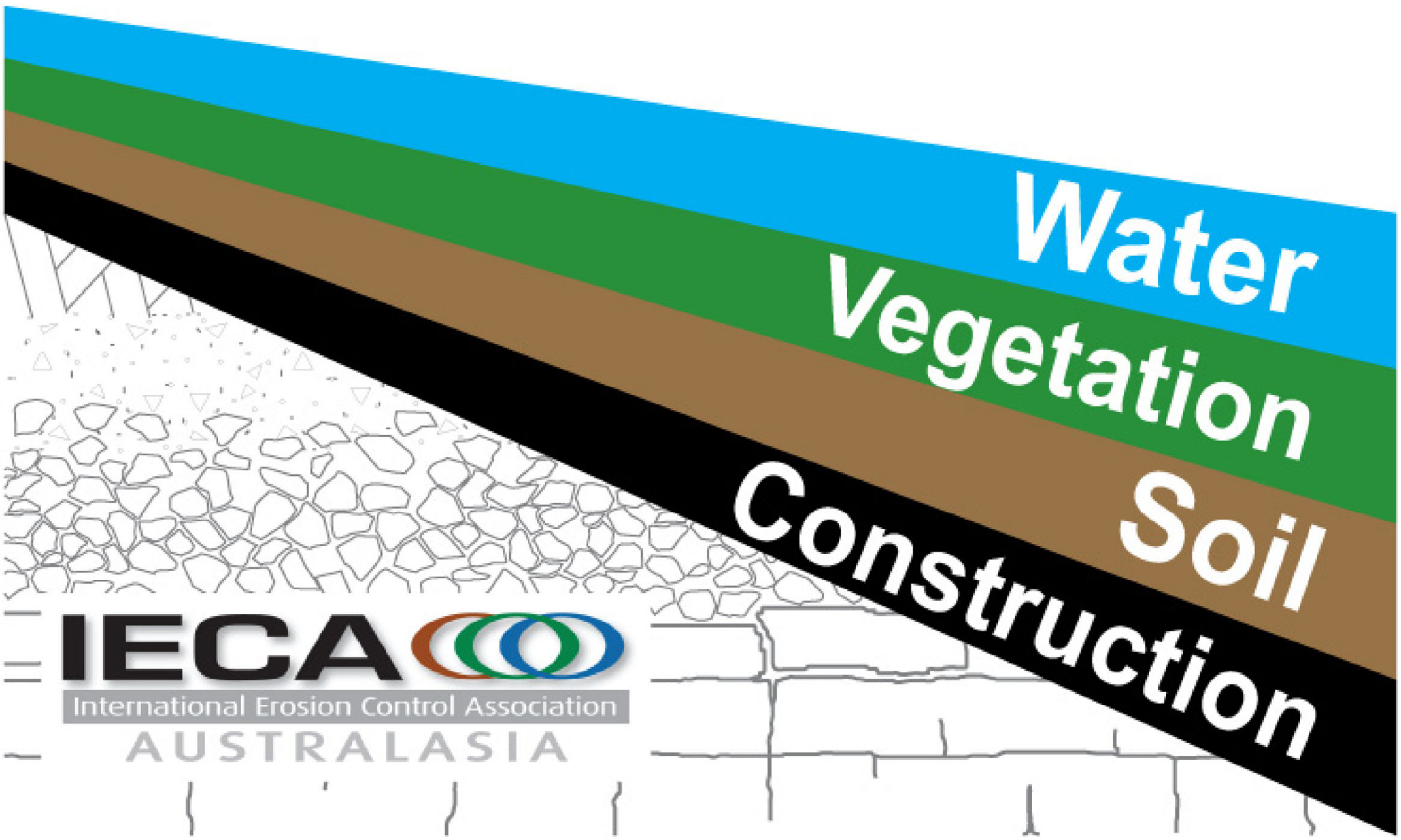
Best Practice
Erosion & Sediment Control

Book 3 – Appendices H - N

November 2008



Best Practice Erosion & Sediment Control

– for building and construction sites

Book 3 – Appendices H-N

November 2008

International Erosion Control Association (Australasia)

Prepared by: Grant Witheridge, Catchments & Creeks Pty Ltd

Diagrams by: Grant Witheridge, Thomas (Jesse) Baber, and Bryde Cameron of Catchments & Creeks Pty Ltd

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Specifically, the adoption of these best practice procedures will not guarantee:

(i) compliance with any statutory obligations;
(ii) compliance with specific water quality objectives;
(iii) avoidance of environmental harm or nuisance.

Appendix H

Building sites

This appendix provides guidelines on the development of Erosion and Sediment Control Plans for detached-dwelling building sites. The primary function of this appendix is to provide government bodies and the building industry with a model Code of Practice for the building industry. Government bodies are encouraged to explore the development of a regional-based Code of Practice using the model code as a template.

H1 Introduction

Residential and small commercial building sites represent a unique set of site conditions within the erosion and sediment control industry. These sites are usually too small to incorporate high standard sediment control measures such as *Sediment Basins*, and it is also often impractical to incorporate erosion control measures until the building activities are near completion. It is for these reasons that the focus of erosion and sediment control on building sites changes slightly from the traditional focus adopted for larger construction sites.

In reality the principles of on-site erosion and sediment control do not change whether the soil disturbance is a small building or large construction site, or if the site is located in the tropics or temperate zone. However, the priority given to each of the principles must change based on the anticipated site conditions.

What is considered reasonable and practicable on a construction site may not be considered reasonable and practicable on a typical building site, and vice versa. However, some building sites can be significant in size, such as many medium density townhouse developments, in which case the building site needs to treated in the same manner as a construction site of equivalent size.

H2 Building design

The following principles need to be incorporated into the building design and site layout where appropriate.

- Investigate site constraints and appropriately integrate the building into the site in a manner that minimises both short- and long-term environmental harm.
- Consider the use of elevated pole homes on steep blocks.
- Allow enough accessible room on the site to store all building materials, especially stockpiles of erodible material.
- Allow enough space to install all necessary sediment control measures, especially along the lower property boundary.
- Do not specify exposed aggregate concrete surfaces in areas where the cement wash-off cannot be fully contained within the site or an associated slurry collection pit.

H3 Principles of building site erosion and sediment control

The following key principles apply, wherever reasonable and practicable, to the management of building sites.

(i) Prepare and implement an Erosion and Sediment Control Plan (ESCP) for the site.

(ii) Allow for the early stabilisation of any disturbed areas located outside the immediate work area. As an example, after the completion of earthworks, it is often possible to stabilise (i.e. turf) the backyard before works commence on the building.

(iii) Minimise the number of site entry points, preferably to one stabilised rock pad.

(iv) Expose the smallest possible area of land for the shortest possible time.

(v) Save and promptly replace the topsoil.

(vi) Divert up-slope stormwater runoff around soil disturbances.

(vii) Connect roof water downpipes to the permanent drainage system immediately the roof and guttering are installed.

(viii) Actively control wind- and rain-induced soil erosion.

(ix) Firmly compact and stabilise all backfilled service trenches.

(x) Minimise sediment released from the property.

(xi) Place all long-term stockpiles of erodible material within the sediment control zone.

(xii) Fully contain all wash-water from concreting, ceramic cutting, and cleaning operations within an on-site area of grass or open soil.

(xiii) Promptly revegetate or otherwise stabilise disturbed areas.

(xiv) Maintain all control measures in proper working order at all times.

H4 Development of Erosion and Sediment Control Plans

The following section has been developed to provide a procedure for the preparation of Erosion and Sediment Control Plans (ESCPs) for single-dwelling building sites. This procedure has been supplied as a guide only.

The following recommendations are not intended to replace the need for site-specific evaluation and design. It is of course important for Erosion and Sediment Control Plans to comply with all relevant local, State and Federal legislation and codes of practice.

The design steps incorporated into this procedure are summarised below:

Step 1. Evaluate site limitations.

Step 2. Stabilise site entry/exit points.

Step 3. Locate material stockpile areas.

Step 4. Control up-slope stormwater.

Step 5. Control sediment runoff.

Step 6. Control erosion on disturbed areas.

Step 7. Control roof water drainage.

Step 8. Define the installation sequence.

Step 9 Prepare technical notes for the ESCP.

Step 1. Evaluate site limitations.

Assess the site constrains and any site-specific concerns, including:

- protected vegetation that may need to be identified and/or fenced;
- highly erodible soils that may require increased erosion control measures;
- up-slope drainage catchments that may need to be diverted around the site;
- work space limitations that may require site-specific sediment control measures and/or the extensive use of mini-skips for material storage and waste removal.

Step 2. Stabilise site entry/exit points.

Where reasonable and practicable, restrict site access to one entry/exit point. A stabilised entry/exit point normally consists of a rock pad.

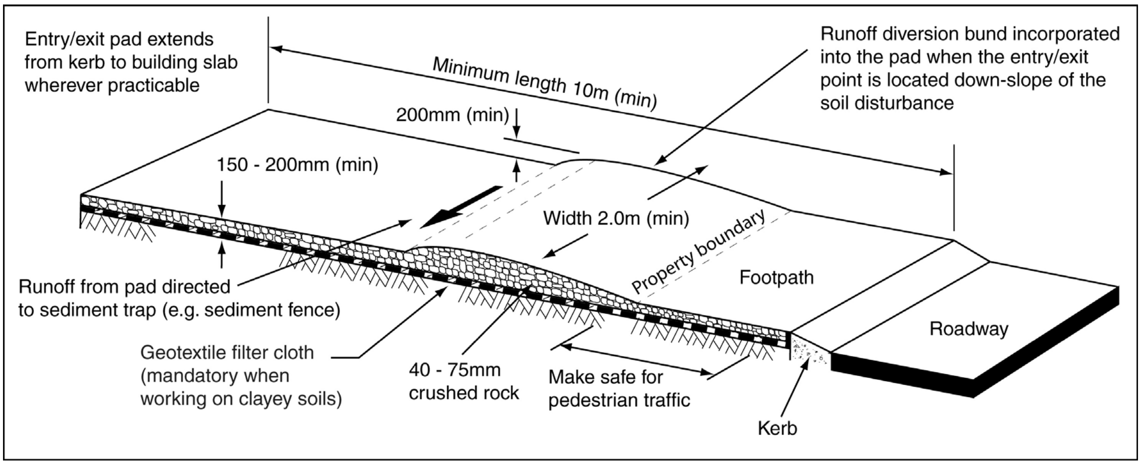


Figure H1 – Entry/exit rock pad for building sites

If the building site is elevated above the road, then it is likely that stormwater runoff will wash sediment from the entry/exit pad onto the roadway. To avoid this, it is usually necessary to construct a raised flow diversion bund across the rock pad (Figures H1 and H2) to direct stormwater runoff into an adjacent *Sediment Fence*.

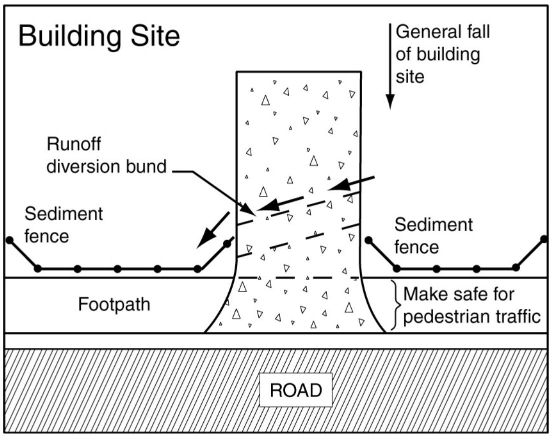


Figure H2 – Stormwater runoff being directed off an entry/exit pad

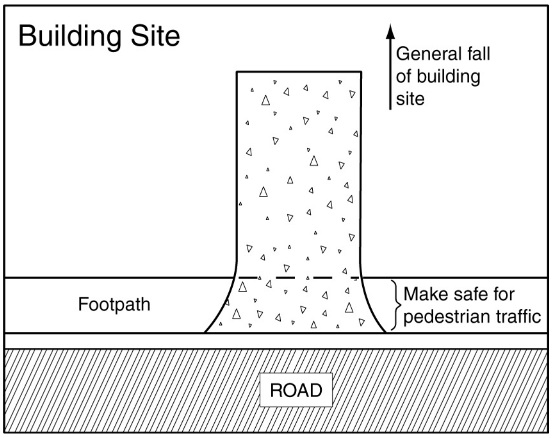


Figure H3 – Example of an entry/exit pad that drains back into a site

The entry/exit pad is usually displayed on the ESCP using either of the following standard symbols.

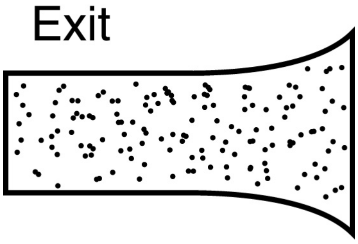


Figure H4 –

Entry/exit pad without drainage control

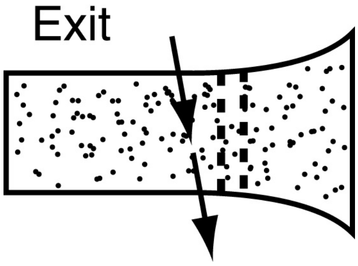


Figure H5 –

Entry/exit pad with drainage control

Step 3. Locate material stockpile areas.

Locate suitable areas up-slope of the main sediment barrier to store materials. The building layout should allow sufficient room on the site to locate all building materials. On steep sites or sites with limited available space, erodible materials may need to be stored in commercial sized bins or mini-skips.

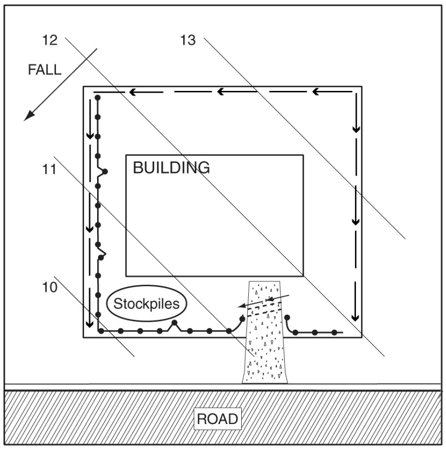


Figure H6 – Placement of stockpile area

Step 4. Control up-slope stormwater.

During those months when the rainfall is expected to exceed 45mm, up-slope catchment area that exceed 1500 m^2 should be diverted around stockpiles, soil disturbances and the building activities wherever reasonable and practicable. However, stormwater must not be diverted if such a flow diversion would inconvenience neighbouring properties, or result in the stormwater being unlawfully diverted into a neighbouring property.

Up-slope stormwater may be collected and moved across the site by constructing either a *Catch Drain* or *Flow Diversion Bank* (Table H1). If the site is steep, then a temporary flow diversion *Chute* may need to be constructed (Table H2).

If flow velocities within these drains are expected to cause erosion, then the options are to either line the surface of the drain with turf, filter cloth, or *Erosion Control Mats*; or to place *Check Dams* in the channel to reduce the flow velocity. *Check Dams* (Table H3) are most effective when used in channels with a gradient less than 10% (1 in 10).

Table H1 – Low gradient flow diversion techniques

Technique	Symbol	Typical Usage
Catch Drains	→ CD →	• Shallow spoon drain cut into soil up-slope of earthworks. • Used for the diversion of sheet flow and minor concentrated flows.
Flow Diversion Banks – earth	→ DB →	• Small embankment of soil placed up-slope of earthworks. • Used for the diversion of minor flow when soils are dispersive or otherwise highly erodible.

Table H2 – Steep gradient flow diversion techniques

Technique	Symbol	Typical Usage
Chutes	→ CH →	• Transfer concentrated water down steep slopes.
Level Spreaders	LS	• Used to convert minor concentrated flows back to "sheet" flow before releasing it down a stable grassed slope.

Table H3 – Types of *Check Dams*

Technique	Symbol [1]	Typical Usage
Sandbag Check Dams	→ SBC →	• Used in shallow channels typically less than 500mm deep because they are usually small in height and are less likely to divert water out of the channel.
Rock Check Dams	→ RCD →	• Used in deep channels typically greater than 500 mm deep.

Note: [1] The standard symbol for a *Check Dam* is not usually used on ESCPs. Instead their use is specified as a technical note on the plan.

Step 5. Control sediment runoff.

On building sites, the control of sediment runoff is normally limited to Type 3 sediment traps such as a *Sediment Fence*. Wherever reasonable and practicable the *Sediment Fence* is supplemented through the placement of *Grass Filter Strips*.

Wherever reasonable and practicable, *Sediment Fences* should be installed along a line of constant elevation to allow stormwater to pass evenly through the fence. On most building sites, however, it is usually only practical to install the *Sediment Fence* along the lower property boundary, thus the fence is often installed down a slight gradient. In such cases, regular returns (i.e. fence turned at least 1 m up the slope) at a maximum 10 m spacing (Figure H8) are required to avoid the Sediment Fence directing all the runoff to the lowest corner of the property.

Figure H7 – Standard symbol for a *Sediment Fence*

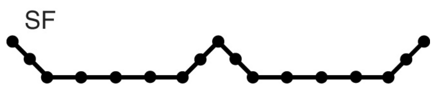


Figure H8 – Symbol for a *Sediment Fence* with intermediate fence return

Step 6. Control erosion on disturbed areas.

Appropriate erosion control measures should be employed to limit soil erosion as soon as reasonable and practicable. Erosion control measures are best identified through the use of technical notes on the plans—refer to Step 9.

The application of erosion control measures greatly depends on the likelihood and intensity of expected rainfall. If building activities occur during the dry months when the monthly rainfall is expected to be less than 45 mm, then erosion control requirements are likely to be significantly less than if building works were to occur during the wetter months.

In addition to a down-slope *Sediment Fence*, long-term stockpiles of "clayey" material may require an impervious cover to minimise the release of turbid runoff. Stockpiles of clean sand that are located behind a *Sediment Fence*, will only need a protective cover if the stockpiles are likely to be exposed to strong winds.

Newly formed earth batters should be covered with topsoil and mulched, vegetated or otherwise stabilised as soon as reasonable and practicable. If the earth batters are not going to be grassed, and the application of loose mulch is unlikely to stabilise the slope, then commercially available *Erosion Control Blankets* may need to be used to stabilise the batter.

Where practicable, the site should be turfed as soon as building activities are completed and a heavy mulch layer should be placed on exposed garden beds to control soil erosion. Builders are encouraged to include such items within the building contract. It must be acknowledged that the use of turf is not appropriate in all climatic regions.

Step 7. Control roof water drainage.

To reduce soil erosion and site wetness, roof water should be discharged away from the active work area and any disturbed soil surface. During periods when there is a reasonable likelihood of rainfall, permanent or temporary downpipes need to be installed to suitably manage roof water as soon as the roof and guttering is laid.

Roof water drainage controls are best identified through the use of technical notes on the plans—refer to Step 9. The use of such controls can significantly reduce down-time and clean-up costs following extended periods of wet weather.

Step 8. Define the installation sequence.

Whether temporary or permanent, there are usually critical drainage, erosion, and sediment control measures that should be the first items installed before building works commence.

An ESC installation or construction sequence should be developed for all specified drainage, erosion, and sediment control measures. A typical construction sequence is presented below. Also refer to Table H6 in Section H7.

1. Obtain all necessary permits, licences and approvals before site establishment.
2. Establish a single, stabilised entry/exit point (e.g. rock pad).
3. Install sediment fence(s) down-slope of the site.
4. Divert up-slope water around the work site and stabilise any drainage channels.

5. Clear only those areas necessary for building works to occur.
6. Strip and stockpile the topsoil before commencing earthworks or excavations.
7. Stockpile erodible materials within the sediment control zone.
8. Stabilise exposed earth banks (e.g. mulch, turf, erosion control blankets).
9. Install on-site waste receptors (e.g. mini-skips, bins, wind-proof litter receptors).
10. Commence building activities.
11. Establish the site's underground drainage system (if any).
12. Connect roof water downpipes to the permanent underground drainage system as soon as the roof and guttering is laid.
13. Regularly inspect all drainage, erosion and sediment control measures and maintain all measures in proper working order at all times.
14. Progressively revegetate/stabilise the site.
15. Remove any remaining temporary drainage, erosion and sediment control measures upon complete stabilisation of the site.

Step 9 Prepare technical notes for the ESCP.

Technical notes should be attached to the Erosion and Sediment Control Plan to highlight site-specific issues and to detail maintenance requirements of the ESC measures. An example of possible technical notes is provided below. Only those notes relevant to a given site should be adopted.

Example technical notes:

- All sediment fences to be installed prior to commencement of earthworks if rain is possible while earthworks are occurring.
- Prior to commencing excavations, topsoil must be stripped from the designated area and stockpiled on site for later use.
- Immediately following the completion of bulk earthworks, all disturbed areas outside the footprint of the base slab (if used, otherwise all disturbed areas) to be mulched (minimum 50 mm) or otherwise stabilised against erosion.
- Designated earth batters to be stabilised, as directed on the plans, immediately after bulk earthworks have been completed on the site.
- Appropriate building waste receptors must be located on the site and suitably maintained during the building phase.
- All ground cover vegetation outside the immediate building area to be preserved during the building phase.
- Damage to the road reserve (i.e. footpath) vegetation to be minimised and repaired as soon as reasonable and practicable at the builder's expense.
- No materials to be stockpiled outside the property boundaries beyond the end of a working day.
- Soil and sand stockpiles to be covered if strong winds are forecast that could displace the material from the site.
- Stockpiles of earth are to be covered with an impervious cover if rain is forecast.
- The site's underground stormwater drainage system to be installed and operational prior to roof installation.

- Roof water downpipes (temporary or permanent) to be connected to the stormwater drainage system immediately after the roof and guttering is laid.
- All temporary drainage and sediment control measures to remain functional during the building phase.
- All erosion and sediment control structures to be inspected each working day and maintained in proper working order at all times.
- Sediment to be removed from up-slope of each sediment fence immediately after rainfall if the depth of sediment exceeds 200 mm.
- Excessive sediment deposition on the rock entry/exit pad to be removed.
- Additional rock to be applied to the rock entry/exit pad as necessary to maintain its function.
- All sediment deposited off the site as a result of work-related activities is to be collected and disposed of in a manner that will prevent any safety or erosion hazard.

H5 Example building site ESCPs

- The *Sediment Fence* may require occasional returns (zigzags) installed to prevent stormwater simply flowing down the fence to the lowest corner of the property. Fence returns are normally installed at a maximum spacing of 10 m. These returns should extend at least 1 m up the slope.
- *Catch Drains* or *Flow Diversion Banks* placed along the up-slope edges of the property are generally required only if there is more than 1500 m^2 of catchment area up-slope of the building and the monthly rainfall is expected to exceed 45 mm.
- A flow diversion bund may or may not be required on the entry/exit pad of building sites depending on the expected quantity of sediment and surface runoff discharging down the rock pad.

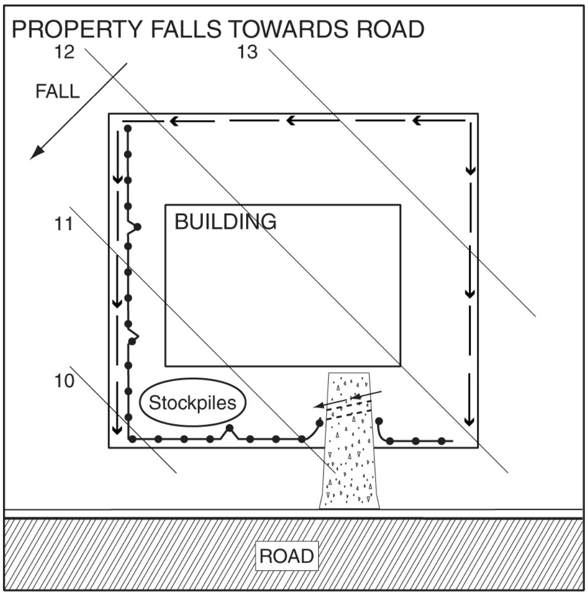


Figure H9 – Example site plan

- In Figure H10 the entry/exit pad does not require a raised flow diversion bund because sediment-laden runoff from the rock pad will not be flowing onto the road.
- Placing a *Sediment Fence* or safety fence along the front of the property can help to restrict traffic movement to the entry/exit pad.
- The *Sediment Fence* may be fixed to the back fence (if available), but must still be suitably buried (anchored).
- Stormwater runoff from stockpiles must drain to the *Sediment Fence* or other suitable sediment trap.

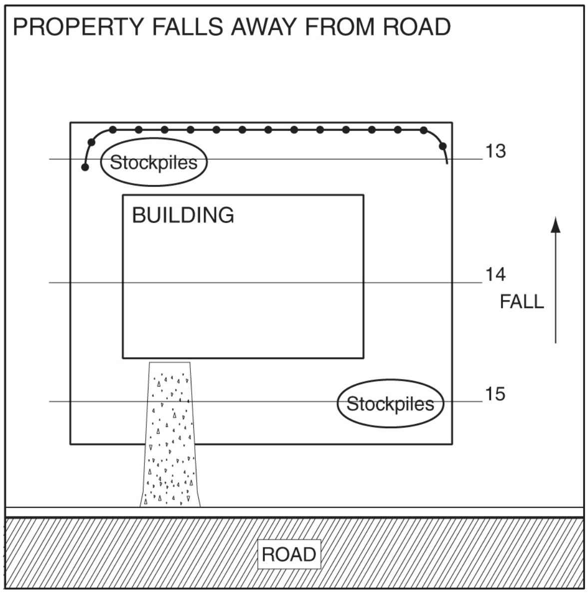


Figure H10 – Example site plan

- If property fencing already exists, then the *Sediment Fence* (suitably anchored) may be fixed to this fence for support.
- Extending the *Sediment Fence* along the front of the property can help to control traffic movement onto the site.
- Intermediate returns are not required on a *Sediment Fence* if it is installed along level ground.
- The entry/exit pad may or may not require a raised flow diversion bund to prevent sediment-laden water flowing off the rock pad onto the road.
- *Catch Drains* or *Flow Diversion Banks* placed along the up-slope edges of the property are generally required only if there is more than 1500 m^2 of catchment area up-slope of the building and the monthly rainfall is expected to exceed 45 mm.

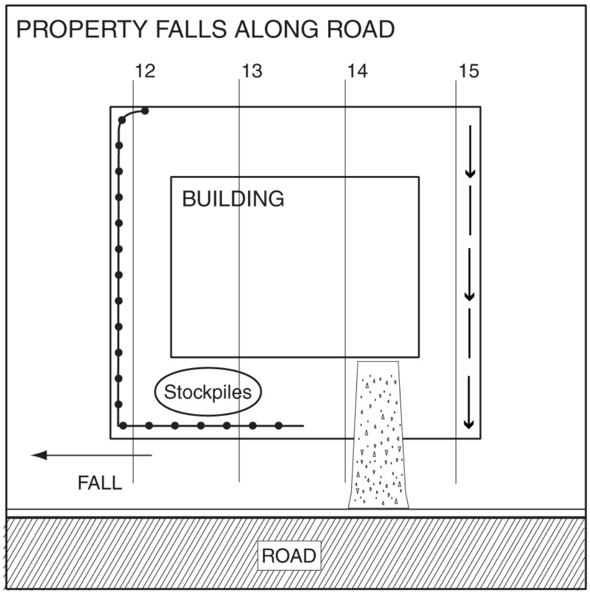


Figure H11 – Example site plan

- Initially a *Sediment Fence* should be located along the full length of the lower property boundaries. Sections of this *Sediment Fence* may be removed to allow foundations and building works to be completed, but it must remain in place and in proper working order for as long a practical.
- *Catch Drains* or *Flow Diversion Banks* placed along the up-slope edges of the property are generally required only if there is more than 1500 m^2 of catchment area up-slope of the building and the monthly rainfall is expected to exceed 45 mm.
- A flow diversion bund may or may not be required on the entry/exit pad of building sites depending on the expected quantity of sediment and surface runoff discharging down the rock pad.

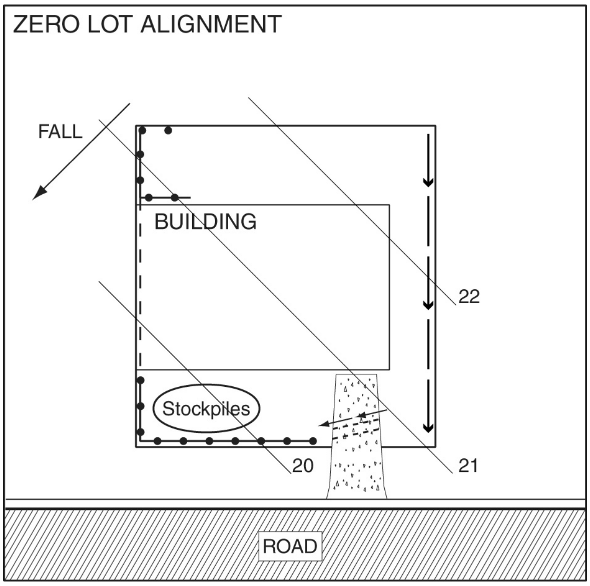


Figure H12 – Example site plan

- *Catch Drains* or *Flow Diversion Banks* placed along the up-slope edges of the property are generally required only if there is more than 1500 m^2 of catchment area up-slope of the building and the monthly rainfall is expected to exceed 45 mm.
- *Catch Drains* located along the side of the property are only required if it is necessary to either permanently direct stormwater away from adjacent properties, or to temporarily direct sediment-laden water to the *Sediment Fences*.
- If the *Catch Drains* carry only “clean” stormwater runoff, then they should be directed **around** the *Sediment Fence* as shown on the right-hand-side of the diagram.
- A flow diversion bund may or may not be required on the entry/exit pad of building sites depending on the expected quantity of sediment and surface runoff discharging down the rock pad.

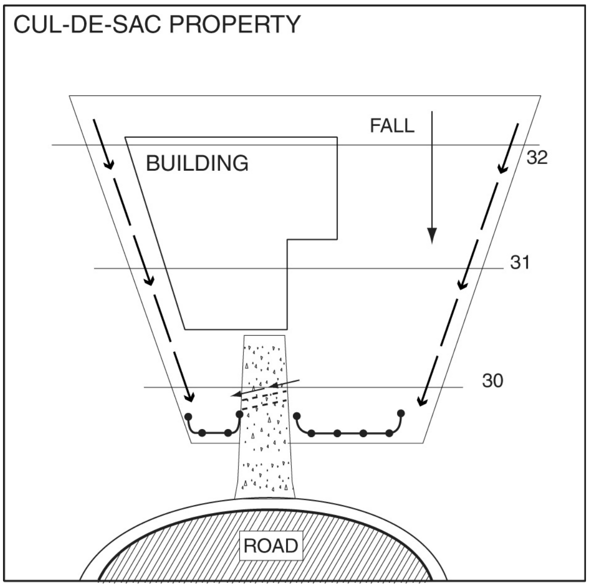


Figure H13 – Example site plan

- In most cases drainage and sediment controls on narrow lots should be as per larger building sites.
- The *Sediment Fence* may need to be located across the full width of the lower property boundary. In such cases, the fence may be lowered during working works to allow access, but must be raised at the end of each working day and while rain is occurring.
- A flow diversion bund may or may not be required on the entry/exit pad of building sites depending on the expected quantity of sediment and surface runoff discharging down the rock pad.

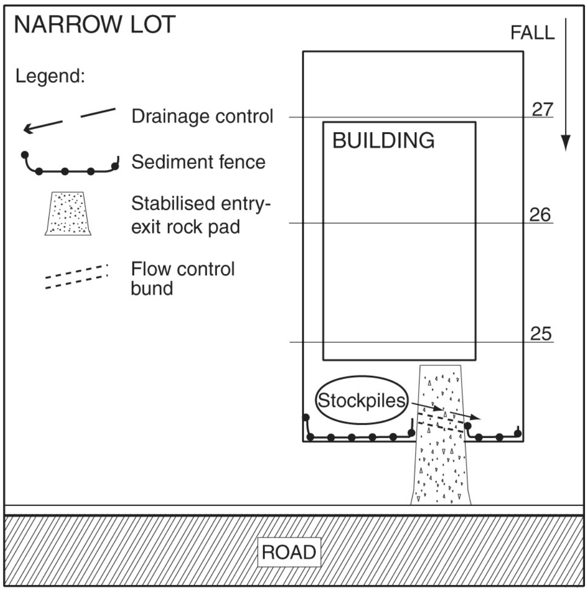


Figure H14 – Example site plan

EROSION AND SEDIMENT CONTROL PLAN

Legend:

- Property boundary
- Dwelling
- Sediment fence
- Diversion drain/bank
- Stabilised entry/exit pad
- Entry/exit pad bund
- Contour line
- Level spreader

Technical notes:

1. All erosion and sediment control structures to be inspected each working day and maintained in good working order.
2. All ground cover vegetation outside the immediate building area to be preserved during the building phase.
3. All erosion and sediment control measures to be installed prior to commencement of major earthworks.
4. Stockpiles of clayey material to be covered with an impervious sheet.
5. Roof water downpipes to be connected to the permanent underground stormwater drainage system as soon as practical after the roof is laid.

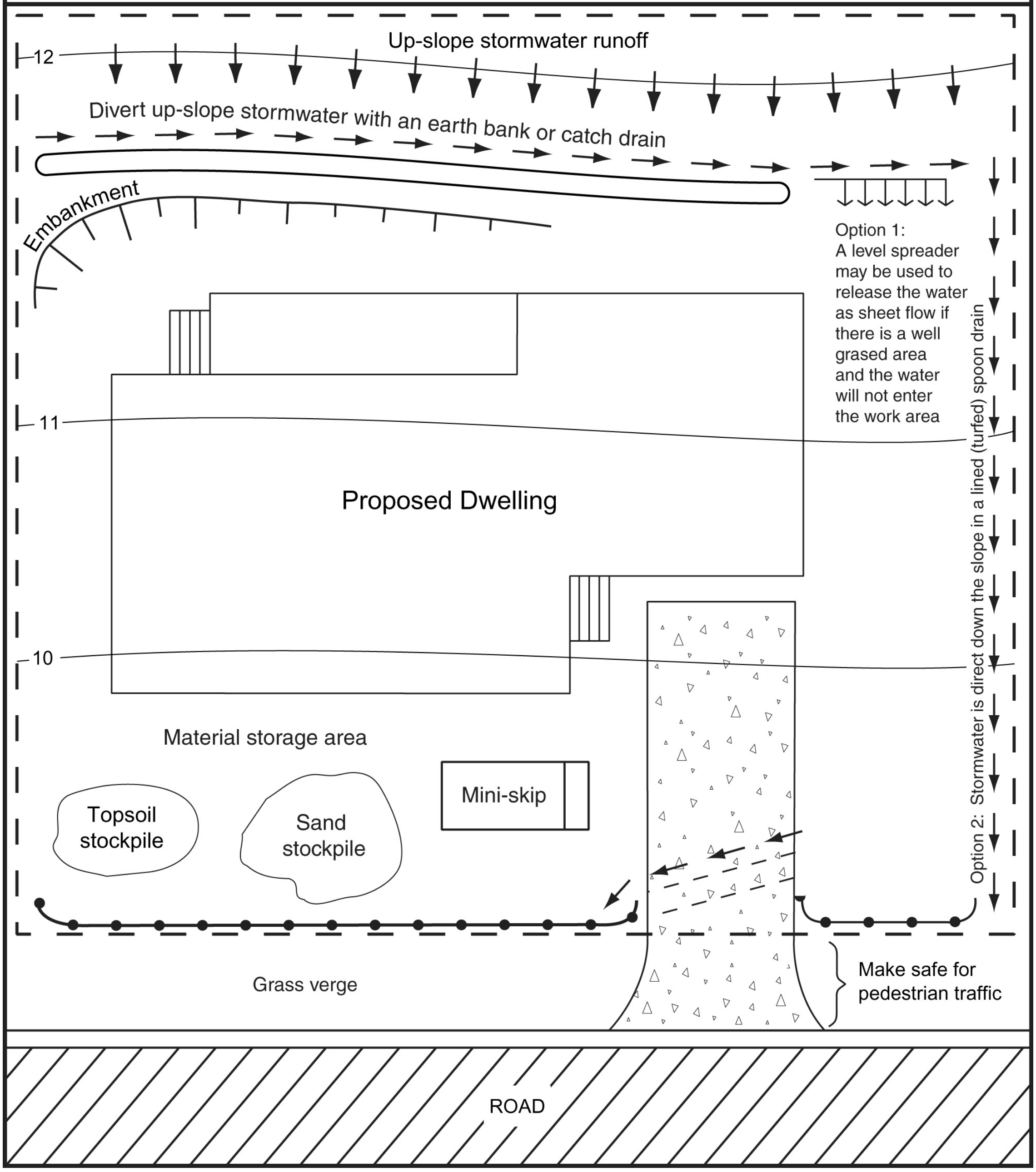


Figure H15 – Example Erosion and Sediment Control Plan

H6 Model Code of Practice for building sites

This model Code of Practice has been provided as an example of a local government building code for the management of erosion and sediment control on detached-dwelling building sites.

Compliance with a given Performance Criterion can only be achieved by:

(i) complying with the all items listed as the Acceptable Solution; or
(ii) formulating an alternative solution which complies with the Performance Criterion, or is shown to be at least equivalent to the acceptable solutions; or
(iii) a combination of (i) and (ii).

The Explanatory Notes (Section H7) form part of this model Code of Practice. The Explanatory Notes provide essential information that is otherwise not contained within the Code.

DRAINAGE CONTROL			
Performance Criteria		**Acceptable Solution**	
P1	Up-slope stormwater runoff is managed to minimise soil erosion and site wetness.	**A1**	(a) If the area of land up-slope of the soil disturbance exceeds 1500 m^2, then all reasonable and practicable measures are taken to divert this stormwater around the soil disturbance in a manner that does not increase soil erosion or result in the contamination of the diverted water. (b) Wherever reasonable and practicable, sandbags, *Catch Drains*, *Flow Diversion Banks* or other appropriate drainage systems are used to divert stormwater around excavations and service trenches. (c) Wherever reasonable and practicable, flow diversion systems are used to direct up-slope stormwater away from unprotected earth batters steeper than 4:1 (H:V).
P2	Stormwater runoff does not cause unacceptable levels of soil erosion.	**A2**	(a) Appropriate measures are used to control soil erosion within all temporary and permanent drainage systems (e.g. through the use of channel linings, turfing, or the placement of velocity control *Check Dams*). (b) All stormwater discharges onto a stable surface.
P3	Stormwater runoff does not cause a nuisance or damage to adjoining properties.	**A3**	(a) Stormwater is discharged in a non-erosive manner at a legal point of discharge. (b) Temporary drainage systems immediately up-slope of existing residential properties are designed to a standard commensurate with the risk of nuisance flooding and/or sediment deposition.
P4	Roof water from within the site does not unreasonably increase soil wetness within the work area.	**A4**	(a) A temporary or permanent roof water drainage system is installed before the roof covering is laid. (b) Roof water is discharged through a temporary or permanent roof drainage system to a location that minimises soil erosion and site wetness.

EROSION CONTROL			
Performance Criteria		**Acceptable Solution**	
P5	Site activities are carried out in a manner that minimises the duration that disturbed soils are exposed to the erosive forces of wind, rain and flowing water.	**A5**	(a) Soil disturbance is not carried out until the principal on-site activities are ready to commence. (b) All reasonable and practicable measures are taken to minimise the removal of, or disturbance to, vegetation and ground covers (organic or inorganic) on the site prior to and during land-disturbing activities. (c) All reasonable efforts are taken to coordinate: (i) the activities of subcontractors to minimise the duration of soil disturbance; and (ii) common trenching of utilities.
P6	Soil erosion resulting from rainfall is minimised.	**A6**	(a) Existing ground covers (grass, mulch, and so on) are protected from damage and retained as long as practicable. (b) All reasonable and practicable measures are taken to cover, stabilise or otherwise protect non-vegetated soil surfaces from the erosive effects of rainfall as soon as reasonable and practicable after works on these surfaces have been completed. (c) Service trenches are: (i) backfilled, compacted and capped with a layer of topsoil to a level at least 75 mm above the adjoining ground level; or (ii) backfilled, compacted and rehabilitated in a manner that best prevents undesirable water flow and soil erosion along the trench.
P7	Soil erosion resulting from strong winds is minimised.	**A7**	Stockpiles of erodible material are covered during periods of strong wind or when strong winds are expected.
P8	Stormwater is not contaminated by unacceptable levels of sediment resulting from material stockpiles.	**A8**	(a) Stockpiles of erodible material are not located within drainage depressions. Otherwise up-slope stormwater runoff is diverted around these stockpiles in a non-erosive manner. (b) Stockpiles of erodible material are covered with a synthetic cover, mulch, or temporary vegetation if not fully used within four (4) weeks. (c) Short-term stockpiles of erodible material located outside of the sediment control zone are covered if it is raining; or rain is imminent; or at the end of the working day.
P9	Exposed soil surfaces are rehabilitated as soon as practicable to prevent or minimise soil erosion.	**A9**	All reasonable and practicable steps are taken to: (i) incorporate all necessary site rehabilitation measures into the building contract such that these works will be completed before the end of the contracted works; and/or (ii) coordinate, facilitate and expedite the prompt rehabilitation of finished earthworks with the land owner and/or external contractors.

<table>
<tr><th colspan="4">SEDIMENT CONTROL</th></tr>
<tr><th colspan="2">Performance Criteria</th><th colspan="2">Acceptable Solution</th></tr>
<tr><td>P10</td><td>Adequate precautions are taken to minimise sediment leaving the work area due to site traffic.</td><td>A10</td><td>(a) Vehicle access to the site is limited to stabilised entry/exit points.
(b) The number of entry/exit points for the site is minimised.
(c) If vehicular access into, or out of, a site is likely to track sediment onto an external sealed roadway, then a stabilised, sediment control entry/exit system (e.g. Rock Pad, Vibration Grid) is placed adjacent the external roadway.</td></tr>
<tr><td>P11</td><td>Site activities do not allow unacceptable levels of sediment to leave the work area.</td><td>A11</td><td>(a) Soil disturbances are not conducted until the associated Erosion and Sediment Control Plan has been approved.
(b) No clearing or soil disturbance is undertaken unless preceded or accompanied by installation of adequate drainage and sediment control measures.
(c) A suitable sediment barrier is placed down-slope of any on-site soil disturbance.
(d) An appropriate sediment barrier is placed around any on-site stormwater inlet that would otherwise be subject to sediment-laden inflow.
(e) Sufficient space is provided for the on-site storage of all erodible materials up-slope of a suitable sediment barrier.
(f) Appropriate additional or alternative ESC measures are undertaken if it is determined that unacceptable off-site sedimentation is occurring.
(g) Material removed from sediment control devices is disposed of in a manner that does not cause ongoing soil erosion or environmental harm.</td></tr>
<tr><td>P12</td><td>Sediment control measures are located within the property boundary.</td><td>A12</td><td>All sediment control measures are located within the property boundary, unless:
(i) it is that portion of the entry/exit pad located between the property boundary and the sealed road; or
(ii) the sediment control measure is required to collect sediment wash-off from building works located along the property boundary; and
(iii) approval has been obtained from the relevant regulatory authority and the relevant landowner or asset manager.</td></tr>
<tr><td>P13</td><td>Extent and duration of damage and/or disturbance to vegetation contained within the road reserve must be minimised.</td><td>A13</td><td>Damage to vegetation contained within the road reserve that is the direct result of the building works, including that resulting from the parking of vehicles or equipment, or the storage of materials, must be:
(i) minimised in both extent and duration, to that required to carry out necessary building works; and
(ii) stabilised, repaired, or revegetated as soon as reasonable and practicable.</td></tr>
</table>

SITE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P14	Off-site material spills and accumulated sediment deposits are managed in a way that minimises environmental harm, safety issues, and damage to public and private property.	**A14**	(a) Sediment and other material that has originated from the work area, or as a result of the transportation of materials to or from the work area, that collects on sealed roads or within gutters or drains outside the immediate work area, is removed: (i) immediately if rain is occurring or imminent; or (ii) immediately if considered a safety hazard; or (iii) if items (i) or (ii) do not apply, before completion of the day's work. (b) Sediment, including clay, silt, sand, gravel, soil, mud, cement and ceramic waste, deposited off the site as a direct result of an on-site activity, is collected and the area appropriately cleaned in accordance with (a) above, and in a manner that gives appropriate consideration to the safety and environmental risks associated with the deposited material. (c) Washing/flushing of sealed roadways only occurs in circumstances where sweeping has failed to remove sufficient deposited material and the remaining material represents a safety risk. In such circumstances, all reasonable and practicable sediment control measures must be used to prevent, or at least minimise, the release of sediment into receiving waters. Any material collected is disposed of in a lawful manner that does not cause ongoing soil erosion or environmental harm.
P15	All reasonable and practicable measures are taken to prevent concrete waste from entering gutters, drains and waterways.	**A15**	(a) Solid and liquid waste from concrete trucks and equipment is fully contained on the site. (b) Cement residue from work activities is: (i) washed onto a pervious surface (e.g. a grassed or open soil area, or excavated trench); or (ii) filtered through a fine-grained, porous embankment lined with an appropriate filter cloth; or (iii) collected and disposed of in a manner that does not cause ongoing environmental harm.
P16	All reasonable and practicable measures must be taken to prevent contaminated water resulting from cutting and cleaning activities entering gutters, drains and waterways.	**A16**	(a) Washing of tools and painting equipment is carried out within the property and over a porous grassed surface or open soil wherever reasonable and practicable. (b) The cutting of concrete, or other fine-grained or sediment-producing material, is carried out in a manner that: (i) fully contains any contaminated water for later treatment or disposal; or (ii) appropriately filters any resulting contaminated water through soil or heavy-duty filter cloth prior to its release from the work area.

P17	Drainage, erosion, and sediment control measures are maintained in proper working order at all times.	**A17**	(a) All temporary ESC measures are maintained in proper working order for: (i) the duration of the soil disturbance; or (ii) the duration of occupation of the site. (b) All ESC measures are inspected after rainfall to assess maintenance requirements and their effectiveness.
P18	Operational safety issues are given due consideration.	**A18**	ESC measures are installed and/or operated in a manner that does not cause a safety risk to the public or site personnel.

PLAN PREPARATION			
Performance Criteria		**Acceptable Solution**	
P19	For high-risk sites, an Erosion and Sediment Control Plan (ESCP) is prepared prior to site disturbance that provides sufficient information on proposed measures to control stormwater drainage, soil erosion, and sediment runoff, in sufficient detail and clarity, to achieve the required environmental protection, soil management, and timely installation of proposed measures.	**A19**	An ESCP is prepared including plan(s) no larger than 1:1000 that can be readily understood and applied on-site. The ESCP contains the following information where applicable: (a) North point and plan scale. (b) Site and easement boundaries. (c) Proposed building works and limits of disturbance. (d) Site access points. (e) Location of stockpiles. (f) Retained vegetation including protected trees. (g) Existing and final site contours. (h) Location of all drainage, erosion and sediment control measures. (i) Site revegetation requirements (if part of building contract). (j) Technical notes on ESC measures, installation sequence and maintenance requirements. (k) Any other information about the ESCP or the site that is considered necessary in order for the satisfactory application of the Plan.
P20	The ESCP is appropriate for the site conditions.	**A20**	(a) The standard of the control measures are commensurate with the degree of environmental risk associated with the proposed works, and the type, cost, and scope of the proposed works. (b) The level of detail supplied in the ESCP is commensurate with the complexity of the proposal.

H7 Explanatory notes for Model Code of Practice

Performance Criterion P1
One of the best ways of controlling sediment runoff is to prevent, or at least minimise, soil erosion in the first place. One of the best ways of minimising soil erosion is to appropriately control the flow of stormwater across a building site.

The intent of this Performance Criterion is to minimise the risk of stormwater runoff (either originating from the site or from up-slope properties) causing the following problems:

(i) soil erosion caused by "sheet" or "concentrated" stormwater runoff;
(ii) soil erosion caused by stormwater spilling down unstable earth batters;
(iii) increased site wetness (i.e. the generation of saturated soil and/or mud);
(iv) excessive quantities of stormwater runoff either overloading, or causing structural damage to, down-slope sediment barriers such as a *Sediment Fence*.

Acceptable Solution A1(a)
The diversion of stormwater runoff around a soil disturbance is always beneficial, unless of course, rainfall is unlikely to occur during the building works.

For the purpose of this Code it has been assessed that a catchment area of 1500 m^2 is likely to produce sufficient quantities of stormwater runoff to warrant the use of a flow diversion system. Local authorities may vary this catchment area based on local hydrological conditions.

Some local authorities may consider that flow diversion is usually only justified during periods of actual rainfall, or during those months when the average monthly rainfall is medium or higher (i.e. greater than 45 mm). In such a case the Solution may be stated as:

If the area of land up-slope of the soil disturbance exceeds 1500 m^2, then during those months when the rainfall is expected to exceed 45 mm, all reasonable and practicable measures are taken to divert this stormwater around the soil disturbance in a manner that does not increase soil erosion or result in the contamination of the diverted water.

Acceptable Solution A1(b)
Minimising the quantity of water entering excavations and trenches will reduce site wetness and the quantity of sediment-laden water that needs to be pumped/drained from these trenches to allow works to continue.

Acceptable Solution A1(c)
Unprotected earth batters can be highly susceptible to soil erosion, including "rilling", if exposed to excessive stormwater flows. Earth batters that expose dispersive soil can also be susceptible to gully erosion and/or structural failure.

Earth batters may be protected with the use of: vegetation, mulch (small batters), *Erosion Control Blankets*, rock or structural retaining walls. Earth batters that expose dispersive soil should always be protected with a layer (minimum 100 mm) of non-dispersive soil before placement of the final batter stabilisation.

Performance Criterion P2
Unacceptable levels of soil erosion include, but are not restricted to, the following examples:

(i) soil erosion caused by "sheet" flow that results in the loss of the equivalent of more than 10mm of soil from an area greater than 1m^2;
(ii) soil erosion that results in clearly visible "rilling" or channelling within the soil, or rill erosion to a depth greater than 100 mm;
(iii) the displacement of more than 10% of the erosion-control mulch placed over previously disturbed soil.

Acceptable Solution A2(a)
Stormwater runoff across the property must be managed in a non-erosive manner. This will require one or more of the following:

(i) stormwater runoff is diverted around disturbed soil;
(ii) flow velocities are controlled to avoid soil erosion;
(iii) drainage surfaces are lined with a material (i.e. turf, erosion control mats, filter cloth, or sediment fence fabric) that prevents erosion of the underlying soil;
(iv) water is transported within suitably sized drainage pipes.

In some cases, flow velocities in open channels can be controlled by installing a series of small *Check Dams* (Figure H16). These *Check Dams* are usually constructed from sand or gravel-filled bags. In deep channels (>500 mm deep), *Rock Check Dams* can be used. It is important to ensure these *Check Dams* do not cause flow to be diverted from the channel.

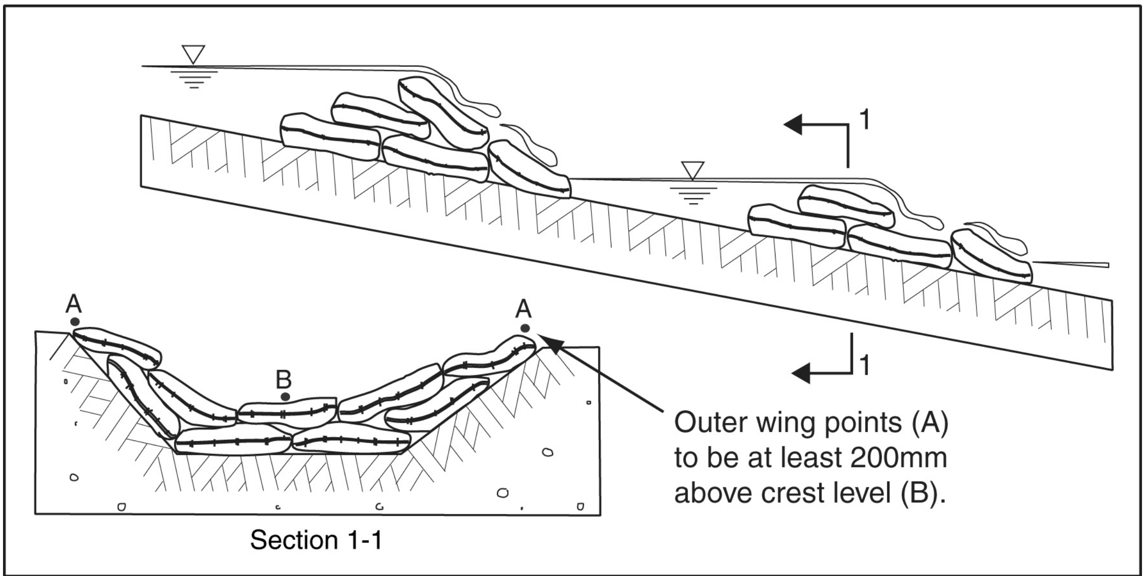


Figure H16 – Sandbag *Check Dams*

Acceptable Solution A2(b)
Diverted stormwater must not be allowed to cause unacceptable soil erosion upon its release from a drainage channel, *Chute* or stormwater pipe. In these circumstances, "unacceptable soil erosion" would mean any obvious form of soil erosion.

Performance Criterion P3
Diverted water must not be directed onto an adjacent property or be allowed to cause a nuisance within an adjoining, or any other downstream property. Some local authorities may accept water being temporarily diverted onto an adjoining property if that property is owned by, and in the control of, the same landowner or builder of the property from where the water was diverted.

Acceptable Solution A3(a)
If the water already flows into the adjoining property and this is considered to be its natural direction of flow, then before it reaches the property boundary, any diverted water must be returned to its original flow conditions in terms of velocity, quantity and direction.

If the adjoining property is owned and controlled by the same builder/owner, then a proposal to divert water into the adjoining property must be addressed in consultation with the appropriate authority. Stormwater must only discharge at a legal point of discharge.

Acceptable Solution A3(b)
The size and stability of a flow diversion system must take appropriate consideration of the expected flow rate, the risk of nuisance flooding to the downstream property, and the likely nuisance that sediment deposition would have on the downstream property.

The design storm standard would likely be between the 1 in 1 year to 1 in 10 year ARI design storm in accordance with the requirements of the regulatory authority. Where appropriate, reference may be made to the recommendation presented in Table 4.3.1, Chapter 4 – *Design standards and technique selection*.

Performance Criterion P4

Stormwater runoff from roofs and other impervious surfaces can unnecessarily disturb the work site and increase the potential for the site to cause environmental harm. Failing to adequately manage roof water can cause the following problems:

- (i) decrease the efficiency of on-site sediment control devices by increasing the volume of water required to be treated by these devices;
- (ii) increase the likelihood that sediment control devices will fail during periods of high rainfall;
- (iii) increase soil erosion, especially near the outlets of downpipes;
- (iv) increase the generation of mud through increased site wetness, thus increasing the transportation of clay-sized particles from the site;
- (v) increase building delays and decrease site safety through increased frequency and duration of soil saturation within the work area;
- (vi) increase soil erosion within or along service trenches.

Acceptable Solution A4(a)

Due to the relative size of the roof to the average urban property, the immediate connection of roof water downpipes to the permanent, underground, stormwater drainage system is arguably the most financially beneficial soil erosion and sediment control measure on building sites.

In some regions of Australia there may be no requirements for the construction of a sub-surface, roof water drainage system. In such cases, all reasonable efforts should be taken to install a temporary above ground drainage pipe that will direct roof water away from disturbed soil and the work area, at least during those months that have an average monthly rainfall greater 45 mm.

If the permanent drainage system incorporates sub-surface drainage pipes from the building to the road reserve, or other legal point of discharge, then this drainage system should be installed prior to the roofing system being laid.

Acceptable Solution A4(b)

During those months when the average monthly rainfall exceeds 45 mm, the roof water drainage system should be connected to either a surface or sub-surface, erosion-resistant drainage system (i.e. pipe) immediately after the roof and guttering is laid. This connection may either be through the use of temporary pipes (Figure H17) or permanent downpipes.

The use of temporary downpipe connections allows for the removal of these pipes during working hours to minimise disruption to building activities. However, these temporary downpipes must be reconnected if rain is occurring, or at the end of the day’s work if rain is imminent or likely to occur after work hours.

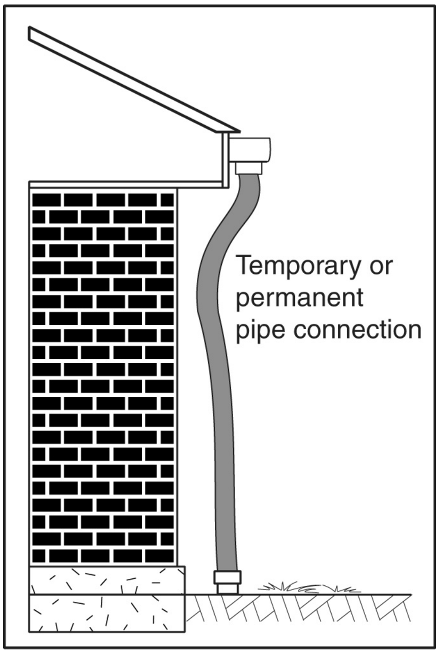


Figure H17 – Temporary downpipe

Performance Criterion P5

It is important to recognise that *Erosion Control* and *Sediment Control* are two very different activities. Erosion control measures aim to prevent soil erosion, whereas sediment control measures aim to trap sediment released by some up-slope erosion process.

There are virtually no sediment control measures that can trap all forms of sediment during all storm events. Specifically, there are very few sediment control measures that successfully trap clay-sized particles (grain size <0.002 mm).

Due to the inadequacy of sediment control measures to prevent the discharge of clay-sized particles from a building site, it is important to minimise the initial erosion of clayey soils. One of the most effective forms of erosion control is the principle of *minimising soil disturbance*.

The most important principle of *minimising soil disturbance* is to minimise the **duration** that soils are exposed to the erosive forces of wind, rain and flowing water.

Acceptable Solution A5(a)

All reasonable and practicable measures must be taken to minimise the time between the initial disturbance of soil on the site, and the commencement of building works.

Acceptable Solution A5(b)

Even if the entire site will eventually be disturbed at some stage, all reasonable efforts should be taken to minimise disturbance to any ground cover whether it is grass, mulch, leaf litter, or gravel, and to delay any required disturbance as long as practicable.

Acceptable Solution A5(c)

Soil disturbance resulting from the excavation of service trenches can result in significant sediment runoff. Minimising the number of service trenches and the duration these trenches are exposed can help reduce soil erosion and sediment runoff.

Performance Criterion P6

Almost any form of rainfall-induced soil erosion will release fine-grained, clayey particles that can readily pass through most sediment traps/barriers. Therefore, all reasonable and practicable measures must be taken to minimise unnecessary soil erosion.

Unnecessary soil erosion means erosion resulting from:

- unnecessary site disturbance; or
- unnecessary delays in site stabilisation or rehabilitation; or
- unnecessary exposure of dispersive soils; or
- concentrated stormwater flowing over unprotected soils.

Acceptable Solution A6(a)

The disturbance to any forms of existing ground cover (including, grasses, gravel, and mulch) should be minimised in order to minimise the exposure of soils to rainfall. In addition, any necessary disturbance to these existing ground covers should be delayed as long as practicable.

Acceptable Solution A6(b)

Appropriate erosion protection may be influenced by the following factors:

- slope of land;
- length of slope;
- expected weather conditions;
- erodible nature of the exposed soil;
- depth of soil to bedrock;
- type and availability of local vegetation;
- area of exposed soil;
- cost effectiveness and financial limitations.

On building sites located upstream of critical waterway habitats, all disturbed areas outside the footprint of the base slab (if used, otherwise all disturbed areas) should be mulched (minimum 50 mm) or otherwise stabilised against erosion immediately following the completion of bulk earthworks.

An example of possible erosion protection on slopes steeper than 10:1 (H:V) for various expected rainfall conditions is provided in Table H4.

Table H4 – Possible erosion protection measures

Expected rainfall conditions [1]	Possible erosion control measures
Extreme rainfall (e.g. months with an average rainfall greater than 225 mm)	• Well-anchored (e.g. pegged) turf. • Erosion control blankets placed over seeded topsoil and/or planted with trees and shrubs on small areas of land. • High strength (e.g. reinforced) *Erosion Control Blankets* placed over seeded topsoil and/or planted with trees and/or shrubs on large areas.
High rainfall (e.g. months with an average rainfall of 100 to 225 mm)	• Appropriately anchored (e.g. pegged) turf. • *Erosion Control Blankets* placed over seeded topsoil and/or planted with trees and/or shrubs.
Low to moderate rainfall (e.g. months with an average rainfall less than 100 mm)	• Heavy mulching planted with trees and/or shrubs. • Light mulching placed over grass-seeded topsoil. • Any option listed for the above categories.

Note [1]: Rainfall conditions do not necessarily correspond to definitions provided in Appendix N – *Glossary of terms*, instead, rainfall conditions are linked to the erosion risk rating presented in Section 4.4, Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A6(c)(i)
If a backfilled trench is not compacted to a firm condition, then soil settlement can occur over time or after significant rainfall. This lack of compaction can lead to the formation of a drainage depression along the trench resulting in the concentration of stormwater runoff and possible soil erosion.

Backfilling the trench to a level at least 75 mm above the adjoining ground level will usually address any future soil settlement (even if appropriate initial compaction is achieved). Variations of this requirement exist in different regions, thus always seek advice from the regulatory authority.

Acceptable Solution A6(c)(ii)
An alternative to A6(c)(i) would be to rehabilitate service trenches in a manner that has proven in the past to prevent unacceptable soil erosion or sediment runoff.

Performance Criterion P7
Wind erosion is typically a problem in coastal regions that have sandy soils. Strong winds are winds of sufficient velocity to erode the exposed soil or stockpiled material.

Acceptable Solution A7
Stockpiles most likely to be affected by strong winds are stockpiles of sandy soils located in coastal regions. Areas likely to be affected by strong winds may be identified by the regulatory authority.

Erosion from these stockpiles can be reduced by covering the stockpile with plastic sheeting, *Erosion Control Blankets*, mulch (light or heavy mulching), or temporary vegetation.

Performance Criterion P8
Stockpiles of erodible material such as soil, sand and mulch can be a major source of pollution. Proposed stockpile management techniques must address the following factors:

- type of material;
- expected duration of storage prior to its use;
- alternative storage arrangements and/or locations;
- the movement of concentrated stormwater runoff through the building site;
- practicability of covering the stockpile (to protect material from raindrop impact);
- likelihood and intensity of rainfall;
- expected environmental harm likely to be caused by the displacement of material.

Acceptable Solution A8(a)
Stockpiles of erodible material should not be placed in a location where up-slope stormwater runoff will likely cause the material to be washed away.

The sediment control zone is defined as that portion of a building site that drains to a sediment control device, excluding the entry/exit pad.

Acceptable Solution A8(b)
Protective cover may include plastic sheeting, filter cloth or *Erosion Control Blankets*. Organic covers such as mulch may be appropriate during periods of low wind. Temporary vegetation is only appropriate for very long-term stockpiles. Clayey material should ideally be covered with an impervious cover to reduce rainwater infiltration into the material.

Synthetic stockpile covers, such as plastic sheeting, may not be practical if regular loss/theft of these covers from the building site places an unreasonable financial burden on the builder.

Acceptable Solution A8(c)
In some circumstances it is not practical to temporarily store some materials in an area protected by a sediment barrier. A short-term stockpile means a stockpile that is located on-site or off-site for less than 24 hours.

Building materials that could reasonably be expected to be removed from the property or storage site by wind, rainfall, or other water may be temporarily stored on hard surfaces in the following circumstances:

(i) where it is necessary to place erodible material on a hard surface (e.g. a road or driveway) to undertake work and no other reasonable options are available (e.g. placing the material on a nearby grassed area or in a mini-skip); and/or

(ii) the material is stockpiled for less than 24 hours.

In such cases, the material must be:

- removed immediately if rainfall or strong winds are imminent or occurring; otherwise
- removed by the end of the day’s work even if rainfall or strong winds are neither imminent nor occurring.

Such materials must not be stored on a road reserve without obtaining permission from the road authority, usually the regulatory authority. Material placed on the road reserve must not block traffic, or cause safety or environmental problems.

If erodible materials are to be temporarily stored within a road reserve, then a suitable waterproof cover must be available on the site for use in the event of rain. Upon removal of the stockpiled material from the road reserve, the area must be appropriately cleaned (swept), stabilised, and rehabilitated.

Performance Criterion P9
Rehabilitation, in particular revegetation, of a site is one of the most effective ways of minimising long-term soil erosion and environmental harm. Vegetation can significantly reduce raindrop impact erosion, thus reducing runoff turbidity. Note, however, some forms of revegetation (e.g.

grass seeding) do not provide effective erosion control during the plant establishment phase unless incorporated with appropriate *Mulching* or *Erosion Control Blankets*. To be effective, at least 70% of the soil surface must be protected from raindrop impact.

Turfing is one of the most effective means of providing instant erosion control to a finished soil surface.

Acceptable Solution A9
The appropriate rehabilitation of a site depends on the many factors, including:

- local soil and weather conditions;
- condition and type of vegetation usually expected within the local area;
- expected long-term use of the land;
- financial considerations.

During periods of actual or expected heavy rainfall (i.e. expected monthly rainfall is greater than 100 mm), it can be highly beneficial for proposed grassed areas to be turfed rather than grass seeded. Future garden beds can be mulched (e.g. heavy mulching, i.e. greater than 50 mm depth).

During periods of extreme rainfall (i.e. actual or expected monthly rainfall is greater than 225 mm), *Erosion Control Blankets* may need to be used on steep sites and in areas of concentrated stormwater runoff.

The higher the expected rainfall intensity, the greater the need to expedite the rehabilitation processes.

Straw mulch (light mulching) can be spread over grass-seeded areas to control soil erosion while the grass is being established. This mulch can also benefit rehabilitation by reducing watering requirements and increasing seed germination.

In those location where turfing is an appropriate means of site rehabilitation, it should be actively promoted, especially during periods of high to extreme rainfall (i.e. expected monthly rainfall is greater than 100 mm).

Performance Criterion P10
Sediment deposited on public roads can create a traffic safety hazard as well as being washed into downstream water bodies. Thus all reasonable and practicable measures need to be taken to minimise the quantity of sediment leaving the site at entry/exit points.

It is noted that a stabilised entry/exit rock pad would have questionable value if access to the building site is via an unsealed (i.e. erodible) public road. Therefore, this Performance Criterion may not need to be satisfied if site access is via an unsealed public road—refer to the relevant regulatory authority for advice.

Acceptable Solution A10(a)
All reasonable efforts should be taken to promote site access only via a stabilised access point that satisfies A10(c). In most cases, the placement of a *Sediment Fence* along the front of the property will promote site access via the stabilised entry/exit point.

Where practicable, heavy machinery such as bobcats, backhoes, and concrete trucks should always access the site via an entry/exit pad.

Acceptable Solution A10(b)
Minimising the number of entry/exit points will reduce the potential for environmental harm.

Acceptable Solution A10(c)
The type of stabilised entry/exit system depends on the site's soil properties and the drainage conditions of the site (i.e. whether stormwater runoff from the entry/exit pad flows into or away from the property).

Stabilised rock entry/exit pads for small, single-dwelling building sites typically consist of a 150 to 200 mm deep, 2 m wide pad containing 40 mm (minimum) to 75 mm crushed rock (Figure H18). Where practicable, the stabilised rock pad should extend from the road to the building, but for a distance of at least 10 m. Where necessary, 20 mm aggregate should be placed over the crushed rock between the property boundary and the sealed road to make the rock pad safe for pedestrian traffic.

Stabilised crushed rock entry/exit pads can be used on both sandy and clay-based soils.

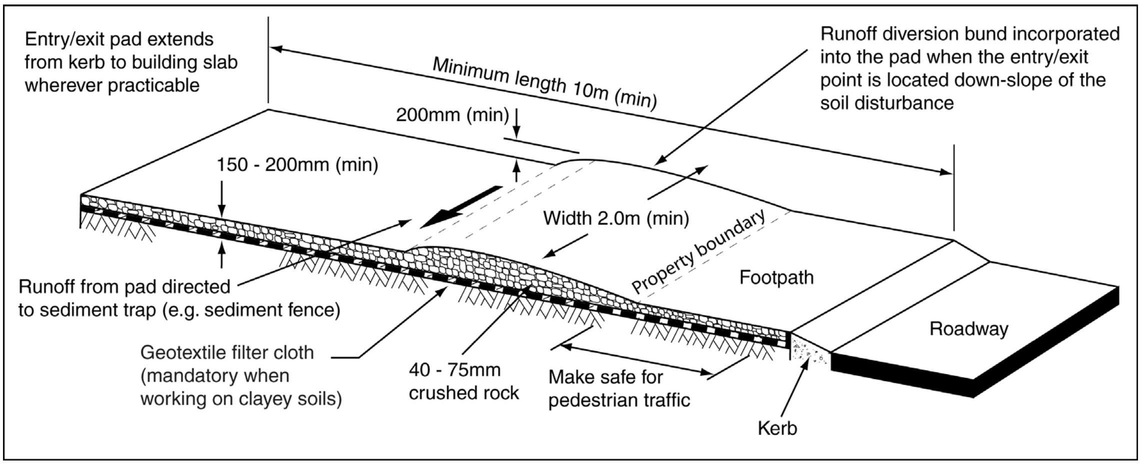


Figure H18 – Stabilised rock entry/exit pad for building sites (not construction sites)

On sites containing sandy soils, a prefabricated *Vibration Grid* (i.e. cattle grid) can be used to shake sand from vehicles. However, a gravel or aggregate pad must exist between the *Vibration Grid* and the road. The length of the *Vibration Grid* should be sufficient to remove loose sediment from vehicles. A minimum length of 3.5 m is recommended. A *Vibration Grid* must not be located within the road reserve.

The environmental benefits of a stabilised entry/exit pad can be greatly diminished if sediment trapped on the pad is allowed to wash from the site during storm events. This problem typically occurs on building sites that are above road level.

Placing a minimum 200 mm high flow diversion bund diagonally across the top of the entry/exit pad can deflect stormwater across the pad and into a suitable sediment trap. This sediment trap may consist of the main *Sediment Fence*, or a separate, *U-shaped Sediment Trap*.

Performance Criterion P11

There are two forms of sediment that can cause harm to the environment, fine sediment and coarse sediment. Fine, clay-sized particles may be controlled using good site drainage and erosion control techniques and by promptly rehabilitating all disturbances. Coarse sediment is usually controlled through the use of sediment control measures.

All reasonable and practicable measures must be taken to minimise the total volume of sediment leaving the work site.

Unacceptable levels of soil and sediment runoff means:

(i) Any quantity of soil or sediment that may cause harm to the environment taking into consideration the cumulative effects of other building and construction activities within the drainage catchment.

(ii) Any quantity of soil or sediment runoff from the site that results in the accumulation of more than 500 g of soil or sediment within any 1 m^2 area outside the property. This quantity of loose, coarse sediment represents approximately two, 70 mm diameter balls of dry sediment, within any 1 m^2.

Acceptable Solution A11(a)
Where an Erosion and Sediment Control Plan is required by a regulatory authority for the building works, then this plan must be approved by the regulatory authority prior to any site disturbance.

Acceptable Solution A11(b)
In most circumstances all necessary up-slope drainage controls and down-slope sediment controls should be installed prior to commencing any soil disturbance including land clearing. The exceptions are:

(i) land clearing and soil disturbance required to allow access to, and installation of, the various drainage and sediment control measures;

(ii) works conducted during an initial period when rainfall is highly unlikely and thus there is no measurable risk of contributing to environmental harm.

Sediment barriers may be removed or lowered to allow site access and building operations, but the barrier must be ready for immediate reinstallation in the case of rain, and the barrier must also be fully operational at the end of each day's work.

Acceptable Solution A11(c)
Sediment barriers are usually placed along the property boundary immediately down-slope of the soil disturbance. Where conditions allow, the barrier should be placed along a line of constant elevation to avoid the barrier concentrating or diverting stormwater runoff.

On most building sites, the most appropriate sediment barrier is a *Sediment Fence* formed from purpose-made fabric (Figure H19). Filter cloth or shade cloth must **not** be used.

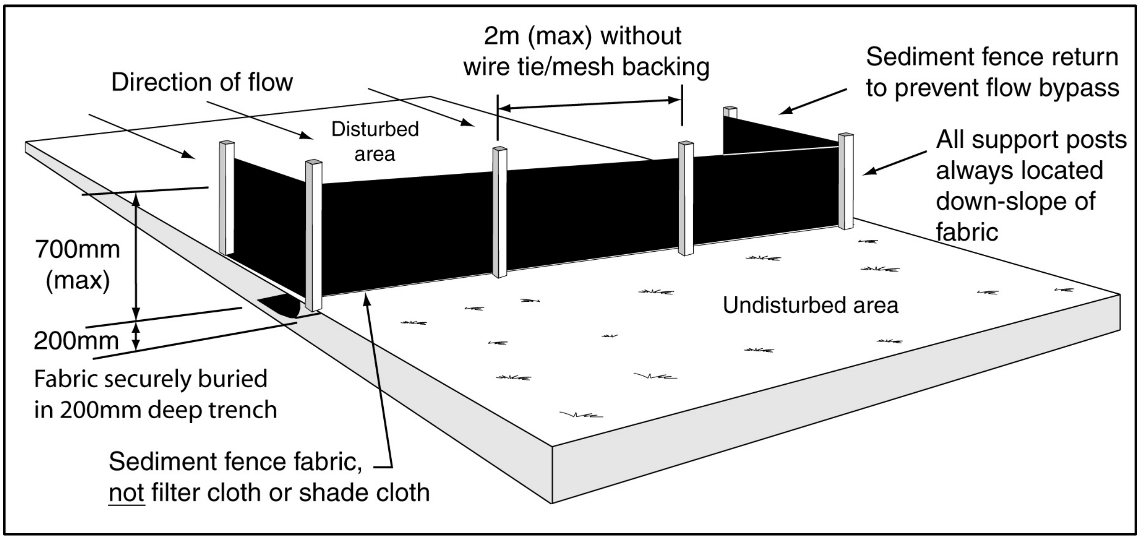


Figure H19 – Installation of a *Sediment Fence*

Sediment fence fabric should be manufactured from a woven UV-stabilised geotextile or non-woven geotextile reinforced with a UV-stabilised polypropylene mesh. The geotextile fabrics are to be either polyester or polypropylene manufactured to the requirements specified in Table H5.

Table H5 - *Sediment Fence* material property requirements

Property	Test Method	Units	Typical Value
Flow rate	AS 3706.9	L/s/m^2 (under 100 mm head)	145
Wide strip tensile strength	AS 3706.2	kN/m	17 both directions
Pore size (EOS) (O_{95})	AS 3706.7	µm	110
Mass per unit area	AS 3706.1	gsm	225

Stakes should consist of 1250 mm^2 (cross section) hardwood, or 1.5 kg/m (minimum) steel star pickets suitable for attaching fabric.

Acceptable Solution A11(d)
An appropriate sediment barrier should be installed around any on-site stormwater inlet to minimise the release of sediment from the property.

Appropriate sediment barriers include heavy-duty filter cloth or *Sediment Fence* fabric wrapped around the grate, or a vertical *Sediment Fence* constructed around the inlet.

Acceptable Solution A11(e)
Building works should not be approved unless it can be demonstrated that there is sufficient room within the property, and within the sediment control zone, to locate all necessary long-term stockpiles of erodible material.

Where necessary, stockpile areas should be clearly identified to prevent materials being delivered to the wrong location.

The sediment control zone is defined as that portion of a building site that drains to a sediment control device, excluding the entry/exit pad.

Acceptable Solution A11(f)
If the adopted erosion and sediment control measures fail to prevent unacceptable levels of off-site sedimentation, then additional measures will be required unless such measures would be considered unreasonable or impracticable.

Acceptable Solution A11(g)
Sediment removed from a sediment control barrier should either be integrated with on-site soils, or removed from the site. In either case, the sediment should not be placed in a position, or in a manner, that would likely result in the sediment being washed or blown from the site, or washed into an external gutter, drain, or water body.

Performance Criterion P12
Wherever reasonable and practicable, all ESC measures should be fully located within the property; however, it must be acknowledged that part of a stabilised entry/exit pad must extend outside the property boundary.

Acceptable Solution A12
No sediment control measure should be located outside the property boundary, unless:

(i) that control measure includes that portion of the entry/exit pad located between the property boundary and the sealed road; or
(ii) the sediment control measure is required to collect sediment wash-off from building works located along the property boundary (such as the construction of a front retaining wall); and
(iii) regulatory authority permission has been obtained for the location of the sediment control measure outside the property.

Performance Criterion P13
One of the best ways of controlling sediment runoff is to prevent, or at least minimise, soil erosion in the first place. One of the best ways of minimising soil erosion is to minimise the disturbance to existing ground covers, including the grassed pedestrian area (verge) located within the road reserve.

Acceptable Solution A13
The road reserve is considered a public asset and as such damage to this public asset, including any vegetation, should only occur if there are no other reasonable options available to carry out the necessary building works.

If vegetation damage does occur within the road reserve, and if this damage could result in soil erosion, then all reasonable and practicable measures should be taken to minimise the extent and duration of this erosion hazard, including prompt stabilisation, repair or revegetation of the area.

Performance Criterion P14
Material spills and sediment deposits located outside the sediment control zone have a higher risk of causing a safety hazard or being washed into a gutter, drain or water body. Such material spills and sediment deposits must be cleared from the area within a reasonable time frame and in an appropriate manner, based on the assessed safety and environmental risks.

Acceptable Solution A14
Some material spills located outside the property boundaries may be beyond the reasonable control of the builder or property owner; however, if these deposits are directly associated with the building activities (e.g. resulting from the delivery of materials), then all reasonable and practicable measures must be taken to minimise both the safety risk and potential environmental harm.

Reasonable and practicable measures may include:

(i) providing appropriate delivery instructions;
(ii) providing adequate and appropriate space for the delivery of materials;
(iii) providing a stabilised access pathway for the delivery of materials;
(iv) actively investigating alternative delivery methods or material suppliers if regular pollution problems occur;
(v) assisting in the prompt removal of sediment deposits and material spills.

To clean materials from hard surfaces, the bulk of the material should first be shovelled, then swept onto an area enclosed by a suitable sediment barrier (i.e. up-slope of a *Sediment Fence*). An acceptable procedure for cleaning the remainder of the material from the surface is detailed below in order of priority.

1. Use a vacuum unit (e.g. hired street sweeper), where the cost can be justified.
2. Manually sweep the material onto an adjacent grassed or open soil surface where sediment controls are in place (e.g. up-slope of a *Sediment Fence*).
3. If a safety hazard may result from the remaining material being left on the hard surface, then, and only then, hose the remaining material onto a grassed surface or into a temporary filter dam constructed in the gutter. After allowing the excess water to drain from the dam, the retained material must be collected and disposed of in a location where it would not be expected to wash off into a gutter, drain or water body.

The above recommendations are based on the principle that less environmental harm will be caused if small amounts of sediment are removed from a sealed road by stormwater runoff rather than by manually washing the road during dry weather.

Performance Criterion P15
Cement and concrete residue can increase water turbidity, alter water pH, and adversely affect the hydraulic capacity of drainage pipes. Typically, state authorities will have legislative requirements regarding the acceptable pH range for site discharges (e.g. 6.5 to 8.5).

Acceptable Solution A15(a)
Cement and concrete residue from concrete trucks or on-site mixers must not be allowed to enter drains or waterways. Excess concrete should be stockpiled on-site for later disposal.

Acceptable Solution A15(b)
Approval should not be given to a proposed concrete surfacing technique if the proponents fail to demonstrate how the proposed surfacing technique will be prepared without causing undue environmental harm.

Where appropriate, the options provided in Acceptable Solution A16 may be used to minimise the potential environmental harm caused by cement/concrete residue.

Any construction technique that would not cause environmental harm, or the release of cement, concrete or contaminated water into a stormwater pipe or water body, would satisfy this Performance Criterion.

Performance Criterion P16

Waste water generated by water-cooled cutting activities and the cleaning of equipment usually contains large quantities of fine-grained sediments that can readily pass through most sediment control devices. Therefore, a sediment control barrier cannot be relied upon to minimise the potential environmental harm caused by these building activities.

On some building sites it may not be practicable to prevent all forms of pollution generated by such activities from leaving the site; however, all reasonable and practicable measures must still be taken to minimise any potential harm.

Acceptable Solution A16(a)

The first priority should always be to conduct all cutting and cleaning activities within the property and specifically within the sediment control zone.

When porous grassed or open soil areas are available, then all mobile, pollution-generating activities should be conducted within these areas to minimise the release of pollutants from the site. If the soil becomes saturated, thus significantly limiting further infiltration of water, then the activity should be relocated, or an alternative pollution control technique should be used.

In some cases it may be beneficial to place filter cloth over the soil before commencing the cutting or cleaning activity.

Acceptable Solution A16(b)(i)

The waste water may be fully contained in an excavated pit and allowed to infiltrate the soil, or pumped from the pit to a mini-skip, or to a *Filter Bag* for treatment.

Acceptable Solution A16(b)(ii)

Some heavy clay soils allow little or no infiltration of water. In such cases, all reasonable and practicable steps should be taken to filter the polluted water through a temporary, porous bank formed from fine-grained material, such as fine sand. The bank must have sufficient width/depth to significantly reduce the turbidity of the polluted water.

The efficiency of the filter bank can be improved by placing heavy-duty filter cloth over the upstream face of the bank and/or placing filter cloth under the pollution-generating activity.

Performance Criterion P17

Proper working order means the control devices are operating in an *efficient manner* that is consistent with intended function of the device, and in a manner that prevents or minimises potential or actual environment harm.

Efficient manner means the control device is functioning in a manner that will:

(i) intercept the maximum quantity of polluted water (within the structural capabilities of the device); and
(ii) trap the maximum quantity of pollutants; and
(iii) contain trapped pollutants for sufficient time to allow for their appropriate removal.

Acceptable Solution A17(a)

Maintaining ESC measures in “proper working order” means taking all reasonable and practicable measures to sustain all ESC measures in such a condition that:

- will best achieve the site’s required environmental protection, including any specified water quality objectives for all discharged water (principle objective); and
- is in accordance with the specified operational standard for each ESC measure; and
- prevents or minimises safety risks.

A soil disturbance may be considered to exist up until a minimum 70% coverage (vegetative, organic or inorganic) is achieved over **all** soils disturbed (directly or indirectly) as a result of the building activities.

A minimum 70% coverage does **not** mean that a minimum of 70% of the site is protected from erosion. Rather it means that all areas of erodible soil on the site have at least 70% coverage of vegetation, mulch or other suitable material to prevent raindrop impact on the soil and erosion by flowing water. As such, 70% coverage is measured by looking vertically down on the soil, and applies to any and all disturbed areas of the building site.

Acceptable Solution A17(b)
All reasonable and practicable measures must be taken to minimise regular structural failures and to facilitate the immediate repair of necessary control measures. Measures may include:

(i) storing on-site, or within the immediate area, sufficient *Sediment Fence* fabric to facilitate necessary repairs;
(ii) modifying damaged control measures to reduce the potential for ongoing failure;
(iii) modify on-site drainage patterns to reduce the risk of ongoing damage to ESC measures;
(iv) install additional and/or alternative ESC measures to minimise the risk of ongoing failure.

Repairs should be sufficient to re-establish the required efficiency of the ESC measure.

Performance Criterion P18
The safety of the public and all site personnel is a high priority.

Acceptable Solution A18
Appropriate consideration should be given to potential safety risks associated with a proposed erosion and sediment control measure. Any ESC measure should not be installed if it represents an unacceptable safety risk. In such cases, suitable alternative ESC measures must be employed.

Performance Criterion P19
High-risk sites may be identified through the use of an appropriate Erosion Hazard Assessment of the site. Land disturbance on sites steeper than 20% may not always be classified as high-risk sites; however, due to the difficulties of working on such sites, it is recommended that they be included within this Performance Criterion. A regulatory authority may exempt a site from the need to submit an Erosion and Sediment Control Plan (ESCP).

It is noted that one or more plans may be required to adequately describe the proposed erosion and sediment control measures, or to describe the various building stages or drainage conditions that will exist on the work site during the building phase.

Building works assessed as low-risk sites are still required to take all reasonable and practicable measures to minimise environmental harm caused by on-site soil erosion and sediment runoff. On low-risk sites, an ESCP may still need to be prepared to convey to site personnel the proposed erosion and sediment control measures, but this plan does not need to be approved unless specifically requested by the regulatory authority.

Low-risk sites will still need to satisfy Performance Criteria P1 to P18.

Acceptable Solution A19
A plan scale of preferably 1:200, 1:250 or 1:500 is recommended, but not larger than 1:1000.

Identifying existing and final contours allows regulators to appreciate the extent of earthworks involved in the building proposal. If major earthworks are to be staged, and if these earthworks affect stormwater drainage patterns, then more than one ESCP may be required to adequately describe the proposed soil erosion and sediment control measures (i.e. one ESCP prepared for each stage of earthworks).

Identifying the proposed building works assists regulators to assess the minimum required limits of disturbance.

Identifying the limits of site clearing allows regulators to determine the extent and likely duration of soil exposure.

In rural areas, often the only sediment control measure required around a building site is the extensive grassed areas that surround the building site. If such areas are to be used as a sediment barrier, then the ESCP should indicate that these areas will remain largely undisturbed.

A stabilised site entry/exit point should form part of the site's sediment control measures, and therefore should be shown on the ESCP. If separate site entry and exit points are required, then this should also be indicated on the plan.

Stockpile locations need to be shown to demonstrate:

(i) adequate room exists for the proposed building activities to occur without causing unnecessary harm to the environment;
(ii) stockpiles will not be located within an overland flow path;
(iii) stockpiles will be located within a sediment control zone.

It is not sufficient to simply list which ESC control measures are proposed for use on a building site. The location of the proposed ESC measures must be shown on the ESCP.

Technical notes on ESC measures should be used to describe those ESC measures that are required in the event of unexpected circumstances, or to provide necessary information on the installation, operation, or maintenance of ESC measures.

The installation sequence is presented to demonstrate that the control measures will be in place at appropriate times relative to the proposed earthworks and building activities. A table may be used to indicate the installation and removal times relative to certain building activities, as demonstrated in Table H6 below.

Table H6 – Example construction sequence table

Item	Plan [1] Number	Installation	Removal
Construct entry/exit pad	1	Before site clearing.	After building works are completed, or sealed driveway is installed.
Install sediment fences SF-1 and SF-2	1	Before earthworks.	After mulching and 70% grass coverage is achieved.
Install catch drain CD-1	1	Before earthworks.	After mulching and 70% grass coverage is achieved.
Strip and stockpile topsoil	2	Immediately before earthworks.	Spread as soon as possible.
Revegetate backyard	1	ASAP, but before building works commence.	
Land shaping and earthworks	2	Immediately prior to commencing building.	
Install on-site waste receptacles	1	Following completion of earthworks.	Upon completion of building works.
Stockpile materials	1	As required.	Before removing sediment fence.
Commence building works	3	Immediately after earthworks.	
Install underground drainage	3	Before installing roof.	
Install temporary downpipes	3	Immediately after laying roof and guttering.	When ready to install permanent downpipes.
Spread topsoil	1	Upon completion of building works.	
Turf and mulch	1	Immediately after spreading topsoil.	

Note [1] Plan number is only required if there are several plans used in the building submission.

Performance Criterion P20

It is important for the ESCP to show control measures that are reasonable and practicable for the site condition, the assessed erosion risk, and the risk of causing or contributing to environmental harm.

Acceptable Solution A20

Small building sites generally require fewer ESC measures than the larger more complicated sites. Similarly, building sites with a low erosion risk generally require fewer ESC measures than high-risk sites.

Regulatory authorities should not unnecessarily burden builders with the development of extensive ESCPs if there is negligible assessed risk of causing or contributing to environmental harm.

Building Site

Erosion Hazard Assessment Form

Project Name: . . . .

Site Address: . . . . **Date:** . . . .

Controlling Factors	Points	Score
Item 1 – Average slope of the whole site prior to building works: [1] • Slope < 3% • 3% </= Slope < 5% • 5% </= Slope < 10% • 10% </= Slope < 15% • Slope >/= 15%	 0 1 2 4 5	
Item 2 – Soil type (of soil to be disturbed): [2] • Sandy soil/gravel • Sandy loam • Clay loam • Clay soil	 0 1 2 2	
Item 3 – Total extent of site disturbance: [3] • Soil disturbance < $10m^2$ • Soil disturbance of $10–100m^2$ • Soil disturbance > $100m^2$	 0 1 2	
Item 4 – Anticipated duration of soil disturbance: [4] • Duration < 2 weeks • 2 weeks </= Duration < 3 months • 3 months </= Duration < 6 months • Duration > 6 months	 0 2 4 5	
Item 5 – Anticipated rainfall risk during soil disturbance: [5] • Low rainfall (average rainfall for any given month < 45mm) • Moderate rainfall (average rainfall for any given month: 46–100mm) • High rainfall (average rainfall for any given month: 101–225mm) • Very high rainfall (average rainfall for any given month: 226–1500mm) • Extreme rainfall (average rainfall for any given month > 1500mm)	 0 1 2 3 4	
Item 6 – Runoff entering the site: • Score 1 point if stormwater runoff entering the site is not diverted around the soil disturbance.	 1	
Total score [6]		

Erosion Hazard Assessment Form Notes

[1] Building sites steeper than 20% are generally considered high-risk sites independent of the total score.

[2] Where there is more than one type of soil within the proposed disturbance area, select the category with the highest point value.

[3] Total area of disturbance excludes the area occupied by the stabilised entry/exit pad provided the entry/exit pad is placed immediately upon initiation of site disturbance.

[4] The time from when the building site will first become vulnerable to erosion (i.e. initial soil disturbance) to the time the disturbed soil will be fully stabilised (e.g. grassing, mulched or covered with erosion control blankets).

[5] Based on average rainfall depths for various months of the year as supplied by the Bureau of Meteorology for the regulatory authority. Points scored shall be based on the anticipated worst month in which soil disturbance is expected to occur. Note that if there is no grass, vegetation, or mulch cover on more than 10% of the site's soil surface before building works are programmed to commence, then the time period shall start from the time this form is completed.

[6] Low-risk sites have a total score less than the "critical hazard value".

High-risk sites have a total score equal to, or greater than the "critical hazard value".

The recommended "critical hazard value" = 11 points. Local authorities may choose to adopt an alternative "critical hazard value" for any or all districts within their jurisdiction.

Daily Site Inspection

LOCATION . . . .

SITE SUPERVISOR . . . . **DATE** . . . .

SIGNATURE . . . .

Legend: □ OK □ Not OK N/A Not applicable

Item	Consideration	Assessment
1	All tradespeople working on the site have been informed of the erosion and sediment control requirements of the site.	. . . .
2	All required builder identification, safety notices, and pollution (e.g. litter and sediment control) management signs are visible.	. . . .
3	The work site and all erosion and sediment control measures do not represent a safety risk to tradespeople or the public.	. . . .
4	Public roadways are clear of sediment.	. . . .
5	Turfing on the footpath area is clear of sediment, sand and mud.	. . . .
6	Entry/exit pads are clear of excessive sediment deposition.	. . . .
7	Entry/exit pads have adequate available void spacing to trap sediment.	. . . .
8	The construction site is clear of litter and unconfined rubbish.	. . . .
9	Long-term (> 24 hours) soil/sand stockpiles are protected from wind, rain, and stormwater flow.	. . . .
10	At end of day, all short-term soil/sand stockpiles located outside the sediment control zone have been removed and cleaned.	. . . .
11	No dust problems exist on the site.	. . . .
12	Up-slope “clean” water is being appropriately diverted through the site in a non-erosive manner.	. . . .
13	Drainage lines are free of soil scour and sediment deposition.	. . . .
14	Stormwater flow down exposed earth batters does not cause erosion.	
15	Appropriate erosion controls of all finished soil disturbances have been discussed with the client.	. . . .
16	Sediment fences have been correctly installed (e.g. fabric buried and standing up-slope of stakes) and are free of damage.	. . . .

