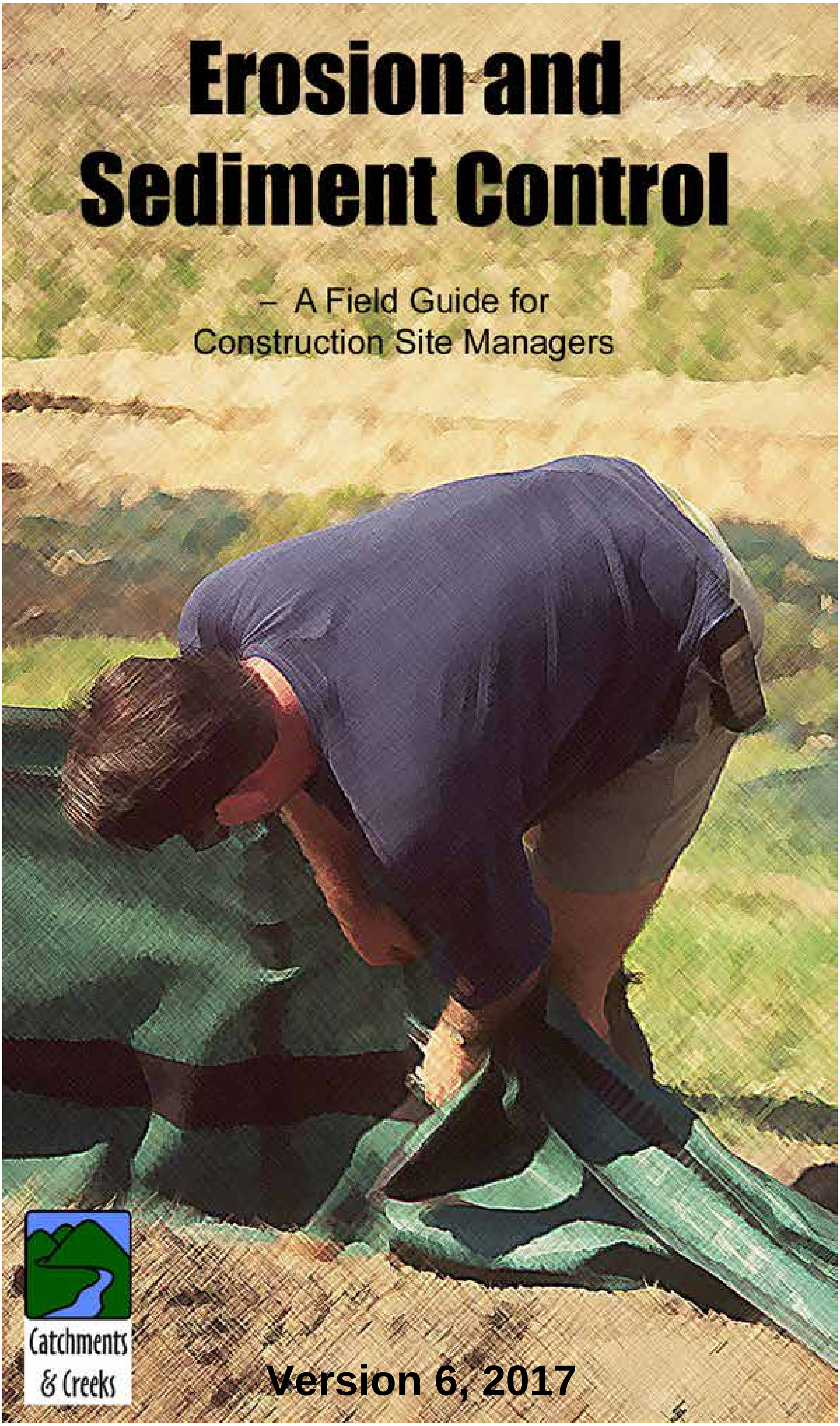
Erosion and Sediment Control

– A Field Guide for Construction Site Managers



Catchments & Creeks

Version 6, 2017

Erosion and Sediment Control – A Field Guide for Construction Site Managers

Version 6, July 2017

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Published by: Catchments & Creeks Pty Ltd

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Photos by: Catchments & Creeks Pty Ltd, Brisbane City Council, Jim Herbert (QDNR), Geofabrics Australia, Wet Earth Australia, Project Rentals, Adam Pullen (Western Pipeline Alliance & MacDow), and DIRTBAG ®

This document should be referenced as:

Witheridge 2017, *Erosion and Sediment Control – A Field Guide for Construction Site Managers*. Catchments & Creeks Pty Ltd., Brisbane, Queensland

Key-words: ESC, erosion and sediment control, soil erosion, erosion control, sediment control, soil management, land management, vegetation management, construction site management.

Disclaimer

Significant effort has been taken to ensure that this document is representative of current (2010) best practice erosion and sediment control; however, the author cannot and does not claim that the document is without error, or that the recommendations presented within this document will not be subject to future amendment.

To be effective, erosion and sediment control measures must be investigated, planned, and designed in a manner appropriate for the given work activity and site conditions.

No warranty or guarantee, express, implied, or statutory is made as to the accuracy, reliability, suitability, or results of the methods or recommendations.

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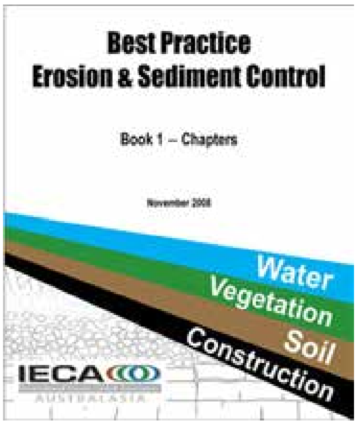
Specifically, adoption of the recommendations and procedures presented within this field guide will not guarantee:

(i) compliance with any statutory obligations;

(ii) compliance with specific water quality objectives;

(iii) avoidance of environmental harm or nuisance.

Principal reference documents:



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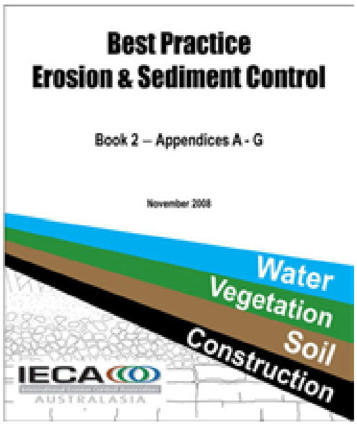

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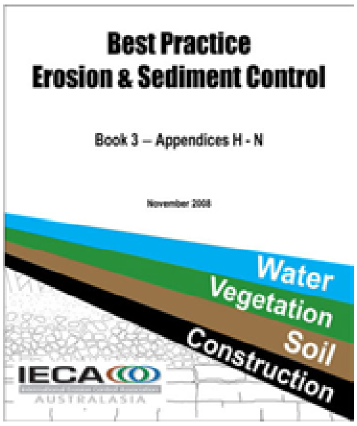

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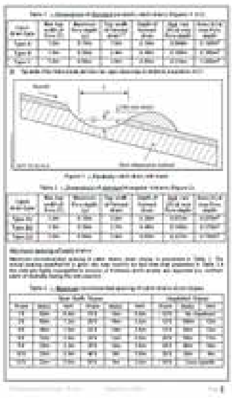

ESC Technique Fact Sheets – Book 4

***Best Practice Erosion & Sediment Control*. International Erosion Control Association, (IECA) Australasia Chapter, 2008**

1. Introduction
2. Principles of erosion and sediment control
3. Site planning
4. Design standards and technique selection
5. Preparation of plans
6. Site management
7. Site inspection
8. Bibliography

Book 2: Appendices

A. Construction site hydrology and hydraulics
B. Sediment basin design and operation
C. Soils and revegetation
D. Example plans
E. Soil loss estimation
F. Erosion hazard assessment
G. Model code of practice

Books 1 to 3 may be purchased through:

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Book 3: Appendices

H. Building sites
I. Instream works
J. Road and rail construction
K. Access tracks and trails
L. Installation of services
M. Erosion processes
N. Glossary of terms
P. Land-based pipeline construction
X. Index (Books 1 to 3)

Book 4 design fact sheets are grouped as:

Drainage control measures
Erosion control measures
Sediment control measures
De-watering sediment control measures
Instream work practices

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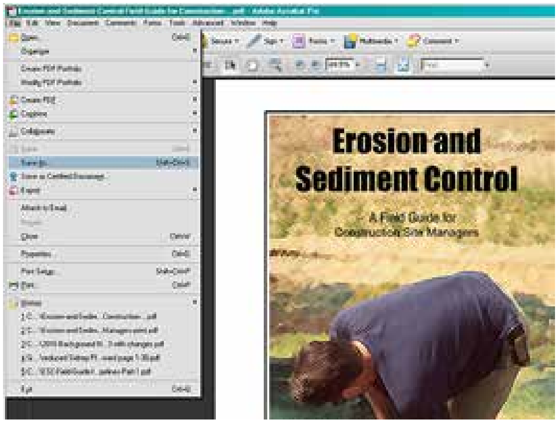

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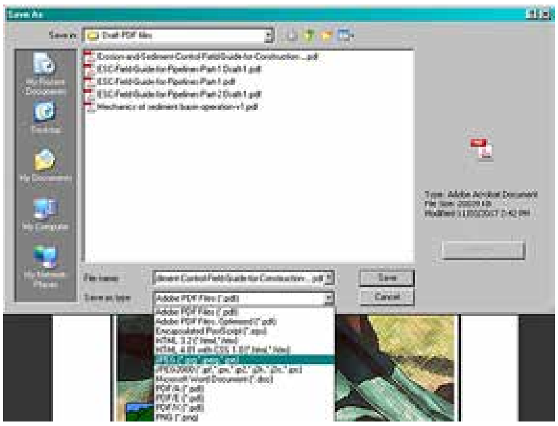

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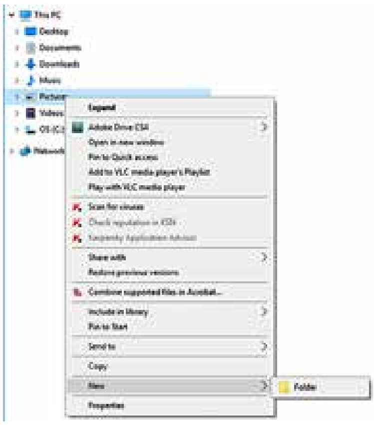

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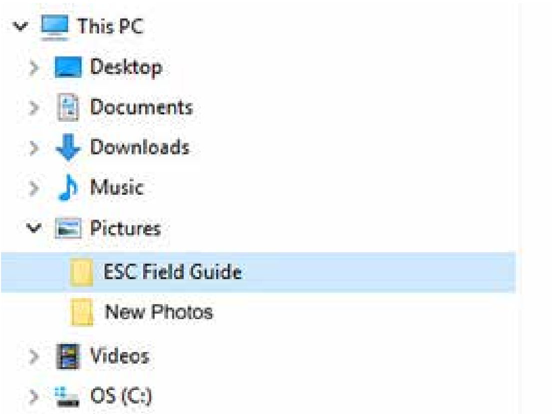

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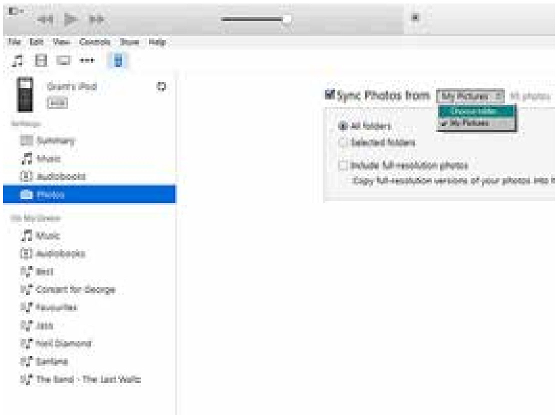

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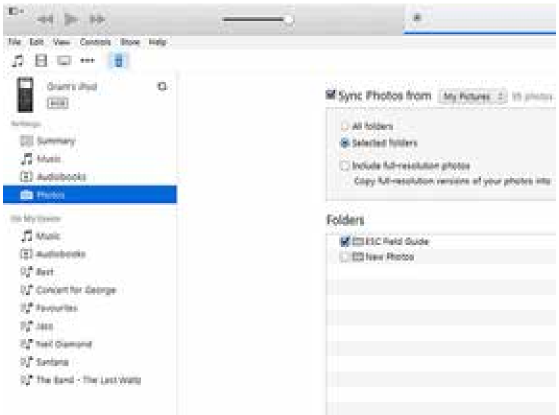

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Contents

Technique Listing

Purpose of field guide

This field guide has been prepared specifically to:

- Provide construction site personnel with general guidelines on the management of construction sites with respect to soil erosion and sediment runoff.
- Provide construction personnel with general guidelines on the selection of appropriate construction phase drainage, erosion and sediment controls in the following circumstances:
  - situations where an appropriate Erosion and Sediment Control Plan (ESCP) does not exist, or does not adequately address the current site conditions; and
  - situations where the existing erosion and sediment control (ESC) practices are failing to achieve the required environmental protection, and site personnel are awaiting instructions from ESC experts and/or the approval of a revised ESCP.

The field guide has **not** been prepared for the purpose of being a site's primary guide to erosion and sediment control. As such, the recommendations provided within this field guide should **not** be used to overrule advice obtained from suitably trained experts, or the recommendations and/or requirements of locally adopted ESC guidelines/manuals.

The field guide has been prepared for use on civil construction and large, multi-dwelling building sites. A separate field guide has been prepared for use on single-dwelling building sites.

About the author

Grant Witheridge is a civil engineer with both Bachelor and Masters degrees from the University of NSW (UNSW). He has over 35 years experience in the fields of hydraulics, stormwater management, creek engineering and erosion & sediment control, during which time he has worked for a variety of federal, state, local government and private organisations.

Grant is the principal author of such publications as the revised *Queensland Urban Drainage Manual* (2007, 2013 & 2017), and IECA (Australasia) *Best Practice Erosion and Sediment Control (2008)* documents. In 2010 Grant was presented with the IECA (International) *Sustained Contributor Award*.

Introduction

The three cornerstones of the 'erosion and sediment control industry are *drainage control*, *erosion control*, and *sediment control*. The functions of construction phase drainage, erosion, and sediment controls are presented below.

- Drainage control measures aim to prevent or reduce soil erosion caused by concentrated flows (including the management of rill and gully erosion), and to appropriately manage the movement of 'clean' and 'dirty' water through the site.
- Erosion control measures aim to prevent or reduce soil erosion caused by raindrop impact and sheet flow (i.e. the control of splash and sheet erosion).
- Sediment control measures aim to trap and retain sediment displaced by up-slope erosion processes.

It is noted that on most work sites, best practice sediment control measures cannot, on their own, provide adequate protection of downstream environments. Therefore, appropriate drainage and erosion control measures must also be applied, at all times, especially on clayey soils. Desirable environmental protection is only achieved when all three control measures are working in a coordinated manner during each stage of the construction process.

One of the most notable features of the erosion and sediment control profession is that there is almost always an exception to every rule and guideline. The fact that a control measure is observed to work well on one site does not mean that it will work well on all sites. Similarly, the fact that a control measure has repeatedly failed within one region does not mean that the technique will not be useful within another region.

Even though erosion and sediment control practices sit at the cutting edge of common sense, their application to a given site must represent an appropriate balance between theory, past experience, and common sense. Also, no rule or recommendation should be allowed to overrule the application of unique, site-specific solutions, where such solutions can be demonstrated to satisfy the environmental objectives and the specified ESC performance standards.

Impacts of soil erosion and sediment runoff

Dust generated on a construction site

Dust generation

- Dust generated on construction sites can cause significant problems to neighbouring properties.

Sedimentation of a drainage pipe

Blockage of stormwater pipes & culverts

- Sediment deposition within stormwater drainage pipes and culverts can:
  - cause property flooding
  - increase flooding and safety risks on roadways
  - increase maintenance costs for the asset owner such as the local government
  - increase the risk of mosquito breading problems.

Deposition of coarse sediment in a creek

Release of coarse sediments into waterways

- The deposition of coarse sediment in minor waterways, such as creeks, can:
  - increase the risk of property flooding
  - cause bank erosion and channel instabilities
  - cause the loss of essential aquatic habitats
  - increase weed infestation of creeks
  - increase maintenance costs for stormwater asset owners such as local governments.

Suspended fine sediments in a creek

Release of fine sediments into waterways

- The release of fine sediments and turbid water into minor waterways can:
  - adversely affect the health and bio-diversity of aquatic life within permanent pools
  - adversely affect fish numbers and fish breeding
  - increase the concentration of nutrients and metals within permanent waters
  - reduce light penetration into pools
  - increased waterway de-silting.

Impacts of soil erosion and sediment runoff

Sedimentation of a wetland

Sedimentation within wetlands

- The deposition of coarse sediment into wetlands can:
  - cause the introduction of weeds and dry-land plant species into the wetland
  - cause a loss of essential aquatic habitats
  - cause significant environmental damage to the wetland and its associated wildlife as a result of de-silting operations
  - increase maintenance costs for the asset owner.

Discolouration of a farm dam

Turbidity within dams, rivers & ponds

- The release of fine sediments and turbid water into ponds, lakes and dams can:
  - adversely affect the health and bio-diversity of aquatic life within these water bodies
  - increase the concentration of nutrients and metals within these waters
  - reduce light penetration into the water
  - increase the risk and cost of water treatment works associated with both farm and town water supplies.

Sedimentation of a river and estuary

Turbidity within rivers and estuaries

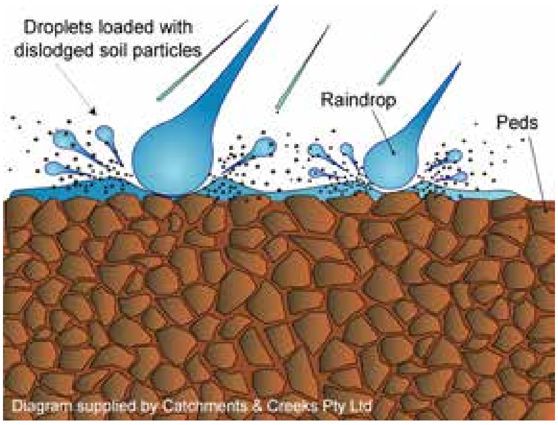
- The release of sediments and turbid water into rivers and estuaries can:
  - adversely affect the health and bio-diversity of aquatic life within these water bodies
  - increase the concentration of nutrients and metals within these waters
  - reduce light penetration into the water
  - increase the risk the cost of water treatment works associated with both farm dam and town water supplies.

Sediment released into the ocean

Damage to the reef and seagrass beds

- The release of fine sediments and turbid water into oceans can:
  - adversely affect the health and bio-diversity of aquatic life within these water bodies
  - increase the concentration of nutrients and metals within these waters
  - smother coral and aquatic habitats
  - cause a significant loss of seagrasses following flood events.

Types of soil erosion



Raindrop impact erosion

Land subject to sheet erosion

Rill erosion

Erosion of a dispersive soil

Raindrop impact erosion

- Raindrops can exert significant force upon the ground.
- The resulting soil erosion is often difficult to detect and consequently is often overlooked.
- Raindrop impact erosion is a major cause of the release of fine, clay-sized particles resulting in highly turbid (brown) runoff.
- It would not be unexpected for raindrop impact erosion to cause the release of 1 to 2 cm of soil during the construction phase, equivalent to 100–200 m^3/ha.

Sheet erosion

- Sheet erosion is the removal of an even layer of surface soil through the actions of raindrop impact and stormwater runoff.
- Sheet erosion is likely to occur if stormwater runoff flows over an exposed soil at a speed greater than walking pace.
- After a distance of around 10 m, sheet erosion is likely to change into ‘rill erosion’.
- It should be noted that 1 cm of soil loss represents the loss of 100 cubic metres or approximately 200 tonne of soil per hectare.

Rill erosion

- A ‘rill’ is an individual eroded channel in the soil that is less than 300 mm deep.
- Rill erosion is typically caused by high velocity concentrated flows (i.e. water flowing at a brisk walking pace or faster).
- Rilling can also result from soil dispersion (see below).
- Along with flow velocity, soil compaction and soil chemistry can also influence the degree of rilling.

Chemically induced erosion

- Soil chemistry can have a significant influence on the severity and extent of soil erosion.
- If a soil is ‘dispersive’ then it is likely to be highly unstable when wet, resulting in severe, deep rilling (or ‘fluting’ as shown left) tunnel erosion and/or gully erosion.
- As a general guide, if an individual ‘rill’ is significantly deeper than it is wide, then soil chemistry is likely to be a major contributing factor in the soil erosion.

Site management

Plans, permits and approvals

Pre-construction conference

Site office

Site signage

Permits and approvals

- Obtain all necessary permits and plan approvals, and assess environmental risks before commencing works.
- Ensure an appropriate Erosion and Sediment Control Plan (ESCP) is prepared prior to initiating any soil disturbance.
- Ensure the degree of detail presented within the ESCP is appropriate for the complexity of the proposed works, and in such detail to allow all control measures to be correctly located and installed.

Pre-construction conference

- A pre-construction conference allows discussion of critical issues, such as:
  - key objectives of the ESCP
  - required water quality objectives
  - monitoring and inspection procedures
  - identification of the responsible site officers
  - identification of critical environmental concerns
  - reporting procedures for non-compliance activities and events.

Set-up of site office

- Limit site entry to the minimum number of locations.
- Stabilise all site entry and exit points.
- Locate the site office as close as possible to the site entrance to minimise the distance visitors need to travel through the site.
- Wherever practical, ensure roof water from buildings and sheds will not cause unnecessary erosion or soil wetness, especially within heavy traffic areas.

Control of sub-contractors

- Assess the need for site signage to help:
  - minimise damage to the site's erosion and sediment control measures
  - minimise damage to buffer zones and retained vegetation
  - remind site personnel of the importance of appropriate environmental management within the site.
- The need for signs will vary from location to location depending on site conditions and environmental risks.

Site management

Stockpile management

Stockpiles

- Establish all necessary stockpile areas.
- Assess the need for:
  - drainage controls up-slope of stockpiles e.g. if drainage area > 1500 m^2
  - erosion controls on stockpiles, such as mulch, soil binders, or tarps
  - sediment controls down-slope of stockpiles (e.g. sediment fence).
- Where appropriate, install boundary fencing to reduce unauthorised dumping of earth and rubbish on the site.

Concrete truck wash-out point

Concrete wash-out points

- If significant concreting is to occur on the site, then establish suitable concrete disposal areas enclosed by permeable, earth filter-banks, or other appropriate filter systems.
- Ensure these areas are well signed so that contractors and delivery drivers will be able to identify their location.

Waste collection bins

Waste management

- Establish waste collection areas.
- Control pollutant runoff from these areas.
- Ensure appropriate storage of chemical and fuels (e.g. AS1940: *The storage and handling of flammable and combustible liquids*).
- Where necessary, establish drip pans, or similar (e.g. filter cloth sheeting) in vehicle maintenance areas to control pollution runoff from road surfacing equipment and the like.

Poor litter control

Litter control

- Ensure responsible environmental management procedures are followed at all times, including controlling the handling of all potential contaminants, such as:
  - litter
  - concrete/cement
  - oil and fuel
  - sand, soil and sediment
  - organic mulches, and fertilisers
- Remind all workers that pollution control is everybody's responsibility.

Site management

On-site training

Staff training

- Site induction courses need to incorporate information on environmental management and incident reporting.
- Ensure employees receive adequate training on:
  - environmental management
  - best practice erosion and sediment control practices
  - incident reporting procedures
  - site inspection and maintenance procedures (selected staff only).

Damaged fence tagged (white) for repair

Site inspections

- Nominate the officer(s) responsible for the erosion and sediment control measures.
- Establish an appropriate site inspection routine, as well as maintenance and reporting procedures.
- Identification tags, such as a strip of filter cloth stapled to sediment fence fabric (shown left), can be used to identify those measures requiring maintenance.

Water quality samples

Water quality testing

- Identify the target water quality objectives (WQOs) for the site. WQOs are normally assigned by the state or local government.
- Typical water quality objectives are:
  - 50 mg/L of total suspended sediment
  - a turbidity level no greater than 10% above that of the receiving water
  - water pH in the range 6.5 to 8.5
- Identify an appropriately trained person to collect all water samples.

Fish kill

Reporting of environmental harm

- Best practice site management requires establishment of appropriate incident reporting procedures, including:
  - identifying the chain of responsibility
  - procedures for recording incidents of non-compliance
  - monthly reporting procedures (if required)
  - procedures for recording corrective actions
  - internal recording and filing procedures.

Site management

Storage of various construction fabrics

On-site storage of emergency materials

- Stockpile all necessary materials to establish and maintain the site's erosion and sediment control (ESC) measures.
- Maintain adequate supplies of emergency ESC materials such as: straw bales, wire, stakes, sediment fence fabric, filter cloth, wire mesh, and clean aggregate.
- The materials shown left are jute blanket (top), shade cloth (not used for erosion or sediment control), and filter cloth (bottom).

Sediment fence in need of maintenance

Maintenance of control measures

- Ensure all erosion and sediment control measures are maintained in proper working order at all times.
- Ensure all materials, whether solid or liquid, removed from ESC devices during maintenance are disposed of in a manner that does not cause ongoing soil erosion or environmental harm.
- Ensure appropriate written records are kept on the site's monitoring and maintenance activities.

Clean-up equipment

Clean-up of spills

- Ensure sufficient materials exist on-site, or within work vehicles, to clean-up accidental sediment spills and the like.
- The clean-up equipment and materials required for a site will need to be assessed on a case-by-case basis based on the assessed environmental risk.

Hosing down road surface

Established clean-up procedures

- Ensure the site's clean-up procedures are conducted in a manner that does not cause environmental harm.
- Sealed roadways should only be washed/flushed in circumstances where sweeping has failed to remove sufficient sediment, **and** there is a compelling need to remove the remaining sediment (e.g. for safety reasons).
- In all cases, all reasonable and practical measures must be taken to minimise environmental and safety risks.

Preparing a site for the expected weather conditions

Approaching storm

Being prepared for storms

- A well-managed site is a site that is appropriately prepared for both likely and unlikely (but possible) weather conditions.
- Only in those regions where extended periods of dry weather can be anticipated with high certainty can erosion and sediment control measures be reduced to a minimum during such periods.

Table 1 – Overview of critical ESC measures for various weather conditions

Expected weather conditions	Likely critical aspects of erosion and sediment control
No rainfall or strong winds expected	· If favourable dry-weather conditions are likely to exist with a reasonable degree of certainty, then avoid unnecessary expenditure on excessive ESC measures (seek expert advice); however, always ensure the site is appropriately prepared for possible, unseasonable weather conditions. · It should be noted that effective sediment controls at site entry/exit points are generally always required, even during dry-weather conditions.
Light rainfall	· In general, the lighter the rainfall, the better the desired quality (mg/L & turbidity) of the water discharged from the site. · Wherever practical, sediment control measures should be designed to maximise the 'filtration' of sediment-laden water during periods of light rainfall, rather than gravity-induced sedimentation. · It should be noted that if a site discharges to a minor watercourse, then the release of sediment-laden water during periods of light rainfall can potentially cause more environmental harm than if the same quantity of sediment were released during periods of moderate to heavy rainfall.
Moderate to heavy rainfall	· It is critical to ensure effective drainage control measures exist on the site to prevent the formation of rill and gully erosion. · It is critical to ensure that sediment traps have an effective flow bypass system to prevent structural failure of the sediment trap. · Wherever practical, sediment control measures should be designed to maximise the gravity-induced 'settlement' of sediment-laden waters during periods of moderate to heavy rainfall. · It is noted that sediment control measures that rely on 'filtration' processes (i.e. filtration through geotextile filter cloth) often experience excessive blockage during such storm events.
Strong winds	· Ensure erosion control measures are appropriately anchored. · Maintain soil surfaces in a roughened condition to reduce dust generation. · Assess the benefits of chemical-based soil stabilises (i.e. soil binders) instead of just using water trucks.

