Soil Conservation Service

NSW Rural Fire Service

Fire Trail Design, Construction and Maintenance

Manual

This manual has been developed by the Soil Conservation Service for the NSW Rural Fire Service

Contents

SECTION 1 - Introduction 5

1.1 Description of fire trails 8

1.2 Fire Trail Terminology 10

1.3 Assessment of vehicle carrying capacity 12

SECTION 2 - Before you start 13

2.1 Relevant legislation, policies and approvals applying to this manual 13

2.2 General planning considerations 14

2.3 Location 16

2.4 Fire trail grade and soil erodibility 16

2.4.1 A general guide to soil type stability and sediment delivery 18

2.5 Grades 20

SECTION 3 - TRAIL WORK: Features and methods 23

3.1 Surface Drainage 24

3.1.1 Crowning 24

3.1.2 Infall and Outfall 25

3.2 Table Drains 28

3.3 Cross Banks 29

3.4 Mitre Drains 31

3.5 Spoon Drains 33

3.6 Drainage Line Crossings 34

3.7 Fire trails across wet swampy areas 38

3.8 Drainage control structures at fire trail junctions with other trails 40

3.9 Firefighting vehicle passing and turning opportunities 41

3.10 Culverts 42

3.11 Bridges 45

3.12 Construction equipment 46

3.13 Construction material selection 46

3.14 Earth moving equipment hygiene 47

3.15 Implementation of construction design and techniques 47

3.16 Fire trail batters 48

3.16.1 Batter drop downs 49

3.17 Clearing and maintaining vegetation for the fire trail 50

3.18 Constructing the fire trail surface 51

3.19 Constructing cross banks 55

3.20 Constructing mitre, table & spoon drains 58

SECTION 4 - Construction of new trails 59

SECTION 5 - Maintenance of existing trails 61

5.1 Problem solving 66

5.2 Do's and don'ts 67

SECTION 6 - References / Glossary 73

This manual has been written for the government authorities responsible for planning, constructing or maintaining of fire trails. To effectively serve their purpose, fire trails must be, designed, constructed and maintained to a standard that allows traffic by standard firefighting vehicles. They must also be built in such a way as to minimise the environmental impacts caused by soil erosion and sediment runoff.

SECTION 1

Introduction

Firefighting agencies in NSW use a network of access ways for the purpose of accessing fires and undertaking subsequent fire fighting operations. Fire trails form a subset of access ways utilised by firefighting vehicles. This manual outlines the principles of planning, construction and maintenance of fire trails to minimise soil erosion and provide access for firefighting purposes.

Firefighters rely on public roads, trails and other tracks on public and private land to access the landscape to prevent and contain bush fires.

Historically, decisions regarding the establishment and maintenance of roads and tracks in the landscape have been for a range of reasons (including access for pastoral needs such as fencing and stock management, timber harvesting activities on forested lands, recreational access, and at times specifically for fire management) with variable standards of construction and maintenance. Regardless of the purpose, many of these trails have also provided access for the purpose of fire management, including access for firefighting.

The NSW government has recognised the need to establish a cooperative framework to achieve a more consistent and strategic network of fire trails across private and public lands, to improve accessibility for firefighters during bush fires (that may also support hazard reduction burns). Amendments to the Rural Fires Act 1997, through the Rural Fires Amendment (Fire Trails) Act 2016, provides a legislative basis for the establishment and maintenance of an enhanced fire trail network.

The Rural Fires Act 1997 provides for the NSW Rural Fire Service (RFS) Commissioner to make Fire Trail Standards that (without limitation) sets out the standards required for Fire Trails, including Fire Trail dimensions.

The purpose of this Manual is to support the Fire Trail Standards by setting out the principles of planning, construction and maintenance of fire trails that are required in order to minimise environmental impacts caused by soil erosion and sedimentation. The Fire Trail Standards in combination with this Manual provides for suitably appropriate access for firefighting vehicles commonly used for bush firefighting operations in NSW.

Many of the existing trails have been built at relatively low cost, follow natural landforms, with construction consisting of minimal earthworks, unsealed surfaces and basic drainage structures. The consideration and application of effective erosion and sediment control measures is critically important from an economic and environmental impact perspective. For any new fire trail construction or maintenance proposal, the application of the principles outlined in this manual, will minimise environmental impact, improve trail durability and decrease maintenance frequency and cost.

NOTE 1: This Manual has been prepared to be consistent with the principles of the Blue Book Section 2c unsealed roads.

NOTE 2: This Manual is for use by public authorities and is designed to provide best practice, low cost, practical measures to be considered when planning, designing, constructing or maintaining fire trails. It does not provide guidance or advice on the Environmental Impact Assessment (EIA) procedures required to undertake these works. It is expected that land management agencies will need to undertake the necessary EIA processed prior to undertaking construction or maintenance works. The

Bush Fire Environmental Assessment Code (the Code) may be an appropriate vehicle for the conduct of EIA, if suitable circumstances apply.

Note 3: This Manual must be used by public authorities for the purpose of constructing and maintaining designated or registered fire trails as per the Fire Trail Standards.

Note 4: This Manual may be used by public authorities for the purpose of constructing and maintaining any fire trail that constitutes part of the fire trail network within a Fire Access and Fire Trail (FAFT) Plan approved for the area, or an existing fire trail identified as a treatment in an approved Bush Fire Risk Management Plan where there is no FAFT plan approved for the area, or vehicular control lines used for a bush fire hazard reduction burn (as per the Bush Fire Environmental Assessment Code).

It is expected that the user will have some level of understanding of appropriate road design, construction and maintenance techniques. The manual provides advice and figures to illustrate appropriate techniques, however, given the variability in any given landscape, the manual may not cover all applications. Where the user is uncertain about the technique to be employed and/or the complexity of the landscape or situation demands, suitable qualified technical advice should be sought. The NSW Soil Conservation Service is one recognised provider, that may be able to assist in providing this advice.

***Photo 1 -** A typical well maintained fire trail*

***Photo 2 -** A poorly maintained trail that limits firefighting access and has caused environmental damage.*

IF YOU ARE:

A Constructing a new trail

B Maintaining an existing trail

Complete reading SECTION 1 to give yourself a general understanding of trail characteristics

Read SECTION 2 for information on what is needed before you start on the ground

Read SECTION 3 to understand the features and techniques involved in maintaining/constructing

Read SECTION 4 for pointers and tips on how to build a trail with the greatest function and least maintenance costs

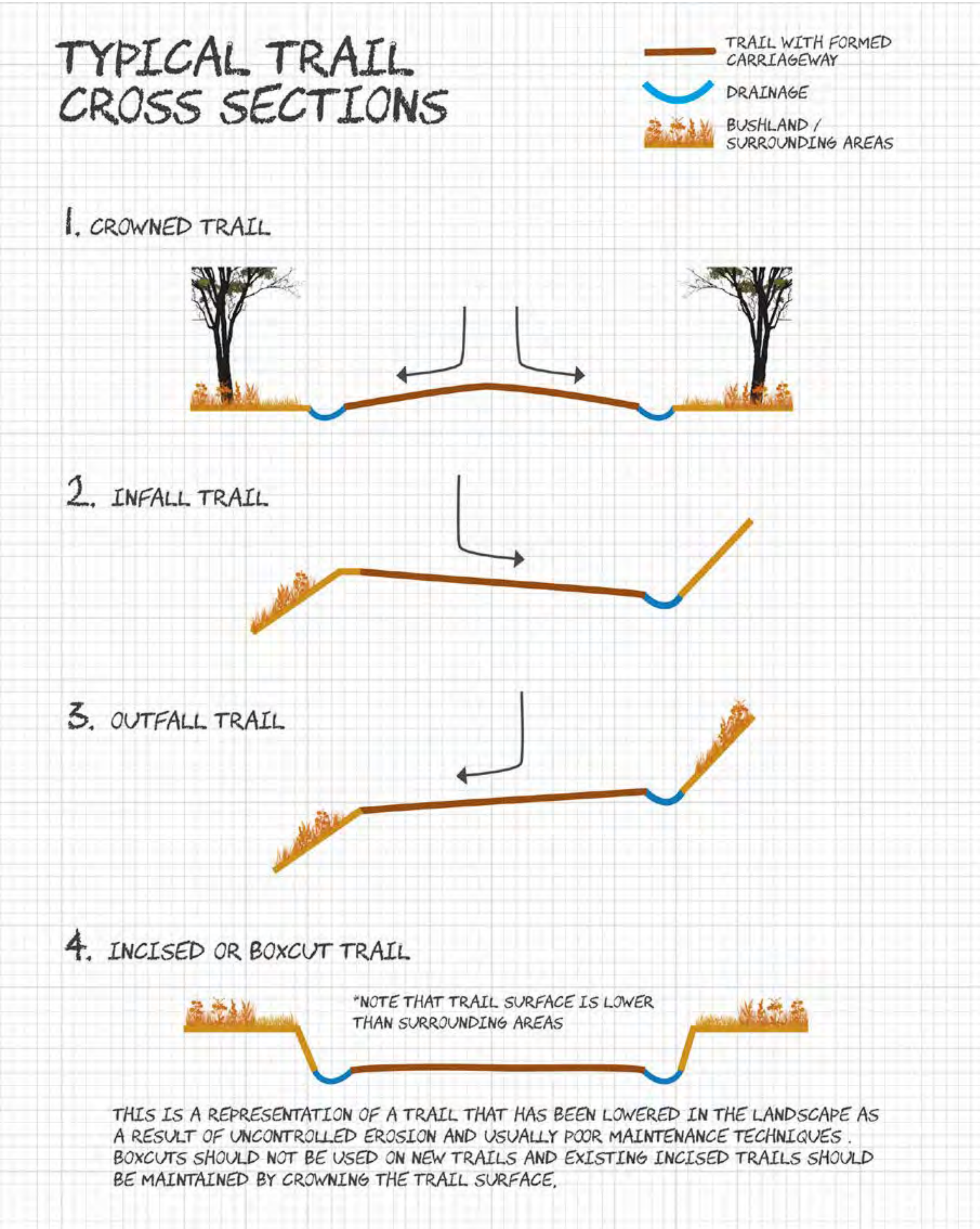
Read SECTION 5 for direction on how to identify, assess and remediate problem areas

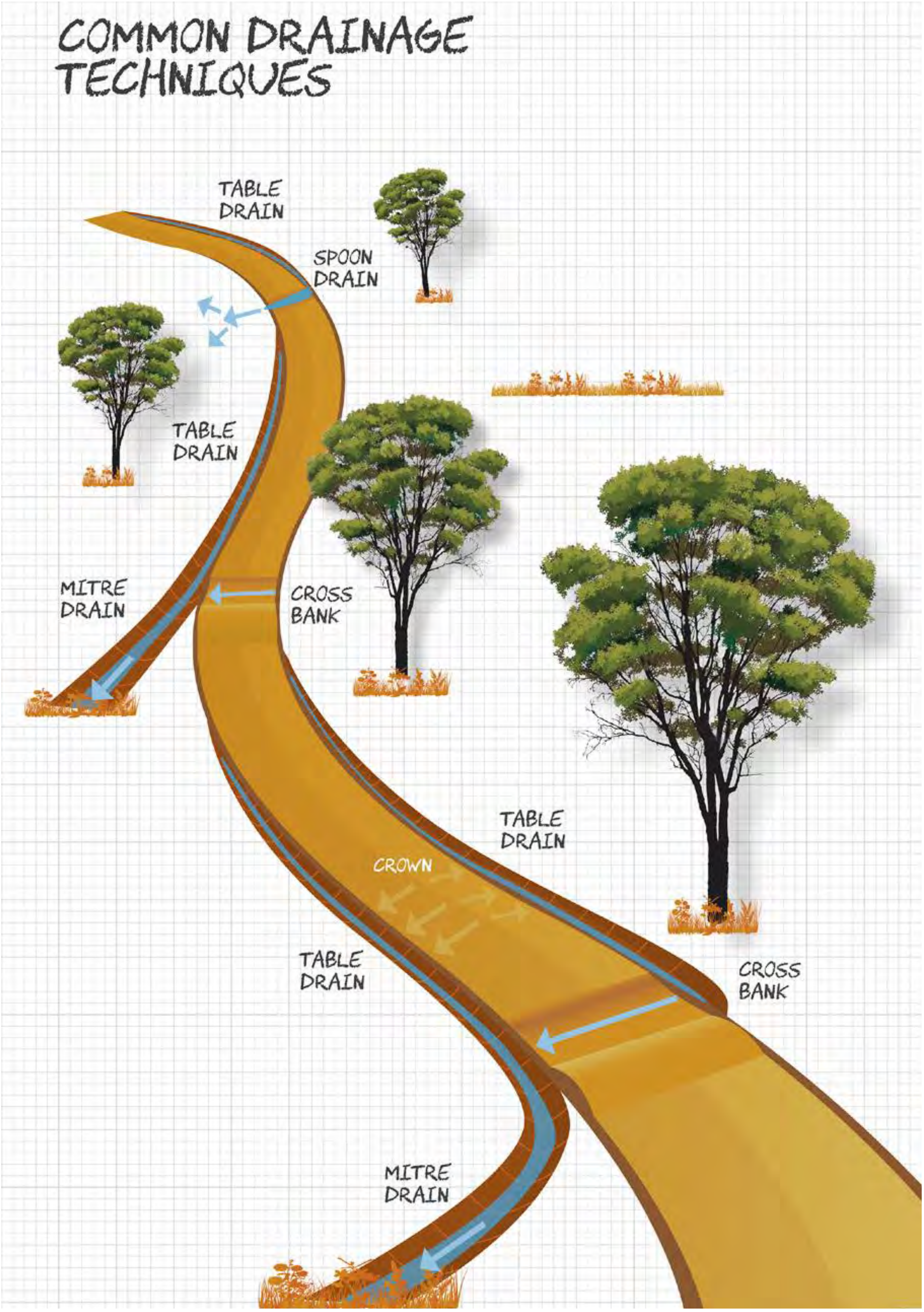
Read SECTION 6 for the glossary and further sources of information

1.1 Description of fire trails

Fire trails must meet the specific needs of fire fighting vehicles. Although trails may have multiple users, the standard for typical fire fighting use and the minimum and maximum dimension for trails are defined in the RFS Fire Standards document.

Fire trails are often defined by their cross-sectional shape within the landscape. This shape, or geometry, of a trail has great impact on management considerations. Typical trail cross-sections are provided below and are referred to throughout the document. In addition, there are many common features of trails relating to batters and drainage that should be understood before starting work.





The most effective way to drain trails is to construct and maintain crowned trails with table drains, mitre drains and cross banks. Infall and outfall drainage are also acceptable for drainage but only where crowning cannot be established. Wet areas on trails will need to be treated by placing rock and gravel.

Wherever possible, pipes and culverts should not be used in drainage lines as both are prone to blockage and drainage failure. Instead open rock armoured flowlines and open rock drains should be constructed. On larger flowlines and small creeks rock armoured bed level crossings can be placed to provide secure access.

There are many fire trails already established in the landscape. Any construction work must not exceed the dimensions as set out in the RFS Fire Trail Standards, unless existing dimensions already exceed the standards and it would create more impact by reducing and redesigning the trail.

Fire trail construction is to follow the undulations in the landscape and keep cut and fill to the absolute minimum. Fire trails must be designed to minimise erosion and the movement of sediment into waterways.

Erosion associated with fire trails can:

- be a factor in destroying trafficability and creating safety problems
- contribute to inferior water quality and the sedimentation of streams and watercourses.

By constructing the fire trail with effective surface drainage, it is possible to reduce erosion damage and the need for frequent maintenance.

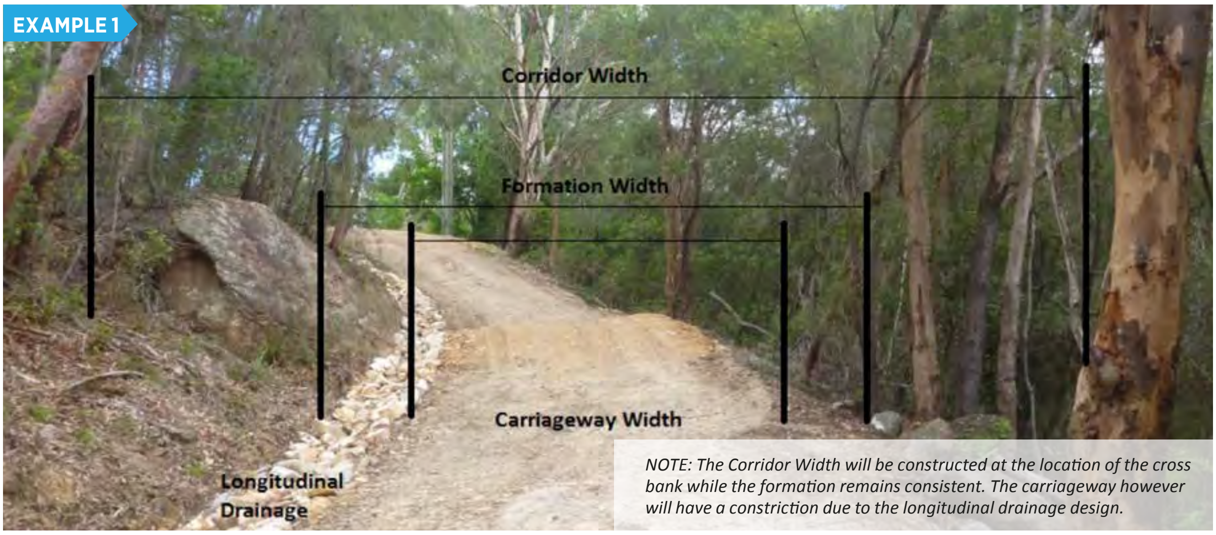
Uncontrolled run-off is the primary factor in causing damage to trails. The key to minimising soil erosion and management costs ***is the provision and maintenance of effective drainage structures*** to drain water from the trail surface.

