Sediment Control on Unsealed Roads:

A Handbook of Practical Guidelines for Improving Stormwater Quality

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Executive Summary

This Handbook is a product of the project 'Minimisation of the impact of unsealed roads on stormwater quality', hereafter called the Unsealed Roads Stormwater Project. With funding by EPA Victoria as part of the Victorian Stormwater Action Program (VSAP), the municipalities of Cardinia, Casey and Mornington Peninsula initiated the project in an effort to protect stormwater quality in the Westernport catchment.

The information contained in the Handbook has been collected from field trials, experiments, literature searches and industry liaison. It aims to provide guidance on best unsealed road maintenance practices, including measures to control sediment and improve stormwater quality. Accompanying this Handbook, are the following:

- *Technical Report*: A comprehensive report detailing the project activities for the twelve-month period (approx. 100 pages).

- *Field Guide*: An on-site guide outlining simple measures for protecting water quality along unsealed roads (4 pages).

- *Video*: A short video demonstrating the main measures for protecting water quality, as outlined in the Field Guide (7 minutes).

A copy of these tools will be distributed to all Victorian councils. Alternatively, copies can be found on the Clearwater website (www.clearwater.asn.au).

The Handbook is designed as an aid for councils to implement erosion and sediment control along unsealed roads. It was developed with council operations and limited resources in mind, thus the practices outlined are typically low cost and relatively easy to install. Complex structures such as large sedimentation basins and wetlands require detailed engineering design, so expert advice should be sought when considering these options. The erosion and sediment control industry is growing and the information detailed here should be supplemented and modified accordingly as new technologies emerge.

The Handbook is divided into six parts:

Section 1: Introduction

An unsealed road pavement has the potential to produce large amounts of sediment. Runoff sampled from an unsealed road in Hastings indicated turbidity levels over 40 times the objective set for waterways in the Westernport catchment. The sediment produced from unsealed roads is typically very fine, with up to 60% of particles in runoff found to be very fine silt and clay. This type of sediment has the potential to be suspended in stormwater for long periods of time, carried long distances and cause environmental harm once reaching waterways. 'Muddy' water can smother animals and plants, clog fish gills and reduce the health of our rivers and streams.

Section 2: Road Surfaces

While an unsealed road pavement road has the potential to produce a large amount of sediment, experiments conducted as part of the Unsealed Roads Stormwater Project found that no single gravel surfacing technique produces significant benefits to sediment runoff. The best practice is to aim for a good quality, well-maintained road pavement. Aim for:

- Crossfall of 4-6%.
- A well compacted surface, using water whenever possible.
- Adequate gravel thickness.
- Minimal rills and corrugations.
- Good quality road material, with a well-graded mix of stone sizes.

Section 3: Road Drainage

Management of roadside drainage is the most effective way of controlling sediment runoff from unsealed roads. Focusing on the maintenance of roadside drainage structures and the treatment of drainage water prior to discharge will provide maximum benefits for the environment for any resources invested. To minimise sediment load, an unsealed road network should have an emphasis on slowing drainage flows and dispersing them more frequently. Stormwater should be diverted away from the road early and often, so as to reduce the catchment area of the road. Sediment filters and traps can also be used to capture sediment before it reaches waterways.

Section 4: Roadside Vegetation

Roadside vegetation is essential to maintaining good stormwater quality. The vegetation performs a variety of different functions, including slowing and filtering stormwater runoff. Machinery working along unsealed roads should keep well clear of any native vegetation, including trees, shrubs and native grasses. The drip line of the tree canopy can be used as a guide for the exclusion area around vegetation within the road reserve. Material from the road pavement or roadside drains should not be windrowed into vegetation. The strategic planting of filter or buffer strips along unsealed roads can be a long-term solution to the treatment of road runoff.

Section 5: Risk Assessment of an Unsealed Road Network

Due to the proximity of the road at stream crossings, these sections are inherently the highest risk to water quality. Management of these high risk sites through the prioritised implementation of sediment control measures is an effective way to improve water quality at the catchment scale. A survey methodology is outlined in this section of the Handbook to identify and assess these high risk areas. This prioritised management of sediment control works can ensure cost effective measures that result in the maximum benefits to the environment.

Section 6: Dust Suppression

Dust suppression is widely used by councils to reduce the amount of dust generated from local roads. Chemical-based dust suppressants have the potential to cause adverse impacts on stormwater quality and the surrounding environment. The use of dust suppression should be a balance between minimising the impacts of the dust itself and minimising the environmental impacts of suppressant application. If dust suppression is to be used, application must be performed in a way that minimises the risk to the environment.

The problem of sediment runoff from unsealed roads is not unique to the Westernport catchment. Many other areas within the state have extensive networks of unsealed roads. All Victorian councils have a legal responsibility to manage unsealed roads so as to minimise erosion, sediment and pollutant transport. Consequently, the results of this study are relevant for other councils and have importance for the protection of water quality across Victoria.

Council staff should be aware of the environmental risks associated with unsealed roads and adopt good environmental practices when working along unsealed roads. This Handbook outlines best practices relating to unsealed road maintenance and measures to control sediment and improve stormwater quality. These guidelines are designed to present the findings of the project in a user friendly format that can easily be transferred into on-ground practices.

1. Unsealed Roads and the Environment

Roads are a feature of the built environment. They provide a trafficable pathway across the landscape. Unsealed roads, in particular, have the potential to interact with the environment due to the unformed and variable nature of the roadway.

An unsealed road, being surfaced mainly with crushed stone and not bounded with bitumen or any other sealant, is subject to erosion by stormwater. Essentially unprotected by vegetation or ground cover, the gravel pavement and associated road surfaces have the potential to generate substantial amounts of sediment. In fact, an unsealed road can produce one hundred times more sediment in stormwater runoff than a sealed road[1].

Photo 1: Sediment runoff from an unsealed road.

Roads interrupt the natural drainage pattern of the landscape. Stormwater is concentrated in drainage channels and directed away from the road into surrounding areas to protect the road structure and road users from flood waters. Consequently, water is concentrated in drainage channels and directed to receiving waters. This combination of exposed surfaces and concentrated stormwater can lead to the significant erosion problems and the potential for stormwater quality issues.

1.1. Why is Sediment Runoff Important?

One of greatest threats to the environment from unsealed roads is sediment runoff from the road surface. Sediment and suspended solids are considered to be the most significant of all road runoff pollutants due to the numerous direct and indirect effects on ecosystem health.

Discharge of muddy or turbid water into waterways can cause serious environmental damage. Reduced amounts of sunlight caused by sediment suspended in the water can affect the growth of plant life and makes it difficult for visual predators such as fish and birds to hunt[2]. Sediment can also clog the gills of fish and other stream life and interfere with the uptake of oxygen[3].

Coarser sediment can be deposited in the waterway, thus changing the nature of the creek bed. High levels of sediment can fill pools, cover rocky bottoms and coat woody debris or 'snags'. This sediment deposition can smother fish eggs, plants, algae, insects, snails, worms and shrimps, and reduce the available habitat for breeding, shelter and feeding[2]. As a result, fish and invertebrate communities within the waterway can be significantly altered.

Many pollutants such as nutrients, heavy metals and organic substances are attached onto and travel with sediment[4]. Small particles, in particular, have the capacity to transport other pollutants from the road surface. Thus the impact of increased suspended sediment maybe exacerbated by increased pollutant loads and potential toxic effects.

1.2. The Bottom Line

By law Victorian councils have a responsibility to:

> '*maintain and, where relevant, manage roads and infrastructure to minimise erosion and sediment and pollutant transport, particularly along urban, unsealed and forestry roads.*'[5]

This responsibility is specified in the State Environment Protection Policy (Waters of Victoria) (SEPP(WOV)), thereby making this a statutory requirement.

Runoff from unsealed roads can reach levels in excess of 1000 turbidity units or NTU. The water quality objective in the State Environment Protection Policy (Waters of Victoria) for rivers and streams in the Westernport catchment is less than 25 NTU[6]. Therefore, **sediment runoff from unsealed roads can be up to 40 times the accepted levels for healthy waterways** (see Table 1).

Table 1: Stormwater quality observed from unsealed roads compared to objectives of Schedule F8 (Waters of Western Port and Catchment) of the SEPP (WOV).

Water quality parameter	*Objective for rivers and streams*[1]	*Observed from trial at Hastings*[2]	*Degree over objective*
Turbidity	25 NTU	1000 NTU[3]	≥40
Suspended Solids	30 mg/L	658 mg/L	22

1. 75th percentile.
2. 75th percentile for a 1-in-1 year storm from a gravel surfaced road.
3. 1000 NTU was the upper limit that the meter could detect. It is likely that this result is actually greater than 1000 NTU.

1.3. Limitations

As outlined above, an unsealed road network has the potential to be a significant sediment source, however, any solution to this environmental issue is limited by the following constraints:

- *Large Scale* - Unsealed road networks can extend throughout a large area. For example, Cardinia Shire Council encompasses approximately 1000km of unsealed roads. Approximately 60% of all roads in Australia are unsealed roads[7]. Sediment control works over such a distance would be cost prohibitive.

- *Diffuse Source of Runoff* – An unsealed road network may have countless discharge points to the environment, making it difficult to implement cost efficient and effective sediment control measures.

- *Always have Exposed Surfaces* – An unsealed road is a continuous source of sediment. As opposed to a temporary disturbance such as a building site or subdivision, a road surface is a permanent structure. The gravel pavement and associated shoulders, drains and batters are subject to the erosive forces of stormwater throughout the life of the road.

- *Variable Pavement* – The gravel surface of an unsealed road pavement is typically variable and changeable. As opposed to a sealed pavement, it is subject to local conditions such as weather and traffic.

- *Require High Levels of Maintenance* – Unsealed roads require periodic maintenance to ensure the serviceability and safety of the road. Table drains, cut-off drains and sediment traps require frequent cleaning to remove sediment that has settled or been trapped. If maintenance is not conducted, the efficiency of erosion and sediment control measures can be substantially reduced.

1.4. Erosion and Sediment Runoff

Erosion is the process by which the earth is worn away by the agents of water or wind. Erosion and sediment release into waterways is a natural occurrence, however human activities such as urban development, agriculture, forestry and roads have accelerated this process. Even small amounts of unprotected or disturbed soil can produce large amounts of sediment runoff during rainfall events. Some soil types are more susceptible to erosion than others, depending on the mechanical, chemical and physical characteristics of the soil[8]. For example, heavy clays tend to resist higher flow velocities than sandy soils[7].

Erosion is the combination of two processes[9]:

- *Detachment* - Particles are separated as a result of raindrops hitting the road surface or bare soil.

- *Transport* – Particles are transported by the movement of stormwater. The road drainage system is the main vehicle for sediment transport along unsealed roads due to the concentration of flows at relatively high velocity.

