5.1.2 Erosion and Sediment Control

Policy and Guidelines for Local Government

Prepared by the Eastern Metropolitan Regional Council Local Government Natural Resource Management (NRM) Policy Development Project

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Executive Summary

Erosion can cause serious degradation to land through the loss of topsoil, however this is not the only detrimental impact. The transportation and redistribution of sediments to streams and stormwater drains can also adversely affect these important environments.

The impacts of erosion and sedimentation also represent significant costs to the developer, purchaser, and the community as a whole. Controlling erosion during land development is the most critical measure to minimise sediment pollution. Good site planning from the beginning is essential to alleviate many potential problems.

The purpose of the *Erosion and Sediment Control Policy and Guidelines for Local Government* is to provide a range of planning and management mechanisms for local government to minimise soil erosion during construction and to prevent downstream sedimentation. The Guidelines focus on building and construction sites as they are generally most vulnerable, however control measures are also considered in a broader context.

The Policy and Guidelines form a part of a suite of best management practice (BMP) policies and guidelines produced for local government by the Local Government Natural Resource Management (NRM) Policy Development Project as part of the Swan River Trust Swan–Canning Cleanup Program (now Healthy Rivers Program). They should be read in conjunction with the other policies and guidelines contained in the Local Government NRM Policy Manual.

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OPERATION OF THIS PLANNING POLICY

(a) This policy does not bind the Council in respect of any application for planning approval but the Council will have due regard to the provisions of the policy and the objectives which the policy is designed to achieve before making its determination.

This policy is also intended to:

(i) guide Councils advice to the Western Australian Planning Commission regarding the imposition and fulfilment of subdivision conditions; and

(ii) ensure erosion and sedimentation control conditions are placed on land use and development when necessary.

(b) If a provision of this policy is inconsistent with the:

(i) *Swan and Canning Rivers Management Act 2006*, the Act prevails

(ii) The [*Name of Council*] Local Planning Scheme, the Scheme prevails.

(c) This policy applies to new proposals throughout the [Name of Council].

STATEMENT OF INTENT

Water erosion and the subsequent sedimentation of streams and watercourses are recognised as a primary contributor to the degradation of waterways and water quality. The potential for accelerated erosion exists wherever vegetation is removed and soil disturbed, and whenever overland flow of stormwater runoff is altered.

Erosion and sedimentation in urban catchments results from the disturbance of soil associated with urban development and building works, changes in land use, the installation of services and infrastructure, and the subsequent disposal of stormwater into receiving waters. Regulation by planning and building authorities is used to reduce the amount of erosion, sedimentation and nutrient export associated with the development of land.

On the Swan Coastal Plain and in the Darling Range there is increased evidence of adverse impacts from erosion and subsequent sediment deposition. These impacts include:

- nutrient enrichment and eutrophication of our rivers, as phosphorus and nitrogen bind to eroded particulates;
- reduced capacity of flood ways, particularly as weeds grow on deposited sediment, stabilising it into permanent barriers;
- adverse impacts on native fauna (including fish) from turbid water reaching the watercourse, weed growth on new sediment and loss of river pools and deep water habitat; and
- reduced capacity of stormwater systems due to drainage pipes becoming blocked with sediment, resulting in a higher risk of properties flooding.

The costs and difficulties associated with remediation of these impacts are significant. Effective control of erosion and sediments is considered to be best management practice. Control of sediment from erosion at source is considered to be a more cost-effective measure.

The *Local Government Guidelines for Subdivisional Development*, produced by the Institute of Municipal Engineering Australia WA Division (IMEA WA) in 1998 states (Section 2.7.1):

Prior to the commencement of any works on a development site involving the movement of soil and/or sand, the developer shall submit a site classification and assessment and soil stabilisation strategy in accordance with “A Guideline for the Prevention of Dust and Smoke Pollution from Land Development Sites in Western Australia.”

It is the intent of this policy to broaden the scope of the soil stabilisation strategy required by the IMEA WA Guidelines to also address the potential for water erosion on the Swan Coastal Plain.