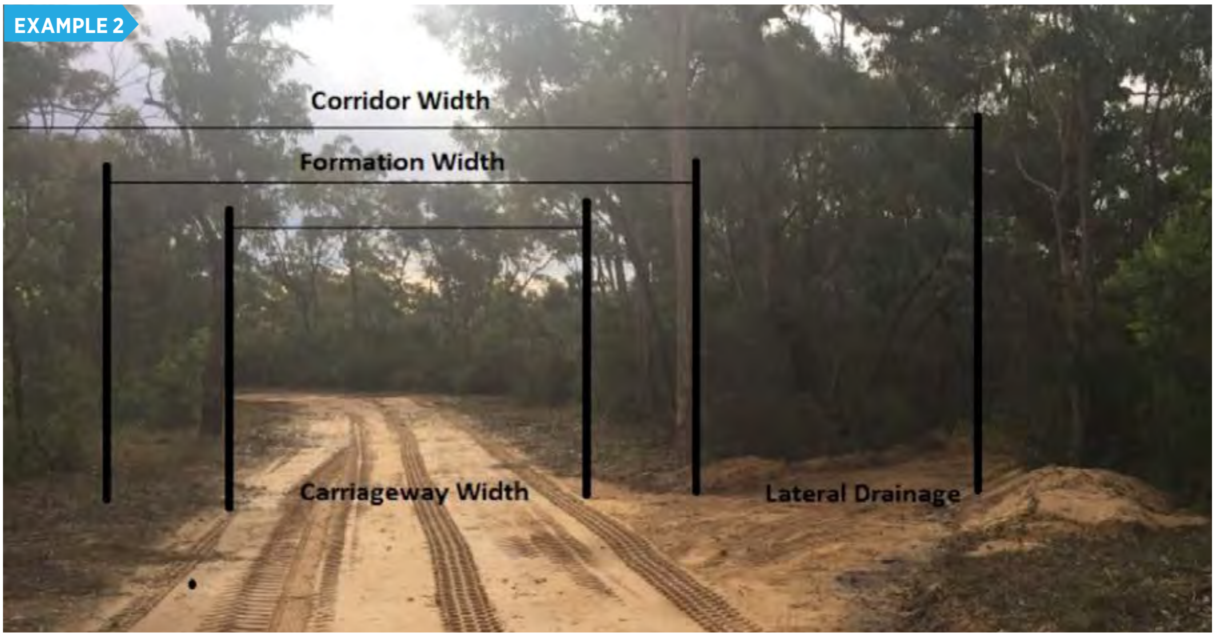
1.2 Fire Trail Terminology

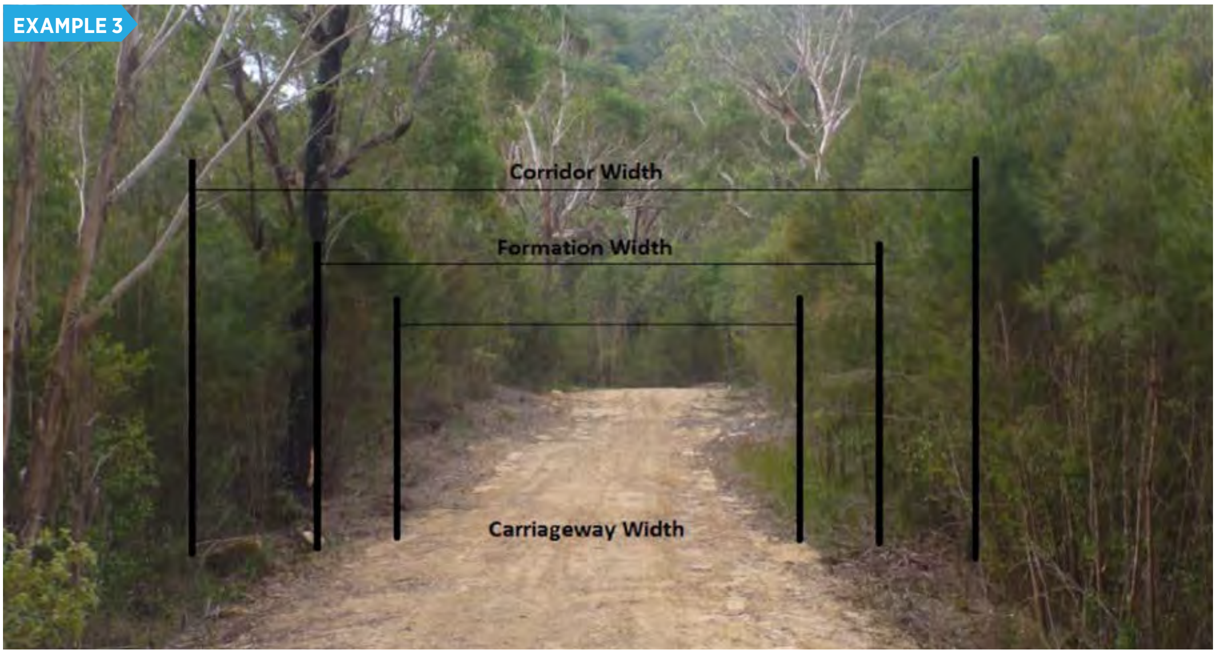
In order for people assessing fire trails to use consistent terminology, when assessing and describing the features of a Fire Trail, the following terms, as set out in the RFS Fire Trail Standard, will be used:

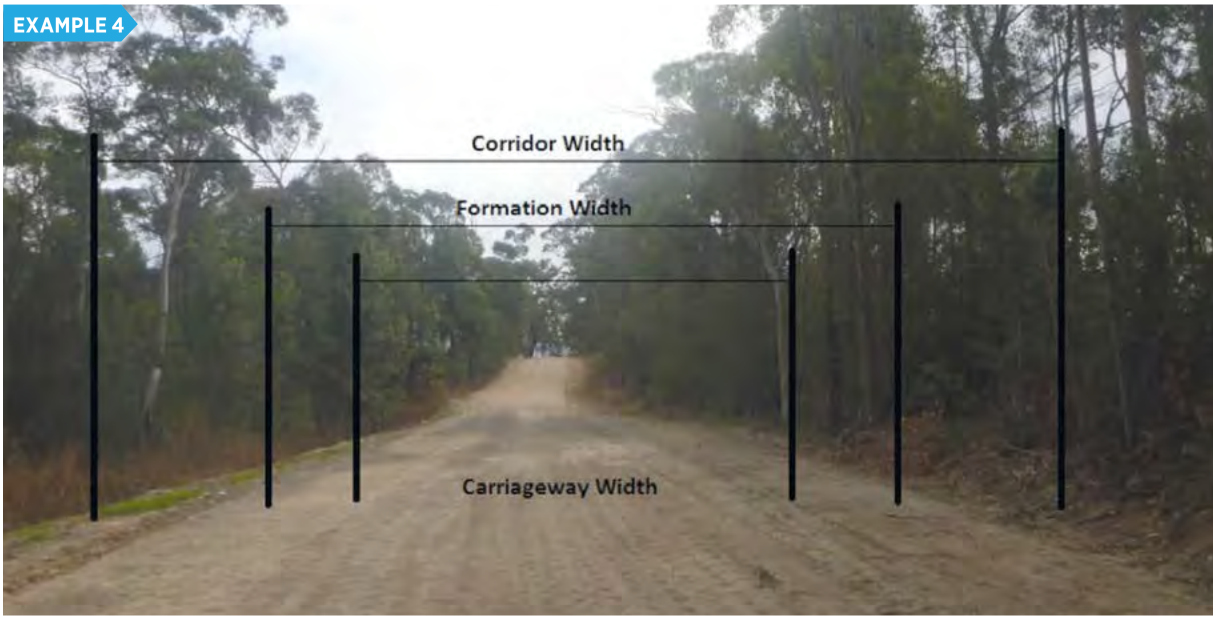
- **Carriage Way Width or Width** – refers to the width of the Trafficable Surface (ie that section of the Fire Trail that provides unobstructed access for the designated VCC). There is no requirement for this to be entirely mineral earth (ie grasses or low vegetation that does not impede access and provides a protective soil cover is acceptable).
- **Formation Width** – refers to the total width of the Fire Trail, including the formed carriageway, Shoulders, Verges and Table Drains. It includes the working corridor for fire fighter access.
- **Road Corridor Width** – refers to the full extent of the cleared (disturbed) corridor required to construct the Fire Trail and includes cut and fill batters, catch drains, mitre drains, turning opportunities and passing bays.

See examples 1 to 6:

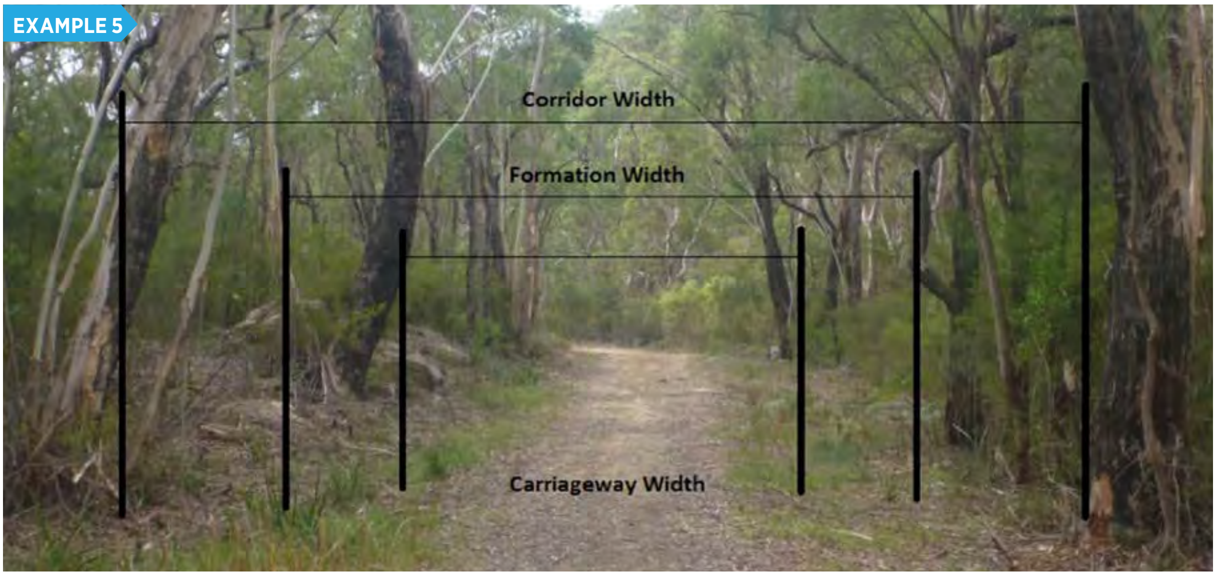



EXAMPLE 2
Corridor Width
Formation Width
Carriageway Width
Lateral Drainage

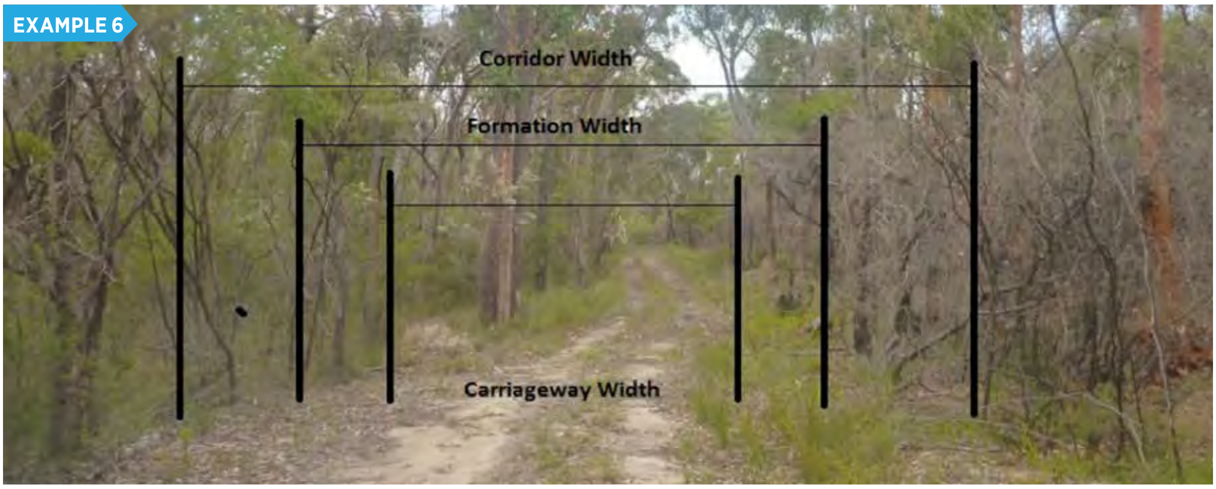

EXAMPLE 3
Corridor Width
Formation Width
Carriageway Width


EXAMPLE 4
Corridor Width
Formation Width
Carriageway Width

EXAMPLE 5



EXAMPLE 6



1.3 Assessment of vehicle carrying capacity

Fire trails are classified on the Vehicle Carrying Capacity (VCC), where VCC describes the type of fire fighting vehicle that the trail is to accommodate.

Three categories are provided:

1. **Category 1** (or CAT 1) large 4WD fire tanker
2. **Category 7** (or CAT 7) medium 4WD tanker
3. **Category 9** (or CAT 9) small 4WD tanker

If you are assessing a trail for its suitability as a fire trail, you will need to be take into account the designated VCC. As the standard required increases with the size of the firefighting vehicle the trail is to accommodate. In order to minimise costs and environmental impact, the trail should be constructed and/or maintained to provide appropriate access for the designated VCC. Unless the road or trail has a primary use which requires a higher standard than that required for firefighting access (ie the road provides 2WD to a popular picnic site in a national park or is a major forest haul road) construction or maintenance over and above that required for the fire access is not recommended.

The trail requirements for each VCC are as set out in the Fire Trail Standard.

LINK https://www.rfs.nsw.gov.au/plan-and-prepare/fire-trails

SECTION 2

Before you start

2.1 Relevant legislation, policies and approvals applying to this manual

It is important to understand the planning framework for fire trails (as per all works) must comply with the relevant legislation and policies prior to commencement including any necessary approvals.

This manual provides the considerations required of government authorities to address soil erosion impacts that may arise as a result of constructing or maintaining a fire trail or a vehicular control line (undertaken in accordance with the RFS Fire Trail Standards). This manual is to be applied as a component of the approval mechanism undertaken.

Approval mechanisms may be in the form of a:

- Bush Fire Hazard Reduction Certificate issued in accordance with the Bush Fire Environmental Assessment Code;
- Review of Environmental Factors (REF) under Part 5 of the *Environmental Planning and Assessment Act 1979*;
- Assessment in accordance with the Infrastructure State Environmental Planning Policy (ISEPP); or
- Any other relevant approval mechanisms.

Each of the various environmental approval mechanisms have differing requirements for a range of other environmental matters. Such considerations are informed and dealt with in accordance with the relevant legislative requirements. Nevertheless, it is important that the proposed works are conditioned to address the requirements of this manual and any other environmental considerations arising.

ALERT - Irrespective of whether for the purpose of construction or maintenance, any watercourse or waterbody crossing, whether temporary or permanent, which:

1. requires placing material on the bed of the watercourse or waterbody (i.e. reclamation) and/or
2. may obstruct the free passage of fish,

may only be undertaken in accordance with an approval issued for that purpose by the Department of Primary Industries - Fisheries.

In addition, any modifications to the bed of the watercourse or waterbody may only be undertaken in accordance with an approval issued for that purpose by the Department of Primary Industries - Fisheries.

2.2 General planning considerations

Construction

Construction of a new fire trail requires the input and direction of an experienced and qualified soil conservation practitioner.

Careful consideration of the following can minimise later fire trail erosion and reduce maintenance needs:

- the purpose of the fire trail
- the type and volume of traffic (firefighting vehicles and other vehicles with access)
- soil erosion hazards present along the fire trail
- the type and number of drainage line crossings
- topographic constraints, for example, steep slopes, rock outcrops, swampy areas
- potential mass movement areas
- vegetation type, density and size
- the feasibility of proposed construction - should an alternative site be examined?

Alternatives to the location of a fire trail must always be considered, both at the landscape scale and along the selected route.

A typical alternative to a difficult creek crossing is to consider accessing the area from the other side rather than crossing the creek.

Fire trails should follow the ups and downs of the land contours, *see Photo 3*. This results in small mini catchments where the runoff can be easily managed with small runoff quantities. Firefighting vehicles have great capability in traversing undulating terrain. Earthmoving contractors have a tendency to construct straight and flat as you would a sealed road. For unsealed trails the opposite is best — undulating and winding trails with numerous locations for the disposal of draining water, *see Photo 4*. Cut and fill construction is to be kept to the absolute minimum as required for fire trails.

