
- Fix by cutting, grading and compaction
- Fix in good weather and when the material is not too wet or dry
- Use a good aggregate

- Heavy traffic can cause severely rutted roads
- This pavement has failed. Water has gone through the metal and weakened the formation. Mud is where metal should be
- Weak or failed subgrade needs fixing

River crossings need regular R&M, especially after storms. R&M is often to clear debris and fix scouring of inlets, outlets and abutments.

- Gravel removed from blocked culverts
- The damage was fixed by rock and concrete re-enforcement
- Road approaches fixed

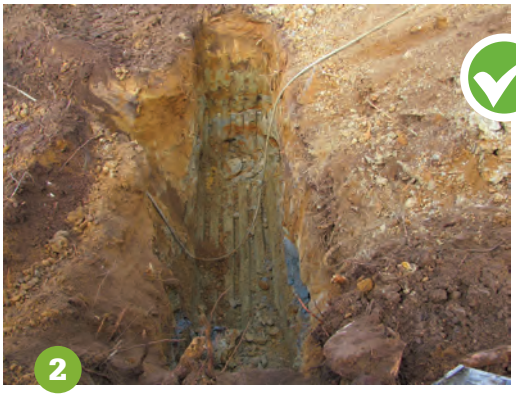
- Do not put storm deposited silt removed from the crossing on the bank
- Truck spoil away from the immediate area

- Remove debris before it becomes a significant problem
- Once debris blocks the culvert, the water needs to go somewhere else
- Since the culvert is located at the lowest point, water will go over the top
- This will scour out the culvert
- This is a common and challenging problem to fix, especially in rivers with lots of woody debris

INSTALLING DEADMEN

When stumps are too small, not strong enough or located in the wrong place, deadmen are used to anchor guy lines on haulers or tethered machines. Install correctly as the safety of others may depend upon it.

- Dig the trench at right angles to the pull of the guy line
- It must be at least 4 m deep and about 7 m long. The notch stops the logs being pulled straight up



- Lay a strop in the trench before a log is put in. The strength of the deadmen strop should be at least equal to the guy rope

- Use green logs at least 50 cm in diameter. Do not use old logs or bundles of smaller diameter logs, as the rope may cut through them
- Compact as you backfill
- Do not enter the trench

- The two strop ends must be equal, so that the tension is similar on both sides when shackled

STOP

LIVES ARE AT RISK IF DEADMEN FAIL. MAKE SURE THEY ARE 'BOMB PROOF'!

INSTALLING DEBRIS TRAPS

Debris traps are constructed in rivers to catch debris with a high risk of mobilising in a flood. They are often made from rammed railway irons or steel beams threaded with wire rope and anchored solidly at each end. They should be engineered. They can easily fail. Debris traps installed into a riverbed require a resource consent.

- Debris trap doing its job well but needs to be cleaned out
- Beams spaced at 1.5 to 2 m
- Beams were driven in more than 1.5 m
- 22 mm wire rope was threaded through the beams
- Wire rope was securely anchored then tensioned

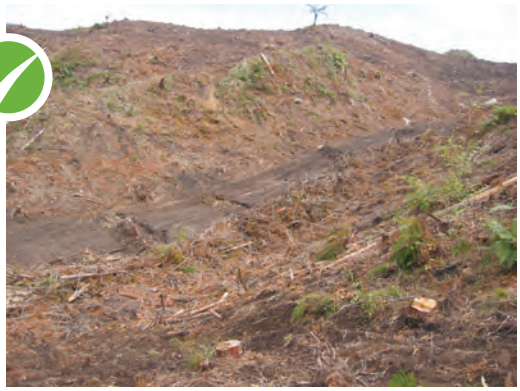
- Constructed to protect a culvert
- Put directly across the river
- Easy to clean out
- Fish passage is not blocked
- Water can flow freely

- Debris traps need to last at least six years
- Locate in a flat section of the river to reduce the risk of it failing

- A poor debris trap anchor caused it to fail
- Consider putting debris traps in the side streams
- Debris trap failures could lead to lots of wood going downstream at once, causing significant damage

HARVESTING TRACK REHABILITATION (REHAB)

Most logging tracks will need rehab. The amount of rehab depends on the terrain and the soil type. Many will need water controls installed or reinstated immediately after harvest. Tracks can rapidly erode and be a major source of sediment in waterways.



