Principles of Construction Site Erosion and Sediment Control

– A training tool for the construction industry

Catchments & Creeks

Version 1, 2012

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Disclaimer

Significant effort has been taken to ensure that this document is representative of current 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.

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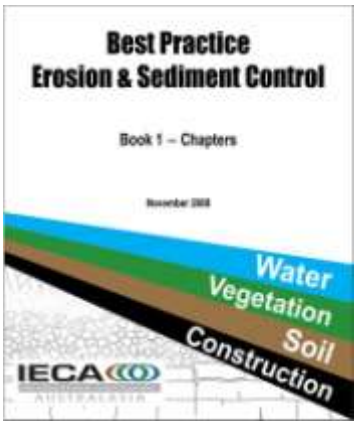
The caption and/or associated discussion should **not** imply that the actual 'site' shown within the photograph represents either good or bad site practice. The actual circumstances (i.e. site conditions and history) of each site are not known in each case and may not be directly relevant to the discussion in which the photo is used. This means that there may be a valid, site-specific reason why the designer chose the design or layout depicted in the photo.

Principal reference documents:

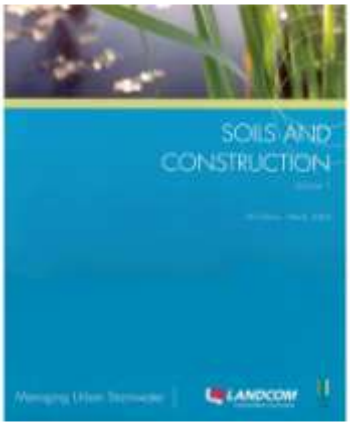


IECA (Rainbow Book) 2008

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

This pictorial guide to the key principles of construction site erosion and sediment control practices has been developed from chapter 2 of this publication.

The principles of construction site erosion and sediment control where in part developed from the three reference documents presented below.



Landcom (Blue Book) 2004

Soils and Construction – Managing Urban Stormwater, Volume 1

Forth Edition, Landcom, New South Wales Government, 2004

CaLM (Green Book) 1992

Urban Erosion and Sediment Control

Edited by J.S. Hunt, NSW Department of Conservation and Land Management, 1992

North Carolina, 1993

Erosion and Sediment Control Planning and Design Manual

North Carolina Sedimentation Control Commission; North Carolina Department of Natural Resources and Community Development; and the Division of Land Resources Land Quality Section, 1993

Contents

Introduction to construction site erosion and sediment control

Sediment-laden runoff from work site

The objective

- To take all reasonable and practicable measures to minimise short and long-term soil erosion and the adverse effects of sediment transport.
- In this context the terms:
  - 'reasonable' means an action based on sound judgement and affordable cost;
  - 'practicable' means an action capable of being put into practice with the available means or with reason or prudence.

Sediment released into ocean

Environmental duty

- The Environmental Duty applies to all persons.
- The Environmental Duty applies to all activities on a construction site.
- Such an Environmental Duty may be described in general terms as:
  - To take all reasonable and practicable measures to prevent or at least minimise environmental harm.

Loose mulch displaced by storms

The first rule of ESC

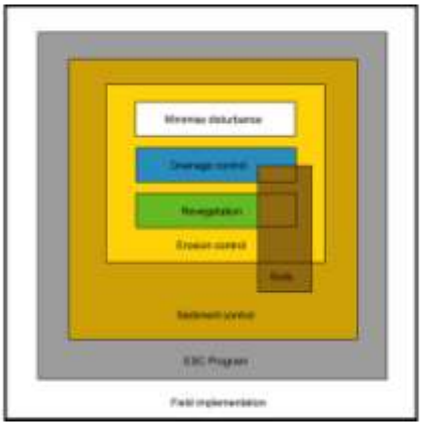
- The first thing to acknowledge within the *Erosion and Sediment Control* profession is that there is an **exception** to almost every rule and recommendation.
- The fact that a control measure is observed to work well in one location does not mean that it will work well in another location.
- Similarly, the fact that a control measure fails in one region of Australia does not mean that the technique will not be useful within another region.

Common sense gone missing!

Application of 'common sense'

- Erosion and sediment control practices **must** represent an appropriate balance between the application of the ideal design philosophy and the application of *common sense*.
- No rule or recommendation should be allowed to overrule the application of a unique, site specific solution where such a solution can be demonstrated to satisfy the principle objective and the specified performance standard.

Key principles of erosion and sediment control



Inter-related management principles

Ten key principles to best practice ESC

- *Erosion and sediment control* (ESC) should **<u>not</u>** be viewed as a single exercise or activity.
- Best practice erosion and sediment control on construction sites is primarily based on the utilisation of ten key principles.
- Each of these key principles can be expended into a series of sub-principles.
- A sound working knowledge of these principles is a cornerstone to best practice construction site management.

Development integrated into hillside

Key principle No. 1

Appropriately integrate the development into the site.

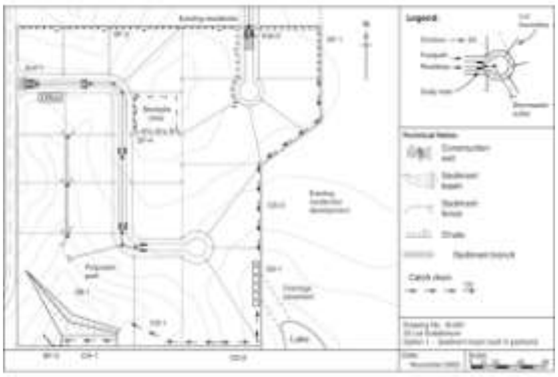
- Best practice development planning involves the determination of the appropriate use for a given site and how best to accommodate that land use within a development layout.
- To achieve this, it is essential to investigate the site conditions including the soil, water, vegetation and topographic features of the property.

Construction site

Key principle No. 2

Integrate erosion and sediment control issues into site and construction planning.

- During the planning of a building or construction project, consideration must be given to how the site layout and construction process can best achieve the principal environmental objective of taking all reasonable and practicable measures to prevent or minimise environmental harm.



Erosion and sediment control plan

Key principle No. 3

Develop effective and flexible Erosion and Sediment Control Plans based on the anticipated soil, weather, and construction conditions.

Erosion and sediment control plans (ESCPs) need to walk a fine line between being formal plans that site operators must follow, and being flexible plans that still allow site personnel to use their ‘common sense’ to:

- Adjust to changing site conditions.
- Focus on the **intent** of any technical notes rather than their literal meaning.

Key principles of erosion and sediment control

Minimal disturbance of allotments

Key principle No. 4

Minimise the extent and duration of soil disturbance.

- This principle has many benefits, including:
  - reduced soil erosion
  - reduced release of fine colloidal soil particles that cause turbit runoff
  - promotion of the rapid stabilisation and revegetation of soil disturbances

Diversion of "clean" run-on water

Key principle No. 5

Control water movement through the site.

- The proper management of stormwater runoff during the construction phase is critical to the implementation of effective erosion and sediment control.
- The importance of stormwater management generally increases with increasing rainfall intensity.
- This means drainage control becomes increasingly important the closer you get to northern Australia.

Hydro-mulching

Key principle No. 6

Minimise soil erosion.

- Soil erosion is the process through which the effects of wind, water, or physical action, displace soil particles causing them to be transported.
- The main factors affecting soil scour are rainfall erosivity, soil erodibility, slope length, slope steepness, soil cover, and the surface flow conditions (i.e. flow type, velocity, duration, and frequency).

Recently stabilised subdivision

Key principle No. 7

Promptly stabilise disturbed areas.

- A healthy and continuous vegetative cover is one of the most effective forms of erosion control.
- Most importantly, vegetation protects the soil against raindrop impact erosion.
- Vegetation also binds the underlying soil to improve its structural strength, improves the soil's infiltration capacity, and increases evaporation thereby decreasing overall stormwater runoff.

Key principles of erosion and sediment control

Sediment basin

Key principle No. 8

Maximise sediment retention on the site.

- It is usually impractical to prevent all soil erosion on construction sites; thus some degree of sediment control is always required.
- The primary purpose of most sediment control measures is to trap the coarser sediment fraction.
- Few sediment traps can capture fine sediments; even fewer can reduce turbidity levels in stormwater runoff.

Site maintenance

Key principle No. 9

Maintain all ESC measures in proper working order at all times.

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

Water samples

Key principle No. 10

Monitor the site and adjust ESC practices to maintain the required performance standard.

- Erosion and Sediment Control Plans (ESCPs) are living documents that can and should be modified as site conditions change, or if the adopted measures fail to achieve the required treatment standard.
- If a site inspection detects a failure in the adopted ESC measures, then the source of this failure must be investigated and corrected.

The influence of site conditions

Regional issues

- Even though the above key principles are applicable to all sites, their application can vary significantly from site to site, and region to region.
- In the northern (tropical) regions of Australia, the primary focus is on effective drainage control. Without effective drainage control, all erosion and sediment controls can be washed away!
- In the southern (temperate) regions, the focus moves to erosion control, or possible sediment control.

Appropriate Integration of the Development into the Site

Appropriate integration of the development into the site

Development integrated into landscape

Key principle No. 1

Appropriately integrate the development into the site.

- Best practice development planning involves the determination of the appropriate use for a given site and how best to accommodate that land use within a development layout.
- To achieve this, it is essential to investigate the site conditions including the soil, water, vegetation and topographic features of the property.

Retention of natural waterways

Principle 1.1

Developments should aim to utilise the existing topography to minimise the need for extensive land reshaping and surface modifications.

- Urban developments that integrate well into the existing topography have many benefits; not the least is minimal soil disturbance.
- In today's market, extensive land reshaping is simply the outcome of a lazy land-use planner!

Elevated "pole home"

Buildings must suit the topography

- Consider the incorporation of elevated pole homes or suspended slab construction on steep sites to avoid the need for significant land reshaping.

Minimal disturbance of existing trees

Avoid unnecessary land clearing

- Investigate the site's land use capabilities and site constraints.
- Plan the development layout to avoid the disturbance of:
  - slopes that will be difficult to stabilise
  - highly valued vegetation and wildlife habitats
  - dispersive or potential acid sulfate soils
- Failure to adopt these basic principles can result in the development causing unnecessary environmental harm.

Water sensitive urban design

Urban stormwater treatment wetland

Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) seeks to:

- Preserve the existing topography
- Integrate public open space with stormwater drainage corridors
- Preserve the natural water cycle
- Utilise surface water and groundwater as a valued resource
- Protect water quality
- Minimise the capital and maintenance costs of drainage works

Roadside bio-filtration cell

Water Sensitive Road Design

Roadways can incorporate many water sensitive features, including:

- Reduced road widths
- Stormwater detention/retention
- Stormwater treatment systems
- Pollution containment systems
- Indirectly connected impervious surface areas
- Appropriate, low leaf-fall, street trees

Retention of waterway corridors

Retention of natural waterways

- Consideration should be given to the retention of existing 'natural' waterways in the following circumstances:
  - Waterways identified as important within a Waterway Corridor Plan, Catchment Management Plan, or similar strategic plan.
  - Natural waterways with well-defined bed and banks, and associated floodplain/s or riparian corridors.

Wetland formed from sediment basin

Stormwater management

- In addition to integrating the development into the existing site conditions, the permanent stormwater drainage and stormwater quality requirements of the site need to be appropriately integrated into the development.
- Ideally, temporary sediment basins utilised during the construction phase should be designed in a manner that allows their later conversion into permanent stormwater retention basins and/or treatment ponds.

Integration of ESC Issues into Construction Site Planning

Integration of ESC issues into construction site planning

New resort development

Key principle No. 2

Integrate erosion and sediment control issues into site and construction planning.

- During the planning of a building or construction project, consideration must be given to how the site layout and construction process can best achieve the principal environmental objective of taking all reasonable and practicable measures to prevent or minimise environmental harm.

Site office

Site planning

- Construction site planning involves the scheduling of construction activities and the planning of the site layout:
  - The site office should be located close to the site entrance to manage the safety of site visitors.
  - On large sites, the site office and car park should have all weather surface conditions to minimise mud generation during wet weather.
  - Material stockpiles should be located away from overland flow paths.

On-site stockpile of ESC fabrics

Construction planning

- Construction planning not only involves the scheduling of work activities, but also the programming of temporary erosion and sediment control measures.
- This activity includes:
  - reviewing the approved ESC plans
  - stockpiling emergency ESC supplies, including sediment fence and erosion control fabrics

Sediment deposition within urban wetland

Long-term impacts from short-term works

- The construction phase may be relatively short in duration compared to the operational phase of the development, but its potential impact on the land and surrounding environment can be both significant and long term.
- Sediment deposition within creeks and wetlands can cause long-term changes to aquatic ecosystems and plant species (e.g. through weed infestation).

Integration of ESC issues into construction site planning

Construction site with sediment basins

Spatial requirements

- A critical component of site management is the early identification of the spatial requirements of major sediment traps, such as sediment basins.
- The spatial requirements of a sediment basin can be significantly greater than just the size of the settling pond.
- Consideration needs to be given to the size of the basin's:
  - embankment
  - emergency spillway
  - outlet and energy dissipater

Topsoil stockpile

Material stockpiles

- Sufficient land area must be provided for the short-term stockpiling of construction materials.
- These stockpiles should ideally be located within areas that would eventually need to be disturbed anyway.
- Stockpiles of erodable materials (e.g. earth and sand) need to be located within the site's sediment control zone.