Site inspection and monitoring

Damage to a drop-inlet sediment trap

Regular site inspections

- All erosion and sediment control measures should be inspected:
  - at least daily when rain is occurring
  - at least weekly (even if work is not occurring on-site)
  - within 24 hours of expected rainfall
  - within 18 hours of a rainfall event of sufficient intensity and duration to cause on-site runoff.
- Don't wait for the next storm before checking that all ESC controls are in place and working properly!

Upstream & downstream water samples

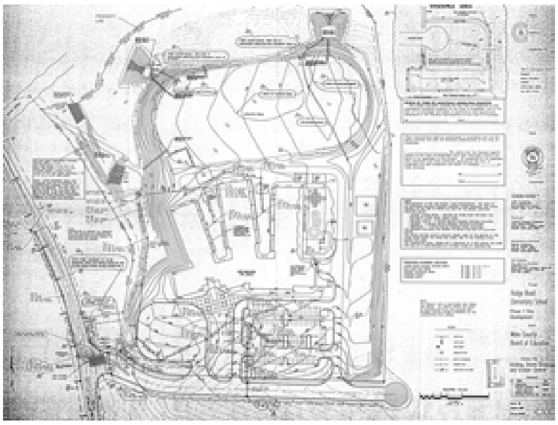
Collection of water samples

- Site inspections need to be conducted during both dry and wet weather.
- Site inspections should be conducted by the nominated ESC officers, or possibly on large or high-risk sites, a third-party inspector.
- On large or high-risk sites, monitoring is likely to include specific water quality sampling and detailed logbook entries of the site's monitoring and maintenance activities.

Dirty water runoff

Investigate the source of sediment runoff

- When a site inspection detects a notable failure in the adopted ESC measures, the source of this failure must be investigated, and appropriate amendments made to the control measures and the ESC plans.
- On sites with a soil disturbance greater than 0.25 ha, a formal *'Monitoring and Maintenance Program'* should be prepared prior to site establishment.



Erosion & Sediment Control Plan

Responding to poor test results

- Erosion and Sediment Control Plans (ESCPs) are living documents that can and should be modified if:
  - site conditions change, or
  - the adopted measures fail to achieve the required treatment standard (e.g. the water quality objectives).
- Conducting regular site inspections and ensuring that appropriate water quality monitoring occurs, are two ways of ensuring the ESCP remains relevant to the site conditions.

Vegetation management

Exclusion fencing

Protection of non-disturbance areas

- Clearly identify any non-disturbance or exclusion areas defined within the *Erosion and Sediment Control Plan* or *Vegetation Management Plan* (VMP).
- Ensure all local and state government approvals are obtained before any disturbance occurs to vegetation, and then disturb only the minimum area of land necessary to complete the works.

Vegetation protection

Protection of retained vegetation

- Where appropriate, prepare a *Vegetation Management Plan*.
- Establish *Tree Protection Zones* around retained vegetation.
- Such zones should extend from the tree a minimum distance of 10 trunk diameters (measured 1 m from the ground), or the width of the tree canopy at its widest point.
- Clearly identify any vegetation protected by government *Vegetation Protection Orders* (VPOs).

Undesirable tree trunk damage

Avoid damage to trees & root systems

- Avoid trunk damage—it can result in long-term vegetation problems.
- Minimise changes in ground elevation (cut or fill) adjacent to retained vegetation.
- If land reshaping must occur adjacent to retained vegetation, then it must be performed in a manner that will not isolate these plants from essential soil moisture—always seek expert advice.

Scarifying the soil surface

Preparation of soils

- Successful site revegetation starts with appropriate soil management, including the rehabilitation of soils compacted by construction activities.
- Ensure revegetation is carried out by qualified personnel/contractors.
- Ensure all potted plants are stored in appropriate conditions prior to their planting.
- Ensure the soils are tested, and where necessary, adjusted prior to planting.

Land clearing

Staged land clearing

Staging of land clearing

- Land clearing should not occur unless preceded by the installation of all necessary drainage and sediment control measures.
- Land clearing should be staged to minimise the extent and duration of soil exposure.
- Sequential clearing provides many advantages for erosion and sediment control, and can also improve the 'natural' relocation of local wildlife.

Tree hollows providing essential habitat

Retention of habitat trees

- Selective clearing should aim to retain a variety of species and plants of varying ages, with an emphasis on healthy plants, plants with habitat value, and tree groups.
- Note; partially hollow trees (dead or living) often need to be saved for the habitat value these trees provide to local wildlife.
- Don't assume a dead tree is a worthless tree.

Land clearing without soil disturbance

Delayed removal of tree roots

- If vegetation clearing must be carried out well in advance of earthworks, then this clearing should be limited to the removal of aboveground woody material only.
- Wherever reasonable and practical, the grubbing (i.e. root removal) and the removal of any ground cover (mulch or vegetation) should not commence until immediately prior to earthworks occurring within that stage of works.

Mulch berm sediment control measure

Beneficial use of mulch on site

- Wherever reasonable and practical, cleared vegetation should be mulched (e.g. via tub grinding) for use on the site as an erosion control aid, and/or to satisfy landscaping requirements.
- Tub grinding cleared vegetation produces a more hydraulically-stable mulch than does a wood chipping process.

Soil management

Soil pH testing

Scraper stripping soil

Replacement of topsoil

Scarifying the soil surface

Topsoil management

- Best practice topsoil management includes:
  - testing topsoils for their nutrient properties and revegetation potential
  - appropriate application of soil ameliorants prior to stockpiling
  - appropriate stripping and stockpiling
  - scarification and treatment of subsoils prior to topsoil replacement
  - application of the remaining soil ameliorants prior to revegetation.

Topsoil stripping

- Stripped topsoil should be preserved for reuse wherever possible.
- Highly contaminated topsoil may need to be buried.
- Topsoil should **not** be stripped when it is either too wet or too dry:
  - too wet means water can be squeezed from the soil
  - too dry means the soil readily crumbles when handled, or the soil cannot be formed into a clump when compressed.

Management of subsoils

- Ensure exposed subsoils are suitably covered as soon as practical.
- Non-dispersive subsoils should be covered with:
  - a suitable layer of topsoil if the area is to be revegetated, or
  - mulch, or a suitable chemical soil binder, if final earthworks are delayed for an extended period.
- Dispersive subsoils should be covered with a non-dispersive soil before placement of final surface material.

Surface roughening

- Ensure the soil surface is scarified before replacement of the topsoil to break up any excessive soil compaction, and enable the appropriate keying of the soil layers.
- On slopes less than about 1:3 (V:H), scarify lightly compacted subsoils to a depth of 50 to 100 mm, and heavily compacted subsoils to a minimum depth of 300 mm.
- On banks steeper than 1:3 (V:H), chain or harrow to break any surface-sealed or crusty soil surfaces.

Topsoil management

Stockpiling of topsoil

Topsoil management

- Ensure topsoil is preserved for reuse on the site wherever possible.
- The practice of removing topsoil from a site should be avoided unless the soil is contaminated or otherwise cannot provide a long-term benefit to the site.
- Ensure that the stripping and respreading of topsoil is stages such that the duration of exposure of the subsoil is appropriate for the site's erosion risk.

Table 2 – General recommendations for the management of topsoil stockpiles

Condition of topsoil	Recommended stockpiling requirements
Topsoils containing valuable native seed content that needs to be preserved for re-establishment	· The upper 50 mm of topsoil should be stockpiled separately in mounds 1.0 to 1.5 m high. · Topsoil more than 50 mm below the surface stockpiled in mounds no higher than 1.5 to 3 m. · The duration of stockpiling should be the minimum practical, but ideally less than 12 months.
Topsoil containing minimal desirable or undesirable seed content	· Maximum desirable stockpile height of 2 m. · The duration of stockpiling should be the minimum practical, but ideally less than 12 months.
Topsoils containing significant undesirable weed seed content	· Seek local expert advice. · Consider burying the topsoil or integrating the topsoil into non load-bearing fill. · Consider the economic viability of replacing the contaminated topsoil with a compost blanket.
Topsoils containing weed seed of a declared noxious or otherwise highly undesirable plant species	· Suitably bury the topsoil on-site, or remove the soil from the site for further treatment in accordance with local and state laws. · Stripped soil must **not** be transported off-site without appropriate warnings and identification.
Previously disturbed sites where the existing surface soil consists of a mixture of topsoil and dispersive subsoil	· Mix the soil with gypsum, lime or other appropriate ameliorants (refer to soil testing) **prior to** stockpiling in either high or low mounds according to required protection of its seed content. · Adding the ameliorants prior to stockpiling allows time for chemical changes to occur.
Arid and semi-arid environments	· Collect and stockpile the natural surface gravels **separately** from the underlying topsoil. · Replace the gravels and organic litter over disturbed surfaces that are to remain unvegetated in a manner consistent with the original surface condition of the soil.

Stockpile management

Inappropriately located sand stockpile

Location of stockpiles

- Ensure that sand/soil/earth stockpiles are not located in a position where the material could cause harm or be washed into a gutter, drain or water body.
- Do not locate stockpiles:
  - on a road pavement
  - within an overland flow path
  - adjacent to stream banks
  - within the 'drip zone' of protected trees (long-term stockpiles).

Flow diversion using a catch drain

Diversion of up-slope runoff

- Ensure, where necessary, a *Flow Diversion Bank* or *Catch Drain* is placed up-slope of a stockpile to direct excessive overland flow around the stockpile.
- Flow diversion around sand/soil/earth stockpiles is generally considered necessary when rainfall is possible <u>and</u> the up-slope catchment area exceeds 1500 m^2.

Long-term stockpile covered with jute

Erosion control measures

- Ensure that long-term stockpiles of material containing some degree of clayey matter (e.g. most soils, but not necessarily imported sand) are:
  - ideally covered with an impervious cover (this may not always practical)
  - covered with mulch or temporary vegetation (grass) if not located within the drainage catchment of a sediment basin.
- Ensure appropriate dust suppression exist for all stockpiles.

Sediment control down-slope of stockpile

Sediment control measures

- Ensure an appropriate sediment control system is located down-slope of sand/soil earth stockpiles, such as:
  - *Filter Fence* or composite *Sediment Fence* for clayey soils
  - Woven *Sediment Fence* for washed sand
  - *Sediment Basin* wherever practical.

Stockpile management

The diversion of up-slope stormwater around stockpiles is recommended during those periods when rainfall is possible, the up-slope catchment area exceeds 1500 m^2, and the average monthly rainfall exceeds 45 mm. Table 3 outlines the recommended erosion control measures applied to sand and soil stockpiles.

Table 3 – Protection of sand and soil stockpiles from wind and rainfall

Material	Stockpile cover [1]	Comments
Sand	No cover	· When wind erosion and dust control is not an issue.
	Synthetic cover, porous or not porous	· When the control of wind erosion is essential for reasons of safety.
Soil	No cover	· When wind erosion and dust control are not an issue.
	Mulching, vegetative cover, chemical stabilisers, soil binders, or impervious blanket [2]	· Long-term (>28 days) stockpiling of dispersive soils. · Long-term (>28 days) stockpiles of clayey soils when turbidity control is desirable. · Long-term (>5/10 days) soil stockpiles during months of Extreme/High erosion risk. · Short and long-term stockpiles of clayey soils when turbidity control is essential.

Notes: [1] Applicable only when displacement of the stockpiled material has the potential to cause environmental harm. The practice of covering stockpiles may need to be modified if theft or damage to covers becomes excessive.

[2] Mulching is normally applied at the first opportunity that mulch or hydromulch can be introduced to the site. Minimum 70% cover is required for both mulch and vegetative covers. Though still desirable, a cover may not be required if runoff from the stockpile is directed to a Type 1 sediment trap.

Table 4 outlines the recommended minimum sediment control practices down-slope of stockpiles.

Table 4 – Sediment control practices down-slope of stockpiles

Material	Sediment control	Comments
Sand or gravel	Woven Sediment Fence or equivalent	· Sediment control is only required if the stockpiled material could be displaced and cause safety risks or environmental harm.
Topsoil	Woven Sediment Fence or equivalent	· If the topsoil is moderately to highly erodible and is likely to release significant clay-rich (turbid) runoff, refer to the recommendations below for subsoil stockpiles.
Subsoil	Woven Sediment Fence or equivalent	· Stockpiles located up-slope of suitably grassed areas that will allow for the infiltration of stormwater runoff from the stockpile (minimum 15 m of flow length), or all runoff is directed to a Type 1 or Type 2 sediment trap.
	Compost Berm, Filter Fence, composite (non-woven) Sediment Fence, or equivalent	· Stockpiles not located up-slope of a suitable grassed area, or Type 1 or Type 2 sediment trap. · Soil stockpiles located adjacent permanent drainage channels or waterways.

Identifying problematic soils

ORGANIC MATTER		
Organic Matter	%	1.7
SALINITY		
Electrical Conductivity	dS/m	0.09
Chloride	mg/kg	28
Sodium	mg/kg	26
EXCHANGEABLE CATIONS		
Exchangeable Sodium	meq/100g	0.11
Exchangeable Potassium	meq/100g	0.37
Exchangeable Calcium	meq/100g	0.40
Exchangeable Magnesium	meq/100g	0.30
Exchangeable Aluminium	meq/100g	Not Applicable
Exchangeable Sodium Percent	%	9.6
Exchangeable Potassium Percent	%	31.6
Exchangeable Calcium Percent	%	33.4
Exchangeable Magnesium Percent	%	25.4
Exchangeable Aluminium Percent	%	Not Applicable
Cation Exchange	meq/100g	1.18
Calcium/Magnesium Ratio		1.32

Soil analysis

Soil testing

- With the exception of small, low-risk construction sites, an appropriate soil analysis should be performed prior to initiating any soil disturbance.
- From a construction perspective, site managers should be aware of those soils that are potentially problematic, such as highly erodible soils (whether the erosion risk is due to the soil composition or land slope), dispersive/slaking soils, and acid sulfate soils.

Dispersive soil

Dispersive and slaking soils

- Ideally, dispersive soils should be identified through appropriate pre-construction soil testing, such as:
  - exchangeable sodium percentage > 6%
  - Emerson aggregate classes 1 to 5, note classes 3(2), 3(1) and 5 have a slight risk of dispersive problems.
- A simple field test such as the *Aggregate Immersion Test* (see over page) can be used as an on-site indicator test.
- Dispersive soils may also be identified by their distinctive erosion patterns.

Culvert damage by acid sulfate soils

Acid sulfate soils

- Prior to the disturbance of soils below an elevation of 5 m AHD, the soil should be tested for its acid sulfate potential.
- These soils can be acidic, or have the potential to become acidic if disturbed.
- Actual and potential acid sulfate soils must be managed in accordance with the local state-approved guidelines.

Saline soils

Saline soils

- Saline soils can introduce complex revegetation problems, as well as long-term structural problems for some engineered structures.
- Saline soils can be identified through appropriate soil testing, such as:
  - electrical conductivity (EC) of either a 1:5 extract > 1.5 dS/m, or a saturated extract > 4 dS/m.
- The management of saline soils requires expert advice.

Non-official soil tests

Aggregate immersion test

Aggregate immersion test

- At best, soil tests conducted on-site can only 'indicate' the existence of a potential soil problem. Such testing is **not** a substitute for official soil sampling, testing and assessment by trained experts.
- An aggregate immersion test (left) can be used as an indicator of potential dispersive soils (sodic soils).
- Slaking soils (soils that readily collapse in water, but do not necessarily cloud the water) can be just as problematic.

Soil pH test

Soil pH

- Soil pH is an indicator of potential revegetation problems.
- Soil pH is **not** a good indicator of potential acid sulfate soils.
- In in-risk areas (i.e. soils lowers than 5 m AHD), professional soil testing and soil management procedures are essential.

Jar settling test (good settlement)

Jar settling test (poor settlement)

Jar settling test

- The jar settling test is a <u>non-scientific</u> test that should only be used as a visual tool to help educate site personnel as to the likely settlement properties of the local soils.
- The test is performed by:
  - first crushing a soil sample and placing it in a jar filled with de-ionised (distilled) water
  - the jar is then sealed and shaken aggressively for a few minutes
  - finally, the jar is left undisturbed for up to 5-days to observe the degree of settlement.
- This test provides only an indication of the potential sediment setting properties.
- The test can also provide an indication of the percentage fraction of fine and coarse sediments within a soil sample.
- A soil sample that fails to settle properly after a day or two indicates that chemical flocculation of sediment basins may be required.
- Such a result also indicates that expert soil advice is likely to be required to achieve desirable environmental outcomes.

Table 5 – Management of problematic soils

Soil type	Erosion control	Sediment Control
Dispersive (sodic) soils	· Dispersive soils are highly susceptible to deep, narrow rilling (fluting) on slopes and drains. · High risk of tunnel erosion if water pathways are not managed properly. · Dispersive soils **must** be treated or buried under a minimum 100 mm layer of non-dispersive soil before placing any revegetation or erosion control measures. · Avoid cutting drainage channels into dispersive soils.	· Dispersive soils usually require the addition of gypsum or similar to improve settlement properties. · Sediment control usually relies on the use of Type D (wet) *Sediment Basins*. · Priority should be given to the application of effective erosion control measures, rather than trying to control runoff sediment and turbidity only through the use of sediment control measures.
Non-cohesive sandy soils	· It is essential to control water flow and flow velocity. · Short-term erosion control may be achieved through *Erosion Control Blankets* or *Mulching* anchored with a suitable tackifier. · Long-term erosion control is best achieved with groundcover vegetation such as grass.	· Sediment control measures are most effective in sandy soil areas. · Use of a woven *Sediment Fence* fabric is preferred. · Grassed *Buffer Zones* can also be effective if ‘sheet’ flow conditions are maintained. · Important to maximise the ‘surface area’ of sediment control ponds.
Highly erodible clayey soils	· Short-term erosion control may be achieved with *Erosion Control Blankets* or *Mulching*. · Long-term erosion control is likely to rely on the establishment of a good vegetative cover.	· Use of a non-woven, composite *Sediment Fence* fabric is preferred. · Sediment control usually relies on the use of Type F or Type D (wet) *Sediment Basins*. · Priority should be given to erosion control measures. · Important to maximise the ‘volume’ of sediment control ponds.
Low fertility soils	· These soils are usually more erodible than fertile soils. · These soils may be protected with the use of *Rock Mulching* unless the soils are modified to allow successful revegetation.	· No special sediment control requirements.
Potential acid sulfate soils	· Minimise disturbance of soil. · Where disturbance is necessary, minimise the duration of exposure, especially sandy soils. · Treat exposed soils in accordance with State policies/guidelines. · Backfill trenches within 24-hours. · Follow established guidelines for site rehabilitation and revegetation.	· Acidic water may wash from sediment control devices and this water may need further treatment to adjust pH.

Management of dispersive soils

'Fluting' erosion

Stabilisation of earth batters

- Dispersive soils are highly susceptible to deep, narrow rilling (fluting) on slopes and along the invert of drains.
- Dispersive soils **must** be treated (with gypsum or the like), or buried under a minimum 100 mm layer of non-dispersive soil before placing any vegetation or erosion control measures.
- Thicker capping with non-dispersive soil may be required on steep slopes and in areas where there is likely to be future soil disturbance such as on creek banks.

Failure of a check dam on a dispersive soil

Stabilisation of open drains

- Avoid cutting drainage channels into dispersive soils.
- Avoid the use of *Check Dams* within any drain that cuts into a dispersive soil.
- The use of *Check Dams* only extends the duration of water pooling, and thus the risk of erosion—instead, line the drain with a non-dispersive soil and vegetate.

Tunnel erosion

Prevention of tunnel erosion

- Dispersive soils are highly susceptible to tunnel erosion.
- Sealing batter chutes with concrete can result in tunnel erosion forming under the concrete if the chute has been cut into a dispersive soil.
- Similarly, tunnel erosion can form under drainage channels lined with rock or rock mattresses (gabions).

Erosion of recently seeded surface

Treatment of soil prior to seeding

- Do not directly seed an untreated dispersive soil.
- A well-established vegetative root system cannot prevent the release (dispersion) of clay particles from the soil, and the inevitable failure of the vegetated surface.
- Instead, treat the soil with gypsum (or the like) and/or cover the dispersive soils with a minimum 100 to 300 mm layer of non-dispersive soil (the required depth depends on the likelihood of future soil disturbance).

Management of temporary access roads

Inadequate drainage and erosion controls

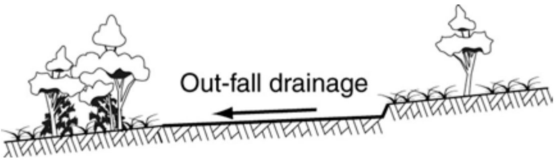
Drainage and erosion controls

- Stormwater runoff (and run-on water) must be allowed to freely discharge from unsealed roads.
- Appropriate drainage controls will be required on all unsealed roads subject to rainfall, even if the road is temporary.
- Gravelling of long-term, unsealed roadways can significantly reduce the release of fine sediments and turbid waters from the roadway.

Gravel road with out-fall drainage

Out-fall drainage

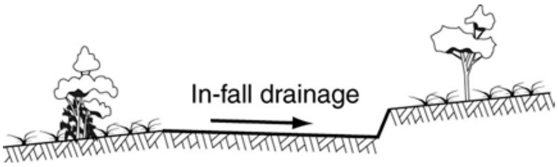
- Out-fall drainage is only used when road runoff can sheet evenly off the road.
- Out-fall drainage can cause erosion problems if:
  - the outer embankment is unstable, or
  - an earth windrow forms along the outer edge of the roadway.



Dirt road with in-fall drainage

In-fall drainage

- In-fall drainage is generally the preferred road drainage system, especially when:
  - the outer road embankment consists of poor or unstable soils, or
  - an earth windrow is likely to form along the outer edge of the road, e.g. during ongoing road grading operations.



Cross bank (whoa-boy) drainage

Cross drainage structures

- Wherever reasonable and practical, allow stormwater to shed from unsealed access roads at regular intervals.
- Typical spacing of cross banks is:
  - 120 m for road grades less than 2%
  - 60 m for road grades of 2 to 4%
  - 30 m for road grades of 4 to 8%
  - 15 m for road grades greater than 8%
- The occurrence of erosion on the road, or within the table drain, is a likely indicator of insufficient drainage control.

Temporary site shutdowns

Application of a temporary grasses

Programmed shutdowns

- Procedures for initiating a site shutdown, whether planned or unplanned, must incorporate the revegetation of all disturbed soils unless otherwise approved by the regulatory authority.
- Revegetation activities associated with a programmed site shutdown should commence at least 30-days prior to the nominated shutdown date.

Soil stabilisation with stabilised mulch

Short-term shutdowns

- The use of non-vegetated erosion controls, such as mulch, blankets and soil binders, is generally not considered adequate treatment, unless:
  - it is known that the shutdown period will be less than three (3) months (check with local authority), and
  - the proposed soil stabilisation measures are appropriate for the expected weather conditions.

Heavy mulching of garden beds

Stabilisation of garden beds

- Future garden beds should be protected with heavy mulching. It is noted that the introduction of grass seeding to these garden beds can cause ongoing weed problems.
- Adequate drainage controls (*Catch Drains*, logs and *Level Spreaders*) will be required to prevent loose mulch being washed from the site.
- Recessed logs (left) can help 'dam' loose mulch, and spread surface runoff.

Temporary site fencing

Limiting access to the site

- Where appropriate, construction sites should be fenced to reduce the risk of illegal soil/rubbish dumping and soil disturbance during extended periods of a site shutdown.

Site rehabilitation

Staged revegetation

Cover requirements

- Exposed soil surfaces must be rehabilitated as soon as practical to minimise the risk of soil erosion and the resulting environmental harm.
- To be effective, at least 70 to 80% cover (refer to Figure 1 over page) must be achieved in order to protect the soil surface from raindrop impact.
- In critical locations, 100% cover may be required—refer to the regulatory authority.

Soil adjustment

Adjustment of soil properties

- Soil surfaces that have experienced excessive compaction during the construction phase must be suitably scarified/ripped prior to revegetation.
- Soil testing should be used to determine if any chemical adjustment is required for the soil (e.g. lime, gypsum, pH adjustments, fertiliser).

Turfing

Turfing

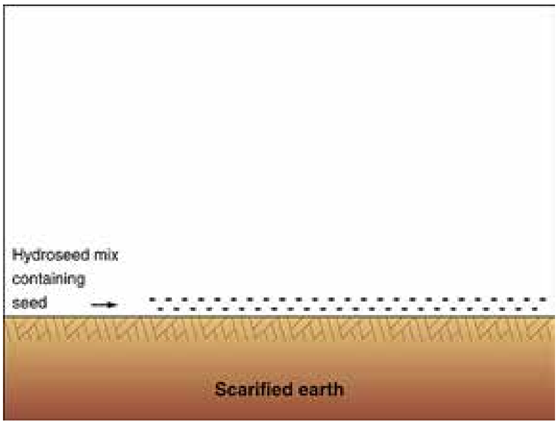
- Turfing can be one of the most effective forms of instant erosion control.
- Turf must **<u>not</u>** be placed on excessively compacted soils.
- If high velocity flows are likely/expected over the turfed area within the first two weeks, then the turf should be anchored with wooden pegs.
- Metal staples (commonly used to anchor erosion control blankets) should not be used to anchor turf (for reasons of future pedestrian safety).

Grass seeding with mulch cover

Light mulching of seeded areas

- If grass seeding is used, then significant benefits can be obtained from the addition of a light mulch cover.
- The use of mulch will reduce raindrop impact, water evaporation, and temperature fluctuation within the topsoil.
- The effective percentage cover achieved by newly seeded surfaces can be increased by mowing the grass as soon as the shoots gain sufficient height (>50 mm).
- All site revegetation measures should be monitored, particularly after rainfall.

Grass seeding techniques



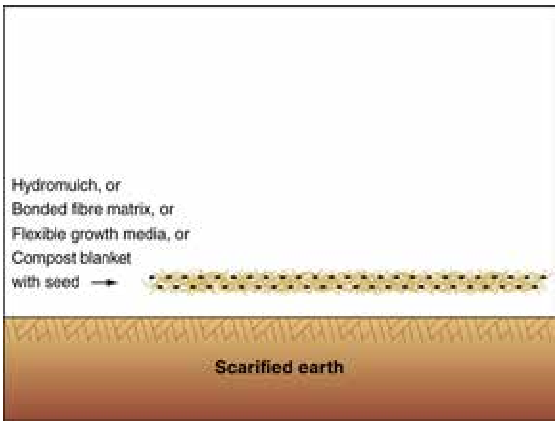
Hydroseeding

Hydraulically applied seed and mulch

- Hydroseeding is the hydraulic application of a liquid mixture containing water, seed and a green dye.
- Hydroseeding does not incorporate mulch fibres, and consequently poor seed germination and survival is expected if the soil surface is allowed to dry under a strong sun.
- Grass cover can be enhanced by covering the treated area with a straw mulch, and/or ensuring soil moisture levels are maintained.