- Track has closely spaced cut-outs
- Cut-outs direct water into slash
- Cut-outs go across the entire track, and are deep enough that water does not go past them

- The water will continue to scour the soft ash soil
- Sediment will continue to enter a nearby waterway
- To fix, put in cut-outs or pull back track to stop erosion

- Spreading slash is an excellent way to reduce erosion, especially where cut-outs cannot work. For example, in gully bottoms
- Slash slows water down and traps sediment

- Maintenance had been identified but was not done before the heavy rain
- Large amounts of sediment can be created even from short tracks
- Installing cut-outs on the track would significantly reduce the sediment

Cut-outs are the most common stormwater control measure used to rehab tracks.

WHERE IS A GOOD PLACE TO PUT IN A CUT-OUT?

Step 1: Get the spacing right

- The steeper the track, and the more erosion-prone the soil is, the closer the cut-outs need to be
- On some tracks, cut-outs need to be very close
- Use the table right as a guide

Table 14: Spacing guide for cut-outs

Gradient	Grade %	Erosion prone land	Non-erosion prone land
1:20	5%	50 m	75 m
1:15	6.5%	40 m	60 m
1:12	8%	30 m	45 m
1:10	10%	25 m	35 m
1:8	12.5%	20 m	30 m
1:7	14%	15 m	22 m
1:6	16%	12 m	18 m
1:5	20%	10 m	15 m

Step 2: Use the terrain to decide where to put them in

Use the shape of the land to help locate the best spots:

1. In the bottom of track dips or undulations
2. Where water can drain off the track and onto stable ground
3. Where they don't go directly into water bodies

HOW DO YOU CONSTRUCT A GOOD CUT-OUT?

These things make a good cut-out:

- Constructed across the entire track
- Angle it downslope to help drain water
- Ensure there is no ponding
- Build a small compacted bund on the downhill side to stop water going over the top of it
- Dig at least 300 mm deep
- Build the exit on stable ground, so it does not erode and create sediment
- Drain water into a slash filter, soak hole or sediment trap where needed

LANDING REHAB

Rehab greatly reduces the chance of landing failure, especially in steep and 'high risk' locations. Landing failure can have a significant environmental impact. Rehab may also increase the area available to re-plant. Slash on and around landings are sometimes burnt before rehab (burning is not covered here).

- A large berm directs water to solid ground
- Slash has been pulled well back from the landing edge and onto hard ground

- No rehab has occurred!
- Debris was pushed into the waterway on two landings
- The area gets heavy rain, and the culvert crossing (arrow) could fail
- Water mobilises the debris

FIXING THE PROBLEM

BEFORE

- Not enough slash was removed. Slash was only pulled up on the other side of the skid
- The landing has major tension cracks are in the fill, and there are minor slumps
- Slash is now beyond an excavator's reach, because no slash bench was built to contain the slash

AFTER

- A bench was made to:
  - Reduce risk of fill failure from tension cracks
  - Remove the risk of landing fill collapse
  - Enable the excavator to reach all the debris
- Debris was put in a safe location. Options include piling up or evenly spreading

These publications from the NZ Forest Owners Association will help you learn more:

These training organisations can help:

Connexis
New Zealand's infrastructure training organisation
http://www.connexis.org.nz/
Tel: 0800 486 626

Competenz
Forestry training
www.competenz.org.nz
Tel: 0800 526 1800

YOUR CONTRACTOR, SUPERVISOR AND FOREST COMPANY MAY ALSO HAVE USEFUL DESIGN AND CONSTRUCTION INFORMATION

GLOSSARY

A

Adverse grade: Uphill grade for a loaded truck

Ash: Very fine soil of volcanic origin

B

Backfill: Soil or other material used to replace material removed during construction

Bank: Cut face near a road or landing

Base course: Bottom layer of road surface rock in a two-layer surfacing system. The base course is the layer between the subgrade and the surface 'running' layer of crushed rock

Batter: Constructed slopes for, for example, a cutting or bank

Bench: Ledge cut into solid ground to contain fill, or a step cut into a batter to make it more stable

Berm: A raised or engineered structure parallel to the edge of a road or track, designed to contain and direct surface water runoff and sediment

Block cut: Cutting that has a batter on either side

Borrow pit: Often an in-forest site where good road construction material has been used. They are smaller than a quarry.