Minimal disturbance of existing vegetation

Avoid unnecessary land clearing

- Adopt construction practices and construction methods that minimise soil erosion and unnecessary land clearing.
- Wherever practical, retain vegetation cover on property allotments so that home -owners can optimise tree retention based on their own needs.
- Restrict the movement of construction equipment to future road reserves to avoid unnecessary soil compaction and tree damage.

Slope being prepared for revegetation

Allow for prompt site rehabilitation

- Program construction activities so disturbed areas can be stabilised as soon as possible after earthworks have been completed.
- Site rehabilitation and site revegetation should **not** be treated as separate phases of construction, but **MUST** be an integral part of the full construction process.
- If site rehabilitation is performed under a separate contract, then both contractors must be able to operate on the site simultaneously.

Integration of ESC issues into construction site planning

Early installation of stormwater pipe

Early installation of drainage system

- The construction process should allow for the early installation of the site's permanent drainage system.
- Such actions can assist in the diversion of up-slope 'clean' stormwater (run-on water) through the site and around major sediment traps.
- The permanent drainage system can also be used to isolate the movement of 'clean' and 'dirty' water, thus improving the efficiency of sediment traps.

Clean water diversion drain

Definition of 'clean' water

- Clean water is water that either:
  - enters the property from an external source and has not been further contaminated within the property; or
  - water that has originated from the site and is of such quality that it cannot be further treated.
- Wherever practical, clean water should be carried through a site without becoming contaminated.

Temporary roof water connection

Early connection of roof water

- On building sites, the permanent stormwater drainage system should be installed and made operational prior to roof installation.
- Roof water downpipes (temporary or permanent) should be connected to the stormwater drainage system immediately after the roof is laid.

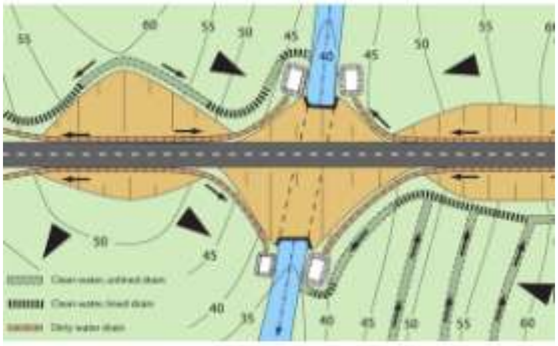


Diagram supplied by Catchments & Creeks Pty Ltd

Sediment-laden water directed to basins

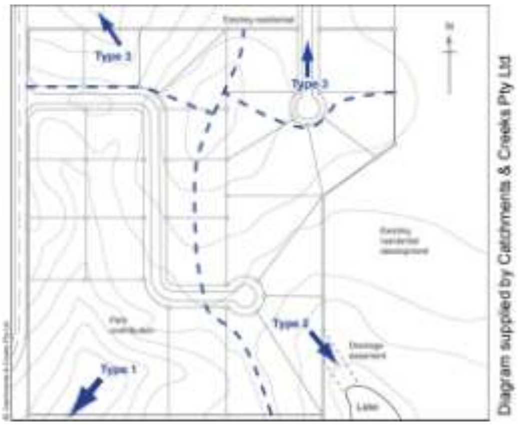
Locating major sediment traps

- It is usually more effective to:
  - locate major sediment traps away from active construction zones and then direct dirty water to these traps, than to
  - locate sediment traps immediately adjacent the soil disturbance where they could potentially interfere with construction activities
- Sediment basins should be placed in locations where they can remain functional throughout the full construction period.

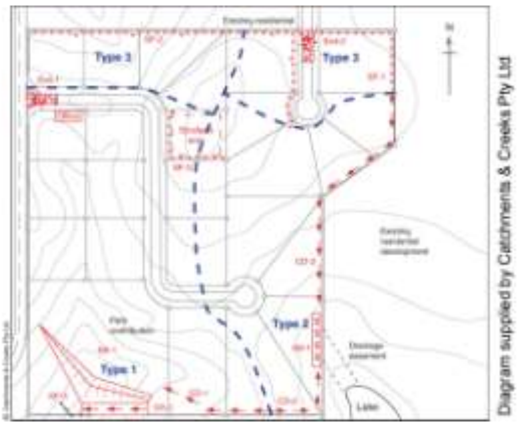
Integration of ESC issues into construction site planning

Water quality testing

Field testing of soil pH



Ranking of sub-catchment erosion risk



Site controls based on erosion risk

Principle 2.1

Ensure the extent and complexity of the data collected during the planning phase is commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance.

- Effective site planning relies of the collection of site data, including:
  - soil testing
  - vegetation maps
  - water quality testing

The importance of soil testing

- Soil data is collected for a variety of reasons including:
  - assess the site's erosion risk
  - identify the existence of potential soil problems such as unstable, dispersive, or acid sulfate soils
  - assist in the selection, design and operation of various drainage, erosion, and sediment control measures
  - assist in the design of site stabilisation measures including site revegetation

Principle 2.2

Identify high-risk areas and high-risk construction activities during site planning.

- Erosion Risk Mapping can be used to identify areas of low, medium, high and extreme erosion risk.
- Soil loss rates can also be used as an indicator of the erosion risk.
- High-risk sites may require the preparation of a *Conceptual Erosion and Sediment Control Plan* during initial site planning.

RUSLE soil loss analysis

The Revised Universal Soil Loss Equation (RUSLE) is commonly used to predict long-time *average* soil loss rates.

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

A = annual soil loss due to erosion (t/ha/yr)

R = rainfall erosivity factor

K = soil erodibility factor

LS = combined slope length & gradient factor

C = cover factor

P = land management/practice factor

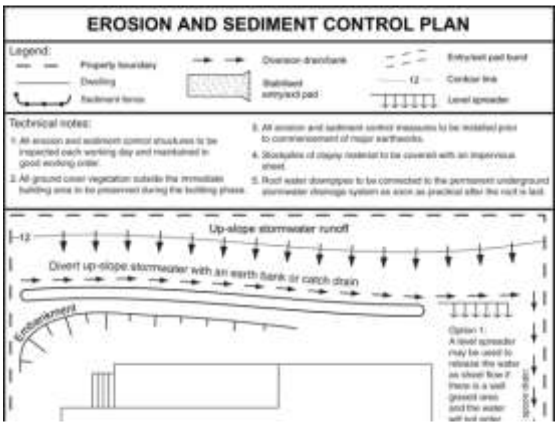
Development of Effective and Flexible ESC Plans

Development of effective and flexible ESC Plans

Erosion and sediment control plan

Failed protection of on-site wetland

Soil map



Building site ESCP with technical notes

Key principle No. 3

Develop effective and flexible Erosion and Sediment Control Plans based on the anticipated soil, weather, and construction conditions.

Erosion and sediment control plans (ESCPs) need to walk a fine line between being formal plans that site operators must follow, and being flexible plans that still allow site personnel to use their 'common sense' to:

- Adjust to changing site conditions.
- Focus on the **intent** of any technical notes rather than their literal meaning.

Site issues and concerns

- Best practice erosion and sediment control involves the identification of local issues and concerns, including:
  - the nature of the land disturbance
  - anticipated site constraints (topography, soils, vegetation, water availability)
  - local environmental values identified within Stormwater Management Plan
  - potential risks to environmental values as a result of the project

Soil survey and mapping

- Where appropriate, a soil map should be prepared for the site to identify:
  - soil K-factors (a measure of erosivity)
  - location of sandy soils
  - location of clayey soils
  - location of dispersive soils
  - location of potential acid sulfate soils

Use of technical notes on plans

- Critical site issues can be identified on ESCPs through the use of technical notes.
- Technical notes can also be used to identify:
  - short-term ESC measures required in the event of an imminent storm
  - typical responses to common erosion and sediment control problems
  - ESC maintenance requirements

Development of effective and flexible ESC Plans

Results of an non-seasonal storm

Principle 3.1

Appropriately amend the adopted erosion and sediment control measures, and where necessary, revise the Erosion and Sediment Control Plan (ESCP), if the implemented works fail to achieve the 'objective' of the ESCP, the required performance standard, or the State's environmental protection requirements.

- Erosion and sediment control plans should **not** be considered static documents.
- It is important to adjust and adapt to changing site conditions.

Inspecting storm damage

Changing site conditions

- Additional erosion and sediment control measures must be implemented and a revised ESCP prepared if site conditions change significantly from those considered during development of the original ESCP.
- Do **not** assume dry conditions will exist—tropical areas may have well-defined seasonal weather, but non-seasonal storms can always occur.

Poor runoff water quality

Failure to achieve water quality objectives

- An amended ESCP should also be prepared if the implemented measures fail to achieve:
  - the objective of the ESCP;
  - the required performance standard; or
  - the state's environmental protection requirements.

Site meeting

Looking for more efficient outcomes

- ESCPs are typically prepared by consulting firms, not contractors.
- Once the works commence, it is typical for site personnel to request amendments to plans because:
  - they have changed the construction program
  - they have experience with alternative ESC materials or techniques
  - they see opportunities for improved efficiency

Minimising the Extent and Duration of Soil Disturbance

Minimising the extent and duration of soil disturbance

New subdivision with retained vegetation

Key principle No. 4

Minimise the extent and duration of soil disturbance.

- This principle has many benefits, including:
  - reduced soil erosion
  - reduced mobilisation of fine colloidal soil particles that cause turbit runoff
  - prompt stabilisation of disturbances areas

Wind-generated construction site dust

Principle 4.1

Construction schedules should aim to minimise the extent and duration that soils are exposed to the erosive effects of wind, rain and flowing water.

- Most construction-related environmental harm relates to the displacement of clay-sized particles in the form of turbid runoff.
- Unfortunately it is very difficult to capture these clay-sized particles.
- Thus, the key to minimising ecological harm is to minimise the *extent* and *duration* of soil exposure.

Cropping land ready for seeding

Agricultural activities

- Soil disturbances during most agricultural activities do **not** have the same potential to cause environmental harm.
- Agricultural activities expose topsoils to rainfall, not subsoils, as is the case in construction.
- The exposed topsoil is generally less erodible and less likely to release fine colloidal particles compared to subsoils.
- The topsoil is generally loose and porous, thus raindrop impact is reduced and runoff volumes are reduced.

Excessive wet-season land clearing

Limiting the extent of land clearing

- The extent of soil disturbance can be reduced by placing restrictions on the allowable width of soil disturbance relative to the construction footprint.
- Ideally, soil disturbances should be limited to no further than 2 to 5 metres from the edge of the building work.
- The allowable extent of land clearing should vary from the dry season to the wet season.

Minimising the extent and duration of soil disturbance

Prompt revegetation of road batters

Minimise the duration of soil exposure

- It is generally more critical to limit the **duration** of soil exposure rather than the total extent of exposure.
- For example, a 1 ha development fully exposed for 12 months has the potential to cause more soil erosion than a 10 ha development that is appropriately managed such that less than 1 ha is exposed at any given time over the same construction period.

Staged land clearing

Principle 4.2

Wherever reasonable and practicable, land clearing and site rehabilitation must be appropriately staged to minimise the duration of soil exposure and the area of exposure at any given instant.

- Two aspects of construction programming that can affect soil exposure are the *Staging of Works* and the *Construction Sequence*.
- Site rehabilitation measures should be staged in sequence with the staging of earthworks.

Staged exposure and rehabilitation

Limits on vertical exposure

- One means of controlling the staged disturbance and rehabilitation of steep earth batters is to contractually limit the unprotected exposure of earth batters to a maximum of 3 vertical-metres at any given time.
- This can be achieved by placing a *Hold Point* in the construction contract specifying that cutting and filling operations must not continue until the previous 3 vertical-metres of the batter are suitably stabilised (e.g. mulched).

Turfing

Effective utilisation of turf

- In critical areas, such as drainage channels and overland flow paths, exposed soils should be stabilised with turf rather than grass seeding.
- Turfing allows the soil disturbance to instantly achieve 100% cover.

Minimising the extent and duration of soil disturbance

Temporary grassing of road works

Principle 4.3

As long as the risks of rainfall or strong winds exist on a site, land disturbances should be restricted to those areas required for the current stage of works.

- Restrictions on land clearing and the total area of exposure generally only apply during periods of the year when there is a risk of significant rainfall or strong winds.
- Greater areas of exposure can be tolerated during periods of a year when rainfall is unlikely to occur.

Seasonal storm

Principle 4.4

Wherever reasonable and practicable, major land disturbances should be scheduled for the least erosive periods of the year.

- Major land disturbances, and disturbances of high-risk areas, should be scheduled for the least erosive periods of the year.
- Large developments should be appropriately staged such that land disturbances are confined to manageable areas, especially during the wet season.

Temporary closure of steep access track

Principle 4.5

Disturbances to high and extreme erosion risk areas should be minimised, if not totally avoided, especially during the most erosive periods of the year.

- The disturbance of land designated as having a *high* or *extreme erosion risk* should be avoided wherever possible.
- Any soil disturbances must attract high-level erosion and sediment control requirements, and strict rehabilitation scheduling and design standards.

Severe tunnelling within a dispersive soil

Principle 4.6

Wherever reasonable and practicable, the disturbance of dispersive or potential acid sulfate soils should be minimised, if not totally avoided.

- Dispersive soils are highly susceptible to deep, narrow rilling on exposed slopes.
- These soils must be appropriately treated or buried under an appropriate layer (100 to 300 mm thick) of non-dispersive soil before placing any revegetation or erosion control measures.