Hydroseeding

Hydroseed



Hydromluching

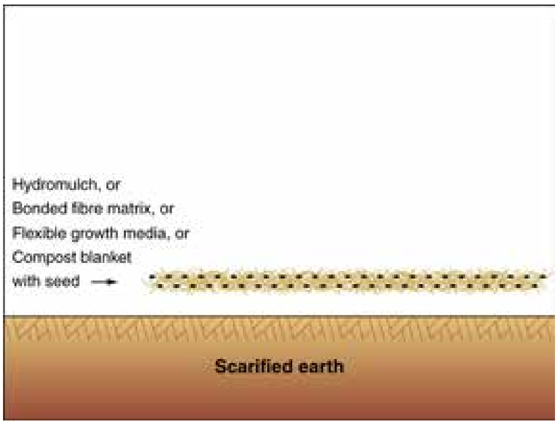
Hydromulching

- Hydromulching can be used for grass establishment and the protection of newly seeded areas.
- Best used on slopes <10% and slopes with a vertical fall of less than 3 m.
- Hydro-mulched surfaces generally have higher watering requirements than surfaces treated with straw mulch.
- Tackifiers incorporated into the mix are normally water soluble and thus easily disturbed by heavy rainfall and concentrated overland flows.

Hydromulching

Hydromulch

Grass seeding techniques



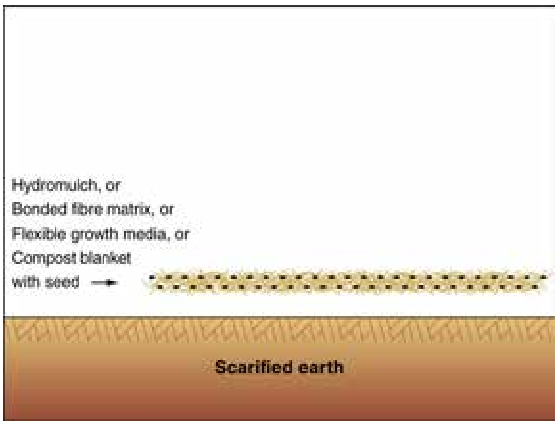
Bonded fibre matrix

Bonded fibre matrix (BFM)

- Bonded fibre matrices are effective for revegetating steep batters.
- Typically it is a highly successful grassing technique, but it requires strict control of application rates and choice of tackifier.
- Often used in wet environments (e.g. the tropics during the wet season, and drainage channels) due to the use of non re-wettable tackifiers.

Bonded fibre matrix

Bonded fibre matrix



Seeded compost blanket

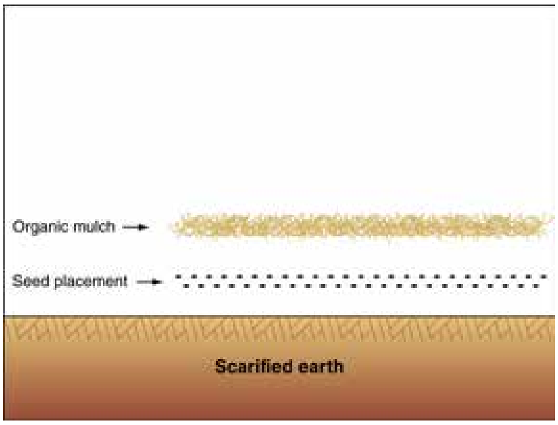
Compost blanket

- Compost blankets are typically used in association with the revegetation of steep slopes using grasses and/or woody species.
- Particularly useful if:
  - the slope is too steep for the placement of topsoil
  - there is insufficient topsoil, or the stripped topsoil cannot be used due to excessive weed content.
- Can be expensive, but usually highly successful.

Compost blanket

Compost blanket

Grass seeding techniques



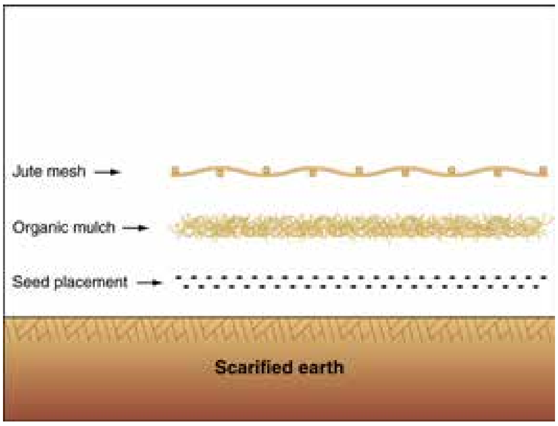
Straw mulching

Straw mulching over seeded soil

- Compared to many other forms of grass seeding, surfaces treated with straw mulch generally require less water to achieve seed germination and growth.
- Straw mulching can be very useful in rural and semi-arid areas where water supplies may be limited, and in urban areas during periods of water restrictions.
- Straw mulches may require the application of a tackifier to reduce the risk of their displacement by wind or water, particularly when applied to steep slopes.

Straw mulching

Straw-mulched surface



Jute mesh and mulch

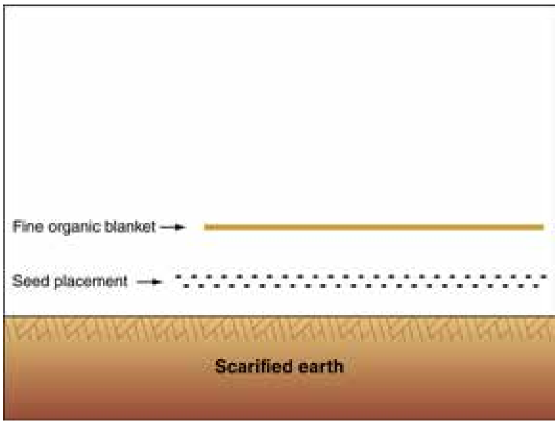
Straw mulching with jute/coir mesh anchor

- This technique is desirable along drainage channels when water supply is limited (e.g. rural roads) and on waterway banks.
- Application: initial water a scarified soil, then spread grass seed, cover with straw, anchor the straw with a well-pegged mesh, and finally apply additional water.
- The mulch controls raindrop impact and reduces water evaporation.
- The mesh anchors the mulch preventing displacement by winds and storm runoff.

Jute mesh anchoring loose mulch

Jute mesh

Grass seeding techniques



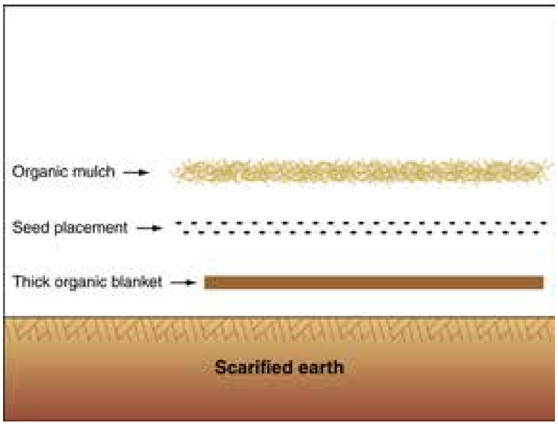
Fine organic (jute) blanket

Fine organic (jute) blankets

- Firstly water the scarified soil, then spread grass seed and cover with a fine blanket, then lightly roll the blanket to achieve good contact with the soil, or heavy water to achieve the same good soil contact.
- This technique can be problematic during hot weather that can dry the soil and kill newly-germinated grass seed.
- Grass will grow up through the blanket.
- This technique will not suppress the growth of weed seed contained within the soil.

Fine jute mat over seeded soil

Fine jute mat



Thick jute blanket used for weed control

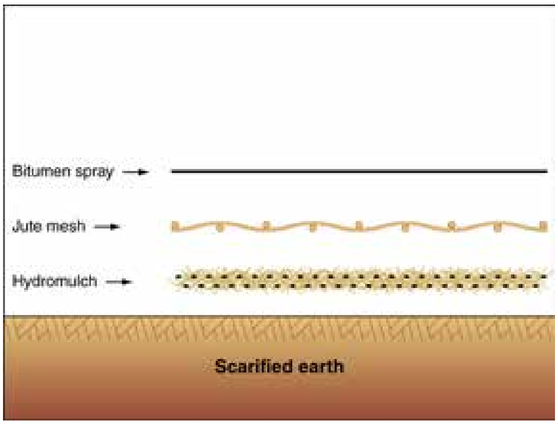
Thick organic (jute) blankets

- Firstly water the scarified soil, cover with a thick blanket, lightly roll the blanket to achieve good contact with the soil, or heavy water to achieve the same good soil contact, then apply a seed/mulch mix.
- This technique is preferred when it is desirable to suppress the growth of weed seed contained within the soil.
- Grass will root down through the blanket.
- WARNING: this technique requires good contact between the soil and blanket with no air pockets.

Thick blanket seeded with BFM

Grass establishing on a thick blanket

Grass seeding techniques



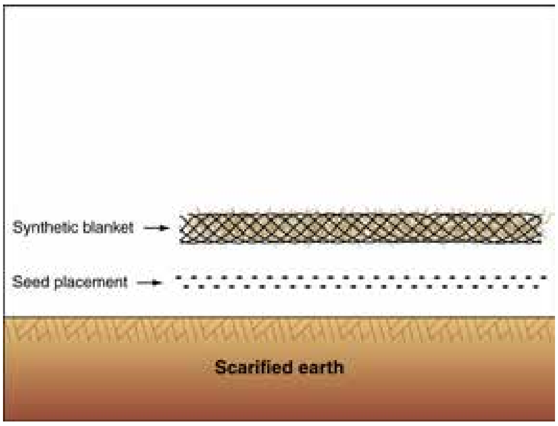
Hydromulch and jute mesh

Hydromulch anchored with jute mesh

- This technique can be beneficial along minor drainage channels, such as table drains.
- Consider the potential benefits of an initial watering of the scarified soil, then apply hydromulch, cover with jute mesh, apply a light spray of anionic bitumen, and finally apply additional water as necessary.
- The jute mesh controls soil scour.
- The bitumen controls raindrop impact and reduces water evaporation.

Jute mesh with bitumen seal

Emergent grass cover



Synthetic erosion control blankets

Synthetic blankets and mats

- Erosion control blankets with temporary, synthetic reinforcing have a low to medium shear strength.
- Temporary (non UV stabilised) blankets have a design life generally < 12 months.
- Permanent synthetic mats (TRMs) are typically used in association with reinforced grass.
- The plastic mesh can represent a threat to wildlife, potentially entrapping animals such as lizards, snakes and birds—do <u>not</u> use along waterways.

Non UV-stabilised synthetic composite mat

Non UV-stabilised synthetic composite mat

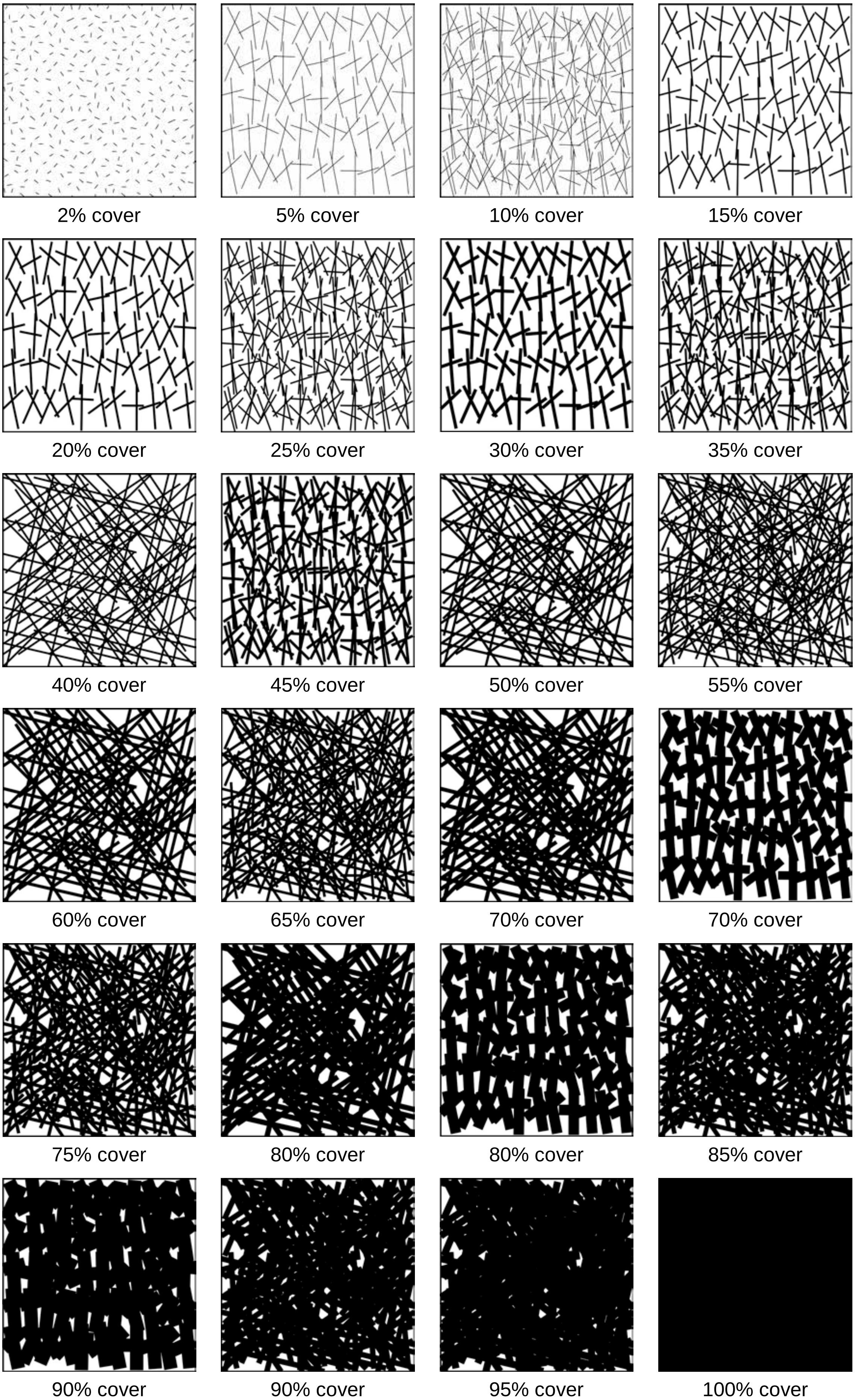
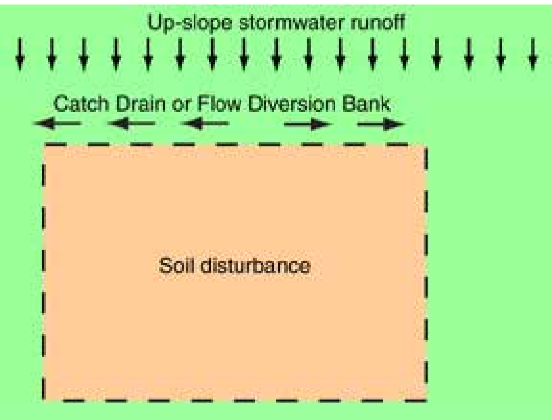


Figure 1 – Visual straw/grass cover estimation template

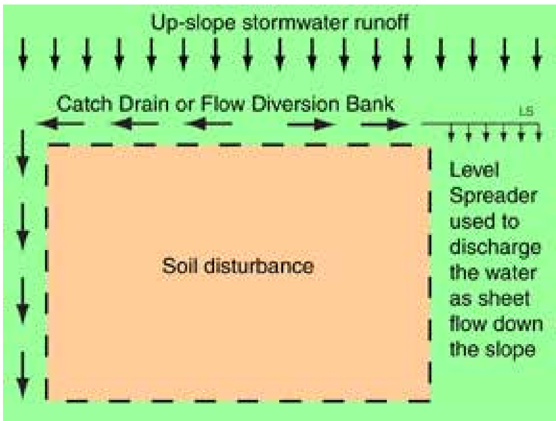
Drainage Control Measures

Management of site drainage during the construction phase

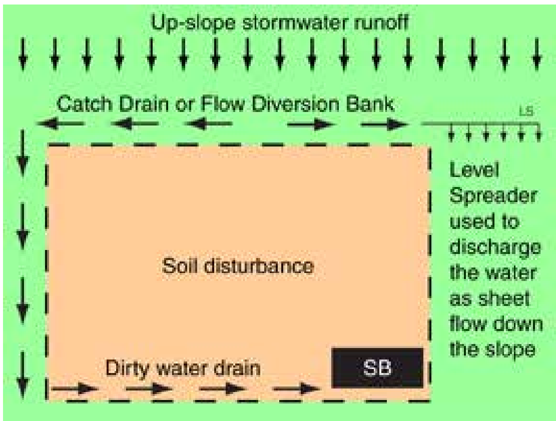
- Appropriate drainage controls must be applied to every construction site. These controls may consist of components of the permanent drainage system, plus temporary drainage measures that are required to be functional only during the construction phase.
- Each site is different, consequently the required drainage control measures must be assessed on a site-by-site basis based on the anticipated catchment and weather conditions.
- On complex sites, a *Construction Drainage Plan* (CDP) should be prepared by a drainage engineer.
- In all cases, it is important to ensure that stormwater is not unlawfully diverted or released into neighbouring properties, or allowed to cause erosion at discharge points.



Flow diversion across the slope



Flow diversion down the slope



Collection of dirty water runoff

Primary drainage control measures:

- **Firstly**, assess the benefits and practicality of diverting up-slope runoff around soil disturbances. This may require large sites to be assessed on a sub-catchment basis.
- Drainage options include ***Flow Diversion Banks*** (possibly formed from the stripped topsoil), and excavated ***Catch Drains***.
- If the subsoils are known to be **dispersive** or highly erodible, then avoid cutting drains into these soils; instead, use ***Flow Diversion Banks*** to redirect water across the slope.
- **Secondly**, choose an appropriate gradient and channel lining for each drain. Unlined soil surfaces may be allowed on some low gradient drains.
- If flow velocities are expected to be high, then either control the water velocity with the use of ***Check Dams***, or select an appropriate channel lining.
- **Thirdly**, consider how best to move stormwater down steep slopes.
- Drainage options include ***Slope Drains*** for minor flows, and suitably lined drainage ***Chutes***. Alternatively, a ***Level Spreader*** can be used to release the water as 'sheet' flow down the slope.
- **Fourthly**, if the site contains a major sediment trap such as a *Sediment Basin* (SB), then consider how best to direct the maximum quantity of sediment-laden water to these sediment traps.
- Drainage options include the use of ***Catch Drains***, ***Flow Diversion Banks***, or for large catchments, formally designed ***Diversion Channels***.
- **Finally**, ensure that stormwater is not unlawfully diverted or released into neighbouring properties, or allowed to cause erosion at discharge points.

The following tables present the suggested identification codes and drawing symbols for various drainage control techniques.

Table 6 – Drainage control techniques

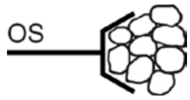
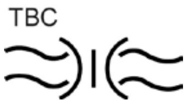
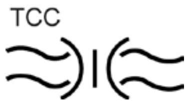
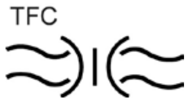
Technique	Code	Symbol	Technique	Code	Symbol
Catch Drain	CD	→ CD →	Chute	CH	→ CH →
Diversion Channel	DC	→ DC →	Flow Diversion Bank	DB	→ DB →
Level Spreader	LS		Outlet Structure	OS	
Recessed Rock Check Dam	RRC	→ RRC →	Rock Check Dam	RCD	→ RCD →
Sandbag Check Dam	SBC	→ SBC →	Slope Drain	SD	→ SD →
Bridge	TBC		Culvert	TCC	
Temporary Downpipe	TD		Ford	TFC	
Triangular Ditch Check	TDC	→ TDC →			

Table 7 – Channel and chute linings

Technique	Code	Symbol	Technique	Code	Symbol
Cellular Confinement System	CCS	→ CCS →	Erosion Control Mat	ECM	→ ECM →
Geosynthetic lining	GEO	→ GEO →	Grass lining	GC	→ GC →
Grass Pavers	GP	→ GP →	Hard Armouring	HA	→ HA →
Rock lining	RR	→ RR →	Rock Mattresses	RM	→ RM →
Turfing	T	→ T →	Turf Reinforcement Mat	TRM	→ TRM →

DRAINAGE ACROSS A SLOPE – Catch drains (CD)

Earth-lined catch drain

Large catch drain

Severe erosion associated with catch drain cut into dispersive soil

Use of catch drains

- Catch drains are used for the collection of sheet runoff and the diversion of such runoff across a slope or around a soil disturbance.
- They can also be used to collect ‘dirty’ water and carry it to a sediment trap.
- These drains are best used on erosion-resistant, non-dispersive soils.
- It is not advisable to cut a catch drain into a dispersive soil.

Construction of catch drains

- Catch drains can be constructed with or without an adjoining down-slope bank.
- Large catch drains are usually formed by pushing the excavated soil down the slope to form an adjoining flow diversion bank.
- Catch drains can be earth-lined (low gradient drains only), or lined with erosion control mats, grass, or rocks.
- Application of a channel lining, however, must not be allowed to reduce the required flow capacity or dimensions of the drain.

Problems of dispersive soils

- Drains cut into dispersive soils can result in severe erosion problems and the loss of large quantities of sediment.
- If a drain is required to be cut into a dispersive soil, then the drain **must** be lined with a non-dispersive soil (minimum 100 mm thick), even if the drain is to be lined with rock, grass, or erosion control mats.

Table 8 – Constructed dimensions of catch drains (including 150 mm freeboard)

Dimensions	Parabolic drains			V-drains		
	Type-A	Type-B	Type-C	Type-AV	Type-BV	Type-CV
Total depth including freeboard	0.30 m	0.45 m	0.65 m	0.30 m	0.45 m	0.65 m
Total width at top of formed drain	1.6 m	2.4 m	3.6 m	2.0 m	2.7 m	3.9 m

DRAINAGE ACROSS A SLOPE – Flow diversion banks and berms (DB)

Sandbag flow control berm

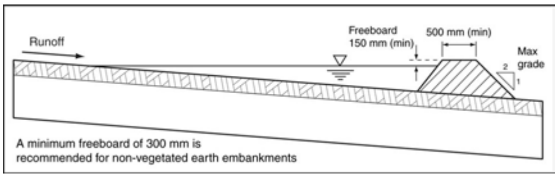
Flow control berms

- Flow control berms are used for the collection and diversion of minor flows from relatively small catchment areas.
- They can also be used to direct minor flows to drainage channels & chutes (left).
- Berms can be highly susceptible to traffic damage and flow leaks.
- Berms can be formed from sandbags (left), compost, or compacted earth.
- If earth is used, then a formally designed flow diversion bank should be constructed.

Flow diversion bank

Flow diversion banks

- Flow diversion banks are typically used for the diversion of flows when in-situ subsoils are dispersive or otherwise highly erodible.
- They may be formed from the stripped topsoil.



Straw bale flow diversion bank under construction (yet to be staked)

Temporary straw bale berms

- Straw bales can be used to form **temporary** flow diversion banks to protect exposed soils and excavations from imminent storms.
- Straw bale berms should **not** be used for periods longer than a week.
- These devices should **not** be operated as sediment traps.
- **Note:** the bales shown (left) are yet to be staked in placed to prevent movement. Straw bales can also be wrapped in filter cloth to increase the overall stability of the bank.

Table 9 – Dimensional requirements of flow diversion banks and berms

Parameter	Earth banks	Compost berms	Sandbag berms
Height (min)	500 mm	300 mm (450 mm)	N/A
Top width (min)	500 mm	100 mm (100 mm)	N/A
Base width (min)	2500 mm	600 mm (900 mm)	N/A
Side slope (max)	2:1 (H:V)	1:1 (H:V)	N/A
Hydraulic freeboard	150 mm (300 mm)	100 mm	50 mm

DRAINAGE DOWN A SLOPE – Chutes (CH)

Geotextile-lined chute

Rock mattress lined spillway chute

Rock-lined chute

Poorly placed rock

Temporary drainage chutes

- Filter cloth is commonly used to line short-term (< 3 months) batter chutes.
- DO NOT use on dispersive soils.
- ALL chutes require:
  - *Flow Diversion Banks*, or similar, to direct flow into the chute
  - a well-defined inlet profile
  - a well-defined cross-sectional profile that can fully contain the flow (including splash) down the chute
  - a stable outlet and energy dissipation system at the base of the chute.

Permanent drainage chutes

- Chutes lined with rock mattresses are commonly used to form spillways on *Sediment Basins*, and as permanent batter chutes.
- In most cases, permanent, rock mattress-lined chutes should be vegetated (grassed), unless located in arid or semi-arid areas.
- The mattress should be laid with the diaphragm (internal dividing wall) at right angles to the dominant direction of water flow.

Rock-lined drainage chutes

- Rock lining is typically used on:
  - permanent drainage chutes
  - *Sediment Basin* spillways.
- Special care must be taken to ensure:
  - use of an appropriate rock size
  - the rocks are recessed into the earth to allow the free entry of inflows
  - the use of geotextile fabric under the rocks if the voids are left open.
- Note; round rock (left) is significantly less stable than angular fractured rock.
- The rocks must be recessed into the soil to prevent inflows being diverted along the outer edges of the rock lining.
- The rock lining must **not** be allowed to reduce the required flow capacity or dimensions of the chute.
- If a chute is placed on dispersive soils, then the chute **must** be lined with a non-dispersive soil (minimum 200 mm thick), even if the chute is to be lined with concrete, rock, rock mattresses, or grass.

DRAINAGE DOWN A SLOPE – Slope drains (SD)

Sediment traps each side of pipe inlet

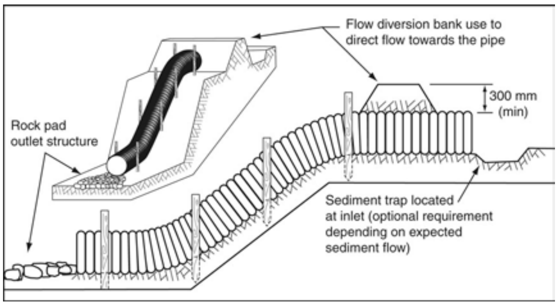
Flow diversion bank controlling flow entry

Slope drains on newly seeded batter

Lay-flat pipe

Slope drains

- Slope drains are most commonly used in low rainfall regions where stormwater runoff discharge is expected to be low (i.e. not exceed the inlet capacity of the pipe).
- Sediment traps can be incorporated into the inlet and/or outlet of these pipes.
- The photo (left) shows an excavated sediment trap formed each side of the entrance to the slope drain (just visible in the centre). *Note; the segment of pipe visible on the top of the earth bank is excess pipe not apart of the slope drain.*
- A flow diversion bank is required at the inlet of the slope drain to direct water into the pipe.

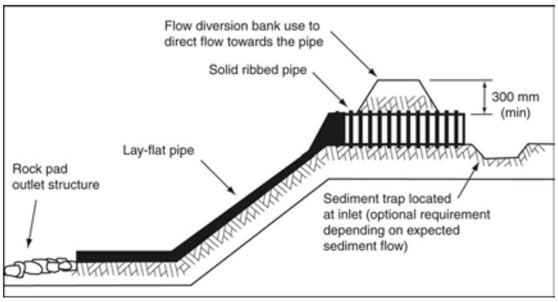


Use of slope drains

- Slope drains are commonly used in road construction to prevent stormwater runoff discharging down newly seeded batters.
- Slope drains can also be uses to direct concentrated flows through bushland.
- ALL slope drains require:
  - suitable *Flow Diversion Banks* at the pipe inlet to control flow entry
  - a stable outlet (*Outlet Structure*) at the end of the slope drain to control erosion.

Use of lay-flat pipes

- Lay-flat pipes can be uses as an alternative to the more commonly used flexible, solid-wall, PVC pipes.