Box culvert: Square culvert pipe to channel water

C

Camber: Gradual downward slope from the centre of the road, for roads that are crowned

Clay: A soil type made up of very fine cohesive particles, plastic when wet, generally brown to yellow. Some clays swell

Clearing (stripping): Removing standing and dead vegetation within a roadway clearing limits. This is the first step of construction on a forest road

Compaction: Applying pressure or vibration to soil or aggregate to strengthen it, resulting in increased density (tons per m^3)

Corduroy: A structured load-bearing surface where the logs are laid horizontally and parallel, with no void areas. Corduroy roads are an engineered road construction technique used in places where the substrate is very weak, and where the load must be spread if the road is to be trafficable. This can be used on skid trails or landings, or with adequate surfacing also on haul roads

Crossfall: Cross slope for roads that are not crowned

Culvert: Either (a) a pipe or box structure that conveys a stormwater flow under a forestry road or forestry track; or (b) the entire structure used to channel a water body under a forestry road or forestry track

Cut: Excavation within the construction batter limits shown on the drawings and above the final subgrade surface. The cut includes side cuts and batters

D

Daylighting: Process of removing trees to allow sunlight and air in to dry out a roadway or landing

Deadman: An object, normally a log, buried in the ground to be an anchor

Debris trap: A structure designed to catch and temporarily store harvest residues from flowing water. Also known as a slash trap or woody debris trap

Ditch: A channel often on the edge of a road to drain the subgrade and carry stormwater to discharge points or cross road culverts. Often called water tables or drains

E

End-haul: Moving excavated roadway material a distance (usually by dump truck) to a designated soil dump site. Often used with full bench construction, as opposed to side casting the cut directly onto the slope

F

Favourable grade: Downhill grade for a loaded truck

Fill: Soil or aggregate, placed to raise the land surface, normally under a strict compaction regime. It can be used to build a structure above natural ground level, as with fill sections on the downhill side of a road

Fill slope: An area on the downhill side of a roadway (or both sides in a through fill section) that must have excavated material placed on it to build a road section up to grade

Flume: An open channel, or conduit, made from plastic, galvanised corrugated steel, and sometimes concrete or timber. It is used to carry runoff from earthworks over loose fill or erodible material so that it can be discharged onto less erodible surfaces

Ford: A hard surface on the bed of a river, permanently or frequently overtopped by water, that allows the crossing of a river by machinery or vehicles

G

Grade (slope): The tangent of the angle of a surface to the horizontal. Grades are typically specified for new road constructions

Gravel: Particles of rock between 5 and 75 mm in size. They can be rounded, semi-rounded or angular

H

Headwall: A wall built at the upstream end of a culvert.

Hydro seeding: A seed mulch and water mix sprayed onto fills and batters

L

Landing (pad, skid): An area of land where logs or tree lengths extracted from a forest are accumulated, processed and loaded for removal

M

Maintenance (R&M): As defined by the NES-PF, it includes activities that reshape and upgrade existing forestry infrastructure, the installation and maintenance of water runoff control measures, and/or road metalling. It does not include road widening or realignment

Marker peg: Placed to mark a road edge, or culvert inlet or outlet

Metal: Angular faced crushed or broken rock used as a top course of a road

O

Organic matter: Topsoil, woody material, vegetation

P

Pavement: The total improvement layer, including the base course and top coat aggregate

Penetrometer: A device used for testing a soil's load-carrying capacity indirectly, by measuring its resistance to an object being forced into the soil with a standard force

Q

Quarry: A large deep pit where rock is blasted, ripped or excavated and extracted

R

Rip rap: Rock put in place to protect a surface from water damage

Riparian strip: An area beside a river or stream; often protected

River: As defined by the NES-PF, a river is a continually or intermittently flowing body of fresh water. For example, a stream (including very small streams) or a modified watercourse. It does not include any artificial watercourse, such as an irrigation canal, water supply race, canal for the supply of water for electricity power generation, or farm drainage canal

Roadway: The portion of a road within the limits of excavation and embankment

Runoff: Water flowing from an area of earthworks or in a water table, or occasionally across the forest

Running course: Final thin layer of metal on top of the road to improve the road surface

Rut: A depression caused by the wheels or tracks of a vehicle

S

Saddle: Low point on a ridge

Salvage: Harvesting of an area for a new road or landing, or for daylighting

Scour: The removal of soil or rock by the power of running water

Sediment: Material that is being transported, usually by water, from one place to another

Sediment trap: A pit to catch and slow down water and sediment from a road or landing, with an outlet

Side cast: Means placing non-compacted fill or spoil, that has been excavated from a cut to create forestry infrastructure, on the downhill slope from the infrastructure

Soak pit: A large hole to catch and drain water, without an outlet. Used mainly in free draining soils

Slope: The ground or earthworks angle

Soil: Dirt that is not rock

Spoil: Disturbed material often used as fill

Subgrade: The native material underneath a constructed road. It can also refer to the finished surface prior to applying the improvement layer, such as the aggregate. It is also called the formation layer

Spur road: Supports a low level of traffic, such as a level that would serve one or two landings. Also called a stub or stab road

Stockpile: Heap or stack of material to be used later. For example, metal stockpile

supported by forestgrowers commodity levy

NEW ZEALAND FARM FORESTRY ASSOCIATION

FOREST OWNERS ASSOCIATION