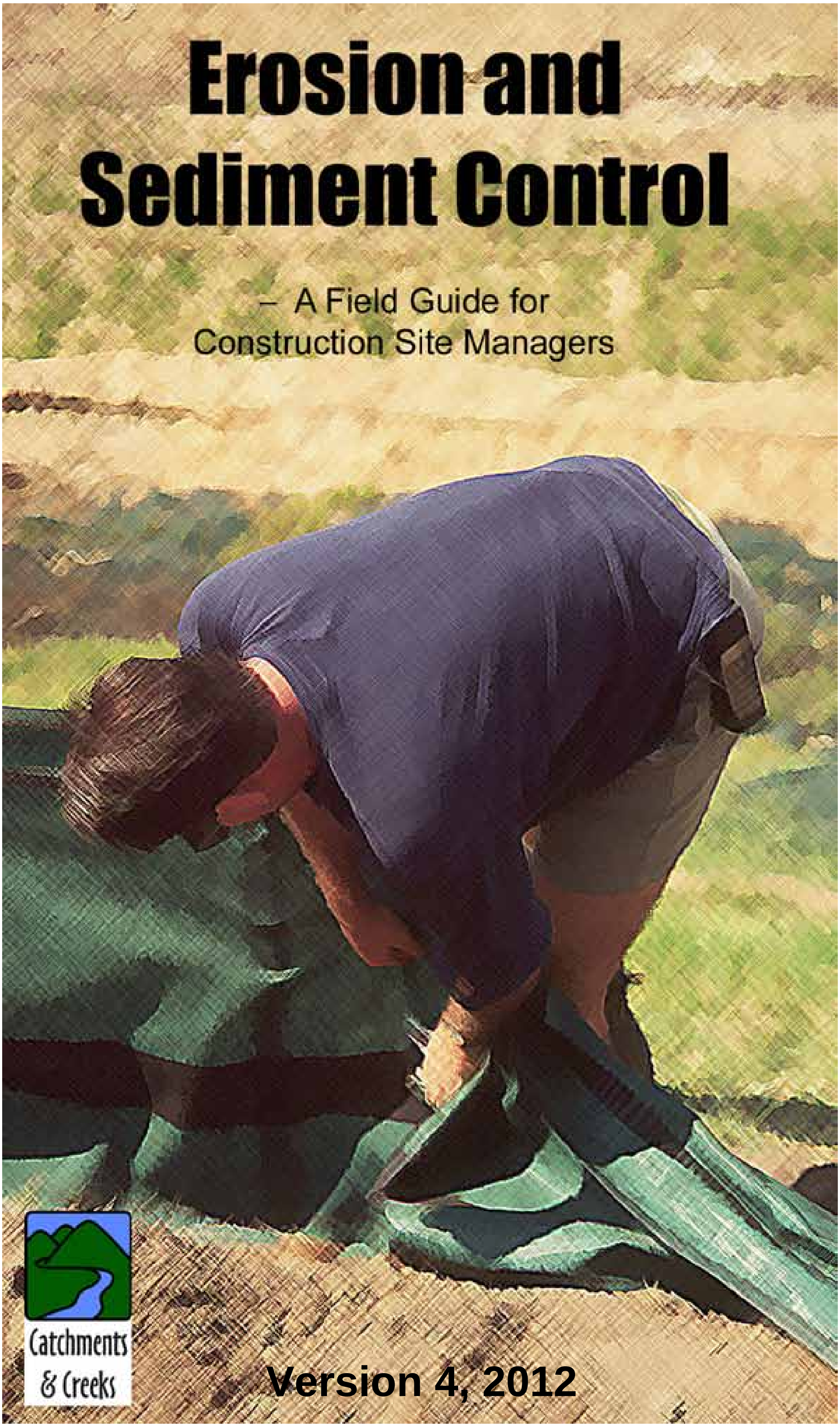
Erosion and Sediment Control

– A Field Guide for Construction Site Managers



Version 4, 2012

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

Version 4, April 2012

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Published by: Catchments & Creeks Pty Ltd

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

This document should be referenced as:

Witheridge 2012, *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 appropriately investigated, planned, and designed in a manner appropriate for the given work activity and site conditions.

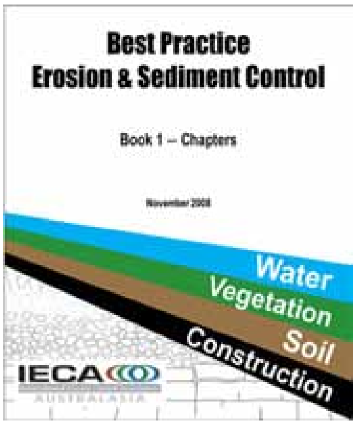
No warranty or guarantee, express, implied, or statutory is made as to the accuracy, reliability, suitability, or results of the methods or recommendations.

The author shall have no liability or responsibility to the user or any other person or entity with respect to any liability, loss, or damage caused, or alleged to be caused, directly or indirectly, by the adoption and use of any part of the document, including, but not limited to, any interruption of service, loss of business or anticipatory profits, or consequential damages resulting from the use of the document.

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.

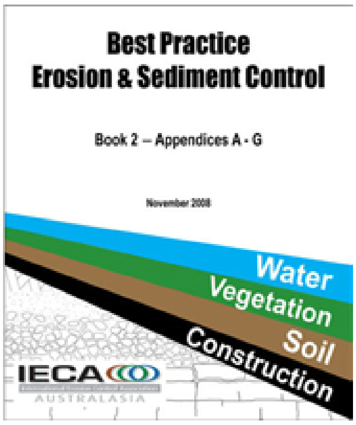
Principal reference documents:



IECA (2008) – Book 1

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

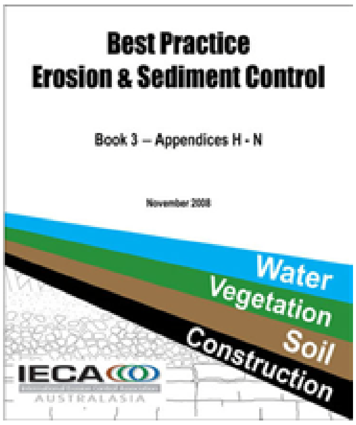
1. Introduction
2. Principles of erosion and sediment control
3. Site planning
4. Design standards and technique selection
5. Preparation of plans
6. Site management
7. Site inspection
8. Bibliography



IECA (2008) – Book 2

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



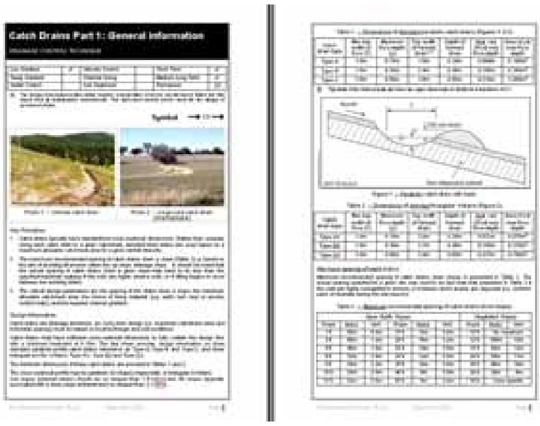
IECA (2008) – Book 3

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
X. Index (Books 1 to 3)

Books 1 to 3 may be purchased through:

www.austieca.com.au



ESC Technique Fact Sheets – Book 4

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

Down-load the fact sheets from:

www.austieca.com.au
www.catchmentsandcreeks.com.au
(Book 6 Standard Drawings are also available)

Contents

Technique Listing	Page

Purpose of field guide

This field guide has been prepared specifically to:

- Provide construction site managers with general guidelines on the management of construction sites with respect to soil erosion and sediment runoff.
- Provide construction site 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 some 30 years experience in the fields of hydraulics, 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), and Engineers Australia's Queensland Division *Soil Erosion and Sediment Control – Engineering Guidelines for Queensland Construction Sites* (1996). 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 performance standards.

Impacts of soil erosion and sediment runoff

Site-generated dust

Dust generation

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

Sedimentation of drainage pipes

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 stormwater asset owners such as local governments
  - increase the risk of mosquito problems

Deposition of coarse sediment in creeks

Sedimentation within 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 the weed infestation of creeks
  - increase maintenance costs for stormwater asset owners such as local governments

Suspended fine sediments in creeks

- 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 breading
  - increase the concentration of nutrients and metals within permanent waters
  - reduce light penetration into pools
  - increase the frequency, cost and damage of de-silting operations

Impacts of soil erosion and sediment runoff

Sedimentation of wetlands

Colouration of ponds and lakes

Sedimentation of rivers and estuaries

Sediment released into the ocean

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 asset owners such as local governments

Turbidity within dams, rivers & ponds

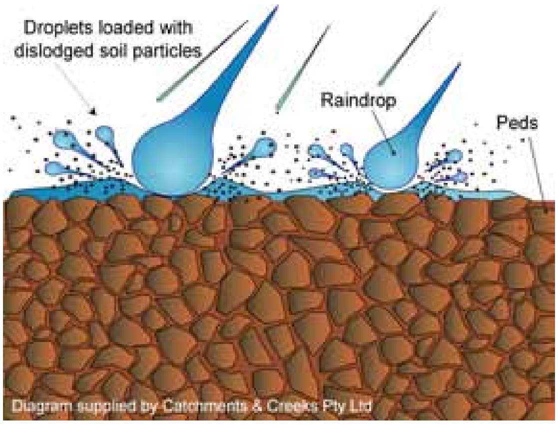
- The release of fine sediments and turbid water into ponds, lakes and dams can:
  - adversely affect the health and bio-diversity of aquatic life within these water bodies
  - increase the concentration of nutrients and metals within these waters
  - reduce light penetration into the water
  - increase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

- 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
  - adversely affects fish numbers and fish breading
  - 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

Damage to the reef & 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

Raindrop impact erosion

- Raindrops can exert significant force upon impact with the ground.
- The resulting soil erosion is often difficult to detect and consequently is often ignored.
- 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 unseasonable for raindrop impact erosion to cause the release of 1 to 2 cm of soil during the construction phase.

Land subject to sheet erosion

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 open 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 of soil per hectare.

Rill erosion

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.

Erosion of a dispersive soil

Chemical-induced erosion

- Soil chemistry can have a significant influence over 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’ shown left), tunnel erosion and/or gully erosion.
- As a general guide, if the soil erosion is significantly deeper than its width, then soil chemistry is likely to be a contributing factor to the soil erosion.