17	Sediment fences have been installed in a manner that will allow sediment-laden stormwater to temporarily pond and settle behind the fence rather than flow around the fence.	....
18	Appropriate sediment controls have been placed adjacent to, or around, stormwater inlets—as appropriate for the type of inlet.	....
19	All sediment traps are free of excessive sediment deposition.	....
20	Finished service trenches have been appropriately backfilled, compacted and stabilised.	....
21	All reasonable and practicable measures are being taken to control sediment runoff from the site.	....
22	The site is adequately prepared for potential storms.	....
23	Adequate stockpiles exist of ESC materials, such as extra sediment fence fabric.	....
24	Temporary downpipes have been correctly connected to any installed roof gutters.	....

Appendix I

Instream works

This appendix demonstrates how the principles of erosion and sediment control are applied to construction and maintenance activities occurring within a drainage channel or watercourse. Specifically, the appendix addresses the management of activities such as vegetation removal and the de-silting of channels, the construction or rehabilitation of drainage channels, and the construction of waterway structures such as stormwater outlets and waterway crossings.

This appendix also provides a model Code of Practice for conducting instream works. Government bodies are encouraged to explore the development of a regional-based Code of Practice using the model code as a template.

The function of this appendix is both educational and prescriptive. Those personnel involved in the management of instream construction or maintenance projects, or those wishing to apply this information to a specific site, should first ensure they are familiar with the general principles of erosion and sediment control outlined in Chapter 2 – Principles of erosion and sediment control.

This appendix does not specifically address the management of construction projects within coastal areas where significant wave action is likely to occur. However, most of the concepts developed within this appendix will be appropriate to all instream construction activities, including those works occurring within coastal waters.

I1. Introduction

Unless adequately managed, instream construction and maintenance activities can represent a significant environmental hazard. These activities have the potential to cause widespread bed and bank disturbances, generating significant quantities of bed load sediment and potentially harmful concentrations of suspended sediment.

Understanding and managing the geological and ecological processes that occur within natural waterways can be very complicated, often requiring specialist training and years of experience. Sometimes the seemingly simple task of stabilising an eroded stream bank can initiate other environmental problems including downstream erosion, increased weed infestation of the stream, or significant alteration to wildlife habitat values. Therefore, no construction or maintenance activities should be performed within a watercourse, natural or constructed, without an appropriate assessment of the potential environmental impacts.

In most states, instream works will require approval by the state government, usually a department of Natural Resources or similar. If the works are within tidal waters, then approval may also be required by a fisheries authority (often a section of the Department of Primary Industries) and/or a department of environmental protection (e.g. EPA).

The potential impact of both temporary instream structures (e.g. flow diversion structures and instream sediment control measures) and permanent structures (e.g. weirs and culverts) on fauna passage, including fish migration, must be considered in consultation with the relevant State and local government bodies.

I2. Terminology

The following terminology will apply specifically to this appendix.

Instream	Any area between the banks of a constructed drainage channel, watercourse, or waterway.
Instream works	Any human-induced mechanical disturbance of the bed or banks of a constructed drainage channel, watercourse, or waterway.
Channel	Any natural or constructed flow path with well defined bed and banks.
Stream	A watercourse.
Watercourse	Any natural or constructed channel with well-defined bed and banks, including constructed drainage channels of a natural appearance, creeks and rivers, but not grass-lined or hard-surface constructed drainage channels void of ecological values.
Waterway	Any natural or constructed channel, watercourse or water body, including creeks, rivers, lakes, wetlands, estuaries, and bays.
Waterway channel	Whichever is the greater of the area of land between the overbank riparian zones, and the area of land located below the top of the lower banks (i.e. not including the floodplain).
Riparian zone	A strip of land usually located along each side of a waterway channel within which vegetation grows that has either a habitat or lifecycle link to the waterway, or directly affects water quality.
River	A major watercourse (relative to others within the region) normally with a significant sediment load transported by flood events. Bed vegetation is normally sparse and usually does not play a significant role in long-term channel stability.
Creek	A minor or intermediate watercourse with either a fixed or mobile bed that is dry (ephemeral) or has a minor constant (perennial) discharge during dry weather. In fixed-bed systems the bed material and bed shape generally do not move or alter during most stream flows. In mobile-bed systems the loose bed material migrates down the channel during floods. Natural creeks with mobile beds include gravel-based and sand-based systems, whereas fixed bed creeks are typically clay-based systems.
Gravel-based creek	Typically a high gradient (steep) fast-flowing watercourse with bed material dominated by loose gravel, rocks, and/or boulders. Bed conditions normally consist of pools and riffles.
Sand-based creek	Typically a medium gradient watercourse with loose, fine-grained (sandy) bed material. If a low-flow channel exists, it can be highly mobile with a constantly changing bed/plan form.
Clay-based creek	A minor watercourse formed into clayey soils. In open canopy creeks, ground cover vegetation is dominant on both the bed and banks. In closed canopy creeks, sparse vegetation cover usually still exists, but generally the bare clayey soils are visible.

I3. Potential impacts of instream works

Sediment released from a work site into a waterway or water body can cause an increase in both turbidity and bed load sediment. Turbidity consists of the clay and fine silt particles that generally do not settle until they reach quiescent or saline waters. Bed load sediment consists of the coarser silts, sands, and gravels that move along, or close to, the bed of a watercourse.

Unnaturally high turbidity levels can cause adverse effects on aquatic life, such as:

- damage to fish gill membranes;
- reduced ability for aquatic life to feed by sighting food;
- general altering of aquatic habitat and behaviour;
- increased susceptibility to disease caused by stress;
- health problems associated with the transportation of pollutants attached to clay particles such as nutrients, metals and pesticides.

Bed load sediment can fill the voids between the stones within riffle systems and natural gravel beds, a process called "matrix infiltration". A consequence of this sedimentation process can be a permanent change to the ecological processes occurring within the stream. In extreme cases the natural gravel bed can be totally smothered by weeds and sediment.

The potential impacts of elevated bed load concentrations depends on the structure of the watercourse, and more importantly, on the natural bed conditions within the watercourse. There are basically four types of streams: clay-based, sand-based, gravel-based, and spilling or steep rocky systems.

Some of the potential impacts likely to result from unnaturally high bed-load sediment concentrations are listed below for the various stream types.

Clay-based creeks

- Smothering of bed vegetation resulting in increased bed erosion. Such erosion can also initiate or aggravate erosion of adjacent channel banks.
- Reduction or total loss of aquatic habitat areas along the bed of the watercourse.
- Filling of natural pools (these pools often act as important habitat areas).

Sand-based creeks

- The potential impacts can be significantly less than in clay or gravel-based streams, especially if the introduced bed load material has a similar grain size distribution to the natural bed material. However, if the introduced sediment contains clay or organic material, then environmental harm can occur, including weed infestation.

Gravel-based creeks

- Fine sediment can fill the voids between natural bed gravels causing the following adverse effects:
  - (i) loss of essential aquatic habitat areas (both within the pools and riffles);
  - (ii) a reduction in the total submerged surface area (by infilling bed and riffle voids and other surface irregularities) thus reducing the potential food supply;
  - (iii) an increase in the stability of riffle rock, thus reducing the "natural" movement and sorting of the bed material.

- A constant supply of introduced bed sediment can eventually turn a gravel-based stream into either a sand or clay-based system.

Rocky spilling creeks

- Filling of pools with coarse sediment.
- Reduction or total loss of aquatic habitat values along the bed of the watercourse.

Tidal waterways

- Fine sediments that enter such waterways can be constantly resuspended into the water column by tidal movement resulting in increased turbidity levels.
- High water column turbidity can reduce habitat diversity.
- Settled bed load sediment can increase local flooding problems and reduce the navigational limits of the waterway.

Coastal regions

- Coarse sediment can smother aquatic vegetation and bed habitats.
- Fine sediments can settle as a fine dusting over the seabed, causing loss of seagrass through reduced photosynthesis, and damage to coral habitats.

All stream types

In all streams, the deposition of sediment (fine or coarse) can damage aquatic habitats by:

- reducing the diversity and abundance of bottom dwelling (benthic) organisms, thus affecting a food supply for other aquatic life;
- destroying spawning areas;
- reducing the survival of fish eggs through the direct deposition of sediment;
- destroying aquatic vegetation.

In addition, unnaturally high levels of coarse sediment can:

- increase weed infestation of creek and wetland systems;
- damage drinking water supplies;
- increase the need for maintenance dredging;
- infill dams, lakes and wetlands;
- decrease recreational and commercial fishing;
- damage the aesthetic, ecological, and recreational values of waterways.

When assessing the potential impacts of proposed instream works on the environment, it is important to recognise and understand the relevance of the following points.

(a) Usually a very complex relationship exists between the quantity of pollution and the resulting environmental harm. Site managers should **not** assume that a 50% reduction in the quantity of sediment released from the site will necessarily achieve a 50% reduction in the resulting environmental harm. Sometimes it is just a small percentage of the sediment (e.g. the clay fraction) that causes most of the environmental harm—this of course will depend on the type of receiving water.

(b) Even though it is always a good idea to minimise the quantity of sediment released from a work site, the focus should always be on minimising the overall environmental harm. For example, the process of installing and removing some instream sediment traps can cause significant disturbance (harm) to the bed and banks of a waterway. Therefore, unless the benefits gained by their use exceed the potential harm caused by the installation and removal process, then their value must be questioned. In which case an alternative sediment trap or construction process must be considered.

(c) In many creeks, natural or modified, it is common for water quality to decrease with increasing flow rate. Thus water clarity is usually highest during those periods of low flow between storm events. Therefore, to minimise the harm caused to small waterways such as creeks, the aim should be to achieve the highest quality water standards during these periods of low flow. Thus, those instream sediment traps that allow the "filtration" of sediment-laden waters during periods of low flow usually provide the greatest environmental benefit.

One of the keys to minimising environmental harm is to program instream works to occur at the least vulnerable times of the year. Ecological activity within a stream, both terrestrial and aquatic, is usually highly variable throughout the year; therefore, the potential impacts of instream disturbances also vary throughout the year. Good environmental management of instream works requires an understanding of ***when*** wildlife moves, breeds and feeds within the waterway.

I4. Design of works in and around waterways

Numerous Federal, State and local guidelines currently exist on the management of waterways and on the design of works in and around waterways. Where appropriate, these guidelines should be referred to when designing waterway channels and instream structures.

The following recommendations summarise some of the key design principles:

(i) Identify and protect essential terrestrial and aquatic habitats and movement corridors. Witheridge (2002) provides guidelines on the design of fish-friendly watercourse crossings.

(ii) Avoid placement of structures within the identified riparian zone, even if such riparian vegetation does not currently exist. If riparian widths or minimum riparian widths have not been identified/mapped for the waterway, then take appropriate steps to identify minimum riparian widths based on geomorphological, hydraulic, and environmental considerations.

(iii) Minimise disturbance to the riparian zones and waterway channel to the minimum necessary to achieve the required project outcomes.

(iv) Minimise the number of waterway crossings (e.g. roadways, footpaths, services).

(v) Minimise the placement of services (e.g. power, water, sewerage) within the waterway channel and riparian zone.

(vi) Avoid the placement of fixed structures:
- adjacent to the outside of sharp, erodible channel bends;
- adjacent to unstable channel banks;
- within 15m of the top of bank, or within a distance of three times the bank height from the toe of the bank (whichever is greater).

(vii) When locating access tracks, utilise the riparian vegetation as an operational buffer zone to separate the track from the stream. Ideally, the minimum width of the riparian zone between the track and the edge of the stream should be at least the width of the stream (measured at the top of the bank) or 30 m whichever is the lesser. Note, the riparian zone must be protected from damage by sediment runoff during construction of the track.

(viii) Avoid causing permanent changes to the natural pool–riffle sequence (size and spacing) within the low-flow channel.

(ix) Give priority to those forms of erosion control and bank stabilisation that allow the successful integration of vegetation, especially adjacent any permanent or near permanent waters.

(x) Maximise the integration of natural vegetation into any erosion control and bank stabilisation works.

(xi) Ensure that if ongoing maintenance activities (e.g. de-silting) will be required on the instream structure, then appropriate allowances, including site access, are made such that these activities can occur in a manner that will minimise potential environmental harm. Discussion on the design of culverts to reduce the need for de-silting operations is provided in Section I7.1.

I5. Instream sediment control vs off-stream sediment control

The well-established principles of off-stream sediment control, as presented in Chapter 2, are primarily based on the gravitational *settlement* of sediment from captured water. In most cases, the captured water results from either local storm runoff, or process water such as de-watering activities, equipment cleaning and material cutting operations.

Instream sediment control measures, however, primarily rely on the *filtration* of sediment from dry weather stream flows. The reasons for focusing on filtration as the preferred treatment process are presented below.

(a) Most off-stream sediment control practices focus on the capture of the coarser sediment fraction—*Sediment Basins* being the one major exception to this rule. On the other hand, instream sediment control practices need to focus on both coarse sediment and turbidity levels.

(b) Most instream maintenance and construction activities are conducted during dry weather, or at least when only low flows are expected within the watercourse.

(c) Thus, environmental protection normally focuses on the appropriate management and treatment of dry weather flows. This is different from traditional off-stream sediment control practices, which primarily focus on the management of wet weather events.

(d) Thus, instream sediment control techniques are normally required to treat much lower flow rates and volumes compared to the design flow rates for off-stream sediment control measures.

(e) Due to the lower flow rates experienced by instream sediment measures, sediment blockages are more easily detected and necessary maintenance can usually be carried out immediately. This is different from traditional off-stream sediment controls where sediment blockages normally occur during storm events when maintenance of the device is usually impracticable.

(f) Also, instream construction and maintenance activities are normally conducted over much shorter time periods compared to off-stream works, therefore, the high maintenance requirements and sediment blockage problems associated with filtration systems are less likely to seen as a significant problem to site managers.

(g) It is also noted that most streams flow much cleaner during periods of dry weather, thus higher treatment standards (i.e. filtration) are usually required during these periods of dry weather flow in order to minimise environmental harm.

I6. Key management principles

The key management principles for instream erosion and sediment control are:

1. Appropriately plan and organise the work activities.
2. Minimise channel disturbance.
3. Control the movement of water.
4. Minimise soil erosion.
5. Minimise the release of sediment and sediment-laden water.
6. Promptly rehabilitate disturbed areas.

The above key principles may be expanded into the following specific management principles.

I6.1 Appropriately plan and organise the work activities

All reasonable and practicable measures must be taken to:

(i) Carry out only those channel maintenance activities (e.g. mechanical weeding, snag removal and channel de-silting) that are considered necessary.

(ii) Program instream works for those times of the year that minimise overall environmental harm, giving appropriate consideration to:

- expected weather conditions and stream flow rates;
- periods of fish migration;
- periods of aquatic bird nesting and/or migration;
- other relevant environmental factors.

(iii) Plan and conduct instream maintenance activities in a manner that will help reduce the potential environmental harm likely to occur if and when similar activities are required some time in the future.

(iv) Give appropriate consideration to the potential harm caused by the installation and removal of proposed instream flow control and sediment control devises in comparison to the environmental protection gained by their use.

I6.2 Minimise channel disturbance

All reasonable and practicable measures must be taken to:

(i) Limit instream disturbances to the minimum area and reach length necessary.

(ii) Limit the disturbance to overbank vegetation (i.e. riparian vegetation) to the minimum necessary, and wherever reasonable and practicable, access the channel through a minimum number of narrow access corridors.

(iii) Where practicable, limit disturbance and channel access to one side of the channel at any given time.

I6.3 Control the movement of water

All reasonable and practicable measures must be taken to:

(i) Divert the lateral (overbank) inflow of stormwater runoff away from the work area. On bridge and culvert construction, this may require the temporary diversion of table drains away from the construction zone.

(ii) Ensure any overbank flow diversions allow water to enter the channel in a non-erosive manner.

(iii) Divert instream flows around the work area by isolating (e.g. bunding or flow diversion barriers) the disturbance area and/or piping or channelling stream flows around the disturbance. Appropriate consideration must be given to fish passage requirements during these periods of flow diversion. As a minimum, consideration needs to be given to the duration of flow diversion, the likelihood and extent of fish movement during this period, and the cost/benefit of alternative construction procedures.

(iv) Avoid the contamination of any water flowing around or through a work site.

(v) Minimise the flow of water, including rainwater, into excavations.

I6.4 Minimise soil erosion

All reasonable and practicable measures must be taken to:

(i) Avoid unnecessary disturbance to bed, bank and overbank vegetation.

(ii) Restrict the area of disturbance to as small an area as possible during those periods when rainfall is possible.

(iii) Use of appropriate erosion control techniques to stabilise disturbed areas and unstable banks as soon as practicable.

I6.5 Minimise the release of sediment and sediment-laden water

All reasonable and practicable measures must be taken to:

(i) Give priority to those work procedures and practices that minimise the contamination of water.

(ii) Give priority to those sediment control techniques that not only achieve the required treatment standard during the *design flow*, but can produce even higher quality discharge during lesser flows. Such sediment control techniques often incorporate *filtration* practices that assist in the treatment of low flows.

(iii) Appropriately treat all water contaminated by the work activities.

(iv) Appropriately treat all contaminated water pumped from excavations and other areas of the work site.

(v) Appropriately treat sediment runoff from the de-watering of material stockpiles.

(vi) Establish work practices that minimise accidental spills and sediment releases.

(vii) Promptly clean up any sediment spills/releases that occur outside the sediment control zone.

I6.6 Promptly rehabilitate disturbed areas

All reasonable and practicable measures must be taken to:

(i) Promptly rehabilitate (e.g. revegetate) disturbed areas.

(ii) Actively stabilise and/or rehabilitate stressed and unstable stream banks rather than waiting for natural regeneration.

(iii) Revegetate areas with appropriate native plants wherever possible. It is noted that in some cases it may be beneficial to establish an initial, temporary, ground cover (e.g. grass) prior to planting the proposed long-term vegetative cover.

(iv) Avoid the use of “plastic” reinforced *Erosion Control Blankets* in bushland areas.

(v) Leave soils in an appropriate firm (i.e. not excessively compacted) condition that will assist in the quick establishment of vegetation.

I7. Investigation procedure

The following investigation and design procedure has been developed for the management of instream maintenance and construction works.

Step 1 Assess the need for and extent of works

Step 2 Initial site assessment

Step 3 Determine the appropriate timing of works

Step 4 Determine an appropriate work procedure

Step 5 Control water movement in and around the work site

Step 6 Select erosion control measures

Step 7 Select sediment control measures

Step 8 Select material handling, transport and disposal methods

Step 9 Assess water quality monitoring requirements

Step 10 Determine site clean up and rehabilitation procedures

Step 11 Prepare an Erosion and Sediment Control Plan (ESCP)

Step 1 Assess the need and extent of works

Instream works may be divided into two categories: construction projects and maintenance activities. The “need” and “extent” of proposed instream disturbances should have been thoroughly investigated and reviewed prior to the detail design, consequently no further discussion will be provided in this section on such projects.

Instream maintenance activities may include vegetation removal for flood management, channel de-silting or dredging, snag removal, tree removal (e.g. removal of weed species), and channel stabilisation or rehabilitation measures.

In flood-prone urban areas, open canopy channels often need routine maintenance to remove excessive sediment and weed growth to maintain the channel’s flood carrying capacity. Much of the bed vegetation, such as reeds, is a direct result of un-natural sediment deposition. **Therefore, one of the most effective ways of reducing the need for regular channel maintenance is to improve erosion and sediment control practices throughout the catchment as part of responsible catchment management.**

Extensive hydraulic modelling is usually required to determine the true benefits of proposed channel de-silting and vegetation control programs. In some circumstances these works can be proposed solely for political reasons to manage a *perceived* flood control problem. However, what at first may appear to the public as an obvious connection between local flooding and the accumulation of weed growth and sediment may actually turn out to be a more complicated hydraulic problem with a variety of previously unconsidered solutions.

Intelligent design, prudent waterway management procedures, and appropriate channel revegetation can often be used to significantly reduce the need and extent of channel maintenance requirements.

De-silting and vegetation control programs should not be done to remove or solve a perceived problem, but should only be done to address actual hydraulic or environmental problems for which there are no other, more appropriate solutions.

When determining the “need” and “extent” for proposed instream maintenance activities, waterway and drainage managers should give the following guidelines and recommendations appropriate consideration.

(a) Stormwater outlets

De-silting and vegetation control is often required at stormwater outlets for the following reasons:

- To allow proper drainage of the pipe—thus avoiding ponding, mosquito breeding and sedimentation in and around the pipe.
- To improve the hydraulic efficiency of the outlet—thus increasing the hydraulic capacity of the stormwater pipe and reducing the likelihood of local flooding problems.
- To remove accumulated sediment and other pollutants from the end of the outlet before they are allowed to migrate into the main channel or into a downstream water body.

Stormwater outlets that discharge into tidal waterways and drains are particularly susceptible to sedimentation problems.

As a general rule, the smaller the diameter of the stormwater pipe, the greater the need to maintain the immediate downstream channel free of sediment, debris, and tall bed vegetation. Larger stormwater outlets, say 1200 mm or greater, have a greater depth of flow and thus a greater ability for the water to flatten bed vegetation during periods of high flow.

The de-silting of stormwater outlets is likely to be warranted in the following situations:

- The hydraulic and/or environmental benefits have been clearly demonstrated by past de-silting operations.
- The sediment has been accumulating for some time and vegetation is beginning to stabilise the sediment causing the outlet channel to be blocked, or flow to be diverted into the adjacent channel banks.
- The outlet is submerged or tidal.

Selective vegetation removal is likely to be warranted in the following situations:

- The pipe size is less than 1200 mm in diameter.
- There is an established history of the bed vegetation (e.g. reeds) not being flattened by typical storm discharges from the pipe.
- The vegetation is causing outflows to be directed into the channel banks, resulting in bank erosion.
- The vegetation is considered noxious or damaging to the ecological integrity of the watercourse.

(b) Drains, channels and waterways

De-silting and vegetation control within drains, channel and waterways is usually required for the following reasons:

- To improve the hydraulic capacity of the channel, thus reducing local flooding or drainage problems.

- To control bank erosion caused by sediment and/or bed vegetation deflecting channel flows into the channel banks.
- To remove accumulated sediment from purpose-built instream sediment traps or ponds.
- To remove undesirable and/or noxious weeds from a watercourse.
- To remove pollutants, including contaminated sediment, from the channel.

As a general guide, vegetation control within drainage channels is unlikely to be warranted if the vegetation consists only of grasses or other flexible plants, and the height of the vegetation is less than the bank height of the stream.

The de-silting of a drain, channel and waterway is likely to be warranted in the following situations:

- The hydraulic and/or environmental benefits have been clearly demonstrated by past de-silting operations.
- The sediment has been accumulating for some time and is significantly restricting the hydraulic capacity of the channel.

If sediment inflow to a drainage channel or watercourse cannot be controlled through the establishment of appropriate catchment management practices, then consideration should be given to the establishment of permanent sediment extraction points at key locations along the channel, such as immediately upstream of road culverts. These permanent instream sediment traps usually require the construction of permanent, low-impact, low-intrusion, maintenance access ramps.

Selective vegetation control within drains, channels and waterways is likely to be warranted in the following situations:

- History has shown that the vegetation is not flattened by normal storm flows.
- The vegetation consists of woody weeds that are likely to aggravate local flooding problems.
- The vegetation is causing flows to be directed into the channel banks resulting in bank erosion.
- The vegetation is considered noxious or damaging to the ecological integrity of the downstream watercourse.

(c) Culverts and bridges

In most circumstances, de-silting and vegetation management occurs upstream and downstream of culverts and bridges to improve the hydraulic efficiency of the structure, thus reducing upstream flood levels.

De-silting of culverts is usually more common in multi-cell culverts. Hydraulically, a multi-cell culvert behaves in a manner similar to an over-excavated (i.e. unnaturally wide) or dredged channel. The sedimentation that occurs within the outer cells of a culvert is the same natural response that would be expected in an unnaturally wide waterway. Eventually low flows begin to concentrate into just one or two of the cells. Over time, sediment in the outer cells can compact and become erosion-resistant, thus reducing the probability of the material being washed from the culvert during high flows.

To reduce the likelihood of sedimentation within existing multi-cell culverts, and therefore to reduce the "need" for regular de-silting activities, a low-flow sediment training wall (Figures I1 and I2) can be constructed in front of the culvert to direct low flows to just one cell, thus allowing the bulk of the sediment to collect within the channel immediately upstream of these walls.

Sediment training walls are specialist hydraulic structures that need to be designed by experienced hydraulic engineers.

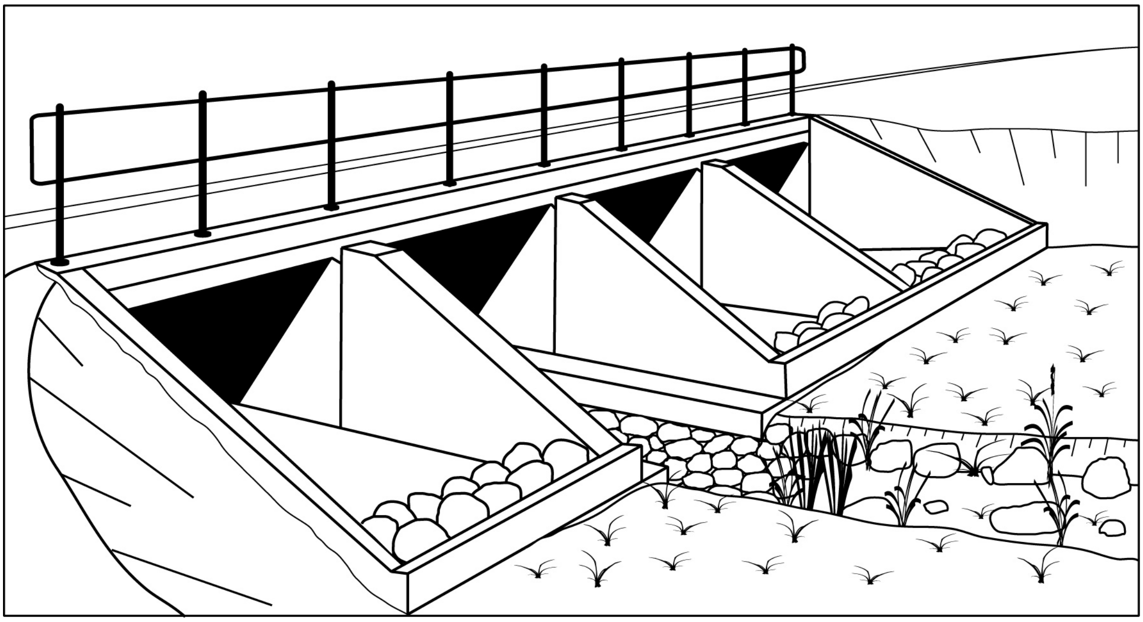


Figure I1 – Sediment training wall incorporated with debris deflection walls

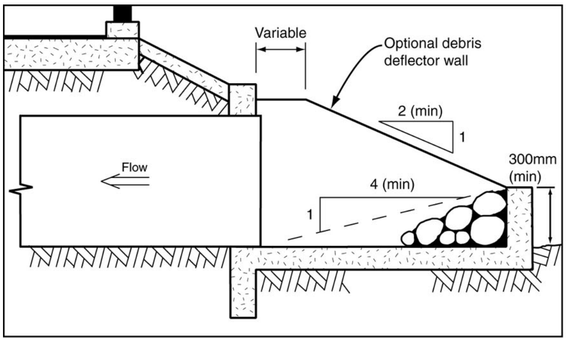


Figure I2(a) – Sediment training wall with debris deflection wall

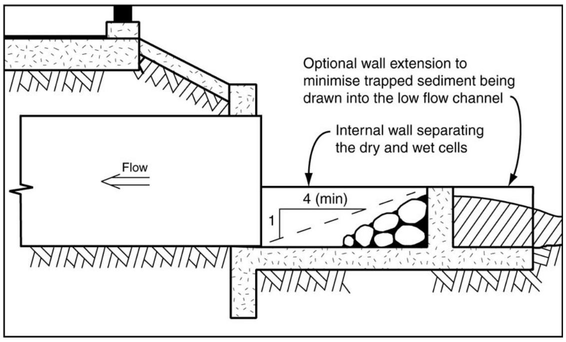


Figure I2(b) – Sediment training wall without debris deflection wall

If de-silting and/or vegetation clearing is proposed immediately upstream of a culvert or bridge to improve its hydraulic capacity, then these works should normally extend upstream a distance no greater than the total width of the culvert or bridge opening (Figure I3). Beyond this point the hydraulic benefits may be questionable.

When removing vegetation downstream of a culvert or bridge, it is important to recognise the following hydraulic requirements.

- The most hydraulically efficient way to expand flood flows exiting from a bridge or culvert is to allow the water to expand gradually, rather than abruptly.
- There are some circumstances where vegetation placed in specific locations adjacent to the abutments of a bridge or culvert can actually improve the hydraulics of the structure by allowing the gradual expansion of the outlet jet. Expert hydraulic advice should always be obtained before designing such vegetation schemes.

- Floodplain vegetation located outside approximately a 45° angle from the inlet or outlet of a bridge or culvert is unlikely to interfere with the hydraulics of the structure.
- If a floodplain exists on one or both sides of the channel, then riparian vegetation along the banks of the channel must allow flood flows from the culvert or bridge to leave the channel and gradually enter the floodplain (Figure I3).

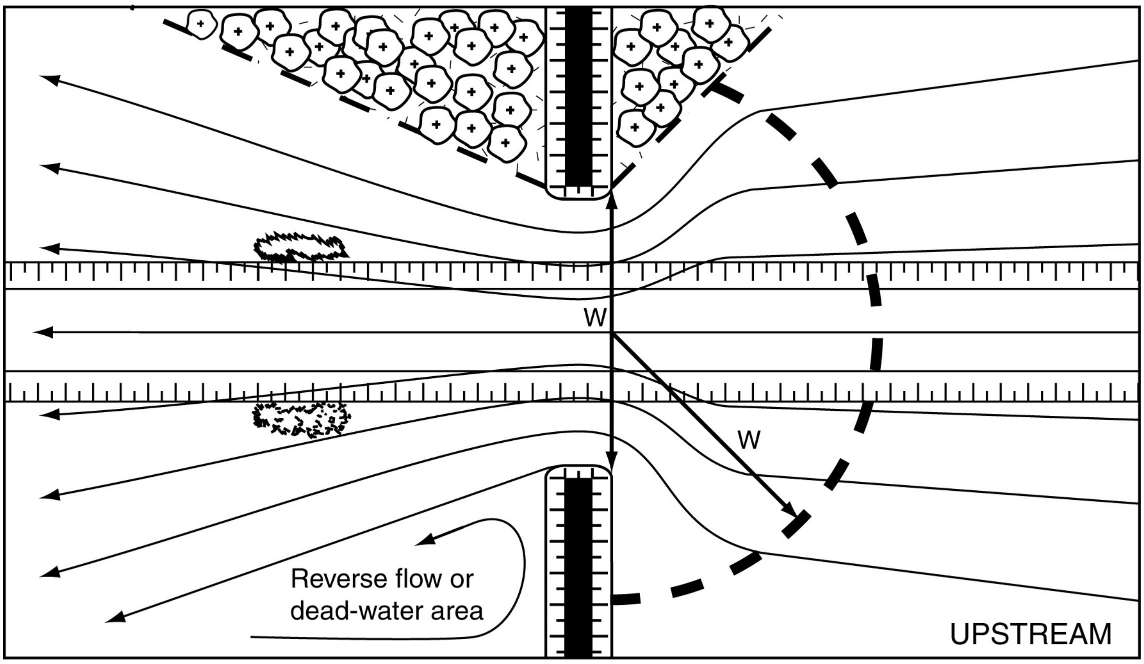


Figure I3 – Critical inflow control zone

De-silting works are likely to be warranted upstream, within, or downstream of a bridge or culvert in the following situations:

- The hydraulic and/or environmental benefits have been clearly demonstrated by past de-silting operations.
- The sediment has been accumulating for some time and has not been removed by past flood events.
- The sediment accumulated downstream of a culvert is causing water to pond within the culvert resulting in water quality, public safety, or public health problems (e.g. mosquito breeding).

Selective vegetation clearing is likely to be warranted upstream or downstream of a bridge or culvert in the following situations:

- The hydraulic and/or environmental benefits have been clearly demonstrated by past clearing operations.
- Woody vegetation is restricting flood flows from leaving the upstream floodplain and entering the bridge or culvert.
- Woody vegetation is restricting the flow of floodwaters exiting the bridge or culvert from entering into the downstream floodplain.
- Woody or inflexible vegetation is growing within an area defined by one culvert/bridge width upstream of the bridge or culvert (Figure I3).
- The vegetation is considered noxious or damaging to the ecological integrity of the downstream watercourse.

Step 2 Initial site assessment

An initial site assessment will usually be required in order to collect site data and assess the erosion and sediment control requirements of the site. During the site visit the following key issues need to be considered.

1. Will the site require flow diversion, and if so, how?
2. Will the site require the implementation of instream sediment control practices, and if so, what systems are likely to be most appropriate?
3. Will the site require the de-watering of excavations or the excavated material?
4. Will it be necessary to maintain fish passage while works are in progress?
5. Will it be necessary to maintain public access along the waterway?

Among other things, the initial site inspection may require determination of the following information to assist in the selection of instream sediment/flow control measures:

- Type of watercourse (e.g. drain, creek, river, tidal, non-tidal)
- Site access conditions (e.g. access for heavy machinery)
- Stockpile and de-watering areas (i.e. suitable areas to allow material de-watering)
- Existing water quality (i.e. is the base flow clear or turbid, and TSS or NTU reading)
- Typical flow depth (i.e. less than or greater than 0.8m)
- Typical flow velocity (e.g. estimate by timing the velocity of surface debris)
- Typical flow rate (determine by estimating the flow area and average velocity)
- Bed material (e.g. clay, sand, gravel, or rock)
- Bed shape (e.g. irregular or flat bed)
- Expected duration of works (e.g. 1–2 days, 3–5 days, > 5 days)

Step 3 Determining the appropriate timing of works

Instream works should be programmed to avoid:

- periods of fish migration;
- known nesting or breeding periods for aquatic birds;
- the wet season, periods of extended wet weather, or periods of above-average stream flow.

Extreme care should be taken when determining the appropriate timing of those works that are to be conducted in streams that exhibit one or more of the following characteristics:

- streams with clear-water, dry weather flows;
- streams with reaches located in the upper parts of a large drainage catchment;
- streams containing aquatic life;
- pristine streams unaffected by urbanisation.

Step 4 Determine an appropriate work procedure

There is almost always more than one way of conducting the proposed construction or maintenance activities. Selection of the preferred work procedure will depend, in part, on the answers obtained to the questions raised in Step 3.

Some of the most common site management procedures are discussed below.

If it is necessary to cause soil disturbance across the full width of the channel without staging the disturbance, then a full-width instream sediment trap may be required.

Such devices are only suitable in “dry” channels or streams with very low flow rates, and only during periods when storm or flood flows are not expected to occur. In all other cases a stream flow diversion system will be required.

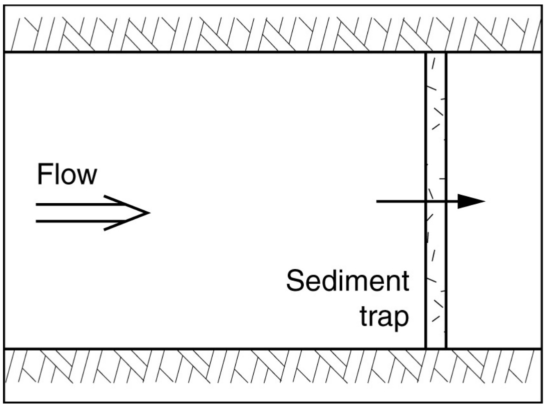


Figure I4 – Full-width sediment trap

If it is necessary to establish a “dry” work area, then cofferdams or *Isolation Barriers* will be needed to isolate the work area from stream flow.

In such cases, it is usually desirable to allow the stream’s base flows to pass through the site within a gravity flow bypass pipe rather an establishing a pumped bypass.

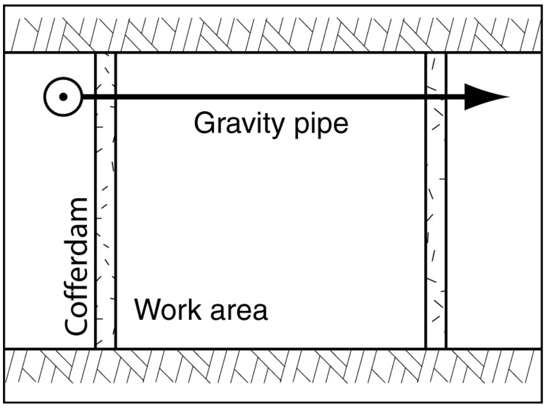


Figure I5 – Gravity flow bypass

If a pumped bypass is required, then special arrangements may need to be made to maintain the pump over weekends, and to manage possible debris blockage and vandalism problems.

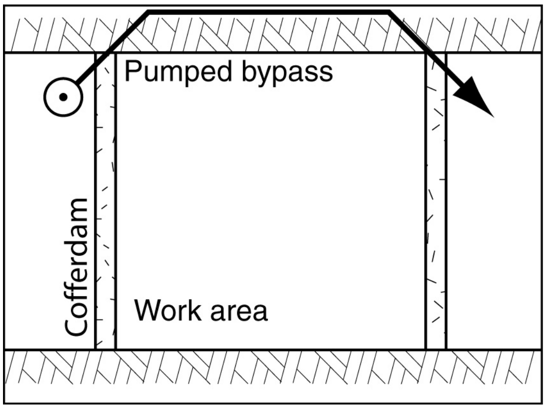


Figure I6 – Pumped flow bypass

If the works can be staged to allow stream flows to be diverted around the soil disturbance, then determine how many construction stages will be required, and what type of *Isolation Barrier* will be needed.

In most circumstances this is the preferred construction method. This procedure requires works, such as the construction of a culvert base-slab, to be divided into at least two stages. This may require changes to the structural design (i.e. steel reinforcing) of the base-slab.

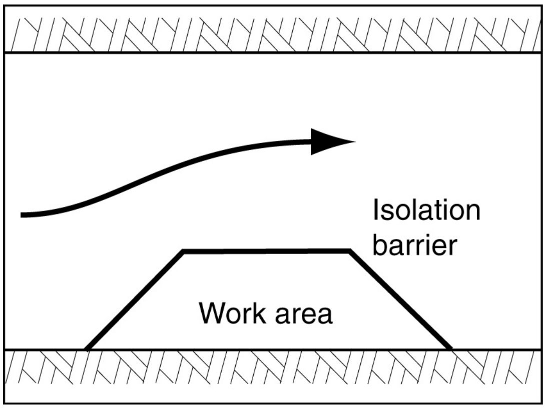


Figure I7 – Isolation barrier

If the work area is likely to be "wet", then the enclosed water will usually need to be treated before it is allowed to re-enter the stream.

The preferred method is usually to pump the water to an off-stream sediment control system (located on the floodplain), then allow the treated water to filter (as "sheet" flow) through bank vegetation before re-entering the channel.

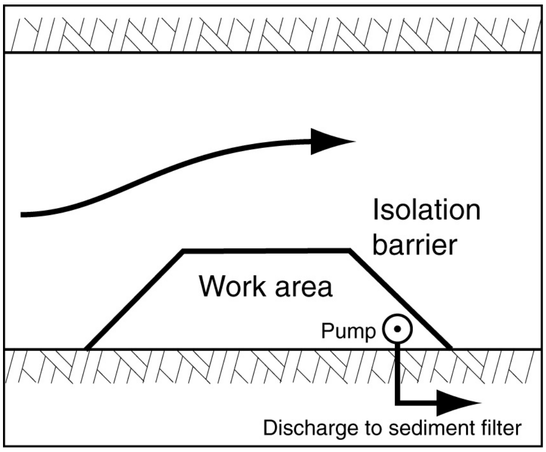


Figure I8 – Isolation barrier

If the material excavated from the channel needs to be de-watered before being transported from the site, then an area needs to be made available for stockpiling the material, and a suitable de-watering procedure needs to be established.

Usually the best method is to stockpile the material as far from the stream as possible, and to ensure any sediment-laden water draining from the stockpile is appropriately filtered through **non-woven**, heavy-duty filter cloth (i.e. *Filter Fence*), **not** woven sediment fence fabric.

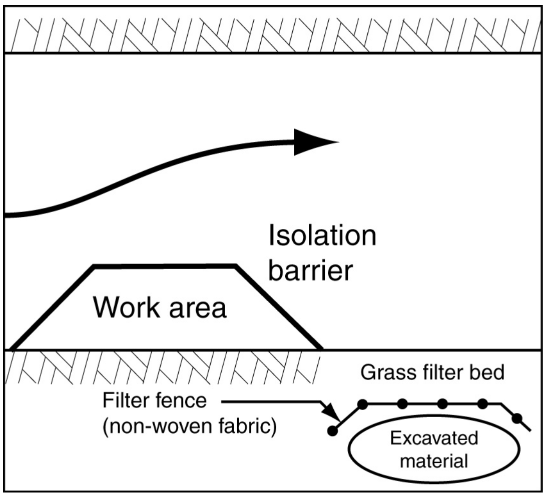


Figure I9 – Isolation barrier

Step 5 Control water movement in and around the work site

There are usually two sources of water flow that need to be managed while conducting instream works: firstly stream flows passing through the work area, and secondly lateral inflows, usually consisting of local stormwater runoff flowing towards the channel.

All reasonable and practicable measures need to be taken to convey the lateral inflow of stormwater runoff around or through the work area in a non-erosive manner. Wherever reasonable and practicable, this inflow of “clean” water should not mix with any “dirty” water generated within the work area.

The diversion of lateral inflow is recommended in the following cases:

(i) when rainfall is expected or likely; and

(ii) material stockpiles on the side of the channel contains clayey, silty or otherwise harmful material, and any materials washed from these stockpiles are likely to wash into the drain or waterway; or

(iii) lateral inflows are likely to flow over exposed soil or cause bank erosion within the work area.

Catch Drains or *Flow Diversion Banks* (earth or straw bales) can be used to divert up-slope stormwater runoff around stockpiles and other soil disturbances. The diverted water can either be directed as sheet flow towards an undisturbed channel bank, or discharged to a temporary geotextile *Chute* constructed down the channel bank.

The most critical flow diversion activities are those used to divert in-bank stream flows around the work site. As discussed in the previous section, there are basically three ways of diverting stream flows, those being:

- use of cofferdams with a gravity bypass pipe;
- use of cofferdams with a pumped bypass;
- use of an *Isolation Barrier*.

The advantages and disadvantages of the three systems are summarised in Table I1.

The greater the flow rate and the cleaner the stream flow, the greater the need and value of instream flow diversion. Therefore, the first option should always be to delay instream soil disturbances until channel flow and the risk of flood flows is at a minimum.

Wherever reasonable and practicable, flow diversion works and temporary bank stabilisation works should be designed to be structurally stable during at least the 1 in 2 year stream flow.

Once an instream work area has been isolated from the stream flow, it is important to take all reasonable and practicable measures to extract wildlife from the enclosure prior to commencing construction or maintenance activities. It should be noted that in most states the capture and release of aquatic wildlife is strictly regulated by State authority, and may only be done by registered wildlife handlers. It is also highly likely that the use of a cofferdam or *Isolation Barrier* will require approval by one or more State authorities.

Recommendations for flow diversion are presented in Table I2.

Table I1 – Advantages and disadvantages of various flow bypass options

Bypass option	Advantages	Disadvantages
Cofferdam with gravity bypass pipe	• No power cost.	• Bypass pipeline may interfere with work activities. • Flood flows still pass through the work site. • Disruption to fish passage.
Cofferdam with pumped bypass	• Bypass pipeline does not interfere with work activities.	• Added power and maintenance costs. • Flood flows still pass through the work site. • Disruption to fish passage.
Isolation barrier	• Minimal disturbance to normal channel flow. • Minimal disruption to fish passage. • Better able to isolate the work area from flood flows.	• Some *Isolation Barriers*, such as *Silt Curtains*, are not watertight. • Requires work across the channel bed to be staged.

Table I2 – Flow diversion recommendations

Condition	Recommendations
Default conditions	• Program works in accordance with Step 3. • Flow diversion shall only occur if it is financially feasible and the environmental benefit gained by its use exceeds the potential harm caused by the installation and removal of the *Isolation Barrier* or cofferdams.
No base flow	• If there is no base flow (i.e. no obvious running water, but permanent pools may be present) and stream flow is **not** expected during the construction or maintenance activity, then refer to the default conditions.
	• If there is no base flow (i.e. no obvious running water, but permanent pools may be present) but stream flow is possible, then appropriate consideration must be given to the installation of an *Isolation Barrier*.
Base flow exists in the stream	• If there is base flow and increased stream flows are **not** expected, then appropriate consideration must be given to the installation of cofferdams with a low-flow bypass system.
	• If there is base flow and increased stream flows (i.e. in response to a storm) are possible, but not likely, then the choice between the use of an *Isolation Barrier* or cofferdams will depend on the likelihood of stream flows overtopping the cofferdams.
	• If there is base flow and increased stream flows are expected (i.e. in response to a storm), then the first option should be to delay the proposed works until stream flows are a minimum. In any event, priority should be given to the install an *Isolation Barrier*.
Fish passage required to be maintained	• First preference: an *Isolation Barrier* that isolates no more than 30% of the stream width at any given time. • Second preference: an *Isolation Barrier* that isolates no more than 50%, of the stream width at any given time if the first preference is either unreasonable or impracticable.

Step 6 Select erosion control measures

Appropriate erosion control measures need to be employed to limit soil erosion especially along the bed and banks of the stream. In particular, clayey or unstable soils need to be stabilised or covered with *Erosion Control Blankets*, *Mats*, or *Mesh* to minimise soil erosion as soon as reasonable and practicable.

Technical Note I1: Blankets, mats and mesh

The term “blanket” generally refers to erosion control fabric used on soils subjected to sheet flow conditions such as the high bank areas of a channel well above normal stream flows.

The term “mat” generally refers to erosion control fabric used on soils subjected to concentrated flow, such as those within a drainage channel.

The term “mesh” refers to erosion control fabric consisting of an open weave (like a net) usually formed from jute or coir. These products are most appropriate within natural waterways when it is important to avoid the use of potentially damaging synthetic (plastic) mesh or mat reinforcing.

A “hydraulically-applied” blanket refers to the liquid spray-on products that dry to form a solid, continuous blanket with a thickness approximating that of an *Erosion Control Blanket*. Hydraulically-applied blankets, also known as *Bonded Fibre Matrix* (BFM), are commonly used in the revegetation of drainage channels due to their higher flow resistance compared to hydromulching.

If dispersive soils are exposed, then these soils should either be treated to stabilise their dispersive nature, or buried under a layer of non-dispersive soil (refer to Step 10). Discussion on dispersive soils and their treatment is supplied within Appendix G – *Soils and revegetation*.

The extent and type of erosion control measures greatly depends on the likelihood and intensity of expected rainfall and/or stream flow. If construction occurs during the dry season when rainfall and stream flow are unlikely, then the degree of erosion protection is likely to be significantly less than if construction occurs during the wet season.

The recommended design flow velocities for various erosion control products are provided in Chapter 4 (Section 4.7, Step 13). Erosion control mesh, whether jute or coir, has proven to be most valuable as a temporary surface stabilisation measure within drainage channels and some low velocity waterways.

Technical notes placed on the Erosion and Sediment Control Plan (ESCP) and/or within the supporting documentation need to clearly specify the degree of erosion control required for different periods of the year, or for different levels of anticipated rainfall and/or stream flow.

One of the best ways of minimising soil erosion is to minimise site disturbance and the disturbance of high-risk areas. This can be achieved by:

- avoiding unnecessary disturbance of bed or bank vegetation;
- avoiding disturbance on the outside bank of a channel bend;
- minimising the soil disturbance needed to provide access to the site;
- not accessing the site via the outside of a channel bend, or via an unstable bank;
- using long-reach excavation equipment that allows all work to be done from the top of bank rather than allowing machinery to access the channel bed.

Step 7 Select sediment control measures

There are potentially three main sources of sediment runoff:

- sediment-laden water released from instream disturbances;
- sediment-laden water released during the de-watering of the work site;
- sediment-laden runoff from the de-watering of material stockpiles.

All three sources of sediment need to be appropriately managed, with each source usually requiring a different sediment control technique.

(a) Instream sediment control techniques

Instream sediment controls are installed to treat only the dry-weather base flow passing down the channel. It is rarely practical to design instream sediment controls to treat stream flows resulting from storms or floods.

The choice of instream sediment control technique depends on a number of variables including channel shape, flow rate, water depth, undisturbed water quality, and the duration of the works. Tables I5 to I7 provide guidelines on appropriate instream sediment control techniques. Wherever reasonable and practicable, preference must be given to Type 1 sediment control systems (Table I3), followed by Type 2, then Type 3 systems as required by Table I4.

Sediment runoff generated outside the waterway channel must be treated prior to its discharge into the watercourse. When constructing waterway crossings, four sediment traps or basins are usually required, one each side of the road, on each side of the waterway (Figure I10).

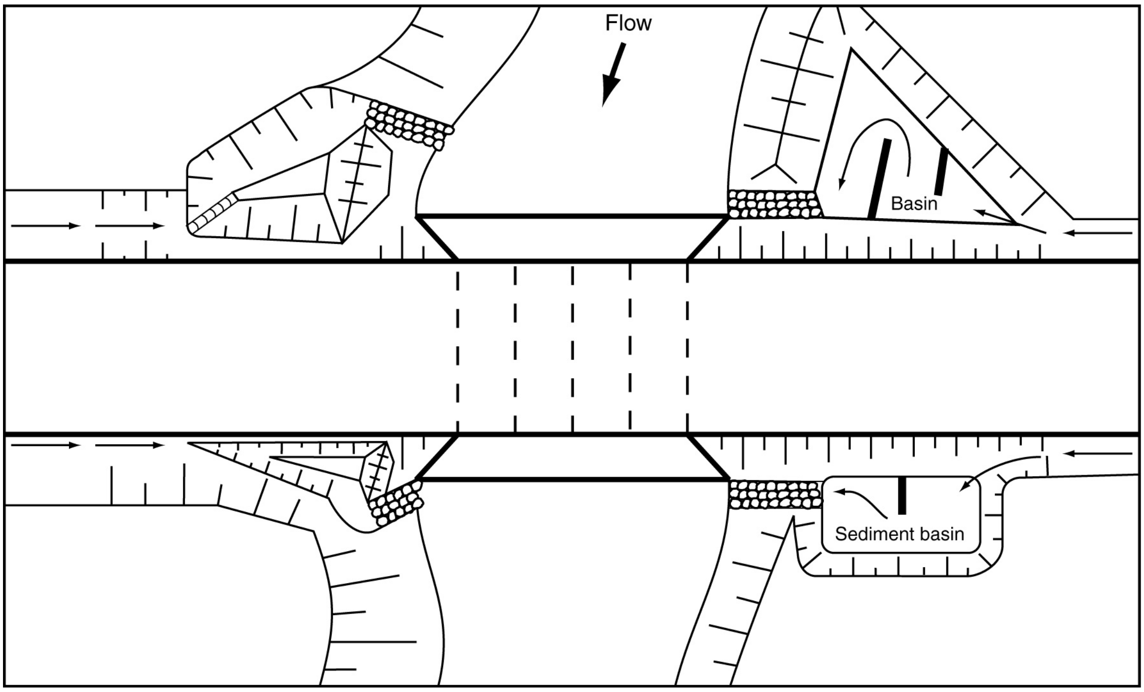


Figure I10 – Sediment basins adjacent to culvert construction

Table I3 – Sediment trap classification system

Classification	Critical entrapment particle size
Type 1	< 0.045mm
Type 2	0.045 to 0.14mm
Type 3	> 0.14mm

Table I4 – Classification of instream sediment control techniques [1]

Type 1	Type 2	Type 3
• Pump sediment-laden water to an off-stream Type F or Type D Sediment Basin or high filtration system	• Filter Tube Barrier • Rock Filter Dam • Sediment Weir	• Modular Sediment Barrier • Sediment Filter Cage • Sediment Fence • Straw Bale Barrier

Note [1] Classification may vary depending on design details

Table I5 – Recommended site conditions of use for various sediment controls

Instream sediment trap	Typical site conditions
Filter Tube Barrier	• Channels with “clear” base flow. • Channels with poor settling (i.e. clayey) sediment. • Suitable for medium and long-term works.
Floating Silt Curtain	• Water depths greater than 0.8m. • Tidal waters. • Very low velocity flow. • Typically only used as an *Isolation Barrier* and thus **not** normally placed across the full channel width.
Modular Sediment Barrier [1]	• Concrete-lined channels and overland flow paths. • Areas with poor access for heavy machinery. • Short-term works where the units can be reused.
Rock Filter Dam [1]	• Long-term works (i.e. more than 5 days). • Dry weather conditions when over-topping flows are not expected. • Constructed or heavily modified channels only. • Channels with turbid or slightly turbid low-flow.
Sediment Filter Cage [1]	• Short-term works (i.e. 1 to 2 days). • Channels with turbid or slightly turbid low-flow. • Channel containing good settling sediments. • Narrow channels.
Sediment Weir [1]	• Medium to long-term works (i.e. more than 2 days). • Channels with turbid or slightly turbid base flows. • Sites with poor machinery access. • Channels with an irregular bed shape. • Wide channels.
Sediment Fence	• Dry channels/drains when channel flow is highly unlikely. • Only suitable for trapping sediment displaced by bed/bank works.
Straw Bale Barrier	• Can be used as a temporary sediment trap while installing the primary instream sediment control device.

Note: [1] Techniques that can be supplemented with the use of one or more Filter Tubes.

Table I6 – Selection of preferred instream sediment control technique [1]

Site Condition	Technique [2]	Comments
Short-term works (1 to 2 days)	Various	Preferred choice of sediment control device depends on site conditions and knowledge gained from past practices.
Default device for medium to long-term works (> 2 days)	Filter Tubes	The *Filter Tubes* may be used in association with an earth embankment, *Rock Filter Dam, Sediment Weir,* or *Modular Sediment Barrier* in accordance with the expected base flow rate and the environmental sensitivity of the watercourse.
Deep water drain or waterway	Floating Silt Curtain	Typically used in water depths greater than 0.8m and near-zero flow velocity.
	Isolation Barrier	If significant channel flows exist, then preference should be given to the use of an *Isolation Barrier*.
No machinery access	Filter Tube Barrier	Used on medium to long-term works. Needs suitable site conditions so the *Filter Tubes* (when full) can be winched or otherwise removed from the channel. The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier, Sediment Weir* or other portable frame.
	Modular Sediment Barrier	Most components, except filter cloth, are reusable. Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
	Sediment Weir	Possible use of straw bales as the filter media within the *Sediment Weir*, or the use of lightweight modular units.
	Sediment Fence	Only suitable if channel flows are highly unlikely. Suitable for trapping minor sediment displaced by works on the bed and banks of a dry channel.
Small, constructed drain	Filter Tube Barrier	The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier, Sediment Weir* or other portable frame.
	Rock Filter Dam	Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
	Modular Sediment Barrier	Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
Low-flow concrete drain or rocky channel	Off-stream de-watering techniques	Consider the feasibility of pumping contaminated water to a *Filter Bag* or other off-stream de-watering sediment control system.
	Modular Sediment Barrier	Modular units must be wrapped in filter cloth and anchored to the channel bed. Can be used in association with *Filter Tubes* to increase allowable flow rate and/or increase service life.
	Filter Tube Barrier	*Filter Tubes* incorporated into modular filter units or an impermeable weir securely anchored to the channel bed.

Notes: [1] Instream sediment traps should only be used when delaying the works and/or the use of an *Isolation Barrier* is not practical.

[2] Techniques listed in general order of preference.

Table I7 – Selection of preferred instream sediment control technique [1]

Site Condition	Technique [2]	Comments
Significant sediment flows (in volume) are expected such as in a sandy bed channel	Sediment Cage	Used in narrow, flat-bed channels or during low flow.
	Sediment Weir	A *Sediment Weir* is a possible option if a *Sediment Cage* could not be suitably installed.
	Filter Tubes	The preferred option if high turbidity levels are expected.
	Rock Filter Dam	Not suitable if there is a high risk of failure caused by high stream flows. Generally only suitable for constructed or modified channels where heavy machinery access exists.
Channels with existing turbid low-flows	Sediment Cage	Used in narrow, flat-bed channels or during low flow.
	Sediment Weir	Possible option if no heavy machinery access exists.
	Rock Filter Dam	Suitable for constructed or modified channels where heavy machinery access exists. May not be suitable if significant stream flows are likely.
Coarse gravel bed channels	Filter Tube Barrier	The preferred option if the *Filter Tubes* can be installed without causing irreversible or unacceptable bed damage.
	Rock Filter Dam	May require the use of a thick filter cloth to separate the gravel bed and *Rock Filter Dam*. May not be suitable if significant stream flows are likely.
Natural dry-bed waterway where stream flows are most unlikely	No instream controls	Site conditions may allow instream works to occur without the need for instream sediment controls if the risk of stream flow is sufficiently low.
	Modular Barrier	Most components can be reusable from site to site.
	Sediment Weir	Use of straw bales as the filter media may allow the bales to be reused if flow does not occur.
Natural dry-bed waterway where stream flows are possible	Isolation Barrier	Stage disturbance across the channel to allow the free, uncontaminated bypass of likely stream flows or lateral inflows resulting from local storms.
	Sediment Weir	Use of straw bales as the filter media may allow the bales to be reused if flow does not occur. Otherwise consider the use of a *Modular Sediment Barrier*.
Natural waterway with minor base flow	Delay works	1st option: Delay works until a suitable low-flow period.
	Isolation Barrier	Stage disturbance across the channel to allow the free, uncontaminated bypass of stream flows with minimal impact on aquatic passage.
	Filter Tube Barrier	The *Filter Tubes* need to be incorporated into an in-situ *Modular Sediment Barrier,* or *Sediment Weir*.
Narrow channels with significant base flow	Delay works	1st option: Delay works until a suitable low flow period.
	Isolation Barrier	Stage channel disturbance wherever practical.
	Cofferdam	Cofferdam with gravity base-flow bypass pipe.
Wide channels with significant base flow	Delay works	1st option: Delay works until a suitable low flow period.
	Isolation Barrier	Stage disturbance across the channel and isolated from the main channel flow.

Notes: [1] Instream sediment traps should only be used when delaying the works and/or the use of an *Isolation Barrier* is not practical.

[2] Techniques listed in general order of preference.

(b) Sediment controls for the de-watering of the work site

The best way to minimise environmental harm is to minimise the volume of external water that is allowed to enter an excavation or trench. This is normally achieved by diverting any surface water away the work area.

All sediment-laden water pumped from the channel or an excavation must be suitably treated before being discharged back into the channel. Wherever reasonable and practicable, preference must be given to Type 1 sediment control systems, followed by Type 2, then Type 3 systems as described in Table 4.5.3 of Chapter 4 – *Design standards and technique selection*.

The preferred technique for treating contaminated water also depends on the volume of water and the frequency of such discharges. Table 4.5.15 of Chapter 4 – *Design standards and technique selection* outlines the attributes of various sediment control techniques used during de-watering operations.

When de-watering instream work sites it is important to instigate appropriate measures to minimise the risk of aquatic wildlife being sucked into the intake pipe. Such measures may include:

- removing trapped animals from enclosures prior to de-watering; and/or
- forming a wire mesh cage or similar fine mesh frame around the intake pipe; and/or
- wrapping the intake pipe in shade cloth (**not** sediment fence fabric); and/or
- placing the intake pipe inside a perforated (fine-hole size) PVC pipe; and/or
- use of a gravel-filled *Sump Pit* to house the intake pipe.

(c) Sediment controls for the de-watering of material stockpiles

The de-watering of material removed from excavations, or dredged from the channel, is normally performed by temporarily stockpiling the material within a designated sediment control area. The process may also be done after the material is loaded into a truck, in which case the truck is required to remain within the sediment control area until sufficient water has drained from the truck.

If the material is loaded directly into a truck, then where practicable, filter cloth should be placed over the ground to capture sediment spills. This also helps in the final clean-up/rehabilitation of the site.

Table 4.5.14 of Chapter 4 – *Design standards and technique selection* outlines best practice sediment control measures for the de-watering of excavated material and other stockpiles.

The recommended water quality standard for de-watering operations is presented in Tables 4.5.13 and 4.5.14 of Chapter 4 – *Design standards and technique selection*.

Table I8 provides general comments on the de-watering of various materials.

Table I8 – De-watering of excavated instream material

Material	Recommendations and comments
Black organic "muck"	**Comments:** • Avoid de-watering such material on-site if the runoff is expected to re-enter the stream, especially if the stream's flow rate is low or non-existing. • Strong odour problems often occur when stockpiling such material. • Runoff can be high in nutrients and very low in dissolved oxygen. • Few sediment controls can adequately treat such runoff unless the volume of water is so small that close to 100% infiltration occurs. • The best form of treatment involves infiltration or filtration through sand or soil. **Recommended control techniques:** • Soil infiltration or *Grass Filter Beds* for very minor quantities of material. • Otherwise, for medium to large quantities of material, establish a runoff collection sump down-slope of the stockpile area, and pump all runoff to a suitable sediment trap as per Step 7(b).
Clayey material	**Comments:** • Significant environmental problems can result if the highly turbid water is allowed to enter a water body. • Runoff is likely to contain high levels of nutrients and other pollutants. • On-site de-watering is generally not practical during extended wet weather. **Recommended control techniques:** • Soil infiltration or *Grass Filter Beds* for very minor quantities of material. • *Filter Fence* formed from well-braced filter cloth. • Otherwise, establish a runoff collection sump down-slope of the stockpile area, and pump all runoff to a suitable sediment trap as per Step 7(b).
Non-clayey material	**Comments:** • On-site de-watering is most effective for these materials. **Recommended control techniques:** • *Grass Filter Beds* for small quantities of material. • *U-shaped (non-woven) Sediment Trap* placed down-slope of stockpile. • *Filter Fence* formed from well-braced filter cloth. • Otherwise, establish a runoff collection sump down-slope of the stockpile area, and pump all runoff to a suitable sediment trap as per Step 7(b).

Step 8 Select material handling, transport, and disposal methods

Discussion is provided in Step 4 on the benefits of various work procedures. It will also be necessary for site managers to determine the preferred means of transporting materials from the site.

In most cases it will be necessary to de-water excavated material before it leaves the site. This is because it is generally unacceptable practice to transport saturated material that may discharge polluted waters along public roadways. Discussion on the de-watering of excavated material is provided in Step 7(c).

Step 9 Assess water quality monitoring requirements

Monitoring the effectiveness of the adopted work procedures and the Erosion and Sediment Control Plan (ESCP) is part of responsible site management.

ESCPs should be looked upon as living documents that can and should be modified as site conditions change. When a monitoring program detects a notable failure in the adopted ESC measures, the source of this failure should be investigated and appropriate amendments made to the plans.

Monitoring the water quality before, during and after construction will, in part, enable the effectiveness of adopted control measures to be assessed. Such monitoring should be done simultaneously upstream and downstream of the channel disturbance.

Monitoring requirements are normally specified as part of the state government licensing requirements of the instream works. Otherwise, contact the relevant State Government department for both monitoring requirements and sampling procedures.

Step 10 Determine site clean-up, stabilisation and rehabilitation

Exposed soil surfaces must be rehabilitated as soon as practicable to prevent or at least minimise the risk of environmental harm caused by long-term soil erosion. Channel banks should be actively revegetated rather than just waiting for natural regeneration (refer to Appendix N for definitions of rehabilitation, revegetation and stabilisation).

Revegetation is one of the most successful long-term stabilisation techniques for both natural and urban waterways. In-stream ecology is greatly enhanced by the re-establishment of riparian vegetation, especially bank vegetation. Riparian vegetation introduces shading for water temperature control; the establishment of habitat diversity; the creation of snags; and the linking of aquatic and riparian habitats.

Wherever reasonable and practicable, revegetate to the water's edge to increase the value and linkage of the aquatic and riparian habitats. Rock protection of the bank toe is usually required to provide stabilisation during plant establishment. Figure I11 to I16 provide examples of partial and full-face rock protection on good soils (Figures I11 to I14) and dispersive soils (Figures I15 and I16) for both open face rock and vegetated rock cases.

During plant establishment it may be necessary to protect the soil from short-term erosion with the aid of an *Erosion Control Blanket, Mat* or *Mesh*. *Erosion Control Blankets* or *Mats* reinforced with synthetic mesh are **not** recommended for use along waterways containing ground-dwelling wildlife (refer to discussion in Step 6).

The short-term maintenance of site rehabilitation can include: watering, weed control, replacement of dead or damaged plants, re-firming plants loosened by wind-rock, pruning plants of dead or diseased parts, and maintenance of protective fencing.

In the absence of a locally adopted risk assessment procedure, Table I9 is presented as the default erosion risk rating system for major drainage channels and watercourses. Table I10 presents an alternative rating system for application to minor drains and waterways where channel flow is directly related to local rainfall. Best practice requirements for the clearing and progressive stabilisation of drainage channels and watercourses are provided in Table I11.

Table I9 – Erosion risk rating based on expected channel flow conditions

Erosion risk rating	Expected flow conditions [1]
Very Low	No rainfall or channel flow expected during plant establishment.
Low	Light local rainfall is expected which is likely to result in only a minor increase in channel flow above the normal dry-weather flow rate.
Moderate	Heavy local rainfall is expected which is likely to cause stormwater inflows into the channel and a minor increase in channel flow above the normal dry-weather flow rate.
High	Medium to high-velocity in-bank flows are expected during the plant establishment period that are likely to inundate unstable, disturbed or recently revegetated channel surfaces.
Extreme	Medium to high-velocity overbank or near bankfull channel flows are expected during the plant establishment period that are likely to inundate unstable, disturbed or recently revegetated channel surfaces.

Note: [1] Erosion risk rating based on worst-case of the expected flow conditions.

Table I10 – Alternative erosion risk rating based on expected daily and average monthly rainfall

Erosion risk rating [1]	Expected 24-hour rainfall	Average monthly rainfall
Very Low	0 to 2 mm	0 to 30 mm
Low	2+ to 10 mm	30+ to 45 mm
Moderate	10+ to 25 mm	45+ to 100 mm
High	25+ to 100 mm	100+ to 225 mm
Extreme	> 100 mm	> 225 mm

Note [1] Erosion risk rating based on worst case of expected rainfall within any 24 hour period or average monthly rainfall.

Table I11 – Best practice channel clearing and stabilisation requirements

Risk [1]	Best practice requirements
All cases	• All reasonable and practicable steps taken to apply best practice erosion control measures to completed channel works, or otherwise stabilise such works, prior to an anticipated increase in stream flow.
Very low	• Channel clearing limited to maximum 8 weeks of programmed work. • Disturbed soil surfaces stabilised with minimum 70% cover [2] within 30 days of completion of works within any constructed drainage channel or waterway. • Non-completed works stabilised if exposed, or expected to be exposed, for a period exceeding 30 days.
Low	• Channel clearing limited to maximum 6 weeks of programmed work. • Disturbed soil surfaces stabilised with minimum 70% cover [2] within 30 days of completion of works within any constructed drainage channel or waterway. • Non-completed channel works stabilised if exposed, or expected to be exposed, for a period exceeding 30 days.
Moderate	• Channel clearing limited to maximum 4 weeks of programmed work. • Disturbed soil surfaces stabilised with minimum 80% cover [2] within 10 days of completion of works within any constructed drainage channel or waterway. • Appropriate consideration given to the use of rock protection, biodegradable *Erosion Control Mesh* or the equivalent, on all erodible stream banks subject to high velocity flows. • Non-completed channel works stabilised if exposed, or expected to be exposed, for a period exceeding 20 days.
High	• Channel clearing limited to maximum 2 weeks of programmed work. • Disturbed soil surfaces stabilised with minimum 90% cover [2] within 5 days of completion of works within any constructed drainage channel or waterway. • Appropriate consideration given to the use of rock protection, biodegradable *Erosion Control Mesh* or the equivalent, on all erodible stream banks subject to high velocity flows. • Non-completed channel works stabilised if exposed, or expected to be exposed, for a period exceeding 10 days.
Extreme	• Channel clearing limited to maximum 1 week of programmed work. • Disturbed soil surfaces stabilised with minimum 90% cover [2] within 5 days of completion of works within any area of a work site. • Appropriate consideration given to the use of rock protection, biodegradable *Erosion Control Mesh* or the equivalent, on all erodible stream banks subject to high velocity flows. • Non-completed channel works stabilised if exposed, or expected to be exposed, for a period exceeding 5 days.

Notes: [1] Erosion risk based on channel flow conditions (Table I9), or daily/monthly rainfall depth (Table I10) as directed by the relevant regulatory authority.

[2] Minimum cover requirement may be reduced if the natural cover of the immediate land is less than the nominated value, for example in arid and semi-arid areas.

Table I12 outlines the attributes of various short- and long-term channel bank stabilisation methods applicable during channel revegetation.

Table I12 – Bank stabilisation methods during channel revegetation

Bank stabilisation method	Uses and attributes
Short-term measures	
Hydraulically applied blankets	• Includes *Bonded Fibre Matrix* and *Compost Blankets*. • Low to medium shear strength, thus only suitable for low velocity channels. • Suitable for application on irregular surfaces and steep bank slopes. • *Compost Blankets* can provide a nutrient source.
Jute or coir blankets/matting	• Low shear strength, thus only suitable for low velocity channels. • Require good soil preparation and removal of surface irregularities from the bank.
Jute or coir mesh	• Medium shear strength. • Generally suitable for the short-term protection of drainage channels and minor stream and creeks. • Typical design life in dry environments of 12 to 24 months. • Do not represent a threat to wildlife.
Synthetic reinforced blankets/matting	• Medium shear strength • Plastic mesh can represent a threat to wildlife. • Generally **not** suitable for the stabilisation of watercourses where wildlife such as lizards, snakes and birds may be present.
Geo Logs	• Diversion of minor high-velocity flows away from seedlings planted close to the water's edge. • Protection of plants along the water's edge from wave action, particularly in lakes. • Must be used with extreme care if placed parallel to the stream flow, otherwise erosion may occur behind the logs.
Long-term measures	
UV-stabilised Turf Reinforcement Matting (TRM)	• High shear strength. • May be damaged by grass fires. • Generally **not** suitable for the stabilisation of watercourses where ground-dwelling wildlife such as platypus and bank-nesting birds may be present.
Rock stabilisation of the water's edge or toe of bank	• Used in areas where channel velocities are high, but near-bankfull flow velocities are low. • Commonly used to minimise the risk of bank erosion caused by minor flows during the revegetation phase.
Rock stabilisation (rock beaching) of full bank	• Stabilisation of very steep channel banks, with or without vegetation. • Commonly used on the outside face of high velocity or sharp channel bends, or to minimise the risk of bank erosion caused by near-bankfull flows during the revegetation phase.

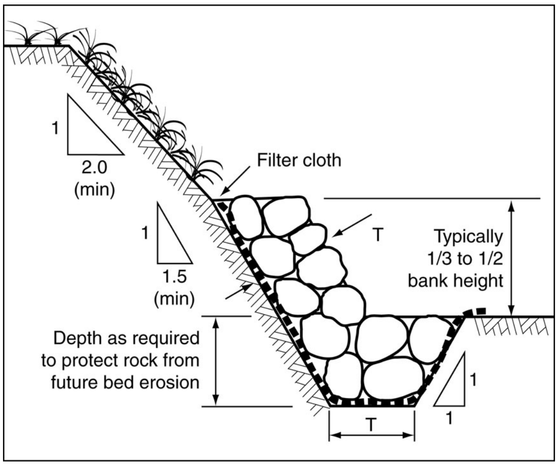


Figure I11 – Open rock, toe protection

Advantages:

Reduced quantity of rock.

Disadvantages:

Problems can occur with lateral inflows (i.e. stormwater runoff) entering into, or washing under, the rock.

Reduced aquatic habitat values in absence of vegetation.

Use:

Partial bank protection is used in areas where channel velocities are high, but upper-bank and overbank velocities are low.

Inside face of fully shaded, high velocity channel bends.

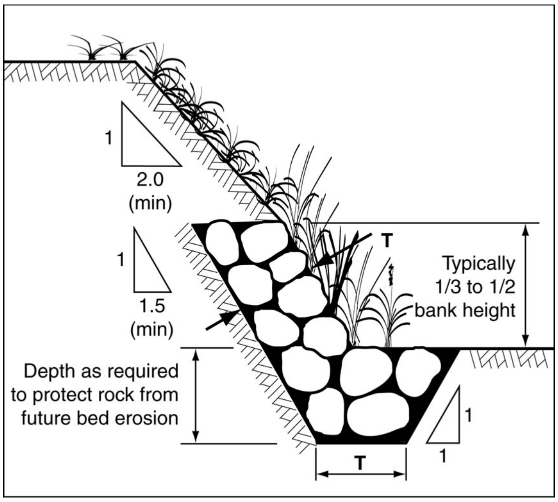


Figure I12 – Vegetated rock, toe protection

Advantages:

Improved aquatic habitat values.

Retention of riparian values.

Disadvantages:

Care must be taken to ensure all voids are filled with soil to prevent loss of upper bank soil into the rock protection.

Use:

Partial bank protection is used in areas where channel velocities are high, but upper-bank and overbank velocities are low.

Toe protection of channel banks in regions of high flow velocity or areas where the channel bed may experience scour.

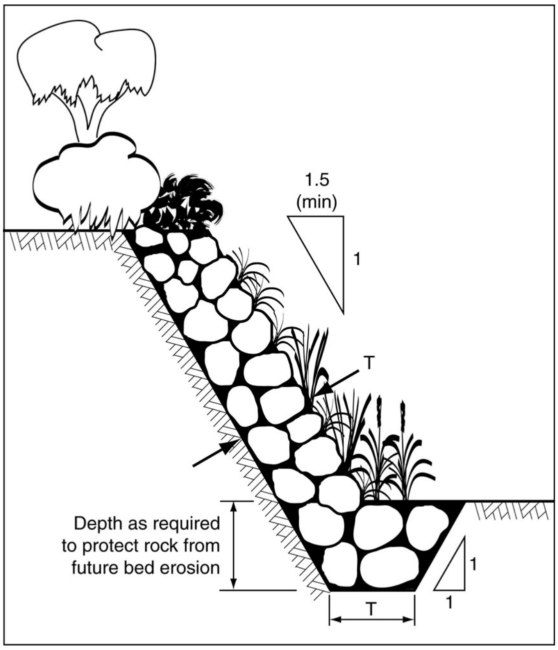


Figure I13 – Full face, vegetated rock

Advantages:

Retention of aquatic habitat values.

Very high scour protection once vegetation is established.

Retention of riparian values.

Banks can be steeper than vegetated banks that do not contain rock protection.

Disadvantages:

High installation cost.

Use:

Outside face of high velocity or sharp channel bends.

Areas where both the channel velocity and overbank flow velocities are likely to be erosive.

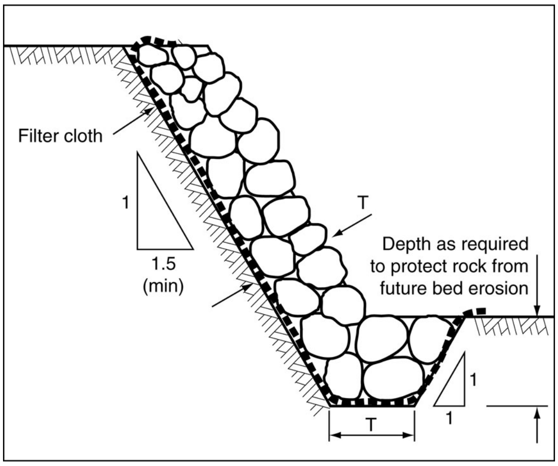


Figure I14 – Full face, open rock

Advantages:

Cheaper installation cost compared to vegetated rock protection.

Generally steeper bank grades can be formed compared to partially protected banks (Figure I11).

Disadvantages:

Poor aesthetics.

High risk of weed invasion unless fully shaded.

Use:

Fully shaded, high velocity areas.

Outside face of fully shaded channel bends.

Very high velocity regions where vegetation is not expected to survive.

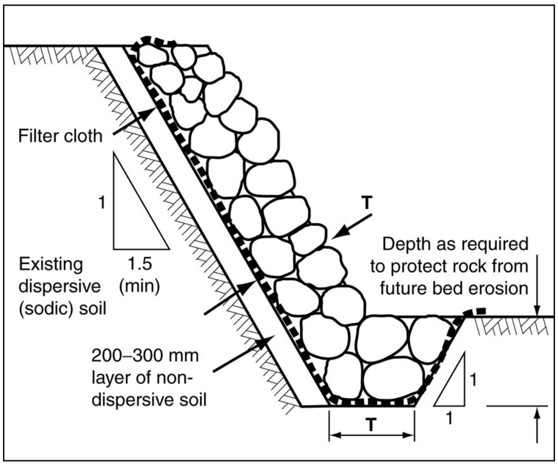


Figure I15 – Full face, open rock on dispersive soil

Advantages:

Long-term protection of highly erodible soils.

Disadvantages:

Poor aesthetics.

High risk of weed invasion unless fully shaded.

Very poor aquatic habitat values.

Use:

Rock protection in fully shaded areas containing dispersive soils.

Outside face of fully shaded channel bends.

Very high velocity regions where vegetation is not expected to survive.

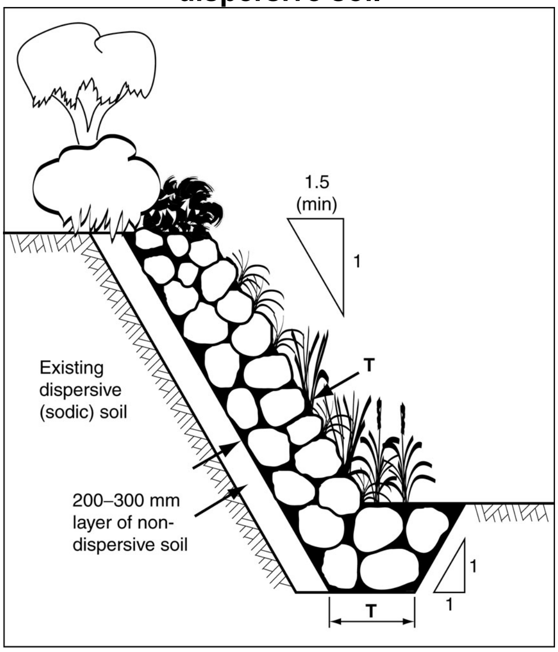


Figure I16 – Full face, vegetated rock on dispersive soil

Advantages:

Retention of aquatic habitat values.

Long-term protection of highly erodible soils.

Reduced maintenance costs.

Disadvantages:

Higher installation cost compared to non-vegetated rock protection.

Use:

Outside face of high velocity or sharp channel bends in dispersive soil regions.

Dispersive soil areas where both the channel velocity and overbank flow velocities are likely to be erosive.

(a) Plant selection:

Selecting the most suitable plant establishment techniques, plant species, seeding rates, planting densities, fertilisers, watering rates, and maintenance techniques, requires the guidance of experts such as local bushland groups, specialist waterway landscape and revegetation consultants, and government bodies.

The type of vegetation most critical to the stabilisation of a waterway depends on a number of factors including:

- channel flow velocity at bankfull flow;
- depth below bankfull elevation;
- frequency of bankfull flows;
- frequency of natural channel erosion (i.e. meandering);
- type and frequency of sediment movement along the channel bed;
- location of the plant within the channel cross section;
- location of the plant relative to the most immediate upstream channel bend.

An emphasis should be placed on the planting of indigenous species, preferably those grown from locally collected seed. However, this may not be the case in regions where expansion of the watercourse—caused by changes in catchment hydrology—have irreversibly converted a closed-canopy watercourse into an open-canopy watercourse. In these areas the preferred species may need to come from a downstream reach of the watercourse where a similar open-canopy occurs naturally.

The type of root system is an important erosion control characteristic of bank vegetation. Ideally, bank vegetation in dynamic creeks should have a root system with the characteristics described in Table I13.

Table I13 – Desirable plant root characteristics

Plant type	Desirable root system characteristics
Ground covers	• Vast, fibrous root ball, including near surface roots
Trees and shrubs	• A vast surface root system. • Ability to withstand long-term exposure to sun and water without drying out or fracturing as a result of debris impact during flood events. • A root system that extends below the bed level of the channel to prevent undermining.

Table I14 provides a general discussion on various vegetation types and their benefit to scour protection.

Table I15 outlines the types of vegetation most likely to be effective in the control of the various forms of channel erosion.

Table I14 – Vegetation types and erosion control characteristics

Type	Scour control	Bank stability	Hydraulic issues
Aquatic plants	Provide good stability to the low-flow channel and waters edge.	Can assist bank stability by protecting the toe of the bank. Some plants (e.g. reeds) can become inflexible as plant density increases. This can cause channel flow to be deflected into the channel bank causing bank erosion.	Minor flow resistance if the water depth is greater than the plant height, i.e. plant height is less than the bank height. Thick stands of reeds can effectively block a channel aggravating upstream flood levels.
Ground covers	The most effective form of soil erosion control. Ground covers (including grasses) generally control only soil scour (i.e. erosion of the surface layer), not the mass movement of soil resulting from bank failures. To be effective, these plants should be flexible and continuous. Isolated, clumped plants may aggravate soil erosion. Plants with a matted or fibrous (hairy) root system are the best in sandy soils.	Usually ineffective in the prevention of mass movement erosion. These plants usually have a shallow root system and thus provide only scour control. They can be very effective in the stabilisation of channel banks during the early stages of revegetation.	Generally have little effect on flood levels. Some plants, such as *Lomandra*, can grow to a height of around 1 m, and thus may choke small channels. These plants are best placed near the toe of the bank where they are fully submerged during regular flood events.
Shrubs	May provide effective scour control if the branches prevent high velocity water from coming into contact with the soil. Localised soil erosion can occur around the edge of isolated plants.	Shrubs can significantly increase bank strength depending on the height of the bank and the depth of the root system. Unlikely to prevent undermining of the bank unless the shrubs are located close to the toe of the bank.	Shrubs have the greatest potential to affect the hydraulics of the waterway and thus increase upstream flood levels. Avoid the planting of shrubs in areas where flood control is important.
Trees	Usually provide little protection against soil scour. Some plants have root systems that can survive when exposed to air. Such plants can control toe erosion.	Trees provide the main form of bank reinforcement to control mass movement. Trees are most effective in the control of bank slumping erosion and bank undercutting (but only if the roots penetrate below bed level).	Grouped trees can significantly affect flood levels if their spacing is less than say, 5 times the trunk diameter. Well-spaced trees with branches above flood level provide little hydraulic interference.

Table I15 – Plant selection for the control of watercourse erosion

Erosion form	Active force	Primary vegetation	Comments
Head-cut (bed) [1] and lateral bank erosion	Velocity		• Controls normally involve hard engineering such as rock chutes, pool–riffle systems, and grade control structures. • In gullies, stiff grasses such as vetiver grass, can be used to slowly stabilise and raise the bed gully.
Scour (bed) [2]	Velocity	Reeds (wet beds) and grasses (dry beds)	• Vegetation can be critical in shallow water channels, otherwise stabilise the bed with rock. • Grasses and other flexible, non-clumping ground covers may be used on ephemeral streambeds. • In gullies, the erosion may expose poor quality soils that require adjustment prior to revegetation.
Scour (bank) [2]	Velocity	Ground covers, vetiver grass, and/or shrubs	• Flexible ground covers in lower bank and along waters edge. • Low-branch woody species (e.g. shrubs) on mid and upper bank, especially on the outer bank of channel bends. • Generally the banks need to be “hydraulically” rougher than the channel bed.
Slumping [3]	Gravity	Trees, shrubs and vetiver grass	• Shrubs on mid and upper bank, especially on the outer bank of channel bends. • Trees on the upper bank and over-bank areas, especially on steep and high banks.
Undercutting [4]	Velocity and gravity	Ground covers, vetiver grass, shrubs and trees	• Stabilisation of the lower bank with rock and ground covers, including tall, flexible, reeds and grasses. • Shrubs on mid and upper bank, especially on the outer bank of channel bends. • Trees on the upper bank and over-bank areas, especially on steep and high banks. • Lower bank often requires mechanical support (e.g. rock and/or groynes) during the plant establishment phase.
Fretting [5]	Wave action	Reeds and mangroves	• Can be stabilised through the formation of a “beach” in front of, or as a replacement for the eroded bank. • Vegetation is often integrated with rock.

Notes:

[1] The rapid deepening of the channel bed usually resulting in the formation of a waterfall or head cut that migrates up the channel.

[2] The direct removal of material from the bed or banks resulting from water flow.

[3] The mass movement (slipping) of bank material due to either, deepening of the channel, surcharging of the bank, or the rapid lowering of flood waters.

[4] The removal of material from the base of the bank by direct water scour resulting in the creation of an overhanging bank which may or may not fail later.

[5] The direct removal of erosion-prone material from the bank by wave action. This erosion usually results in the undercutting and eventual failure of the bank.

I8. Model Code of Practice (Instream works)

Compliance with a given Performance Criterion can only be achieved by:

(i) complying with the Acceptable Solution; or
(ii) formulating an alternative solution which complies with the Performance Criterion, or is shown to be at least equivalent to the acceptable solutions; or
(iii) a combination of (i) and (ii).

Unless otherwise indicated, all outcomes listed within the Acceptable Solution must be satisfied in order to comply with the Acceptable Solution.

Attachment A forms part of this Code. The Attachment provides essential information and requirements not otherwise provided within the Code.

If the scheduled works incorporate off-stream construction activities, then the model code of practice provided in Appendix G – *Model code of practice* shall apply.

In the event of a conflict over the desired outcome of a *Performance Criterion* or an *Acceptable Solution*, then the outcome shall be that which best achieves the *objective* of the Code, that being:

> *To protect the environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.*

To achieve this objective a person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm.

In assessing all reasonable and practicable measures, appropriate consideration must be given to:

(i) the nature of the potential harm; and
(ii) the sensitivity of the receiving environment; and
(iii) the current state of technical knowledge for the activity; and
(iv) the likelihood of successful application of the various measures that might be undertaken; and
(v) the financial implications of the various measures relative to the type of activity.

The various recommendations presented in this guideline are an indication of what may be considered *reasonable and practicable* for the construction industry.

This model code of practice does not provide all the information necessary to adequately control soil erosion and sediment runoff in all situations. Users of the Code should always make their own site-specific evaluation, testing and design, and refer to their own advisers and consultants as appropriate.

Specifically, the adoption of this model code of practice will not necessarily guarantee:

(i) compliance with any statutory obligations or licence conditions;
(ii) avoidance of all environmental harm or nuisance.

SITE PLANNING AND DESIGN			
Performance Criteria		**Acceptable Solution**	
P1	Adequate data is obtained to allow appropriate site planning and design.	**A1**	(a) The extent and complexity of data collection is commensurate with the potential environmental risk, and the extent and complexity of the instream disturbance. (b) Adequate soil data is obtained for the site to: (i) identify dispersive soils; (ii) identify potential acid sulfate soils; (iii) assess site revegetation/stabilisation works; (iv) select and design ESC measures.
P2	The design and layout of instream works minimise the risk of environmental harm occurring during the construction phase.	**A2**	(a) Potential high-risk instream activities are identified during site planning. (b) Environmental risk, cost and safety are appropriately considered when determining the construction/maintenance process. (c) The design and layout of the instream works do not cause unnecessary soil disturbance if an alternative design or layout (which reduces the potential environmental harm) is available that achieves the same or equivalent project outcomes at a reasonable cost. (d) Site planning minimises the duration that any and all areas of soil will be exposed to the erosive effects of wind, rain and flowing water, in part through the progressive and prompt stabilisation of disturbed areas. (e) Instream sediment control measures are not employed if there is an appropriate off-stream sediment control process. (f) Development of the Erosion and Sediment Control Plan is an integral part of site planning. (g) Essential ESC control measures are appropriately integrated into the project's design and costing. (h) Adequate space is provided for the installation and maintenance of essential ESC measures. (i) The number of temporary watercourse crossings is minimised.
P3	The programming of instream works minimises the risk of environmental harm occurring during the construction phase.	**A3**	(a) Instream disturbances are programmed to occur during the least erosive and environmentally damaging period of the year. (b) Instream works that require the construction of a weir or cofferdam, or an alteration in stream flow conditions, including flow velocity, bed roughness or flow rate, are not programmed for those periods when essential fish migration is expected to occur.
P4	The design and layout of instream works minimise the risk of post-construction environmental harm.	**A4**	(a) Flow velocities at the inlet and outlet of permanent drainage systems (e.g. stormwater pipes) are controlled to minimise ongoing erosion. (b) To the maximum degree reasonable and practicable, instream works are designed to minimise potential environmental harm during operational works and ongoing maintenance.

EROSION AND SEDIMENT CONTROL PLAN (ESCP)			
Performance Criteria		**Acceptable Solution**	
P5	An Erosion and Sediment Control Plan (ESCP) is prepared prior to site disturbance that provides sufficient information to achieve the required environmental protection.	**A5**	(a) The design standard of drainage, erosion and sediment controls (whether instream or off-stream) comply with the requirements of the relevant regulatory authority, or where such a standard does not exist, are designed in accordance with current best practice. (b) As a minimum, the standard of drainage, erosion and sediment controls are commensurate with the site conditions, (e.g. soil type, flow rate and erosion hazard), type of watercourse, local environmental values, and the type, cost and scope of the works. (c) The level of information and detail supplied in the ESCP is commensurate with the potential environmental risk, and the complexity of the proposed works; and is of sufficient clarity to allow on-site personnel to appropriately implement the plan.
P6	The ESCP is prepared by, or under the supervision of, suitably qualified and experienced personnel.	**A6**	(a) The qualifications and experience of the personnel preparing and/or supervising the preparation of the ESCP is commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance. (b) On sites with a soil disturbance greater than $50m^2$, the ESCP is signed-off by a suitably qualified and experienced professional. (c) On sites with a flow diversion barrier extending over one-third of the channel width, or a temporary structure extending over the full channel width (e.g. watercourse crossing or instream sediment trap) the ESCP is signed-off by an engineer experienced in waterway hydraulics.
P7	The ESCP remains relevant, at all times, to the current site conditions.	**A7**	(a) The ESCP remains both effective and flexible, and is based on anticipated soil, weather, stream flow, and construction conditions (as may vary from time to time). (b) The ESCP is appropriately amended if the implemented works fail to achieve the *objective* of the ESCP, the required performance standard, or the State's environmental protection requirements, or otherwise if there is the risk of serious or material environmental harm.

SITE ESTABLISHMENT			
Performance Criteria		**Acceptable Solution**	
P8	Site personnel are provided with all necessary information prior to site establishment.	**A8**	The Development Approval Conditions, Waterways Permit/Licence, Erosion and Sediment Control Plan, Monitoring and Maintenance Program, Site Rehabilitation Plan, and any other document required for the management of soil erosion and sediment control, are provided to the principal contractor prior to the commencement of land disturbing activities.

P9	Appropriate personnel are engaged to monitor the site prior to commencement of site disturbance.	**A9**	(a) Prior to the commencement of any instream disturbance, appropriately trained and experienced personnel are engaged to undertake regular ESC audits of the site. (b) Prior to commencement of site works, a “chain of command” in relation to the implementation, modification, and maintenance of ESC measures is established.
P10	Site establishment does not cause unnecessary soil disturbance or environmental harm.	**A10**	(a) No land-disturbing activities occur on the site until all appropriate ESC measures have been constructed in accordance with the ESCP and best practice erosion and sediment control. (b) All site office facilities and operational activities are located such that all effluent, including wash-down water, can be totally contained and treated within the site.
P11	Site access is appropriately managed to minimise the risk of environmental harm.	**A11**	(a) All reasonable and practicable measures are taken to ensure stormwater runoff from site access tracks and stabilised entry/exit systems, drains to an appropriate sediment control device. (b) Wherever reasonable and practicable, access tracks, whether temporary or permanent, are located a distance from the top of bank of at least 30 m, or the width of the stream (measured at the top of the bank), whichever is the lesser.