Photo 3 - *An undulating trail with cross banks creates small catchments to control drainage flows.*

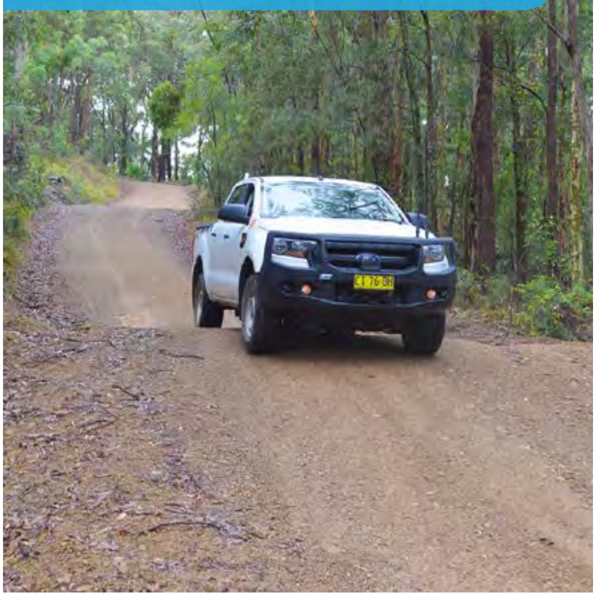


Photo 4 - *An undulating trail with cross banks creates small catchments to control drainage flows.*

Construction And Maintenance

Locations of threatened biodiversity, and Aboriginal and other heritage identified for protection as a result of an Environmental Impact Assessment (EIA) should be avoided in the planning of new fire trails. Whether constructing a new fire trail or maintaining an existing trail, these sensitive locations must be marked and protected prior to carrying out any work, *see Photo 5*.

***Photo 5 -** Threatened species and heritage items are identified for protection prior to any work.*

Planning considerations, prior to works should also include, but should not be limited to:

1. Preparation of a briefing by the land manager to contractors outlining "sensitive areas" and work site restrictions (ie this may include instructions on earth moving machinery hygiene measures, access restrictions – earth moving machinery is not to exit the previously disturbed footprint, etc)
2. "Dial Before you Dig"
3. Preparation of a sediment control plan
4. Preparation of Safe Work Method Statements (SWMS) – that identify work place hazards such as power lines and dial before you dig precautions

CAUTION - If works should disturb an item of potential Aboriginal cultural heritage, works should stop immediately. The site supervisor should advise the land manager, who in turn will need to contact the Office of Environment and Heritage for further advice.

2.3 Location

A correctly located trail will provide satisfactory access and minimise maintenance requirements.

When locating a fire trail:

- follow the contour of the land or a ridgeline, avoiding steep slopes and minimising cut and fill batters
- use topographical maps and geo-spatial information to locate obstacles to be avoided
- select a proposed route and walk it to ensure the route is the best option
- use natural features such as benches and shelves
- maximise the distance of a fire trail from a stream to allow an effective vegetation buffer to contain any sediment flowing from the fire trail.
- A minimum riparian vegetation buffer of 20m is generally required, but check your approvals.

Avoid physical features which may indicate the possibility of mass movement problems such as:

- high "erosion hazard" soils – Class C and Class D, *see Table 1.*
- slopes with steps, clay beds or hummocky topography
- long, steep, unstable slopes, especially where bedrock is highly weathered
- moisture laden footslopes.

The construction of fire trails should only be undertaken within riparian areas if:

- there is no practicable alternative route available because of topography and slope constraints,
- it is located as far as practically possible from the waterway or waterbody, and
- clearing of native vegetation in riparian buffer zones is kept to the minimum necessary.

New fire trails may be constructed within riparian areas if they are for the purpose of crossing a watercourse or waterbody. Watercourse or waterbody crossings are inclusive of means such as bed level crossings or bridges. The number of crossings must be no more than the minimum required and where there is no other suitable alternative. Construction includes widening or a change of alignment. Always check whether an approval is required from the Department of Primary Industries - Fisheries

2.4 Fire trail grade and soil erodibility

Irrespective of whether constructing a new fire trail or maintaining an existing trail, it is important to identify the fire trail grade and soil erodibility.

The slope of the fire trail and the ability of the soil to resist the energy in flowing water (soil erodibility) contribute to the quantity and type of sediment that leaves the trail. The two main soil characteristics that contribute to a soil's ability to resist erosion, and the level of trail erosion and sedimentation that results, are the soil's coherence and sediment delivery.

Soil coherence refers to the ability of the soil particles to resist the erosive energy applied by flowing water. For example, low coherence soils are typically sandy soils or fine particle soils dominated by silt or dispersible clay. These soils do not have enough bonding agents to bind the particles together and are prone to detach from the larger soil aggregates and move easily in the presence of flowing water.

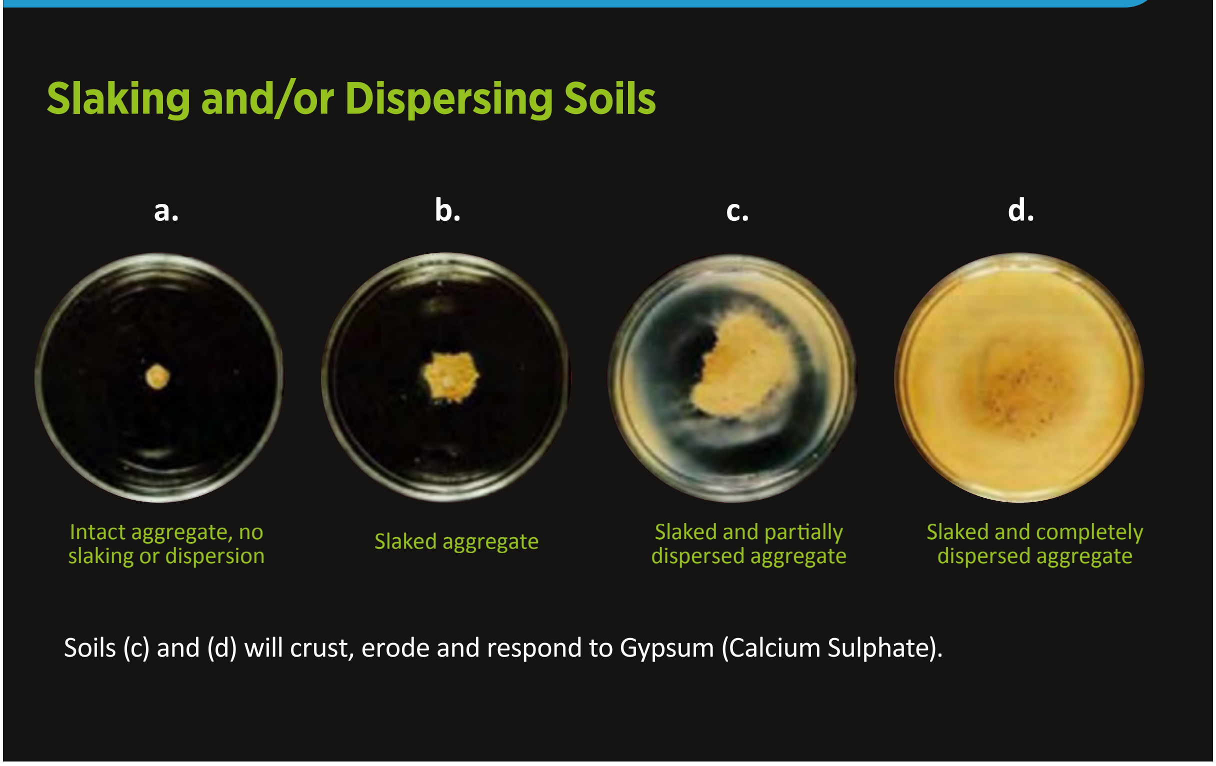
Sediment delivery refers to the type of sediment that results from the eroding soil type, and therefore determines how far the sediment will travel from the trail. Key soil characteristics that determine the type of sediment delivered off site are the size of the soil particle and the stability of the soil aggregate (groupings of soil particles). For example, soils that have sand size particles will produce coarse size sediment that, in general, will not travel far from the erosion site, whereas silty and clay type soils will produce sediment that will travel a long way in flowing water.

Soil aggregate stability has two aspects that have a direct bearing on the type of sediment and how far it will travel off site. Slaking and dispersion both influence the type of sediment that will result from an eroded soil. The level of clay in a soil can influence the amount of sediment that is generated. Stable clays usually have a strong binding influence on soil aggregates and lead to stable aggregates in the presence of water. Unstable clays have a high level of sodium attached to the clay particle and are termed 'sodic soils'. Usually these soils are stable when they are dry, however, they become unstable in the presence of water, *see Figure 1*.

Slaking is the partial breakdown of soil aggregates in water due to the swelling of clay and the expulsion of air from pore spaces as the soil is wetted. If the soil is a sandy soil then the particles will be large and will not travel too far from the erosion site. Clay particles are usually stable and are still attached to the sand and silt and so clay will not leave an area, *see photo b in Figure 1*.

Dispersion is the process whereby a soil aggregate will break down into their separate constituent parts (clay, silt and sand) when in the presence of water. The sediment that results will be transported easily by flowing water with the sand particles usually deposited close to the erosion site, but the silt and clay particles will be transported until the flowing water stops moving, *see photos c and d in Figure 1*.

***Figure 1 -** The sediment types that result from slaking and dispersion of soil aggregates.*



2.4.1 A general guide to soil type stability and sediment delivery

A soil erodibility /stability classification system is used on a routine basis to determine the trail management practices required for fire trail construction and maintenance activities in order to minimise the amount of sediment that will flow off site into local waterways. It is a useful predictor of how likely a soil is to cause turbidity in receiving waters and how far the sediment is likely to travel. The general concept is outlined in *Table 1* below, with four soil classes resulting that combine the soils coherence and type of sediment that results. Each of the four classes are defined as follows:

- **Class A soils** are stable, well aggregated with low potential to erode
- **Class B soils** are coarse grain / sandy, have weaker structure throughout, are erodible but, because they are coarse grained, sediment doesn't travel far
- **Class C soils** have medium to fine grain B horizon, are relatively stable but, because they have a high silt and/or clay content, their sediment will travel much further than Class B soil sediment.
- **Class D soils** are highly erosive and dispersive and because they also have a high silt and clay content pose the greatest hazard.

An appreciation of the soil types present in an area and their corresponding soil stability is necessary to understand how these soils will react if a trail is to be built on them and to understand that the drainage requirements for them will vary. An inspection of existing roads and trails in an area, particularly an inspection of cut batters and fill batters can provide some guidance as to how stable/ unstable the soils in an area are likely to be and what drainage structures will be required to minimise erosion and subsequent maintenance requirements.

***TABLE 1 -** A soil classification system that shows the general relationship between soil coherence and sediment delivery.*

SOIL ERODIBILITY (potential for soil to release sediment)	**POTENTIAL FOR SEDIMENT TO MOVE LONG DISTANCE**	
	Low sediment delivery (sediment is coarse)	**High sediment delivery** (fine clay particles)
Low soil erodibility (Ie High soil coherence)	**CLASS A** Low soil erodibility	**CLASS C** Very high soil erodibility
Hi soil erodibility (Ie Low soil coherence)	**CLASS B** High soil erodibility	**CLASS D** Extreme soil erodibility

The Soil Class Map of NSW will guide practitioners as to the likely soil classes present along a trail. The information in *Table 2* below will help to confirm the soil class and to identify the potential soil stability. Note, there will be many fire trail routes where more than one soil stability class will be present.

TABLE 2 - *Detailed information on soil Classes used in Fire Trail assessment.*

	Low sediment delivery	**High sediment delivery**
High coherence	**Class A soils** are stable, well aggregated with low potential to erode. Brown and red soils derived from darker geology like basalt and dolerite. Stable soils with high gravel content derived from siltstones and sediments such as on ridgelines where the high stone content 'armours' the soil. Soils derived from organic sources such as peats. These soils have a strong structure, are freely drained, usually red & darker coloured soils due to high iron content. These soils show few signs of erosion and sediment movement, with little signs of sheet or rill erosion on exposed surfaces. These soils generally require little management effort to achieve revegetation.	**Class C soils** have medium to fine grain B horizon, are relatively stable but, because they have a high silt and/or clay content, their sediment will travel much further than Class B soil sediment. Soils formed on fine-grained acid volcanic, metasedimentary and sedimentary rocks as well as found on colluvial/alluvial surfaces, range of fine-grained highly-weathered siliceous rocks and some basic and intermediate volcanic lithologies, such as trachyte. Two main soil types: • **Duplex soils**, called red and yellow podzolic, red-brown earths with sandy silt to loamy topsoils, with clay or silty B horizon, that are slowly permeable, weakly to moderately structured, often with a pronounced pale A2 horizon. B horizons usually yellow or grey to light brown colours, commonly mottled • **Weakly to moderately structured soils**, called red and yellow earths, have silty to clay textures that change gradually down the profile or have a uniform texture throughout the profiles. • Both have a tendency to slake to small stable aggregates (not individual particles) and not highly dispersible • These soils hard set when dry but are often boggy when wet.
Low coherence	**Class B soils** are coarse grain/sandy, have weaker structure throughout, are erodible but, because they are coarse grained, does not travel far. Due to their sandy nature they have a weak structure and can be crushed by finger. These soils contain little clay. These soils develop on coarser grained granites and sedimentary rock, and coarser alluvial materials. These soils have weak inter-aggregate strength and, as such, it is easy to detach soil particles, but the coarse nature of the eroded particles means that they will not move too far from the erosion source. They exhibit sheet wash that is confined to trail drains. It is relatively easy to control the erosion that does result so that sediment is not delivered to local waterways. Roads, table drains & exposed areas often contain a loose sandy wash on the surface of the soil.	**Class D soils** Clay or silt textured soils, which slake to very fine particles and/or are **highly dispersible**. Massive to coarsely structured, frequently sodic. Often have bleached surface horizon. May include duplex soils with sandy non-coherent surface over unstable clay subsoil. Generally found on lower slopes and low undulating terrain associated with weathered colluvium and alluvium or siliceous rocks.

An appreciation of the soil types present in an area and their corresponding soil stability is necessary to understand how these soils will react if a trail is to be built on them and to understand that the drainage requirements for them will vary. An inspection of existing roads and trails in an area, particularly an inspection of cut batters and fill batters can provide some guidance as to how stable/ unstable the soils in an area are likely to be and what drainage structures will be required to minimise erosion and subsequent maintenance requirements.

2.5 Grades

In planning the fire trail for the best grades, consider all the alternative routes, firstly from the topographic maps and then by inspection in the field. Aim to limit soil and vegetation disturbance when selecting the route.

Refer to RFS Fire Trail Standard and use *Table 2 and 3* as a guide to the relationship between soil type and trail slope and vehicle safety. A summary guide to track location and construction in relation to slope and soil type is as follows:

- Fire trails should have at least a slight grade to allow free surface drainage and to avoid excessive ponding in the wheel tracks.
- It is difficult to construct trails on steep slopes and still take care of the trail drainage without erosion taking place.
- The grade of a track should be less than 18% (10˚) for ease of firefighting vehicle movement. Note that the RFS Fire Trail Standards has set a maximum track grade of 15˚ (or 26.6% or 3.73:1), unless a performance solution is approved. See RFS Trail Standard and Table 3 above.
- Note that effective, easily trafficable cross banks can be built only on trails to approximately 21% (12˚) grade. Sections steeper than 21% (12˚) will require special drainage works.
- Where it is necessary for grades to exceed 28% (15˚) on Class A and Class B soils and 21 % (12˚) on Class C soils, gravelling and more sophisticated road drainage will be required.
- Trails in Class D soils should avoid sloping land above 10 % (approx. 5 degrees).
- In some soil types (especially Class C and D) erosion will occur on much lower slopes than is expected. As a result, these trails will create sediment on slopes that are lower than a four wheel drive vehicle can negotiate with ease. It is critical to consider this issue in the assessment of trail location and its proximity to waterways.
- Sections of poorly drained trails can quickly become un-trafficable, especially if located on Class B, Class C or Class D soils as described in *Table 1*
- See *Table 4 page 28* Cross Bank Spacing, Section 3.3 for guidance on cross bank spacing on the different soil types.