Site management

Plans, permits and approvals

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 site 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 constructed.

Pre-construction conference

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

Site office

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 common traffic areas.

Site signage

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 a concrete disposal area(s) 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 every ones 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:
  - work place health and safety issues
  - environmental management
  - best practice erosion and sediment control practices
  - incident reporting procedures
  - site inspection and maintenance procedures (selected staff only)

Damaged fence tagged for repair

Site inspections

- Nominate the officer(s) responsible for on-site 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 areas 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 in the photo (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.

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; 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 higher the expected 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 traps. · 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 instead of just using water trucks.

Site inspection and monitoring

Storm damage to 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 prior to 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

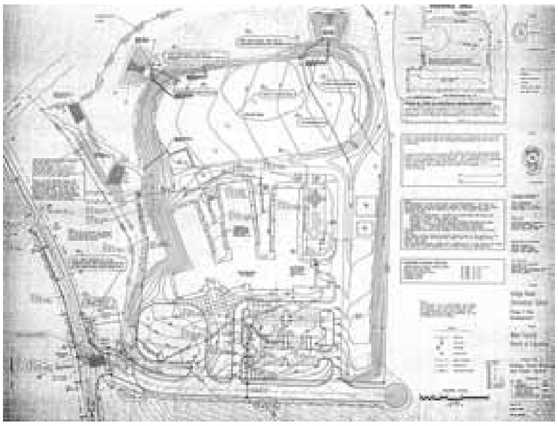
Collection of water samples

- 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 site 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 professional water quality monitoring occurs, are two ways of ensuring the ESCP remains relevant to the site conditions.

Vegetation management

Exclusion fencing

Vegetation protection

Undesirable tree trunk damage

Scarifying the soil surface

Protection of non-disturbance areas

- Establish any non-disturbance or exclusion areas identified within the Erosion and Sediment Control Plan or *Vegetation Management Plan* (VMP).
- Where appropriate, identify, isolate and/or protect retained vegetation.
- Ensure all local and State Government approvals are obtained before any disturbance occurs to vegetation, and then disturb only the minimum necessary to complete the works.

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 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).

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.

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 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 can provide 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 groups of trees.
- Note; partially hollow trees (dead or living) often need to be saved for the habitat value these trees provide to local wildlife.

Land clearing without soil disturbance

Delayed clearing 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 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 to satisfy landscaping requirements.
- Tub grinding cleared vegetation produces a more hydraulically-stable mulch than chipping processes.

Soil management

Truck bogged in wet soil

Inappropriate earthworks practice

Replacement of topsoil

Scarifying the soil surface

Timing of earthworks

- Ensure earthworks are avoided during those periods when rainfall is either occurring or the soil is saturated.
- Working the soil when it is too wet can:
  - damage the soil structure
  - reduce the soil's drainage properties
  - increase erosion and sediment runoff
- Working the soil when it is too dry can:
  - damage the soil structure
  - adversely affect site revegetation
  - increase the risk of dust problems

Location of stockpiles

- Ensure that excavated material is not stockpiled in locations where it could cause harm, or be washed into a gutter, drain or water body, such as:
  - within an overland flow path
  - adjacent to stream banks
  - within the canopy drip zone of protected trees

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 and/or construction is 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 3:1(H:V), 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 about 3:1(H:V), 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 plant seed content that needs to be preserved for re-establishment.	· Upper 50 mm of soil 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.
Imported topsoil, or in-situ 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 seed content.	· Ideally replace soil with alternative local topsoil free of weed seed content—seek expert advice. · Depending on expert advice, stripped topsoil maybe appropriately treated to prevent germination of weed seed content, covered with clear plastic sheeting to help burn-off the weed seed content, or buried under a minimum 100 mm of soil.
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 surface soils consist of a mixture of topsoil and dispersive subsoil.	· Mix the soil with gypsum, lime or other appropriate ameliorants prior to stockpiling in either high or low mounds according to required protection of seed content. · Choice of chemical treatment of the dispersive soil depends on desired pH adjustments—seek expert advice.

Stockpile management

Inappropriately located sand stockpile

Flow diversion using a catch drain

Long-term stockpile covered with mulch

Sediment control down-slope of 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, such as:
  - on a road pavement
  - within an overland flow path
  - adjacent to stream banks
  - within the canopy drip zone of protected trees (long-term stockpiles)

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 and the up-slope catchment area exceeds 1500 m^2.

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 (not always practical)
  - covered with mulch or temporary vegetation (grass) if not located within the drainage catchment of a sediment basin
- Ensure appropriate dust controls exist for all stockpiles.

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.

Recognising and managing problematic soils

- With the exception of small, low-risk sites, an appropriate soil analysis should be performed on every construction site prior to commencing any soil disturbance.
- From a construction perspective, site managers should be aware of any potentially problematic soils, such as highly erodible soils (whether the erosion risk is due to the soil composition or land slope), dispersive soils, and acid sulfate soils.
- From a revegetation perspective, site managers should be aware of any soil that will require the addition of ameliorants prior to planting, and any soil surface that is likely to experience excessive soil compaction prior to being revegetated.

Dispersive soil

Culvert damage resulting from the exposure of acid sulfate soils

Saline soils

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 (left).

Acid sulfate soils

- Prior to the disturbance of soils below an elevation of 5 m AHD, the soils should be tested for their acid sulfate potential.
- Potential acid sulfate soils must be managed in accordance with State approved guidelines, such as:
  - Queensland's State Planning Policy 2/02 *Guideline: Planning and Managing Development involving Acid Sulfate Soils*
  - Dear, et al., 2002, *Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines*

Saline soils

- Saline soils can introduce complex revegetation problems as well as long-term structural problems to some 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 sols requires expert advice.

In theory, there are no 'problematic soils', just inappropriate soil management practices!

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 be used as an indicator 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 the desired environmental protection.

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.

Table drain erosion

Stabilisation of open drains

- Avoid cutting drainage channels into dispersive soils.
- Avoid the use of *Check Dams* within any drain that cuts into dispersive soils.
- The use of *Check Dams* only extends the duration of water ponding, and thus the risk of erosion. Instead, line the drain with a non-dispersive soil and then revegetate as appropriate.

Tunnel erosion

Prevention of tunnel erosion

- Dispersive soils are highly susceptible to tunnel erosion.
- Sealing dispersive soils with concrete can result in tunnel erosion forming under the concrete.
- Similarly, tunnel erosion can form under rock and rock mattress channel linings.

Damage to access road

Treatment of soil prior to seeding

- Do not directly seed dispersive soils. A well-established grass root system cannot prevent the release of clay particles from the soil, and the inevitable failure of the grassed surface.
- Instead, treat the soil with gypsum (or the like), and/or cover the dispersive soils with a minimum 100 to 300 mm of non-dispersive soil depending on the land slope and the likely degree of future soil disturbance.

Management of temporary access roads

Inadequate drainage and erosion controls

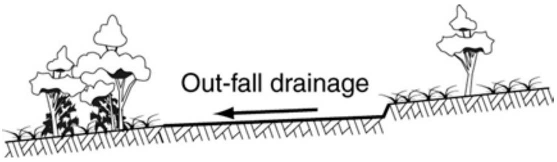
Drainage and erosion controls

- 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

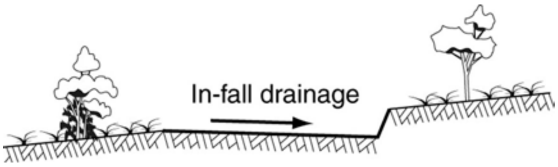
- Out-fall drainage is only used when road runoff can sheet evenly off the road.
- Out-fall drainage can cause erosion problems if:
  - the outer embankment is unstable, or
  - an earth windrow forms along the outer edge of the roadway



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 practicable, 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

Planned shutdowns

- Procedures for initiating a site shutdown, whether planned or unplanned, must incorporate the revegetation of all soil disturbances 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 shutdown periods.

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 any required chemical adjustment of 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 2-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 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 addition 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.

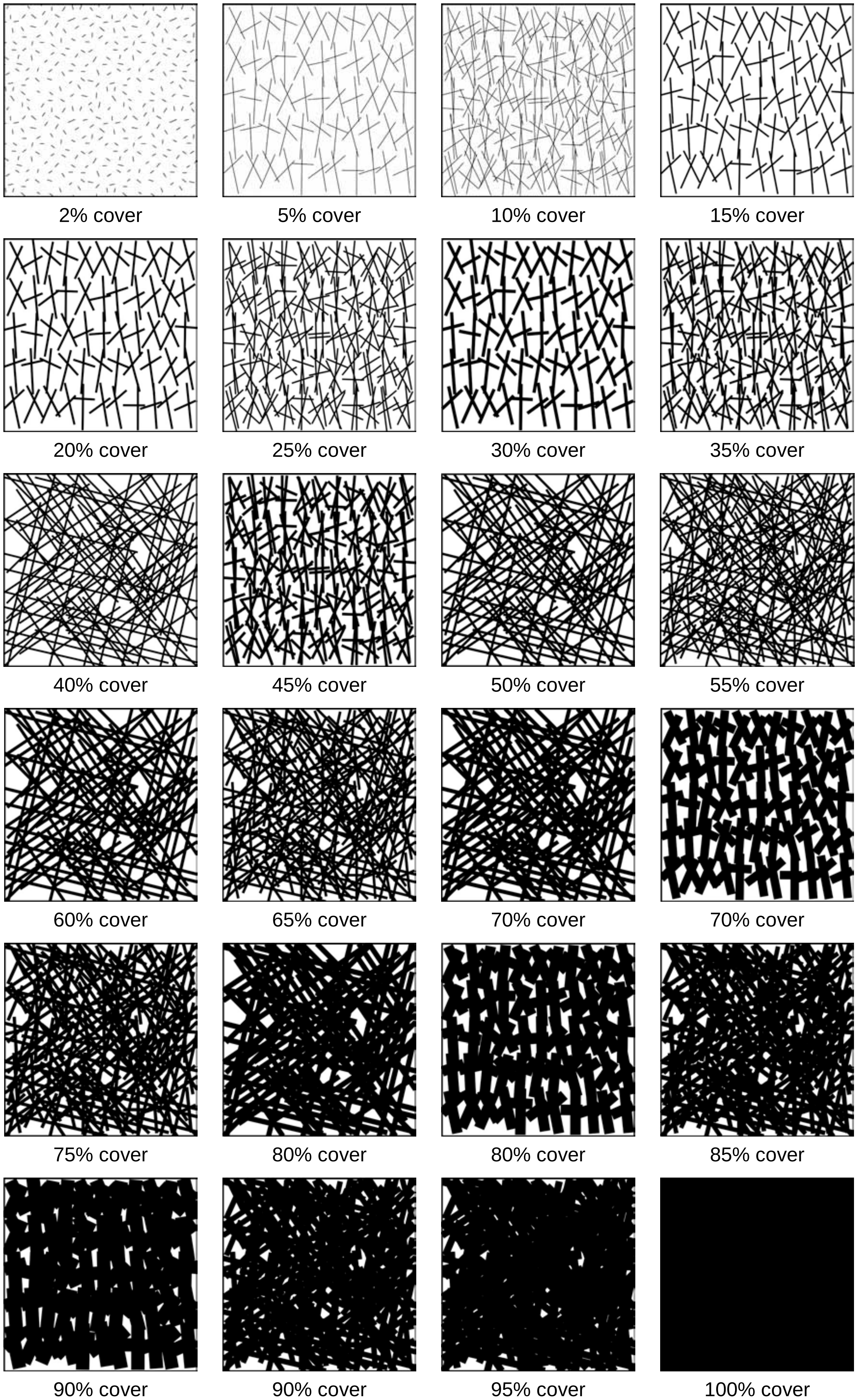
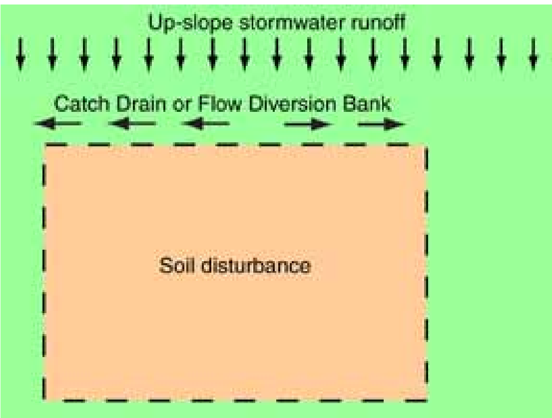