SITE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P12	The work site is managed such that environmental harm is minimised.	**A12**	(a) No land-disturbing activities (instream or off-stream) are undertaken prior to appropriate consideration being given to erosion and sediment control issues. (b) All works subject to an Erosion and Sediment Control Plan (ESCP) are carried out in accordance with the ESCP (as amended from time to time) unless circumstances arise where compliance with the ESCP would increase the potential for environmental harm as assessed by a recognised authority. (c) All ESC measures are installed, operated and maintained in accordance with current best management practice. (d) Land-disturbing activities are undertaken in such a manner that allows all reasonable and practicable measures to be undertaken to: (i) allow stormwater and stream flow to pass through the site in a controlled manner and at non-erosive flow velocities; and (ii) minimise soil erosion resulting from wind, rain and flowing water; and (iii) minimise the duration that disturbed soils are exposed to the erosive forces of wind, rain and flowing water; and (iv) prevent, or at least minimise, environmental harm (including public nuisance and safety issues) resulting from work-related soil

			erosion and sediment runoff. (e) Site spoil is lawfully disposed of in a manner that does not result in ongoing soil erosion or environmental harm.
P13	Those responsible for erosion and sediment control are appropriately trained and equipped.	**A13**	Site managers and/or the nominated responsible ESC personnel achieve and maintain a good working knowledge of the correct installation and operational procedures of all ESC measures used on the site.
P14	Disturbance to ESC measures by on-site personnel is minimised.	**A14**	(a) On-site personnel are appropriately instructed and educated as to the purpose and operation of adopted drainage, erosion and sediment control (ESC) measures, and the need to maintain such measures in proper working order at all times. (b) Unnecessary disturbance to ESC measures by on-site personnel, sub-contractors and construction traffic (including site management and material delivery vehicles) is minimised.
P15	The adopted ESC measures remain relevant at all times to the current site conditions.	**A15**	(a) Performance of the site's ESC measures is monitored in accordance with the site's Monitoring and Maintenance Program. (b) The adopted erosion and sediment control measures are appropriately amended if site conditions significantly change, or are expected to significantly change, from those conditions assumed during development of the ESCP. (c) The adopted erosion and sediment control measures are appropriately amended if the implemented works fail to achieve the "objective" of the ESCP, or the required performance standard, or the State's environmental protection requirements, or unacceptable environmental harm is occurring or is likely to occur.
P16	The work site is appropriately prepared for imminent construction activities and weather conditions.	**A16**	(a) Adequate supplies of drainage, erosion and sediment control, and relevant pollution clean-up materials, are retained on-site during the construction period. (b) Appropriate short-term drainage control measures (e.g. flow diversion around soil disturbances and recently opened trenches) are installed and operational prior to impending storms or increased stream flows.
P17	Land disturbing activities do not cause unnecessary soil disturbance.	**A17**	(a) Land disturbing activities do not cause unnecessary soil disturbance if an alternative construction process (that reduces potential environmental harm) is available that achieves the same or equivalent project outcomes at a reasonable cost. (b) The extent of unnecessary soil disturbance, including disturbances outside the designated work area, is minimised.
P18	Damage to retained or protected vegetation is minimised.	**A18**	(a) Prior to the commencement of land disturbing activities within any given area, all protected vegetation and significant areas of retained vegetation within that area, are appropriately identified to minimise the risk of disturbance to such areas.

			(b) No damage is allowed to occur to roots, trunk or branches of retained vegetation, unless under the direction of an appropriate Vegetation Management Plan.
P19	Adopted work practices minimise the release of pollutants into receiving waters.	**A19**	(a) Emergency and pollution control procedures are commensurate with the site conditions, local environmental values, and the type, cost, scope and complexity of the works. (b) All liquid chemicals, including petroleum products, that could potentially be washed or discharged from the site in association with sediment, are stored and handled on-site in accordance with relevant standards such as AS1940. (c) Adequate supplies of erosion control, sediment control, and pollution clean-up materials are retained on-site during the construction period. (d) Cement-laden runoff, concrete waste, and chemical products (including petroleum and oil-based products), are managed on-site in accordance with current best management practice. (e) All equipment is washed down (cleaned) well away from the water's edge, and in a manner that prevents sediment-laden water entering the waters. (f) All non water-soluble pollutants washed or blown onto waters are collected and secured as soon as practicable. (g) All waste receptors are sealed and/or covered outside working hours to prevent the entry of water and vermin, or wind disturbance of the contained material.
P20	Adopted work practices minimise the release of pollutants into tidal waters.	**A20**	(a) No erodible material is stockpiled within 40m from the high tide mark. (b) Sediment deposition within the voids between natural and introduced rock located within the tidal zone is minimised. (c) All materials being transported by boats or barges are adequately secured during transportation. (d) Drip pans are placed under all vehicles and motorised equipment placed on docks, barges, or other structures that extend over water bodies, if the vehicle or equipment is expected to be idle for more than 1 hour. (e) All barges are fitted with watertight curbs or toe boards to contain spills and prevent materials, tools, and debris from leaving the barge. (f) All appropriate measures are deployed to provide secondary containment for any spills while materials and/or equipment are being transferred on and off barges to (e.g. floating sediment curtains).

P21	Environmental harm, safety issues, and nuisance or damage to public and private property resulting from off-site sediment deposits, material spills, and/or the adopted ESC measures is minimised.	**A21**	(a) Sediment and other material originating from the work area, or as a result of the transportation of materials to or from the work area, that collect on sealed roads, or within gutters, drains or drainage channels outside the immediate work area, is removed: (i) immediately if rain is occurring or imminent; or (ii) immediately if considered a safety hazard; or (iii) if items (i) or (ii) do not apply, as soon as practicable, but before completion of the day's work. (b) The adopted ESC measures do not adversely affect drainage or flooding conditions within neighbouring properties.
P22	Potential safety risks to site workers and the public as a result of ESC measures are minimised.	**A22**	All stream flow diversion and ESC measures are installed and operated in a manner that does not cause a safety risk to the public or site personnel.
P23	Potential harm to wildlife as a result of ESC measures is minimised.	**A23**	(a) Disturbance to wildlife habitats is limited to the minimum necessary to complete the approved works. (b) Synthetic (plastic) reinforced fabrics are not placed within, or adjacent to, bushland areas, riparian zones and watercourses if such materials are likely to cause harm to wildlife or wildlife habitats. (c) The design of temporary instream structures does not adversely impact on terrestrial and aquatic passage along the waterway. (d) To the maximum degree reasonable and practicable, instream disturbances are programmed to occur during periods of least impact to fish migration. (e) Sediment traps, flow diversion systems and isolation barriers allow appropriate egress of wildlife where such wildlife could enter such areas. (f) Site rehabilitation procedures and outcomes are compatible with site conditions and local environmental values (including local wildlife).

SITE DISTURBANCE			
Performance Criteria		**Acceptable Solution**	
P24	Potential environmental harm resulting from land clearing is minimised.	**A24**	(a) All land clearing is conducted in accordance with State and local government Vegetation Protection and/or Preservation requirements and/or policies. (b) No instream disturbances are undertaken prior to development of a Vegetation Management Plan. (c) No instream soil disturbance occurs until the principal instream works are ready to commence. (d) Controls placed on the extent and duration of soil disturbance are commensurate with the potential erosion risk and/or erosion hazard.

			(e) To the maximum degree reasonable and practicable, disturbance to deep-rooted vegetation on slopes susceptible to mass movement is minimised, if not totally avoided. (f) Compliance with Performance Criterion P18.
P25	Disturbance to natural watercourses is minimised.	**A25**	(a) Disturbance to natural watercourses (including bed and bank vegetation) and their associated riparian zones is limited to the minimum necessary to complete the approved works. (b) The number, location, type and size of temporary watercourse crossing are such that the overall adverse impact on the environment is minimised. (c) All temporary watercourse crossings, including their approach roads, employ appropriate drainage, erosion and sediment controls to minimise sediment inflow into the watercourse.
P26	Disturbance to tidal and intertidal areas including any associated riparian zones is minimised.	**A26**	(a) Disturbance to aquatic vegetation, particularly seagrasses and mangroves, is minimised. (b) Vehicle/boat damage to seawalls (e.g. due to wave and wash conditions) is minimised.

SOIL AND STOCKPILE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P27	Maximum benefit is obtained from existing topsoil.	**A27**	(a) The topsoil is managed (i.e. stripped, treated, stockpiled and reused) in accordance with the recommendations of an approved Vegetation Management Plan or similar. OR (b) Topsoil is stripped, stockpiled, placed, and where necessary treated, in accordance with current best practice.
P28	Environmental harm caused by the temporary stockpiling of erodible material is minimised.	**A28**	Stockpiles of erodible material are: (i) appropriately protected from wind, rain and surface flows in accordance with current best practice; and (ii) located at least 2 m from hazardous areas, retained vegetation; and (iii) located up-slope of an appropriate sediment control system.
P29	Exposed dispersive soils are managed such that the risk of ongoing soil erosion is minimised.	**A29**	Construction details for drainage systems and bank stabilisation works within dispersive soil areas clearly demonstrate how these soils will be managed to prevent future erosion problems.
P30	Exposed potential acid sulfate soils are appropriately managed.	**A30**	(a) If acid sulfate soils conditions exist on site, then appropriate warnings are placed on the ESCP. (b) All exposed actual or potential acid sulfate soils are managed in accordance with current best practice. (c) On-site personnel involved in the disturbance of actual or potential acid sulfate soils are appropriately trained and/or supervised.

MANAGEMENT OF STREAM FLOW			
Performance Criteria		**Acceptable Solution**	
P31	Temporary drainage control measures are designed, constructed and maintained to an appropriate standard.	**A31**	(a) The standard of stream flow control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, flow controls are designed in accordance with current best practice. (b) The adopted stream flow control measures remain relevant, at all times, to the current and imminent site conditions. (c) Instream flow diversion structures are structurally sound during a 1 in 2 year ARI channel flow. (d) Wherever reasonable and practicable, isolation barriers do not isolate more than 30% of the channel width at any given time, otherwise not more than 50%, while channel flows are occurring.

DRAINAGE CONTROL			
Performance Criteria		**Acceptable Solution**	
P32	Temporary drainage control measures are designed, constructed and maintained to an appropriate standard.	**A32**	(a) The standard of drainage control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, drainage controls are designed in accordance with current best practice. (b) The adopted drainage control measures remain relevant, at all times, to the current and imminent site conditions.
P33	Stormwater movement through the site is appropriately managed to minimise soil erosion.	**A33**	(a) If the overbank drainage area up-slope of a soil disturbance exceeds 1500 m^2, and the average monthly rainfall exceeds 45 mm, all stormwater discharged from this area (up to the design storm) is diverted around or through the soil disturbance in a manner that minimises soil erosion. (b) Appropriate drainage controls are installed above an exposed stream bank to minimise soil erosion on the bank. (c) Flow velocities within flow diversion channels and at the entrance and exit of all drainage structures (including *Chutes*, and *Slope Drains*) are controlled in such a manner that prevents soil erosion during all discharges up to the relevant design discharge.
P34	Stormwater movement through the site is appropriately managed to minimise environmental harm.	**A34**	(a) Overbank stormwater runoff passing around or through the work site does not cause erosion to the banks of water bodies. (b) All reasonable and practicable measures are taken to ensure stormwater runoff entering an area of soil disturbance is diverted around or through that area in a manner that minimises soil erosion and contamination of that water for all discharges up to the specified design discharge.

			(c) Adequate drainage controls (e.g. cross drainage systems and/or longitudinal drainage) are applied to access tracks to minimise erosion on, and sediment runoff from, such areas.

EROSION CONTROL			
Performance Criteria		**Acceptable Solution**	
P35	Erosion control measures are designed, installed and maintained to an appropriate standard.	**A35**	(a) The standard of erosion control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, erosion controls are designed in accordance with current best practice. (b) As a minimum, the type and degree of erosion control are commensurate with the expected site conditions, soil type, stream flow, potential environmental risk, and the type, cost and scope of the works. (c) The adopted erosion control measures remain relevant, at all times, to the current and imminent site conditions.
P36	The control of soil erosion is given appropriate priority.	**A36**	(a) Wherever reasonable and practicable, priority is given to the prevention, or at least minimisation, of soil erosion, rather than allowing soil erosion to occur and trying to trap the resulting sediment. (b) The existence of best practice sediment control measures within a given sub-catchment does not diminish the need for the application of current best-practice erosion control measures.
P37	Soil erosion is minimised.	**A37**	(a) Existing ground covers are protected from damage and retained as long as practicable. (b) Site activities are carried out in a manner that minimises the duration that any and all disturbed soil surfaces are exposed to the erosive forces of wind, rain and flowing water. (c) All temporary erosion control measures are appropriately anchored to the soil as appropriate for the expected flow conditions. (d) Mechanical equipment does not enter the channel if alternative equipment or construction procedures are available that would allow the works to be conducted from an overbank location.
P38	Soil erosion resulting from stream flow is minimised.	**A38**	(a) All reasonable and practicable steps are taken to apply best practice erosion control measures to completed channel works, or otherwise stabilise such works, prior to an anticipated increase in stream flow. (b) Bed and bank stabilisation and revegetation methods are appropriate for the expected stream flow conditions such that ongoing soil erosion is minimised. (c) Dispersive soils are either treated, or covered with a layer of non-dispersible soil (200 mm minimum) before being covered with vegetation, rock, mulch, or erosion control blankets.

SEDIMENT CONTROL			
Performance Criteria		**Acceptable Solution**	
P39	Sediment control measures are designed, installed, operated and maintained to an appropriate standard.	**A39**	(a) The standard of sediment control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, sediment controls are designed in accordance with current best practice. (b) As a minimum, the type and degree of sediment controls are commensurate with the expected site conditions, soil type, stream flow, potential environmental risk, and the type, cost and scope of the works. (c) Instream sediment control measures are designed for the expected base flow (i.e. stream flow not affected by flood flows or storm runoff). (d) The adopted sediment control measures remain relevant at all times to the current and imminent site conditions.
P40	Sediment contamination of instream waters is minimised.	**A40**	(a) All reasonable and practicable measures are taken to prevent, or at least minimise, the release of sediment from overbank areas into waters. (b) Wherever reasonable and practicable, instream disturbances are managed in accordance with the following hierarchy: (i) minimise, if not totally avoid, direct contamination of stream flows (e.g. through the use of flow diversion systems and the appropriate timing of instream works); (ii) treatment of sediment-laden water within off-stream sediment traps; (iii) treatment of sediment-laden water within instream sediment traps. (c) A suitable off-stream sediment trap is placed down-slope of any off-stream soil disturbance prior to the disturbance occurring. (d) Appropriate stream flow and/or sediment controls are installed and made operational before any instream soil disturbance occurs.
P41	Sediment displaced off site by vehicular traffic is minimised.	**A41**	(a) Number of site entry/exit points is limited to the minimum practical number. (b) Site entry/exit points are appropriately designed and stabilised to minimise sediment being washed off the site or into adjacent waters. (c) Sediment-laden stormwater runoff from access tracks and stabilised entry/exit systems drains to an appropriate sediment control device.
P42	Sediment-related environmental harm resulting from de-watering activities is minimised.	**A42**	(a) Flow diversion barriers, or other appropriate systems, are used to minimise the quantity of watering entering excavations and trenches. (b) As a minimum, sediment control measures implemented for the control of sediment-laden discharge from de-watering activities are designed to satisfy current best practice.

SITE STABILISATION AND REHABILITATION			
Performance Criteria		**Acceptable Solution**	
P43	Site rehabilitation, including site revegetation, is designed, installed and maintained to an appropriate standard.	**A43**	(a) A Site Stabilisation Plan or similar is prepared and approved by the relevant regulatory authority prior to site establishment. (b) The standard of site rehabilitation complies with the requirements of the relevant regulatory authority or, where such a standard does not exist, complies with current best practice. (c) As a minimum, the type and degree of site rehabilitation is commensurate with the expected site conditions, soil type, stream flow, potential environmental risk, and the type, cost and scope of the works.
P44	Site rehabilitation methods and procedures minimise the risk of environmental harm.	**A44**	(a) Site revegetation (excluding temporary revegetation conducted for purposes of erosion control) is conducted in accordance with a Site Stabilisation Plan or similar, where such a plan exists. (b) Disturbed soil surfaces are appropriately stabilised to minimise the risk of short-term soil erosion. (c) All temporary ESC measures are removed and the land rehabilitated as soon as practicable after their use is no longer needed.
P45	Site rehabilitation methods, procedures and outcomes are compatible with site conditions and local environmental values.	**A45**	(a) The qualifications and experience of the personnel preparing and/or supervising the preparation of any Site Stabilisation Plan, Vegetation Management Plan, or similar, is commensurate with the potential environmental risk, and the extent and complexity of the works. (b) Plant selection and landscape design are compatible with identified environmental values.

SITE INSPECTION AND MONITORING			
Performance Criteria		**Acceptable Solution**	
P46	A Monitoring Program is prepared by, or under the supervision of, suitably qualified and experienced personnel.	**A46**	(a) A Water Quality Monitoring Program is prepared and approved by the relevant regulatory authority prior to site establishment. (b) The qualifications and experience of the personnel preparing and/or supervising the preparation of the Monitoring and Maintenance Program is commensurate with the potential environmental risk, and the extent and complexity of the works.
P47	The performance of the site's drainage, erosion and sediment control measures is regularly monitored.	**A47**	(a) The extent and complexity of site monitoring (including water quality monitoring) is commensurate with the potential environmental risk, and the extent and complexity of the works. (b) A record is maintained of the site's compliance and non-compliance with erosion and sediment control approval requirements. (c) All site monitoring data including environmental incidents, rainfall records, dates of water quality testing, testing results, and records of controlled water releases for the site, are kept in a register.
P48	The site's stream flow, drainage, erosion and sediment control measures remain relevant at all times to the current site conditions.	**A48**	All stream flow and ESC measures are inspected by site personnel: (i) at least daily (when work is occurring on-site); (ii) at least weekly (when work is not occurring on-site); (iii) within 24 hours of expected rainfall; and (iv) within 18 hours of a rainfall event of sufficient intensity and duration to cause runoff on the site.

SITE MAINTENANCE			
Performance Criteria		**Acceptable Solution**	
P49	All ESC measures are maintained in proper working order at all times during their required operational life.	**A49**	(a) All ESC measures are maintained in proper working order for the duration of the period in which their operation is required in order to satisfy the required treatment standard, and/or the objective of the ESCP. (b) All sediment control measures are maintained in accordance with the requirements of the relevant regulatory authority, or where such a standard does not exist, in accordance with current best practice. (c) As a minimum, the maintenance of all ESC measures is commensurate with the expected site conditions, and potential environmental risk.
P50	The maintenance of ESC measures does not cause environmental harm.	**A50**	All materials removed from ESC devices during maintenance or decommissioning, whether solid or liquid, is lawfully disposed of in a manner that does not cause ongoing soil erosion or environmental harm.

Attachment A (Instream works code of practice)

SITE PLANNING AND DESIGN

The *intent* of the Site Planning and Design section is to:

- Enable erosion and sediment control issues to appropriately influence the planning and design of instream works for the purpose of minimising their overall adverse environmental impact.
- Enable planners and designers to recognise that along with consideration of the operational phase of a development, appropriate consideration must be given to how something is to be constructed and maintained, and the potential adverse impacts of the construction and maintenance phases.
- Take all reasonable and practicable measures to actively avoid foreseeable soil erosion problems and associated environmental hazards during the construction phase.

The term "maintenance phase" refers to such activities as the de-silting of instream structures such culverts, stormwater pipes, and permanent instream sediment traps.

Acceptable Solution A1(a)
Data collection may include: soil testing, identification of potential site constraints, and development of a Conceptual Erosion and Sediment Control Plan (where such data and/or plans are considered reasonably necessary to enable appropriate site planning and design). Appropriate site planning and design refers to the aim of minimising the potential environmental harm (both during the construction and operational phases) of the instream works. The extent and complexity of data collection is discussed further in Chapter 3 – *Site planning*.

The "potential environmental risk" relates to the potential of a land-disturbing activity to cause harm, whether material, serious, reversible or irreversible, to an environmental value, including nuisance to a neighbouring property or person. The potential environmental risk is related, in part, to the assessed Erosion Hazard (refer to Appendix F – *Erosion hazard assessment*).

Acceptable Solution A1(b)
Data collection necessary to assist the design of site revegetation is outlined in Sections C3 and C9 of Appendix C – *Soils and revegetation*.

Acceptable Solution A2(a)
Construction activities that are deemed to represent a high to extreme erosion hazard include:

- Any disturbance of high to extreme hazard areas, or a problematic soil that could result in unmanageable soil erosion and/or environmental harm.
- Any construction or building activity, or procedure, that could potentially cause "serious" environmental harm.
- Any soil disturbance that could cause the transformation of significant quantities of potential acid sulfate soils (PASS) into actual acid sulfate soils (AASS), such as to cause "material" or "serious" environmental harm.

Acceptable Solution A2(f)
Ideally, Erosion and Sediment Control Plans (ESCPs) should be developed in close association with construction planning because the needs and limitations of the construction process represent an important component of the ESCP. In theory, a construction process cannot be finalised without reference to an ESCP, and an ESCP cannot be finalised without knowledge of the construction process.

Acceptable Solution A2(g)
Essential ESC control measures includes any instream sediment control and flow diversion systems, and bank and overbank drainage, erosion or sediment control measures.

Acceptable Solution A2(h)
The most critical issue is ensuring sufficient space is available to construct and maintain all *Sediment Basins* and flow diversion systems.

Acceptable Solution A2(i)
"Temporary" watercourse crossings refer to those crossings constructed for use only during the construction phase.

Acceptable Solution A3(a)
Minimising the potential environmental harm can be achieved, in part, by scheduling major land disturbances, and disturbances to high and extreme erosion risk areas, for the least erosive periods of the year.

The least erosive period of the year is usually the period of lowest stream flow. The least environmentally damaging period of the year usually relates to periods of no, or minimum, fish migration. Refer to State fisheries authorities for advice.

Acceptable Solution A4(a)
Ongoing erosion problems can result from any of the following:
- changes to the volume, duration, frequency or rate of stormwater runoff;
- excessive (i.e. erosive) flow velocities;
- inappropriate distribution of flow velocities throughout the depth and width of flow discharged from a stormwater drain into a receiving water;
- inappropriate direction of flow discharged from a stormwater drain into a receiving water.

Acceptable Solution A4(b)
"Ongoing maintenance" refers to such activities as the de-silting of instream structures such culverts, stormwater pipes, and permanent instream sediment traps.

EROSION AND SEDIMENT CONTROL PLAN (ESCP)

The *intent* of this section is to ensure Erosion and Sediment Control Plans (ESCPs):
- are appropriate for the site conditions, which may vary from time to time;
- are prepared by, or under the supervision of, suitable personnel;
- are able to achieve the required design standard and environmental protection.

Acceptable Solution A5(a)
Such a clause shall not reduce the responsibility of applying and maintaining, at all times, all necessary sediment control measures in accordance with the sediment control standard.

Acceptable Solution A5(b)
Refer to A1(a) for discussion on "environmental risk".
It is recognised that the degree of erosion and sediment control is related to the type, cost and scope of works in addition to the environmental risk. This association is acknowledged within the terms of current best practice erosion and sediment control as defined within this document (2008 conditions).

Acceptable Solution A5(c)
On very minor works, such as regular council maintenance activities, or the installation of minor services, the ESCP may be represented by standard drawings prepared by the principle company/organisation as part of an in-house Code of Practice. The key *intent* is to ensure that appropriate consideration is given to erosion and sediment control requirements **before** works commence.

For instream works with a soil disturbance greater than 50 m^2, the Erosion and Sediment Control Plan (including supporting documentation and construction specifications) must include:
(i) North point and plan scale.
(ii) Site and easement boundaries and adjoining roadways.
(iii) Construction access points.
(iv) Site office, car park and location of stockpiles.
(v) Proposed construction activities and limits of disturbance.
(vi) Retained vegetation including protected trees.
(vii) General soil information and location of problem soils.
(viii) Location of critical environmental values (where appropriate).
(ix) Existing site contours (unless the provision of these contours adversely impacts the clarity of the ESCP).

(x) Final site contours including locations of cut and fill.
(xi) General layout and staging of proposed works.
(xii) Location of all drainage, erosion and sediment control measures.
(xiii) Full design and construction details (e.g. cross-sections, minimum channel grades, channel linings,) for all drainage and sediment control devices, including *Flow Diversion Barriers* and instream sediment traps.
(xiv) Construction specifications for adopted ESC measures (as appropriate).
(xv) Site revegetation requirements (if not contained within separate plans).
(xvi) Site Monitoring and Maintenance Program, including the location of proposed water quality monitoring stations.
(xvii) Technical notes relating to:
- site preparation and land clearing;
- extent, timing and application of erosion control measures;
- temporary ESC measures installed at end of working day;
- temporary ESC measure in case of impending storms or elevated stream flows, or emergency situations;
- installation sequence for ESC measures;
- application rates (or at least the minimum application rates) for mulching and revegetation measures;
- legend of standard symbols used within the plans.

(xviii) Calculation sheets for the sizing of ESC measures.
(xix) A completed Erosion and Sediment Control Plan checklist such as presented in *(insert publication).*
(xx) Any other relevant information the regulatory authority may require to properly assess the ESCP.

The ESCP must clearly state that no land-disturbing activities shall occur on the site until all associated perimeter ESC measures, including flow diversion barriers, sediment traps and temporary drainage controls, have been constructed in accordance with the ESCP and current best practice erosion and sediment control procedures.

Acceptable Solution A6(a) & (b)
A suitably qualified and experienced professional is defined as a person with:
(i) training and/or qualifications in erosion and sediment control that are recognised by the regulatory authority; and
(ii) professional affiliations with an engineering, environmental engineering, soil science, and/or scientific organisation (e.g. the International Erosion Control Association; Engineers Australia; Environment Institute of Australia and New Zealand; or the Australian Society of Soil Science Inc.) and
(iii) at least 2 years experience in the management of erosion and sediment control that can be verified by an independent third party.

ESCPs for high-risk sites should be reviewed by a suitably qualified and experienced third party reviewer prior to its implementation.

The assessment and categorisation of high-risk sites may be defined by the relevant regulatory authority; otherwise, refer to the discussion in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

Acceptable Solution A6(c)
The *intent* is to ensure the adoption of appropriate design procedures for temporary instream structures, and to minimise the risk of avoidable harm to the waterway.

Acceptable Solution A7(a)
The timing and degree of ESC specified in the Erosion and Sediment Control Plan(s) needs to be appropriate for the given soil properties, expected weather conditions, and susceptibility of the receiving waters to environmental harm resulting from sediment-laden runoff. Current (2008) best practice design standard of the drainage, erosion and sediment control measures are outlined in Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A7(b)
Additional and/or alternative erosion and sediment control measures must be implemented, and a revised Erosion and Sediment Control Plan (ESCP) must be prepared and submitted to relevant regulatory authority for approval (where required) in the event that:

(i) site conditions significantly change from those previously anticipated; or
(ii) there is a high probability that serious or material environmental harm might occur as a result of sediment leaving the site; or
(iii) the implemented works fail to achieve the adopted ESC standard, or the State's environmental protection requirements; or
(iv) site inspections indicate that the implemented works are failing to achieve the "objective" of this ESCP.

SITE ESTABLISHMENT

The *intent* of this section is to ensure that during site establishment:

- on-site personnel are provided with all necessary information to fully comply with all legal requirements, minimise environmental harm, and achieve the objective of the ESCP; and
- land disturbing activities proceed in a manner consistent with the objective of the ESCP.

Acceptable Solution A8
Supply of such material is relevant only to that material that exists, or is required to exist.

Acceptable Solution A9(a)
On low-risk site, ESC audits (including site inspections and water quality monitoring) may be performed by site personnel; however, as the risk of environmental harm increases, the need for third-party site inspections and water quality monitoring increases.

In reference to instream works, "low-risk sites" would include works conducted within dry-bed channels during periods when stream flow is highly unlikely.

Personnel undertaking ESC audits of a site must, collectively, have the following capabilities:

(i) an understanding of the local environmental values that could potentially be affected by the proposed works; and
(ii) a good working knowledge of the site's Erosion and Sediment Control (ESC) issues, and potential environmental impacts, that is commensurate with the complexity of the site and the degree of environmental risk; and
(iii) a good working knowledge of current best practice ESC measures for the given site conditions and type of works; and
(iv) ability to appropriately monitor, interpret, and report on the site's ESC performance, including the ability to recognise poor performance and potential ESC problems; and
(v) ability to provide advice and guidance on appropriate measures and procedures to maintain the site at all times in a condition representative of current best practice, and that is reasonably likely to achieve the required ESC standard; and
(vi) a good working knowledge of the correct installation, operational and maintenance procedures for the full range of ESC measures used on the site.

Acceptable Solution A9(b)
The construction industry's method of dealing with workplace safety issues is a good model for the development of an appropriate "chain of command" for the protection of environmental values. The aim is to produce a fair, reasonable and practicable approach based on environmental risk.

As in workplace safety, the responsibility of environmental protection, and therefore erosion and sediment control, rests with **all** site personnel, whether or not the work site is the normal place of work of any and all personnel. Establishing a "chain of command" does **not** diminish the responsibility of each and every person to take all reasonable and practicable measures to minimise environmental harm resulting from their actions as per their "environmental duty of care".

Acceptable Solution A10(a)
The exception to this clause is land disturbance necessary to provide access and allow the installation the initial ESC measures.

In general, initial land-disturbing activities should be limited to the establishment of the site compound, site entry/exit points, temporary drainage controls (including drain stabilisation measures), haul road(s), perimeter sediment controls, installation of flow diversion barriers, and any sediment basins/traps required for the first stage of works.

Acceptable Solution A10(b)
"Operational activities" include such things as material stockpiles, storage areas, or concrete waste receptors.

Acceptable Solution A11(a)
It is recognised that it may not be practicable for **all** stormwater runoff from **all** areas of site entry/exit paths to be directed to a sediment trap; however, such areas must be limited to the minimum practicable.

SITE MANAGEMENT

Acceptable Solution A12(a)
Where appropriate, an Erosion and Sediment Control Plan is prepared (in accordance with Section G3.3), and where necessary approved by a relevant regulatory authority, prior to commencing any land-disturbing activities.

Acceptable Solution A12(b)
The potential for environmental harm must be assessed by a recognised expert or authority.

Acceptable Solution A12(c)
Refer to A1(a) for a discussion on "potential environmental risk".

Acceptable Solution A12(d)
Applies to all land-disturbing activities, whether planned or unplanned, and especially to any works that are required to be conducted without an associated Erosion and Sediment Control Plan.

Acceptable Solution A12(d)(iv)
Includes ensuring that the value and use of land/properties adjacent to the development (including roads) are not diminished as a result of work-related soil erosion and sediment runoff.

Acceptable Solution A13
"Responsible ESC personnel" are those persons employed or contracted by the landowner and/or developer as the principal officer(s) responsible for ensuring appropriate application of the planned ESC measures and for the provision of advice in response to unplanned ESC issues.

Acceptable Solution A14(a)
Recommended training requirements are discussed in Section 6.19 of Chapter 6 – *Site management*.

Acceptable Solution A14(b)
Necessary disturbance to ESC measures would include the short-term removal of an ESC measure to allow the installation of services under the ESC measure, or to allow vehicular or material access.

Performance Criterion P15
Performance Criteria P15 and P16 require work sites to be appropriately prepared for both current and imminent site conditions. Compliance with these criteria requires ESCPs to be living documents that remain both effective and flexible, and thus are able to appropriately adapt to changing site conditions.

Acceptable Solution A15(b)
A significant change in site conditions includes:
- unseasonable weather conditions;
- unseasonable stream flow;
- exposure of problematic soil conditions not previously anticipated;
- significant change in construction methodology, staging or programming of earthworks and/or site stabilisation activities;
- significant change in the development design or layout;
- an unprogrammed site shutdown.

Performance Criterion P16
Performance Criteria P15 and P16 require work sites to be appropriately prepared for both current and imminent site conditions. Compliance with these criteria requires ESCPs to be living documents that remain both effective and flexible, and thus are able to appropriately adapt to changing site conditions.

Acceptable Solution A18(a)
Appropriate identification depends on the level of risk of damage to protected or retained vegetation. Appropriate identification does not necessarily mean markers, signs or fencing; however, such measures may be appropriate in some areas.

Acceptable Solution A19(b)
AS1940 *The storage and handling of flammable and combustible liquids* (as amended from time to time).

In addition to the above:
- Impervious bunds must be constructed around all storage areas containing more than 1m^3 of petroleum and oil-based products such that the enclosed volume is large enough to contain 110% of the volume held in the largest, individual storage tank.
- On-site personnel involved in the handling and storage of flammable and combustible liquids, including all liquid chemicals, must be appropriately trained and/or supervised, as required in order to allow such personnel to appropriately preform such activities.

Acceptable Solution A19(d)
Current (2008) best practice requires that all reasonable and practicable measures are taken to:
(i) prevent the release of cement-laden runoff, concrete waste, and chemical products (including petroleum and oil-based products), into an internal or external water body, completed internal drainage systems, or any external drainage system, excluding those on-site drains and water bodies specifically designed to contain and/or treat such material;
(ii) ensure all solid and liquid waste from concrete production, concreting equipment (including delivery and placement vehicles), is fully contained within the property;
(iii) ensure cement residue from work activities is:
  - retained on a pervious surface (e.g. a grassed or open soil area, or excavated trench); or
  - filtered through a fine-grained, porous, earth embankment; or
  - collected and disposed of in a manner that minimise ongoing environmental harm.

Acceptable Solution A19(e)
Current (2008) best practice requires that wherever practicable, the washing of tools and painting equipment is carried out in a manner that:
(i) complies with current State guidelines, policies and legislation; and
(ii) fully contains any contaminated waste water for later treatment and/or lawful disposal; or
(iii) appropriately filters (e.g. through a fine-grained, porous earth embankment) any contaminated liquid prior to its release from the immediate work area; or
(iv) appropriately infiltrates all contaminated liquid matter into an area of porous grass or open soil.

Acceptable Solution A21(a)
"Sediment and other material" includes clay, silt, sand, gravel, soil, mud, cement and fine-ceramic waste.

Acceptable Solution A21(b)
Sealed surfaces include sealed roads and car parks.

In circumstances where the washing/flushing of sealed surfaces is required, all reasonable and practicable sediment control measures must be employed to prevent, or at least minimise, the release of sediment into receiving waters. Only those measures that will not cause safety issues or adverse property flooding to third parties shall be employed.

Acceptable Solution A22
"Appropriate consideration" includes taking all reasonable and practicable measures to minimise safety risks. As a general rule, safety issues take a higher priority than ESC issues; however, this does **not** mean that the existence of potential safety issues diminishes the ESC standard required of a work site.

Public safety risks include potential damage to public vehicles resulting from the use of inappropriate kerb-inlet sediment traps on public roads. The potential safety risk of a proposed sediment trap to site workers and the public must be given appropriate consideration **before** its installation, especially those sediment traps located within publicly accessible areas.

Sediment and sediment-laden runoff must not settle or collect on public roadways where such material could result in a traffic or safety hazard.

Performance Criterion P23
The protection of wildlife does not diminish the required ESC standard, or the need to take all reasonable and practicable measures to minimise environmental harm resulting from soil erosion and displaced sediment.

Acceptable Solution A23(c)
Refer to Witheridge (2002) for guidelines on the design of fish-friendly watercourse crossings.

Acceptable Solution A23(b)
Synthetic reinforced fabrics include "plastic" reinforced *Erosion Control Blankets*, *Mats* and *Meshes*.

SITE DISTURBANCE

Acceptable Solution A24(d)
Operational restrictions on the extent and duration of land disturbance, including land clearing only apply when such land disturbance is at risk, or potentially at risk, of erosion by wind, rain or flowing water.

The potential erosion risk is related (in part) to the potential rainfall erosivity as defined in Section 4.4 of Chapter 4 – *Design standards and technique selection*. The potential erosion hazard may be identified through the application of an appropriate Erosion Hazard Assessment scheme such as those discussed in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

Acceptable Solution A24(e)
The full impact of the removal of deep-rooted vegetation from steep slopes may not be evident for 5 to 10 years, or until such time as the plant root system begins to fail (assuming that the root system remains within the soil profile after removal of the upper portion of the plant). Planners and designers must appreciate that plants provide many essential roles besides the provision of "scenery".

Periods of high and extreme erosion potential refers to the variation in the erosion hazard throughout a calender year based on variations in the rainfall erosivity as described in Appendix E – *Soil loss estimation*. Periods of high to extreme erosion potential include:
- periods of high to extreme erosion risk as defined in Section 4.4 of Chapter 4 – *Design standards and technique selection*; and
- periods of strong winds sufficient to cause significant dust problems.

Acceptable Solution A25(a)
The extent of unnecessary soil disturbance, including disturbances outside the designated work area, must be minimised at all times.

Wherever reasonable and practicable, land clearing must be limited to the current stage of works. Current (2008) best practice recommends that land clearing not extend beyond the parameters indicated in Table I11.

Table I11 does not imply that land clearing should occur to the full extent of these limits, rather than all reasonable and practicable measures are taken to limit land clearing to no more than these limits. In all cases, land clearing must be limited to the minimum necessary to complete the approved works.

SOIL AND STOCKPILE MANAGEMENT

Performance Criterion A27
Applies to all areas of proposed soil disturbance, including footprint of proposed stockpiles prior to placement of soil within such areas. Does not include any material best described as subsoil.

Acceptable Solution A27(b)
Current (2008) best practice recommendations for the management of topsoil are presented in Table 6.2 in Chapter 6 – *Site management*.

Acceptable Solution A28(ii)
The diversion of overbank, stormwater is recommended during those periods when rainfall is possible and the overbank catchment area exceeds.

Current (2008) best practice recommendations for the protection of sand and soil stockpiles from the erosive effects of wind and rainfall are presented in Table 4.6.1 in Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A28(iv)
Current (2008) best practice recommendations for the selection of an appropriate sediment control system is presented in Table 4.6.2 in Chapter 4 – *Design standards and technique selection*.

Short-term stockpiles of erodible material located outside of an appropriate sediment control zone must be covered if it is raining, or if rain is imminent or possible.

Acceptable Solution A29
Dispersive soils normally need to be stabilised (i.e. treated with gypsum or lime depending on desired pH adjustment) and/or buried under a layer of non-dispersive soil prior to placement of channel lining (whether rock, gabion, synthetic material, or concrete), or initiation of revegetation.

Refer to Section 6.12 in Chapter 6 – *Site management*, or Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of dispersive soils.

Acceptable Solution A30
Refer to Section 6.12 in Chapter 6 – *Site management*, or Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of acid sulfate soils.

Within Queensland, guidelines on the management of acid sulfate soils is provided in State Planning Policy 2/02 *Guideline: Planning and Managing Development involving Acid Sulfate Soils*, and Dear, et al. 2002, *Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines.* Department of Natural Resources and Mines, Indooroopilly, Queensland.

DRAINAGE CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure of soil to the erosive forces of flowing water. It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining drainage control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A32(a)
Current (2008) best practice construction phase drainage standards are presented in Table 4.3.1 of Chapter 4 – *Design standards and technique selection*. Drainage systems must be designed to have a minimum non-erosive hydraulic capacity (excluding 150 mm freeboard) in accordance with this table.

Acceptable Solution A32(b)
Construction Drainage Plans are normally prepared for sites with a soil disturbance exceeding 50 m^2. Further discussion on the requirements of *Construction Drainage Plans* is presented in Acceptable Solution A11(d).

Acceptable Solution A33(b)
Sandbag flow diversion banks, catch drains, and flow diversion banks are examples of appropriate drainage systems that can be used to divert stormwater around excavations and other soil disturbances.

EROSION CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure of soil, sand, silt, mud or cement to the erosive forces of wind, rain and flowing water. It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining erosion control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A35(a)
Current (2008) best practice (construction phase) land clearing and site rehabilitation standards are presented in Table I11. Unless otherwise stated by the relevant regulatory authority, the potential erosion risk is based on the rating outlined in Tables I9 and I10.

In addition, all temporary earth banks, flow diversion systems, and off-stream *Sediment Basin* embankments should be machine-compacted, seeded and mulched within ten (10) days of formation for the purpose of establishing a vegetative cover, unless otherwise stated within an approved Site Stabilisation Plan, Revegetation Plan, or Vegetation Management Plan.

Acceptable Solution A35(b)
Erosion control measures primarily focus on the control of fine sediments such as clay and silt-sized particles. Thus, with respect to the value of “erosion control measures”, potential environmental harm is strongly related to the susceptibility of the receiving waters to environmental harm resulting from turbid runoff (i.e. suspended fine sediments).

Erosion control measures need to be appropriate for the land slope and the expected wind, rain and hydraulic conditions. Application of effective drainage control measures should help to control hydraulic conditions such that damage to adopted erosion control measures during regular rainfall events is minimised.

Acceptable Solution A35(c)
This clause requires compliance with Performance Criteria P15 and P16.

Acceptable Solution A36(a)
Such a clause shall not reduce the responsibility to apply and maintain, at all times, all necessary sediment control measures.

The minimisation of soil erosion requires the application of effective drainage and erosion control throughout each and all sub-catchments.

Acceptable Solution A37(b)
Compliance with this clause requires:

- soil disturbance within any sub-catchment to be delayed as long as possible, and ideally, not until the principal on-site activities within that area are ready to commence;
- soil disturbance at any given time to be limited to the minimum necessary to perform the required works;
- the extent of unnecessary soil disturbance, including disturbances outside the designated work area, to be minimised.

The stabilisation of non-completed earthworks that are likely to be exposed to rainfall is discussed in Table I11.

Compliance with the requirements outlined within Table I11 does not diminish the need to apply all reasonable erosion control measures as soon as practicable.

Acceptable Solution A38(c)
Dispersive soils normally need to be stabilised (i.e. treated with gypsum or lime depending on desired pH adjustment) and/or buried under a layer of non-dispersive soil prior to placement of channel lining (whether rock, gabion, synthetic material, or concrete), or initiation of revegetation.

Refer to Figures I15 and I16 (Appendix I), Section 6.12 in Chapter 6 – *Site management*, and Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of dispersive soils.

SEDIMENT CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure, placement, or displacement of sediment (including soil, sand, silt, mud and cement). It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining sediment control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A39(a)
Current (2008) best practice (construction phase) sediment control standards are presented in Table 4.5.1 of Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A39(b)
Relevant site conditions include the soil type, design flow rate, flow condition (i.e. sheet flow or concentrated flow) and erosion hazard.

Unless otherwise noted within this document, or specified by the regulatory authority, the design storm for off-stream sediment traps (excluding de-watering and instream sediment control measures) must be taken as 0.5 times the 1 in 1 year ARI peak discharge.

The “potential environmental risk” is discussed in Acceptable Solution A1(a), and is summarised in Table 5.1 of Chapter 5 – *Preparation of plans*.

Acceptable Solution A42(a)
The *intent* of this clause is to minimise the quantity of water that needs to be de-watered from excavations and trenches. Thus, if water does not need to be de-watered from such areas, then the clause does not apply.

Acceptable Solution A42(b)
Current (2008) best practice sediment control standards for de-watering activities are outlined in Table 4.5.13 of Chapter 4 – *Design standards and technique selection*.

Alternatively, Table 4.5.14 of Chapter 4 presents a water quality standard for de-watering operations based on Nephelometric Turbidity Units (NTU).

Appropriate sediment controls placed down-slope of material stockpiles during the de-watering of such stockpiles are summarised in Table 4.5.14 of Chapter 4 – *Design standards and technique selection*.

SITE STABILISATION AND REHABILITATION

Acceptable Solution A43(a)
Site Stabilisation Plans, Landscape Plans, and/or Vegetation Management Plans must show progressive stabilisation of exposed soil for the purposes of erosion control, including but not limited to, all of the following:

(i) schedule for stabilisation of exposed soil areas; and
(ii) specifications for subsoil and topsoil preparation and application; and
(iii) specification of stabilisation by mulching or other appropriate surface treatment (note, grass seeding without adequate mulching is generally not considered best practice); and
(iv) details on the type and application rate of any tackifiers to be used in the application of mulches (including *hydromulch*, *Bonded Fibre Matrix*, and *Compost Blankets*).

Water Quality Monitoring Programs must document proposed water quality monitoring, and include:

(i) location of all instream water quality monitoring stations;
(ii) water quality monitoring, sampling, and analysis procedures and standards.

Acceptable Solution A43(b)
Current (2008) best practice site rehabilitation standards are presented in Table I11. Unless otherwise stated by the relevant regulatory authority, the potential erosion risk is based on the rating outlined in Tables I9 and I10.

Acceptable Solution A44(a)
Temporary revegetation conducted for the purpose of erosion control must be conducted in accordance with a Site Stabilisation Plan, Landscape Plan, Revegetation Plan, or Vegetation Management Plan, where such a plan specifically refers to such activities.

Acceptable Solution A44(b)
The type of permanent vegetation applied to completed earthworks must be compatible with the anticipated long-term land use, current and ongoing erosion risk, environmental requirements (including weed control), and associated components of the site rehabilitation.

Performance Criterion P45
Local environment includes local wildlife.

SITE INSPECTION AND MONITORING

Acceptable Solution A46(b)
Personnel preparing and/or supervising the preparation of the Monitoring and Maintenance Program must, collectively, have the following capabilities:

(i) an understanding of the local environmental values that could potentially be affected by the proposed works; and
(ii) a good working knowledge of the site's Erosion and Sediment Control (ESC) issues, and potential environmental impacts, that is commensurate with the complexity of the site and the degree of environmental risk; and
(iii) a good working knowledge of current best practice Erosion and Sediment Control measures appropriate for the given site conditions and type of works; and
(iv) a good working knowledge of the correct installation, operational and maintenance procedures for the full range of ESC measures used on the site.

Refer to A1(a) for discussion on “potential environmental risk “.

Acceptable Solution A47(a)
Discussion on scheduling and conducting site inspections by internal and external parties is provided in Chapter 7 – *Site inspection*.

In those instances where specific site monitoring stations are identified within the Monitoring and Maintenance Program, then:

- during periods of water discharge from the site, water quality samples are collected at each monitoring station at least once on each calendar day until such discharge stops; and
- a minimum of 3 water samples are taken and analysed, and the average result used to determine quality.

Current (2008) best-practice procedures for "high-risk" sites, requires regular ESC audits to be:

(i) undertaken by a person suitably qualified and experienced in erosion and sediment control that can be verified by an independent third-party (this person must not be an employee or agent of the principal contractor); and
(ii) conducted on the next business day following a rainfall event in which greater than 10 mm of rainfall has been recorded by the Bureau of Meteorology rain gauge nearest to the site; and
(iii) conducted at intervals of not more than one (1) calendar month commencing from the day of site disturbance until all disturbed areas have been adequately stabilised against erosion to the acceptance of the relevant regulatory authority; and
(iv) conducted using an appropriate Site Inspection Checklist.

"High-risk sites" are work sites that:

- satisfy the requirements of a high-risk site as defined by either the State or local government; or
- satisfy the requirements of 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 "critical hazard value").

Discussion on the assessment of *erosion hazard* and *site risk assessment* is presented in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

ESC audits must include, as a minimum:

- copies of all original Site Inspection Checklists; and
- non-conformance and corrective action reports;
- sediment basin water quality and site discharge water quality monitoring results;
- a plan showing the areas of completed soil stabilisation; and
- rainfall records including date and rainfall depth.

Acceptable Solution A48
Discussion on scheduling and conducting of site inspections is provided in Chapter 7 – *Site inspection*.

SITE MAINTENANCE

Performance Criterion P49
Proper working order includes maintaining the required hydraulic capacity and operational effectiveness.

Acceptable Solution A49(b)
Current (2008) best practice requirements for the maintenance of sediment control devices requires these devices to be maintained and made fully operational as soon as reasonable and practicable in accordance with Table 6.1 of Chapter 6 – *Site management*.

I9. Example ESCP for a bridge construction

The site is covered with native vegetation with a 20m wide riparian zone on the northern bank and a depleted riparian zone along the southern bank. The site is well drained and slopes towards the river from both the north and south. At present there exists minimal erosion on the site or within the waterway.

The river has a constant flow and the water depth exceeds 1m close to the southern bank even during extended dry weather. Downstream of the site the river flows into a tidal estuary that eventually discharges into the ocean. The river has high environmental values and fish passage must be maintained during construction.

The overpass (Figure I17) consists of a 4-lane highway that falls towards the south. The proposed underpass is a minor 2-lane rural road with grass swale drainage falling slightly towards the west.

As a result of the bridge works, rock protection of the river banks will be required within the region of the bridge. This work will require partial clearing of the bank and overbank vegetation.

Geotechnical investigations of the site reveal that the topsoil consists of a highly fertile, non-dispersive, dark sandy loam with depths varying from 100 to 200 mm.

Subsoils comprise a reddish, non-dispersible clayey loam. Rock outcrops are not expected; however, high groundwater levels are anticipated.

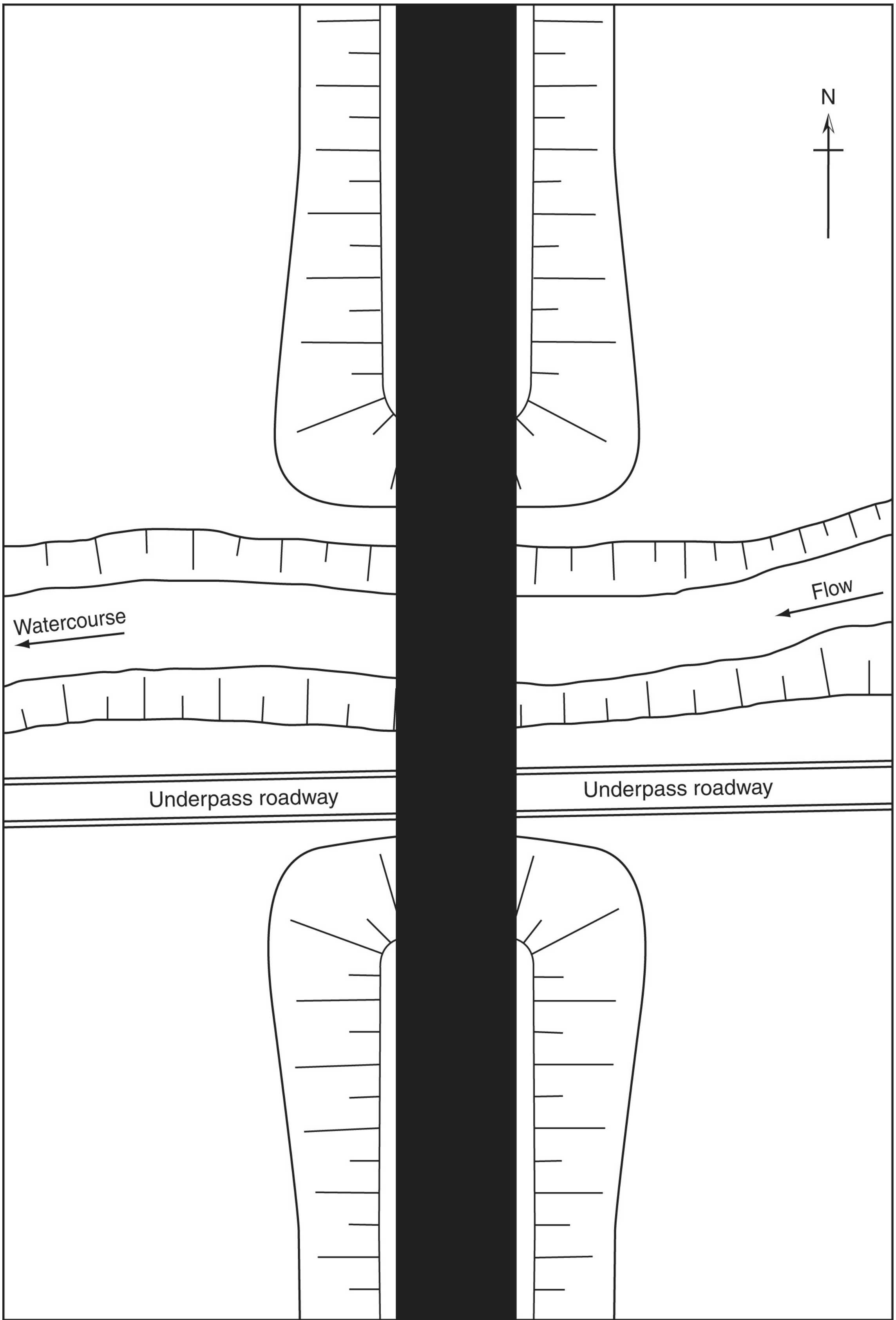
ESCP Explanatory Notes:

1. Note, the site's entry/exit point, site office and stockpile areas are not defined in this example.
2. The work site effectively acts as two separate work areas (north and south of river) during most of the construction phase and thus two separate ESCPs could be developed; however, in this example the two sites are combined.
3. The Isolation Barrier (IB-1) consists of a floating silt curtain anchored in the stream using a combination of land and marine posts and anchors.
4. Isolation Barrier (IB-2) consists of a floating silt curtain. This barrier is used because the water depth adjacent to the southern bank is greater than 0.8 m and there is a need to recess the bank stabilisation rock at least 1m below the existing toe of the bank.
5. Isolation Barrier (IB-3) consists of a *Sediment Fence Isolation Barrier*. The first staked sediment fence is located at the toe of the rock stabilisation, with the second fence located 2 m instream (south) of the first fence at a location where the river flow depth is less than 0.8 m. This type of barrier can be used because of the relatively shallow water depth adjacent to the north bank.
6. All Sediment Fences should consist of high quality non-woven composite fabric.
7. This example ESCP demonstrates the use of various types of sediment basins with four types of outlet systems and spillways. *Sediment Basin* (SB-1) is a Type C basin with a riser pipe outlet. The riser pipe outlet is trenched through to the river bank. During storm events the basin discharges down the riverbank via a rock mattress *Chute* (CH-1).

8. *Sediment Basin* (SB-2) is a Type F basin which is de-watered using a portable pump. During storm events, the basin discharges down the river bank via a high strength geotextile *Chute* (CH-4).
9. *Sediment Basin* (SB-3) is a Type C basin with a *Rock Filter Dam* outlet. During storm events the basin discharges down the river bank via a rock *Chute* (CH-2). The *Rock Filter Dam* outlet makes this a Type 2 sediment trap.
10. *Sediment Basin* (SB-4) is a "wet" Type C basin with pumped outlet. During storm events the basin discharges down the river bank via a gabion *Chute* (CH-3).
11. Inflow into each *Sediment Basin* will be controlled with the use of a geotextile *Chute*.
12. As the road embankments are formed, the temporary drainage *Chutes* (CH-5, 6, 7 & 8) are extended by successive placement of filter cloth, which forms the chutes.
13. *Catch Drains* (CD-9, 10, 11 & 12) are formed at the end of each day's filling to allow adequate drainage to the temporary embankment chutes.
14. Construction "Hold Points" exist at each 3 m lift within the embankments. The embankments will be stabilised with a *Bonded Fibre Matrix* (BMF) after each 3m lift is obtained.

Installation sequence:

Item	Plan No.	Installed	Removed
Mark out initial limits of disturbance	D-002	Prior to site disturbance	
IB-2	D-002	Prior to vegetation clearing	After pocket planting the river bank rock protection.
IB-3	D-002	Prior to vegetation clearing	Partial removal prior to installation of IB-1.
CH-1	D-002	After IB-2	After decommissioning SB-1
CH-2	D-002	After IB-3	After decommissioning SB-3
CH-3	D-002	After IB-3	After decommissioning SB-4
CH-4	D-002	After IB-2	After decommissioning SB-2
IB-1	D-003	After rock placement	After pier installation
Construction of central bridge pier within waterway			
SF-1	D-003	Prior to overbank land clearing	After site revegetation
SF-2	D-003	Prior to overbank land clearing	After site revegetation
SF-3	D-003	Prior to overbank land clearing	After site revegetation
SF-4	D-003	Prior to overbank land clearing	After site revegetation
Commencement of land clearing			
SB-1	D-003	After land clearing	After site stabilisation
SB-2	D-003	After land clearing	After site stabilisation
SB-3	D-003	After land clearing	After site stabilisation
SB-4	D-003	After land clearing	After site stabilisation
CD-2, -3, -6, -7	D-003	After land clearing	After site stabilisation
CD-1, -4, -5, -8	D-003	After land clearing	After site stabilisation
Commence embankment and underpass construction			
CD-9, -10, -11, -12	D-003	At end of each day's earth works on the embankments	Prior to sealing roadway
CH-5, -6, -7, -8	D-003	At end of each day's earth works on the embankments	After decommissioning CD-9, CD-10, CD-11 & CD-12



Drawing No. D-001 Bridge construction Final layout	Date: November, 2003	Scale: 0 10 20 30

Figure I17 – Proposed bridge layout

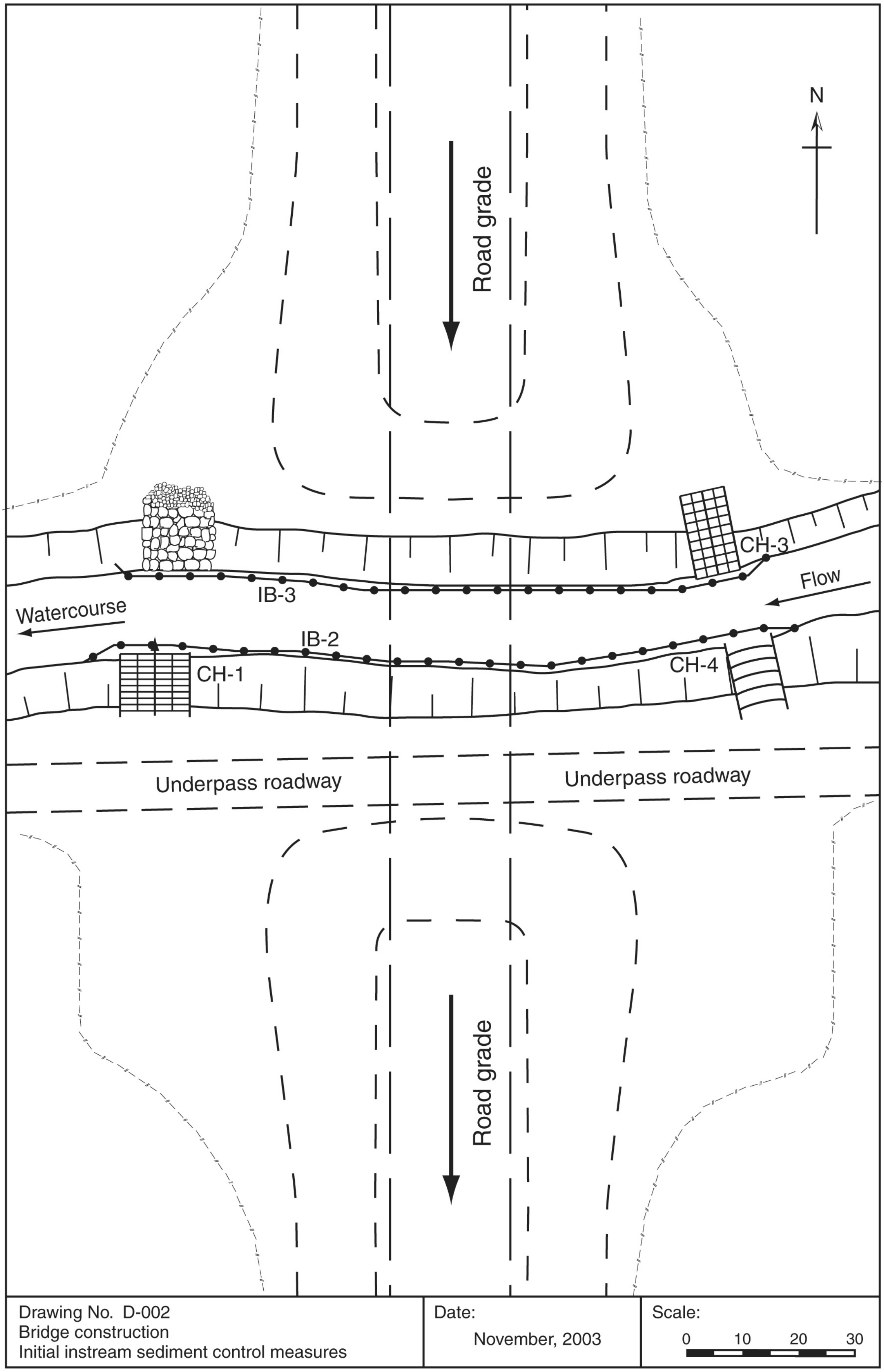
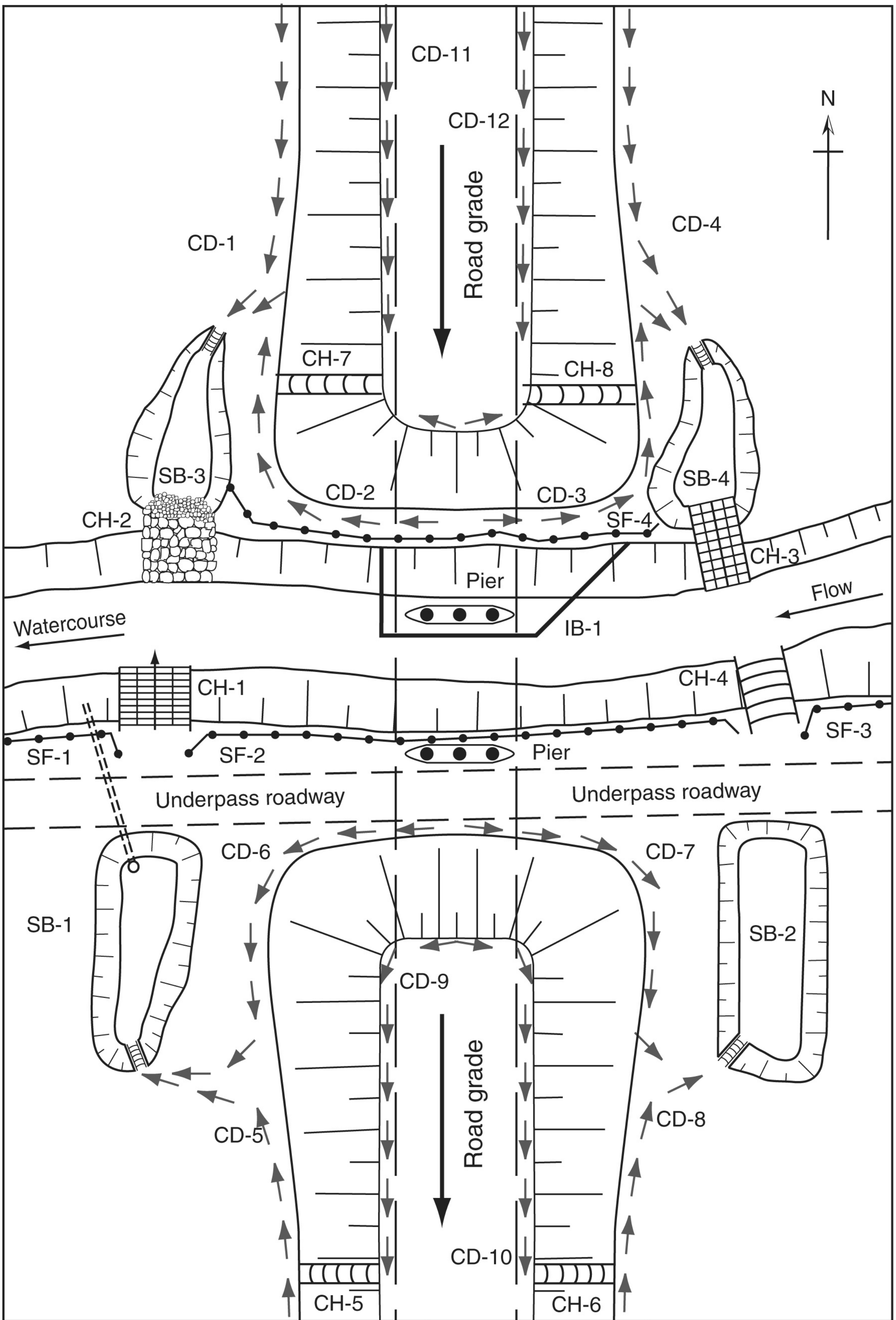


Figure I18 – Initial land clearing



Drawing No. D-003 Bridge construction Embankment construction	Date: November, 2003	Scale: 0 10 20 30

Figure I19 – Construction phase

I10. Culvert construction and the installation of buried pipeline crossings

There are usually a number of variables that must be considered before finalising the construction procedure for a culvert. These variables may include the following.

(i) risk of flood flows during the construction period;
(ii) risk of adjacent property flooding during the construction period;
(iii) fish passage requirements;
(iv) construction issues relating to the type of culvert;
(v) degree and clarity of base flow within stream;
(vi) requirements for construction access across the stream;
(vii) requirements for public traffic during construction;
(viii) erosion and sediment control requirements during the construction period.

The following information and examples are provided **not** as a code of practice, but as a guide to assist in the development of creative solutions.

I10.1 Risk of flood flows during the construction period

Condition	Comments
High flows unlikely (dry season)	• Cofferdams and temporary watercourse crossings are unlikely to wash away.
High flows possible (dry/wet season)	• Temporary crossing to be structurally sound during 1 in 1 year to 1 in 10 year flood risk depending on economic practicality. • Desired flood immunity of a temporary crossing also depends on desired trafficability during the construction phase. • Consider the use of *Isolation Barriers* to separate construction works from stream flows. • *Isolation Barriers* should ideally not block more than 1/3 to 1/2 of the channel's bed width depending on flood risk.
High flows likely (wet season)	• Temporary crossing designed to be structurally sound during minimum 1 in 10 year flood event. • Desired flood immunity of a temporary crossing also depends on desired trafficability during the construction phase. • Consider the use of *Isolation Barriers* to separate construction works from stream flows. • *Isolation Barriers* should ideally not block more than 1/3 to 1/2 the channel bed width depending on flood risk.

I10.2 Risk of adjacent property flooding during the construction period

Condition	Comments
Flooding would not inundate floor levels	• No extra considerations.
Flooding could inundate floor level of adjacent properties	• Construction should avoid periods of high flood risk. • Hydraulic analysis must be performed on each stage of construction to assess flood risk. • When diverting low-flows away from some or all of the culvert cells, avoid partially blocking the entrance to the culvert. Wherever practicable, flow diversion barriers should be located well upstream of the culvert inlet.

I10.3 Fish passage requirements

Condition	Comments
No fish passage requirements exist	• Instream sediment control measures can be constructed without risk to fish passage. • Minor flow bypassing can be achieved with cofferdams using either pumped or gravity bypass lines. • A temporary sidetrack crossing may be used as a cofferdam.
Short-term interruption acceptable to fish passage	• Temporary instream sediment controls may be employed while installing long-term sediment controls, or constructing minor instream works. • Temporary watercourse crossings and temporary sidetrack culverts might or might not need to be fish friendly. Obtain expert Fisheries advice/approval.
No fish passage interruptions allowable	• Consider the use of *Isolation Barriers* to separate construction activities from stream flows. • Temporary watercourse crossing and sidetrack culverts must be fish friendly. Obtain expert Fisheries advice/approval. • Minimum hydraulic capacity of a temporary watercourse crossing should be equal to the stream's base flow rate.

I10.4 Construction issues relating to the type of culvert

Condition	Comments
Single pipe culvert	• Two-stage fish-friendly construction may be impractical on a single pipe culvert.
Single box culvert	• Two-stage fish-friendly construction may be impractical on a single box culvert. • The need to form a base slab makes it difficult to construct a single cell box culvert in streams with a high base-flow, especially when fish passage must not be interrupted.
Multi-cell pipe culvert	• Allow for two-stage construction and the use of *Isolation Barriers* to separate construction works from stream flows.
Multi-cell box culvert	• Allow for two-stage construction and the use of *Isolation Barriers* to separate construction works from stream flows • Base slab must be structurally designed and detailed to allow two-stage construction.

I10.5 Degree of base flow within stream

Condition	Comments
No flow (dry creek)	• Minor flow bypassing can be achieved using cofferdam with either pumped or gravity bypass line. • A temporary sidetrack crossing may be used as a cofferdam.
No flow but permanent pools	• Fish passage requirements may exist that may prevent the use of cofferdams and flow bypassing.
Minor base flow (wet creek)	• Fish passage requirements are likely to exist that may prevent the use of cofferdams and flow bypassing. • Minimum hydraulic capacity of a temporary watercourse crossing equal to the stream's base flow rate. • Choice between piped flow bypass or *Isolation Barriers* is likely to depend on flow rate and fish passage requirements.
Significant base flow	• Use an *Isolation Barrier* to construct the culvert in isolation from the stream flow.

(a) Examples of stream flow bypass and diversion systems

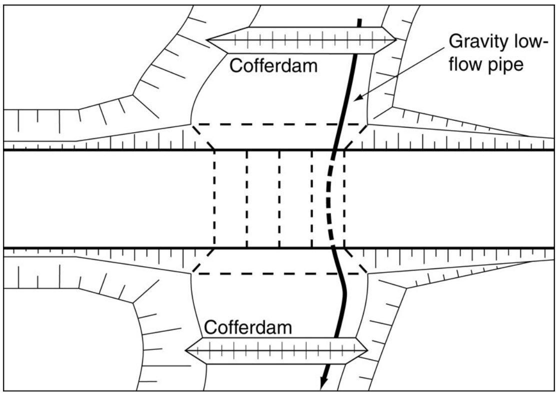


Figure I20 – Cofferdam with gravity bypass pipe

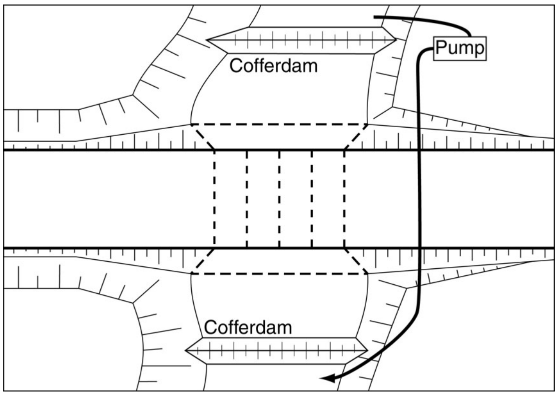


Figure I21 – Cofferdam with pumped bypass flow

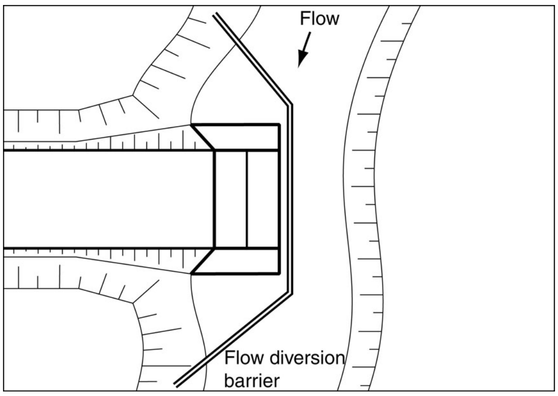


Figure I22 – Stage 1: Use of flow diversion barrier

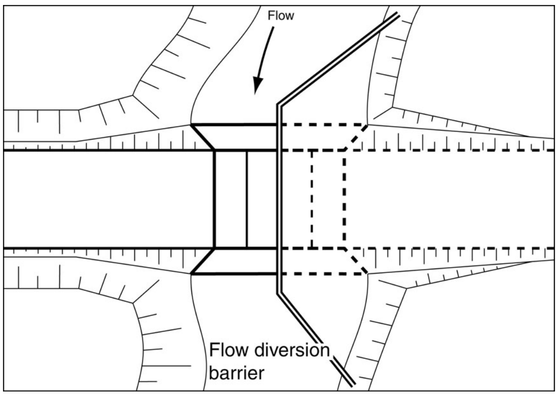


Figure I23 – Stage 2: Use of flow diversion barrier

I10.6 Requirements for construction access across the stream

Condition	Comments
No need for temporary watercourse crossing	• No additional requirements.
Temporary construction access required across stream	• Possible fish passage requirements for the temporary crossing. Minimum hydraulic capacity of a temporary watercourse crossing equal to the stream's base flow rate. • Temporary bed level crossings (fords) can introduce high sediment flows into the stream unless the creek is dry or base flows are bypassed around the crossing. Sandy channel beds may need to be reinforced with a synthetic *Cellular Confinement System*. Bed level (ford) crossings are not normally recommended in clay-based streams. • Temporary culvert crossings can cause significant bed disturbance during installation and removal. • Temporary bridge crossing (possibly using precast box culvert bridging slabs) are least likely to adversely affect fish passage.

Examples of temporary waterway crossings:

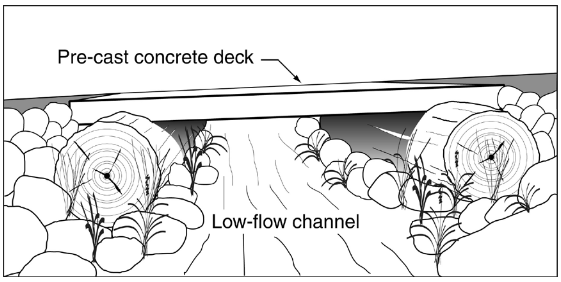


Figure I24 – Bridge formed from logs and a box culvert bridging slab

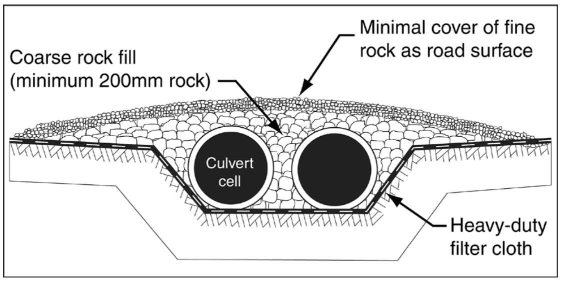


Figure I25 – Temporary pipe culvert

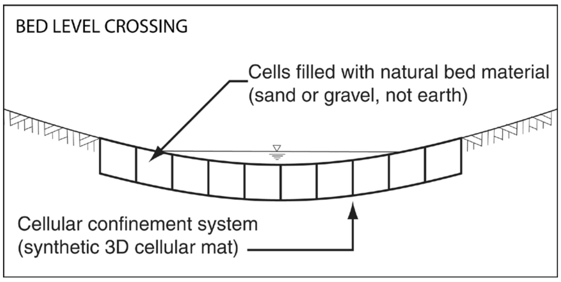


Figure I26 – Ford crossing stabilised with a cellular confinement system (CCS) mat

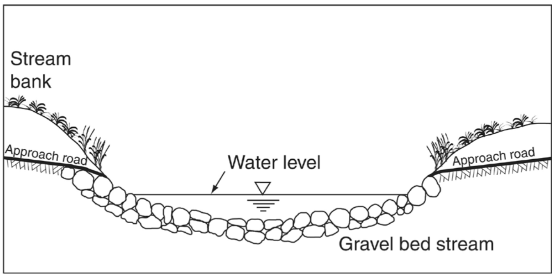


Figure I27 – Natural ford crossing of a gravel-based stream bed

Witheridge (2002) provides guidelines on the design of fish-friendly watercourse crossings.

I10.7 Requirements for vehicular traffic during construction

Condition	Comments
No traffic	• No additional requirements.
Traffic via temporary side road	• Possible fish passage requirements may apply to the side road crossing.
Traffic via adjacent roadway	• Possible use of the land between the two roads as a sediment trap/basin.
Traffic needs to be maintained on the road being built	• Construction of culvert must be staged.

Case Study A – Expansion of an existing culvert

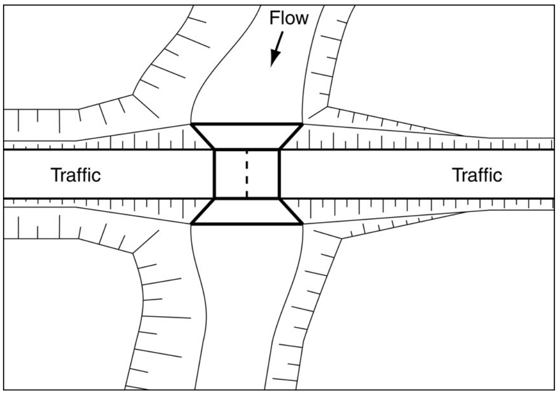


Figure I28 – Existing culvert

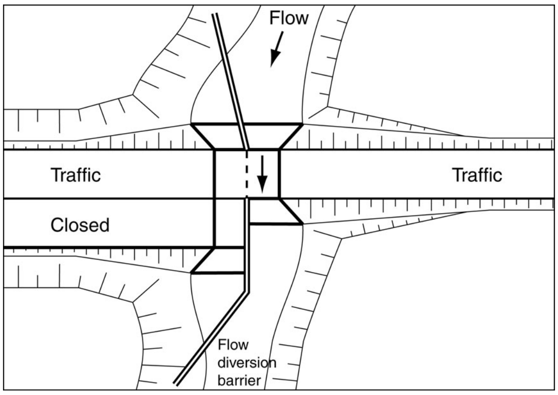


Figure I29 – Stage 1: Partial construction of culvert

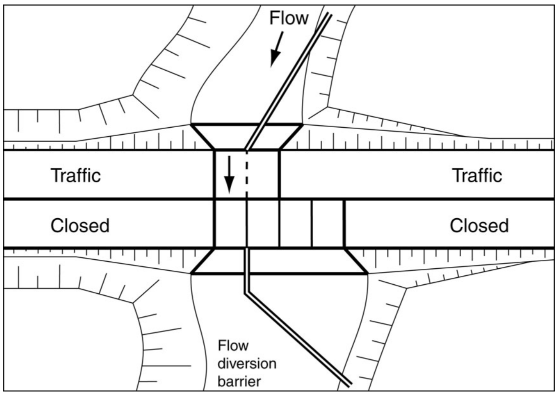


Figure I30 – Stage 2: Partial construction of culvert

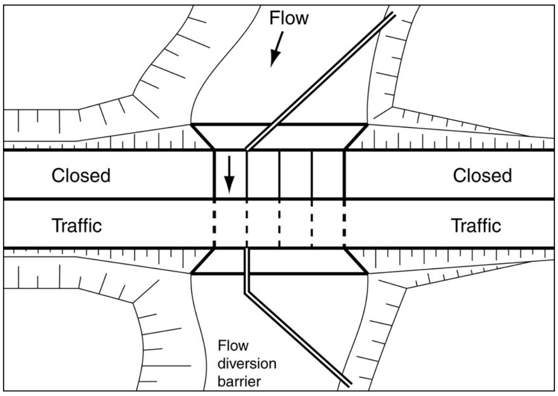


Figure I31 – Stage 3: Relocate traffic and final culvert construction

Case Study B – Construction of a new culvert

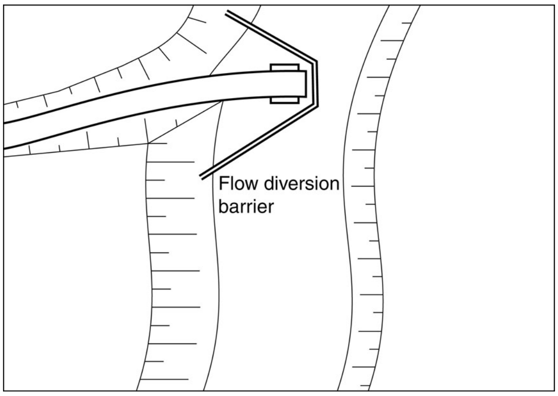


Figure I32 – Stage 1: Construct half of access track

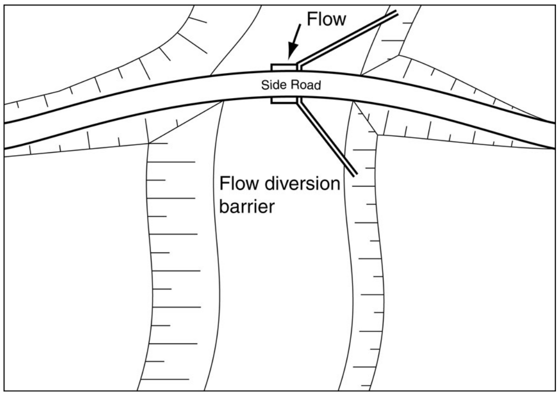


Figure I33 – Stage 2: Construct rest of access track

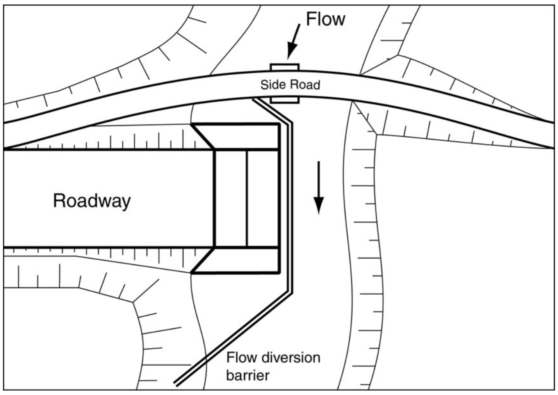


Figure I34 – Stage 3: Construction of half culvert

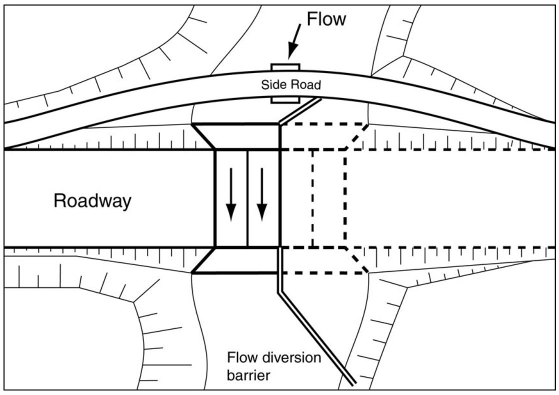


Figure I35 – Stage 4: Finish culvert

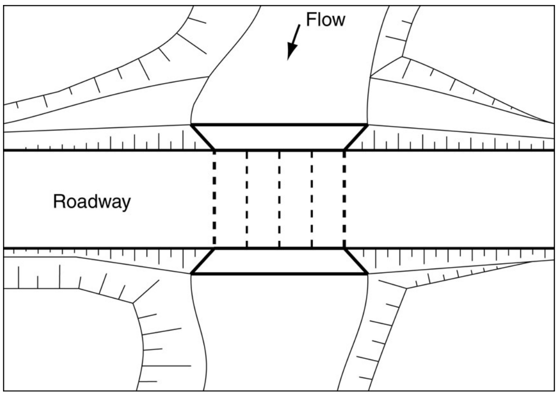


Figure I36 – Stage 5: Construct roadway

I10.8 Erosion and sediment control requirements during the construction period

Condition	Comments
Space is available for off-road *Sediment Basins*	• Sediment traps/basins formed each side of road, each side of the stream. • Sediment traps operational during all stages of construction and revegetation. • Possible retention of sediment traps as permanent stormwater treatment system.
No room available for off-road *Sediment Basins*	• Consideration given to the formation of sediment traps/basins within the road reserve each side of the culvert. These *Sediment Basins* will be slowly backfilled as earthworks are completed.

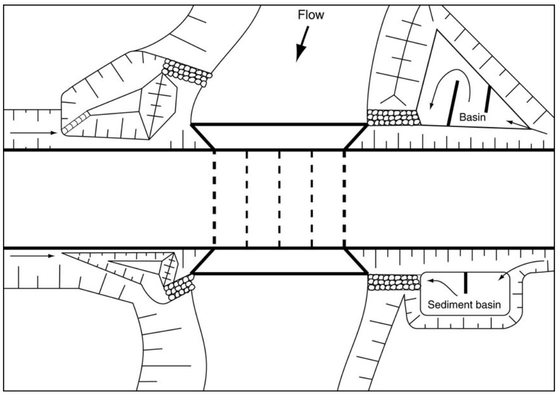


Figure I37 – Incorporation of four off-stream *Sediment Basins*/traps

Off-stream sediment traps:

Sediment Basins used to treat runoff from adjacent road works and to treat water pumped from the culvert excavations.

Preference should always be given to the use of off-stream sediment traps.

Sediment traps may be retained after the construction phase as permanent stormwater treatment ponds.

Case Study C – Construction of a major cross drainage stormwater pipe on a new road

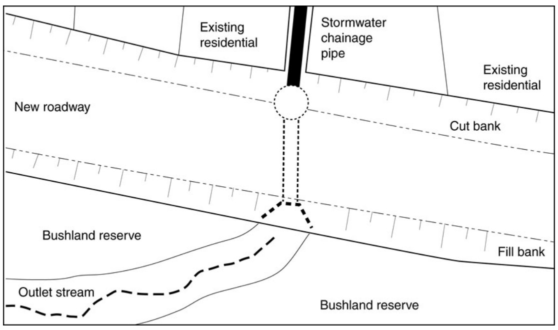


Figure I38 – Stage 1: Major stormwater pipe extended across proposed roadway

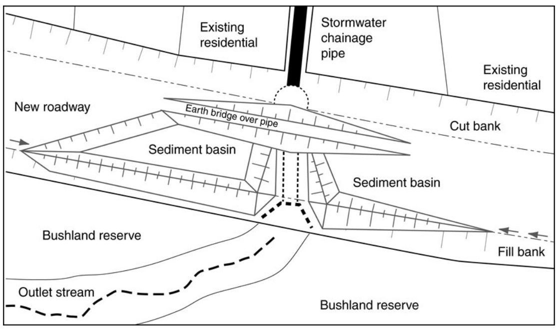


Figure I39 – Stage 2: Earth bridge built over pipe to allow construction access and *Sediment Basins* formed within the road reserve to minimise damage to the adjacent stream and bushland reserve

Case Study D – Construction of culvert within restricted road width

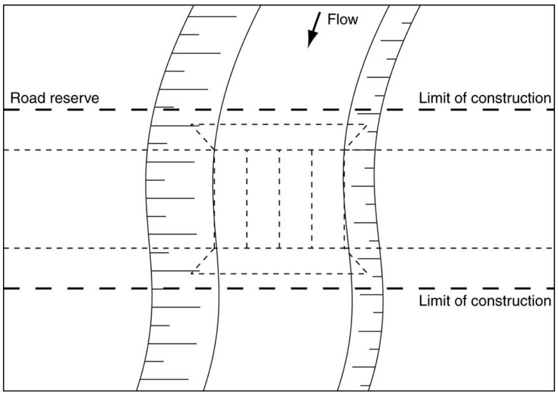


Figure I40 – Example of new culvert constructed within a narrow road reserve

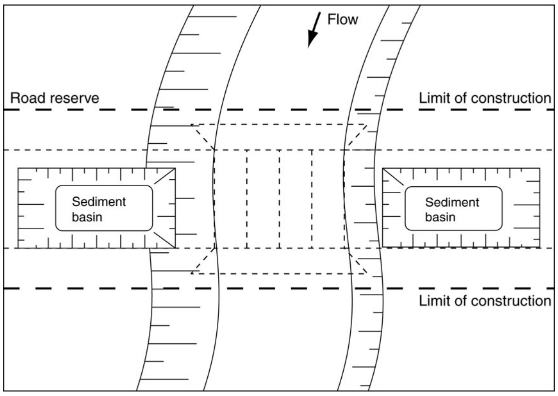


Figure I41 – Stage 1: Construct off-stream *Sediment Basins*

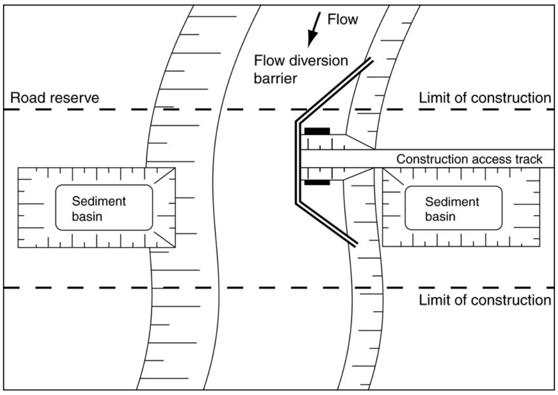


Figure I42 – Stage 2: Partial construction of access track across stream

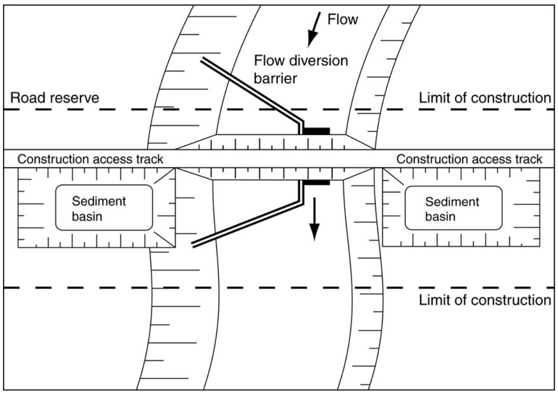


Figure I43 – Stage 3: Construct remainder of the access track

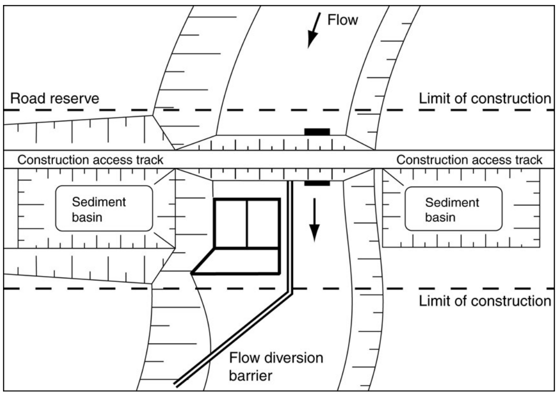


Figure I44 – Stage 4: Construct first phase of culvert

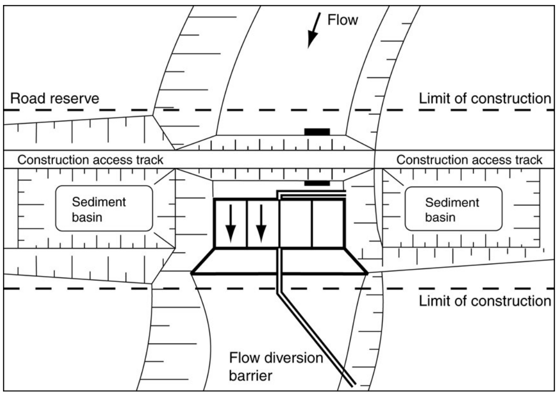


Figure I45 – Stage 5: Construct second phase of culvert

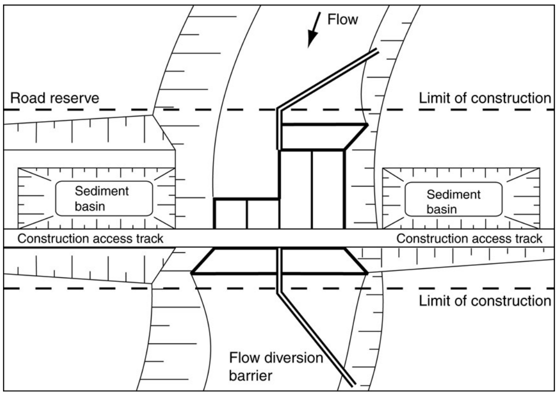


Figure I46 – Stage 6: Relocate access track by partially backfilling the *Sediment Basins*, then construct third phase of the culvert

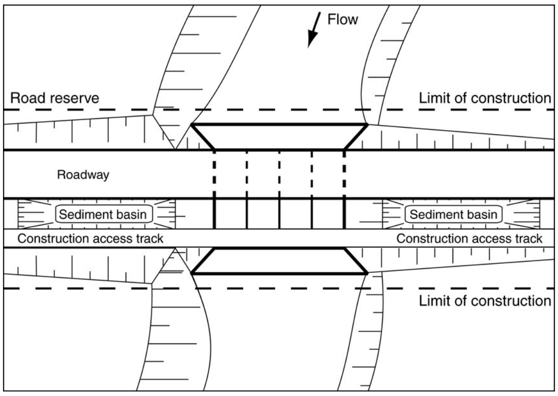


Figure I47 – Stage 7: Finish culvert and construct half of the roadway slowly backfilling the *Sediment Basins*

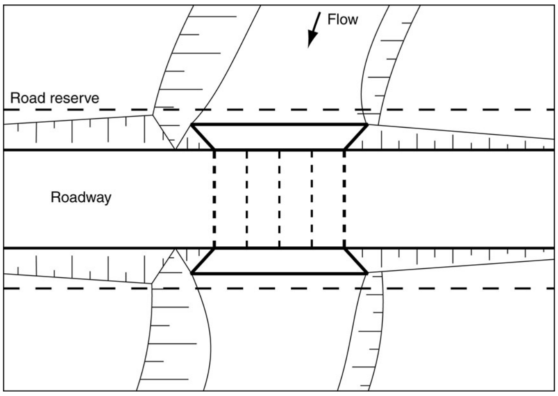


Figure I48 – Stage 8: Finish construction of roadway

The above Case Study represents a worst case scenario with the following conditions applying to the construction phase:

- Fish passage must be maintained.
- Wet stream with significant base flow requiring use of flow diversion barriers.
- Continuous construction access required across the stream.
- No construction allowed outside the road reserve limits, thus requiring all sediment traps to be located within the roadway.