Erosion is the process by which sediment is produced. By preferentially controlling erosion, stormwater quality issues further downstream can be prevented. Erosion control focuses on stabilisation (source control), whereas sediment control focuses on filtration and deposition (downstream treatments).

Many factors can influence the detachment and transport of sediment particles on unsealed roads. Figure 1 shows a typical unsealed road and the main features influencing sediment runoff. While there are common factors contributing to erosion on unsealed roads, site specific characteristics will determine the extent to which these factors contribute to water quality impacts.

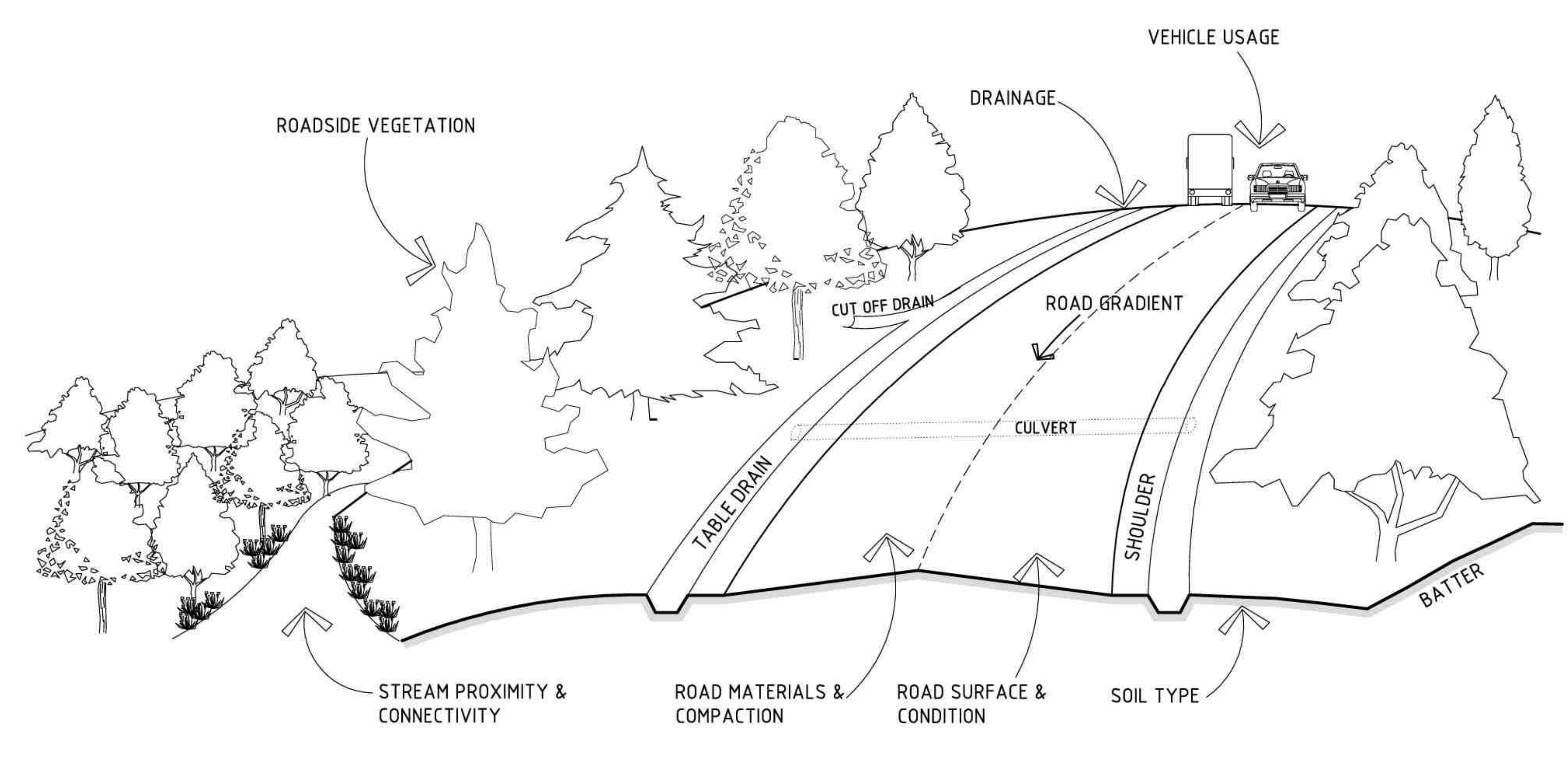

Figure 1: Common factors influencing sediment runoff from unsealed roads.

1.5. Sediment from Unsealed Roads

Sediment from unsealed roads is typically very fine. Figure 2 shows that approximately 60% of the sediment collected in runoff from an unsealed road in Hastings, Victoria was very fine silt and a further 30-40% was silt.

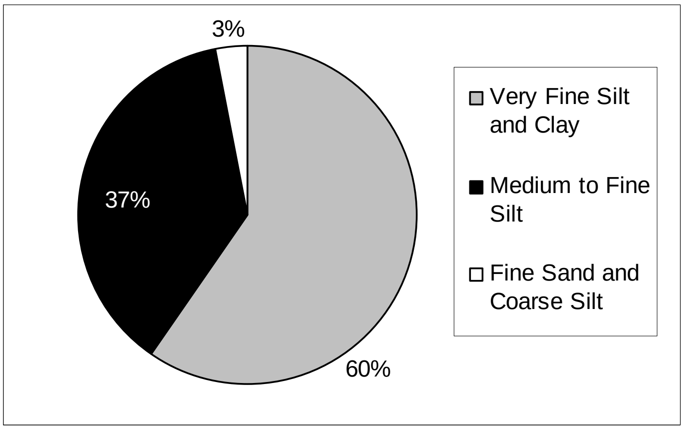

Figure 2: Particle Size Distribution of Sediment Runoff from an Unsealed Road Pavement in Hastings, Victoria.

Small sized particles are generally hard to control due to the long detention times required for the particles to settle. A proportion of the material will be suspended indefinitely because the particle size is too small to fall out of suspension, even if detained for long periods. The Westernport Sediment Study found that a proportion of the fine material delivered to the north arm of the bay was sourced from unsealed roads[10]. This provides evidence that these fine materials from unsealed roads can be transported relatively long distances through the catchment.

Other road pollutants such as nutrients, heavy metals and toxicants generally attach to particles less than 0.063mm[33]. The Unsealed Roads Stormwater Project found that 97% of the material from an unsealed pavement in Hastings was less than 0.043mm in size. This indicates that these fine materials are likely to transport other stormwater pollutants, and subsequently have additional environmental impacts.

During large storms a higher proportion of coarse sediment is produced because the increased volume and velocity of the stormwater has the capacity to pick-up and transport larger road particles. Therefore, during large storm events coarse material may be transported to waterways and contribute to stream bedload. This deposition of sediment can smother aquatic life and negatively alter the nature of the stream bed habitat.

Road managers should take into account the high proportion of fine sediment contained in unsealed road runoff when selecting appropriate stormwater treatment measures along unsealed roads. A key to dealing with these fine particles is to ensure stormwater is diverted away from the road early and often.

1.6. The Benefits of Sediment Control

As detailed in Section 1.2, councils are required to manage unsealed roads so as to minimise erosion, sediment and pollutant transport. In doing so, the environment impacts will be minimised and councils can also receive the following benefits.

1.6.1. Cost Savings

In Cardinia Shire Council, approximately 90 000 tonne of rock is placed on unsealed roads per year. In 2004/05, Cardinia Shire Council budgeted $730 000 for the purchase of road materials. Most of the rock that is placed on the road each year is replacing material that has been displaced or broken down by processes such as vehicle usage, erosion and dust. By controlling erosion and sediment loss on unsealed roads, these maintenance costs can be reduced by preventing the road materials from literally being washed away.

1.6.2. Reduced Maintenance

Active erosion can cause significant damage to the road structure. In such cases, remediation of the erosion can be time consuming and costly. By stabilising erosion and controlling sediment, the condition of the road will be improved, thus requiring less maintenance and resources. Preventative measures may, in the long-term, be more cost effective than remedial measures.

1.6.3. Customer Satisfaction

On reaching waterways, sediment runoff from unsealed roads can potentially pollute farm dams, irrigation channels and private water supplies. As a result, council may receive complaints from downstream users and requests for cleaning of such supplies.

A large proportion of the community is increasingly becoming environmentally aware. Councils being proactive in protecting water quality in local catchments can have a positive impression on this sector of the community.

SECTION 1 KEY POINTS - Unsealed roads are a significant sediment source:

- The variable nature of an unsealed road is subject to erosion by stormwater.
- Sediment discharge directly into waterways can cause serious environmental damage.
- Victorian councils have a legal responsibility to manage unsealed roads so as to minimise erosion, sediment and pollutant transport.
- Sediment produced from unsealed roads is typically very fine. These types of particles have the potential to be suspended in stormwater for long periods and carried long distances through the catchment.

2. Road Surfaces

The gravel pavement of an unsealed road pavement, shoulders, drains and batters are subject to the erosive forces of stormwater. The rate of erosion on unprotected or disturbed surfaces such as these may increase by a factor of one hundred or more compared to natural rates[11]. Other factors such as vehicle traffic and maintenance practices can also increase the potential for sediment production.

While an unsealed road pavement road has the potential to produce a large amount of sediment, experiments conducted as part of the Unsealed Roads Stormwater Project found that no single gravel surfacing technique produces significant benefits to sediment runoff. A gravel pavement is highly variable. The best practice is to aim for a good quality, well-maintained road pavement with the following considerations.

2.1. Road Pavement

2.1.1. Road Materials

A higher quality road material tends to produce less sediment[12,13]. A study in North America found that a marginal quality aggregate on a forestry road produced up to 12 times more sediment compared to a similar section surfaced with a good quality aggregate[14].

Unsealed road materials should have the following characteristics[7]:

- Good quality, locally available aggregate.
- 100% of the material passing through a 26.5mm sieve. Figure 3 shows the approximate proportions of material size that perform best as an unsealed surface.
- Free from oversized rocks, vegetation and organic matter.
- Plasticity Index (PI) between 4 and 8.
- Linear shrinkage (LS) between 2 and 8.

More information on the above specifications can be found in the 'Unsealed Roads Manual: Guidelines to Good Practice'[7].