Minimising the extent and duration of soil disturbance

Acidic runoff drains into a pond

Acid sulfate soils

- Potential acid sulfate soils occur naturally over extensive low-lying coastal areas, predominantly below an elevation of 5 m Australian Height Datum (AHD).
- If disturbed, potential acid sulfate soils can become acidic and release acidic runoff.
- Works to be avoided within potential acid sulfate soils include the construction of sediment basins, and the construction of drains that unnecessarily lowers groundwater levels.

Tree clearing with minimal soil disturbance

Principle 4.7

Disturbances to the existing ground cover should be delayed as long as possible.

- One of the best ways to minimise soil erosion is to delay disturbances to any ground cover (such as grasses, fallen leaves, and mulches) until the last practical moment.
- If tree clearing is required well in advance of future earthworks, then try to delay the grubbing (root removal) of the area until the last practical moment.

Site office

Principle 4.8

Construction procedures should aim to minimise the extent of unnecessary soil disturbance, including any disturbances outside the designated work area.

- Ideally, the site office, car park and material stockpiles should be located in areas that would have eventually been disturbed as part of the essential works.

Marking the limits of clearing

Protection of existing vegetation

- Buffer zones and non-disturbance areas need to be protected from unnecessary disturbance through the use of physical barriers.
- These barriers may consist of marker tape or light fencing.
- In addition, detailed instructions should be placed on ESCPs and appropriate site supervision should be organised.

Drainage Control Practices

Drainage control practices

Control of "clean" run-on water

Loss of mulch by storm flows

Protection of permanent storm drain

Erosion along channel invert

Key principle No. 5

Control water movement through the site.

- The proper management of stormwater runoff during the construction phase is critical to the implementation of effective erosion and sediment control.
- The importance of stormwater management generally increases with increasing rainfall intensity.
- This means drainage control becomes increasingly important in northern Australia.

More than just *Erosion Control!*

- *Drainage Control* practices have traditionally been viewed as a component of on-site *Erosion Control*.
- However, effective site drainage not only aims to control erosion within drainage channels, but also:
  - the separation of 'clean' and 'dirty' water; and
  - the diversion of 'clean' water around sediment traps.
- These latter aims are more closely linked to the aims of on-site *Sediment Control*.

Principle 5.1

The permanent and temporary drainage requirements of a site need to be appropriately considered during development of the Erosion and Sediment Control Plan.

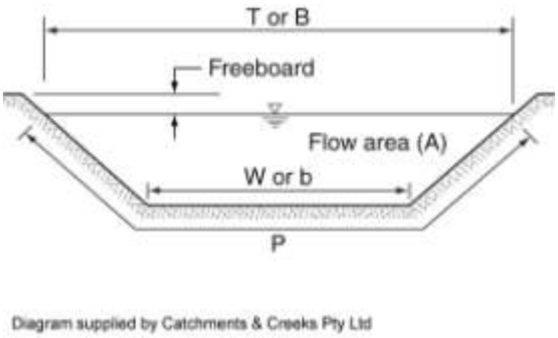
- Failure to recognise the drainage requirements of a construction site can severely impact on the outcomes of an erosion and sediment control program.
- The effective management of stormwater involves managing the velocity, volume and location of stormwater runoff.

Principle 5.2

Flow velocities need to be limited to the maximum allowable velocity for each individual drainage system.

- Drainage channels need to be designed and constructed such that the flow velocity does not exceed the maximum allowable flow velocity for the channel' s surface conditions.
- Excessive flow velocities can cause channel erosion, usually along the invert (bottom) of the drain.

Drainage control practices



Channel geometry and flow conditions

Temporary diversion drain

Unlined catch drain

Poor sediment basin spillway design

Calculation of flow velocity

- The **average** channel flow velocity may be calculated using Manning's equation:

$$V = (1/n) \cdot R^{2/3} \cdot S^{1/2}$$

where:

V = average flow velocity (m/s)

n = Manning's roughness coefficient

R = hydraulic radius (m) = A/P

A = Effective flow area of channel (m^2)

P = Wetted perimeter of flow (m)

S = channel slope (m/m)

Allowable flow velocity

- Drainage channels are designed to achieve an average flow velocity that is below the scour velocity of the surface material.
- This design velocity is referred to as the *allowable flow velocity.*
- Typical design values are:
  - 1.5 to 2.0 m/s for grass-lined channels
  - 1.5 to 3.0 m/s for 100 to 350 mm rock
  - 1.3 to 5.0 m/s for channels lined with temporary *Erosion Control Mats*

Unlined drains

- Not all drainage channels need to be lined with erosion-resistant material.
- If the drain can be formed at a suitable slope (S), then the flow velocity may be low enough to allow an unlined drain.
- The allowable flow velocity for unlined drains vary with the soil type:
  - 0.3 m/s for extremely erodible soils
  - 0.45 m/s for sandy soils
  - 0.5 m/s for sandy loams
  - 0.6 m/s for non-dispersive silty loams

The need for appropriate training and experience

- Choosing an appropriate value for the Manning's roughness (n) requires experience and training.
- Hydraulic analysis is best carried out by experienced hydraulic engineers.
- Critical structures, such as sediment basin spillways, **<u>must</u>** be designed by qualified hydraulic engineers.
- Inappropriate hydraulic designs can result in significant structure damage, or worse, loss of life.

Drainage control practices

Wide, shallow, grass-lined drain

Temporary drain lined with filter cloth

Rock check dam

Batter chute lined with filter cloth

Controlling flow velocity through appropriate channel design

- Flow velocities within drainage channels can be reduced by:
  - reducing the depth of flow (by increasing the width of the channel)
  - reducing the bed slope
  - reducing the peak discharge (by reducing the effective catchment area, or diverting water away from the channel)
  - increasing the channel roughness

Controlling flow velocity <u>without</u> changing the channel design

- If the channel width, depth, or gradient cannot be altered, then there are two options for controlling invert erosion, either:
  - reduce the flow velocity through the use of *Check Dams*; or
  - increase the effective scour resistance of the drain through the use of a suitable channel liner, such as rock, turf or erosion control mats.

Use of check dams

- Check dams are most effective when used in channels with a gradient less than 10% (1 in 10), i.e. <u>not</u> batter chutes.
- There are basically three types of check dams: sandbags, rock, and synthetic open-mesh check dams (triangular silt berms).
- Sandbags are generally used in shallow drains less than 500 mm deep.
- Rock check dams should only be used in deep drains (i.e. > 500 mm deep).

Use of channel linings

There are basically five types of channel linings, including:

- Temporary, non-woven filter cloth.
- Temporary biodegradable mats—usually made from plant-based products such as jute (hemp) or coir (from coconut tree).
- Temporary, synthetic-reinforced mats.
- Permanent, UV-stabilised, turf reinforcement mats (TRMs).
- Permanent materials such as grass, rock and concrete.

Drainage control practices

Temporary erosion control mat

Temporary erosion control mats

- Temporary mats include both the 100% biodegradable jute and coir products, plus those mats that contain temporary synthetic reinforcing (left).
- Jute and coir-based mats have many advantages and are generally preferred.
- Synthetic reinforced mats usually contain an organic mulch layer reinforced with a synthetic (plastic) mesh that will eventually breakdown under direct sunlight.

New grass growth through a jute mesh

Benefits of a bio-degradable mesh

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

Turf reinforcement mat

Permanent channel linings

- Permanent channel linings most commonly include turf and rock; however, there are also some permanent erosion control mats.
- Turf reinforcement mats (TRMs) are used for the lining of high-velocity, grass-lined channels and drainage chutes.
- **Caution** should be taken when using any synthetic reinforced mats in bushland areas as ground dwelling animals, such as lizards, snakes and birds, can become tangled in the netting.

Turf reinforcement mat

Terminology: 'blankets' vs 'mats'

- When used in areas of concentrated flow, fabric-based channel linings are normally referred to as 'mats'.
- When used on banks to control erosion from raindrop impact and sheet flow, these fabrics are normally called 'blankets'.
- Both products can also be referred to as *Rolled Erosion Control Products* (RECPs).
- Many of the products sold as mats can also be used as blankets, but not all blankets are suitable for use as mats.

Drainage control practices

Bales should not be used to slow the flow

Stormwater diverted around a pit

Road runoff diverted away from a slope

Batter drain cut into a dispersive soil

Principle 5.3

All drainage channels, temporary or permanent, need to be constructed and maintained with sufficient gradient and surface conditions to maintain the required hydraulic capacity.

- Erosion and Sediment Control Plans must clearly identify the size and gradient of all temporary drainage channels.
- All drainage channels (temporary or permanent) need to be inspected regularly for sediment deposition or damage caused by construction vehicles.

Principle 5.4

Wherever reasonable and practicable, up-slope stormwater runoff, whether dirty or clean, needs to be diverted around soil disturbances and unstable slopes in a manner that minimises soil erosion and the saturation of soils within active work areas.

- Diverting clean stormwater runoff around sediment traps helps to improve the efficiency of these sediment traps.
- Ideally, clean water entering a site should be carried through the site without becoming dirty.

Benefits of diverting clean water

Diverting up-slope 'clean' water around active work areas can:

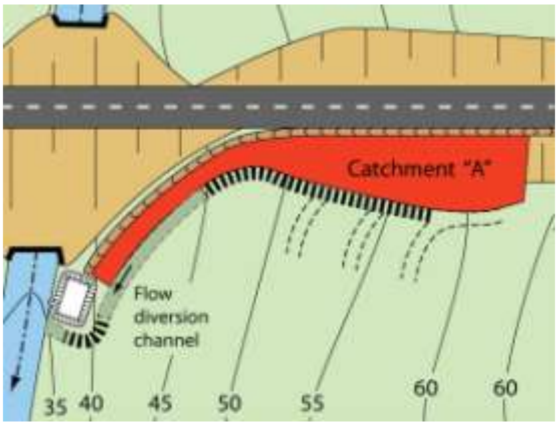
- reduce the generation of mud on the site
- reduce site clean-up costs and down-time following storms
- reduce damage to trenches
- reduce damage to the soil structure resulting from the soil being worked when it is too wet
- reduce the volume of dirty water that needs to be pumped from trenches

Avoid cutting drains into dispersive soils

- Cutting a drain usually results in the exposure of the subsoils to concentrated flows.
- Drains cut into dispersive soils can erode quickly and deeply.
- If the subsoils are dispersive, or otherwise highly erodible, then temporary flow diversion is usually best achieved through the use of *Flow Diversion Banks*.

Drainage control practices

Flow diversion bank



Clean water diversion around a basin

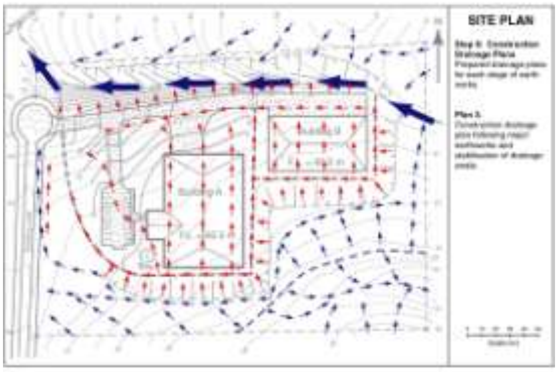


Diagram supplied by Catchments & Creeks Pty Ltd

Construction drainage plan

Early establishment of a diversion drain

Use of 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:
  - stripped topsoil
  - earth
  - sandbags
  - straw bales
- Straw bales generally should not be used for periods longer than a week.

Principle 5.5

To the maximum degree reasonable and practicable, clean water needs to be diverted around sediment traps in a manner that maximises the sediment trapping efficiency of the sediment trap.

- The volume of water requiring treatment by a sediment trap can be reduced by:
  - minimising the area of disturbance
  - diverting clean water around traps
  - promoting the infiltration of rainwater
  - promptly installing the permanent drainage system

Principle 5.6

On disturbances exceeding 1500 m^2, Construction Drainage Plans need to be prepared for each stage of earth works.

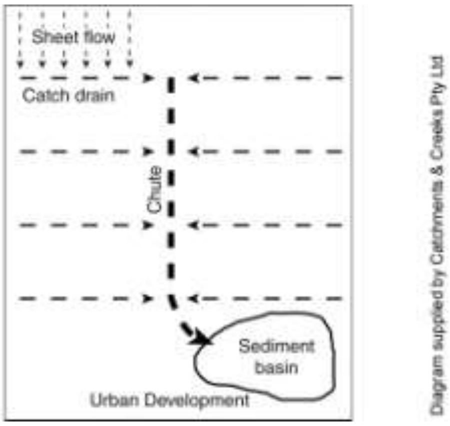
- Construction Drainage Plans need to show:
  - flow entry and exit points
  - areas of sheet flow and lines of concentrated flow (including all drainage channels)
  - sub-catchment boundaries
  - all permanent and temporary roads

Principle 5.7

The construction schedule and ESC installation sequence should allow for the installation of the temporary drainage system, and preferably the permanent stormwater drainage system, as soon a practicable.

- Drainage controls should be functional and stable before earthworks commence.
- This will reduce damage to completed down-slope works, and will allow up-slope sediment-laden runoff to be directed to appropriate sediment traps.

Drainage control practices



Division of site into small drainage areas

Principle 5.8

Long slopes of disturbed or otherwise unstable soil should be divided into small, manageable drainage areas to prevent, or at least minimise, rill erosion.

- *Catch Drains* and *Flow Diversion Banks* can be used to break slope lengths up into manageable drainage areas.
- On steep slopes, benching can be used to collect runoff and move it laterally across the slope to a stable outlet.