The policy therefore acknowledges the need to:

- conserve vegetation cover throughout the catchment through the control of the location, timing, extent and nature of clearing;

- minimise erosion of disturbed ground within building and development sites through the control of surface water quantity and flow paths;
- intercept and contain eroded material from building and development sites, and avoid transfer of mobilised sediment from these sites to adjoining lands and waters; and
- ensure prompt, practical and effective stabilisation of disturbed lands through control of the location, timing, extent and nature of rehabilitation and landscaping measures.

The Eastern Metropolitan Regional Council has prepared *Erosion and Sediment Control Guidelines for Local Government*. The guidelines review best practice in Eastern and Western Australia and provide recommendations for best management practice in erosion and sedimentation control, based on an assessment of local soil and rainfall conditions.

This policy seeks to ensure best management practice erosion and sedimentation control measures are implemented for all land use, subdivision and development in the [Name of Council] to prevent sediment reaching waterways.

DEFINITIONS

'Best management practice' means best management practices identified in the Eastern Metropolitan Regional Council *Erosion and Sedimentation Guidelines for Local Government* (2008).

'Local structure plan/outline development plan' means any plan that is intended to guide the pattern of land use, subdivision and development.

POLICY OBJECTIVES

(a) Assist in protecting the beneficial uses of the Swan and Canning rivers and watercourses, consistent with the requirements of the *Swan and Canning Rivers Management Act 2006*. In particular, by preventing adverse impacts from sedimentation of eroded material, this policy seeks to enhance protection of the following beneficial uses of the Swan and Canning rivers and waterways to be protected under this policy:

(i) as a habitat for:

(i) locally indigenous fauna, including migratory and threatened species;

(ii) locally indigenous flora, including threatened species;

(ii) for the maintenance of the diversity and abundance of locally indigenous fauna and flora species;

(iii) to provide a biologically productive and genetically diverse natural environment;

(iv) to maintain ecological processes; and

(v) together with their beds, banks and contours, the use of fringing native vegetation as an important element of the natural landscape of the policy area.

(b) Reduce turbidity of runoff from disturbed sites by taking measures to prevent erosion and detain any sediment.

APPLICATION OF THE POLICY

During the undertaking of any urban development works, all soil materials arising from clearing, levelling, filling, excavation and/or disturbance of any site, including the placement of any building material stockpiles on that site, shall be wholly contained on-site and not be permitted to enter adjacent lands or waters. The principles of erosion and sedimentation control are to be incorporated into urban development through the application of best management practices. The extent to which the various best management practices are selected for implementation will depend on the site and scale of development.

Local structure plans/outline development plans

Local structure plans/outline development plans on the Swan Coastal Plain should ensure the potential for erosion is minimised.

The following guidelines should be considered (where practical) in the preparation and assessment of local structure plans/outline development plans on the Swan Coastal Plain:

(i) erosion risk should be assessed using the Work Sheet reproduced as Attachment 1 to this policy;

(ii) roads should be located on or parallel to ridges and have gentle slopes generally following contours or be located perpendicular to the contours if necessary. Roads should not be placed obliquely to contours. Consideration may need to be given to visual amenity in the location of roads;

(iii) lot boundaries or roads should not cross watercourses if it can be avoided;

(iv) lot orientation should maximise boundary length along contours and minimise boundary lengths down slopes. If practical, in order to minimise the need to construct cross-drains on firebreaks, property boundary lengths should not exceed 80m for slopes of less than 10% or 35m for slopes greater than 10%;

(v) location of existing proposed erosion prevention control measures such as diversion drains, level spreaders or level sills, level banks, and contour banks or contour sills should be indicated on the plan;

(vi) strategic firebreaks should be utilised if lot boundaries have steep slopes;

(vii) strategic firebreaks should have gentle slopes (i.e. less than 10%) to reduce the likelihood of erosion and need for cross drains; and

(viii) stands of remnant vegetation should be retained where practical and should not be fragmented by lot boundaries. Revegetation to prevent or control erosion should be utilised where appropriate and practical.

Subdivision

Where the [Name of Council] is of the opinion that soil stabilisation is likely to be necessary to prevent erosion from drainage runoff during or after subdivision construction, it will recommend the following 'Conditions' and 'Advice to applicant'. This should be included when responding to the Western Australian Planning Commission's request for comment in relation to that subdivision:

CONDITIONS

1. No work shall commence until construction and soil stabilisation plans have been lodged with and approved by the local government to the satisfaction of the Western Australian Planning Commission. The work is to be undertaken in accordance with the approved plans (LG).