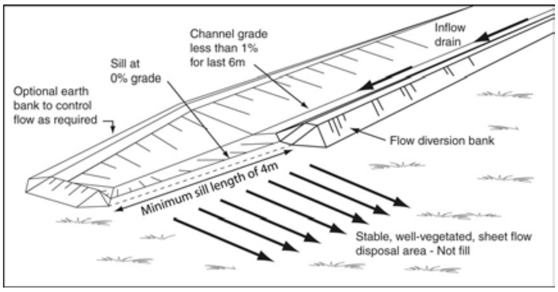


END-OF-DRAIN STRUCTURES – Outlet structures

Level spreader used to release road runoff into the adjacent farmland

Level spreaders (LS)

- Level spreaders are used at the end of *Flow Diversion Banks* and *Catch Drains* to discharge minor flows down stable, grassed slopes, or into bushland.
- They can also be used to discharge road runoff into grassland or bushland.



Rock pad outlet structure

Outlet structures (OS)

- Outlet structures are used at the end of temporary *Chutes* and *Slope Drains* to dissipate flow energy and control scour.
- They can also be used as a permanent energy dissipater on pipe and culvert outlets.
- The final size and shape of the outlet structure (Figure 2) may need to be modified to match the size and surface conditions of the receiving channel.

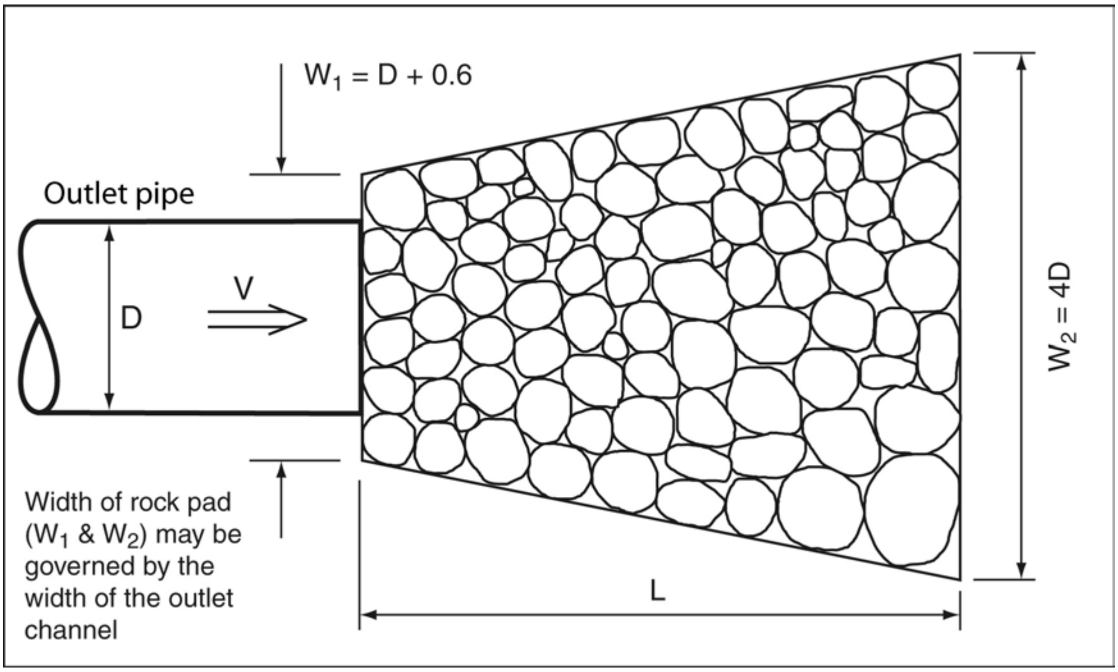


Figure 2 – Typical layout of a rock pad for a single pipe outlet (plan view)

VELOCITY CONTROL STRUCTURES – Check dams

Fibre rolls

Fibre rolls (FCD)

- Fibre rolls consist of small-diameter (150–200 mm)biodegradable straw-filled logs.
- They can be used as check dams in wide, shallow drains so long as the logs can be anchored to prevent movement.
- Best used in locations where it is desirable to allow the fibre rolls to integrate into the permanent vegetation, such as in vegetated channels; however, some products contain a plastic mesh that may present a wildlife/environmental risk.

Geo Logs

Geo log check dams (GCD)

- Geo logs have a larger diameter (approx 300 mm) compared to fibre rolls.
- Geo logs made from coir (coconut fibres) can be very durable and last for a year or more (depending on the frequency of wetting and drying).
- It is very important to ensure that:
  - flows do not undermine the logs, and
  - flows spill **over** the logs, **not** around the ends of the logs.

Sandbag check dam

Sandbag check dams (SBC)

- Sandbag check dams are typically used in drains less than 500 mm deep, with a gradient less than 10% (1 in 10).
- These check dams are small (in height) and therefore are less likely to divert water out of the drain in comparison to rock check dams.
- The biodegradable sandbags are usually left in-place and allowed to integrate into the final drain vegetation.

Rock check dam

Rock check dams (RCD)

- Rock check dams should **only** be used in drains at least 500 mm deep, with a gradient less than 10%.
- They should only be used in locations where it is known that they will be removed once a suitable grass cover has been established within the drain.
- They can act as minor sediment traps.
- Rock check dams can be used as a permanent velocity-control device and/or sediment trap in non-vegetated, earth-lined drains (check with road authority).

Channel and chute linings

Geotextile lined drainage chute

Geotextile linings (GEO)

- Used to provide temporary scour protection in low to medium velocity drains.
- Heavy-duty filter cloth can be used to form temporary drainage chutes down steep batters.
- Plastic sheeting can also be used to form short, temporary drainage chutes down earth batters, but they must be used with caution—water flow must be prevented from passing under the plastic.

Jute mesh

Jute & coir mesh

- Jute or coir mesh is a form of *erosion control mat* used to provide temporary scour protection in low to medium velocity drains.
- These products are generally preferred in natural environments and bushland areas.
- Overall erosion control and channel revegetation can be improved by:
  - placing the mesh over a mulch layer, or
  - spraying the mats with an anionic bitumen emulsion or soil binder.

Temporary erosion control mat

Erosion control mat (ECM)

- Some temporary erosion control mats contain an organic mulch reinforced with a synthetic mesh that will eventually breakdown under direct sunlight.
- Used to provide temporary scour protection in low & medium velocity drains.
- **Caution** should be taken when using any synthetic reinforced mats in bushland areas as ground dwelling animals, such as lizards, snakes, and granivorous (seed-eating) birds, can become tangled in the fine netting.

Turf reinforcement mat

Turf reinforcement mat (TRM)

- Turf reinforcement mats (TRMs) are used for the lining of high-velocity, permanent drains and chutes.
- Also used to line grassed *bywash* spillways on dams and *Sediment Basins*.
- These permanent reinforced mats are usually distinguished from temporary mats by their dark colour, or the inclusion of a black synthetic reinforcing mesh—the black colour identifying the inclusion of UV-stabilising carbon.

Channel and chute linings

Turf lined diversion drain

Turfing (T)

- Turf can be used for the lining of low velocity *Chutes*, *Catch Drains* and *Diversion Channels*.
- If high velocity flows are likely within the first two weeks, then the turf should be anchored with wooden pegs.
- Metal staples (commonly used to anchor erosion control blankets) should not be used (for reasons on pedestrian safety).
- It is important to ensure that water entering the turfed area is not diverted along the up-slope edge of the turf.

Pre-grown reinforced grass

Reinforced grass (TRM)

- Pre-grown reinforced grass can be used for the lining of high-velocity, permanent drains and chutes.
- Also used to line grassed *bywash* spillways on dams and *Sediment Basins*.
- Particular attention (i.e. placement and anchorage) should be given to the crest, toe and sides of the mat during installation to avoid the potential for future erosion and/or uplifting.

Cellular confinement system

Cellular confinement system (CCS)

- Cellular confinement systems can be used to stabilise low to medium velocity chutes.
- The pockets may be filled with small rocks or vegetated (grassed) soil to form a temporary or permanent chute.
- These products can also used to form temporary construction access across dry, sandy bed streams.
- This product is also discussed within the section on *Erosion Control Measures*.

Rock lining (RR)

Rock lining (RR)

- Rock can be used for the lining of high-velocity, permanent drains and *Chutes*.
- Also used to line spillways on dams and *Sediment Basins*.
- An underlying geotextile or rock filter layer is generally required unless all voids are filled with soil and vegetated.
- Note; round rock is significantly less stable than angular, fractured rock (left).

Temporary watercourse crossings

Barge crossing of tidal inlet

Barge crossings

- A barge can be used as a mobile transportation system to cross estuaries and protected waterways.
- Barges can be used as a fixed bridge structure (left) to cross narrow estuary inlets.

Temporary access construction bridge

Temporary bridge crossings (TBC)

- A temporary bridge crossing is used when it is important to maintain fish passage during the construction period.
- Pre-case culvert bridging slabs (left) can be used to form a bridge deck across narrow streams.
- It is important to control stormwater drainage on the access tracks leading to watercourse crossings in a way that will minimise the risk of sediment-laden water from these tracks being discharged, untreated, into the watercourse.

Temporary pipe culvert

Temporary culvert crossings (TCC)

- Temporary culvert crossings are typically used on wide stream crossings.
- They are best used when fish passage is not critical; however, suitable fish passage can be achieved through appropriate design.
- Recycled steel pipes are commonly used for this purpose.

Ford crossing of alluvial stream

Temporary ford crossings (TFC)

- Ford crossings are used on alluvial creek and river crossings when stream flows are not expected.
- The regular crossing of 'wet' creek beds by construction vehicles should be avoided.
- These crossings are typically used in shallow, intermittent streams that are expected to have negligible base flow during the construction period.
- *Cellular Confinement Systems* can be used to stabilise dry sandy-bed crossings.

Works in and around watercourses

Long-reach excavator

Isolation barrier

Instream sediment control system

Bank rehabilitation

Basic principles

- Ensure all necessary government approvals are obtained **prior** to any disturbance of a watercourse.
- To the maximum degree practical, minimise disturbance to the riparian vegetation each side of the watercourse.
- Minimise the number of temporary watercourse crossings.
- Take all reasonable and practical measures to avoid the operation of construction equipment within the main channel of the stream.

Isolation of disturbances from stream flow

- Wherever practical, priority should be given to the use of instream flow diversion systems that successfully isolate all soil disturbances from the stream flow.
- Isolation barriers can be formed from sediment fence fabric (flow depth < 0.8 m), floating silt curtains (depth > 0.8 m), large water-filled rubber dams, and sheet piling.
- Photo (left) shows a non-woven composite sediment fence (adjacent bank) forming a coarse sediment trap, with a woven fabric (adjacent stream channel) forming a quiescent, fine sediment, settling pond.

Instream sediment control measures

- The use of instream sediment control measures should only be used as a last resort, and only when it is not practical to divert dry weather flows around all disturbances.
- Instream sediment control measures usually require the incorporation of 'filtration' systems such as *Filter Tubes* (left).
- Instream sediment control measures must not be used during periods of essential fish migration—seek expert advice.

Erosion control measures

- All disturbed surfaces, bed, banks and overbank areas, must be appropriately rehabilitated as soon as practical.
- Temporary erosion control measures include the use of rock (along the toe of the bank), 100% biodegradable erosion control blankets, and native vegetation.
- Alternatively, *Jute or Coir Logs* may be incorporated into the toe of the bank to protect newly stabilised banks from minor flows.

Erosion Control Measures

The following tables present the suggested identification codes and drawing symbols for various erosion control techniques.

Table 10 – Erosion control techniques

Technique	Code	Symbol	Technique	Code	Symbol
Bonded Fibre Matrix	BFM	BFM	Cellular Confinement System	CCS	CCS
Compost Blanket	CBT	CBT	Erosion Control Blanket	ECB	ECB
Gravelling	Gravel	GRAVEL	Heavy Mulching	MH	MH
Light Mulching	M	M	Poly-acrylamide	Poly or PAM	Poly
Revegetation	R	R	Rock Mulching	MR	MR
Soil Binders	SBS	SBS	Surface Roughening	SR	SR

The appropriate application of erosion control products typically related to the slope of the land and the expected shear stress resulting from stormwater runoff down the slope. Table 11 provides a general guide to the application of various erosion control measures.

Table 11 – Typical application of erosion control measures to soil slopes

Flat land **(flatter than 1 in 10)**	**Mild slopes** **(1 in 10 – 1 in 4)**	**Steep slopes** **(steeper than 1 in 4)**
Erosion Control Blankets Gravelling Mulching Revegetation Rock Mulching Soil Binder Turfing	Bonded Fibre Matrix Compost Blankets Erosion Control Blankets, Mats and Mesh Mulching well anchored Revegetation Rock Mulching Turfing	Bonded Fibre Matrix Cellular Confinement Systems Compost Blankets Erosion Control Blankets, Mats and Mesh Revegetation Rock Armouring Turfing

Light mulching (M) – mulching in association with grass seeding

Straw mulching

Hydromulching

Bonded fibre matrix

Temporary grass cover

Straw mulching

- Compared to many other forms of mulch, surfaces treated with straw mulch generally require less water to achieve seed germination and growth.
- Straw mulching is best used in rural and semi-arid areas where water supplies may be limited, and in urban areas during periods of water restrictions.
- Straw mulches may require the application of a tackifier to reduce displacement of the mulch by wind or water, particularly when applied to steep slopes.

Hydromulching

- Hydromulching can be used for grass establishment and the protection of newly seeded areas.
- Best used on slopes <10% and slopes with a vertical fall of less than 3 m.
- Hydro-mulched surfaces generally have higher watering requirements than surfaces treated with straw mulch.
- Tackifiers incorporated into the mix are normally water soluble and thus easily disturbed by heavy rainfall and concentrated overland flows.

Bonded fibre matrix (BFM)

- Bonded fibre matrices are effective for revegetating steep batters.
- It can be a highly successful grassing technique, but it requires strict control of application rates and choice of tackifier—a light application of a BFM is generally no better than a normal hydromulch.
- Often the preferred grass seeding technique in wet environments (e.g. in the tropics during the wet season, and in drainage channels) due to the use of non re-wettable tackifiers.

Temporary seeding (TS)

- In certain situations, a rapid and complete cover of 'annual grasses' can act as an effective, well-anchored mulch on embankments, batters and table drains.
- Even if the grass is allowed to die-off immediately after establishment (i.e. given only start-up watering), the surface can still provide effective erosion control—this can be useful during periods of drought.
- Can be a useful technique in rural and semi-arid areas.

Heavy mulching (HM)

Bush mulch

Bush, bark and woodchip mulch (BM)

- Bush mulch is typically used on garden beds, and for the temporary protection of exposed soils prior to the completion of earthworks (i.e. when it is desirable not to introduce grass seed to the soil).
- **Caution**; some wood-based (woodchip) mulches can reduce nitrogen levels within the soil.

Compost blanket

Compost blankets (CBT)

- Typically used in association with the revegetation of steep slopes using grasses and/or woody species.
- Particularly useful if:
  - the slope is too steep for the placement of topsoil
  - there is insufficient topsoil, or the stripped topsoil cannot be used due to excessive weed content.
- Can be expensive, but usually highly successful.

Rock mulching

Rock mulching (MR)

- Rock mulching is typically used in arid and semi-arid areas as a replacement for vegetation.
- Can be used on garden beds that may be subjected to high velocity and/or high volume overland flows.
- Also used on heavily shaded areas (e.g. under bridges and suspended slabs).
- Can be used in association with a *Cellular Confinement System* (see over page).

Table 12 – Relative attributes (L-low, M-medium, H-high) of various mulches

	Cost	Water usage	Control of raindrop impact	Stability in wet areas	Durability	Placement on steep slopes	Can be used with seeding
BFM	H	M	H	H	M	H	Y
Brush mulch	L-M	M	H	M	M	M	Y
Compost blanket	H	M	H	H	H	H	Y
Hydromulch	M	H	M	L	L-M	M	Y
Rock mulching	M	L	H	H	H	M	N
Straw mulch	M	L	H	variable	M	difficult	N
Wood chip	L-M	M	H	L	M	L	N

Erosion control blankets (ECB)

Jute blanket

Jute mesh

Synthetic-reinforced blanket

Weed control blanket

Biodegradable blankets

- Organic-based blankets have low shear strength, and thus a low allowable flow velocity.
- Critical performance parameters include their ability to control raindrop impact and sheet erosion.
- The key to successful revegetation in association with these blankets is:
  - good soil condition
  - good surface preparation, and
  - intimate contact between the blanket and the soil (i.e. no 'tenting').

Open mesh-type blankets

- A 'mesh' is an open weave blanket made from rope-like strands such a hessian (jute) or coir rope (coconut tree product).
- A typical design life in dry environments of 12 to 24 months.
- Jute blankets have a service life similar to that of a hessian bag placed on the ground (i.e. approximately 3 months).
- Coir blankets have a service life similar to that of a common domestic coir doormat placed directly on the ground.

Temporary synthetic-reinforced blankets

- Erosion control blankets with temporary, synthetic reinforcing have a low to medium shear strength.
- These temporary (non UV stabilised) blankets have a design life generally less than 12 months.
- The design life of the organic mulch varies with the type of mulch.
- The plastic mesh can represent a threat to wildlife, potentially entrapping wildlife such as lizards, snakes and birds.

Weed control blankets

- Weed control features can be incorporated into some erosion control blankets.
- These weed control features are generally long-term, but not permanent.
- 'Thick' organic-based (jute) blankets and woven synthetic blankets can also be used to suppress weed germination (short-term control only).

Anchorage systems for erosion control <u>blankets</u>

Timber stakes

Timber pegs and stakes

- Short timber pegs can be used in a wide variety of soils.
- Stakes are typically used to anchor turf placed in areas likely to experience high-velocity flows soon after turf placement.
- They can also be used to anchor erosion control blankets, especially if storms or strong winds are imminent.

Metal staples

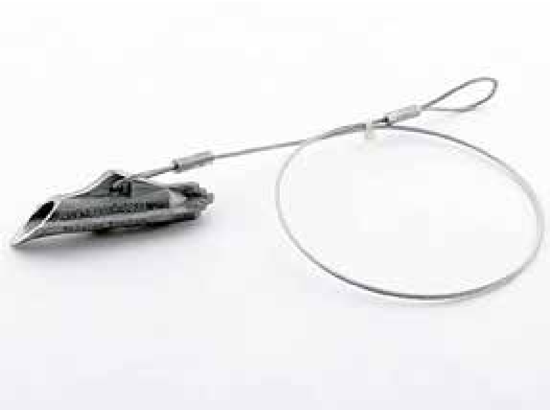
Metal pins or staples

- Metal staples/pins are best used on firm to hard (compacted) clayey soils.
- Anchorage of these pins is partially by friction, and partially through the rusting of the pins; therefore, conditions must exist that will allow the pins to rust.
- Initially (i.e first few day/weeks) metal pins provide only marginal anchorage, and as such, erosion control blankets can be displaced by strong winds unless also anchored by rocks, sandbags or tree debris.

Barbed plastic pins

Barbed plastic pins

- Barbed plastic pins are best used in soft to firm clayey soils, but generally <u>not</u> very sandy soils.
- They can be difficult to use if the soil is heavily compacted or natural (i.e. undisturbed).
- Care must be taken when used to anchor a ‘mesh’ to ensure the pin adequately captures or twists around the mesh.



Duck-billed soil anchor

Duck-billed soil anchor

- Duck-billed soils anchors are best used in soft sandy or silty soils, or any soil that has insufficient strength to hold other anchor types.
- These anchors can be used to anchor logs and fallen trees, which in-turn can be used to anchor erosion control blankets and mats on the banks of **<u>some</u>** waterways.

Common problems experienced with erosion control blankets

Blankets displaced by winds

Poor anchorage of blankets

- Erosion control blankets are normally anchored with metal staples, or barbed plastic pegs.
- Blankets anchored solely with metal staples are susceptible to disturbance by strong winds, especially if the soil is soft to firm, and the staples have not rusted.
- Additional anchorage can be provided by tree debris and timber stakes/pegs.

Blanket stretched over rough ground

Blankets placed over irregular ground

- Four key requirements exist for the placement of erosion control blankets:
  - seepage flows that may pass under the blanket should be discouraged
  - irregularities removed from the soil surface
  - intimate contact between the soil and blanket is achieved
  - good anchorage of the blanket.

Inappropriate anchorage pegs

Blankets placed on dispersive or slaking soil

- Erosion control blankets are **not** the solution to all soil erosion problems.
- Dispersive and slaking soils require appropriate amelioration and/or sealing with topsoil **prior** to the placement of blankets or the seeding of the soil.
- Slaking soils (left) are likely to require barbed pins or timber pegs in order to secure the blankets.

Mats overlapped in wrong direction

Blankets and mats overlapped against the direction of flow

- Erosion control 'blankets' (meant for areas subject to sheet flow) and erosion control 'mats' (meant for areas subject to concentrated flow) **must** overlap in the direction of flow (i.e. upper over lower).
- The direction of flow may be determined by:
  - the direction of overland sheet flow, and/or
  - the direction of channel flow.

Cellular confinement systems (CCS)

Anchorage system

Installation on road batter

Cellular confinement systems

- Cellular confinement systems can be used to stabilise low to medium velocity *Chutes*.
- The pockets can be filled with sand, small rocks (gravel), or vegetated (soil & grass) to form a temporary or permanent chute.
- Cellular confinement systems are manufactured with smooth, textured, or perforated sidewalls. Each surface condition is used for a specific purpose.
- Perforated, textured surfaces (left) are the most common.
- Typical uses include:
  - containment of topsoil or rock mulch on medium to steep slopes
  - control of erosion on non-vegetated medium to steep slopes such as bridge abutments and heavily shaded areas.
- These products can also used to form temporary construction access across ‘dry’, sandy streambeds (i.e. a temporary ford crossing).

Installation on road batter

Final grassed batter

Gravelled car park

Gravelled batter slope

Dust suppression measures

Straw mulching of road shoulder

Mulching (M)

- Well-anchored (e.g. crimped or tackified) mulch can be used for dust control on large, open soil areas.
- Mulching is primarily used in association with temporary grass seeding.
- Mulch can also be used as an alternative to grass seeding during times of water restrictions or severe drought, or as a longer-term ground cover in sparse woodland areas where the natural ground cover consists primarily of natural mulch.

Application of soil binders

Soil binders (SBS)

- Soil binders are typically used for dust control on unsealed roads and mining operations.
- Selection of the best product depends on the potential environmental impacts, and required trafficability and longevity.
- The application and success of soil binders varies from region to region.
- Seek local expert advice.
- It may be necessary to trial various measures and learn from experience.

Seeding road batter

Temporary seeding (TS)

- Temporary grass seeding is typically used in association with mulching for medium to long-term dust control on large, open soil areas.
- At least 70% ground cover (combined plant and mulch) is considered necessary to provide a satisfactory level of erosion control.
- Temporary grass seeding is most commonly used to stabilise the embankments of long-term sediment basins.

Water truck

Water trucks

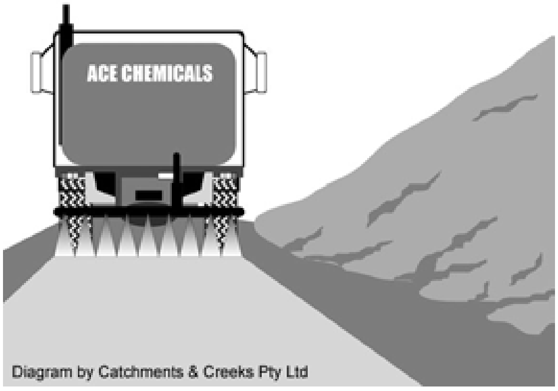
- Water trucks can be used for dust control on unsealed roads and access tracks.
- Dust levels can also be controlled by minimising the movement of site traffic outside designated areas.
- The addition of wetting agents and polymer binders to the water can decrease both the water usage and the required application frequency—seek expert advice.

Miscellaneous erosion control measures

Gravel-stabilised car park

Gravelling (GRAVEL)

- Typical uses of gravelling include:
  - protection of non-vegetated soils from raindrop impact erosion
  - stabilisation of the site office area, temporary car parks, and access roads.
- Where appropriate (e.g. long-term construction sites) gravelling can also be used to minimise soil compaction and the generation of excessive mud around car parks and the site compound.



Application of polyacrylamide

Polyacrylamide (Poly or PAM)

- Typical uses of polyacrylamide (PAM) include dust control and the stabilisation of unsealed roads.
- Polyacrylamide **must** only be used under strict environmental controls prepared by suitably qualified personnel.
- If rainfall is possible, PAMs should not be the only cover material or surface stabiliser applied to the treated area.
- PAM, combined with water, can be very slippery and can represent a safety hazard.

Recently stabilised area

Revegetation (R)

- The best way to control soil erosion is to promptly revegetate all disturbed areas.
- This technique includes turfing and temporary seeding.
- At least 70% ground cover (combined plant and mulch) is considered necessary to provide a satisfactory level of erosion control.

Roughened earth batter

Surface roughening (SR)

- On recently vegetated or exposed earth surfaces, erosion protection can be enhanced by roughening the soil surface to increase water infiltration and delay the formation of rutting.
- Surface roughening can also reduce dust generation.
- Surface roughening can be applied by walking a tracked vehicle up and down the slope, but in some cases, special equipment is required.

Sediment Control

The following tables present the suggested identification codes and drawing symbols for various sediment control techniques.