Batter slope			Horizontal spacing (m)	Vertical spacing (m)
Percentage	Degrees	(H):(V)		
1%	0.57	100:1	80 [1]	0.8 [1]
2%	1.15	50:1	60	1.2
4%	2.29	25:1	40	1.6
6%	3.43	16.7:1	32	1.9
8%	4.57	12.5:1	28	2.2
10%	5.71	10:1	25	2.5
12%	6.84	8.33:1	22	2.6
15%	8.53	6.67:1	19	2.9
20%	11.3	5:1	16	3.2
25%	14.0	4:1	14	3.5
30%	16.7	3.33:1	12	3.5
35%	19.3	2.86:1	10	3.5
40%	21.8	2.5:1	9	3.5
50%	26.6	2:1	6	3.0

Maximum spacing of drains on slopes

Maximum spacing of drains

- Sheet flow should be allowed to pass down a slope until just before it gains sufficient strength to cause rill erosion.
- Design tables often provide the **maximum** spacing of drains—in some instances the spacing of the drains will need to be less than this maximum value.
- The spacing of the lateral drainage system may need to be reduced in areas of high rainfall intensity, or on sites containing highly erodible soils.

Turf filter strips on steep slope

Use of turf filter strips

- Turf filter strips are commonly used to filter sediment from minor sheet flow.
- Turf strips can also be placed along the contour at an appropriate spacing to help maintain sheet flow conditions down the slope.
- Typically the turf strips are placed at a maximum vertical spacing of 2 m.

Failed drain in a dispersive soil

Principle 5.9

In regions containing dispersive soils, construction details of drainage systems and bank stabilisation works need to demonstrate how these soils are to be stabilised and/or buried under a layer of non-dispersive soil.

- Drains cut into dispersive soils are highly susceptible to deep invert erosion.
- These soils must be appropriately treated or buried, usually under a minimum 100 mm layer of non-dispersive soil, before placing any revegetation or channel liner.

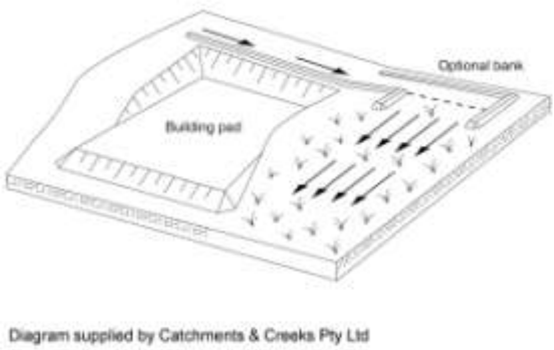
Drainage control practices

Diversion drain outlet structure

Principle 5.10

Appropriate outlet scour protection needs to be placed on all stormwater outlets, chutes, spillways and slope drains to dissipate flow energy and minimise the risk of soil erosion.

- Drainage outlets require:
  - a lawful point of discharge
  - a stable surface that can withstand the expected erosive forces
  - discharge conditions that release the water in a manner that does not cause a nuisance to the public or environment



Use of a level spreader to release flows

Use of level spreaders

- Level spreaders can be used to convert minor concentrated flows back into sheet flow so it can be released onto an even grassed surface, or into undisturbed bushland.
- It is very important that the outlet weir (within the level spreader) is strengthened to protect it from scour

Temporary flow diversion system

Principle 5.11

Building and construction sites need to employ appropriate short-term drainage control measures to deal with impending storms.

- High and extreme erosion risk areas should be protected from possible rainfall by installing temporary drainage systems at the end of each day's work.
- Straw bales can be used to form a temporary (overnight) flow diversion bank to divert stormwater around recently constructed works or excavations.

Temporary downpipes

Principle 5.12

Clean sealed surfaces, such as roofs, should be connected to the permanent underground drainage system (if available) as soon as they are constructed.

- Non-contaminated sealed surfaces, such as roofs, should be connected to the permanent drainage system as soon as practical.
- Roof drainage can be connected with permanent or temporary downpipes.

Drainage control practices

Drainage damage to an access road

Principle 5.13

Adequate drainage controls need to be applied to all permanent and temporary, unsealed roads and tracks to minimise environmental harm caused by runoff from such surfaces.

- Drainage controls will be required on all unsealed roads subject to rainfall, whether the road is permanent or just a temporary access road.
- Stormwater runoff should be encouraged to flow down the side of the road away from the main traffic path.

Temporary culvert crossing

Principle 5.14

Disturbances to natural watercourses and riparian zones need to be minimised wherever possible, and all temporary watercourse crossings need to employ appropriate drainage, erosion, and sediment controls to minimise sediment inflow into the stream.

- Temporary watercourse crossings must be constructed and maintained in a manner that minimises harm to the watercourse.
- The approach roads to all watercourse crossings must be appropriately stabilised.

Temporary bridge crossing

Fish passage considerations

- Consideration will need to be given to fish passage requirements.
- Maintaining fish passage along waterways is most important during periods of fish migration—that is fish passage for reasons of breeding or life cycle requirements.
- Specialist advice should be obtained from government Fisheries officers.

Drainage structure	Anticipated design life		
	< 12 months	12–24 months	> 24 months
Temporary drainage structures [1] Queensland, Northern Territory, and northern Western Australia	1 in 2 year	1 in 5 year	1 in 10 year
Temporary drainage structures [2] New South Wales, Victoria, Tasmania, South Australia and southern Western Australia	1 in 5 year	1 in 10 year	1 in 10 year
Temporary drainage structures (e.g. *Catch Drain, Flow Diversion Bank*) located immediately up-slope of an occupied property that would be adversely affected by the failure or overtopping of the structure. [1,2]	1 in 10 year	1 in 10 year	1 in 10 year
Temporary culvert crossing	Minimum 1 in 1 year ARI hydraulic capacity wherever reasonable and practicable.		

Table sourced from IECA Australasia (2008)

Typical drainage design standard

Principle 5.15

All drainage systems, whether temporary or permanent, need to be designed to an appropriate drainage standard.

- Temporary drainage control measures are designed to a variety of hydraulic standards depending on:
  - the expected life of the structure
  - the risk of environmental harm
  - the potential for risk to life
  - the potential for flood risks

Erosion Control Practices

Erosion control practices

Raindrop impact splash

Hydro-mulching

Straw mulching

Basin full and ready to overflow

Key principle No. 6

Minimise soil erosion.

- Soil erosion is the process through which the effects of wind, water, or physical action, displace soil particles allowing them to be transported.
- The main factors affecting soil scour are rainfall erosivity, soil erodibility, slope length, slope steepness, soil cover, and the surface flow conditions (i.e. flow type, velocity, duration, and frequency).

Principle 6.1

Wherever reasonable and practicable, priority needs to be given to preventing, or at least minimising soil erosion—through drainage and erosion control measures—rather than allowing the erosion to occur and trying to trap the resulting sediment.

Where this is not practical, then all reasonable and practicable measures need to be taken to minimise soil erosion even if the adopted sediment control measures comply with the required treatment standard.

Sediment controls do not replace the need for erosion controls

- Controlling the initial erosion of soils is often the only feasible strategy for minimising environmental impacts.
- Preventing soil erosion is generally more cost-effective than trying to trap the sediment.
- The presence of on-site sediment control measures does **not** negate the need for all reasonable and practicable measures to be taken to minimise soil erosion during all phases of construction.

Limited effectiveness of sediment basins

- On construction sites, too much faith is often placed in the operation of sediment basins.
- Unfortunately, most sediment basins are designed to treat only minor flows.
- During the larger storms, sediments and turbid runoff can wash from the site.
- In most cases, the required environmental outcomes cannot be achieved solely through the use of sediment basins.

Erosion control practices

Impending thunder storm

Various suspended solids concentrations

Elevated turbidity level within creek flow

Turbid water in creek after recent storm

Principle 6.2

The standard of erosion control needs to be appropriate for the given soil properties, expected weather conditions, and susceptibility of the receiving waters to environmental harm resulting from turbid runoff.

- Operators should first look up-slope to inspect the type of soil being exposed.
- Then look down-slope to identify the type of receiving waters.
- Finally they should look up to the sky to identify the expected weather conditions.

Impact of coarse and fine sediment

- In general, the runoff of coarse sediment primarily causes human-related problems, such as traffic safety issues, and drainage and flooding problems.
- The runoff of finer sediment particles generally causes most of the ecological harm, such as damage to aquatic ecosystems.
- The displacement of finer sediments, including silt and clay-sized particles, is closely linked to turbidity and suspended solids concentrations in runoff.

Protection of ephemeral streams

- There are four types of creeks: clay-based, sand-based, gravel-based and rock-based (spilling creeks).
- Significant ecological benefit will be obtained by limiting the inflow of coarse sediments into clay and gravel-based creeks.
- For most creeks, the lighter the rainfall, the greater the need to minimise turbidity levels within stormwater released from building and construction sites.

Sediment impacts on creeks

- The impact of sediment releases into minor waterways depends on:
  - the type of watercourse
  - the natural clarity of the water
- Some creeks have a high clarity even during floods, while other creeks are only clear during periods of low flow.
- Streams in arid and semi-arid areas are typically more turbid than streams in tropical and temperate regions.

Erosion control practices

Clay-based watercourse

Sand-based watercourse

Gravel-based watercourse

Rock-based watercourse

Clay-based creeks

- The release of coarse sediments can:
  - infill permanent pools
  - smother bed vegetation
  - promote weed growth
  - increase maintenance costs
- The release of fine sediments can:
  - adversely affect the health and bio-diversity of aquatic life
  - increase the concentration of nutrients and metals within permanent waters
  - reduce light penetration into pools

Sand-based creeks

- Sand-based creeks have naturally high quantities of coarse sediment (sand) flowing along the bed.
- In general, sand-based creeks are not significantly impacted upon by the inflow of coarse sediment because the bed is formed is formed of such material.
- These creeks often have clear base flows and can be severely impacted upon by the release of turbid runoff (fine sediments) from construction sites.

Gravel-based creeks

- In many ways, gravel-based creeks can experience the most severe impacts as a result of sediment inflows.
- However, in high-energy streams, sediment inflows can be quickly mobilised.
- The release of sediments can:
  - infill permanent pools
  - damage riffle systems
  - promote weed growth
  - adversely affect the health and bio-diversity of aquatic life

Rock-based (spilling) creeks

- Rock-based creeks can experience similar problems to clay-based creeks.
- However, these are mostly high-energy streams that can readily mobilise sediment inflows.
- The release sediments can:
  - infill permanent pools
  - promote weed growth
  - adversely affect the health and bio-diversity of aquatic life
  - reduce light penetration into waters

Erosion control practices

Sedimentation of wetlands

Sediment impacts on wetlands

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

Colouration of ponds and lakes

Sediment impacts on ponds and dams

- 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
  - reduce light penetration into the water
  - increase the risk and cost of water treatment works associated with both farm and town water supplies

Sedimentation of rivers and estuaries

Sediment impacts on rivers and estuaries

- The release of sediments and turbid water into rivers and estuaries can:
  - adversely affect the health and bio-diversity of aquatic life
  - increase the concentration of nutrients and metals
  - increase the deposition of bed sediments
  - reduce light penetration into the water
  - reduce navigation capabilities

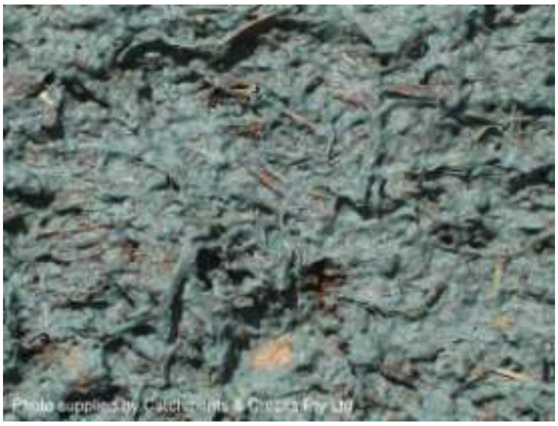
Sediment released into the ocean

Sediment impacts on oceans and bays

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

Erosion control practices

Hydro-mulching



Special glues can be used in mulching

Straw mulching

Tree clearing with minimal soil disturbance

Principle 6.3

Appropriate erosion control measures need to be incorporated into all stages of a soil disturbance.

- Erosion control should **not** be restricted to just post-construction activities.
- Erosion control is **not** another term for 'landscaping'.
- If site revegetation is programmed for the end of the construction phase (an action not considered best practice), then appropriate erosion control measures must still be applied.

Erosion control measures

- Erosion control can be achieved by:
  - appropriately staging earthworks
  - finalising earthworks as soon as reasonable and practicable
  - covering finished surfaces as soon as reasonable and practicable
  - preventing machinery from trafficking over finished soil surfaces
  - utilising temporary erosion control measures to minimises erosion resulting from imminent storms

Principle 6.4

The timing and degree of erosion control specified in the Erosion and Sediment Control Plan needs to be appropriate for the given soil properties, expected weather conditions, and susceptibility of the receiving waters to environmental harm resulting from turbid runoff.

- Erosion control measures primarily focus on the control of raindrop impact erosion.
- If rainfall erosivity varies throughout the year, then so too should the degree of erosion control.

Principle 6.5

If tree clearing is required well in advance of future earthworks, then tree clearing methods that will minimise potential soil erosion need to be employed, especially in areas of unstable or highly erodible soil.

- Best practice land clearing involves:
  - land clearing linked to the staging of earthworks
  - bulk tree clearing done without causing ground disturbance.
  - final grubbing delayed until just before earthworks

Erosion control practices

Straw mulching

Principle 6.6

Erosion and Sediment Control Plans need to specify the required application rates for mulching and revegetation measures.