I11. Construction of buried pipeline crossings

The variables to be considered when preparing installation procedures for major pipeline crossings are very similar to those variables presented in Section I11 for culvert construction. The main difference is that in pipeline construction there is often the potential to significantly reduce disturbances to the bed and banks of the watercourse. The degree of channel disturbance depends on:

- the width of the watercourse;
- base flow conditions within the watercourse;
- whether or not it is necessary for heavy machinery to enter the channel;
- if heavy machinery must enter or cross the channel, whether or not it will be necessary to construct an elevated access track across the bed.

In most cases the least intrusive installation procedure involves directional drilling. The following Case Studies provide examples of various open trench installation procedures in cases where directional drilling is not practicable.

Case Study E – Pipeline installation across a narrow watercourse with all construction equipment operating from the channel banks

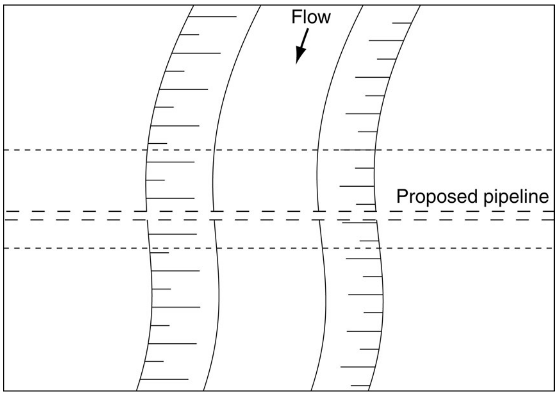


Figure I49 – Proposed pipeline across flowing watercourse

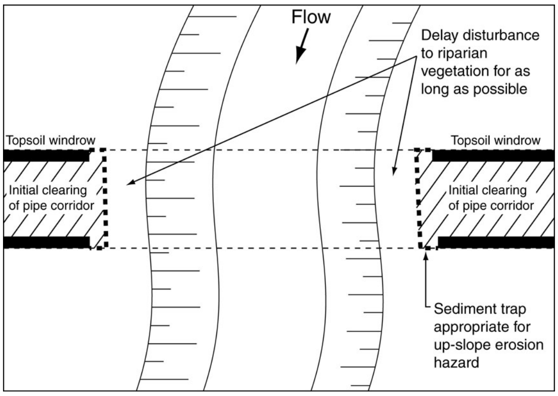


Figure I50 – Initial clearing prior to pipe installation

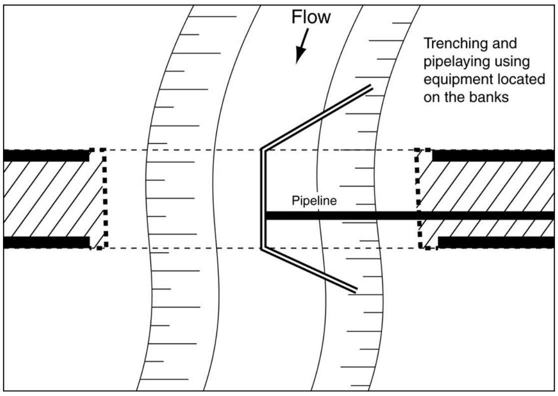


Figure I51 – Stage 1: Pipeline installation

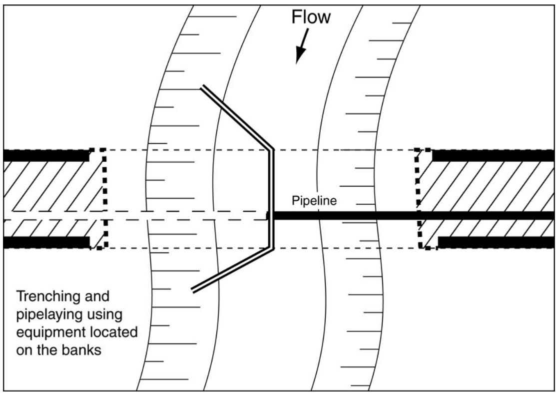


Figure I52 – Stage 2: Pipeline installation

Case Study F – Pipeline installation across a wide, dry-bed watercourse where minor channel flows are possible

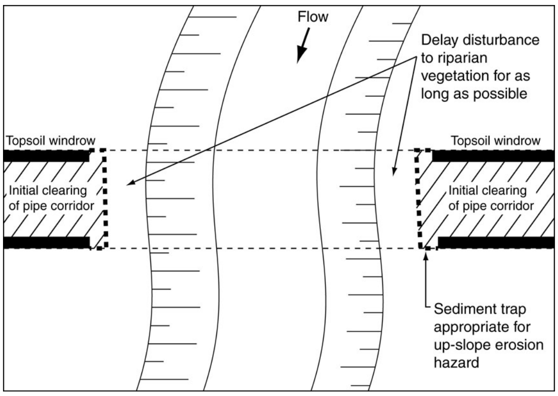


Figure I53 – Initial clearing of the easement prior to the pipe being ready for installation

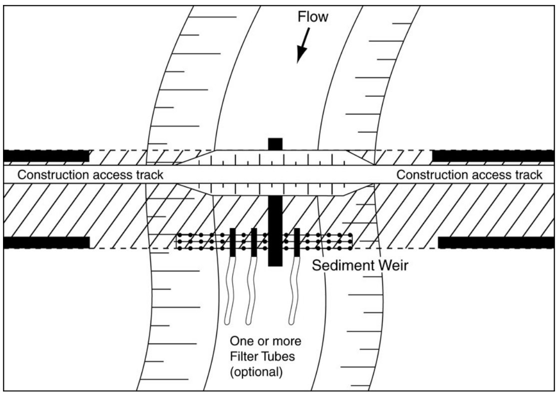


Figure I54 – Construction of instream sediment trap and construction access with bypass pipe in case of minor stream flows

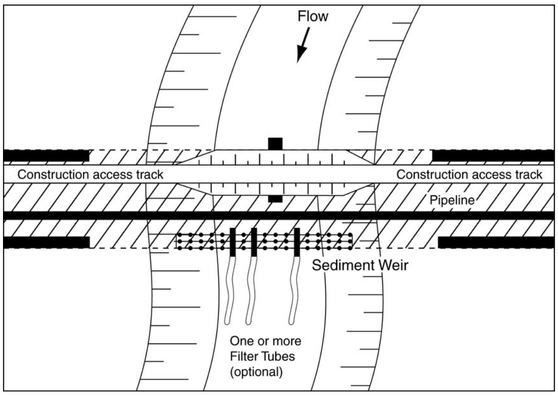


Figure I55 – Installation of pipeline. Note part of the bypass pipe may need to be removed to allow pipe installation

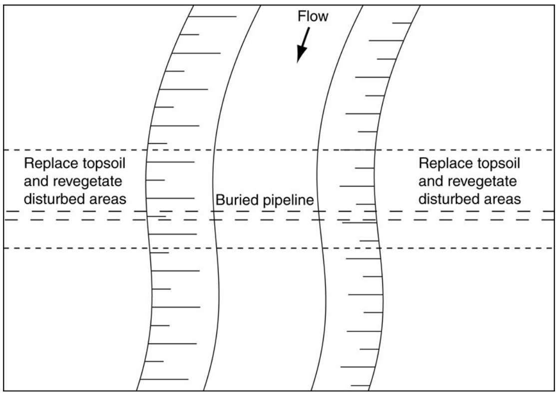


Figure I56 – Removal of access track and instream sediment trap followed by site rehabilitation

Case Study G – Pipeline installation across a wide watercourse with constant low flow and where increased channel flows are possible

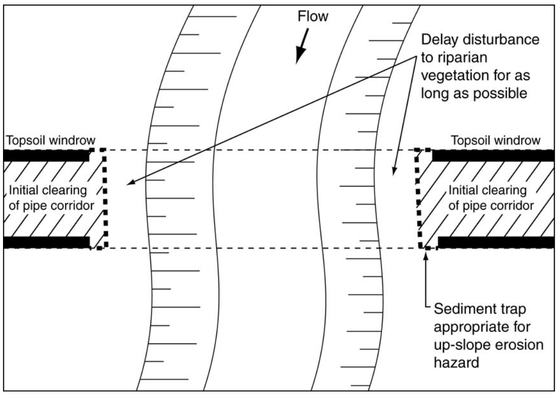


Figure I57 – Initial clearing of the easement prior to the pipe being ready for installation

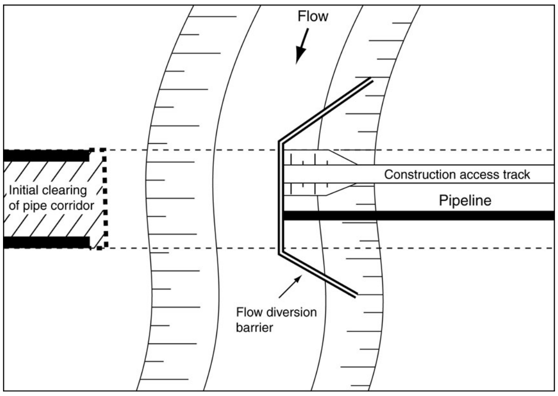


Figure I58 – Stage 1 of pipe installation using an isolation barrier

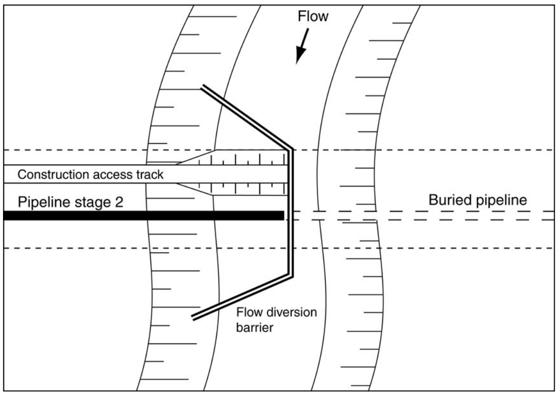


Figure I59 – Stage 2 of pipe installation using an isolation barrier

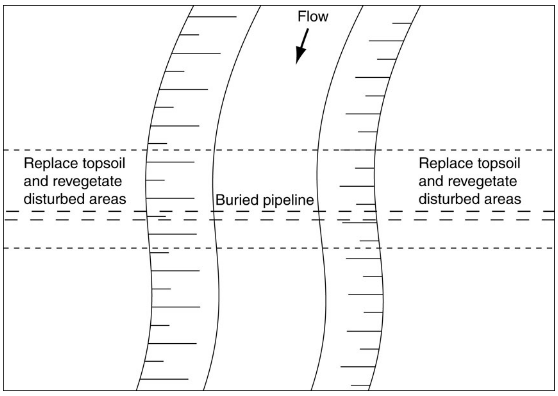


Figure I60 – Removal of access track and instream sediment trap followed by site rehabilitation

Case Study H – Alternative pipeline installation across a wide, watercourse with constant low flow and where increased channel flows are possible

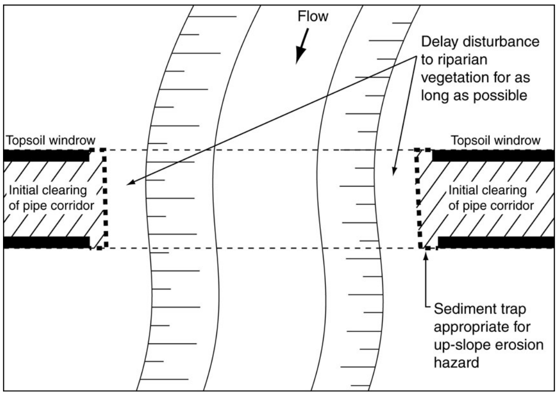


Figure I61 – Initial clearing of the easement prior to the pipe being ready for installation

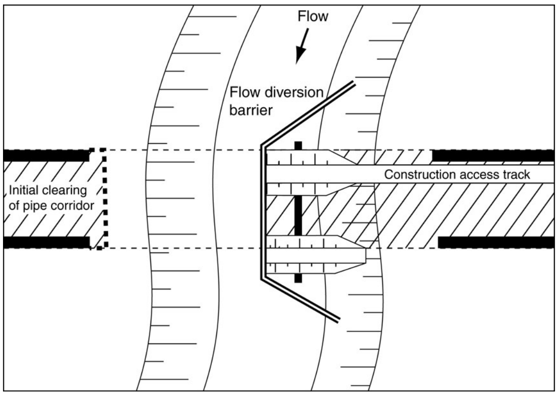


Figure I62 – Partial channel clearing and partial installation of cofferdam and construction access

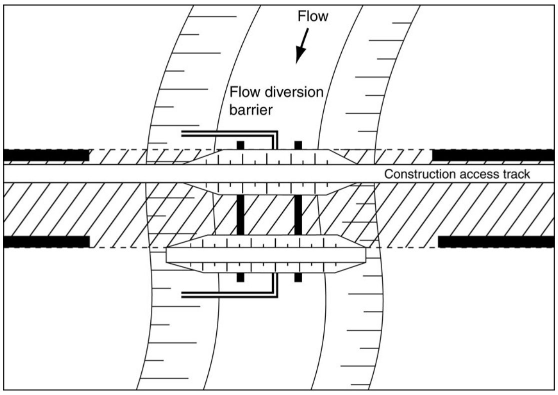


Figure I63 – Final channel clearing and final installation of cofferdam and construction access with full channel flow bypass

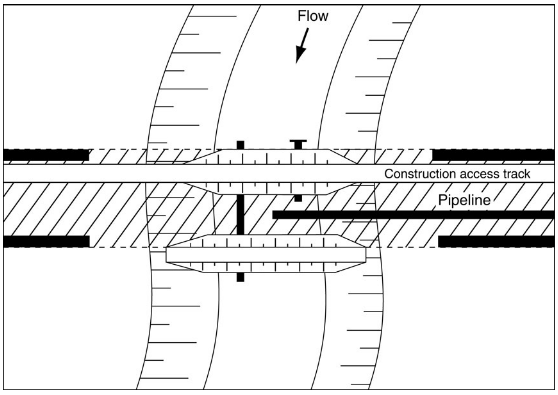


Figure I64 – Stage 1 of pipeline installation with one of the bypass pipes taken off-line to allow better access for pipe installation

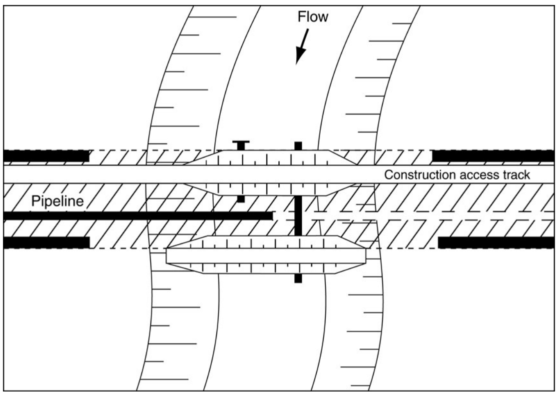


Figure I65 – Stage 2 of pipeline installation with the other bypass pipe taken off-line to allow better access for pipe installation

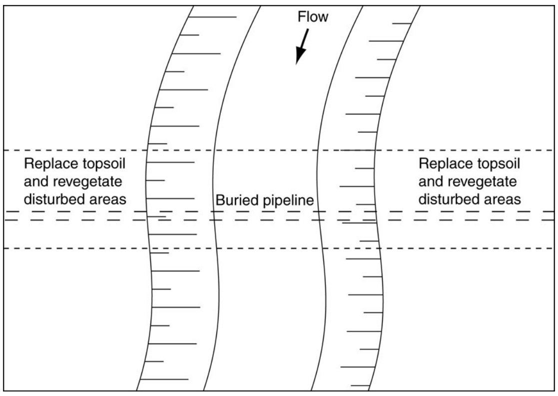


Figure I66 – Removal of access track and instream sediment trap followed by site rehabilitation

I.12 References

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Appendix J

Road and rail construction

This appendix provides specific guidelines on how the principles of erosion and sediment control are adapted to road and rail construction projects. Its function within this document is primarily educational. Those people involved within the road and rail construction industry, or wishing to apply erosion and sediment control measures to a specific site, should first ensure that they familiar with the general principles outlined in Chapter 2 – Principles of erosion and sediment control.

J1. Introduction

Road construction can be one of the most difficult environments for controlling sediment runoff. What is considered reasonable and practicable on an open (broad acre) construction site is often significantly different from what is considered reasonable and practicable in road construction.

Road construction activities can vary from minor road works associated with subdivisions and local government activities, to major highways. Similarly rail works can vary from the construction of car parks and track duplications to the formation of new branch lines. Independent of the size of the works, all road and rail construction projects are likely to experience some common ESC issues.

(i) The works usually involve “strip” construction within a well defined and often narrow transportation reserve. In urban areas it is often impractical to locate any form of temporary sediment control outside the designated reserve. However, there is usually inadequate space inside the reserve to construct a desirable *Sediment Basin*.

(ii) Road and rail works can cross several drainage catchments, thus requiring several major sediment traps instead of just one.

(iii) While under construction, the road/rail reserve effectively becomes a major drainage channel collecting up-slope water and feeding it through the length of the construction site. This problem is often amplified by the fact that the unfinished road surface is below the lip of the constructed kerb drainage system.

(iv) Road works often incorporate several site entry/exit points that may move from week to week as works progress. This means considerable care needs to be taken to reduce the tracking of sediment onto an adjacent sealed roadway, especially if the roadway is open to public use.

(v) Pedestrian and vehicular passage through the site may need to continue while the works are in progress, thus public safety issues can significantly influence the selection and design of the ESC measures.

(vi) Some aspects of sediment control on road construction projects can be closely linked to those activities associated with controlling the undesirable transport of weed seed by construction equipment, for example, cleaning mud and dirt from equipment.

Though focused on road construction, the majority of the following discussion applies equally to rail construction activities.

J2. Road planning

It is essential for erosion and sediment control issues to be incorporated into the planning phase of road design and road construction, especially on major projects. If land is being acquired to build a road, then consideration must also be given to the resumption or short-term leasing of any additional land required for the construction of major sediment traps such as *Sediment Basins*.

In the planning of traffic routes, *Erosion Risk Mapping*, as discussed in Chapter 3, can be used to assess the erosion hazard rating of each road layout. The assessed erosion hazard can then be weighed against other engineering, social, economic, and environmental considerations when appraising alternative proposals.

It must be clearly recognised that the *Erosion Hazard* is just one of the factors requiring consideration in the planning and design of roads. The relative weighting of this factor will vary from project to project, and possibly from location to location within a given project.

Factors that should be considered when preparing Erosion Risk Maps for road works include soil erodibility, rainfall erosivity, topography, vegetation cover, land use, and the proximity to water bodies, high-risk habitats and valued ecosystems.

When planning the road alignment, wherever reasonable and practicable, the existing topography should be utilised to eliminate the need for extreme landform modifications. The degree of cut and fill should be minimised by judicious selection of the vertical alignment.

Technical Note J1 – Retention of remnant vegetation

Rural road reserves often contain the only remaining examples of mature, native trees and other remnant vegetation such as grasses shrubs and herbs. Tree-lined roadsides can act as essential corridors for wildlife movement and as a gene pool for indigenous flora. Unfortunately, the need to retain existing roadside vegetation is often in conflict with the desire to construct roadside drainage channels (instead of kerb and channel), and cut and fill batters that are flat enough to control long-term soil erosion and allow effective revegetation.

J3. Batter design

The design of a road is rarely controlled by the short-term requirements of erosion and sediment control; however, road design, and in particular drainage and batter design, can significantly affect the long-term erosion potential of a roadway. The benching of long batter slopes can help reduce ongoing erosion problems by allowing better control of runoff-producing erosion, in particular, the control of rilling.

Batters should be designed to a stable gradient based on consideration of topography, soil type, vegetation, and the presence of rock formations. Typical **maximum** batter slopes are presented in Table J1 (Hunt, 1992).

Table J1 – Typical maximum batter slopes

Erosion hazard of soil	Maximum desirable batter slope
Low	2:1 (H:V)
High	3:1 (H:V)
Extreme	4:1 (H:V)

Technical Note J2 – Erosion hazard and soil erodibility

The erosion hazard rating of an earth embankment depends on a number of variables including soil erodibility, and the type and extent of vegetative cover.

Soil erodibility is the susceptibility of a soil to erosion. It is independent of such factors as topography, land use, rainfall intensity and plant cover, but may be changed by land management practices.

A minimum organic content of 3% is required for good soil structure (i.e. low erodibility) and nutrient supply in the surface horizon, while 5% is considered desirable. Structural problems become significant if the organic matter fall below 1.5% (Bridge and Probert, 1993).

Table J2 – Soil erodibility classes for water erosion (Charman & Murphy, 2007)

<table>
<tr><th>Erodibility</th><th>Topsoil</th><th>Subsoil</th></tr>
<tr><td rowspan="2">Low</td><td>High organic matter (>3%) (soils have a dark colour and feel greasy when textured).
High coarse sand.</td><td>Cemented layers including silcrete, ortstein and laterite iron, manganese, and silica pans.
High coarse sand.</td></tr>
<tr><td colspan="2">Well-structured, non-dispersible clay loams and clays having aggregates that do not slake in water to particles less than 2mm (Emerson Aggregate Classes 4, 6, 7 and 8), such as Red Ferrosols, some Vertosols, some structured loams, and Chromosols with friable surface soils.</td></tr>
<tr><td>Moderate</td><td>Moderate organic matter (1.5 to 3%).
Moderate fine sand and silt, such as some surface soils of Red Chromosols and Red Kandosols.
Well-structured clay loams and clays that slake in water to particles less than 2mm (Emerson Aggregate Classes 3 to 6), such as strongly self-mulching Vertosols.</td><td>Stable, non-dispersible loams and clay loams, such as Red and Yellow Kandosols.
Non-dispersible or slightly dispersible clays with particles that slake to finer than 2mm (Emerson Aggregate Classes 3 to 6), such as some Chromosols.</td></tr>
<tr><td>High</td><td>Low (0.9 to 1.5%) to very low (<0.9%) organic matter, such as soils with bleached A2 horizons.
High to very high silt and fine sand (>65%).</td><td>Dispersible clays (Emerson Aggregate Classes 1 and 2), such as Sodosols.
Unstable, dispersible clayey sands and sandy clays, such as Yellow and Grey Kandosols formed on sandstone and some granites.
Unstable materials high in silt and fine sand, such as unconsolidated sediments and alluvial materials.</td></tr>
</table>

Soil erodibility may also be linked to the soil erodibility K-factor used within the Universal Soil Loss Equation (USLE) and RUSLE analysis as presented in Table J3.

Table J3 – Soil erodibility based on USLE K-factor

RUSLE K-factor	Rating	Typical soil groups	
0.0–0.01	Very low	(SP)*	S
0.01–0.02	Low	GW, GP (GM, GC, SW, SP)*	CLS, SC, LMC, MC, HC
0.02–0.04	Moderate	SM, SC, OL (GM, GC, SW, SP)*	LS, SL, FSL, SCL, CL, FSCL, SiC, LC
0.04–0.06	High	ML, CL, (MH, CH)*	L, Lfsy, SCL, SiCL
>0.06	Extreme	(MH)*	Dispersive soils

* Classification is highly variable for this soil group (Unified Soil Class System)

Geotechnical advice on the design of batter slopes is always recommended; however, geotechnical advice that is excessively conservative often results in soil compaction specifications for earth batters that are inconsistent with desirable revegetation requirements. It is noted that even though well-compacted, non-vegetated earth batters may appear to exhibit good short-term stability, they often experience long-term "sheet" erosion problems resulting in ongoing environmental harm.

It is usually preferable to concentrate on the provision of suitable revegetation conditions on the road batter, than to focus on high surface compaction and short-term erosion control. To achieve suitable revegetation conditions, the bulk density of the soil should not exceed the values presented in Table J4 throughout the depth of the proposed root zone. Desirable soil bulk densities for revegetation may be obtained from Table J5.

Table J4 – Critical bulk density for restricted plant growth [1]

Texture	Critical bulk density (g/cm^3)
Sandy loam	1.8
Fine sandy loam	1.7
Loam and clay loam	1.6
Clay	1.4

[1] After Hazelton and Murphy (1992)

Table J5 – Desirable soil bulk density conditions for revegetation

Bulk Density (g/mL)	Sands	Loams	Clays
< 1.0	N/A	good conditions	satisfactory
1.0–1.2	N/A	satisfactory	satisfactory
1.2–1.4	very open	satisfactory	some too compact
1.4–1.6	satisfactory	some too compact	too compact
1.6–1.8	most too compact	too compact	extremely compact
> 1.8	too compact	extremely compact	N/A

In general, the following design guidelines should be considered.

- Earth batters that are likely to be vegetated should be as flat as possible—with due regard to economics, loss of existing mature trees, and so on.
- Earth batters that are **not** likely to be vegetated (i.e. within arid and semi-arid zones) should be as steep as possible—with due regard to soil stability, safety issues, and so on.

In areas of low rainfall it is often rare in nature for a healthy continuous vegetation cover to exist close to the edge of a sharp change in grade, such as is often found at the top of cut batters. Infiltrated rainwater quickly moves away from these extreme edges and thus plants can be starved of water. To avoid this problem, the very top of a batter may need to be rolled back (i.e. rounded-off) to form a more natural land formation as demonstrated in Figure J1.

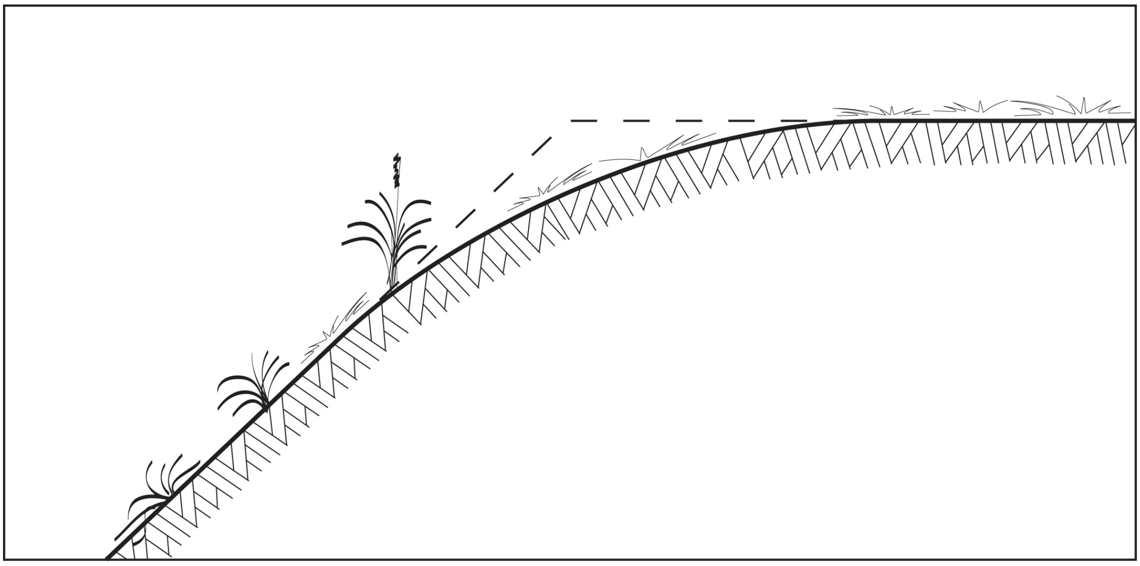

Figure J1 – Rounding-off the batter crest

Berms or benches are recommended on batters with a vertical height greater than 5m. The bench should be at least 1m wide, but a greater width may be necessary to allow for the movement of equipment used to establish and maintain vegetation on the batter.

Benches should have a positive slope in towards the hill and have a minimum longitudinal grade of 1% if vegetated, or 0.5% if paved. The maximum grades should be restricted to a level consistent with the maximum permissible velocity for the type of surface lining used. A maximum lateral bench slope of 10% (10:1) towards the toe of the upper batter should apply.

The appropriate spacing of benches down a slope should always be based on site-specific investigation and design. Numerous factors can change the bench spacing including soil condition, local hydrology, the potential hazards associated with bank failure, and of course the type and extent of vegetation cover. The typical spacing of benches down long grassed slopes is provided in Table J6.

Table J6 – Recommended maximum bench spacing on vegetated slopes

Batter slope			Horizontal spacing (m)	Vertical spacing (m)
Percentage	Degrees	(H):(V)		
< 10%	5.71	10:1	Site specific	Site specific
12%	6.84	8.33:1	100	12
15%	8.53	6.67:1	80	12
20%	11.3	5:1	55	11
25%	14.0	4:1	40	10
30%	16.7	3.33:1	30	9
> 36%	> 19.8	> 2.78:1	Site specific	Site specific

J4. Construction activities

J4.1 Environmental considerations

On major road projects, formal *Environmental Site Induction* procedures should be established for all site personnel, including subcontractors. These documented procedures should include the creation of a site register of induction and job training activities. Environmental Site Induction would include such items as:

- objectives of the *Environmental Management Plan, Stormwater Management Plan,* and/or *Erosion and Sediment Control Plan* as appropriate for the site;
- statement of *duty of care;*
- identification of site specific *Environmental Values;*
- specific conditions of any *Environmental Licence, Permit* and *Approvals;*
- use of the site's *Environmental Emergency Plan;*
- incident reporting procedures;
- specific equipment operational and maintenance procedures.

J4.2 Erosion and sediment control

The principles and guidelines of *Erosion and Sediment Control* presented throughout this document for general civil construction projects are equally applicable to road and rail construction projects.

Due to the nature of most major road projects, erosion and sediment control planning is often best subdivided into clearly defined ESC zones or sectors, usually based on catchment boundaries. In addition to the road easement boundaries, ESC zones should be established around:

- compound areas, including site office and concrete batching plant;
- access and haulage roads;
- borrow pits;
- stockpile and material storage areas.

Soil disturbances should not be conducted within these ESC zones until an appropriate Erosion and Sediment Control Plan (ESCP) has been approved for this area. Subdividing the ESCP into well-defined ESC zones can also assist in the preparation and approval of amended ESCPs.

The submission of an ESCP for a specific ESC zone should be recognised as a ***Milestone***, and the subsequent approval/acceptance of the ESCP by the Superintendent should be recognised as a ***Hold Point*** within the construction contract and/or Environmental Management Plan.

Common sediment-related construction activities, such as those listed below, should be detailed within Environmental Management Plan, or an overall site ESCP:

- equipment cleaning;
- site and material de-watering procedures;
- treatment of acid sulfate soils;
- treatment of dispersive soils;
- rock pad sediment traps at site entry/exit points;

J4.3 Batter construction

Embankments should be constructed so that adequate drainage of the embankment is maintained throughout the construction period.

The following principles of batter construction and stabilisation (Hunt, 1992) should be reviewed when preparing design and construction specifications.

(i) Provision must be made to prevent surface runoff damaging cut and fill batters. *Catch Drains* and *Flow Diversion Banks* above and below batters, and benches within batter slopes, can be used to intercept surface runoff and transport it to safe disposal points.

(ii) With cut batters, a *Catch Drain* or *Flow Diversion Bank* should be constructed above the top of the cut before excavation commences. Temporary toe drainage should be maintained as the work progresses, with permanent toe drainage installed when the final landform is achieved.

(iii) As the batter is excavated, serrated cuts may be placed in the batter to help hold topsoil and to assist with the establishment of vegetation.

(iv) For fill batters, permanent toe drainage should be installed at an early stage and should discharge to a suitable outlet. At the completion of each day's work, or at the onset of rain, a windrow of suitably compacted soil material should be constructed along the recently completed fill slope. Permanent top drainage measures should be installed on completion of the filling operation.

(v) *Chutes* or *Slope Drains* may be required at points along a *Catch Drain* or channel to allow safe disposal of runoff down the face of the batter.

Batters should be topsoiled, seeded and mulched (where appropriate) as work progresses. Revegetation should be programmed in stages at approximately equal increments with a maximum desirable unprotected batter fall height of around 3m. Ideally, the staged placement of erosion control measures (e.g. seeding and mulching) on earth batters in 3m lifts should become ***Hold Points*** within the construction contract.

Recommendations for surface roughening techniques applicable to earth batters is provided below (North Carolina SCC & DEHNR, 1993).

(a) Non-mowable cut slopes:

(i) For cut slopes steeper than 3:1 (H:V) that are not to be mown, stair-step or groove the slopes.

(ii) Use stair-step grading on any erodible material soft enough to be ripped with a bulldozer. Slopes consisting of soft rock with some subsoil are particularly suited to stair-step grading.

(iii) Make the vertical cut distance less than the horizontal distance, and slightly slope the horizontal portion of the step in towards the vertical wall.

(iv) Do not make individual vertical cuts more than 600mm in soft materials or more than 900mm in rocky materials.

(v) Grooves consisting of a series of ridges and depressions that run across the slope (i.e. along the contour) should be created by any appropriate implement that can be safely operated on the slope. These grooves should be not less than 75mm deep and spaced no more than 375mm apart.

(b) Non-mowable fill slopes:

(i) Place fill slopes with a gradient not steeper than 3:1(H:V) in lifts not to exceed 225m, and make sure each lift is properly compacted. Ensure that the face of the slope consists of loose, uncompacted fill 100–150mm deep. Use grooving to roughen the face of the slopes, if necessary.

(ii) Do not blade or scrape the final slope face.

(c) Mowable cuts, fills and graded areas:

(i) Make mowed slopes no steeper than 4:1(H:V).

(ii) Roughen these areas to shallow grooves by normal tilling, discing, harrowing, or other suitable means. Make the final pass of any such tillage implement on the contour.

(iii) Such grooves should be spaced no less than 250mm and not less than 25mm deep. Excessive grooving is undesirable where mowing is planned. Areas should generally be mulched.

(iv) Limit roughening by tracked machinery to sandy soils to avoid undue compaction of the soil surface.

(v) Operate tracked machinery up and down the slope to leave horizontal depressions in the soil. Do not back-blade during the final grading operation.

J4.4 Bridge and culvert construction

There are a number of variables that must be considered before finalising the construction procedure for a bridge or culvert. These variables may include the following:

- risk of flood flows during the construction period;
- risk of adjacent property flooding during the construction period;
- fish passage requirements;
- construction issues relating to the type of bridge or culvert;
- degree of base flow within stream;
- requirements for construction access across the stream;
- requirements for vehicular traffic across the existing bridge during construction;
- erosion and sediment control requirements during the construction period.

Detailed discussion on instream sediment control practices for bridge and culvert construction is provided in Appendix I – *Instream works*.

J4.5 Revegetation of road batters

Early stabilisation of exposed batters is essential. They should be adequately protected from erosion by vegetation, or other means. *Grass Filter Strips* can be used to maintain sheet flow down the embankment. Typically these turf strips (minimum 300mm wide) are placed in continuous rows along the contour, and at a spacing of 1 to 2m (Figure J2). These turf strips also assist as a Type 3 sediment trap.

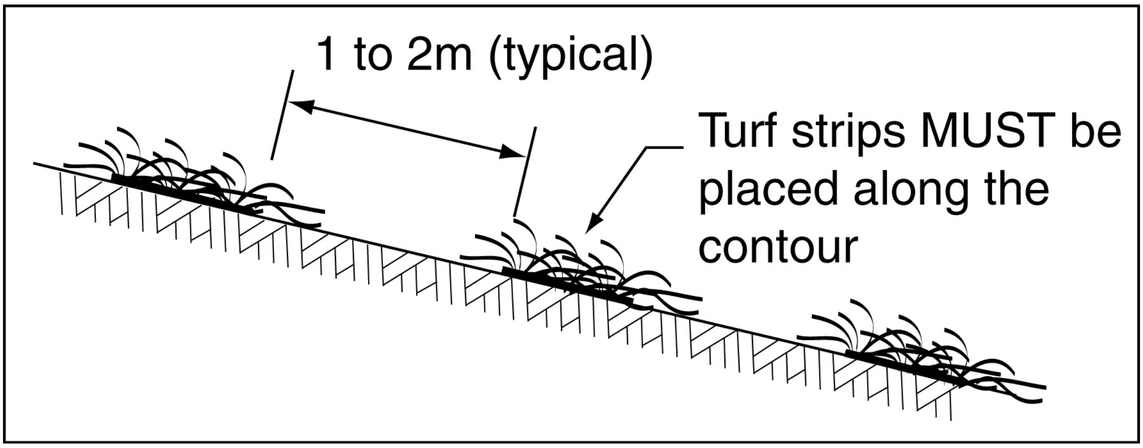

Figure J2 – Use of turf to maintain sheet flow down earth batters during the revegetation phase

J5. Rural roads

In rural areas, landholders can often make good use of stormwater runoff from roads. Long-term cooperation with landholders can reduce road and property drainage design problems with the potential of providing long-term financial savings. The real difficulty is maintaining this successful long-term partnership within an ever-changing political and social environment.

If roads are managed in conjunction with the surrounding land, both erosion and siltation problems can be reduced by coordinating erosion control structures, such as contour banks on the properties, and diversion channels within the road reserve. Where land under cultivation adjoining the road reserve is not contour banked, it is not advisable for diversion banks or drains to direct concentrated runoff onto it, because this may result in massive erosion of the unprotected topsoil.

Adjoining landholders can greatly increase the catchment areas of their dams by constructing diversion banks across pasture or cultivation to discharge water from roadside table drains into these dams. Construction of such diversion banks or channels requires permission from the local road authority and adjacent landowners. Before constructing drainage works, the road authority and landholder will need to negotiate an agreement for responsibility for maintenance of the channels and banks.

These roadside drainage structures can be more easily maintained if provision is made for opening of fences where they enter adjoining properties. Care must also be taken to control cattle movement along adjoining fence lines and to prevent the formation of deep cattle tracks along these fences.

In locations where landholders are keen to preserve trees within the road reserve, they should offer cleared land inside their boundary fence lines to the road authority for use as a temporary side track while new roads are being constructed or upgraded.

Discussion on the revegetation of rural road works is provided in Section C15 of Appendix C – *Soils and revegetation*.

J5.1 Table drains

The depth and width of table drains varies largely with soil type and vegetation cover. Extreme care is required on very erodible soils, or drains with highly dispersive subsoils, as exposure of such soils can have disastrous consequences. In such cases the proper management of the topsoil and the choice of drain depth are extremely important.

In areas known to have dispersive subsoils, soil chemistry should be analysed to determine whether the soil properties can be economically improved to aid soil stability and revegetation.

To avoid exposing the subsoil, it is preferable to design wide shallow table drains. However, where possible, table drains should be at least 300mm below the bottom of a pavement to prevent water entering the pavement material.

To reduce water velocity, table drains should be flat-bottomed with a slight slope away from the road at all times. To allow maintenance by earthmoving equipment, the flat-bed width should be a minimum of 2.5m.

J5.2 Diversion drains

Diversion drains are the constructed drainage channels that collect water from the table drain and direct it to a suitable disposal area. Ideally these drains should be flat-bottomed and not V-shaped. The drains should have an excavated cross-sectional area at least equal to that of the upstream table drain.

The initial grade ("kick out" grade) in the diversion drain should approximate the grade of the table drain to avoid energy loss, and hence siltation and bank failure. As the drain increases in length, the grade in the channel should progressively decrease. Ideally, diversion drains should have a surveyed grade of 0.2% for the final 30m (i.e. 6 cm fall in 30m).

Herbert and Evans (1992) provides the recommended spacing for diversion drain outlets along table drains (always seek local guidelines):

- 120m for slopes up to 2%
- 60m for slopes from 2% to 4%
- 30m for slopes from 4% to 8%
- 15m for slopes greater than 8%

If the diversion drain is built through a fence, it is preferable that landholders ensure that a floodgate is constructed so the fence can be easily reopened for maintenance.

Discharge from a diversion drain may also be spread over a pasture to ensure grass growth. This can be achieved with the use of a *Level Spreader*.

In areas with known dispersive subsoils, the use of *Flow Diversion Banks* rather than excavated diversion drains may be preferred.

J6. Road maintenance

In some cases, poorly maintained drainage works can be more detrimental to roads and adjoining properties than no drainage at all.

During maintenance, the area of exposed soil should be minimised. Ways to do this include those listed below:

- Use slashers or controlled herbicides rather than graders to maintain roadside vegetation. Where possible, slashed vegetation and debris should be removed from the drain to avoid blockages downstream.
- Ensure that adequate provision is made for drainage during road construction and maintenance. It is important to avoid sudden changes in direction and/or height.
- Suitably line drainage inverts in scour-prone country.

J6.1 Maintenance of unsealed roads

Grader operators play a major role in any attempt to control erosion. It is important that they receive adequate training in erosion control and maintenance techniques. Such techniques include the following.

- Grading diversion channels from the outlet end towards the road. If this is possible, it will aid in topdressing the drain and rebuilding the table drain block (the earth mound constructed in the table drain to divert water into the diversion channel).
- Where practicable, table and diversion drains should be converted from V-drains to flat-bottom drains.
- When de-silting table drains or when road construction operations are carried out with a grader, silt should **not** be left in a windrow along the side of the table drain. These windrows can cause concentration of surface runoff and possible erosion.
- When removing the windrow, the overseer or engineer should investigate the suitability of using the material for road construction. However, windrow material has often lost its fines and is not acceptable as paving material.
- Maintaining road height and form. During regular maintenance, grading should start from both edges, with material being moved towards the centre of the road. Then, to achieve crossfall and height, the material should be spread away from the centre line to the edge ensuring that any excess is suitably spread. If this operation is not carried out, the continual grading of the road results in the carriageway eventually being lower than the surrounding land.
- Adequate crowning needs to be provided for all roads. The cross-fall on unsealed roads should be between 4% and 5% to prevent longitudinal scour along wheel path ruts.

Where fines have been lost from unsealed road surfaces, investigate the possibility of importing and mixing clay or loam binder, or crushing oversize rock. This is considered preferable to wasting material on the side of the road reserve.

Correct crowning, road surfacing, and road cross-drainage should alleviate the need for banks across unsealed roads (whoa-boys). Whoa-boys present an obstacle to motorists, and can be dangerous to traffic even when newly constructed and adequately maintained. Whoa-boys should only be considered as a temporary measure to limit the extent of erosion while waiting for maintenance works to restore suitable drainage controls.

J6.2 Maintenance of table drains and earth batters

The grader maintenance of table drains adjacent to rural arterial roads has resulted in a common erosion problem occurring at a number of locations. For reasons of traffic safety, graders are forced to pass on the embankment side of guideposts often forcing the grader to ride up the toe of the embankment (Figure J3).

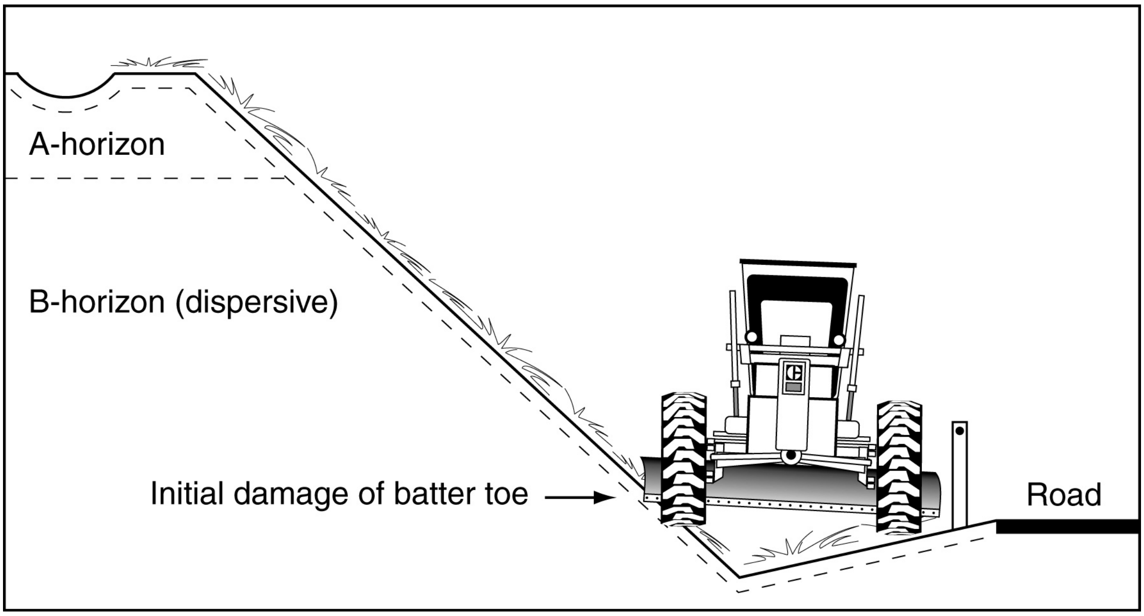

Figure J3 – Grader maintenance of table drains

If the embankment subsoils are dispersive (a common situation) then these dispersive soils can become exposed to erosion at the toe of the road batter (Figure J4). This erosion eventually migrates up the slope until all the topsoil and grass cover is removed and the road batter is left as a concave, poorly vegetated, eroding slope (Figure J5).

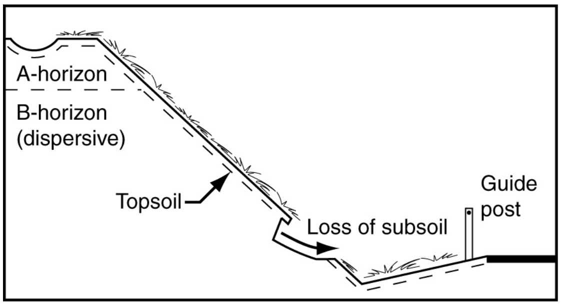

Figure J4 – Initial toe damage

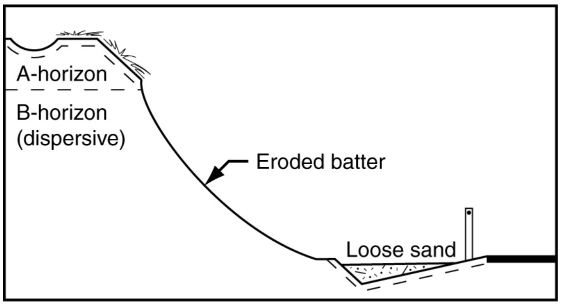

Figure J5 – Final outcome

The most desirable preventative measure is to ensure that there is sufficient room between the guideposts and the toe of the batter to allow typical maintenance machinery such as slashers and graders to pass.

Technical Note J3 – Dispersive soils

Dispersive soil road batters are often identified by the following common indicators:

- “clean” , lightly coloured sand deposited along the toe of the batter;
- closely spaced, deep rilling down all or part of the batter (known as *fluting*, with the depth of each rill usually significantly greater than its top width);
- appearance of erosion (rilling) can change significantly from one layer of soil to another (indicating soils of different degrees of dispersibility).

J7. References

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Appendix K

Access Tracks and Trails

This appendix provides specific guidelines on how the principles of erosion and sediment control are applied to the construction and maintenance of unsealed access tracks and trails. Its function within this document is primarily educational. Those people wishing to apply erosion and sediment control measures to the construction or management of access tracks and trails should first ensure that they familiar with the general principles outlined in Chapter 2 – Principles of erosion and sediment control.

K1. Introduction

Access tracks are used in engineering to provide temporary access on construction sites, or permanent low-traffic access for ongoing maintenance activities. Trails are typically walking tracks that may be used by small, all-terrain vehicles for fire fighting or maintenance access. Aspects of the following discussion also apply to long, unsealed driveways in rural residential areas. Discussion on the design and maintenance of low to medium use unsealed roadways is provided in Appendix J – *Road and rail construction*.

The degree of planning and design that goes into the engineering of tracks and trails should **not** be related to the volume of expected traffic, but to the potential environment risk exposed through the construction and operation of these pathways.

K2. Planning considerations

The planning of tracks and trails should consider the following factors (Soil Conservation Service, 1984):

- purpose and service life of the track;
- type and volume of authorised and possible unauthorised traffic;
- restrictions introduced to limit unauthorised traffic and public usage;
- soil properties and identified erosion hazard areas;
- topographic restrictions (steep slopes, rocky outcrops, areas subject to mass movement, swampy areas, etc.);
- location of natural drainage lines;
- location of protected, rare, or otherwise highly valued vegetation;
- location of alterative access routes.

A track or trail should be located to minimise both short and long-term soil and vegetation disturbance, while giving appropriate consideration to the intended purpose of the pathway. When planning the location of a track or trail, the following points should be given appropriate consideration.

(i) Tracks should generally follow the land contour with a gentle gradient of between 1 and 4%.

(ii) Avoid long, sustained grades where stormwater cannot be regularly removed from the track or its associated side drain.

(iii) Avoid locating tracks or trails down the centre of a valley or along the centre of an overland flow path. Unsealed tracks and trails should only act as drainage paths in exceptional circumstances.

(iv) Avoid steep grades, areas of dense timber, or locations where it may be difficult to control drainage. In particular, avoid circumstances where the track may collect and transport stormwater runoff.

(v) Allow the track to regularly rise and fall in elevation so that stormwater is forced to leave the track at regular intervals.

(vi) Aim to minimise the number of gully and stream crossings, and place any crossings at locations that have stable bed and banks.

(vii) Wherever reasonable and practicable, locate permanent tracks above the 1 in 2 year flood level, and temporary tracks above the 1 in 1 year flood level, and at least above the low bank of streams.

(viii) Avoid any unnecessary disturbance to the riparian zone of streams, and where possible, utilise this vegetation as a buffer zone to separate the track from the stream. Ideally, the minimum width of the riparian zone between the track and the edge of the stream should be at least the width of the stream (measured at the top of the bank) or 30m whichever is the lesser.

(ix) Avoid potential mass movement areas and highly erodible soils, such as:

(a) grey and yellow soils derived from granite, sedimentary and meta-sedimentary (slightly metamorphosed sedimentary rock), especially coarse grained types;

(b) unconsolidated sediment;

(c) slopes with steps, clay beds, hummocky topography (i.e. an elevated track rising above the general level of a marshy region);

(d) dispersive soils.

(x) Avoid crossing long, steep, unstable slopes, especially where the bedrock is highly weathered.

(xi) Avoid opening up moisture-laden foot-slopes.

(xii) Ensure the maximum gradient of tracks used as fire trails is 16% (NSW Department of Housing – Fire Trail Details, Dwg. RM26)

(xiii) Ensure that if the track is used as a fire trail and the track has insufficient width to allow passing, then passing bays are provided at intervals of between 200 to 400m (NSW Department of Housing – Fire Trail Details, Dwg. RM26).

(xiv) If a track follows a fence line on a long, steep slope, deviate the track every 60 to 80m to help divert runoff from the track at regular intervals (Figure K1).

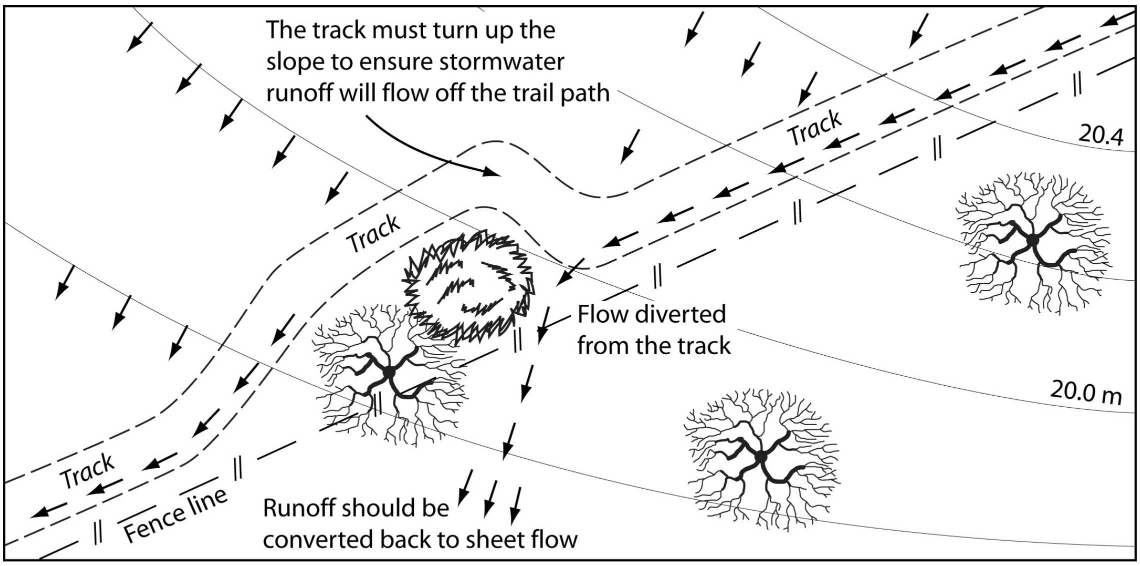


Figure K1 – Control of drainage along fence-line tracks

Where access is required across a slope, the track should be sited as close as possible to the contour of the land. This allows up-slope stormwater runoff to pass evenly across the track, thus avoiding flow concentration. If the track surface is allowed to erode forming a drainage channel, or if a windrow is allowed to form along the down-slope edge of the track, then drainage problems are likely to exist, even if the track is located along the contour. In such cases, regular maintenance of the track should aim to appropriately control the movement and ponding of surface water.

In situations where a track diagonally traverses a slope, the track will likely collect and concentrate up-slope stormwater runoff. Where practicable, these tracks should be zigzagged to allow the regular discharge of stormwater from the track, otherwise appropriate drainage controls need to be constructed to allow runoff to be regularly removed from the track.

Ridges often provide an excellent location for tracks because runoff can discharge each side of the track. If no suitable ridge is available, and slope gradients are not too steep, an alternative is to run the track alignment directly up the slope, provided that this does not initiate excessive erosion on the track.

K3. Design aspects

There are basically three types of track cross sections: sub-surface, ground level, and formed roads (Figure K2). Sub-surface tracks are generally not recommended. They collect large quantities of up-slope runoff effectively turning the track into a drainage channel.

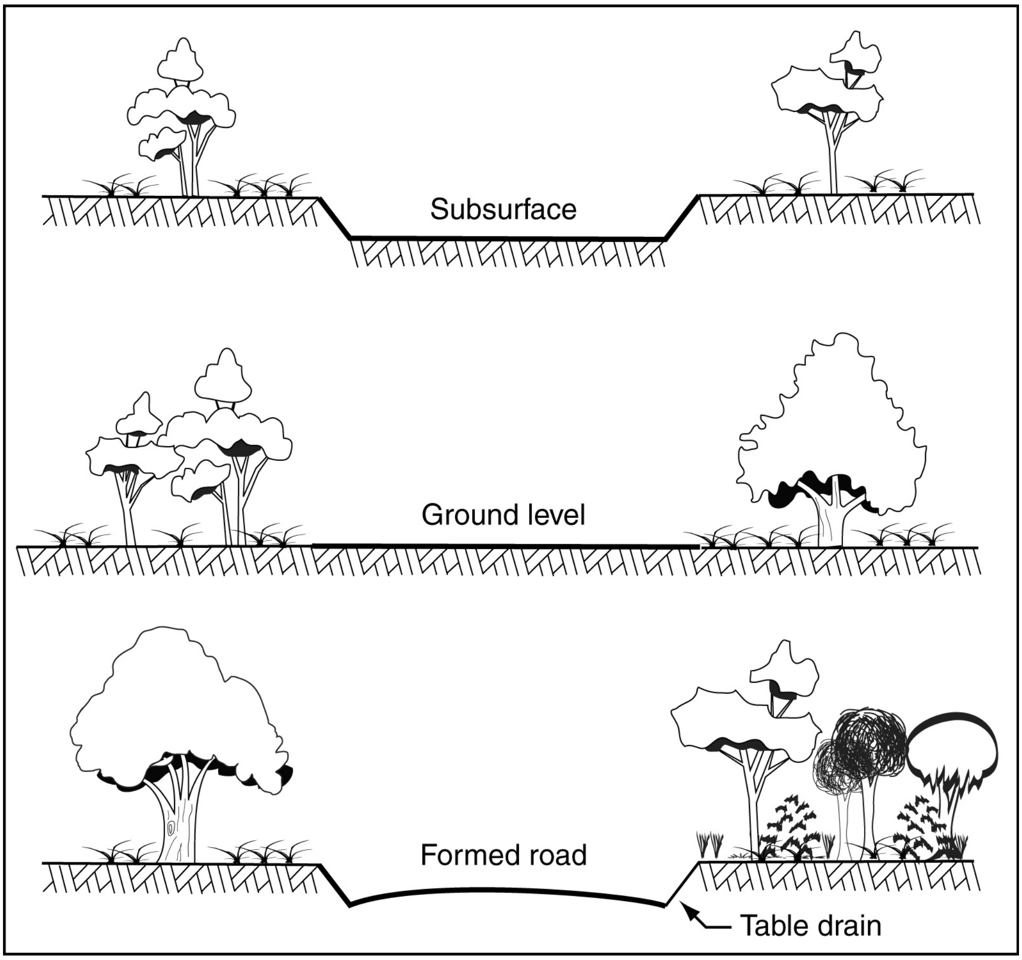


Figure K2 – Typical track cross sections (after Carey, 1992)

Ground level tracks are formed by slashing or blading the surface vegetation. Low cost, low traffic temporary tracks are best constructed at ground level. Unfortunately, many ground level tracks eventually become sub-surface tracks through excessive soil compaction, traffic erosion, stormwater erosion, or through the application of inappropriate maintenance procedures.

Formed roads should be used where a track is likely to be permanent and when it is likely to carry significant volumes of traffic. Formed roads have a raised formation with table drains on each side of the road. Further discussion on unsealed, formed roadways is provided in Appendix J – *Road and rail construction*.

In locations where sediment runoff from the track may cause environmental problems, the track can be covered with gravel to reduce runoff turbidity caused by raindrop impact erosion. Low-traffic tracks can also be formed using "structural soils".

Technical Note K1 – Vegetated structural soils

Structural soil tracks are formed by boxing out the track to a depth of around 100mm, then filling it with a mixture of uniformly-graded aggregate and a small quantity of sandy soil (sufficient only to fill the voids). The track is then seeded with appropriate grass species.

The benefit of this construction technique is that the weight of vehicular traffic is transferred directly through aggregate to aggregate contact, thus reducing soil compaction and damage to the root system of the grass cover. The disadvantages with this form of track construction include the long establishment time (i.e. grass growth from seed during which traffic must be avoided on the track), and the potential for these grassed tracks to become a fire hazard.

The trafficable track width is generally 3 to 4m, with a maximum desirable clearing width of 5m for minor tracks (though not always practical). Haul roads may require much wider widths to allow passing and to provide safe slight lines. Track clearing should be reduced to the minimum practicable if located within 30m of any watercourse.

Tracks should have at least a slight longitudinal grade to allow free surface drainage and to avoid excessive ponding within wheel tracks. Generally the grade of a track should be less than 10° (1 in 5.7 or 17.5%). Short lengths of steeper grades may be needed to negotiate difficult sections, or to take advantage of favourable terrain. Such sections may need to be sealed with bitumen or concrete, or otherwise stabilised (timber sleepers, soil-cement treatment, gravel, and so on).

If it is necessary to design track sections with grades exceeding 10°, then it should be noted that trafficable drainage cross banks are generally limited to a maximum track grade of approximately 12° (1 in 4.7 or 21%). Tracks steeper than 12° will normally require special drainage works.

The sealing of earth tracks can greatly reduce soil erosion resulting from vehicular traffic, stormwater runoff, raindrop impact erosion and wind erosion. Table K1 provides suggested surface treatments that may assist in the reduction of sediment-laden runoff from low to medium traffic tracks. These recommendations are only a general guide—appropriate consideration should always be given to experience gained from past practices within different regions.

In addition to the surfacing treatments presented in Table K1, there is also a variety of *Surface Stabilisers* (soil binders) which are discussed in more detail in Book 4.

Of course, many of the options listed in Table K1 would result in the track becoming a sealed roadway. Wherever reasonable and practicable, sealed tracks should be profiled to allow sheet flow off the track.

Table K1 – General guide to the surface treatment of low to medium traffic areas

Road Grade	Option	Road Finish
< 5%	1st option	Compacted crushed rock.
	2nd option	Resin-impregnated for added wear.
	3rd option	Bitumen.
5 to 10%	1st option	Hot-rolled bituminous surface over compacted sub-base.
	2nd option	Resin-impregnated soil.
	3rd option	Bitumen.
10 to 20%	1st option	Asphaltic AC10 concrete over compacted sub-base.
	2nd option	Resin-impregnated soil.
	3rd option	Bitumen.
> 20%	1st option	Mesh-reinforced concrete (40MPa) over compacted sub-base.

K4. Track drainage

There are three forms of track crossfall: outfall, infall and crowned (i.e. formed road). Tracks constructed on a ridge or gentler slope should be crowned; however, minor tracks may not have sufficient width to make a crowed profile practicable. Crowning can ease drainage problems by allowing water to be shed from both sides of the track.

Outfall drainage (i.e. drainage directed away from the hillside) allows stormwater to discharge from the track as “sheet” flow. If outfall drainage is installed, then any “windrows” that develop along the down-slope side of the track during the construction, operational or maintenance phase need to be removed. Outfall drainage should **not** be used when any of the following conditions exist, in which case infall drainage is usually preferred:

- down-slope fill batters are unconsolidated and likely to erode;
- down-slope fill batters exceed 1.5m in height;
- sediment-laden runoff needs to be directed to a sediment trap;
- the track is subject to rutting causing stormwater to be redirected down the track rather than across the track;
- maintenance procedures are likely to result in the formation of an earth “windrow” along the outside edge of the track. Such windrows can cause stormwater to pond on the track and to eventually discharge as concentrated flow at breach points.

When using infall drainage, the formed table drains should represent the primary drainage path within road reserves. Stormwater should be removed from the trafficable road surface as soon as practicable. The crossfall required to achieve effective drainage is generally 4% (1 in 25). For safety reasons, the maximum crossfall should not exceed 10%.

To ensure stormwater sheets off the track into the table drain it may be necessary to construct either infall or outfall cross banks (also known as “whoa-boys”) at selected locations.

Outfall cross banks (Figure K3) or outfall drains (e.g. culverts) are used to remove water from the table drain at appropriate outfall locations. *Infall cross banks* (Figure K4) are used at locations where a cross bank is required to direct water off the road surface (as per the recommended drainage spacing presented in Table K2), but it is inappropriate to direct this water off the side of the road.

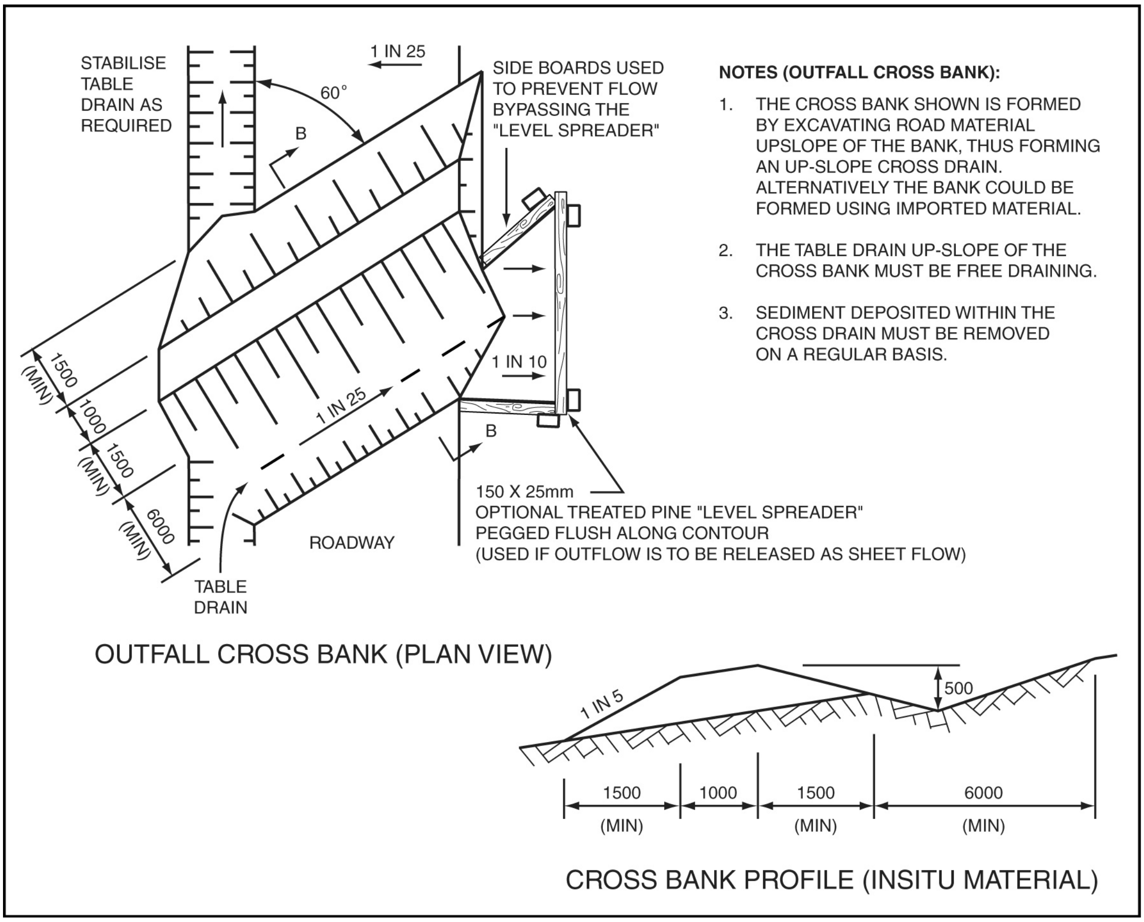


Figure K3 – Outfall cross bank for low speed tracks

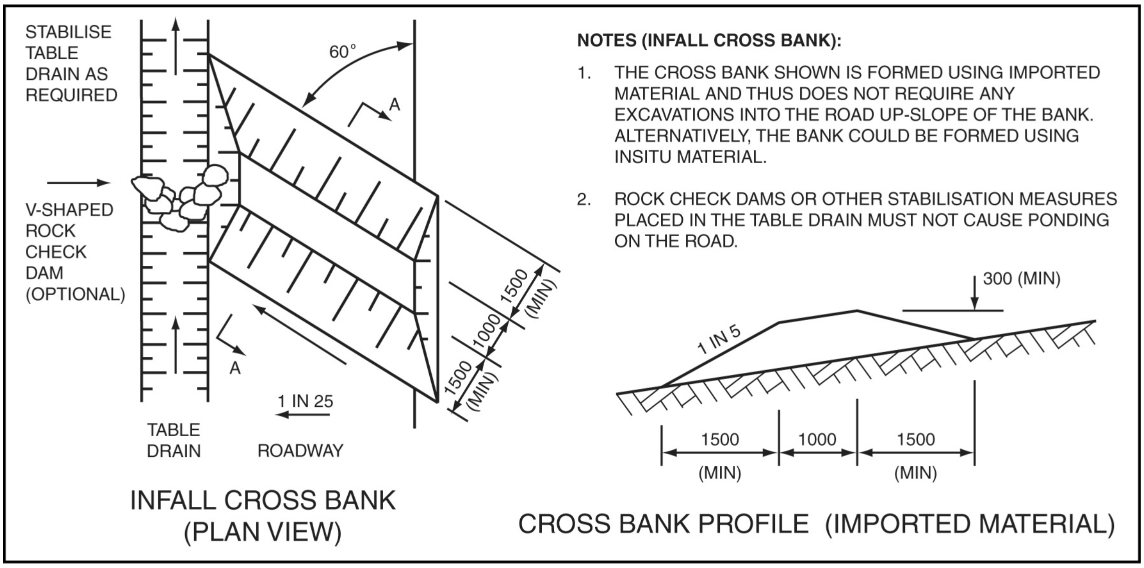


Figure K4 – Infall cross bank for low speed tracks

Cross banks consist of a trafficable earth mound (speed bump) constructed across a track to collect and divert runoff. Cross banks are used in low speed areas and can be used as speed control devices (hence the term "whoa-boys"). In medium or high-speed areas, sub-surface cross drainage (i.e. culverts) should be used.

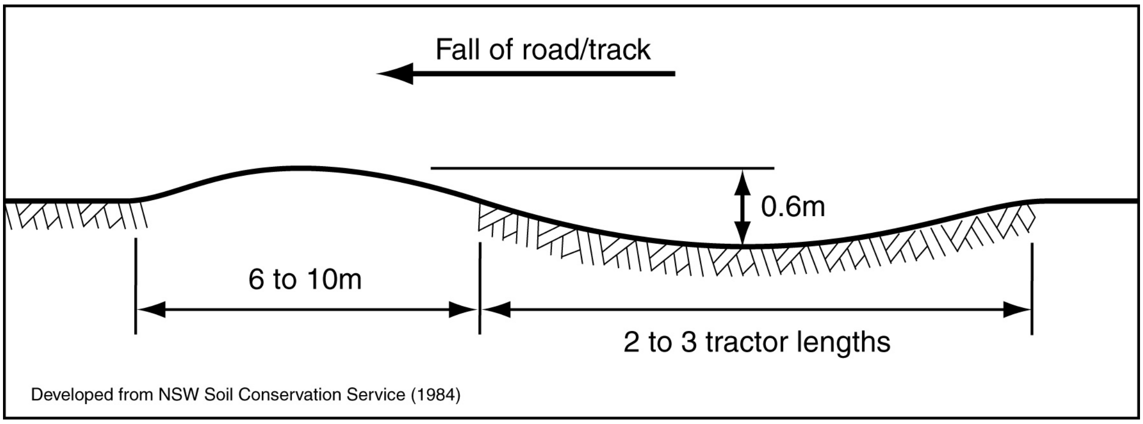


Figure K5 – Typical cross bank profile for low to medium speed traffic areas

The profile of the cross bank should be of sufficient length to ensure comfortable vehicle passage. The height of the cross bank should be sufficient to allow adequate drainage taking into account slope and soil type. The preferred dimensions of a cross bank will depend on the type, speed and frequency of vehicular traffic.

The dimensions provided in Figures K3 to K5 may need to be adjusted based on local conditions. The drainage outlet of the cross bank should allow water to escape rapidly from the track. Ideally this water should be converted back to sheet flow using a suitable *Level Spreader. Level Spreaders* are only used when it is desirable to release the water as "sheet" flow. *Level Spreaders* can be formed from earth or from treated timber (as shown in Figure K3).

If the track runs parallel to a watercourse, then every effort should be made to sheet water off the track, discharging it as "sheet" flow through the adjoining riparian zone. Maximum use should be made of this riparian zone to filter sediment from stormwater runoff before it enters the watercourse.

If the track runs along a ridge, then ideally, stormwater runoff should be discharged evenly off each side of the ridge. Examples of possible drainage for ridge tracks are provided in Figure K6. For the unformed road example provided in Figure K6, if a ground level road profile is used, then the cross banks may alternate to discharge water each side of the ridge.

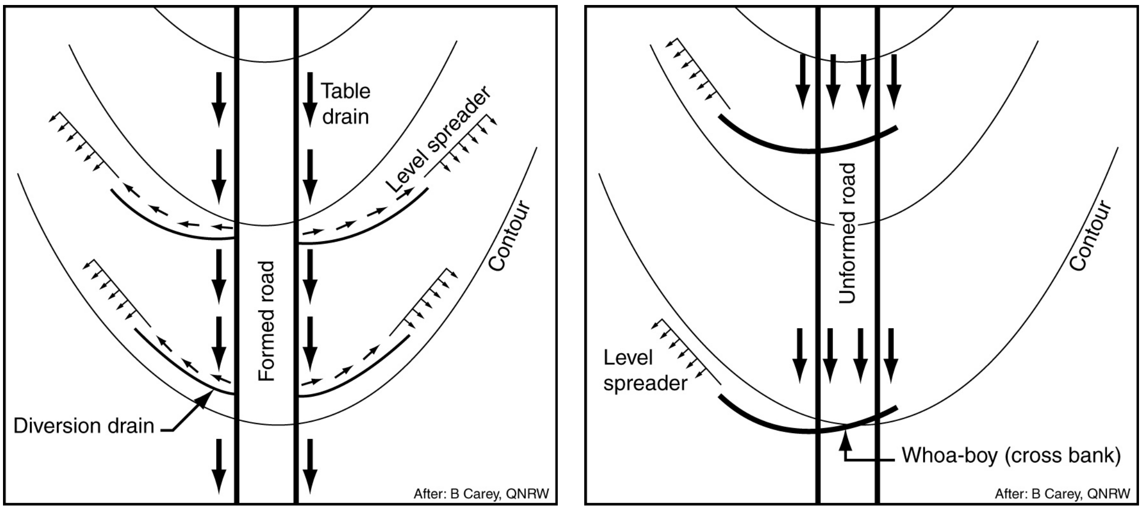


Figure K6 – Drainage of formed and unformed roads on a ridge (Carey, 1992)

In the absence of locally accepted guidelines, cross banks should be constructed at the spacing presented in Table K2.

Table K2 – Maximum spacing of cross drains [1]

Grade of track	Maximum spacing of cross drains (m)			
	Low hazard [2]		Moderate and high hazard [2]	
	North of Rockhampton [3]	Other areas	North of Rockhampton [3]	Other areas
< 9% (5°)	60	80	30	40
9–27% (5-15°)	40	50	20	30
27–47% (15-25°)	20	30	10	20
> 47% (25°) [4]	10	20	10 [4]	10 [4]

Notes:

[1] Sourced from Department of Primary Industries, Queensland – Forest Service, 1988.

[2] Soil erodibility may be recognised by the soil descriptions provided in Table K3.

[3] Only applicable in areas north and/or east of the 1000mm isohyet.

[4] Cover crop establishment of all drains is recommended on slopes exceeding 47%. Gradients of this magnitude are only recommended for short distances on these soil types.

Table K3 – Soil erodibility classification [1]

Erosion hazard rating	Soil type		Parent material [2]
	Surface texture and subsoil colour	Soil groups	
High	Shallow gravelly soils.	Lithosols	Coarse textured igneous rocks, (granites, granodiorite, diorite, gabbro).
	Sands or sandy loams with yellow, pale grey or black subsoils (or derived from granitic material).	Alluvials, podzols, siliceous sands	
	Loams or clay loams with pale grey or black subsoils.	Soloths, solodized solonetz, grey podzolics	Deeply weathered sandstones.
Moderate	Sands or sandy loams with red subsoils (except on granitic material, then erosion hazard rating is high).	Red earths, red podzolics	Sedimentary rocks (shales, mudstones, conglomerates, lightly weathered sandstones).
	Loams or clay loams with red or yellow subsoils.	Red or yellow podzolics	
	Clays with yellow, grey or black colours.	Black earths, grey or brown clays, prairie soils	Moderately hard metamorphics.
Low	Clay with yellow subsoils.	Xanthozem, euchrozem	Fine textured igneous rocks (basalt, andesite, rhyolite, trachyte).
	Clay with red subsoils.	Krasnozem	Hard metamorphics.

Notes:

[1] Sourced from Department of Primary Industries, Queensland – Forest Service, 1988.

[2] Refers to the erosion hazard of exposed weathered material other than true soil. It is not implied that the above soils are derived directly from the rocks in the adjoining column.

Notwithstanding the above guidelines, observations of actual track performance will eventually dictate the location and spacing of cross banks.

The following points should be considered when locating cross bank drainage:

- any spacing recommendations contained in regional guidelines, with appropriate adjustments made based on past experience and existing track conditions;
- location of concentrated stormwater inflow and preferred points of discharge;
- location of short sections of flatter track grade within a length of steep track that would facilitate the construction of a cross bank.

Whoa-boys cannot be used on slopes steeper than 20% because the back batter becomes too steep to be negotiated by a vehicle.

The consolidated bank should be shaped with batters no steeper than 5:1(H:V) in relation to the track grade. The bank can be shaped with the tractor blade, and the entire length of the bank should be track or wheel rolled to obtain maximum compaction and a smooth even bank.

If it is necessary to fill an eroded table drain in order to form the cross bank, then the bank should be compacted at this point with extra earth to allow for slumping and to cope with concentrated runoff within the drain.

Following construction, a small, temporary *U-Shaped Sediment Trap* may need to be constructed at the drainage outlet to collect sediment. These traps should only be constructed if they do not promote down-slope erosion or ponding on the track.

If the soil up-slope of the bank is likely to be saturated on a regular basis, and if past experience has shown that this soil will eventually turn into a “bog”, then it may be necessary to embed a sheet of synthetic earth reinforcing mesh into the soil (Figure K7). This reinforcing mesh will reduce the risk of track damage by pedestrian and vehicular traffic.

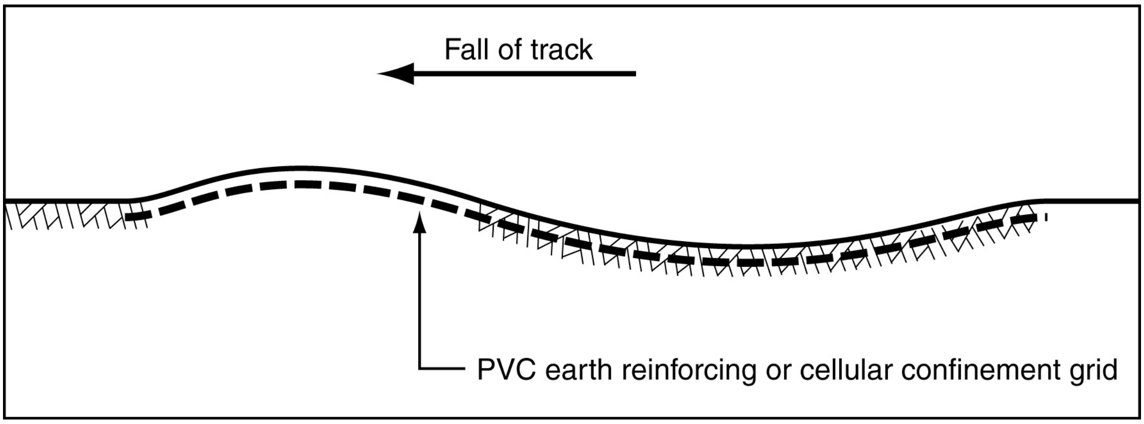


Figure K7 – Cross bank reinforced with sheet of synthetic earth reinforcing mesh

Avoid the formation of deep V-shape table drains. Wherever practicable, form wide U-shape drains to minimise potential invert erosion.

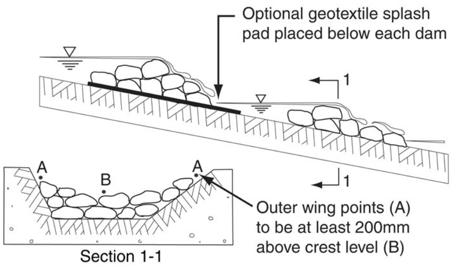
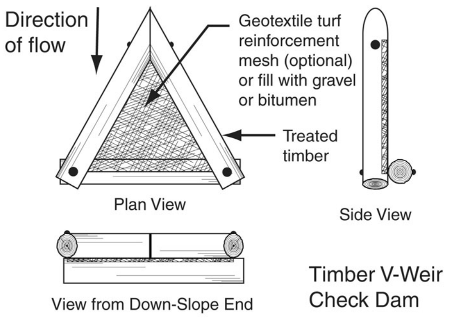
Table drain lining options are presented in Table K4. Table drains should not be sealed with an inflexible material such as concrete until the adjacent roadway is sealed or otherwise stabilised to prevent erosion.

Table K4 – Advantages and disadvantages of table drain sealing options

Option	Advantages	Disadvantages
Concrete	• Suitable in high flow velocity areas.	• Can only be used adjacent to sealed roads. • Failures may occur at driveway junctions unless care is taken in the design of the road and driveway.
Bitumen	• In most cases grass will eventually invade and replace the bitumen.	• Can only be used adjacent to sealed roads. • Grass growth can cause the bitumen to eventually fail.
Rock	• Easy to place. • Can be very stable if vegetation is allowed to interlock the rocks. • For a 300mm deep V-drain use: (i) 100mm (min) rock for slopes 5 to 12%. (ii) 150mm (min) rock for slopes 12 to 20%. (iii) 200mm (min) rock for slopes steeper than 20%.	• Difficult to clear of sediment without displacing the rocks. • Grass can eventually grow too thick and block the drains. • May require regular spraying of the grass or "wicking" to control grass growth. • High risk of failure, especially if gully erosion progresses up the drain.
Reinforced grass	• Easy placement. • Can be progressively installed.	• Difficult to clear of sediment without damaging the mats. • Grass can eventually grow too thick and block the drains. • May require regular spraying of the grass to control growth. • Introduces "plastic" to the environment. • Maintenance of the drain can be difficult. • Turf reinforcing may be damaged by grass fires.
Grass	• For a 300mm deep V-drain, grass lining is suitable for slopes of 0 to 5%.	• Requires regular cutting to prevent hydraulic blockages.

Table drain velocity-control *Check Dam* options are presented in Table K5.

Table K5 – Typical semi-permanent velocity control *Check Dams* options for unsealed table drains

Option	Advantages	Disadvantages
 **Rock Check Dam**	• Easy to place. • Rock size is 200mm to 300mm and thus can be placed by hand.	• May interfere with grass mowing. • Can lose their value when placed in drains steeper than 10% (1 in 10 fall).
 **Log V-Weir**	• Treated timber units can be assembled prior to installation. • Light to carry and thus easy to transport to remote locations.	• More expensive. • Typically can only be used in the flatter drains compared to *Rock Check Dams*. • Long-term release of wood treatment chemicals into the soils and drainage system.

"Sag" points on tracks are often subject to damage either by excessive stormwater flow across the track, or by traffic damaging the saturated track surface. In such cases it may be desirable to construct a concrete dish crossing as shown in Figure K8.

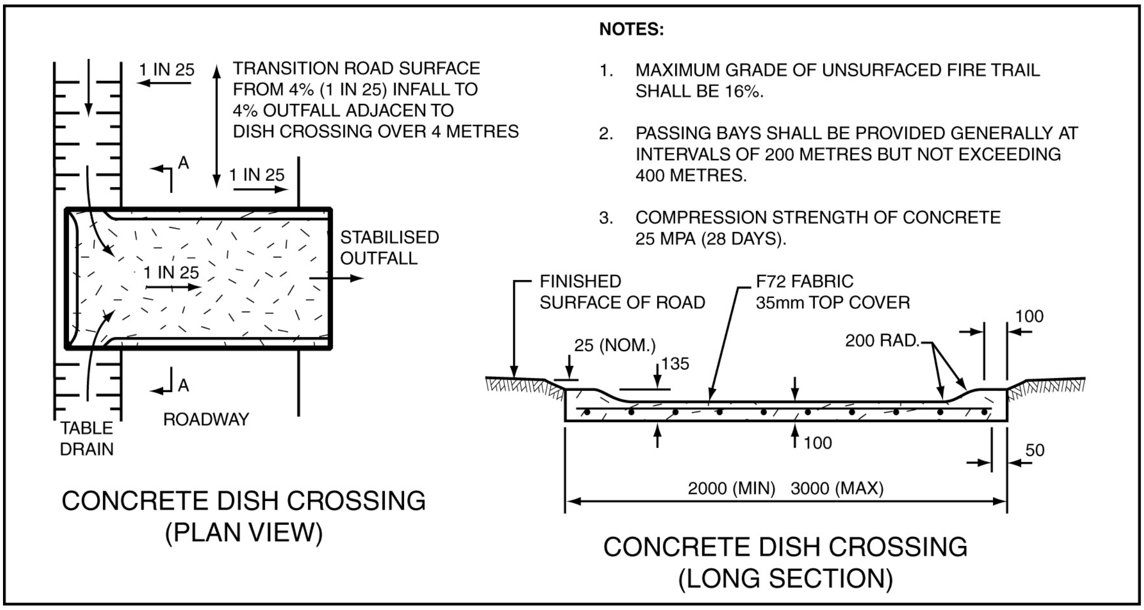


Figure K8 – Details of concrete dish crossing

(NSW Department of Housing – Fire Trail Details)

K5. Watercourse crossings

Where possible, crossings of streams should be constructed at right angles to the stream and in locations where the stream channel is straight and has well-defined banks.

When suitable materials are available, approaches to crossings should be covered with non-erodible materials such as rock or gravel. Otherwise, track layout and drainage measures should be designed to prevent sediment-laden water from running down the approaches directly into the stream as shown in Figure K9.

Access to a gully or watercourse should be protected with a cross bank immediately above the access cut (Figure K9). If the access is longer than 15m it may be necessary to construct additional flow diversions down the cutting.

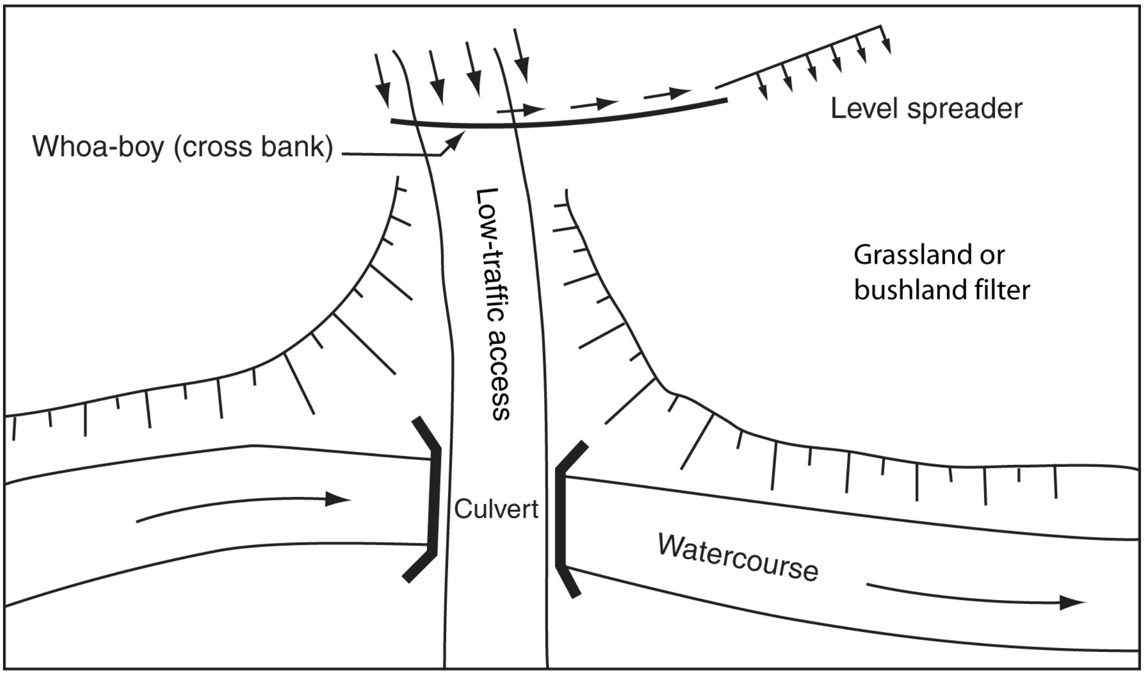


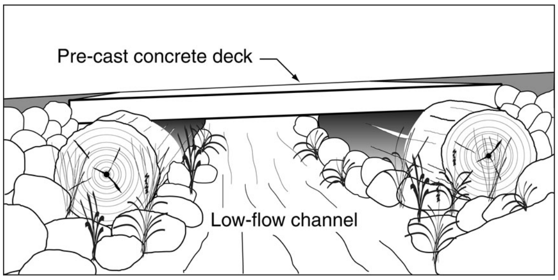
Figure K9 – Track drainage control adjacent stream crossings

Cleared vegetation and other debris should be removed from the floodplain if there is the potential for this material to cause damage to downstream structures if carried away by floodwaters.

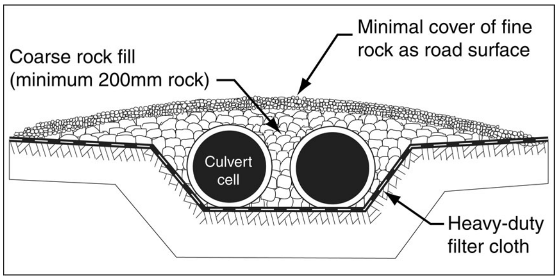
Watercourse crossings may consist of fords, culverts or bridges (Figure K10). Log dam crossings are generally not recommended because they can obstruct flood flows and create excessive turbulence and erosion.

In all cases, requirements for fish passage must be considered. In critical fish passage areas, the order of preference for waterway crossings is:

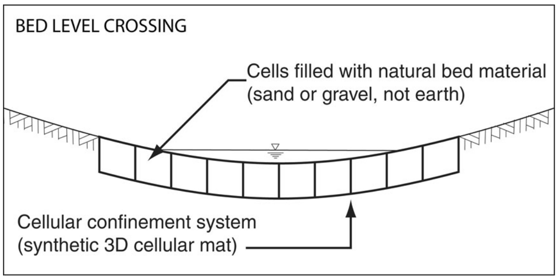
1. Bridge (preferred option)
2. Precast arch structure
3. Ford (natural bed material, or stabilised where required)
4. Buried box culvert with earth/rock bed
5. Box culvert
6. Pipe culvert
7. Causeway (least preferred)



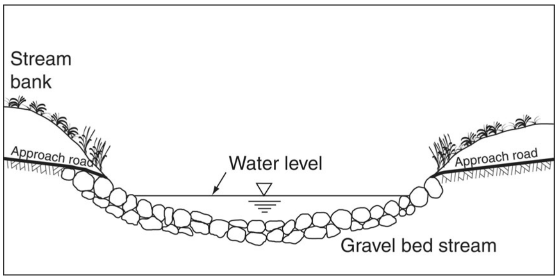
(a) Bridge formed from logs and a box culvert bridging slab



(b) Temporary pipe culvert



(c) Ford crossing stabilised with a Cellular Confinement System



(d) Natural ford crossing of a gravel-based stream bed

Figure K10 – Temporary stream crossings

Temporary bridge crossings may be formed from felled timber, or a culvert bridging slab (SLBC) suspended between well-anchored logs (as shown in Figure K10a).

Culvert designs should always consider the effects of debris blockages and potential erosive forces caused by overtopping flows. The assumed risk of debris blockage should reflect both the degree of upstream vegetation and the frequency of maintenance inspections.

The culvert diameter should be 450mm or larger, and the culvert should not discharge onto, or over, fill material. Ideally, culverts should have a flow capacity at least equal to the normal channel capacity of the watercourse when the water level is just below the crest of the culvert deck.

Embankments on a major crossing should be protected with suitable abutments, e.g. concrete, timber abutments, logs or rocks.