Figure 1 – Visual cover estimation template

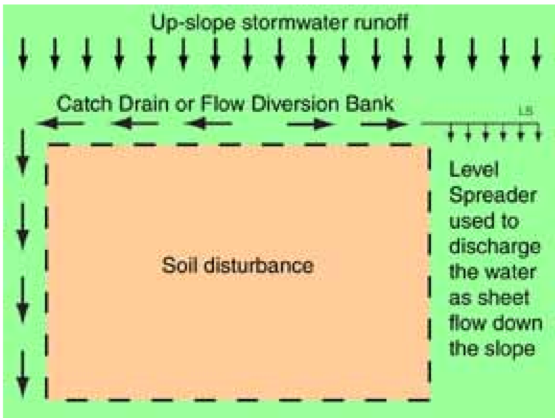
Drainage Control Measures

Management of site drainage during the construction phase

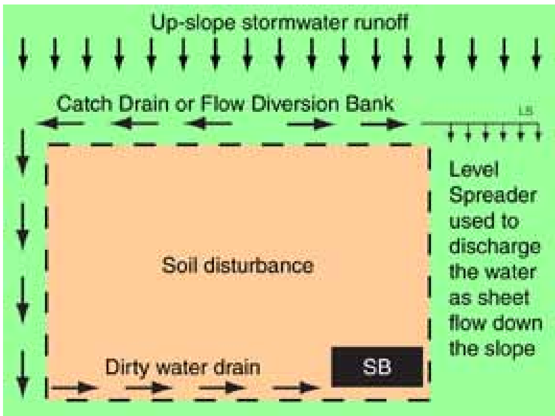
- Appropriate drainage controls must be applied to every construction site. These controls may consist of components of the permanent drainage system, plus temporary drainage measures that are required to be functional only during the construction phase.
- Each site is different and thus the required 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/ stormwater 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 any given soil disturbance. This may require large sites to be viewed as a series of adjoining sub-catchments.
- 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. Low gradient drains can often be left with an open soil surface.
- 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 any 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 recommended standard 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	LS	Outlet Structure	OS	OS
Recessed Rock Check Dam	RRC	→ RRC →	Rock Check Dam	RCD	→ RCD →
Sandbag Check Dam	SBC	→ SBC →	Slope Drain	SD	→ SD →
Bridge	TBC	TBC	Culvert	TCC	TCC
Temporary Downpipe	TD	TD	Ford	TFC	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

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.

Large catch drain

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.

Severe erosion associated with catch drain cut into dispersive soil

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 dispersive soils, 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 diversion bank

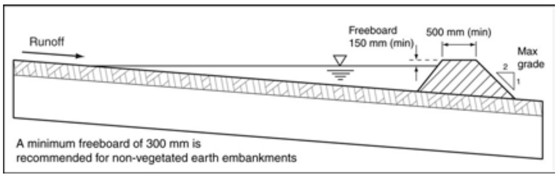
Straw bale flow diversion bank under construction (yet to be staked)

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 and chutes (as shown 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 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 as an alternative to stockpiling.



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 bales 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. The 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 face of 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 and 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
  - 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.
- Rock must be recessed into the soil to prevent inflows being diverted along the 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

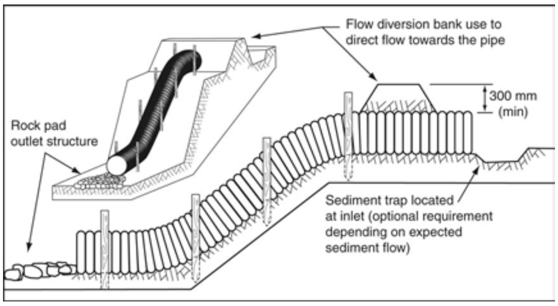
Flow diversion bank controlling flow entry

Slope drains on newly seeded batter

Lay-flat pipe

Slope drains

- Slope drains are most commonly used in low rainfall regions where the limited capacity of these drains will not become an issue.
- Sediment traps can be incorporated into the inlet and/or outlet of these pipes.
- 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 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.

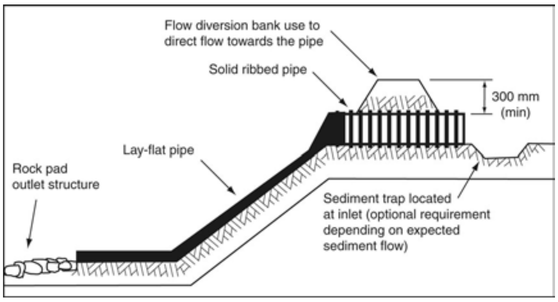


Use of slope drains

- Slope drains are commonly used in road construction to prevent road 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.

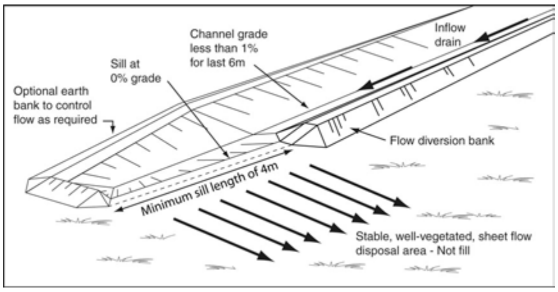


END-OF-DRAIN STRUCTURES – Outlet structures

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.

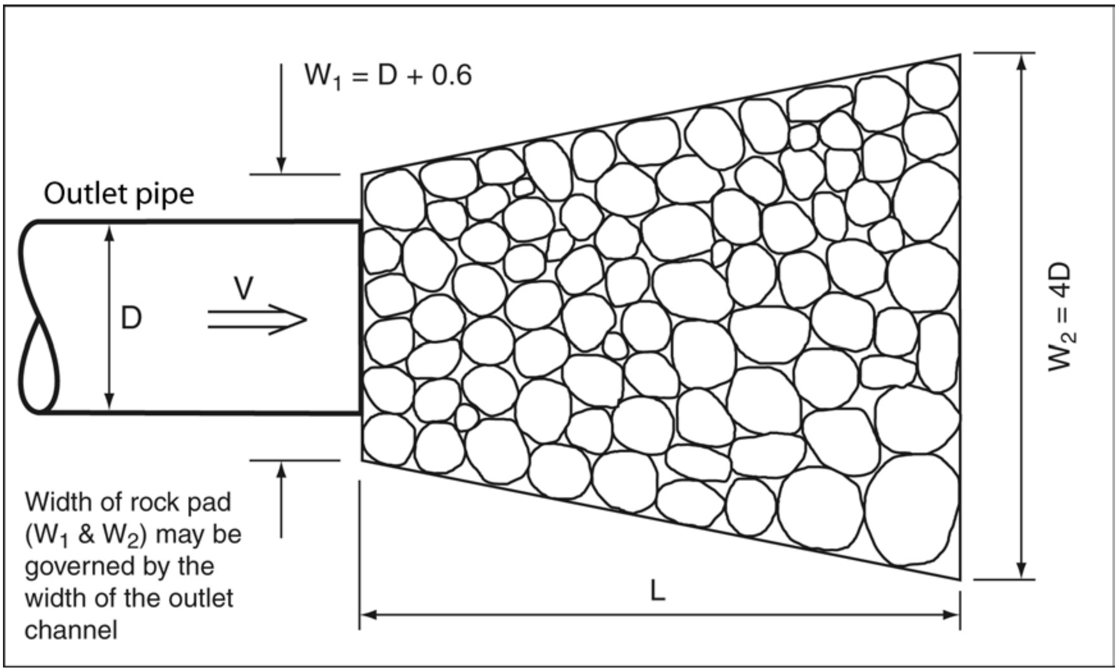


Figure 2 – Typical layout of a rock pad for a single pipe outlet (plan view)

VELOCITY CONTROL STRUCTURES – Check dams

Fibre rolls

Fibre rolls (FCD)

- Fibre rolls consist of small-diameter, 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 log to integrate into the vegetation, such as in vegetated channels; however, some products contain a plastic mesh that may represent an wildlife/ environmental risk.

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%.
- These check dams are typically small (in height) and therefore less likely to divert water out of the drain compared to rock check dams.
- Sandbag check dams can also be used as a temporary (supplementary) sediment trap.

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.
- Can also 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).

Triangular ditch check

Triangular ditch check dams (TDC)

- Triangular ditch checks are commercially available, re-useable products.
- Commonly used to stabilise wide, shallow table drains with less than 10% gradient.
- These check dams can also be used as a temporary (supplementary) sediment trap.