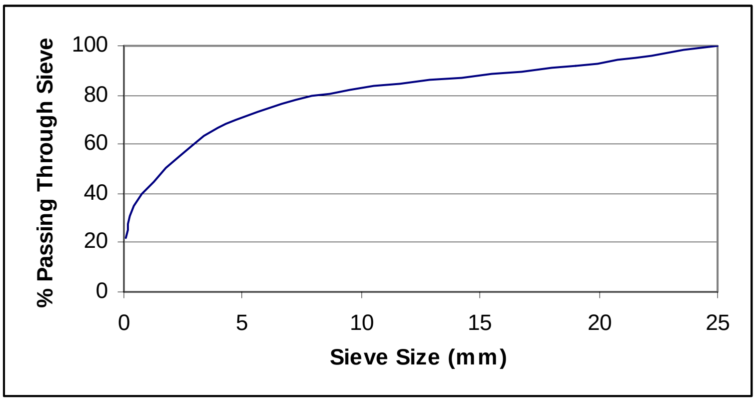

Figure 3: Approximate proportions of particle sizes for an unsealed road pavement.

2.1.2. Wearing Course

A wearing course can be added as a surface layer on the road pavement to form a hard crust. This additional layer can resist wheel abrasion and minimise water infiltration into the layers below. A wearing course also has the potential to reduce surface scour by creating a mix that will easily bind together and minimise detachment of particles[7,15]. A wearing course should meet the following depth, grading and plasticity specification:

Minimum depth:	70mm
Passing 19 mm sieve:	100 %
Passing 6.70 mm sieve:	60-80 %
Passing 2.36 mm sieve:	40-60 %
Passing 0.300 mm sieve:	25-35 %
Passing 0.075mm sieve:	10-20 %
PI should be in the range of:	8-12

2.1.3. Thickness

A thicker layer of road material has found to substantially reduce sediment production from the road pavement[16,13,17,18]. A study in the Yarra catchment of Victoria found that a gravel layer of 70-100mm produced less sediment, while a thin gravel layer of 40-50mm deteriorated quickly and produced more sediment[19]. A thicker layer of road material can increase the structural stability of the road, avoid breaking up and reduce deterioration. The 'Unsealed Roads Manual' recommends a minimum pavement thickness of 100mm[7].

2.1.4. Compaction

Compaction increases the density of a material by expelling air from the spaces between particles. Good compaction of road material prevents the detachment and dispersion of material by passing vehicles[15]. This strengthening of the road surface can produce a surface that is less prone to deterioration and provide some protection from erosion[7].

The moisture content of the material strongly influences the level of compaction[7]. By adding water during road maintenance, compaction levels can be increased and grading frequency can be reduced[24]. If a water cart is not available during maintenance, taking advantage of wet weather periods can provide a more compacted and coherent surface than dry grading alone. As a general guide, eight passes of an appropriate roller will provide effective compaction on a typical unsealed pavement[7]. When the roller is no longer observed to leave an imprint on the surface, the material can be regarded as having sufficient compaction. It is important that compaction is conducted with the correct plant and equipment. Using vehicle traffic to compact newly graded roads can cause excessive pavement material loss[7].

Photo 2: Multi-wheel roller compacting a section of Boes Rd Hastings.

2.2. Road Condition

Over time the surface of an unsealed road will deteriorate due to wear by vehicle traffic and climatic conditions. Defects such as corrugations (parallel ridges at right angles to the direction of the traffic), rutting (longitudinal depressions) and potholes are common[7]. When the road surface deteriorates, the amount of sediment available for runoff is increased.

The shape of the road pavement influences water flow across the surface, which in turn affects sediment transport[20]. For example, stormwater will follow ruts or rills instead of flowing uniformly across the surface. This concentrates the water flow and subsequently increases erosion of the road surface[12]. Concentrated flow from the road pavement can also increase erosion of adjacent areas, such as shoulders and table drains[12,21].

Photo 3: Potholes in an unsealed pavement.

2.3. Grading

Road grading rectifies surface defects such as corrugations and potholes, which is important in reducing erosion[12]. A study by Melbourne Water found that on roads that were well-maintained, the impact of vehicle traffic on sediment production was reduced[17, 19]. Maintenance should be set at frequency appropriate to the function and classification of the road[22]. Councils are required to develop a Road Management Plan, which outlines intervention levels for local roads.

While road grading repairs defects to the road surface, it can temporarily increase sediment because a layer of soil is disturbed on the road pavement, shoulders and drains that is a source of easily eroded material[21,23]. In one study, twelve times more sediment was collected the week after grading as compared to ungraded roads. It is important to achieve sufficient compaction immediately after grading to ensure the new road surface can adequately resist erosion.

When grading, avoid widening the road formation. The area of work should be kept as small as possible, while minimising soil disturbance and damage to vegetated areas. Avoid leaving windrows on the roadside. Grading should start from the table drain or road edge and work inwards, thus creating windrows in the road centre. The deposited material can then be spread back across the road on the following pass. Grading off the crown of the road should be avoided as this can accelerate the loss of road profile (See Section 2.4)[24].

2.4. Road Profile

There are three types of road profile[24, 25]:

- *Crowned (two-way crossfall)*: The road is formed with an apex in the middle so that the both sides of the road are sloped outwards, usually at a 4-6% crossfall.
- *Outsloping (one-way crossfall)*: The road drainage directed towards the outer edge of the road. Runoff is not concentrated into a drain but continuously dispersed into the surrounding environment. This profile is restricted to straight sections or low speed roads due to safety considerations.
- *Insloping (one-way crossfall)*: Drainage is directed to the inner edge of the road towards the batter.

The three alternative crossfall designs for unsealed roads are illustrated in Figure 4. The use of an outsloping crossfall can be effective in reducing the concentration of road drainage water. It allows diffuse drainage off the road into the environment and avoids the need to concentrate drainage in table drains. Alternatively, where there are erosive soils and drainage water needs to be contained, the use of an insloped crossfall can be effective in reducing drainage impacts. The choice of the most appropriate pavement crossfall design will depend on the local environmental, topographical and safety factors.

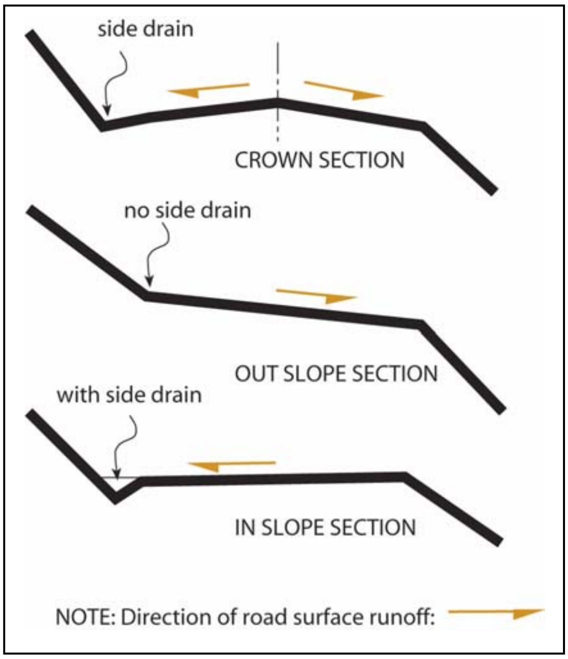

Figure 4: Three types of road profile[26].

Regular maintenance of the profile by grading ensures adequate drainage, reduces erosion and prevents surface defects[15,25]. Roads maintained to a reasonable crossfall i.e. 4–6%, will shed water more rapidly and are less likely to deteriorate[7]. The road formation should always be maintained at a higher elevation than the drainage system to prevent the road becoming a drain itself[25].

2.5. Traffic

Road surface erosion is extremely sensitive to traffic levels, with heavily used roads generating substantially more sediment than lesser used roads. Heavy traffic on a forestry road in North America contributed 7.5 times more sediment than light traffic use on the same road[27]. In a forested catchment in New South Wales, sediment runoff was 5 to 8 times higher in well used roads than abandoned roads[20]. High levels of traffic increase sediment production because the vehicle passage generates loose material which can be carried away with each rain event. The loose material is then replenished after each rainfall by continued vehicle use. After periods of dry weather these stores of material can build up to large quantities.

2.6. Shoulders

Road shoulders provide a number of functions to the road formation, such as structural support to the pavement, drainage and extra width for the passage of traffic[7]. Unsealed shoulders should be maintained at 4-6% crossfall and be the same grade as the road pavement to facilitate drainage[24]. Materials used to construct or maintain shoulders should be a similar quality to the pavement to minimise the formation of defects such as rutting and potholes. More information on unsealed shoulders can be found in Chapter 8 of the 'Unsealed Roads Manual: Guidelines to Good Practice'[7].

2.7. Batters

During road construction, batters may be formed on the low side of the road (fillslope) and high side of the road (cutslope). Being an exposed area, batters can make a substantial contribution to sediment runoff. A study in the Central Highlands of Victoria found that one of the principal sources of sediment from an unsealed forest road was the fillslope batter which contributed coarse bedload to an adjacent waterway[28].

Catch drains or earthen banks can be constructed above cutslope batters to protect the surface from erosion. These divert runoff away from the slope to prevent uncontrolled stormwater flow from surrounding areas eroding the surface. Catch drains should be installed during construction to prevent erosion over the life of the road.

Sediment production from road batters can be minimised by using vegetation or fabrics to stabilise the slope. Grass vegetation and matting have been found to significantly reduced sediment yield on both cutslopes and fillslopes as compared to bare soil[29]. For best results, it is important that these stabilisation measures are installed immediately after construction is complete. Vegetation can be established quickly using a variety of techniques, including rapid seeding of sterile rye grass. Installation of biodegradable matting can control erosion while the vegetation is being established. During maintenance, grading should avoid the toe of batter slopes to prevent the risk of the bank collapsing[24].

SECTION 2 KEY POINTS - Maintain a good quality road surface:

- Use good quality road surfacing materials, with a well-graded mix of rock sizes.
- Aim for at least 100mm pavement thickness.
- Construct a well compacted surface, using water whenever possible.
- Aim for 4-6% crossfall.
- Minimise rills and corrugations.
- Stabilise batters as soon as possible after construction.

3. Road Drainage

Traditional road design and maintenance practices aim to collect and convey stormwater runoff in the most efficient manner possible. These characteristics of roadside drainage provide an easy pathway for the transport of sediment and other stormwater pollutants. Once a particle is picked up by the flow, it may travel long distances depending on the particle properties and the transport capacity of the flow[30].

Roadside drainage is a critical factor in controlling water quality impacts from unsealed roads. Data collected as part of the Unsealed Roads Stormwater Project indicate that the road surface treatments tested provided minimal differences to stormwater quality. **Efforts should be directed at improving maintenance of roadside drainage and treatment of stormwater prior to reaching waterways.** Focus on these areas will provide maximum benefits for the environment for the resources invested.

To minimise sediment load, an unsealed road network should have an emphasis on slowing drainage flows and dispersing them more frequently into the roadside environment. Stormwater should be diverted away from the road early and often, so as to reduce the catchment area of the road and prevent the concentration of flows. Use the following principles, when considered drainage options along unsealed roads:

- **Slow the flow**

  Where the velocity of water is doubled, its capacity to erode and transport sediment increases 64 times[31]. Slowing the flow of stormwater will reduce its carrying capacity and allow particles to settle.

