FOREST OWNERS ASSOCIATION

FICA FOREST INDUSTRY CONTRACTORS ASSOCIATION

NEW ZEALAND FARM FORESTRY ASSOCIATION

Forest Practice Guides

Document History

Version	Practice Guides amended	Pages
Version 1.1, June 2019	FPG 1.1	5, 6
Version 2.0 January 2020	Extensive editing and photographic updates across all 28 guides, including 200+ revisions to text, commentary in each series, updated website links and other updates to documentation.	

Contents

Version 2.0, January 2020

How to Use

The NES-PF has provided a consistent regulatory approach for various forestry activities including earthworks, crossings and harvesting. A major platform of the regulation is that a forestry earthworks management plan and harvest plan (a Management Plan) is to be prepared. The specifications in schedule 3 of the NES-PF set out the details of the matters to be included in such a plan. There is a requirement to describe the management practices that will be carried out.

The guides provide various options, a tool box, of management practices. It is anticipated that in describing management practices that a Management Plan may refer to a guide or part of a guide.

The guides are not statutory documents however, care must be taken to references to a guide. If a Management Plan states that a certain guide or part of a guide is going to be followed then those provisions of that guide will form part of compliance with the NES-PF regulations. In other words, the provisions will form part of your regulatory obligation under the RMA.

It is recommended that when considering management practices that the choice of specific provisions of a guide be clearly identified in a Management Plan. This is the preferred approach rather than a general comment that a particular guide will be followed.

The guides do not have to be used but they do describe forestry best practices.

Provisions of other documents such as individual company best practice documents and or operational specifications, council technical publications, the New Zealand Forest Owners Road Engineering Manual may be used to describe the management practices that will form part of any Management Plan

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Forest Practice Guide
Non-Regulatory

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Earthworks Construction

Earthworks Construction
1.1 Planning and Design

Road construction is a particularly important forestry operation to enable access to all stages of the forest cycle, from establishment through to tending and protection, and harvesting.

The construction of roads and *landings* can involve earthworks on steep, erosion prone terrain. These earthworks are recognised as a primary source of erosion and *sedimentation* from forests.

If not appropriately planned and managed, earthworks associated with plantation forestry can result in the following adverse environmental effects:

- Accelerated erosion due to slope instability and mass soil movements (e.g. collapse of slopes around cuts), and
- Excessive *sediment* discharges to sensitive areas (e.g. *rivers*) from exposed earth (e.g. through soil disturbance and slope failures).

Some natural slopes exist in a state of only marginal stability and relatively minor works such as trenching, excavation for roads or *landings*, or removal of scrub or vegetation can lead to failure.

Version 2.0, January 2020

Earthworks Construction
1.1 Planning and Design

Scope

This guide should be used for planning and designing all forest road earthworks. Users of this guide are also referred to the following useful references:

- National Environmental Standards for Plantation Forestry (regulations 22-35)
- New Zealand Forest Owners Association – New Zealand Forest Road Engineering Manual (2020)
- NZTA Standard Specification F/1 – Earthworks Construction www.nzta.govt.nz/assets/resources/earthworks-const/docs/earthworks-const.pdf
- Guideline for the Field Classification and Description of Soils and Rock for Engineering Purposes: NZ Geotechnical Society, December 2005 www.nzgs.org/library/field-description-of-soil-and-rock-field-sheet

Earthworks Construction
1.1 Planning and Design

General planning and design considerations

Planning and design are important processes in mitigating the adverse effects of earthworks and ensuring cost effective, fit for purpose roading infrastructure is developed. These activities should be carried out by an experienced and/or qualified person, who can adequately address the following:

1. **Road and landing design standards –** the first step in the design process is to confirm operating requirements and the design standards. Appropriate design standards will ensure fit for purpose infrastructure that is safe and efficient for road users and the harvesting operation, and is established whilst minimising the foot print (scale and extent) and environmental impact of the earthworks.
2. **Site topography –** will influence the location/position of road and *landing* infrastructure, and the earthworks construction techniques employed. Obtaining suitably detailed mapping and survey data is an essential step in the planning and design process. 1:5,000 scale topographical maps with 5 m contour are often used for planning, however more detailed topographical and engineering surveys may be necessary for the design of large scale and high risk earthworks.
3. **Site geology –** the stability of steep slopes should be assessed during the planning phase and care taken to avoid, as far as practicable, locating infrastructure on high risk areas (terrain hazards) such as gully heads, landslide scarps (slips), earthflows or near *riparian margins*. Terrain models produced from LiDAR survey are particularly useful in identifying hazardous landforms and features such as hummocky surfaces and crescent shaped depressions. Field inspections will identify other signs, such as trees leaning uphill or downhill, *wetlands* or wet ground in elevated positions, plants such as rushes growing on a slope, and water seeping from the ground.
4. **Water bodies and drainage –** avoiding *sediment* discharge to *water bodies* and protecting aquatic ecosystems is a critical element of road construction. The design process must consider the impact the construction and ongoing use of the road and *landing* infrastructure, will have on *water bodies*. The natural drainage patterns should be identified with roads positioned/designed to cater for sensitive areas. During and post-construction drainage should aim to minimise stormwater *run-off* from exposed earth and cater for the safe disposal of stormwater.
5. **Soil properties/geotechnical design –** soil classification and understanding slope stability are important factors in the design of earthworks. The Guideline for Field Classification and Description of Soils and Rocks for Engineering Purposes is a good reference document.

Earthworks Construction
1.1 Planning and Design

General planning and design considerations continued

6. **Construction methodology (constructability) –** the design process should include a constructability review, considering the timing and sequencing of work, *road-line salvage* operations, the safe placement (disposal) of stumps and stripping, the disposal (dumping) of unsuitable material and cut to waste (end-haul). The review should be seen as a risk assessment.
7. **Earthworks management –** effective earthworks projects include good production planning. The contractor needs to understand the designer's intention for the earthworks in order to plan and implement the earthworks successfully. This requires the designer to provide clear project specifications regarding the material and standard of workmanship required.

Earthworks Construction
1.1 Planning and Design

Recommended planning and design processes

Green zone: Low erosion susceptibility

General

Green zone areas are generally characterised by well-developed soils and stable geology. Green zones are not exclusive to flat and rolling contour and encroach into steeper hill country in some parts of the country. Whilst these steeper areas will typically be geologically stable, road and *landing* design needs to be managed carefully.

If good earthworks techniques are employed (FPGs Earthworks Construction), green zones should present a low erosion risk.

Forest engineering

A basic understanding of local geology and soils is adequate.

Geometric design

Not critical on flat to rolling contour. However, a simple road design may be necessary for an isolated section of road or *landing* located in difficult areas (i.e. adjacent to a *riparian margin*).

Note: green zone may reach into steep hill country. Detailed engineering design is recommended for green zone sites on steep slopes.

Construction specifications

Operational prescriptions detailing the project requirements – including, but not limited to, material specifications and standards of workmanship – need to be provided to contractors and operators undertaking the work.

Earthworks prescriptions should specify the required cut and fill *batter* slopes, standards of *compaction*, and hold points for inspections and testing.

Survey and setting out

The road centre-line or grade and *landing* locations should be flagged.

Yellow zone: Moderate erosion susceptibility

General

Yellow zone areas are generally characterised by rolling to moderately incised terrain, with well-developed soils and stable geology. If good earthworks techniques are employed (FPGs Earthworks Construction), yellow zones should present a low erosion risk.

Yellow zones encroach into steeper terrain in some parts of the country. Whilst these steeper areas will typically be geologically stable and present a reduced erosion risk than a red or orange zone, the design of roads and *landings* should be carefully managed on steep slopes.

Forest engineering

A basic understanding of local geology and soils is adequate.

Geometric design

Not critical on flat to rolling contour. However, a simple road design may be necessary for isolated sections of road or *landings* located in difficult areas (i.e. adjacent to a *riparian margin*).

Note: yellow zone may reach into steep hill country. Detailed engineering design is recommended for green zone sites on steep slopes.

Construction specifications

Operational prescriptions detailing the project requirements – including, but not limited to, material specifications and standards of workmanship – need to be provided to contractors and operators undertaking the work. Earthworks prescriptions should specify the required cut and fill *batter* slopes, standards of *compaction*, and hold points for inspections and testing.

Survey and setting out

The road centre-line or grade and *landing* locations should be flagged.

Earthworks Construction
1.1 Planning and Design

Recommended planning and design processes continued

Orange zone: High erosion susceptibility

General

Orange zones are characterised by rolling steep to incised terrain, with shallow soils and a shallow landslide risk. Soils become increasingly susceptible to slipping as the hill slope increases. Carrying out earthworks in an orange zone on slopes < 25 degrees represents a moderate but manageable risk, if good earthworks construction techniques are implemented.

Where the slopes are > 25 degrees the erosion susceptibility is higher and there are limits on the scale of earthworks that are permitted (refer to NES-PF regulation 24 (2) (c)). Resource Consent (Restricted Discretionary) will be required where the permitted activity thresholds will be exceeded – in these situations specialist advice should be sought. Consent applications will typically need to be supported by engineering design appropriate for the level of risk.

Forest /Geotechnical engineering

Soil classification and slope stability should be assessed. This information is required for the design of cut and fill *batter* slopes, specifying *compaction* standards for structural *fills*.

Geometric design

Geometric design is critical in orange zones with slopes > 25 degrees in order to confirm the scale and extent of earthworks meets NES-PF regulation 24 (2) (c). Designs developed using appropriate engineering design processes and tools (RoadEng, Civil 3D or similar) will optimise the road alignments.

Construction specifications

Operational prescriptions detailing the project requirements – including, but not limited to, material specifications and standards of workmanship – need to be provided to contractors and operators undertaking the work.

Earthworks prescriptions should specify the required cut and fill *batter* slopes, standards of *compaction*, and hold points for inspections and testing.

Survey and setting out

Consider pegging or flagging the extent of the earthworks at regular intervals (typically 20 m).

Red zone: Very high erosion susceptibility

General

Red zones are characterised by a combination of fragile, highly erodible soils and steep slopes. Carrying out earthworks in a red zone represents a significant risk. Resource Consent (Restricted Discretionary) will be required. Where earthworks in a red zone are necessary, seeking specialist advice should be considered. Consent applications will typically need to be supported by engineering design appropriate for the level of risk.

Forest/Geotechnical engineering

Soil classification and slope stability should be assessed. This information is required for the design of cut and fill *batter* slopes, specifying *compaction* standards for structural *fills*.

Geometric design

Geometric designs confirming the optimum road alignment and the extent and scale (volume) of the earthworks should be developed using appropriate engineering design processes and tools (RoadEng, Civil 3D or similar).

Construction specifications

Operational prescriptions detailing the project requirements – including, but not limited to, material specifications and standards of workmanship – need to be provided to contractors and operators undertaking the work.

Earthworks prescriptions should specify the required cut and *fill batter* slopes, standards of *compaction*, and hold points for inspections and testing.

Survey and setting out

The extent of the earthworks should be pegged or flagged at regular intervals (typically 20 m). The top of cut and the toe of *fill* slopes should be marked with *batter* pegs. Setting out should give consideration of the *road-line salvage* requirements and, where necessary, the extent of tree clearance marked.

Earthworks Construction
1.1 Planning and Design

Contact

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Earthworks Construction
1.2 Clearing and Stripping

It is engineering best practice that the construction of earth formations (*fills*) should be free of organic material. Organic material, such as tree stumps and roots, surface vegetation (grass and scrub), *slash* and branches, and topsoil is unable to be *compacted*, decays over time, and can be a point of water entry, resulting in weak and unstable *fills* that may collapse.

Regulation 30 (1) of the NES-PF requires that *fill* must contain no more than 5% (by volume) of vegetation and wood.

Version 2.0, January 2020

Earthworks Construction
1.2 Clearing and Stripping

Scope

This guide covers preliminary earthworks processes of vegetation clearance and stripping. It also includes removal of trees from the road corridor and *landing* sites *(road-line salvage)* and *stumping*.

Where to use

Clearing and stripping must be carried out in advance of all bulk earthworks including cut and side-cast, and cut and bench formation (refer to FPG EC #3 Bulk Earthworks) and full bench construction (refer to FPG EC #4 Fill Placement and Compaction). The interrelationship with these other Forest Practice Guides should be considered, where appropriate, when developing earthworks prescriptions.

Borrow pits and *overburden* dumps should also be cleared and stripped of vegetation and organic material.

Excavator and bull dozer clearing stumps and stripping prior to bulk earthworks.

Excavators clearing vegetation and stripping topsoil ahead of *landing* construction.

Earthworks Construction
1.2 Clearing and Stripping

Earthworks management

All clearing and stripping should be carefully planned and executed with attention to both the short and long term effects on potential soil erosion. Local conditions pertaining to the operation should be detailed on the earthworks prescriptions.

The extent of *road-line salvage*, site clearance and stripping should be determined as part of the planning and design process (refer to FPG EC #1 Planning and Design) and clearly specified in the *road-line salvage* and earthworks prescriptions provided to contractors.

Road-line salvage

The establishment of new harvest access roads into a forest typically requires the felling and removal of trees (roadside salvage). This is often carried out by a specialist harvesting contractor, prior to the earthmoving contractor taking possession of site.

Where separate harvesting and engineering contractors are engaged the hand-over of the site, from the harvesting to engineering contractor, on completion of the *road-line salvage* operation needs to be managed carefully. A site inspection should be carried out to confirm clearance widths are sufficient to construct the road or *landing* effectively.
Note: allowance needs to be made for cut and fill slopes.

Earthworks should not commence if insufficient trees have been cleared and there is a risk that the cut and fill *batters* will encroach into standing trees.

Road corridor after *road-line salvage* and prior to clearing and stripping.

Example of good *road-line salvage* with a sufficient number of trees removed providing adequate width road formation.

Example of poor *road-line salvage* where adequate allowance has not been made for road formation and *fill* has been run into standing trees.

Earthworks Construction
1.2 Clearing and Stripping

Health, safety and environmental considerations

The planning and execution of *road-line salvage* and clearing operations must consider safety and environmental impacts and not create or leave hazards that will affect future operations.

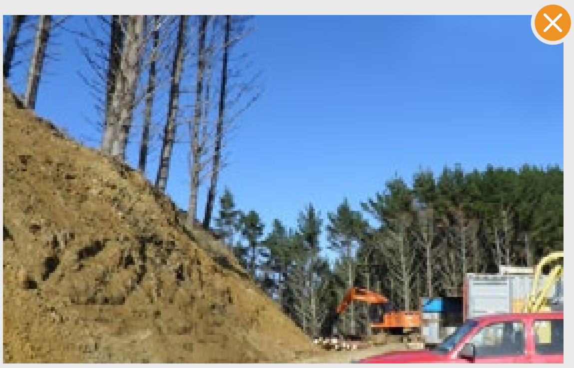
Hazards arising from *road-line salvage* and stripping operations are:

1. Poor placement of tree stumps on steep slopes where they may be dislodged by future log tree felling and extraction operations.
2. Leaving trees standing above *landing* sites or operational areas. These may present wind fall risk to road users and workers on *landings*.

Place stumps and debris in a stable location where they will not interfere or cause safety issues for other forestry operations or have adverse environmental effects.

An example of good stump placement. Stumps have been placed on a shallow bench away from standing trees and the construction *fill* during clearing and stripping.

Poor placement of stumps, left resting on hill slope amongst standing trees – this represents a significant hazard to tree fallers and breaker outs during harvest.



Trees left standing above a *landing* site present a significant hazard. This risk would have been eliminated if trees were removed during *road-line salvage*.

Earthworks Construction
1.2 Clearing and Stripping

Summary of key requirements

1. Ensure the extent of *road-line salvage* and site clearing requirements is confirmed during the planning and design phase and these are clearly communicated in the relevant operational prescriptions. On steep sites ensure allowance is made for cut and fill *batter* slopes.
2. Ensure a forestry earthworks management plan for the site is in place prior to earthwork commencing – Refer to Schedule 3 of NES-PF.
3. For orange and red zone sites and all others on sloping ground the extent of cut and fill *batters* (plus *buffers*) should be marked on the ground prior to *road-line salvage* and site clearing commencing.
4. Prior to earthworks commencing ensure that required (sufficient) trees have been removed to enable safe construction of the road or *landing*.
5. Choose the right machinery size and combination for the terrain, stump size and soil type. Excavator/dozer combinations can work best.
6. Strip all organic matter, including top soil and stumps, prior to constructing the road or *landing,* to minimise the vegetation and wood within the *fill*.
7. Place stumps on flat stable ground or a secure bench or beyond the toe of *fills*. Where there is no suitable placement option, cart to a safe disposal site.
8. Keep stripped material away from *water bodies* or any restricted areas.

Maintenance

Not applicable, as clearing and stripping is the first step in constructing a road or *landing*.

National Environmental Standards for Plantation Forestry

Relevant regulations for earthworks are 25 – 35.

Contact

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Forest Practice Guide
Non-Regulatory

Earthworks Construction
1.3 Bulk Earthworks

The construction of forest roads, in particular harvest access roads suitable for logging trucks, can often involve the movement of large volumes of earth. Construction of roads on steep hill slopes can require large cuts and generate significant volumes of earth disturbance.

Poor construction techniques will result in *sediment* generation, unstable earth formations, and present longer term slope instability and accelerated erosion risks.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Earthworks Construction
1.3 Bulk Earthworks

Scope

This guide covers bulk earthworks for the construction of forest roads and *landings*, including side-cast construction, sidling cut to *fill* (cut and bench construction), sidling cut (full bench construction), and embankment *fills*.

It outlines best practice techniques for forestry earthworks construction and should be used in conjunction with FPG EC #1 Planning and Design, and FPG EC #2 Stripping and Clearing. Users of the guide are also referred to the following reference documents:

- National Environmental Standards for Plantation Forestry (regulations 22–35)
- New Zealand Forest Owners Association – New Zealand Forest Road Engineering Manual (2020)
- NZTA Standard Specification F/1 – Earthworks Construction www.nzta.govt.nz/assets/resources/earthworks-const/docs/earthworks-const.pdf
- Guideline for the Field Classification and Description of Soils and Rock for Engineering Purposes: NZ Geotechnical Society, December 2005 www.nzgs.org/library/field-description-of-soil-and-rock-field-sheet

Construction methods

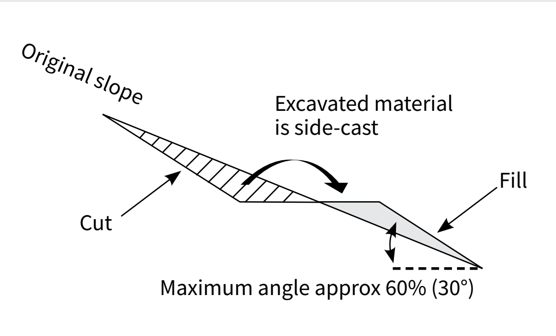
The construction of a single road may involve any combination of the following construction methods, depending on the site characteristic and project requirements. The planning and design process should assess site requirements and specify the methodology in earthworks prescriptions.

1 Cut and side-cast

Cut and side-cast construction is the simplest and lowest cost construction method. Material (*fill*) cut from the hill side is simply pushed (cast) into its final position without benching or otherwise modifying the surrounding terrain.

Cut and side-cast construction will result in loose *uncompacted fill* that is prone to erosion and can create *sediment* issues if the road and *landing* water control is not well-managed.