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.
- Sheets of plastic can also be used to form short, temporary drainage chutes down earth batters, but must be used with caution.

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 other suitable tackifier (e.g. in table drains)

Temporary erosion control mat

Erosion control mat (ECM)

- These erosion control mats contain an organic mulch layer 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 for 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 outer 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 for 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 for dams and *Sediment Basins*.
- An underlying geotextile or rock filter layer is generally required unless all voids are filled with soil and pocket planted.
- 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 waterways that are too wide for a temporary bridge.

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.
- Culvert bridging slabs (left) may be used to form a bridge deck across narrow streams.
- It is important to control stormwater drainage on access tracks/roads 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 (left) are most commonly used.

Ford crossing or alluvial stream

Temporary ford crossings (TFC)

- Ford crossings are used on 'dry' creek and river crossings when stream flows are not expected. The regular crossing of 'wet' creek beds (left) 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 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 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 recommended standard 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 other mulches, surfaces treated with straw mulch generally require the least amount of 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 the risk of displacement 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 surface 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.
- Typically it is a highly successful grassing technique, but it requires strict control of application rates and choice of tackifier.
- Often the preferred grass seeding technique in wet environments (e.g. tropics during the wet season) 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 (left), the surface can still provide effective erosion control, thus avoiding the need for ongoing watering.
- 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 or other construction activities.
- **Caution**; some wood-based (woodchip) mulches can reduce nitrogen levels within the soil.

Compost blanket

Compost blankets (CBT)

- Compost blankets are typically used in association with the revegetation of steep slopes using grasses and/or other plants.
- Particularly useful when the slope is too steep for the placement of topsoil, or when insufficient topsoil exists on the site.
- 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

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 of the underlying soil.
- 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')

Jute mesh

Open mesh-type blankets

- A 'mesh' is an open weave blanket made from rope-like strands such a hessian (jute) or coir rope.
- 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 (made from coconut fibres) have a service life similar to that of a common domestic doormat placed directly on the ground.

Synthetic-reinforced blanket

Temporary synthetic-reinforced blankets

- Erosion control blankets with temporary, synthetic reinforcing have a low to medium shear strength.
- The plastic mesh can represent a threat to wildlife, potentially entrapping wildlife such as lizards, snakes and birds.
- Their design life is generally less than 12 months.

Weed control blanket

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).

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 may 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 tackifier) mulch can be used for dust control on large, open soil areas.
- 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.

Application of soil binders

Soil binders (SBS)

- Soil binders are typically used for dust control of unsealed roads and mining operations.
- Selection of product depends on the potential environmental impacts, trafficability and longevity.
- The application and success of soil binders vary from region to region.
- Usually best 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.

Water truck

Water trucks

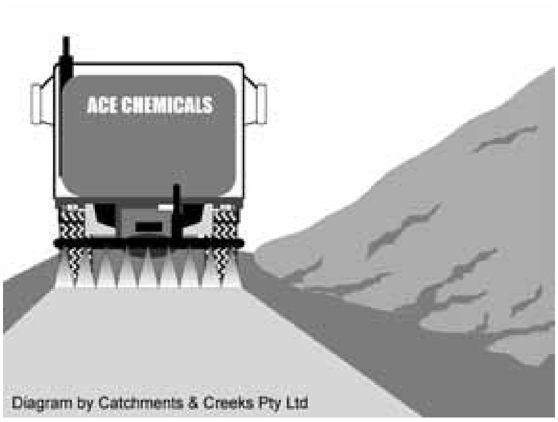
- Water trucks can be used for dust control of unsealed roads and access tracks.
- Dust levels can also be controlled by minimising site traffic and the movement of site traffic outside designated areas.
- The addition of wetting agents and polymer binders (*Soil Binders*) to the water can decrease both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

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 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 increased by roughening the soil surface to increase water infiltration and delay the formation of rutting.
- Surface roughening also reduces 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 Measures

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

Table 13 – Sediment control techniques

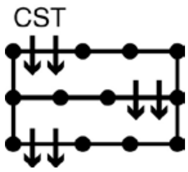
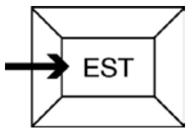
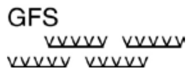
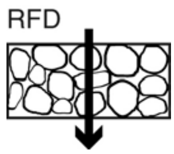
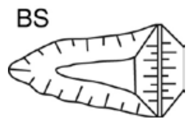
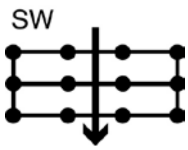
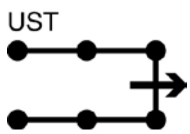
Technique	Code	Symbol	Technique	Code	Symbol
Buffer Zones	BZ		Check Dam Sediment Trap	CDT	
Coarse Sediment Trap	CST		Compost Berm	CB	CB
Excavated Sediment Trap	EST		Fibre Roll	FR	FR
Filter Fence	FF	FF	Filter Sock	FS	FS
Filter Tube Dam	FTD		Grass Filter Strips	GFS	
Modular Sediment Trap	MST	MST	Mulch Berm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

Table 14 – Sediment control – entry/exit control techniques

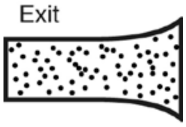
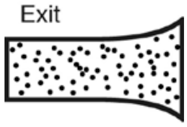
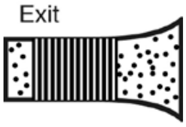
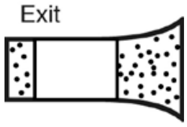
Technique	Code	Symbol	Technique	Code	Symbol
Construction Exit	Exit		Rock Pad	Exit	
Vibration Grid	Exit		Wash Bay	Exit	

Table 15 – Sediment control – roadside kerb inlet control techniques

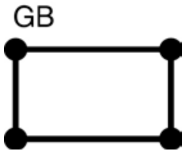
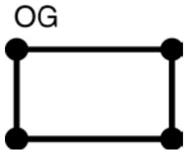
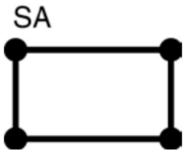
Technique	Code	Symbol	Technique	Code	Symbol
Gully Bag	GB		On-grade Kerb Inlet Sediment Trap	OG	
Sag Inlet Sediment Trap	SA				

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

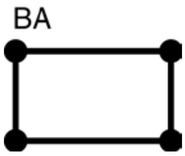
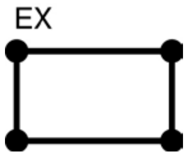
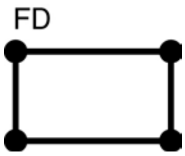
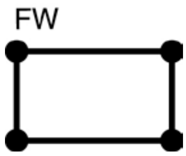
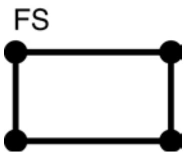
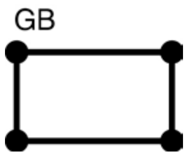
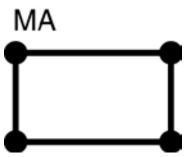
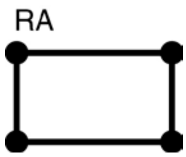
Technique	Code	Symbol	Technique	Code	Symbol
Block & Aggregate Drop Inlet Protection	BA		Excavated Drop Inlet Protection	EX	
Fabric Drop Inlet Protection	FD		Fabric Wrap Inlet Protection	FW	
Filter Sock Drop Inlet Protection	FS		Gully Bag	GB	
Mesh & Aggregate Drop Inlet Protection	MA		Rock & Aggregate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

Entry/exit sediment controls (Exit)

Rock pad

Rock pads

- Suitable for all soil types.
- The critical design parameter is the total void spacing 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. cross bank) may need to be incorporated into the rock pad to direct sediment-laden runoff to an appropriate sediment trap.

Vibration grid

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 must extend from the vibration grid to the sealed road surface.

Wash bay

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.

Site signage

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, and covers.

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.

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 instead of the traditional, 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 containing clayey material instead of the traditional, 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.
- 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 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 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 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.
- Grass filter trips are mostly suited to sandy soils.
- Can act as a supplementary sediment trap if placed around impervious surfaces, 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)

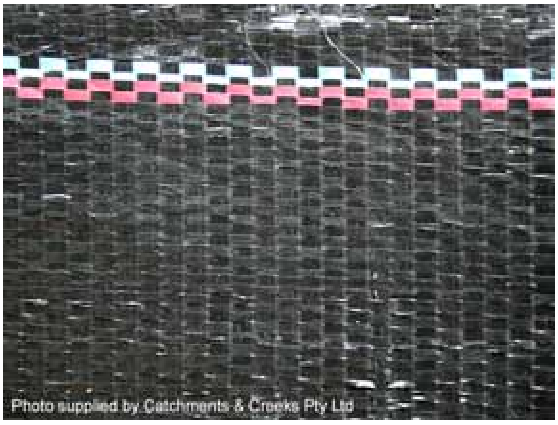
- A Type 2 sediment trap.
- Mulch berms are suitable for all soil types.
- The mulch must be produced through the use of tube grinders or the like, but **not** by chipping. The mulch needs to be very fibrous with the woody splinters allowing good interlocking. The mulch should not appear as clean cut (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/or table drains.

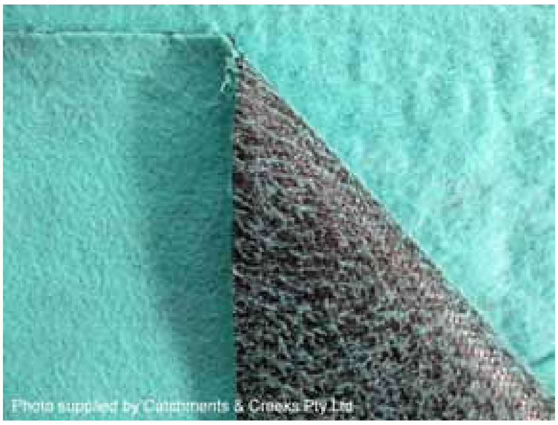
Sediment fence (SF) – suitable for 'sheet' flow conditions



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.