2. Land being graded and stabilised at subdividers cost to the satisfaction of the Western Australian Planning Commission (LG).

ADVICE TO APPLICANT

1. With regard to Condition 1 the local government has indicated soil stabilisation plans should be prepared utilising the *Erosion and Sediment Control Guidelines for Local Government* published by the Eastern Metropolitan Regional Council that is available at no charge from the local government. The plans to include measures for the continuous stabilisation of earthworks during and after the construction period to ensure all soils will be retained within the bounds of the subject land.

Where Condition 1 applies, the local government's advice to the Commission regarding fulfilment of the condition will have regard to whether the procedure below has been followed by the developer:

(a) an erosion risk assessment has been carried out for areas to be disturbed by subdivisional works using the Worksheet reproduced as Attachment 1 to this policy;

(b) a soil stabilisation plan has been prepared consistent with the development approaches identified in table 3 of the Worksheet reproduced as Attachment 1 to this policy; and

(c) erosion and sedimentation control measures described in section 4.0 of the *Erosion and Sediment Control Guidelines for Local Government* (EMRC, 2008) have been considered and applied where appropriate and practical.

Development

Where the [Name of Council] is of the opinion that soil stabilisation is likely to be necessary to prevent erosion from drainage runoff from a proposed development during or after construction, the following condition and footnote should be applied to that development approval:

1. 'All soil shall be retained on-site and appropriate measures implemented to prevent soil erosion by wind and rain during and after development.

FN-1 In relation to Condition 1 above, an advice note[a] is available from the [Name of Council] describing measures that should be taken to retain soil on-site'.

[a] The advice note should be a copy of the EMRC Erosion and Sediment Control Guidelines for Local Government (2008).

End.

1 Introduction

The Swan Coastal Plain is showing evidence of erosion related impacts from the disturbance of soil associated with urban development and construction sites.

Erosion can cause serious degradation to land through the loss of topsoil, however this is not the only detrimental impact. The transportation and redistribution of sediments to streams and stormwater drains can also adversely affect these important environments.

Dislodged and suspended soil particles can silt up drains and streams causing flooding and further exacerbate erosion problems. It can also result in filling of natural wetlands and river pools, the degradation of natural vegetation, increased turbidity of waters and subsequent impacts on aquatic life.

Eroded soil particles may also carry pollutants such as heavy metals, pesticides and nutrients (e.g. nitrogen and phosphorus). Nutrients attached to the transported sediments promote algal growth, odour and increased midge problems. Decaying algae can lead to depletion of oxygen. in the water and stress aquatic animals.

Controlling erosion during land development is the most critical measure to minimise sediment pollution. The impacts of erosion and sedimentation also represent significant costs to the developer, purchaser, and the community as a whole. It is more efficient and cost-effective to minimise erosion before it occurs than it is to attempt clean up measures, at a later stage, most of which are expensive and not practical without other significant environmental impacts. Good site planning from the beginning is essential to alleviate many potential problems. Many erosion prevention measures can be done at little additional cost to the builder or owner.

1.1 Purpose

Regulation by planning and building authorities is needed to reduce erosion, sedimentation and nutrient export associated with the development of land. The purpose of these Guidelines is to provide a range of planning and management mechanisms for local government to minimise soil erosion during construction and to prevent downstream sedimentation. The Guidelines focus on building and construction sites as they are generally most vulnerable, however control measures are also considered in a broader context.

The focus of the Guideline's recommendations is on **temporary** measures rather than permanent works required as part of a wider stormwater management strategy. After establishment, some developments may require ongoing erosion and sedimentation control. The risk of on-going erosion problems should be identified at the planning stage and permanent erosion and sedimentation control devices need to be budgeted for and installed.

The suite of recommended control measures are considered to be the most practical and cost-effective management practices at the time of writing these Guidelines. The recommendations are intended to encourage the use of good judgement based on an assessment of risk and

consequence, and the use of new and innovative techniques is encouraged as new erosion control technologies are developed. These Guidelines are intended for use on the Swan Coastal Plain and augment the *Erosion and Sediment Control Manual for the Darling Range* released by the Upper Canning Southern Wungong Catchment Team in 2001.