***TABLE 3 -** Relationship between gradient, percent slope and degrees.*

Gradient x m (H):1m (V)	Percent slope	Degrees	Comment
100m horizontal :1m vertical	1	0.57	
50:1	2	1.15	
25:1	4	2.3	Min cross fall slope on fire trails
20:1	5	2.86	
15:1	6.67	3.82	Outfall slope
10:1	10	5.71	Avoid Class D soils on slopes above 10%. This is the Max safe outfall slope before vehicles slip sideways on wet surfaces.
7.12:1	14.4	8	
4.7:1	21.3	12	Upper limit of cross bank constructability. Gravelling and sophisticated road drainage required on Class C soils
3.73	26.6	15	Upper limit of slope for a Cat 1, 7 & 9 vehicle in RFS Fire Trail Standards.
3.5:1	28.7	16	Gravelling and sophisticated road drainage required on Class A and B soils
3:1	33	18.26	State Protected Lands
2.75:1	36.4	20	Upper limit of safe slope for a Cat 7 & 9 vehicles
2.48:1	40.4	22	Upper limit of construction of roll over banks on Class A soil
2:1	50	26.6	
1:1	100	45	

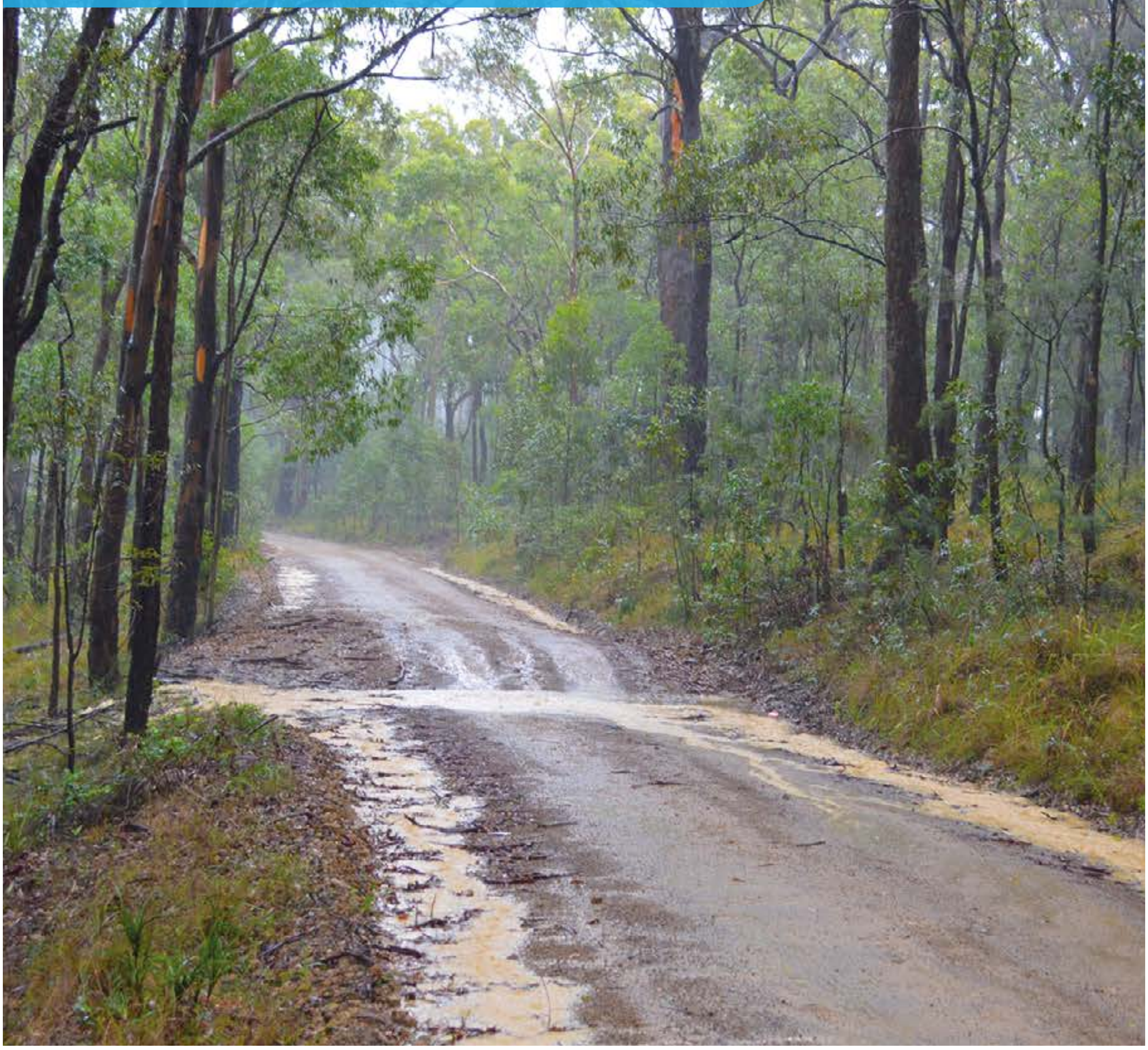
SECTION 3

TRAIL WORK: Features and methods

After taking soil capability into consideration the key aspect to erosion control is to drain water off the fire trail as soon as possible and to determine where water will run off in a controlled way, so the water's energy is dissipated.

These disposal points where water leaves the trail will be determined by the landscape immediately adjacent to the track, *see Photo 6*. When constructing fire trails, choose these points first and then maintain or construct to these drainage disposal points. Water disposal areas should preferably be located on flat ground and preferably vegetated. If not vegetated, an appropriate method of slowing the runoff of silt (ie, sump or silt fencing) should be employed. For examples, *see section 6*. All disposal points should be on hardstand or vegetation where possible, where this is not achieveable sediment control measures can be installed and maintained.

Photo 6 - *A well maintained crowned trail with functioning drainage measures managing runoff after intense rainfall.*



3.1 Surface Drainage

Effective surface drainage is required on fire trails to control runoff, preventing it from concentrating and reaching erosive speeds. A number of techniques can be used to provide surface drainage, one of which is to provide crossfall on the trail.

There are three forms of crossfall drainage:-

1. Crowning

2. Infall

3. Outfall.

3.1.1 Crowning

Fire trails constructed on ridges or gentler slopes should be crowned, *Figure 2 and Photo 7*. Drainage is easiest on tracks that are "crowned" because crowning of the fire trail surface will allow water to be shed to both sides of the track.

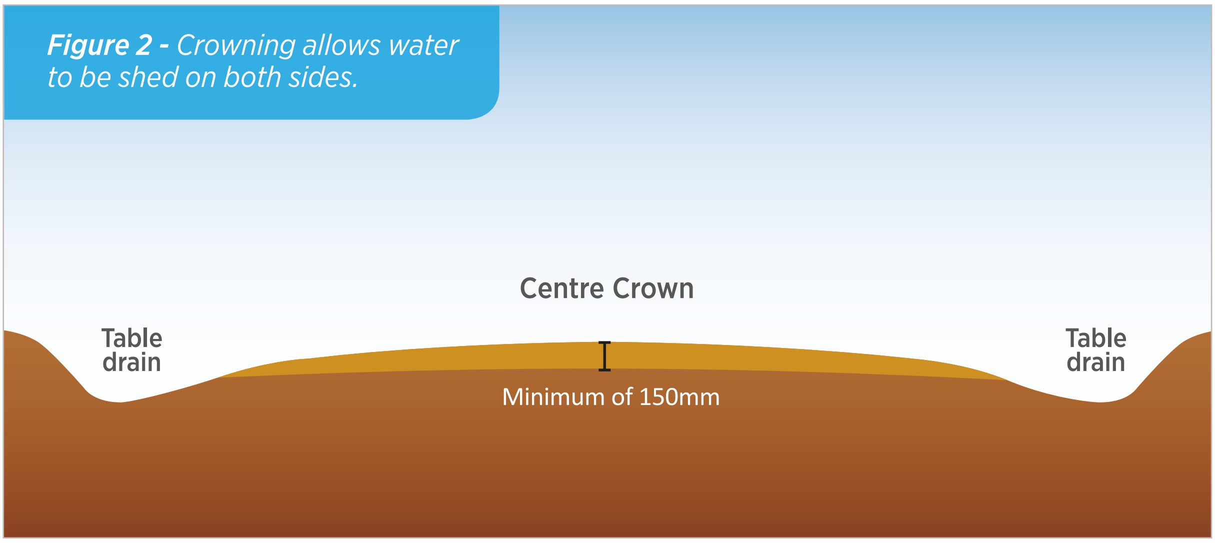


Figure 2 - *Crowning allows water to be shed on both sides.*

Crowning is particularly suitable on steep sections of track in conjunction with spoon drains.

Photo 7 - *Trail crowning*

3.1.2 Infall and Outfall

Infall

Occurs when the surface of the fire trail has sufficient cross slope to cause water to flow off the trail into the hillside rather than along it. *See Figure 3 and Photo 8 below*.

The minimum cross slope required to achieve such crossfall is 1:25. For safety reasons the maximum crossfall used should generally not exceed 1:10. Infall may be used for areas with large, unconsolidated batters, conversely, outfall may be used in areas of small fill area or batter.

Figure 3 - *Infall drainage*

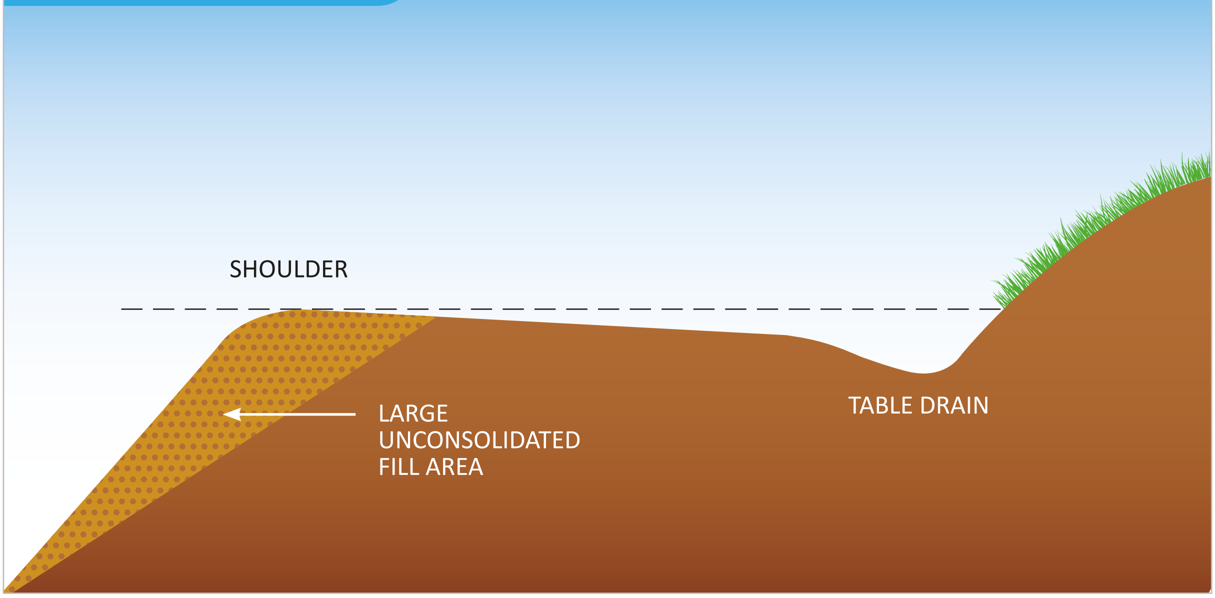
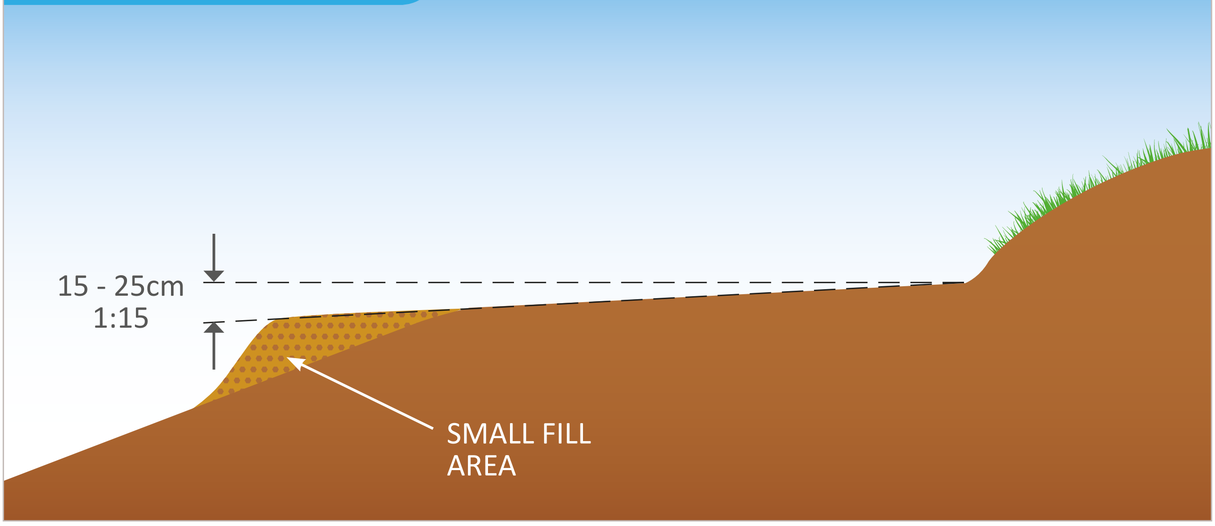


Photo 8 - *An infall trail*

Outfall

Occurs when the surface of the fire trail is built sloping away from the hillside. In such cases, runoff will flow across the trail, away from the hillside and over the road batter. *See Figure 4 and Photo 9 below*.

Figure 4 - *Outfall drainage*



Outfall drainage is preferred to infall drainage except when:

- fill batters are poorly consolidated and likely to erode
- fill batters exceed 1.5 m in height. (See Section 3.16 for an explanation.)

In these situations, use infall drainage. Table drains, cross banks and batter drop down drains may also be required as described in Sections 3.2, 3.3 & 3.10.

Outfall drainage is generally sufficient to ensure control of runoff. This form of drainage reduces runoff along the trail, directing it across the surface and over the trail edge. The low fill batters associated with this standard of trail can often withstand the dispersed flow of outfall drainage.

Photo 9 - *Outfall drainage*

To ensure effectiveness of the outfall, remove any earth windrow which develops at construction or grading on the downslope side of the fire trail. *See Photo 10*.

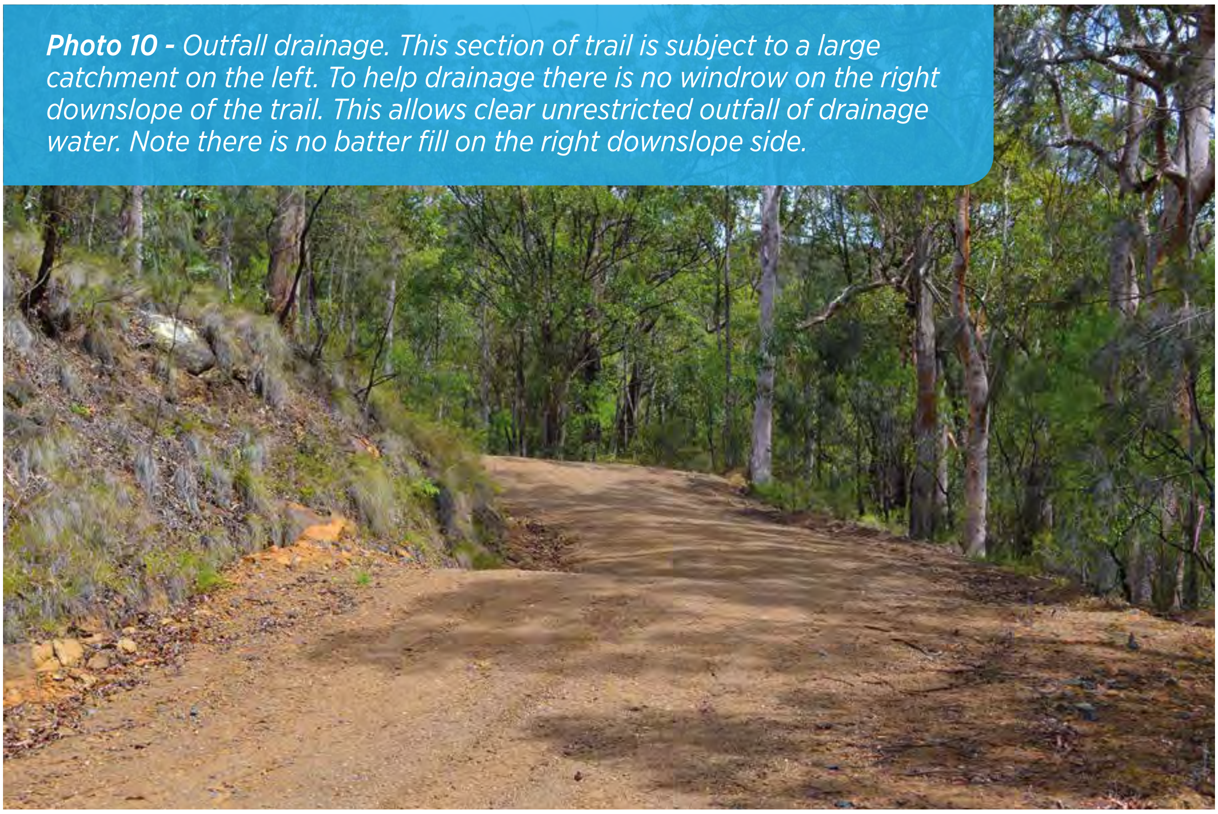


Photo 10 - *Outfall drainage. This section of trail is subject to a large catchment on the left. To help drainage there is no windrow on the right downslope of the trail. This allows clear unrestricted outfall of drainage water. Note there is no batter fill on the right downslope side.*

Where highly eroded trails are being repaired, outfall drainage can be facilitated by a rock lined table drain. *See Photo 11*.

Photo 11 - *An outfall on a re-established and previously highly eroded trail. This trail includes a rock lined table drain as these soils are highly erodible.*

The rock lined table drain, checks water flow and protects the erodable soils in the table drain from erosion.

3.2 Table Drains

Table drains are the side drains of a fire trail. They run parallel with the shoulders and form part of the trail, see *Photo's 12 & 13*. Their purpose, when properly constructed, is to conduct runoff safely away from the trail area.

They are usually parabolic in shape and drained at predetermined intervals by cross banks or mitre drains. See Sections 3.3, 3.4 and 3.5. The steeper the slope and more erodible the soil, the shorter the distance between these outlets.

Photo 12 - *Table drains.*

Table drains need to have depth and capacity to accomodate drainage volume with frequent drainage outlets such as mitre drains. *See Photo 13*.

Photo 13 - *A table drain. The right-hand table drain is too shallow and the meanders will erode the trail over time. An additional mitre drain is required. The left-hand table drain is well formed and functioning correctly.*

3.3 Cross Banks

Where runoff cannot be controlled simply with outfall drainage, banks can be constructed across the fire trail to intercept runoff and direct it across the trail surface. Correctly located and built, cross banks can be easily negotiated by vehicles and achieve long-term and low maintenance trail drainage, *see Photo's 14 and 15 below.*

In choosing sites for cross banks, common sense dictates selecting the most suitable outlet in the vicinity of the recommended locations, for example, a rock outcrop, well vegetated area or naturally occurring flat areas (sills).

On an established or existing fire trail, a good rule of thumb for locating cross banks is to construct a bank wherever rilling (small gullies) starts to appear on the trail surface.

Photo 14 - A cross bank directing runoff across the trail surface to a mitre drain.

Photo 15- A cross bank directing runoff across the trail surface and into a mitre drain.