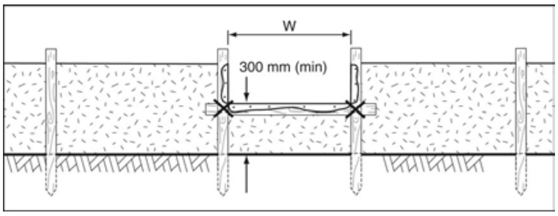
Composite sediment fence fabric

Composite sediment fence fabrics

- Non-woven, composite fabrics (left) are generally suitable for all soil types. It is generally considered that these composite fabrics have a greater potential to capture the finer sediment particles.
- Non-woven fabrics are generally preferred on short duration construction sites and in locations where the sediment fence represents the last line of defence.
- The non-woven (green) face must point up-slope.

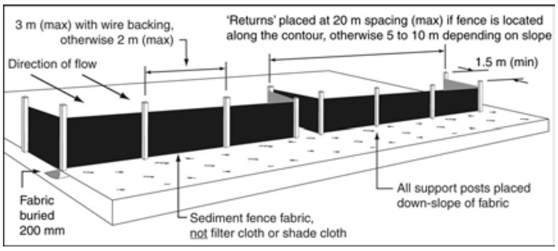
Wire mesh backing

- Support post must be placed at a maximum 2 m spacing unless the fence has a top wire (anchored at 1m spacing), or a wire mesh backing, in which case a 3 m spacing of support post is allowed.
- A spill-through weir can be used to reduce hydraulic pressures in large catchments.



Placement of regular 'returns'

- Ideally installed along the contour.
- 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

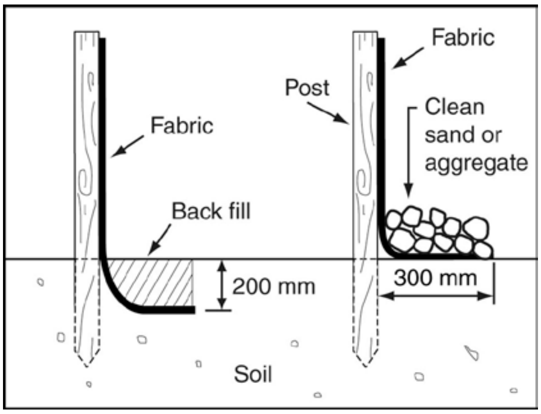
- The ends of a sediment fence **must** be turned up the slope (a 'return') to prevent water readily passing around the ends of the fence.

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 (bottom right), but **not** randomly spaced rocks (left).
- The support posts must be placed down-slope of the fabric (<u>not</u> as shown below 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 the 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) may incorporate gully bags or 'barrier' type sediment traps (filter socks) placed around the inlet.
4. **Warning** – a sediment trap must not surround or block an 'on-grade' kerb inlet.

Gully bag

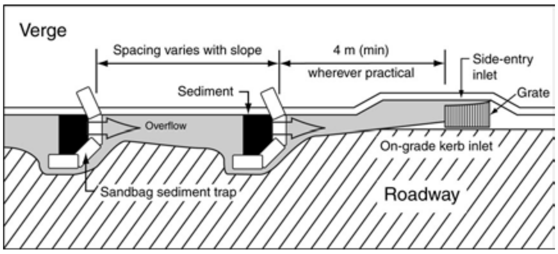
Gully bags (GB)

- 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.

Filter sock sediment trap

On-grade kerb inlet sediment traps (OG)

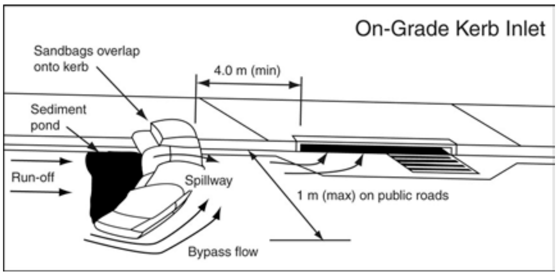
- A supplementary sediment trap.
- 'On-grade' inlets require a different sediment control system to 'sag' inlets.
- A series of sediment traps may be required to achieve optimum performance.



Installation of sandbag sediment traps

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

Sandbag sediment trap



Kerb inlet sediment traps

Sag inlet sediment trap

Sag inlet sediment trap

Inappropriate on-grade sediment trap

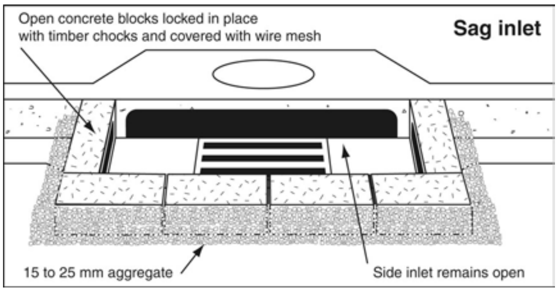
Insufficient sediment control

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 system, 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 simply 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

Ineffective kerb inlet sediment traps

- A single sandbag is generally insufficient to provide adequate sediment control.
- To be effective, a sediment trap **must** be able to trap and retain sediment, not just divert the stormwater and sediment down the roadway!

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.

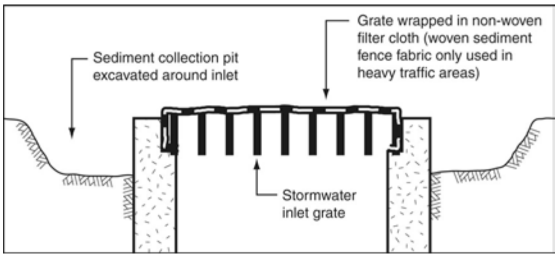
Table 19 – Preferred sediment control technique for various catchment conditions

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)

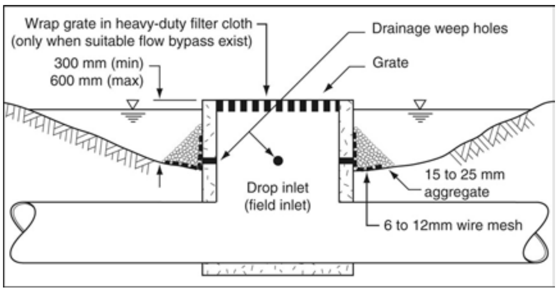
- Very small catchment areas.
- Most commonly used on building sites.
- Formation of the excavated pit is critical.



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)

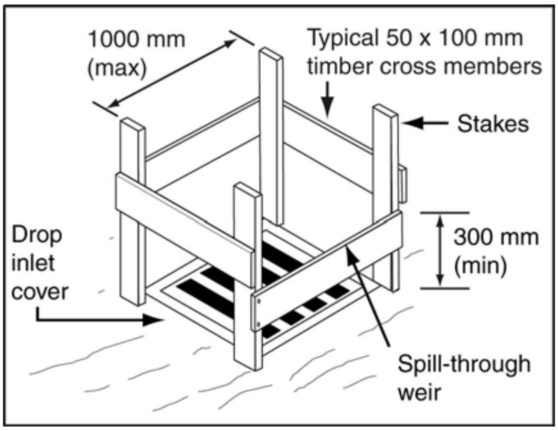
- Excavated drop inlet protection is used in locations where water ponding around the stormwater inlet is not allowed to reach a level significantly higher than the existing ground level.
- Safety issues may require the excavated pit to be surrounded by appropriate safety fencing.

Field (drop) inlet sediment traps

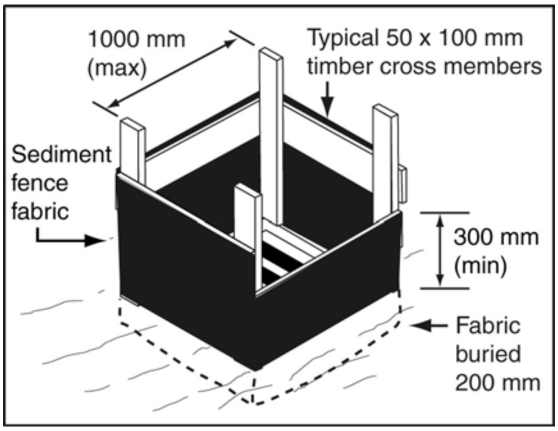
Fabric drop inlet protection

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

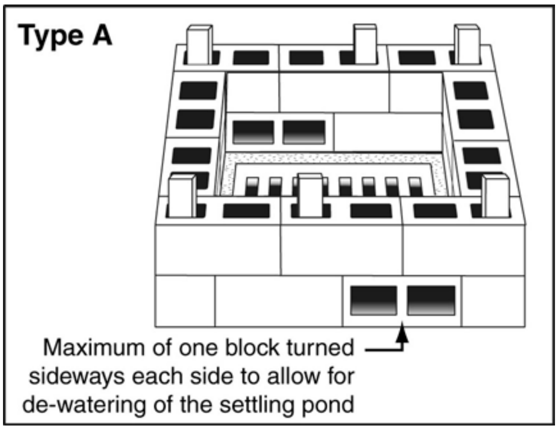


Placement of fabric

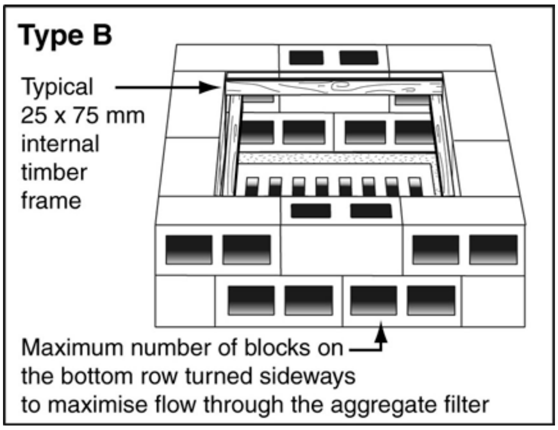
Block & aggregate drop inlet protection

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).