- In the mulching industry, the lowest tender price usually means the lightest application rate.
- To avoid poor performance, minimum application rates need to be specified within tender documents.
- People often confuse the concepts of ‘light’ and ‘heavy’ (garden) mulching.

Hydro-mulching

Hydro-mulching

- Hydro-mulching 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 seeded-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

Bonded fibre matrix

- 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.

Compost blanket

Compost blankets

- 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 also highly successful.

Erosion control practices

Delivery of turf to a construction site

Thin and thick jute blankets

Mulching

Poorly applied blanket

Principle 6.7

Erosion control measures need to be appropriate for the slope of the land and the expected wind and surface flow conditions.

- On exposed **flat areas** (say, less than 1 in 10 grade), erosion protection can be achieved with the use of *Soil Binders, Erosion Control Blankets, Light or Heavy Mulching, Gravelling* or vegetation.
- While vegetation is one of the best long-term options, it can also provide instantaneous protection if turf is used.

Erosion control on medium slopes

- On **medium grade slopes,** protection from both raindrop impact and possibly concentrated runoff will be required.
- Typical erosion control measures include *Erosion Control Blankets*, appropriately anchored *Light or Heavy Mulching*, *Rock Mulching*, *Compost Blankets* and turf.
- Thin blankets perform a task similar to light mulching, while thick blankets perform a task similar to heavy mulching.

Erosion control on steep slopes

- On **steep slopes** (say, greater than 1 in 4) erosion control measures usually include *Erosion Control Blankets*, *Compost Blankets*, rock armouring and turf.
- On such slopes, loose organic mulch may not be appropriate if moderate to heavy rainfall is expected, or if stormwater runoff is allowed to concentrate down the slope.
- Loose mulch needs to be stabilised with appropriate, non re-wetting tackifiers (glues).

Placement of erosion control blankets

- In most applications of erosion control blankets, vegetation is meant to grow either up through, or down through, the blanket.
- In such cases it is important for the blanket to be placed over a well-prepared soil surface with the fabric in good contact with the soil.
- If the soil surface cannot be suitably prepared, then consideration should be given to the use of a hydraulically applied (spray-on) blanket.

Erosion control practices

Misuse of synthetic blanket on creek bank

Principle 6.8

Wherever reasonable and practicable, the use of synthetic reinforced Erosion Control Mats and Erosion Control Blankets needs to be avoided within bushland and other areas where they could endanger wildlife such as ground-dwelling animals.

- Extreme caution should be taken when using synthetic reinforced blankets because birds and small ground-dwelling animals can become entangled in the synthetic mesh.

Gravelled work compound

Principle 6.9

Wherever reasonable and practicable, measures need to be taken to apply appropriate erosion control practices around the site office area and on temporary access roads to minimise raindrop impact erosion and the generation of mud.

- The gravelling of long-term car parks, the site office compound, and other common traffic areas.
- Roof water from building should be directed away from common walking areas to minimise the generation of mud.

Surface roughening

Principle 6.10

Finished soil surfaces need to be left in a suitably roughened state and quality to encourage revegetation where appropriate.

- Erosion protection on recently vegetated surfaces can be increased by roughening the soil surface.
- Surface roughening increases water infiltration and delays surface rilling—caution is needed in high rainfall areas.
- Surface roughening can be used on subsoils and topsoils, either before and/or after seeding.

Use of dust control soil binders

Principle 6.11

Where appropriate, Erosion and Sediment Control Plans need to incorporate technical notes on suitable dust control measures.

- Site generated dust problems are usually controlled with the use of water trucks.
- Dust may also be controlled with the use of temporary vegetation, mulching, erosion control blankets, or soil binders.
- The use of soil binders and dust suppressing chemicals requires guidance from experts.

Site Stabilisation Practices

Site stabilisation practices

Newly grassed subdivision

Demonstration of hydro-seeding

Approximately 40% cover

Simple surface cover survey

Key principle No. 7

Promptly stabilise disturbed areas.

- A healthy and continuous vegetative cover is one of the most effective forms of erosion control.
- Most importantly, vegetation protects the soil against raindrop impact erosion.
- Vegetation also binds the underlying soil to improve its structural strength, improves the soil's infiltration capacity, and increases evaporation thereby decreasing overall stormwater runoff.

Principle 7.1

The construction schedule or ESC installation sequence needs to ensure that soil stabilisation procedures, including site preparation and revegetation, are commenced as soon as practicable after each stage of earthworks is completed.

- Finished soil surfaces need to be appropriately stabilised as soon as reasonable and practicable.
- Only when rainfall is highly seasonal can revegetation be delayed.

Required cover

- Approximately 40% cover is required to anchor the soil.
- However, such a light cover would **not** provide adequate protection against raindrop impact erosion.
- **Around 70 to 80% ground cover** is considered necessary to provide a satisfactory level of erosion control in most urban areas.
- Some highly erodible, clayey soils need a minimum 90 to 100% cover.

Measuring soil cover

- It is noted that the percentage cover is a measure of the percentage of soil surface covered by vegetation, blankets or mulch, as observed in plan view.
- It is **not** a measure of how much of the site's revegetation program has been completed.
- The simplest test method involves randomly tossing a hoop into the air and then measuring the soil cover by comparing it with standard charts.

Site stabilisation practices

Scraper stripping soil

Soil being worked when it is too wet

Topsoil stockpile

Stockpile covered with jute blankets

Principle 7.2

Topsoil needs to be appropriately managed to preserve its long-term value.

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

Stripping topsoils

- Stripped topsoil should be preserved for reuse wherever possible.
- Inappropriate working of soils can damage the soil structure.
- Topsoil should not be stripped when it is either too wet or too dry:
  - too wet means water can be squeezed from the soil
  - too dry means the soil readily crumbles when handled, or the soil cannot be formed into a clump when compressed

Protecting the soil properties

- Topsoil contains living matter; it has physical, biological, and chemical properties that can be damaged if inappropriately managed.
- The soil's physical properties may be damaged through excessive compaction, over-working the soil, or working the soil at the wrong moisture content.
- The soil's biological and chemical properties may be damaged through inappropriate stockpiling.

Topsoil stockpiles

- Ideally the top 50 mm of soil should be stockpiled separately and respread as the top layer.
- In those circumstances when it is desirable to retain the seed content of the soil, the stockpiling should consist of long low mounds, no higher than 1.5 m.
- Stripped topsoil should be used as soon as possible, and preferably not stockpiled for more than 12 months.

Site stabilisation practices

Site inspection

Principle 7.3

Plant species need to be appropriate for the site conditions, including compatibility with local environmental values, and anticipated erosive forces.

- Selecting the most suitable plant establishment techniques, plant species, seeding rates, planting densities, fertilisers, watering rates, and maintenance techniques, requires the guidance of experts.

Soil adjustment

Soil preparation

- The long-term success of a revegetation program usually depends more on what happens to the soil **before** seeds or plants are placed.
- 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 adjustments.

Inspection of tube stock

Inspection of plants

- Inspect the rootball of all trees once removed from the pot.
- Any roots circling around the outside of the rootball must be either cut through or pulled from the rootball.
- Any roots circling around the base of the rootball should be removed.
- Any plant with excessive root curling, especially when older and thicker roots are curling, should be rejected.

Mulching of plants

Maintenance of plants

- It is important to monitor planting activities to ensure that the vegetation is controlling erosion and stabilising soil slopes as required.
- Check and maintain protective fencing.
- Re-firm plants loosened by wind-rock, livestock or wildlife.
- Replace dead or severely retarded plants.
- Control weeds, especially within a 1 m radius of immature trees.

Sediment Control Practices

Introducing sediment control practices

Sediment basin

Sediment deposition within a wetland

Site with limited drainage & erosion control

Failed sediment control measures

Key principle No. 8

Maximise sediment retention on the site.

- It is usually impractical to prevent all soil erosion on a construction site; thus some degree of sediment control is always required.
- The primary purpose of <u>most</u> sediment control measures is to trap the coarser sediment fraction (i.e. sand and silts).
- Few sediment traps can capture fine sediments; even fewer can reduce turbidity levels in stormwater runoff.

Principle 8.1

All reasonable and practicable measures need to be taken to protect adjacent properties and downstream environments from the adverse effects of sediment and sediment-laden water displaced from the site.

- The adopted erosion and sediment control measures must adequately address all forms of sediment (e.g. cement, clay, silt and sand) in a manner that best protects downstream environments.

Principle 8.2

Work sites must not rely solely on the application of sediment control measures to provide adequate environmental protection.

- Best practice sediment control measures, in isolation, cannot be relied upon to provide adequate environmental protection.
- In most cases, the most efficient and economical means of controlling the release of the finer sediment fraction is through the application of best practice drainage and erosion control.

Principle 8.3

Sediment control measures need to be appropriate for the given soil properties, expected weather conditions, required treatment standard, and the type, cost and scope of the works.

- Sediment control measures can be grouped into four levels of treatment (Type 1, 2 & 3 and supplementary systems).
- The selection of treatment level depends on many factors, but is commonly linked to the expected soil loss rate (t/ha/yr) for the sub-catchment.

Revised Universal Soil Loss Equation (RUSLE)

Sediment laden runoff

Sediment retained in a basin

Evidence of sheet erosion

USLE

- Soil loss rates are most commonly estimated using the *Universal Soil Loss Equation* also known as USLE.
- Over its many years of use the parameters used within the USLE have been modified resulting in the formation of a revised equation.
- The Revised Universal Loss Equation (RUSLE) is now the more commonly used equation—both equations take the following form:

$$A = R . K . LS . C . P$$

RUSLE

The terms used in the RUSLE equation are:

- A = soil loss rate (tonnes/ha/yr)
- R = rainfall erosivity factor
- K = soil erodibility factor
- LS = combined length-slope factor
- C = cover and land management factor
- P = erosion control practice factor

To determine the **tonnage** (t) of soil loss:

- multiply by the area (ha) and time (yr)

To determine the **volume** (m^3) of soil loss:

- divided by the soil density (t/m^3)

Application of RUSLE to construction sites

- Both the USLE and RUSLE formulas where primarily developed and calibrated for the assessment of erosion rates on low-gradient rural properties.
- The equation assesses only 'sheet' and mild 'rill' erosion.
- The equation does **<u>not</u>** take into account of gully erosion or erosion within creeks and drainage channels.

The erosion hazard is linked to the tonnage of soil loss, rather than the rate (t/ha/yr). Thus, the sediment standard is best linked to <u>both</u> the soil loss rate and area of disturbance, as below.

Area limit (m^2)	Soil loss rate limit (t/ha/yr)			Soil loss rate limit (t/ha/month)		
	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3
250	N/A	N/A	Special case	N/A	N/A	Special case
1000	N/A	N/A	All cases	N/A	N/A	All cases
2500	N/A	> 75	75	N/A	> 6.25	6.25
>2500	> 150	150	75	> 12.5	12.5	6.25

Example sediment control standard (IECA, 2008)

Types of sediment traps

Sediment basin

Type 1 sediment traps

- The adopted sediment trap classifications are Type 1, Type 2, Type 3 and supplementary sediment traps.
- Type 1 sediment traps are designed to collect fine sediment particles less than 0.045 mm.
- In general terms these traps target the full range of sediment grain sizes from clay to silt to sand.
- These sediment traps include *Sediment Basins* and some of the advanced filtration systems used in de-watering operations.

Sediment weir field inlet control

Type 2 sediment traps

- Type 2 sediment traps are designed to capture sediments down to a particle size of between 0.045 and 0.14 mm.
- In general terms these traps target sediment particles from sands down to coarse silts.
- Type 2 sediment traps include *Rock Filter Dams, Sediment Weirs* and *Filter Ponds.*

Sediment fence

Type 3 sediment traps

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

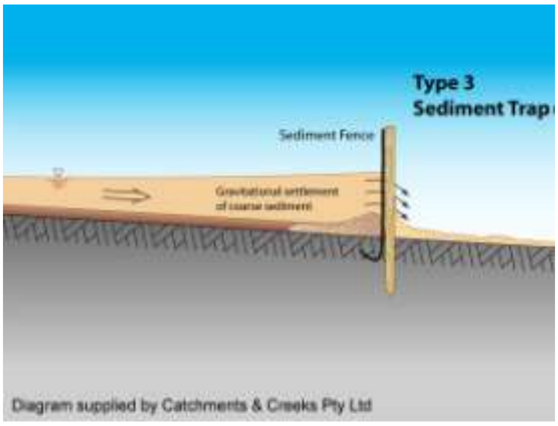
Sag-type kerb inlet protection

Supplementary sediment traps

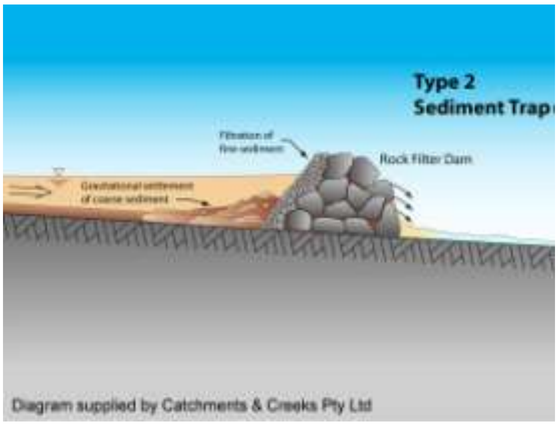
- Some sediment traps, such as *Grass Filter Strips* and most kerb inlet sediment traps, have such limited efficiency or are so easily damaged, that they must only be used to *supplement* a type 1, 2 or 3 sediment trap.
- Even though these sediment traps have a relatively low effectiveness, their use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

Types of sediment traps

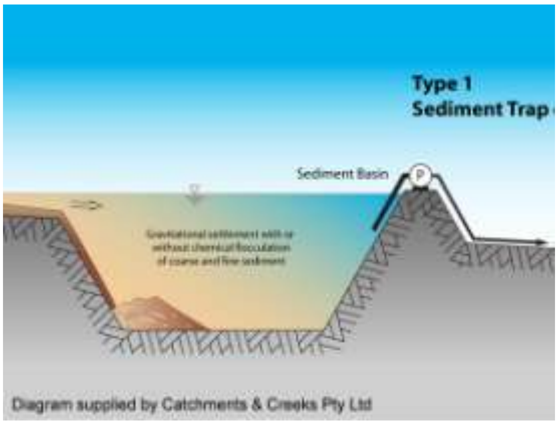
Rock filter dam with geotextile filter



Type 3 treatment system



Type 2 treatment system



Type 1 treatment system

Types of sediment traps

- There are many different types of sediment traps, but they generally can be divided into the following groups:
  - pooling traps that primarily utilise gravity-induced particle settlement
  - pooling traps that also incorporate a coarse low-flow filter
  - extended detention settling basins
  - geotextile filters
  - sand and aggregate filters
  - compost filters

Type 3 sediment traps

- Most type 3 sediment traps are designed to slow the passage of water to such a degree that ponding occurs up-slope of the trap.
- It is this pooling of water that allows gravity-induced settlement of the coarser sediment fraction.
- A sediment fence is **not** a 'filter'.
- A sediment fence is just a porous dam that encourages the up-slope ponding of water.