TABLE 4 - *Drainage feature spacing.*

Road Grade	Soil Class A	Soil Class B	Soil Class C	Soil Class D
Up to 14% (8^0)	70 to 90m	60 to 70m	20 to 30m	*
14 - 21% (8^0-12^0)	60 to 70m	50 to 60m	*	*
21-28% (12^0-16^0)	40 to 60m	*	*	*
28-36% (16^0-20^0)	30 to 40m	*	*	*
36-40% (20^0-22^0)	20m	*	*	*

Note: *indicates that fire trails should not be constructed on these soil types within this slope range. For example Soil Class D soils can only handle trail construction below 14%, preferably below 10%.

Note: Where trails are constructed on slopes exceeding 21% (12˚), only light and infrequent traffic should be allowed.

Note: State Land steeper than 33% (18˚) may be identified as State Protected Lands and is denoted as the bottom two rows coloured red. Extreme caution is to apply in construction and maintenance works on these lands, and an increased level of drainage protection and trail surface protection is required to minimise the potential for erosion and sediment generation off these trails.

Notwithstanding the above guidelines, the stability of the fire trail in operation will eventually dictate the need for variations in the location and spacing of cross banks.

Fire trails for firefighting vehicles will require lower and broader cross banks with flatter batter grades. Crossbanks must be constructed so that a fire fighting vehicle of the designated VCC can traverse the cross bank without touching the undercarriage of the vehicle.

Consideration must be given to the sharpness of bends, the steepness of the fire trail and the height of cross banks so that firefighting vehicles can gain easy access. A poorly designed fire trail may endanger life during bush fires. *See Section 3.19 for construction of cross banks*.

3.4 Mitre Drains

Mitre drains, so called because of the angle they usually make with the direction of the trail, take water from the shoulders or table drain of a trail to a safe disposal area. *See Photo's 16, 17, 18 and Figure 5*.

To keep the volume of water in each mitre drain down to a minimum, it is desirable to split the runoff at regular intervals. This can be achieved by spacing the drains as close together as practical. The spacing should be in accordance with Table 4.

***Photo 16 -** Mitre drains carrying runoff away from the trail.*

***Photo 17 -** A well functioning mitre drain being fed by table drains and a spoon drain in front of a cross bank.*

Figure 5 - Mitre drains carry runoff away from track

Photo 18 - A well functioning mitre drain with small sump at the end, discharging onto well vegetated area.

Mitre drains should be spaced closer together where slopes are steeper and where soil is more erodible.

Mitre drain grades must be less than 9% (5˚) grade and they should discharge onto a well grassed area or rock outcrop. *See Photo 18*.

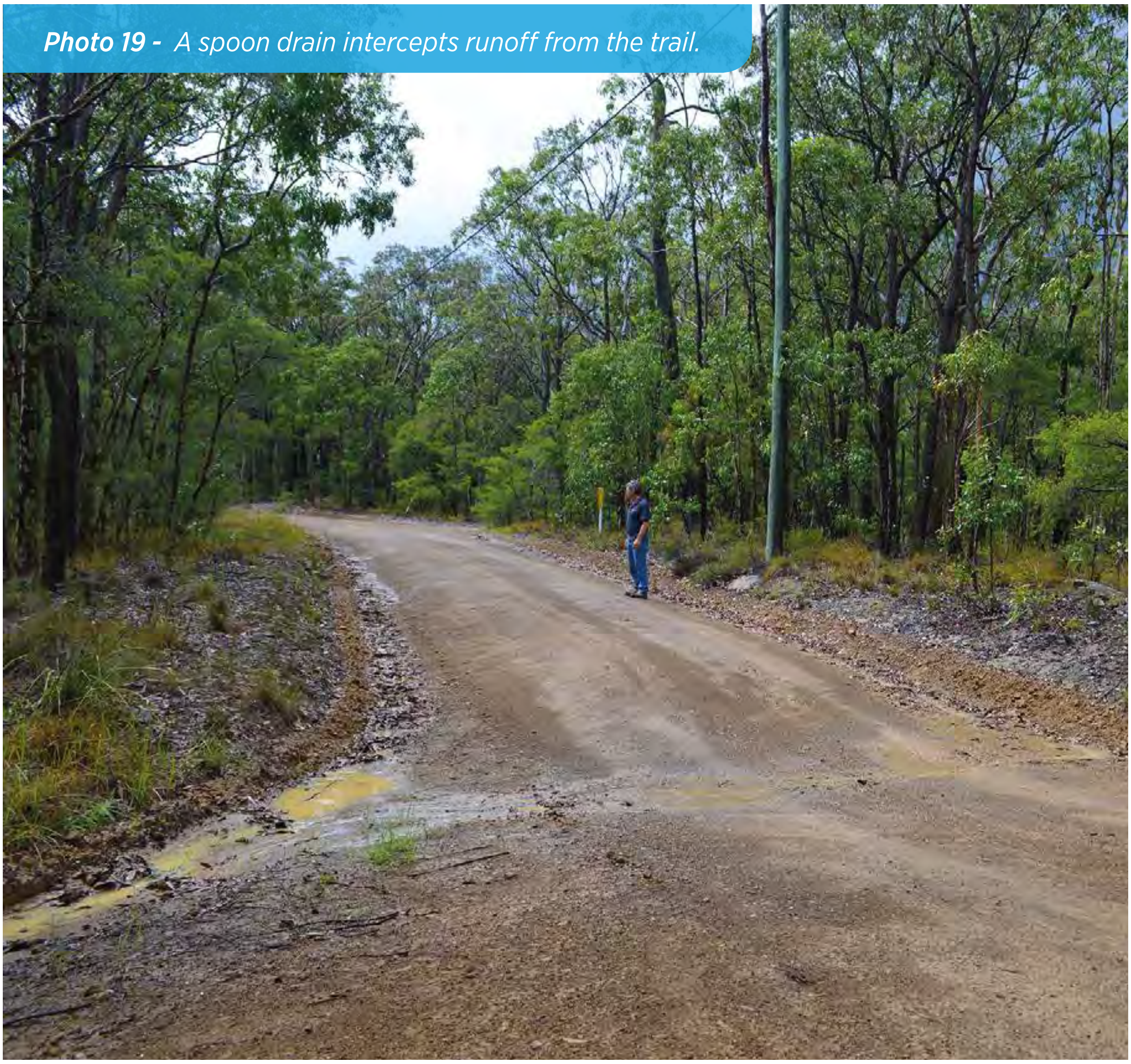
When considering the siting of mitre drains or maintaining current mitres, ensure that the topography does not allow the water to drain back onto the fire trail.

When siting mitre drains make sure that drainage is not concentrated down slope and onto the fire trail further down slope.

3.5 Spoon Drains

Spoon drains are similar to cross banks and are built by digging a small depression across the trail and spreading the excavated earth thinly along the trail. Spoon drains can be used on any slope, and are particularly suitable where the slope is too high to successfully construct cross banks.

Photo 19 - *A spoon drain intercepts runoff from the trail.*



3.6 Drainage Line Crossings

Drainage lines should be crossed at bed level crossings (rock filled fords). See *Photo's 20, 21, 23, 24 and Figure 6*. Where this is not possible, culverts or bridges can be considered. Bridge and culverts will need specific qualified design. Log dam crossings are unsuitable as they obstruct flood flows and can create turbulent flow and erosion.

ALERT - Irrespective of whether for the purpose of construction or maintenance, any watercourse or waterbody crossing, whether temporary or permanent, which:

1. requires placing material on the bed of the watercourse or waterbody (i.e. reclamation) and/or
2. may obstruct the free passage of fish,

may only be undertaken in accordance with an approval issued for that purpose by the Department of Primary Industries - Fisheries.

In addition, any modifications to the bed of the watercourse or waterbody may only be undertaken in accordance with an approval issued for that purpose by the Department of Primary Industries - Fisheries.

Where the situation allows, drainage lines should be crossed at bed level crossings, in preference to the use of culverts or bridges, as they:

- may occur naturally and can be readily modified to provide a suitable vehicle crossing
- may be less environmentally intrusive, requiring less disturbance to stream bed and banks
- may provide greater durability to high flows and
- provide a lower cost and lower maintenance alternative.

Bed level crossings may not be suitable for all situations, such as deeply incised gullies where considerable excavation is required to meet vehicle approach and departure angles and to reach gully bottom.

In these situations a bridge or culvert may be required. Both these alternatives should be designed by a qualified person and certified accordingly. As such, these options will not be discussed in this document and qualified advice on their use should be sought.

On existing trails, culverts may be one of, or possibly the primary drainage structure in place. It may not be practical or desirable to remove them. For this reason, culverts will be discussed in more detail in Section 3.10.

Bed level crossings not fords should be constructed from specifically sized rock, crushed rock, or hardfill and thoroughly compacted. A geotextile cloth should be placed underneath the rock. Smaller rock can be placed to make a trafficable surface.

Photo 20 - *A bed level crossing/rockfill ford at natural gully floor level. Smaller rock is placed over much larger armour stone that will stay in place in high flows. This bed level crossing has been designed to allow fish passage and will not block or dam the flowline.*

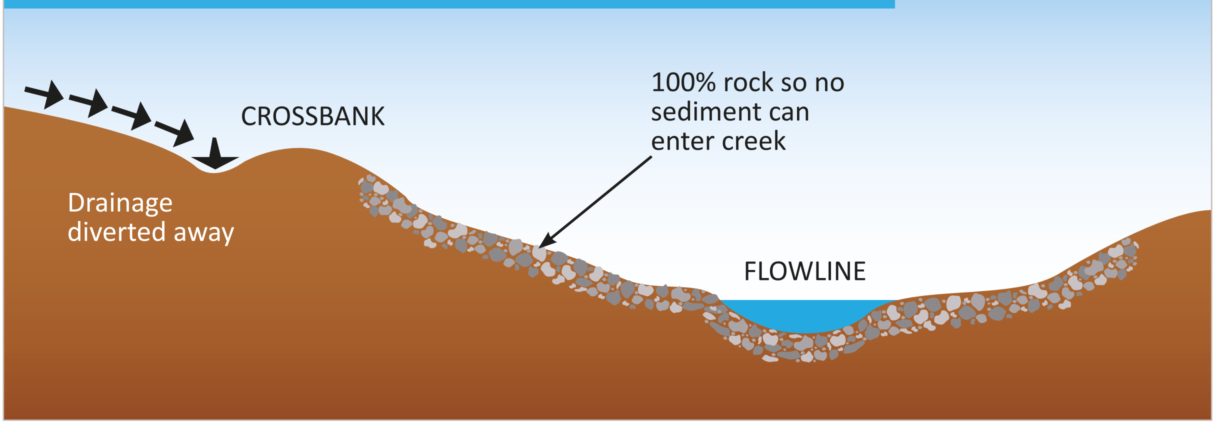
Bed level crossings/rockfill fords need to be extended higher at the sides than the depth of flows. Bed level crossing not ford should be at natural ground level in the gully floor.

Rockfill or stone paving and geotextile cloth should be used in low sloping, boggy areas to avoid excessive soil disturbance and maintain a trafficable surface.

The strength of the geofabric should be in line with the rock type and size used. This can be advised by the geofabric supplier.

Avoid culverts as much as possible and do not use culverts where debris blockages are likely to occur See Section 3.10.

Figure 6 - *Drainage control - So that crossbank prevents drainage entering creek environment (must be NSW Fisheries approved).*



The flow line (*figure 6*) must be protected from trail runoff. Trail drainage must be directed away from entering flow lines, by using cross banks. Forestry use a good rule of thumb called the "5 and 30 rule". This ensures that cross banks should be no closer than 5 m to the flow line and no further than 30m away from the flow line.

Photo 21 - *A bed level crossing. These should be used instead of culverts.*

Photo 22 - *Use of concrete as a cause way in a wet flow line and associated armouring for a batter drop down structure to control erosion.*

In some conditions concrete may have to be used to provide a causeway. *See Photo 22*. In constructing bed level crossings and flow line crossings, keep soil and vegetation disturbance to a minimum. Disturbed areas may need a cover of organic jute mesh and reseeding to protect them from erosion. An ideal seed mix is a mixture of a quick germinating sterile cover crop and local native seed.

Do not dump timber, scrub, soil or other debris in drainage lines, but stack them well above flood levels. Shallow depressions and swampy areas should be stone paved and use geotextile cloth and/or a plastic geomesh. *See Photo 23*.

***Photo 23 -** Rock and stone paving allows access across a wet flow line*

***Photo 24 -** Creek crossing protected by cross banks to divert trail drainage away from creek*

3.7 Fire trails across wet swampy areas

Only plan fire trails across wet swampy areas if there is absolutely no alternative route. Construct fire trails in such areas using geotextile cloth, plastic geogrid and multiple layers of rock. *See Photo's 25, 26 and 27.*

Photo 25 - *A combination of rock, plastic geo mesh and geotextile cloth is used to access across a very wet area*

Photo 26 - *Using Geotextile cloth, plastic geomesh and rock to construct access across a very wet area.*

Photo 27 - *Here a combination of rock, plastic geo mesh and geotextile cloth is used to access across a very wet area.*

3.8 Drainage control structures at junctions with other trails

All work scopes must include controlling drainage from adjacent trails, even if these are dormant trails and not part of the fire trail network. This intersection requires a series of cross banks above the junction directing water away from the main trail. *See Photo's 28 & 29.* A sequence of cross banks are also required on the right hand trail to divert drainage away and off the dormant trail before the intersection.

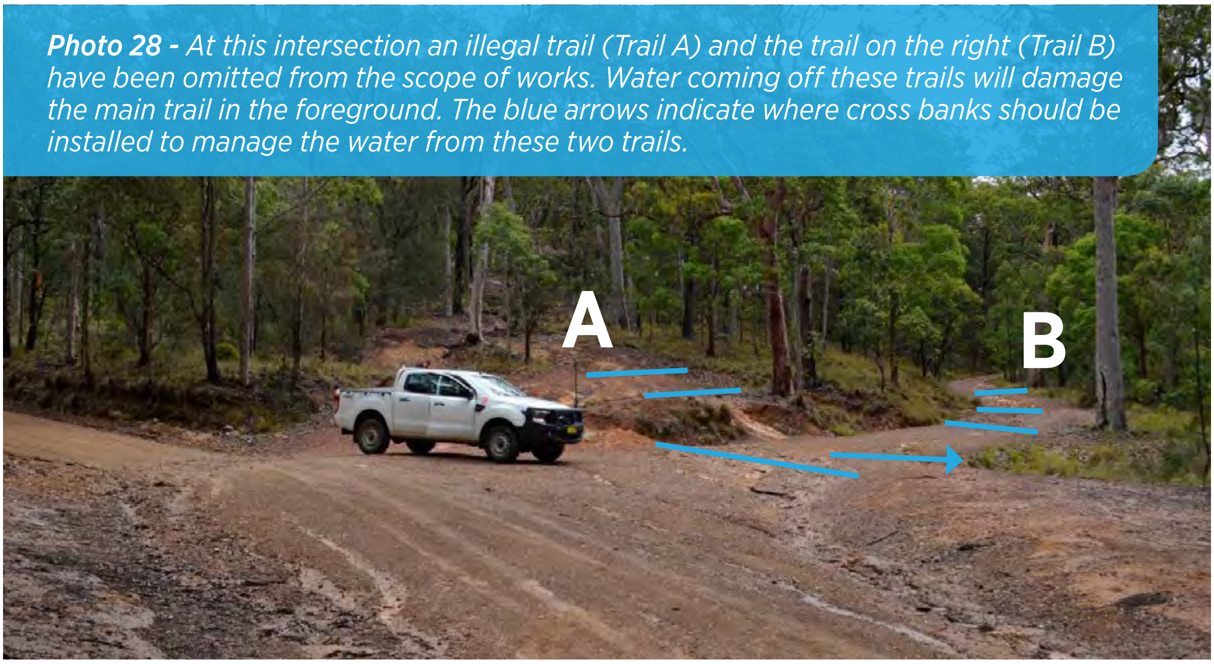


Photo 28 - *At this intersection an illegal trail (Trail A) and the trail on the right (Trail B) have been omitted from the scope of works. Water coming off these trails will damage the main trail in the foreground. The blue arrows indicate where cross banks should be installed to manage the water from these two trails.*

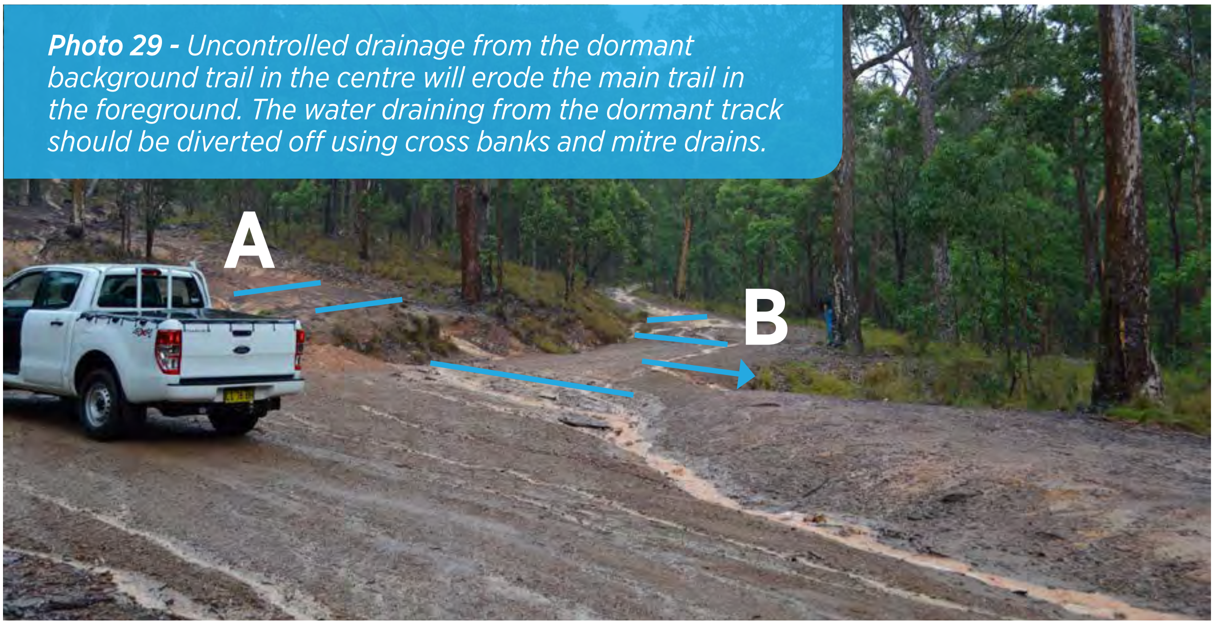


Photo 29 - *Uncontrolled drainage from the dormant background trail in the centre will erode the main trail in the foreground. The water draining from the dormant track should be diverted off using cross banks and mitre drains.*

A simple way to assess erosion controls on a fire trail is to look up the trail from where the water is coming, look at the ground underfoot and look down the trail. Treatment of an erosion site focuses not on the site itself but on where the drainage water is coming from. An additional cross bank and spoon drain or mitre drain will most likely to be needed back up the trail to shed water before it becomes erosive.