Cut and side-cast cross section



Where and when to use

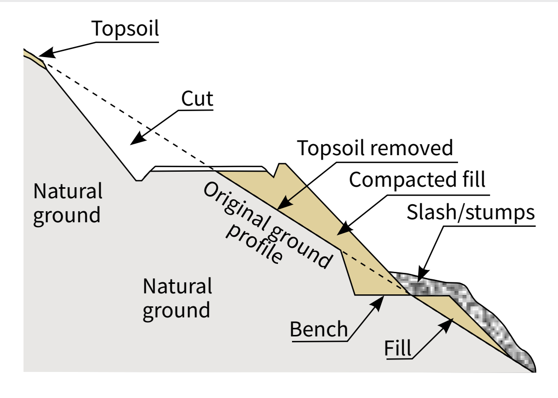
Cut and side-cast construction should only be carried out on **flat to rolling contour** and where there is **no risk of *sediment* being deposited in a *water body*** (i.e. not above a *perennial stream* regardless of slope). To mitigate ongoing erosion and *sedimentation* risks, the bare earth (side-cast material) should be *stabilised* or vegetated immediately after construction.

Consideration should be given to the loading requirements of the formation. *Uncompacted fill* may not support heavy logging traffic and collapse under loading. It is important to assess structural requirements of the *fill* during the planning phase – side-cast may not be suitable.

Construction methods continued

2 Cut and benched fill

Cut and benched fill



Cut and bench construction is a common method for constructing roads on moderate to steep hill country, where *fill* side cast onto the natural slope (un-benched) cannot be retained in a stable state.

A level bench (or multiple benches) should be established to provide a base for constructing structural *fill*. The bench location should be established in relation to the finished road formation level and the safe *fill batter* slope with a view to balancing cut and *fill* volumes.

Benches should be constructed wide enough for the safe and effective operation of *compaction* equipment.

A typical cross-section confirming cut and fill *batter* heights and slopes should be developed during the planning and design phase – refer to FPG EC #1 Planning and Design. The design process should assess whether or not the slope is suitable for cut and bench construction.

Where it is anticipated that subsurface water will be encountered within the bench formations, special provision should be made for the installation of sub-soil drainage.

With cut to fill construction, the *fill* zone will typically be part of the trafficked road formation and therefore needs to be structurally competent. The *fill* should be spread and *compacted* in layers of uniform quality and thickness, parallel to the *camber* and grade for the full width of the cross-section. The thickness of each layer should be limited to ensure that the specified compaction is achieved for the full depth of each layer.

On steep slopes, fill *batters* formed using cut and bench construction can produce significant areas of exposed soil. Bare earth should be *stabilised* or vegetated immediately after construction to minimise the risk of *rill* erosion. Surface water controls need be established above the slope to direct stormwater *run-off* away from the *fill* to prevent scour and *rill* erosion, and *fill* saturation and slumping. Downstream *sediment* controls should be installed to contain *sediment* generated from the fill *batter* and prevent discharge to a *water body*.

An example of a well-constructed fill *batter* slope, note *flumes* controlling the discharge of stormwater *run-off* and downstream *sediment* retention pond.

Earthworks Construction
1.3 Bulk Earthworks

Construction methods continued

Where and when to use

Cut and bench construction is only effective where the fill *batter* can safely stand (hold) at a slope steeper than the natural ground slope. It is appropriate:

1. On slopes that are too steep for side-cast and/or where side-cast formation is required to support logging traffic (therefore requires *compaction*).
2. On moderate to steep slopes up to 35 degrees. However, the practicable limits may often be less (c.30 degrees) depending on soil characteristics and the fill *batter* slope that can be safely achieved.

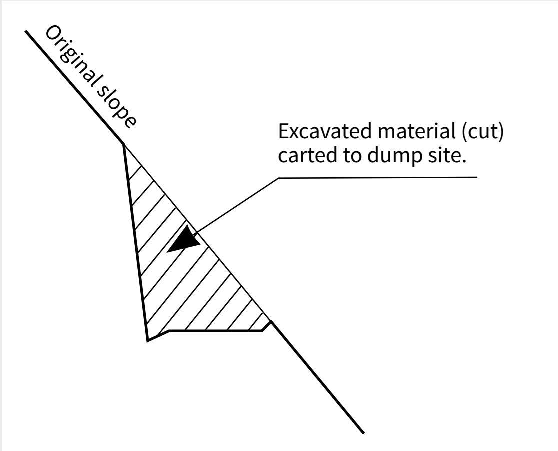
Note: The recommended *fill* slope for most soils is 1:5 H to 1.0 V (33 degrees). Specialist advice should be sought if constructing *fill* slopes greater than this on steep slopes.

3 Partial cut and benched fill and end haul

On steeper slopes, a combination of cut and benched *fill* and end-haul should be considered. This can provide a practical and cost-effective solution for earthworks in steeper terrain. Refer to the sections before and after for detail.

4 Full bench (end haul construction)

Cross section of full bench construction



Full bench construction involves establishing the full road formation width into the hill slope. This is carried out using end-haul construction methods, where cut material (spoil) is carted away to a dump site.

Full bench roads are major engineering works that can generate large volumes of spoil (e.g. a 6-metre-wide formation cut into a 35-degree slope will generate c.15 m^3 of spoil per m).

Full bench construction requires careful planning to optimise road location and volume of material to be cut (refer to FPG EC #1 Planning and Design). *Batter* pegs or flags should be set out at regular intervals to provide the necessary level of construction control.

Earthworks Construction
1.3 Bulk Earthworks

Construction method continued

Cut batter slopes – Large (visible) cut *batters* are a characteristic of full bench road formations. The cut *batter* height will be a function of the hill slope and soil properties (governing steepness of the cut *batter*). The following table provides recommended cut *batter* slopes for different soil types.

Cut batter slopes[1]

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

A knowledge of local geotechnical conditions is important. Materials should be assessed and cut *batters* specified before work commences.

Large cuttings may pass through layers of different soil types with variable soil strength. Cut *batter* slopes should ensure any weak basement layer can support upper layers.

Where cut *batters* exceed 5 m, or the soil profile is variable, specialist advice should be sought.

End haul dump sites – A critical element of full bench construction is establishing a site to safely dispose of the cut material. Disposal areas should be identified during the design and planning phase and indicated on the operational prescription provided to the earthworks contractor. Ideal locations for dump sites include shallow basins and areas of flat to gentle contour that are away from *water bodies*, and for operational efficiency, as close as possible to the work site. Avoid slip zones and visible earthflows, and areas above sensitive receiving environments (*water bodies* or neighbouring property) that could be at risk from *sedimentation*.

Dump sites should be treated as *fill* zones and cleared and stripped of vegetation and logging debris prior to the placement of *fill*. Erosion and *sediment* controls also need to be established to prevent /contain *sedimentation*. The long-term stability of the *fill* must be considered and, where necessary, *fill* should be placed and *compacted* in layers to prevent slumping.

On completion of the operation, the *fill* site should be reinstated by contouring into the natural ground and vegetating.

Haul roads – should be designed, constructed and maintained to support the safe passage of dump trucks for the duration of the construction operation. Where necessary to prevent the generation and transportation of *sediment* haul, roads should be surfaced.

Where and when to use

Full bench (end haul) construction should be used where slopes are too steep to contain *fill* constructed using cut to bench methods and/or where there are unacceptable consequences of a *fill* failure (e.g. slumping and discharge of *sediment* to a *water body* or significant natural area).

Full bench (end haul) construction should be considered for slopes greater than 35 degrees.

1 NZFOA Forest Road Engineering manual (2012), page 68.

Earthworks Construction
1.3 Bulk Earthworks

Drainage control

Water is one of the main enemies of earthworks construction. All earthworks should be carried out in fully drained conditions with no free water on the working surfaces.

Temporary drainage controls should be constructed to direct stormwater away from areas of operation and/or to drain water whenever it is seen to pond. Temporary drainage will frequently include *cut-off* drains to deflect stormwater *run-off*, temporary diversion of natural drainage *(ephemeral flows)* away from the work site, and sloping the cut and *fill* surfaces to prevent ponding and infiltration.

Any materials that have become too wet or soft should be removed and dried or replaced. All *fill* surfaces should be graded and rolled at the end of each day's work to prevent ponding and erosion.

Precaution should also be taken to control stormwater *run-off* from the construction site to ensure *sediment* is not discharged into a sensitive area.

It is considered good policy to leave a low bank *(bund)* on the outside of sidling cuttings. This practice not only provides traffic with additional safety but enables stormwater *run-off* to be led to a suitable discharge position instead of spilling over and causing fill *batter* erosion.

National Environmental Standards for Plantation Forestry

Relevant regulations for earthworks are 25 – 35.

Earthworks Construction
1.3 Bulk Earthworks

Examples

Dozer constructing a pilot roadway.

Example of well constructed road.

The construction of a track or road above the *river* requires careful planning and site management. End haul construction should have been carried out to avoid discharge into the *stream*.

Poor construction practice. The *fill* material has not been contained and has spilled up to 60 m down the slope. End haul construction or a configuration of cut + bench/side cast + endhaul should have been carried out to lessen the amount of spoil.

Earthworks Construction
1.3 Bulk Earthworks

Fill on top of woody debris is unacceptable practice. The *fill* is highly likely to move.

New earthworks formations need to be surfaced to prevent erosion.

Contact

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Earthworks Construction 1.4 Fill Placement and Compaction

The construction of forest roads and *landings* in steep country often requires the construction of embankment *fills*. Poorly *compacted fills* present a slope instability risk and can be prone to slumping and *sediment* generation.

Compaction is an essential earthworks process to ensure that the strength and stability requirements of road or *landing* formations are achieved.

The aim of the *compaction* process is to increase the soils' shear strength, limit future settlement and reduce permeability.

Landing site constructed of a well graded granular *fill* material – note the range of particle sizes.

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Version 2.0, January 2020

Earthworks Construction
1.4 Fill Placement and Compaction

Scope

This guide covers the construction of embankments *fills* and outlines best practice techniques for placing and *compacting fill*. It should be read in conjunction with FPG EC #1 Planning and Design, FPG EC #2 Stripping and Clearing and FPG EC #3 Bulk Earthworks. Users of the guide are also referred to the following reference documents:

- National Environmental Standards for Plantation Forestry (regulations 22-35)
- New Zealand Forest Owners Association – New Zealand Forest Road Engineering Manual (2020)
- NZTA Standard Specification F/1 – Earthworks Construction www.nzta.govt.nz/assets/resources/earthworks-const/docs/earthworks-const.pdf
- Guideline for the Field Classification and Description of Soils and Rock for Engineering Purposes: NZ Geotechnical Society, December 2005 www.nzgs.org/library/field-description-of-soil-and-rock-field-sheet
- NZS 4402.4.1:1986 Methods of testing soils for civil engineering purposes – Part 4 Soil Compaction tests

Fill construction materials

Fill placement and *compaction* methods will depend on the available material and the structural requirements of the *fill*. Distinction needs to be made between cohesive and non-cohesive (granular) *fill* materials.

Cohesive soils – fine grained soils with a high **clay** content where the particles of the soil bond to one another.

A quick and simple way to test whether or not a soil is a clay is to moisten the soil sample and test its pliability with your hands. A clay content is indicated if the moist soil feels sticky and continues to stick to your hands or when rolled into a 'snake-like' form it stays connected without splitting.

Clay content test

Simple test for clay content – soil rolled into a snake by hand holds it form.

Granular soils – are relatively coarse-grained soils, such as **sand** (particle size of 0.06 mm to 2 mm) and **gravels** (particle size between 2 mm and 200 mm), where the particles lie side by side without bonding. Most pumice material will be classified as granular.

Earthworks Construction
1.4 Fill Placement and Compaction

Operational planning and management

The suitability of the in-situ soils should be assessed against the *fill* requirements prior to earthworks commencing. *Fills* should be classified as structural (load bearing) and non-structural (landscape *fill*). The planning process should optimise the use of materials (notably achieve cut to *fill* balance and reduce unnecessary cut to waste) and confirm what soil material is not suitable for bulk *fill*.

Often there will be more than one soil type on a construction site. Consideration will need to be given to how best to manage the range of soil types that may be present. *Fill* design should consider how soils will be mixed (and behave) depending on the site geology and geography and the contractor's construction methodology.

Batter **slope and** ***compaction*** are integral components of embankment *fill* stability. Steeper *batter* slopes require a higher shear strength to maintain stability. **It is important that** ***fills*** **are not over-steepened relative to the soil strength that can be achieved**. *Compaction* needs to be optimised to ensure that the soil strength and *batter* slope stability is achieved.

Fill *batters* should be overfilled to support earthmoving equipment and allow *compaction* plant to compact the full width of the design cross-section and then trimmed back to the design *batter* slope as the *fill* is built up. This will ensure the full width, including the outer edge of the *fill*, is effectively *compacted*.

Batter slope and *compaction* requirements should be provided to the contractor in the project prescription.

Batter slope

Well constructed *fill*. The *batter* slope has been controlled and effective *compaction* achieved. Benches have been constructed to avoid overloading the *fill*.

Earthworks Construction
1.4 Fill Placement and Compaction

Operational planning and management

continued

Fill placement

Fill material should be spread and *compacted* in layers of uniform quality and thickness across the full cross-section for the road/*landing*.

The thickness of each layer shall be limited to ensure that the required level of *compaction* is achieved for the full depth of each layer. The following maximum layer thicknesses are recommended:

Recommended maximum layer thickness

Nominal maximum particle size	Maximum layer thickness
Up to 100 mm	200 mm
100 mm to 200 mm	1.5 times the 85th percentile size
Over 200 mm	Determine on site

The movement of all construction vehicles and other traffic should, where practicable to do so, be evenly distributed over the full width of the *filling* area, so as not to damage or overstress the construction.

Compaction

Compaction of a large embankment *fill* in shallow layers using a pad foot roller.

Compaction processes

Compaction is the process of increasing the density of a soil by packing the particles closer together through the application of external forces. Specialist *compaction* equipment (such as steel drum rollers, pneumatic-tyre rollers, sheep foot or cleated rollers) is necessary. *Compaction* cannot be effectively achieved by tracked machinery as tracks distribute the load over a wider area effectively minimising *compaction*. *Compaction* processes vary for cohesive and granular material.

Cohesive soils

Compaction of cohesive soils is achieved by impact and weight to break down the 'cohesive' bonds to increase the soil density. Kneading *compactors* with high point loads, such as **sheep and pad foot rollers** are required for cohesive soils (see photo overleaf).

The strength of cohesive soils is influenced by moisture content. *Compaction* should be carried out at the optimum moisture content (OMC) to produce a required *compaction* outcome (maximum dry density – MDD). The general rule of thumb is, that if materials are *compacted* at OMC, then the MDD should be achievable.

A rough check for most materials is to squeeze a lump in the hand and, if it just holds together when pressure is taken off and the material does not stick to the fingers, the water content will be approximately at optimum.

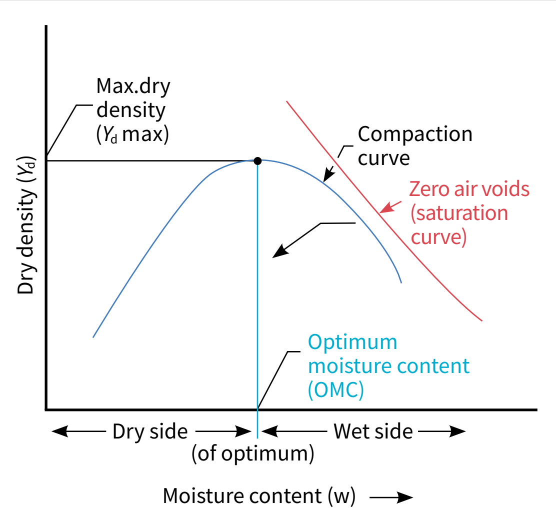
Earthworks Construction
1.4 Fill Placement and Compaction

Compaction processes continued

Notes:

1. If cohesive material is rolled when it is too wet or too dry for efficient *compaction*, the consequences can be high air void and lower short and long term strength. Further rolling is of limited value and may be detrimental to the *fill* stability.
2. Cohesive soils placed in *fills* when drier than optimum moisture content may appear to have good strength but may suffer a marked reduction in strength when wetted at a later date.

Compaction curve



A *compaction* curve showing the relationship between density and moisture and water content.

Site management should consider soil water content and apply any corrections necessary to facilitate soil placement and *compaction* to satisfy the strength and stability requirements of the *fill*. In some materials a significant gain in strength is obtained if the water content is adjusted to be nearer optimum. The feasibility and economics of changing in-situ water content should be considered during the operational planning phase.

Soil compaction machinery

Pad foot roller suitable for *compacting* cohesive soils.

Granular soils

Compaction of granular soils can be carried out with static *compactors* that simply apply weight and tend to *compact* from the bottom of the layer up; vibratory *compactors* that use a mechanical action to consolidate soil particles; impact *compactors* that use a high-amplitude whack to *compact* material.

Granular *fills* are usually suitable for *fill* construction as strength is usually adequate over a range of moisture conditions.

Earthworks Construction
1.4 Fill Placement and Compaction

Compaction testing and field monitoring

The following are recognised methods for testing the quality of *fill* materials and construction. The specific tests and testing frequency should be determined during the planning and design phase and reflect the scale and complexity of the earthworks, and the consequence of the *fill* failing.

Parameter	Test description	Test method
In-situ density	"Rapid"	NZS 4407:1991, Test 4.2.1 (Nuclear Densometer Direct Mode) NZS 4407:1991, Test 4.2.2 (Nuclear Densometer Backscatter Mode)
	"Fully Specified"	NZS 4402:1986, Test 5.1.1, 5.1.2, 5.1.3 (Sand replacement, balloon densometer or core cutter)
MDD & OMC determination	Standard *Compaction*	NZS 4402: 1986, Test 4.1.1
	Heavy *Compaction*	NZS 4402: 1986, Test 4.1.2
Strength	Scala Penetrometer	NZS 4402: 1986, Test 6.5.2
	Pilcon Shear Vane	NZ Geotechnical Society Inc "Guideline for hand held share vane"
	Clegg Impact Test	ASTM D5874-95
Permeability	Laboratory Triaxle Permeability	Based on Head, Vol. 3, 1988, Section 20.4.2
Solid density	Solid Density	NZS 4402: 1986, Test 2.7.1
Moisture content	Moisture Content	NZS 4402:1986, Test 2.1
Particle size distribution	PSD Wet Sieving	NZS 4402:1986, Test 2.1
	Hydrometer	NZS 4402:1986, Test 2.1

The following field testing equipment is considered suitable for *compaction* testing on most forest earthworks projects:

- Scala Pentrometer – strength testing in cohesionless soils. Results are converted into an 'inferred CBR'.
- Shear Vane – strength testing in cohesive soils. The results are expressed in kPa.
- Clegg Impact Test – testing surface hardness or stiffness. The result (impact value) can be used as an indication of *compaction* but is not a direct measurement. Impact values can be converted into an inferred CBR (Inferred CBR = 0.07 x (IV)2).
- Nuclear Densometer – testing of water content and percentage *compaction* (if MDD target is provided).