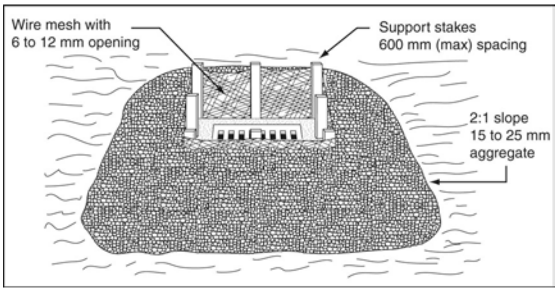
Block details for low flow rate system



Block details for high flow rate system

Field (drop) inlet sediment traps

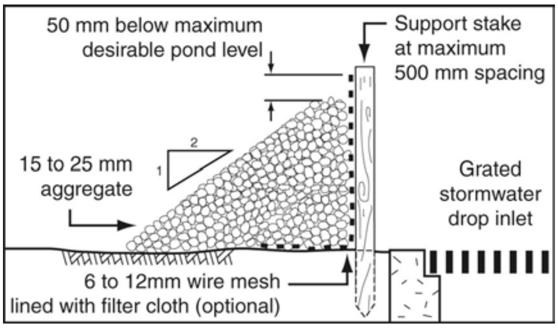
Mesh & aggregate drop inlet protection



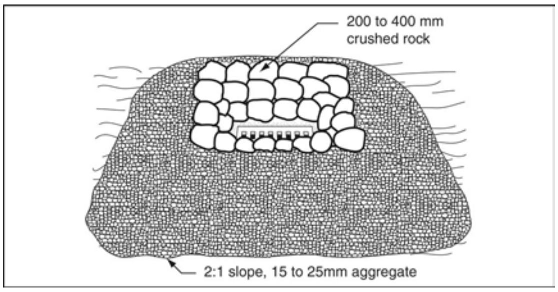
Mesh & aggregate drop inlet protection

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 (below) shows details without use of filter cloth.



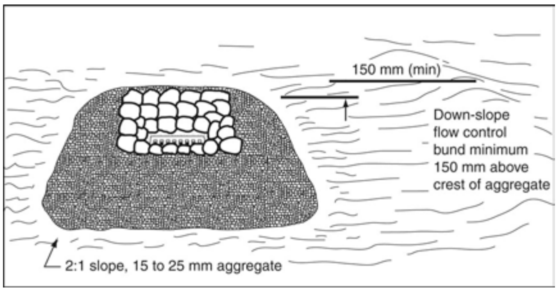
Rock & aggregate drop inlet protection



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. Designs should aim to maximise the surface area of the surrounding settling pond.
- *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.
- Ponded water should not be allowed to spill onto trafficable roadways.



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 dams can be used as minor sediment traps 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 compost-filled socks.
- Compost-filled socks can adsorb some dissolved and fine particulate matter.

Coarse sediment trap

Coarse sediment traps (CST)

- A Type 3 sediment trap.
- Coarse sediment traps are best used on sandy soils.
- Commonly used as 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 to reduce the deposition of coarse sediment at the filter tube inlets.
- *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 trap (UST) – suitable for minor concentrated flow

U-shaped sediment trap

U-shaped sediment trap in steep drain

Inappropriate installation

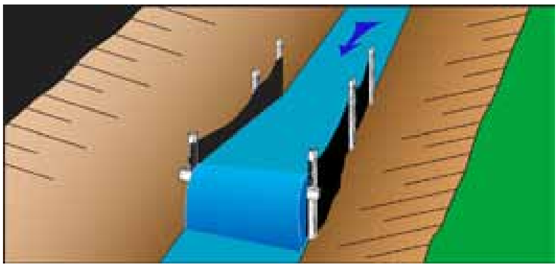
Inappropriate installation

U-shaped sediment traps (UST)

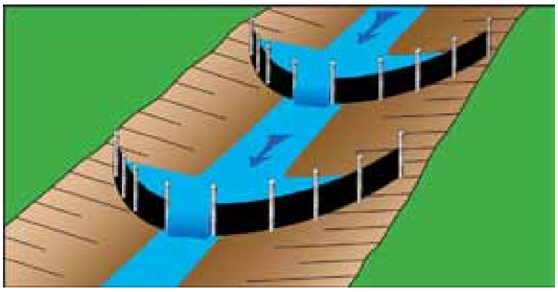
- A Type 3 sediment trap.
- U-shaped sediment traps are commonly used as a coarse sediment trap (Type 3) within table drains having a medium to steep gradient.
- The sediment fence **must** be constructed in a U-shape, **not** formed in a gradual arc, or placed straight across the drain.
- In drains with a medium gradient, a spill-through weir is usually required to prevent flow bypassing.
- The width of the sediment trap is usually determined by the width of an excavator or backhoe bucket used for sediment removal.
- Filter tubes can be integrated into a *U-Shaped Sediment Trap* to increase the effective hydraulic capacity and to improve the treatment of low-flows.
- On low-gradient drains, preference may need to be given to a *Check Dam Sediment Trap*.
- Spill-through weirs are only effective if the weir crest is at least 300 mm high, and the crest is below the ground level at the end of the wing walls (below).

Installation of U-shaped sediment traps

- Sediment fence fabric must **not** be placed straight across the drain as shown (left).

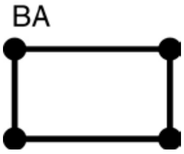
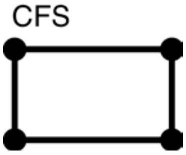
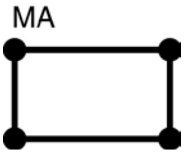
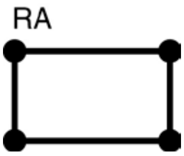
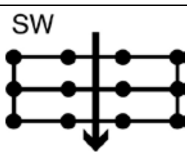


- A U-shape sediment trap must not be formed in a gradual arc across the drain as shown (left), but as shown above and below.

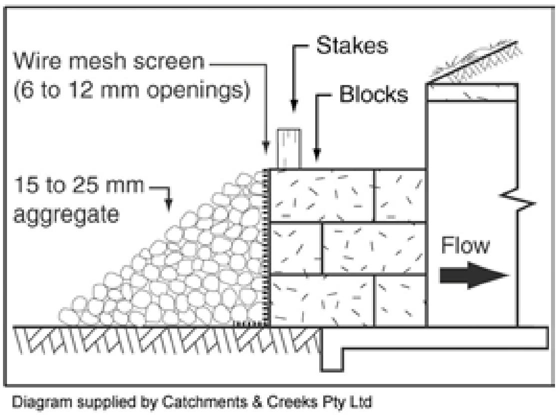


Sediment control suitable for pipe and culvert inlets

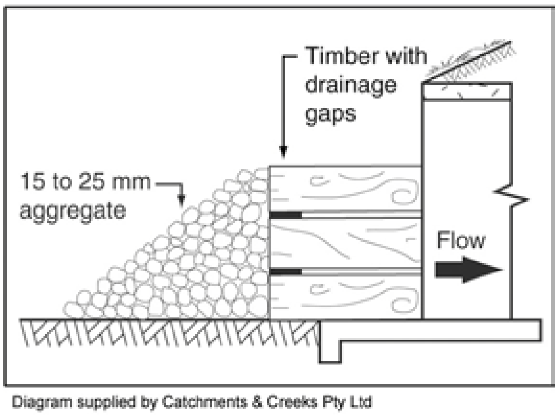
Table 21 – Temporary (construction phase) sediment controls placed at the entrance to culverts and open stormwater pipes

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.

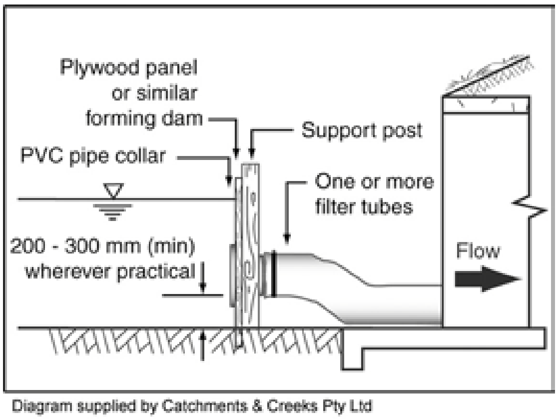
Sediment control suitable for pipe and culvert inlets



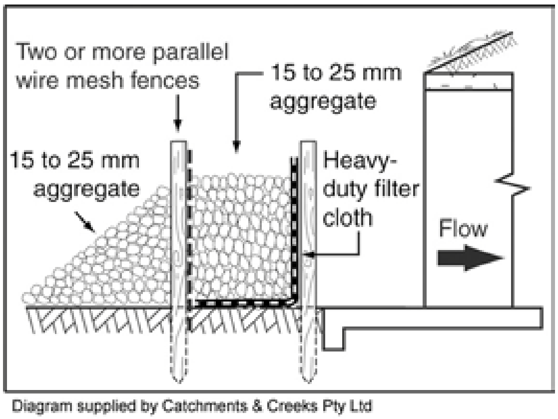
Block and aggregate sediment trap



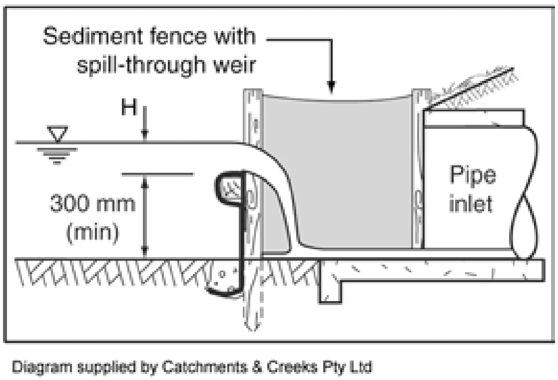
Plank and aggregate sediment trap



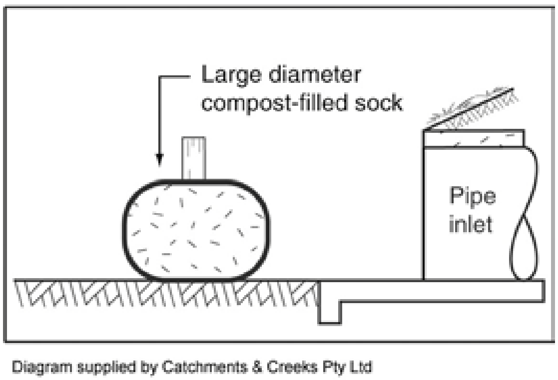
Filter tube dam



Sediment weir



Sediment fence (minor flow only)



Compost-filled filter sock

Inappropriate sediment control

Inappropriate sediment control

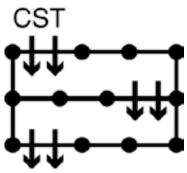
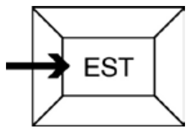
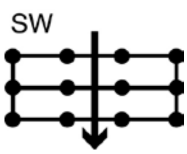
Sediment control suitable for stormwater outlets

Table 22 outlines the attributes of various **temporary** sediment control techniques that may be suitable for placement at the outlet of stormwater pipes. 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

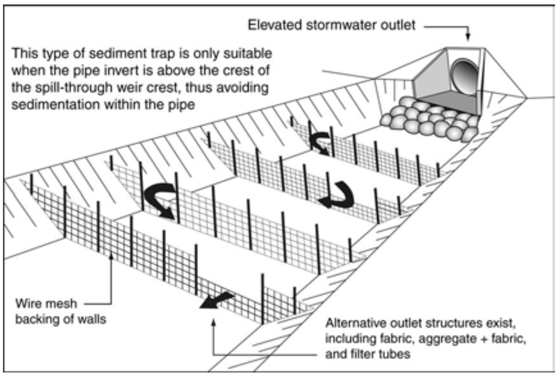
Excavated sediment trap

Straw bale barrier

Inappropriate choice of sediment trap

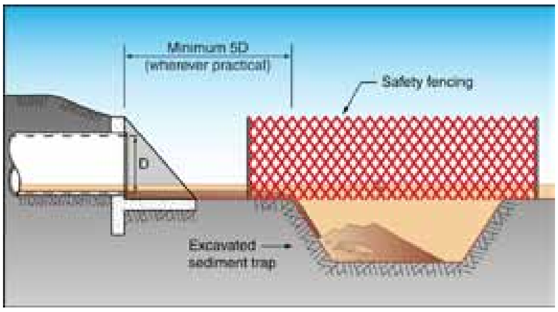
Coarse sediment trap (CST)

- Suitable for low fall outlets.