Table 13 – Sediment control techniques

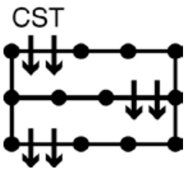
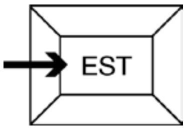
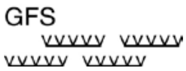
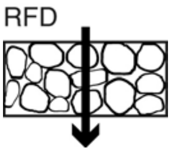
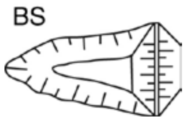
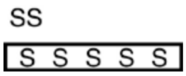
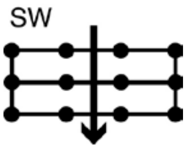
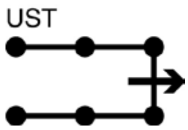
Technique	Code	Symbol	Technique	Code	Symbol
Buffer Zones	BZ		Check Dam Sediment Trap	CDT	
Coarse Sediment Trap	CST		Compost Berm	CB	
Excavated Sediment Trap	EST		Fibre Roll	FR	
Filter Fence	FF		Filter Sock	FS	
Filter Tube Dam	FTD		Grass Filter Strips	GFS	
Modular Sediment Trap	MST		Mulch Berm	MB	
Rock Filter Dam	RFD		Sediment Basin	SB	
Sediment Fence – woven fabric	SF		Sediment Trench	SS	
Sediment Weir	SW		Stiff Grass Barrier	SGB	
Straw Bale Barrier	SBB		U-Shaped Sediment Trap	UST	

Table 14 – Sediment control – entry/exit control techniques

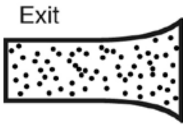
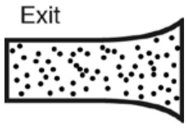
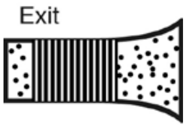
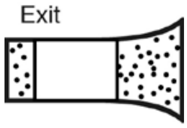
Technique	Code	Symbol	Technique	Code	Symbol
Construction Exit	Exit		Rock Pad	Exit	
Vibration Grid	Exit		Wash Bay	Exit	

Table 15 – Sediment control – roadside kerb inlet control techniques

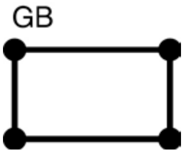
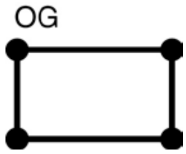
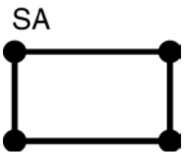
Technique	Code	Symbol	Technique	Code	Symbol
Gully Bag	GB		On-grade Kerb Inlet Sediment Trap	OG	
Sag Inlet Sediment Trap	SA				

Table 16 – Sediment control – field (drop) inlet control techniques

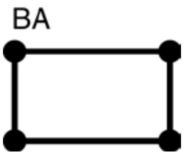
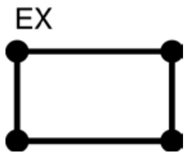
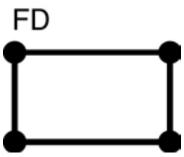
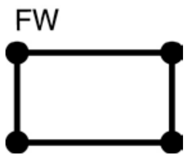
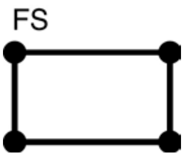
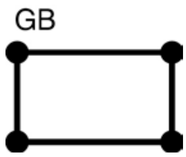
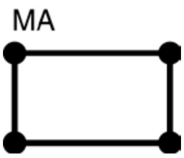
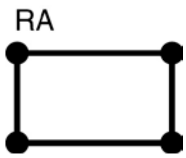
Technique	Code	Symbol	Technique	Code	Symbol
Block & Aggregate Drop Inlet Protection	BA		Excavated Drop Inlet Protection	EX	
Fabric Drop Inlet Protection	FD		Fabric Wrap Inlet Protection	FW	
Filter Sock Drop Inlet Protection	FS		Gully Bag	GB	
Mesh & Aggregate Drop Inlet Protection	MA		Rock & Aggregate Drop Inlet Protection	RA	

Table 17 – Classification of sediment traps based on particle size

Classification	Minimum particle size	Typical trapped particles
Type 1	<0.045 mm	Clay, silt and sand
Type 2	0.045 to 0.14 mm	Silt and sand [1]
Type 3	>0.14 mm	Sand
Supplementary	>0.42 mm	Coarse sand

[1] Technically, silt particles have a grain size between 0.002 and 0.02 mm, which means that only Type-1 sediment traps are likely to capture silt-sized particles. However, for general discussion purposes, it can be assumed that Type 2 systems capture a significant proportion of silt-sized particles.

Table 18 – Default classification of sediment control techniques

Type 1	Type 2	Type 3
Sheet flow treatment techniques		
· Buffer Zone capable of infiltrating 100% of stormwater runoff or process water * · Infiltration basin or sand filter bed capable of infiltrating 100% of flow	· Buffer Zone * capable of infiltrating the majority of flows from design storms · Compost/Mulch Berm	· Buffer Zone * · Filter Fence · Modular Sediment Trap · Sediment Fence
Concentrated flow treatment techniques		
· Sediment Basin * (sized in accordance with design standard)	· Block & Aggregate Drop Inlet Protection · Excavated Sediment Trap with Type 2 outlet · Filter Sock · Filter Tube Dam · Mesh & Aggregate Drop Inlet Protection · Rock & Aggregate Drop Inlet Protection · Rock Filter Dam · Sediment Trench * · Sediment Weir	· Coarse Sediment Trap · Excavated Drop Inlet Protection * · Excavated Sediment Trap with Type 3 outlet · Fabric Drop Inlet Protection · Fabric Wrap Field Inlet Sediment Trap · Modular Sediment Trap · Straw Bale Barrier · U-Shaped Sediment Trap
De-watering sediment control techniques (selection not based on soil loss rate)		
· Type F/D Sediment Basin · Stilling Pond	· Filter Bag or Filter Tube · Filter Pond · Filter Tube Dam · Portable Sediment Tank * · Settling Pond * · Sump Pit	· Compost Berm * · Filter Fence * · Grass Filter Bed * · Hydrocyclone * · Portable Sediment Tank * · Sediment Fence
Instream sediment control techniques (selection not based on soil loss rate)		
· Pump sediment-laden water to an off-stream Type F or Type D Sediment Basin or high filtration system	· Filter Tube Barrier · Modular Sediment Barrier* · Rock Filter Dam · Sediment Weir	· Modular Sediment Barrier* · Sediment Filter Cage

* Classification depends on design details.

Types of sediment traps

Sediment basin (Type 1)

Type 1 sediment traps

- Sediment traps can be classified as Type 1, Type 2, Type 3 or supplementary sediment traps.
- Type 1 sediment traps are designed to collect a full range of sediment particles down to less than 0.045 mm.
- In general terms these traps target sediment grain sizes from clays to sands.
- Type 1 sediment traps include *Sediment Basins* and some of the advanced filtration systems used in de-watering operations.

Rock filter dam (Type 2)

Type 2 sediment traps

- Type 2 sediment traps are designed to capture sediments down to a particle size of between 0.045 and 0.14 mm.
- In general terms these sediment traps target particle sizes from sands down to coarse silts.
- Type 2 sediment traps generally do **not** reduce turbidity levels (i.e. water clarity).
- Type 2 sediment traps include *Mulch Berms, Rock Filter Dams, Sediment Weirs* and *Filter Ponds.*

Sediment fence (Type 3)

Type 3 sediment traps

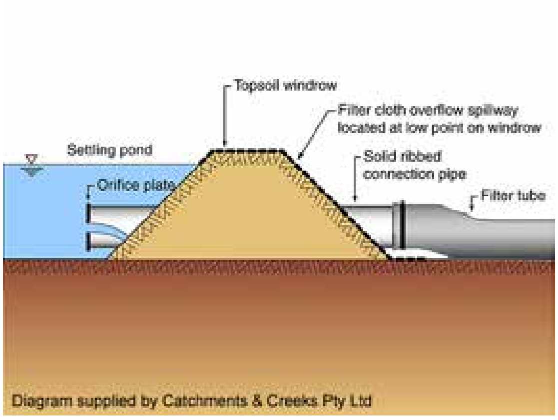
- Type 3 sediment traps are primarily designed to trap coarse-grained particles larger than 0.14 mm.
- These systems include *Sediment Fences, Buffer Zones* and some stormwater inlet protection systems.
- There is no doubt that these traps can capture small quantities of fine sediments; however, there should be **no** expectation of a change in water colour (turbidity) as flows pass through the sediment trap.

Sag-type kerb inlet protection

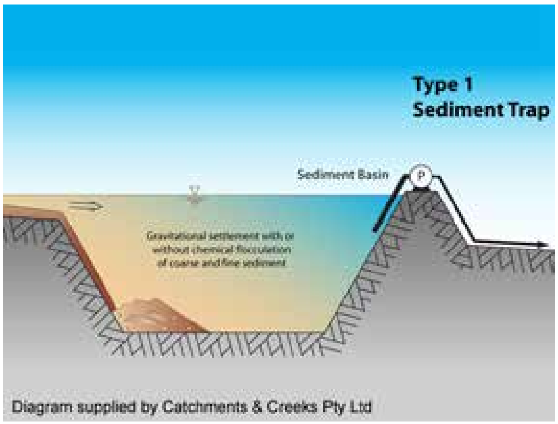
Supplementary sediment traps

- Some sediment traps, such as *Grass Filter Strips* and most kerb inlet sediment traps, have such limited efficiency, or are so easily damaged, that they can only be used to *supplement* a type 1, 2 or 3 sediment trap.
- Even though these sediment traps are potentially unreliable, their use on urban construction projects is still considered to be a component of best practice sediment control.

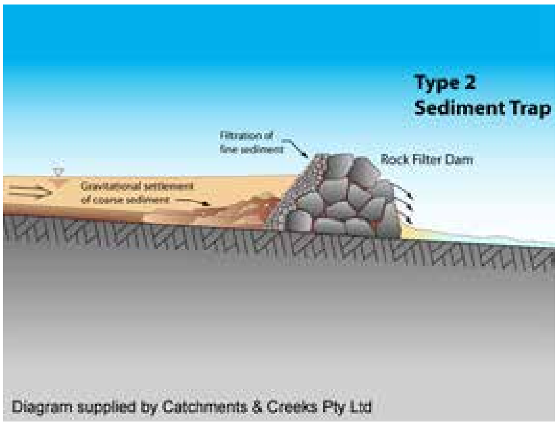
Types of sediment traps



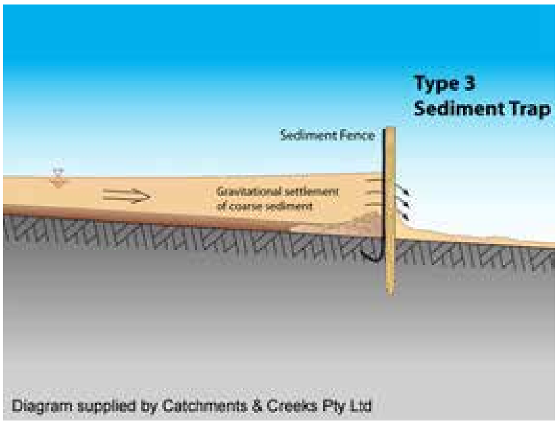
Sediment trap with filter tube outlet



Type 1 treatment system



Type 2 treatment system



Type 3 treatment system

Mechanics of sediment traps

- The mechanics of sediment trapping can generally be categorised into the following groups:
  - ponding traps that primarily utilise gravity-induced particle settlement
  - ponding traps that utilise a filtration system for the treatment of low-flows
  - extended detention settling basins
  - geotextile filters
  - sand and aggregate filters
  - compost filters.

Type 1 sediment traps

- Type 1 sediment traps utilise either:
  - extended detention to encourage the settlement of clay-sized particles; or
  - super-fine, high-pressure filters.
- Sediment basins operate as either:
  - continuous-flow 'dry' basins; or
  - plug-flow 'wet' basins.
- High-pressure filters are normally only used during specialist de-watering operations, typically only used in urban areas.

Type 2 sediment traps

- The key components of a type 2 sediment trap are a 'settling pond' followed by a 'coarse-particle filter'.
- Just like a sediment fence, a type 2 sediment trap is designed to encourage the pooling of water up-slope of the trap.
- Gravity-induced settlement is then supplemented by either a geotextile, aggregate or compost filter.
- A compost filter is simply a compost berm through which water can percolate.

Type 3 sediment traps

- Most type 3 sediment traps are designed to slow the passage of water to such a degree that ponding occurs up-slope of the trap.
- It is this pooling of water that allows gravity-induced settlement of the coarser grained particles (i.e. sands).
- A sediment fence is **<u>not</u>** a 'filter'.
- A sediment fence is just a porous dam that encourages sediment-laden water to pond up-slope of the fence.

Critical features of sediment traps

Sag-type kerb inlet control system

Type D sediment basin

Stormwater runoff bypasses sediment trap

Failed sediment traps on steep ramp

Critical features of a sediment trap

- Most sediment traps incorporate the following critical features:
  - the ability to pool water
  - adequate retention time to allow the settlement of suspended particles
  - the capacity to collect and retain a specific volume of settled sediment
  - adequate hydraulic capacity prior to the commencement of flow bypassing
  - limits on the maximum depth of pooling in areas where public safety is a concern.

Critical features of the settling pond

- The presence of a settling pond means the focus is on gravity-induced settlement.
- In a continuous-flow system, the critical design parameter is the **surface area** of the pond (as in the design of Type-A, B & C sediment basins).
- In a plug-flow system, the critical design parameter is the **volume** of the settling pond (as in the design of a wet or Type D sediment basin).

Ability to capture and hold sediment

- A sediment trap should not just divert sediment-laden water from one location to another.
- When constructing a sediment trap, ask yourself:
  - Will the device cause a safety problem?
  - Where is the water going to flow?
  - Where is the sediment going to settle?
  - How will the trapped sediment be collected and removed?

Caution regarding the placement of sediment traps on steep slopes

- On steep slopes, say steeper than 10% (1 in 10), the focus should firstly be on controlling soil erosion, and secondly on controlling the flow of water down the slope.
- Wherever practical, the trapping of sediment should occur at the base of the slope, or at a location well away from the slope where it is safe and convenient to temporarily pond water.

Types of sediment filters

Sand-filled filter sock

Rock filter dam with aggregate filter

Filter tube attached to an embankment

Compost-filled filter sock

Types of sediment filters

- Many sediment traps incorporate some type of filtration system.
- The filter media may consist of straw, sand, aggregate, geotextile or compost.
- Straw-based filters are very inefficient and their primary purpose is usually to encourage the pooling of water rather than the filtration of sediments.
- Most sand-based filters are also very inefficient due to their low through-flow discharge.

Aggregate filters

- The most important thing to know about aggregate filters is that they rely on the effects of partial sediment blockage to activate the filtration process.
- A filter formed from clean aggregate does not provide much ‘filtration’; at best it simply helps to slow water flow to encourage up-slope pooling.
- Aggregate filters are best used in sandy or silty soils (i.e. soils with a clay content less than, say 20%).

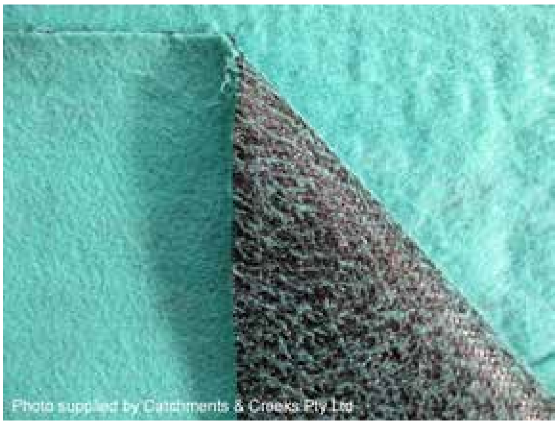
Geotextile filters

- Geotextile filters are made from non-woven fabrics (woven fabrics should **not** be used).
- Most geotextile filters initially have a high flow rate, but sediment blockage can eventually reduce this to zero.
- The use of geotextile filters is preferred if the capture of fine-grained sediments is critical.
- Geotextile filters rarely reduce turbidity levels, thus the water remains ‘brown’.

Compost filters

- Compost filters use both *filtration* and *adsorption* processes to clean the through-flow.
- Thus compost filters can adsorb minor amounts of dissolved and fine particulate matter such as metals.
- These filters are considered to perform better than most sand, aggregate or geotextile filters, provided the filter remains undamaged and outflows are not allowed to bypass the filter.

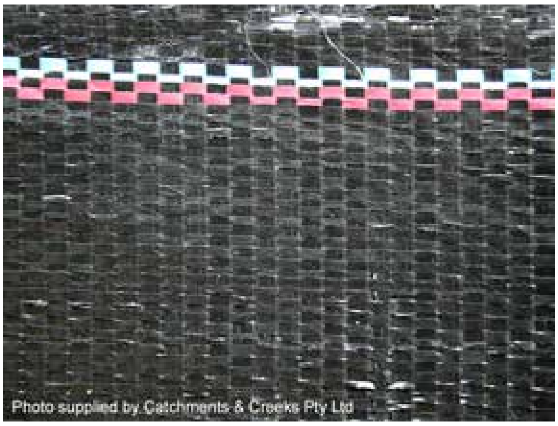
Use of geotextiles in sediment control



Composite sediment fence fabric

Use of geotextiles in sediment control

- Geotextiles can be used for a number of purposes, including:
  - slowing water flow to encourage pooling and gravity-induced sedimentation
  - the filtration of flows
  - geotechnical engineering.
- Composite fabrics are sometimes used when it is desirable to perform more than one of the above tasks.
- Composite ESC fabrics are not always commercially available.



Woven sediment fence fabric

Woven fabrics

- The primary purpose of a woven fabric is to **<u>slow</u>** the passage of water—these fabrics are **<u>not</u>** used for filtration.
- In most cases, the fabric is made from thin strips of impervious material; thus water can only weep through the small gaps where the fabric strips overlap.
- These fabrics are normally carbon stabilised (often producing the black colour) to reduce UV damage, thus extending their working life.

Non-woven filter cloth

Non-woven fabrics

- Non-woven fabrics are primarily used for filtration and geotechnical engineering.
- Most non-woven fabrics are not UV stabilised, thus they have a limited working life if exposed to direct sunlight.
- *Filter cloth* is the most common non-woven fabric found on construction sites.
- In Australia, filter cloth is commonly graded using the ‘bidim’ grading of A12 (thin) to A64 (thickest).

Filter sock

Hessian fabric

- Hessian fabrics fall outside the normal rules because they are woven fabrics, but unlike most woven fabrics, they encourage filtration.
- Hessian fabrics can be used to form erosion control blankets as well as hessian sandbags.
- Hessian sandbags can be filled with sand or aggregate to form a filter berm.

Maintenance of sediment traps

Sediment fence in need of maintenance

The need for maintenance

- All ESC measures must be maintained in proper working order at all times until their function is no longer required.
- To assist in achieving this requirement, technical notes and/or construction specifications attached to the Erosion and Sediment Control Plan (ESCP) must specify the maintenance requirements of all sediment traps.

Maintenance of control measures

Proper working order

- The term 'proper working order' means:
  - a condition that achieves the site's required environmental protection, including specified water quality objectives
  - in accordance with the specified operational standard for each ESC measure, and
  - prevents or minimises safety risks.

Poor maintenance practice

Proper disposal of sediment

- All water (clean or dirty), debris and sediment removed from ESC measures must be disposed of in a manner that will not create an erosion or pollution hazard.
- It is **not** sufficient to throw shovelfuls of sediment into the adjacent bushland, or to hose the sediment into a roadside stormwater drain!

Sediment fence well past it's 'use-by' date

Decommissioning control measures

- Upon decommissioning any ESC measures, all materials used to form the control measure must be disposed of in a manner that will not create an erosion or pollution hazard.
- The area upon which the ESC measure was located must be properly stabilised and rehabilitated.
- Sediment fences must not be left in-situ to simply collapse from wear and tear!

Sediment Control Techniques

Entry/exit sediment controls (Exit)

Rock pad

Vibration grid

Wash bay

Site signage

Rock pads

- Suitable for all soil types.
- The critical design parameter is the total void spacing (volume) between the rocks.
- Minimum 10 m length for single dwelling building sites, and 15 m for construction sites.
- Generally perform better than *Vibration Grids* during wet weather.
- Drainage controls (e.g. a cross bank) may need to be incorporated into the rock pad to direct sediment-laden runoff to an appropriate sediment trap.

Vibration grids

- Vibration grids are best suited to sandy soils.
- Can also be used in clayey soil regions to control sediment movement from heavy construction traffic during dry weather.
- A rock pad, or similar, must extend from the vibration grid to the sealed road surface to prevent dirt from returning to the tyres.

Wash bays

- Wash bays are preferred when working near fragile environments, when turbidity control is critical, or when working with highly cohesive clays.
- Wash bays can operate with or without water jets, which can be manual or automatically operated.
- Wash bays generally need to operate as 'dry' vibration grids during periods of dry weather, otherwise mud can slowly be tracked off the site.

Environmental and safety controls

- It is important to ensure trucks and other construction equipment leaving the site do not transport sediment or rocks onto public roads.
- Rock of a size 75 to 100 mm can become wedged between dual tyres and transported off the site.
- Where appropriate, place signs to remind drivers to check their loads, tie ropes, covers, and tyres for trapped rocks.

Stockpile sediment controls

Impervious cover

Impervious covers

- Impervious covers can be used on short and long-term stockpiles of clayey soils to reduce the creation of turbit runoff.
- Impervious covers are most beneficial when stockpiling dispersive soils.
- Stockpile covers (tarps) may not be practical in circumstances where theft of the covers is likely to become an issue.
- Pervious covers, such as filter cloth of hessian blankets, can e used to control raindrop impact erosion.

Filter fence

Filter fence (FF)

- Filter fences, made from heavy-duty, non-woven filter cloth, are generally preferred down-slope of stockpiles containing clayey material—this is in preference to woven sediment fence fabric.
- Typically used down-slope of stockpiles that are:
  - not located within the catchment area of a suitable Type 1 or Type 2 sediment trap, or
  - located adjacent permanent drainage channels or waterways.

Mulch berm

Compost berms (CB) & mulch berms (MB)

- Compost berms (either free standing or contained within a sock) are generally preferred down-slope of stockpiles of clayey material—this is in preference to woven sediment fence fabric.
- Typically used down-slope of stockpiles that are:
  - not located within the catchment area of a suitable Type 1 or Type 2 sediment trap, or
  - located adjacent permanent drainage channels or waterways.

Sediment fence

Sediment fence (SF)

- Sediment fences formed from a composite (non-woven) fabric are generally preferred down-slope of stockpiles containing clayey material instead of the traditional, woven sediment fence fabric.
- Composite sediment fence fabric is not always commercially available.
- Woven fabric sediment fences (left) are best used for sandy soils and stockpiles located up-slope of a suitably grassed buffer zone that will allow for the infiltration of stormwater runoff from the stockpile.

Sediment control techniques suitable for 'sheet' flow conditions

Vegetated buffer zone

Buffer zones (BZ)

- A Type 3 sediment trap.
- Sheet flow conditions only.
- Mostly suited to sandy soils.
- Generally only suitable for rural and rural-residential building and construction sites.
- Can provide some degree of turbidity control while the soil in the buffer zone remains unsaturated.
- Minimum width (in direction of sheet flow) of 15 m, or 5 times the percentage slope, whichever is greater.

Mulch berm

Compost berms (CB)

- A Type 2 sediment trap.
- Sheet flow conditions only.
- Suitable for all soil types.
- Compost berms may either be free standing or contained within a sock (*Filter Sock*).
- Can perform better than a traditional sediment fence, but only while the berm remains undamaged (e.g. by construction traffic or shifting stockpile material).

Fibre roll sediment trap

Fibre rolls (FR)

- A supplementary sediment trap.
- Sheet flow conditions only.
- Fibre rolls (straw rolls) are best used as a supplementary sediment trap on sandy soils.
- Suitable for minor flows only.
- These systems are highly susceptible to damage by construction traffic, and thus they generally cannot be relied upon as an effective sediment trap.

Filter fence

Filter fence (FF)

- A Type 3 sediment trap.
- Sheet flow conditions only.
- Very small catchment areas (e.g. stockpiles).
- Non-woven fabrics generally provide better capture of the finer (sand/silt) sediments compared to woven fabric such as traditional sediment fence fabric.

Sediment control techniques suitable for 'sheet' flow conditions

Grass filter strip

Grass filter strips (GFS)

- A supplementary sediment trap.
- Sheet flow conditions only.
- Best suited to sandy soils.
- Can act as a supplementary sediment trap if placed around impervious surfaces (e.g footpaths) or placed along the contour at regular intervals (max. 2 m vertical fall) down earth banks.
- Can be used as a drainage control technique to help maintain sheet flow down earth batters during revegetation.

Modular sediment trap being installed

Modular sediment traps (MST)

- A Type 3 sediment trap.
- Modular sediment traps are the modern replacement for straw bales.
- These units can be used as a sediment trap in many of the circumstances where straw bale barriers had previously been employed.
- Note; the units shown (left) are still in the process of being installed, and have not yet been adequately braced and anchored.

Mulch berm

Mulch berms (MB)

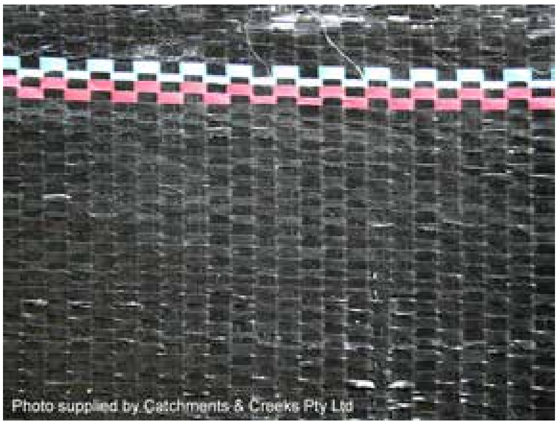
- A Type 2 sediment trap.
- Mulch berms are suitable for all soil types.
- The mulch must be produced through the use of tub grinders or the like.
- The mulch needs to be very fibrous with the woody splinters allowing good interlocking—the mulch should not appear as clean cut (i.e. chipped by blades).
- Mulch and compost berms can act as both a drainage control system, and a sediment control system.

Vetiver grass

Stiff grass barriers (SGB)

- A supplementary sediment trap.
- Stiff grass barriers are mostly suited to sandy soils.
- Requires a long establishment time.
- Typically used as a component of long-term gully stabilisation in rural areas.
- Can be used as a minor, permanent sediment trap to treat runoff from unsealed roads and table drains.

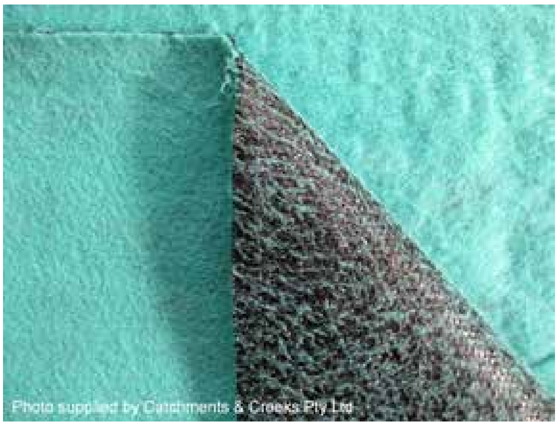
Sediment fence (SF) – suitable for ‘sheet’ flow conditions



Woven sediment fence fabric

Woven sediment fence

- A Type 3 sediment trap.
- Sheet flow conditions only.
- Woven fabrics (left) are generally suitable for all soil types, but sediment capture is limited to the coarser sediment fraction.
- The traditional woven fabrics are generally preferred on long-term construction sites that are likely to experience several storm events.



Composite sediment fence fabric

Composite sediment fence fabrics

- Composite fabrics (consisting of woven and non-woven fabrics) are suitable for all soil types.
- It is generally considered that these fabrics have a greater potential to capture the finer sediment particles.
- Composite fabrics are generally preferred on short duration construction sites.
- The non-woven (green) face must face up the slope.
- These fabrics are not always commercially available.

Sediment fence with top wire

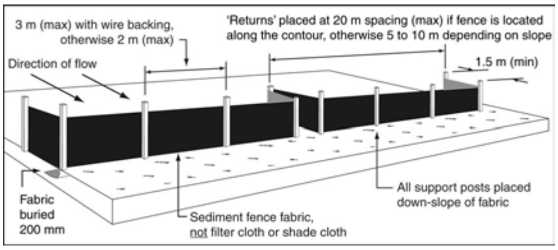
Support posts and wire ties

- Support post must be placed at a maximum 2 m spacing unless the fence has:
  - a top wire (anchored at 1 m spacing), or
  - a wire mesh backing, in which case a 3 m spacing of support post is allowed.
- Sediment fences are ideally installed along the contour, but site conditions do not always make this practical, in which case regular ‘returns’ (see below) must be installed.

Placement of regular ‘returns’

Installation of ‘returns’ within a fence

- Sediment fences must incorporate regular ‘returns’, generally at a maximum 20 m spacing, but can be less as the slope along the fence increases.



Sediment fence (SF) – suitable for 'sheet' flow conditions

Inappropriate use of shade cloth

Inappropriate fabrics

- DO NOT construct sediment fences from 'shade cloth' or open weave fabrics.
- Sediment fences should also not be constructed from filter cloth—the only exception being the formation of a *Filter Fence* down-slope of a stockpile or as used in association with material de-watering.