Earthworks Construction
1.4 Fill Placement and Compaction

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Forest Practice Guide

Non-Regulatory

Erosion and Sediment Control Measures

Forest Practice Guide
Non-Regulatory

Erosion and Sediment Control Measures
2.1 Water Tables

A *water table* is a drain to channel and direct stormwater from cut banks or *berms* along a road or at a *landing* to an appropriate discharge point. A *water table* collects stormwater from across the road surface. This keeps the road subgrade drier, making a stronger road.

Stormwater needs to be regularly discharged from *water tables* to minimise scour. To help reduce scour, *water tables* can be rock armoured. *Sediment* traps and *check dams* can also assist in reducing water speed and its erosive power.

Water tables are one of a family of stormwater control measures that increase the life of a road or *landing* by reducing erosion and maintenance costs. They also reduce the likelihood of *sediment* delivery to *rivers*.

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Version 2.0, January 2020

Erosion and Sediment Control Measures
2.1 Water Tables

A Where and when to use

1. Use *water tables* on all roads and to drain *landings* (where stormwater needs to be diverted away from the *landing*).

B Where not to use

Not applicable for this FPG.

C Design

1. Stormwater needs to be regularly discharged from water tables to reduce quantity and velocity.
2. Ensure the road has adequate cross fall so that stormwater drains off the carriageway into the *water table* drains.

D Construction

1. Construct *water tables* to an adequate depth.
2. Construct the bottom of the *water table* as flat as possible. "V" shaped *water tables* are more prone to erosion as the water is more concentrated.
3. Construct *water table* outlet control measures (i.e. *culverts* and *flumes*) at the same time as the *water tables* to minimise scour.

Rock armouring

4. Consider using rock armouring:
   a. Where the *culvert* or *cut-out* spacing distance is restricted by the terrain.
   b. In steep gradient *water tables* if concentrated water flow and potential *culvert* failure could lead to significant adverse environmental risk and infrastructure failure.
5. Rock armouring is placing larger aggregate (preferably fractured to avoid rolling) in the *water table.* This slows water flow and limits erosion, as the rock protects the *water table* by reducing the energy of the water.
6. Standard road aggregate can be used by applying it to the full width of the road, not just the driving surface.
7. Ensure the aggregate is both large enough and placed deep enough to take stormwater flow. This avoids aggregate being displaced or washed into *culverts* and blocking or partially blocking them.
8. *Compact* the *water table* aggregate, if possible.
9. If standard road aggregate is not suitable for lining the *water table*, use a different aggregate after the subgrade aggregate is applied to the road surface.

Water table with road base course used for rock armouring.

Erosion and Sediment Control Measures
2.1 Water Tables

D Construction continued

Check dams

10. Consider using *check dams* (very small temporary or semi-permanent dams constructed across a *water table*), where *water tables* are prone to erosion, primarily due to water speed with a large volume flow. They may be used in tandem with rock armour.
11. Use larger aggregate or sand bags filled with aggregate.
12. Ensure water goes over the middle of the *check dam* and not around the edges, otherwise this will lead to scour.
13. Do not form *check dams* higher or wider than the *water table* itself.

Water table check dams.

Polymers

14. Polymers can be applied to *water table* drains to lock the soil particles together and therefore prevent drainage water from eroding the *water table* surface. www.rst.co.nz/soil-stabilisers.html or www.vitalindustries.com.au.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Maintain *water tables*. They can require regular maintenance due to cut bank slumping which can disrupt their drainage pathway.
3. Check them after a heavy rain event.
4. Ensure sufficient road drainage *culvert* spacing and cut-outs to control the stormwater *run-off*. If not, either construct additional *culverts* or *cut-outs* to reduce *water table* erosion, or build rock armour *check dams* or apply polymers in areas that drain to highly sensitive receiving areas.

F Other methods

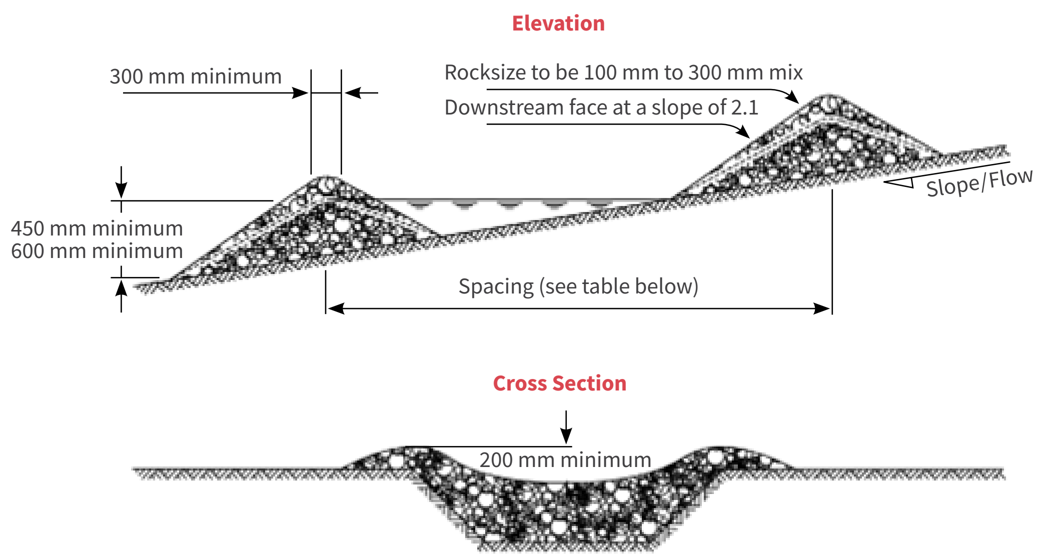
These are complementary measures: *berms*, *cut-outs*, road drainage *culverts* and *flumes*.

Erosion and Sediment Control Measures
2.1 Water Tables

G Technical specification guidelines

1. The lowest point of the *water table* should be below subgrade level, about 500 mm below the crown of the road.
2. *Check dam*:

Rock check dam diagram



Slope	Spacing (m) between dams (450 mm centre height)	Spacing (m) between dams (600 mm centre height)
2% or less	24	30
2% to 4%	12	15
4% to 7%	8	11
7% to 10%	5	6
over 10%	Use stabilised channel	Use stabilised channel

National Environmental Standards for Plantation Forestry

Relevant regulations for *sedimentation* are 26, 27, 31, 33, 56.

Erosion and Sediment Control Measures
2.1 Water Tables

Examples

A *water table* with a high flow of stormwater.

Scoured road edge after the *water table* was blocked by a slump from the cut *batter*.

Erosion and Sediment Control Measures
2.1 Water Tables

Angular rock armoured *water table*.

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Erosion and Sediment Control Measures
2.2 Cut-outs

A *cut-out* (also known as water bar) is a constructed channel that directs stormwater from a track.

Cut-outs are also used to *decommission* roads or tracks after an operation is completed, to control stormwater *run-off*.

They are simple to construct, effective, and easily maintained. They may be used to divert stormwater into stormwater or *sediment* control measures like *flumes* or *sediment* traps.

Cut-outs are one of a family of stormwater control measures that increase the life of the road or track and road *water table* by reducing erosion and maintenance costs. They can also reduce the likelihood of *sediment* delivery to *rivers*.

Effective *cut-out* on harvesting extraction track.

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Erosion and Sediment Control Measures
2.2 Cut-outs

A Where and when to use

1. Use *cut-outs* to direct stormwater:
   a. On all tracks as necessary to control stormwater on the track.
   b. On roads that have been *decommissioned* as necessary to control stormwater.
   c. On low volume roads where road *culverts* have been removed and access is required.

B Where not to use

Not applicable for this FPG.

C Design

1. Consider *cut-out* location as part of road or *landing sediment* and/or stormwater control measures.
2. Where there are highly erodible soils, consider additional measures (e.g. armour the *water table* or *berm*) if *cut-off* spacing is restricted by the terrain.

D Construction

1. Construct sufficient *cut-outs* to reduce the volume and velocity of *run-off* to reduce the erosive power of the water.
2. Locate *cut-outs* where the outlet would not cause additional erosion.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. *Cut-outs* need regular maintenance, especially on new construction.
3. Check critical *cut-outs* to ensure they are functioning after a heavy rain event.

F Other methods

1. *Water tables* and road drainage *culverts*, *flumes* and *berms*.
2. *Cut-outs* also complement *sediment* control measures such as *sediment* traps, soak holes, *sediment* ponds and *slash bunds*.

Erosion and Sediment Control Measures
2.2 Cut-outs

G Technical specification guidelines

The following table is for recommended *culvert* spacing and can be used as a guide for *cut-outs*.

Grade	Soil or rock erodibility – separation distance in metres			
	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

National Environmental Standards for Plantation Forestry

Relevant regulations for *sedimentation* are 26, 27, 31, 33, 56.

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Erosion and Sediment Control Measures
2.3 Berms

Berms are low embankments typically on the outside edge of a road or *landing*. They are constructed to channel stormwater to *culverts* or outlets and act as additional erosion and *sediment* control measures.

Berms are part of a family of stormwater control measures that can increase the life of a road or *landing* and associated *fill* slopes, by reducing erosion.

Low *compacted berm*.

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Erosion and Sediment Control Measures
2.3 Berms

A Where and when to use

1. Use *berms* to direct stormwater:
    a. Away from erosion prone *fill* slopes and old slip faces.
    b. Onto stable ground (this may be via additional stormwater control measures such as *cut-outs* or *flumes*).
    c. To stormwater and *sediment* control measures including *sediment* traps, or *sediment* retention ponds, where necessary.

B Where not to use

1. Most roads do not require *berms*, especially roads constructed though rock or stable material.

C Design

1. Plan *berm* location as part of the overall road or *landing* engineering design. If they are added as an afterthought, they may narrow the carriageway or result in over-steepening the *fill* face.

D Construction

1. Use appropriate equipment. An excavator can *compact* and shape the *berm*.
2. Construct *berms* at the same time as the road/ *landing*.
3. Ensure the outside edge of the road has been *compacted* and the *fill* slope has not been over-steepened. *Fills* that are too steep are more prone to failure if the soil's natural angle of repose has been exceeded. Adding a *berm* will increase the load on the outside road edge and may create an additional risk in highly erodible soils (exceed shear strength).
4. Oversow or hydro-seed *berms* to protect them in sensitive areas, if necessary, to minimise erosion.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Check *berms* are still functioning after a heavy rain event.
3. Do not dump spoil (e.g. road bank slump material) on top of an existing *berm* during maintenance. This can overload the outside edge and cause *fill* failure.
4. If machinery has been driven/sited on the *berm*, repair the damage as soon as practicable.
5. Where practicable, avoid spraying vegetation on the *berm* when pre-plant desiccation spraying.

F Other methods

1. Other construction practices such as water bars or broad-based rolling dips can effectively drain water from the cut slope on the inside of the road to the outside edge. These require the right soil type and careful construction to work effectively and are generally more suited to low-volume roads.

National Environmental Standards for Plantation Forestry

Relevant regulations for *sedimentation* are 26, 27, 31, 33, 56.

Erosion and Sediment Control Measures
2.3 Berms

Examples

Well-*compacted berms* were used to protect a large *fill* slope by directing stormwater away from the more vulnerable earthworks.

Un-*compacted berm*.

Erosion and Sediment Control Measures
2.3 Berms

Berm with hydro-seeding.

This *berm* is too large for the slope and road verge. Material is spilling from it.

Erosion and Sediment Control Measures
2.3 Berms

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Erosion and Sediment Control Measures 2.4 Road Drainage (Stormwater) Culverts

A road drainage *culvert* drains water from a *water table* to the outside of a road. It is often made of corrugated PVC. It is also common practice to construct a *sediment* trap immediately before a *culvert* inlet.

Culverts used to cross *rivers* are described in FPG Crossings series (1–6).

Road drainage *culvert* outlets that drain onto stable non-modified ground require no additional erosion and *sediment* controls, although using *slash* to armour the *culvert* outlet from potential erosion is good practice. Road drainage *culverts* may have additional *sediment* control and stormwater measures down slope of their outlet including *flumes*, *sediment* traps, soak holes or *sediment* retention ponds.

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Erosion and Sediment Control Measures
2.4 Road Drainage (Stormwater) Culverts

A Where and when to use

1. Use road drainage *culverts* to convey stormwater under a road.

B Where not to use

Not applicable to this FPG.

C Design

1. Aim to install a road drainage *culvert* a short distance up gradient and river crossings to minimise stormwater being directly discharged into a *river*.
2. Space and locate road drainage *culverts* correctly. *Culvert* spacing is often determined by topographical requirements as *culvert* outlets are best located on solid ground and not on *fill*. *Culvert* spacing is also dependent on the location of the road, for example a mid-slope road would require more *culverts* than a road on a ridge.
3. Intensity of rainfall should also be taken into account. A greater frequency of *culverts*, deeper *water tables* and larger *culvert* sizes may be required.
4. Use *culverts* of the correct size for the location.

D Construction

1. Provide the contractor with details on the required road drainage *culvert* specifications and location as part of the overall construction specification (prescription).
2. Install to the pipe manufacturer's specifications.
3. Install road drainage *culverts* during road construction and prior to metalling the carriageway.
4. Consider building culvert inlet *bunds* so that water does not bypass the entrance.
5. Consider building *culvert* inlet protection to stop *slash* and debris blocking the *culvert*.
6. Armour *culvert* inlets and outlets if necessary.
7. Construct *culvert* inlets with associated silt traps so they are easy to clean out with an excavator. Make sure the dimensions allow easy bucket access so that the *culvert* mouth does not accidently get damaged when collected *sediment* is removed.
8. *Compact* the *culvert* bed and ensure there are no rocks or objects sharp enough to damage the pipe in the backfill. *Compact* soil around and on top of the pipe.
9. Do not use untreated wood or pine logs on permanent road drainage *culverts*.
10. It is recommended to use a *culvert* marker or scrape a clear identifier in the cut *batter* and GPS their location (to enable them be easily relocated when the road verges are overgrown).

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Road drainage *culverts* need regular maintenance, especially on new construction as the inlets can easily block. Blockage may occur with deposited material or soil that has eroded from a cut slope.
3. Check *culverts* for functionality after heavy rain.
4. Check that the *culvert* spacing is sufficient to adequately drain the stormwater *run-off*. If not, consider constructing additional *culverts*.

F Other methods

1. For low volume roads, other construction practices such as the use of water bars or broad-based rolling dips can effectively move water from the cut bank side of the road to the outside edge.
2. For sensitive receiving environments, use *sediment* and/or stormwater control measures such as rock armouring, *slash* filters, *flumes*, *sediment* traps or soak holes or, if necessary, a combination of these.
3. Consider larger pipes and rock armouring at *culvert* inlets and outlets where *culvert* spacing is wider than ideal due to topographical constraints.

Erosion and Sediment Control Measures
2.4 Road Drainage (Stormwater) Culverts

G Technical specification guidelines

Culvert spacing guide:

Grade	Soil or rock erodibility and distance spacing guide (m)			
	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

1. Use *culverts* of the correct size:
   - 325 mm internal diameter minimum for NES-PF zones green, yellow or orange < 25°
   - 375 mm internal diameter minimum for NES-PF zone red or orange > 25°.
2. Set the *culvert* at a minimum 20 degrees across the road or at the same/similar road grade.
3. Ensure the *culvert* has a minimum 3% cross-fall to reduce the risk of blockage.

National Environmental Standards for Plantation Forestry

Relevant regulations for *sedimentation* are 26, 27, 31, 33, 56.

Erosion and Sediment Control Measures
2.4 Road Drainage (Stormwater) Culverts

Examples

Culvert inlet with *batter* cut back to allow for maintenance.

Erosion and Sediment Control Measures
2.4 Road Drainage (Stormwater) Culverts

Culvert installation

Constructing the inlet.

Digging the trench at an angle to the road.

Bedding in the *culvert*.

Compacting fill around and over the *culvert*.

Erosion and Sediment Control Measures
2.4 Road Drainage (Stormwater) Culverts

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Erosion and Sediment Control Measures
2.5 Flumes

Flumes help to protect *fill* from erosion by conveying stormwater to more stable ground. They can also be used to safely convey *run-off* from the top to the base of a *batter* slope and prevent soil erosion from concentrated stormwater discharges onto exposed soil.

Flumes can also be used to direct water through additional *sediment* and stormwater control measures such as *slash* and *sediment* traps.

Flumes are often made of half round sections of flexible corrugated materials. *Culvert* sock *flumes* are enclosed fabric sock *flumes* – these can also be used where standard *fluming* would not work effectively.

This guide is provided as a reference document and does not constitute a statutory obligation under the Resource Management Act 1991 or the National Environmental Standards for Plantation Forestry.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Erosion and Sediment Control Measures
2.5 Flumes

A Where and when to use

1. Use *flumes* (if necessary), in conjunction with *cut-outs* or *culverts*, to divert water:
   a. Onto stable ground.
   b. Away from *fill* slopes that could erode if water was directly discharged onto them and cause adverse environmental effects.
   c. Into *sediment* and stormwater control measures such as *slash*, *sediment* traps and *sediment* detention ponds, where necessary.

B Where not to use

Not applicable to this FPG.

C Design

1. Use flexible *flume* materials. They are less prone to failure, bend to follow the terrain and decrease the water speed (corrugated iron should not be used).
2. Consider using flexible, full round *flumes* for very windy sites as they can better withstand windy conditions compared to ½ round *flumes*.

D Construction

Plastic pipe flumes

1. Construct the *flume* inlet to not be bypassed by stormwater flow – *flume* inlets are a common failure point.
2. Ensure the *flume* is anchored and well supported to avoid displacement or separation from the *culvert* outlet.
3. Ensure the *flume* is located at a suitable site to construct additional *sediment* retaining controls, if necessary.
4. Consider using technique to slow and disperse concentrated water.

Culvert sock flumes

5. Secure the sock to the *culvert* so that water does not undercut or rip off the sock.
6. Ensure the sock has a minimum slope of 5%. This will stop the sock from infilling with *sediment*.
7. Anchor the sock eyelet and attach it to the ground for its entire length to avoid twisting. Twisting can lead to the sock malfunctioning and the weight of *sediment* and water can pull it off the *culvert*.
8. Consider installing socks upside down, with tie-down points tied up to the holes in steel Y-posts (waratahs), to stop potential rolling in strong wind locations if other installation methods have failed.
9. Where the sock discharges to unstable ground, consider *slash*, rock or half pipe energy dissipation at the sock outlet to reduce the velocity and energy of the discharge.
10. Ensure the sock is located at a suitable site to construct additional *sediment* retaining controls, if necessary.
11. If using an entrance structure, it should be at least twice the height of the *flume* or pipe diameter as measured from the invert.

Flume Baffle.

Erosion and Sediment Control Measures
2.5 Flumes

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. *Flumes* need regular maintenance, especially on new construction.
3. Check *flumes* for functionality after a heavy rain event.
4. Check that the *fluming* has sufficient capacity to control stormwater *run-off*. If not, add additional controls.

F Other methods

1. Complementary structures include *berms*, *water table* drains and *cut-outs*.

National Environmental Standards for Plantation Forestry

Relevant regulations for *sedimentation* are 26, 27, 31, 33, 56.

Erosion and Sediment Control Measures
2.5 Flumes

Example

Full round flexible *flume* best used in exposed, windy locations.

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Forest Practice Guide

Non-Regulatory

Erosion and Sediment Control Measures
2.6 Sediment Traps and Soak Holes

Sediment traps and soak holes are small excavated structures that capture *sediment*-laden water, allow *sediment* to settle and then allow the water to either discharge or drain.