3.9 Firefighting vehicle passing and turning opportunities

The RFS Fire Trail Standards sets out the spacing and dimension requirements for passing and turning opportunities (such as turning circles and T-junctions).

Passing and turning opportunities should be constructed as far from creeks, natural flowlines, swampy ground or waterways as practically possible.

Passing bays should be placed along a single trail so vehicles can pass each other, *see Photo 30*. The minimum requirements for passing and turnaround opportunities for each VCC are provided in the Fire Trail Standard.

RFS Fire Trail Standard document

LINK https://www.rfs.nsw.gov.au/plan-and-prepare/fire-trails

***Photo 30 -** Four examples of a passing opportunity.*

Passing of firefighting vehicles can often be accommodated with a modest extension of the formation width, using naturally occurring gaps between trees and or by modest vegetation management, using a slasher or tritter, exploiting naturally occurring gaps in the vegetation cover. Provided a suitable cross fall is maintained to support vehicle traffic and the surface is capable of carrying the required vehicle mass, this level of passing bay is considered adequate. The creation of bare mineral earth passing bays is not required or desirable from a soil conservation perspective and may trigger a more detailed EIA process.

Similarly turnarounds can be either in a T configuration or circle configuration, as long as minimum turning radius are adhered to.

Figure 7 - *Passing bays*

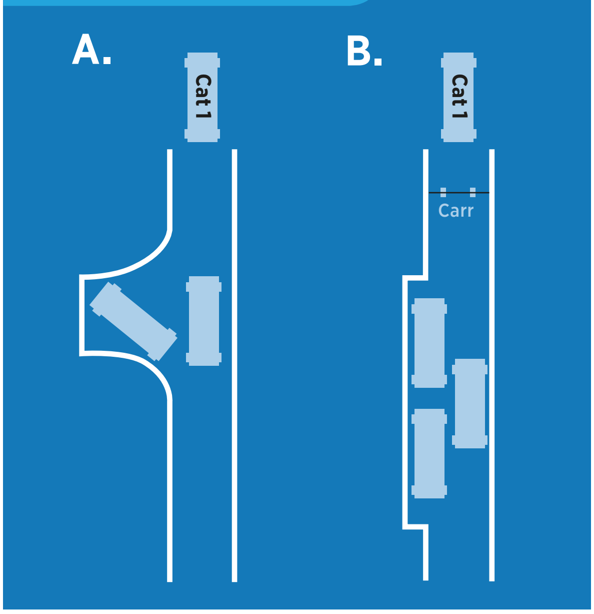
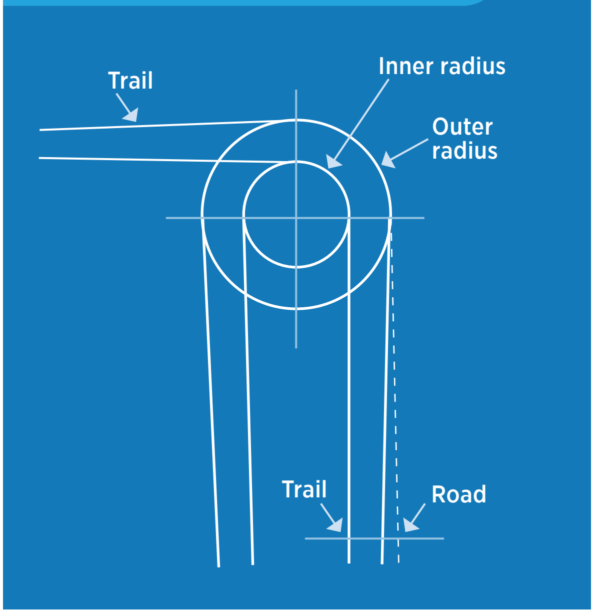


Figure 8 - *Turning opportunity*



When siting passing bays and turnaround opportunities, they should not be constructed in or next to creeks, natural flow lines, swampy ground or waterways. Where possible try to use existing advantages to site these features ie in certain situations (where the terrain allows) bends in trails, natural clearings and mitre drains may provide opportunities for the siting of these features, on the proviso that their primary purpose is not compromised.

3.10 Culverts

A culvert is a pipe or similar structure used to direct water under the fire trail. While there are many well-functioning culverts, the problem with culverts is that they block easily and many are too small for their associated catchments. When doing fire trail work, do not install culverts. Instead, seek an alternative such as a bed level crossing or rock armoured spoon drains.

These open structures will not block easily and can direct high flows across the trail. Remove culverts that are not functioning properly and replace with either of these alternatives.

Very occasionally there is no viable alternative to a culvert. In these cases, the size of the culvert will need to calculated by a qualified person, to ensure that the culvert can accommodate major flows from the catchment. Where culverts are installed in fill, some form of protection may be necessary on both upstream and downstream fill faces (head walls). This will help ensure that water flow does not erode or damage the batter, *see Photo 33*.

CAUTION - Never use culverts where debris blockages are likely. *See Photo's 31, 32 and 34*.

Photo 31 - *Example of a blocked culvert.*

Photo 32 - *This blocked culvert is redirecting and concentrating drainage down the formed trail and causing erosion. Drainage using cross banks and open rock paved spoon drains is a better option.*

Drop down structures will be necessary where a culvert could discharge over a fill area. Where ever possible do not use rigid materials like steel or plastic for drop down structures as they are easily out flanked particularly if the batter soil moves. Always use geotextile and rock as these will move and mold with any soil movement and remain functional.

Figure 9 - *Constructed batter drop down*

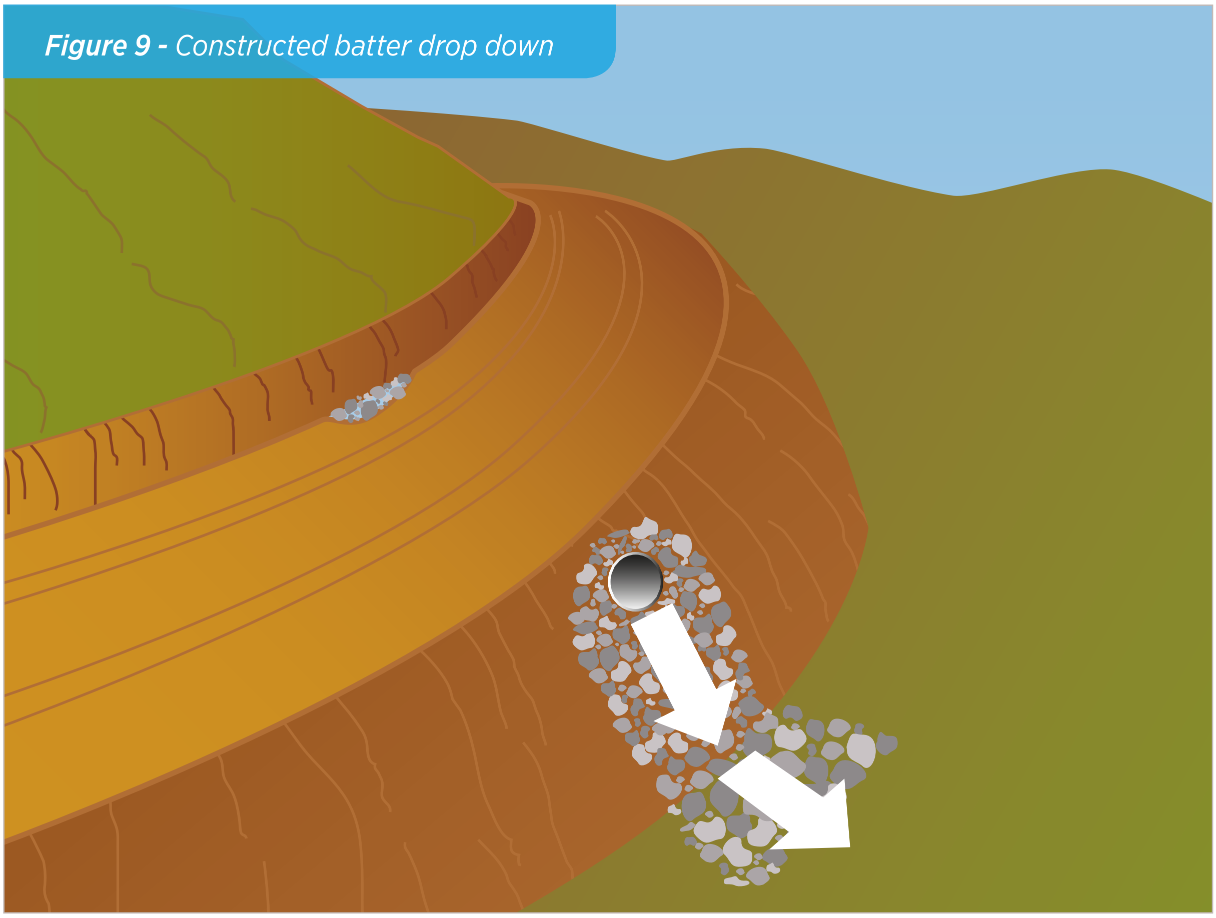


Photo 33 - *A Culvert with a rock batter drop down structure to protect infil from eroding away.*

If used, culverts should be sized correctly. *Photo 34* below shows a culvert that is too small for its associated catchment and prone to blockage and failure. A rock armoured bed level crossing would be a better solution.

***Photo 34 -** This culvert is too small and therefore prone to blocking, which will damage the trail. A rock armoured bed level crossings is a better alternative.*

CAUTION - In all cases the Department of Primary Industries - Fisheries must be consulted before the designing and building of culverts.

3.11 Bridges

Bridges are complex structures and should be designed, constructed and maintained by qualified persons and therefore are generally outside of the scope of this manual.

When undertaking an assessment of fire trail condition, assessors should note and record the general condition of bridges - ie note obvious defects, such as broken stringers, rotted decking, eroded abutments, etc and report this to the land manager, for followup with detailed inspection, by a qualified person.

3.12 Construction equipment

Construction is generally carried out by bulldozers, excavators and rollers. Bulldozers are best suited for initial construction and building cross banks.

The selection of machinery depends on a range of factors, including whether the works are new construction and/or maintenance. When scoping and costing fire trail work, it is recommended that equipment is selected in consultation with either an experienced and qualified soil conservation practitioner or a trusted contractor with experience in fire trail work.

In general:

- a D3–D6 bulldozer with angle tilt blade or grader may be good for maintenance,
- a D6 bulldozer with angle tilt blade and rippers is required for construction and installing cross banks
- excavators are highly effective for working near drainage lines as they can cleanly remove generated spoil and minimise spoil spill into drainage lines
- excavators are also very effective at installing cross banks.

There are two types of bulldozer blades that can be used — trail or straight. A trail blade, which can be angled either way to side cast the earth, is the most efficient when forming a fire trail. While a straight or bull blade can be used, it is less efficient when side casting is required.

Excavators with tilt buckets are also very good for shaping eroded fire trails. Small excavators can be used for installation of rock. They can also be used for excavation with the least amount of disturbance in sensitive areas and for preparing rock fills.

See the RFS Fire Trails Standard for the specific dimensions of firefighting vehicles and equipment, to determine the minimum size of passing and turning opportunities, vehicle transmission clearance heights and frequency of passing and turning opportunities, particularly on dead- end fire trails.

3.13 Construction material selection

Trail wearing surface treatments

If the fire trail requires material to be added to the trail surface, then the best materials for trail surfaces are a 100 mm minus or a 75 mm minus, graded, quarried rock- based material that contains plenty of large rock but also a high proportion of fine material. The fine materials bind the larger rock. Many road base and fill materials are made to Road and Maritime Services (RMS) specifications, while these specifications are not needed for trails they can determine minimum proportions of large rock, aggregates and finer material to achieve a good trail wearing surface. Seek advice from your local quarry supplier.

Your local quarry supplier can advise what materials they have in stock, including suitable materials that may not meet a particular specification or are surplus but may be fit for fire trail purpose and less costly.

Always specify VENM (virgin excavated natural material) to suppliers for trail surfaces and make sure this is recorded on the delivery docket. *See Photo 35*.

CAUTION - Do not use recycled materials.

On occasion water may need to be added on site to improve the compaction performance of quarried materials.

***Photo 35 -** A durable VENM shale quarried material supplied by a local quarry supplier for a trail surface.*

3.14 Earth moving equipment hygiene

Plant machinery works in a range of environments and can spread soil disease pests and weeds between sites, potentially creating bio security risks to agriculture and the environment.

It is extremely important to clean plant machinery thoroughly of dirt and debris both before arriving at a new site and on leaving a site. This will minimise any tracking of loose dirt clods during transport and minimise the potential for spread of weed seed or soil borne diseases.

For compliance with these requirements see the Department of Primary Industries - Decontamination of vehicles and equipment procedure.

LINK www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/545554/procedure-decontamination-vehicles-and-equipment.pdf

3.15 Implementation of construction design and techniques

If the proposed works are not in accordance with this manual, or beyond its scope, expert advice from a suitable, qualified source must be sought to ensure compliance with the principles of this manual.

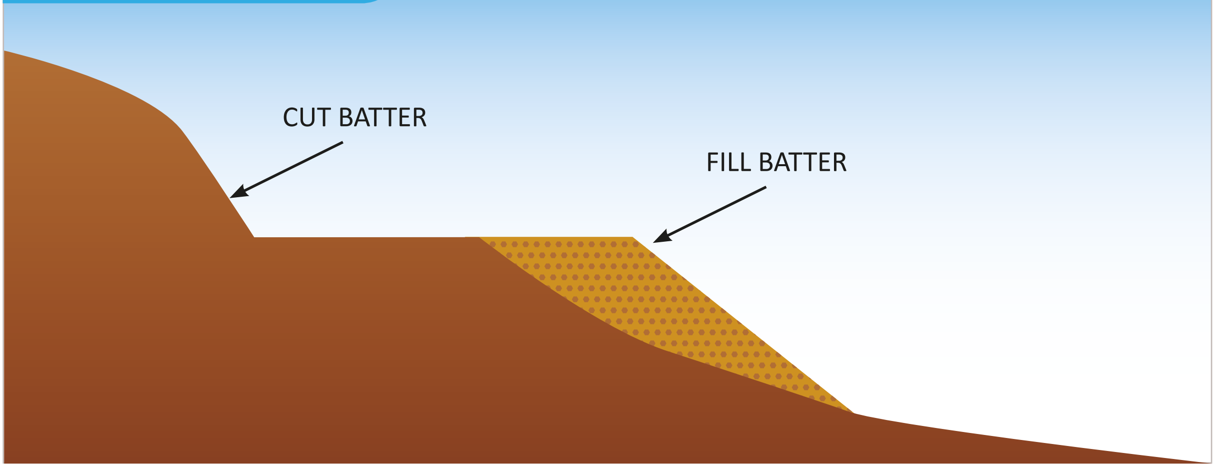
Fire trail construction should be done with minimum disturbance of soil and vegetation both on and adjacent to the trail. Care must be taken to follow the planned course of the trail, taking special account of specific features like large trees (including potential damage to roots) or rocky outcrops that might necessitate diversion. It's essential therefore to walk and mark the fire trail prior to construction as discussed in Section 2.3. Machine operators should be given a thorough briefing on the trail alignment, marking technique and preferably walk the line in advance of operations.

Despite maintenance over the decades, many fire trails have been degraded by erosion and lowered by successive passes of construction equipment, particularly graders. This successive lowering traps water within the road profile and creates what is called a "box cut or incised trail". Box cuts create a concentration of drainage, which results in more damaging erosion effects downslope, which are expensive and difficult to remedy. For this reason, specified works should always look to raising sections of the trail crowning, or opening outlets away from incised sections of the trail, in order to allow them to more effectively shed runoff. Works should not specify lowering the road profile in the landscape.

3.16 Fire trail batters

A trail batter is a constructed earth slope, either of placed fill material or cut from the natural hillside, *see Figure 10*. To minimise the area of exposed soil, cut batters to 1.5 m should be cut vertically. This form of cut batter may suffer from initial slumping but will generally stabilise with follow-up maintenance. Cut batters higher than 1.5 m will require special stabilisation measures including laying back, jute mesh, revegetation and drainage.