Fence not returned up-slope at end

Inappropriate installation techniques

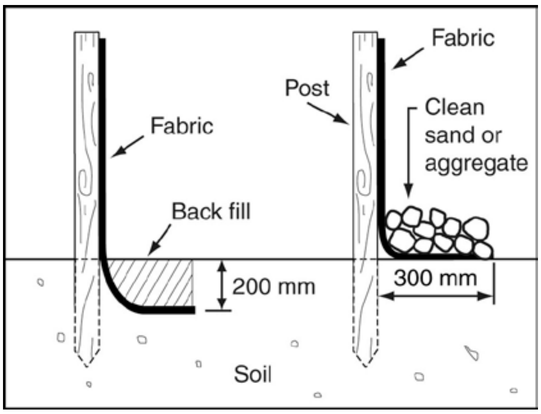
- The ends of a sediment fence **must** be turned up the slope (known as a 'return') to prevent water simply passing around the end of the fence.

Toe of fabric incorrectly anchored

Inappropriate anchorage of fabric

- The bottom of the fabric **must** be anchored to prevent wash-outs.
- The bottom 300 mm of fabric must be suitably anchored either in a 200 mm deep trench, or under clean sand or aggregate (below), but **not** randomly spaced rocks (as shown left).
- The support posts must be placed down-slope of the fabric (<u>not</u> as shown bottom left).

Post placed on wrong side of fence



Recommended installation options

Kerb inlet sediment traps

Selection criteria for the use of kerb inlet sediment traps:

1. **Safety first** – do not use any sediment control system if that system represents a safety risk to persons or property. On open public roadways, consider the use of commercial gully bags to collect sediment within the gully chamber. Caution, sediment traps that extend into a trafficable lane may also represent a hazard to passing cyclists and motor vehicles.
2. **Flooding risk** – any adopted sediment control system must not result in flooding of neighbouring properties.
3. **Type of kerb inlet** – the choice of sediment control system depends on the type of kerb inlet. Kerb inlets located on the slope of a roadway (on-grade inlets) may incorporate gully bags or 'dam' type sediment traps (sandbags or filter socks) placed up-slope of the inlet.

   Kerb inlets located at depressions in a roadway (sag inlets) should incorporate gully bags or 'barrier' type sediment traps (filter socks) placed around the inlet.
4. **Warning** – a sediment trap must not surround or fully block an 'on-grade' kerb inlet.

Gully bag

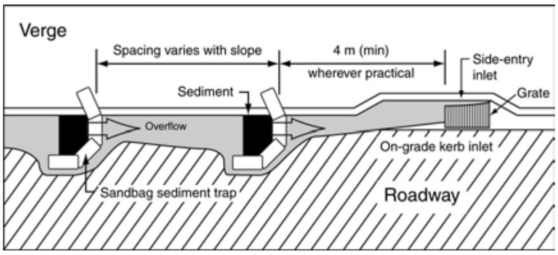
Gully bags (GB)

- A supplementary sediment trap.
- Commercial gully bags are generally considered to perform better than sediment traps placed on the road surface.
- They are typically used when it is considered unsafe to cause ponding or sediment deposition on the roadway.
- The types of gully traps include the flexible filter bags (left) and solid filter boxes lined with filter cloth.

On-grade kerb inlet sediment trap

On-grade kerb inlet sediment traps (OG)

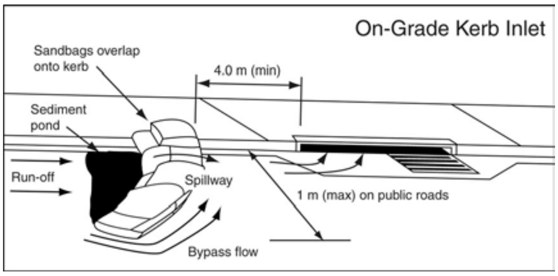
- 'On-grade' inlets require a different sediment control system to 'sag' inlets.
- A series of sediment traps may be required to achieve optimum performance.



Sandbag sediment trap

Installation of sandbag sediment traps

- Forming a 'spillway' helps to improve sedimentation by allowing the sediment-laden water to pass through the pond rather than around it.



Kerb inlet sediment traps

Sag inlet sediment trap

Sag inlet sediment trap

Inappropriate on-grade sediment trap

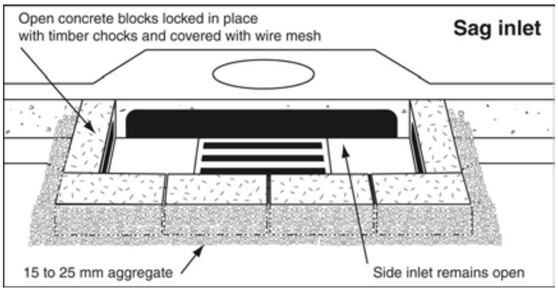
Flooded road surface

Sag inlet sediment traps (SA)

- A supplementary sediment trap.
- Used as a minor sediment trap constructed around kerb inlets located at sag points along a roadway.
- As a general rule, the filter sock must not be allowed to fully block the kerb inlet. Exceptions apply only when:
  - there is no risk of causing flooding of adjacent properties; and
  - where there is a suitable flow bypass, such as a stable overland flow path.

Alternative sag inlet sediment trap

- Alternative designs include filter socks and block and aggregate systems (below).



Inappropriate kerb inlet sediment traps

- Sediment traps must **not** be placed across the opening of 'on-grade' kerb inlets. This will cause the water to bypass the inlet and continue to flow down the roadway.
- Exceptions apply only when:
  - **all** flow bypassing the inlet is directed to a suitable down-slope sediment trap; and
  - where there is a suitable flow bypass system at the road sag, such as a stable overland flow path.

Safety issues

- Public safety must always take priority.
- If the installation of the sediment trap is likely to represent an unmanageable and/or unacceptable safety risk, then an alternative sediment trap must be used, such as a gully bag.
- Roadside sediment traps can also be damaged by road traffic; thus operators must exercise extreme care and caution when placing these devices on public roadways.

Field (drop) inlet sediment traps

Selection criteria for the use of field inlet sediment traps:

1. **Safety first** – do not use any sediment control system if that system represents a safety risk to persons or property.
2. **Flooding risk** – any adopted sediment control system must not result in flooding of neighbouring properties. A spill-through weir, or the like, may need to be incorporated into the sediment trap to control the depth and extent of ponding.

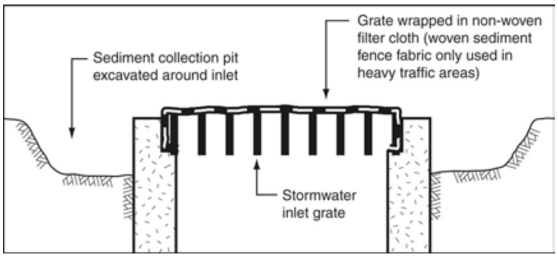
Table 19 – Preferred sediment control technique for various catchment conditions

Soil type	Small catchments	Medium catchments	Large catchments
Sandy soils	· Fabric wrap · Fabric drop inlet	· Block & aggregate · Mesh & aggregate	· Rock & aggregate
Clayey soils	· Filter sock · Fabric wrap or drop inlet using reinforced non-woven filter cloth	· Block & aggregate, or mesh & aggregate incorporating a filter cloth wrap	· Block & aggregate, or mesh & aggregate incorporating a filter cloth wrap

Fabric wrap inlet protection

Fabric wrap inlet protection (FW)

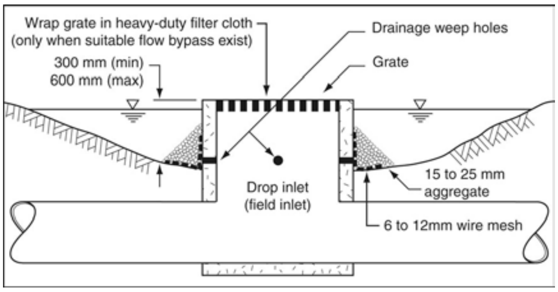
- Very small catchment areas.
- Most commonly used on building sites.
- Formation of the excavated pit is critical.



Filter sock drop inlet protection

Filter sock drop inlet protection (FS)

- A Type 3 sediment trap.
- Filter socks (including straw or compost-filled *Fibre Rolls*, and *Compost Berms*) are only suitable for small catchments.
- Fibre (straw) filled socks are mostly suited to sandy soils.
- Compost berms or compost-filled socks work best in clayey soil areas.
- Compost-filled socks can adsorb some dissolved and fine particulate matter.



Excavated drop inlet protection

Excavated drop inlet protection (EX)

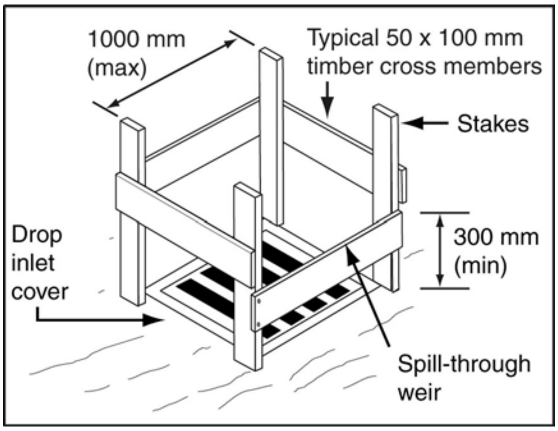
- Excavated drop inlet protection is used in locations where water pooling around the stormwater inlet is not allowed to reach a level significantly higher than the existing ground level.
- Safety issues may require the excavated pit to be surrounded by appropriate safety fencing.

Field (drop) inlet sediment traps

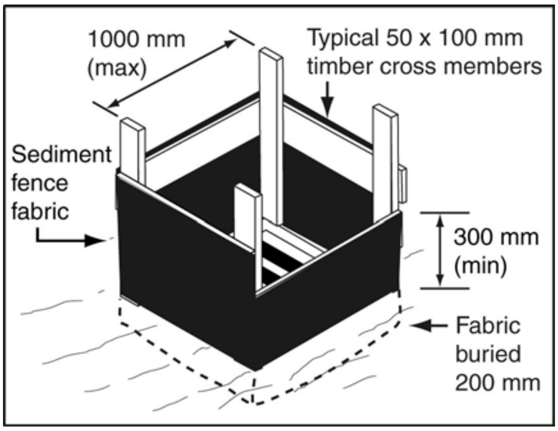
Fabric drop inlet protection

Fabric drop inlet protection (FD)

- A Type 3 sediment trap.
- Fabric drop inlet protection is best used on sandy soils.
- Suitable for relatively small catchment areas.
- Maximum spacing of support posts is 1 m (photo left is a poor example).
- A spill-through weir normally needs to be incorporated into one side of the sediment trap to control the depth of ponding.



Installation of support frame

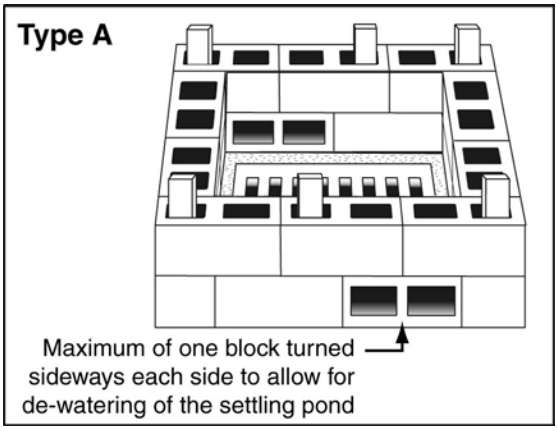


Placement of fabric

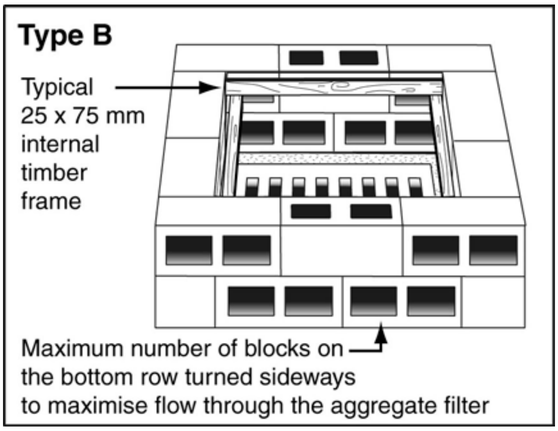
Block & aggregate drop inlet protection

Block & aggregate inlet protection (BA)

- Block & aggregate drop inlet protection is suitable for small to medium catchments.
- In clayey soils, filter cloth is placed between the aggregate and blocks to improve the removal of fine sediments.
- The depth of ponding upstream of the field inlet is governed by the height of the blocks.
- The diagrams below show two types of block arrangements (prior to placement of the aggregate).



Block details for low flow rate system



Block details for high flow rate system

Field (drop) inlet sediment traps

Mesh & aggregate drop inlet protection

Mesh & aggregate inlet protection (MA)

- A Type 2 or 3 sediment trap.
- Mesh & aggregate drop inlet protection is suitable for small to medium catchments.
- The depth of ponding upstream of the field inlet is governed by the height of the aggregate filter placed around the wire mesh.
- In clayey soils, filter cloth may be placed over the aggregate to improve the removal of fine sediments (as per *Rock Filter Dams*).

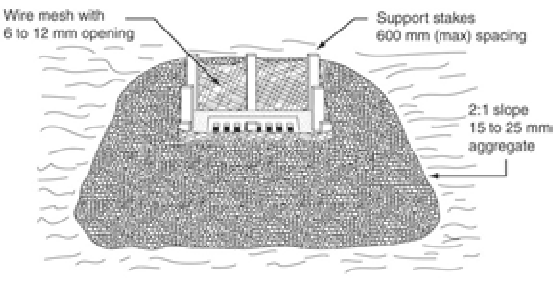


Diagram supplied by Catchments & Creeks Pty Ltd

Mesh & aggregate drop inlet protection

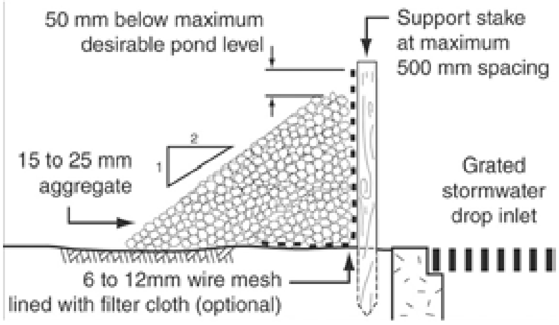


Diagram supplied by Catchments & Creeks Pty Ltd

Construction detail

Rock & aggregate drop inlet protection

Rock & aggregate inlet protection (RA)

- Rock & aggregate drop inlet protection is best used in sandy soil areas.
- Most commonly used in highway construction such as a duel-carriage road with the drop inlet located within the median strip.
- The critical design parameter is the surface area of the settling pond that forms around the protected drop inlet.
- *Flow Diversion Banks* (below) may need to be incorporated into any of the above drop inlet protection systems to control the depth and extent of ponding.
- Pooled water should not be allowed to spill onto trafficable lanes.

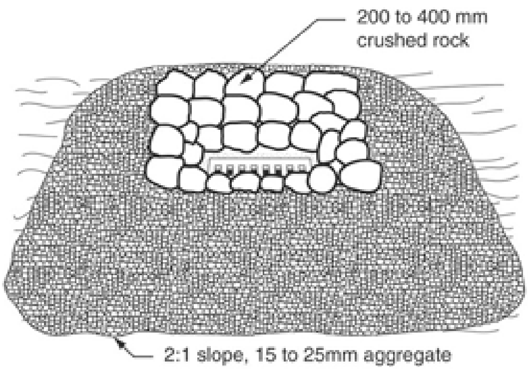
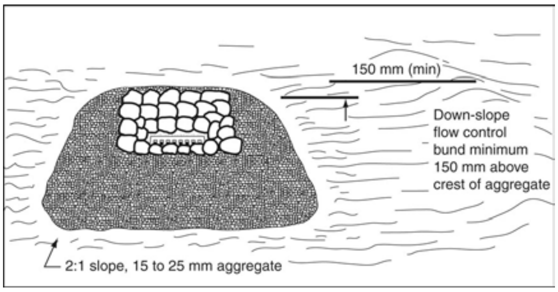


Diagram supplied by Catchments & Creeks Pty Ltd

Rock & aggregate drop inlet protection



Flow diversion bank adjacent drop inlet

Sediment control techniques suitable for 'minor' concentrated flow

Table 20 provides guidance on the selection of a sediment control technique suitable for placement within a table drain, minor channel or overland flow path.

Table 20 – Selection of sediment control technique for minor concentrated flows [1]

	Sandbag - Check dam sediment trap	**Rock - Check dam sediment trap**	**Coarse sediment trap**	**Excavated sediment trap**	**Filter tube dam**	**Modular sediment barrier**	**Stiff grass barrier**	**Straw bale barrier**	**U-shaped sediment trap**
Standard drawing code	SBC	RC	CST	EST	FTD	MSB	SGB	SBB	UST
Typical treatment standard [2]	L	L	M	L	H	M-H	L	L	M
TABLE DRAINS AND MINOR DRAINAGE CHANNELS – Less than 5% grade:									
Channel depth < 500 mm	4			4					
Channel depth > 500 mm		4		4					
TABLE DRAINS AND MINOR DRAINAGE CHANNELS – More than 5% grade:									
Channel depth < 500 mm	4			4					4
Channel depth > 500 mm		4	4		4	4			4
Rural (long-term usage)							4		
STORMWATER OUTLET SEDIMENT TRAPS:									
Outlet fall < 300 mm				4					
Outlet fall > 300 mm			4		4	4			
Difficult access					4	4		4	
OUTLET STRUCTURES FOR SEDIMENT FENCES:									
Situations where the sediment fence is expected to concentrated outflows			4		4				

[1] Final selection should be based on actual site conditions.

[2] H = high treatment standard (e.g Type 2), M = medium treatment standard (e.g Type 3), L = low treatment standard (e.g. supplementary sediment trap).

Sediment control techniques suitable for 'minor' concentrated flow

Check dam sediment trap

Check dam sediment traps (CDT)

- A supplementary sediment trap.
- Check dam sediment traps can be used to supplement the site's primary sediment control system.
- Typically used in table drains during the revegetation phase.
- Check dams may be constructed from rock, sand bags, or geo-logs.
- Check dams can operate as both drainage control and sediment control devices.

Coarse sediment trap

Coarse sediment traps (CST)

- A Type 3 sediment trap.
- Coarse sediment traps are best used on sandy soils.
- Commonly used as a sediment trap at the low point of a *Sediment Fence* placed on a medium-sized catchment, and on certain stormwater outlets (see latter discussion).
- Can be used as an alternative to a spill-through weir on a *Sediment Fence* placed on a medium-sized catchment.

Filter tube dam sediment trap

Filter tube dams (FTD)

- Filter tube dams are typically used to trap sediment in minor drainage lines.
- Normally placed down-slope of a Type 3 sediment trap, which is used to reduce the deposition of coarse sediment at the filter tube inlet.
- *Filter Tubes* can be integrated into a variety of Type 2 and 3 sediment traps (including *Rock Check Dams, U-Shaped Sediment Traps, Rock Filter Dams*, and *Sediment Weirs*) to improve their efficiency during minor flows.

Modular sediment trap

Modular sediment traps (MST)

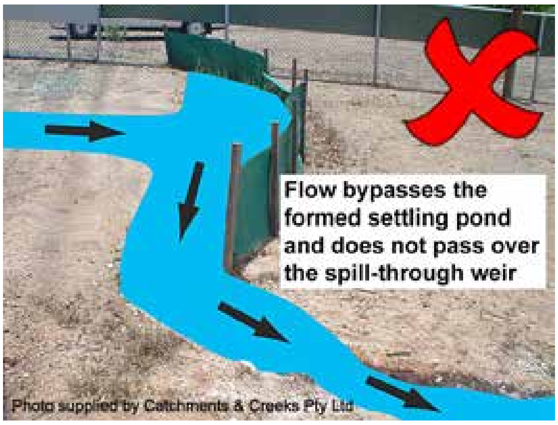
- A Type 3 sediment trap.
- Modular systems are the modern replacement for *Straw Bale Barriers*.
- The filtration system is only capable of treating minor flows, but the units can be structurally sound in higher flows if adequately anchored in place.
- *Filter Tubes* can be incorporated into the plastic blocks to increase the allowable treatment flow rate.

U-Shaped sediment traps (UST) – suitable for minor concentrated flow

U-shaped sediment trap

U-shaped sediment trap in steep drain

Inappropriate installation



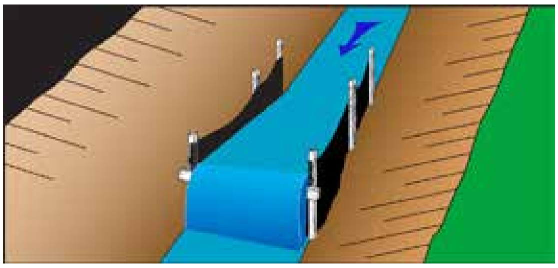
Inappropriate installation

U-shaped sediment traps

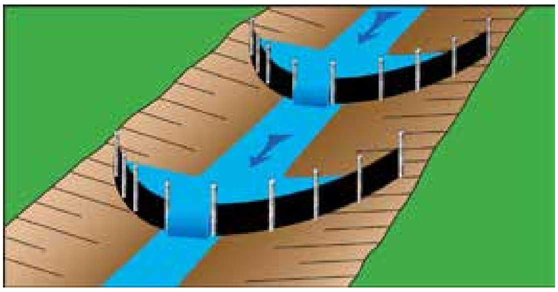
- A Type 3 sediment trap.
- U-shaped sediment traps are commonly used as coarse sediment traps within table drains on medium to steep gradients.
- The sediment fence **must** be constructed in a U-shape, **not** formed in a shallow arc, or placed straight across the drain.
- A spill-through weir is usually required to prevent flow bypassing in drains placed on a medium gradient.
- The width of the sediment trap is usually determined by the width of the excavator bucket used for sediment removal.
- Filter tubes can be integrated into the trap (forming a *Filter Tube Dam)* to increase the trap's hydraulic capacity and to improve the treatment of low-flows.
- On low-gradient drains, preference should be given to the use of *Check Dam Sediment Traps*.
- **Note:** spill-through weirs are only effective if the weir crest is at least 300 mm high, and the weir crest is below the height of the ground at the trap's inlet.

Installation of U-shaped sediment traps

- A sediment fence must **<u>not</u>** be placed straight across the drain.
- The correct flow condition is shown below.

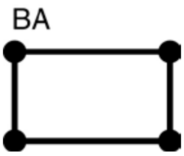
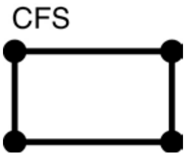
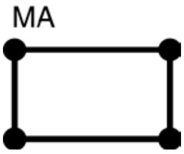
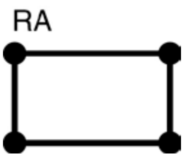
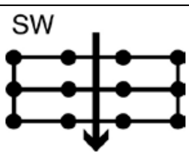


- A U-shape sediment trap must not be formed in a 'shallow' arc across the drain as shown (left), but if the drain is wide, a semi-circular shape trap with spill-through weir can be used.

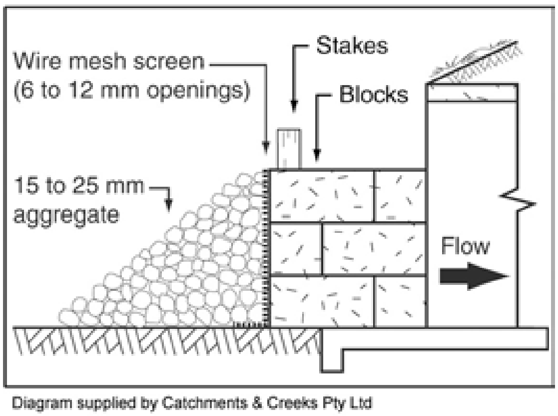


Sediment control suitable for pipe and culvert inlets

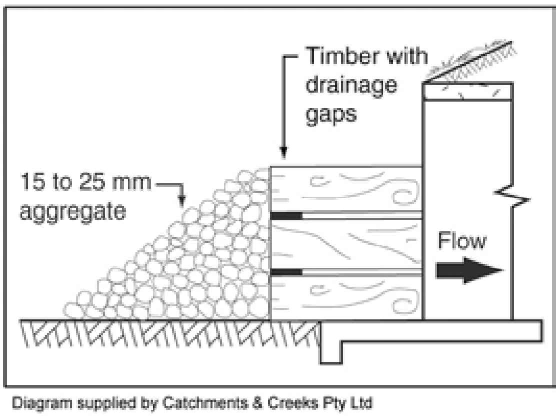
Table 21 – Temporary (construction phase) sediment controls placed at the entrance to culverts and open stormwater pipes

Technique	Code	Symbol	Typical use
Block & Aggregate sediment trap	BA		· Type 2 or 3 sediment trap. · Small to medium catchment areas. · It is usually necessary for the *Block & Aggregate* barrier to be constructed in a manner that does **not** block, or partially block, the pipe or culvert entrance. · Filter cloth may be placed between the aggregate and the support blocks to improve the removal of fine sediments. · Heavy, solid timber planks can be used as an alternative to concrete blocks.
Compost-Filled Filter Sock	CFS		· For small inlets, the compost is usually contained within a larger-diameter filter sock. · Techniques can include *Filter Socks* and *Compost Berms.* · Large compost or mulch berms usually require too much space to be located around most field inlets.
Filter Tube Dam	FTD		· Type 2 or 3 sediment trap. · Small to medium catchments. · Filter tube usually can extend into the pipe or culvert.
Mesh & Aggregate sediment trap	MA		· Type 2 or 3 sediment trap. · Small to medium catchments. · Depth of ponding upstream of the inlet is governed by the height of the aggregate filter placed in front of the wire mesh.
Rock & Aggregate Drop Inlet Protection	RA		· Type 2 or 3 sediment trap. · Best used in coarse-grained (i.e. low clay) soil areas. · Locations where space is not critical as these structures have a large footprint.
Sediment Fence (woven or non-woven)	SF		· Type 3 sediment trap. · **Not** recommended unless there is a very high expectation that flows will be very low. · **Not** suitable for culvert inlets.
Sediment Weir	SW		· Type 2 or 3 sediment trap. · Generally stronger than a *Mesh & Aggregate* sediment trap. · Best used when high flow rates are expected. · Best results are achieved when filter tubes are incorporated into the weir.