1.2 What is Erosion and Sedimentation?

Erosion is a natural process where soil material is detached and removed from a given area by the processes of wind, water and/or gravity. It can occur over long and short geological periods under a variety of natural environmental conditions. However, human activities can accelerate natural erosion processes and move more soil material from the land over a shorter period of time than would otherwise occur.

The risk of erosion and sedimentation is a direct consequence of exposure of soil to rainfall droplets and stormwater runoff. Vegetation cover helps protect the soil from the impact of rainfall by preventing the dislodgment of soil particles, and also promotes infiltration of water into the ground. Plant roots hold the soil in place and filter out sediments. The risk of erosion increases whenever vegetation is removed, soil is disturbed and/or overland flow of stormwater runoff is altered. When the protective vegetation cover is removed, the soil is left bare and becomes prone to both water and wind erosion. The risk of erosion is directly proportional to the intensity of rainfall, the amount of soil exposed to water, and the slope of the exposed land. Stockpiles of unconsolidated or unprotected sand and topsoil can provide another significant source of sediment.

Sedimentation involves the deposition of eroded material in areas on-site, off-site on neighbouring land, within street gutters, drains, bushland and/or waters. Sedimentation occurs wherever water velocity slows down enough to deposit the silt and sediment load from upstream. Much of this sediment is deposited only temporarily, and subsequent run-off events may wash the sediment further downslope or downstream. Most erosion occurs during and immediately after land development or construction.

1.2.1 Types of soil erosion by water

The main forms of erosion by water are:

Sheet erosion – Occurs when sheets of water flows over bare areas of sloping ground without forming well defined streamlets. Sheet erosion results in a relatively uniform layer of topsoil being removed from the land surface without leaving obvious channels.

Rill erosion – Occurs when water flows across the soil surface and gradually concentrates into miniature streamlets called rills. Rill erosion is a consequence of the development of these streamlets and increased flow velocities. It results in very small multiple gullies that together can remove large volumes of soil from the landscape.

Gully erosion – Occurs as a consequence of concentrated flows entailing large volumes of water and high flow velocities. A gully develops by erosion of exposed and erodible soil often eroding down to an erosion resistant material (i.e. bedrock). Once a gully forms, it becomes a favoured path for water movement. As more water flows through the gully, more and more soil is eroded, increasing the area of degraded land.

Channel erosion – Occurs when the channel velocity exceeds the threshold velocity of the materials forming the channel.

1.3 Associated Impacts

The focus on erosion prevention and sediment control from construction sites has primarily been driven by water quality concerns. Ecological problems associated with sedimentation include:

- Y Water may become muddy, reducing transparency and sunlight penetration and decreasing photosynthesis by aquatic plants. The subsequent reduction in oxygenation of the water may stress fish and other aquatic animals;
- Y Eroded soil particles may transport contaminants such as heavy metals, fertilisers and pesticides into waterways, which may adversely affect the condition of receiving waters. For example increased nutrient loads to a waterway promotes plant growth and can lead to nuisance or toxic algal blooms;
- Y Increased sediments can smother filter feeders in the aquatic system, irritate the gills of fish, and damage other animals in the water column; and
- Y Sedimentation can block urban drains and waterways and cause increased seasonal flooding. Sediment may also fill river pools leading to loss of habitat for aquatic flora and fauna.

Other detrimental impacts associated with erosion and sedimentation include:

- Y Increased cost of maintenance of stormwater systems;
- Y Repair of erosion damage due to increased flooding downstream, such as undermined roads, destroyed fences etc;
- Y Increased frequency and cost of street sweeping;
- Y Increased 'lost time' for contractors/developers following rainfall events causing erosion and sedimentation and thus repair and delays;
- Y Reduced value of land in terms of reduced ability to use the land, accessibility, land capability and aesthetic value; and
- Y Safety aspects to the community e.g. flooded or undermined roads, etc. In wet conditions, silt-covered streets are slippery and can create an accident hazard if sediment is allowed to remain.

1.4 Current Government Regulation

The *Soil and Land Conservation Act (1945)* is the principal Western Australian Act relating to the control of soil erosion. The Act provides for the use of *Soil Conservation Notices* where land degradation occurs or is likely to occur. Remedial actions including directing the prevention of erosion, drift or the movement of sand, soil, dust or water on or from specified land may be required by a Soil Conservation Notice (Upper Canning/Southern Wungong Catchment Team, 2001).