- **Reduce the volume of runoff**

  A large volume of stormwater has increased capacity to erode and transport sediment. By diverting and dispersing water away from the road at periodic intervals, the catchment area of the roadway is reduced.

  In urban areas, private land, houses and other structures may pose barriers to slowing and dispersing stormwater from the road. As a final alternative, try to:

- **Catch and treat the runoff**

  Most roads deliver their runoff at concentrated outlets[32]. By identifying discharge points from the road, the runoff can be detained and treated before it reaches the stream. A variety of sediment trapping techniques are available depending on the characteristics of the site.

Figure 5 outlines options available for erosion and sediment control along unsealed roads. This list is not exhaustive but includes measures that are typically low cost and relatively easy to install. The options are separated into source (erosion control) and downstream measures (sediment control). Larger sediment control structures that require detailed planning and involve higher costs are discussed in Section 3.9.

OPTIONS:

- Table drain shape (p15)
- Drain maintenance practices (p16)
- Drain liners (p16)
- Grass swale (p17)
- Check dam (p18)

← **Source Controls**

- Cut-off drain (p19)
- Cross drain (p21)
- Culvert rock apron (p21)
- Sediment trap (p22)
- Filter / buffer strip (p28)

← **Downstream Treatments**

Figure 5: Options for erosion and sediment control along unsealed roads.

3.1. Treatment Train Approach

No single treatment measure can remove all pollutants from road runoff. Treatment measures can typically only target a particular range of particle sizes. For example, sedimentation basins are effective at removing coarse to medium-sized sediment particles, whereas wetlands are more effective at removing very fine particulates[33]. A number of management measures placed in a series, thus forming a 'treatment train', can be effective approach for removing a large majority of pollutants from road runoff[33, 15]. The treatment train approach is a key principle of Water Sensitive Urban Design (WSUD). For example, rather than installing a single sediment trap at a stream crossing (outlet approach), a more effective approach is to place additional measures upstream to slow and disperse water before entering the sediment trap (distributed approach)[45].

3.2. Stream Proximity & Connectivity

More important than any sediment control measure, is simply preventing table drains and cut-off drains from discharging directly into waterways. These types of drains typically have concentrated, high-velocity flows and can frequently form channels direct to waterways. These channels provide an easy pathway for sediment to reach streams and adversely impact on water quality.

Photo 4: Runoff from an unsealed road flowing directly into Cockatoo Creek.

Try to divert stormwater away from the road before it reaches a stream so that sediment is deposited before entering waterways. As a general rule, cut-off drains should be installed at least 50 metres prior to a stream crossing[7]. If cut-off drains are not possible, alternatively trap sediment via basins, barriers or filters at the drainage outlet. Section 3.8 provides information on the construction of sediment traps.

At stream crossings in particular, the proximity of the road means that stormwater only has a short distance to travel to reach the stream. These sections of roads have the potential to contribute high loads of sediment. Sealing the road at waterway crossings can be an option to limit sediment discharge in these areas[15]. Section 5 of this Handbook details a method by which stream crossings within an unsealed road network can be surveyed and a priority management approach adopted.

3.3. Table Drains

Roadside drains are a key element of the road drainage system. They collect runoff from the road formation to channel flow away from the pavement. This concentration of flow has the potential to dislodge soil particles and transport sediment runoff long distances. If the road is well maintained, the majority of erosion is in the table drain[34]. A study conducted in the Blue Mountains, New South Wales found that the concentration of sediment runoff from the road gutter can be more than 100 times the concentration derived from the road pavement[1]. Only runoff from the road formation should enter table drains. Table drain should not collect stormwater from surrounding areas. In doing so, good quality overland drainage water is being contaminated by the road runoff and increases the demand on the roadside drainage system.

3.3.1. Table Drain Shape

The cross-sectional area, shape and longitudinal grade of a table drain effects the potential for erosion. Channels should have sufficient capacity to carry the required flows and have adequate stability to resist the erosive action of the stormwater. A flat-based profile will minimise scour by providing wide, shallow channel. Low sloping sides will also reduce the risk of the drain sides undermining and failing. Drains should be of parabolic or trapezoid cross section. 'V' or steep-sided 'U' shapes should to be avoided[35]. Drain sides should be sides no steeper than 3 horizontal:1 vertical. An excavator or backhoe is better suited to achieving this shape than a grader.

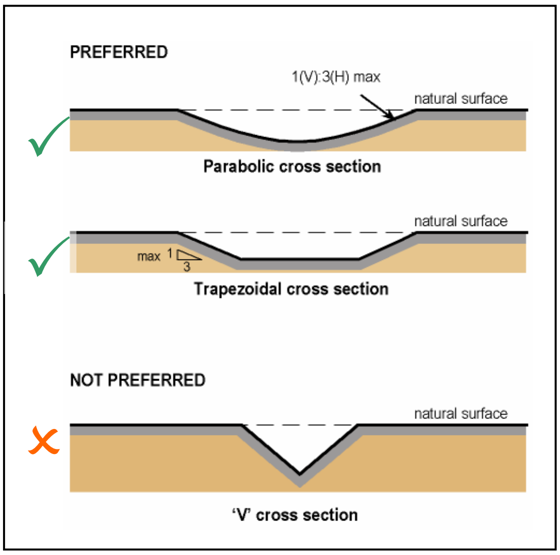

Figure 6: Optimum table drain shape[36].

3.3.2. *Drain Maintenance*

The cleaning of table drains produces a smooth, readily erodable surface. Table drains that have recently been cleaned are more prone to erosion and produce more sediment[21]. A 'dirty' drain may contain vegetation and obstacles such as logs, fallen debris and leaf litter, which act to slow flow velocities and allow sediment to deposit[20]. Newly constructed or recently cleaned drains can temporarily increase flow velocity and sediment production by providing a smooth, unprotected channel. By keeping road drains wide, rough and irregular shaped, flow velocity can be reduced and sediment is more easily trapped[20]. As a result, drains should be cleaned only when it is necessary to restore drainage capacity.

Table drains require regular cleaning to ensure water is effectively carried away from the road[20, 25]. If table drains do not have adequate capacity, then runoff will overtop banks and cause erosion in other areas[8]. When table drains are cleaned, the original shape should be restored as detailed in Figure 6. Cleaning drains by mowing and raking rather than scraping or grading can generate fewer particles of silt and sediment[24].

Photo 5: A recently cleaned table drain.

Avoid windrowing drain material into roadside vegetation. Spoil should not be dumped near the outlet of culverts or cut-offs because the sediment then can be remobilised by stormwater. If the material cannot be recycled into the pavement, the soil should be removed to a designated disposal site.

3.3.3. *Lining of Table Drains*

Artificial drain liners are essentially a replacement of surface cover. They in no way can replace the benefits of natural vegetation but can perform similar functions such as slowing and filtering runoff. Where necessary, such as on highly erodable soils, table drains can be stabilised with matting or rock rubble so that the drain does not become a source of sediment itself. Table 2 outlines different types of liners that can be used in table drains. Drain liners are also a useful tool in areas with small median strips that do not permit a wide, shallow drain as indicated in Figure 6. If the gradient is more than 5%, the drain can be intercepted with small check dams to slow runoff velocity and improve sedimentation[15]. Check dams are discussed in Section 3.5.

Photo 6: A table drain lined with rock rubble.

Table 2: Table drain liners.

Type	*Description*	*Specifications*
Vegetation	See Section 3.4. Grass Swales	Grade <5%
Matting	A large variety of biodegradable matting and geotextiles are available for stabilising soil. Selection of an appropriate material will depend on the flow velocity, cost and durability required to stabilise the surface and/or establish vegetation. Fabrics should be correctly installed to ensure their effectiveness and long-term efficiency (see supplier for guidance on correct installation). Ensure the fabric is laid over a smooth even foundation to prevent water undermining the material.	Grade <5%
Rock Rubble or 'RipRap'	Rock rubble can be placed in drain sections to slow and disperse the flow. When determining the size of rock, ensure that the rocks are large enough to resist dislodgment by peak water flows[37]. It is recommended that an assortment of rock sizes is used, instead of one uniform size[38]. Rough angular rock is more resistant to scouring, as it interlocks and resist overturning better than smooth rounded rock[30]. The base of such drains should be evenly graded to prevent water ponding and becoming stagnant[8]. The rock rubble should be laid in the same shape as the table drain (Figure 6) to prevent water diverting around the rock. Use of a geotextile underneath the rock will reduce the likelihood of water undermining the rock.	Grade 5-10%: ▪ 50-150mm diameter rock ▪ 200mm thick Grade >10% ▪ 100-300mm diameter rock ▪ 300mm thick (Adapted from [39])

3.4. Grass Swales

Grass swales are shallow, open drains with a dense cover of vegetation. Often used as drainage features in water sensitive urban developments, they are an alternative to the conventional piped drainage[40]. Essentially, swales are specially constructed table drains, with the vegetation providing additional functions such as infiltration and treatment of sediment and other pollutants[33]. Swales are most effective on low to moderate slopes with a gradient between 2% to 4% [15]. They should be located on well drained soils with a deep water table[25]. The vegetation cover should be maintained though watering, reseeding, weeding or fertilising, to ensure the treatment capacity of the swale.

In some situations, table drains alongside unsealed roads are not able to sustain vegetation growth due to large volumes of runoff at high velocities. The large volumes of sediment generated from unsealed roads also can smother vegetation and prevent growth[41]. The maintenance requirements of table drains also mean that drains require frequent cleaning, thus removing vegetation. Alternative drain liners are outlined in Table 2.

When considering installation of a grass swale, qualified personnel should be consulted so that these structures are constructed adequately and for optimum performance. Information on grass swales can be found in the Water Sensitive Urban Design Engineering Manual available from Melbourne Water. Appendix B of the WSUD Engineering Manual contains detailed guidance on plant species suitable for grass swales.

3.5. Check Dams

Devices such as silt fences, straw bales or rock rubble can be placed in table drains to slow stormwater runoff. These temporary structures use the process of deposition to remove sediment from road runoff.

Deposition occurs when flow velocity is reduced, thus reducing the energy of the stormwater and causing particles to drop out of suspension. Structures which appear to act as filters such as sediment fences and straw bale barriers actually work via deposition[25]. Each structure is essentially a small dam or 'check dam' that slows the flow and results in the settling out of sediment. Check dams are also effective at keeping vegetation, litter and other debris from reaching and plugging culverts [39]. Table 3 lists a number of different devices that can be used to construct check dams.

Photo 7: A series of rock check dams.