Appropriate consideration should be given to the following guidelines when designing culverts:

- culvert cells aligned with the downstream channel;
- culvert cells recessed 10% of their height/diameter into the bed (if fish passage is an issue);
- culvert cells should extend well beyond the fill embankment;
- riprap placed on the upstream embankment face to prevent fill material being swept into the culvert during high flows;
- armour rock placed on the downstream embankment face to control erosion caused by overtopping flows;
- where circumstances allow, the overtopping spillway may be formed adjacent the culvert to improve scour protection of the embankment.

When fish passage is critical, the low-flow conditions through culverts should be designed to simulate the existing low-flow geometry and flow velocities. Typical conditions include:

- maximum low-flow velocity over short reaches (e.g. at riffles) of 1m/s;
- maximum low-flow velocity over long reaches of 0.3m/s;
- minimum flow depth during periods of fish passage of 0.2 to 0.5m.

Witheridge (2002) provides guidelines on the design of fish-friendly watercourse crossing.

Fords should not be used where the stream has a deep channel cross-section that would require considerable bank excavation to form the approach roads, or when medium to high traffic volumes are expected. Ford crossings are generally only suitable on alluvial streams (i.e. sand-based or gravel-based streams). If the ford crossing is stabilised with a concrete pad, then fish passage problems can occur over time if the downstream bed lowers in elevation relative to the concrete pad.

Appropriate consideration should be given to the following guidelines when designing ford crossings:

- crossings at right angles to stream;
- ideally, no more than 10m road width;
- use of straight approaches that make the location of the crossing obvious even when flooded;
- use of non-erodible road surfacing material on the surface of the crossing, and for at least 15m each side of the crossing;
- bed stabilisation, if used, must be recessed to align with normal bed level;
- preferred use of flexible surfacing materials on the surface of the ford (such as rock or granular material contained within a *Cellular Confinement System* – Figure K10c) rather than concrete.

Temporary watercourse crossings should be located on sites with stable streambed material and where bank restoration will be possible. Construction activities should be timed to coincide with dry weather, and wherever practicable, removed before the commencement of the wet season. Upon removal of the crossing, the stream's bed and banks should be restored as near as possible to their original condition.

K6. Track construction

Track construction should incorporate the following practices wherever reasonable and practicable.

(i) Access tracks should be constructed with the general aim of minimising total disturbance to both soil and vegetation.

(ii) Construct the track by slashing or "blading" the surface vegetation. Avoid blading the soil except where it is necessary to build a track bench on side-slopes, to form drainage line approaches, or to make rough surfaces trafficable.

(iii) Tree clearing should be limited to 0.5m either side of the track. Where extra clearing widths are needed to allow for sun drying of the track or adequate safe-sight distance, or similar, then clear by felling rather than dozing to limit the amount of soil disturbance.

(iv) Track clearing should be reduced to the minimum practical within 30m of any watercourse.

(v) Where drainage conditions and soil properties allow, batters less than 1.5m in height should be cut vertically or to the maximum sustainable gradient for the given soil conditions.

(vi) If the soil exposed in batter construction is dispersive, then the batter should be cut back at a sufficient gradient to allow the placement of a minimum 200mm layer of non-dispersive soil on the batter.

(vii) Cut batters that are higher than 1.5m may require special stabilisation measures including laying back, revegetation and installation of suitable drainage.

(viii) Excessive or concentrated stormwater runoff up-slope of a batter should be suitably controlled and discharged either along or down the batter with the use of *Catch Drains,* or *Chutes*.

(ix) Fill batters should be no steeper than 2:1(H:V) and flatter where possible to encourage natural revegetation. Vegetation debris should not be allowed to contaminate fill because this will result in poor compaction with hollows and slumping occurring as the vegetation rots.

(x) When work is necessary next to a watercourse, precautions should be taken to contain sediment and stabilise the work area during construction to minimise erosion. The area should be stabilised within 1 week, unless stream flows are considered extremely unlikely during the proposed revegetation period.

(xi) Push-outs should be suitably cleared prior to any earthworks such that displaced earth will not cause trees to fall onto surrounding vegetation.

(xii) Where necessary, swampy or unstable ground should be reinforced with synthetic earth reinforcement mesh (e.g. geogrid) to allow construction of the track to progress and to reduce the risk of bogging heavy equipment.

(xiii) Grubbing in fine-grained soil should be avoided during wet weather.

(xiv) Exposed springs should be managed with appropriate sub-surface drainage (e.g. subsoil drainage or aggregate drain).

(xv) Appropriately bench the virgin soil before placement of fill to prevent slippage along the interface.

(xvi) If the track is temporary, then culverts and fill deposited within floodplain areas should be removed when no longer required.

K7. Maintenance

Frequent maintenance is essential to ensure effective erosion control and track stability, especially in the early years after construction. It is essential that a sound cover of vegetation and/or forest litter develops on the surface of the track, on constructed batters, and on approaches to watercourse crossings.

A maintenance program should consider the following points (Soil Conservation Services of NSW, 1990).

(i) Inspect all tracks at least annually and following heavy traffic usage or exceptionally heavy rainfall, especially if culvert crossings are used.

(ii) Restrict destruction of vegetation to the removal of excess regrowth preferably by slashing or spraying.

(iii) Do not remove any more vegetation than is necessary to maintain safety on the track. Fell timber rather than bulldozing. Where possible, stumps should be left intact, especially above cut batters and adjacent to drainage lines.

(iv) Avoid unnecessary grading or blading during maintenance. This usually requires the appropriate training of maintenance personnel.

(v) Leave material slumping from cut batters untouched if it does not unduly restrict the operating width of the track. If it is necessary to remove material, take care to avoid undercutting the toe of the batter.

(vi) Encourage effective outfall drainage by removing any windrows along the outside edge of the trail.

(vii) The location, spacing and size of cross banks should be reviewed when developing a maintenance program. An appropriate cross bank spacing will be indicated by the distance water runs on a track or within the table drain before rilling commences.

(viii) All table drains should be stable. If scouring occurs, they should be reformed to a broad dish shape, seeded, fertilised and protected with jute mesh and bitumen, or other similar surface protection or flow control structures.

(ix) Do not dispose of timber, scrub, soil or debris along drainage lines or within flood prone areas.

(x) Fencing should be installed and maintained, as required, to control unauthorised traffic or material dumping, especially if public safety problems can occur as a result of such unauthorised activities.

(xi) During grading operations, loose material should be moved towards the centre of the roadway to avoid the loss of essential fines from the surface mix and to avoid the creation of windrows.

K8. Track sediment yield

Expected track sediment yield may be estimated from the work of Melbourne Water (1991).

(i) The rate of coarse sediment production from a typical Melbourne Water unsealed road is in the order of 30t/ha/yr. By comparison, an undisturbed forested catchment may produce approximately 0.3t/ha/yr in total sediment.

(ii) The case of a high use and low maintenance regime produces approximately 35t/ha/yr of coarse sediment; however, under high maintenance this drops to 27t/ha/yr. This compares with the low use, low maintenance test road that, in the long-term, produced approximately 18t/ha/yr of coarse sediment. The low use, low maintenance test road produced 30t/ha/yr lying between the two high use maintenance regimes.

(iii) As would have been intuitively expected, a properly gravelled road produces less sediment than an unsealed road. However, if a road is to be gravelled using the local high clay, unsorted, unwashed “gravelly” material, the gravelling thickness must be adequate, because a “thinly” gravelled road produced the most sediment and deteriorated quickly. Data from the gravelling phases show 38t/ha/yr of coarse sediment and 41g/L of suspended sediment from the thinly gravelled road was produced, compared with 20t/ha/yr and 35g/L for the thicker gravelling treatment.

(iv) Under a low use regime, the level of road maintenance was not a factor in sediment production. However, under a high use regime, the level of maintenance had a significant impact on erosion rates.

(v) Suspended sediment production was of the order of 23g/L under low use, low maintenance, ranging up to 35 to 40g/L under high use, low maintenance. Under high use, high maintenance conditions the suspended sediment rate dropped to 23g/L. However, these figures should be treated with caution due to expected sampling problems.

Melbourne Water (1991) made the following recommendations and conclusions.

- Unsealed earth roads of about 10% grade built in a stable clay subsoil can produce an average 45–60t/ha/yr of sediment.
- About one-third of the above load is coarse sediment and two-thirds is suspended sediment.
- Where such a road is subject to a low level of use only, a low level of surface maintenance is required between periodic gradings. Where the road is subject to a high level of use, a high level of surface maintenance is required to reduce sediment production.
- Roads are most susceptible to disturbance and have their sediment production increased during periods of wet weather (longitudinal wheel rutting occurs, concentrating surface runoff and erosion). Minimising use during these periods will reduce sediment production.
- The surface of thinly gravelled roads rapidly deteriorates compared to the surface of thickly gravelled roads.
- Gravelled roads can produce high volumes of sediment immediately after gravelling. This may present a significant management problem.
- To protect water quality, maintenance, good road design, drainage and appropriate management (i.e. access) policies are essential.

K9. References

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Melbourne Water 1991, *The Effect of Vehicle Use and Road Maintenance on Erosion from Unsealed Roads in Forests: The Road 11 Experiment*. Editors, S.R. Haydon, M.D.A. Jayasuriya and P.J. O'Shaughnessy, Water Supply Catchment Hydrology Research, Report No. MMBW-W-0018.

Ontario Ministry of Natural Resources 1990, *Environmental Guidelines for Access Roads and Water Crossings*. Ministry of Natural Resources, Toronto, Canada.

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Witheridge, G.M. 2002, *Fish Passage Requirements at Waterway Crossings – Engineering Guidelines.* Catchments & Creeks Pty Ltd, Brisbane.

Appendix L

Installation of services

This appendix provides a model code of practice for the installation of minor underground services such as stormwater, water supply, wastewater, gas and telecommunications. The function of this appendix is both educational and prescriptive. Those people wishing to apply erosion and sediment control measures to the installation of services should first ensure that they familiar with the general principles outlined in Chapter 2 – Principles of erosion and sediment control.

Service providers are encouraged to adopt the following code of practice or develop their own in-house code using the model code as a guide. Such a code should include default erosion and sediment control procedures and plans for typical site activities.

L1. Introduction

The principles of Erosion and Sediment Control (ESC) as used by service providers and those contracted to install services are the same as those used by the general building and construction industry. Differences exist only in which principles attract a greater degree of attention.

Broad acre residential construction normally focuses on the management of water movement and soil erosion across wide areas, with sediment control occurring at key stormwater collection points. On the other hand, service providers often operate within an existing building envelope, and the primary focus of their sediment control is usually on the appropriate management of stockpiles and trench de-watering activities.

As for all aspects of the construction industry, service providers must take all reasonable and practicable measures to:

- minimise the adverse environmental impacts resulting from their products, processes and activities;
- actively promote employee awareness of the potential environmental risks associated with their work activities, and the means of managing these risks;
- monitor and review environmental outcomes, making appropriate modifications to work practices and operational guidelines;
- appropriately address areas of non-conformance;
- report the provider's environmental performance both internally and externally.

The application of erosion and sediment control on the small soil disturbances commonly associated with the installation of services can generally be achieved through consideration of the following rules:

1. **Safety first**—don't install or operate an ESC device in a manner that may cause a safety hazard.
2. **Look up the slope**—judge where stormwater runoff may come from, then if practicable, and if rain is likely, divert this runoff around any soil disturbance.
3. **Look at the site**—judge the best way to access the site, stockpile materials, perform the necessary works, and de-water trenches, while taking all reasonable and practicable measures to minimise the extent and duration of soil disturbance.

4. **Look down the slope**—judge where sediment runoff will flow, then place appropriate sediment traps to filter or settle-out sediment.

5. **Look at the sediment controls**—immediately following the installation of any sediment trap, confirm that water will temporarily pond up-slope of the trap, and will **not** simply be diverted around the trap.

6. **Leave the site in a stable condition**—it is important to minimise the duration disturbed soils will be exposed to rainfall and ongoing soil erosion problems.

L2. Model Code of Practice

This model Code of Practice has been provided as a practical example of an operational guideline for erosion and sediment control during the installation of minor services.

Compliance with a given Performance Criterion can only be achieved by:
- (i) complying with the Acceptable Solution; or
- (ii) formulating an alternative solution which complies with the Performance Criterion, or is shown to be at least equivalent to the acceptable solutions; or
- (iii) a combination of (i) and (ii).

Attachment A forms part of this Code. The Attachment provides essential information and requirements not otherwise provided within the Code.

In the event of a conflict over the desired outcome of a *Performance Criterion* or an *Acceptable Solution*, then the outcome must be that which best achieves the *"objective"* of the Code, that being:

> *To protect the environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.*

If the scheduled works incorporate the following construction activities, then the relevant operational Code of Practice should be consulted:
- (i) construction of a building—refer to Appendix H (*Building sites*) for management practices;
- (ii) major service installation, construction or earthmoving activity—refer to Appendix G (*Model code of practice*) for management practices.

This model Code of Practice does not provide all the information necessary to adequately control soil erosion and sediment runoff in all situations. Users of the Code should always make their own site-specific evaluation, testing and design and rely on their own advisers and consultants.

Specifically, the adoption of this model code of practice will not guarantee:
- (i) compliance with any statutory obligations;
- (ii) avoidance of environmental harm or nuisance.

SITE PLANNING			
Performance Criteria		**Acceptable Solution**	
P1	Adequate site data is obtained to allow appropriate site planning.	**A1**	The extent and complexity of site data, including soil mapping, is commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance.
P2	Site planning aims to minimise the risk of environmental harm.	**A2**	(a) Development of the Erosion and Sediment Control Plan (ESCP) is an integral part of site planning. (b) High-risk construction activities are identified during site planning. (c) High-risk construction activities and disturbances of high to extreme erosion hazard areas are minimised, if no totally avoided, especially during periods of high to extreme erosion potential. (d) All reasonable and practicable measures are taken to design/plan the site layout, programming, staging and methodology to minimise environmental risks associated with high-risk work activities. (e) Site planning aims to minimise the duration that any and all areas of soil will be exposed to the erosive effects of wind, rain and flowing water, in part through the progressive and prompt stabilisation of disturbed areas.

EROSION AND SEDIMENT CONTROL PLAN (ESCP)			
Performance Criteria		**Acceptable Solution**	
P3	An Erosion and Sediment Control Plan (ESCP) is prepared prior to site disturbance that provides sufficient information to achieve the required environmental protection.	**A3**	(a) The design standard of drainage, erosion and sediment controls comply with the requirements of the relevant regulatory authority, or where such a standard does not exist, are designed in accordance with current best practice. (b) As a minimum, the ESC design standard applied to a site at any given instant is commensurate with the degree of environmental risk, and the type, cost, and scope of the proposed works. (c) The level of information and detail supplied in the ESCP is commensurate with the potential environmental risk and the complexity of the proposed works; and of sufficient clarity to allow on-site personnel to appropriately implement the plan. (d) The ESCP is appropriate for the site conditions and the potential environmental risk. (e) The ESCP remains both effective and flexible, and is based on anticipated soil, weather, and construction conditions (as may vary from time to time). (f) The ESCP is appropriately amended if the implemented works fail to achieve the "objective" of the ESCP, the required performance standard, or the State's environmental protection requirements.

P4	The ESCP is prepared by, or under the supervision of, suitably qualified and experienced personnel.	**A4**	(a) The qualifications and experience of the personnel preparing and/or supervising the preparation of the ESCP is commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance. (b) On sites with a soil disturbance greater than 2500m^2, the degree of review of the ESCP is consistent with best-practice requirements for general construction projects.

SITE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P5	The work site is managed such that environmental harm is minimised.	**A5**	(a) No land-disturbing activities are undertaken prior to appropriate consideration being given to erosion and sediment control issues. (b) All works subject to an Erosion and Sediment Control Plan (ESCP) are carried out in accordance with the ESCP (as amended from time to time) unless circumstances arise where compliance with the ESCP would increase the potential for environmental harm as assessed by a recognised authority. (c) All ESC measures are installed, operated and maintained in accordance with current best management practice. (d) Land-disturbing activities are undertaken in such a manner that allows all reasonable and practicable measures to be undertaken to: (i) allow stormwater to pass through the site in a controlled manner and at non-erosive flow velocities; and (ii) minimise soil erosion resulting from wind, rain and flowing water; and (iii) minimise the duration that disturbed soils are exposed to the erosive forces of wind, rain and flowing water; and (iv) prevent, or at least minimise, environmental harm (including public nuisance and safety issues) resulting from work-related soil erosion and sediment runoff. (e) Land-disturbing activities do not cause unnecessary soil disturbance. (f) Site spoil is lawfully disposed of in a manner that does not result in ongoing soil erosion or environmental harm.
P6	Disturbance to ESC measures by on-site personnel is minimised.	**A6**	(a) On-site personnel are appropriately instructed and educated as to the purpose and operation of adopted drainage, erosion and sediment control (ESC) measures, and the need to maintain such measures in proper working order at all times. (b) Unnecessary disturbance to ESC measures by on-site personnel, sub-contractors and construction traffic (including site management and material delivery vehicles) is minimised.

P7	The adopted ESC measures remain relevant at all times to the current site conditions.	**A7**	(a) The adopted erosion and sediment control measures are appropriately amended if site conditions significantly change, or are expected to significantly change, from those conditions assumed during development of the ESCP. (b) The adopted erosion and sediment control measures are appropriately amended if the implemented works fail to achieve the “objective” of the ESCP, or the required performance standard, or the State’s environmental protection requirements, or unacceptable environmental harm is occurring or is likely to occur.
P8	The work site is appropriately prepared for imminent construction activities and weather conditions.	**A8**	(a) Adequate supplies of drainage, erosion and sediment control, and relevant pollution clean-up materials, are retained on-site during the construction period. (b) Appropriate short-term drainage control measures (e.g. flow diversion around recently opened trenches and excavations) are installed and operational prior to impending storms.
P9	Damage to retained or protected vegetation is minimised.	**A9**	(a) Prior to the commencement of land disturbing activities within any given area, all protected vegetation and significant areas of retained vegetation within that area, are appropriately identified to minimise the risk of disturbance to such areas. (b) No damage is allowed to occur to roots, trunk or branches of “retained” vegetation, unless under the direction of an appropriate Vegetation Management Plan.
P10	Adopted work practices minimise the release of pollutants into receiving waters.	**A10**	(a) Emergency and pollution control procedures are commensurate with the site conditions, local environmental values, and the type, cost, scope and complexity of the works. (b) Cement-laden runoff, concrete waste, and chemical products (including petroleum and oil-based products), are managed on-site in accordance with current best management practice. (c) Brick-, tile- and masonry-cutting activities are carried out in accordance with current best management practice. (d) Washing of tools and painting equipment is carried out in accordance with current best management practice.
P11	Environmental harm, safety issues, and nuisance or damage to public and private property resulting from off-site sediment deposits, material spills, and/or the adopted ESC measures is minimised.	**A11**	(a) Sediment and other material originating from the work area, or as a result of the transportation of materials to or from the work area, that collects on sealed roads, or within gutters, drains or waterways outside the immediate work area, is removed: (i) immediately if rain is occurring or imminent; or (ii) immediately if considered a safety hazard; or (iii) if items (i) or (ii) do not apply, as soon as practicable, but before completion of the day’s work. (b) Washing/flushing of sealed surfaces only occurs where sweeping has failed to remove sufficient

			sediment, and there is a compelling need to remove the remaining sediment (e.g. for safety reasons). (c) Sediment deposits that cause nuisance to, or adversely affect the use or value of, neighbouring properties are removed and the area rehabilitated as soon as practicable. (d) The adopted ESC measures do not adversely affect drainage or flooding conditions within neighbouring properties.
P12	Potential safety risks to site workers and the public as a result of ESC measures are minimised.	**A12**	Operational safety issues (public and site personnel) are given appropriate consideration during the installation, operation, maintenance and removal of ESC measures.
P13	Potential harm to wildlife as a result of ESC measures is minimised.	**A13**	Synthetic (plastic) reinforced fabrics are not placed within, or adjacent to, bushland areas, riparian zones and watercourses if such materials are likely to cause harm to wildlife or wildlife habitats.
P14	Disturbance to natural watercourses is minimised.	**A14**	(a) Instream works are conducted in accordance with an approved Code of Practice for instream works. (b) No instream land-disturbing activities are undertaken prior to development of a Vegetation Management Plan. (c) Disturbance to natural watercourses (including bed and bank vegetation) and their associated riparian zones is limited to the minimum necessary to complete the approved works.

LAND CLEARING			
Performance Criteria		**Acceptable Solution**	
P15	Potential environmental harm is minimised as a result of land clearing.	**A15**	(a) All land clearing is conducted in accordance with State and local government Vegetation Protection and/or Preservation requirements and/or policies. (b) On sites with a soil disturbance greater than one (1) hectare, no land clearing is undertaken prior to approval of a Vegetation Management Plan. (c) Limits on the extent and duration of soil disturbance are commensurate with the potential erosion risk and/or erosion hazard.
P16	Land clearing is limited to the minimum necessary.	**A16**	(a) Land clearing does not cause unnecessary soil disturbance if an alternative process (which reduces the potential environmental harm) is available that achieves the same or equivalent project outcomes at a reasonable cost. (b) Land clearing at any given time during periods of potential soil erosion is restricted to only those areas required for the current stage of works.
P17	Soil erosion during and following land clearing is minimised.	**A17**	(a) Land clearing within any sub-area is delayed as long as reasonable and practicable. (b) Land clearing and site rehabilitation are staged to minimise the extent and duration that any and all areas of soil are exposed to the erosive effects of wind, rain and flowing water.

			(c) If tree clearing is required well in advance of future earthworks, then tree clearing methods that will minimise potential soil erosion are employed, especially in areas of high to extreme erosion risk.

SOIL AND STOCKPILE MANAGEMENT			
Performance Criteria		**Acceptable Solution**	
P18	Maximum benefit is obtained from existing topsoil.	**A18**	(a) The topsoil is managed (i.e. stripped, treated, stockpiled and reused) in accordance with the recommendations of an approved Vegetation Management Plan or similar. OR (b) Topsoil is stripped, stockpiled, placed, and where necessary treated, in accordance with current best practice. AND (c) Topsoil originating from the site is respread as the topsoil to maximise erosion control and revegetation, except where it has been assessed that such soil will not improve erosion control and/or revegetation on the site.
P19	Environmental harm caused by the temporary stockpiling of erodible material is minimised.	**A19**	Stockpiles of erodible material are: (i) located fully within the relevant property; (ii) appropriately protected from wind, rain and excessive surface flows in accordance with current best practice; and (iii) located at least 2m from hazardous areas, retained vegetation, and overland flow paths; and (iv) located up-slope of an appropriate sediment control system.
P20	Exposed dispersive soils are managed such that the risk of ongoing soil erosion is minimised.	**A20**	Construction details for drainage systems and bank stabilisation works within dispersive soil areas clearly demonstrate how these soils will be managed to prevent future erosion problems.
P21	Exposed potential acid sulfate soils are appropriately managed.	**A21**	(a) If acid sulfate soils conditions exist on site, then appropriate warnings are placed on the ESCP. (b) All exposed actual or potential acid sulfate soils are managed in accordance with current best practice. (c) On-site personnel involved in the disturbance of actual or potential acid sulfate soils are appropriately trained and/or supervised.

DRAINAGE CONTROL			
Performance Criteria		**Acceptable Solution**	
P22	Temporary drainage control measures are designed, constructed and maintained to an appropriate standard.	**A22**	The standard of drainage control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, drainage controls are designed in accordance with current best practice.
P23	Stormwater movement through the site is appropriately managed to minimise soil erosion.	**A23**	(a) If the drainage area up-slope of a soil disturbance exceeds 1500m^2, and the average monthly rainfall exceeds 45mm, all stormwater discharged from this area (up to the design storm) is diverted around or through the soil disturbance in a manner that minimises soil erosion. (b) Flow velocities within drainage channels and at the entrance and exit of all drainage structures (including chutes, slope drains and spillways) are controlled in such a manner that prevents soil erosion during all discharges up to the relevant design discharge.
P24	Stormwater movement through the site is appropriately managed to minimise environmental harm.	**A24**	(a) All temporary and permanent drainage systems are installed as soon a practicable. (b) “Clean” water is diverted around sediment traps in a manner that maximises the sediment trapping efficiency of the sediment trap. (c) All reasonable and practicable measures are taken to ensure stormwater runoff entering an area of soil disturbance is diverted around or through that area in a manner that minimises soil erosion and contamination of that water for all discharges up to the specified design discharge. (d) Adequate drainage controls (e.g. cross drainage systems and/or longitudinal drainage) are applied to all unsealed roads and tracks to minimise erosion on, and sediment runoff from, such surfaces. (e) All reasonable and practicable measures are taken to ensure sediment-laden runoff from access roads and stabilised entry/exit systems drains to an appropriate sediment control device. (f) All reasonable and practicable measures are taken to divert stormwater around excavations and trenches.
P25	Stormwater entering into, or discharged from, the site is appropriately managed to minimise flooding, damage and nuisance to neighbouring properties.	**A25**	(a) All waters discharged during the construction phase are discharged onto stable land, in a non-erosive manner, and at a legal point of discharge. (b) All drainage channels up-slope of neighbouring properties are constructed and maintained with sufficient size, gradient and surface conditions to maintain the required hydraulic capacity. (c) Stormwater is not unlawfully diverted into neighbouring properties.

EROSION CONTROL			
Performance Criteria		**Acceptable Solution**	
P26	Erosion control measures are designed, installed and maintained to an appropriate standard.	**A26**	(a) The standard of erosion control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, erosion controls are designed in accordance with current best practice. (b) As a minimum, the type and degree of erosion control are commensurate with the expected site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.
P27	The control of soil erosion is given appropriate priority.	**A27**	(a) Wherever reasonable and practicable, priority is given to the prevention, or at least minimisation, of soil erosion, rather than allowing soil erosion to occur and trying to trap the resulting sediment. (b) The existence of best practice sediment control measures within a given sub-catchment does not diminish the need for the application of best-practice erosion control measures.
P28	Soil erosion is minimised.	**A28**	(a) Site activities are carried out in a manner that minimises the duration that any and all disturbed soil surfaces are exposed to the erosive forces of wind, rain and surface water. (b) Erosion control measures are applied to exposed soils as soon as practicable after earthworks have been completed within each sub-area. (c) Unfinished earthworks that are not expected to be disturbed for an extended period of time (relative to the erosion risk) are appropriately stabilised in accordance with current best practice.
P29	Soil erosion resulting from surface water flow is minimised.	**A29**	Service trenches are: (i) backfilled, compacted, capped with a layer of topsoil to a level at least 75mm above the adjoining ground level, and rehabilitated; or (ii) backfilled, compacted and rehabilitated in a manner that best prevents undesirable water flow and soil erosion along the trench.
P30	Soil erosion resulting from wind erosion is minimised.	**A30**	(a) Erosion control measures used to control wind erosion are commensurate with soil exposure and the expected wind conditions in terms of speed and direction. (b) Stockpiles of erodible material are covered during periods of strong wind or when strong winds are imminent.

SEDIMENT CONTROL			
Performance Criteria		**Acceptable Solution**	
P31	Sediment control measures are designed, installed, operated and maintained to an appropriate standard.	**A31**	(a) The standard of sediment control complies with the requirements of the relevant regulatory authority, or where such a standard does not exist, sediment controls are designed in accordance with current best practice. (b) As a minimum, the type and degree of sediment controls are commensurate with the site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.
P32	The on-site retention of sediment is maximised.	**A32**	(a) All reasonable and practicable measures are taken to prevent, or at least minimise, the release of sediment from the site, or into water where it is likely to cause environmental harm. (b) Appropriate sediment controls are installed and made operational before any up-slope soil disturbance occurs. (c) All sediment-laden runoff from the site is directed to an appropriate sediment control device in accordance with the required treatment standard. (d) Sediment traps are designed, constructed, and maintained to collect and **retain** sediment.
P33	Sediment displaced off-site by vehicular traffic is minimised.	**A33**	(a) Number of site entry/exit points is limited to the minimum practical number. (b) Site entry/exit points are appropriately designed and stabilised to minimise sediment being washed off the site by stormwater and/or being transported off the site by vehicles. (c) All reasonable and practicable measures are taken to ensure sediment-laden stormwater runoff from access roads and stabilised entry/exit systems drains to an appropriate sediment control device.
P34	Sediment-related environmental harm resulting from de-watering activities is minimised.	**A34**	(a) Flow diversion barriers, or other appropriate systems, are used to minimise the quantity of watering entering excavations and trenches. (b) All sediment control measures implemented for the control of sediment-laden discharge from de-watering activities are designed to satisfy, as a minimum, current best practice discharge standards. (c) As a minimum, the type and degree of sediment controls utilised during de-watering operations are commensurate with the site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.
P35	The quantity of sediment released within process water resulting from work activities is minimised.	**A35**	Waste water from work activities such as “directional drilling” is: (i) suitably treated on-site to minimised turbidity levels and suspended sediment; or (ii) collected and transported from the site in a manner that does not cause ongoing environmental harm.

SITE STABILISATION AND REHABILITATION			
Performance Criteria		**Acceptable Solution**	
P36	Site rehabilitation, including site revegetation, is designed, installed and maintained to an appropriate standard.	**A36**	(a) The standard of site rehabilitation complies with the requirements of the relevant regulatory authority or, where such a standard does not exist, complies with current best practice. (b) As a minimum, the type and degree of site rehabilitation is commensurate with the expected site conditions, soil type, potential environmental risk, and the type, cost and scope of the works.
P37	Site rehabilitation methods and procedures minimise the risk of environmental harm.	**A37**	(a) Disturbed soil surfaces are appropriately stabilised to minimise the risk of short-term soil erosion. (b) Site stabilisation and/or revegetation are commenced as soon as practicable after earthworks are completed within any given manageable drainage area. (c) All temporary ESC measures are removed and the land rehabilitated as soon as practicable after they are no longer needed.
P38	Site rehabilitation methods, procedures, and outcomes are compatible with site conditions and local environmental values.	**A38**	The qualifications and experience of the personnel preparing and/or supervising the preparation of any Site Stabilisation Plan, Vegetation Management Plan, or similar, are commensurate with the potential environmental risk, and the extent and complexity of the works.

SITE INSPECTION AND MONITORING			
Performance Criteria		**Acceptable Solution**	
P39	Appropriate personnel are engaged to implement and monitor all necessary ESC measures.	**A39**	(a) Prior to the commencement of any construction activities or soil disturbance, appropriately trained and experienced personnel are engaged to undertake regular ESC audits of the site. (b) Prior to commencement of site works, a “Chain of Command” in relation to the implementation, modification, and maintenance of Site Erosion and Sediment Control measures is established. (c) Site managers and/or the nominated responsible ESC personnel achieve and maintain a good working knowledge of the correct installation and operational procedures of all ESC measures used on the site.
P40	A Monitoring and Maintenance Program is prepared by, or under the supervision of, suitably qualified and experienced personnel.	**A40**	The qualifications and experience of the personnel preparing and/or supervising the preparation of the Monitoring and Maintenance Program is commensurate with the potential environmental risk, and the extent and complexity of the works.
P41	The performance of the site’s drainage, erosion and sediment control measures is regularly monitored.	**A41**	(a) The extent and complexity of site monitoring (including water quality monitoring) is commensurate with the potential environmental risk, and the extent and complexity of the works. (b) A record is maintained of the site’s compliance and non-compliance with erosion and sediment

			control approval requirements. (c) All site monitoring data including environmental incidents, rainfall records, dates of water quality testing, testing results, and records of controlled water releases for the site, are kept in an on-site register.
P42	The site's drainage, erosion and sediment control measures remain relevant at all times to the current site conditions.	**A42**	(a) The adopted ESC measures remain relevant at all times to the current and imminent site conditions. (b) All ESC measures are inspected by site personnel: (i) at least daily (when work is occurring on-site); (ii) at least weekly (when work is not occurring on-site); (iii) within 24 hours of expected rainfall; and (iv) within 18 hours of a rainfall event of sufficient intensity and duration to cause runoff on the site.

SITE MAINTENANCE			
Performance Criteria		**Acceptable Solution**	
P43	All ESC measures are maintained in proper working order at all times during their required operational life.	**A43**	(a) All ESC measures are maintained in proper working order for the duration of the period in which their operation is required in order to satisfy the required treatment standard, and/or the objective of the ESCP. (b) All sediment control measures are maintained in accordance with the requirements of the relevant regulatory authority, or where such a standard does not exist, in accordance with current best practice.
P44	The maintenance of ESC measures does not cause environmental harm.	**A44**	All materials removed from ESC devices during maintenance or decommissioning, whether solid or liquid, is lawfully disposed of in a manner that does not cause ongoing soil erosion or environmental harm.

Attachment A (Services code of practice)

SITE PLANNING

The *intent* of the Site Planning section is to:
- take all reasonable and practicable measures to actively avoid foreseeable soil erosion problems and associated environmental hazards during the construction/installation phase; and
- ensure that those involved in construction planning do **not** assume that the environmental impact of such hazards can be totally resolved (irrespective of the site's layout, methodology, staging, and programming) through applying best practice erosion and sediment control.

"Site planning" refers to planning the layout, methodology, staging, and programming (timing and scheduling) of the construction/installation phase.

Acceptable Solution A1
Data collection may include soil testing, identification of potential site constraints, and development of a Conceptual Erosion and Sediment Control Plan (where such data and/or plans are considered reasonably necessary to enable appropriate site planning and design). Appropriate site planning and design refers to the aim of minimising the potential environmental harm (both during the construction and operational phases) of the development. The extent and complexity of data collection is discussed further in Chapter 3 – *Site planning*.

Sufficient soil data must be obtained on the site to:
(i) reasonable identify the location of dispersive soils;
(ii) reasonable identify the location of potential acid sulfate soils;
(iii) allow the appropriate selection, design and specification of ESC measures;
(iv) maximise the erosion control benefits of the proposed site revegetation and stabilisation works.

The "potential environmental risk" relates to the potential of a land disturbing activity to cause harm, whether material, serious, reversible or irreversible, to an environmental value, including nuisance to a neighbouring property or person. The potential environmental risk is related, in part, to the assessed Erosion Hazard (refer to Appendix F – *Erosion hazard assessment*).

Acceptable Solution A2(a)
Ideally, Erosion and Sediment Control Plans (ESCPs) should be developed in close association with construction planning because the needs and limitations of the construction process represent an important component of the ESCP. In theory, a construction process cannot be finalised without reference to an ESCP, and an ESCP cannot be finalised without knowledge of the construction process.

Acceptable Solution A2(b) & (c)
Construction activities that are deemed to represent a high to extreme erosion hazard include:
- Any disturbance of high to extreme hazard areas, or a problematic soil that could result in unmanageable soil erosion and/or environmental harm.
- Any installation, construction or building activity, or procedure, that could potentially cause "serious" environmental harm.
- Any soil disturbance that could cause the transformation of significant quantities of potential acid sulfate soils (PASS) into actual acid sulfate soils (AASS), such as to cause "material" or "serious" environmental harm.

Periods of high and extreme erosion potential refers to the variation in the erosion hazard throughout a calendar year based on variations in the rainfall erosivity as described in Appendix E – *Soil loss estimation*. Periods of high to extreme erosion potential include:
- periods of high to extreme erosion risk as defined in Section 4.4 of Chapter 4 – *Design standards and technique selection*; and
- periods of strong winds sufficient to cause significant dust problems.

EROSION AND SEDIMENT CONTROL PLAN (ESCP)

The *intent* of this section is to ensure Erosion and Sediment Control Plans (ESCPs):

- are appropriate for the site conditions, which may vary from time to time;
- are prepared by, or under the supervision of, suitable personnel;
- are able to achieve the required design standard and environmental protection.

Acceptable Solution A3(a)
Such a clause shall not reduce the responsibility of applying and maintaining, at all times, all necessary sediment control measures in accordance with the sediment control standard.

Acceptable Solution A3(b)
It is recognised that the degree of erosion and sediment control is related to the type, cost and scope of works in addition to the environmental risk. This association is acknowledged within the terms of current best practice erosion and sediment control as defined within this document (2008 conditions).

Acceptable Solution A3(c)
On very minor works, such as regular council maintenance activities, or the installation of minor services, the ESCP may be represented by standard drawings prepared by the principle company/organisation as part of an adopted Code of Practice. The key *intent* is to ensure that appropriate consideration is given to erosion and sediment control requirements **before** works commence.

Site-specific ESCPs must address all aspects of proposed site disturbance, temporary drainage works, erosion and sediment control measures, installation sequence, and site rehabilitation for the duration of the construction phase, including (where appropriate) the nominated maintenance period.

Acceptable Solution A3(e)
The timing and degree of ESC specified in the Erosion and Sediment Control Plan(s) needs to be appropriate for the given soil properties, expected weather conditions, and susceptibility of the receiving waters to environmental harm resulting from sediment-laden runoff. Current (2008) best practice design standard of the drainage, erosion and sediment control measures are outlined in Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A3(f)
Additional and/or alternative erosion and sediment control measures must be implemented, and a revised Erosion and Sediment Control Plan (ESCP) must be prepared and submitted to relevant regulatory authority for approval (where required) in the event that:

(i) site conditions significantly change from those previously anticipated; or

(ii) there is a high probability that serious or material environmental harm might occur as a result of sediment leaving the site; or

(iii) the implemented works fail to achieve the adopted ESC standard, or the State's environmental protection requirements; or

(iv) site inspections indicate that the implemented works are failing to achieve the objective of this ESCP.

SITE MANAGEMENT

Acceptable Solution A5(a)
Where appropriate, an Erosion and Sediment Control Plan is prepared (in accordance with Section G3.3), and where necessary approved by a relevant regulatory authority, prior to commencing any land-disturbing activities.

Acceptable Solution A5(b)
The potential for environmental harm must be assessed by a recognised expert or authority.

Acceptable Solution A5(c)
Refer to A1(a) for discussion on "potential environmental risk".

Acceptable Solution A5(d)
Applies to all land-disturbing activities, whether planned or unplanned, and especially to any works that are required to be conducted without an associated Erosion and Sediment Control Plan.

Acceptable Solution A5(d)(iv)
Includes ensuring that the value and use of land/properties adjacent to the development (including roads) are not diminished as a result of work-related soil erosion and sediment runoff.

Acceptable Solution A6(a)
Recommended training requirements are discussed in Section 6.19 of Chapter 6 – *Site management*.

Acceptable Solution A6(b)
Necessary disturbance to ESC measures would include the short-term removal of an ESC measure to allow the installation of services under the ESC measure, or to allow vehicular or material access.

Performance Criterion P7
Performance Criteria P7 and P8 require work sites to be appropriately prepared for both current and imminent site conditions. Compliance with these criteria requires ESCPs to be living documents that remain both effective and flexible, and thus are able to appropriately adapt to changing site conditions.

Acceptable Solution A7(a)
A significant change in site conditions includes:

- unseasonable weather conditions;
- exposure of problematic soil conditions not previously anticipated;
- significant change in construction methodology, staging or programming of earthworks and/or site stabilisation activities;
- significant change in the development design or layout;
- an unprogrammed site shutdown.

Performance Criterion P8
Performance Criteria P7 and P8 require work sites to be appropriately prepared for both current and imminent site conditions. Compliance with these criteria requires ESCPs to be living documents that remain both effective and flexible, and thus are able to appropriately adapt to changing site conditions.

Acceptable Solution A9(a)
Appropriate identification depends on the level of risk of damage to protected or retained vegetation. Appropriate identification does not necessarily mean markers, signs or fencing; however, such measures may be appropriate in some areas.

Acceptable Solution A10(b)
Current (2008) best practice requires that all reasonable and practicable measures are taken to:

(i) prevent the release of cement-laden runoff, concrete waste, and chemical products (including petroleum and oil-based products) into an internal or external water body, completed internal drainage systems, or any external drainage system, excluding those on-site drains and water bodies specifically designed to contain and/or treat such material;

(ii) ensure all solid and liquid waste from concrete production, and concreting equipment (including delivery and placement vehicles), is fully contained within the property;

(iii) ensure cement residue from work activities is:
  - retained on a pervious surface (e.g. a grassed or open soil area, or excavated trench); or
  - filtered through a fine-grained, porous earth embankment; or
  - collected and disposed of in a manner that minimises ongoing environmental harm.

Acceptable Solution A10(c)
Current (2008) best practice requires that wherever practicable, the cutting of bricks, concrete, ceramics, and other slurry-producing materials must be carried out in a manner that:

(i) complies with current State guidelines, policies and legislation; and
(ii) fully contains any contaminated waste water for later treatment and/or lawful disposal; or
(iii) appropriately filters (e.g. through a fine-grained, porous, earth embankment) any contaminated slurry/water prior to its release from the immediate work area.

Acceptable Solution A10(d)
Current (2008) best practice requires that wherever practicable, the washing of tools and painting equipment is carried out in a manner that:

(i) complies with current State guidelines, policies and legislation; and
(ii) fully contains any contaminated waste water for later treatment and/or lawful disposal; or
(iii) appropriately filters (e.g. through a fine-grained, porous earth embankment) any contaminated liquid prior to its release from the immediate work area; or
(iv) appropriately infiltrates all contaminated liquid matter into an area of porous grass or open soil.

Acceptable Solution A11(a)
"Sediment and other material" includes clay, silt, sand, gravel, soil, mud, cement and fine-ceramic waste.

Acceptable Solution A11(b)
Sealed surfaces include sealed roads and car parks.

In circumstances where the washing/flushing of sealed surfaces is required, all reasonable and practicable sediment control measures must be employed to prevent, or at least minimise, the release of sediment into receiving waters. Only those measures that will not cause safety issues or adverse property flooding to third parties shall be employed.

Acceptable Solution A12
"Appropriate consideration" includes taking all reasonable and practicable measures to minimise safety risks. As a general rule, safety issues take a higher priority than ESC issues; however, this does **not** mean that the existence of potential safety issues diminishes the ESC standard required of a work site.

Public safety risks include potential damage to public vehicles resulting from the use of inappropriate kerb-inlet sediment traps on public roads. The potential safety risk of a proposed sediment trap to site workers and the public must be given appropriate consideration **before** its installation, especially those sediment traps located within publicly accessible areas.

Performance Criterion P13
The protection of wildlife does not diminish the required ESC standard, or the need to take all reasonable and practicable measures to minimise environmental harm resulting from soil erosion and displaced sediment.

Performance Criterion P14
Further discussion on the protection of waterways and the conducting of instream works is provided in Appendix I – *Instream works*.

LAND CLEARING

Acceptable Solution A15(c)
Operational restrictions on the extent and duration of land disturbance, including land clearing (as presented by Performance Criterion P15), only apply when such land disturbance is at risk, or potentially at risk, of erosion by wind, rain or flowing water.

The potential erosion risk is related (in part) to the potential rainfall erosivity as defined in Section 4.4 of Chapter 4 – *Design standards and technique selection*. The potential erosion hazard may be identified through the application of an appropriate Erosion Hazard Assessment scheme such as those discussed in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

Acceptable Solution A16(b)
The extent of unnecessary soil disturbance, including disturbances outside the designated work area, must be minimised at all times.

Wherever reasonable and practicable, land clearing must be limited to the current stage of works. Current (2008) best practice recommends that land clearing not extend beyond the parameters indicated in Table 4.4.7 of Chapter 4 – *Design standards and technique selection;* that being the minimum necessary to provide:

(i) up to eight (8) weeks of site activity during those months when the expected rainfall erosivity is less than 100, six (6) if between 100 and 285, four (4) weeks if between 285 and 1500, and two (2) weeks if greater than 1500; or

(ii) up to eight (8) weeks of site activity during those months when the actual or average rainfall is less than 45mm, six (6) if between 45 and 100mm, four (4) weeks if between 100 and 225mm, and two (2) weeks if greater than 225mm.

Condition (ii) generally only applies if directed by the relevant regulatory authority.

Acceptable Solution A17(c)
During such tree clearing, all reasonable and practicable measures must be taken to minimise unnecessary removal of, or disturbance to, any existing ground cover (organic or inorganic) until just prior to final grubbing and topsoil removal.

In some cases is might be advantageous to perform bulk removal of trees and shrubs at the beginning of each stage of works, followed by the establishment of a temporary grass, mulch or other ground cover. Final grubbing of roots and topsoil removal should then be delayed until just prior to commencement of bulk earthworks.

SOIL AND STOCKPILE MANAGEMENT

Performance Criterion A18
Applies to all areas of proposed soil disturbance, including footprint of proposed stockpiles prior to placement of soil within such areas. Does not include any material best described as subsoil.

Acceptable Solution A18(b)
Current (2008) best practice recommendations for the management of topsoil are presented in Table 6.2 in Chapter 6 – *Site management*.

Acceptable Solution A19(ii)
The diversion of up-slope stormwater is recommended during those periods when rainfall is possible and the up-slope catchment area exceeds 1500m^2.

Current (2008) best practice recommendations for the protection of sand and soil stockpiles from the erosive effects of wind and rainfall are presented in Table 4.6.1 in Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A19(iv)
Current (2008) best practice recommendations for the selection of an appropriate sediment control system is presented in Table 4.6.2 in Chapter 4 – *Design standards and technique selection*.

Short-term stockpiles of erodible material located outside of an appropriate sediment control zone must be covered if it is raining, or if rain is imminent or possible.

Acceptable Solution A20
Dispersive soils normally need to be stabilised (i.e. treated with gypsum or lime depending on desired pH adjustment) and/or buried under a layer of non-dispersive soil prior to placement of channel lining (whether rock, gabion, synthetic material, or concrete), or initiation of revegetation.

Refer to Section 6.12 in Chapter 6 – *Site management*, or Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of dispersive soils.

Acceptable Solution A21
Refer to Section 6.12 in Chapter 6 – *Site management*, or Section C11 in Appendix C – *Soils and revegetation* for further discussion on the management of acid sulfate soils.

Within Queensland, guidelines on the management of acid sulfate soils is provided in State Planning Policy 2/02 *"Guideline: Planning and Managing Development involving Acid Sulfate Soils"*, and Dear, et al. 2002, *Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines.* Department of Natural Resources and Mines, Indooroopilly, Queensland.

DRAINAGE CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure of soil to the erosive forces of flowing water. It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining drainage control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A22
Current (2008) best practice construction phase drainage standards are presented in Table 4.3.1 of Chapter 4 – *Design standards and technique selection*. Drainage systems must be designed to have a minimum non-erosive hydraulic capacity (excluding 150mm freeboard) in accordance with this table.

Acceptable Solution A23(b)
Sandbag flow diversion banks, catch drains, and flow diversion banks are examples of appropriate drainage systems that can be used to divert stormwater around excavations and other soil disturbances.

Acceptable Solution A23(b)
The relevant design discharge is related to Acceptable Solution A22. The "design flow" or "design discharge" is the design hydraulic capacity of that component of the drainage system.

All temporary and permanent drainage systems must be able to accept the design flow within 10 days of construction. This may require the application of an appropriate permanent or temporary channel liner, or the use of velocity control *Check Dams*.

Acceptable Solution A24(a)
"Temporary" drainage systems are only utilised during the construction phase, and only until the permanent drainage systems are constructed and made operational.

The *intent* of installing the permanent drainage system as soon as practicable is to maximise the effective passage of "clean" water through the site without the risk of contamination by on-site sediment.

Acceptable Solution A24(b)
"Clean" water is defined as water that either enters the property from an external source and has not been further contaminated by sediment within the property; 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 site.

Acceptable Solution A24(f)
Does not refer to excavations and trenches that form or act as sediment traps.

EROSION CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure of soil, sand, silt, mud or cement to the erosive forces of wind, rain and flowing water. It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining erosion control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A26(a)
Current (2008) best practice (construction phase) land clearing and site rehabilitation standards are presented in Table 4.4.7 of Chapter 4 – *Design standards and technique selection*. Unless otherwise stated by the relevant regulatory authority, the potential erosion risk is based on the rating outlined in Table 4.4.1 of Chapter 4 – *Design standards and technique selection*.

In addition, all temporary earth banks, flow diversion systems, and sediment basin embankments should be machine-compacted, seeded and mulched within ten (10) days of formation for the purpose of establishing a vegetative cover, unless otherwise stated within an approved Site Stabilisation Plan, Revegetation Plan, or Vegetation Management Plan.

Acceptable Solution A26(b)
Erosion control measures primarily focus on the control of fine sediments such as clay and silt-sized particles. Thus, with respect to the value of “erosion control measures”, potential environmental harm is strongly related to the susceptibility of the receiving waters to environmental harm resulting from turbid runoff (i.e. suspended fine sediments).

Erosion control measures need to be appropriate for the land slope and the expected wind, rain and hydraulic conditions. Application of effective drainage control measures should help to control hydraulic conditions such that damage to adopted erosion control measures during regular rainfall events is minimised.

Acceptable Solution A27(a)
Such a clause shall not reduce the responsibility to apply and maintain, at all times, all necessary sediment control measures.

The minimisation of soil erosion requires the application of effective drainage and erosion control throughout each and all sub-catchments.

Acceptable Solution A28(a)
Compliance with this clause requires:
- soil disturbance within any sub-catchment to be delayed as long as possible, and ideally, not until the principal on-site activities within that area are ready to commence;
- soil disturbance at any given time to be limited to the minimum necessary to perform the required works;
- the extent of unnecessary soil disturbance, including disturbances outside the designated work area, to be minimised.

Acceptable Solution A28(b)
Compliance with the requirements outlined within Table 4.4.7 of Chapter 4 – *Design standards and technique selection* does not diminish the need to apply all reasonable erosion control measures as soon as practicable.

A “sub-area” being an area within a given sub-catchment fully contained within a set of drainage control structures designed to minimise the risk of rill erosion within that area.

Acceptable Solution A28(c)
Disturbed soils associated with non-completed earthworks that are likely to be exposed to rainfall are protected from soil erosion:
(i) if further soil disturbances are likely to be delayed for more than 30 days during those months when the expected rainfall erosivity is less than 100, or 20 days if between 100 and 285, or 10 days if between 285 and 1500, or 5 days if greater than 1500; or
(ii) where directed by the regulatory authority, further soil disturbances are likely to be delayed for more than 30 days during those months when the expected rainfall is less than 45mm, or 20 days if between 45 and 100mm, or 10 days if between 100 and 225mm, or 5 days if greater than 225mm.

Condition (ii) generally only applies if directed by the relevant regulatory authority.

Acceptable Solution A29(i) & (ii)
All stormwater, sewer line and other service trenches not in streets are mulched and seeded, or otherwise appropriately stabilised, within 7 days after backfill, or otherwise rehabilitated in accordance with an approved Site Stabilisation Plan, Landscape Plan, Revegetation Plan, or Vegetation Management Plan.

Acceptable Solution A29(i)
If a backfilled trench is not compacted to a firm condition, then soil settlement can occur over time or after significant rainfall. This lack of compaction can lead to the formation of a drainage depression along the trench resulting in the concentration of stormwater runoff and possible soil erosion.

Backfilling the trench to a level at least 75mm above the adjoining ground level will usually address any future soil settlement (even if appropriate initial compaction is achieved). Variations of this requirement exist in different regions, thus always seek advice from the local government and/or appropriate regulatory authority.

Acceptable Solution A29(ii)
An alternative to A29(i) would be to rehabilitate service trenches in a manner that has proven in the past to prevent unacceptable soil erosion or sediment runoff.

Acceptable Solution A30(b)
This clause requires compliance with Performance Criterion P19.

SEDIMENT CONTROL

The *intent* of this section is to take all reasonable and practicable measures to prevent, or at least minimise, environmental harm and public nuisance resulting from the exposure, placement, or displacement of sediment (including soil, sand, silt, mud and cement). It is not the intent to unfairly burden those performing land-disturbing activities with the cost and inconvenience of installing and maintaining sediment control measures if there is no risk of such environmental harm and public nuisance.

Acceptable Solution A31(a)
Current (2008) best practice (construction phase) sediment control standards are presented in Table 4.5.1 of Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A31(b)
Relevant site conditions include the soil type, design flow rate, flow condition (i.e. sheet flow or concentrated flow) and erosion hazard. The erosion hazard may be related to the expected soil loss rate (as presented in Table 4.5.1 of Chapter 4, and Appendix E – *Soil loss estimation*), or other factors such as discussed in Appendix F – *Erosion hazard assessment*.

Unless otherwise noted within this document, or specified by the regulatory authority, the design storm for sediment traps (excluding de-watering and instream sediment control measures) must be taken as 0.5 times the 1 in 1 year ARI peak discharge.

The “potential environmental risk” is summarised in Table 5.1 of Chapter 5 – *Preparation of plans*.

Acceptable Solution A32(a)
Compliance with this clause means that no sediment control system is utilised if another more appropriate system (of equivalent treatment standard, i.e. Type 1, 2 or 3) is available. This means that straw bale sediment traps (appropriately wrapped in filter cloth) must not be used unless site conditions prevent the use of any other more appropriate sediment control systems.

Acceptable Solution A32(b)
This means that the catchment area of a *Sediment Basin* is not grubbed of vegetation, or stripped of topsoil, until the sediment basin is fully constructed and operational.

Acceptable Solution A32(d)
This clause means that sediment traps are **not** designed to simply divert sediment and sediment-laden waters away from stormwater inlets.

Compliance with this clause includes the following actions:
(i) Wherever practical, *Sediment Fences* are located along the contour to maintain "sheet" flow conditions down-slope of each fence. Where this is not practical, regular returns are utilised to allow water to pond at regular intervals along the length of the fence.
(ii) Adopted roadside kerb inlet sediment traps are appropriate for the type of inlet (i.e. sag or on-grade), for further discussion refer to Principle 8.14 in Chapter 2 – *Principles of erosion and sediment control*.

Acceptable Solution A34(a)
The *intent* of this clause is to minimise the quantity of water that needs to be de-watered from excavations and trenches. Thus, if water does not need to be de-watered from such areas, then the clause does not apply.

Acceptable Solution A34(b)
Current (2008) best practice sediment control standards for de-watering activities are outlined in Table 4.5.13 of Chapter 4 – *Design standards and technique selection*.

Alternatively, Table 4.5.14 of Chapter 4 presents a water quality standard for de-watering operations based on Nephelometric Turbidity Units (NTU).

Appropriate sediment controls placed down-slope of material stockpiles during the de-watering of such stockpiles are summarised in Table 4.5.14 of Chapter 4 – *Design standards and technique selection*.

Acceptable Solution A34(c)
The "potential environmental risk" is summarised in Table 5.1 of Chapter 5 – *Preparation of plans*.

Acceptable Solution A35(i)
Current (2008) best practice requires treatment of sediment-laden process water in a manner that:
(i) complies with current State guidelines, policies and legislation; and
(ii) fully contains any contaminated waste water for later treatment and/or lawful disposal; or
(iii) appropriately filters (e.g. through a fine-grained, porous earth embankment) any contaminated liquid prior to its release from the immediate work area; or
(iv) appropriately infiltrates all contaminated liquid matter into an area of porous grass or open soil.

SITE STABILISATION AND REHABILITATION

Acceptable Solution A36(a)
Current (2008) best-practice site rehabilitation standards are presented in Table 4.4.7 of Chapter 4 – *Design standards and technique selection*. Unless otherwise stated by the relevant regulatory authority, the potential erosion risk shall be based on the rating outlined in Table 4.4.1 of Chapter 4.

Acceptable Solution A37(a)
The type of permanent vegetation applied to completed earthworks must be compatible with the anticipated long-term land use, current and ongoing erosion risk, environmental requirements (including weed control), and associated components of the site rehabilitation.

Acceptable Solution A37(b)
A "manageable drainage area" refers to an area of open soil that can be managed (at any given time) within the limits of the specified ESC treatment standard without the need for the placement of erosion control measures (e.g. mulching) on any part of the soil.

On a well-managed site, it is typical for a "manageable drainage area" to consist of a series of "sub-areas" interconnected by temporary or permanent drainage channels. A "sub-area" being an area within a given sub-catchment fully contained within a set of drainage control structures designed to minimise the risk of rill erosion within that area.

Performance Criterion P38
Local environment includes local wildlife.

SITE INSPECTION AND MONITORING

Acceptable Solution A39(a)
On low-risk sites, ESC audits (including site inspections and water quality monitoring) may be performed by site personnel; however, as the risk of environmental harm increases, the need for third-party site inspections and water quality monitoring increases.

Personnel undertaking ESC audits of a site must, collectively, have the following capabilities:

(i) an understanding of the local environmental values that could potentially be affected by the proposed works; and
(ii) a good working knowledge of the site's Erosion and Sediment Control (ESC) issues, and potential environmental impacts, that is commensurate with the complexity of the site and the degree of environmental risk; and
(iii) a good working knowledge of current best practice Erosion and Sediment Control measures for the given site conditions and type of works; and
(iv) ability to appropriately monitor, interpret, and report on the site's ESC performance, including the ability to recognise poor performance and potential ESC problems; and
(v) ability to provide advice and guidance on appropriate measures and procedures to maintain the site at all times in a condition representative of current best practice, and that is reasonably likely to achieve the required ESC standard; and
(vi) a good working knowledge of the correct installation, operational and maintenance procedures for the full range of ESC measures used on the site.

Acceptable Solution A39(b)
The construction industry's dealing of workplace safety issues provides a good model for the development of an appropriate "Chain of Command" for the protection of environmental values. The aim is to produce a fair, reasonable and practicable approach based on environmental risk.

As in workplace safety, the responsibility of environmental protection, and therefore erosion and sediment control, rests with **all** site personnel, whether or not the work site is the normal place of work of any and all personnel. Establishing a "chain of command" does **not** diminish the responsibility of each and every person to take all reasonable and practicable measures to minimise environmental harm resulting from their actions as per their "environmental duty of care".

Acceptable Solution A39(c)
"Responsible ESC personnel" are those people employed or contracted by the land owner and/or developer as the principal officer(s) responsible for ensuring appropriate application of the planned ESC measures and for the provision of advice in response to unplanned ESC issues.

Acceptable Solution A40
Personnel preparing and/or supervising the preparation of the Monitoring and Maintenance Program must, collectively, have the following capabilities:

(i) an understanding of the local environmental values that could potentially be affected by the proposed works; and
(ii) a good working knowledge of the site's Erosion and Sediment Control (ESC) issues, and potential environmental impacts, that is commensurate with the complexity of the site and the degree of environmental risk; and
(iii) a good working knowledge of current best practice Erosion and Sediment Control measures appropriate for the given site conditions and type of works; and
(iv) a good working knowledge of the correct installation, operational and maintenance procedures for the full range of ESC measures used on the site.

Acceptable Solution A41(a)
Discussion on scheduling and conducting site inspections by internal and external parties is provided in Chapter 7 – *Site inspection*.

In those instances where specific site monitoring stations are identified within the Monitoring and Maintenance Program, then:
- during periods of water discharge from the site, water quality samples are collected at each monitoring station at least once on each calendar day until such discharge stops; and
- a minimum of 3 water samples are taken and analysed, and the average result used to determine quality.

Sediment basin water quality samples are taken at a depth no greater than 200mm above the top surface of the settled sediment within the basin.

Current (2008) best-practice procedures for "high-risk" sites, requires regular ESC audits to be:
(i) undertaken by a person suitably qualified and experienced in erosion and sediment control that can be verified by an independent third-party (this person must not be an employee or agent of the principal contractor); and
(ii) conducted on the next business day following a rainfall event in which greater than 10mm of rainfall has been recorded by the Bureau of Meteorology rain gauge nearest to the site; and
(iii) conducted at intervals of not more than one (1) calendar month commencing from the day of site disturbance until all disturbed areas have been adequately stabilised against erosion to the acceptance of the relevant regulatory authority; and
(iv) conducted using an appropriate Site Inspection Checklist.

"High-risk sites" are work sites that:
- satisfy the requirements of a high-risk site as defined by either the State or local government; or
- satisfy the requirements of 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 "critical hazard value").

Discussion on the assessment of *erosion hazard* and *site risk assessment* is presented in Chapter 3 – *Site planning*, and Appendix F – *Erosion hazard assessment*.

ESC audits must include, as a minimum:
- copies of all original Site Inspection Checklists;
- non-conformance and corrective action reports;
- sediment basin water quality and site discharge water quality monitoring results;
- a plan showing the areas of completed soil stabilisation; and
- rainfall records including date and rainfall depth.

Acceptable Solution A42(b)
Discussion on scheduling and conducting of site inspections is provided in Chapter 7 – *Site inspection*.

SITE MAINTENANCE

Performance Criterion P43
Proper working order includes maintaining the required hydraulic capacity and operational effectiveness.

Acceptable Solution A43(b)
Current (2008) best practice requirements for the maintenance of sediment control devices requires these devices to be maintained and made fully operational as soon as reasonable and practicable in accordance with Table 6.1 of Chapter 6 – *Site management*.

The top of a *Sediment Basin's* sediment storage volume must be clearly identified by the horizontal member of a marker post (cross).

Appendix M

Erosion processes

This appendix provides information on the processes of soil erosion. Its function within this document is primarily educational.

M1. Introduction

Soil erosion is the process through which the effects of wind, water, or physical action, displace soil particles, causing them to be transported. It is important to note that the force causing the transportation of soil may be different from the force that originated the erosion.

Soil erosion falls into one of two groups: natural geological erosion and accelerated human-induced erosion. In geological erosion the erosion processes are caused by naturally occurring agents. In a balanced system soil loss by natural geological erosion is equal to the formation rate of soil from natural weathering of surface and sub-surface materials. Such an erosion rate would be around 0.01 to 0.1mm/yr of the soil depth.

In accelerated erosion, the deterioration and eventual loss of soil is usually strongly influenced by human activities. Accelerated erosion rates are generally much greater than the soil formation rate.

M2. Water erosion

M2.1 Forms of water erosion

The most common forms of water erosion are:

- Splash erosion (raindrop impact)
- Sheet erosion (includes splash erosion)
- Rill erosion
- Gully erosion
- Tunnel erosion
- Watercourse erosion
- Coastal erosion

Splash erosion (raindrop impact):
Splash erosion (Figure M1) is the spattering of soil particles caused by the impact of raindrops on soil. Displaced soil particles are typically moved distances up to 1m when initially dislodged. Splash erosion is usually a major contributor to runoff turbidity.

Disturbed soil particles may or may not be subsequently removed by surface runoff. Soil particles dislodged by raindrop impact can also reduce infiltration rates by sealing the soil pores, resulting in increased surface runoff and possibly increased down-slope rill erosion.

Splash erosion is significantly reduced when water depths covering the soil surface exceed 2mm.

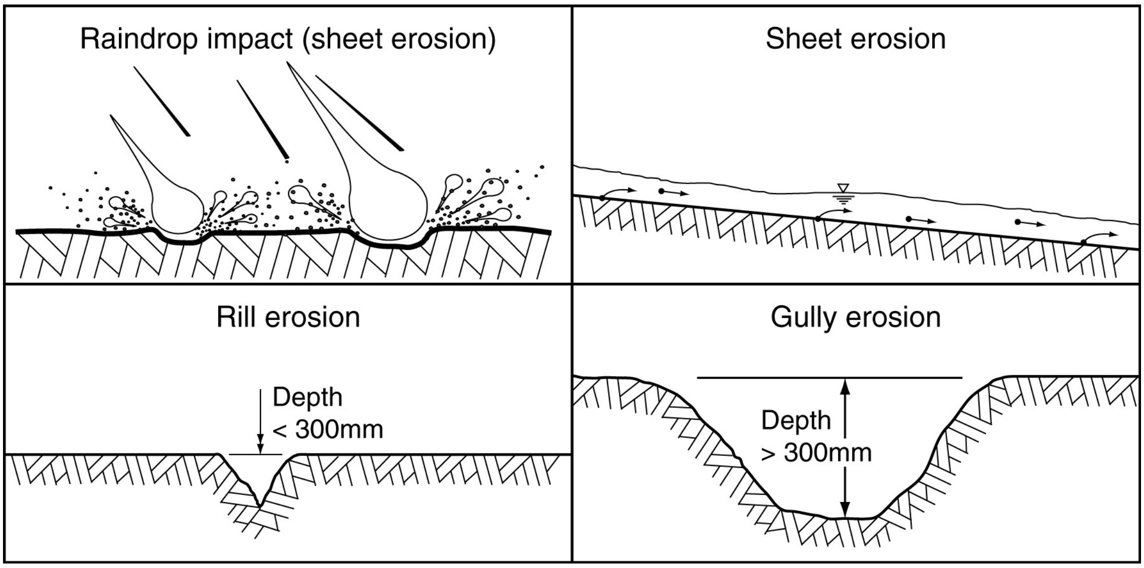

Figure M1 – Forms of water erosion

In general, soil detachability increases with increasing particle size, while soil transportability decreases with increasing particle size. That is, clay particles are generally more difficult to detach than sand particles if they are totally cohesive, but clay particles is more easily transported once detached. The exceptions are (a) dispersive clays which readily "disperse" when wet, and (b) aggregated soils, particularly those that self-mulch.

Factors affecting the rate of detachment are slope, wind, surface condition and impediments to splash such as vegetative cover, both living and dead.

Sheet erosion

Sheet erosion or inter-rill erosion as it is also known, is the uniform removal of soil in thin layers from sloping land (Figure M1). Although important, sheet erosion often remains unnoticed because it occurs gradually and evenly across a slope, and thus is often not obvious to the untrained observer.

The detachment of soil particles by raindrop impact, combined with shallow surface flow leads to sheet erosion. From an energy standpoint, splash erosion is by far the most important for detachment because raindrops have velocities of about 6 to 9m/s, whereas overland flow velocities are about 0.3 to 0.6m/s.

Rill erosion

Rill erosion (Figure M1) is the removal of soil by water concentrated in small but well-defined channels. There is no sharp line of demarcation between sheet erosion and rill erosion. Rills (generally up to 300mm deep) are small enough to be easily removed by normal agricultural equipment.

Although rill erosion is more apparent than sheet erosion, it likewise is often overlooked. On poorly managed sites, rill erosion can contribute around 50% of the eroded sediment leaving a site. Therefore, avoiding, or at least minimising rill erosion on an active construction site can significantly reduce the quantity of displaced soil.

Rill erosion is most serious where intense storms occur on soils that are exposed, loose and shallow. This situation often occurs on development sites.

Gully erosion

Gully erosion (Figure M1) produces channels deeper and larger than rills (generally greater than 300mm deep). These channels carry water during and immediately after rainfall. Gullies are generally too large to be simply ploughed over by normal agricultural equipment.

Gully erosion is not just an advanced stage of rill erosion. Most gully erosion is caused by changes to the hydrology or hydraulics of a valley or sub-catchment, or the up-slope movement of a "head-cut". Once formed, the head of the gully usually migrates, or "cuts" its way up the slope.

The rate of gully erosion depends primarily on the runoff-producing features of the catchment: the drainage area; surface soil characteristics; subsoil characteristics; the alignment, size and shape of the gully; and the slope in the channel.

Tunnel erosion

Tunnel erosion is the removal of subsoils along a sub-surface tunnel. This form of erosion is usually associated with dispersive soils and normally occurs near gullies, creek lines and constructed embankments.

Tunnel erosion can form through a variety of mechanics. Water can pass through the ground along paths of soils that are dispersible and hence break down into individual particles. The dispersion process allows these individual soil particles to be displaced (flow) from the soil profile, forming minor tunnels that usually grow with time, possibly collapsing to form gullies. Water can also pass through non-dispersible soil and find weak drainage paths, or open cracks in an underlying dispersible soil causing a tunnel to form.

Tunnel erosion can also occur when water moves down through a permeable soil layer and then encounters a less permeable layer (e.g. duplex soil). Lateral movement tends to take place to an outlet lower down the slope or in the side of a gully. With relatively rapid flow, very fine material is then transported towards the outlet and a tunnel is formed.

The slow decay of old tree roots passing through dispersible soil can also initiate tunnel erosion. As the tree root decays it forms a small, open drainage path through the soil that can quickly erode to form a tunnel. In order for the tunnel to form, however, this sub-surface drainage path must eventually discharge to the surface or to an existing tunnel. Thus, this form of tunnel erosion is most commonly associated with trees placed on embankments, or along the bank of a waterway or drainage channel.

Watercourse erosion

Nature protects stream banks often through a delicate interaction between the stream flow, channel capacity, the soil/rock exposure, and the bed and bank vegetation. The removal or modification of any of these components will normally result in the initiation and/or propagation of bed and/or bank erosion.

Factors that influence the stability of stream bank material include:

- the slope and height of the bank;
- the size of the particles that make up the stream banks;
- the amount of vegetative ground cover binding the bank material;
- the relative hydraulic roughness of the bed and banks;
- the dispersibility and erodibility of the bank material;
- the frequency, duration and velocity of near-bankfull flows.

Appropriate treatment of watercourse erosion is assisted through the development of Waterway Management Plans, revegetation programs, control of human and stock access to banks, and by minimising changes to the volume, frequency, duration and velocity of stream flows. Structural treatments are expensive and thus the implementation of catchment management options that reduce the likelihood of watercourse erosion are generally preferred.

Developments adjacent to stream banks should avoid causing disturbance to the riparian zone and should incorporate adequate buffer zones to compensate for likely future erosion and stream migration.

Watercourse erosion occurs when fluvial energy exceeds the resistance of the bed and bank material. Watercourse erosion may result from the following actions:

- changes to the frequency, duration and velocity of near-bankfull flows;
- changes to the ratio of stream curvature to stream width;
- straightening of the channel resulting in an increase in channel slope;
- dredging the stream channel, thus increasing flow velocities;
- artificial constrictions placed within the channel that increase local turbulence;
- obstacles, whether natural (e.g. fallen tree) or artificial, that divert channel flows towards an unprotected or lightly vegetated stream bank.

Coastal erosion
The coastlines are where tides, winds and waves can attack the land, and where the land responds to these forces through a variety of “give and take” measures that effectively dissipate the sea’s energy. The areas most directly affected by the forces of the sea are the beaches and the near-shore zone regions that experience the full impact of the sea’s energy.

Coastal erosion includes wave-induced erosion to the banks of large enclosed water bodies such as lakes. Areas of land located adjacent to large water bodies (lakes, rivers and oceans) are often subjected to the effects of wind-generated waves. This can result in shoreline and bank erosion, the undermining of structures, and localised flooding.

Coastal dunes are constantly under threat from the erosive forces of wind and wave energy. To overcome this threat, appropriate vegetation cover and urban development controls are required to prevent the winds removing sands and to allow wave energy to dissipate “naturally”. When vegetation is removed, vast volumes of sand usually become mobile.

M2.2 Factors affecting water erosion

In general terms, soils that exhibit any of the following features are likely to be prone to water induced erosion:

- soil with low surface cover;
- shallow surface soils overlying low permeable subsoils or rock;
- surface soils with a high percentage of fine sands or silts;
- surface soils that are hardsetting or have a surface crust;
- soils with low levels of organic matter;
- soils with dispersible properties.

The main factors affecting soil erosion are related to the local climate, topography, soil type and surface cover. Climate and topographic factors, excluding slope length, usually cannot be controlled, whereas vegetation cover—and to some extent the soil characteristics—may be varied.

Surface cover

The most important surface condition relating to erosion is cover. Increasing the effective surface cover has a direct influence on potential soil erosion. The retention of a well vegetated cover is recognised as the best long-term mechanism for maintaining infiltration rates and soil hydraulic properties, reducing runoff amounts and rates, limiting sediment detachment and transport, and thus preventing erosion. If raindrops fall on vegetation, not only is the energy absorbed, but fewer drops make direct contact with the soil surface.

A good surface cover does not have to be vegetative to be effective. Rock mulching has similar soil conservation properties. In arid areas, soils tend to be protected by either a layer of sand or rocks. Hence deserts are normally either sandy or rocky (with the exception of floodplains), the clay having long ago being washed or blown from the surface.

The main benefits of vegetation, roots and organic matter in the reduction of soil erosion are listed below:

- the interception of rainfall and absorption of the energy of the raindrops;
- reduced surface flow velocities resulting from increased surface roughness;
- the physical anchoring of bulk soils to prevent mass movement;
- improvement of aggregation and porosity of the soil thus increasing infiltration and reducing runoff;
- increased biological activity within the soil, thus improving soil structure;
- transpiration of soil moisture resulting in a drier soil, thus increasing annual infiltration rates.

Climate

Climatic factors affecting erosion are precipitation, temperature, wind, humidity and solar radiation. Of these, precipitation (rainfall erosivity) gains increasing importance within tropical regions. Temperature and wind affect evaporation and transpiration. Wind, however, also affects the angle of impact and velocity of raindrops. Humidity and solar radiation affect temperature and are less directly involved.

The amount and intensity of rainfall both affect soil loss. Rainfall "intensity" is usually more important than the "volume" of rainfall. In many instances, one or two high-intensity storms can cause as much soil loss as all other storms during a given season.

Rainfall erosivity

Rainfall intensity is one of the most potent factors that influence soil erosion. Rainfall erosivity represents the ability of rain to cause erosion. In most regions this erosivity varies with the seasons, because raindrop size and rainfall intensity are generally greater during summer months—even if the actual rainfall volume is less than in the winter months.

Topography

Topographic features that influence erosion are the degree of slope; length of slope; and size and shape of the catchment. Specifically:

- the steeper the slope the greater the runoff velocity;
- longer slopes permit more of the runoff to concentrate; and

- convex slopes spread surface runoff more evenly resulting in less runoff concentration.

Sheet and rill erosion will increase with both the slope steepness and the length of the slope, the former being more influential. The length of the slope is important because it provides a greater opportunity for runoff to concentrate and increase its velocity.

Soil erodibility

The physical properties of soil affect the soil's infiltration capacity, and the extent to which soil particles can be detached and transported. Properties that influence soil erosion include: soil structure, texture, organic matter, moisture content and density (compaction), as well as the chemical and biological characteristics of soil.

When exposed to the same rainfall erosivity, different soils will display different rates of erosion. The vulnerability or susceptibility of the soil to erosion is known as its *erodibility*. The erodibility of a soil depends on the tendency for its aggregates to breakdown, and also on way the soil is managed.

Soils with large, water-stable aggregates separated by large pore spaces, absorb water rapidly and are resistant to erosion. These soils generally have a high clay content; however, some clays are dispersive and break down when wet making them highly erodible.

Soils with fine aggregates or no aggregates, or aggregates that break down when wet (unstable aggregates) are usually highly erodible.

Sandy soils are generally less erodible on gently sloping land, but the reverse is true on steep slopes. Duplex soils that have characteristically high clay content subsoils beneath a loose surface, favour erosion. The installation of underground services down a mild, vegetated slope can result in gully erosion in such fragile soils.

Dispersible soils are structurally unstable in water, breaking down into their constituent particles (sand, silt and clay) and consequently allowing the dispersive clay fraction to disperse and cloud the water. Further discussion on dispersive soils is provided within Appendix C – *Soils and revegetation*.

Surface condition

Loose, uncompacted soil will always be more readily detached and transported by flowing water; however, the critical issue is determining the ideal degree of compaction—not too loose to control rill erosion, but also not too hard to aid in complete and rapid revegetation. As a general guide, exposed soil on flat land should be rough and loose prior to revegetation; whereas exposed soil on sloping ground should be rough, but firm, and only "hard" (i.e. well compacted) when revegetation is undesirable.

The roughness of an exposed soil surface modifies the process of raindrop impact. A roughened soil surface acts as a barrier that absorbs energy released during raindrop impact. This reduction in energy results in fewer soil particles becoming detached and thus reduced erosion rates.

It is often mistakenly thought that by leaving a soil surface smooth and compacted, erosion will be reduced. Even though soil compaction will generally reduce the risk of rill erosion, it will also increase the runoff potential of the surface and may even increase soil detachment by raindrop impact. High soil compaction is also likely to reduce and/or delay revegetation, which in turn will prolong soil erosion. A roughened soil surface can also counteract the effects of slope by reducing the potential for surface runoff to concentrate.

M3. Wind erosion

M3.1 Introduction

Wind erosion is usually significant in regions where severe winds occur during the drier periods of the year. It can be widespread in the semi-arid and arid areas, and along coastal areas where dunal sands are exposed. The problem is usually associated with non-vegetated, dry, non-cohesive, granular soils that predominantly consist of fine sands and silts.

Movement of soil by wind involves three processes:

- surface creep
- saltation
- suspension

Surface creep
Surface creep is the rolling and sliding of large particles generally in excess of 1mm that are too heavy to be lifted into the air. The horizontal component of wind rolls these particles across the soil surface, bumping soil particles against each other and dislodging other surface particles in the process.

Saltation
Saltation refers to the action of wind on soil particles with diameters generally between 0.1 and 0.5mm causing them to hop and bounce across the surface of the soil. This type of movement dislodges other particles on impact and breaks up soil crumbs, thus exposing them to further wind or water induced erosion.

Suspension
Suspension refers to the movement of small dust particles less than 0.1mm in diameter into the air through the vertical component of wind. These particles are lifted higher into the air and are sometimes carried into high altitude air streams, thus forming storm clouds. In the past, severe dust storms in Victoria have carried Australian soils as far as New Zealand.

M3.2 Mechanics of wind erosion

Wind erosion takes place in three distinct phases:

- initial detachment;
- transportation;
- deposition.

Detachment
Soil movement initiates as a result of wind velocity and turbulence. The fluid threshold velocity is the minimum velocity required to produce soil movement by direct action of the wind, whereas the impact threshold velocity is the velocity required to initiate movement from the impact of soil particles carried in saltation.

Except near the surface and at very low velocities (less than about 3kph), the surface wind is always turbulent. Saltation begins at about 12kph.

Transportation
The quantity of soil moved is influenced by particle size, the gradation of particle sizes, wind velocity and distance across the eroding area (fetch length).

The rate of soil movement increases with distance from the windward edge of the field or eroded area. Fine particles drift and accumulate on the leeward side of the area or pile up in dunes. The rate of erosion varies for different soils, some being as much as 10 times more erodible than others.

The atmosphere has a tremendous capacity for transporting soil, particularly those soil fractions less than 0.1mm in diameter. It is estimated that the potential carrying capacity of 1km^3 of the atmosphere is up to 31,000 tonnes of soil, depending on wind velocity.

Deposition
Deposition occurs when either the wind velocity drops or turbulence drops. The heavier soil particles are deposited first. A solid obstacle to the wind path can cause a drop in velocity and sediment (sand) deposition, but the same obstacle may also increase turbulence thus increasing the pick up of fine particles (silts and clays). A semi-permeable obstacle decreases both velocity and turbulence.

M3.3 Factors affecting wind erosion

The major factors affecting erosion by wind are land use, exposure, climate, soil, and vegetation. Topography appears to be relatively unimportant in the wind erosion process, but the length of the eroding surface greatly influences soil movement.

Land use and exposure
Any permanent land use or temporary construction activity that leaves the soil surface bare during dry, windy periods will increase the soil's susceptibility to wind erosion.

Climate
The principal characteristics of wind that affects erosion are velocity, direction, duration and turbulence. The rate of soil movement is proportional to the cube of the wind velocity.

Wind erosion is greater in the dry season when soils are more likely to be vulnerable. A hot wind rapidly dries the soil surface and reduces the effectiveness of ground cover vegetation.

Soil characteristics
The soil factors affecting wind erosion are texture, structure, particle density, density of soil mass, organic matter, moisture content, and surface roughness. The moisture content is especially significant because only a relatively dry soil is subject to wind erosion.

Surface roughness generally decreases wind erosion. Surface crusts have a retarding influence on soil movement, even though they have a tendency to decrease the effective surface roughness.

Sandy soils with a low clay content lack cohesion and are therefore prone to wind erosion.

Vegetation
The vegetation factors affecting wind erosion are the height and density of cover, type of vegetation and seasonal distribution. Living plant roots and tops are more effective in retarding erosion than surface litter, but the latter often provide a practical solution. Windbreaks can be important in decreasing wind velocities.

M4. Mass movement

M4.1 Introduction

Mass movement is the general term used to describe the movement of large volumes of soil and/or rock down steep slopes, or the movement of deep subsoils on slopes of various gradients. The most common triggering agent is heavy rainfall, which infiltrates the soil profile, reduces shear strength and increases slope load on susceptible soil surfaces.

M4.2 Contributing factors

Charman and Murphy (1991) identified the following factors that can lead to an increase in slope mass loading.

(a) removal of lateral or underlying support:

- undercutting by water (for example, rivers and waves);
- weathering of weaker rock strata at the toe of the slope;
- washing out of granular material by seepage;
- cuts and fills, excavations, draining of lakes or reservoirs.

(b) increased disturbing forces:

- natural accumulation of water, snow, talus;
- artificially increased pressures (such as stockpiles or ore, tip-heaps, rubbish dumps or buildings);
- build-up of pore-water pressure (such as in joints and cracks, especially in the tension crack zone at the rear of the slide).

(c) transitory earth stresses:

- earthquakes;
- continual passing of heavy traffic.

Charman and Murphy (1991) also identified the following factors that can lead to a reduction in the shear strength of the soil material.

(a) weakness in materials:

- for example, some bed materials decrease in shear strength if water content increases e.g. clays, shale, mica, schist, talc, serpentine (the watertable may be artificially increased in height by reservoir construction, or as a result of stress release, vertical and/or horizontal, following slope modification);
- low internal cohesion (such as consolidated clays, sands, porous organic matter);
- in bedrock for example faults, bedding planes, joints, foliation in schists, cleavage, brachiated zones and pre-existing shears;
- higher groundwater table as a result of increased precipitation or because of human interference (for example, dam construction).

(b) weathering or other changes:

- weathering reduces effective cohesion and, to a lesser extent, the angle of shearing resistance;
- absorption of water leading to changes in the fabric of clays (such as loss of bonds between particles, or the formation of fissures).

M4.3 Soil testing

To define the physical behaviour of a soil in relation to mass movement the following laboratory tests are used:

- Particle size distribution to define soil texture
- Attenberg limits and plastic and liquid limits, plasticity index
- Linear shrinkage
- Dispersiveness – determined by Emerson Aggregate Test
- Shear strength including California Bearing Rates
- Proctor compaction for bulk density and optimum moisture content
- Cone penetrometer
- Field moisture content
- Cation exchange capacity
- Mineral identification with X-ray techniques

Not all of these analyses are required all the time. The severity of the problem on the development site will usually determine the extent of analysis.

M4.4 Planning and design considerations

Charman and Murphy (1991) recommend a number of techniques be adopted to reduce mass movement hazards on sites where the hazard is assessed as marginal and the cost of control measures is warranted. These techniques are listed below:

(a) Cut and fill operations should be restricted to a minimum, and deep cuts and excessive fill should be avoided to reduce slope loading and avoid reducing shear strength. Location of roads up and down rather than across the slope, and construction of houses raised above ground level, can assist this aim (for example, pole houses).

(b) Where batters are formed, low angles of cut or fill are desirable. High batters should, if possible be benched and provided with adequate drainage. A structural facing such as gabions or a crib wall can be used to strengthen batters against failure, subject to engineering design.

(c) Removal of subsoil moisture assists stabilisation of areas prone to mass movement by reducing the amount of soil water available to trigger failures.

(d) Efficient surface drainage up-slope of slip-prone areas will also reduce the hazard of failure, removing surface runoff before it can enter the rock and soil of the unstable zone. Diversion channels may be installed immediately up-slope of batters for this purpose.

(e) Sealed diversion drains formed at intervals down the face of high batters, or on berms if these have been formed on the batter face, will prevent the accumulation of local runoff.

(f) An impervious surface course is desirable on pavements to limit infiltration and water movement into the subsoil.

(g) Surface drainage of road pavements should not direct runoff onto fill batters.

(h) All household and road drainage should be carried in pipes or sealed drains away from unstable areas. The use of vegetated waterways and runoff-retarding measures is not generally applicable to such areas, because the primary aim must be to remove surplus water as quickly as possible.

(i) Apart from drainage and structural techniques, the stability of slip-prone areas can be improved, though not so rapidly, by extensive planting of native trees and shrubs. Their strong and extensive root systems bind the soil, and the trees significantly reduce soil moisture. They will regenerate if their roots are broken by soil movement. However, the roots can be a hazard to sewers and drainage pipes.

(j) Further engineering techniques such as grouting, electro-osmotic draining and chemical treatment of highly plastic clays are also sometimes used to stabilise slip-prone areas where development must take place on them.

While all these measures may reduce slip hazard, they will not always eliminate it. As a general rule, when a development is proposed on suspect areas, prior geotechnical survey should be carried out. If this survey confirms a hazard of mass movement, advice should be obtained from professionals experienced in the field of slope stabilisation for the design and installation of all cuts, fills, foundations and drainage.

M5 References

Charman, P.E.V. and Murphy, B.W. 1991, *Soils – Their Properties and Management*. A Soil Conservation Handbook for New South Wales, Sydney University Press and NSW Soil Conservation Service, Sydney, NSW, ISBN 042 400183 7.

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Appendix N

Glossary of terms

Accelerated erosion	Any increase over the rate of natural erosion from wind or water as a result of human activities.
Acceptable solution	An action or solution that satisfy the relevant Performance Criteria, but which does not preclude other solutions.
Aggregate	Commercially processed rock of near-uniform size. Similar to commercial “gravel” but without the finer rock sizes. This is different from the common soil science description.
AHD	Australian Height Datum. A common datum used in land survey.
Ameliorant	A substance used to improve the chemical or physical qualities of a soil.
Annual exceedance probability (AEP)	The probability of exceedance of a given discharge within a period of one year. AEP is generally expressed as 1 in Y (years). The terminology of AEP is generally used where the data and procedures are based on an annual series analysis.
Annual plant	A plant which completes its life cycle and dies within one year or less. The life cycle includes production of roots, stems, leaves, flowers and finally seed for further regeneration.
Anticipated weather conditions	Likely weather conditions given reliable weather forecasting or normal seasonal weather patterns, whichever represents the worst case.
ARI	Average Recurrence Interval.
Assessing authority	Any regulatory authority, whether Federal, state, local government or other, involved in the approval and/or setting of conditions of approval for a land development, building or other soil disturbance.
Average Recurrence Interval (ARI)	The average or expected value of the period between exceedances of a given discharge. ARI is generally expressed as Y years. The terminology of ARI is generally used where the data and procedures are based on a partial series analysis.
Base flow	Underlying stream flow rate that cannot be directly attributed to storm events, and is present during part or all of dry periods.
Bench	A constructed ledge formed at one or more levels between the top and bottom of a batter. Its purpose to intercept runoff and reduce slope instability.
Benching	The incorporation of benches within an earth batter.
Best practice	Any program, technology, process, siting criteria, operating method, or device recognised as best practice when assessed against those processes currently used nationally and internationally.
Blading	Trimming or shaving the soil surface with the blade of a grader.
Buffer zone	1. A significant area of vegetation primarily containing an even cover of long grass (>50mm strand length) located down-slope of a soil disturbance and used as a sediment trap. To be effective as a sediment trap, the buffer zone must not contain any drainage depressions, swales or spoon drains that may concentrate flow. The height of the grass must be at least as high

	as the maximum depth of sheet flow expected to pass through the buffer. The buffer should contain at least 70% ground cover. 2. A formal land buffer, often permanent, established between to areas of potentially conflicting land usage such as a buffer separating urban development from a waterway, protected bushland, or sensitive environmental habitat.
Building	A habitable room; retail or commercial space; factory or warehouse; basement providing car parking space, building services or equipment; or enclosed car park or enclosed garage.
Building envelope	1. The enclosed area or areas on a lot defining the limits of building works, including all soil disturbance, outbuildings, landscaping and driveways. 2. The representation of such areas on a diagram or plan.
Building phase	1. The duration of a building work on a given lot. The building phase would extend beyond the duration of the building contract if the contracted works do not result in the final stabilisation (i.e. adequate control of soil erosion) of the building site. 2. That phase of land development following the construction phase on any stage of works during which building work occurs within that stage (zone) of the site. On large, multi-stage sites, the site may experience periods when the construction, maintenance and building phases are occurring concurrently within different stages (zones) of the land development.
Building site	A site where the fabrication or erection of a building or structure is the primary activity.
Building work	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.
Bypass flow	That portion of the flow redirected out of a system, or around a device (such as a sediment trap or stormwater treatment system) such that the bypassed flow does not pass through, or is treated by, the device.
Causeway	A raised carriageway across a watercourse or across tidal water, specially constructed to resist the effects of submergence.
Cement residue	Cement and cement-laden water washed from concrete surfaces or from the cleaning of equipment.
Channel freeboard	Vertical distance between the design water surface elevation in an open channel and the level of the top of the channel bank.
Clay	Soil particles less than 0.002mm in equivalent diameter. When used as a soil texture group such soil contains at least 35% clay and no more than 40% silt. Clay mineral groups include: • *Kandite group* (e.g. kaolinite and halloysite) extremely stable clay minerals, very low swell and shrink, low CEC (about 5 cmol(+)/kg clay), used for pottery and chinaware; • *Mica group* (e.g. illite) stable under wetting and drying, potassium ions act as a “glue” sticking the unit cells together, medium CEC (about 30 cmol(+)/kg clay);

- *Smectite group* (e.g. montmorillonite and bentonite) high shrink-swell capacity due to high surface area per unit weight, usually very unstable under wetting and drying, high CEC (about 100 cmol(+)/kg clay), these clays have been used to seal minor cracks in earth dams.

Clay-based creek A minor watercourse formed in clayey soils. In open canopy creeks, groundcover vegetation is dominant on both the bed and banks. In closed canopy creeks, sparse vegetation cover usually still exists, but generally the bare clay soils are clearly visible. Typically watercourse stability in such streams is dominated by bed and bank vegetation and in their natural state there is usually very little sediment flow along the creek during most storm events.

Clay-based soil A soil that contains at least 10% clay.

Clayey soil A soil that contains at least 20% clay. These are fine-grained soils that readily form a clod when compressed in the hand, feel very smooth and sticky when wet, and are very difficult to shovel or break-up when compacted.

Clay loam A soil texture group representing a well-graded soil composed of approximately equal parts by weight of clay, silt and sand [when dispersed].

Clean water Water that either enters the property from an external source and has not been further contaminated by sediment within the property; or water that has originated from the site and is of such quality that it either does not need to be treated in order to achieve the required water quality standard, or would not be further improved if it was to pass through the type of sediment trap specified for the sub-catchment.

Clod A large compact and coherent soil aggregate produced artificially.

Coefficient of discharge A dimensionless coefficient, used in the Rational Method for the calculation of the peak rate of storm runoff.

Coefficient of runoff Alternative name for “coefficient of discharge”.

Conceptual ESCP A conceptual Erosion and Sediment Control Plan used to assist in the appropriate integration of ESC and construction issues into the planning of developments and other land disturbances. These plans are generally not as detailed as the final ESCPs because their very purpose requires them to be prepared before key site layout and design information are finalised.

Concrete waste Wet or dry concrete or cement residue removed from a concrete surface or from the cleaning of equipment, or excess concrete wasted from a delivery truck or manufacture process. Also see “cement residue”.

Construction planning Planning and design of the site layout, methodology, staging, and programming (timing and scheduling) of the construction phase.

Construction phase That period of civil works extending from initial site access (excluding preliminary site survey and data collection) to the commencement of the contracted/specified maintenance period. On staged works, the construction phase extends to the commencement of the maintenance period of the final stage of completed works.

A regulatory authority may specify on a site-by-site basis that the construction phase includes the maintenance period.

Construction site A site where major earthworks, civil construction (e.g. construction of public works and infrastructure) and/or non-domestic building works are conducted.

Contaminant Toxic substances within the environment that represent a health hazard to biota.

Contour An imaginary line connecting a series of points on the surface of the ground that are all the same elevation. It is also the line representing this on a map or plan.

Controllable erosion Accelerated (unnatural) soil erosion that can be controlled or prevented through reasonable and practicable measures while allowing necessary development and land-disturbing activities to continue.

Cover crop A cover crop is a temporary, fast growing, vegetative cover grown to provide protection for the soil during the establishment phase of slower growing plants. The latter may be introduced by under-sowing and in due course provide permanent vegetative cover to stabilise the area concerned. The term can include an "intermediate crop" that can be removed with selective herbicides.