Type 2 sediment traps

- The basic components of a type 2 sediment trap are a settling pond followed by a coarse filter.
- Just like a sediment fence, a type 2 sediment trap is designed to encourage the pooling of water up-slope of the trap.
- Gravity-induced settlement is then supplemented by either a:
  - geotextile filter
  - aggregate filter
  - compost filter

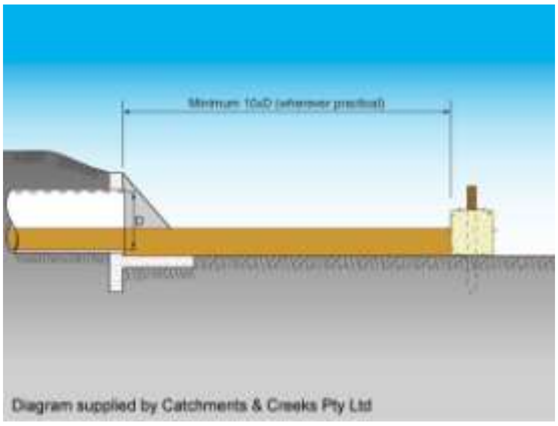
Type 1 sediment traps

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

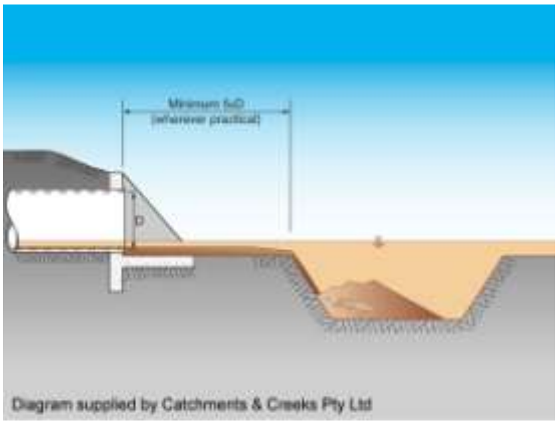
Critical features of sediment traps

Sag-type kerb inlet control system

"Wet" type sediment basin



Example of above-ground ponding



Excavated sediment trap at pipe outlet

Critical features of a sediment trap

- Most sediment traps should incorporate the following critical features:
  - the ability to pond water
  - adequate retention time to allow settlement of suspended particles
  - the capacity to collect and retain a specific volume of sediment
  - adequate hydraulic capacity prior to the commencement of flow bypassing
  - limits on the maximum depth of pooling for reasons of public safety

Critical features of the pond

- The presence of a settling pond means the focus is on gravity-induced settlement.
- In continuous-flow systems, the critical design parameter is the **surface area** of the pond (as per the design of dry basins).
- In plug-flow systems the critical design parameter is the **volume** of the settling pond (as per the design of wet basins).

Above or below-ground ponding

- There are many circumstances where it is undesirable to pond water above ground.
- These circumstances include:
  - sediment traps placed on roadways where ponding could cause flooding or traffic safety risks
  - sediment traps placed at the end of stormwater pipes where the ponding can cause sediment to settle within the pipe; thus making de-silting difficult

Consideration of safety risks

- Safety concerns must always take priority.
- However, this does not excuse contractors from their legal obligations to take all reasonable and practicable measures to prevent or at least minimise environmental harm.
- Water ponding on roadways can cause passing vehicles to aquaplane or the flooding of adjacent properties.
- Open water ponds can also represent a drowning risk to children.

Types of sediment filters

Sand-filled filter sock

Rock filter dam with aggregate filter

Filter tube dam

Compost-filled filter sock

Types of filters

- Both **type 2** and **supplementary** sediment traps usually incorporate some type of filter.
- The filter media may consist of straw, sand, aggregate, geotextile or compost.
- Straw-based filters are very inefficient and their primary purpose is usually to encourage ponding rather than filtration.
- Most sand-based filters are also very inefficient due to their low through-flow discharge.

Aggregate filters

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

Geotextile filters

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

Compost filters

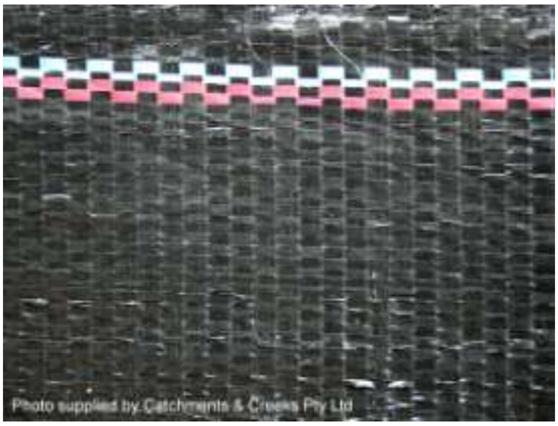
- Compost filters use both *filtration* and *adsorption* processes to clean through-flows.
- Thus compost filters can adsorb minor amounts of dissolved and fine particulate matter such as metals.
- These filters can perform better than most sand, aggregate or geotextile filters, provided the filter remains undamaged by construction traffic or shifting stockpiles.

Use of geotextiles in sediment control

Composite sediment fence fabric

Use of geotextiles in sediment control

- Geotextiles can be used for a number of purposes in the construction industry, including:
  - the slowing of flows to encourage pooling and sedimentation
  - the filtration of flows
  - the separation of soils or fill material where the two materials have significantly different textures
- Composite fabrics are sometimes used when it is desirable to perform more than one of the above tasks.



Woven sediment fence fabric

Woven fabrics

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

Non-woven filter cloth

Non-woven fabrics

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

Filter sock

Hessian fabric

- Hessian fabrics fall outside the normal rules because they are woven fabrics, but unlike most woven fabrics, they encourage filtration.
- Hessian fabrics can be used to form erosion control blankets and well as filter socks.
- Typically these filter socks are filled with sand or aggregate to provide stability against movement.

Problems associated with supplementary sediment traps

The problems of supplementary traps

- Wide vegetated *Buffer Zones*, especially flat grassed areas, can be effective type 3 sediment traps as long as flow through the buffer remains as 'sheet flow'.
- Once flows become concentrated, the sediment either doesn't settle, of if it does settle out, is washed across the grass surface.

The problems with grass filters

- Erosion problems often occur when *Grass Filter Strips* are placed either down a slope or at an angle to the slope.
- This can cause stormwater runoff to be deflected along the edge of the turf rather than passing through the grass.
- To avoid these problems, strips of turf should be placed at a transverse angle at regular intervals along the upper edge of the turf.

Results of vehicle damage

The problems with kerb inlet sediment traps

- Due to the high risk of physical displacement or damage by passing vehicles, most roadside kerb inlet sediment traps are classified as *supplementary sediment traps*.
- If sand is used as the filter media, or if the bags are make from woven fabric, then 'filtration' is unlikely to occur and sediment trapping will rely on up-slope pooling.

Crushed fibre roll

The problems with fibre rolls

- Fibre rolls are highly likely to experience performance-affecting damage within a work site due to such things as vandalism, and foot or construction traffic.
- Fibre rolls crushed by pedestrian or vehicular traffic do not stop working, but their sediment-trapping efficiency is diminished.

Use of sediment basins

Post-construction sediment basins

Principle 8.4

Sediment Basins need to be designed and constructed under the supervision of appropriate experts.

- A *Sediment Basin* is a purpose built dam usually containing an inlet structure, settling pond, controlled or free-draining de-watering system, and an emergency spillway.
- Sediment basins are usually classified as type 1 sediment traps and are designed to retain a wide range of sediment particle sizes.

Type C basin

Types of sediment basins

- There are basically three types of operating systems for sediment basins: Type C, Type F and Type D basins.
- Type C basins are appropriate when working in coarse grain soils.
- These basins can be operated as either free-draining dry basins, or non-draining wet basins—which are designed to retain water between storms so the water can be used for dust control or site revegetation.

Type F sediment basin

Type F or D basins

- Type F basins are used when working in fine grain soils.
- Type D basins are used when the disturbed soils are dispersive.
- Type F and D basins are designed to retain the water for long periods (up to 5 days) allowing extended time for the particle settlement.
- These basins must be fully drained between storm events to ensure the basins have the required storage volume prior to the start of the next storm.

Undersized sediment basin

Under-sized basins

- A constructed sediment basin that has a volume or surface area less than specified by the standard equation must be classified as either a type 2 or type 3 system in accordance with the basin's effective sediment trapping capability.
- Such basins can still provide an important role in sediment control, but the performance will be less than a type 1 basin.

Sediment control practices

Sediment trapped in off-site wetland

Principle 8.5

On-site sediment control practices should not rely on off-site sediment control systems.

- A site's sediment control system should not rely on off-site sediment control systems, especially those systems operated by other organisations.
- Exceptions to this rule apply only with the agreement of the regulatory authority and the owner/manager of the off-site sediment trap.

Failed straw bale sediment trap

Principle 8.6

The use of straw bales to form sediment traps should be avoided, unless site conditions prevent the use of other more appropriate sediment control systems.

- Experienced erosion and sediment control officers generally agree that sediment traps should **not** be constructed from straw bales.
- Straw bale sediment traps regularly fail and are rarely effective in the long term (i.e. if subjected to more than one storm).

Straw bale sediment trap on a steep slope

Use of straw bale barriers

- In some circumstances, however, straw bales can be used as short-term sediment control systems during the installation of a more substantial sediment trap.
- Straw bale sediment traps have also been used in poorly accessible locations where it is impractical to transport and construct other types of sediment traps.
- If used for sediment control, the straw bales should be wrapped in filter cloth.

Straw bales diverting stormwater runoff

Use as a flow diversion system

- Straw bales can also be used as short-term *Flow Diversion Banks* (i.e. as a drainage control measure) to direct up-slope runoff around newly opened trenches and other excavations.

Sediment control practices

Basin with limited maintenance access

Principle 8.7

Suitable construction access needs to be provided to allow for the installation and maintenance of all sediment traps.

- Most sediment control measures will require some degree of maintenance, including sediment removal.
- Suitable maintenance access must be provided to all sediment control measures.
- On steep slopes it can be very difficult to install certain sediment traps, especially if rock or aggregate is required.

Sediment fence in need of maintenance

Removal of trapped sediment

- It is not good enough to simply trap sediment—actions must be taken to ensure the sediment is:
  - removed from the trap
  - placed in a location where it will not cause harm
  - stabilised in a manner that minimises the risk of future erosion
- The materials used to form the sediment trap must also be suitably disposed of.

Poorly designed sediment trap

Principle 8.8

Sediment traps, including sediment basins, need to be appropriately designed for the required hydraulic (flow) conditions.

- Most sediment control systems are hydraulic structures that need to be designed for a specified design storm.
- Sediment control devices should be designed so as not to divert flows from their desired flow path during all storms, even when the device is blocked with sediment or debris.

Mesh and aggregate drop inlet protection

Principle 8.9

Optimum benefit needs to be made of every opportunity to trap sediment within the work site.

- The existence of a sediment basin on a work site does **not** remove the need for the appropriate use of additional sediment traps throughout the work area.
- Where practical, sediment traps should be placed around all stormwater inlets, even those that flow to a sediment basin.

Sediment control practices

Inappropriate controls on a steep slope

Caution placement on steep slopes

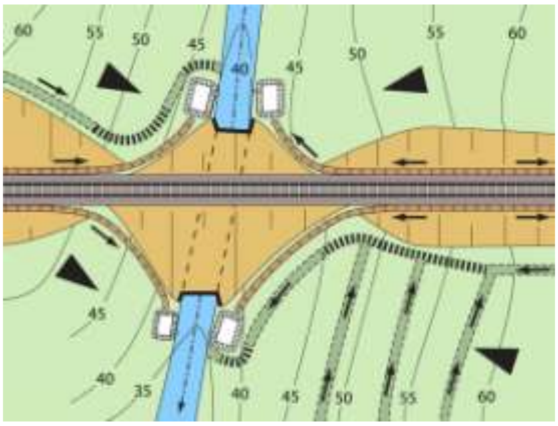
- On steep slopes, say steeper than 10% (1 in 10), the focus should primarily be on preventing soil erosion, and secondly on controlling the flow of water through the site.
- Wherever practical, the trapping of sediment should occur at the base of the slope, or any other location where it is safe and convenient to temporarily pond water.