Table 3: Devices that can be placed in table drains to act as check dams.

Type	*Description*
Rock Rubble	Rock rubble is recommended for sites with large flow volumes. Rock should be of adequate size to resist dislodgment by peak water flows. It is recommended that an assortment of rock sizes is used, instead of one uniform size. Rough angular rock is more resistant to scouring as it interlocks and resists overturning better than smooth rounded rock.
Silt Fence & Straw Bales	Silt fence and straw bales should be used in conjunction to increase strength and minimise dam failure. The straw bales should be placed downstream of the silt fence. For maximum strength, both need to be supported with star pickets or wooden posts, entrenched 200mm deep, backfilled and compacted to ground level. Due to the decomposition of bales, straw bales generally require replacement approximately every 3 months.
Biodegradable Logs	Biodegradable logs can be made from coir (fibre from coconut husks[38]), straw or wool and typically break down over three to six months. The logs are usually anchored with pins, or star pickets. The area beneath the log should be stripped to ensure firm contact with the ground.
Synthetic Logs	As above. Synthetic logs have a longer life than biodegradable materials and some can also be reused.
Gravel Sausages	Permeable sacks (either geotextile or synthetic netting) filled with coarse sand or rock aggregate up to 50mm[38].
Gabions	A gabion is a wire basket (typical dimensions: 2x1x1 metres) filled with rock. Wire baskets are available either galvanised or coated with plastic to resist corrosion. Due to size and installation requirements, gabions are only recommended for sites with large flow volumes at high velocities.

Check dams should be placed so that the base of the upslope dam is level with the crest of the downslope dam[38]. The centre of the check dam should be lower than the edges to create a spillway. Figure 7 provides guidance on correct installation. Check dams should only treat a relatively small catchment area, maximum of one hectare[43].

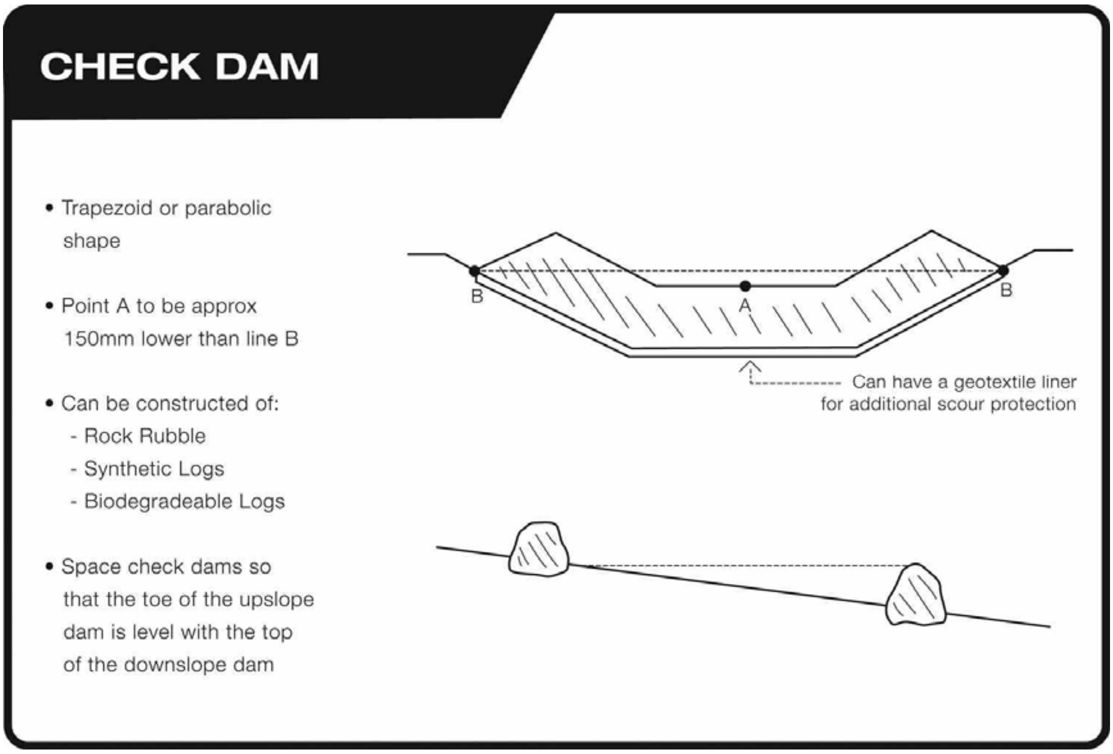

Figure 7: Appropriate placement of check-dams.

3.6. Cut-off Drains

Cut-off drains, also called turn-outs, push-outs or mitre drains, divert water away from the table drain into the surrounding area[7]. This reduces the volume and velocity of water flow from the above section of road, disperses stormwater and allows sediment to settle. Cut-off drains have been found to effectively remove sediment load of runoff water by up to 50% [20]. They should be have a broad flat base (>1m width) with gentle sides and feathered at the exit point[24].

Photo 8: Cut-off drain diverts runoff into a stable vegetated area.

Cut-off drains should be adequately spaced. The greater the distance between cut-off drains, the greater the stormwater volume and velocity[25]. The distance between cut-offs should be determined by the gradient of the landscape. For example in the Cuttagee Creek catchment in NSW, where the road gradient is 5 degrees and the discharge gradient is 7½ degrees, the optimum length between cut-offs is 95 metres. As a general rule, cut-off drains should be placed at approximately 100 metres apart, if the landscape permits. Intervals between cut-off drain should be shortened with increasing steepness[24]. If construction of a cut-off drain is not possible due to barriers such as steep slopes, private land or buildings, catch and treat the runoff at another outlet point further downstream. Other methods such as a table drain liners or check dams can also be used as an alternative to control erosion and sediment.

Careful placement of cut-off drains is necessary because they can potentially relocate highly erosive stormwater from the road to surrounding areas. Cut-off drains should be placed on a gentle slope that slows stormwater and allows sediment to deposit. Discharge onto steep slopes can cause further erosion beyond the road structure. Evenly shape the outlet of the cut-off drain so that the concentrated flow is converted back to sheet flow. Treatments at the end of cut-off drains have been found to decrease sediment discharge by 40%[42]. By treating the cut-off outlet with either vegetation, rock rubble or silt fence the sediment load of the runoff can be substantially decreased. Figure 8 shows treatments that can be used in cut-off drains to increase treatment capacity.

Cut-off drains have the potential to negatively impact on roadside vegetation. Excessive runoff from cut-off drains can waterlog soil and effect vegetation health. Some areas of roadside vegetation have significant environmental values, which may contain rare or threatened species, and so extra caution is needed. Swale type vegetation can be used at the base of cut-off drains to reduce waterlogging of roadside vegetation and create sheet flow at the outlet of the cut-off drain. Use Appendix B from the WSUD Engineering Manual to determine the appropriate plant species.

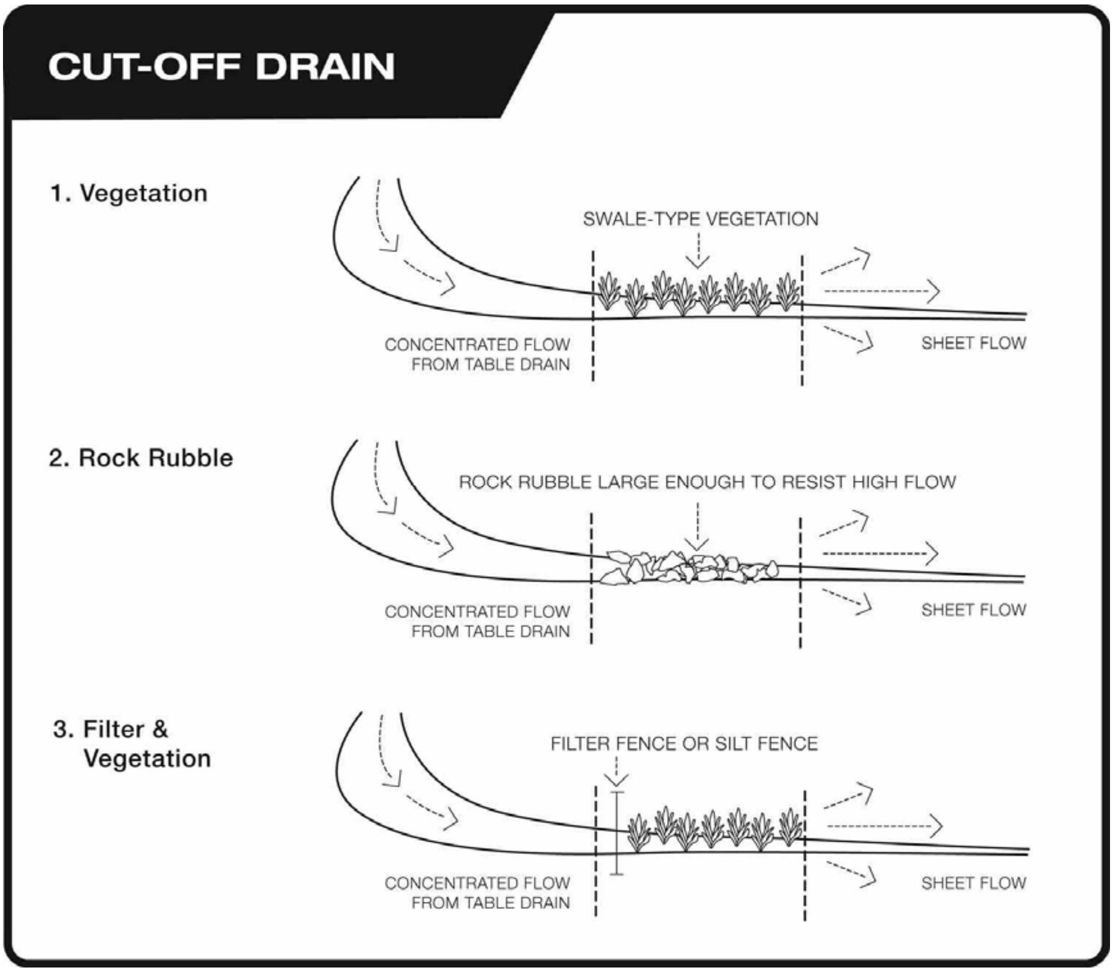

Figure 8: Treatment methods for cut-off drains.

3.6.1. Maintenance Requirements

Cut-off drains require regular inspections to monitor weed infestations, the condition of surrounding vegetation and erosion at the outlet. The drain inlet may also need to be reopened if blocked by road grading. Regular maintenance to remove deposited sediment should ensure that cut-off drains do not gradually become deeper and wider. Machinery should avoid damaging or removing adjacent vegetation.