***Figure 10 -** A trail batter.*



Fill batters on all soil classes should be no steeper than 3h :1v (h = horizontal and v = vertical) and flatter where possible. This will encourage revegetation naturally and better accept seed and fertiliser. Batters higher than 1.5 m will require special stabilisation works such as drop down drains, organic jute mesh with seed for vegetation cover, straw mulching or similar, *see Photo 36*. Cut and fill batters should be designed to be no steeper than the in-situ soil stability permits. Any batter angle greater than 18 degrees, 3h:1v (h = horizontal and v = vertical) design input from an qualified and suitable engineer and geotech is required. There are certain situations where advice from a suitably qualified person (an Engineer) is required.

These situations include:

- Where the batter angle exceeds 18 degrees
- Where a newly constructed fill batter is to subjected to traffic and
- Where a retaining structure is required.

DO NOT:

- incorporate vegetation debris in fill batters, as this results in poor compaction with hollows and slumping occurring as the vegetation rots, with potential safety issues
- create borrow pits. Import quarried materials and use rock materials that may have accumulated in table drains and on the trail shoulders.

Wherever practicable, stockpile topsoil and litter (free of timber debris) in a recoverable position for re-spreading over disturbed areas. This material contains valuable seed and nutrients which will greatly assist revegetation.

Topsoil should be stored to a maximum height of 1.2 m. Any higher and heat generation will destroy the microbial processes and render the soil inert. The best way to prevent the establishment of weeds in topsoil stockpiles is to seed it with a mixture of a sterile cover crop and native seed.

Photo 36 - A batter slope protected with jute mesh on an infall trail.

3.16.1 Batter drop downs

These are a constructed and stabilised drain to carry runoff down the trail batters, typically down the line of greatest slope, *see Figure 9 on page 42*.

3.17 Clearing and maintaining vegetation for the fire trail

Clear the fire trail of any trees or scrub, and do not incorporate them into any fill batters. If in doubt of trail direction, the operator should step down from the machine and walk the proposed trail to ensure the correct line is followed.

Clearing widths along the trail are to be in accordance with the RFS Fire Trail Standards. Cut any timber rather than dozing it to minimise the amount of soil disturbance. A mulching tritter head is highly effective in clearing vegetation, *See Photo's 37 and 38*.

Photo 37 - *An overgrown and inaccessible trail.*

Photo 38 - *An 8 t excavator with a mulching head clears the trail of the vegetation. This occurs prior to any required surface works.*

3.18 Constructing the fire trail surface

Fire trails can often be established on level to slightly sloping sites simply by brushing the surface to remove stones and scrub but not disturbing the actual ground cover. *Photos 39 & 40* show a trail after clearing vegetation and constructing a new trail surface.

***Photo 39 -** After clearing the trail of vegetation, before constructing the trail surface.*

***Photo 40 -** A constructed trail surface.*

Fire trail construction should start from the top of a cut where the operator dozes downhill to allow the weight of the machine to assist construction. (Power is lost on uphill pushing due to lack of traction).

ALERT: Always exercise extreme care when side cutting in steep terrain.
Unconsolidated fill batters may slip with the weight of the machine.
Large rocks may also cause the machine to slide

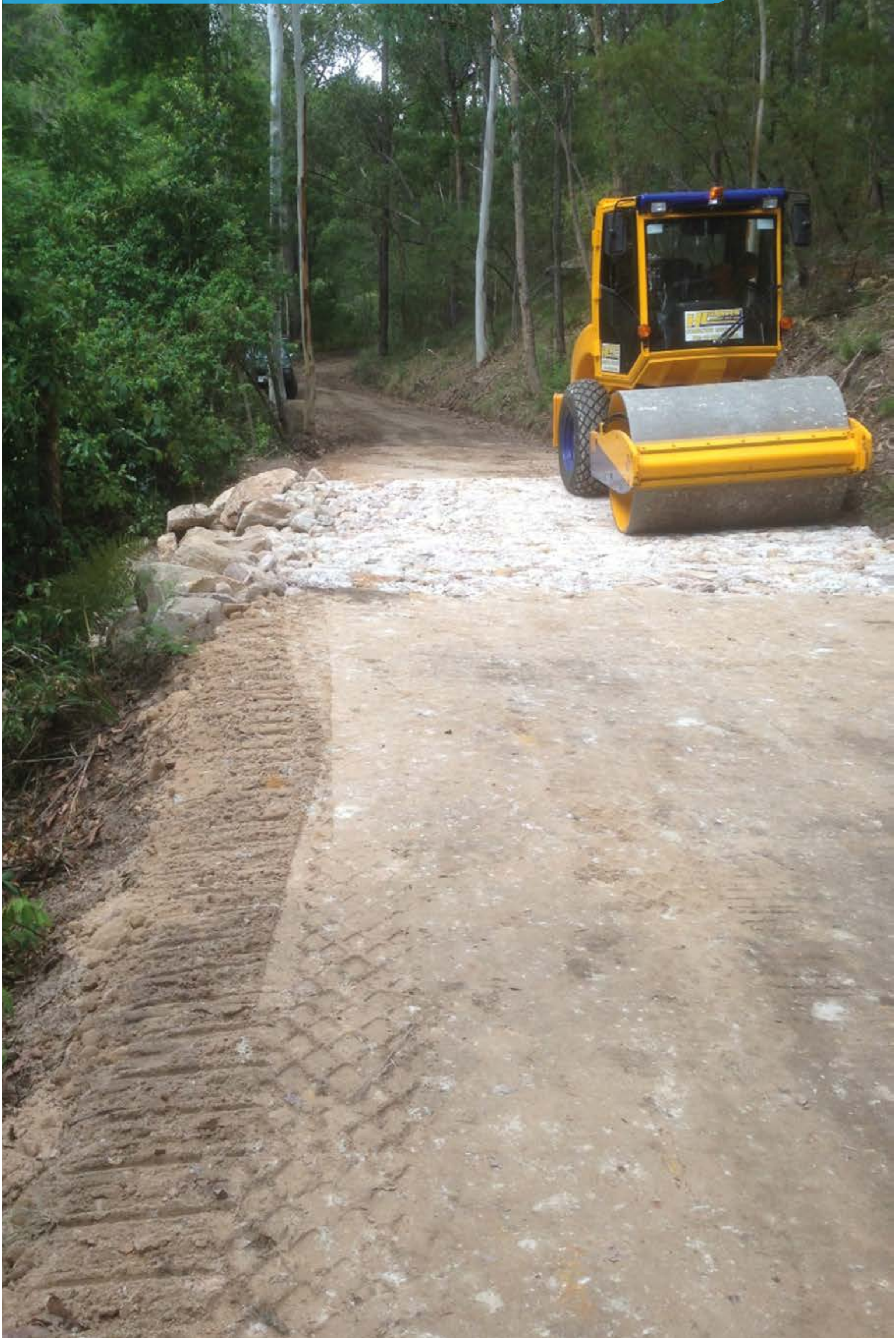
At this stage the cut batter should be considered, vertical or sloping. Crowning, infall, outfall and camber should also be installed as the trail surface is formed. *Photo's 41 and 42* show a D6 bulldozer crowning a trail.

***Photo 41-** A D6 bulldozer with an angle trail blade putting a crown on an trail.*

***Photo 42 -** D6 bulldozer capping and crowning a trail.*

Rollers are used to compact the wearing surface of the fire trail to increase durability. *See Photo 43*.

Photo 43 - *A small roller compacts the constructed trail wearing surfaces. Note use of rock paved spoon drain to control flow line across the trail.*



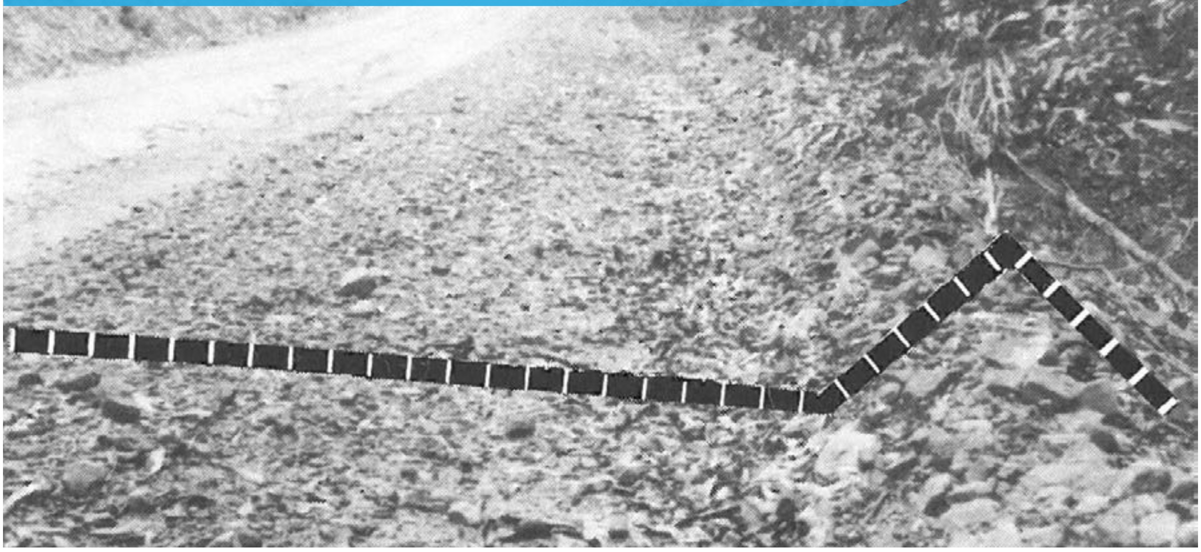
Particularly under dry conditions, the assistance of a water cart may be need to assist with compaction to achieve a wearing surface, *see Photo 44*.

Photo 44- *The addition of water and a roller greatly improve compaction, particularly if conditions are dry.*

When applying infall or outfall, remember there may be some settling or slumping of the trail surface following construction, particularly of fill batters.

The mound of earth that often builds up along the edge of the trail during construction is called a windrow and will form a barrier preventing runoff from leaving the road. This earth windrow should be bladed from the trail.

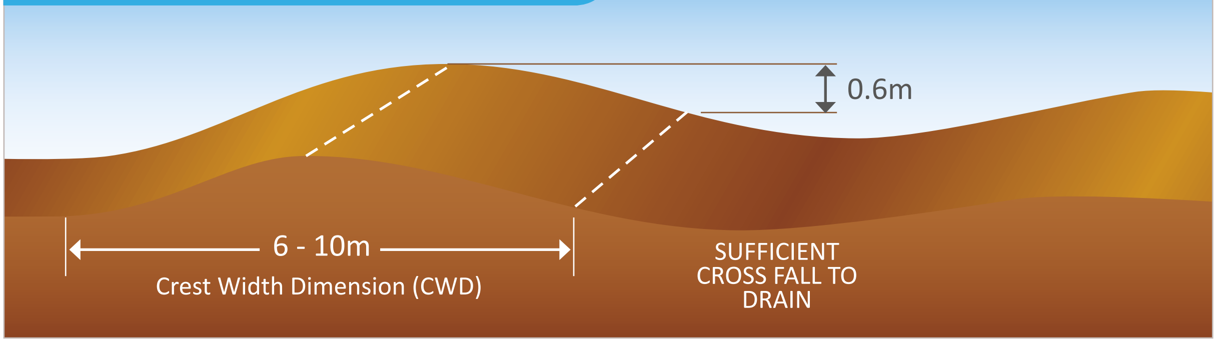
Figure 11 - *Windrows of earth and vegetation that build up during construction and prevent out fall drainage should be removed.*



3.19 Constructing cross banks

The earth required for the construction of a cross bank is usually borrowed from the trail on the top side of bank, but often additional material may have to be ordered in.

***Figure 12 -** Typical cross bank dimensions*



Cross banks must be constructed so firefighting vehicles can clear without causing vehicle damage. *See Photo's 46, 47, 48 & 49*. For tanker dimensions see RFS Fire Trail Standards *Table 4*.

***Photo 45 -** A small excavator constructs a cross bank.*

__Photo 46 -__ Cross banks must be constructed so firefighting vehicles can clear without vehicle damage.

__Photo 47 -__ Cross banks must be constructed so firefighting vehicles can clear without vehicle damage.

Photo 48 - *Cross banks must be constructed so firefighting vehicles can clear without vehicle damage.*

For cross bank construction, first rip the trail line to a depth of 20 to 30 cm for a distance of one or two dozer lengths back from the chosen outlet point. Then push the loose earth down the trail line into a bank, commencing at the uphill side of the trail and working across to the outlet side. A long, shallow excavation for the bank is preferred to a short, deep excavation.

Sufficient loose earth must be used to give the required dimensions, *see Figure 13 on page 55*, after shaping and compaction. Depending on the size of the machine being used, up to eight bladefuls of earth may be required. Ensure that the crest width dimensions are long enough to ensure comfortable vehicle access over the cross bank. The channel depth dimensions are essential to prevent runoff from overtopping the bank.

Cross banks are most effective if constructed with only a slight angle to the trail, with a cross fall of approximately 1:20. This ensures that runoff does not pond in the bank channel. *See Photo 49 on next page*.

A good rule of thumb is to make the crest width dimension roughly equal to the wheel base of the vehicle to travesrse the trail. This ensures that the vehicle will easily traverse the cross bank. Specifications for each VCC are provided in the Fire Trail Standard.

Photo 49 - *There is no ponding of water in the cross bank channel confirming that the cross bank has adequate cross fall. Cross banks should be well compacted with sufficient grade to drain.*

The bank can be shaped with the dozer blade and the entire length of the bank should be rolled to obtain maximum compaction and a smooth, even bank. *See Photo 46*.

A sweep with the blade will clean loose earth from the channel of the bank. The small bank of earth resulting at the outlet can often be left as a silt trap and water spreader. Push this earth only just far enough to allow water to clear the trail effectively.

If filling an eroded table drain to build a bank, compact the bank at that point with extra earth to allow for slumping and to cope with the concentrated runoff in the table drain.

3.20 Constructing mitre, table & spoon drains

Mitre drains and table drains can be constructed simply by lowering one side of a dozer or grader blade and then pushing in the required direction for two or three passes to provide a gentle and obstruction-free passage.

CAUTION: Always reinstate existing mitre drains, unless they are wrongly placed or are not capable of being modified to function properly. Ensure that the construction of any new mitre drains in existing trails have appropriate approval.

SECTION 4

Construction of new trails

There are occasions when new fire trails must be constructed, where no fire trail has been built before. Additionally, some fire trails may become so disused that they are essentially "rebuilt" rather than maintained. Finally, when ongoing maintenance problems are a cause of its siting in the landscape, it may be more effective to realign parts of the fire trail.

In all instances, these construction activities have a high potential to degrade land and careful planning must be undertaken prior to any works being undertaken on the ground. Consideration must be given to the receiving environment to reduce impacts as far as practicable.

In general, the flow of new fire trail construction is as follows:

1. Need for the construction is identified
   (See opening paragraph)
2. Preliminary assessment of landscape and high-risk areas identified
   (Refer to Section 2.3 for information on siting the track within the landscape)
3. Concept designs considered and best option chosen from these
   (Input from interested parties may influence the final design)
4. Development of preferred design
   (The design should include detail on how water flow will be managed through the site, using the drainage techniques provided in Section 5)
5. Environmental impact assessment undertaken and permits/licenses acquired (Refer to Section 2 for information on this)
6. Construction works undertaken
   (Refer to Section 5 for construction methods)

During the construction phase, it is possible to find variations between what was expected on site, and what has been encountered. Examples may include hard rock in an area that you need to cut, or the presence of a spring that needs drainage. This can sometimes be mitigated against by performing higher-quality assessments (Phase 2), but unforeseen circumstances can and do occur. Should your design need to be changed, this may trigger a need to re-evaluate the environmental impact, or change the conditions of your work permits.

It is important to ensure that checks, permits and licenses are obtained prior to undertaking works, and that environmental controls specified within your assessments are in place. Fines and penalties may apply if not done.

On high risk projects, it is prudent to engage the assistance of technical specialists.

Maintenance of existing trails

Frequent maintenance is essential, especially in the early years after construction, to ensure effective erosion control and trail stability. *See Photo 50.*

Maintenance is usually highest during this early period while soils are still consolidating and vegetation is becoming established.

Existing fire trails are generally maintained on a defect basis. However, routine maintenance can prevent erosion and therefore avoiding more substantial and costly problems later on. A small erosion repair will prevent a much larger problem emerging after the next substantial rain event.

Bulldozers and excavators can carry out maintenance tasks but graders are also best suited to the task of grading the trail surface to remove washouts and rilling. Graders are also especially suitable for maintenance and cleaning out of table drains and mitre drains. If washout and rilling is occurring construct cross banks to control drainage.

On a cautionary note, graders and other maintenance equipment, if not supervised properly, have a tendency to drop trails lower causing runoff to concentrate and further erosion problems. When maintaining trails do not create earth windrows as these concentrate water flow. Materials for trail surfaces can often be gained by recovering the materials that have been previously eroded from the trail surface and deposited into table drains. Sediment deposited in mitre drains can also be retrieved for trail works using an excavator.

Activities should be restricted to periods of dry weather in order to minimise impact on soil disturbance and damage to ground that could exacerbate erosion.