Further information on the requirements of this Act can be obtained from the nearest District Office of Department of Agriculture and Food Western Australia.

Other legislation that may be applicable to soil erosion and land development are:

- *Environmental Protection Act (1986)* – land development proposals that are likely to have a significant effect on the environment;
- *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* – Clearing of native vegetation, regardless of the area or number of trees, will require a permit from the DEC, unless clearing is for an exempt purpose. All clearing applications greater than 1 ha must be assessed for impact on soils (as well as biodiversity and water) resources;
- *Local Government Act (1995)* – local law provisions;
- *Planning and Development Act (2005)* – planning and property development processes;
- *Swan and Canning Rivers Management Act (2006)* – waters, parks and recreation areas covered by this Act;
- *Waterways Conservation Act (1976)*; and
- *Wildlife Conservation Act (1976).*

2 Erosion and Sediment Control Plans

In order to minimise the potential for erosion and sedimentation, it is essential to gain an understanding of the erosive forces operating at the site in question. This is achieved through the preparation and implementation of an **Erosion and Sediment Control Plan (ESCP)**.

An ESCP is a plan showing how to minimise erosion and trap sediment occurring as a result of a particular development or building activity. The complexity of the plan will vary with the nature and scale of the development, particularly the amount of ground disturbance likely to result. It should be a 'stand alone' document, consisting of drawings and notes that can be fully interpreted by site personnel.

2.1 Why have an Erosion and Sediment Control Plan?

An ESCP is necessary to ensure that:

- A strategy to manage erosion and sedimentation is considered at an early stage in the planning process;
- The minimal disturbance of the site resulting in minimal amounts of erosion and sediment movement;
- Erosion and sediment control measures and practices are an integral part of the initial site development plan; and
- Construction activities and erosion and sediment control measures and practices are jointly planned and implemented.

2.2 Preparation of an Erosion and Sediment Control Plan

2.2.1 Site Assessment – Erosion risk evaluation

Erosion and sedimentation control must begin before earth disturbance takes place. The first step to preparing an ESCP is to assess the risk of erosion at the particular site. The assessment of the site should be undertaken as early as possible so that any design or planning considerations can be built into the project without unnecessary delays or expense.

Outlined below is a simplified method for assessing the erosion risk of a site. Alternatively, more rigorous approaches to assessing erosion risk are outlined in the following documents:

- Erosion and Sediment Control Manual for the Darling Range, Perth Western Australia (Upper Canning/Southern Wungong Catchment Team, 2001)
- Appendix A of Managing Urban Stormwater: Soils and Construction (NSW Department of Housing, 1998).

The methods outlined in these documents may be preferable for sensitive sites.

Site assessment should consider the following factors:

- Slope;
- Soil type;
- Area of disturbance;
- Extent of remnant vegetation down slope of disturbance;
- Distance of building site to existing drains/watercourses; and
- Land capability, based on available land unit information such as water erosion and water pollution risk.

Paths of natural drainage on the site should also be noted. It is important at this stage to also identify any existing areas of the site subject to erosion so that remedial measures can be put in place.

Table 1 below uses the site assessment factors in conjunction with a rating table to determine an erosion potential score for the site.

Table 1. Erosion risk assessment

Assessment Factor	**High (4 points)**	**Moderate (2 points)**	**Low (1 point)**
Slope	1 in 5	1 in 5 – 1 in 10	< 1 in 10
Area of disturbance	> 5000m^2	1000 m^2 - 5000 m^2	< 1000 m^2
Remnant vegetation down slope of development site	Lacking cover	Some shrub and grass cover, 1-5m wide, intermittent	Continuous cover >5m wide
Distance to drains/watercourses	<50m	50m – 200m	>200m
Land capability (soil type, water pollution potential etc.)	High	Moderate	Low

Land capability or land resource information is generally available for most areas of the Swan Coastal Plain from the Department of Agriculture and Food (Resource Management Technical Report 181, 1999). The above table can be used to provide an overall erosion potential score by adding the rating score for each assessment factor. This enables the proponent to ascertain the erosion potential of their development site prior to planning and design.