3.7. Cross Drains

Culverts are used on unsealed roads as cross drains to direct the flow of water from the high side to the low side of the road. Similar to cut-off drains, cross drains should be adequately spaced to reduce the volume and velocity of stormwater in the table drain. Under average conditions cross drains should be a maximum of 150 metres apart. Optimum spacing distance can be determined by the 'rule of thumb method'[41]:

$$\text{Spacing in metres} = \frac{300}{\%\ \text{grade}}$$

A study in a forested catchment in NSW found that the majority of gullies occurred at culvert outlets[20]. To reduce velocity at the culvert outlet, the pipe should be aligned on an angle that allows adequate drainage by gravity but keeps runoff at low velocities at the culvert outlet. Any increase in slope or pipe length will increase the velocity and erosive potential of the stormwater.

Photo 9: Culvert outlet.

Culverts discharge concentrated flow at the pipe outlet and as such can be subject to erosion. Culvert outlets should be constructed and maintained with sufficient resistance to the erosive forces of the stormwater[43]. Erosion can be controlled using an energy dissipater, whereby energy is absorbed by impact through an obstruction in the flow path[35]. The most common type is a rock apron, which uses rock rubble in a fanned arrangement to slow and disperse the flow. Figure 9 provides guidance on constructing a culvert rock apron. The rock should be large enough to resist flow and of sufficient area to slow flow enough to prevent erosion beyond the outlet. The rock can be underlain with geotextile to provide additional scour protection[35].

A change in flow height, also known as a hydraulic jump or 'head'[30], is often present at culvert outlets. A waterfall is an example of a hydraulic jump, where the calm waters above the waterfall are changed into turbulent and high-energy flow below the waterfall. This abrupt transition has significant erosion potential. Where possible, culvert outlets should be placed flush with the ground surface to prevent the formation of a hydraulic jump. If a jump is present, the energy can be lost via a stilling pool[35], whereby a small basin is created at the culvert outlet to contain the turbulent flows. Once the stormwater leaves the stilling pool, the energy has been lost and the risk of erosion downstream is decreased.

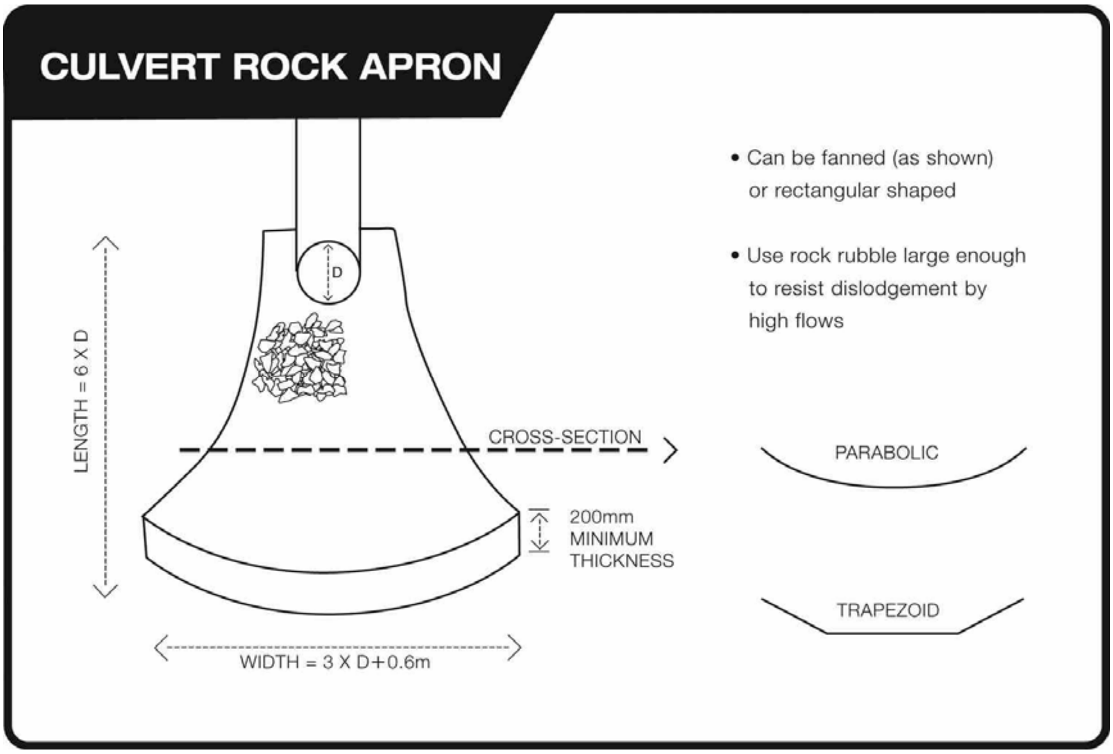

Figure 9: Guidance for constructing a culvert rock apron.

3.8. Sediment Traps

Sediment traps are typically small, temporary structures that slow or catch stormwater runoff. Devices such as silt fence, straw bales or rock rubble can be used in drainage outlets, such as cut-off drains or culvert outlets, to act as small sediment traps. By slowing the velocity of the runoff, the sediment is deposited. Depending of the type of structure used, the runoff is also able to be filtered to remove fine sediment particles.

Sediment traps can be created from a variety of means. For example, a sediment trap can simply be an excavated area with earth banks. Alternatively, a sediment trap can use temporary structures such as sediment fence or barriers. Figure 11 provides guidance on constructing a sediment trap and the types of devices that can also be used as sediment barriers. Primarily, the trap should hold the majority of stormwater flows so that runoff can be detained and sediment can settle out of suspension. It is important that a spillway is created so that large flows will bypass the trap and not cause flooding or failure of the structure.

A well constructed sediment trap will[35]:

- Minimise land and vegetation disturbance of the surrounding area,
- Be placed as close to the source of sediment as possible,
- Have adequate capacity to settle the desired proportion of sediment from the runoff,
- Ensure only polluted waters should enter the sediment trap,
- Allow for frequent maintenance,
- Contain a spillway to divert high flows,

Photo 10 shows a site in the City of Casey where gabions have been used to provide a highly permeable sediment trap. Photo 11 shows a site where a sediment filter was installed at a discharge point into a tributary of Cardinia Creek. The filter was a simple structure that cost less than $500, was easy to install and effectively removed both coarse and fine sediment from the stormwater.

Photo 10: A sediment trap constructed from gabions.

Photo 11: A sediment filter used to construct a sediment trap.

Over a period of a few weeks, a substantial mass of sediment had built up behind the filter. Figure 10 shows the levels of sediment that gradually accumulated behind the filter. Before the filter was installed, all this material would have been discharged directly to a local stream, which is a tributary of Cardinia Creek and Westernport Bay. These types of measures can protect local catchments from stormwater pollutants.

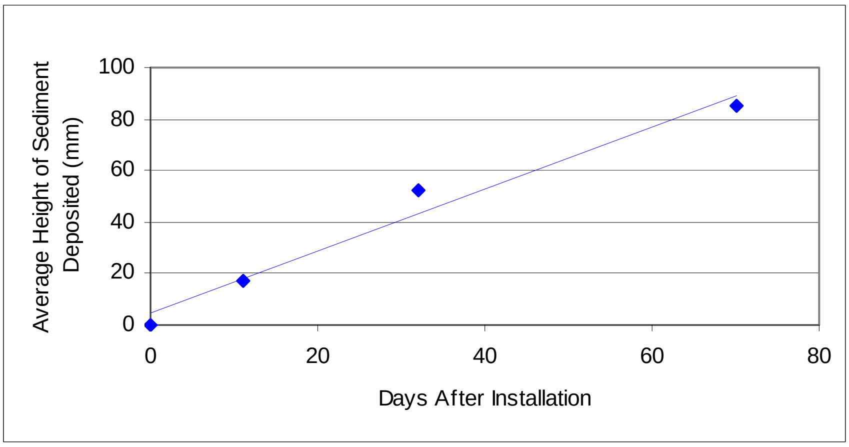

Figure 10: The level of sediment deposited after installation of the sediment filter (indicative only).

3.8.1. Maintenance Requirements

Sediment traps are ineffective unless adequately maintained[41]. Sediment needs to be removed from traps and basins at sufficient frequencies to maintain storage capacities and to ensure their ongoing effective operation[37]. Sediment traps should be located to allow easy sediment removal and minimise disturbance to surrounding areas.

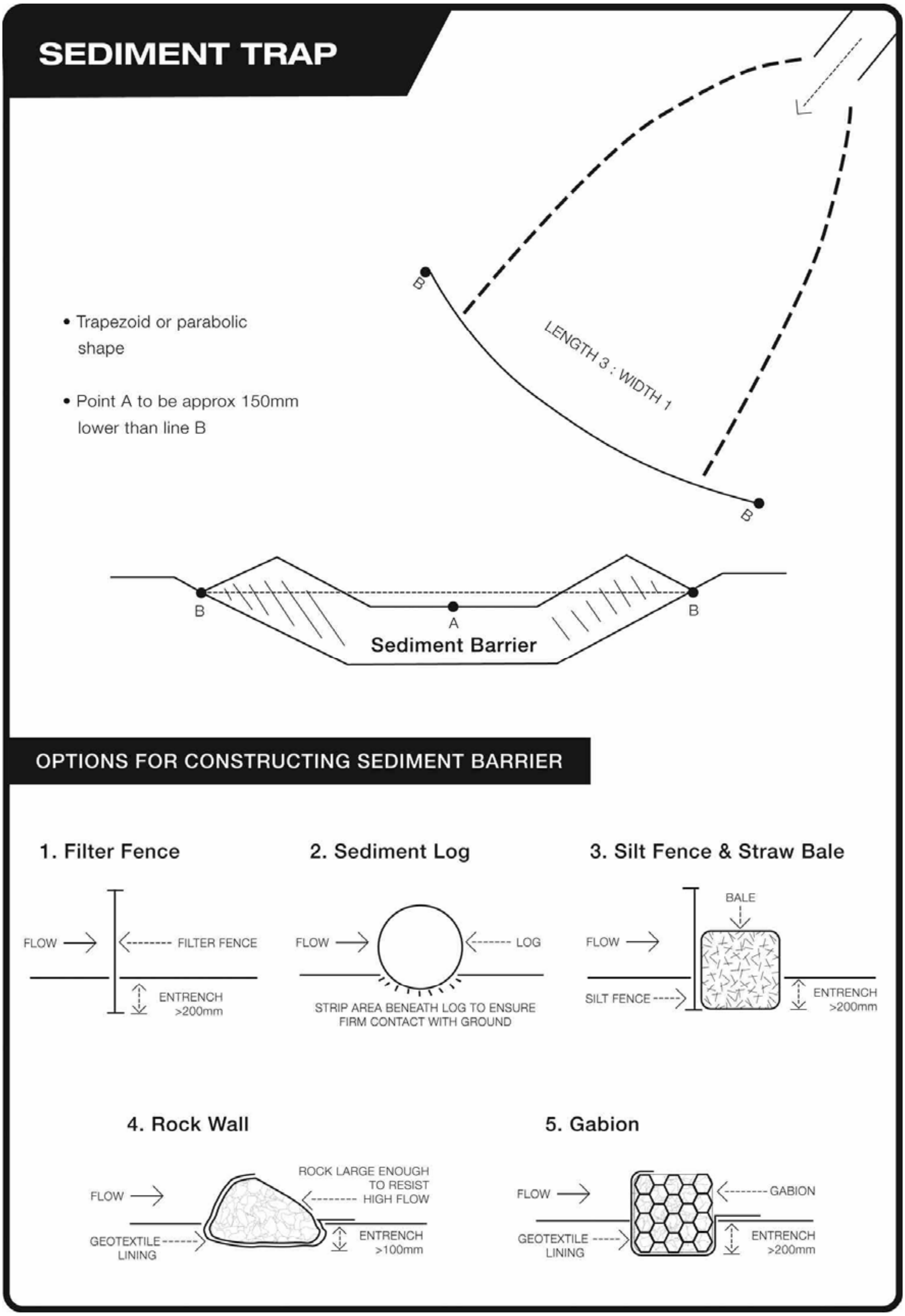

Figure 11: Guidance for constructing a sediment trap.