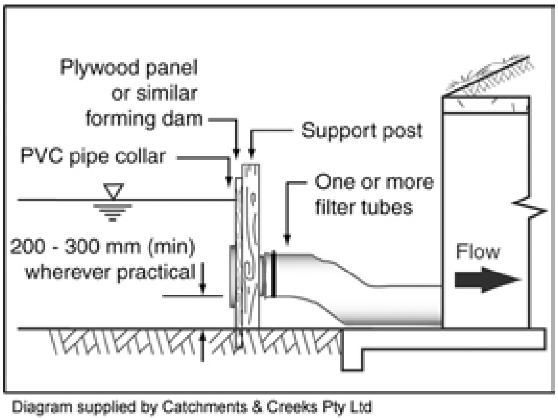
Sediment control suitable for pipe and culvert inlets



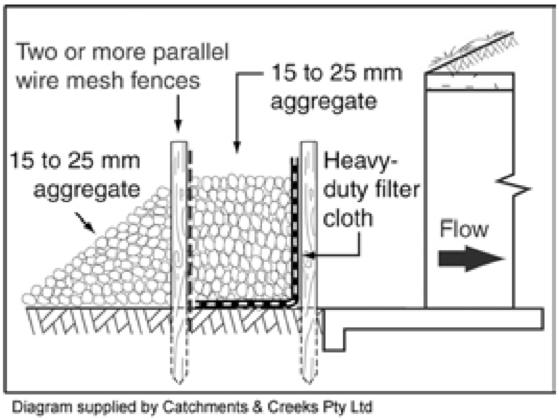
Block and aggregate sediment trap



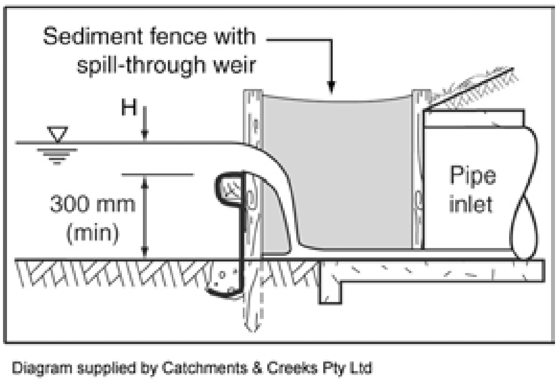
Plank and aggregate sediment trap



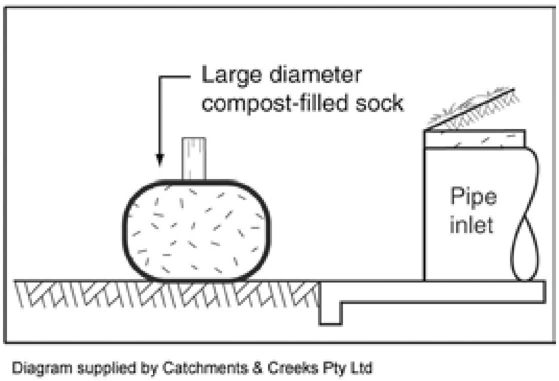
Filter tube dam



Sediment weir



Sediment fence (minor flow only)



Compost-filled filter sock

Inappropriate sediment control

Inappropriate sediment control

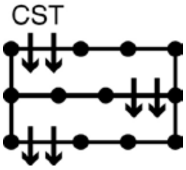
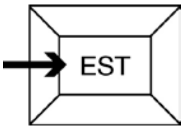
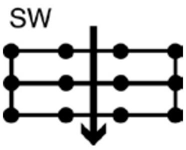
Sediment control suitable for stormwater outlets

Table 22 outlines the attributes of various **temporary** sediment control techniques that may be suitable for placement at stormwater pipe outlets. Extreme care must be taken when selecting the preferred technique because not all of the techniques are suitable in all circumstances.

When locating a sediment trap at the outlet of a stormwater pipe, the sediment trap should ideally be located downstream of the influence of outlet 'jetting' (i.e. 10–13 x pipe diameters downstream of the outlet). As a minimum, the sediment trap should be located at least 5 pipe diameters downstream of the outlet.

All sediment traps must be located totally within the relevant property boundaries unless otherwise approved in writing by the appropriate regulatory authority and landowner.

Table 22 – Sediment control techniques at the outlet of stormwater pipes

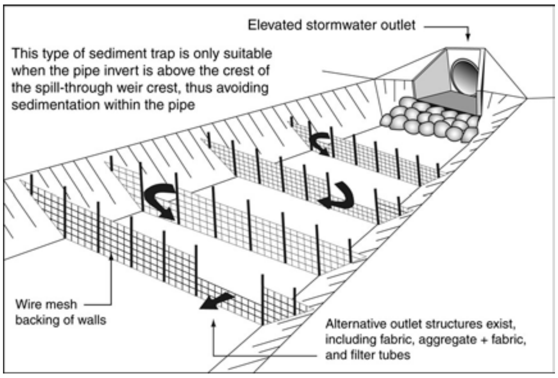
Technique	Code	Symbol	Typical use
Coarse Sediment Trap	CST		· Type 3 sediment trap. · Best used on sandy soils. · Only suitable if the outlet is elevated at least 300 mm above the outlet channel.
Excavated Sediment Trap	EST		· Supplementary sediment trap. · Best used when it is necessary to avoid backwater ponding and thus sedimentation within the stormwater pipe. · Safety issues may require the excavated pit to be surrounded by appropriate safety fencing.
Filter Tube Dam	FTD		· Type 2 or 3 sediment trap. · Only suitable if the outlet is elevated at least 300 to 500 mm above the outlet channel. · It may not be practical to incorporate enough *Filter Tubes* to cater for the expected design flow rate. In such cases the sediment trap may only be considered a Type 3 system. · A supplementary (coarse) sediment trap may be required upstream of the filter tubes to prevent sediment blockage of the filter tubes.
Modular Sediment Trap	MST		· Type 3 sediment trap. · Modern replacement for *Straw Bale Barriers*. · Capability of accepting concentrated flows depends on construction technique.
Sediment Weir	SW		· Type 2 sediment trap. · Best used when high flow rates are expected. · *Filter Tubes* can be incorporated into the *Sediment Weir* to improve the treatment of low-flows. · Gabion walls can be used as an alternative to a *Sediment Weir*.
Straw Bale Barrier	SBB		· Type 3 sediment trap. · Only suitable when poor site access prevents the use of other, more suitable, sediment traps.

Sediment control suitable for stormwater outlets

Coarse sediment trap

Coarse sediment trap (CST)

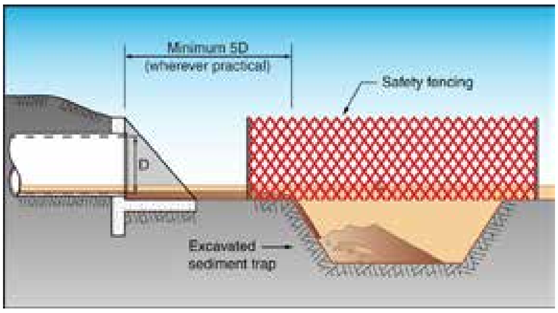
- Suitable for outlets with a low-fall outlet.



Excavated sediment trap

Excavated sediment trap (ECT)

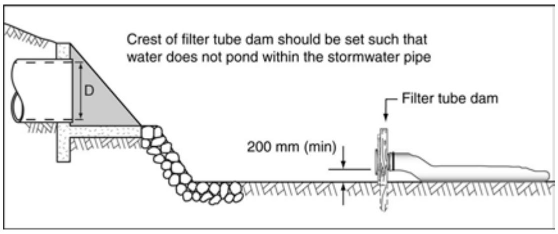
- Suitable for stormwater outlets with little or no fall at the outlet.



Straw bale barrier

Straw bale barrier (SBB)

- Warning: straw bale barriers can be easily damaged by high-velocity outflows.
- Alternatives include filter tube dams (below).



Inappropriate choice of sediment trap

Outlets with minimal outlet fall

- If the stormwater pipe discharges into an outlet channel with little or no fall, then any sediment trap with a crest level above the pipe invert (left) will pool water, and therefore settle sediment, within the pipe.
- Such sediment traps can be very difficult to clean-out without releasing significant quantities of sediment downstream.
- An *Excavated Sediment Trap* (above) is generally more suitable for such low-fall outlets.

Rock filter dams (RFD) – Type 2 sediment trap for concentrated flows

Rock filter dam - aggregate filer

Use of rock filter dams

- A Type 2 sediment trap.
- Rock filter dams can be used as sediment traps connected to the outlets of mulch berms and topsoil windrows.
- Rock filter dams wrapped in filter cloth can also be used as 'instream' sediment traps when working in ephemeral channels.

Rock filter dam with geotextile filter

Rock filter dam - geotextile filter (RFD)

- Rock filter dams are used in locations where it is impractical to construct a formal *Sediment Basin*.
- The critical design parameter is the surface area of the settling pond, which needs to be maximised.
- The incorporation of filter cloth is the preferred construction technique if the removal of fine-grained sediment is critical.

Rock filter dam with aggregate filer

Rock filter dam - aggregate filer (RFD)

- Aggregate-based filtration systems are best used in sandy soil areas.
- Note: aggregate filters generally rely on the effects of partial sediment blockage to achieve their optimum filtration performance.
- Aggregate filters are normally used on long-term sediment trap, and sediment traps that are likely to be regularly de-silted.

Excavated sediment trap and RFD

Sediment collection pits

- **Caution;** placing an excavated pit immediately up-slope of an 'aggregate filter' may reduce the filtration performance of the rock filter dam.
- It is noted that aggregate filters rely upon the partial blockage of the aggregate with coarse and fine sediments in order to commence the 'filtration' process.

Sediment weirs (SW) – Type 2 sediment trap for concentrated flows

Sediment weir (field inlet protection)

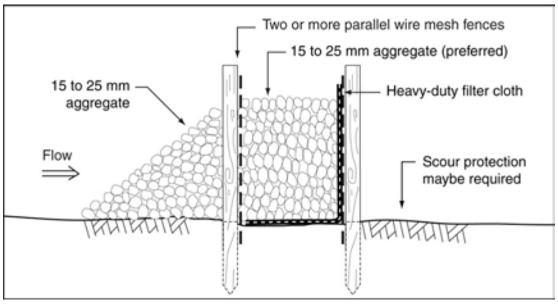
Use of sediment weirs

- A Type 2 sediment trap
- Sediment weirs are used where space is limited (i.e. when space is not available for the construction of a *Rock Filter Dam*).
- Sediment weirs can be very effective in conditions of high flow rates where the sediment trap may be subjected to regular over-topping flows.
- They can also be used as a primary outlet structure on a Type 2 sediment basin (as is the case shown left).

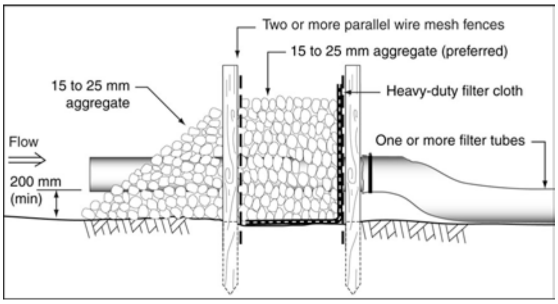
Sediment weir

Use as an instream sediment trap

- Sediment weirs can be used as temporary instream sediment traps for construction works within drainage channels and minor waterways that are likely to experience only minor dry weather flows.
- *Filter Tubes* can be incorporated into the sediment weir to increase the treatable flow rate.
- The critical design parameter is the 'surface area' of the upstream settling pond, which needs to be maximised.



Sediment weir with aggregate filter



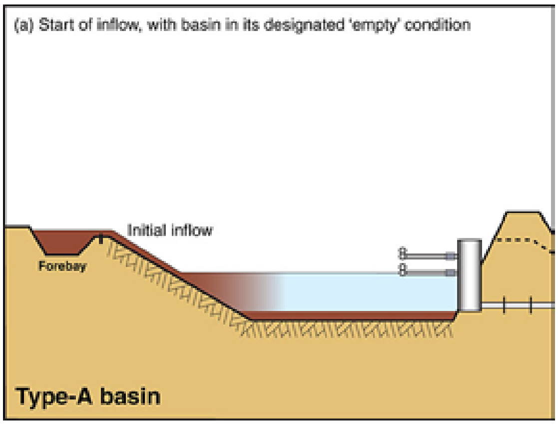
Sediment weir with filter tube incorporated into the weir

Construction of a sediment weir

Construction difficulties

- Sediment weirs can also be used when crossings of rural drainage lines; however, the time and labour costs of their installation makes them of questionable for short-term construction disturbances.

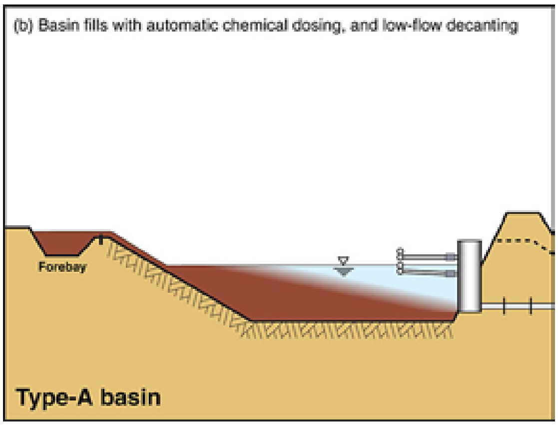
Sediment basins (SB) – Type A basins



Initial filling of a Type A sediment basin

Use of Type A sediment basins

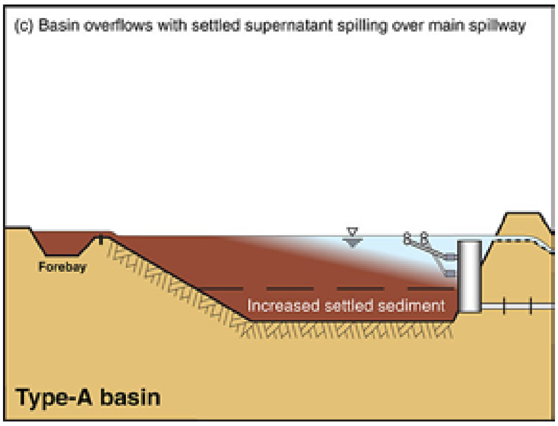
- A Type 1 sediment trap.
- Used on drainage catchments greater than 2500 m^2.
- It is recommended that individual basins are limited to catchment areas less than 5 hectares.
- Used when the duration of the soil disturbance, within a given drainage catchment, exceeds 12 months.



Low-flow decanting of a Type A basin

Features of a Type A sediment basin

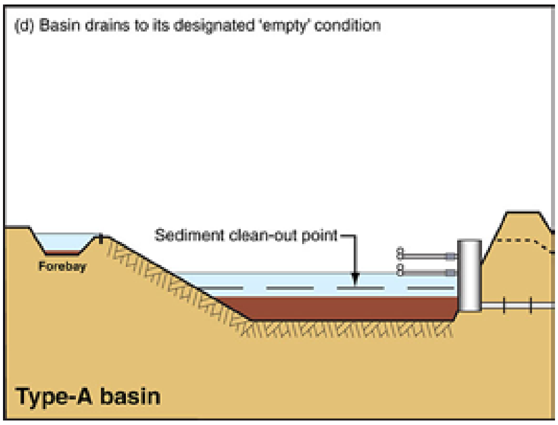
- Minimum length to width ratio of 3:1.
- Settling pond depth can vary from 0.6 to 3.0 metres.
- The size of the settling pond depends on the design of the floating low-flow decant system, which can have a design flow rate of 0.3 to 0.9 L/s/ha.
- Total settling pond volume = settling volume + the lower storage volume.
- Lower storage volume = dead water volume + sediment storage volume.



High-flow decanting of a Type A basin

Critical design issues of Type A basins

- Typically sized for a 1 in 1 year (63% AEP) storm for civil construction sites.
- The design storm may increase for permanent basins on quarry sites.
- Automatic chemical dosing is essential.
- Critical sediment particle size = 0.01 mm.
- Minimum settling pond depth = 0.6 m.
- Lower storage = 40% of settling volume.
- Sediment storage (which is part of the lower storage volume) = 30% settling volume.

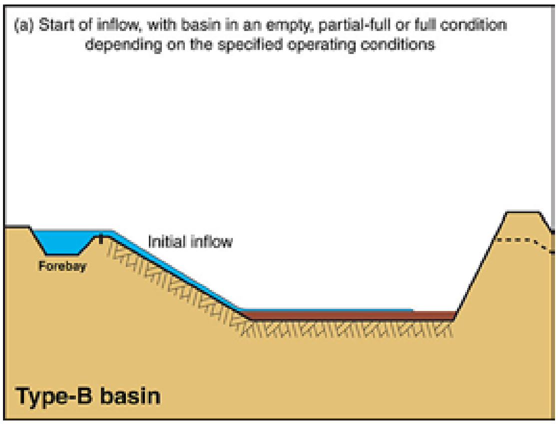


End of storm draining of Type A basin

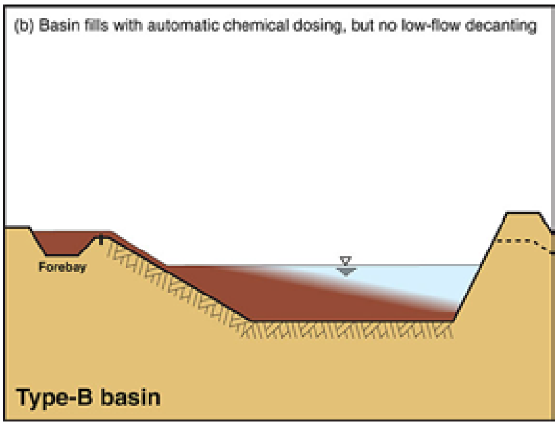
Critical construction issues for Type A basins

- Chemical dosing must be injected at a location that allows sufficient time for mixing to occur.
- Flow turbulence is desirable after chemical dosing (to cause mixing) but the forebay <u>must</u> remove all turbulence prior to the flow entering the settling pond.
- Construction of the forebay is critical to ensure uniform, low-turbulence flow entry into the settling pond.

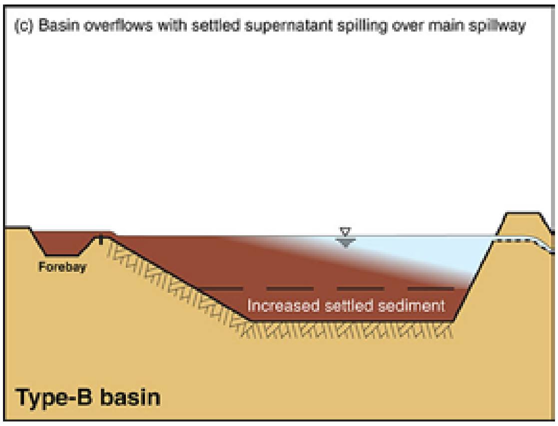
Sediment basins (SB) – Type B basins



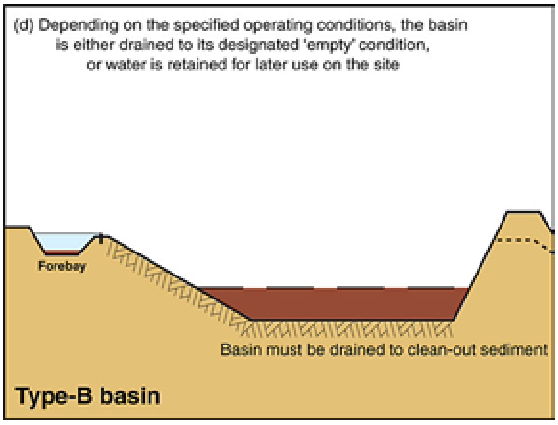
Initial filling of a Type B sediment basin



Filling of Type B basin



Overflow of a Type B basin



Type B basin fully de-watered

Use of Type B sediment basins

- A Type 1 sediment trap.
- Used on drainage catchments greater than 2500 m^2.
- Maximum recommended catchment area is 5 hectares.
- Used when the duration of the soil disturbance within a given drainage catchment does not exceed 12 months.
- Water can be retained in these basins for use on-site for revegetation watering and dust control.

Features of a Type B sediment basin

- The same basic geometry as a Type A basin, but without low-flow decant system.
- Minimum length to width ratio of 3:1.
- The size of the settling pond depends on the actual (measured in a laboratory) settlement characteristics of a chemically-dosed sediment.
- Type B basins do not feature a floating, low-flow decant system, which increases their size (compared to Type A basins) but reduces their technical complexity.

Critical design issues of Type B basins

- Typically sized for 50% of the 1 in 1 year storm discharge (0.5 Q1).
- The design storm may increase for permanent basins on quarry sites.
- Automatic chemical dosing is essential.
- Minimum settling pond depth = 0.5 m, but conditions can exist where this minimum depth must increase.
- Sediment storage volume = 30% of the calculated settling volume.

Critical construction issues for Type B basins

- Chemical dosing must be injected at a location that allows sufficient time for mixing to occur.
- Flow turbulence is desirable after chemical dosing (to cause mixing) but the forebay must remove all turbulence prior to the flow entering the settling pond.
- Construction of the forebay is critical to ensure uniform, low-turbulence flow entry into the settling pond.

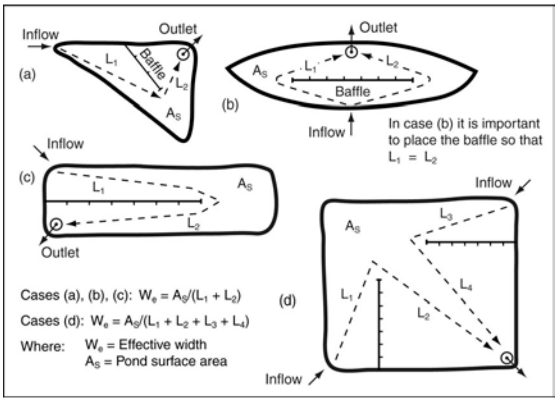
Sediment basins (SB) – Type C basins

Type C sediment basin

Use of Type C sediment basins

- A Type 1 sediment trap
- Type C basins are used to treat the runoff from coarse-grained soils.
- Sometimes referred to as 'dry' basins, which refers to the fact that the basins are free draining, which does not allow time for chemical flocculation.
- Internal baffles (below) help to control water flow and improve settlement characteristics.

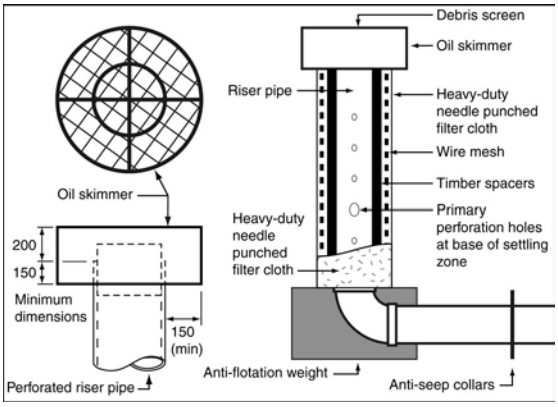
Internal baffle system



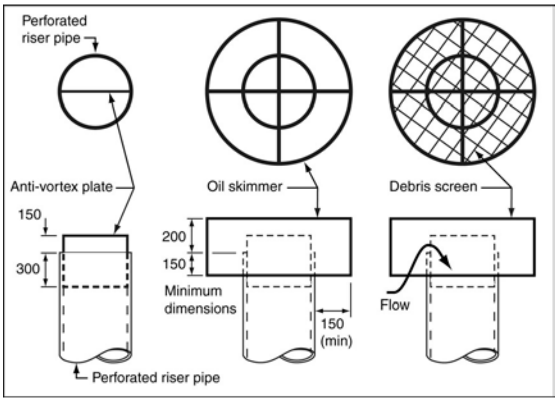
Typical layout of internal baffles

Riser pipe outlet

- Debris screens and anti-vortex plates need to be incorporated into the outlet.



'Skimmer' type outlet system



Anti-vortex and debris screen details

Sediment basins (SB) – Type D basins

Type D sediment basin

Use of Type D sediment basins

- Type D basins are best suited to fine-grained and/or dispersive soils—use of Type A basins is preferred wherever practical.
- Sometimes referred to as ‘wet’ basins, which refers to the fact that the basins retain inflows without free-draining, which allows more time for particle settlement.
- These basins can be up to twice the size of Type C basins, but are significantly more effective at controlling turbidity.

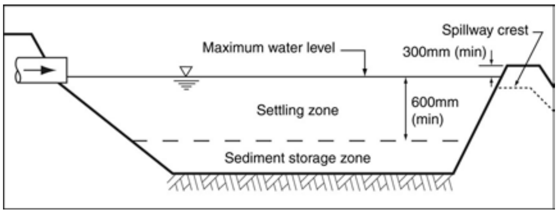
Fully recessed sediment basin

Operation of Type D basins

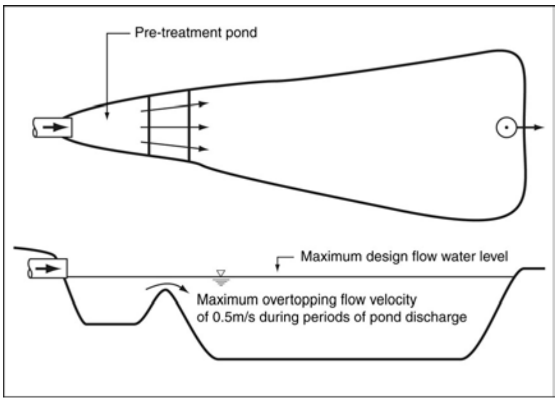
- Water must be retained within the basin and treated (coagulated/flocculated) until the required water quality is achieved, typically 50 mg/L TSS.
- Ideally, the critical water quality standard should be based on a locally-calibrated NTU standard, which is easier to measure on-site then TSS.
- The basin **must** be de-watered as soon as practical such that the basin is (ideally) empty prior to the next storm.

De-watering of sediment basin

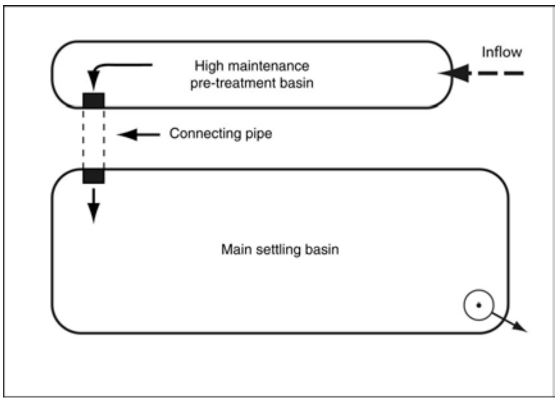
- Basin de-watering is normally achieved through the use of pumps.
- It is important to ensure that the pump’s intake pipe does not rest on, or come into close contact with the settled sediment.



Wet basin



Basin with coarse sediment pond

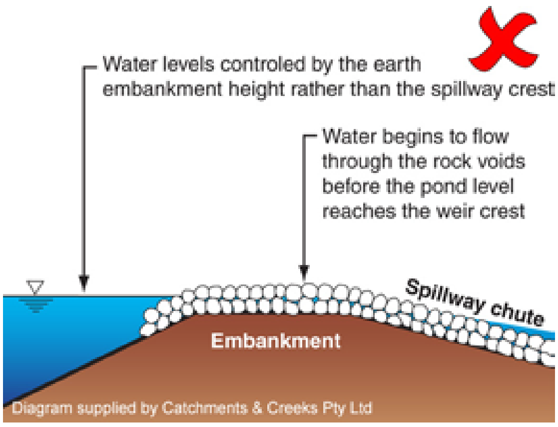


Basin with pre-treatment pond

Sediment basin spillways

Spillway with well-defined weir profile

Spillway formed within virgin soil



Flows can pass through the rock voids

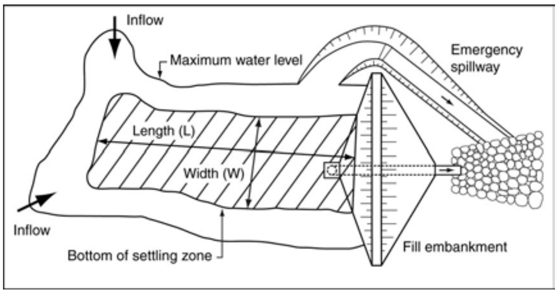
Inappropriate spillway crest profile

Function of a basin spillway

- All sediment basins that are not fully recessed below natural ground level will require the construction of a formally designed spillway.
- The spillway must have a well-defined weir profile (cross-section) that fully contains the nominated peak discharge.
- A suitable energy dissipater will be required at the base of the spillway.
- Spillways are critical engineering structures that need to be designed by suitably qualified engineers.

Preferred location of spillways

- Ideally, the emergency spillway should be constructed in virgin soil (i.e. adjacent to the fill embankment).