Creek A minor or intermediate watercourse with either a fixed or mobile bed that is either dry (ephemeral) or has a minor constant (perennial) discharge during dry weather. In fixed bed systems the bed material and bed shape generally do not move or alter during most flood events. In mobile bed systems the loose bed material migrates down the channel during flood events. Creeks with mobile beds include gravel-based and sand-based systems while fixed bed creeks are typically clay-based systems.

Critical depth The depth occurring in an open channel or part full conduit at a condition of flow between subcritical and supercritical flow, such that the specific energy is a minimum for the given flow per unit width.

Critical flow The condition of flow in a section of an open channel or part full conduit when the flow is at critical depth and the specific energy is a minimum for the given flow per unit width.

Critical hazard value The erosion hazard value nominated by the regulatory authority that distinguishes "high-risk" and "low-risk" sites.

Critical velocity The average velocity of flow in a section of an open channel or part full conduit when the flow is at critical depth the specific energy is a minimum for the given flow per unit width.

Cross bank A raised embankment, in a form similar to a traffic "speed bump", with low vertical curvature placed diagonally across an unsealed road or track to collect and divert stormwater runoff off the track to a table drain or suitable discharge point.

Cross drain A drain of various forms that collect the flow of water down a track and divert it across the track surface. The capacity of the drain is defined by its cross section. Cross drains are designed to handle smaller flows than cross banks, but larger flows than can be controlled by crossfall drainage.

Dead water zone That part of a sediment basin or settling basin that does not form part of the effective flow path and thus does not significantly contribute to the design efficiency (i.e. sediment trapping efficiency) of the basin.

Detached dwelling A separate house on an individual lot, including a community title lot.

Development site A building or construction site.

Dirty water Water not classified as clean water.

Dispersible soil A structurally unstable soil that readily disperses into its constituent particles (clay, silt and sand) when placed in water. Moderately to highly dispersible soils are normally highly erodible and are likely to be susceptible to tunnel erosion.

Most sodic soils are dispersible, but not all dispersible soils may be classified as sodic.

Some dispersible soils are resistant to erosion unless mechanically disturbed.

Dispersive soil Terminology commonly used in engineering. See “dispersible soil”.

Dispersion percentage A measure of soil dispersibility representing the proportion of clay plus fine silt (< 0.005mm approx) in a soil that is dispersible, expressed as a percentage. It is a measure of the amount of soil material that is easily dispersible in water, as opposed to the ease of such dispersion.

Dispersion potential The likelihood that soils will release a cloud of fine clay particles when brought into contact with water.

Domestic building site A site where domestic building work is the primary activity, or where the land is being prepared for domestic building works to commence.

Domestic building work Those works associated with:

- the erection or construction of a detached dwelling; or
- the renovation, alteration, extension, improvement, or repair of a domestic dwelling; or
- removal or resiting of a detached dwelling; or
- works directly associated with the erection or construction of a detached dwelling including the installation of services, landscaping, paving, or the erection or construction of a building or fixture associated with the detached dwelling such as a garage or carport.

Drainage control measure Any system, procedure or material employed to:

- prevent or minimise soil erosion caused by “concentrated” overland flow (including the management of rill and gully erosion);
- divert flow around or through a work site or soil disturbance; or divert “clean” water away from a sediment trap;
- to appropriately manage the movement of “clean” and “dirty” water through a work site.

Drop inlet An inlet to a sub-surface drainage system located within an open area where the water falls vertically into the connecting chamber. Known also as a “field inlet”.

Dry basin A sediment basin that is free draining, and thus begins to de-water soon after water enters the basin.

Dyke A ridge or bank of earth formed to control the movement of overland flow. Usually formed using imported material, or in-situ material during the excavation of a trench. Usually larger than a “berm”. (USA: Dike)

Ecological harm Any adverse effect, or potential adverse effect (whether temporary or permanent) on an environmental value directly associated with an ecological feature.

Entry/exit pad A well-defined, rock-lined surface (pad) placed immediately adjacent a sealed roadway over which vehicles access to into or from a work site. The entry/exit pad is used to extract and retain sediment from the tyres of vehicles entering and leaving a work site.

Known also as *Rock Pads*, *Rumble Pads* and *Construction Exits*.

Environmental harm	Any adverse effect, or potential adverse effect (whether temporary or permanent) on an environmental value.
Environmental risk	The potential of an activity to cause harm, whether material, serious, reversible or irreversible, to an environmental value. It includes potential nuisance caused to a property or person.
Environmental value	A particular attribute or use of the environment that is conducive to public welfare, safety, health or benefit (whether social, economic cultural or environmental). Several environmental values may be designated for a specific environment or component of the environment.
Erosion	Detachment and movement of granular material (including soil, earth, sand, silt, mud, sediment, or cement) by water, wind, ice or gravity. Includes accelerated, geological, gully, natural, rill, sheet, splash, gully or wind erosion.
Erosion and sediment control (ESC)	The application of structural and non structural measures to control stormwater drainage, soil erosion and sediment runoff during the construction and building phases of land development. Some measures often being retained as part of the permanent site rehabilitation and stormwater management practices.
Erosion and Sediment Control Plan (ESCP)	A site plan, or set of plans, including diagrams and explanatory notes, that demonstrate proposed measures to control stormwater drainage, soil erosion, and sediment runoff during the conduction/building, site stabilisation, and maintenance phases of a construction, building or other soil disturbance activity.
Erosion and Sediment Control Program (ESC Program)	Referring to a collection of ESC plans, specifications and supporting documentation relating to a specific site. The term may be interchangeable with ESCP.
Erosion and Sediment Control standard	Specific design criteria or specifications used in the design of erosion and sediment control measures (including temporary drainage measures) that comply with a given policy or water quality standard.
Erosion and sediment control techniques, measures and work practices	Those techniques, measures and work practices used to control stormwater drainage, soil erosion and sediment runoff during the construction and building phases of land development (including site stabilisation, and construction maintenance phases). It includes those techniques, measures and work practices referred to as *Drainage Control, Erosion Control* and *Sediment Control.*
Erosion control blanket	A blanket of synthetic and/or natural material, used to protect soil against erosion caused by wind, rain and minor overland flows. The term “blanket” generally refers to products best used in areas of sheet flow (e.g. on earth banks) rather than in drainage channels where “erosion control mats” are generally preferred. Known also as a rolled erosion control product (RECP) which is primarily used in areas of sheet flow.
Erosion control mat	A mat of synthetic and/or natural material, used to protect soil against erosion caused by wind, rain and concentrated surface flows. Known also as a rolled erosion control product (RECP) that is primarily used in areas of concentrated flow, such as a drainage channel.
Erosion control measure	A system, procedure or material used to prevent or reduce the effects of erosion on soil and other granular material. Within this document, *erosion control measures* primarily refer to those measures that can aid in the control of raindrop impact and

	sheet erosion.
Erosion control mesh	An open weave blanket formed from synthetic or natural twine such as hessian rope, which is used to protect soil against erosion caused by concentrated surface flows. Usually formed from jute, coir or synthetic twine.
Erosion control technique	A term interchangeable with the term “erosion control measure”.
Erosion Hazard Assessment Form	A standard site assessment procedure (presented on a standard form) used to access a work site’s potential to cause environmental harm as a consequence of on-site soil erosion and the resulting off-site deposition of sediment.
Erosion risk	An evaluation of the “risk” of soil erosion when consideration is given to both the degree of erosion and the likelihood of the erosion occurring.
Erosion Risk Mapping	The identification and mapping of areas of varying erosion risk. Usually performed by land developers as part of initial site planning, or as part of the conceptual planning of construction procedures. Only those site constraints that directly relate to soil erosion are mapped (i.e. does not assess overall environmental risk). In effect, it is a mapping exercise based on a suitable soil erosion model such as the Revised Universal Soil Loss Equation (RUSLE).
Erosivity (rainfall)	The erosive potential of rainfall expressed as the product of total storm energy and the maximum 30 minute intensity of each storm.
ESC	Erosion and sediment control.
ESC measure	Any erosion and sediment control technique or work practice.
ESC Plan	Erosion and Sediment Control Plan.
ESC Program	Erosion and Sediment Control Program. Referring to a collection of ESC plans, specifications and supporting documentation relating to a specific site. The term may be interchangeable with ESCP.
ESC standard	Refer to *Performance standard* or *Treatment standard.*
ESCP	Erosion and Sediment Control Plan.
Exposed aggregate concrete surface	A concrete surface that has had the upper layer of cement removed (washed-off prior to final setting) to expose a layer of aggregate.
Extreme erosion risk (or potential)	A extreme likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).
Extreme rainfall	Rainfall with an intensity greater than 50mm/hr, and a total rainfall depth greater than the equivalent of the 1hr duration, 1 in 10 year ARI design storm rainfall depth over a 24 hour period. For example, if the 1hr duration, 1 in 10 year ARI average rainfall intensity at a given location is 70mm/hr, then extreme rainfall would be a rainfall depth greater than 70mm within any 24 hour period, or a rainfall intensity exceeding 50mm/hr at any given time.
Fetch length	The distance the wind blows over a water surface in generating waves.
Field inlet	An inlet to a sub-surface drainage system located within an open area where the water falls vertically into the connecting chamber. Known also as a “drop inlet”.

Filter cloth	Industrial grade, non-woven synthetic fabric traditionally used to separate soils and rock of different textures or grain size, but also used as a short-term filter for the removal of medium to coarse sediment from a liquid (usually water).
Filter dam	A small porous embankment formed from fine-grained material such as loam or fine sand, and covered or wrapped with a heavy-duty, non-woven filter cloth. Alternatively, a heavy-duty, non-woven filter cloth placed over a pollution containment dam formed from sand or gravel-filled bags. The purpose being the removal of medium to coarse sediment from water passing through the sediment trap.
Flocculation	The process by which colloidal or very fine clay particles, that repel one another when suspended in water, come together into larger masses or loose “flocs” which eventually settle out of suspension.
Flood	The temporary inundation of land by expanses of water that overtop the natural or artificial banks of a watercourse, including a drainage channel, stream, creek, river, estuary, lake or dam, and any associated water holding structures.
Floodplain	The extent of land inundated by the *Probable Maximum Flood*.
Fluting	A process of rilling or gully erosion whereby a series of vertically elongated grooves, called flutes, is created down the surface of the soil. The rilling, or fluting, is caused by runoff passing vertically down the slope dissolving the dispersive soil. Typically these rills are deeper than they are wide.
Ford	A shallow place in a stream where the bed may be crossed by traffic.
Freeboard	The vertical distance between a design water level and the top of a channel or embankment used as a factor of safety.
Frequency factor	A factor that is multiplied by the coefficient of runoff for the 10 year ARI to determine the coefficient of runoff for the design ARI, for the location being considered.
Geotechnical specialist	A person suitably trained and competent to practice geotechnical engineering or science.
Gravel	A mixture of coarse mineral particles larger than 2mm but less than 75mm in equivalent diameter.
Gravel-based watercourse	A watercourse that contains a layer of loose gravel and rocks (including boulders) along the bed. A slow, progressive movement of the bed material down the watercourse is normally expected during periods of flood. Minor watercourses are normally shaded by riparian vegetation and as such may not contain significant quantities of stabilising bed vegetation.
Ground cover	A vegetative layer of grasses, low-growing plants or plant residues providing protection to the soil against erosive agents. A good ground cover is an essential part of the majority of soil conservation programs.
Grubbing	The clearing of roots. Normally refers to the removal of tree roots following land clearing.
Hazard	A source of potential harm.
Hazard rating	The erosion hazard number (score) assigned to a work site following site assessment using an Erosion Hazard Assessment Form.

Heavy rainfall	Rainfall with: (i) an intensity equal to, or greater than, 10mm/hr but less than 50mm/hr; or (ii) a total rainfall depth equal to, or greater than, the equivalent of the 1hr duration, 1 in 2 year ARI design storm rainfall depth over a 24 hour period, but less than the equivalent of the 1hr duration, 1 in 10 year ARI design storm rainfall depth over a 24 hour period. For example, if the 1hr duration, 1 in 2yr and 1 in 10yr ARI average rainfall intensity at a given location is 47mm/hr and 70mm/hr respectively, then heavy rainfall would be a rainfall depth of 47 to 70mm within any 24 hour period, or a rainfall intensity between 10 and 50mm/hr at any given time.
High level basin outlet	The outlet of a sediment basin provided for discharging flows in excess of the capacity of the low-level outlet.
High erosion risk (or potential)	A high likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).
High-risk site	A building or construction site that satisfies the requirements of: (i) a high-risk site as defined by either the State or local government; or (ii) 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”).
Highly erodible material	Material that can readily wash from a stockpile or work site, or can readily discolour stormwater during regular rainfall events.
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).
Hydraulic design	The component of drainage design that involves the determination of velocities, pressure heads and water levels as storm runoff passes through the drainage system.
Hydraulic efficiency correction factor	A factor used in the formula for sizing Type C sediment basins. Its value depends on flow conditions entering the basin and the shape of the settling pond.
Hydraulic radius	The ratio A/P, where A is the cross-sectional area and P the wetted perimeter—that being the length of the line of contact (on the cross section) between the water and the channel boundary.
Hydraulically-applied blanket	Erosion control products applied as a liquid spray (spray-on products) that dry to form a solid, continuous blanket with a thickness approximating that of a rolled *Erosion Control Blanket*. It does not include *Soil Binders*.
In-bank areas	That part of a channel, including bed and banks, below the channel bank elevation above which the water would spill out of the channel or begin to enter the floodplain.
Independent third party	Any person, organisation or authority considered independent of a given person, organisation or authority.
Infiltration bed	An excavated basin designed to capture and temporarily retain stormwater runoff specifically for the purpose of allowing the stormwater to infiltrate into the underlying soil profile. Commonly used as part of the permanent stormwater treatment system. If the underlying bed consists of a constructed filter media, then the

	system is referred to as a “filter bed” or “filtration bed”.
Instream	Any area between the banks of a constructed drainage channel, watercourse or waterway.
Instream works	Any construction, building or land-disturbing activities conducted between the banks of a constructed drainage channel, watercourse or waterway.
Intent	A statement of the desired and/or required outcomes to be achieved in the completed development, building or work activity (including those activities relating to the planning, design and maintenance of soil disturbing activity), relating to a particular design element or activity.
Invert	The lowest portion of the internal surface of a drain.
Invert erosion	Erosion along the invert of a channel or drain usually as a result of water scour.
Land-disturbing activity	Any carrying out of construction or building work, plumbing or drainage work, or reconfiguring of a lot (i.e. subdivision) where there is potential for accelerated erosion from wind or water and/or the discharge of sediment to drains or waterways.
Lawful point of discharge	A point of discharge which is either under the control of a local government or statutory authority, or at which discharge rights have been granted by registered easement in favour of the local government or statutory authority, and at which discharge from a development will not create a worse situation for downstream property owners than that which existed prior to the development.
Legal point of discharge	A point of discharge which is either under the control of a local government or statutory authority, or at which discharge rights have been granted by registered easement in favour of the local government or statutory authority.
Light rainfall	Rainfall with an intensity less than 2mm/hr, and a total rainfall depth less than the equivalent of the 1hr duration, 1 in 1 year ARI design storm rainfall depth over a 24 hour period. For example, if the 1hr duration, 1 in 1 year ARI average rainfall intensity at a given location is 36mm/hr, then light rainfall would be a rainfall depth less than 36mm within any 24 hour period with an intensity not exceeding 2mm/hr at any given time.
Likelihood	Probability or frequency of an event.
Loam	A medium-textured soil of approximate composition 10 to 25% clay, 25 to 50% silt, and less than 50% sand when dispersed. Such a soil is typically well-graded.
Local authority	Any local or regional external authority—whether government or non-government, including local governments and the State Government—that has a legal interest in the regulation or management of a given activity, or the land on which the activity is occurring, or is proposed to occur. Reference to “the local authority” shall also imply the plural.
Local government	The local city or shire council with jurisdiction over the land in which the activity in question is occurring, or is proposed to occur.
Long-term stockpile	On a building site it is a stockpile that is located on-site or off-site for more than 24 hours. On a construction site it is a stockpile that is located on-site or off-site for more than 30 days.
Low gradient flow diversion technique	A flow diversion drain, channel or bank with a gradient sufficiently low to maintain subcritical flow along its length.

Low level basin outlet	The outlet of a free-drainage sediment basin from which discharge will first occur (usually via a pipe).
Low erosion risk (or potential)	A low likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).
Low-risk site	A building or construction site that scores a hazard rating (within a given Erosion Hazard assessment procedure) less than the “critical hazard value”.
Maintenance phase	That period of civil works extending from completion the construction phase on any given stage (zone) of works to that instance when ongoing maintenance of works is handed over to the asset manager (i.e. commencement of off-maintenance period). Known also as the on-maintenance period. Regulatory authorities may specify on a site-by-site basis that the maintenance period is part of the construction period.
Major sediment trap	Any sediment control measure or device that constitutes part of the most critical components of a site’s sediment control measures. Any device with a sediment control ranking (e.g. Type 1, 2 or 3) equivalent to the highest ranked sediment control device on a given site. Within this document a Type 1 sediment trap ranks higher than Type 2, which ranks higher than Type 3.
Manageable drainage area	An area of open soil that can be managed (at any given time) within the limits of the specified ESC treatment standard without the need for the placement of erosion control measures (e.g. mulching) on any part of the soil. On a well-managed site, it is typical for a “manageable drainage area” to consist of a series of “sub-areas” interconnected by temporary or permanent drainage channels.
Manning’s roughness coefficient	A measure of the surface roughness of a conduit or channel to be applied in the Manning’s equation.
Media (filter)	The material that constitutes a filter or filter medium.
Medium (filter)	An intervening substance, layer of material, or composite material, that acts as a filter such that liquid (typically water) is allowed to pass, but adjacent particulate matter, or particulate matter contained within the liquid, is restricted in its movement.
Moderate erosion risk (or potential)	A moderate likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).
Moderate rainfall	Rainfall with: (iii) an intensity equal to, or greater than, 2mm/hr but less than 10mm/hr; or (iv) a total rainfall depth equal to, or greater than, the equivalent of the 1hr duration, 1 in 1 year ARI design storm rainfall depth over a 24 hour period, but less than the equivalent of the 1hr duration, 1 in 2 year ARI design storm rainfall depth over a 24 hour period. For example, if the 1hr duration, 1 in 1yr and 1 in 2yr ARI average rainfall intensity at a given location is 36mm/hr and 47mm/hr respectively, then heavy rainfall would be a rainfall depth of 36 to 47mm within any 24 hour period, <u>or</u> an intensity between 2 and 10mm/hr at any given time.

Monitoring A term that is generally interchangeable (within this document) with the term “site inspection”.

The term “monitoring” more commonly refers to the observation, inspection, and/or testing of the performance of a work site (as an entity), or a given erosion and sediment control measure. The term may refer specifically to “water quality monitoring” which involves the sampling, testing, interpretation and reporting of water quality at specific locations. Such monitoring may be performed before, during or after rainfall, especially if the monitoring locations include a watercourse that passes through, or adjacent to, the work site.

NATA National Association of Testing Authorities.

Natural erosion Erosion that occurs at a rate that would be expected if the ground surface had not experienced disturbance due to development.

Nature strip Refer to “verge”.

NTU Nephelometric Turbidity Units.

A measure of water turbidity or the optical clarity of a liquid.

On-grade kerb inlet Stormwater inlet formed into the kerb of a roadway where the roadway has a positive longitudinal grade (i.e. water approaches the inlet from only one direction).

Operational phase 1. For civil works, that period immediately following the construction phase on any given stage (zone) of works. It includes the maintenance phase (unless specified as part of the construction phase) and the building phase (if any).

2. For building works, that period immediately following the contracted building works. It includes the period of final site stabilisation/revegetation if not completed prior to termination of the contracted building works.

Overbank Any region located outside that region between the top of the banks of a channel.

Overbank flow That portion of a flood flow which flows outside the main river channel, flowing at relatively small depths over part of, or the full width of the floodplain, and flowing in a direction essentially parallel with the direction of the main channel.

Overland flow path The travel path of:

- storm flows in excess of the capacity of the underground drainage system (where a piped drainage system exists); or
- surface runoff from the higher parts of the catchment to a watercourse, channel or gully.

It does not include a watercourse, channel or gully with well-defined bed and banks.

Perennial plant A plant whose lifecycle extends for more than two years and continues to live from year to year.

Performance Criteria The criteria to be used in the preparation, submission and assessment of building and development proposals for measuring performance of the proposal against the “objective” or “intent”.

Performance standard The minimum performance or outcome required for a specific ESC measure, process, sub-catchment, or work site as a whole. Performance may be measured in relation to water quality objectives, or the ability of an ESC measure to perform its required function during a given flow rate or weather condition.

Person Includes a body of persons, whether incorporated or unincorporated.

Planners Any person who contributes to the initial planning of a building or other land development, the design of the spatial layout of such a building or development, or the conceptual planning of the building/construction procedures including the conceptual design of erosion and sediment control practices.

Pollutant Any constituent present in sufficient quantity to impair the beneficial uses of a receiving water body.

Pollution containment system Typically a non-free-draining pond designed to capture and hold pollution spills, such as that resulting from traffic accidents. The trapped pollution usually being collected and treated and/or disposed of off-site.

Practical completion The completion of works except for minor defects and omissions that do not prevent the works from being used for their intended purpose.

Preliminary Erosion and Sediment Control Plan A conceptual Erosion and Sediment Control Plan prepared, usually during the planning phase, prior to preparation of the final, development approval, Erosion and Sediment Control Plan.

Known also as a “conceptual Erosion and Sediment Control Plan”.

Probable Maximum Flood (PMF) The largest flood that could conceivably occur at a particular location, resulting from the probable maximum precipitation (PMP) and, where applicable, snowmelt, coupled with the worst flood-producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.

The PMF defines the extent of flood-prone land (floodplain).

Problematic soil Any soil type of condition that potentially could result in significant short-term or ongoing environmental harm if disturbed, even if current best practice construction and ESC procedures are adopted during the disturbance. Such soil conditions are likely to include highly dispersive soils (ESP >15%) and actual or potential acid sulfate soils.

It should be noted that “soils” are not in themselves a “problem” or “problematic”. The problem only arises through disturbance or management of the soil.

Project manager Principal officer or entity in charge of the management of a development site, whether or not such management activities are performed on-site or off-site.

Proper working order Means taking all reasonable and practicable measures to sustain all ESC measures in a condition that:

- will best achieve the site’s required environmental protection, including specified water quality objectives for all discharged water (principal objective);
- is in accordance with the specified operational standard for each ESC measure, where such a standard is consistent with the site’s required environmental protection including specified water quality objectives for all discharged water, or where such a standard is not specified, is consistent with current best practice for each individual ESC measure; and
- prevents or minimises safety risks.

Raindrop impact erosion The spattering of soil particles caused by the impact of raindrops on the soil. The loosened particles may or may not be subsequently removed by runoff.

Rainfall Rainwater that falls directly onto a surface of the earth. Periods of low, medium, high, very high and extreme rainfall are defined below:

Low rainfall means those months when the long-term average

	rainfall over the month is not greater than 50mm. Medium rainfall means those months when the long-term average rainfall over the month is greater than 50mm but not greater than 100mm. High rainfall means those months when the long-term average rainfall over the month is greater than 100mm but not greater than 150mm. Very high rainfall means those months when the long-term average rainfall over the month is greater than 150mm but not greater than 200mm. Extreme rainfall means those months when the long-term average rainfall over the month is greater than 200mm.
Rainfall erosivity	The erosive potential of rainfall expressed as the product of total storm energy and the maximum 30-minute intensity of each storm.
Ramsar wetland	A wetland identified as internationally important for the protection of migrating birds by the Ramsar Convention on Wetlands of 1971 held in the Iranian town of Ramsar which resulted in a United Nations treaty enacted in 1975.
Regular storm event	A storm or rainfall event of a given rainfall intensity that is expected to be equalled or exceeded at least twice within a given 28 day period.
Regulatory authority	Any local or regional external authority—whether government or non-government, including local governments and the State Government—that has a legal interest in the regulation or management of either the activity in question, or the land on which the activity is occurring, or is proposed to occur.
Rehabilitate	To restore land to a condition appropriate for the desired ongoing land use, and sufficiently stable to achieve the desired discharge water quality objectives.
Rehabilitation (watercourse)	Improving the geomorphological and ecological conditions of a watercourse to those more closely resembling natural conditions. This includes channel enhancement to minimise erosion and siltation, stream bank protection and revegetation of the watercourse channel and corridor.
Resin-impregnated earth	The method of soil stabilisation using pine resin. Stabilisation may be done on either the subgrade or the pavement itself.
Responsible ESC officer	That person, or team of people of which there is a principal officer, employed or contracted by the land owner and/or developer as the principal officer/entity responsible for ensuring appropriate application of the planned ESC measures and for the provision of advice in response to unplanned ESC issues. Terminology will vary from site to site and region to region. May also be referred to as the *ESC Officer*, *Erosion & Sediment Control Officer*, *Sediment Control Officer*, *Environmental Officer*.
Restoration (watercourse)	To restore original (natural) values and structure, such as returning a watercourse ecosystem back to a pre-impact condition.
Return (sediment fence)	That part of a sediment fence that is turned up a slope to either prevent water flowing along the fence, or flowing around the end of the fence.
Revegetate	The re-establishment of plants on an area of ground depleted or devoid of vegetation in order to provide protection against erosive agents and to improve the nutrient and sediment interception and filtration capacity as well as to provide improved fauna habitat.

Rilling The removal of soil by runoff from the land surface as sheet flow begins to concentrate in one or more small channels, generally up to 300mm deep.

Riparian zone That part of the landscape adjacent to streams that exert a direct influence on streams or lake margins and on the water and aquatic ecosystems contained within them.

Riparian zones includes both the stream banks and a variable sized belt of land alongside the banks. Riparian zones have been defined in a legal context in some States as a fixed width along designated rivers and streams.

Risk The chance of something happening that will have an impact on objectives. It is measured in terms of a combination of the consequences of an event and their likelihood.

River A major watercourse relative to other streams within a given region, ordinarily with a high natural sediment flow, a near constant base flow and with sufficient bed width to result in an open canopy. Bed vegetation is normally sparse and usually does not play a significant role in channel stability due to the disturbing influence of the high sediment load.

It is noted that a watercourse that is recognised as a river in a region of low rainfall may be smaller than some watercourses referred to as creeks in regions of high rainfall.

Rivers in arid and semi-arid areas can run dry.

Road reserve The land between property boundaries and that has been so classified. Within the road reserve there is the central carriageway with or without kerb or “kerb and gutter”, and flanked on either side by the road verge.

Rolled erosion control products (RECPs) Erosion control mats and blankets that are delivered to a site in large rolls and are installed by rolling the synthetic material over the ground surface.

Roof drainage system A system complying with AS3500.3.2, which discharges at a point approved by the local government.

Runoff 1. That part of rainfall which is not lost to infiltration, evaporation, transpiration or depression storage.

2. That part of the water precipitated on to a catchment area which flows from the catchment area past a specified point, or the surface flow of “waste” water originating from on-site activities such as equipment cleaning or cutting operations.

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 kerb inlet Stormwater inlet formed into the kerb of a roadway where the roadway has a zero longitudinal grade (i.e. stormwater approached the inlet from both directions).

Sand A soil separate consisting of particles between 0.02 and 2.0mm in equivalent diameter when dispersed. Fine sand is defined as particles between 0.02 and 0.2mm, and coarse sand as those between 0.2 and 2.0mm.

Sand-based stream A watercourse that contains a layer of loose sand along the channel bed. The progressive movement of this material down the watercourse is normally expected during flood events.

The channel bed may contain significant quantities of vegetation, but the vegetation is usually smothered by sediment during flood events and thus usually does not play a significant role in the long-

	term stability of the channel. If a low-flow channel exists, it can be highly mobile with a constantly changing bed/plan form.
Sand filter bed	A bed of sand or other media through which surface runoff passes. The filtered water is then collected by a subsurface drainage system and discharged. Sand filters are normally operated in association with an upstream pre-treatment system to remove coarse sediment and to ensure an even inflow distribution across the filter.
Sandy soil	A soil that contains at least 50% sand. These are coarse-grained soils that are easy to shovel and break-up when compacted. It is very difficult to form a clod when sandy soils are compressed in the hand.
Scarifier	A tillage implement used for both primary and secondary tillage at depths up to 150mm. Medium duty tines are fitted at an overall tyne spacing ranging from 150 to 250mm.
Sediment	Any clay, silt, sand, gravel, soil, mud, cement, fine-ceramic waste, or combination thereof, transported from its area of origin.
Sediment barrier	Any sediment control device that prevents the passage of coarse sediment either by filtration, or physical blockage of a potential flow path, such as the sealing of a stormwater inlet to prevent the inflow of all water and sediment. The definition of a sediment barrier varies from region to region. Some authorities use the term to refer to the less effective sediment traps such as Type 3 sediment traps and supplementary sediment traps.
Sediment basin	A dam and associated basin used to capture and retain sediment-laden runoff from a land disturbance primarily through the actions of sedimentation. A key design component is the promotion of low-velocity, low-turbulent water flow to facilitate the settling process. Chemical flocculation or coagulation maybe used to assist in the settlement of dispersive or slow-settling particles. Sediment basins commonly consist of an excavated or natural basin, stabilised flow entry points, de-watering system and high-flow emergency spillway. Temporary sediment basins used during the construction phase of civil projects are normally designed to different standards to those incorporated into permanent stormwater management systems, such as those ordinarily located immediately upstream of wetlands, lakes and stormwater treatment ponds.
Sediment control measure	Any system, procedure or material used to filter, trap or settle sediment from sediment-laden waters.
Sediment control technique	A term interchangeable with the term “sediment control measure”.
Sediment control zone	That portion of a work site that drains to a sediment control device, excluding the entry/exit pad.
Sediment deposit	Any gravel, sand, silt, clay, soil, mud, cement, or combination thereof, deposited in an area from where it did not originate.
Sediment fence	A purpose-made, woven or composite (non-woven with woven backing), geotextile fabric sediment trap constructed as a vertical fence in continuous (buried) contact with the ground and supported by posts.

Sediment runoff	Sediment transported by the movement of water.
Sediment trap	Any sediment control device that collects and retains sediment from a fluid either by filtration or gravity-induced settlement. The definition of a sediment trap varies from region to region. Generally the term applies to settling ponds smaller than traditional sediment basins (i.e. Type 2 sediment traps). Throughout this document the term generally applies to any device that traps sediment.
Sedimentation basin	A permanent sediment collection basin as opposed to a temporary construction site "sediment basin". A tank or basin designed for low-velocity, low-turbulent flows suitable for settling coarse sediment particles from stormwater runoff. When attached to a wetland the basin may also be referred to as an *inlet pond*. When attached to a bioretention/biofiltration system it may be referred to as a *coarse sediment forebay*. In each case the design procedures and target sediment size are different.
Settling pond	1. That portion of a sediment basin in which sediment-laden water ponds and sedimentation occurs. 2. A sediment trap typically used in de-watering operations to settle sediment from sediment-laden water. A settling pond differs from a *Stilling Pond* in that it incorporates an outlet structure that allows the pond to freely drain.
Sheet flow	Water flowing at a thin, near-uniform depth that is significantly less than the width of flow.
Short-term stockpile	On a building site it is a stockpile that is located on-site or off-site for less than 24 hours. On a construction site it is a stockpile that is located on-site or off-site for less than 30 days.
Shutdown period	Any period during which construction, building and other land-disturbing activities are suspended for an extended period of time (usually greater than three days) prior to the works being continued or completed. Typically during such periods the site is required to be operating in a condition of low erosion risk in accordance with a specified development approval condition or self imposed operating condition.
Significant rainfall	Unless otherwise defined, rainfall that is sufficient to cause runoff given a specific soil type and soil moisture condition.
Silt	Silt is a soil separate consisting of particles between 0.002 and 0.02mm in equivalent diameter i.e., intermediate between clay and fine sand sized particles.
Site	The lot or lots of land on which building, construction, or other soil disturbing activities are occurring or proposed to occur.
Site inspection	A term that is generally interchangeable (within this document) with the term "site monitoring". The term more commonly refers to the observation (at close range) and reporting of the physical condition of a work site (as an entity) and its associated erosion and sediment control measures. Site inspections may be performed before, during or after rainfall, especially if runoff-producing rain occurs, stormwater runoff discharges from the site, or significant volumes of water enter any sediment basin.
Site manager	Principal officer in charge of the day to day activities on a work site.
Site monitoring	The monitoring of a site.

Slaking	The partial breakdown of soil aggregates in water due to the swelling of clay and the rapid expulsion of air from pore spaces. It does not include the effects of soil dispersion.
Sodic soil	A soil containing sufficient exchangeable sodium for the clay in the soil to readily disperse when placed in water.
Soil erosion	The process whereby wind, water and physical action detach soil particles (including soil, earth, sand, silt, mud, sediment, or cement) and cause them to be transported.
Soil map	A map or plan defining the location and extent of specific soil groups. Such a map may also contain relevant soil information.
Spill-through weir	A level weir installed in a sediment fence, U-shaped sediment trap, or other sediment trap to control the maximum water levels within the trap specifically to reduce the risk of undesirable flooding and/or to reduce the risk of hydraulic failure of the device.
Sprig	Section of plant stem material (rhizome, shoot, or stolon) used in vegetative planting.
Stabilisation (watercourse)	To make the channel surface, form and location stable relative to its natural (undisturbed) conditions, including the application of short-term stabilisation measures to the channel surface for the purpose of controlling soil erosion during the revegetation phase.
Stabilise	To make stable or to achieve a stabilised surface.
Stabilised surface	Any surface, or region of a drainage catchment, which has sufficient resistance to erosion to limit the displacement of granular materials, including clay, silt, sand and gravel, and other specified matter to an acceptable rate. The acceptable rate is based on a specified water quality objective. In cases where an acceptable rate has not been defined, a stabilised surface may be defined as a surface which erodes or otherwise allows the displacement of pollutants from its surface at a rate no greater than a similar surface in its natural (i.e. undisturbed) condition.
Steep gradient flow diversion technique	A flow diversion drain, channel or chute with a gradient sufficiently steep to cause supercritical flow within its length.
Steep site	A site where the predominant ground slope is greater than 10% (i.e. 10:1 [H:V]) when measured perpendicular to the contour.
Stilling pond	A sediment trap typically used in de-watering operations to settle sediment from sediment-laden water. A stilling pond differs from a "settling pond" in that it does not incorporate a low-flow outlet structure. Thus, following settlement of the suspended sediment, the pond is normally de-watered using a pump.
Stolon	Modified plant stem that grows horizontally on the soil surface.
Stormwater	1. Surface water runoff following a rain event (including piped flows). 2. Rainwater that runs off pervious and impervious surfaces such as soil, vegetation, rock, roofs, roads and car parks.
Stormwater inlet	Any inlet to a stormwater pipe, including "field inlets" (also known as drop inlets) and "kerb inlets".
Stream	A small watercourse such as a creek or brook with a sustained base flow that may or may not be permanent. When used in the terms streambed, stream bank and stream flow, it may refer to any type of watercourse, whether or not there is a sustained base flow.

Structural soil	A soil profile artificially reinforced with interconnecting aggregate or synthetic products to improve the trafficability, wear characteristics or strength of the soil.
Sub-area	An area within a given sub-catchment fully contained within a set of drainage control structures designed to minimise the risk of rill erosion within that area. Known also as a “manageable drainage area”.
Sub-catchment	That part of a drainage catchment draining to a specific sediment trap.
Subcritical flow	Flow in a channel or conduit that has a depth greater than the critical depth and a velocity less than the critical velocity.
Subsoil	Sub-surface soil material comprising the B-horizons of soils with distinct profiles.
Supercritical flow	Flow in a channel or conduit that has a depth less than the critical depth and a velocity greater than the critical velocity.
Supplementary sediment trap	A minor sediment trap, such as *Grass Filter Strips* and most kerb inlet sediment traps, that is not effective enough to be classified as a Type 3 sediment trap. Even though these sediment traps are relatively ineffective, their incorporation into most Erosion and Sediment Control Plans is considered a relevant part of the best practice sediment control.
Table drain	The side drain of a road adjacent to the shoulders, and comprising part of the formation.
Toe drain	A drain located along the toe of a slope or batter specifically for draining runoff discharged from the slope.
Topsoil	Topsoil is that part of the soil profile, typically the A1 horizon, containing material which is usually more fertile and better structured than underlying layers.
Total area-time-exposure	The sum of the product of the area (ha) of each sub-area of disturbance times the duration (days) of exposure of that sub-area.
Treatment standard	The specified minimum performance of a drainage, erosion or sediment control technique, or the specified water quality objective. It includes the drainage control standard, erosion control standard and sediment control standard. The treatment standard for sediment control measures may also be specified in accordance with the treatment classification (i.e. Type 1, Type 2 or Type 3).
Treatment train	A series of water quality treatment systems through which contaminated water flows and is treated where the treatment systems vary in both the type of treatment (i.e. settlement, filtration, infiltration, adsorption) and the standard of treatment (i.e. Type 1, Type 2 and Type 3 sediment retention standard).
Tree protection zone	A temporary (construction phase) exclusion zone established around protected and/or retained vegetation.
TSS	Total suspended solids, usually reported in units of mg/L.
Turbid water	Discoloured water usually resulting from the suspension of fine sediment particles.
Turbidity	A measure of the clarity of water. Commonly measured in terms of Nephelometric Turbidity Units (NTU).
Type 1, Type 2, Type 3 sediment traps	A classification system used to rank sediment control measures based on their ability to trap a specified grain size.

Type 1 sediment traps are designed to collect sediment particles less than 0.045mm in size. These sediment traps include sediment basins and some of the more sophisticated filtration systems used in de-watering operations.

Type 2 sediment containment systems are designed to capture sediments down to a particle size of between 0.045 and 0.14mm. Type 2 sediment traps include rock filter dams, sediment weirs and filter ponds.

Type 3 sediment containment systems are primarily designed to trap sediment particles larger than 0.14mm. These systems include sediment fences, grass buffer zones, and certain stormwater inlet protection systems.

Type C sediment basin These basins are mostly suitable for <u>coarse</u> grained, good settling soils (defined as Type C soils). Type C basins may be operated as either "dry" or "wet" basins depending on the requirement for stormwater reuse on the site.

Type C soil A soil that contains a significant proportion of coarse-grained particles (less than 33% finer than 0.02mm) and will settle relatively quickly without the need for flocculation.

Type D sediment basin These basins are required for the treatment of <u>dispersive</u> soils that do not readily settle without the use of flocculating agents (defined as Type D soils). Type D basins can only be operated as wet basins.

Type D soil A soil that contains a significant proportion (>10%) of fine (<0.005mm) "dispersible" materials that will never settle unless flocculated or coagulated. That is, where the percentage of clay plus half the percentage of silt (roughly the fraction <0.005mm) multiplied by the dispersion percentage is equal to or greater than 10.

Type F sediment basin These basins are generally suitable for <u>fine</u>-grained soils that can readily settle without the need for flocculating agents (defined as Type F soils). Type F basins can only be operated as wet basins.

Type F soil A soil that contains a significant proportion of fine-grained particles (33% or more finer than 0.02mm) and require extended settlement periods to achieve efficient settlement that may or may not benefit from chemical flocculation.

Typical seasonal storm A storm event that is likely to occur at least twice during a specified "season" of a year taking into consideration anticipated variations in weather from year to year.

Uncontaminated runoff Stormwater runoff that has not been contaminated by sediment from the work site, or has not been directly or indirectly contaminated as a result of actions associated with the work site.

Unified soil classification system A widely used soil classification system that groups soils according to particle size, grading, liquid limit and plasticity index.

Unit catchment area A term used to define the product of the catchment area (A) and the coefficient of discharge (C). It is equivalent to the maximum allowable catchment area for a coefficient of discharge equal to unity (C = 1.0).

Universal Soil Loss Equation (USLE) 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. The equation does not account for soil erosion occurring within drainage channels or resulting from gully erosion.

The equation's soil loss output (A) has units of tonnes per hectare per year, and incorporates variables accounting for rainfall erosivity

	(R), soil erodibility (K), slope length and grade (SL), erosion control practices (P) and ground cover and management (C). USLE equation: A = R.K.LS.P.C [t/ha/yr]
Up-slope	Any location or activity that exists within the higher part of a slope relative to a reference point on the slope. Ordinarily used in reference to overland flow paths or other areas primarily subjected to sheet flow. When referring to drainage lines, channels and watercourses, the term "upstream" is normally used.
Upstream	Any location or activity that exists within, or moves towards, the higher part of a channel or watercourse relative to a reference point within the channel or watercourse. Ordinarily used in reference to drainage lines, channels and watercourses. When referring to overland flow paths or other areas primarily subjected to sheet flow, the term "up-slope" is normally used.
USCS	Unified Soil Classification System.
USLE	Universal Soil Loss Equation.
Values	That property of a thing by which it is esteemed, desirable, or useful, or the degree of worth (monetary or intangible) this property possesses. Refer also to "environmental values".
Vegetation Management Plan (VMP)	A plan and/or document outlining how site vegetation will be managed, including site clearing, tree protection and preservation, and the management of earthworks adjacent to retained vegetation.
Verge	That part of the street or road reserve between the carriageway and the boundary of adjacent lots (or other limit to street reserve).
Vertical metre	A distance of 1 metre measured in a vertical direction. Typically used to define a section of a slope that has the equivalent vertical fall as the specified vertical metre distance.
Very low erosion risk (or potential)	A very low likelihood of soil erosion resulting from rain, wind or flowing water relative to a given risk rating (such as the various erosion risk ratings presented in Section 4.4 of Chapter 4).
Violent rainfall	Refer to "Extreme rainfall".
VMP	Vegetation Management Plan.
Volumetric runoff coefficient	The ratio of the volume of stormwater runoff to the volume of rainfall that produced the runoff. Different coefficients will be obtained when analysing single storm events compared to the assessment of the average annual runoff.
Waste water	Water runoff, including any contaminants, discharged from cutting equipment (e.g. cooling water), the washing of tools, surfaces or equipment, or any waters containing cement residue. A term different from "wastewater" which refers to water discharged from residential, commercial and industrial properties (during the normal operational phase) through a formal sewer system.
Water bar	A raised embankment, cut drain, timber step or other device placed diagonally across an unsealed road or track to collect and divert stormwater runoff.
Watercourse	Any natural or constructed drainage channel with well-defined bed and banks, including constructed drainage channels of a natural

	appearance, creeks and rivers.
Waters	Any significant body of water whether natural or constructed, or natural drainage system, including creeks, rivers, ponds, lakes and wetlands.
Waterway	Any natural or constructed drainage line, watercourse with well-defined bed and banks, including creeks and rivers, and any water body including lakes, wetlands, estuaries, bays and oceans.
Waterway channel	Whichever is the greater of, the area of land between the riparian zones, or the area of land located below the top of the lower bank (i.e. excluding the floodplain).
Wet basin	A sediment basin that is not free-draining, and thus needs to be de-watered after a storm.
Whoa-boy	A raised embankment, in a form similar to speed bump, with low vertical curvature placed diagonally across an unsealed road or track to collect and divert stormwater runoff across the track to a table drain or suitable discharge point. Also see "cross bank".
Wicking	A procedure for selectively applying herbicide to tall grasses within small drains. A length of stiff wire is shaped to the approximate cross-section of the drain, then wrapped in cloth soaked with herbicide. The "wick" is then passed down the drain such that the herbicide only comes in contact with the taller grasses.
Windbreak	Any device used to reduce the velocity of wind passing over exposed soil.
Windrow	A ridge of soil that may build up along the edge of a track during its construction or maintenance. Windrows can be used to direct road/track runoff to a stable outlet, in which case it is called a "windrow drain".
Witness point	A construction activity that is to be observed by a nominated "witness" such as the Site Superintendent.
Work area	The area that will be disturbed by building or construction works, including the area that fully encloses any soil disturbances, the building activities, materials stockpiles and vehicle pathways.
Work site	The area of potential disturbance by building or construction works, or any other soil disturbance that could potentially cause environmental harm, including: any area enclosed by temporary exclusion fencing, the area of ground disturbance and material stockpiles, and the footprint of all new structures and vehicle pathways.

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Appendix P

Land-based pipeline construction

This appendix provides specific guidelines on the application of best practice erosion and sediment control to the construction of land-based pipelines, and pipeline crossings of waterways, but not offshore pipelines. Its purpose is to describe the various temporary drainage, erosion and sediment control measures that are available for use during the construction of land-based pipelines, and where possible, outline the circumstances in which their use is likely to be warranted.

It is not the intent of this appendix to over-rule the ESC standards set by regulatory authorities for pipeline construction. The intent is to define, from an industry perspective, what is considered 'reasonable and practicable' with regards to temporary erosion and sediment control measures applied during the construction of pipelines.

As such, the appendix is not intended to be used as a prescriptive regulatory tool. It is acknowledged that unique site conditions often require site-specific solutions that may fall outside the generic recommendations presented within this appendix. The appendix also does not contain complete and comprehensive details on all aspects of erosion and sediment control (ESC) relating to pipeline construction; and thus cannot be used in isolation from other industry based publications.

The information presented in this appendix is intended to 'supplement' the recommendations provided within the pipeline industry's Code of Environmental Practice. This appendix specifically refers to the 2013 edition of this Code (APIA, 2013) however readers should always refer to the latest edition of this Code.

The primary focus of this appendix is on major, land-based pipeline construction projects. In general it is not applicable to the installation of minor sewer, water and stormwater pipe connections within residential areas, or the construction of offshore pipelines; however, part of the appendix can reasonably be applied to major projects associated with domestic pipeline installation. Similarly, only parts of this appendix may be applicable to the installation of cables and rural irrigation systems.

It is assumed that readers have an understanding of the principles of erosion and sediment control outlined in Chapter 2, and the contents of the Code of Environmental Practice.

As in all sections of this document, ESC techniques that are presented within the text in italics and with capitals are those techniques on which the reader can find further information within the Book 4 Fact Sheets.

P1 Introduction

In Australia, pipelines are used for a range of purposes including:

- domestic, agricultural, mining and industrial water supply
- stormwater, sewage and wastewater transportation, including recycled water
- gas transmission and petrochemical liquids transmission
- slurry transportation
- powerline, telecommunication and cable conduits.

'Strip' or 'linear' construction, which includes pipeline, road and railway construction, represents one of the most difficult site environments for achieving effective erosion and sediment control. What is considered reasonable and feasible on an open construction site (broad-acre construction) is often significantly different from what is considered reasonable and feasible in strip construction.

Independent of the varying environments, type and size of these construction projects, all pipeline construction activities are likely to experience some common erosion and sediment control issues, including:

- Construction activities are typically restricted to a narrow easement or Right of Way (RoW) where it is not possible to locate erosion and sediment control (ESC) measures outside of the RoW.
- The narrow RoW typically prevents the construction of Type 1 sediment control measures, such as *Sediment Basins*, which means that potential environmental harm is best managed through enhanced erosion and drainage control measures. Thus the key to effective hazard reduction is not to focus on sediment control, but to focus on the 'timing' of construction activities, such as land clearing and site stabilisation, with the aim of minimising the duration soils are exposed to the erosive forces of wind, rain and overland flow.
- Pipeline construction is typically a rapid form of 'strip construction'. The environmental risks associated with such works are often significantly less than slower forms of strip construction such as road construction, or static 'broadacre construction' such as urban development. The most notable exception to this rule is when several pipe and cable services are intended to be installed along a common RoW by different contractors. In such cases it can become impractical to coordinate the activities of all contractors, especially on large projects. Similar problems exist when the concept of 'common trenching' is applied to urban development.
- During the construction phase, RoWs can effectively become drainage channels collecting local rainfall and feeding it along the RoW. This problem is often amplified by the fact that the working surface of the RoW is usually lower (after the stripping of topsoil) than the adjacent land surface, making it difficult to release this water from the RoW at regular intervals, consequently increasing the quantity and velocity of surface water passing down the RoW.
- Pipeline RoWs often cover long distances and cross multiple drainage lines of varying topography, plant communities and soil types. The ESC measures applicable to one drainage catchment may not be appropriate for the adjoining catchment. Consequently, construction personnel need clear guidance on when a generic ESC treatment process is acceptable, and when a site-specific treatment process is required.
- Pipeline crossings of waterways can be a high-risk construction activity, largely dependent on the type of waterway and flow conditions at the time of construction. However, flow conditions within any given waterway will generally not be known at the time of construction tendering, or during the development of the project's generic or primary Erosion and Sediment Control Plans; thus site-specific plans will usually be required for each waterway crossing.
- Pipeline trenches are frequently excavated through problematic soils (dispersive, sodic, saline, or acidic) where soil properties can vary significantly with depth, typically becoming more problematic with increasing depth. It is usually impractical to excavate, stockpile and backfill the trench soil **without** causing some degree of soil mixing.
- Managing problematic soils on pipeline construction sites is complicated by the fact that the majority of the soil disturbance within the RoW is relatively shallow (i.e. just the temporary removal of topsoil) while the complex issues associated with deep subsoil disturbance are usually limited to the relatively narrow region of the actual pipe trench. This means that it can be difficult to assign generic industry-wide

solutions to soil management. Instead, the focus should be on site-based advice received from soil specialists contracted to individual projects.

The overall objectives of environmental protection within the pipeline industry are outlined within the pipeline industry's Code of Environmental Practice (APIA, 2013). With respect to the task of 'erosion and sediment control', the overall objectives may be defined as:

- to take all reasonable and practicable measures to minimise actual or potential environmental harm resulting from soil or water movement as a consequence of either the construction or operational phases (with regard to soil erosion and land rehabilitation) of pipeline installations
- to maintain, and where practical, enhance the land use capabilities of disturbed areas with respect to land's soil, water and vegetation attributes
- to ensure that permanent erosion control measures applied to pipeline and road crossings of waterways are compatible, to the maximum degree practical, to the geomorphological attributes of the waterway
- to ensure temporary ESC measures do not unreasonably impact upon the economic and safety-related attributes of an individual project.

This appendix aims to focus on those issues and site conditions that are unique to pipeline construction; however, there will be circumstances where designers and construction personnel will be required to refer to other chapters or appendices within this document. Table P1 outlines those circumstances where reference to other sections of this document is recommended.

Table P1 – Recommended referencing to other chapters of this IECA document

Chapter / appendix	Issues relating to erosion and sediment control
Chapter 2	• Generic guidance on the application of erosion and sediment control principles to construction sites.
Chapter 3	• Guidance on soil testing for broad-acre (i.e. non-RoW) construction works associated with pipelines, such as gas processing plants.
Chapter 4	• Guidance on ESC technique selection for broad-acre (i.e. non-RoW) construction works associated with pipelines, such as gas processing plants.
Chapter 5	• General guidance on the preparation of Erosion and Sediment Control Plans (ESCPs) for all works, and generic ESCP check list.
Chapter 6	• Guidance on the management of construction sites specifically relevant to site managers, on-site environmental officers, and regulators. • General guidance on the management of pipeline construction sites may be found in Section P3 of this appendix.
Chapter 7	• General guidance for environmental officers and regulators on conducting erosion and sediment based site inspections.
Appendix A	• Guideline on hydrology and hydraulic analysis of ESC measures.
Appendix B	• Design and construction of sediment basins.
Appendix C	• Educational material on the management of soil and vegetation.
Appendix E	• Guidance on the application of soil loss RUSLE calculations.
Appendix I	• Generic guidance on the management of instream works such as pipeline crossings of waterways. • Section P3.6 of this appendix directs the reader to Appendix I as required.
Appendix K	• Guidance on the construction of unsealed access track outside the pipeline RoW.
Book 4 Fact Sheets	• Design, installation and maintenance information on various drainage, erosion and sediment control measures.
Book 6 Standard Drawings	• Typical installation drawings and specifications for various drainage, erosion and sediment control measures.

It is not the intention of this appendix to reproduce issues or recommendations provided within the pipeline industry's Code of Environmental Practice. Table P2 outlines those site issues which are either addressed solely within the Code of Environmental Practice (APIA, 2013 edition) or are addressed collectively by the Code and this appendix.

Table P2 – Referencing to the Code of Environmental Practice (APIA, 2013)

Section	Issues relating to erosion and sediment control
5.0 Pipeline planning activities	• Appropriate integration of ESC issues (as raised within this appendix) into the planning of pipeline route selection.
6.1 Access to site	• Guidance on those issues that influence the planning of site access and the selection of appropriate access points.
6.2 Clearing	• Minimising the area of disturbance is a critical ESC objective. This section of the Code outlines those issues, in addition to ESC, that need to be considered when selecting the width of the RoW. • Guidance on selective clearing and clearing procedures adjacent to waterway crossings.
6.3 Grading	• Guidance on the stripping of topsoil. • The information provided in the Code shall be considered to ‘supplement’, not supersede, that presented within this appendix.
6.5 Trenching	• Guidance on the environmental management of acid sulfate soils. • Detailed guidance on the management of acid sulfate soils is neither provided in APIA (2013) or this appendix, but should be sought from local state guidelines.
6.7 Trenchless technology	• Guidance on the use of micro-tunnelling (closed-face boring), thrust boring, directional drilling, and plough-in pipe laying techniques.
6.9, Borrow pits, 6.10 Construction camps & work sites	• Guidance on issues associated with ancillary works associated with the pipeline, such as site office, lay-down areas, pipe-yards, and borrow pits.
6.11 Watercourse crossings	• Guidance on appropriate risk assessment procedures for selecting the preferred construction (pipe installation) technique. It is noted that the issues that need to be considered are beyond the scope of this appendix.
6.13 Reinstatement and Rehabilitation	• Guidance on the environmental management of site rehabilitation activities. • The information provided in the Code shall be considered to ‘supplement’, not supersede, that presented within this appendix.
9.1 Flora management	• Guidance on flora management during the construction and operational phases.
9.3 Biosecurity management	• Guidance on weed management with respect to imported soils.
9.6 Soil management	• Guidance on the environmental management of soils. • Guidance on the management of dispersive and slaking soils (9.6.2), acid sulfate soils (9.6.3), high shrink/swell soils (9.6.4), saline soils (9.6.5), soils in dry/desert environments (9.6.6), wetland soils (9.6.7), soils with pH extremes (9.6.8), and shallow rocky soils (9.6.9).
9.7 Drainage, erosion and sediment management	• Guidance on temporary erosion and sediment control requirements. • The information provided in the Code shall be considered to ‘supplement’, not supersede, that presented within this appendix.
9.8 Water management	• Guidance on the environmental management of natural water bodies and the discharge of site water.
9.11 Dust and other air emissions	• Guidance on dust control.

P2 Planning and design phase

There are numerous environmental, technical, social and economic factors that need to be considered when selecting a pipeline easement route. Readers are directed to the pipeline industry's Code of Environmental Practice (APIA, 2013) for guidance on the various factors that need to be considered, and how best to select an easement route. As in all cases throughout this appendix, reference to APIA (2013) implies that readers should refer to the latest version of this Code

The following discussion summarises those issues that relate directly to the practices of erosion and sediment control (ESC). The intent of this discussion is to 'supplement' the discussion already contained within the Code. It is of course recognised that ESC issues will rarely be the defining factor that determines the preferred pipeline route.

P2.1 Erosion and sediment control issues that may influence pipeline planning

The factors that typically influence soil erosion are discussed in Appendix M – *Erosion processes*. With respect to pipeline construction, these factors include:

- rainfall erosivity
- soil erodibility
- topography
- degree of surface cover
- layout of surface drainage (i.e. the division of 'sheet' and 'concentrated' flow)
- area and duration of soil exposure to wind, rain and surface flow.

The geological factors that should be considered when selecting the pipeline route, include:

- local topography associated with small hillsides where alternative routes are available across the hillside
- existence, depth, nature and hardness of bed rock
- existence of unstable or unfavourable land surfaces, including slopes subject to mass movement, areas of rock outcrops and areas of existing erosion
- possible waterway crossings, including alternative route options that minimises the number of waterway crossings, and/or minimise the disturbance of unstable or highly mobile reaches of a waterway.

Rainfall erosivity is normally independent of route selection. Rainfall erosivity is more likely to influence the timing of works relative to a 'wet season', the desirable extent (area) of soil exposure at any given time, and the timing and method of site rehabilitation.

Topography is only likely to influence route selection if the route options allow alternative passage over or around a hill, such as passing over a hill perpendicular to the contours, across the contours, or passing around the hill. Passing over a hill perpendicular to the contours will usually result in the pipeline ascending the steepest gradient, which increases the potential for high velocity surface flows passing down the RoW. However, this option can also reduce the potential up-slope catchment area feeding run-on water into the RoW.

Passing over a hill along an alignment that crosses the contours will usually result in lower pipeline gradients, and thus reduced surface flow velocities; however, this option will likely increase the potential up-slope catchment area feeding run-on water into the

RoW, and this option can present safety issues associated with the operation of heavy machinery on cross slopes.

Passing around a hill can significantly reduce pipeline gradients, but can increase the easement length and the up-slope catchment area feeding run-on water into the RoW.

Rock outcrops can occur when either bedrock or large fragments of dissected bedrock occur at or near the ground surface. The combination of bare rock surfaces and shallow soils can result in reduced infiltration, increased runoff rates, and an increased erosion hazard.

Common examples of existing erosion that may present a hazard to pipelines include active gully erosion, head-cut erosion migrating up drainage lines, slopes subject to mass movement (land slips) and larger areas of exposed subsoil (e.g. scalds). Head-cuts, gully erosion and landslips can not only expose a previously buried pipeline, but can also cause some pipelines to fracture.

P2.2 Waterway crossings

Constructing pipelines across waterways is expensive and is usually subject to a high environmental risk. Minimising the number of waterway crossings provides obvious financial benefits during the construction phase; however, this should not be the only consideration. Crossing waterways at suitably stable locations can **significantly** reduce ongoing maintenance expenditure.

During the planning phase, designers can seek guidance on the selection of suitably stable waterway reaches in the following ways:

- seek the advice of waterway experts, such as a river morphologist, or geologist specialising in waterways; however, it is noted that there can be numerous subtle differences between the behaviour of rivers and creeks, and while some professionals may have experience with a wide range of waterway types, others may specialise in only one type of waterway
- obtain historical aerial photographs of the waterway for the purpose of assessing the past movement history of the waterway
- obtain the advice of local authorities and/or long-term land owners.

Waterway rehabilitation is a specialist industry in terms of both the choice of armouring materials and plant selection. Selecting appropriate bank vegetation that is compatible with the waterway morphology, the required fauna passage, and the requirements for maintenance access to the pipeline, is a specialist task that often requires reference to state codes and guidelines.

Planners and designers need to be aware of the fact that there are many different types of waterways, from creeks to rivers, saline to freshwater, fixed-bed to alluvial. The same rules do not apply to all waterways. Therefore, it is important to ensure that the planners and designers of pipelines receive appropriate advice from waterway experts that have experience in the types of waterways being crossed by the pipeline.

If the proponents of a pipeline project are concerned about a possible environmentally, politically, or socially sensitive waterway crossing, then consideration should be given to highlighting these issues within the tender process, and/or issuing the waterway crossing as a separate contract or cost item.

P2.3 Soil hazards and soil testing

If soil properties are expected to vary significantly along a pipeline corridor, then the construction project will either need to employ a resident soil scientist, or have ready access to the consulting services of a soil scientist. In such cases, any advice or recommendations presented in the following text should be considered subservient to the advice of the resident soil scientist.

It is noted that engineering-based geotechnical advice is usually required in addition to, and **not** in replacement of, soil science. Geotechnical advice is often critical in determining the trenching method (e.g. degree of benching) and the post-works stabilisation of steep slopes.

Readers that wish to expand their knowledge of soil issues are encouraged to review Appendix C – *Soils and revegetation*, which is an educational appendix provided for the benefit of non soil scientists.

The soil properties that are most likely to present hazards to pipeline construction are:

- soil acidity
- potential acid sulfate soils
- hydrophobic soils
- expansive and reactive soils
- hardsetting soils
- sodic soils
- non-cohesive soils
- low water-holding capacity
- soils of low fertility
- saline soils

Of most concern to pipeline projects is the management of dispersive and slaking soils. Considerations in determining clay dispersion hazard are outlined in Table P3.

Table P3 – Clay dispersion hazard [1]

Dispersion hazard rating	Emerson class number	ESP	Ca:Mg ratio	ESI [2]	Typical clay content	Cation:clay ratio
Low	4–8	< 6%	> 0.5	> 0.1	< 10%	< 0.2
Moderate	3	6 to 15%	0.5	< 0.05	10–30%	> 0.2
High	1–2	> 15%	< 0.5	< 0.05	> 30%	> 0.2

Notes:

[1] Each of these parameters are an ‘indicator’ of dispersion potential. The preferred indicator is the exchangeable sodium percentage (ESP). A common indicator used in civil construction is the Emerson class; however, it is not considered as reliable as ESP.

[2] Electrochemical Stability Index (ESI) = (EC1:5 in dS/m)/ESP.

General guidance on soil testing is provided in Appendix C – *Soils and revegetation*. It is strongly recommended that the services of a soil expert and the resident land operator are consulted in regards to soil testing and amelioration in any circumstance where pipeline construction crosses active agricultural land.

Soil sampling and testing is recommended to determine those soil characteristics that might influence revegetation outcomes (e.g. soil fertility, pH, depth, structure, particle size distribution) and asset stability/safety (e.g. soil dispersion, bulk density).

Wherever possible, soil sampling and testing should be conducted by a suitably qualified person (e.g. a CPSS or CPESC). If this occurs, the frequency of sampling can be determined by the suitably qualified person, based on the likely distribution and variation of 'soil landscapes' (i.e. areas containing a relatively consistent suite of soils) along the right-of-way. These 'soil landscapes' can be determined based on existing soil mapping, land topography, geology changes, vegetation changes or landscape position.

By determining 'soil landscapes', the number of soil samples and tests undertaken can be reduced because only representative or typical soil samples need to be sampled and tested from each 'soil landscape' along the right-of-way. In addition to sampling and testing these representative or typical soil profiles, additional soil observations should be made at other locations within each 'soil landscape' to confirm the sampled soils are indeed representative of that 'soil landscape'.

If the above method of sampling only representative samples from 'soil landscapes' is not used, soil sampling is recommended at minimum intervals along the right-of-way equivalent to $3 \times \sqrt{d}$, where d is the length (in km) of the proposed right-of-way. For example, on a 64 km long right-of-way, a minimum of 24 samples should be collected and tested ($3 \times \sqrt{64} = 24$).

Chapter 3 – *Site planning*, provides guidance on the density of soil sampling in broad-acre (i.e. non-RoW) construction areas, such as the larger ancillary works often associated with pipeline projects.

P2.4 Erosion hazard and risk assessment

Regulatory standards as they relate to the assessment of environmental impact of pipeline projects are highly variable across Australia. In the absence of state-specific requirements, APIA (2013) provides guidance on the type of documents that need to be prepared, plus broad guidance on the issues that should be addressed.

Data collection and interpretation is the key to understanding the erosion hazards and designing appropriate management systems for these hazards. The extent of data collected about soils, vegetation, hydrology and river morphology (if waterway crossings are involved) must be commensurate with the potential environmental risk, and the extent and complexity of the proposed soil disturbance.

Project characteristics and constraints that should be investigated and evaluated during project planning include:

- existing and likely areas of soil disturbance
- existing vegetation and land use
- land slopes and contours
- location of drainage lines, waterways, creeks and rivers
- soil constraints, such as erodibility, dispersibility, sodicity, salinity, texture, pH, depth, fertility, areas susceptible to tunnel erosion, expansive or reactive soils, potential acid sulfate and contaminated soils
- landscape constraints, such as mass movement, flood hazard, water logging, high watertable and rock outcrops
- the expected variation in rainfall erosivity across the construction period, or throughout the full year if the construction period is unknown.

Chapter 3 – *Site planning* provides guidance on data collection and the possible impacts of a range of site constraints, as well as introducing the concept of erosion hazard assessment.

Erosion hazard assessment is a procedure for undertaking a 'preliminary' assessment of the erosion hazards associated with a construction project. For pipelines, this assessment is typically carried out on a corridor segment (hilltop to hilltop) but may also be performed on individual sub-catchments (refer to discussion in Section P2.5).

Erosion Risk Mapping may be derived from a combination of the various parameters presented in Table P4 depending on available information.

Table P4 – Erosion risk parameters and suggested ratings [1]

Site conditions during soil disturbance	Erosion risk rating [2]				
	Very low	**Low**	**Moderate**	**High**	**Extreme**
Average gradient of disturbed area (%)	≤ 3	> 3 & ≤ 5	> 5 & ≤ 10	> 10 & ≤ 15	> 15
Clay dispersion hazard [3]	Low	Low	Moderate	Moderate	High
Average monthly erosivity (RUSLE R-factor) [4]	0–60	61–100	101–285	286–1500	> 1500
Average monthly rainfall depth (mm) [4]	0–30	31–45	46–100	101–225	> 225

Notes:

[1] This table is derived from tables 4.4.1, 4.4.2, F4 and P3 (refer to Chapter 4 and Appendix F).

[2] The erosion risk rating for any given corridor segment or sub-catchment is taken as the highest rating of: the land slope rating, clay dispersion hazard, and either the average monthly R-factor or average monthly rainfall classification.

[3] Clay dispersion hazard is determined from Table P3, and is based on the properties of dominant subsoil exposed across the RoW (not the subsoils exposed within the pipe trench).

[4] Both the 'average monthly erosivity' and the 'average monthly rainfall depth' (which ever is adopted) should be determined as an average of the months during which soil disturbance is occurring, or scheduled to occur, whenever this time period is known; otherwise the annual average value shall be adopted.

At the discretion of the asset owner or regulatory authority, the erosion hazard can be used to provide guidance on:

- assessing the attributes of alternative pipeline routes (along with other factors)
- the spacing of trench breakers (more likely linked to just the dispersion hazard)
- the need for special treatment of trench backfill
- when it is necessary to engage specialists in the fields of soil, vegetation, hydrology, or erosion and sediment control
- areas where soil disturbances should be avoided during certain periods of the year
- the required erosion and sediment control design standards and techniques to be adopted in regions of a given erosion risk and/or specific periods of the year.

Each erosion hazard should be assessed individually to determine appropriate management strategies and techniques to address the specific erosion risk. There are no specific outcomes that apply to all sites and all circumstances. The adopted solutions must consider the parameters that contribute to the erosion risk, potential environmental impacts, the mechanics of the erosion, the availability of suitable materials, required performance outcomes, lifespan and cost.

The erodibility of soil is typically influenced by particle size distribution, organic matter content, clay type and the percentage of sodium or magnesium ions in relation to the other soil cations. Expansive/reactive soils, hardsetting soils, sodic soils and non-cohesive soils all potentially have high erosion risk when disturbed. Although it can be technically possible to ameliorate such soils to reduce their erosion potential, the cost and practicality of doing so along a pipeline RoW is unlikely to be feasible.

Details on the application of erosion hazard assessment to broad-acre (i.e. non-RoW) construction sites (i.e. large scale disturbances associated with ancillary works) are provided in Appendix F – *Erosion hazard assessment*.

P2.5 Drainage catchment and sub-catchment boundaries

Large-scale pipeline corridors can cross several drainage catchments, each of which can be divided into several sub-catchments by temporary drainage control measures. To avoid confusion, it is important for the pipeline industry to have a clear definition of these two terms, 'catchment' and 'sub-catchment'.

Traditionally, the term 'catchment' referred to any land that contributed surface runoff to a specific waterway or receiving water. As such, it could be claimed that any pipeline being constructed in the south-western region of NSW would exist within the single drainage catchment of the Darling River. Clearly, such a broad definition would have little meaning within erosion risk mapping. Consequently, for the purposes of erosion risk mapping, the following definitions have been adopted.

Catchment	That part of a drainage catchment, including the land up-slope of a pipeline corridor, that would naturally drain to a single waterway or drainage line passing through the pipeline corridor. The expression 'naturally drain' means the natural topographic drainage of a catchment excluding the effects of permanent or temporary drainage diversions such as roads and flow diversion banks. Typically the 'catchment' includes the full surface area of the pipeline corridor from ridge-top to ridge-top. It is noted than in parts of this document, the term 'catchment' may be used in a generic sense to simply imply the drainage catchment contributing flow to a given structure.
Corridor segment	That part of an individual 'catchment' that is contained within the pipeline corridor or Right-of-Way. In effect, this is the full surface area of the pipeline corridor from ridge-top to ridge-top. Typically this means that a 'segment' would include only one waterway or drainage line crossing; however, some drainage lines may be considered too minor to be considered as an individual catchment. Professional judgement is therefore required to select meaningful corridor segments.
Sub-catchment	Any sub-section of a drainage catchment, whether temporary or permanent, that drains to an individual drainage control measure, sediment trap, or flow release point from the pipeline corridor. A 'sub-catchment' is typically the drainage area considered when designing an individual flow diversion system or sediment trap.

Figure P1 demonstrates the three drainage terms diagrammatically.

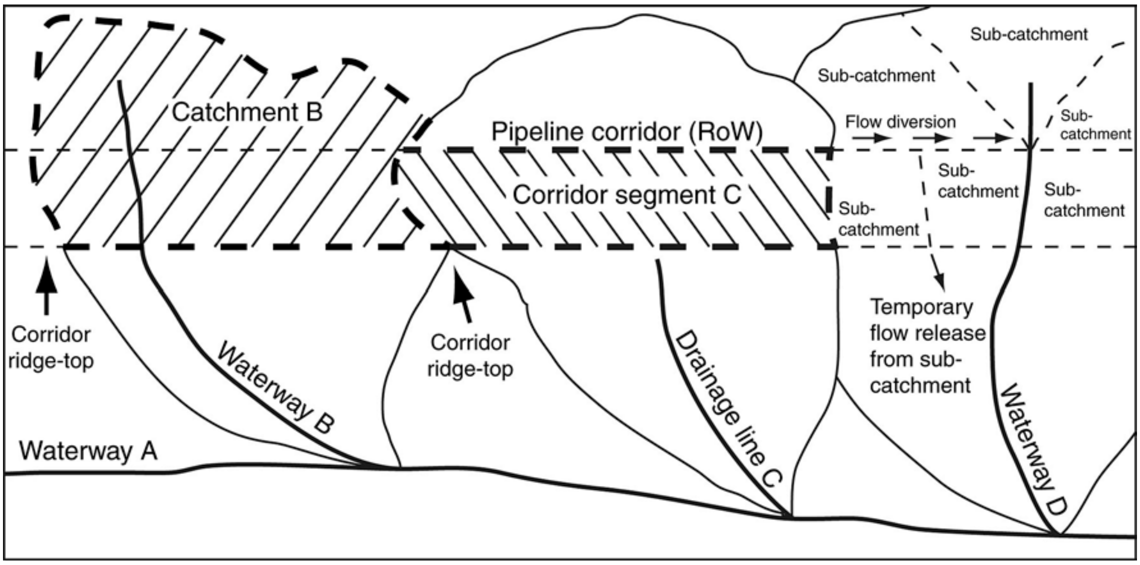

Figure P1 – Definition of a catchment, corridor segment and sub-catchment

P2.6 Erosion and Sediment Control Plans

The minimum standard of documentation that should be prepared for pipeline construction is Erosion and Sediment Control Plans (ESCPs). Due to the unique, often fast moving nature of pipeline construction, a two-tier ESCP process is **recommended** (but not mandatory). The first ESCP is termed the ‘Primary ESCP’. The Primary ESCP is an overarching ESCP that demonstrates general drainage, erosion and sediment control practices for the whole construction project. Typically these plans would be produced during the planning and design phase.

In some cases these plans will need to document actual site conditions along the full length of the pipeline. In other cases, such as irrigation and cable installation, these plans may only need to provide generic solutions that can be applied to a wide range of topographic conditions. The extent and complexity of these plans needs to be commensurate with the potential environmental risk, the project scale, and the extent and complexity of the proposed soil disturbance.

The second level of ESCPs is termed the ‘Progressive ESCP’. Progressive ESCPs are developed as the project progresses, as site conditions evolve, and as flow paths change. These plans provide up-to-date details on the location and installation of the required control measures, and are usually prepared at the expense of the contractor.

The two-tier ESCP approach has been proven to work well on linear construction projects such as roads, rail and pipelines. It reduces unnecessary repetition of information as projects progress, and allows timely updating of ESCPs to reflect actual site conditions and to demonstrate ongoing compliance.

Progressive ESCPs should be presented as a series of drawings and associated tables and report outlining temporary drainage, erosion and sediment control procedures to address a given sub-catchment, corridor segment, or high-risk area (e.g. waterway crossings). In most cases, individual plans will be needed for each waterway crossing, but not necessarily for each drainage line crossing.

Table P5 outlines the recommended production of Primary and Progressive Erosion and Sediment Control Plans. Table P5 also outlines those conditions when generic (non site-specific) plans are considered a suitable replacement for Primary ESCPs.

Table P5 – Recommended development of ESCPs for pipeline construction

Activity or installation type	Primary ESCPs	Progressive ESCPs
Timing of plan development	Prior to site establishment	Prior to soil disturbance at the specified location or within a specific corridor segment
All cases	All ESCPs provide guidance on variations in ESC measures required for different seasonal weather conditions	Revised ESCP in the event that the Primary ESCP no longer addresses actual site conditions (e.g. variable soil conditions, or construction site layout)
Width of soil disturbance along the RoW is less than 6 metres	Generic ESCPs [1] showing typical ESC layouts (content as discussed below)	Individual plans required for corridor segments or sub-catchments with a high or extreme erosion risk rating [2] and all waterway crossings [3]
Width of soil disturbance along the RoW is greater than 6 metres but less than 20 metres	Generic ESCPs showing typical ESC layouts (content as discussed below)	Individual plans required for corridor segments or sub-catchments with a moderate or higher erosion risk rating [2] and all waterway crossings [3] Progressive ESCPs may be required at some road crossing, depending on the degree of complexity
Width of soil disturbance along the RoW is greater than 20 metres	Large-scale, site-specific ESCPs (content as discussed below)	Individual plans required for corridor segments or sub-catchments with a moderate or higher erosion risk rating [2] and all road, drainage line and waterway crossings [3]

Notes:

[1] A ‘generic’ Primary ESCP is a plan that is not specific to any given project or location.

[2] Erosion risk rating as derived from Table P4.

[3] Refers to waterways that have a reasonable possibility of carrying surface flow during the period from initial soil disturbance below top-of-bank to a time when a stable surface has been achieved on the channel banks. Does not refer to drainage lines or overland flow paths. If multiple waterway crossings exists of a similar nature (i.e. not a mixture of clay, sand, gravel and rock-based waterways), then these individual plans can be linked back to a single generic plan. Also, refer to the discussion below on the development of Progressive ESCPs for drainage line and waterway crossings.

A key difference between Primary and Progressive ESCPs is that the time of year, and thus the likely flow conditions within drainage lines and waterways, should be known during development of the Progressive ESCP. This allows ESC issues at drainage line and waterway crossings to be more appropriately addressed for the expected flow conditions.

Table P5 (above) recommends that Progressive ESCPs should be developed for all individual drainage line and waterway crossings if the RoW width exceeds 20 metres. The ‘intent’ here is to ensure that the detail of information provided within the ESCP is appropriate for the local topography and expected flow conditions. Given this ‘intent’, if on a particular pipeline project, the site conditions (including local topography and likely flow conditions) are similar for a number of drainage line or waterway crossings, then the Progressive ESCPs may revert back to a generic form for each crossing type so long as the ‘intent’ is always satisfied.

Recommended contents of a ‘generic’ **Primary ESCP** are:

- document control information
- generic ESC layout for: trench spoil stockpiled up-slope of trench, trench spoil stockpiled down-slope of trench, drainage line crossings, site entry and exit points, and vehicle crossings of drainage lines and waterways
- standard drawings of all ESC measures likely to be used
- materials, operation, maintenance and removal procedures of the of the ESC measures, including procedures for site stabilisation and revegetation.

Recommended contents of a ‘site-specific’ **Primary ESCP** are:

- document control information
- project description outlining the nature and scale of the works
- location of primary receiving waters, soil sampling and site entry/exit points
- location of non disturbance areas, areas of restricted clearing, and protected vegetation
- primary sub-catchment boundaries and erosion risk mapping
- management strategies for:
  - minimising the extent and duration of soil disturbance
  - controlling water movement through disturbed areas
  - minimising risk of ongoing tunnel erosion within the backfilled pipe trench
  - ESC procedures adopted for wet weather and temporary site shut down
  - proposed staging of site rehabilitation relative to anticipated weather conditions and time of year
  - site monitoring and inspecting procedures
  - procedures for revising ESCPs and the production of Progressive ESCPs
- standard drawings of all ESC measures likely to be used
- materials, operation, maintenance and removal procedures of the of the ESC measures, including procedures for site stabilisation and revegetation
- calculations and work sheets.

Recommended contents of a **Progressive ESCP** are:

- pre and post disturbance/shaping contours
- description of specific works covered by the plan
- clean and dirty water drainage paths
- local soil, water and landscape issues (if not included in Primary ESCP)
- location of sensitive features and non disturbance areas
- limits of disturbance
- erosion Risk assessment (if sub-divisions exist within plan’s coverage area)
- installation sequence for ESC measures
- location and identification coding/numbering of control measures
- directions for controlling water movement along and across the RoW
- location of local monitoring sites (if specific location have been identified)
- specific installation details, notes and calculations for ESC measures
- specific operating procedures
- relevant standard drawings (if not already included within the Primary ESCP).

Erosion and Sediment Control Plans should be prepared and certified by a suitably experienced and qualified erosion and sediment control professional. Some states and territories in Australia nominate the minimum training requirements for those certifying ESCPs.

It is also important to note that some states (e.g. Queensland) and some organisations, require hydraulic or hydrologic calculations and designs associated with engineering structures (such as sediment basin spillways) to be reviewed and certified by an appropriately qualified/certified engineer.

However, it is not the intent of this appendix to imply that **all** persons involved in the development of ESCPs should be trained in the field of erosion and sediment control. The key to the development of appropriate ESCPs is to engage a team of people with varying expertise (soil, water, vegetation, construction, ecology and waterway experts) that are guided by a suitably experienced and qualified ESC professional, who ultimately signs off on the plan.

It is difficult to clearly define the 'measure' of a suitably experienced and qualified ESC professional, because it varies with the complexity and erosion risk of the project. In the absence of local requirements, Table P6 provides a **guide** to the level of training likely to be required to sign off on an ESCP for different project conditions.

Table P6 – Recommended minimum training of a 'suitably qualified and experienced ESC professional'

<table>
<tr><th>Project type</th><th>Erosion risk [1]</th><th>Primary ESCPs</th><th>Progressive ESCPs</th></tr>
<tr><td rowspan="2">Width of soil disturbance along the RoW is less than 6 m</td><td>Very low to high</td><td colspan="2">Introductory (1-day) ESC training</td></tr>
<tr><td>Extreme</td><td colspan="2">Advanced (2-day) ESC training</td></tr>
<tr><td rowspan="2">Width of soil disturbance along the RoW is greater than 6 metres but less than 20 metres</td><td>Very low to moderate</td><td>Introductory (1-day) ESC training</td><td>Advanced (2-day) ESC training</td></tr>
<tr><td>High to extreme</td><td>Advanced (2-day) ESC training</td><td>Comprehensive (4-day) ESC training</td></tr>
<tr><td rowspan="3">Width of soil disturbance along the RoW is greater than 20 metres</td><td>Very low to moderate</td><td colspan="2">Advanced (2-day) ESC training</td></tr>
<tr><td>High</td><td colspan="2">Comprehensive (4-day) ESC training</td></tr>
<tr><td>Extreme</td><td>Comprehensive (4-day) ESC training</td><td>Certified Professional in Erosion and Sediment Control (CPESC)</td></tr>
</table>

Note:

[1] Erosion risk rating as derived from Table P4.

P2.7 Developing project-specific targets and responses

Numerous aspects of pipeline construction can be site, regional or project-specific. As such, many of these issues either, cannot reasonable be addressed in detail within this national guideline, or if address, could benefit from further refinement based on regional considerations. The following discussion outlines some of the ESC-related issues that are possibly best addressed on a regional or project basis.

Planners and designers of major pipeline projects are encouraged to expand upon the generic recommendations presented within this appendix, and develop appropriate regional or project-based targets and/or responses to local soil and erosion issues. However, all regional or project-based targets should at least achieve the environmental protection established by the generic responses, unless appropriately justified to the satisfaction of the regulating authority. Typical examples of issues that can benefit from a regional adjustment are provided below.

(i) Erosion risk rating

The default ‘erosion risk rating’ is provided in Table P4. This table may be refined to a project level based on the following:

- Refinement of the land slope divisions based on the range of land slopes expected on a given project. Noting also, that in some regions of Australia, such as arid areas, only very minor changes in land slope can cause significant increases in the erosion risk.
- Refinement of the range of monthly rainfall depths.

(ii) Development of Erosion and Sediment Control Plans

Table P5 provides recommendations on the development of Primary ESCPs and Progressive ESCPs. This table may be refined to a project level based on the following:

- The definitions of, and environmental risks associated with, drainage lines and waterways can vary significantly across Australia. Where appropriate, this table may be refined to ensure Progressive ESCPs are only developed where the environmental risks warrant such refinement.
- The need for Progressive ESCPs also depends on the degree of refinement of any generic ESCPs developed for the project. The more effort that is applied to the development of the generic ESCPs such that they address a range of common site issues or conditions, then the less reliance need be placed on Progressive ESCPs.

(iii) Temporary stabilisation of topsoil windrows and flow diversion banks

The need for the temporary stabilisation of topsoil windows and other flow diversion banks is a complex issue. Unlike subsoils, topsoils can be highly resistant to erosion by raindrop impact, and what erosion does occur is unlikely to cause environmental harm. Of course, exceptions do exist, and if the land that has a long history of pastoral activity, then the stripped topsoil may be heavily degraded from its original condition.

Recommendations for the temporary stabilisation of topsoil windows and other flow diversion banks can be refined to a project level based on the following site variables:

- The erosion potential of the topsoil.
- The risk of the eroded soil causing adverse impacts on down-slope environments.
- The expected velocity of concentrated flows passing along the up-slope face of the windrow.
- The expected working life of the window prior to site rehabilitation.

(iv) Construction details for trafficable cross banks (berms)

The typical profile of trafficable drainage berms is provided in Section P3.3.1. The specification for these drainage berms can be refined to a project level based on the following site variables:

- The risk of exposure of highly dispersive subsoils.
- The existence of soils on the RoW that are highly unstable when wet, thus requiring the inclusion of rock or geotextiles to improve the berm’s wet weather trafficability.
- The speed of vehicles travelling along the RoW.

(v) Temporary soil stabilisation (erosion control) of RoW at drainage line crossings

The temporary stabilisation of soils exposed at drainage line crossings is discussed in sections P3.3.2, P3.5 & P6.8, and tables P23, P32 & P33. Given the high variability of drainage lines conditions across the country, and the number of drainage lines that a single project can cross, the treatment of drainage line crossings may need to be refined for a specific project or region. Ideally, a simple technique/treatment selection table could be produced that would typically be based on:

- The likelihood of flows within the drainage line—possibly related to the time of year of the construction, and the expected duration of the exposure.
- The catchment area—it is noted that catchment area influences the possible discharge, and that subdivision of catchment areas into various categories can vary significantly across different climatic regions.
- The gradient of the drainage line—which influences the likely flow velocity.
- The duration of exposure—this may or may not have been considered in regards to the likelihood of flow occurring.
- The staging of works—it is noted that if a project has a long lead time between land clearing and the opening of the pipe trench across a drainage line, then a temporary soil treatment may be required at this early stage, followed by a secondary treatment after pipe installation and equipment disturbance of the crossing has largely been completed.
- The occurrence of unexpected site shut-downs.

An example of a 'regional' treatment of drainage line crossings is provided in Table P7 for demonstration purposes only. This example is provided for the Western Downs region of Queensland, and would not be appropriate in other regions.

Table P7 – Example of the treatment of drainage line crossing in the Western Downs region of Queensland

Catchment area	Pre open trench	Post pipe installation [1]
Less than 5 hectares with gradient less than 4%	*Soil binder* [2]	*Jute blanket* or *Jute mesh* securely pinned over seeded loose mulch
Less than 5 hectares with gradient more than 4%	Filter cloth [3]	*Bonded Fibre Matrix* or *Flexible growth media* with a suitable velocity-control *Check Dam* placed along the down-slope edge of the RoW to control flow velocities
5 to 25 hectares	Filter cloth [3]	*Jute mesh* over *Bonded Fibre Matrix* or *Flexible growth media*
Greater than 25 hectares	Filter cloth [3]	Filter cloth prior to placement of site revegetation measures *Jute or coir mesh* over *Bonded Fibre Matrix* or *Flexible growth media* as part of site revegetation measures

Notes:

[1] Treatment may be altered by the nominated revegetation measures.

[2] Appropriate only if rainfall is possible during this period, and the exposure period prior to pipe installation exceeds two weeks.

[3] Placement of filter cloth depends on the expected duration of exposure prior to active pipe installation activities (i.e. works that are likely to heavily disturb the soil in the region of the drainage line).

(vi) Temporary soil stabilisation (erosion control) of RoW at waterway crossings

The temporary stabilisation of soils exposed at waterway crossings is discussed in sections P3.3.2, P3.6, P3.9 & P6.9, and tables P23, P27, P28 & P33. Given the high variability of waterways across the country, the treatment of waterway crossings may need to be refined for a specific waterway, region or project. If the waterway conditions are highly variable, then it may be necessary to treat each waterway on a case-by-case basis. If waterway conditions are not highly variable throughout the project, then it may be possible to develop a simple treatment selection table similar to that discussed above for drainage line crossing.

(vii) Stabilisation of vehicle crossings of drainage lines and waterways

The stabilisation of vehicle crossing of drainage lines and waterway is discussed in sections P3.5, P3.6 & P5.1, and Table P24. Given the high variability of drainage lines and waterways across the country, the treatment of these vehicle crossings may need to be refined to a regional or project level based on the following site variables:

- The type of drainage line or waterway (e.g. clay-based, sand or gravel-based, rock-based, ephemeral, continuous flow).
- The type of soils over which vehicles will travel.
- The likelihood of stream flows—possibly related to the time of year.
- The catchment area— it is noted that catchment area influences the possible discharge, and that subdivision of catchment areas into various categories can vary significantly across different climatic regions.
- The duration of exposure and/or degree of vehicle traffic.

(viii) Sediment control standard

The suggested sediment control standard is discussed in sections P3.3.3, P3.3.4 & P3.6, and Table P24. On large pipeline projects it would be appropriate for a regional or project-specific version of Table P24 to be developed. Such a revised table would need to take into account the allowable flexibility in the RoW width, and the type of equipment used in the project to excavate and backfill the pipe trench.

(ix) Site rehabilitation

Site rehabilitation issues are discussed in sections P3.8, P3.9 & P6.6. Given the high variability of climatic conditions across the country, and the variability from season to season, it is appropriate for site-specific soil conditioning and site rehabilitation procedures to be established, including the fine-tuning of tables P16 and P17.

P3 Construction and stabilisation phase

P3.1 Introduction

Pipeline construction is a unique form of civil construction practice that warrants its own approach to erosion and sediment control (ESC) practices. General ESC practices, as outlined in other chapters of this publication, may not be not considered 'fair and reasonable' or even 'practicable' in pipeline construction due to:

- the relatively short duration of soil disturbance
- the narrow width of allowable soil disturbance (as defined by the RoW).

Due to the relatively narrow width of the pipeline RoW, the adopted ESC practices are usually required to interact closely with other construction practices within the RoW. This means that the selection and layout of ESC measures cannot be done in isolation from the many other construction issues that exist within the RoW. Specifically, the adopted ESC practices must be sited in a manner that does not unnecessarily interfere with other construction activities, including material and pipe deliveries.

All erosion and sediment control measures have design and durability limitations, for example, ESC measure can fail due to the occurrence of excessive rainfall; however, it is not acceptable for such failures to occur due to:

- failure to install the measures correctly
- failure to install all the specified ESC measures
- failure to use appropriate ESC measures for the site, soil and weather conditions
- failure to regularly inspect, monitor and maintain ESC measures in proper working order
- failure to report to those in authority any information about an ESC measure that would identify the measure as being either inappropriate or otherwise not fit-for-purpose.

P3.2 Right of ways (RoW)

RoWs generally range in width from 6 to 40 m, and can extend for hundreds of metres to hundreds of kilometres. APIA (2013) provides guidance on the factors to be considered when determining the required corridor width. Flexibility in RoW width is desirable or necessary at critical locations (e.g. creek crossings); however changes to the ROW width must comply with environmental constraints and approval conditions. Variations in the RoW width may be desirable to allow for the construction of appropriate sediment traps that:

- may not fit within the normal RoW width, or
- to allow the formation of a sediment trap that best allows the formation of a continuous or near-continuous topsoil or trench spoil windrow.

It is inevitable that the pipeline construction will intercept overland flows (run-on water) from up-slope catchments. In most cases this run-on water will consist of shallow, low-velocity sheet flow that, in its undisturbed condition, has a low erosive potential. However, while passing through the RoW these overland flows can quickly convert to highly-erosive concentrated flows if not appropriately managed.

Erosion and sediment control strategies for RoWs should therefore aim to maintain sheet flow conditions for as long as possible, restore sheet flow conditions once the flows pass through the construction site, and aim to re-establish the original sheet flow conditions as quickly as possible upon completion of the construction activities.

Recommended ESC strategies within the RoW include:

- minimise forward clearing
- maximise the retention of soil surface cover, especially where dispersive soils are present (this can be achieved, for example, by optimising the width of the RoW in areas of dispersive soils, and modifying construction practices to further reduce the duration that such soils are exposed during those times when rainfall is likely)
- control water movement through the RoW
- divert clean run-on water away from soil disturbances (if practical), or ensure this water passes through the RoW in a controlled manner (water should only be diverted if it can be achieved without causing environmental harm or nuisance, including public safety and flood risk)
- identify and preserve site materials for use in erosion control
- strip topsoil in two layers where possible to preserve the seed bank (not always practical or necessary depending on the depth of topsoil)
- stockpile topsoils and subsoils (trench spoil) separately
- ameliorate problematic topsoils during the stripping process (this is best achieved by applying the ameliorants to the soil surface before stripping)
- ameliorate problematic trench soil during the excavation process (if possible), otherwise ameliorants can be placed onto the trench spoil and mixed in with the padding machine during backfill
- aim to place subsoil layers back in the trench in the same order as excavated where dispersive and/or saline soils are present (this action is not always practical, or even possible in cases where the RoW is narrow)
- suitably compact, and where necessary, gypsum treat trench spoil to minimise the risk of tunnel erosion (asset owners and contractors should ensure that the management of dispersive soils is outlined and costed within construction contracts)
- early installation of control measures and site preparation for wet weather and holiday shutdown periods
- inspect and maintain control measures in proper working order
- progressively rehabilitate the RoW to minimise the extent and duration of soil disturbance.

Figures P2 and P3 show typical layouts of a pipeline RoW with the access track either up-slope or down-slope of the pipe trench.