Erosion Potential	-	15 – 20 points	HIGH
	-	10 – 15 points	MODERATE
	-	5 – 10 points	LOW

A ‘High’ score will require careful site specific planning and a variety of management measures to address the erosion potential at a number of locations within the site. A ‘Moderate’ score will require management controls for erosion, and a ‘Low’ score may only require a basic level of erosion control.

The following points should be noted regarding the erosion risk of a site:

1. Soil loss is normally greater during winter than summer, however an intense rainfall event during drier months can cause significant soil loss. The provision of erosion control measures for developments where construction occurs through the drier months of the year is equally important as those planned for development during winter months;
2. Soil loss from a site is related to the time that the soils are exposed prior to rehabilitation/stabilisation. The time from commencement of construction to rehabilitation should be minimised and it is recommended that the period should be less than six months;
3. Erosion control measures are still important for sites that have a low erosion risk; and
4. The extent of the disturbance will influence the risk and consequences of erosion at a site.

Once the erosion risk has been determined, an Erosion and Sediment Control Plan can be prepared for the site. The standard format of an ESCP will vary depending on the complexity of the proposal and its potential environmental impact. They may be individual statements or plans, or they may be detailed engineering drawings. For most ESCPs the plan will incorporate the following components:

- Map(s)
- Supporting information
- Construction details, calculations and notes.

An Erosion and Sediment Control Plan must address all aspects of site disturbance, flow rate changes, erosion and sediment control and site rehabilitation for the duration of the project from the initial clearing to project completion. If at project completion there is any area that is in an erosion-prone state, then the ESCP will need to be reviewed in light of additional works required.

2.2.2 The Map

The map is the most important component of the ESCP. Although the supporting information is important when designing the plan, these can get neglected at the construction site. The more erosion and sediment control information included on the map, the better the chances that the plan will be implemented properly.

The map should be at a scale of 1:500 or greater and clearly show the following:

- Locality of the site, north point and scale;
- Property boundaries;
- Existing contours of the site and indications of direction of fall;
- Construction site/disturbance area boundary – outside of which no works, vehicle movements or stockpiling of materials are to occur;
- Details of access points to construction site;
- Erosion potential ratings over the site;

- Location, details and dimensions of all permanent and temporary sediment control structures;
- Location of existing vegetation to be retained and location of vegetation protection fences or belts;
- Location of vegetation to be removed and method of removal;
- All existing watercourses and/or drainage structures;
- Details of the sites catchment area;
- Temporary and permanent stormwater management measures;
- Material stockpile areas;
- Staging of works, including erosion/sedimentation control;
- Maintenance schedule; and
- Site rehabilitation proposals including revegetation techniques and final contours.

2.2.3 Supporting Information

The information on the map should be supported by a brief description of the overall erosion and sediment control strategy for the proposed development. This summary document should include:

- A brief description of the existing site conditions such as soils, proposed works, impact on the site and adjacent areas that may be affected by the proposal;
- A description of any areas within the site that have the potential for serious erosion and or sedimentation, together with their proposed management details;
- The construction sequence over the duration of the works. This may include a chart outlining the sequence of works, including erosion and sedimentation control measures and their maintenance;
- A brief description of the overall site rehabilitation program;
- A maintenance strategy for all control measures, including the nomination of responsibility for the follow-up maintenance required on any permanent measures;
- Estimation of 1 in 5 rainfall event and 1 in 20 year event (see Section 4); and
- Estimation of peak flow using Rational Method (see Section 4).

2.2.4 Construction details

All design criteria and calculations used to size controls should be shown. Construction drawings or written specifications should be provided on each type of structural erosion and sediment control measure proposed. (See Appendix B for control measure construction notes) Specifications for all rehabilitation and revegetation components of the plan should include volume and rates of materials used (seeding, fertilising and mulch) and methods of application. Where possible local indigenous native vegetation should be used to stabilise and revegetate the site.

3 Basic Site Management Principles

The way in which a building site is managed can have a significant impact on the amount of pollution in stormwater runoff. Problems can arise from:

- Building materials (such as sand, soil and gravel) being dumped too near drains or street gutters, not properly stockpiled, washing into the stormwater system;
- Poorly cleaned sites that may result in leftover building materials, litter and concrete slurry entering waterways via stormwater runoff; and
- The way erosion and sediment control measures are maintained can make the erosion problems worse.