Sediment traps allow for the temporary storage of *sediment* laden water. They allow some of the larger *sediment* particle sizes to settle before the water is discharged.

Soak holes are constructed in porous soils (such as sand and pumice), allowing *sediment* laden water to soak into the soil. *Sediment* traps and soak holes are part of the family of water control techniques that can increase the life of the road, reduce maintenance costs, and mitigate potential *sedimentation* issues.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Erosion and Sediment Control Measures
2.6 Sediment Traps and Soak Holes

A Where and when to use

1. Use *sediment* traps and soak holes:
   a. To help capture mobile *sediment*.
   b. To limit the risk of *sediment* entering sensitive sites such as *water bodies* or significant natural areas.
   c. In conjunction with other water control measures, where necessary, such as at the inlet or outlet of road drainage *culverts*, *cut-outs* or *flumes*.

B Where not to use

1. Where the site doesn't allow for suitable construction. For example, in a fill *batter* or where they increase the risk of bank collapse.
2. Where the site is located within land area occupied by flood flows of *rivers*.

   Note: On steep terrain adequately sized *cut-outs* are difficult to construct near *culvert* mouths as they may encroach into the roadway.

C Design

1. Sediment traps and soak holes are located to suit the terrain.

D Construction

1. Construct *sediment* traps near *culvert* inlets and outlets and immediately after the water is directed a road, track, or *landing*, as necessary.
2. Excavate the trap to well below the *culvert* inlet level, to ensure maximum stormwater *sediment* retention capacity for the trap.
3. Do not construct in *fill* or disturbed soil. If the inflow or outflow must pass through *fill*, then *flume* the water into or out of the *sediment* trap.
4. Excavate a hole of sufficient size to allow for an excavator bucket to remove the retained *sediment*.
5. Keep the slope of the inlet into the soak hole reasonably flat, to avoid erosion.
6. Ensure the outflow is on erosion resistant soil. *Slash* or long grass can assist with *sediment* retention from the outflow.
7. Construct soak holes in free draining soils (e.g. pumice, sand or non-cohesive ash) and immediately after the water is directed off a road or *landing*.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Check *sediment* traps for functionality after a heavy rain event. They require regular maintenance, especially on new construction.
3. Check that spacing of *sediment* traps and soak holes is sufficient to manage the stormwater *run-off*.
4. When emptying a *sediment* trap, take care not to damage the *culvert* (where present).
5. When cleaning out a *sediment* trap or soak hole, place the *sediment* where it cannot wash back into the structure, be subjected to erosion or enter a sensitive area.

F Other methods

1. Sediment pond.
2. Slash can also be used downslope of sediment trap outlets.

Erosion and Sediment Control Measures
2.6 Sediment Traps and Soak Holes

G Technical specification guidelines

Soak hole spacing guide

Site slope	Soak hole spacing
Less than 12%	40 m
More than 12%	30 m down to 10 m

1. Effective sediment trap size: 1 m deep x 1.5 m long and to at least the bucket width. A good length to width ratio is 3:1, but this is not always practical at *culvert* inlets due to topographical constraints and safety concerns. Multiple small traps may be an alternative option.

National Environmental Standards for Plantation Forestry

Relevant regulations for *sedimentation* are 26, 27, 31, 33, 56.

Erosion and Sediment Control Measures
2.6 Sediment Traps and Soak Holes

Examples

Sediment retained in a *sediment* trap.

Sediment traps on either side of a *culvert*.

Erosion and Sediment Control Measures
2.6 Sediment Traps and Soak Holes

A good example of a *sediment* trap with minimal ground disturbance and provision of an outlet.

Soak hole.

Erosion and Sediment Control Measures
2.6 Sediment Traps and Soak Holes

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Erosion and Sediment Control Measures
2.7 Silt Fences

Silt fences are designed to intercept sheet flow *sediment* laden stormwater *run-off* and filter out both the larger and smaller particles of *sediment*. Silt fences and the larger "super" silt fences are a short-term solution to reduce *sediment* movement until the site stabilises and vegetation re-establishes. Silt fences can be used in conjunction with other *sediment* treatment measures such as *sediment* traps or ponds.

Only use silt fences to intercept sheet flow water or in conjunction with soak holes. Silt fences should not be used in *stream* channels, gullies or *water table* drains (due to concentrated flows).

Silt fences are usually made from geotechnical fabric, but at times shade cloth can also be used to allow water to pass through it while filtering larger particle sizes.

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Erosion and Sediment Control Measures
2.7 Silt Fences

A Where and when to use

1. To reduce the risk of *sediment* entrained in sheet flow from entering sensitive sites such *water bodies*.
2. In conjunction with *sediment* traps and *sediment* ponds and *cut-outs* and *flumes*.
3. On low gradient sites or for confined areas where the contributing area is small and *sediment* can be contained by the fence.

B Where not to use

1. As a velocity check in *water tables* or in any other concentrated flow paths to capture *sediment* or reduce water flow velocity, as they are likely to fail in these situations.

C Design

1. Plan the location of silt fences to be constructed where they will not be overwhelmed by large flows (generally receiving less than 0.5 ha). Stormwater flow from large *catchments* may cause them to fill too rapidly, for water to bypass around them, or cause them to fail.

D Construction

1. Select the correct fabric for the silt fence. Silt fence fabric is a close weave and intended to capture fine *sediment*. Shade cloth and open weave fabrics will trap larger *sediment* grain sizes, but not fine *sediment*, and are suitable in some geologies.
2. Install the fence along the contour. If this is not possible, or where there are long sections of silt fence, install short silt fence returns projecting upslope from the silt fence, to minimise concentration of flow.
3. Construct silt fence wings at either end to contain *sediment* where there is a risk of it going around the sides.
4. Use longer 'super' silt fences for larger areas (e.g. *catchments* greater than 0.5 ha).

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Check silt fences regularly and after any moderate rainfall especially on new construction sites. They need regular maintenance because they can fill rapidly on very erodible soil sites.
3. Check that the silt fence is working correctly and is sized to the site. If not, enlarge if possible, or re-direct some of the flow to another stormwater control measure.
4. When cleaning the fence, remove *sediment* to a safe location where it cannot wash back into the fence, enter a sensitive area or be subject to further erosion.

F Other methods

1. Use in conjunction with *sediment* traps and soak holes, and *sediment* retention ponds.
2. Consider using other vegetative *stabilisation* methods (e.g. hydro-seed, grassing, logging *slash*) in conjunction with silt fences.

Erosion and Sediment Control Measures
2.7 Silt Fences

G Technical specification guidelines

1. Silt fence returns should be a minimum of 2 m in length and can incorporate a tie-back if required. Continue the silt fence around the return and double back to eliminate joins.
2. Use support posts or Y-post (waratah or similar) steel standards at a maximum 2 m apart unless tensioned wire (2.5 mm HT along the top of the silt fence) is used between posts top and bottom. If tensioned, the distance can be widened to 4 m.
3. Double the silt fence fabric over and fasten to the wire and posts with wire ties or cloth fastening clips at 150 mm spacing.
4. Join lengths of fabric by doubling over fabric ends around a wooden post or batten or by stapling the fabric ends to a batten and butting the battens together.
5. Maximum slope lengths, spacing of returns and angles for silt fences are:

Silt fence design criteria

Slope steepness %	Max slope length (m)	Spacing of returns (m)	Max silt fence length (m)
Flatter than 2%	Unlimited	N/A	Unlimited
2 – 10%	40	60	300
10 – 20%	30	50	230
20 – 33%	20	40	150
33 – 50%	15	30	75
Over 50%	6	20	40

6. Excavate a trench at least 100 mm wide and 200 mm deep along the proposed line of the silt fence.
7. Install the support posts (tanalised timber a minimum of 50 mm square, or waratahs at least 1.5 m in length) on the downslope edge of the trench. Drive in until solid, at least 400 mm deep.
8. Tie silt fence fabric on the upslope side of the support posts to the full depth of the trench.
9. Silt fence height should not exceed 300 – 400 mm above ground level.
10. Backfill the trench with *compacted fill*.
11. Use angled waratahs at the end of the silt fence to tension wires.
12. Reinforce and tension the top of the silt fence with a 2.5 mm support wire.
13. Double the silt fence fabric over and fasten to the wire and posts with wire ties or cloth fastening clips at 150 mm spacing.
14. Where ends of silt fence fabric come together, ensure they are overlapped, folded and stapled to prevent *sediment* bypass.
15. Construct extra tie-backs, on the upward side, where water may pond behind the silt fence.

National Environmental Standards for Plantation Forestry

Relevant regulations for *sedimentation* are 26, 27, 31, 33, 56.

Erosion and Sediment Control Measures
2.7 Silt Fences

Examples

Sediment trapped by a silt fence.

Silt fence in the wrong location – a *river* bed.

Erosion and Sediment Control Measures
2.7 Silt Fences

Poorly constructed silt fence.

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Erosion and Sediment Control Measures 2.8 Sediment Retention Ponds

Sediment retention ponds allow coarse to moderately fine particles to settle out of water before it is discharged. They are used in situations to minimise the discharge of *sediment* laden stormwater into highly sensitive receiving environments. These controls are used when other methods of control are inadequate for the site.

Sediment retention ponds can hold high volumes of *sediment* laden water. The outlet is generally at the opposite end to the inlet. *Sediment* retention ponds are not effective where *colloidal clay particles* are in suspension and in a concentrated flow. Decanting earth ponds are a retention pond variant that uses an inverted syphon pipe in the pond centre as an outlet.

Version 2.0, January 2020

Erosion and Sediment Control Measures
2.8 Sediment Retention Ponds

A Where and when to use

1. Where *sediment* has a very high risk of entering sensitive sites and causing significant adverse effects.
2. To help limit the movement of highly mobile *sediment*.

B Where not to use

1. If the site does not have sufficient construction area to size them properly, as they can be significant structures.
2. In *fill* – large volumes of water are involved which creates high static pressure that could cause *fill* to saturate and fail.
3. Within the active flood plain of *rivers.*

C Design

1. Seek advice from a forest engineer or specialist to determine sizing and design flow capacity, to ensure the risk of failure is minimised.
2. Design the structure to fit the terrain.
3. Consider potential hazards from large ponds to personnel and machinery.
4. The length to width ratio should be at least 3:1 to extend the flow path from the inlet to the outlet and provide time for *sediment* to settle out from the stormwater.

D Construction

1. Excavate in cut earth rather than in *fill* or disturbed soil. If the inflow or outflow has to pass through *fill*, then *flume* the water into or out of the structure.
2. Keep the slope of the inlet/outlet reasonably flat to avoid erosion. Otherwise form a rock armoured spillway or *flume*.
3. Ensure outflow is on stable ground. *Slash* or long grass can assist with *sediment* retention.
4. Note: concentrating water into a retention pond, rather than dispersing it, can create risk of failure. The consequences of failure can be significant.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Check *sediment* ponds for structural integrity and capacity as part of any heavy rain or post-storm event road maintenance assessment. They need regular maintenance, especially on new construction.
3. Check that the structure is appropriately sized with a sufficient safety factor to control the stormwater *run-off*. Alternatively, re-direct some of the flow to another stormwater control measure.

F Other methods

1. *Slash* can be used downslope of *sediment* retention pond outlets.
2. Stormwater control measures, such as road drainage *culverts*, *cut-outs* and *flumes*.
3. Silt fences can also be incorporated.

National Environmental Standards for Plantation Forestry

Relevant regulations for *sedimentation* are 26, 27, 31, 33, 56.

Erosion and Sediment Control Measures
2.8 Sediment Retention Ponds

Examples

Sediment retention pond draining a *landing*.

Stable outlet.

Poorly sited (in *fill*) and designed/constructed *sediment* retention pond.

Erosion and Sediment Control Measures
2.8 Sediment Retention Ponds

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Forest Practice Guide
Non-Regulatory

Crossings

Forest Practice Guide

Non-Regulatory

Crossings
3.1 Battery Culvert River Crossings

Battery *culverts* are a series of pipe or box *culverts* installed alongside each other to form a low profile crossing. The *river's* base flow passes through the *culverts*, but during flood events, water flows over the top of the crossing. This allows for the dry passage of vehicles in base flow conditions but may result in the road occasionally being closed to vehicles for short periods during flood flow. Battery *culverts* need careful planning and installation to prevent failure.

Fit for purpose battery *culvert*.

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Crossings
3.1 Battery Culvert River Crossings

A Where and when to use

1. Where fording the bed of a *river* would generate fine *sediment*.
2. Where there will be more than 20 axle crossings per day.
3. Where the installation of a single *culvert* to carry the full design flood flow is impractical.
4. Where a bridge is too expensive or has other design challenges.

B Where not to use

1. In *river* reaches that are susceptible to high rates of bed load movement, as this can result in blocked *culvert* pipes.
2. In high gradient, high energy *rivers* or *river* beds that are mobile and unconsolidated.
3. In reaches of *rivers* with large mobile boulders of a similar size to the *culvert* pipe diameters as these boulders can become lodged inside the *culvert* pipes, resulting in blockages.

C 4. Design

1. To reduce scour of the approaches, locate the crossing on a straight section of *river*, if possible.
2. Ensure the approaches are perpendicular to the *river*, so that water does not get directed to either end of the structure.
3. Ensure carriageway height is above base to moderate flows, to limit crossing closure.
4. Ensure approaches have suitable gradient and transitions so that vehicles are not grounded, especially low loader transporters.
5. Design to resist hydraulic pressure and erosion effects during flood flow conditions or debris flows. This may require reinforced aprons or deeply set rip rap on the outflow of the crossing.
6. Design to resist damage or blockage from woody debris. This may require the design of flared or chamfered *culvert* inlets or *slash* deflectors.
7. Ensure upstream and downstream passage of fish is maintained except where approved by a relevant fisheries manager (e.g. to protect populations of upland native galaxids from predation by introduced fish species such as trout).
8. Avoid locations that alter the natural course and gradient of the *river* channel or create erosion of the banks and bed of the *river*.
9. Determine the correct type and size of *culvert* pipes for the structure. Calculate the flood design and use engineering formulae to determine the required *culvert* size (refer to Schedule 2 of the NES-PF for design flood flow calculators and or https://stream-explorer.niwa.co.nz). In higher risk situations, consult with a forest engineer, hydrologist or other specialist to help with design and construction if necessary. Given the costs and risks involved, it is recommended that flood design calculations are peer reviewed.
   a. Reinforced concrete pipes have very good hydraulic characteristics as they are smooth and have a high load bearing capacity – but they may create a barrier to fish passage.
   b. Use existing structures, where present, as a tool to gauge the *culvert* pipe size against that derived from the flow calculations.
   c. Ensure the contributing *catchment* area and average annual flow are considered.

Crossings
3.1 Battery Culvert River Crossings

D Construction

Ensure the installation specifications and procedures are followed.

1. Construct in suitable weather and with low base water flow.
2. Check for any fish spawning timing constraints under the NES-PF.
3. Limit earthwork disturbance to the immediate construction site, which will include an area upstream and downstream of the crossing.
4. Minimise the need for machinery to operate in flowing water.
5. Wet or curing concrete must not be in contact with flowing water. Cement is a contaminant and is toxic to invertebrates and fish. When pouring concrete, the water channel will need to be temporarily diverted.
6. Elevated *sediment* discharge levels will occur during construction, but must not occur for more than eight consecutive hours.
7. Divert water flow around the construction site to assist in the foundation work, reduce the risk of contaminants entering water, and minimise discharge of *sediment*.
8. Excavate the crossing bed, as required, to the correct depth and grade.
9. Ensure one of the *culverts* is at least 100 mm below *river* bed level and located to carry low or base flow. This will allow for fish passage.
10. Take care not to damage the *culverts* during installation. Concrete pipes are heavy, hard to place into position and need heavy equipment to transport, load, unload, and position them.
11. Bed *culverts* so they lie flat and are supported on a firm or concrete base.
12. Ensure *culvert* pipes lie at or below the natural *stream* gradient, otherwise they may create plunge pool erosion in the bed of the watercourse at the outfall of the *culverts*.
13. *Stabilise* the banks upstream of the structure inlet, if necessary, to prevent bank erosion.
14. Protect the inlet and outlet of the structure. Armour outlets with concrete aprons, rip rap, *reno mattress*, or other energy dissipating structures. Inlets are best protected by having deflectors that force most woody debris up and over the structure.
15. Limit *sedimentation* entering the crossing from the approaches by:
    a. Diverting road surface water off the approaches, as close as practicable to the structure, and ideally within 10 m. To limit *sediment* entry into the *river* use stormwater and *sediment* control measures such as *berms*, *cut-outs*, *water table* drains and *culverts*, *flumes* and *sediment* traps. Build these above the annual flood flow level.
    b. Avoiding long steep road approaches as these are ongoing sources of *sediment*.
    c. Using clean gravel on approaches where the existing road surface could create a *sedimentation* problem.
16. Check regularly during and on completion of construction. If the work does not meet the design plan and standards then initiate corrective actions.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Check new structures after a flood flow. Initially they can require regular maintenance especially to the headwall, *batters* and outlet. Fix any issues promptly.

F Other methods

1. Fords, drift decks or bridges are alternate structures (note NES-PF truck movement limitation for fords).

National Environmental Standards for Plantation Forestry

Particular relevant provisions for crossings are Regulations 38 – 49.

Refer also to the Department of Conservation **Fish Passage Guidelines**: https://www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/nz-fish-passage-guidelines/

Crossings
3.1 Battery Culvert River Crossings

Example

Battery *culverts* must provide for the *river's* base flow, with at least one pipe buried 100 mm into the *river* bed. Note the side wall overflow protection works.

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Forest Practice Guide

Non-Regulatory

Crossings
3.2 Drift Deck River Crossings

Drift decks are *river* crossing structures designed for flood water to overtop the structure carriageway. They can be a series of open bottomed inverted “U” precast concrete components, or a series of rectangular concrete box segments. Each box segment is secured to the adjacent box segment for the length of the structure. Those with an open bottom typically need a concrete base or piers for support and as an anchor. Alternatively, cast in-situ piers with precast concrete bridging slabs may be employed.

The design may allow for the open bottom and concrete bridging slabs to be removed for use at a different site. When the crossing is no longer required, the slabs can be lifted from the *river* bed and re-used elsewhere, leaving the piers in place for the next harvest rotation.

A well-constructed drift deck.

Please refer to the ‘how to use’ section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Crossings
3.2 Drift Deck River Crossings

A Where and when to use

1. Where a ford may generate fine *sediment*, where there will be more than 20 axle crossings per day, where a single *culvert* to carry the full design flood flow is impractical, or where a bridge is too expensive or has other design challenges.
2. Drift decks can accommodate significantly larger flows than battery *culverts* due to their shape, and do not obstruct fish passage. They are a cost-effective alternative to a battery *culvert*.
3. Can be used over the top of an existing concrete ford, to ensure intensive traffic use can occur without impacting on water quality.

B Where not to use

Not applicable for this FPG.