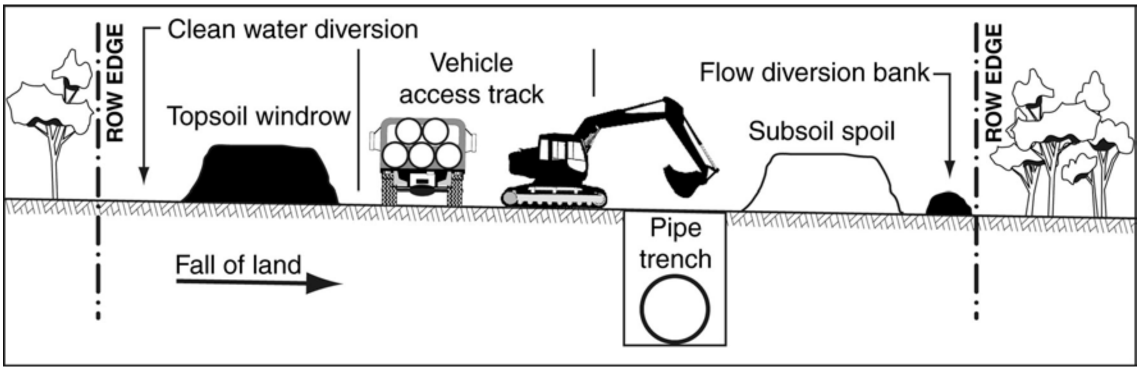

Figure P2 – Typical RoW with trench down-slope of the vehicle access track

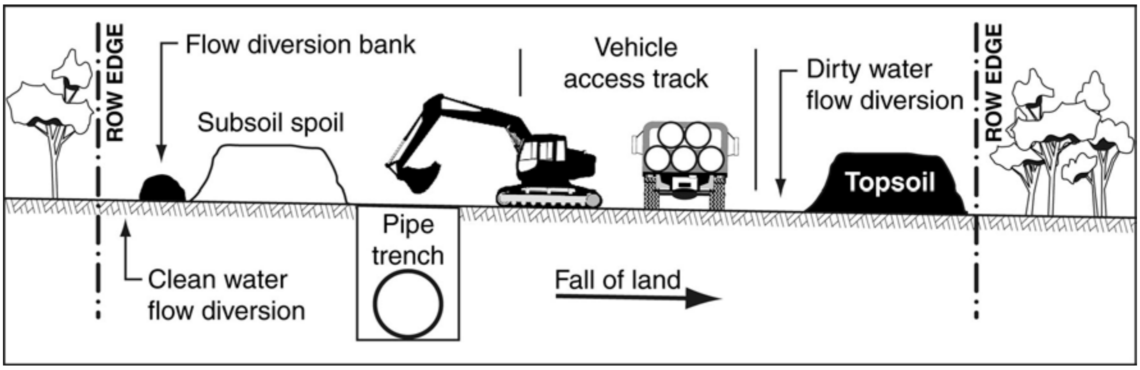

Figure P3 – Typical RoW with trench up-slope of the vehicle access track

P3.3 Erosion and sediment control practices

In most cases, erosion and sediment control practices within pipeline construction can be reduced to the tasks outlined in Table P8.

Table P8 – Typical ESC practices within pipeline construction

Category	Key tasks
Drainage control	• Diversion of 'clean' up-slope run-on water either around or through the construction site. • Collection of 'dirty' runoff generated within the RoW and the delivery of this water to an appropriate sediment trap. • Minimising the risk of soil erosion caused by site-generated flows passing along the RoW through the use of 'intermediate' flow treatment and release points. • Control of the flow velocity of water passing through the RoW at drainage line and waterway crossings.
Erosion control	• Appropriate management of work programming and the scheduling of forward works with the aim of minimising the erosion risk. • Control soil erosion at drainage line and waterway crossings caused by run-on water passing through (across) the RoW (this task is closely linked to the 'drainage control' task listed above). • Control of soil erosion at vehicle crossings of drainage line and waterway crossings • Minimising the extent of vegetation and soil disturbance at drainage line and waterway crossings. • Erosion control practices during site rehabilitation.
Sediment control	• Treatment of 'dirty' water runoff generated within the RoW. • Sediment control at vehicle exit points from the pipeline RoW. • Integration of sediment control attributes into the drainage/erosion control practices installed at drainage line and waterway crossings.

In many instances, the drainage and erosion control practices utilised on a particular pipeline project will be strongly influenced by the choice of sediment control practices. For this season, the ESCP designer will first be required to answer the following questions:

- What sediment control layout is warranted at a given location?
- Are flow releases and/or sediment controls required at intermediate locations (i.e. at locations other than roadway, drainage line and waterway crossings?

- What sediment control layout is required at intermediate locations (i.e. at locations other than roadway, drainage line and waterway crossings?

P3.3.1 Drainage control practices

In order to perform the drainage control tasks listed in Table P8 it is necessary for the ESC designer to perform the following actions:

- assess if the up-slope topsoil windrow has sufficient hydraulic capacity (i.e. height) and scour-resistance to divert the expected quantity of run-on water
- determine if it will be necessary for the up-slope run-on water to be diverted across (through) the RoW at intermediate locations between a given ridge-top and drainage line crossing
- nominate appropriate locations for the installation of flow control berms along the RoW (typically associated with intermediate flow release points, and drainage lines and waterway crossings)
- determine the best way to release both 'clean' and treated water from the RoW (i.e. as 'sheet' flow or 'concentrated' flow)
- assess the risk of soil erosion at drainage line and waterway crossings, and determine the need for, and suitability of, placing a velocity control device, such as a temporary *Check Dam*, along the downstream edge of the RoW (refer to Figure P14), or the use of *Erosion Control Mats* (Figure P9).

Unfortunately there is no simple way to determine the answer to the first task. A response is either achieved through the hydrologic analysis of the up-slope drainage catchment (i.e using Appendix A of this document), or is assessed based on local experience.

'Drainage control option D1' involves diverting all up-slope run-on water to the adjacent drainage line and waterway crossing without the use of intermediate release points. Site conditions where drainage control option D1 may be considered appropriate include:

- the up-slope catchment area is small and only minor quantities of run-on water are expected during the construction period
- the length of the pipeline segment from ridge-top to drainage line is short
- the countryside down-slope of the pipeline corridor is highly susceptible to gully erosion resulting from the un-natural concentration of surface flows (meaning that intermediate flow releases from the pipeline corridor are considered undesirable).

'Drainage control option D2' (Figure P4) involves diverting up-slope run-on water through the RoW at intermediate locations between the adjacent ridgeline and the drainage line or waterway crossing. This drainage option is usually linked to the 'sediment control option' of capturing and treatment of site runoff at intermediate locations (as per Section P3.3.4).

Site conditions where drainage control option D2 may be considered appropriate include:

- the up-slope catchment area is relatively large and/or the quantity of run-on water during the construction period is expected to exceed the hydraulic capacity of the up-slope flow diversion system
- the length of the pipeline segment from ridge-top to drainage line is significant

- the countryside down-slope of the pipeline corridor is **not** susceptible to gully erosion resulting from the release of these surface flows.

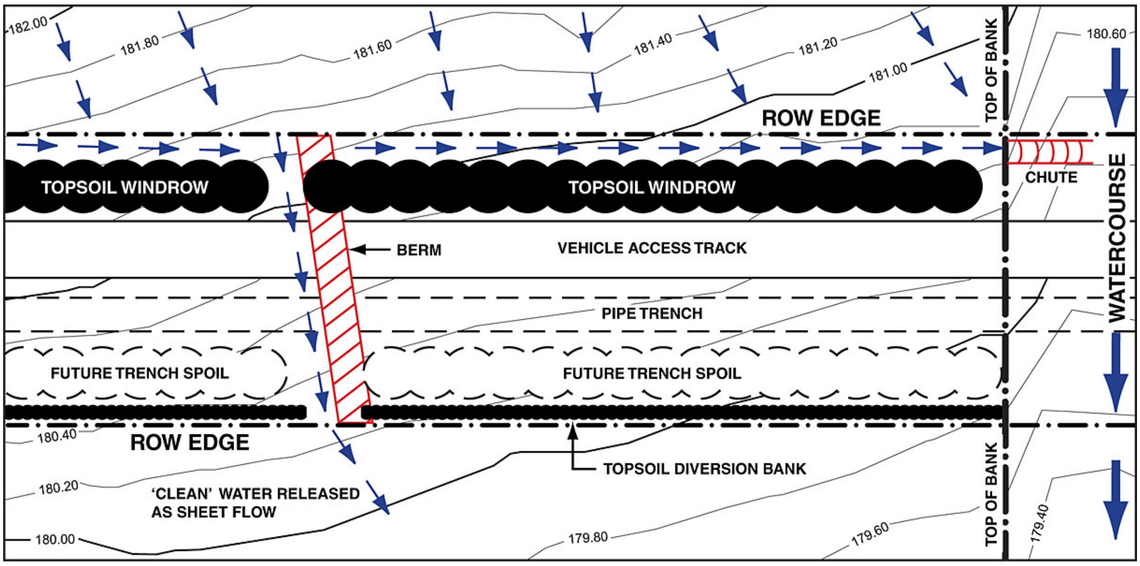

Figure P4 – Drainage control option D2 (intermediate flow release point)

Surface flows are captured and directed across the RoW through the use of cross drainage structures such as flow control berms (cross banks). Figures P5 and P6 shows construction details for two cross banks formed from materials excavated from the up-slope face. The wider the berm the smoother the travel path over the berm, and thus the faster vehicles can travel. Narrower berms may be desirable on steeper gradient tracks.

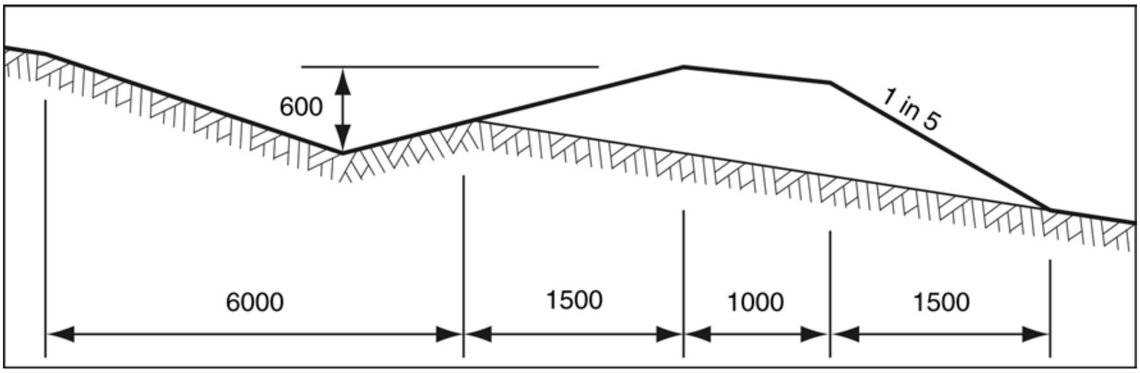

Figure P5 – Trafficable cross bank (berm) construction (10 width)

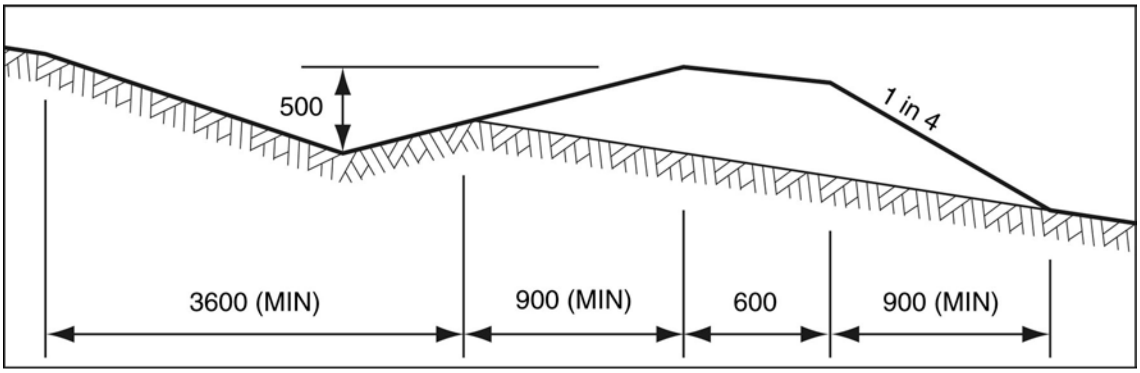

Figure P6 – Trafficable cross bank (berm) construction (6 width)

In some cases it may be desirable not to cut deep into the subsoils up-slope of cross banks. In such cases the cross bank details provided in figures P7 and P8 may be more desirable. The advantages and disadvantages of both design options are listed in Table P9. It is noted that in most cases these cross banks will be constructed after topsoil has been stripped from the RoW; therefore both options can result in the exposure of dispersive subsoils.

Table P9 – Advantages of the alternative cross bank design options

Earth excavated up-slope of berm (Figures P5 and P6)	Earth excavated from down-slope of berm (Figures P7 and P8)
• Greater drainage capacity. • Likely to require less maintenance in order to maintain sufficient drainage capacity as the berm is slowly compressed in height.	• Invert of the up-slope drainage diversion has a high elevation, thus increasing its ability to freely drain from the RoW. • Reduced risk of the exposure of dispersive subsoils up-slope of the berm

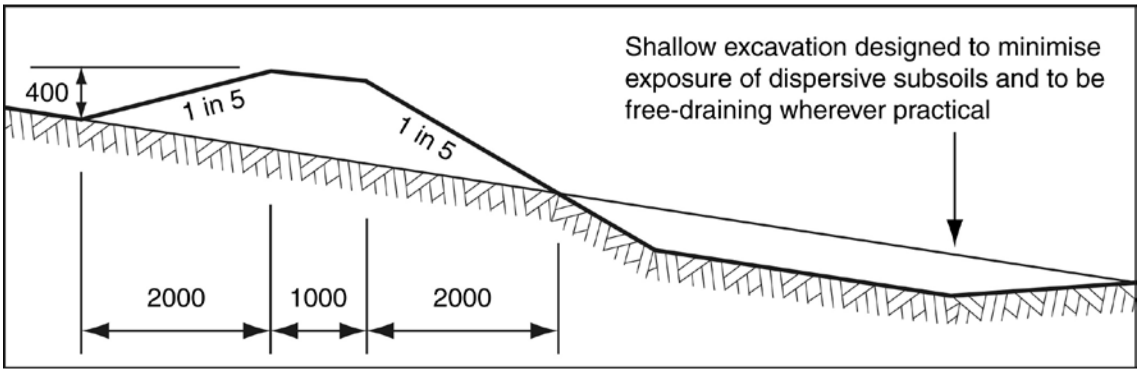

Figure P7 – Alternative trafficable cross bank (berm) construction (wide)

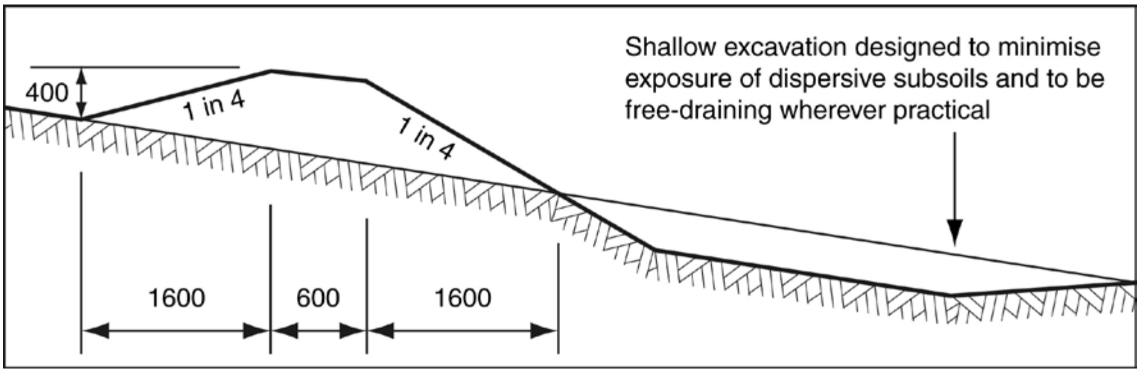

Figure P8 – Alternative trafficable cross bank (berm) construction (narrow)

P3.3.2 Erosion control practices

In order to perform the erosion control tasks listed in Table P8 it is necessary for the ESC designer to perform the following actions:

- determine the 'erosion risk' for each corridor segment (refer to Table P4 and Figure P1) and use this information to determine an appropriate construction program and the scheduling of forward works
- analyse the soil erosion risk at drainage line and waterway crossings, and access the need for (i) drainage control devices to control flow velocities, and/or (ii) *Erosion Control Matting* placed over the expected flow path (Figure P9)

- assess the need for rock stabilisation of vehicle crossing of drainage line and waterway crossings
- analyse each individual waterway crossing and assess the net benefit of minimising the extent of vegetation and soil disturbance at the crossings (refer to Section P3.6 – *Waterway crossings*), and determine the minimum set-back of soil stockpiles from the drainage line or waterway
- assess the need for erosion control measures during the site rehabilitation phase.

In pipeline construction, erosion control practices are most commonly restricted to the site rehabilitation phase, and during construction and cycle breaks. Given the narrow width of the pipeline RoW it is usually impractical to employ general erosion control practices during the construction phase.

The key to effective 'erosion control' is to:

- minimise the extent and duration of soil disturbance during periods when significant rainfall is possible, and
- promptly cover exposed soils once the construction phase has been completed.

Stabilising any exposed or disturbed soil at drainage line and waterway crossing can be viewed as a combined task of erosion control and drainage control. If site conditions warrant the use of *Soil Binders* or *Erosion Control Mats*, then the ESC designer should refer to tables P32 and P33 (Section P5.3) for guidance on the selection of an appropriate type of material.

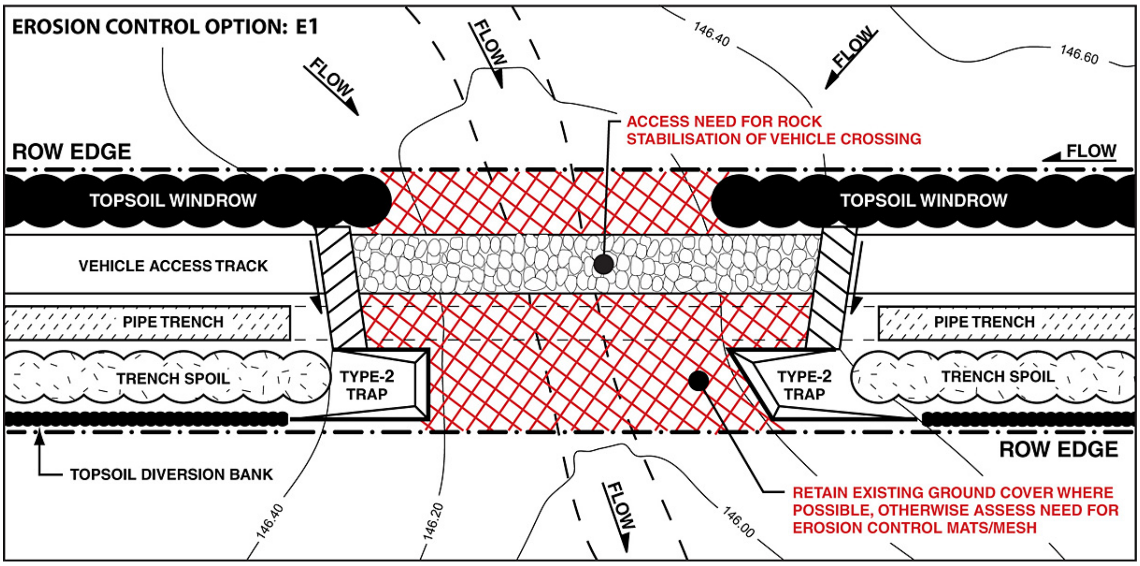

Figure P9 – Typical layout of erosion control option E1

P3.3.3 Sediment control practices at drainage line and waterway crossings

In order to perform the sediment control tasks listed in Table P8 it is necessary for the ESC designer to perform the following actions:

- determination of the sediment control system (e.g. sediment control options S1 to S7) at each 'dirty' water release point
- determine if 'intermediate' sediment collection and treatment points will be required between each ridge-top and valley floor (refer to Section P3.3.4). This analysis is usually based on an assessment of the maximum allowable/desirable RoW sub-

catchment area for the treatment of 'dirty' water within a nominated sediment control system (e.g. Type-2 or Type-3)

- determine the need (value) of integrating sediment control attributes into the drainage/erosion control practices installed along the downstream edge of the RoW at drainage line and waterway crossings.

Figures P10 to P25 show seven different approaches (options S1 to S7) to the management of sediment control at drainage line and waterway crossings. Similar approaches can be applied to roadway crossings where the open table drains of the roadway are treated as 'drainage lines'.

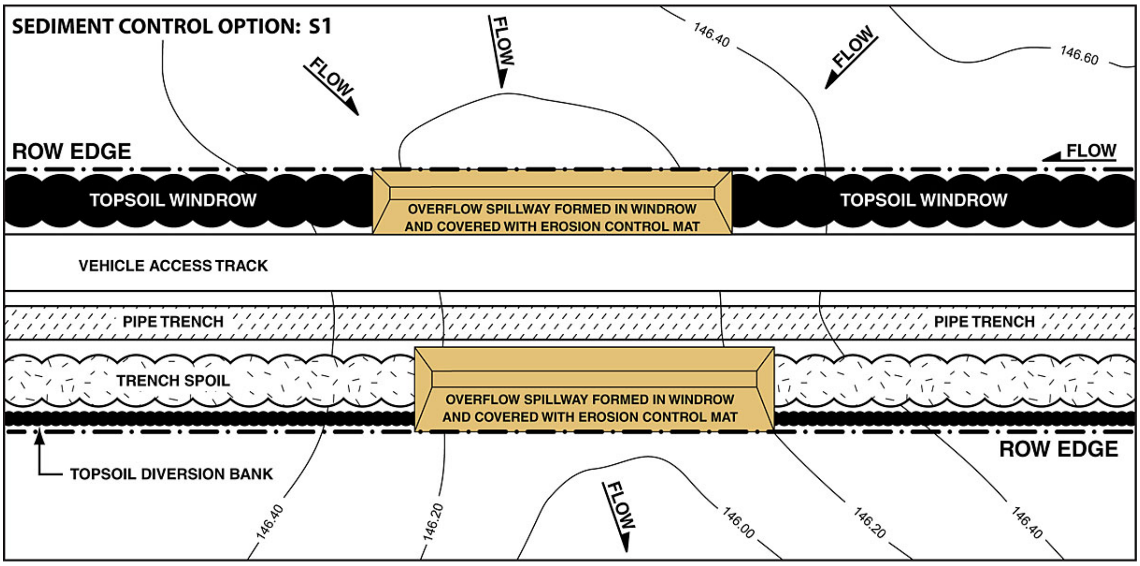

Figure P10 – Sediment control option S1

Figure P10 shows the layout of **sediment control option S1** where sediment trapping is primarily provided by water pooling up-slope of continuous topsoil and/or trench spoil windrows. The features of this treatment option are:

- Generally only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.
- Typically the topsoil and trench spoil windrows need to be suitably profiled (i.e. lowered and shaped to form a level overflow weir as per figures P11 and P12) at locations where flows are expected to overtop the windrows. This profiling is usually required even if overtopping flows are unexpected.
- If flows along the drainage line or waterway are possible during the construction period, then the overflow weirs should be protection from scour with suitable erosion control mats, or more commonly, filter cloth.
- Only minor changes need to be made to the above sediment control layout if the pipe trench is located up-slope of the vehicle access track.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

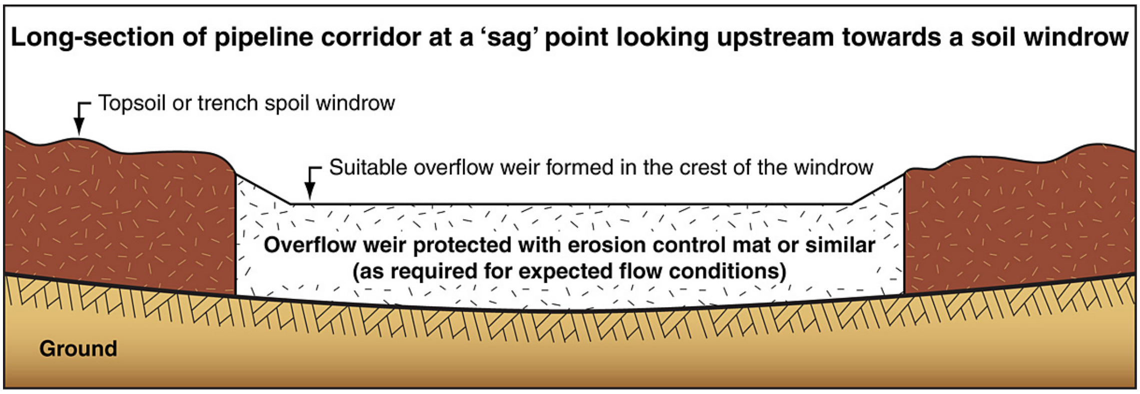

Figure P11 – Long-section of typical overflow weir formed into soil windrow

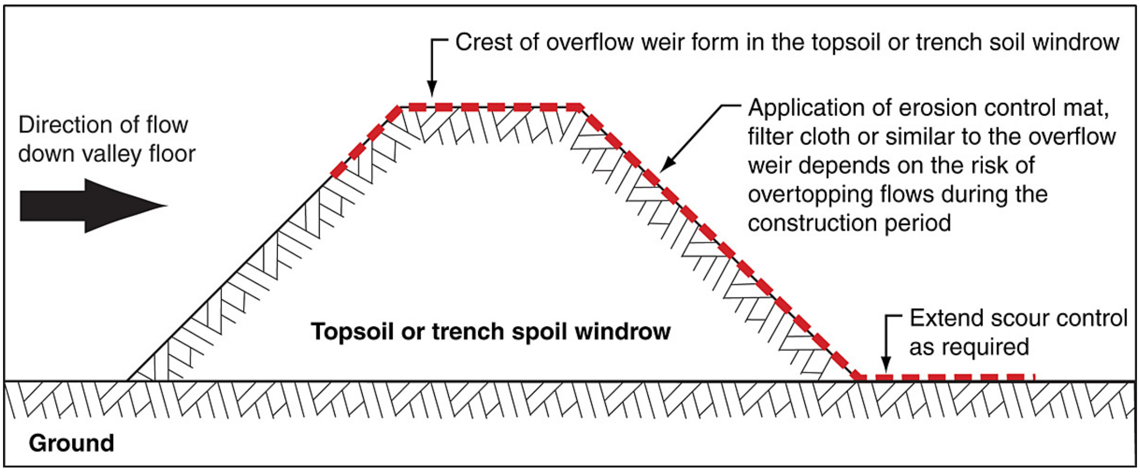

Figure P12 – Cross-section of typical overflow weir formed into soil windrow

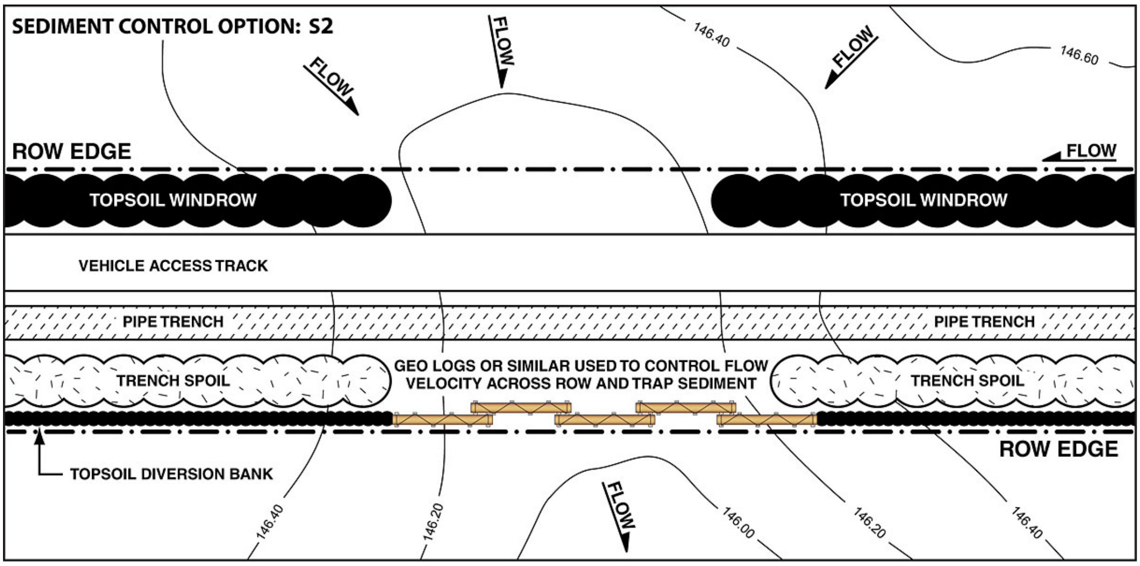

Figure P13 – Sediment control option S2

Figure P13 shows the layout of **sediment control option S2** where sediment trapping is primarily achieved as a by-product of installing an appropriate scour control *Check Dam* along the down-slope edge of the RoW. The primary purpose of the *Check Dam* is to minimise the risk of soil scour as concentrated run-on water passes across (through) the RoW.

Figure P14 shows a typical RoW profile with a *Geo Log* check dam/sediment trap. The types of *Check Dam* flow control structures that can be used include, large diameter *Geo Logs, Rock Check Dams*, and in extreme cases, *Sediment Weirs*.

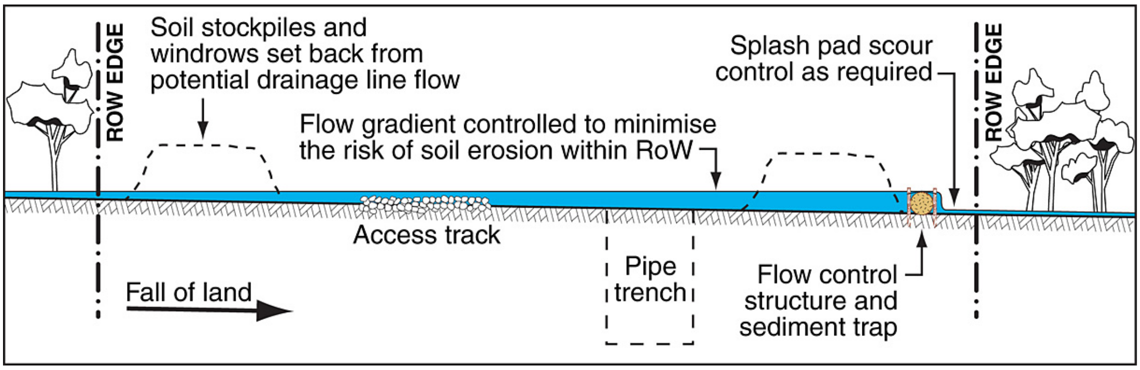

Figure P14 – Cross-section of RoW based on sediment control option S2

The features of sediment control option S2 are:

- Generally only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.
- Only minor changes need to be made to the above sediment control layout if the pipe trench is located up-slope of the vehicle access track.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

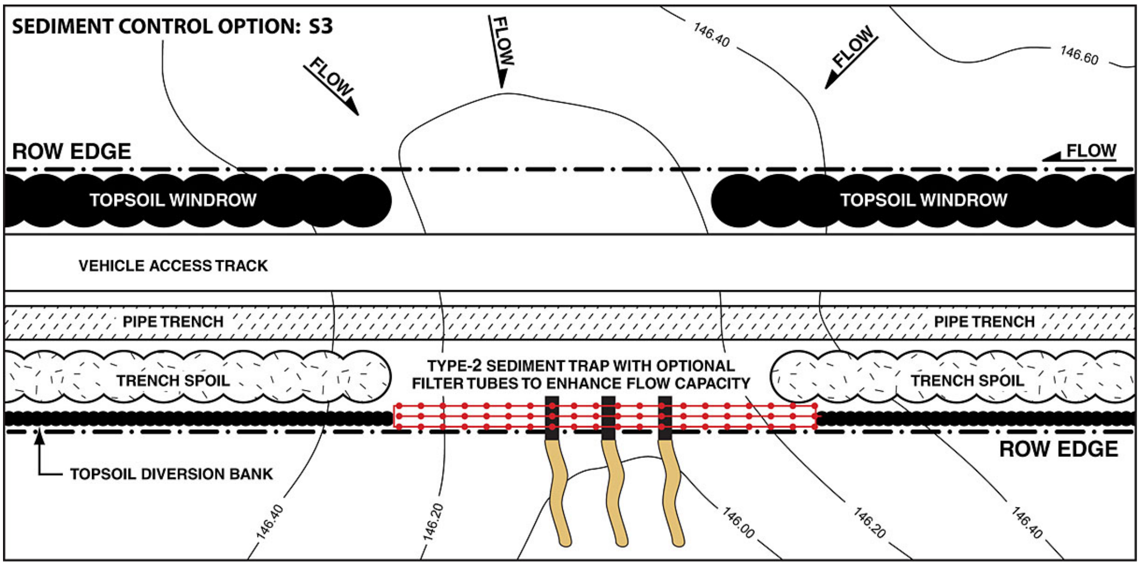

Figure P15 – Sediment control option S3

Figure P15 shows the layout of **sediment control option S3** where sediment trapping is provided by an 'instream' Type-2 sediment trap, such as a *Sediment Weir*. The features of this treatment option are:

- Generally only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.
- The hydraulic capacity and sediment trapping ability of the sediment trap can be enhanced by integrating one or more *Filter Tubes* into the structures. Permission

will be required from the down-slope property owner for the *Filter Tubes* to extend beyond the edge of the RoW.

- Only minor changes need to be made to the above sediment control layout if the pipe trench is located up-slope of the vehicle access track.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

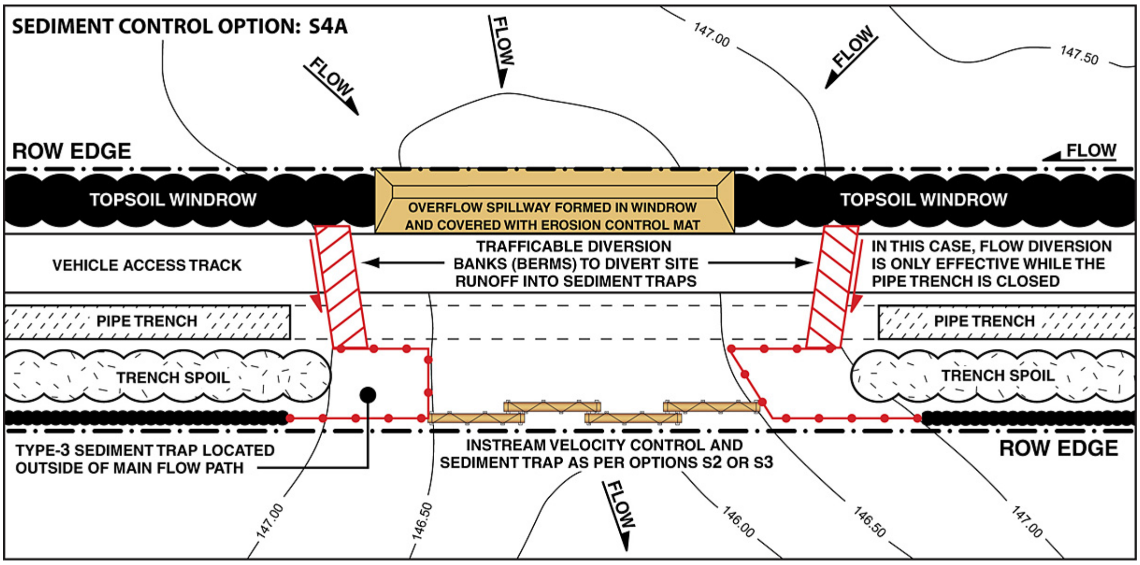

Figure P16 – Sediment control option S4A (pipe trench down-slope of track)

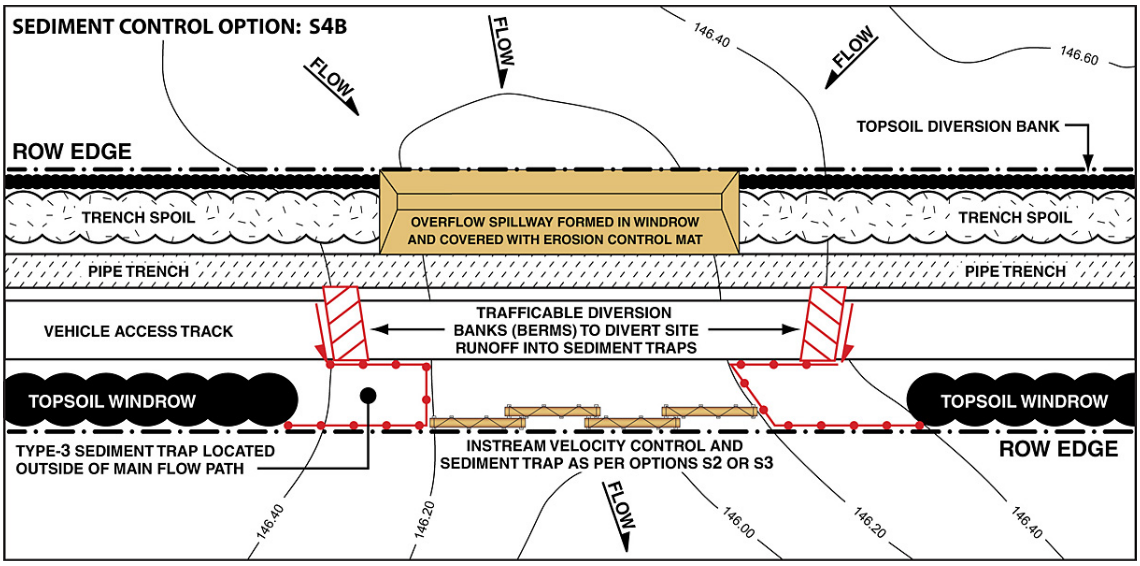

Figure P17 – Sediment control option S4B (pipe trench up-slope of track)

Figures P16 and P17 show the layout of **sediment control options S4A and S4B** where sediment trapping is primarily provided by 'off-stream' Type-3 sediment traps. The features of these treatment options are:

- Generally only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.
- Typically the up-slope topsoil or trench spoil windrow will need to be suitably profiled (i.e. lowered and shaped to form a level overflow weir) at the location where

flows are expected to overtop the windrow. This profiling is usually required even if overtopping flows are unexpected.

- If flows along the drainage line or waterway are possible during the construction period, then the overflow weir should be protection from scour with suitable erosion control mats, or more commonly, filter cloth.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

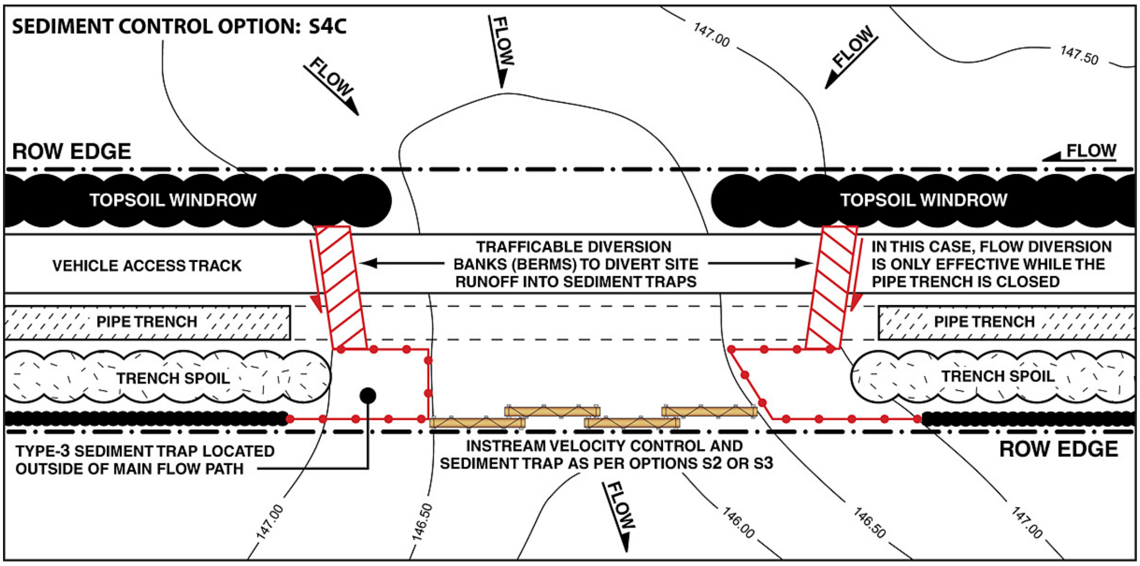

Figure P18 – Sediment control option S4C (pipe trench down-slope of track)

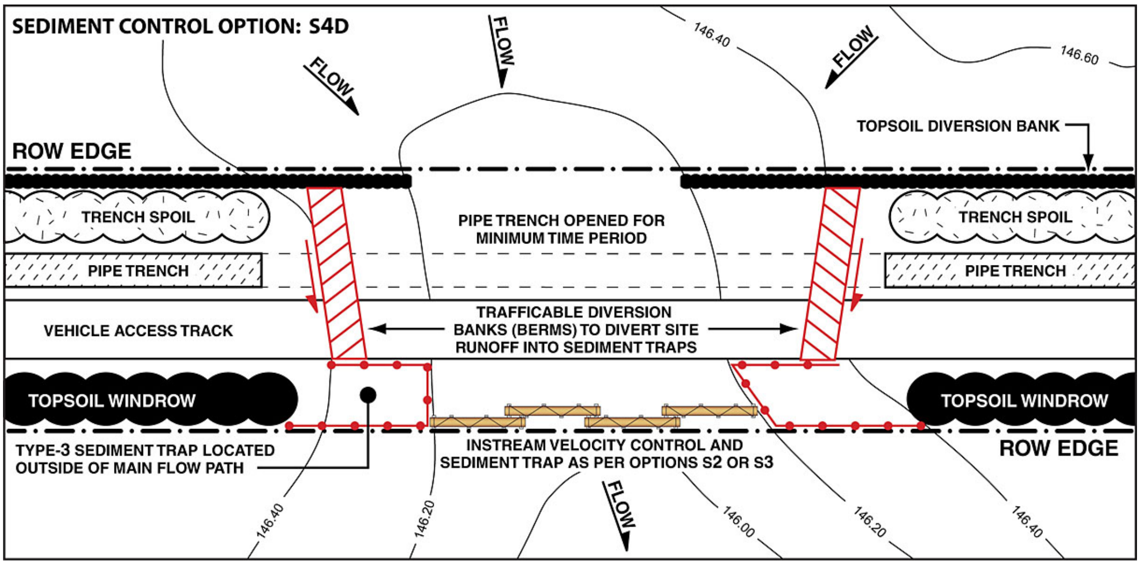

Figure P19 – Sediment control option S4D (showing site conditions while the pipe trench remains closed across the drainage line)

Figures P18 and P19 show the layout of **sediment control options S4C and S4D** where sediment trapping is provided by ‘off-stream’ Type-3 sediment traps. The features of these treatment options are:

- Generally considered appropriate when flows within the drainage line or ephemeral waterway are expected to be either continuous or significant in peak discharge.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

Figure P20 shows one possible layout of **sediment control option S5** where sediment trapping is primarily provided by 'off-stream' Type-2 sediment traps. Sediment control options S5A, S5B, S5C & S5D mimic the four variations of sediment control option S4 (S4A, S4B, S4C & S4D) except the Type-3 sediment trap is replaced with a Type-2 sediment trap. The features of sediment control option S5 are:

- This elevated (Type-2) treatment standard is generally preferred over option S4 when crossing waterways, as opposed to drainage lines, or when significant sediment runoff is expected from the RoW during the construction period.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

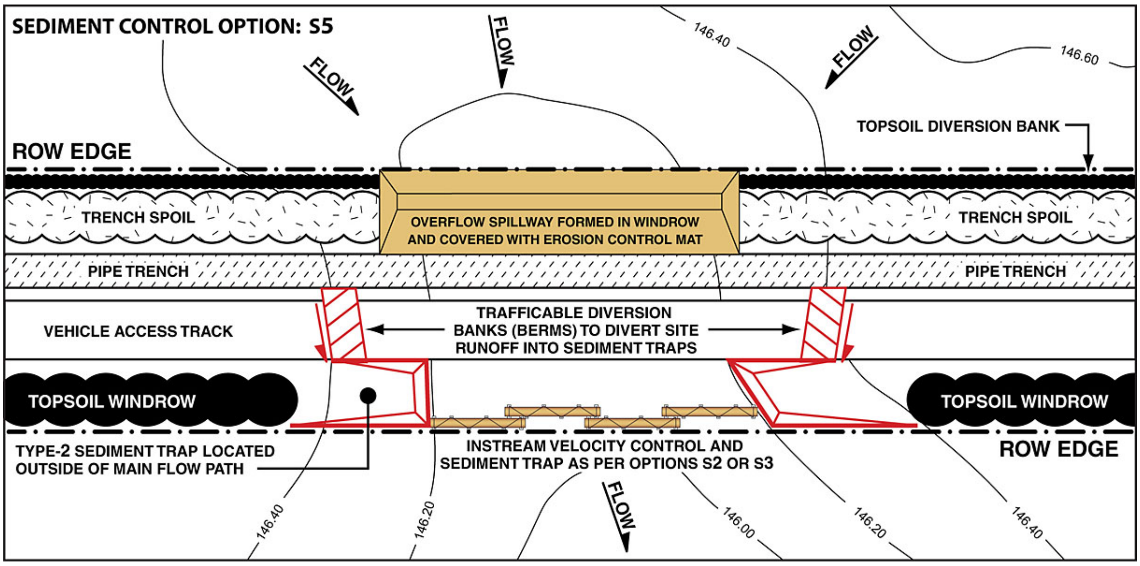

Figure P20 – Sediment control option S5 (this layout mimics option S4B)

Figures P21 and P22 show two possible layouts of **sediment control option S6** where sediment trapping is primarily provided by 'off-stream' Type-3 sediment traps that are located within an expanded RoW. The features of this treatment option are:

- Expanding the width of the RoW at key locations can allow construction practices to utilise near continuous topsoil and trench soil windrows. This option is generally only required when the utilised construction equipment (e.g. 'padders') require a near-continuous windrow.
- This treatment option is only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.

- Typically the topsoil and/or trench spoil windrows need to be suitably profiled (i.e. lowered and shaped to form a level overflow weir) at locations where flows are expected to overtop the windrows. This profiling is usually required even if overtopping flows are unexpected.
- If flows along the drainage line or waterway are possible during the construction period, then the overflow weirs should be protection from erosion with suitable erosion control mats, or more commonly, filter cloth.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

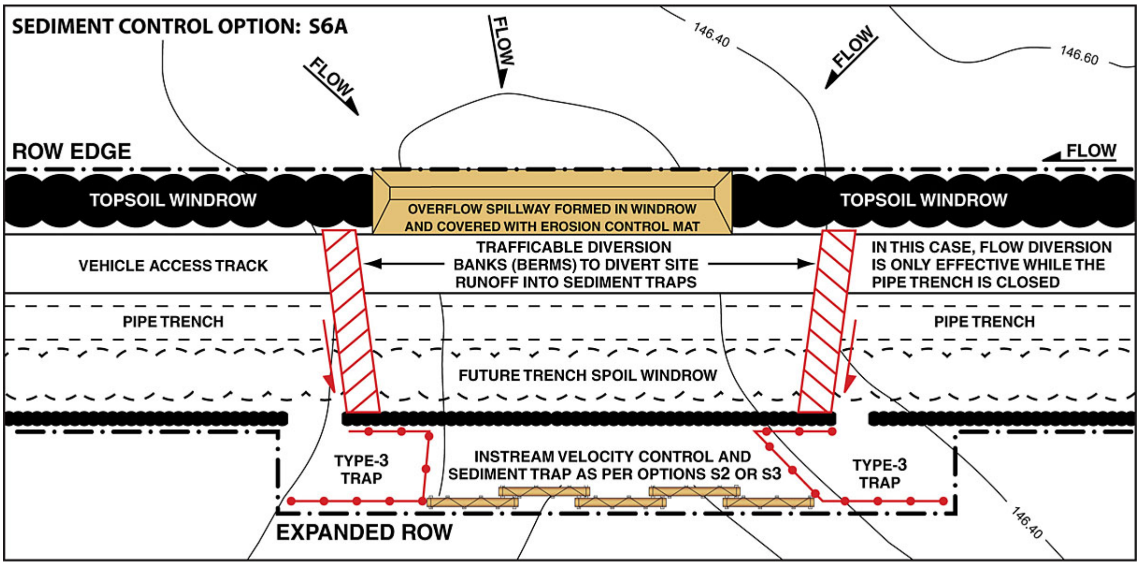

Figure P21 – Sediment control option S6A (pipe trench down-slope of track)

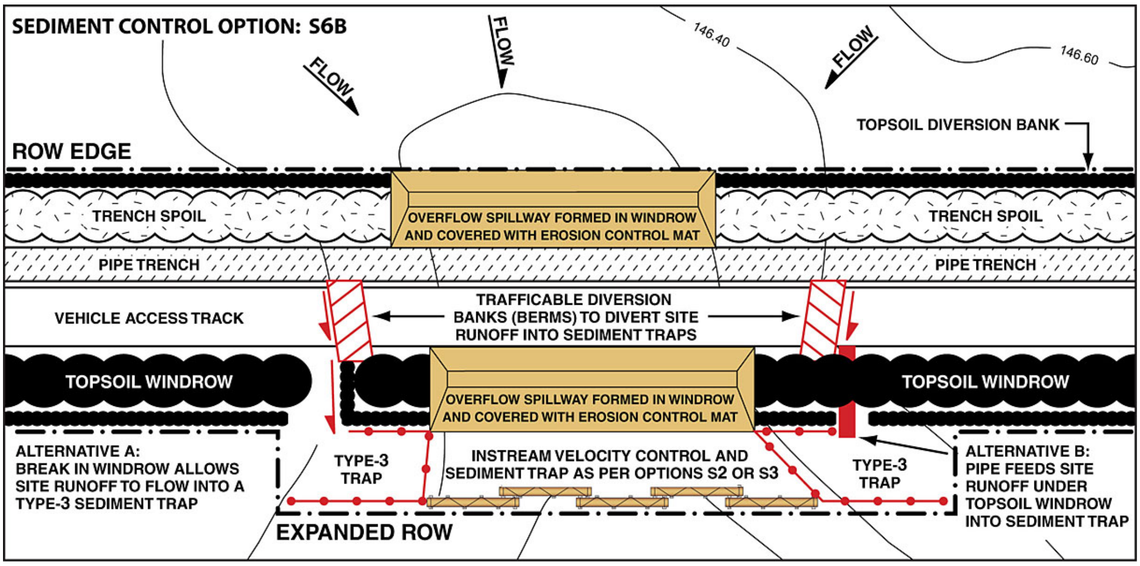

Figure P22 – Sediment control option S6B (pipe trench up-slope of track)

Figures P23 and P24 show two alternative layouts of sediment control option S6 where sediment trapping is primarily provided by 'off-stream' Type-3 sediment traps that are located within an expanded RoW. The features of this treatment option are:

- Generally considered appropriate when flows within the drainage line or ephemeral waterway are expected to be either continuous or significant in peak discharge.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

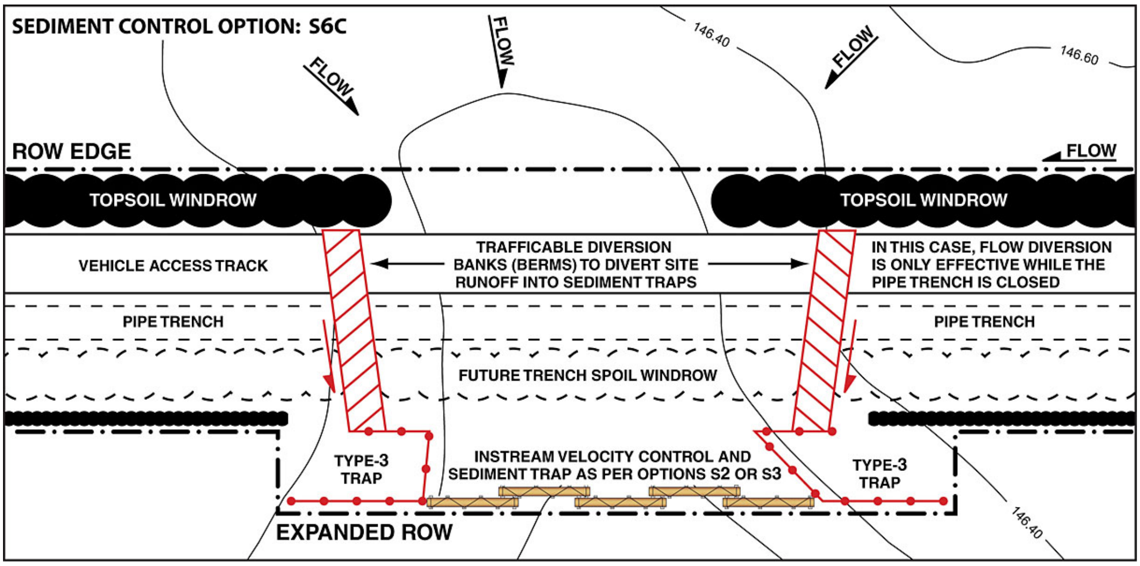

Figure P23 – Sediment control option S6C (pipe trench down-slope of track)

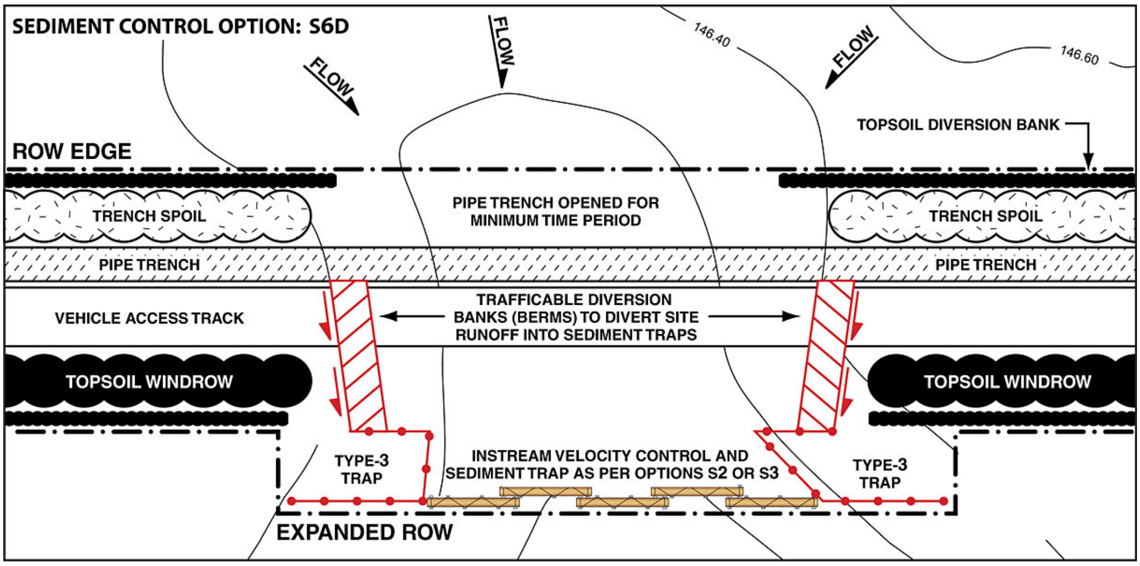

Figure P24 – Sediment control option S6D (showing site conditions while the pipe trench across the drainage line is open)

Figure P25 shows one possible layout of **sediment control option S7** where sediment trapping is primarily provided by 'off-stream' Type-2 sediment traps that are located within an expanded RoW. Sediment control options S7A, S7B, S7C & S7D mimic the four variations of sediment control option S6 (S6A, S6B, S6C & S6D) except the Type-3 sediment trap is replaced with a Type-2 sediment trap. The features of sediment control option S5 are:

- This elevated (Type-2) treatment standard is generally preferred over option S6 when crossing waterways, as opposed to drainage lines, or when significant sediment runoff is expected from the RoW during the construction period.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

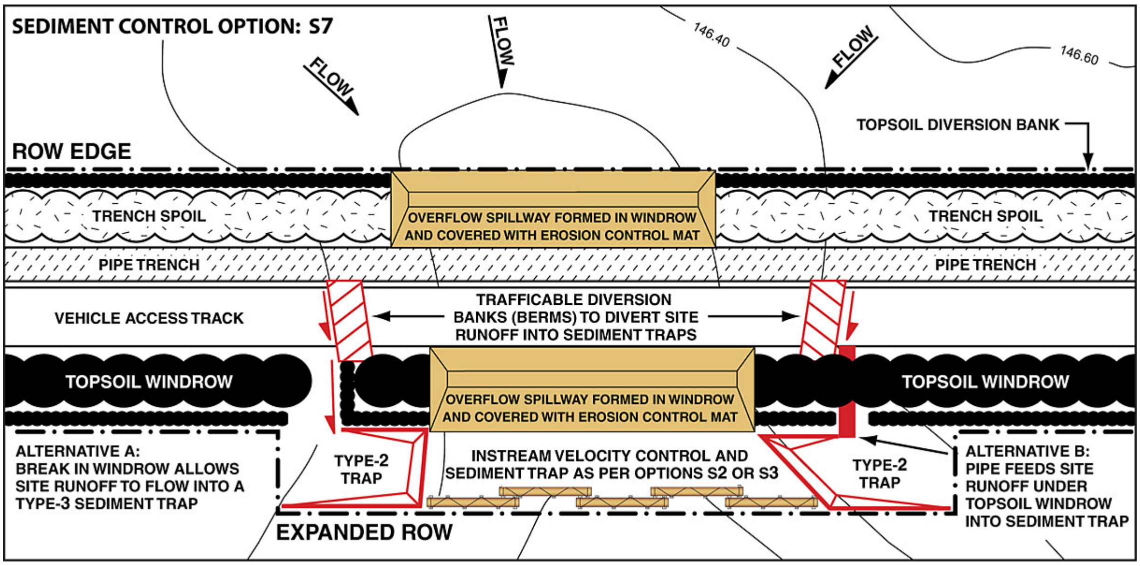

Figure P25 – Sediment control option S7 (this layout mimics option S6B)

P3.3.4 Sediment control practices at 'on-grade' locations along the RoW

Figures P26 to P29 show two possible approaches (options SO1 and SO2) to the management of sediment control at 'intermediate' (on-grade) flow release points located between the ridge-top and valley floor.

Figures P26 and P27 show the layout of **sediment control options SO1A and SO1B** where sediment trapping is typically provided by a Type-3 sediment trap. Site conditions that may trigger the need for this treatment option include:

- Site conditions exist where it is necessary for up-slope 'clean' run-on water is required to be diverted through (across) the RoW.
- The RoW sub-catchment area exceeds the maximum desirable catchment area for the nominated sediment control system (e.g. Type-2 or Type-3).

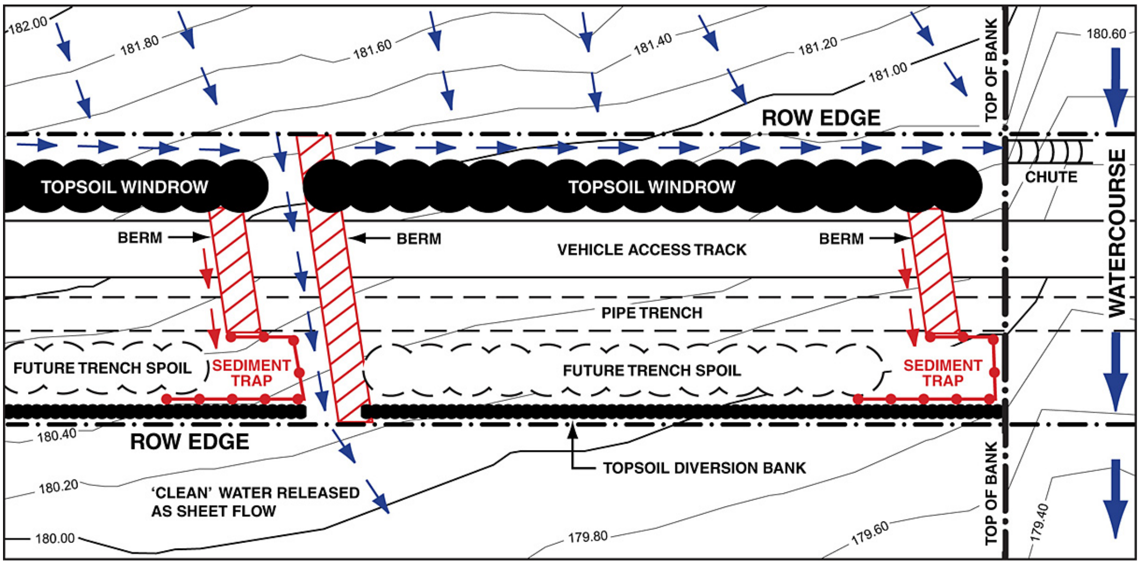

Figure P26 – Sediment control option SO1A: pipe trench down-slope of vehicle access track

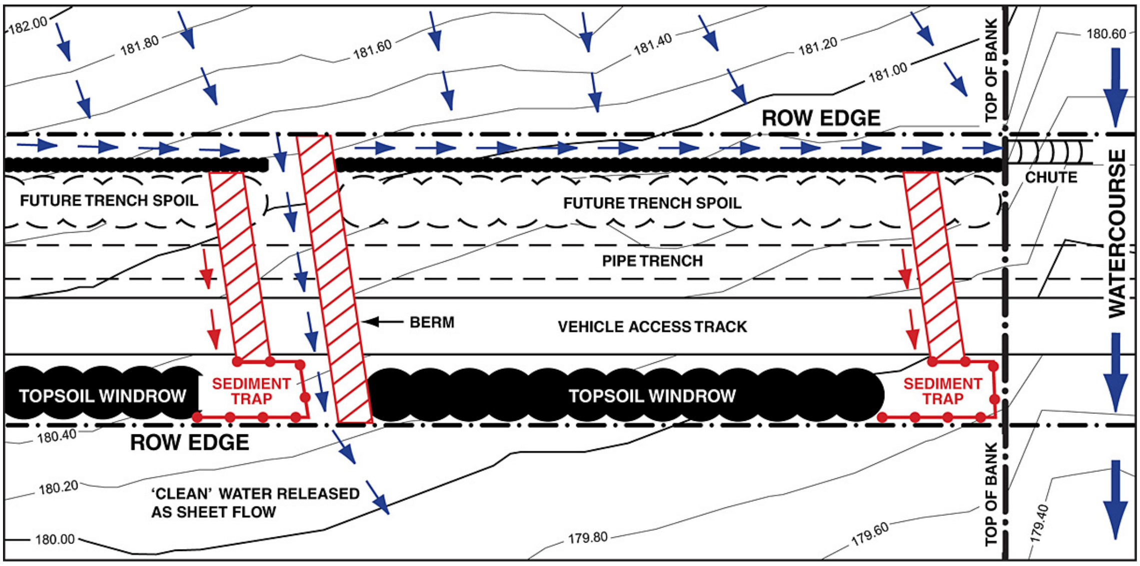

Figure P27 – Sediment control option SO1B: pipe trench up-slope of vehicle access track

Figures P28 and P29 show the layout of **sediment control options SO2A and SO2B** where sediment trapping is typically provided by a Type-3 sediment trap which is located within an expanded RoW. Site conditions that may trigger the need for this treatment option include:

- Site conditions exist where it is necessary for up-slope 'clean' run-on water is required to be diverted through (across) the RoW.
- The RoW sub-catchment area exceeds the maximum desirable catchment area for the nominated sediment control system (e.g. Type-2 or Type-3).
- The utilised construction equipment (e.g. 'padders') require a near-continuous windrow.

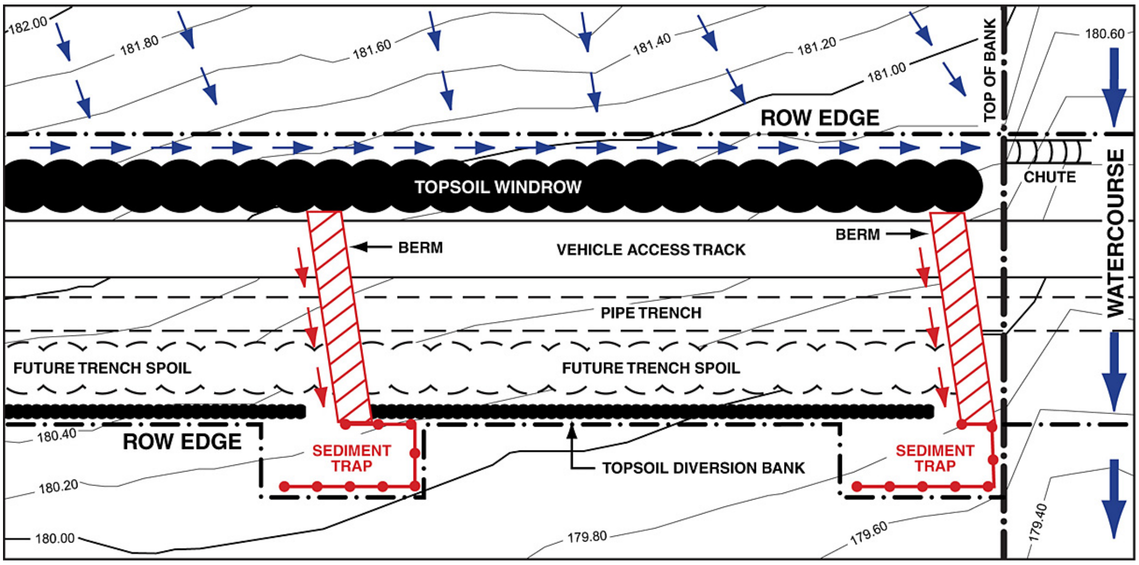

Figure P28 – Sediment control option SO2A: pipe trench down-slope of vehicle access track

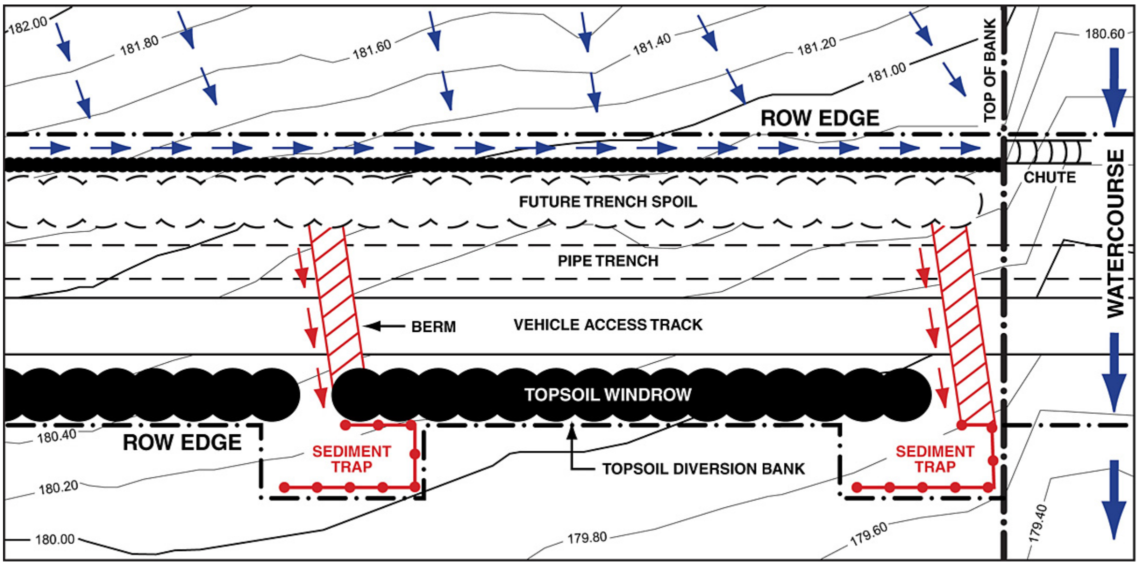

Figure P29 – Sediment control option SO2B: pipe trench up-slope of vehicle access track

P3.4 Steep slopes

Many pipeline projects intersect steep slopes during their construction. The Revised Universal Soil Loss equation (RUSLE) demonstrates that slope gradient and slope length are significant factors when determining erosion risk on sloping sites. The longer and steeper the slope, the greater the erosion risk, and the more sophisticated the control techniques typically required to stabilise the slope.

In addition to the risk of soil scour, disturbances to naturally-steep slopes during the construction of pipelines may result in geotechnical instability due to changes in topography, groundwater flows, loss of soil strength, stress changes and weathering.

Table P4 indicates that slopes greater than 10% but less than 15% have a high erosion risk, while slopes steeper than 15% have an extreme erosion risk. Conventional flow diversion techniques such as *Cross Banks* (berms) should not be used on slopes steeper than 18% without expert advice due to:

- the increased erosion and slope stability risk associated with cutting the back batter
- likely inability to source sufficient material to build the bank
- likely difficulty in sourcing a safe and stable discharge point.

Sediment control measures typically rely on the pooling of water in order to allow the settlement of coarse sediments. However, on steep slopes, the pooling of water can significantly increase the risk of hydraulic failures and soil scour. Therefore, on steep slopes the focus should primarily be on the utilisation of drainage and erosion control measures, with sediment control measures generally only used at the base of steep slopes where it is safe to pool water.

The following erosion and sediment controls should be considered when constructing works in steep areas:

- minimise forward clearing
- avoid soil disturbance during periods of high rainfall risk
- maintain soil surface cover particularly where dispersive soils are present
- minimise erosion on travel roads and other exposed areas
- divert clean run-on water away from, or in a non erosive manner through the RoW
- identify and preserve site materials that can aid erosion control and site stabilisation
- divert stormwater off the RoW as regularly as possible if it can help to maintain sheet flow conditions down-slope of the RoW
- install regular trench breakers keyed into the bottom and side of the trench to minimise tunnel erosion (in cases where the pipe trench is formed along a steep slope)
- compact, and where necessary treat with gypsum, trench spoil to minimise the risk of tunnel erosion
- progressively rehabilitate the RoW to minimise the extent and duration of disturbance
- re-establish sheet flow conditions where possible.

P3.5 Drainage line and roadway crossings

A drainage line is a natural or constructed stormwater drainage path that:

- carries 'concentrated' rather than 'sheet' flow
- is likely to flow only during periods of rainfall, and for short periods (hours rather than days) after rain has stopped
- is a drainage path that cannot be classified as a 'watercourse' based on a locally or regionally-adopted classification system (e.g. state policies).

Drainage lines may also be referred to under other names, such as 'overland flow paths' or dry-land gullies. However, a 'gully' is generally more physically defined by steep banks than a traditional drainage line. In most cases, pipelines can cross gullies following the same procedures outlined below for drainage lines. However, discretion is required by the designer/civil contractor as to when a deep, well-formed or active gully should be treated as an ephemeral waterway.

It is noted that most roadway crossings can be treated in a manner similar to drainage line crossings. In effect, the table drains located each side of the roadway are just another form of drainage line. Typically the differences are only in regards to the detail of the site entry/exit points, which do not occur at normal drainage line crossings.

In cases where there is the risk of accelerated soil erosion occurring within the drainage line during the construction phase, then the management options include:

- stabilise the soil within the RoW with *Erosion Control Mats* (Figure P9), and/or
- install a velocity control structure (e.g. *Geo Log* or *Check Dam*) along the downstream edge of the RoW (Figure P14).

Typically these velocity control structures are looked upon by regulators as 'sediment control' systems; however, in reality their ability to capture sediment is highly limited. Instead these devices should be viewed as a form of 'drainage control' that **primarily** aims to reduce the velocity of water flowing across the RoW, with sediment control being a secondary by-product.

Figure P30 shows the profile of a typical vehicle crossing at an ephemeral drainage line. The need for rock stabilisation (or other treatment options) of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

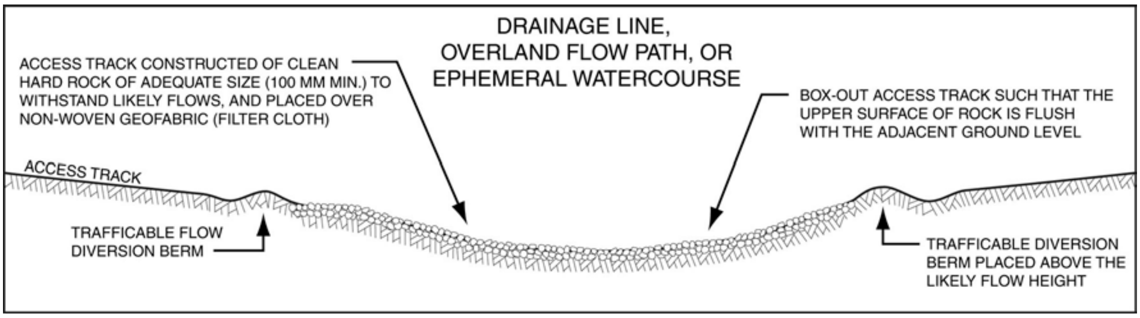

Figure P30 – Typical profile of bed-level vehicle crossing of a drainage line

P3.6 Waterway crossings

As discussed in Section P2.2, there are significant environmental risks associated with open trenching through waterways including:

- increased quantity and frequency of suspended sediment within stream flows during the construction phase
- erosion of stream banks and subsequent sedimentation issues that can harm aquatic fauna, smother aquatic habitats, increase instream turbidity, and decrease light transmission in the water body (this issue can be linked to both the construction phase and rehabilitation phase)
- unnatural alteration of bed and bank stability, thereby increasing the likelihood of scouring of the backfilled pipeline trench (some soils become less stable once disturbed, even if compacted to a pre-disturbance condition and vegetated)
- contamination of surface water and groundwater by construction-related chemicals (associated with some trenchless construction processes)
- disruption and fragmentation of riparian ecosystems, including breaks in movement corridors for small terrestrial animals associated with a permanent change in type and density of riparian vegetation within the RoW (a post-work revegetation issue).

Guidance on the management of instream works is provided in Section P3.9 *'Waterway crossings'* and Appendix I – *'Instream works'*.

There are numerous methods for installing pipelines across waterways. Section 6.11 of APIA (2013) and the Canadian publication (CAPP, CEPA & CGA, 2005) provide discussion on various construction techniques, including:

Open trench techniques:

- Dozer or spider plough
- Open cut trench
- Dragline (excavation of open trench by a dragline)
- Dredging (excavation of open trench by a floating dredge)

Cofferdams and isolation barriers:

- Flume (cofferdam system with gravity bypass flow line)
- Cofferdam with pumped flow bypassing
- Two-stage open trenching behind impervious isolation barriers
- Channel diversion

Trenchless techniques:

- Horizontal bore, punching, or pipe jacking
- Horizontal directional drilling

Aerial techniques: (may not be appropriate for all types of pipeline, e.g. gas)

- Bridge attachment (attachment to existing bridge)
- Self-supporting bridge/truss

Consideration of trenchless or bridging techniques is recommended when the environmental or social risks associated with open trenching of waterways cannot be eliminated or adequately mitigated.

The method used to construct a pipeline across a waterway is largely dependent on the experience and capabilities of the construction company that wins the pipeline project. If the proponents of a pipeline project are concerned about a possible environmentally, politically, or socially sensitive waterway crossing, then consideration should be given to highlighting these issues within the tender process, and/or issuing the waterway crossing as a separate contract or cost item.

Factors that need to be considered when selecting a construction method include:

- cost of pipe installation and site rehabilitation
- environmental ‘values’ of the waterway and associated riparian zones
- required fish passage and navigation needs during the construction phase
- the width of the watercourse
- soil properties within the bed and banks
- base flow conditions within the watercourse, including the depth, flow rate and velocity of flow, and the risk of elevated flows
- stability and potential mobility of the waterway (this primarily impacts on the design of the pipe crossing)
- the type of bed material (which usually defines the type of waterway) and the stability, depth and potential mobility of any loose bed material (e.g. sand or gravel).

Wherever practical, the construction methodology should avoid the need for, and use of, instream sediment control systems. Instead, preference should be given to:

- procedures that isolate construction works and soil disturbances from stream flows
- procedures that treat sediment-laden water, including site runoff, lateral inflows and stream flows, within sediment control system located above the low bank, and preferably outside the critical riparian zone (the latter typically being defined as at least three times the bank height measured from the edge of the low-flow channel).

Figures P31 and P33 show typical stabilised waterway crossings prior to the opening of the pipe trench. Figure P34 shows typical ESC controls during open trenching of a waterway where clean upstream water is pumped around the active construction zone. The layout of each crossing would change depending on whether the vehicle access track is upstream or downstream of the pipe trench.

Figures P35 to P44 provide examples of various open trench installation procedures that aim to isolate construction activities from stream flows. These options are presented as a guide only, and should not imply that such methods will always be practical.

Technical note P1: Use of instream sediment traps

Instream sediment control systems were developed in response to a particular regulatory framework where the success of ESC measures was primarily based on water quality sampling upstream and downstream of the works. In cases where the waterway has only a minor trickle flow, a greater than 10% increase in turbidity or suspended solids would register as a ‘failure’ even though at such low flow rates the risk of causing environmental harm was potentially very low.

Thus in general construction practice, instream sediment traps generally aim to treat only those low flows that cannot otherwise be prevented or bypassed around the instream disturbance. In the case of pipeline construction, the primary purpose of these in-channel sediment traps is usually to act as a temporary, low-height, velocity-control check dam that reduces the risk of soil scour across the RoW. Any sediment control outcomes are just a secondary benefit.

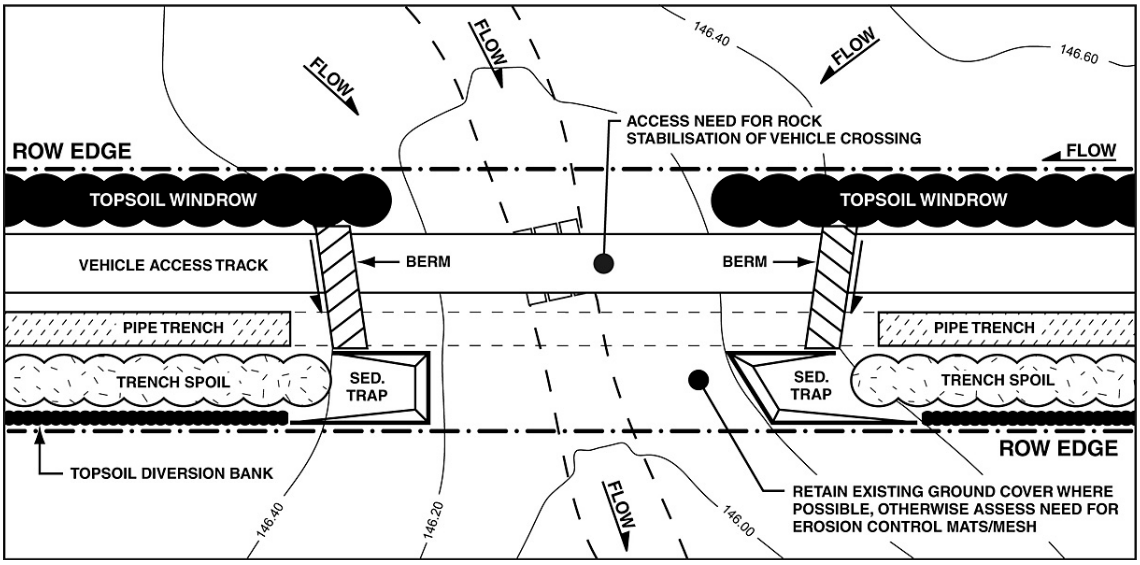

Figure P31 – Possible layout of pipe crossing of waterway with pipe trench located down-slope of the vehicle crossing

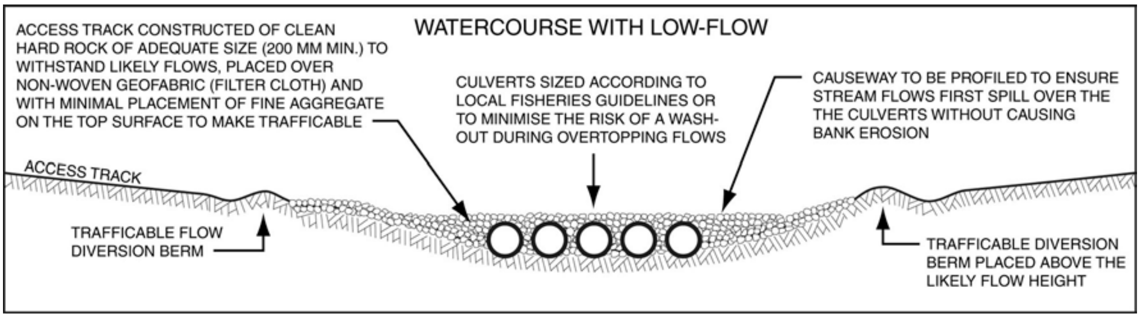

Figure P32 – Typical profile of temporary culvert crossing (cross-section)

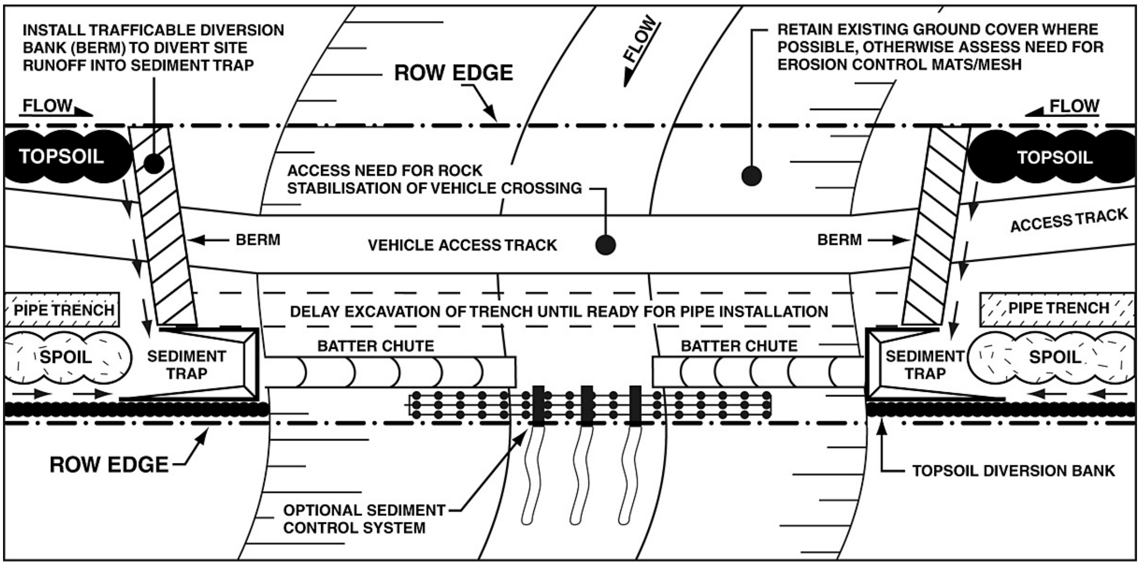

Figure P33 – Alternative layout of pipe crossing of waterway with pipe trench located down-slope of the vehicle crossing

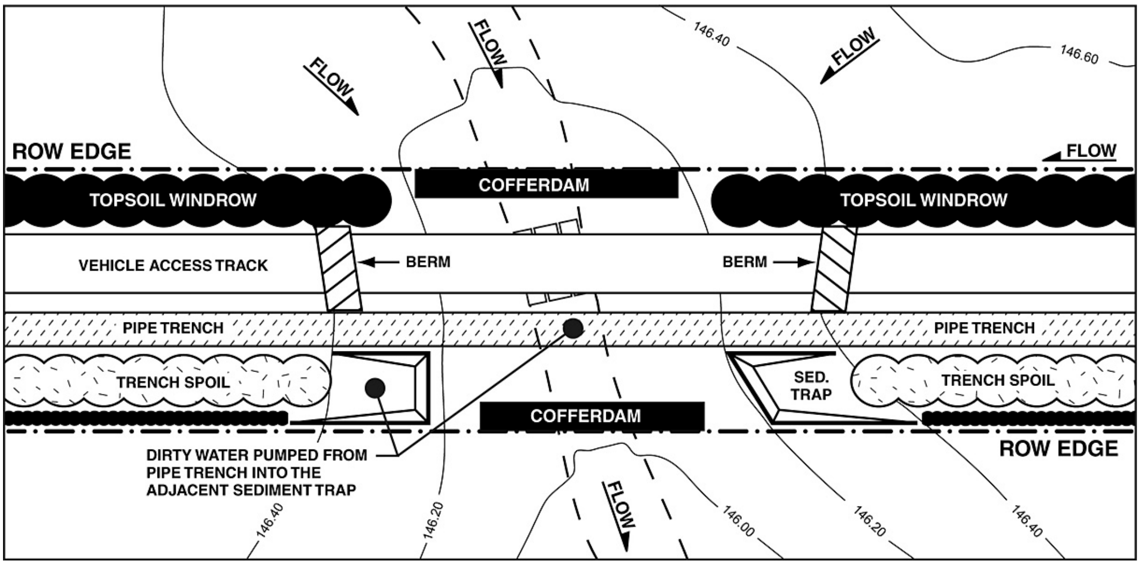

Figure P34 – Typical ESC control measures for a waterway crossing while the pipe trench is open

Example A: Pipeline installation across a narrow watercourse with all construction equipment operating from the channel banks

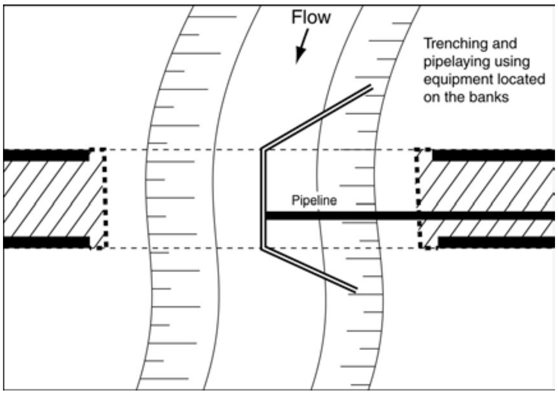

Figure P35 – Stage 1

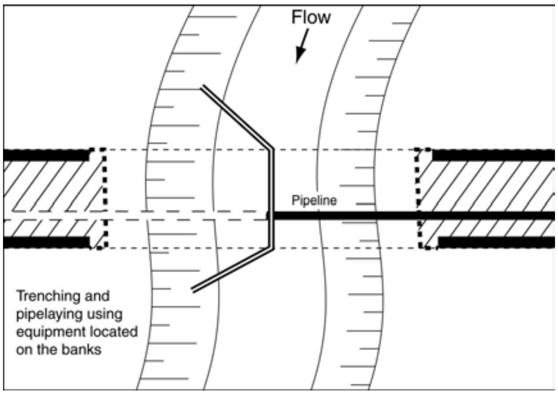

Figure P36 – Stage 2

Example B: Pipeline installation across a wide, dry-bed waterway where minor channel flows are possible

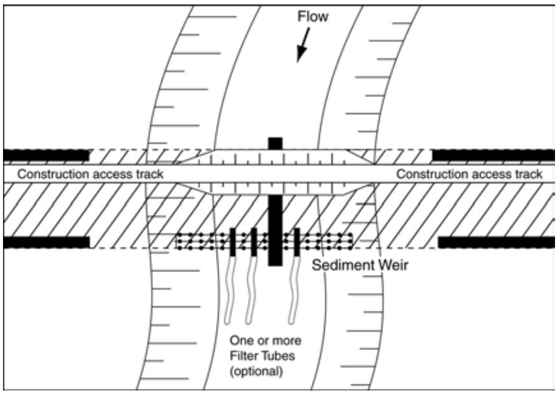

Figure P37 – Provision of vehicle access across the waterway

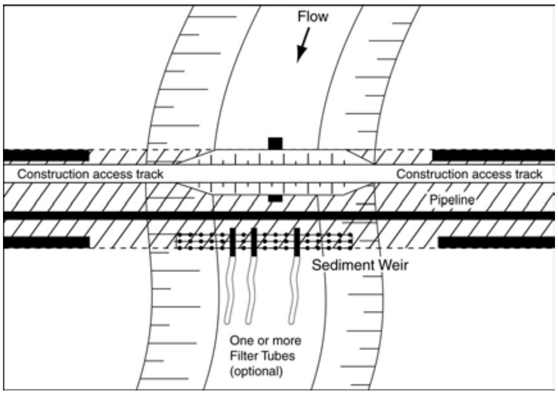

Figure P38 – Installation of pipeline (part of the bypass pipe may need to be removed to allow pipe installation)

Example C: Pipeline installation across a wide watercourse with constant dry-weather flow and where increased channel flows are possible

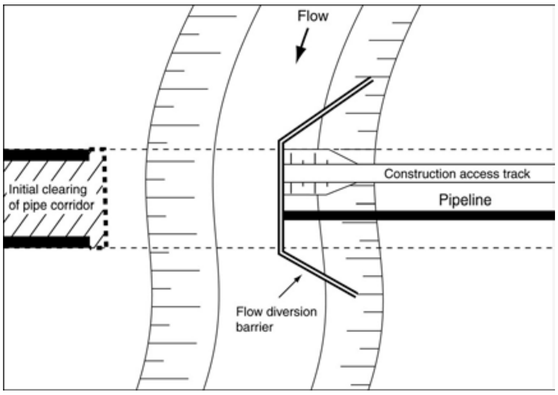

Figure P39 – Stage 1 of pipe installation using an isolation barrier

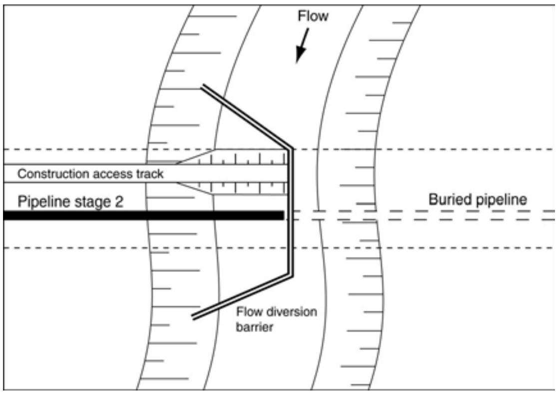

Figure P40 – Stage 2 of pipe installation

Example D: Alternative pipeline installation across a wide, watercourse with constant dry-weather flow and where increased channel flows are possible

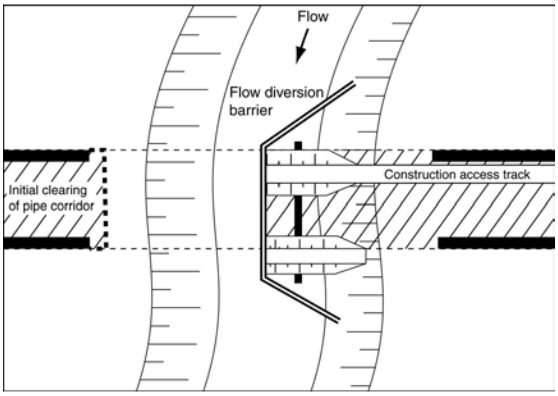

Figure P41 – Partial channel clearing and partial installation of cofferdam and construction access

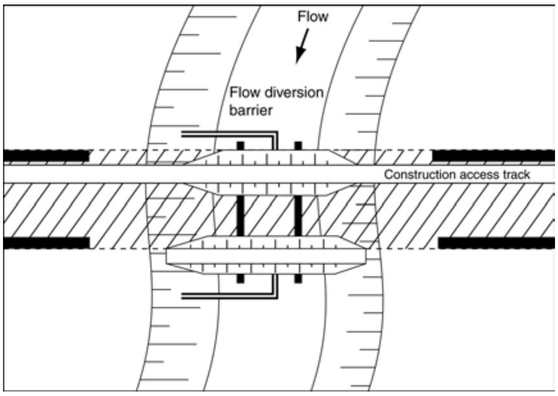

Figure P42 – Final channel clearing and final installation of cofferdam and construction access with full channel flow bypass

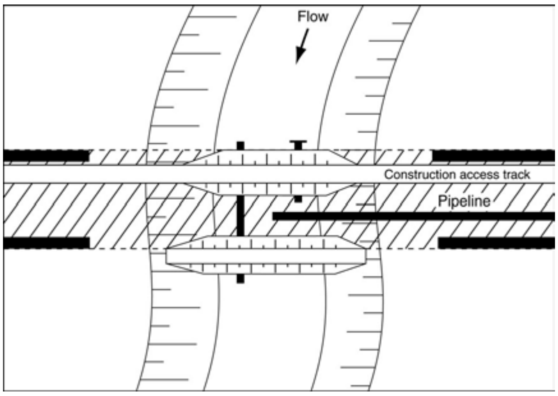

Figure P43 – Stage 1 of pipeline installation with one of the bypass pipes taken off-line to allow better access for pipe installation

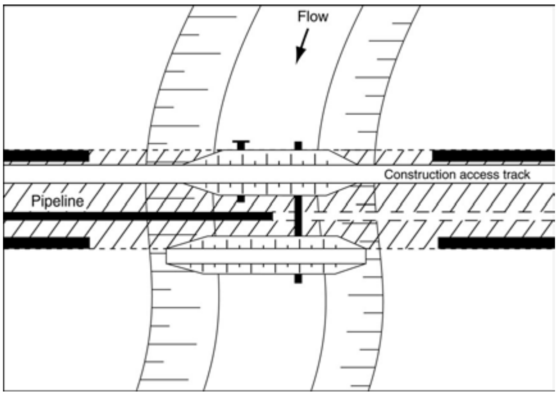

Figure P44 – Stage 2 of pipeline installation with the other bypass pipe taken off-line to allow better access for pipe installation

P3.7 Responding to adverse weather conditions

Although rain forecasting has improved in recent times, unexpected rainfall can still occur. Only in specific regions of Australia can construction works occur with a high degree of certainty that rainfall will not occur in the near future. As such, appropriate ESC measures will usually be required all year round on most pipeline projects.