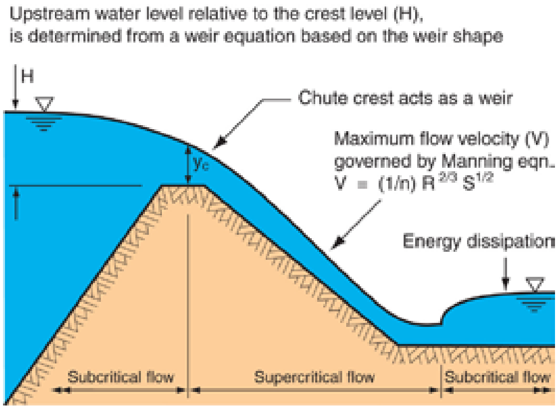
Controlling leakage at spillway crest

- For rock and rock mattress lined spillways, it is important to control seepage flows through the rocks located near the crest of the spillway.
- Seepage control is required so that the settling pond can achieve its required maximum water level prior to flows discharging over the spillway.
- Concrete capping of the spillway crest may be required in order to prevent these seepage flows.

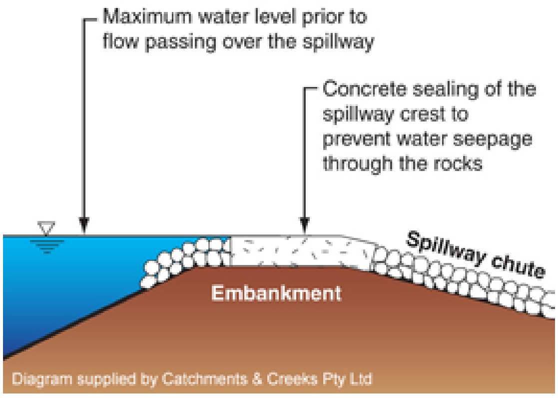
Preferred crest profile

- It is important to ensure that the spillway crest has sufficient depth and width to fully contain the nominated design storm discharge.
- The spillway crest normally requires a greater depth, but equal width, to that of the downstream spillway chute.
- Photo (left) shows a spillway crest that has inadequate depth or flow profile, in fact the rock-lined crest sits 'above' the adjacent earth embankment crest!

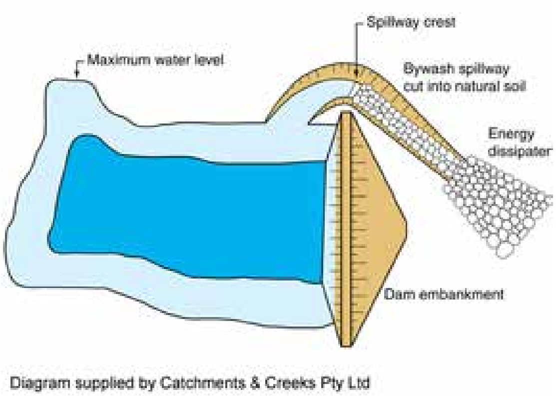
Sediment basin spillways



Dam spillway hydraulics



Sealing of spillway crest



Dam spillway cut into virgin soil

Energy dissipation pond

Hydraulic design

- Basin spillways are hydraulic structures that need to be designed for a specified design storm.
- The hydraulic design can be broken down into three components:
  - design of the spillway inlet using an appropriate weir equation
  - sizing rock for the face of the chute based on Manning's equation velocity
  - sizing rock for the energy dissipater.

Design of spillway crest

- Flow conditions at the spillway crest may be determined using an appropriate weir equation.
- It is important to ensure that the required maximum potential water level within the basin can be fully contained by the basin's embankments.
- The sealing of the spillway crest is often necessary to maximise basin storage and prevent leakage through the rock voids.

Design of spillway chute

- Determination of rock size on the spillway is based on either the maximum unit flow rate (q, $m^3/s/m$) or the maximum flow velocity (V, m/s) down the spillway.
- The upstream portion of the spillway's inflow channel can be curved (i.e. that section upstream of the spillway crest).
- Once the spillway begins to descend down the embankment (i.e. where the flow is supercritical) the spillway chute **must** be straight.

Design of energy dissipater

- A suitable energy dissipater or outlet structure is required at the base of the spillway.
- The design of the energy dissipater **must** be assessed on a case-by-case basis.
- Energy dissipation ponds often need to be recessed below the downstream discharge channel in order to achieve ideal energy dissipation—this may mean that water is retained within these ponds for some time after an overtopping event.

Common spillway design and construction problems

Poorly defined spillway crest

Inadequate spillway crest profile

- A poorly defined spillway crest profile (e.g. insufficient cross-sectional width or depth) can result in flows bypassing the spillway.
- In such cases (left) damage to the earth embankment is likely to occur.

Insufficient scour protection at outlet

Insufficient scour control at base of spillway

- Rock protection should extend beyond the embankment toe to form a suitable energy dissipater (outlet structure).

Rocks sit above the embankment height

Spillway crest not recessed below the embankment crest

- It is essential to ensure that the crest of the rock-lined spillway is set well below the crest of the adjacent earth embankment.
- In such cases (left) damage to the earth embankment is likely to occur.

Inadequate rock size

Inadequate rock size

- Selection of appropriate rock (size, density and shape) is critical.
- If sufficient quantities of the specified rock size cannot be obtained, then an alternative spillway design will be required.

De-Watering Sediment Control Measures

The following table presents the recommended standard identification codes and drawing symbols for various de-watering sediment control techniques.

Table 23 – De-watering sediment control techniques

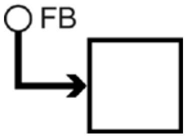
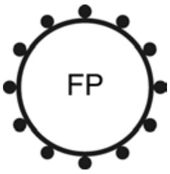
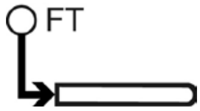
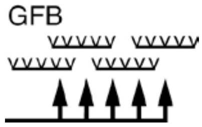
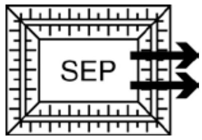
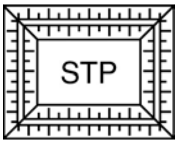
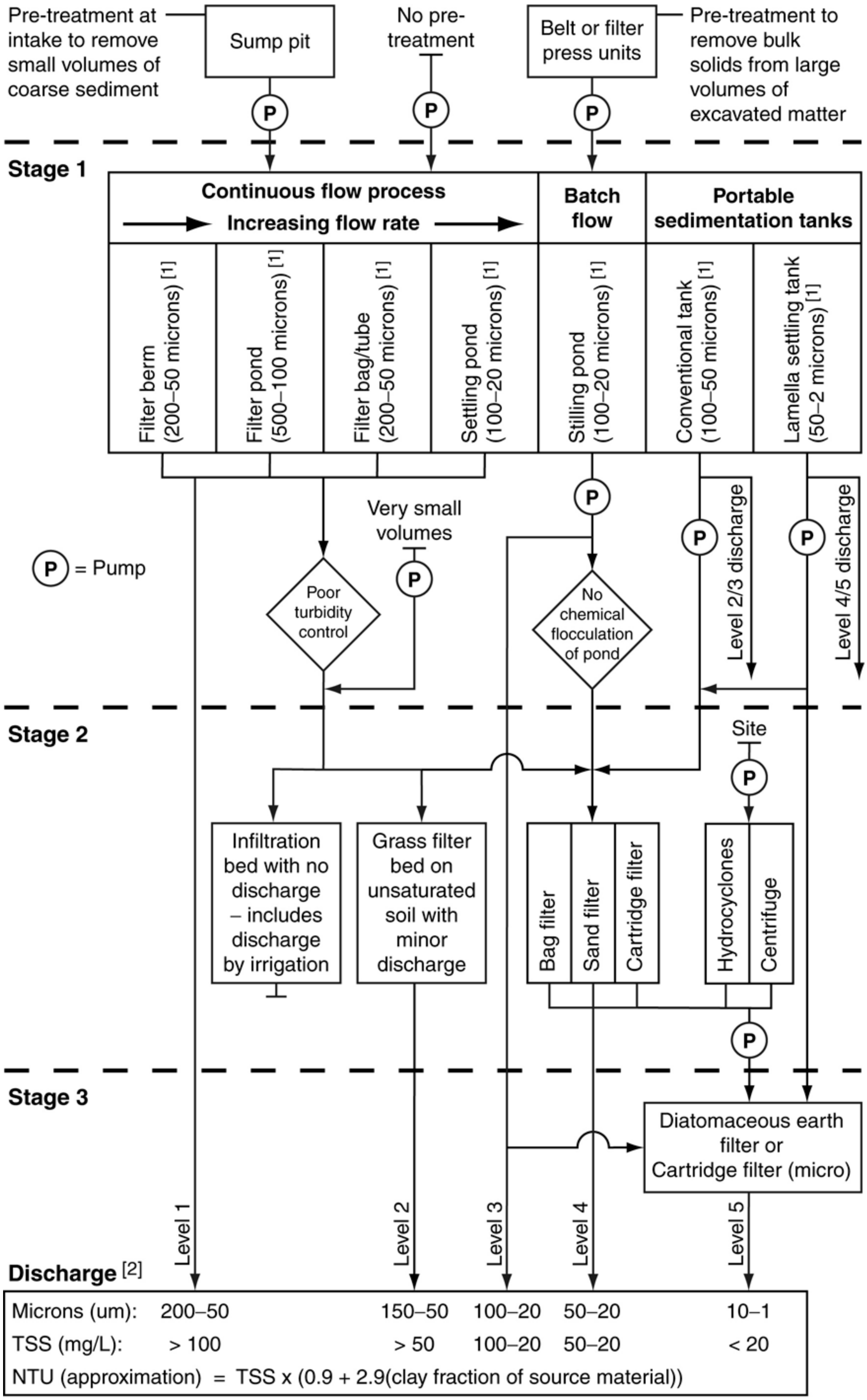
Technique	Code	Symbol	Technique	Code	Symbol
Filter Bag	FB		Filter Fence	FF	
Filter Pond	FP		Filter Tube	FT	
Filter Tube Dam	FTD		Grass Filter Bed	GFB	
Portable Sediment Tank	PST		Settling pond	SEP	
Stilling Pond	STP		Sump Pit	SP	

Table 24 outlines best practice sediment control measures for the de-watering stockpiles of excavated materials.

Table 24 – Sediment control practices for de-watering stockpiles

Material	Sediment control	Comments
Non-clayey material	Grass Filter Beds or equivalent	· Ensure grassed area remains unsaturated during de-watering operation.
Clayey material	Filter Fence (non-woven filter cloth)	· Filter cloth must be supported by wire mesh, or aggregate berm. · Woven *Sediment Fence* fabric should **<u>not</u>** be used.
	Compost Berm or Mulch Berm or Filter Sock	· Ensure the berm/sock is placed along the contour to ensure flow is distributed evenly along the length of the berm/sock. · Ensure water does not bypass around the end of the berm or sock.
Contaminated material	Not applicable	· Seek expert advice on case-by-case basis.

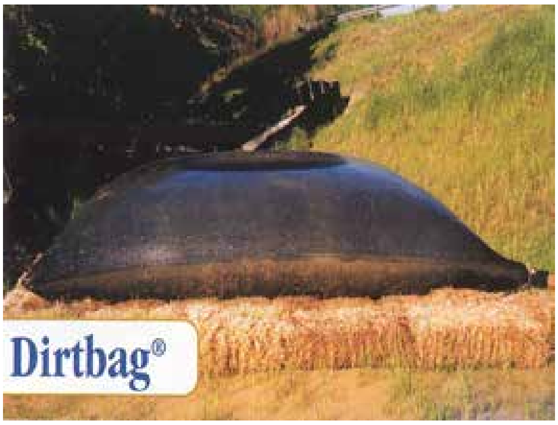
Overview of de-watering treatment train options



[1] Approximate critical sediment particle size – results variable depending on design details.

[2] Approximate values only – results vary depending on equipment, operating conditions and soil type.

De-watering sediment controls



Filter bag

Filter bags (FB)

- Commercial filter bags are suitable for the treatment of low flow rates.
- The bags collect only coarse-grained sediments (they provide minimal control of turbidity levels).
- It is important to ensure that there are suitable means of collecting and removing the bags once they are full of sediment.
- Placing the filter bags within a mini skip (drainage plug removed) can reduce the complications of removing the used bags.

Filter fence

Filter fence (FF)

- Suitable for the coarse and fine-grained soils, but **not** for turbidity control.
- Non-woven fabrics must be used.

Compost berms (CFB)

- Can provide good filtration and limited turbidity control.
- Compost-filled socks (*Filter Socks*) can also be used.
- Performance of both systems can be improved if incorporated with a substantial grass filter bed (e.g. a wide floodplain).

Filter pond

Filter ponds (FP)

- Used on flat or near-flat ground.
- Most effective for the treatment of water containing coarse-grained sediment.
- Limited control over turbidity unless the pond is placed on highly porous soil.
- Diameter of the pond and the composition of the filter wall depends on the soil type and design flow rate.
- Performance can be improved if located adjacent a substantial grass filter bed (e.g. a wide floodplain).

Filter tube

Filter tubes (FT)

- Commercial filter tubes are suitable for the treatment of low to medium flow rates.
- Filter tubes collect only coarse-grained sediments, with minimal control of turbidity.
- It is important to ensure that there are suitable means of collecting and removing the filter tubes once full of sediment.
- Placing the filter tube up-slope of a substantial grass filter bed can improve the collection of fine sediments and turbidity control.

De-watering sediment controls

Lamella settling tank

Portable settling tanks (PST)

- Wide variety of different systems can be employed.
- *Lamella* settling tanks utilise laminar flow conditions to optimise the settlement of non-dispersive soils, but allowable flow rates are low.
- Some systems have good control over turbidity, while other systems have little or no control over turbidity.
- High initial purchase cost, but operation costs can be low.

Settling pond

Settling ponds (SEP)

- Settling ponds contain a free draining outlet system, usually consisting of a *Rock Filter Dam,* or a series of *Filter Tubes*.
- Only suitable for waters containing fast settling (coarse) sediments.

Stilling ponds (STP)

- Stilling ponds do not incorporate a free draining outlet system.
- These ponds are operated similar to 'wet' sediment basins.
- Turbidity control can be achieved.

Sump pit acting as a pipe intake filter

Sump pits (SP)

- Sump pits can be used as a pre-treatment system in association with an outlet-type treatment system (i.e. any of the above treatment systems).
- Filtration occurs at the pump inlet rather than at the outlet of the pipe.
- Commonly used as a pre-treatment system when de-watering instream works.

Truck-mounted belt press

Mobile treatment units

- Wide variety of commercial water treatment units.
- Treatment systems include vacuum drum filters, filter-presses, belt-presses (left), truck-mounted centrifuges, and banks of hydro-cyclones.
- Small mobile units can be assembled from a variety of swimming pool filters mounted on a trailer.
- Sediment-laden water can also be collected and transported to another location for specialist treatment.

Glossary of terms

AHD	Australian Height Datum. A common datum used in land survey.
Base flow	Underlying stream flow rate that cannot be directly attributed to storm events, and is present during part or all of dry periods.
Clay	Soil particles less than 0.002 mm in equivalent diameter. When used as a soil texture group such soil contains at least 35% clay and no more than 40% silt.
Clayey soil	A soil that contains at least 20% clay. These are fine-grained soils that readily form a clod when compressed in the hand, feel very smooth and sticky when wet, and are very difficult to shovel or break-up when compacted.
Clay loam	A soil texture group representing a well-graded soil composed of approximately equal parts by weight of clay, silt and sand [when dispersed].
Clean water	Water that either enters the property from an external source and has not been further contaminated by sediment within the property; or water that has originated from the site and is of such quality that it either does not need to be treated in order to achieve the required water quality standard, or would not be further improved if it was to pass through the type of sediment trap specified for the sub-catchment.
Construction phase	That period of civil works extending from initial site access (excluding preliminary site survey and data collection) to the commencement of the contracted/specified maintenance period. On staged works, the construction phase extends to the commencement of the maintenance period of the final stage of completed works. A regulatory authority may specify on a site-by-site basis that the construction phase includes the maintenance period.
Construction site	A site where major earthworks, civil construction (e.g. construction of public works and infrastructure) and/or non-domestic building works are conducted.
Contaminant	Toxic substances within the environment that represent a health hazard to biota.
Cross bank	A raised embankment, in a form similar to a traffic ‘speed bump’, with low vertical curvature placed diagonally across an unsealed road or track to collect and divert stormwater runoff off the track to a table drain or suitable discharge point.
Cross drain	A drain of various forms that collect the flow of water down a track and divert it across the track surface. The capacity of the drain is defined by its cross section. Cross drains are designed to handle smaller flows than cross banks, but larger flows than can be controlled by crossfall drainage.
Dirty water	Water not classified as clean water.
Dispersible soil	A structurally unstable soil that readily disperses into its constituent particles (clay, silt and sand) when placed in water. Moderately to highly dispersible soils are normally highly erodible and are likely to be susceptible to tunnel erosion. Most sodic soils are dispersible, but not all dispersible soils may be classified as sodic. Some dispersible soils are resistant to erosion unless mechanically disturbed.
Dispersive soil	Terminology commonly used in engineering. See ‘dispersible soil’.

Drainage control measure	Any system, procedure or material employed to: · prevent or minimise soil erosion caused by 'concentrated' overland flow (including the management of rill and gully erosion); · divert flow around or through a work site or soil disturbance; or divert 'clean' water away from a sediment trap; · to appropriately manage the movement of 'clean' and 'dirty' water through a work site.
Drop inlet	An inlet to a sub-surface drainage system located within an open area where the water falls vertically into the connecting chamber. Known also as a 'field inlet'.
Dry basin	A sediment basin that is free draining, and thus begins to de-water soon after water enters the basin.
Environmental harm	Any adverse effect, or potential adverse effect (whether temporary or permanent) on an environmental value.
Environmental risk	The potential of an activity to cause harm, whether material, serious, reversible or irreversible, to an environmental value. It includes potential nuisance caused to a property or person.
Erosion and sediment control (ESC)	The application of structural and non structural measures to control stormwater drainage, soil erosion and sediment runoff during the construction and building phases of land development. Some measures often being retained as part of the permanent site rehabilitation and stormwater management practices.
Erosion and Sediment Control Plan (ESCP)	A site plan, or set of plans, including diagrams and explanatory notes, that demonstrate proposed measures to control stormwater drainage, soil erosion, and sediment runoff during the conduction/building, site stabilisation, and maintenance phases of a construction, building or other soil disturbance activity.
Erosion and Sediment Control Program (ESC Program)	Referring to a collection of ESC plans, specifications and supporting documentation relating to a specific site. The term may be interchangeable with ESCP.
Erosion control measure	A system, procedure or material used to prevent or reduce the effects of erosion on soil and other granular material. Within this document, *erosion control measures* primarily refer to those measures that can aid in the control of raindrop impact and sheet erosion.
ESC	Erosion and sediment control.
ESCP	Erosion and Sediment Control Plan.
Field inlet	An inlet to a sub-surface drainage system located within an open area where the water falls vertically into the connecting chamber. Known also as a 'drop inlet'.
Filter cloth	Industrial grade, non-woven synthetic fabric traditionally used to separate soils and rock of different textures or grain size, but also used as a short-term filter for the removal of medium to coarse sediment from a liquid (usually water).
Flocculation	The process by which colloidal or very fine clay particles, that repel one another when suspended in water, come together into larger masses or loose 'flocs' which eventually settle out of suspension.
Ford	A shallow place in a stream where the bed may be crossed by traffic.
Gravel	A mixture of coarse mineral particles larger than 2 mm but less than 75 mm in equivalent diameter.

Instream	Any area between the banks of a constructed drainage channel, watercourse or waterway.
Instream works	Any construction, building or land-disturbing activities conducted between the banks of a constructed drainage channel, watercourse or waterway.
Loam	A medium-textured soil of approximate composition 10 to 25% clay, 25 to 50% silt, and less than 50% sand when dispersed. Such a soil is typically well-graded.
On-grade kerb inlet	Stormwater inlet formed into the kerb of a roadway where the roadway has a positive longitudinal grade (i.e. water approaches the inlet from only one direction).
Problematic soil	Any soil type of condition that potentially could result in significant short-term or ongoing environmental harm if disturbed, even if current best practice construction and ESC procedures are adopted during the disturbance. Such soil conditions are likely to include highly dispersive soils (ESP >15%) and actual or potential acid sulfate soils. It should be noted that 'soils' are not in themselves a 'problem' or 'problematic'. The problem only arises through disturbance or management of the soil.
Proper working order	Means taking all reasonable and practicable measures to sustain all ESC measures in a condition that: · will best achieve the site's required environmental protection, including specified water quality objectives for all discharged water (principal objective); · is in accordance with the specified operational standard for each ESC measure, where such a standard is consistent with the site's required environmental protection including specified water quality objectives for all discharged water, or where such a standard is not specified, is consistent with current best practice for each individual ESC measure; and · prevents or minimises safety risks.
Regulatory authority	Any local or regional external authority—whether government or non-government, including local governments and the state government—that has a legal interest in the regulation or management of either the activity in question, or the land on which the activity is occurring, or is proposed to occur.
Responsible ESC officer	That person, or team of people of which there is a principal officer, employed or contracted by the land owner and/or developer as the principal officer/entity responsible for ensuring appropriate application of the planned ESC measures and for the provision of advice in response to unplanned ESC issues. Terminology will vary from site to site and region to region. May also be referred to as the *ESC Officer*, *Erosion & Sediment Control Officer*, *Sediment Control Officer*, *Environmental Officer*.
Return (sediment fence)	That part of a sediment fence that is turned up a slope to either prevent water flowing along the fence, or flowing around the end of the fence.
Riparian zone	That part of the landscape adjacent to streams that exert a direct influence on streams or lake margins and on the water and aquatic ecosystems contained within them. Riparian zones include both the stream banks and a variable sized belt of land alongside the banks. Riparian zones have been defined in a legal context in some States as a fixed width along designated rivers and streams.

Sag kerb inlet	Stormwater inlet formed into the kerb of a roadway where the roadway has a zero longitudinal grade (i.e. stormwater approaches the inlet from both directions).
Sand	A soil separate consisting of particles between 0.02 and 2.0 mm in equivalent diameter when dispersed. Fine sand is defined as particles between 0.02 and 0.2 mm, and coarse sand as those between 0.2 and 2.0 mm.
Sandy soil	A soil that contains at least 50% sand. These are coarse-grained soils that are easy to shovel and break-up when compacted. It is very difficult to form a clod when sandy soils are compressed in the hand.
Scarifier	A tillage implement used for both primary and secondary tillage at depths up to 150m. Medium duty tines are fitted at an overall tyne spacing ranging from 150 to 250m.
Sediment	Any clay, silt, sand, gravel, soil, mud, cement, fine-ceramic waste, or combination thereof, transported from its area of origin.
Sediment control measure	Any system, procedure or material used to filter, trap or settle sediment from sediment-laden waters.
Sediment control zone	That portion of a work site that drains to a sediment control device, excluding the entry/exit pad.
Settling pond	1. That portion of a sediment basin in which sediment-laden water ponds and sedimentation occurs. 2. A sediment trap typically used in de-watering operations to settle sediment from sediment-laden water. A settling pond differs from a *Stilling Pond* in that it incorporates an outlet structure that allows the pond to freely drain.
Sheet flow	Water flowing at a thin, near-uniform depth that is significantly less than the width of flow.
Short-term stockpile	On a building site it is a stockpile that is located on-site or off-site for less than 24 hours. On a construction site it is a stockpile that is located on-site or off-site for less than 30 days.
Shutdown period	Any period during which construction, building and other land-disturbing activities are suspended for an extended period of time (usually greater than three days) prior to the works being continued or completed. Typically during such periods the site is required to be operating in a condition of low erosion risk in accordance with a specified development approval condition or self imposed operating condition.
Significant rainfall	Unless otherwise defined, rainfall that is sufficient to cause runoff given a specific soil type and soil moisture condition.
Silt	Silt is a soil separate consisting of particles between 0.002 and 0.02 mm in equivalent diameter i.e., intermediate between clay and fine sand sized particles.
Site	The lot or lots of land on which building, construction, or other soil disturbing activities are occurring or proposed to occur.
Spill-through weir	A level weir installed in a sediment fence, U-shaped sediment trap, or other sediment trap to control the maximum water levels within the trap specifically to reduce the risk of undesirable flooding and/or to reduce the risk of hydraulic failure of the device.
Table drain	The side drain of a road adjacent to the shoulders, and comprising part of the formation.
TSS	Total suspended solids, usually reported in units of mg/L.

Turbid water	Discoloured water usually resulting from the suspension of fine sediment particles.
Turbidity	A measure of the clarity of water. Commonly measured in terms of Nephelometric Turbidity Units (NTU).
Type 1, Type 2, Type 3 sediment traps	A classification system used to rank sediment control measures based on their ability to trap a specified grain size. Type 1 sediment traps are designed to collect sediment particles less than 0.045 mm in size. These sediment traps include sediment basins and some of the more sophisticated filtration systems used in de-watering operations. Type 2 sediment containment systems are designed to capture sediments down to a particle size of between 0.045 and 0.14 mm. Type 2 sediment traps include rock filter dams, sediment weirs and filter ponds. Type 3 sediment containment systems are primarily designed to trap sediment particles larger than 0.14 mm. These systems include sediment fences, grass buffer zones, and certain stormwater inlet protection systems.
Type C soil	A soil that contains a significant proportion of coarse-grained particles (less than 33% finer than 0.02 mm) and will settle relatively quickly without the need for flocculation.
Type D soil	A soil that contains a significant proportion (>10%) of fine (<0.005 mm) 'dispersible' materials that will never settle unless flocculated or coagulated. That is, where the percentage of clay plus half the percentage of silt (roughly the fraction <0.005 mm) multiplied by the dispersion percentage is equal to or greater than 10.
Type F soil	A soil that contains a significant proportion of fine-grained particles (33% or more finer than 0.02 mm) and require extended settlement periods to achieve efficient settlement that may or may not benefit from chemical flocculation.
Up-slope	Any location or activity that exists within the higher part of a slope relative to a reference point on the slope. Ordinarily used in reference to overland flow paths or other areas primarily subjected to sheet flow. When referring to drainage lines, channels and watercourses, the term 'upstream' is normally used.
Upstream	Any location or activity that exists within, or moves towards, the higher part of a channel or watercourse relative to a reference point within the channel or watercourse. Ordinarily used in reference to drainage lines, channels and watercourses. When referring to overland flow paths or other areas primarily subjected to sheet flow, the term 'up-slope' is normally used.
Vertical metre	A distance of 1 metre measured in a vertical direction. Typically used to define a section of a slope that has the equivalent vertical fall as the specified vertical metre distance.
Watercourse	Any natural or constructed drainage channel with well-defined bed and banks, including constructed drainage channels of a natural appearance, creeks and rivers.
Waters	Any significant body of water whether natural or constructed, or natural drainage system, including creeks, rivers, ponds, lakes and wetlands.

Waterway	Any natural or constructed drainage line, watercourse with well-defined bed and banks, including creeks and rivers, and any water body including lakes, wetlands, estuaries, bays and oceans.
Windrow	A ridge of soil that may build up along the edge of a track during its construction or maintenance. Windrows can be used to direct road/track runoff to a stable outlet, in which case it is called a 'windrow drain'.
Work area	The area that will be disturbed by building or construction works, including the area that fully encloses any soil disturbances, the building activities, materials stockpiles and vehicle pathways.
Work site	The area of potential disturbance by building or construction works, or any other soil disturbance that could potentially cause environmental harm, including: any area enclosed by temporary exclusion fencing, the area of ground disturbance and material stockpiles, and the footprint of all new structures and vehicle pathways.