C Design

1. To reduce scour of the approaches, locate the crossing on a straight section of a *river*, if possible.
2. Ensure the approaches are perpendicular to the *river* to avoid water being directed to either end of the structure.
3. Ensure the carriageway height is above base to moderate flows to pass through the deck, to limit crossing closure.
4. Ensure the approaches have suitable gradient and transitions so that vehicles are not grounded, especially low loader transporters.
5. Determine the correct type and size of the drift deck sections for the site.
6. Calculate the flood design and use engineering formulae to determine the required *culvert* size (refer to Schedule 2 of the NES-PF for design flood flow calculators and or https://stream-explorer.niwa.co.nz). Consult with a forest engineer, hydrologist or other specialist to help with design and construction, if necessary. Given the costs and risks involved, it is recommended that flood design calculations are peer reviewed.
7. A building consent will be required if the height of the structure is greater than 1.5 m above the *river* bed.

D Construction

1. Ensure any installation specifications and procedures are followed.
2. Construct in suitable weather and in low water flow.
3. Check for any fish spawning timing constraints under the NES-PF.
4. Limit earthwork disturbance to the immediate construction site, which will include an area upstream and downstream of the crossing site.
5. Minimise the need for machinery to operate in flowing water.
6. Wet or curing concrete must not be in contact with flowing water. Cement is a contaminant and is toxic to invertebrates and fish. When pouring concrete, the water channel will need to be temporarily diverted.
7. Divert water flow around where the piers are to be constructed, if these are used. This is essential for the foundation work to reduce the risk of contaminants entering water and to minimise discharge of *sediment*. Elevated *sediment* discharge levels will occur during construction, but must not occur for more than eight consecutive hours.
8. Protect the drift deck inlets and outlets. Inlets are more challenging to protect from large woody debris as this cannot be deflected as easily as for a battery *culvert*. Where necessary, armour outlets with rip rap, *reno mattress*, or other energy dissipating structures.
9. Limit *sedimentation* entering the *river* from the approaches by:
    a. Diverting road surface water from the drift deck approaches, as close as practicable to the structure, and ideally within 10 m. To limit *sediment* entry into the *river* use stormwater and *sediment* control measures such as *berms*, *cut-outs*, water table drains and *culverts*, *flumes* and *sediment* traps. Build these above the annual flood flow level.
    b. Avoiding long steep road approaches, as these are ongoing sources of *sediment*.
    c. Using clean gravel on approaches where the existing road surface could create a *sedimentation* problem.

Crossings
3.2 Drift Deck River Crossings

D Construction continued

Open bottomed structures

10. Construct on a suitable foundation slab or piers.
11. Construct level bearing pads at locations to match the drift deck unit's size.
12. Check regularly during and on completion of construction. If the work does not meet the design plan and standards then initiate corrective actions.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Check drift decks after a heavy rain event or flood flows as they can require regular maintenance, especially to inlets and outlets. Fix any issues promptly.

F Other methods

1. Bridges are alternative measures.

G Technical specification guidelines

1. Use dowel condition techniques as specified – drill holes at each joint location, align drift deck units at the correct centres, insert dowels, then grout.
2. Join the sections (Hynds have a proprietary attachment system).
3. Complete the deck by fixing timber kerbing.

National Environmental Standards for Plantation Forestry

Particular relevant provisions for crossings are Regulations 38 – 49.

Refer also to the Department of Conservation **Fish Passage Guidelines**: https://www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/nz-fish-passage-guidelines/

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Crossings
3.3 Ford Crossings

Fords are generally used on low volume roads to cross broad, shallow *rivers* and where alternative *river* crossings are not feasible. This makes it easy for the road grade to be brought down to the level of the *river* bed. Fords can be natural *river* beds or can have a concrete pad to assist with vehicle traction and to reduce *sedimentation* from vehicle passes.

The use of fords can create significantly more *sedimentation* than other forms of *river* crossings.

Clean ford with minimal *sediment* running down road into *stream*.

Version 2.0, January 2020

Crossings
3.3 Ford Crossings

A Where and when to use

1. Where traffic volume is light or traffic will be for a short duration (e.g. a small woodlot harvest with a very low productivity contractor – essentially only one truck and trailer per day).
2. Where crossings are broad, the water is shallow or intermittent, and the *river* bed is stable and shingle or rock.
3. As a secondary crossing point where bridges cannot provide access for heavy and large forestry machinery (e.g. haulers or construction machinery) due to weight or width restrictions.

B Where not to use

1. When there will be more than 20 axle crossings per day.

C Design

1. Decide on whether to use the natural *river* bed or to construct a concrete pad crossing. Factors to consider include *river* bed substrate, volume of traffic movement, acceptable risk of road closure, and downstream impact of *sediment* generation.
2. To reduce scour of the approaches, locate the crossing on a straight section of *river*, if possible.
3. Try to avoid locations that alter the natural course and gradient of the *river* or create erosion of the banks and bed of the *river*.
4. Identify suitable water depth and *river* bed substrate.
5. Ensure approaches have suitable gradient and transitions so that vehicles are not grounded, especially low loader transporters.
6. Consult with a forest engineer, hydrologist or other specialist to help with design and construction, if necessary.

D Construction

1. Construct in suitable weather and with low base water flows.
2. Check for any fish spawning timing constraints under the NES-PF.
3. Limit earthwork disturbance to the immediate construction site.
4. Minimise the need for machinery to operate in flowing water.
5. Limit *sedimentation* entering the ford from the approaches. Stormwater *run-off* from wheels is a major source of *sediment* generation.
   a. Divert road surface water off the approaches, as close as practicable to the crossing, and ideally within 10 m. To limit *sediment* entry into the *river*, use stormwater and *sediment* control measures such as *berms*, *cut-outs*, *water table* drains and *culverts*, *flumes* and *sediment* traps. Build these above the annual flood flow level.
   b. Avoid long steep road approaches, as these are ongoing sources of *sediment*.
   c. Use clean gravel on approaches where the existing road surface would create a *sedimentation* problem.
6. Ensure fish passage is not impeded.
7. Divert the *river* during construction to assist in the foundation work, reduce the risk of contaminants entering water, and to minimise discharge of *sediment*.
8. Armour the leading edges of the ford with aprons. This will reduce erosion under the structure.
9. Check regularly during and on completion of construction. If the work does not meet the design plan and standards then initiate corrective actions.

Crossings
3.3 Ford Crossings

D Construction continued

Additional factors for natural river bed crossings

10. Locate where the *river* bed is hard and stable. Avoid soft substrates as these generate *sediment* and may be difficult to strengthen or provide access for some vehicles.
11. Use clean rock *fill* where the carriageway requires strengthening on the *river* bed. Use graded rock that is large enough to resist displacement by the flow of water. Fill the voids with clean, small rocks or gravel to provide a better driving surface.

Additional factors for concrete pad crossings

12. Build a concrete pad only on stable and low gradient sites.
13. Design for flood flows. *Rivers* are prone to bed shifting. If water gets under the pad it can be undermined and displaced.
14. Divert the *river* during construction to assist in the foundation work, reduce the risk of contaminants entering water, and minimise discharge of *sediment*.
15. Armour the leading edges of the ford with aprons. This will reduce erosion under the structure.
16. Construct so that the pad extends well beyond the extent of the *river* channel occupied by medium flow events. This will help reduce entry and exit erosion at the transition from the concrete pad to gravel, and further reduce *sedimentation* from the wet area generated by vehicle wheels displacing water when exiting the crossing.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Check ford crossings after heavy rain or a flood flow event. Fords can create serious safety issues if the *river* bed has shifted, or there is *river* bed erosion affecting a concrete structure.
3. Natural bed crossings are likely to need maintenance after most flood events.

F Other methods

1. Consider converting a ford to a drift deck, battery *culvert* or bridge crossing when traffic volumes increase at harvest. This will create a better structure and help reduce *sedimentation*.

National Environmental Standards for Plantation Forestry

Relevant regulations for fords are 37 – 49 and 97.

Refer also to the Department of Conservation **Fish Passage Guidelines:** https://www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/nz-fish-passage-guidelines/

Crossings
3.3 Ford Crossings

Examples

An example of a concrete pad crossing which will minimise *sediment* mobilisation caused by vehicle crossings.

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Forest Practice Guide
Non-Regulatory

Crossings
3.4 Single Culvert River Crossings

Single *culvert* crossings are the most common structure used to cross small to medium sized *rivers*.

Culverts are relatively easy to install and low cost compared to other crossing structures. Designed, constructed and maintained correctly they will endure, but careful planning and installation is required to prevent failure and ensure fish passage.

Culvert pipes can be smooth or corrugated and can be made from a wide range of materials – plastic, concrete, galvanised steel or aluminium.

Culvert installation.

This guide is provided as a reference document and does not constitute a statutory obligation under the Resource Management Act 1991 or the National Environmental Standards for Plantation Forestry.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Crossings
3.4 Single Culvert River Crossings

A Where and when to use

1. To cross small to medium sized *rivers*.
2. Where there is a low gravel movement that could infill the *culvert*.
3. Where there are greater than low volumes of traffic (e.g. greater than 20 axle movements per day).

B Where not to use

1. A resource consent would be needed where the *culvert* is:
   a. within 500 m of a dwelling that is within 15 m of a *river* bed greater than 3 m wide, or
   b. downstream of a dwelling with a ground floor level that is less than 1 m above the highest part of the *culvert* crossing.

C Design

1. Consider geology, soil type, topography, rainfall, storm events, and traffic usage in the design.
2. Consider whether there are other downstream values in the *catchment* that could be affected by a *culvert* crossing (e.g. infrastructure and dwellings).
3. To reduce scour of the approaches, locate the crossing on a straight section of *river*, if possible.
4. Try to avoid locations that alter the natural course and gradient of the *river* or create erosion of the banks and bed of the *river*.
5. Design to not cause flooding or ponding to any other property or impact on other existing structures.
6. Design the *culvert* to convey a one in 20 year flood flow event (5% *AEP*) without *heading up*. Calculate the flood design and use engineering formulae to determine the required *culvert* size (refer to Schedule 2 of the NES-PF for flood design flow calculators and/or https://stream-explorer.niwa.co.nz). In higher risk situations, consult with a forest engineer, hydrologist or other specialist to help with design and construction if necessary. Given the costs and risks involved for large *culverts*, or *culverts* higher than 3.5 m (measured up from the bed of the *river* at the inlet – including the pipe and *fill*), it is recommended that flood design calculations are peer reviewed.
   a. Reinforced concrete pipes have very good hydraulic characteristics, as they are smooth, and have a high load bearing capacity – but they may create a barrier to fish passage.
   b. Use existing structures, where present, as a tool to gauge the *culvert* pipe size against that derived from the flow calculations.
   c. Ensure the contributing *catchment* area and average annual flow are considered.
7. Consider designing armoured spillways where *culverts* may be at risk of overtopping.
8. Design for upstream and downstream passage of fish.
9. The minimum diameter for a single *culvert river* crossing is 450 mm.
10. Ensure sufficient *culvert* length. If the *culvert* is too short the *batter* slopes are over-steepened. This can lead to the *fill* slope slumping and the discharge of *sediment* into the *river*.

Crossings
3.4 Single Culvert River Crossings

D Construction

1. Ensure any installation specifications and procedures are followed.
2. Construct in suitable weather and with low *river* flow.
3. Check for any fish spawning timing constraints under the NES-PF.
4. Limit earthwork disturbance to the immediate work site, which will include an area upstream and downstream of the crossing site.
5. Minimise the need for machinery to operate in flowing water.
6. Divert the *river* around the *culvert* trench temporarily to make sure the *culvert* foundation is properly prepared, to reduce the risk of contaminants entering water and minimise discharge of *sediment*.
7. Construct the *culvert* trench or bed at the correct depth and grade so that when constructed both the inlet and outlet are 20% below *river* bed level. This will allow for fish passage.
8. Bed the *culvert* in so that it lies flat and is supported on the firm base of the trench.
9. Take care not to damage the *culvert* during installation. Some *culvert* materials are more prone to damage than others.
10. Backfill, using clean *fill* with no organic matter, and *compact* around the pipe to eliminate water bypassing the *culvert*, and resulting in it scouring out.
11. *Compact* the *fill* in layers to strengthen and stabilise the *fill*.
12. Wet or curing concrete must not be in contact with flowing water. Cement is a contaminant and is toxic to invertebrates and fish. When pouring concrete, the water channel will need to be temporarily diverted.
13. If necessary, protect the inlet headwall and outlet. Armour if necessary. Use rip rap, *reno mattress*, durable logs, *gabions*, wing walls or energy dissipating structures.
14. Do not use tyres, untreated wood or logs to construct the headwalls of the structure.
15. Where practicable, divert road surface water away from *culvert fill*.
16. Use stormwater and *sediment* control measures to limit *sediment* entry into the *river* (e.g. *berms*, *cut-outs*, *water table* drains, *flumes* and *sediment* traps).
17. Check regularly during and on completion of construction. If the work does not meet the design plan and standards then initiate corrective actions.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Check *culverts* after a heavy rain or a flood event. They may require regular maintenance especially to the headwall, *batters* and outlet, and maintenance of fish passage.
3. *Culvert* pipe inverts (the base of the pipe) and headwall and/or outlets wear out over time. They erode through debris and bed load abrasion or from water chemistry, especially corrugated steel. Re-strengthen steel and concrete bottoms. This often requires specialist engineering assistance.
4. Consider fish passage retrofits if necessary for fish passage.

Crossings
3.4 Single Culvert River Crossings

F Other methods

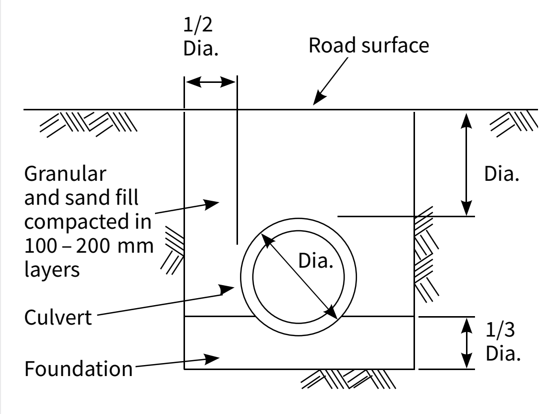
1. Box *culverts* can accommodate significantly larger flows than cylindrical corrugated pipe alternatives. Another advantage is the minimal excavation and backfilling required. Box *culverts* can also be designed to carry heavy wheel loadings with little or no *fill* material placed over the *culvert* to distribute the load.

Box culvert

Refer also to the Department of Conservation **Fish Passage Guidelines:** https://www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/nz-fish-passage-guidelines/

G Technical specification guidelines

Culvert installation practices/recommendations[1]



1. Construct a spillway/secondary flow path if required:
   a. Establish the low point at one end of the crossing.
   b. Build an armoured flow path using rock or engineered structures such as *reno mattress*.
   c. Construct a spillway on undisturbed ground adjacent to the structure to accommodate exceptional flood flow events.
2. For fish passage re-instatement, spat rope or fish ladder options can be used:
   a. Use spat ropes for native fish passage in *culverts* less than 1 m internal diameter.
   b. Use at least two spat ropes.
   c. Anchor ropes to shackles attached to waratah sections upstream of the *culvert*.
   d. Drive anchors below *river* bed level or on the *river* banks.
   e. Seek specialist assistance and view online resources.

National Environmental Standards for Plantation Forestry

Particular relevant provisions for crossings are Regulations 38 – 49.

1 From the Forest Roading Manual page 115. http://www.nzfoa.org.nz/resources/file-libraries-resources/transport-and-roading/484-nz-forest-road-engineering-manual-2012/file

Crossings
3.4 Single Culvert River Crossings

Examples

A well sited *culvert*, with stable *stream* banks and fish passage.

Poorly constructed *culvert* – with untreated logs, a substandard headwall and *sediment* discharges from the *culvert fill*. The pipe is too short for road carriageway.

Crossings

3.4 Single Culvert River Crossings

Perched *culverts* do not allow for fish passage.

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Crossings
3.5 Single Span Bridge River Crossings

There are a variety of bridges used for forestry purposes. Beam and deck construction are common. Beams are usually steel "I", stressed concrete, steel truss, post-tensioned treated LVL or glue-laminated treated sawn lumber. Decks are pre-stressed concrete or timber. Shorter decks may be made from concrete slabs.

Bridges typically cost more to construct than *culverts* or low-level crossings. In some instances, temporary portable bridges are used for short-term harvesting and transport access. These are designed for rapid construction and dismantling. Most consist of prefabricated combined beams and decking.


Examples of single span bridges using structural steel and reinforced concrete.

Version 2.0, January 2020

Crossings
3.5 Single Span Bridge River Crossings

A Where and when to use

1. Bridges are recommended for the following conditions:
   a. Rivers that have large and variable water flow.
   b. Rivers that have high *river* banks and where a *culvert* would require a significant *fill*.
   c. High debris potential or *river* bed load movement where a *culvert* would likely block.
   d. Steep *river* bed gradient with high water energy (*culverts* are less suitable).
   e. Sensitive *river* bed and banks that require minimal disturbance.
   f. Where *culverts* or other river crossings are not appropriate.
2. The advantages of bridges over other *river* crossing structures include:
   a. Reduced or no modification to the *river* bed and banks.
   b. No barrier to fish passage.
   c. Reduced erosion, as the channel capacity has generally not been changed by structures within the *river* bed.
   d. Typically low ongoing maintenance.
   e. Useable regardless of weather.

B Where not to use

Not applicable for this FPG.

C Design

1. Bridges require specialist engineering design and construction supervision. Given the costs and risks involved, it is recommended that flood and other design calculations are peer reviewed.
2. Almost all bridges will require a Building Permit and Code Compliance Certificate under the Building Act 2004 from the District Council.
3. Permanent bridges must pass at least a 1 in 50-year flood event (2% *AEP*). Allow at least 1 m of freeboard above the calculated maximum water level to ensure floating debris does not damage the structure or design the bridge to allow for overtopping.
4. Locate the bridge crossing site to meet these criteria if possible:
   a. On a straight and uniform reach of *river*, to reduce scour of the *abutments* or bridge approaches.
   b. At a narrow point – span length affects cost.
   c. Where the crossing is square on to the *river* – to manage span length.
   d. With stable *river* banks at the bridge site and upstream of the crossing.
5. Factor in potential natural channel adjustment changes over the bridge's design life.
6. Avoid bridge design that places structural foundations on soil susceptible to erosion or structural failure.

Crossings
3.5 Single Span Bridge River Crossings

D Construction

1. Construct in suitable weather.
2. Check for any fish spawning timing constraints under the NES-PF.
3. Limit earthwork disturbance to the immediate construction site – which may include an area up and downstream of the bridge site if the approaches and *abutments* need strengthening or protection from *river* bank erosion.
4. Minimise the need for machinery to operate in flowing water.
5. Construct foundations onto non-erosion prone material, preferably rock. If this is not possible, then build to below the maximum level of potential erosion, or provide an acceptable alternate engineering solution.
6. Bridge *abutments* or footings should be on natural ground. This ensures that the length of the bridge is wider than the *river* channel and provides a good bed for the bridge.
7. Wet or curing concrete must not be in contact with flowing water. Cement is a contaminant and is toxic to invertebrates and fish. When pouring concrete, the water channel will need to be temporarily diverted.
8. Elevated *sediment* discharge levels will occur during construction but must not occur for more than eight consecutive hours.
9. Protect the *abutments*, footings and approaches. If necessary, armour with concrete, rip rap, *gabions*, wing walls and other deflectors.
10. Limit *sediment* entering the *river* from the road approaches by:
    a. Raising the bridge deck slightly or lowering the road approaches, to direct stormwater away from the *river* if possible.
    b. Diverting road surface water off the bridge approaches, as close as practicable to the bridge, and ideally within 10 m. Use stormwater and *sediment* control measures such as *berms*, *cut-outs*, *water table* drains and *culverts*, *flumes* and *sediment* traps.
    c. Using clean gravel on road approaches where the existing road surface could create a *sedimentation* problem.
    d. Minimising the potential for aggregate being tracked onto the bridge.
11. Check regularly during and on completion of construction. If the work does not meet the design plan and standards then initiate corrective actions.
12. At the end of construction all excess equipment and materials must be removed from the *river* bed within five working days.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Initiate a regular two-year engineering inspection programme. Maintenance includes repairing *river* bank protection measures, and cleaning signs, kerb rails, the deck and the girder seatings.