3.9. Large Scale Sediment Control Structures

The majority of techniques discussed up to this point have been small-scale, low cost and relatively easy to install. In some cases more complex structures are required to provide more long-term solutions to sediment control. Qualified expertise should be sought to ensure adequate design and construction of these options.

Further information can be sourced from the following texts:

- Melbourne Water. 2004. Water Sensitive Urban Design – Engineering Guidelines. Ecological Engineering, WBM, Parsons Brinkerhoff.
- Stormwater Committee. 1999. Urban Stormwater: Best Practice Environmental Management Guidelines. Environment Protection Authority, Melbourne Water Corporation, Dept. Natural Resources and Environment, Municipal Association of Victoria. CSIRO Publishing, Melbourne.
- Melbourne Water. 2002. Constructed Wetland Systems – Design Guidelines for developers. Melbourne Water July 2002.

3.9.1. Sedimentation basins

Sedimentation basins are permanent earthen or concrete ponds, constructed individually or in series[33] that detain stormwater to allow the sediment particles to settle. Sedimentation basins are often used to settle coarse to medium sized sediment and as such are important as a primary measure in the treatment train. Sediment basins take into consideration the time required for the desired particle size to settle and adequate capacity to store and trap sediment. For example, if a basin has a 10 hour retention period for an average five-year recurrence interval stormwater flow, most clay sized particles (<0.002 mm diameter) will tend to be retained[37].

3.9.2. Wetlands

The use of wetlands for stormwater treatment is becoming a more widely used practice as a stormwater detention system and a means to improve water quality. A constructed wetland is an artificial structure design to replicate natural processes for retention or removal of stormwater pollutants such as nutrients, heavy metals, pathogens, hydrocarbons and fine sediments[43]. A wetland is typically a combination of vegetated areas and open water areas[40]. The aquatic vegetation performs several treatment processes including sedimentation, fine particle filtration, nutrient uptake and storage, energy dissipation, flow redirection and soil stabilisation[33]. Wetlands are complex to design and need to take into account many factors including location, sizing, pre-treatment, outlet structures, vegetation, maintenance, loading of organic matter, public safety, groundwater interaction, mosquito control[40].

Photo 12: A wetland used to treat stormwater runoff from a subdivision in Officer.

3.9.3. *Infiltration*

Infiltration can be used as a means to reduce the amount of urban runoff. The stormwater is retained by encouraging infiltration and permeation into the soil. The typical operation of an infiltration system is to divert flow into soak wells, sumps or gravel-filled trenches where the stormwater infiltrates into the ground[40]. Alternatively, porous pavements, constructed from lattice or modular paving, allow infiltration into the ground while still maintaining structural support[33]. Infiltration measures are best suited to sandy soils with deep groundwater.

3.9.4. *Bioretention*

Bioretention systems combine a number of water sensitive urban design elements into one system. They use an arrangement of filtration and detention measures plus biological processes to retard and treat stormwater[44]. Bioretention can either be in the form of a vegetated swale or a static basin. They are typically made up of a vegetated area with an underground bioretention trench. Investigation and development of bioretention systems is currently being conducted by the Institute for Sustainable Water Resources at Monash University, in conjunction with the Cooperative Research Centre for Catchment Hydrology[45].

SECTION 3 KEY POINTS - Roadside drainage:

- Efforts should be directed at improving maintenance of roadside drainage and treatment of stormwater prior to reaching waterways.
- To minimise sediment load, an unsealed road network should have an emphasis on slowing drainage flows and dispersing them more frequently.
- Avoid directing roadside drainage from unsealed roads into waterways. Either divert stormwater away from the road or catch sediment before it reaches a stream.
- Where possible, place cut-off drains at 100 metre intervals along the road and at least 50 metres prior to a stream crossing.
- Clean table drains only when necessary. Aim for a shallow, flat-based profile when restoring drain shape.

4. Roadside Vegetation

Roadside vegetation is essential to maintaining good stormwater quality by[46]:

- Slowing stormwater runoff
- Breaking the fall of raindrops and thereby reducing the erosion potential of rain drops on the ground surface,
- Reducing the total amount of runoff through uptake by the root system,
- Increasing infiltration into the soil,
- Acting as a filter to sediment and other pollutants.

Photo 13: Native vegetation along Foott Rd, Upper Beaconsfield.

When the natural vegetative cover is removed and the ground surface is exposed, erosion can increase above natural rates by one hundred times or more[11]. A stabilised surface is more resistant to the detachment of particles. When working along unsealed roads, soil disturbance should be kept to a minimum and the natural vegetation conserved as much as practicable. If an area has been disturbed, the area should be stabilised using matting or vegetation.

Roadside vegetation should always be protected when working along unsealed roads. During road grading and drain cleaning, machinery should keep well clear of any vegetation such as large trees, small shrubs and native grasses. Machinery can not only directly damage limbs and branches but also cause soil compaction. Increased compaction can reduce the amount of the air and water reaching plant roots and contribute to the decline of vegetation[7]. The drip of the tree canopy can be used a guide for the exclusion area around vegetation. Some areas of vegetation are more significant than others. If disturbance is necessary, check with the council's Environment Department.

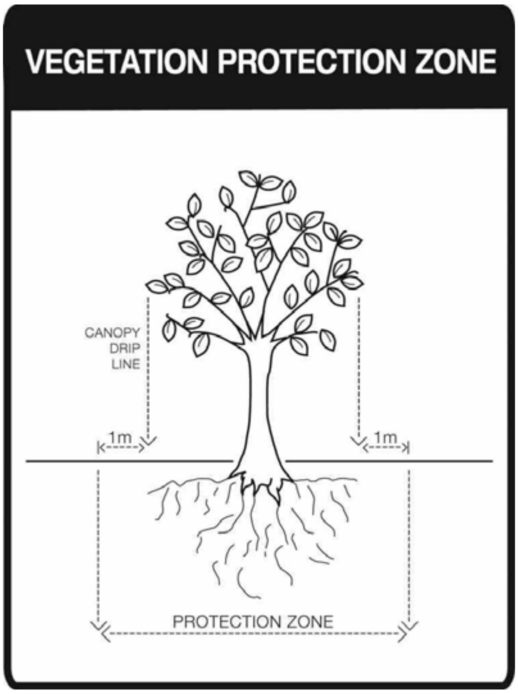

Figure 12: The canopy drip line outlines the area around vegetation to be avoided.

Any spoil from the road or drains should be directed towards the road pavement or removed from the site. Material should not be windrowed onto the roadside vegetation or into the table drains[47].

Machinery can potentially transport weeds and other introduced plant species. Weed infestations are a major environmental problem because they can invade native vegetation and contribute to its decline. To avoid transporting weeds, machinery tyres and tracks, should be washed or brushed down prior to leaving a site. The Council's Environment Department can assist with identification and appropriate management.

4.1. Filter & Buffer Strips

Filter strips, also known as buffer strips, are areas of natural vegetation used to treat stormwater by slowing runoff, settling sediment and filtering pollutants[15]. As discussed above, the vegetation provides protection from raindrop impact, slows flow velocities and traps sediment particles. The roots also help to bind the soil surface, thus minimising erosion[43]. Some studies have found that filter strips can trap more than 90% of sediment and more than 70% of nitrogen and phosphorus in stormwater[48].

Filter strips can be used along unsealed roads to remove sediment and other pollutants from stormwater runoff. Frequent dispersion of road runoff into filter strips can reduce sediment and pollutants loads. Filter strips can also be used as an alternative to cut-off drains, whereby runoff is directed to a designated filter strip rather than a cut-off drain. Whilst revegetation of roadsides and stream crossings can be time consuming and relatively costly, it can be a long-term solution to managing road runoff.

Filter strips should be of sufficient width to ensure optimum filtering capacity. A grass filter strip of six metres have found to substantially increase sediment and nutrient filtering capacity compared to a three metre width strip[48]. As outlined in Table 4, the width of the filter strip should increase as the gradient of the slope increases.

Table 4: Recommended filter zone widths.

Slope of land between road and waterway	*Recommended filter strip width*
0-10%	15 metres
10-20%	15-20 metres
20-40%	20-35 metres
40-70%	35-45 metres

(Amended from [39])

Ideally, filter strips should be located on an area of low grade to ensure sheet flow rather than concentrated flow. Generally, slopes steeper than 17% would result in formation of rills, which results in a higher flow velocity and a significant reduction in pollutant removal efficiency. Under such circumstances, flow spreaders such as check dams can be constructed at regular intervals[15, 40]. A filter strip may also be underlaid by rocks and geotextile fabric prior to planting to provide additional infiltration capacity and protection against erosion[40].

Species selection for a filter strips should be in line with the native vegetation of the local area. By replacing the vegetation communities that are native to the area, survival and growth is typically higher thus requiring less resources for maintenance of the vegetation. Council's Environment Department can provide advice on suitable species and planting techniques.

SECTION 4 KEY POINTS - Always protect roadside vegetation:

- When working along unsealed roads keep well clear of any native vegetation, including trees, shrubs and native grasses.
- Use the drip line of the canopy as a guide for the exclusion area around vegetation.
- Avoid transporting weeds from one site to another.
- Material from the road pavement or roadside drains should not be windrowed into vegetation or table drains.
- By frequently diverting road runoff into filter strips, the sediment and pollutant load of the stormwater can be reduced.
- Where possible, use vegetation to minimise scour and sediment transport.