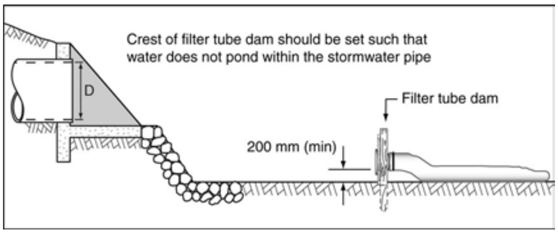
Excavated sediment trap (ECT)

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



Straw bale barrier (SBB)

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



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 pond 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* is normally used for such low-fall outlets.

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

Selection criteria for the use of sediment traps within drainage channels:

1. **Safety first** – do not use any sediment control system if that system represents a safety risk persons or property.
2. **Flooding risk** – any adopted sediment control system must not result in flooding of neighbouring properties. A flow bypass system may need to be incorporated into the sediment trap to control the depth and extent of ponding.
3. **Soil type** – aggregate-based filtration systems are best used in sandy soil regions and for long-term installations. Geotextile filters (filter cloth) are generally required in clayey soil areas; however, these systems can be difficult to maintain on a long-term basis.

Rock filter dam - geotextile filter

Rock filter dam - geotextile filter (RFD)

- A Type 2 sediment trap
- 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 must be maximised.
- The incorporation of filter cloth is the preferred construction technique if the removal of fine-grained sediment is critical.

Rock filter dam - aggregate filer

Rock filter dam - aggregate filer (RFD)

- A Type 2 sediment trap
- Aggregate-based filtration systems are best used in sandy soil areas.
- 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

Excavated sediment trap (EST)

- A Type 2 or 3 sediment trap
- Excavated sediment traps are often combined with *Rock Filter Dams.*
- **Caution;** placing an excavated pit immediately up-slope of an 'aggregate filter' may reduce the filtration performance of the rock filter dam.
- Placing an excavated pit immediately up-slope of an 'geotextile filter' will help to reduce blockage of the filter, and thus should extend the effective operation life of the sediment trap.

These sediment control systems are often referred to simply as '*Sediment Traps*'.

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

Sediment weir (field inlet protection)

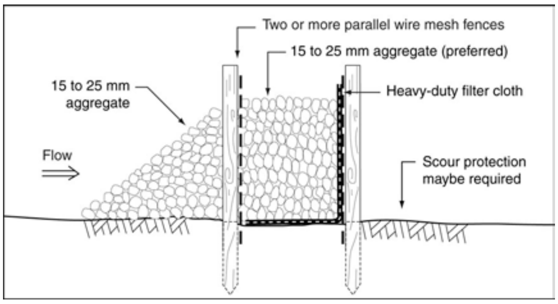
Sediment weir (SW)

Use of sediment weirs

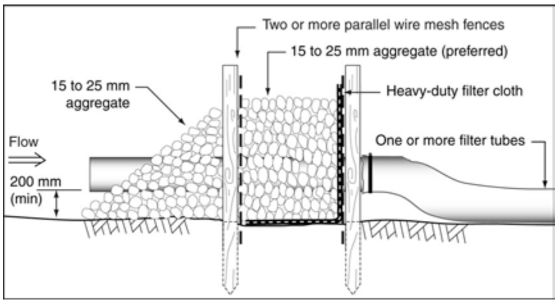
- A Type 2 sediment trap
- Sediment weirs are used where space is limited (i.e. when space is not available for installation of a *Rock Filter Dam*).
- Sediment weirs can be very effective in conditions of high flow rates where the sediment trap may be subjected to regular over-topping flows.
- They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

Use as an instream sediment trap

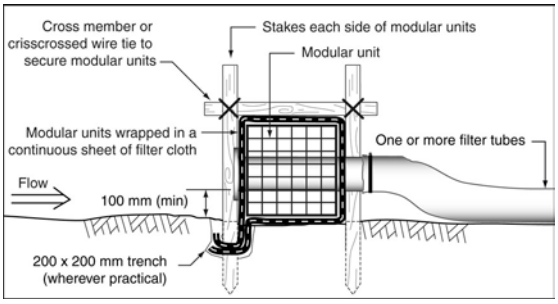
- Sediment weirs can also be used as temporary instream sediment traps during the construction phase of instream works within drainage channels and minor waterways that are likely to experience only minor dry weather flows.
- *Filter Tubes* can be incorporated into the sediment weir to increase the treatable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



Sediment weir with aggregate filter



Sediment weir with filter tube incorporated into the weir



Modular sediment trap

Modular sediment trap (MST)

- A Type 2 or 3 sediment trap
- Modular systems can be used to form a sediment weir; however, a suitable aggregate filter is usually still required on the up-slope face in order to achieve the required flow rate and settling pond surface area.
- Special pollutant adsorbent bags can be placed inside the modular units.
- *Filter Tubes* can be incorporated into the plastic blocks to increase the allowable treatment flow rate.

Sediment basins (SB) – Type C (dry) basins

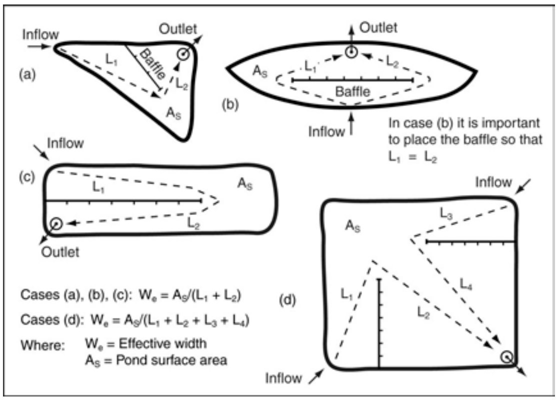
Sediment basin – dry basin

Use of Type C sediment basins

- A Type 1 sediment trap
- Type C basins are best suited to coarse-grained soils.
- Used when a major (Type 1) sediment trap is required when working in areas containing coarse-grained, good settling soils.
- Sediment basins are generally required if the soil disturbance exceeds 0.25 ha.

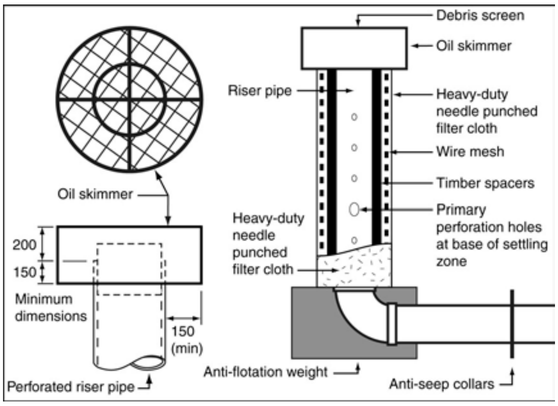
Internal baffle (submerged)

- Internal baffles help to control water flow and improve settlement characteristics.

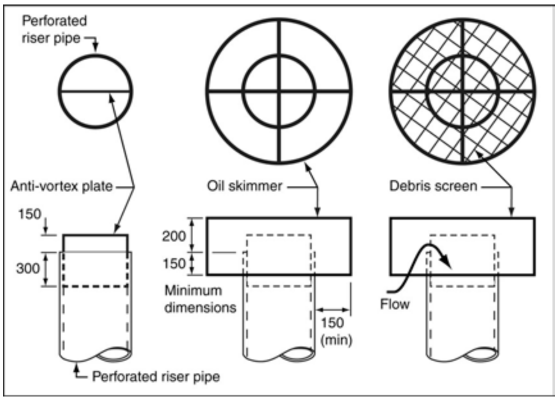


Riser pipe outlet

- Anti-vortex plates reduce the risk of floating debris being drawn into the outlet.



'Skimmer' type outlet system



Anti-vortex and debris screen details

Sediment basins (SB) – Type F & D (wet) basins

Sediment basin – wet basin

Use of Type F & D sediment basins

- Type F (fine soils) and Type D (dispersive soils) basins are best suited to fine-grained and/or dispersive soils.
- Used when a major (Type 1) sediment trap is required when working in areas containing fine-grained, dispersive or poor settling soils.
- These basins can also be used when regular de-watering operations are required.
- Sediment basins are generally required if the soil disturbance exceeds 0.25 ha.

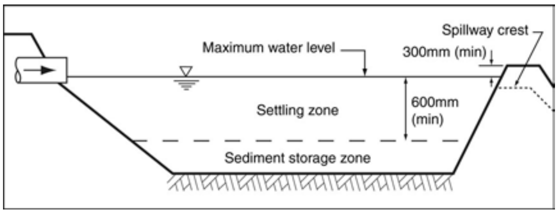
Fully recessed wet basin

Operation of Type F & D basins

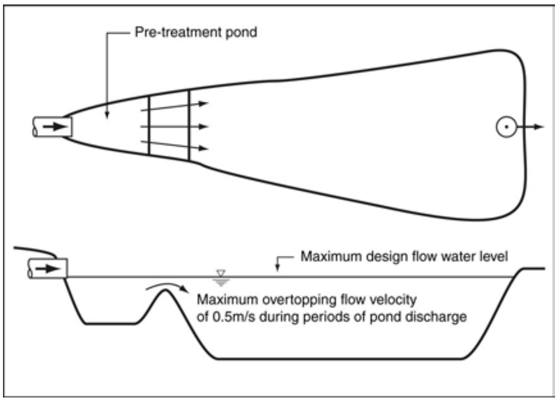
- Type F and Type D basins are operated in a 'wet' mode, and thus are often referred to as wet basins.
- Water must be retained within the basin and treated (flocculated) until the required water quality (usually 50 mg/L TSS) is achieved.
- The basins **must** be de-watered as soon as practical such that the basins are (ideally) empty prior to the next storm event.