National Environmental Standards for Plantation Forestry

Particular relevant provisions for bridges are Regulations 38 – 49.

Refer also to the Department of Conservation **Fish Passage Guidelines**: https://www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/nz-fish-passage-guidelines/

Crossings

3.5 Single Span Bridge River Crossings

Examples

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Crossings
3.6 Temporary Crossings

Many forestry operations require *rivers* to be temporarily crossed. Temporary *river* crossing designs can include a *culvert* and log structure sitting in the bed of the flow path, or log bridges that span across it. The design varies with the *river* and approach of the extraction track.

Poorly planned, constructed or maintained temporary crossings pose one of the greatest opportunities for *sediment* delivery to water.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Crossings
3.6 Temporary Crossings

A Where and when to use

1. When temporary access is required across a *river.*

B Where not to use

1. When crossing permanently dry gullies.

C Design

1. Plan for temporary harvest crossings at the harvest planning phase.
2. Consider factors such as the *catchment* size, the *river's* banks, width and substrate, and downstream infrastructure.
3. Aim to minimise the number of crossings needed to safely and productively harvest.
4. Ensure the crossing locations are clearly marked out for the operator.

D Construction

1. Minimise the disturbance of the natural shape of the *river*.
2. Minimise soil entering the *river* during construction.
3. Reduce potential *sediment* entering the *water body* from the approach tracks:
   a. Wherever practicable, maintain the track grade over the crossing.
   b. Consider *corduroying* the approaches or use *slash* on the approaches to limit rutting.
   c. Construct the track approaches so that extracted logs do not sweep off the crossing into the *river* (e.g. logs can be driven vertically at corners and crossing entrances to keep trees aligned to the crossing).
4. If logs are placed in the bed of the *river*, a *culvert* of at least 300 mm diameter must be installed at the base of the crossing.

E Maintenance and removal

Maintenance

1. Maintain *river* crossings and approaches so that stormwater control is effective. *River* crossings can be difficult to maintain in wet periods.
2. Ensure *culverts* are not getting blocked with woody debris from the harvest operation.
3. Maintain the integrity of log crossings.
4. During wet weather limit the use of the crossing to minimise mud accumulating on the track leading into and away from the crossing.
5. Stop operations when the approach tracks or the crossing are releasing *sediment* to the *river* and divert any track stormwater onto the cut-over.

Crossing removal

6. Remove the material used to construct the crossing within one week of finishing the harvesting operation.
7. Crossing material should be placed in a location that minimises the risk of it entering the *river*.
8. Rehabilitate or *decommission* the approaches.

National Environmental Standards for Plantation Forestry

Particular relevant provisions for crossings are Regulations 38 – 49.

Refer also to the Department of Conservation **Fish Passage Guidelines:** https://www.doc.govt.nz/nature/habitats/freshwater/fish-passage-management/nz-fish-passage-guidelines/

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3.6 Temporary Crossings

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Forest Practice Guide
Non-Regulatory

Tracks

Tracks
4.1 Track Construction and Use

Many forestry operations require tracks.

- Ground based harvesting extraction tracks are needed for tractors, skidders, forwarders and shovel logging.
- Establishment – tracks are built for planting access, pest control, fire protection, and for future operations.
- Mechanised felling.
- Two stage tracks between hauler and processing *landing*.
- Access for backline cable logging mobile tail holds – for bulldozers or excavators.

A number of factors affect the risk of *sedimentation* from track construction and use:

- Track location proximity to *water bodies*.
- Construction technique.
- Stormwater controls.
- Maintenance.
- Post-harvest rehabilitation.
- Soil type.
- Topography (slope, vegetation cover).
- Rainfall.

Improperly constructed, maintained or rehabilitated tracks can become a channel for water, creating a long-term *sediment* source. The use of tracks permanently *compacts* soil which can limit site productivity.

Note: Under the NES-PF tracks do not include soil disturbances caused by machinery passes.

Version 2.0, January 2020

Tracks
4.1 Track Construction and Use

A Where and when to use

1. Construct tracks for operations that improve access, productivity and safety.

B Where not to use

1. When maintenance of stormwater control is difficult. For example, downhill harvesting, especially in steeper, confined gullies, may result in tracks and stormwater *run-off* converging, leading to *sediment* concentrating in the gully floor. Post-harvest rehabilitation is much harder to manage if tracks are poorly located.
2. Where tracks are readily erodible (unless the erosion can be managed with erosion and *sediment* controls). For example, in lightly structured soils, and gully floors that show signs of periodic wetness. Tracks should not be constructed in *wetlands*. Note the presence of any *wetland* vegetation (e.g. sedges or other vegetation that thrives in wet soils).
3. Tracks in wetlands require resource consent.
4. Where necessary, "no-tracking areas" should be defined in operational plans and prescriptions.

C Design

1. Limit the number of tracks. For ground-based harvesting, if possible, space tracks greater than 60 m apart, except where they converge to main haul tracks.
2. Limit tracks near to *rivers*. Consider that a lower gradient track parallel to a *river* may be a lower risk option than steep tracks heading cross-contour to the *river*.
3. Recognise that wet areas may be unsuitable for a track. Consider using logging *slash* or log *corduroy* if tracks have to cross through wet areas.
4. Set track construction standards to provide clear guidance.
5. Consider gently out-sloping tracks (no more than 1 – 4% otherwise logs will roll off the track). These help direct stormwater off the track and reduce soil erosion.

D Construction

1. Discuss the planned track locations and construction requirements with the contractor. Tracks should ideally be constructed prior to starting harvest.
2. Consider *stabilisation* options at the time of construction for harvesting tracks such as *thatching* (placement of *slash*) and *corduroy*, especially when potential problems are foreseen, such as erodible soil or wet weather. Use *corduroy* on high impact areas such as access onto *landings*, approaching *stream* crossings or where other methods are not working. *Corduroy* significantly lowers the machine's ground pressure (by spreading the weight across a wider area) and creates a barrier between the soil and subsurface. Purposefully placed *slash* is good for *stabilisation*, plentiful and effective. It also reduces machinery ground pressure.
3. Construct tracks to reduce site disturbance:
   a. Manage stormwater control.
   b. Limit *stumping*.
   c. Keep tracks to a minimum, but safe, width.
   d. Any *river* crossings on tracks require a minimum 450 mm internal diameter *culvert*.

Tracks
4.1 Track Construction and Use

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Have a regular inspection programme for tracks that require ongoing maintenance.
3. Check tracks after a heavy rain event.
4. Start maintenance when problems are first identified, well before track failure.
5. Maintain stormwater and *sediment* control measures (e.g. *water tables*, water bars, *cut-outs* and *sediment* traps). Drain or re-establish clogged drainage points.
6. Maintain cut banks and *fills*, and remove any spoil that has led to a stormwater control issue or that impedes access.
7. Maintain when there has been significant deterioration such as where:
    a. The track's natural drainage points have blocked and stormwater is not being discharged off the track.
    b. Mud is being discharged with *run-off* into sensitive areas or dedicated *setbacks*.
8. Use *slash* to help bind/protect the soil and reduce rutting. It also lowers machinery ground pressure by spreading the machine's weight across a wider area.
9. Ensure the tracks are rehabilitated once harvesting has been completed.

F Other methods

Locate gully crossing points at suitable sites.

National Environmental Standards for Plantation Forestry

Particular relevant provisions for tracks are Regulations 23 – 35.

Tracks
4.1 Track Construction and Use

Examples

Tracks in gullies need to be carefully managed to avoid increased risk of *sedimentation*.

Backline harvest track, similar to other types of tracks, *cut-outs* are required.

Tracks
4.1 Track Construction and Use

Extensive tracking.

Maintained track with stormwater controls.

Tracks
4.1 Track Construction and Use

Poorly maintained track – lacking stormwater controls.

Tracks
4.1 Track Construction and Use

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Tracks
4.2 Track Rehabilitation

Track rehabilitation is undertaken to reduce soil erosion. *Decommissioning* (permanently closing the track) or installing well-located stormwater controls will reduce the potential for tracks to deliver *sediment* into sensitive areas, long after operations have been completed.

Significant soil movement may occur if rehabilitation is not undertaken in a timely manner.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Tracks
4.2 Track Rehabilitation

A Where and when to use

1. On all tracks.
2. On flat to gently rolling land forms, minor rehabilitation works such as spreading *slash*, installing *cut-offs*, water bars or soak holes is likely to be sufficient to control erosion and *sedimentation*.
3. On steeper slopes, rehabilitation can mean significant works to ensure that stormwater will be appropriately directed so it does not build up sufficient energy and volume to scour the track and create *sediment* problems. In some instances, this may involve restoring the site back to near-original land form and contour *(decommissioning)*.
4. The NES-PF requires tracks in any orange or red zone that are not required for harvesting within 12 months to be *stabilised* within 20 working days of their completion.

B Where not to use

Not applicable for this FPG.

C Design

1. Determine who is responsible for post-harvest rehabilitation. Set out and specify in works proposals whether it is to be completed by the:
   a. Harvesting contractor, or
   b. Earthworks contractor, or
   c. Both contractors. For example, the harvesting contractor may be required to leave the site with critical stormwater controls in place, followed by the earthworks contractor with an excavator that can construct the stormwater control measures better and more efficiently.
2. If the track is required for replanting operations, it should be rehabilitated and stormwater controls maintained after harvest and before replanting. Do not wait until after replanting is completed to undertake this work.

D Construction

Stormwater controls

1. Construct stormwater control measures even if tracks will have ongoing use such as for replanting. Use methods to control stormwater that allow vehicle access (where necessary), such as rolling water bars.
2. Construct stormwater control measures to last and to be self-clearing. Once *cut-outs* are completed they are hard to maintain. Access with machinery can damage the other control measures on the track.
3. *Cut-outs* are the most common stormwater control measure.

Track decommissioning

4. Consider rehabilitating tracks back to the original land form where long-term water control is difficult or tracks are close to sensitive areas (e.g. *rivers* or if there are concerns about visibility or other off-site effects). In some situations, track *decommissioning* should be anticipated and budgeted for as part of the operational cost.

E Maintenance

1. Maintenance is not generally required after rehabilitation has been completed. *Cut-outs* and *decommissioning* limit access. Some tracks may be left operational until replanting, after which the track may require additional rehabilitation.

F Other methods

1. *Slash* stabilisation. *Slash* is effective for slowing stormwater, reducing erosion, and trapping *sediment*. It can be used by itself or in conjunction with track *cut-outs*.
2. Compacted *slash* is also effective on steep slopes.

Tracks
4.2 Track Rehabilitation

G Technical specification guidelines

Cut-outs

1. Cut-outs are best constructed by a machine operator who understands the construction methods.
2. Locate and construct *cut-outs* using these criteria:
   a. Where possible, use natural track undulations or dips to locate *cut-outs*. *Cut-outs* must drain water off the track onto stable ground to limit *sediment* discharge into *water bodies*.
   b. Construct across the entire width of the track.
   c. Install *cut-outs* to drain and not pond water.
   d. Construct at an angle to the track to avoid ponding and to assist with directing stormwater to the exit point.
   e. *Cut-outs* must have a small *compacted bund* on the downhill side to stop water overtopping them.
   f. The *cut-out* must be deep enough so that water cannot bypass it, and so that it is effective for a long period. Depth should generally be greater than 300 mm.
   g. The *cut-out* exit point should not generate *sediment*. Channel any stormwater onto stable ground, into a *slash* filter, or *sediment* trap.
3. Construct *cut-outs* at regular intervals if the track is of consistent grade, the slope is even and other factors allow for consistent spacing. However, reduce *cut-out* spacing on steeper tracks and more erosion prone soil.
4. Around *fill* and *water bodies* it may be better to increase spacing, but do so in conjunction with other measures to slow stormwater flow, such as *slash* or *mulch*.
5. Spacing guide for *cut-outs*:

Minor tracking disestablishment

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

National Environmental Standards for Plantation Forestry

Particular relevant provisions for tracks are Regulations 26 – 35.

Tracks
4.2 Track Rehabilitation

Examples

The angle helps direct stormwater off the track to a *sediment* trap.

This track has been smoothed, which will accelerate water *run-off*. The water bar is ineffective as there is no outlet for the water it catches.

Tracks
4.2 Track Rehabilitation

Closer spacing of *cut-outs* is required in pumice and granite soils as they are prone to severe erosion over short distances.

Well-spaced *cut-outs* used to rehabilitate the track.

Tracks
4.2 Track Rehabilitation

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Forest Practice Guide
Non-Regulatory

Vegetation to Manage Erosion

Forest Practice Guide
Non-Regulatory

Vegetation to Manage Erosion 5.1 Grassing

Grassing (grass seeding) can be used to protect bare earth from raindrop impact, sheet erosion or minor *rill* erosion in the medium to long term. It can also be used as a *stabilisation* tool to minimise *sediment* entering water.

Hand or machine applied grass and legume seed can produce a dense grass cover.

A good example of grassing to protect road edges from raindrop impact.

This guide is provided as a reference document and does not constitute a statutory obligation under the Resource Management Act 1991 or the National Environmental Standards for Plantation Forestry.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Vegetation to Manage Erosion
5.1 Grassing

A Where and when to use

1. Apply seed on sites that are suitable for retaining seed, germinating and growing grass. Apply seed on critical sites, to reduce the risk of erosion and the effects of *sedimentation*.
2. When used in conjunction with hay *mulch*, the periods for successful germination can be extended into both early summer and early winter months.
3. Where practicable, retain and use topsoil as cover for erosion prone *fill* areas to improve and sustain grass growth.

B Where not to use

1. Sun baked, *compacted fills* – these often have a hard crust and poor fertility which makes grass establishment difficult.
2. Forestry sites and soils are generally low in fertility, so need resilient or pioneering grass species and some sites may need fertiliser and / or lime to lift pH.
3. Dry sites (e.g. steep cut banks and earthworks with dry aspects).
4. Sites where needle ice and frost heave occur in winter.
5. Cut *batters* where only exposed *mineral soils* or rock remain.

C Design

1. Use local knowledge or seek assistance from an experienced seed merchant to get the seed mix appropriate to the site.
2. Germination is most successful during spring or autumn when soil moisture is higher or where rainfall is evenly distributed.

D Application

1. Distribute seed evenly to achieve best results, by hand, hand-held seed spreader, or aerial application.
2. Where practicable, hand seed and fertilise (if necessary) earthworks sites daily (i.e. while earthworks are underway), before the surface develops a crust.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Inspect regularly for the first two months to assess strike rate and growth.
3. Reapply seed and fertiliser in autumn where there is a poor strike, if necessary.

F Technical specification guidelines

1. The sites need to be of moderate pH (not below 5), good fertility (or be fertilised), not so steep the seed will wash off, nor on earthworks sites that are heavily *compacted*.
2. Roughened surfaces will improve results if slopes are steeper.
3. Lime is best spun onto fresh earthworks using a mini spinner mounted on a small excavator if necessary.
4. When deciding on the type of seed mix, consider:
   a. Whether it is adaptable to the local soil type(s) and environment.
   b. The associated logistics of getting lime and fertiliser to the site.

Two seed mixes suitable for disturbed sites are:

	Seed mix A	Seed mix B
Lotus Major 'Maku'	10%	5%
Annual ryegrass 'Moata'	25%	20%
Yorkshire fog 'Massey Basyn'	25%	15%
Cocksfoot	5%	15%
White cover	10%	15%
Subterranean clover	10%	20%
Suckling clover	10%	5%
Browntop	5%	5%

Vegetation to Manage Erosion
5.1 Grassing

F Technical specification guidelines
continued

5. Seed requires moisture, correct soil temperature and sunlight for germination and growth. Early autumn is often best as soil temperatures are ideal and there is good soil moisture.
6. Apply lime if the pH is low (less than 5) – rates of up to 5 tonnes per hectare may be needed on acid soils of volcanic parent material. Add fertiliser to the seed mix if the site/soil fertility is poor.
7. Make sure legumes are inoculated with the correct Rhizobium bacteria. Seed can be purchased pelleted (with fertiliser) and inoculated.
8. Use higher percentages of Yorkshire fog in coarse ash or pumice soils.

National Environmental Standards for Plantation Forestry

Particular relevant regulations for soil stabilisation are 32, 55, 60.

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Vegetation to Manage Erosion
5.2 Hydro-seeding

Hydro-seeding can be used to rapidly establish a vegetation cover, to protect exposed soil from sheet and *rill* erosion. It can also be used as a *stabilisation* tool to minimise *sediment* entering water.

A mixture of water, seed, fertilisers, organic binders and *mulch* is sprayed onto the surface to be vegetated. The binders and *mulch* improve the strike rate and reduce the opportunity for seed to be washed or blown away. In good growing conditions, with the right seed mix on a suitable site, grass strike can be within about 14 days.

Hydro-seeding is expensive, so it is often reserved for high risk sites where conventional grassing techniques would be inadequate.

Although hydro-seed can be applied to almost any surface, it can still be difficult to get a good strike and good growth on:

- Dry sites such as steep cut banks, earthworks with dry aspects, and areas with hot, dry climates.
- Low nutrient sites such as many cuts and *fills*.

As with other grassing techniques, hydro-seeding can only protect the soil surface. It does not provide erosion control for soil slips or other deeper-seated erosion features.

Good example of hydro-seeding on a steep roadside.

Cut *batter* being hydro-seeded to assist *stabilisation*.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

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Vegetation to Manage Erosion
5.2 Hydro-seeding

A Where and when to use

1. On critical sites, such as steep areas and on infertile soils where conventional sowing methods don't work and there is a need to establish a rapid vegetation cover.
2. When seasonal timing is less favourable for conventional seed sowing methods.
3. When establishment of a protective vegetation cover faster than conventional grassing is required.
4. When road construction, water control, and erosion and *sediment* control structures are completed (if necessary).
5. When growing conditions are good. It still requires moisture, correct soil temperature and sunlight for germination and growth. Early autumn is often best. Newly germinated seed will die without good root structure if soil moisture is lost.

B Where not to use

1. Applications on steep cut faces with a *smooth glazed surface* and non-cohesive soils on steep *batters* as the hydro-seed layer will peel off with gravity, wind or water.
2. Application in late spring (due to equinox weather conditions such as gales or long dry periods), as germinated seeds can easily die off as root structures have not had a chance to develop.
3. Delay hydro-seeding if heavy rain is forecast. The rain can wash hydro seed off, especially from smooth surfaces and in water flow paths. Check the Metservice ten-day forecast.

C Design

Refer to the “Where and when to use” section.

D Construction

1. Use a dry-tolerant and deep-rooted seed mix (deeper rooting legumes) to reduce the risk of hydro-seed peel-off.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Inspect regularly for the first two months to assess strike rate and growth.
3. On critical sites where the original hydro-seed has failed, consider the need to reapply hydro-seed. Assess why the hydro-seeding did not strike or grow on the site and whether the timing is suitable for reapplication.