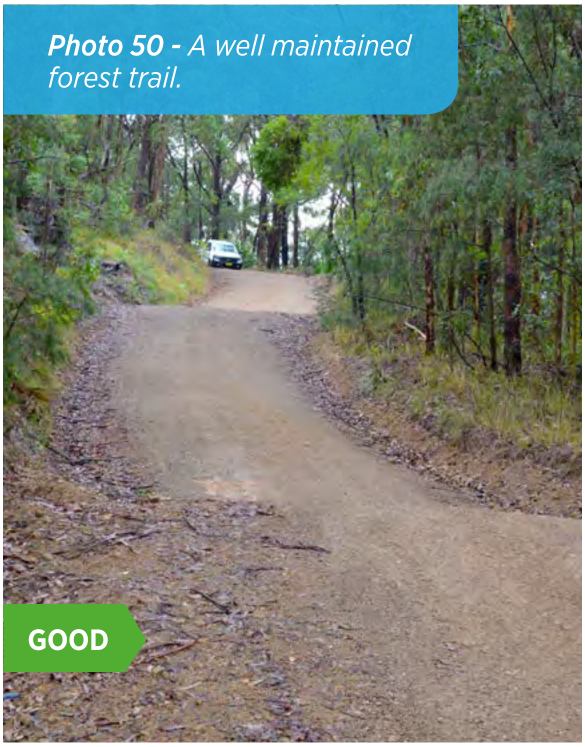


***Photo 50 -** A well maintained forest trail.*

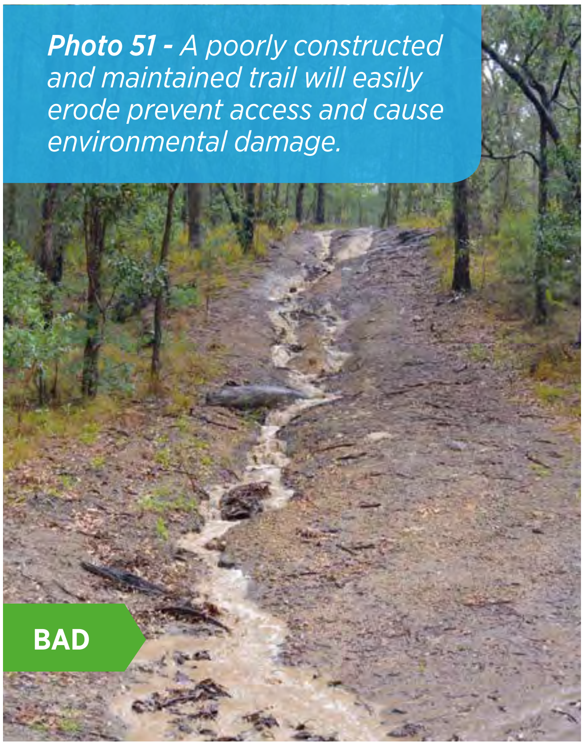


***Photo 51 -** A poorly constructed and maintained trail will easily erode prevent access and cause environmental damage.*

Fire trails should be inspected following heavy traffic usage or exceptionally heavy rainfall to determine maintenance requirements, *See Photo 50*.

Photo 52 - *Removal of excess vegetation using a mulching head.*

Restrict the removal of excess vegetation, preferably by mulching. *See Photo 52 and 53*. Avoid unnecessary grading or blading to reduce soil disturbance.

Photo 53 - *An 8 t excavator with tritter mulching head is effective in managing vegetation.*

Photo 54 - Maintenance of table drains a 100HP skid steer with tilt blade cleaning out table drains.

Encourage outfall drainage by removing any earth windrow along the outside edge of the trail.

Keep fire trails well crowned.

Leave material which has slumped from cut batters untouched, particularly if it does not unduly restrict the operating width of the trail. If it is necessary to remove material, take care to avoid undercutting the toe of the batter.

Do not remove any more vegetation than is necessary to maintain access. Remember to always cut timber rather than doze it. This is especially important above cut batters and adjacent to stream banks.

Periodic maintenance should also include checking the trail drainage system and removing any debris that may block culverts and cross drain outlets, *see Photo 54*. Table drains can become blocked by litter resulting in the flow of water onto the trail surface, *see Photo 55*.

In the early years after construction, the trail should be regularly inspected. If rilling occurs on the trail surface, then there may be insufficient crossfall or cross banks may be spaced too widely. This should be noted and modifications made or planned so that further erosion is avoided.

Photo 55 - *Culverts should be kept clear of material that can block them.*

As part of any maintenance program, illegally formed trails should be managed as soon as possible, *see Photo 56.*

***Photo 56 -** Unplanned and illegally formed trails quickly erode and cause damage to the environment. The water erodes the formed trail and the sediment blocks drainage structures. These trees will also collapse, causing further soil disturbance.*

It is important to restrict unauthorised vehicle access where possible. These vehicles can cause damage, particularly in wet conditions, *see Photo 57*.

***Photo 57 -** Fire trails may need to be secured so they are not damaged by unauthorised vehicles.*

5.1 Problem solving

PROBLEM	REASON	SOLUTION
Ponding in crossbanks channel	May be due to insufficient crossfall grade or blocked outlet	Maintain outlets and increase crossfall if required
Scouring of cross bank channel	May be due to excessive crossfall grade	Reduce crossfall of trail
Overtopping of cross banks	Insufficient Height of cross banks or channel has silted due to ponding	Maintain crossbanks and remove silt, increase crossbank height if required
Eroding of table drains	Excessive grade on drain causing water velocity to increase Cross banks, culverts, or mitre drains not sufficiently close together to break up the flow of water	Re evaluate the spacing of drainage features add addition features where required
Eroding of trail surface	Cross banks too far apart →	Install additional crossbanks
	Earth windrow alongside trail preventing outfall drainage from working →	Remove windrow where possible
	Trail surface not sufficiently crowned or cambered →	Crown trail surface
	Culverts blocked due to incorrect alignment →	Re-align culvert or investigate alternate treatment such as bed level crossing
	Debris blocking pipes →	Clean and maintain pipes

5.2 Do's and don'ts

Do's

- Get all required approvals
- Mark all sensitive areas in the field with flagging tape or similar high visibility markers
- Provide the contractor doing the works with a thorough site induction, including the location and constraints associated with "sensitive areas" and/or "exclusion areas"
- Ensure the project plan identifies environmental and heritage matters to be protected
- Always implement controls for the protection of environmental and heritage factors as stipulated by the approvals
- Seek approvals from the Department of Primary Industries - Fisheries as required for waterway crossings
- Road plant is to remain within the road formation and shall not park, traverse or turnaround on areas of native vegetation
- Retained vegetation is not to be damaged
- Gravel, stockpiles and materials are not to be stored on undisturbed areas or under the drip line of mature trees
- All contaminants and waste are to be removed from the site and disposed of according to relevant regulations
- The source of all imported material is to be specifically approved by the land manager, to ensure that the potential for the materials to be infected with fungal disease or environmental weeds is minimised
- Suitable machinery and equipment hygiene measures to minimise the potential for the spread of fungal disease or environmental weeds
- Have a safe work method statement and "Dial before you dig"
- Construct dimensions in accordance with the relevant requirements for firefighting vehicles as specified in the RFS Fire Trail Standards
- Use the erosion control measures from this manual, these should be incorporated into an erosion and sediment control plan before any works commence. Let the trail follow the shape of the landscape, don't go flat and straight
- Only take construction materials from approved sources and only use VENM construction materials
- Get advice from an experienced and qualified soil conservation practitioner if required, *see Photo 58*.

Don'ts

- Maximise the distance of a fire trail from a stream to allow an effective vegetation buffer to contain any sediment flowing from the fire trail
- Do not install culverts to drain.
- Passing and turning opportunities are to be constructed as far from creeks, natural flowlines, swampy ground or waterways as practically possible.

***Photo 58 -** This was once a trail. Do not construct fire trails on Class D soils without direction from an experienced and qualified soil conservation practitioner.*

See Photo's 59 to 66 as examples of how not to do work on fire trails.

Photo 59 - *A poorly constructed trail with no crown or table drains, repaired only 18 months ago. The newly formed gullies will soon make this trail impassable.*

Photo 60 - *This trail is too narrow and the table drain on the right hand side has not been formed properly. It blocked easily, causing water to be redirected onto the trail and led to erosion.*

***Photo 61 -** The new works shown have failed to reinstate the existing mitre drain on the right, hence flows are too large and are eroding the bottom of the trail.*

***Photo 62 -** The reinstatement works have not reformed this existing mitre drain on the right hand side. As a result, flow rates will be too high and cause erosion further down.*

Photo 63 - *This cross bank is too small and is already being overtopped. The resulting flows in the middle will erode the trail. Water has also ponded in the up slope cross bank channel.*

Photo 64 - *This cross bank is too small and too sharp for a firefighting vehicle to traverse and likely cause very serious damage.*

***Photo 65 -** This trail should be crowned to shed water. There should be no pooling of water on the trail.*

***Photo 66 -** This infall trail has failed because the culvert has blocked, causing the drainage to go over the top of the trail and erode out the batter.*

References / Glossary

REFERENCES

1. Marshall,C.J., Cathcart, R.J and O'Neill-Fuller, K.J. (1984), *Guidelines for the planning, construction and maintenance of trails*, Soil Conservation Service of NSW, Sydney.
2. Beatty, R. (Ed)(1995), *Guidelines for the planning, construction and maintenance of tracks*, NSW Department of Land and Water Conservation, Sydney.
3. Marshall, C.J., and Norvill, M. (1990), *Earthmover's Training Course: Unit 17, Access Tracks*, Soil Conservation Service of NSW, Sydney.
4. Murphy, C.L., Fogarty, P.J. and Ryan, P.J. 1998, *Soil Regolith Stability Classification for State Forests in Eastern New South Wales*, Technical report No 41, Department of Land and Water Conservation, Sydney.

GLOSSARY

1. **Armouring** - The process of development of a layer of coarse particles on the surface of a soil, which is capable of protecting the soil below from running water. Typically this is achieved by the placement of rock.
2. **Batter** – the face of an embankment or cutting, produced as a result of earthmoving operations involving cutting and filling.
3. **Batter drop down** – A constructed and stabilized drain to carry runoff down the trail batters, typically down the line of greatest slope.
4. **Bed level crossing** - A constructed rock armoured surface within a natural flowline which is at the same level as the natural bed of the flowline. Under normal conditions the surface would be submerged.
5. **Borrow Pit** - An area of excavation from which soil, clay, sand, rock or gravel has been extracted for specific purpose.
6. **Box-cut** - Refer to Incised Trail
7. **Camber** - A constructed slant, tilt or slope in the track surface.
8. **Causeway** - A roadway across a watercourse specifically constructed to resist the effects of submergence
9. **Compaction** - The process of increasing the density of a material by removing the air and inducing the closer packing of its particles. Typically achieved by rolling and sometimes combined with adding water.
10. **Crest width dimension** - The width of the top of a raised structure, such as a cross-bank. A narrow crest width dimension will be sharp and decrease the ability of vehicles to traverse it.
11. **Cross Bank** – A mound of earth constructed across a trail so that runoff is effectively diverted from it. Cross banks are designed to handle larger flows than cross drains.
12. **Cross Drains (Spoon Drains)**– Drains of various forms that baulk the flow of water down a trail and divert it across the trail's surface. The capacity of the drain is defined by the cross section. Cross drains are designed to handle smaller flows than cross banks but larger flows than can be controlled by crossfall drainage.

13. **Crossfall Drainage** – Drainage occurs when the surface of the trail has sufficient cross slope to cause water to flow across and off the trail surface, rather than along it.

14. **Crowned trail** - The centre of the trail is raised higher than the outer edges of the trail by a minimum of 150mm. This will shed water to both sides and to the edges of the trail and into erosion control and associated drainage, usually table drains.

15. **Culvert** – A pipe or similar structure used to direct water under the trail.

16. **Dispersion** - Dispersion is the process whereby a soil aggregate will break down into their separate constituent parts (clay, silt and sand) when in the presence of water. The sediment that results will be transported easily by flowing water with the sand particles usually deposit close to the erosion site, but the silt and clay particles will be transported until the flowing water stops moving.

17. **Earth Windrow** - a ridge of soil created due to spillage at the edge of a bulldozer or grader blade during earthmoving operations. These prevent runoff to a stable outlet in which case it is called a WINDROW DRAIN. However, in other circumstances it may prevent runoff leaving the trail, thus cause flows to travel along the trail surface and cause erosion.

18. **Erosion** - The wearing away of land by either running water, rainfall, wind, ice or other geological agents, including such processes as detachment, entrainment, suspension, transportation and mass movement.

19. **Fire Trail Standard** - As defined in the Rural Fires Act (Fire Trails) Amendment Act, 2017.

20. **Flowline** - A well defined route down which water naturally concentrates and flows. It is a general term including drainage depression, gully, drainage line, creek and river.

21. **Geofrabic, Geotextile** - specifically manufactured polyester fabric cloth that can be placed under rock and gravels to disperse load and separate finer material from becoming mobile. See manufacturers' product information and applications.

22. **Incised Trail** - A trail in which the trafficable surface has been successively lowered by erosion due to ineffective erosion and drainage control structures. This is often exacerbated by successive passes by graders. The subsequent trail surface is lower than the surrounding natural ground level.

23. **Infall Drainage** - water flows into the hillside, ie in towards a trail cutting.

24. **Jute Mesh** - A coarsely woven jute material which is biodegradeable. Highly versatile normally used with a sowing of plant seeds to establish a vegetation cover whilst protecting soil from rainfall erosion.

25. **Log Dam crossing** - Not to be used, where logs are piled into a creek to form a crossing.

26. **Mass Movement** - A general term encompassing erosion processes in which gravity is the primary force acting to dislodge and transport land surface materials. It is a function of the gravitational stress acting on the land surface and the resistance of the materials to dislodgement. When the gravitational stress exceeds this resistance, mass movement occurs. The occurrence of mass movement depends on the interaction of various factors including landform, lithology, soil type, rainfall intensity and duration, drainage characteristics, vegetation cover and human intervention.

27. **Mitre drain** – A drain to conduct runoff from the shoulders of a trail to a disposal area away from the trail alignment.

28. **Outfall Drainage** – Water flows away from the hillside ie to the outer edge of the trail. The cross slope required to achieve such drainage is 1:25. For safety reasons the maximum crossfal (either infall or outfall) should generally not exceed 1:10.

29. **Rilling** - Small channels cut by concentrated runoff, through which water flows during and immediately after rain.

30. **Sediment** - Material of varying size, both mineral and organic, that is being, or has been, moved from its site of origin by the action of erosion.

31. **Sediment Delivery** – refers to the type of sediment that results from the eroding soil type, and therefore determines how far the sediment will travel from the trail. Key soil characteristics that determine the type of sediment delivered off site are the size of the soil particle and the stability of the

soil aggregate (groupings of soil particles). For example, soils that have sand size particles will produce coarse size sediment that, in general, will not travel to far from the erosion site, whereas silty and clay type soils will produce sediment that will travel a long way in flowing water.

32. **Sedimentation** - Deposition of sediment. Typically this is deposition by water in a soil conservation context, sedimentation is an endpoint in the erosion process – with transported soil material being deposited.

33. **Sill** - A flat horizontal area at the outlet of a soil conservation structure or naturally occurring flat area onto which a drain can discharge to dissipate energy.

34. **Slaking** – Slaking is the partial breakdown of soil aggregates in water due to the swelling of clay and the expulsion of air from pore spaces as the soil is wetted. If the soil is a sandy soil then the particles will be large and will not travel too far from the erosion site. Clay particles are usually stable and are still attached to the sand and silt and so clay will not leave an area.

35. **Soil Aggregate Stability** – is the ability of soil particles to resist the erosive power of rain drop impact and flowing water or wind. There are two aspects to aggregate stability that have a direct bearing on the type of sediment and how far it will travel off site. Slaking and dispersion both influence the type of sediment that will result from an eroded soil. The level of clay in a soil can influence the amount of sediment that is generated. Stable clays usually have a strong binding influence on soil aggregates and lead to stable aggregates in the presence of water. Unstable clays are clays that has have a high level of sodium attached to the clay particle and are termed 'sodic soils'. Usually these soils are stable when they are dry, however, they become unstable in the presence of water.

36. **Soil Coherence** – Soil coherence refers to the ability of the soil particles to resist the erosive energy applied by flowing water. For example, low coherence soils are typically sandy soils or fine particle soils dominated by silt or dispersible clay. Each of these soils do not have enough bonding agents to bind the particles together and they then are prone to detach from the larger soil aggregates and move easily in the presence of flowing water.

37. **Spoon Drain** – a drain with a semi circular cross-section having no associated ridge of soil. Its capacity is solely defined by the excavated channel dimensions.

38. **Sump** - A small basin to collect water and dissipates its energy.

39. **Table Drain** – The side drain of a trail running adjacent to and parallel with the shoulders and forming part of the trail formation.

EROSION CLASSES IN RELATION TO SOIL TYPES

1. **Class A – Low Soil Erodibility**. These are stable soils that are well aggregated with low potential to erode. Usually brown and red soils derived from finer sediment derived from basalt or siltstone parent material. These soils show few signs of erosion and sediment movement, with little signs of sheet and rill erosion on bare surfaces.

2. **Class B – High Soil Erodibility**. These are red soils found on granites, sedimentary rocks or coarser alluvial materials. Due to their weaker inter aggregate strength they are easily detached and erode. The coarse nature of the sediment means that the sediment will not move too far from the erosion point. The sediment is relatively easy to control in trail drains and gutters.

3. **Class C – Very high soil erodibility**. These are grey and yellow soils derived from granites and sedimentary rocks. They usually have topsoil that is dominated by fine sands and silts which are highly mobile once detached by flowing water. If this sediment is captured it will drop out of the water due to gravity, but will easily move again in flowing water. Hence this sediment will travel further into local water ways.

4. **Class D – Extreme soil erodibility.** These soils are highly erosive and show signs of clay dispersion, and are unstable in the presence of water. The fine soil particles (dispersed clay, silt and some fine sand) produce sediment that stays suspended in water. The sediment will not drop out of the water due to gravity. As a general rule, trails should not be built on Class D soils.

SOIL CONSERVATION SERVICE

SCS

NEW SOUTH WALES