Sediment fence adjacent a building site

Principle 8.10

Wherever reasonable and practicable, sediment should be trapped as close to its source as possible.

- Locating the sediment trap close to the source of the sediment reduces the breakdown of the soil particles (i.e. the breaking apart of soil crumbs into smaller particles of sand, silt and clay).
- This in turn reduces the risk of fine silts and clay-sized particles being released into the water.



Dirty water directed to sediment basins

An exception to the rule

- Even though it is beneficial to trap sediment as close as possible to the source of erosion, there is an important exception.
- Given the active nature of most construction sites, it is often beneficial to located sediment basins away from construction activities, thus sediment-laden water must be directed to these basins.
- This is better than trying to place sediment basins in the middle of active sites.

Sediment slowing washing into the inlet

Principle 8.11

Sediment traps need to be designed, constructed and operated to collect and retain sediment, not just divert the sediment and sediment-laden water to another location.

Before placing a sediment trap, ask yourself:

- Will the device cause a safety problem?
- Where is the water going to flow?
- Where is the sediment going to end up?
- How will the trapped sediment be collected and removed?

Sediment control practices

Safety cap on sediment fence stake

Sediment deposition on roadway

Sediment trap blocking inflows

Sag inlet sediment trap

Principle 8.12

The potential safety risk of a proposed sediment trap to site workers and the public needs to be given appropriate consideration and management, especially those devices located within publicly accessible areas.

- Some sediment traps can represent a safety risk if inappropriately installed or maintained.
- Safety issues, relating to both the public and site personnel, must be given appropriate consideration when designing and operating sediment control measures.

Principle 8.13

To the maximum degree reasonable and practicable, sediment needs to be contained within appropriate sediment traps before entering a sealed roadway, whether or not the road is part of the construction site.

- Ideally, sediment should be trapped **before** it is allowed to enter a roadway.
- Ideally, the site's sediment control strategy should **not** rely on kerb inlet sediment control measures.

Avoiding flooding and drainage problems

- Most roadside sediment traps generally aim to prevent sediment from entering stormwater pipes.
- However, these sediment traps can also prevent stormwater from entering the kerb inlet, possibly resulting in drainage or flooding problems on adjacent properties or somewhere else down the roadway.
- Some kerb-side sediment traps can also cause traffic safety problems.

Principle 8.14

Roadside kerb inlet sediment traps need to be appropriate for the type of inlet (i.e. 'sag' or 'on-grade' inlets).

- An *on-grade kerb inlet* (or gully inlet) is an in-kerb stormwater inlet located on a part of a roadway that has a positive gradient such that water would flow past the inlet if the inlet was blocked or sealed.
- A *sag kerb inlet* is an in-kerb stormwater inlet located at a low point in a roadway where water would collect and pond if the inlet was blocked or sealed.

Kerb inlet sediment traps

Sag inlet sediment trap

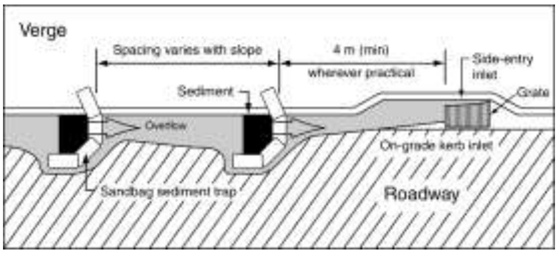
Sag inlet sediment traps

- A sag inlet must allow water to pond on the road adjacent to the inlet in order to achieve particle settlement.
- Sag inlet sediment traps should **not** block the inlet opening, but should be set back from the inlet (normally using spacers) to allow the drain to function, especially during periods of heavy rainfall.
- The exception to this rule is when it is necessary or desirable for the road to convey sediment-laden (dirty) water to a down-slope sediment trap.

On-grade kerb inlet sediment trap

On-grade inlet sediment traps

- An on-grade sediment trap consists of one or more U-shaped sandbag dams constructed up-slope of the inlet.
- Typically more than one such sediment trap is required up-slope of the inlet.



Gully bag sediment trap

Gully bag sediment traps

- *Gully bag sediment traps* (i.e. special filter bags installed below the inlet grate) can be used on both sag and on-grade kerb inlets.
- The types of gully traps include the flexible filter bags (left) and solid filter boxes lined with filter cloth.

Flooded road surface

Safety issues

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

Problematic use of kerb inlet sediment traps

On-grade kerb inlet

Sag-type traps placed on on-grade inlets

- It is not uncommon for sag type sediment traps to be incorrectly placed in front of around on-grade inlets.
- Such inappropriate practice will cause stormwater runoff to be diverted around the inlet and down the roadway, possibly towards an unprotected stormwater inlet.
- Appropriate consideration must always be given to the likely flow path of any flows bypassing the inlet.

On-grade kerb inlet

Putting the right product in the right place

- Kerb-side sediment traps like these (left) can be useful tools in the sediment control industry.
- However, it is important to ensure site personnel are aware of their correct placement.
- Devices such as these are best used at sag inlets, not adjacent on-grade inlets.
- If used adjacent on-grade inlets, sediment will simply be washed down the roadway.

Sag inlet

Use of ag-pipe

- Many kerb inlet sediment traps incorporate ag-pipes as a 'filter' for the side entry slot.
- Often these ag-pipes are simply pushed into the gully pit by the force of the water.
- The ag-pipe may also fail to allow adequate stormwater inflow; thus potentially causing undesirable flooding on the roadway.
- Spacers (i.e. sections of PVC pipe) should be used to separate the ag-pipe from the inlet.

Inappropriate use of fabrics

Choice of fabric

- Gully grates at sage inlets are often wrapped in fabric as part of the sediment control system.
- Commonly, woven sediment fence fabric is used, but this should only be used if it is desired to minimise the through-flow of water.
- Alternatively, heavy-duty, non-woven filter cloth should be used if it is desirable to 'filter' sediment from the through-flow.
- Fabric wraps provide little value if they are <u>inside</u> the filter berm as shown left.

Questions to ask before installing kerb inlet sediment traps

Potential traffic hazard

Will the device cause a safety or flooding problem?

- Water retained on roadways by kerb inlet sediment traps can cause traffic problems, or/and flood adjacent properties.
- Sediment deposited on roads by these devices can also represent a safety risk to pedestrians and traffic.
- Even the actual sediment trap can sometimes become a traffic safety hazard.
- Safety concerns **<u>must</u>** always take priority.

Sediment simply flows off the roadway

Where will the water flow?

- If the water is unable to enter a particular stormwater inlet, then it must be allowed to flow to an alternative sediment trap.
- If the sediment-laden water is prevented from entering the kerb inlet, then it may cause problems if it:
  - passing down the road to an unprotected stormwater inlet
  - leaves the roadway without being treated
  - overloads a downstream stormwater inlet

Fully blocked on-grade inlet

Where will the sediment be deposited?

- If the sediment settled is allowed to wash down the road into an unprotected stormwater inlet, then the sediment control system has failed.
- It is important to note that the aim is to prevent the sediment entering downstream waterways, **<u>not</u>** to just prevent the sediment entering the stormwater pipe.

Inappropriate clean-up procedures

How will the trapped sediment be removed from the roadway?

- Unfortunate, the sediment deposited on roadways is often simply washing off the road into the drain!
- Such practices are both unlawful and inappropriate.
- Appropriate maintenance procedure must be adopted for the disposal of all sediment that collects on roadways.

Controls at site entry and exit points

Inappropriate practice

Principle 8.15

Site entry and exit points need to be limited to the minimum practical number, and need to be appropriately designed and stabilised to minimise sediment being washed off the site by stormwater and/or being transport off the site by vehicles.

- The tracking of sediment onto public roads by construction vehicles is one of the most common sources of public complaint.
- Site entry and exit points should be limited to the minimum practical number.

Rock pad

Rock pads

- Rock pads are typically used in clayey soil areas.
- The critical design parameter is the total void spacing between the rocks. It is this void spacing that is the sediment trap, not the rocks!
- If the work site is elevated above the public road, then stormwater runoff should be diverted off the rock pad into a suitable sediment trap.

Vibration grid

Vibration grids

- Vibration grids are best suited to sandy soils.
- They 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

- On long-term construction sites, sites containing heavy clayey soils, and construction sites located near sensitive receiving waters, it may be necessary to install an automatic or manually operated wash bay to limit the tracking of sediment off the site.
- During periods of dry weather these wash bays are often drained to prevent vehicles tracking wet soil off the site.

Controls for the site office and stockpiles


Site office

Principle 8.16

Appropriate sediment control measures need to be applied to all temporary building and construction works, including the site office and stockpile areas.

- It is important to ensure the work site's office and car park areas do not become a source of sediment runoff.
- Appropriate drainage control measures placed up-slope and within the site office and car park areas can significantly reduce the generation of mud.


Gravelled car park

Stabilisation of high traffic areas

- On long-term construction sites it may be appropriate to cover the car park and office areas with gravel to minimise damage to the soil and the generation of mud during extended periods of wet weather.


Material stockpile area

Management of stockpiles

- Stockpiles should not be located within the pathway of concentrated flow. This especially applies to stockpiles of fine, non-cohesive (sandy) material.
- Stockpiles should also be protected from wind and rain.
- Stockpiles of clayey soil are more susceptible to raindrop impact erosion then stockpiles of sand.
- The filtration capabilities of non-woven fabrics can prove beneficial adjacent soil stockpiles.

Inappropriate practice

Earth should not be placed on roadways

- Erodible materials must not be stored within a road reserve without obtaining permission from the appropriate road authority.
- Materials placed within the road reserve must not block traffic or cause safety problems.
- If erodible materials must be temporarily placed within a road reserve, then an appropriate waterproof cover should be stored on site for use in the event of rain.

Use of sediment fence

Sediment fence with regular "returns"

Sediment fence with settled sediment

Inappropriate installation of a fence

Installation of a sediment fence

Principle 8.17

Wherever practicable, sediment fences need to be located along the contour to maintain sheet flow conditions down-slope of each fence. Where this is not practicable, the Erosion and Sediment Control Plan needs to indicate appropriate installation measures (i.e. fence returns) to allow water to pond at regular intervals along the length of the fence.

- A sediment fence must be constructed in a way that temporarily ponds water at regular intervals along the fence.

Purpose of a sediment fence

- Sediment fences primarily trap the coarser sediments, such as sands.
- In general, these sediment traps have little impact on silts and clay-sized particles.
- A sediment fence should **not** be viewed as a filtration system.
- It is best to consider a sediment fence as a porous dam wall.
- Its primary job is to temporarily pond water during a storm, not to filter the water.

Placement of sediment fences on slopes

- Ideally, the fence should be installed along the contour with the ends of the fence turned up the slope to prevent or limit water bypassing around the fence.
- If the sediment fence is located across the contours (i.e. at an angle to the slope) then a straight fence will simply cause water to be diverted along the fence.
- This may lead to failure of the sediment fence and the release of concentrated sediment-laden flow around the end of the fence.

Installation of sediment fences

- If it is necessary to locate a sediment fence at an angle to the slope, then regular returns must be installed along the fence to allow water to pond at regular intervals.
- The maximum allowable spacing of the support posts is 2 m unless the fence is supported by an upper tie wire or wire mesh (both being tied to the back of the fabric at 1 m spacings) in which case the maximum allowable spacing is 3 m.

Sediment control practices

Inappropriate installation

Principle 8.18

*Sediment fences, installed in the standard (i.e. straight) manner, must **not** be placed across concentrated flow.*

- As a general rule, sediment fences should not be used in concentrated flow.
- When used in minor drainage lines, such as table drains, the sediment fence must **not** be placed straight across the drain.
- Instead, a special *U-Shaped Sediment Trap* must be installed with an appropriate spill-through weir installed.

U-shaped sediment trap

Sediment controls placed in table drains

- U-shaped sediment traps can only be used within relatively steep table drains.
- When the drain geometry is not suitable for the installation of a U-shaped sediment trap, then an alternative sediment containment system must be used, such as a *Check Dam Sediment Trap.*

Inappropriate use of sediment fences

Principle 8.19

As a general guide, sediment-laden water should not pass through more than one sediment fence within a given work area. If further treatment is required after passing through a sediment fence, then wherever reasonable and practicable, the sediment-laden water needs to be directed to a suitable type 1 or type 2 sediment trap.

- The practice of placing several parallel sediment fences down long exposed slopes is highly risky, especially in regions of high rainfall, and should generally **not** be promoted as best practice.

Inappropriate use of sediment fences

Inappropriate use of sediment fences

- Sediment fences are possibly one of the most misused sediment control devices on construction sites.
- In general, the best-managed construction sites have very few sediment fences—there are of course exceptions to this rule.
- A sediment fence should only be used to capture coarse sediment and only within small sub-catchments.

Sediment control practices

Portable settling (lamella) tank

Sediment fence isolation barrier

Off-stream filter pond

Instream rock filter dam with filter tubes

Principle 8.20

Sediment control measures employed during de-watering operations need to be appropriate for the expected site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.

- Appropriate water treatment is required for all sediment-laden water discharged from de-watering operations.
- De-watering sediment control systems primarily use filtration processes—rather than gravity-induced settlement—in order to achieve the desired treatment standard.

Principle 8.21

When constructing works or causing soil disturbances in or around a watercourse, priority must first be given to construction practices that avoid contamination of stream flows.