F Other methods

1. Use hydro-*mulch* on critical areas such as loose soil in close proximity to sensitive sites such as *water bodies*.
2. Use grassing as a cost-effective alternative, especially on easier to strike areas.
3. Use hay *mulch* and grass seed or *slash* as an alternative.
4. Polymers can also be applied to lock soil particles together and therefore prevent erosion of the surface.

National Environmental Standards for Plantation Forestry

Particular relevant regulations for soil *stabilisation* are: 32, 55, 60.

Vegetation to Manage Erosion
5.2 Hydro-seeding

Examples

A recently hydro-seeded *fill* slope.

Vegetation to Manage Erosion
5.2 Hydro-seeding

Success of hydro-seeding is dependent on weather and soil moisture conditions. Hydro-seed has germinated only on the lower section of this cut *batter* where soil moisture was highest.

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Vegetation to Manage Erosion
5.3 Applying Mulch

Spreading *mulch* made, for example, of bark, jute coconut fibre matting, woody material or hay intercepts rain and protects the soil from sheet erosion and *rill* erosion. Its effect is immediate.

Mulch also retains soil moisture, which helps a vegetative cover to quickly establish. It can be used in conjunction with grassing and will usually improve the germination rate and extend the period in which grass can be used.

Mulch applied to a road edge providing protection and support for grass seeding.

Version 2.0, January 2020

Vegetation to Manage Erosion
5.3 Applying Mulch

A Where and when to use

1. Where an instant barrier is necessary to reduce surface erosion on sites where there is high risk of soil erosion that would cause problems to the site infrastructure or sensitive areas such as *water bodies*.
2. Where hydro-seeding would be too costly.
3. When seasonal timing will not allow conventional sowing or hydro-seeding methods.
4. Around *fills* on road/track 'in-bends' where there is flowing water or a risk of direct connection of *sediment* to flowing water or on earthworks for *river* crossings.
5. Use *mulch* once road or track construction, stormwater control, and erosion and *sediment* control measures are completed.
6. Jute is effective in highly sensitive environments and can be combined with other sediment control methods.

B Where not to use

1. On steep and exposed earthworks where wind and rain may blow or wash the *mulch* away.
2. If the *mulch* contains pest plant seeds.

C Application

1. Spread hay *mulch* evenly by hand for smaller areas.
2. Apply hay ensuring exposed soil cannot be seen through the *mulch* (this typically requires about 6000 kg/ha).
3. Bark or woody chip *mulch* can be applied with an excavator.

D Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Re-apply after one month in specific areas (high risk) if grass seed germination is normally expected and/or ground cover vegetation has not established well.
3. If the *mulch* cover has been lost reapply it immediately on high risk sites. The target should be to an 80%+ maintenance free cover.

E Other methods

1. Hay *mulch* followed by grassing generally improves the strike rate.

F Technical specification guidelines

Not applicable to this guide.

National Environmental Standards for Plantation Forestry

Particular relevant regulations for soil *stabilisation* are 32, 55, 60.

Vegetation to Manage Erosion
5.3 Applying Mulch

Examples


Examples of jute in use.

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Forest Practice Guide
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Vegetation to Manage Erosion
5.4 Slash

Slash for the purposes of this Forest Practice Guide refers to branches, tree tops, slovens, bark and other woody residue created during harvesting operations.

Slash is plentiful and can be useful for reducing erosion and *sediment* discharged from new construction, exposed soil generated during harvesting operations, and for post-harvest site rehabilitation. When it is spread over *fill* slopes during construction, or more commonly for post-harvest track rehabilitation, it is a form of *mulch*. It is an effective tool for trapping a wide range of *sediment* particle sizes.

Slash cover on track to minimise *sediment* movement.

Version 2.0, January 2020

Vegetation to Manage Erosion
5.4 Slash

A Where and when to use

1. Use *slash as a mulch*:
    a. Where an instant barrier is required to reduce surface erosion on critical sites, such as soil disturbance close to flowing water.
    b. To assist in getting a vegetative cover back on sites where the soil is *compacted*, such as tracks, as it can help to retain soil moisture.
    c. On steep and exposed areas where wind and rain may blow or wash hay *mulch* away.
    d. When seasonal timing does not allow conventional sowing or hydro-seeding.
    e. On new construction *fill* slopes, after road or *landing* water control, and erosion and *sediment* control measures are completed.
    f. Where machinery is on site or readily available for application.
2. To reduce water velocity and to trap *sediment* outside of any watercourse.
3. *Slash* can form an effective *bund* when placed at the base of earthworks *fill* slopes, or at the exits of *water table* drainage *culverts*, *cut-outs*, *flumes*, and *sediment* traps and ponds.
4. To reduce the impact of logging machinery on tracks during wet weather, by laying *slash* over harvest tracks. This acts to spread the machinery load across a wider footprint, and reduces water *run-off* velocity and volume. It also acts as a partial barrier to reduce mud coming to the surface.
5. To trap *sediment* on tracks and in *water tables* with low gradients, by laying *slash* in and over tracks and *compacting* it.

B Where not to use

1. Where it can mobilise and block *culverts* and *cut-outs* or be transported off site.
2. Slash can effectively dissipate the energy of a concentrated flow, but do not rely on coarse *slash bunds* to intercept *sediment* from concentrated flows (e.g. a storm flow path or *culvert* discharge).

C Application

1. Ensure the contractor knows where and how to use *slash* as *mulch*. Train earthworks and harvesting contractors on the use of *slash*, as they will be the likely applicators.

Slash used with water table drainage culverts, cut-outs, flumes, sediment traps and ponds

2. Place *slash* by hand or machine at the outlets of *water table* drainage *culverts*, *cut-outs*, *flumes*, *sediment* traps and ponds.
3. Match the *slash* material and size to the job.
4. At drainage *culvert*, *cut-out* and *flume* exits use medium to smaller branches. The aim is to primarily reduce water speed then use the *slash* as a filter. Bark tends to mobilise with the water so it is not so suitable.
5. Spread the *slash* in the drainage pathway several metres below the structure.
6. Where the stormwater control measure exits drain directly onto *slash* in a cut-over – this effectively filters without additional work.
7. Use finer *slash* as a filter below the outlet of *sediment* traps and ponds.

Slash as a road or landing bund

8. When clearing and stripping, use *slash* to form a *bund* downslope of the toe of the *fill* as a *sediment* trap.

Slash and track rehabilitation

9. Apply on logging tracks for post-harvest rehabilitation.
10. Place *slash* on *fill* faces to minimise bare earth.

Vegetation to Manage Erosion
5.4 Slash

D Maintenance

1. Slash typically does not require maintenance. However, check slash filters around sediment traps and ponds after heavy rain and storms. If slash has become sediment laden, add more slash so that it can keep slowing incoming water and acting as a filter.

E Other methods

1. For instant soil surface protection, mulch or apply hydro-seed.
2. Grassing.
3. For *sediment* control on tracks refer to FPGs Tracks #1 – Track Construction and #2 – Track Rehabilitation.
4. Polymers can also be applied to lock soil particles together and therefore prevent erosion of the surface.

National Environmental Standards for Plantation Forestry

Particular relevant regulations for soil *stabilisation* are 32, 55, 60.

Vegetation to Manage Erosion
5.4 Slash

Examples


Examples of *slash* being used to rehabilitate ground-based logging tracks.

Vegetation to Manage Erosion
5.4 Slash

Sediment at a road *culvert* drain trapped by *slash*.

A *slash bund* intercepts *sediment* before it reaches the *river*.

Vegetation to Manage Erosion
5.4 Slash

Slash has been used like hay *mulch* as an instant *stabiliser*.

Slash on an extraction track – effectively trapping *sediment*.

Vegetation to Manage Erosion
5.4 Slash

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Harvest Slash

Harvest Slash
6.1 Managing Processing Slash on Landings

When extracted trees are processed on a *landing* the process creates woody debris or *slash*. Processing *slash* is often pushed or stacked into large piles around or on the slope below the *landing*, called a *"birds nest"*. Processing *slash* stored around *landings* occupies productive land for the next crop. If poorly managed, its weight, in addition to saturated, unstable or potentially unstable ground, can create a significant risk of failure. There is also risk of spontaneous ignition if *slash* piles are too high (>3 m) or organic material (needles/dirt) or rubbish is mixed with *slash*.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Harvest Slash
6.1 Managing Processing Slash on Landings

A Where and when to use

1. Around all *skids* or *landings*.
2. Minimise locating *slash* where it will be difficult to contain or manage, or where the ground is unstable or could become unstable.

B Where not to use

Not applicable for this FPG.

C Design

1. Before harvesting, assess whether on-site processing will create large volumes of *slash*.
2. Develop a *slash* management plan, especially if harvesting steep country where large amounts of processing *slash* will be produced.
   a. Estimate the quantity of *slash* that is likely to be produced.
   b. Identify and plan for the placement of processing *slash* (where appropriate, incorporate *slash* benches as part of the *landing* design and construction). *Slash* areas should be on stable land, well away from *streams*, steep slopes, non-engineered *fill* material, slips, gully heads and *riparian areas*. This will mitigate the risk of processing *slash* entering *water bodies* and causing damage downstream.
   c. Designate "No-Go" zones where *slash* is not to be deposited.
   d. Determine if off-site *slash* disposal sites are required and where they are located. Detail how and when the processing *slash* will be removed as the operation progresses.
   e. Identify the potential for storing *slash* on *landings* once harvesting has been completed, consider further processing of *slash* into wood fibre if economic.
   f. Document the plan before the operation commences.

D Operational controls

1. Construct *slash* benches or designated *slash* placement areas, especially on sites with limited natural storage options for processing *slash*.
2. Ensure the contractor knows and is familiar with the *slash* management plan. Sign it off as part of the pre-harvest brief.
3. Ensure that machines have unrestricted access to the identified processing *slash* placement areas.
4. Plan for temporary *slash* storage if there is insufficient space for onsite processing *slash* storage. This will allow processing *slash* to be temporarily accumulated and trucked off site to a disposal site (for example, another *landing*).
5. Keep *birds nests* free of soil, organic material and wire rope/metal which can act as a catalyst for spontaneous ignition. Do not blade off mud and dirt into them as this makes post-harvest rehabilitation more difficult and can create instability.

Harvest Slash
6.1 Managing Processing Slash on Landings

D Operational controls continued

Burning

6. Burning can be an effective option to reduce the amount of *slash* in a *birds nest*. The processing *slash* can sometimes burn for weeks which can pose a severe fire risk in dry or windy conditions. Burning debris can also roll downslope creating a risk of starting fires. High levels of fire supervision and resourcing are required when burning processing *slash*.
7. Seek specialist advice if you wish to use burning as a *slash* management technique.
8. Have a fire permit if required, a Burn Plan and Fire Control Plan, and follow all local fire authority requirements. Check the relevant council's air plan and forest insurance requirements and consider any ecological implications.
9. Ensure designated areas of protected vegetation are protected from burning. Consider over-sowing burnt areas to reduce the risk of surface erosion.

E Maintenance

During the operation

1. Manage stormwater control around *slash* areas during operations to prevent water entering *birds nests*. Reinstate stormwater controls if they are damaged by operations.
2. Monitor *birds nests* to ensure they are stable and fully utilise the available space. This may require benching and shifting or reworking of the processing *slash*.
3. Monitor processing *slash* storage space. If it is likely to be exceeded, find an alternative site. Make sure that processing *slash* does not accumulate beyond the reach of the excavator if it needs to be repositioned.

Post-harvest rehabilitation or decommissioning

4. Pull any unstable processing *slash* back from the *landing* edge with an excavator.
5. Install drainage as required to minimise the entry of stormwater into *birds nests*.
6. On steep erodible slopes, processing *slash* should be reduced to a level that the ground is visible through the remaining material, if the *slash* is not contained on purpose-built *slash* benches.
7. Check *landing* edges for thick build-ups of processor-generated bark. Large deposits of bark can form deep, wet, heavy layers that are prone to failure. Remove the bark to solid ground.

F Other methods

1. Processing *slash* can be minimised by harvesting full or longer length stems and transporting them to a central processing site or yard.
2. Remove all lower grade logs (e.g. overcuts or bin wood) during extraction, or process logs in the forest.

   Note: Some of these options may not be feasible or economic in all circumstances.
3. Refer to FPGs Earthworks Construction for construction of *slash* benches.

National Environmental Standards for Plantation Forestry

Particular relevant provisions for managing *slash* are Regulations 20, 69, 83 – 92.

Harvest Slash
6.1 Managing Processing Slash on Landings

Examples

A constructed *slash* bench.

Burning can be an effective method of removing *slash* where it is carefully managed.

Harvest Slash
6.1 Managing Processing Slash on Landings

Landings need to be rehabilitated and *decommissioned*. This *landing* has had the *slash* pile stored on the *landing*. *Water tables* and *bunding* have directed stormwater away from *fill* and on to the hard surface.

Constructed *slash* bench below the *landing*.

Harvest Slash
6.1 Managing Processing Slash on Landings

Rehabilitated *landing* – *slash* stored in a safe location and water controls installed.

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Harvest Slash
6.2 Managing Cut-over Slash on High Risk Slopes

A high risk slope is where slope failure may have major adverse consequences as a result of cut-over *slash* being mobilised in the slope failure.

High risk slopes are usually identified on steep terrain that is susceptible to slope failure, soil slip, *stream* bank and gully erosion, or more damaging debris flows. High risk slopes also include slopes that may not be highly risky in themselves but are located above a sensitive site (e.g. a valued *water body* or downstream infrastructure) that, if the slope fails, could be adversely affected.

Risk factors include:

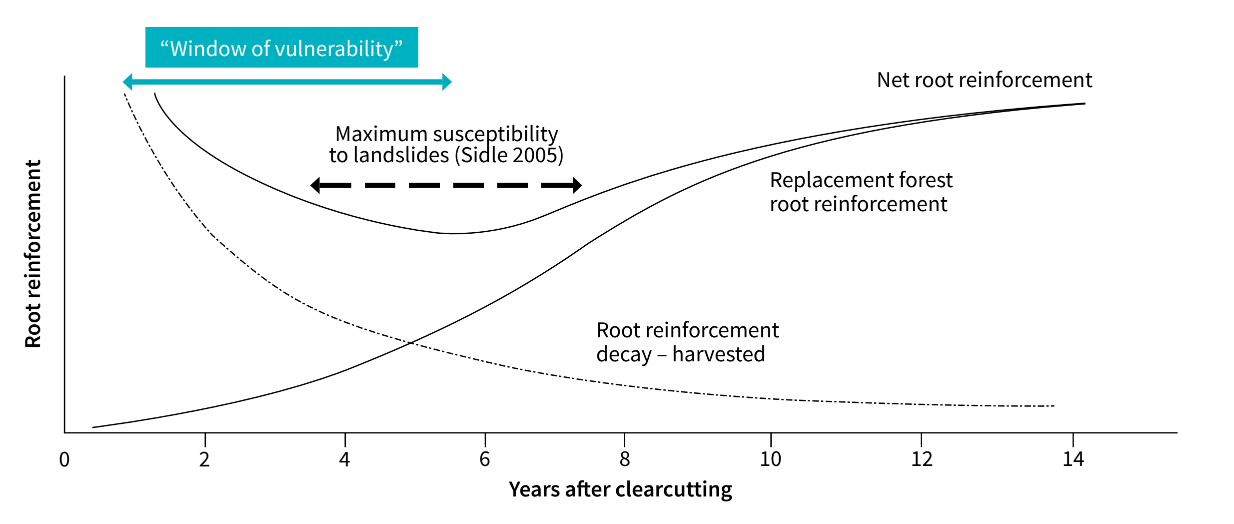
- Extended periods of rainfall.
- High intensity rainfall.
- The type and number of *water bodies*.
- The size of forest clear cut areas.
- Highly erodible/unstable soils.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Harvest Slash
6.2 Managing Cut-over Slash on High Risk Slopes

Window of vulnerability



Cut-over *slash* will move in conjunction with slope failure. If a slope failure takes cut-over *slash* with it to a *stream* which then transports the *slash* off site, it may have significant adverse environmental, social and economic effects.

Cut-over *slash* on a steep slope is at risk for a number of years. The 'window of vulnerability' is the time between when the logged trees' roots rot and the new crop's roots replace them. **The window of vulnerability can be up to five years.**

A key way to reduce risk is to reduce the amount of cut-over *slash* left on the slope, particularly at places where it is evident that the slope is susceptible to slope failure.

Harvest Slash
6.2 Managing Cut-over Slash on High Risk Slopes

A Where and when to use

1. On slopes with soils susceptible to mid-slope failure in the post-harvest period.
2. On slopes with significant risks that material could be transported off site

B Where not to use

Not applicable to this FPG.

C Design

1. Do a *slash* mobilisation risk assessment and consider the possibilities:
   - If cut-over *slash* did move, where would it end up?

   a. Are there parts of the slope that present a higher risk?

   b. What would be the potential damage to downstream land, *rivers* and infrastructure if the slope failed? In the assessment consider:
      - Rainfall intensity and duration.
      - Harvest area size.
      - Topography, geology and soils.
      - Social and community implications of visible *slash* outside the forest.
      - Water supply intakes.
      - Proximity to neighbouring properties, beaches, harbours, *rivers*, recreational areas.
      - Infrastructure such as *culverts*, roads, bridges, and state highways.
      - *Riparian areas* and remaining forested areas.

   Note: LidAR maps can help predict where slope failure might occur, based on the pattern of previous erosion events. The Erosion Susceptibility Classification[1] mapping provides a high-level overview of greatest risk and the underlying Land Use Capability maps[2] and the Extended Legend explain the land use limitations for that terrain.

2. Where possible, plan *landing* and blackline positions to get the most direct pull possible across high risk slopes. This will maximise suspension and minimise cut-over *slash* sweeping into gullies.
3. Select an appropriate harvesting system for the terrain and slope. Consider:

   a. Partially or fully suspended logs will generate less *slash* during in-hauling.

   b. Trees dragged across a slope can sweep cut-over *slash* into *rivers* (where it will be difficult or impossible to extract).
4. Consider risk mitigation strategies, such as:

   a. If it is not possible to remove *slash* from identified high-risk slopes, install *slash* traps at strategic locations downstream. This could be on an adjoining property. Larger traps may need resource consent – seek specialist advice.

   b. Leave areas of standing forest, if the harvesting of the trees would present an unacceptable risk of cut-over *slash* mobilising and causing significant downstream adverse effects. Retained areas of forest could remain standing or be poisoned if necessary.

   c. Reducing merchantable products in the cut-over (e.g. smaller dimension logs or shorter stems for bin wood or boiler fuel).

   d. Staging the harvest over a series of years in large *catchments* with identified high risk landforms.

   e. Be aware that areas of significant *windthrow* will increase the quantity of cut-over *slash*.

   f. Techniques that minimise felling breakage.

1 https://www.mpi.govt.nz/growing-and-harvesting/forestry/national-environmental-standards-for-plantation-forestry/erosion-susceptibility-classification/
2 https://soils.landcareresearch.co.nz/soil-data/nzlri-soils/

Harvest Slash
6.2 Managing Cut-over Slash on High Risk Slopes

D Operational controls

1. Aim to reduce the amount of cut-over *slash* at the time of harvest in high risk areas. At critical sites, this may include extracting non-merchantable stems (e.g. *windthrow* and smaller dimension stems and heads).