5. Assessing Roads for Environmental Risks

An unsealed road network may contribute disproportionate amounts of sediment to the local catchment. Only some road sections may have the necessary characteristics to potentially impact on water quality of receiving waters. Identifying these areas is an important step in ensuring cost effective sediment control measures that result in the maximum benefits to the environment. This strategic management approach provides a long-term solution to minimising stormwater impacts from unsealed roads.

Figure 13 outlines a framework for the assessment of potential water quality impacts from unsealed roads:

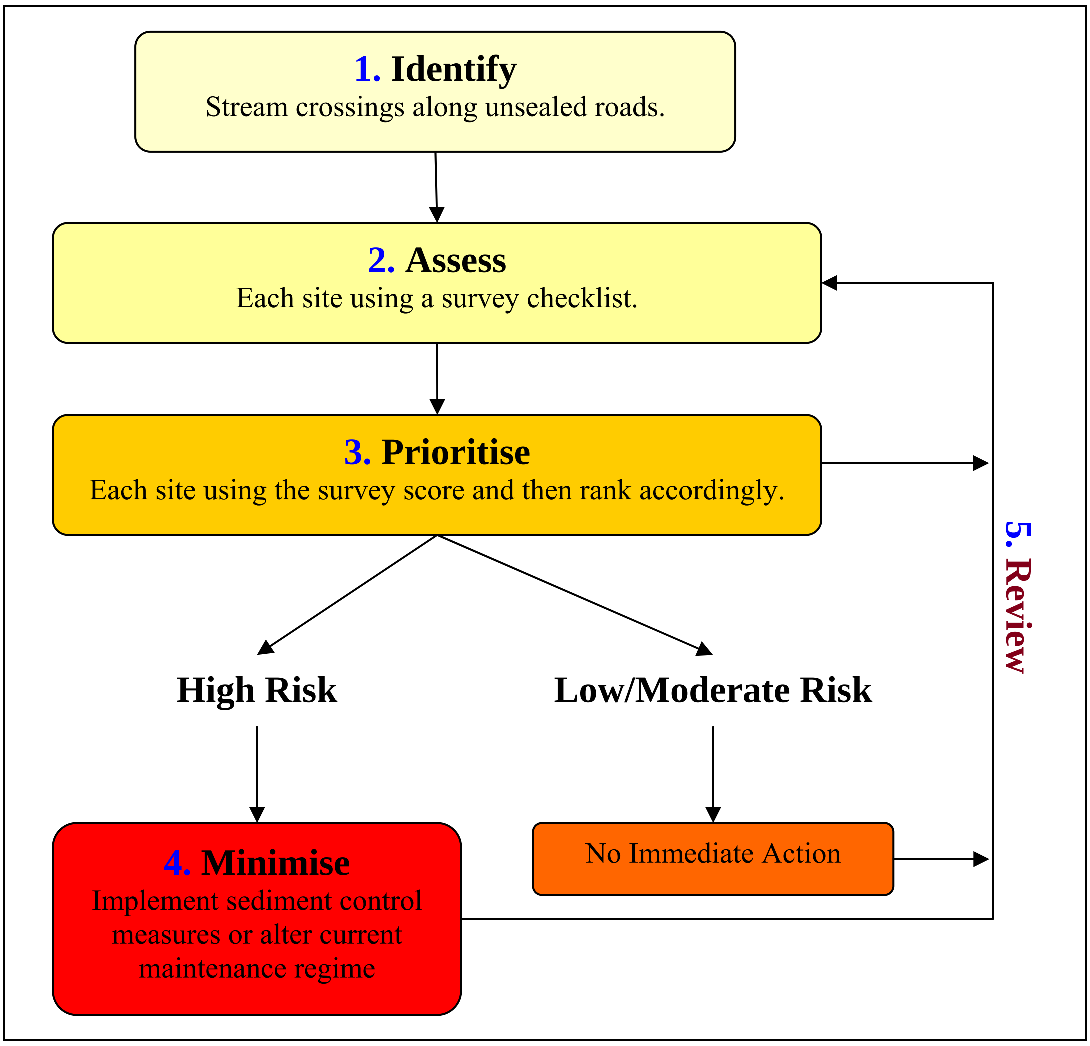

Figure 13: A framework for the strategic reduction in sediment input from an unsealed road network.

The following steps provide a simple method of assessing unsealed roads for environmental risks:

Step One – Identify Stream Crossings on Unsealed Roads

Due to the proximity of the road at stream crossings, these sections are inherently the highest risk to water quality. Rather than assessing the entire road network, only a small proportion of which will contribution to water pollution, stream crossings can be separated out as the first step of the assessment process. This division may have the potential to exclude sites contributing to water quality, but the benefits of this exclusion have far greater time and cost savings. The stream crossing plus the section of road 100 metres either side of the stream crossing is termed a 'site'.

Step Two - Assess the Unsealed Network:

Each site is assessed systematically using the same criteria. The following criteria can be used to visually assess water quality impacts from unsealed roads:

- Drainage outlets,
- Drainage area of stream crossing,
- Presence of erosion,
- Roadside vegetation,
- Stream type,
- Conservation status of catchment,
- Vehicle traffic,
- Road gradient,
- Road surface condition.

The criteria are primarily based on the capacity of the road to transport and deliver sediment from the road to the stream. The criteria are founded on the criteria used for the North East Water Quality Strategy[49] and further developed for use by local government. Appendix 1 contains a detailed explanation of each criteria and guidance for scoring each parameter.

Figure 14 shows a sample assessment sheet designed to be simple and user-friendly method to record the survey results. Appendix 2 contains an electronic database that can be used to enter, store and rank site data.

Step Three – Prioritise Each Site

Based on the visual assessment, an overall score is calculated using the score and weighting of each parameter. The sites can then be ranked accordingly into 'High', 'Medium' and 'Low' categories using Table 5.

Category	*Score*
Low	0-9
Medium	10-24
High	25-40

Table 5: Score ranges for High, Medium and Low categories.

Figure 14: Sample assessment sheet.

Date:	
Assessor:	
Road name:	

Road section from:	
Road section to:	
Distance to nearest intersection::	

								Weight	Score
Drainage Outlets:	0 -	No Linkage to stream	1 -	Partial linkage to stream	2 -	Direct discharge to stream		5	
Drainage Area of Stream Crossing:	0 -	0-50 lineal metres	1 -	50-100 lineal metres	2 -	> 100 lineal metres		3	
Presence of Erosion:	0 -	Stable	1 -	Relatively Stable	2 -	Unstable		3	
Roadside Vegetation:	0 -	Good	1 -	Fair	2 -	Poor		2	
Stream Type:	0 -	Temporary	1 -	Permanent	2 -	Wetland		2	
Conservation Status of Catchment:	0 -	Highly disturbed	1 -	Slightly or moderately disturbed	2 -	High conservation value		2	
Vehicle Traffic	0 -	Low	1 -	Medium	2 -	High		1	
Road Gradient:	0 -	Flat	1 -	Moderate Slope	2 -	Steep		1	
Road Surface Condition:	0 -	Good	1 -	Fair	2 -	Poor		1	
							Overall Score:		

Photos: **1.** ______________________ **2.** ______________________

Step Four – Minimise

The list of ranked sites forms a prioritised action plan for sediment control works. All 'High' risk sites should be actioned as soon as possible, while 'Moderate' to 'Low' risk sites require no immediate action.

Step Five – Review

The assessment process should be revisited periodically. Factors such as vehicle traffic, drainage and catchment development may change over time. As a result, the categories of High, Medium and Low also may change i.e. Medium sites may escalate to High risk, or High risk sites may become Low risk following the sediment control works.

The sediment control measures implemented on the high risk sites should be reviewed. As local characteristics are important in controlling sediment on unsealed roads, it is essential that sediment control works are reviewed for effectiveness so that in future this knowledge can be applied to other local sites.

SECTION 5 KEY POINTS - Plan sediment control works:

- Due to the proximity of the road at stream crossings, these areas of an unsealed roads network are inherently the highest risk to water quality.
- Councils should assess stream crossings within a road network to evaluate risks to water quality and prioritise sediment control works.
- The strategic planning of sediment control works can ensure cost effective measures that result in the maximum benefits to the environment.

6. Dust Suppression

Road dust can have significant implications for human health, road safety, aesthetics and the environment. Dust suppression techniques are widely used by local governments to reduce the amount of dust generated from local roads. Traditionally, dust suppression was simply the application of water, however in recent times new technologies have resulted in a large variety of dust suppression chemicals.

Research conducted as part of the Unsealed Roads Stormwater Project has found that dust suppressants have the potential to impact on stormwater quality and subsequently effect the surrounding environment. See the project Technical Report for more information on the research undertaken.

All products may have adverse environmental impacts if used improperly[7]. The use of dust suppression is a balance between minimising the impacts of the dust itself and minimising the environmental impacts of suppressant application. If dust suppression is to be used, application must be performed in a way that minimises the risk to the environment. The following guidelines provide some common sense principles for the application of dust suppression. This guide is designed to minimise the environment risks during application, however it is by no means absolute. The application of dust suppression should take into account the characteristics and requirements of the site.

During application, use the following guidelines:

1. **Use the minimum quantity of product required to obtain the desired result**. Follow the supplier's specifications, but be aware of the need to account for local conditions. It is advisable to start with lower levels and increase the level if not initially effective.

Photo 14: Dust suppression application.

2. **Keep a record**. Write down the date, location, area, rate of application, total volume applied and weather conditions (including conditions before and after application). This information will help to assess the effectiveness of the treatment and allow applications to be tailored in the following year/s to achieve the best result. A control section i.e. an untreated road section, can be useful to compare results.

3. **Apply during the dry season**. Apply dust suppression when it is needed most. Avoid application during or prior to the wet season of the year.

4. **Check weather forecasts before applying**. Do not apply when it is raining or when rainfall is forecast within the next three days. Rainfall immediately after application of the dust suppressant is likely to wash the chemical away. This results in wasted time, money and possible contamination of stormwater.

5. **Apply only on the road pavement**. Do not apply on road shoulder, drainage channels or road verge. During application, prevent drift of the chemical through either airborne droplets or run-off.

6. **Use calibrated equipment**. If the product is to be applied using a tanker or pump system, make sure the equipment is calibrated and set to the correct flow rate before commencing.

7. **Aim to maintain a buffer distance of 100 metres between the application area and waterways**. Proximity to surface waters and the water table can mean that the chemical is easily transported to waterways. Avoid applying dust suppressants near stream crossings, wetlands or flood-prone areas.

SECTION 6 KET POINTS - Dust suppression:

- Chemical-based dust suppressants have the potential to cause adverse impacts on stormwater quality and the surrounding environment.
- If dust suppression is to be used, application should be performed in a way that minimises the risk to the environment.

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