It is therefore important to ensure that everyone working on the site understands how important it is to prevent stormwater pollution, and to report potential problems to site management.

3.1 Five Steps to Controlling Erosion and Sedimentation

There are five basic steps to reducing the impacts of erosion and sedimentation from all urban development sites. These steps should be followed when preparing an Erosion and Sediment Control Plan. They are:

1) Stopping it before it gets started
2) Keeping topsoil on the site
3) Preventing soil being washed off-site
4) Catching what does wash off
5) Keeping soil out of the drainage system.

3.1.1 Stopping it before it gets started:

Tests show that up to 100 times more soil can be lost where the ground cover has been disturbed than from where cover has been maintained (Launceston City Council, 2001). Therefore, minimising the amount of the site you disturb is critical. Ways to achieve this include:

- Wherever possible, maintain a good grass cover along the road verge during construction;
- Ensure that the only vehicles that go on the site are essential for works activities;
- Consider temporary fencing to keep some areas ‘out of bounds’;
- Disturb only the ground where it is essential for the construction process;
- Do not disturb a neighbours land unless essential, and only then with the approval of that neighbour;
- Consider erosion potential during planning of site works and minimise period of disturbance; and

- Construct a single, stabilised entrance to ensure vehicles can access the site in wet conditions and not track mud/sand back out onto the road when they leave.

3.1.2 Keeping the topsoil on the site:

The topsoil which must be disturbed needs to be protected and kept for reuse later. Management methods include:

- Create a stockpile to one side where it will be secure;
- Put the stockpile on the block (not the footpath or the neighbours land);
- Construct a sediment fence on the downhill side of the stockpile;
- Keep stockpile away from areas where water may flow;
- Cover the topsoil if it will be stockpiled for more than a three or four week period; and
- Never place a stockpile within two metres of a stormwater inlet pit unless the pit is inactive and covered.

3.1.3 Preventing the soil being washed off the site:

Water flowing over the disturbed surface is the main cause of erosion. By reducing the amount of water flowing over the site or by directing water to safe areas, soil can be kept on the site. Re-establishing disturbed areas quickly is also essential to reduce the potential for erosion.

- Where surface water can run along a path more than 100 metres long before it reaches the construction site, construct earth banks along the topside to divert water around the disturbed area;
- Do not divert water onto neighbours land without permission;
- Consider putting in some temporary pipe works in critical areas;
- Put in the permanent stormwater system before roofing is commenced. This is so water from the new roof has somewhere to go to and does not drain straight over the disturbed ground;
- Plan to finish the paved areas (at least to a gravel standard) early in the process rather than leaving them bare for the duration of the job;
- Once a section of work is completed, reinstate the disturbed ground around it before moving on to the next part of the job (reinstatement can be sowing of grass, laying of turf or mulching); and
- Reinstate all disturbed areas as soon as possible after completion of works.

3.1.4 Catching what does wash off:

Even when the land disturbance is kept to a minimum, significant soil losses can still occur. Acknowledging that some erosion is going to occur, steps must be taken to intercept and retain mobile sediment within the work site. An effective way to retain sediment on-site is to erect a sediment fence.

- Erect sediment fences along the bottom edge of the disturbed area to collect the materials being washed off;
- Use an approved filter fabric with the bottom 150mm buried to prevent soil washing under the fence;
- Make sure there are no gaps. Repair any holes or missing sections quickly;
- Inspect the fence regularly, particularly after a rainstorm – you may need to remove collected soil from the fence from time to time; and
- Where the stabilised access is on the low side of the block, ensure that the small hump in the stabilised access diverts water to the sediment fence.

3.1.5 Keeping the soil out of the drainage system:

Finally, despite the application of the above practices, some eroded material may still leave the site. The last line of defence involves protection of active stormwater inlets.

- Place a sock made of geotextile and filled with gravel over the entrance to the stormwater pit;
- Inspect the sock regularly after rain and clean up any collected soil before it overtops the sock;
- Do not use a sock where it can become a traffic hazard or where it might simply divert water to another stormwater inlet; and
- Do not wash down equipment or dispose of waste into the stormwater system.