E Maintenance

Post-operation

1. Maintain or rehabilitate roads, tracks, and *landings*. No or poor maintenance may exacerbate the size and frequency of slope failure and resulting debris flows on high risk slopes.
2. Where necessary and appropriate, construct *slash* or *slash* traps in *catchments* where there is risk of debris damaging downstream infrastructure.
3. Consider poisoning trees that cannot be harvested so they break down slowly. Leaving unharvested trees to grow may create an additional risk of slope failure.
4. To reduce *slash* from high risk, steeply incised gullies, consider burning. While burning is not recommended as a wide-spread solution, at some specific sites it may produce the safest and most environmentally effective solution.

National Environmental Standards for Plantation Forestry

Particular relevant provisions for managing *slash* are Regulations 68, 69, 83 – 92.

Harvest Slash
6.2 Managing Cut-over Slash on High Risk Slopes

Examples

Mid-slope failures.

Windthrow significantly increases the volume of cut-over *slash*.

Harvest Slash
6.2 Managing Cut-over Slash on High Risk Slopes

The blue arrow identifies an area with a high likelihood of slope failure. In this case, the amount of cut-over *slash* was reduced in the high-risk area.

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Harvest Slash
6.3 Managing Slash in and around Rivers

Large quantities of *slash* are undesirable in *rivers* and may have significant adverse effects on instream ecology, channel stability and infrastructure in and outside the forest boundary. *Slash* must be managed where it could enter a *river*.

Small amounts of stable *slash* can provide instream benefits (e.g. food and shelter for insects and fish, and by reducing post-harvest fluctuations in *stream* temperature).

This guide is provided as a reference document and does not constitute a statutory obligation under the Resource Management Act 1991 or the National Environmental Standards for Plantation Forestry.

Please refer to the 'how to use' section of the introduction at http://docs.nzfoa.org.nz/forest-practice-guides/ for advice on how to use this guide.

Version 2.0, January 2020

Harvest Slash
6.3 Managing Slash in and around Rivers

A Where and when to use

1. Try to avoid or minimise *slash* entering *rivers* where there is an identified risk of:
   a. Blocking or damming a *water body*, contributing to bank erosion or a debris flow.
   b. Damaging downstream infrastructure or *water bodies*.
   c. It being difficult or impossible to manually extract (e.g. from steep sided *rivers*).

B Where not to use

Not applicable for this FPG

C Design

1. Assess the terrain, *river* type, values, and risk associated with inputs of *slash*.
2. Undertake a *water body* risk assessment to identify the likelihood and severity of effects if *slash* did move off site. In the assessment consider:
   a. Likelihood of high intensity rainfall events, and their frequency.
   b. *Catchment* size – bigger *catchments* often have higher energy flows and this can be exacerbated by the cumulative effects of harvest in the same catchment.
   c. Topography – steep land sheds water more quickly. High energy water flows will mobilise *slash*.
   d. Receiving environment. For example, does a high energy *river* deliver into a high-volume *river*, or one with stop-banks? This increases the risk that *slash* could be transported long distances.
   e. *Water body* ecological values. Identify species present and their rarity. Refer to the NES-PF Fish Spawning Indicator[1].
   f. Social effects of *slash* moving off site. How close is it to neighbouring properties – houses, fences, water supply intakes, beaches, recreational areas etc?
   g. In-forest and off-site infrastructure (e.g. roads, *culverts*, bridges, state highways).
   h. *Riparian areas* and remaining forest. These can be operational risks or benefits (e.g. standing/live tree *slash* traps) or, depending on the situation, riparian width and vegetation type can prevent *slash* movement by forming a barrier.
3. Decide how to manage *slash* after the risk assessment has been completed. Harvest methods should minimise the amount of *slash* and length of *stream* damage where practicable (e.g. bridle to a fixed skyline and pull through strategically located narrow corridors).
4. Risk mitigation strategies. If it is not possible to remove *slash* from *rivers*, install *slash* traps at strategic locations downstream. This could be on an adjoining property. Larger traps may need resource consent – seek engineering or specialist advice. Be prepared to clean these out on a regular basis.
5. Be aware that areas of significant *windthrow* will increase the quantity of *slash* that could be in and around *streams*.

1 http://www.mpi.govt.nz/growing-and-harvesting/forestry/national-environmental-standards-for-plantation-forestry/fish-spawning-indicator/

Harvest Slash
6.3 Managing Slash in and around Rivers

D Operational controls

1. Minimise the amount of *slash* that is deposited in the *river* by using directional felling, extracting away from rivers, or other measures where possible.
2. Consider measures that limit stem breakage during falling and extraction.
3. Minimise damage to *riparian vegetation areas*. These protect *water bodies*, help reduce erosion and *sedimentation*, and may have important ecological values.
4. Follow a *slash* management plan. Remove as much *slash as* needed to meet the plan's performance standards.
5. It is often better to remove *slash* from or adjacent to *water bodies* before a line shift.
6. Ensure that *slash* left adjacent to a *water body* is not in a position where it could be picked up by large flood flows (e.g. a one in 20-year event), where possible.
7. Consider extracting non-merchantable smaller dimension stems and heads above *water bodies* with steep convex slopes (steeper closer to the *water body*).

National Environmental Standards for Plantation Forestry

Particular relevant provisions for managing *slash* are Regulations 20, 69, 83 – 92.

Harvest Slash
6.3 Managing Slash in and around Rivers

Examples

Unacceptable *slash* loading in a small *river*.

Minimal *slash* removed from a *river* therefore posing a risk of blocking or damming the *river* or damaging downstream infrastructure.

Harvest Slash

6.3 Managing Slash in and around Rivers

Trees have been left standing, where extraction would have been difficult and added non-retrievable *slash* into the *river*. Harvesting trees from either side of the *river* also minimises damage to the *riparian margins*.

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Harvest Slash
6.4 Slash Traps

What is a slash trap?

Slash traps are generally constructed in the channel of a *river*. The aim is to catch larger pieces of *slash* that would otherwise be transported out of a *catchment* in flood flow conditions.

Slash traps are best made from rammed railway irons or steel beams threaded with wire rope and anchored solidly at each end. They have proven effective in *catchments* of several hundred hectares.

Version 2.0, January 2020

Harvest Slash
6.4 Slash Traps

A Where and when to use

1. Use in high risk harvest and post-harvest *river* and *stream catchments*, where *slash* could be mobilised in flood events.
2. Use to limit *slash* movement downstream from the forest where it could cause problems for downstream property owners or infrastructure (e.g. roads, *culverts*)
3. Aim to install *slash* traps when road lining operations commence, where practicable.

B Where not to use

1. If the natural alignment of the *river* or *stream* channel will be altered.
2. If the *slash* trap will change the *river* gradient, by debris building up behind the structure and creating a weir.
3. If the *slash* trap will cause erosion of the banks and bed of a *river*.
4. If the *slash* trap will adversely affect downstream properties.

C Design

1. Design for:
    a. A minimum six year engineered life. *Slash* traps need to last long term.
    b. Free movement of water through the structure.
    c. Fish passage.
    d. Trapping the larger debris only, rather than trapping or damming all debris.
    e. Machine access to clean and maintain the structure.
    f. Ease of checking after storm events (near road access or good drone access).
2. Position at right angles to the *river* or *stream.* If there is a natural bench then slightly angle it downstream to aid *slash* being deposited onto it.
3. Construct the slash trap in a low gradient reach of the *river* to minimise the combined energy of water and weight of debris on the trap during peak flows. This helps to minimise the chance of structural failure.
4. A resource consent is needed to install *slash* traps in *catchments* larger than 20 ha, unless the *slash* trap is located on a terrace on one side of the *river* or on a low *river* terrace. The terrace(s) should allow the overflow of any excess material that may build up against the trap, to reduce pressure and risk of the structure failing.
5. Locating the *slash* trap adjacent to a large flat area above flood flow level is preferable, to provide storage for any debris that has been intercepted by the trap and needs to be removed. This will reduce the cost of maintaining the *slash* trap.
6. Document and take photos of location, design and construction.
7. Resource consent may be required, check prior to construction.
8. Consider whether a series of *slash* traps (two or more) would be a better solution than one *slash* trap.

Harvest Slash
6.4 Slash Traps

D Construction

1. For maximum structural strength, use the largest railway iron gauge available or appropriately specified steel universal beams, such as I-beams or RSJ's.
2. Drive the irons/beams into the *river* bed.
3. Ensure the spaced iron/beam uprights are not too close to each other to avoid trapping too much material.
4. Support railway iron/beam uprights with a wire rope.
5. Anchor the wire rope to deadmen or large trees on either *river* bank to secure the *slash* trap.

Slash captured by *slash* trap installed upstream of road and bridge. Accessible site allows removal of *slash* and maintenance of the *slash* trap.

E Maintenance

1. Prepare a routine maintenance plan including heavy rainfall response measures.
2. Maintain the slash trap to a maximum of two thirds storage capacity at all times.
3. Visit *slash* traps within five working days after a storm event that could have mobilised *slash* (5% *AEP* or greater).
4. Clear debris within 20 working days after a storm event.
5. Put cleared debris beyond the flood plain, or beyond where it could be mobilised by a flood event up to a 1 in 20-year event (5% *AEP*).

F Reporting

(to meet the National Environmental Standards for Plantation Forests)

1. Provide a written report to the regional council within 20 days of the construction of a *slash* trap.
2. Provide a written report to the regional council by 31 March each year that includes:
   a. Frequency of maintenance and clearing.
   b. *Slash* trap condition and performance.
   c. Any damage to downstream property, *stream* bed disturbance, fish passage blockages.

Harvest Slash
6.4 Slash Traps

G Technical specification guidelines

1. Build the trap at least 0.5 to 1.0 m higher than the *river* banks.
2. The irons/beams should be up to 2 m above the *river* bed (if higher, a resource consent is required).
3. Drive irons/beams into the *river* bed to a depth of at least 1.5 m.
4. Space railway irons/beams 1.5 to 2 m apart and no closer than 1.5 m.
5. The irons should be no more than 2 m above the *river* bed (if higher, a resource consent is required).
6. Use a wire rope (minimum 22 mm diameter).
7. Ensure there are smooth-sided holes cut in the upper sections of the irons/beams (for threading the wire).
8. When anchoring the wire rope to the deadmen or large trees, insert a knot in the rope and supporting clamps, on either streambank to secure the *slash* trap.
9. Maximise tension in the rope.
10. Secure clamps to the wire rope immediately on either side of each railway irons/beams to create rigidity. Clamps stop the irons/beams from being forced out of alignment when under pressure.
11. Short logs or railway irons/beams can be driven into the terraces adjacent to the *slash* trap, to catch more material in high flows.
12. If it is likely that trapped debris could divert *stream* flow during a flood event, the bank should be armoured to prevent scouring.
13. Refer to Debris Flow Control Structures for Forest Engineering, D.F. VanDine, British Colombia Ministry of Forests 1996 and www.geobrugg.com/en/Debris-flow-barrier-UX-7949,7859.html.

National Environmental Standards for Plantation Forestry

Particular relevant provisions for managing *slash* are Regulations 83 – 92.

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Forest Practice Guide

Non-Regulatory

Glossary

Glossary

A

Abutment: A construction that supports the end of a bridge **(NES-PF)**.

AEP: The annual exceedance probability, which is the chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage (generally used in hydrology to define rainstorm intensity and frequency). For example, a five percent AEP event has a five percent chance of being exceeded in any one year. A five percent AEP event expresses approximately the same sized event as a twenty year return period event.

Assessment of Environmental Effects: A process of systematically identifying elements of the environment that may be impacted on by an operation or undertaking, the estimation of the degree, certainty and longevity of any effects and the specifying of the means to avoid, remedy or mitigate these effects **(E-COP)**.

B

Bank full channel width: A distance across a river channel formed by the dominant channel-forming flow with a recurrence interval seldom outside a 1 20 2-year range (measured at right angle to the channel flow) **(NES-PF)**.

Batter: A constructed slope of uniform gradient. **(NES-PF)**.

Berm: A raised earth or engineered structure parallel to the edge of a road or track, designed to contain and direct surface water run-off and sediment to controlled discharge points **(E-COP)**.

Birds nest: Accumulation of slash and waste wood material around the edge of a landing arising from harvesting operations **(E-COP)**.

Buffer/Buffer zone: An area adjacent to a perennial stream, lake, wetland or other sensitive area, where special care and consideration is given to activities to minimise soil disturbance, or other adverse environmental effects **(E-COP)**.

Bunds/Bunding: Secondary containment system around an operation or storage facility to contain or prevent leakage that may contaminate ground water, natural watercourses or susceptible soils. Generally either a purpose built steel or plastic tray, or placement of soil or other material to form an earth barrier **(E-COP)**.

C

Camber: A gradual downward slope from the centre of a road to each side of it.

Catchment: A geographical unit that carries surface run-off under gravity by a single drainage system to a common outlet or outlets. Also commonly referred to as a watershed or drainage basin **(E-COP)**.

Catchment hydrology: Term describing the measurable patterns of water flow from a catchment including water yield, flood flows, flood response and other characteristics **(E-COP)**.

Check dam: A small, sometimes temporary, dam constructed within a watertable drain to counteract erosion by reducing water flow velocity.

Colloidal clay particles: Fine clay particles entrained and suspended in water.

Compaction: To apply pressure or vibration to soil or aggregate to strengthen it **(NES-PF)** (Compaction is any process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby increasing the weight of solid material per unit of volume, increasing their shear and bearing strength and reducing permeability.)

Corduroy: A structured load-bearing surface where the logs are laid horizontally and parallel, and there are 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 **(MPI guidance)**.

Culvert:

i. A pipe or box structure that conveys a stormwater flow, or
ii. The entire structure used to channel a water body under a forestry road or forestry track **(NES-PF)**.

Cut-off or cut-out: Shallow channels/earth mounds constructed across a road, track or firebreak and used to divert and control run-off. Cut-offs are constructed to minimise sediment movement and scouring by preventing the accumulation of sufficient flow and velocity to support erosion. Unlike water bars, cut-offs are normally used in impermeable soils and are not used for retaining run-off **(E-COP)**.

Glossary

D

Decommission: The process of actively removing, deconstructing and making safe and secure, engineered structures such as roads and landings that are no longer needed after completion of operations **(E-COP)**.

Deposition: The build-up of material that has settled because of reduced velocity of the transporting agent (water or wind) **(E-COP)**.

Earthflow terrain: Land classified in the electronic tool referred to in item 1 of Schedule 2 (http://www.mpi.govt.nz/growing-and-producing/forestry/overview/national-environmental-standards-for-plantation-forestry/erosion-susceptibility-classification/), and having the dominant erosion process of earthflows and the terrain grouping as follows:

a. hill country developed on crushed argillite or on tertiary-aged mudstone or sandstone, with moderate earthflow-dominated erosion; or

b. hill country developed on crushed argillite, mudstone, or greywacke, with severe earthflow-dominated erosion **(NES-PF)**.

E

Ephemeral flow: A flowpath that flows only briefly during and following a period of rainfall in the immediate locality.

F

Fill: Soil or aggregate, placed to raise the land surface, normally under a strict compaction regime **(NES-PF)**.

Flume/Fluming: An open channel, conduit, made from plastic, galvanised corrugated steel, and sometimes concrete, or timber, which is used to carry run-off from earthworks over loose fill or erodible material so that it can be discharged onto less erodible surfaces **(E-COP)**.

G

Gabion: A cage, cylinder, or box filled with rocks, concrete, or sometimes sand and soil for use in civil engineering and road building.

H

Heading up: A hydraulic head of water above the culvert inlet at times when the culvert's nominal capacity is exceeded **(NES-PF)**.

I

Indigenous vegetation: Vegetation that is predominantly vegetation that occurs naturally in New Zealand or that arrived in New Zealand without human assistance **(NES-PF)**.

Intermittent river/stream: A stream, or reach of a stream, that does not flow year-round (commonly dry for 3 or more months out of 12) and whose channel is generally below the local water table; it flows only when it receives a) base flow (i.e., solely during wet periods), or b) ground-water discharge or protracted contributions from melting snow or other erratic surface and shallow subsurface sources.

L

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

M

Mineral soil: Any soil consisting primarily of mineral (sand, silt and clay) material, rather than organic matter.

Mulch: Covering of loose organic or other materials applied over the surface of soil to protect it from raindrop impact and to enhance certain characteristics, such as improved water retention and seed germination **(E-COP)**.

O

Overburden: The overlying soil and rock that is removed to allow quarrying of the underlying material **(NES-PF)**.

P

Perennial river/stream: A river that is a continually or intermittently flowing body of freshwater, if the intermittent flows provide habitats for the continuation of the aquatic ecosystem **(NES-PF)**.

R

Reno mattress: A double twisted hexagonal woven galvanized steel wire mesh compartmented basket with a rectangular mattress shape. Even distribution of the stone fill ensures that the reno mattress maintains intimate contact with the foundation soil.

Rill: A shallow channel (no more than a few tens of centimetres deep) cut into soil by the erosive action of flowing water.

Riparian zone: That margin and bank of a water body, including the area where direct interaction occurs between land and water systems, that is important for the management of water quality and ecological values **(NES-PF)**.

Glossary

River: A continually or intermittently flowing body of fresh water; and includes a stream and modified watercourse; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal) **(RMA)**.

Road-line salvage: Harvesting of trees from the intended route of a new road prior to its construction **(E-COP)**.

Rock bucket: A specialised excavator bucket with strengthened teeth used to excavate into rock.

Run-off: Surface water from rainfall that flows off sloped areas **(E-COP)**.

Sediment: Solid material that –

a. is mineral or is mineral and organic; and

b. is in suspension, is being transported, or has been moved from the site of origin by air, water, gravity, or ice and has come to rest on the earth's surface, either above or below water **(NES-PF)**.

S

Setback: The distance measured horizontally from a feature or boundary that creates a buffer within which certain activities cannot take place **(NES-PF)**.

Slash: Any tree waste left behind after plantation forestry activities **(NES-PF)**.

Smooth glazed surface: In conjunction with a cut batter, where an application of hydro-seeding will not adhere to the cut surface.

Stabilisation: Includes –

a. seeding:

b. vegetative cover, mulch, or slash cover:

c. compacting, draining, roughening, or armouring by the placement of rock or the use of other rigid materials. **(NES-PF regulation 32(2))**.

Stream: A continually or intermittently flowing body of fresh water; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal) **(RMA)**.

Stumping: The removal/excavation of tree stumps from the ground, usually associated with the construction of infrastructure.

T

Thatching: A cover of loose organic or other materials applied over the surface of soil to protect it from raindrop impact and to enhance certain characteristics, such as improved water retention and seed germination.

W

Water body: Fresh water or geothermal water in a river, lake, stream, pond, wetland, or aquifer, or any part thereof, that is not located within the coastal marine area **(RMA)**.

Water run-off control measure: Structure or measure to reduce the volume or velocity of water run-off and consequently reduce its power to entrain sediment **(NES-PF)**.

Water table: A shaped or engineered depression running parallel to the edge of a road surface that is designed to catch stormwater run-off from the road surface and carry it to suitably located and constructed discharge points **(E-COP)**.

Wetland: Permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions **(RMA)**.

Windthrow: Trees blown down by action of wind **(E-COP)**.