De-watering of basin

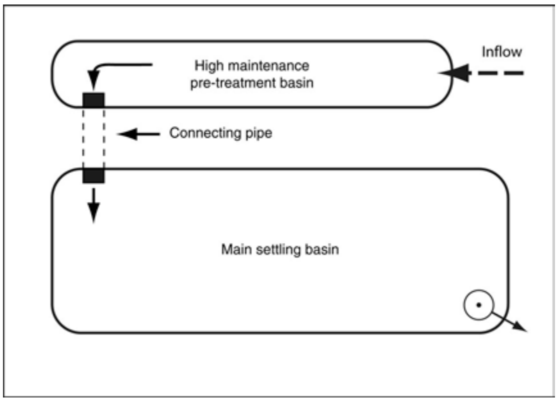
- Basin de-watering is normally achieved through the use of pumps.
- It is important to ensure that the pump's intake pipe does not rest or come into close contact with the settled sediment.



Wet basin



Basin with coarse sediment pond



Basin with pre-treatment pond

Sediment basin spillways

Spillway formed with fill embankment

Spillway formed within virgin soil

Seepage control a spillway crest

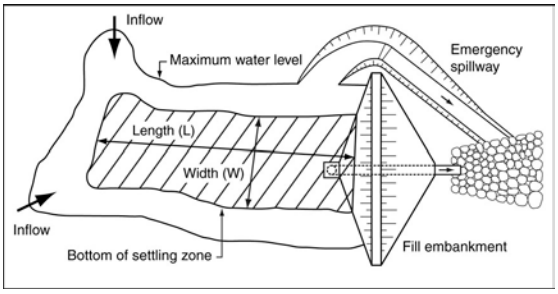
Inappropriate spillway crest profile

Function of a basin spillway

- All sediment basins, not fully recessed below natural ground level, will required the construction of a formally designed emergency spillway.
- The spillway must have a well-defined channel profile that fully contains the nominated design storm 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 persons.

Preferred location of spillways

- Ideally, the emergency spillway should be constructed in virgin soil (i.e. around 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 across the crest of the spillway. Seepage control is required so that the settling pond can achieve its required maximum water level prior to discharging down the spillway.
- Concrete capping of the spillway crest can be used to control excess seepage flows.
- Failure to control seepage flows may result in the basin failing to achieve the required treatment standard.

Preferred crest profile

- It is important to ensure that the spillway crest has sufficient depth and width to fully contain the nominated design storm peak discharge.
- The spillway crest normally requires a greater depth, but equal width, to that of the downstream face of the spillway.
- Photo (left) shows a spillway crest with inadequate depth or flow profile.

De-Watering Sediment Control Measures

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

Table 23 – De-watering sediment control techniques

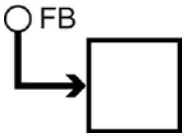
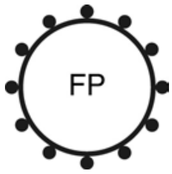
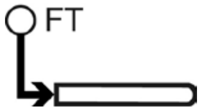
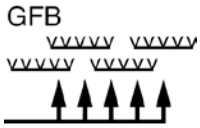
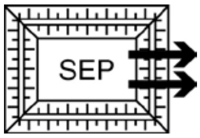
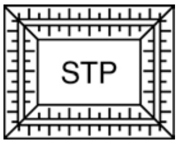
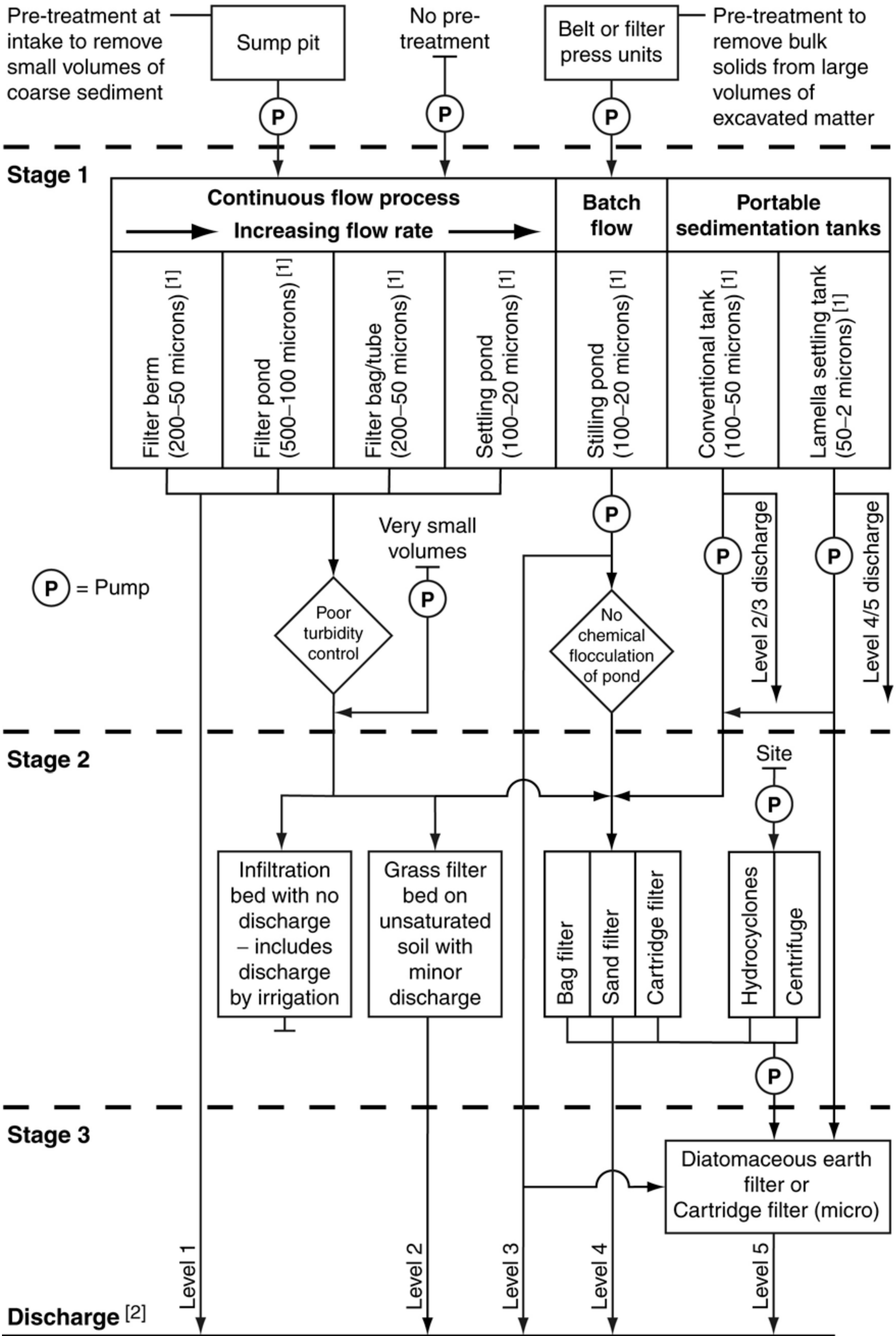
Technique	Code	Symbol	Technique	Code	Symbol
Filter Bag	FB		Filter Fence	FF	
Filter Pond	FP		Filter Tube	FT	
Filter Tube Dam	FTD		Grass Filter Bed	GFB	
Portable Sediment Tank	PST		Settling pond	SEP	
Stilling Pond	STP		Sump Pit	SP	

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 **not** 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



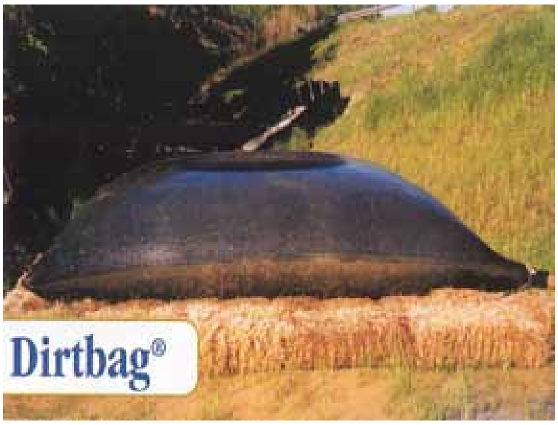
	Level 1	Level 2	Level 3	Level 4	Level 5
Microns (um):	200–50	150–50	100–20	50–20	10–1
TSS (mg/L):	> 100	> 50	100–20	50–20	< 20

NTU (approximation) = TSS x (0.9 + 2.9(clay fraction of source material))

[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 fence

Filter pond

Filter tube

Filter bags (FB)

- Commercial filter bags are suitable for the treatment of low flow rates.
- The bags collect only coarse-grained sediments, within minimal control of turbidity.
- 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 (drain plug removed) can reduce the complications of removing the used bags.

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 (*Buffer Zone*).

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 used on highly porous soil.
- Diameter pond and the composition of the filter wall depend on the soil type and design flow rate.
- Performance can be improved if incorporated into a substantial grass filter bed (*Buffer Zone*).

Filter tubes (FT)

- Commercial filter tubes are suitable for the treatment of low to medium flow rates.
- The filter tubes collect only coarse-grained sediments, within 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 bag up-slope of a substantial grass filter bed (*Buffer Zone*) 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 employ laminar flow conditions to optimise the settlement of non-dispersive soils.
- 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 sediments.

Stilling ponds (STP)

- Stilling ponds do not incorporate a free draining outlet system.
- The ponds are operated similarly 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 in instream works.

Truck-mounted belt press

Mobile treatment units

- Wide variety of commercial water treatment units.
- Large treatment systems include vacuum drum filters, filter-presses, belt-presses (left), truck-mounted centrifuges, and banks of hydrocyclones.
- Small mobile units can be assembled from a variety of swimming pool filters mounted to 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 0.045mm 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.