- Disturbances to existing watercourses must be avoided, or at least minimised, wherever reasonable and practicable.
- If such disturbances must occur, then priority must be given to the use of isolation barriers that prevent, or at least minimise, the contamination of passing stream flow.

Where such practices are not practical, priority must then be given to the treatment of sediment-laden water within off-stream sediment traps.

- Wherever reasonable and practicable, the treatment of sediment-laden water must occur within off-stream sediment traps rather than instream sediment traps.
- Only in extremely exceptional circumstances should a sediment control device be placed within a natural watercourse.

The use of instream sediment traps must only be considered as a management option when all other options can be demonstrated to be ineffective, unreasonable, or impracticable.

- The existence of a permanent instream sediment control device, such as a gross pollutant trap, should **not** be used as the primary sediment control measure.
- These sediment traps generally have a very low sediment trapping efficiency and are extremely limited in their ability to capture the finer sediments typically discharged from construction sites.

Sediment control practices

Urban development

Principle 8.22

The ESC installation schedule and/or supporting documentation must clearly indicate which sediment control measures need be functional before up-slope soil disturbances commence, and what degree of site stabilisation is required prior to the decommissioning of each sediment control device.

- Appropriate sediment control measures must be functional before significant earthworks commence on a site.

Newly revegetated subdivision

De-commissioning of devices

- As a general rule, down-slope sediment control measures should be maintained until at least 70 to 80% coverage is achieved on all unsealed soil surfaces.
- It is noted that the percentage cover is a measure of the percentage of soil surface covered by vegetation, blankets or mulch as observed in plan view, it is **not** a measure of how much of the site's revegetation program has been completed.

Emergency material stockpile

On-site ESC training

Principle 8.23

Site managers and/or the nominated responsible ESC personnel need to maintain a good working knowledge of the correct installation and operational procedures of all ESC measures used on the site.

The key elements of best practice site management vary from site to site, but generally incorporate the following concepts:

- The appointment of a responsible on-site ESC officer.
- Maintaining a stockpile of emergency erosion and sediment control materials throughout the construction period.
- Adopting flexible work procedures that can accommodate necessary amendments to the site's ESC measures.
- Ensuring appropriate staff training and the control of subcontractors.
- Adopting appropriate clean-up procedures for off-site sediment deposits and spills.
- Regularly monitoring the site and all erosion and sediment control measures, and maintaining such measures in proper working order at all times.

Maintenance of ESC Measures

Maintenance of ESC measures

Sediment fence in need of maintenance

Key principle No. 9

Maintain all ESC measures in proper working order at all times.

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

Maintenance of control measures

Proper working order

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

Poor maintenance practice

Proper disposal of sediment

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

Sediment fence well past it’s ‘use-by’ date

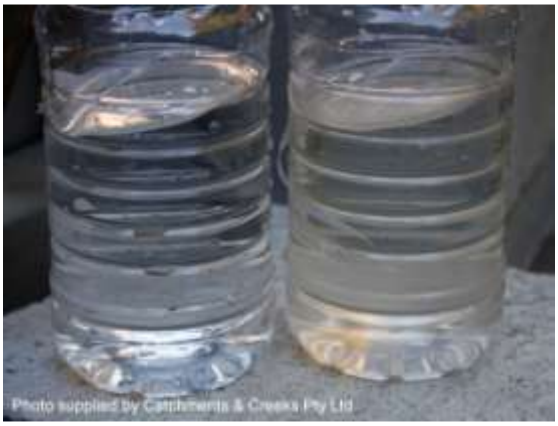
Decommissioning control measures

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

Monitoring Site Performance

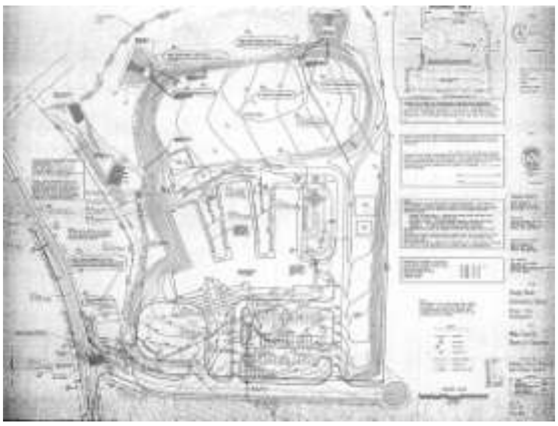
Monitoring site performance

Sediment-laden runoff



Water samples for visual inspection

Site checklist



Erosion and sediment control plan

Key principle No. 10

Monitor the site and adjust ESC practices to maintain the required performance standard.

- Erosion and Sediment Control Plans (ESCPs) are living documents that can and should be modified as site conditions change, or if the adopted measures fail to achieve the required treatment standard.
- If a site inspection detects a failure in the adopted ESC measures, then the source of this failure must be investigated and corrected.

Water quality monitoring

- Monitoring the effectiveness of an ESCP—through a combination of site inspections and water quality monitoring—is part of responsible site management.
- On some small low-risk sites, reporting requirements may only need to consist of diary notes listing inspection times, field observations and maintenance activities.
- On larger or high-risk sites, monitoring is likely to include specific water quality sampling.

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
- Site inspections should involve the completion of a standard *Site Checklist*.

Responding to poor test results

- If poor results are detected, then a revised Erosion and Sediment Control Plan may need to be prepared.
- While this revised plan is being prepared, site personnel should take appropriate steps (under the supervision of trained ESC officers) to minimise environmental harm.

Glossary of terms

Acid sulfate soil A soil type containing significant amounts of iron sulfide (usually pyrite, FeS_2) which generates sulfuric acid when exposed to oxygen; typically associated with coastal lowlands (< 5 m AHD) and estuarine floodplains.

Ag-pipe A flexible, perforated, corrugated drainage pipe used in agricultural sub-drainage. Also known as an 'agricultural (sub-drainage) pipe'.

Buffer zone A significant area of vegetation containing at least 70% ground cover which allows overland flow to pass as sheet flow through the buffer area without the concentration of flow. Primarily used as a coarse sediment and/or pollutant filter.

Building works Those works associated with:

- the erection or construction of a building; or
- the renovation, alteration, extension, improvement, or repair of a building; or
- removal or resiting of a building; or
- works directly associated with the erection or construction of a building including the installation of services, landscaping and paving.

Catch drain Small open channels formed at regular intervals down a slope, or immediately up-slope or down-slope of a soil disturbance. They are usually excavated with a grader blade, or U-shaped excavation tools.

Check dam Small, regularly spaced, flow control structures that reduce the velocity of water in drains by 'damming' the water and so increasing the flow depth. Typically used to control soil erosion in newly formed drains, and/or to act as minor sediment traps. These dams may be constructed from semipervious or impervious materials, including timber, rock, sand/gravel bags or synthetic mesh.

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.

Clay-sized particle Any particle of a size equivalent to a clay particle, i.e. less than 0.002 mm in equivalent diameter.

Clean stormwater runoff Surface runoff that has not been contaminated by a given work site, or by the actions of a construction or building activity.

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.

Colloidal particles The finest clay and organic material, with a particle size generally less than 0.001 mm diameter. This material is made up of the finest particles removed by erosion. They remain permanently in suspension, unless subject to coagulation.

Compost blanket A surface applied high-grade compost containing selected plant seed, soil ameliorants, tackifiers, soil wetting agents, and bacteria and fungi foods.

Unlike conventional mulches, composted mulches have been allowed to biologically degrade for a predetermined period resulting in a relatively stable product generally free of viable seed content, thus reducing the risk of importing weed species.

Construction footprint	The total surface area over which construction works occur, including associated short-term disturbances.
Dirty water	Water not classified as clean water.
Dispersive soil	A structurally unstable soil that readily disperses into its constituent particles (clay, silt and sand) when placed in water. Moderately to highly dispersive soils are normally highly erodible and are likely to be susceptible to tunnel erosion. Most sodic soils are dispersive, but not all dispersive soils may be classified as sodic. Some dispersive soils are resistant to erosion unless mechanically disturbed.
Dry basin	A sediment basin that is free-draining and thus begins to de-water soon after water enters the basin.
Emergency ESC supplies	Erosion and sediment control materials needed to conduct normal maintenance or perform emergency repairs.
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 or building phase, site stabilisation, and maintenance phases of a construction, building or other soil disturbance activity.
Erosion control blanket	A blanket of synthetic and/or natural material used to cover and protect soil against erosion caused by wind, rain, and minor overland flows.
Erosion control mats	A mat of synthetic and/or natural material that is primarily used to protect soil against erosion caused by concentrated surface flows.
Erosion risk mapping	The process of identifying and mapping of areas of erosion risk. Usually undertaken by land developers as part of initial site planning, or as part of the conceptual planning of construction procedures. Only maps those site constraints directly related to soil erosion (i.e. not overall environmental risk). In effect, a mapping exercise based on a suitable soil erosion model such as the Revised Universal Soil Loss Equation (RUSLE).
ESC	Erosion and sediment control.
ESCP	Erosion and Sediment Control Plan.
Extremely erodible soil	Material that can readily wash from a stockpile or work site, or can readily discolour stormwater during regular rainfall events.
Fibre roll	Straw, cane mulch, or other similar fibrous materials bound into a tight tubular roll. Fibre rolls normally have a tubular roll (sock) formed from open mesh that does not aid in the 'filtration' of pollutants.
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).
Filter pond	A pit into which sediment-laden water is pumped so that the water can drain out, leaving the sediment. Usually built of pervious materials, such as filter cloth, aggregate, sediment fence fabric, or a combination of these. Typically used as a sediment control measure during de-watering operations.

Flow diversion bank	Flow diversion banks typically consist of a raised earth embankment normally placed along level or near level ground. Minor flow diversion berms can also be formed from tightly packed sandbags, or compost.
Grass filter strip	A strip of turf placed along the contour and at regular intervals down a slope on exposed soil slopes, or around newly formed impervious surfaces, such as kerbs and footpaths as a minor (supplementary) sediment trap. When placed along the contour and at regular intervals down a slope of exposed soil, grass filter strips can also delay the formation of rill erosion by maintaining even sheet runoff down the slope.
High-risk areas	A building or construction site that satisfies the requirements of: • a high-risk site as defined by either the state or local government; or • those risk categories greater than high-risk (such as extreme-risk) where such categories have been defined (i.e. score a hazard rating equal to or greater than the specified 'critical hazard value').
Hold point	A stage in the construction program beyond which work must not proceed unless either a stated activity has been completed, or the works have been authorised by an appropriate officer (e.g. Site Superintendent, or representative from the regulatory authority).
Hydro-mulching	Hydro-mulching involves the spraying of a slurry mix consisting of seed, fertiliser, paper pulp (1.5 to 2 t/ha) or wood pulp (not less than 2.5 t/ha) and acrylic polymer or other tackifier (5 to 10% by weight).
Level spreader	Finely contoured end-of-drain profile designed to allow concentrated flow to be released as even sheet flow over a nominated width of stable vegetated (grassed) land.
Non-woven fabric	A geotextile formed from fibres arranged in an oriented or random pattern to form a sheet. The fibres are bonded chemically, thermally or mechanically.
On-grade 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).
Potential acid sulfate soil	A soil that is likely to convert into an acid soil if exposed to air.
Rock filter dam	A sediment trap consisting of a rock embankment lined with aggregate and/or filter cloth on the upstream face. The embankment provides structural support while the aggregate and/or filter cloth acts as both a filter medium and flow control system.
Run-on water	Surface water flowing onto an area as a result of runoff occurring higher up the slope. Commonly used in an urban context as a contributing factor to increased erosion hazard.
RUSLE	The Revised Universal Soil Loss Equation (RUSLE) is commonly used to predict long-time 'average' soil loss rates resulting from sheet and rill flow (not wind or gully erosion).
Sag 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).

Sandy loam	A loam containing enough sand or grit to make the material friable. A bolus formed in the hand will have some coherence and can be rolled into a stable ball, but not a thread. Sand grains can be felt during manipulation. Clay content is approximately 10 to 15%.
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.
Sediment basin	A dam and associated settling/stilling pond used to capture and retain sediment from the passing flow. The design component generally consist of an excavated or natural basin, stabilised flow entry points, de-watering system, and high-flow emergency spillway.
Sediment control zone	That part of a works site from which sediment-laden runoff will flow to an appropriate sediment control system.
Sediment weir	A self-supporting vertical rock weir usually constructed from uniform-sized rocks, with a filter medium placed on the upstream face of the weir.
Stormwater management plan	A plan or policy developed for the management of stormwater within a specified region or catchment.
Table drain	The side drain of a road adjacent to the shoulders, and comprising part of the formation.
Turbid water	Discoloured water usually resulting from the suspension of fine sediment particles.
USLE	The abbreviation for Universal Soil Loss Equation. A soil loss estimation equation developed to predict the long-term, average annual soil loss resulting from sheet and rill erosion acting on a given soil area.
Water sensitive road design	Application of water sensitive urban design principles to road design.
Water sensitive urban design	A holistic approach to the planning and design of urban development with aims of minimising negative impacts on the natural water cycle, protecting the health of aquatic ecosystems, and promoting the integration of stormwater, water supply and sewage management at a development scale.
Wet basin	A sediment basin that is not free-draining and thus needs to be manually de-watered after a storm.
Wet season	In tropical and sub-tropical climates, the period of the year in which most rainfall occurs.
Woven fabric	A geotextile formed from by systematically interlacing two sets (warp and filling) of parallel yarns to form a sheet.