In many instances, pipeline construction will occur with only Primary Erosion and Sediment Control Plans (ESCPs) as a guide to managing stormwater flows, soil erosion and sediment runoff. These Primary ESCPs will either consist of generic plans (i.e. plans that show the typical layout of ESC measures without specifically relating to a given project or location) or project-specific plans. In any case, these plans should describe (or list) information about the types of 'temporary' ESC measures that should be considered in the hours or days before the onset of adverse weather conditions.

What constitutes 'adverse weather conditions' will vary from location to location, and is at the discretion of the ESC designer. In some cases it may refer to any runoff-producing rainfall, in other cases it may only refer to rainfall that is expected to exceed a specified rainfall depth (or intensity). If the term 'adverse weather conditions' has not been defined within the ESCP, then the adoption of temporary control measures should be considered whenever the forecast rainfall is likely to approach, or exceed, the nominated 'design' storm.

It is noted that these 'temporary' ESC measures will only need to be operational while the adverse weather conditions are imminent or occurring, and that these measures are considered **additional** to those measures already detailed within the ESCP.

If suitable temporary control measures are not identified within the ESCP, then the following actions should be given **appropriate consideration** in the days prior to any forecast rainfall that is likely to approach or exceed the nominated design storm. It is noted that not all of the following measures will be appropriate in all circumstances.

- Formation of temporary flow diversion berms (e.g. earth windrows or geo-log diversion banks) up-slope of open trenches to minimise inflows, but only if suitable flow diversion systems do not already exist, and space is available within the RoW.
- Stabilisation of any potentially unstable flow diversion systems (including flow diversion windrows, drains and batter chutes) possibly through the use of filer cloth or a suitable spray-on channel lining or *Soil Binder*. If rainfall is imminent, then *Erosion Control Mats* (which includes filter cloth) will usually need to be secured with timber stakes, not metal pins. Alternatively, ensure the correct placement of *Check Dams* to prevent the occurrence of excessive flow velocities that may cause damage to these flow diversion systems.
- Stabilisation of 'drainage line' and 'waterway' crossings in a manner that suitably protects these surfaces from excessive scour.
- If strong winds are imminent, then secure recently pinned *Erosion Control Blankets* with rocks, logs, or timber stakes, if displacement of the blankets is a concern.
- Where appropriate, construct and stabilise suitable spill-through points along earth or mulch berms/banks to avoid such structures overtopping in a manner that may cause their structural failure.

P3.8 Reinstatement and rehabilitation

P3.8.1 Introduction

Section 6.13 of APIA (2013) details the environmental management considerations for the reinstatement and rehabilitation of areas disturbed by pipeline construction. The following section of this appendix details those aspects of this final stage of pipeline construction that relate directly to the activity of erosion and sediment control.

In these regards, the erosion and sediment control industry is not so much focused on the type of rehabilitation, or the selection of plant species, but on the following issues:

- how best to achieve the site revegetation (e.g. *Hydromuching*, *Bonded Fibre Matrix*) given the expected weather conditions and risk of overland flows
- how best to prepare the soil for successful revegetation
- how best to prepare the land surface for successful revegetation (e.g. smooth or rough surface, hard or firm compaction, mulched or un-mulched)
- how best to minimise the risk of long-term erosion that may undermine the short-term success of the site revegetation and/or impact on the pipeline asset.

In the majority of cases, the pipeline corridor should be returned to its pre-disturbance conditions in respect to both land form and surface cover (as recommended in APIA, 2013) however, circumstances can exist where pre-existing land forms will not be stable if reinstated. Some soils become significantly more unstable once disturbed, even if recommended compaction is achieved.

Material characterisation, particularly with respect to dispersive subsoils, is critical in identifying the risks of future tunnel erosion and potential difficulties for site revegetation. Equally, information on soil erodibility can be combined with data on rainfall erosivity to develop regional batter guidelines for slope height, gradient, and target cover levels. Once established, erosion models can be used to rapidly, and at minimum cost, assess a wide range of design options, identify major risks for a specific site and soil conditions, consider impacts of various design storms, and estimate likely costs for sediment clean-up and removal.

The key to successful site rehabilitation is being able to identify those conditions where generic solutions can be applied (i.e. reinstatement of pre-disturbance conditions) and where specialist advice and site specific-site rehabilitation plans will be required. As such, the extent and complexity of the risk assessment must be commensurate with the complexity of the environment, and the extent and complexity of the soil disturbance.

P3.8.2 Slope gradient

Slope gradient influences:

- the ability to apply and hold topsoil or other growing media on the slope
- the complexity of incorporating ameliorants into soil
- the type of machinery needed to prepare the slope and apply revegetation
- the erosion risk presented by overland flows and potential land slips.

It can be difficult to replace and initially retain topsoil on slopes steeper than 1:2 (V:H). The recommended treatment of slopes is provided in Table P10.

Table P10 – Recommended thickness of placed topsoil

Land slope	Recommended topsoil treatment
Steeper than 1:2 (V:H)	• Stair-stepping steep cut batters may assist in securing topsoil. • Coir mesh (or similar) may be used to help secure topsoil on steep batters. • If slopes are too steep for the replacement of topsoil, then give appropriate consideration to the attributes of *Compost Blankets*. • In exceptional circumstances, *Cellular Confinement Systems* can be used to secure topsoil, but **not** at waterway crossings. • All reasonable efforts should be taken to replace topsoil on watercourse banks independent of bank slope. In exceptional circumstances, consideration should be given to the revegetation technique of 'jute bagging', where topsoil and seedlings are placed in small pockets formed from 'thick' jute blanket.
Slopes of 1:2 to 1:3	• Recommended topsoil depth of 50 mm.
Slope flatter than 1:3	• Desirable minimum topsoil thickness of 100 mm; however, consideration should also be given to the original undisturbed topsoil depth.

Slope gradient can significantly influence (or limit) the ability to successfully ameliorate the soil once it has been placed on the slope. Conventional earthmoving equipment can typically operate on slopes up to 1:3 (V:H). This allows soil ameliorants to be cost-effectively applied with broadcast type fertiliser spreaders. The applied chemicals can then be incorporated into the soil using ripper tynes or scarifiers attached to the machinery.

The maximum slope a dozer can walk (up and down a slope) varies with the machine weight and the experience of the operator. Typically the maximum slope is between 1:2 and 1:1(V:H) the latter being under ideal soil conditions. Although it may be possible to apply ameliorants to a steep slope, the difficulty is in mixing the amelioration into the soil without causing permanent vertical scarification marks that can increase the bank's erosion potential.

Excavators with a swivelling head attachment can use the bucket teeth to incorporate soil ameliorants. However, in most instances the depth of amelioration is too shallow and much of the loose soil needed to provide an appropriate seed bed is lost down the slope.

All bank stabilisation measures, including topsoil placement, are subject to damage as a result of excessive overland flows. If a permanent formed cut batter is required (i.e. a landform different from the pre-disturbance condition) then it may be necessary to establish a permanent flow diversion system up-slope of the cut batter.

If the pipeline corridor is reinstated to the pre-disturbance land contours, then the slope may still be subject to erosion if the up-slope catchment is capable of delivering excessive run-on flows. The majority of slope stabilisation techniques are only suitable if flow velocities do not exceed 1 m/s. There is no simple method of determining if excessive overland flows can occur other than performing a normal hydrologic analysis (refer to Appendix A – *Construction site hydrology and hydraulics*).

Independent of the up-slope catchment area, special care must be taken during site rehabilitation if the land fall <u>across</u> the pipeline corridor exceeds 3 metres.

P3.8.3 Suitability of growing media

Readers are referred to Appendix C – *Soils and revegetation* for detailed guidance on soil management and revegetation.

Plants need suitable soil conditions to germinate, grow and persist. During construction the natural soil profile can be substantially disturbed. Typically the focus of this disturbance is over the relatively narrow pipe trench. The practice of excavating, stockpiling and replacing subsoil within the trench can mix soil layers, thereby significantly altering the physical, chemical and biological properties of the soil.

However, in some cases the practice of stripping, stockpiling and respreading the topsoil layer can also result in the mixing of soil properties, especially if there is a substantial change in soil properties between the A and B-horizons (e.g. duplex soils).

RoW stabilisation may also involve revegetating subsoils that, if not adequately treated, will not have adequate soil conditions to sustain plant growth, for example when:

- the stripped topsoil contains excessive weed infestation and/or weed seed, and the construction contract requires the contractor to be responsible for weed management during a specified maintenance phase
- construction practices lead to excessive compaction or structural decline of topsoils
- the pipeline crosses land previously degraded by past farming practices—in such cases, very little natural topsoil may exist on the land prior to the commencement of the pipeline installation.

There are a range of physical, chemical and biological factors that are important for plant growth. These factors are summarised below.

Physical factors include:

- plant available water capacity (storage volume and energy required to extract it)
- infiltration rates and hydraulic conductivity (ability of water to flow into and through the soil, water logging)
- aeration and gaseous exchange (oxygen availability and exchange of carbon dioxide)
- mechanical impedance (seed and soil contact, root and shoot penetration).

Chemical factors include:

- plant available nutrients (particularly phosphorous, nitrogen, potassium)
- soil acidity (nutrient availability, metal and metalloid toxicity)
- cation exchange capacity
- salinity (water uptake)
- dispersion (surface crusting, water logging, chemical erosion).

Biological factors include:

- nitrogen fixation (rhizobium)
- nutrient and water uptake (mycorrhizae)
- organic carbon (nutrient release and cycling)
- raw carbon conversion.

P3.8.4 Soil amelioration

The ability to rapidly establish and then sustain vegetation growth is essential for RoW stability during rehabilitation works. It may therefore be essential to treat all or parts of the exposed soil to ensure that desirable vegetation outcomes are achieved.

A wide range of soil ameliorants are available, and include:

- fertiliser (nutrient deficiencies)
- lime or dolomite (low pH)
- sulfur (high pH, legume stimulant in some conditions)
- gypsum (sodicity, dispersion, and as a clay breaker and to improve soil structure)
- compost (low organic carbon, structure, water holding capacity)
- wetting agents (hydrophobicity)
- biological inoculants (Rhizobium, Mycorrhizae, humates).

The use of ameliorants, along with the selection of type, formulation, rate, and method of delivery of such ameliorants should ideally be based on the pre-construction soil analysis. As in all cases, the extent and complexity of the soil analysis, and the expertise of those providing such analysis, must be commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance.

Ameliorants **must** be mixed into the soil to be effective. Ameliorants applied to the soil surface without mixing may be washed away before appropriate treatment of the soil occurs. For example, ameliorants applied by hydroseeding or *Hydromulching* to steep slopes are likely to be washed off the slope by either rainfall or plant watering.

The depth of amelioration depends on the desired outcome. Common ameliorants for plant growth such as lime, compost and fertiliser are typically incorporated to a depth of 150 mm to 300 mm by ripping. In some situations, such as highly dispersive subsoil exposed by a pipe trench, it may be necessary to incorporate gypsum to a depth of 1 m or more if pre-construction soil testing deems it necessary. For that reason, soil amelioration is most effective if undertaken during soil stripping; that is, the ameliorants are applied to the soil surface prior to soil stripping, thus allowing mixing during the stripping and stockpiling process.

It is extremely difficult to ameliorate the soil ‘in-situ’ on slopes steeper than 1:3 (V:H). The ability of heavy machinery to scarify the soil and appropriately incorporate ameliorants is highly variable given the range of equipment typically available at pipeline installations. It would therefore be preferable to look for opportunities to incorporate the ameliorants into the soil prior to its replacement on such steep slopes.

P3.8.5 Rehabilitation of waterways

The rehabilitation of pipeline corridors that cross waterways can be a complex issue requiring input from various professionals. The vegetation requirements best suited to the long-term maintenance of the pipelines are often in conflict with the vegetation requirements best suited to the long-term stability and functions of the waterway.

It MUST be accepted that in some circumstances the needs of the waterway will overrule the needs of the pipeline, while in other locations the needs of the pipeline will overrule the needs of the waterway. Unfortunately there is no ‘measure’ that can be developed that would allow the clear identification of each circumstance.

From an *erosion and sediment control* perspective, the emphasis is on:

- minimising the risk of causing unnatural or undesirable waterway instabilities that could lead to bed or bank erosion and/or exposure of the pipeline, and

- minimising the frequency and extent of future bed and bank disturbances associated with pipe maintenance.

It is acknowledged that establishing the pipe at a depth well below the waterway can reduce the interaction between the pipe and vegetation root system, thus allowing better revegetation outcomes; however, such a design would also increase the cost of construction, and the likely extent of damage to the waterway during pipe installation.

To assist designers in this area, the following **hierarchy** is recommended when considering issues associated with the revegetation of **waterways**. It is acknowledged that such a hierarchy is **<u>not</u>** appropriate for all waterways.

1. Ensure plants placed over the pipeline do not interfere with the structural integrity of the pipe. To the maximum degree practical, pipe crossings should be designed to avoid this problem (e.g. pipe type and depth below bed).
2. Ensure plants placed over the pipeline can be readily removed (including the root ball) in a manner that does not endanger the structural integrity of the pipe.
3. Ensure plants placed over the pipeline do not contribute to channel instabilities (including channel relocation and bank erosion) that would expose or endanger the pipe.
4. Ensure that in waterways containing permanent water, plants established along the water's edge and on the banks do not cause a 'barrier' to fish passage (expert advice will be required in order to assign the importance of bank and water's edge planting to fish passage).
5. Ensure plants placed over the pipeline can be readily removed (including the root ball) in a manner that does not cause undesirable disturbance to the waterway or bank stability.
6. Ensure plants placed over the pipeline do not cause an undesirable break in the movement corridor frequented by terrestrial wildlife.

Of course, in many cases, waterway rehabilitation requirements will be controlled by state legislation and/or waterway permits/licences.

P3.8.6 Revegetation techniques

Table P11 provides a list of common vegetative stabilisation techniques that are applicable to the majority of RoW stabilisation requirements in Australia. The table provides a quick reference for the application and limitations of each technique.

Table P12 summarises the quality control requirements of the various vegetative stabilisation techniques.

Table P13 provides some general guidance on possible plant establishment options for difficult site conditions.

Table P11 – Vegetative stabilisation techniques, application and limitations

Attributes of plant establishment techniques, or preferred site conditions		**Drill & broadcast seeding**	**Hydroseeding**	**Hydromulching**	**Bonded Fibre Matrix (BFM)**	**Hydro-composting**	**Straw mulching**	**Compost blankets**	**Turf**
Maximum grade (V:H)		1:3	1:2	1:2	[9]	[9]	1:2	[9]	1:2
Application:	Topsoil	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Subsoil					[13]		Yes	
Can be incorporated with erosion blankets or TRMs			Yes	Yes	Yes	Yes			Yes
Types of vegetation:	Grasses [1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Native grass	Yes	Yes	Yes	Yes	Yes		Yes	
	Trees/shrubs	Yes	Yes		Yes	Yes		Yes	
Erosion protection [2]		Nil	Nil	M	M-H	M-H	M	H	H
Incorporation of ameliorants		[6]	[8]	[8]	[10]	[14]	[15]	[16]	Nil
Overland flow conditions:	Sheet flow	Yes	Yes	Yes	Yes	Yes	[17]	Yes	Yes
	Concentrated				[11]	[11]		[11]	Yes
Soil preparation		[7]	[7]	[7]	[7]	[7]	[7]	[18]	[19]
Rate of establishment [3]		Slow	Slow	S-M	M-R	M-R	M	R	R

Notes:

[1] Typically includes cover crops and legumes.

[2] Protection against raindrop impact during plant establishment: M = moderate, H = high.

[3] S = slow, M = moderate, R = rapid, Yes = immediate erosion protection.

[4] Reapplication may be required if materials are displaced by storms or insufficient germination occurs.

[5] Further application of soil amelioration may be required if soil condition remains unsatisfactory.

[6] Soil ameliorants are delivered with the seed. Fertiliser can cause seed burn.

[7] Soil scarification and amelioration of topsoil and subsoil.

[8] Very low. Multiple applications may be required. Ameliorants can be easily washed off the slope.

[9] Generally no limits to bank slope for this application provided operators have good access.

[10] Moderate. Only a small quantity of ameliorants can be retained in the mulch.

[11] Concentrated flow may occur over the ordinary BFM, but only if combined with an erosion control mesh or TRM. Minor concentrated flows can pass over mechanically *Bonded Fibre Matrix Hydromulching* without the incorporation of erosion control mesh or TRM.

[12] Weed control may be required if weeds are present on adjacent lands.

[13] Assuming sufficient organic carbon can be applied to the subsoil by the hydro-compost.

[14] Moderate. Only a small quantity of ameliorants can be retained in the mulch. There is less nitrogen draw down with a hydro-compost than a BFM.

[15] Nil. Ameliorants provided by hydroseeding prior to the application of straw mulch. Hydroseeding has a very low ability to provide ameliorants. The subsoil and topsoil must be ameliorated prior to hydroseeding and the application of straw mulch.

[16] A 50 mm thick compost blanket has an excellent ability to store and leach ameliorants into the soil.

[17] Pneumatically applied straw mulch (applied with a binder e.g. emulsion or polymer) can be used in sheet flows. Hydraulically applied straw-based BFM's can be used in both 'concentrated' and 'sheet'.

[18] Soil scarification and amelioration of dispersive subsoils if present.

[19] Soil amelioration and raking or harrowing to provide an even surface and fine tilth.

Table P12 – Quality control requirements of vegetative stabilisation techniques

Typical quality control issues	Drill seeding	Hydroseeding	Hydromulching	Bonded Fibre Matrix (BFM)	Hydro-composting	Straw mulching	Compost blankets	Turf
Soil testing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil preparation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil amelioration type	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil amelioration rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seed germination	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Seed purity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Seed application rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Seed carrier application rate [1]		Yes				Yes		
Binder type			Yes			Yes		
Binder application rate [1]		Yes	Yes	Yes	Yes	Yes		
Mulch type			Yes	Yes		Yes		
Mulch application rate			Yes	Yes		Yes		
Application surface cover [2]			Yes	Yes	Yes	Yes	Yes	
Compost quality					Yes		Yes	
Compost application rate					Yes		Yes	
Turf species								Yes
Turf placement								Yes

Notes:

[1] Where application rate has been specified.

[2] Percentage cover of treated soil, e.g. percentage cover of an square metre of the treatment area. This is not the fraction of the overall soil disturbance or overall work site treated.

Hydromulching

- The rate of plant establishment is slow to moderate.
- Typical organic matter application rate is 1500 kg/ha.

BFM hydromulching and Mechanically Bonded Fibre Matrix

- Requires good quality topsoil for vegetation growth (i.e. the treatment cannot compensate for poor topsoil conditions).
- A minimum organic matter application rate of 3500 kg/ha is required (and recommended) to achieve 100% soil surface cover on raked soil.

Hydro-compost

- Requires good quality topsoil for vegetation growth.
- A minimum organic matter application rate of 3500 kg/ha is required (and recommended) to achieve 100% soil surface cover on raked soil.

Compost blanket

- Can be used where topsoil is of poor quality or non-existent.
- Compost should be applied 25 to 50 mm thick (minimum) depending on slope conditions, supplier recommendations and desired outcomes.

Table P13 – Possible options for site revegetation in difficult locations

Site conditions	Possible responses and issues for consideration
Steep land subject to significant run-on water	• Consider applying a *Jute Mesh* (or similar) to the soil surface, or a combination of a *Jute Mesh* placed over a 'fine' jute *Erosion Control Blanket* to the soil surface. In either case, the topsoil is either seeded prior to application of the jute, or after placement of the jute, the surface is planted with tube stock. • Consider applying a *Compost Blanket* with incorporated seed and non re-wettable tackifier. • Consider applying well staked turf laid across the direction of surface flow. • Though less stable in such conditions, consider applying a *Bonded Fibre Matrix* at the maximum recommended application rate such that 100% coverage (i.e. fibre linkage) is achieved.
Steep land subject to possible high intensity rainfall during plant establishment	• Consider applying an *Erosion Control Blanket*, a *Jute Mesh* over loose mulch, or a *Jute Mesh* over a 'fine' jute blanket to the soil. • Consider applying a *Bonded Fibre Matrix* at an application rate that achieves 100% coverage. • Consider increasing the amount of tackifier used in hydraulically-applied products.
Land unlikely to experience good rainfall in the near future due to drought conditions or the normal dry season	• Consider applying plant seed to the soil, covering with straw, and anchoring the mulch (against wind) with a *Jute Mesh* (or similar). • In either case, the seeded surface can either be: – left unwatered, waiting for seasonal rainfall – watered with imported water to establish a cover crop, which is allowed to die (after watering has stopped) and is then allowed to capture and retain natural wind-blown seed that germinates when seasonal rains return – watered to establish the desired final plant cover.
Land with minimal existing topsoil	• Consider applying a *Compost Blanket* as a replacement. • Consider importing a replacement topsoil. • Both options can be uneconomical in a large scale.
Land subject to high weed infestation due to weed seed content of in-situ topsoil	• Consider burying the in-situ topsoil, and applying a *Compost Blanket* or imported topsoil as a replacement. • Consider thick mulches to control weeds. • Consider applying a 'thick' jute blanket (or similar) to the surface of the reinstated topsoil, watering or rolling to achieve good soil contact, and then planting with tube stock or a seed matrix (e.g. BFM) to the blanket surface.
Land likely to be subject to concentrated flows, such as drainage line crossings	• Consider the benefits provided by jute or coir mesh applied either in isolation, or over a cover of loose mulch or a jute blanket. • Consider a combination of rock, blankets and vegetation as commonly applied to many waterways. • Consider the suitability of initially stabilising the area with a fast-growing, sterile grass, and then planting native seedlings later. Alternatively, use selective herbicides to control the initial grass growth prior to it seeding, followed by the planting of native seedlings.

P3.9 Timing of rehabilitation works

The re-establishment of surface cover on disturbed soils is a fundamental component of reducing the risk of erosion and offsite sediment and turbid water release. Tables P14 and P15 outline the suggested timing of rehabilitation works based on erosion risk parameters and proximity to sensitive receiving environments.

Tables P14 and P15 should not be considered mandatory. Wherever practical, the contracted site rehabilitation conditions (e.g. timing of works and minimum required surface cover) should reflect actual site conditions and outcomes from site specific environmental management studies.

Table P14 – Recommended timing for rehabilitation works based on erosion risk

Site conditions during soil disturbance	Erosion risk rating [1]				
	Very low	**Low**	**Moderate**	**High**	**Extreme**
Maximum delay before start of site stabilisation [2]	10	10	10	10	5
Maximum days to achieve soil coverage [3, 4]	50	50	30	10	5

Notes:

[1] Erosion risk rating determined from Table P4 typically applied to a given 'corridor segment', but can be applied to a specific sub-catchment or landform such as a permanent cut or fill batter.

[2] Maximum days following completion of pipe laying and trenching or construction works before stabilisation and rehabilitation works commence.

[3] Maximum days following completion of pipe laying and trenching or construction works before the stabilised area achieves the specified soil cover.

[4] Soil cover may consist of organic or rock mulch, synthetic blankets, vegetation or combination there of, as appropriate for the area. Though uncommon in pipeline installation, this may, in certain instances, require the utilisation of techniques that achieve 'immediate' soil coverage with products such as mulch, blankets or turf. Turfing is more likely to be associated with installation of domestic pipe work along a road verge (refer to the ESC standards of the local council or regulatory authority).

Table P15 – Timing for rehabilitation works for specific site conditions

Proximity to sensitive receiving environments	Maximum [1] delay before start of site stabilisation	Maximum [2] days to achieve soil coverage
Identified Good Quality Agricultural Land (GQAL)	10	30
Works within 50 m of an ephemeral watercourse. Works less than 200 m upstream of a cultural heritage site, regional ecosystem, or organic farm.	10	10
Works within the banks of a watercourse that is likely to experience flow within the stabilisation period. Works within 100 m of a watercourse.	5	5

Notes:

[1] Maximum days following completion of pipe laying and trenching or construction works before stabilisation and rehabilitation works commence.

[2] Maximum days following completion of pipe laying and trenching or construction works before the stabilised area achieves the specified soil cover. In some cases this may require the utilisation of techniques that achieve immediate coverage with mulch or *Erosion Control Mats*.

P4 Operation and maintenance phase

During the operation and maintenance phase, RoWs should be inspected after rainfall and flood events to identify any areas of erosion, off-site sedimentation, and poor vegetation establishment. Some common issues and mitigation options are provided in tables P16 to P21.

Table P16 – Management of gully erosion forming along the pipe trench

Potential mechanism of failure	Potential solutions
Issue 1.1: Settlement of backfill has resulted in the collection and concentration of flow along the pipe trench	Steps: 1. Excavate loose material from the pipe trench. 2. Install polyurethane foam trench breakers ensuring that key trenches are cut into the base and sides of the trench if possible. 3. Determine compaction levels of surrounding in-situ soils. 4. Backfill trench with non-dispersive, non-saline fill allowing space for topsoil placement. 5. Compact the backfill. 6. Determine from local experience if the finished level of the trench needs to be above (say 50 mm) adjacent ground levels to allow for expected soil settlement. 7. Place topsoil (if slope is no steeper than 1:2 (V:H) or other suitable growing media and revegetate. 8. Ensure the finished surface does not allow concentration of flow (may require the adjustment of final trench levels and cross banks). 9. Protect with appropriate erosion protection (BFM hydromulch, compost blanket, tree debris, rock, etc.).
Issue 1.2: Excessive up-slope run-on water can: (i) concentrate within the trench (ii) cause soil scour while passing over the trench (iii) cause the displacement of erosion control measures applied to the trench	• Identify opportunities to divert run-on at the top of the slope using structural controls if slope is ≤ 1:3 (V:H). • Identify opportunities to divert lateral flows across the RoW using structural controls if slope is ≤ 1:3 (V:H) and the soils are not dispersive, saline or non-cohesive. • If slope is steeper than 1:3 (V:H) and diversion is required, plant overlapping rows of deep-rooted grasses following implementation of the steps for Issue 1.1 above. • If diversion cannot be achieved, then complete the steps for issue 1.1 above, then armour the slope with tree debris or rock.
Issue 1.3: Flow diversion systems (berms, catch drains, etc.) either do not discharge outside of RoW or have failed	• If lawful to do so, extend the berms such that flows are diverted away from the pipe trench. • If the berms have failed due to overtopping or poor compaction, then re-establish the berm. • If the berm has failed due to dispersion or the presence of non-cohesive soils, then reconstruct the berms with treated soil or apply appropriate ameliorants.
Issue 1.4: Roof of tunnel erosion in trench has collapsed forming a gully	• Investigate the solutions provided in Table P17, and reinstate the trench as per Issue 1.1 above.

Table P17 – Management of tunnel erosion forming along the pipe trench

Potential mechanism of failure	Potential solutions
Issue 2.1: Tunnel erosion associated with poorly compacted backfill	• Identify tunnel inlet points and outlet points. • Treat as per Issue 1.1, but with a focus on achieving non dispersive soil properties.
Issue 2.2: Pipe trench backfilled with dispersive soil	• Identify tunnel inlet points and outlet points. • Remove or adjust any berms or other structural controls that can pond water over the pipe trench. • Treat as per Issue 1.1 using imported backfill or gypsum-treated in-situ soil.

Table P18 – Management of soil erosion due to low surface cover

Potential mechanism of failure	Potential solutions
Issue 3.1: Poor vegetation cover due to animal/stock damage	• Examine options for de-stocking or providing temporary fencing. • If vegetation establishment remains sub-optimal following de-stocking/fencing and adequate rainfall, then test soils, ameliorate if necessary, and re-seed.
Issue 3.2: Poor vegetation cover due to excessive soil compaction	• Scarify along the contour and re-seed. • If scarifying the soil is likely to cause undesirable damage to established root systems, then consider the benefits of heavy mulch/compost application.
Issue 3.3: Poor vegetation cover due to lack of suitable topsoil	• Test in-situ soil for physical, chemical and biological aspects and determine if soil can be ameliorated to form a suitable growing media. • If the slope is too steep, or the soil is too degraded to ameliorate, a proprietary growing media such as a compost blanket may need to be considered.
Issue 3.4: Poor vegetation cover due to unsuitable establishment technique	• Review site conditions to determine primary mechanisms of failure (e.g. seed/soil contact, lack of moisture, temperature, overland or concentrated flow, ant predation, bird predation, soil compaction from stock or vehicles). • Once mechanisms of failure have been determined, identify a more appropriate technique from tables P11 to P13 to address site constraints.
Issue 3.5: Poor vegetation cover due to unknown issues	Steps: 1. Test soil, and if necessary, also test plant tissue. 2. Check if germination tests were performed at time of planting. 3. Check for excessive shading of revegetation area. 4. Test soil compaction relative to adjacent undisturbed ground. 5. Check recent rainfall and scheduled watering records. 6. Check for stock damage. 7. Once mechanisms of failure have been determined, adjust site conditions and replant.

Table P19 – Management of rill or gully erosion along the service tracks

Potential mechanism of failure	Potential solutions
Issue 4.1: Surface of the service track is lower than the adjacent ground surface	• If slope is no steeper than 1:3 (V:H) and soils are non-dispersive or cohesive, install trafficable berms diverting flows away from the pipeline trench if appropriate stable outlet points can be located. • Treat the berms and track with a trafficable polymer or emulsion based soil stabiliser.
Issue 4.2: Runoff concentrates in the wheel ruts	• Adopt the techniques listed above for Issue 4.1. • Import suitable road base/gravel and reshape the track with either crowned or cross fall drainage depending on site conditions.
Issue 4.3: Service track is located <u>along</u> or adjacent to a drainage line	• Extend the rock protection on the track as appropriate to manage the gully erosion. • If suitable rock is not available, apply a trafficable polymer or emulsion-based soil stabiliser to the track surface.
Issue 4.4: Service track is located <u>across</u> a drainage line or ephemeral watercourse	• Ensure a trafficable berm (whoa-boy) is located back from the crest of the high flow bank to prevent run-on water running down the track. • Apply rock stabilisation to the in-bank section of track.

Table P20 – Management of service tracks that cross waterway beds

Potential mechanism of failure	Potential solutions
Issue 5.1: Existing scour protection rocks are displaced by stream/flood flows	• Confirm that the use of rock is appropriate. • Remove rock and replace with rock sized for the flow velocity, but do not adversely impact fish passage. • Rock less than 200 mm may not be appropriate in clay-based creeks.
Issue 5.2: Ford crossing not at bed level, thus potentially impacting on fish passage or bed erosion	• Check with state fisheries if fish passage is an issue. • Remove rock crossing, excavate bed material to the thickness of the rock backfill and reinstall; or consider utilising a different type of crossing.
Issue 5.3: Permanent culvert crossing is damaged by a minor flood event	• Request a professional review of the culvert design. • Check if the damage was caused by excessive flow velocity or debris blockage that is unlikely to re-occur. • Replace rock with rock sized for the design flow. • Reconstruct the culvert crossing with more pipes.
Issue 5.4: Insufficient flow capacity within the low-flow pipes (permanent culvert crossing)	• Request a professional review of the culvert design. • Confirm culvert sizing with local fisheries guidelines. • Ensure sufficient number of pipes are used to cover the full width of the low-flow channel, but preferably the full width of the channel bed. • Ensure pipe length allows for 1:3 (V:H) upstream and downstream batter slopes if rock fill is used.
Issue 5.5: Pipes are not located at bed level (permanent culvert crossing)	• Remove pipes and reinstall at or below bed level (seek local fisheries advice). • Ensure the culvert does not adversely affect fish passage or the natural migration of bed sediments (sand and gravel-based waterways).

Table P21 – Management of damages to waterway bank stabilisation measures

Potential mechanism of failure	Potential solutions
Issue 6.1: Erosion control blanket damaged by concentrated run-on flows OR Failure of an Erosion Control Mesh or Turf Reinforcement Mat (TRM)	• Remove failed blanket/mat. • Determine cause of failure. • If tunnel erosion exists (either initiated in pipe trench or in berms at the top of the bank) then repair in accordance with Table P17. • If a velocity-based failure, then either divert run-on water or replace with appropriate blanket/mesh. • Ensure blankets/mesh are appropriately anchored and overlap in the direction of flow (channel & lateral). • Ensure anchors are appropriate for soil type (e.g. duck-billed anchors for silty or sandy soils).
Issue 6.2: Failure of rock stabilisation or rock-filled baskets	• Determine reason for failure, possible causes include: – stream flows were above the specified design event – post-flood bank slumping – movement of stream bed during a flood – displacement of rock by high velocity flood flows – bank scour immediately downstream of rocks/baskets – tunnel erosion under the rocks/baskets. • Consider benching stream banks that are subject to post-flood bank slumping. • Rock protection should be used with caution in sand-based streams due to bed liquefaction during floods. • If the bank slope exceeds 1:3 (V:H) then ensure the stabilisation measures are linked to a stable bank toe. • If rocks are displaced by flow velocity, then replace with larger rocks or cover existing rocks with vegetation—ideally, the voids between rocks should be filled with soil and pocket planted. • The establishment of deep rooted vegetation at the rock/soil margins is critical on high (>2 m) steep (>1:3) banks where the weight of the rock can increase the risk of post-flood bank slumping. • If the bank protection measures are placed on the outside bank of a channel bend, then ensure the measures have sufficient hydraulic roughness to prevent induced bank scour immediately downstream of the bank protection measures. • Refer to Table P17 for the treatment of bank slumping resulting from tunnel erosion.

P5 Technique selection and treatment standard

P5.1 Introduction

The purpose of this section is to:

- Define a recommended design standard for ESC measures for use in pipeline construction (tables P22, P23 & P24). These tables supersede the equivalent tables and recommendations presented in Chapter 4 – *Design standard and technique selection*.
- Provide general guidance on the selection of drainage, erosion and sediment control measures (sections P5.2 to P5.4).

In many cases, the design standard for ESC measures will be set by the regulating authority, an industry code, or specified with a set of licence conditions. However, if a design standard has not been set, then the design standards outlined below are considered representative of current (2015) best practice.

As outlined within Chapter 2 of this document, Erosion and Sediment Control measures primarily consist of three groups of techniques; those being 'drainage control', 'erosion control' and 'sediment control'. As a general guide, every work site should aim to incorporate control measures from each of these three groups of techniques. However, in pipeline construction it is common for exceptions to this rule to exist.

Both the speed of the construction process, and the environment in which the works often occur, can present circumstances where it is not considered fair and reasonable for all three groups of techniques to be applied to each segment of a pipeline. As a result, it is necessary to outline those circumstances when reduced ESC standards are considered warranted.

Also, it is typical, and in fact strongly recommended, that different design standards (or design storms) are set for each of the key site activities of drainage, erosion and sediment control. An example of this would be the design of a *Flow Diversion Bank*. It would not be unreasonable for the flow velocities adjacent to these banks (or windrows) to be checked for a design storm of only a 4-EY (four exceedances per year), but for any stabilised overflow weirs formed in these banks to be designed for a 1-year or 2-year ARI event. Similarly, a sediment trap may be sized to function appropriately during a 4-EY storm, while the emergency spillway of a *Sediment Basin* may be sized for a 10-year or 20-year ARI storm.

Table P22 – Recommended drainage control standard for pipeline RoW [1]

Site conditions		Required drainage control standard
Average monthly rainfall < 10 mm [2]		• No specific drainage controls required other than the utilisation of topsoil windrows as *Flow Diversion Banks*.
Erosion risk rating for corridor segment [3]	Very low	• No specific drainage controls required other than the utilisation of topsoil windrows as *Flow Diversion Banks*.
	Low	As above plus: • Any formed drainage controls are designed for a 4-EY (four exceedences per year) storm event.
	Moderate	As above, except: • Any formed drainage controls (e.g. *Flow Diversion Banks* and temporary drainage chutes, but not *Cross Banks* (berms) located across the RoW) designed for at least a 1 year ARI storm.
	High	As above, plus: • Spill-through weirs formed into *Flow Diversion Banks* and are designed for at least a 1 year ARI design storm. • Appropriate consideration given to the need for intermediate flow release points for up-slope run-on water collected by the up-slope *Flow Diversion Bank* (windrow). Refer to the discussion in Section P3.3.1. • Appropriate consideration given to releasing locally generated stormwater runoff from the RoW at regular intervals down long slopes to reduce the risk of soil scour along the RoW. Refer to the discussion in Section P3.3.4.
	Extreme	As above, except: • Drainage control standard specified for each individual project based on assessed erosion risk and the potential for causing environmental harm. Otherwise, adopt the drainage design standards specified elsewhere in this document for general construction works.

Notes:

[1] Based on all months during which there is elevated soil disturbance within the RoW, but excludes drainage line and waterway crossings where channel flows can be independent of local rainfall.

[2] Includes all months from time of grubbing and/or topsoil stripping to achieving a soil cover of 40% (independent of specified target soil cover). In arid areas the minimum soil cover may be reduced. This condition supersedes the requirements set out below of various erosion risk ratings, but **only** if the soil disturbance period is **known** to exist wholly within months of low rainfall (< 10 mm).

[3] Refer to erosion risk rating defined in Table P4.

Table P23 – Recommended erosion control standard [1]

Site conditions		Required erosion control standard
All locations:		
Average monthly rainfall < 10 mm [2]		• No specific erosion controls required other than normal best practice requirements for minimising the duration of soil disturbance, and promptly rehabilitating disturbed areas.
Drainage line crossings:		
Rainfall erosivity rating [2]	Very low to low	• No specific erosion controls required other than normal best practice requirements for minimising the duration of soil disturbance, and promptly rehabilitating disturbed areas.
	Moderate	• Use an appropriate down-slope velocity control device (e.g. *Geo Log*) to minimise the risk of soil erosion within the disturbed area of the drainage line. • Give appropriate consideration to the need/benefits for rock stabilisation of the vehicle crossing, and the placement of flow control *Cross Banks* (berms) within the RoW either side of the drainage line.
	High to extreme	• Use an appropriate down-slope velocity control device (e.g. *Geo Log*) to minimise the risk of soil erosion within the disturbed area of the drainage line. • Stabilise the vehicle crossing with rock or similar. • Install flow control *Cross Banks* (berms) across the RoW either side of the drainage line.
Waterway crossing:		
Rainfall erosivity rating [3]	Very low	• No specific erosion controls required other than normal best practice requirements for minimising the duration of soil disturbance, and promptly rehabilitating disturbed areas.
	Low	• Give appropriate consideration to the need/benefits of applying suitable erosion control measures to disturbed in-bank areas as soon as works are completed within the waterway. • Stabilise the vehicle crossing with rock or similar, and install flow control *Cross Banks* (berms) across the RoW either side of waterway. • Recommended minimum ‘design discharge’ for a vehicle crossings (e.g. temporary culvert) is the expected base flow of the waterway (i.e. no allowance for stream flows elevated by wet weather).
	Moderate	• Apply appropriate erosion control measures to disturbed in-bank areas before and after pipe trenching. • Stabilise the vehicle crossing with rock or similar, and install flow control *Cross Banks* (berms) across the RoW either side of waterway. • Recommended minimum ‘design discharge’ for a vehicle crossings (e.g. temporary culvert) is twice the expected base flow.
	High to extreme	• Take all reasonable and practicable measures to delay any waterway disturbances until suitable stream conditions exist. • Obtain site-specific advice on waterway stabilisation measures from an appropriate waterway specialist. • Recommended minimum ‘design discharge’ for a vehicle crossings (e.g. temporary culvert) is the 1 year ARI stream flow. The crossing should be structurally stable during a 2 year ARI stream flow.

Notes:

[1] All measures are in additions to the erosion control measures specified in Table P24.

[2] Based on all months during which there is elevated in-bank soil disturbance.

[3] Refer to the rainfall erosivity rating defined in Table P39 in Section P6.4.

Table P24 – Recommended erosion and sediment control treatment options [1]

Type of crossing	**Drainage line crossings**		**Waterway crossings**		
Expected channel flow conditions	**Channel flow unlikely**	**Channel flow possible**	**Stream flow unlikely**	**Stream flow possible**	**Flowing stream [2]**
Ave. monthly rainfall < 10 mm [3]	No specific sediment controls required other than normal best practice ESC requirements for responding to forecast storms			E1 & S2 or S3	E1 & S3
Default	S1 (but all options are possible)	S1, S2, S3 or S4	S1 (only if flows are extremely unlikely) S2 or S3	E1 & S2 or S3	E1 & S5C, S5D, S7C or S7D
Construction equipment requires near-continuous windrows	S1 (but all options are possible)	S1, S2, S3, S4, S6A or S6B	S1, S2, S3, S5, S7A or S7B	E1 & S3, S5C, S5D, S7C or S7D	E1 & S5C, S5D, S7C or S7D
Expanded RoW width allowable at sediment traps	S1 (but all options are possible)	S1, S2, S3, S4 or S6	S1, S2, S3, S5 or S7	E1 & S3, S5 or S7	E1 & S5C, S5D, S7C or S7D

Notes:

[1] Refer to Section P3.3 for discussion on erosion and sediment control options (E1, S1 to S7). It should not be assumed that all listed options for a given category will be appropriate or viable is all circumstances, ultimately it is the task of the ESCP designer to identify which treatment option is most appropriate in any given situation.

[2] Other site issues may require an alternative construction process. Refer to Section P3.6 for further discussion on pipeline construction across waterways.

[3] Based on all months during which there is elevated soil disturbance at the crossing.

Erosion control options E1 (refer to Section P3.3.2) refers to the stabilisation of any exposed or disturbed soil within the drainage line and waterway crossing.

Sediment control options S1 to S7 (refer to Section P3.3.3) refer to the following:

S1 Continuous soil windrows with no specific sediment controls other than that provided by water pooling up-slope of the soil windrows.

S2 A break in soil windrows across the drainage line with a suitable velocity/scour control *Check Dam*, or similar, structure formed across the valley floor.

S3 A break in soil windrows across the drainage line with a Type-3 sediment control system integrated into a suitable velocity/scour control *Check Dam*, or similar, structure formed across the valley floor.

S4 Four layout options, either with a continuous upstream soil windrow (S4A & S4B) or non-continuous upstream soil windrow (S4C & S4D), and with off-stream Type-3 sediment traps.

S5 Four layout options, either with a continuous upstream soil windrow (S5A & S5B) or non-continuous upstream soil windrow (S5C & S5D), and with off-stream Type-2 sediment traps.

S6 As per S4, but with the off-stream Type-3 sediment traps located within an expanded RoW width.

S7 As per S5, but with the off-stream Type-2 sediment traps located within an expanded RoW width.

P5.2 Technique selection – drainage control

Table P25 outlines key features of temporary drainage control techniques commonly associated with the diversion of run-on water along the up-slope boundary of a pipeline RoW.

Table P25 – Techniques for the diversion of clean up-slope water

Technique	Recommended conditions of use
Catch Drains	• Cutting drainage channels into the in-situ soil is generally considered the **least preferred option**, and typically only adopted when the drainage channel will remain as a permanent structure. • Drains used to divert 'clean' water must be suitably lined to prevent clean water coming into contact with exposed soil. • Formal design is required to manage flow velocity and erosion problems associated with poor (dispersive) subsoils.
Flow Diversion Banks [1]	• The use of *Flow Diversion Banks* are preferred if subsoils are dispersive or otherwise highly erodible. • *Flow Diversion Banks* are most commonly formed from topsoil (refer to topsoil windrows below). • Diversion banks formed from local subsoil should be used with caution. • The determination of flow velocity adjacent the bank should assume 2D flow conditions with a flow depth equal to the maximum flow depth adjacent the bank (i.e. hydraulic radius 'R' = max flow depth) rather than on the average flow velocity determined from Manning's equation.
Mulch Berms	• *Mulch Berms* can be formed from imported compost or locally generated (tub ground) mulch. 'Chipped' mulch should not be used for flow diversion. • The mulch must contain some proportion of topsoil to help bind it together.
Topsoil Windrows	• Wherever practical, the stripped topsoil should be stockpiled into stable windrows to act as *Flow Diversion Banks*.

Note:

[1] Average flow velocities within drainage channels have traditionally been determined using the Manning's equation, which adopts a 'hydraulic radius' ($R = A/P$) as the best representation of flow depth. This approach is appropriate when the channel has a depth and width of similar dimensions. However, if the drainage channel is wide and shallow, as is the case for the hydraulic properties of a *Flow Diversion Bank*, then Manning' equation can grossly underestimate the flow velocity at the point of maximum flow depth. To compensate for this hydraulic problem, flow velocity calculations should be based on the hydraulic radius being set equal to the maximum flow depth (i.e. $R = Y$); however, the actual discharge (Q) passing down the *Flow Diversion Bank* should be based on normal Manning's calculations with the hydraulic radius being set equal to the ratio: $R = A/P$.

Tables P26 to P28 outline key features of temporary drainage control techniques commonly associated with the management of soil scour along constructed drainage channels and flow diversion systems.

In general, soil scour within drainage channels can be managed by either slowing the flow velocity through the use of *Check Dams*, or increasing the scour resistance of the channel through the use of a temporary or permanent channel liner.

Table P26 – Velocity control check dams

Technique	Recommended conditions of use
All Check Dams	• Only suitable for use in low to medium gradient (< 10%) drains. • Use with EXTREME caution if the soils are dispersive. Instead, treat the exposed soil or line the drain with a non-dispersive soil. • Critical to ensure water does not spill around the ends of the *Check Dams* causing erosion.
Geo Logs	• Their use is often favourable on pipeline projects. • Use of the smaller-diameter flexible logs, not the larger (> 300 mm) low flexibility jute and coir logs. • Can be used in both shallow (> 400 mm) and deep (> 500 mm) drains.
Gravel-filled Sandbags	• Their use is often preferred if the channel is shallow (< 400 mm). • Use of *Geo Logs* is often preferred because of their quicker installation.
Rock Check Dams	• Can only be used in deep (> 500 mm) drainage channels.

Table P27 – Temporary drain and channel linings

Technique	Recommended conditions of use
Erosion Control Mats	• Suitable for use in both low and steep gradient drains. • A better option than *Check Dams* in shallow (< 300 mm) drains.
Flexible Hydraulically Applied Liners	• Their use depends on the expected life-span of the drain and the expected flow velocity. • Used to provide durable, temporary erosion protection in concentrated flow environments. • Minimal soil preparation required. Can be applied to steep or remote sites using hydromulching equipment. Grass will grow through the liner over time. Observed life to be greater than two years.
Filter cloth	• Typically used to line temporary batter drains and temporary concentrated flow paths that pass across the RoW.
Jute/Coir Mesh	• Best used in medium-gradient permanent drains while a grass cover is being established.

Table P28 – Permanent drain and channel linings

Technique	Recommended conditions of use
Concrete Lining	• Do NOT place directly on untreated dispersive soil. • Often preferred on steep batter chutes. • The finished concrete surface should be flush with the surrounding soil so that lateral flows can enter the channel and minimise the potential for erosion between the concrete and soil. • Should not be used in environments where differential settlement can be anticipated as cracking may occur.
Grass Lining	• The allowable flow velocity depends on the soil condition and the percentage cover of grass. • Soil and climatic conditions must be able to maintain vegetation cover. If not, a TRM or suitable hard armour should be used.
Rock Mattress Lining	• Used to stabilise steep, high-velocity batter chutes and *Sediment Basin* spillways. Best used when large rock is not available or affordable. • Dispersive subsoils will need to be treated otherwise tunnel and gully erosion under or at the edges of the channel can be anticipated. • Channel failures are commonly associated with the finished rock surface being above the adjacent land thus preventing or restricting the free entry of lateral flows into the channel. • The mesh must be appropriate for the environment, e.g. a high gravel bed load may abrade the mesh causing the mattress to fail.
Rock Lining	• Used to stabilise steep, high-velocity batter chutes and *Sediment Basin* spillways. • Dispersive subsoils will need to be treated otherwise tunnel and gully erosion under or at the edges of the channel can be anticipated. • Channel failures are commonly associated with the finished rock surface being above the adjacent land thus preventing or restricting the free entry of lateral flows into the channel.
Turfing	• Best used in medium-gradient permanent drains. • Maximum permissible flow velocity ranges from 1.5 to 2 m/s depending on soil type and grass species. The subsoil must have physical and chemical properties to sustain grass growth. • The turf may need to be anchored to the soils if flow is anticipated before roots have time to penetrate the subsoil.
Turf Reinforcement Mats (TRMs)	• *Turf Reinforcement Mats* are non-biodegradable 3-dimensional mesh designed to interact with the roots and stems of grasses to protect soil in concentrated flow from erosion. • Used to stabilise steep, high-velocity drains that are intended to be grassed. Best used when large rock is not available or affordable. • The two key types are soil or compost filled TRMs and non-soil filled TRMs. Soil-filled 3D poly-amide TRM's are recommended to minimise UV exposure, fire damage, stock damage and animal entrapment. Where suitable topsoil is not available, high quality compost may be substituted. • Anchors/staples must be appropriate for the soil type, e.g. wire staples in clay soils, duck-billed soil anchors in sandy or silty soils.

Tables P29 and P30 outline key features of temporary drainage control techniques commonly associated with the interception and diversion of site runoff (dirty water) to sediment traps.

Table P29 – General drainage techniques

Technique	Recommended conditions of use
Catch Drains	• Cutting drainage channels into the exposed subsoil is generally considered highly undesirable. • Preference should be given to the use of *Flow Diversion Banks* wherever possible, especially if the surface soil is dispersive.
Cross Banks (berms)	• Used to reduce erosion potential of flows by reducing the volume and velocity of the flow along access tracks, travel roads and RoWs. • They may be permanent structures on permanent access tracks, or temporary structures on travel roads and RoWs. • Should not be used as permanent controls where dispersive soils are present on RoWs, due to the high risk of long-term ponding leading to tunnel erosion in the pipe trench.
Flow Diversion Banks	• The use of *Flow Diversion Banks* are preferred if subsoils are dispersive or otherwise highly erodible. • *Flow Diversion Banks* are most commonly formed from topsoil (refer to topsoil windrows below).
Mulch Berms	• The use of *Mulch Berms* to divert 'dirty' water depends on the local stormwater release standards because a portion of the dirty water will filter through the berm and thus will not flow towards the nominated sediment trap. • *Mulch Berms* can be formed from imported compost or locally generated (tub grinded) mulch. 'Chipped' mulch must not be used. • The mulch must contain some proportion of topsoil to help bind it together.
Topsoil Windrows	• Stockpiled topsoil formed into long windrows can be used to capture and direct dirty water flows when the access track is located down-slope of the pipe trench. • If scouring of the up-slope face of the topsoil berm is possible due to the expected flow velocity, then where practical, protect the up-slope face from erosion with applied erosion control measures, or through the use of velocity-control *Check Dams*. • Subject to issues of cost and scour resistance, suitable temporary scour protection measures include: polymer or emulsion geobinder (*Soil Binders*), geofabric, erosion control mesh (≥ 700 g/m^2), grasses and legumes, BFM (*Bonded Fibre Matrix*) *Hydromulch* and hydraulically applied *Erosion Control Blankets*.

Table P30 – Batter drainage techniques

Technique	Recommended conditions of use
Batter Chutes	• Used to direct flows (including ‘clean’ water) down steep slopes. • Also used to carry concentrated flows down the face of watercourse banks during construction of pipeline crossings. • Temporary batter chutes may be lined with geofabric, flexible hydraulically-applied channel liners, or commercial drains. • Permanent batter chutes are typically constructed from rock, rock filled mattresses or concrete.
Benching	• Used to reduce effective slope length of cut and fill batters, or to increase the stability of reinstated high watercourse banks. • Permanent benching on high risk locations should be designed by a geotechnical engineer. ‘High risk locations’ refer to the degree of complications and adverse effects that may result from the hydraulic or geotechnical failure of the bench. • Benches cut into dispersive or silty soils have a very high risk of tunnel erosion and slope failure. Extreme care must be taken in their design and construction.
Slope Drains	• *Slope Drains* are temporary pipe drains used to convey stormwater runoff down cut or fill banks, or redirect flows around soil disturbances. • *Slope Drains* may be formed from flexible solid-wall or lay-flat pipes.

P5.3 Technique selection – erosion control

Tables P31 to P34 outline key features associated with mulches, soil binders and erosion control blankets.

Table P31 – Mulches

Technique	Recommended conditions of use
Compost	• Instant erosion control in areas of sheet flow and minor concentrated flow (the latter case may require additional treatment). • **Hydro-compost** is best used in circumstances similar to a Bonded Fibre Matrix, but when the area contains good topsoil cover. • **Compost Blankets** are best used when it is not desirable or possible to replace the original topsoil (e.g. the topsoil contains excessive weed seed, the land slope is so steep it restricts the placement of topsoil, or insufficient topsoil exists).
Cover Crops	• Fast-growing, temporary vegetation cover of the RoW and some embankments.
Mulching	• **Straw mulching** is best suited to site revegetation in cases where water supply is limited and it is important to minimise water loss (evaporation) from the soil. Areas subject to sheet flow only. Caution the potential bio-security (weed) hazard. • **Tree mulch** is used as a form of erosion control when excess tree mulch is generated during initial land clearing. Areas subject to sheet flow only. • **Hydromulch** is possibly best used in temperate zones when weather conditions are not hot, dry or windy, which can result in high soil moisture loss and failure of the hydromulch treatment. Areas subject to sheet flow only. • ***Bonded Fibre Matrix*** is also best used in areas subject to sheet flow, but has the advantage of increased stability during periods of high intensity rainfall during the plant growth phase.
Rock Mulching and Gravelling	• Commonly used as a natural soil cover in arid and semi-arid lands. • Site derived or imported gravel and rock can be placed on the soil surface. • Can be integrated with a *Cellular Confinement System* to allow placement of the rock/gravel on steep slopes. • Can be integrated with grasses to form a *Structural Soil* that can improve a soil's bearing strength when wet, or used to improve a soil's resistance to light traffic (i.e. maintenance access tracks).
Tree Debris	• Commonly applied to steep slopes where the RoW was cleared of natural bushland. • It is not a form of mulch, rather it is used to help anchor or stabilise an underlying applied mulch. • The spreading of site-gained tree mulch over steep slopes can help to maintain sheet flows over the site thus reducing the risk of the underlying topsoil, mulch and applied seed being washed from the site. • Retained or imported timber debris is cut/sheared into short (approximately 1 m) lengths and placed on the contour. It is then track rolled or compressed to ensure intimate soil contact.

Table P32 – Soil binders

Technique	Recommended conditions of use
Soil Binders (geobinders)	• Various soil binders exist including cross-linking and non-cross linking polymers. • They can be used for the stabilisation of stockpile, RoW and temporary embankment protection. • Cross-linking and non-cross linking polymers include: – cross linking and non-crossing hydrocolloids – Lignosulphonates – vegetable oil based – emulsion based. • To minimise erosion due to raindrop impact and minor overland and concentrated flows by: – gluing soil particles together – partially sealing the surface to minimise water ingress, and/or – aggregation of soil particles providing increased water infiltration and reduced runoff. • For stockpile, RoW and embankment protection, give preference to products that penetrate the soil and cause aggregation of the soil particles. • For concentrated flows such as temporary drains, give preference to non re-wettable products that seal the soil.

Table P33 – Stabilisation of windrow overflow weirs, and drainage line and waterway crossings during construction period

Technique	Recommended conditions of use
Filter cloth	• Suitable for short-term use only (i.e. during the active construction phase).
Erosion Control Mats	• These mats typically have a high allowable shear stress. • Can be used during both the construction phase and site rehabilitation phase. • Caution the use of synthetic reinforced mats in waterway habitats where the plastic mesh can entangle wildlife.
Erosion Control Mesh	• Unlikely to provide adequate scour protection to overflow weirs formed in soil windrows. • Typically only used during the rehabilitation of drainage line and waterway crossings. • generally manufactured from biodegradable jute or coir (coconut fibre) mesh. Coir mesh is more durable than jute mesh.

Table P34 – Erosion control blankets (areas not subject to concentrated flows)

Technique	Recommended conditions of use
Erosion Control Blankets (fine)	• ‘Fine’ or ‘thin’ *Erosion Control Blankets* are used to promote grass growth and provide raindrop splash and low velocity overland flow protection of newly seeded areas in sheet flow environments. • Typically applied to areas that will be grassed. • Intensive soil preparation is required. These blankets must have intimate soil contact (the soil must be raked smooth, but take care to avoid excessive compaction of topsoils). They must be securely anchored in anchor trenches and pinned at 300 mm centres. The pins must be suitable for the soil type.
Erosion Control Blankets (thick)	• ‘Thick’ *Erosion Control Blankets* are used to suppress weed growth when planting seedlings, and to provide raindrop splash and low velocity overland flow protection of newly seeded areas in sheet flow environments. • Typically used on areas to be planted with trees and shrubs. • These blankets are typically made from jute or recycled fibres. • Intensive soil preparation is required. These blankets must have intimate soil contact (the soil must be raked smooth, but take care to avoid excessive compaction of topsoils). • They must be securely anchored in anchor trenches and pinned at 300 mm centres. The pins must be suitable for the soil type. • Design life typically less than one year (depending on weather conditions). • Any holes cut for seedlings must be done in a way that minimises the ingress of water under the blanket. • Generally not recommended on pipelines due to their cost and effectiveness compared with hydraulically and pneumatically applied mulches and compost.
Erosion Control Mesh	• Unlike a ‘blanket’ or a ‘mat’, a ‘mesh’ is an open weave fabric that provides minimal protection of soils from raindrop impact; rather these fabrics are used to provide temporary scour control and anchorage of loose mulches and seeded surfaces. • May consist of biodegradable jute or coir (coconut fibre) mesh. Coir mesh is more durable than jute mesh. • Although maximum permissible velocities may be up to 2.3 m/s for short time periods, as the mesh biodegrades the maximum permissible velocity will reduce to that able to be carried by the soil and grass. • Intensive soil preparation, anchoring and pinning is required for this technique to work effectively. The anchors/pins must be appropriate for the soil type, e.g. wire pins in clay soils, duck-billed soil anchors in sandy or silty soils.

P5.4 Technique selection – sediment control

Table P35 – Treatment of sheet flow

Technique	Recommended conditions of use
Fibre Rolls	• Used as a minor (supplementary) sediment trap on cut and fill batters, and to help maintain sheet flow conditions down these batters. • *Fibre Rolls* are typically made from straw or wood fibres contained within a synthetic mesh. • They are more flexible and have a smaller diameter than geo logs.
Geo Logs	• Typically used when it is desirable to combine the functions of a velocity-control *Check Dam* and a minor Type 3 sediment trap. • Typically manufactured from coir or jute. • Typically coir logs are used at the end of cross banks or in drains to trap primarily small quantities of sand-sized particles. • These systems are generally less effective than *U-Shaped Sediment Traps* and excavated sediment traps as it is difficult to achieve an effective seal with the soil to prevent leakage under the logs.
Mulch Berms	• A *Mulch Berm* is either a Type 2 or Type 3 control measure depending on the particle size of the mulch, thickness and height of the berm. • Primarily used to remove silt and sand-sized particles from sheet flow. • *Mulch Berms* must have stable outlets at regular intervals along the RoW to minimise berm failure. • Some regulators are concerned about tannin releases from *Mulch Berms* to waterways. As such, they may require *Mulch Berms* be located at least 20 m away from any watercourse for *Mulch Berms* with a design life of less than 1 month, and at least 50 m away from a watercourse for *Mulch Berms* with a design life greater than 1 month.
Sediment Fences	• A Type 3 control measure designed to trap small quantities of primarily sand-sized particles in sheet flow environments.

Table P36 – Treatment of minor concentrated flow

Technique	Recommended conditions of use
Filter Tube Dams	• Filter tubes can be used to enhance the hydraulic capacity of various Type 2 and Type 3 sediment traps. • Filter Tube Dams can be used in narrow work environments where space does not permit the use of a sediment sump.
Rock Filter Dams	• A Type 2 sediment trap designed to retain primarily silt and sand-sized particles for the design storm event. • Gravel or geofabric may be used as the ‘filter component’ to assist in sediment retention; however, for short-term installations such as used in pipeline construction, only geofabric filters are recommended.
Sediment Sumps	• An excavated Type 2 or Type 3 sediment trap designed to retain primarily silt and sand-sized particles for the design storm event. • Typically used at the end of a cross bank and at RoW release points.
U-Shaped Sediment Traps	• A Type 3 sediment trap designed to retain primarily silt and sand sized particles for the design storm event. • Typically used in pipeline construction when an excavated sediment trap cannot be used at the end of a cross bank.

Table P37 – Construction exits

Technique	Recommended conditions of use
All Construction Exits	• Used to minimise mud being tracked onto sealed public roads. • Generally all *Construction Exits* are listed as 'supplementary' sediment traps, which means they cannot be relied upon to treat runoff from adjacent soil disturbances.
Rock Pads	• Generally best used in light traffic areas. • Rock sizes 75 to 100 mm are generally avoided due to their increased risk of capture between dual tyres. • Gravel is generally considered unsuitable as a surface material because it contains a wide range of rock sizes and therefore has insufficient void spacing to capture and hold sediment. • Rock or gravel must be placed between the *Vibration Grid* and the sealed roadway to prevent re-contamination of the tyres.
Vibration Grids	• Commonly used in heavy traffic areas, particularly during extended periods of dry weather.
Wash Bays	• Used to wash sediment and weed seeds from vehicles and machinery. • The complexity of design is dependent on the function of the wash-down facility, volume of traffic and anticipated life. A simple bunded rock pad draining to a sediment basin, with a water tank and portable high pressure spray unit may be adequate for most pipeline constructions situations.

Table P38 – Sediment basins [1]

Technique	Recommended conditions of use
Type C Basins	• A Type 1 control sized to capture all sediment sizes from the design storm in coarse-grained soils (refer to Appendix B). • They are not suitable for use in clay or dispersive soil regions.
Type F & D Basins	• Type 1 control sized to capture all sediment sizes from the design rainfall depth in clay or dispersive soils (refer to Appendix B). • Primarily used when turbidity reduction is required. • The embankment should not be constructed from dispersive soil. • Coagulants and flocculants are used to aggregate suspended particles to form larger particles that settle faster. • Ideally should be constructed with a forebay to aid coagulant/ flocculant mixing and reduce sediment removal costs.
High efficiency basins	• Used when it is essential to minimise the size of the basin without reducing treatment standards compared to traditional Type F/D basins.

Note:

[1] Space limitations within the pipeline RoW means that *Sediment Basins* are generally only used on broad-acre ancillary works (e.g. processing plants) and for the treatment of process water and stream de-watering associated with some trenchless waterway crossing procedures.

P6 Overview of planning, construction & maintenance actions

P6.1 Introduction

Planners, designers, contractors and maintenance teams often need to respond to similar site issues. In most cases, the preferred response to any given ‘issue’ will be the same. This section of the appendix has been presented in order to avoid repetition of key statements, and to provide a single location for the listing of key ESC-related actions.

Unless otherwise stated, it should be assumed that each of the following dot points is preceded with the statement *‘All reasonable and practicable measures must be taken to’*. Also, any reference to a ‘high’ level of rainfall, erosion risk, or other risk-based parameter, should also include ‘very high’ and ‘extreme’ levels of that same parameter if such levels exist within the adopted ranking system.

P6.2 Preparation of Erosion and Sediment Control Plans

Activity	Management measures
Design phase	• Ensure the extent and complexity of ESC-related data collection is commensurate with the environmental risk, and the extent and complexity of the proposed soil disturbance. • Ensure the adopted risk assessment procedures are appropriate for the type of works and assessed environmental sensitivity. • Develop ‘Primary ESCPs’ that outline the ‘default’ drainage, erosion and sediment control processes for the project. • Ensure ESC measures are only applied in response to a recognised ‘need’ or assessed environmental risk. • Ensure ESCPs contain sufficient information to allow the specified ESC measures to be adjusted for the season of the year in which the soil disturbance is occurring, and as such, ensure time and money is not wasted installing ESC measures that are not required. • Ensure the extent and complexity of the applied ESC measures are commensurate with the assessed environmental risk, and the extent and complexity of the proposed soil disturbance. • Ensure the cost and time consumption associated with the application of ESC measures are consistent with the expected duration of the soil disturbance and the potential risk of environmental harm. • Ensure the maximum value is obtained from materials won from the site (e.g. rock mulch, organic matter, woody debris) for the control of erosion and aiding site rehabilitation. • Ensure that the adopted ESC strategy is not unnecessarily complex. • Ensure, where practical, ESC measures do not impede safe and efficient construction practices. • Ensure the RoW width, particularly at waterway crossings, is

	sufficient to allow the construction and operation of the required sediment controls (Type 1, 2 or 3) without undue interference to construction activities, including material and pipe deliveries. This may require an allowance for variations in the RoW width at specific locations.
Construction	• Ensure 'Progressive ESCPs' are prepared for any area where the site conditions are significantly different from those assumed within the Primary ESCP, and for all waterway crossings. • Ensure ESC measures are installed in accordance with the specified 'installation sequence'. • Ensure ESC measures are installed, maintained and removed correctly (contract Standard Drawings should provide installation, maintenance and removal procedures for all specified ESC measures). • Ensure that synthetic materials associated with ESC measures (e.g. fabric and stakes) are appropriately removed from the site when they are no longer needed. • Ensure all ESC measures are inspected, and repaired and/or cleaned out if necessary, prior to forecast rain.

P6.3 Management of forward clearing and soil disturbance

Erosion risk rating	Management measures
Very low to low (refer to Table P4 for erosion risk rating)	• Land clearing limited to 8 weeks work if rainfall is possible. • Maximum of 10 days delay after trench backfilling within any corridor segment before commencement of site stabilisation. • Maximum of 50 days after commencement of site stabilisation within any corridor segment before the specified minimum ground cover (e.g. organic or rock mulch, synthetic blankets, vegetation or combination there of) is achieved.
Moderate	• Land clearing limited to 6 weeks work if rainfall is reasonably possible. • Maximum of 10 days delay after trench backfilling within any corridor segment before commencement of site stabilisation. • Maximum of 30 days after commencement of site stabilisation within any corridor segment before the specified minimum ground cover is achieved.
High	• Land clearing limited to 4 weeks work if rainfall is reasonably possible. • Maximum of 10 days delay after trench backfilling within any corridor segment before commencement of site stabilisation. • Maximum of 10 days after commencement of site stabilisation within any corridor segment before the specified minimum ground cover is achieved.
Extreme	• Land clearing limited to 2 weeks work if rainfall is reasonably possible.

	• Maximum of 5 days delay after trench backfilling within any corridor segment before commencement of site stabilisation. • Maximum of 5 days after commencement of site stabilisation within any corridor segment before the specified minimum ground cover is achieved.

P6.4 Weather conditions

Table P39 outlines a procedure for determining the rainfall erosivity rating in circumstances when the likely weather conditions during the time of construction or maintenance are known (i.e. when preparing a Progressive ESCP). This table is different from the 'erosion risk rating' presented in Table P4 because the focus is solely on the expected weather conditions, and not land slope or soil erodibility.

Table P39 – Rainfall erosivity rating [1]

Site conditions during soil disturbance	Rainfall erosivity rating [2]				
	Very low	Low	Moderate	High	Extreme
Average monthly erosivity (RUSLE R-factor) [3]	0–60	61–100	101–285	286–1500	> 1500
Average monthly rainfall depth (mm)	0–30	31–45	46–100	101–225	> 225
Forecast rainfall [4]	< 4-EY	< 4-EY	4-EY to 1-EY	1–2yr ARI	> 2 yr ARI

Notes:

[1] This table is used to define a rainfall be adopted in the absence of an adopted regional scale

[2] The R-factor classification system should be given preference over the average monthly rainfall depth in circumstances where reliable monthly R-factor values are available for the local area.

[3] Refer to Appendix E – *Soil loss estimation* for details on the R-factor as used in RUSLE analysis.

[4] Forecast rainfall depth or intensity for an imminent 24 hour period. 4-EY means four exceedances per year in accordance with current Australian Rainfall and Runoff rainfall classification system.

Activity	Management measures
Planning and design	• Where practical, schedule construction works to avoid periods of high rainfall erosivity (Table P39). In particular, this should apply to higher-risk corridor segments such as steep lands or waterway crossings. • Consider specifying within the contract conditions a maximum allowable area of disturbance during specified high-risk months of the year (preferably based on Table P39). • Consider specifying within the contract conditions the minimum percentage cover required on rehabilitated land prior to the commencement of a month with a specified rainfall rating (preferably based on Table P39). • If the annual average rainfall limits the ability to establish vegetation cover (e.g. arid and semi-arid regions) give preference to those RoW alignments and slope gradients that can be considered stable with reduced vegetative cover.
Construction, operation and maintenance	• Where practical, ensure soil disturbances on steep slopes (> 10%) and within 50 m of a waterway are scheduled to avoid periods of high rainfall and/or stream flows (Table P39).

- Minimise forward clearing during months of high to extreme rainfall (Table P39).
- If works are conducted in areas subject to cyclones and/or severe tropical storms, then construction site planning must consider (prior to the wet season) the required response to any such storm warnings, even though such storms are in excess of the adopted 'design' storm for ESC measures.
- Ensure that if runoff-producing rainfall or elevated stream flows are forecast, appropriate temporary drainage and erosion control measures are implemented (in accordance with the technical notes attached to the ESCP) prior to the start of rainfall. If such technical notes do not exist, then appropriate consideration shall be given to:
  (i) forming temporary diversion berms (e.g. *Straw Bale* or *Geo Log* banks) up-slope of trenches to minimise inflows
  (ii) lining unstable drains with well-secured (staked, not pinned) filter cloth, *Erosion Control Mats*, or fast-drying hydraulically-applied channel linings (as appropriate for the expected flow conditions)
  (iii) protecting exposed drainage line and waterway surfaces with filter cloth or purpose-made *Erosion Control Mats*
  (iv) constructing suitable spill-through points into earth and mulch berms to avoid such structures overtopping at inappropriate locations.
- Ensure that during expected periods of persistent strong winds, appropriate steps are taken to minimise dust, for example, the use of water carts, *Soil Binders, Surface Roughening* techniques and construction scheduling to minimise the duration of soil exposure.
- Schedule rehabilitation works to minimise the duration disturbed soils are exposed to erosive wind, rainfall or overland flow as appropriate for the assessed erosion risk (refer to Table P4, Section P2.4).
- During those months when rainfall is not expected to be sufficient to establish the required surface cover, consider:
  (i) using, on cut and fill batters, heavy duty *Hydromulches* or *Compost Blankets*, and coated seed (to protect the seed) until suitable rainfall occurs
  (ii) using soil polymers to provide short-term erosion protection following completion of construction works and undertaking seeding immediately prior to predicted rainfall
  (iii) identifying and preserving site materials that can be used to provide soil surface protection until suitable vegetation cover can be established (e.g. woody debris, rock mulch).
- If climatic conditions limit the ability to establish vegetation cover (e.g. arid and semi-arid regions) consider identifying and preserving site materials that can be used to provide soil surface protection until suitable vegetation cover can be established (e.g. woody debris, rock mulch).

Operation and maintenance	• Where practical, schedule maintenance works within drainage lines and waterways to avoid periods when rainfall is likely to elevate normal dry weather flow conditions.

P6.5 Topography issues

Activity	Management measures
Planning and design	• Give appropriate consideration to 'land slope' as a factor in pipeline route selection, including safety risks associated with working on cross slopes, the severity of flow velocities passing along the RoW, the desire to reduce the catchment area feeding run-on water into the RoW, and the difficulties of revegetating steep slopes. • Avoid RoW alignments that require the permanent formation of cut and fill batters; instead, aim to always return the RoW back to the natural contours. • Where options exist, select alignments where run-on water can be temporarily diverted away from the RoW. • Utilise ridge lines wherever possible. • Specify the spacing of trench breakers relative to trench slope in order to minimise the risk of tunnel erosion.
Construction, operation and maintenance	• To the maximum degree practicable, aim to release water from the RoW (during both construction and operational phases) in a manner similar to the pre-disturbance condition. • Utilise temporary drainage control measures on slopes less than 18% to reduce the adverse impacts of run-on stormwater flows, but only when exposed soils are not dispersive, and suitable discharge points exist. • Seek expert drainage/erosion control advice if: (i) slopes exceed 18% (ii) the dispersion hazard rating is high (Table P3) (iii) slopes are considered too steep for placement of topsoil (iv) stable flow release points do not exist. • Ensure trench breakers are suitably keyed into the base and sides of the trench. • Ensure that if compaction standards are not specified, trench backfill is compacted to a soil compaction equivalent to the surrounding (in-situ) soil on steep slopes and other areas where the risk of tunnel erosion within the pipe trench is a major concern. • If final land contours are not provided, ensure that pre-disturbance contours are re-established. • Favour slope stabilisation solutions that maintain pre-construction sheet flow conditions. • On slopes steeper than 10% (either down or across the RoW) identify and preserve site materials that can be used to help stabilise disturbed soils and help maintain sheet flow

	conditions down the slope (e.g. woody debris, rock mulch). • Consider the practicality of erosion control measures (e.g. trafficable spray-on soil stabilisers) to provide soil stabilisation during the rehabilitation phase.

P6.6 Soil issues (supplementary to APIA, 2013, Section 9.6)

Activity	Management measures
Planning and design (all soils)	• Ensure the extent and complexity of collected soil data is commensurate with the potential environmental risk, and the extent and complexity of the proposed soil disturbance (refer to Section P2.3). • Ensure sufficient information on the appropriate management of problematic soils is provided with the construction contract, or otherwise ensure the contract specifies a level of consultation with soil experts that is commensurate with the potential environmental risk, and the extent and complexity of the proposed soil disturbance. • When traversing cropping land: (i) the objective should be to minimise changes to the 'value' of the land for agriculture (ii) soil testing (type and density) shall occur in consultation with a soil specialist and the land owner/operator (iii) subsoils are sampled to the full depth of the pipeline trench to identify if adverse soil properties increase with depth (iv) where necessary to achieve the specified outcomes, and where sufficient space exists within the RoW, the most problematic subsoil is stockpiled separately, and is the first to be backfilled in the trench (v) soil amelioration shall occur in consultation with a soil specialist and the land owner/operator (vi) for acid soils, soil amelioration is carried out to a depth of at least 1.0 m.
Acid soils	• Refer to APIA (2013) Section 9.6.8.
Acid sulfate soils (actual or potential ASS)	• Refer to APIA (2013) Section 9.6.3. • Soil testing, sampling locations and treatment to be conducted in accordance with state-approved guidelines.
Arid or semi arid soils	• Refer to APIA (2013) Section 9.6.6.
Expansive/reactive soils	• Refer to APIA (2013) Section 9.6.4.
Hard-setting soils (Planning and design)	• Ensure surface soil amelioration, mulch application, and watering program are signed-off by the project's soil specialist and revegetation contractor.

Hydrophobic soils (Planning and design issue if soil is identified during this phase, otherwise a construction issue)	• Identify and preserve site-generated organic matter that can be respread over the hydrophobic soils as a mulch during rehabilitation works. • Ensure soil treatment specifications supplied to revegetation contractors give appropriate consideration to the use of wetting agents. • Ensure specifications for rehabilitation works include contouring and scarification to encourage the ponding and infiltration of water.
Saline soils (Planning, design and construction)	• Refer to APIA (2013) Section 9.6.5. • Soil testing, sampling locations and treatment to be conducted in accordance with regional soil-conservation / land-management guidelines. • Ensure careful selection of suitable species for revegetation.
Shallow rocky soils	• Refer to APIA (2013) Section 9.6.9.
Slaking or sodic (dispersive) soils	• Refer to APIA (2013) Section 9.6.2. **Planning and design issues:** • Wherever practical, favour pipeline alignments that minimise longitudinal gradient with the aim of minimising the potential for tunnel erosion. • Use trench breakers at regular intervals to minimise tunnel erosion in the pipe trench. The trench breakers must be keyed into the base and sides of the trench. **Construction issue:** • Take all reasonable measures to minimise the mixing of the topsoil with the dispersive and/or slaking subsoils during trenching, stockpiling and backfilling. • Consider gypsum treating dispersive backfill prior to backfilling to minimise the risk of tunnel erosion, especially immediately adjacent any waterway crossing. Ideally the upper 300 mm of the sodic soil should be treated with gypsum to reduce ESP to approximately 4% or less, and/or capped with a 300 mm layer of (site sourced) non-dispersive soils. • Compact the trench spoil to the equivalent compaction of the surrounding soil on steep slopes and other areas where the risk of tunnel erosion within the pipe trench is a major concern.
Soils of low fertility	**Planning and design issues:** • Prepare rehabilitation specifications that include soil fertility amendment where appropriate. **Construction issue:** • Schedule forward topsoil stripping works to minimise the duration topsoil is stockpiled to help maintain soil fertility. • Within cropping land, take all reasonable measures to

	protect topsoil stockpiles from wind and water erosion with the primary objective being to minimise the loss of fertility from the rehabilitated land. • Avoid mixing topsoil and subsoil.
Wetland soils	• Refer to APIA (2013) Section 9.6.7.

P6.7 Water management

Activity	Management measures
Planning and design	• Where options exist, select alignments where run-on water can be temporarily diverted away from the RoW.
Construction, operation and maintenance	• Ensure topsoil flow diversion windrows (if any) are installed as soon as possible. • To the maximum degree practicable, ensure water is released from the RoW in a manner similar to the pre-disturbance conditions. • Minimise the risk of soil erosion along drainage line crossings of the RoW either by: (i) stabilising the exposed soil with rock, geotextile mat, or other suitable material, or (ii) minimising the velocity of flows passing over exposed soil (e.g. by minimising the hydraulic gradient of the flow through the use of velocity-control *Check Dams* or other drainage/sediment control measures, such as Geo Logs). • Maintain sheet flow conditions across the rehabilitated area wherever practical. • Stabilise rehabilitated areas with appropriate *Erosion Control Matting* or similar if these areas are likely to be subjected to unacceptable erosion risk as a result of concentrated flow. • If final land contours are not provided, ensure that pre-disturbance contours are re-established. • If it is not practical to release run-on water at regular intervals from the **rehabilitated** RoW, or in a manner that simulates pre-disturbance conditions, then take reasonable steps to ensure a formal drainage design is prepared before establishing final land contours. • Favour slope stabilisation solutions that maintain pre-construction sheet flow conditions.

P6.8 Gully and drainage line crossings

Activity	Management measures
Planning and design	• Give preference to route options that avoid the crossing of actively eroding gullies. • If the pipeline must cross an active gully, then either: (i) set the pipe invert below the expected long-term bed elevation of the gully, or

	(ii) design appropriate scour protection measures to avoid the future exposure of the pipe.
Construction, operation and maintenance	• Schedule construction activities for periods when surface flows are least likely. • Minimise the extent and duration of works within gullies and drainage lines to the shortest time possible. • If the soils exposed within the pipe trench are dispersive, then ensure: (i) trench breakers are installed as close as possible to the gully (usually below top-of-bank) but beyond the likely extent of future bank erosion (ii) trench breakers are keyed into the base and sides of the trench (iii) the excavated trench in the region of the gully's bed and banks is backfilled only with suitably treated soil. • Compact the trench spoil to a compaction equivalent to the surrounding soil (the *intent* being to reduce the risk of tunnel erosion within the trench, and to avoid the redirection of groundwater flows passing through the backfilled trench). **Gullies only:** • Unless otherwise directed within a drainage plan, install a flow diversion bank at the top-of-bank to temporarily divert run-on water away from all disturbed gully banks both during the construction and rehabilitation phases. • Where appropriate, provide temporary fencing adjacent to the bank rehabilitation to minimise the risk of animal or vehicle damage to the gully banks.

P6.9 Waterway crossings

Activity	Management measures
Planning and design	• Give preference to route options that minimise the number of waterway crossings. • Consult with appropriate experts (creeks or rivers) with regards: (i) waterway stability (ii) expected movement of bed sediments (iii) preferred bed and bank stabilisation methods. • Give preference to route options that cross waterways at: (i) stable channel sections not subject to concentrated lateral inflow that could initiate lateral bank erosion (ii) a straight channel reach, or the mid point between channel bends (iii) pools, not riffles (if a pool-riffle system exists); however, pools are often located at channel bends, and riffles at inflection points, so there are many circumstances where

	the riffle is more likely to be located at the most stable section of the channel reach. • Give preference to route options that <u>avoid</u>: (i) permanent flowing waterways (ii) permanent pools within ephemeral waterways (iii) situations where it would be necessary to alter the natural bed conditions in order to protect the buried pipe (iv) sections of waterway containing unique, protected, or critical riparian vegetation, for example, mature canopy trees that provide shading of habitat pools (v) sections of waterway that are likely to experience future bed lowering that may expose the pipeline (vi) actively eroding channel banks, such at the outside of channel bends (vii) waterway reaches containing dispersive subsoils (viii) waterway reaches that contain deep layers of bed sediment that are likely to mobilise during severe floods. • Refer to additional measures listed in the following table that address issues related to specific types of waterways.
Construction, operation and maintenance	• All works to comply with local waterway policies, codes and approvals. • Select the construction method based on an appropriate risk-based process—refer to APIA (2013). • Wherever practical, schedule construction activities within waterways for periods of least flow, and periods when elevated (storm related) stream flows are least likely. • Minimise the duration of works within flowing waterways. • Maintain the maximum soil surface cover below the low bank, particularly where dispersive soils are present. This may require a narrowing of the RoW in the region of the waterway. • Minimise forward clearing of the waterway banks, especially below the low bank, even if forward clearing occurs above the elevation of the low bank. • Minimise the contamination of stream flows passing through the RoW. • Give preference to the use of off-stream sediment control systems (i.e. dirty water pumped to sediment traps located on the floodplain) instead of instream sediment traps. • Give preference to work practices that avoid the need for, and use of, instream sediment control systems. • Maintain fish passage as required by state regulators/ fisheries. This may require consultation with fisheries experts with regards to potential impacts of temporary barriers or sediment control measures.

- Ensure soil and other material stockpiles are located:
  - (i) outside any area from where the material could reasonably be expected to wash into the waterway
  - (ii) outside the bankful zone (i.e. stockpiled above the elevation of the low bank)
  - (iii) outside the riparian zone (if such actions aid in reducing the required clearing of riparian vegetation).
- Manage stormwater runoff from travel/access roads in a manner that minimises harm to the waterway. This may require such runoff to be diverted through sediment traps or an adjacent riparian filter before entering the waterway.
- Ensure temporary vehicle access crossings of waterways are either located at bed level, or just above the dry weather water level, and are structurally stable during the 2 year ARI (39% AEP) flow event.
- Ensure vehicle crossings are constructed from clean durable rock primarily 200 mm in diameter or larger, with geofabric underlay (the *intent* being to minimise disturbance to the bed, minimise the risk of rocks being washed away if flows overtop the crossing, and minimise sediment releases into the waterway).
- Strip topsoil from the waterway channel (below the low bank) in a manner that best preserves the natural riparian seed bank, but only if the RoW requires the re-establishment of natural riparian vegetation (which may not be desirable for all pipeline crossings).
- If soils exposed on the banks are dispersive, slaking or non cohesive, then ensure:
  - (i) trench breakers are installed as close as possible to the waterway (usually below top-of-bank) but beyond the likely extent of future bank erosion
  - (ii) trench breakers are keyed into the base and sides of the trench
  - (iii) the excavated trench in the region of the waterway's bed and banks is backfilled only with suitably treated soil
  - (iv) top-of-bank flow diversion systems do not allow dispersive, slaking or non cohesive soils to be exposed to surface flows.
- Compact the trench spoil to a compaction equivalent to the surrounding soil (the *intent* being to reduce the risk of tunnel erosion within the trench, and to avoid the redirection of groundwater flows passing through the backfilled trench).
- Wherever possible, restore the natural (pre-construction) bed conditions to the waterway.
- Unless otherwise directed within a drainage plan, install a flow diversion bank at the top-of-bank to temporarily divert run-on water away from all disturbed waterway banks both during the construction and rehabilitation phases.

	• Apply appropriate erosion control measures to disturbed areas of the waterway banks for the purpose of minimising rill erosion, minimising the risk of initiating lateral bank erosion, and minimising the disturbance of introduced revegetation measures. • Unless otherwise directed by a waterway expert, use stream flow re-directive techniques and vegetative erosion control measures on stream banks instead of hard engineering scour control techniques. • Identify and preserve site materials (e.g. rocks and tree debris) that can be used safety to enhance post-works erosion control on the waterway banks. Such measures may not be appropriate in all circumstances. • Where appropriate, provide temporary fencing adjacent to the bank rehabilitation to minimise the risk of animal or vehicle damage to the banks.

P6.10 Management issues associated with specific waterway types

Activity	Management measures
Alluvial (sand and gravel-based) waterways	• Locate the pipe at an elevation that is below any mobile bed material, such as deep sand or gravel, that is likely to be mobilised during severe floods. • Ensure any pipe scour protection measures are finished flush with the solid bed material and do not extend into the bed load material that is expected to move (migrate) during severe floods. • Exercise extreme care when using rock bank stabilisation measures in sand-based creeks as the rock can slump and fail when the sandy bed liquefies during severe flood events. If rock is used, then it must rest firmly on stable channel bank material (i.e. bank slopes of 1:3 (V:H) of flatter may be required). • Never place rock, rock-mattress, or hard armouring measures directly on sandy bed material.
Clay-based waterways	• Avoid introducing sand and gravel sized materials to clay-based creeks, particularly on temporary access tracks, as these materials, if displaced by unexpected high flows, can damage bed and bank vegetation in high flows. • Favour vegetative solutions over hard armour solutions where possible.

P7 Glossary of terms

Bankful elevation – A water surface elevation estimated by various procedures that describe the channel flow condition preceding significant overbank flow. If *benches* are well established within the channel, then significant *overbank flows* might occur prior to the inundation of the floodplain. To avoid erroneous and/or highly variable results, bankful elevation should not be determined by the shape of a single cross-section, but with observations made along a length of the channel.

Catchment – That part of a drainage catchment, including the land up-slope of a pipeline corridor, that would naturally drain to a single waterway or drainage line passing through the pipeline corridor.

Corridor segment – That part of an individual ‘catchment’ that is contained within the pipeline corridor or Right-of-Way. In effect, this is the full surface area of the pipeline corridor from hilltop to hilltop.

Cross bank (berm) – A mound of earth constructed across a RoW or track with a channel on the up-slope side so that runoff is effectively diverted from the RoW or track to a suitable discharge area. Cross banks can convey larger flows than cross drains. They need to be constructed of material that won't scour, particularly where maintenance budgets / regimes are not guaranteed.

Drainage line – A lower category of watercourse or drainage swale that does not have clearly defined bed or banks. It carries water only during or immediately after periods of heavy rainfall, and riparian vegetation may or may not be present.

ESC – Means ‘Erosion and Sediment Control’. This term includes and control measures that fall under the headings of temporary ‘drainage control’, ‘erosion control’ and ‘sediment control’.

ESCP – Means ‘Erosion and Sediment Control Plan’. These plans include generic ESCPs, Primary ESCPs and Progressive ESCPs.

Expert – Means a person suitably trained (either through formal tertiary training and/or on-site training) and experienced (meaning having successfully managed or addresses similar situations or issues in the past) within a given topic or activity. For example, a ‘waterway expert’ would require appropriate tertiary training river morphology or creek engineering, as well as field experience managing waterways for the same type as that experienced on a site.

Filter cloth – A non-woven geofabric used as a coarse filter in the sediment control industry, or to separate different soil/rock groups within a manufactured soil profile.

Generic ESCP or Generic Primary ESCP – A Primary ESCP that is not specific to a given location or pipeline project. These plans are typically applied on low risk projects and during regular maintenance activities.

Geofabric – A woven or non-woven fabric used in soil engineering.

Geotextile – A woven fabric used in soil engineering.

Gully – An open, incised erosion channel in the landscape generally deeper than 30 centimetres. These are ‘drainage lines’ that have experienced recent (in geological terms) erosion, and as such, may or may not be stable at the time of pipeline construction.

High bank – The high bank normally defines the outer limits of the floodplain. In circumstances where a waterway has a well defined floodplain, and the far reaches of the floodplain are defined by a well defined topographic feature (i.e. bank) then the high bank is the top elevation of this topographic feature. In circumstances where a waterway does not have a well defined floodplain, but consists of a deep irregular or multi-staged trapezoidal channel, then the high bank may be defined as the highest bank of the channel.

Low bank – The low bank of a waterway is usually defined by the elevation of the lowest floodplain (assuming a floodplain exists on both sides of the main channel). If the waterway has only one floodplain, then the low bank is the waterway bank that immediately adjoins the floodplain. If the waterway does not have a well defined floodplain, then the low bank may be defined as the lowest bank of the main channel. The 'low bank' should not be confused with the channel bed or banks immediately adjacent the low-flow channel that would regularly flood when the waterway experiences elevated flows.

Low-flow channel – The channel or portion of a waterway bed that contains waterway discharge (i.e the low-flow or base flow) that cannot be directly attributed to recent storms. It includes any regular, long-term inflows such as environmental flows from regulated lakes or reservoirs. This low-flow is usually not constant throughout the year, and typically varies with groundwater levels and long-term weather conditions.

Primary ESCP – An overarching ESCP that demonstrates general drainage, erosion and sediment control practices for the whole construction project. Typically these plans are produced during the planning and design phase.

Progressive ESCP – Detailed ESCPs developed as the project progresses and the actual site conditions and time of year of the soil disturbance are known. These plans provide up-to-date details on the location and installation of the required ESC control measures, and are usually prepared at the expense of the contractor.

Rainfall erosivity – A numeric representation of the ability of soils to resist the erosive energy of rain that considers texture, organic matter content and soil dispersion.

Riparian zone – That part of the landscape adjacent to a waterway that influences, and is influenced by, waterway processes. Usually includes the instream habitats, beds, banks and floodplains of waterways, or their parts. As a guide only, in partially cleared catchments, the retained riparian zone (measured from the water's edge) should be as wide as the top-of-bank width, or three times the bank height, whichever is the greater.

Sub-catchment – Any sub-section of a drainage catchment, whether temporary or permanent, that drains to an individual drainage control measure, sediment trap, or flow release point from the pipeline corridor. A 'sub-catchment' is typically the drainage area considered when designing an individual flow diversion system or sediment trap.

Top-of-bank width – In circumstances where the main waterway channel can be clearly distinguished from the floodplain, and the low bank is defined by the elevation of the lowest floodplain, then the top-of-bank width is the channel width measured at the elevation of the low bank.

Waterway/watercourse – A channel with defined bed and banks, including any gullies and culverts associated with the channel, down which surface water flows on a permanent or semi-permanent basis or at least, under natural conditions, for a substantial time following periods of heavy rainfall within its catchment.

P8 References

1. Australian Pipeline Industry Association, 2013 Code of Environmental Practice Onshore Pipelines.
2. Canadian Association of Petroleum Producers (CAPP), Canadian Energy Pipeline Association (CEPA) and Canadian Gas Association (CGA), 2005 Pipeline Associated Watercourse Crossings. Prepared by TERA Environmental Consultants and Salmo Consulting Inc. Calgary, AB.

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