4 Erosion And Sediment Control Measures

This section outlines a number of structures or tools used to control erosion and sediment movement from development sites. The selection and number of tools used at a particular site will depend on a number of factors including the erosion risk of the site and scale of the development. The selection of the right control and careful installation is required for the control to be effective. It is important to provide adequate instruction and supervision during installation to ensure that structures are installed in accordance with the manufacturers recommended specifications. In all cases, maintenance of the controls is critical to their continued effective functioning.

4.1 Erosion Control Measures

Measures described in this section are source controls that limit the amount of site erosion. The measures rely on the principles of limiting runoff velocities and stabilising disturbed surfaces to limit erosion. The appropriate controls, or combination of controls, should be selected to suit the relevant site conditions.

4.1.1 Diversion Drains

Diversion or catch drains are channels constructed across a slope to convey runoff at a non-erosive velocity. They are provided to divert runoff from upslope areas around the site of disturbance. The drains may also be used in areas upslope of long cut or fill slopes to prevent erosion of the disturbed slopes.

Diversion drains should divert clean runoff (i.e. before it enters the site) to natural drainage depressions (utilising appropriate water-dispersing structures to avoid erosion upon entry of water), culverts (under roads, etc.) or drop structures where appropriate, in order to prevent mixing of clean and sediment-laden water. Diversion drains should not be constructed in such a manner that discharge could affect other parties e.g. neighbours.

Temporary diversion drains should be designed for a minimum design flow of a 1 in 5 year Average Recurrence Interval (ARI) storm event and permanent diversion drains should be designed for a minimum design flow of a 1 in 20 year ARI. The structure should be designed to cater for a peak flow estimated using the Rational Method (Institute of Engineers, Australia 1987). The channels require construction on a relatively flat grade to minimise velocities and prevent scour. Channel stabilisation measures should be used where this is not achievable.

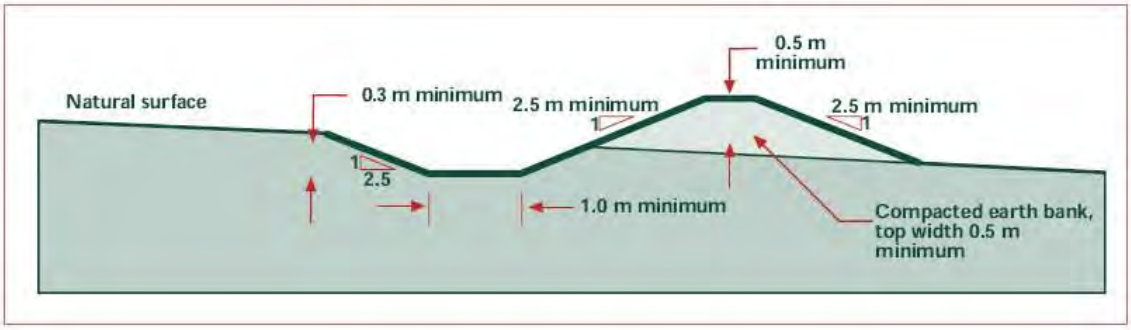

Figure 1: Example diversion drain installation method

4.1.2 Drop Structures

Drop structures are required where runoff is to be directed down slopes where there is potential for rill or gully erosion to develop. Temporary drop structures should be designed for a minimum design flow of a 1 in 5 year ARI and permanent drop structures should be designed for a minimum design flow of a 1 in 20 year ARI. The structure should be designed to cater for a peak flow as estimated using the Rational Method (Institute of Engineers, Australia 1987).

Floodplains and land adjacent to watercourses often comprise silty material with a high erodibility potential. Therefore erosion protection where water enters the watercourse from the outlets of drainage structures should be provided, in order to prevent channel erosion at the point of entry.

4.1.3 Level Spreaders

A level spreader is a structure built across the slope at the outlet of a channel or drain, which has a wide level overflow sill discharging on to an undisturbed area stabilised by vegetation cover. The purpose of the level spreader is to convert a concentrated potentially erosive outflow from a drain or channel into non-erosive sheet flow.

Level spreaders are usually used at the outlet of diversion channels, however they may be more widely used in general drainage practice at the outlet of any concentrated discharge.

The spreaders require careful construction to ensure that the outlet sill is level over its entire length. They can only be used in locations where the overflow sill can be constructed parallel to the slope and discharges onto undisturbed soil that is stabilised with vegetation. Discharge from the sill should only be allowed as shallow, slow moving sheet flows.

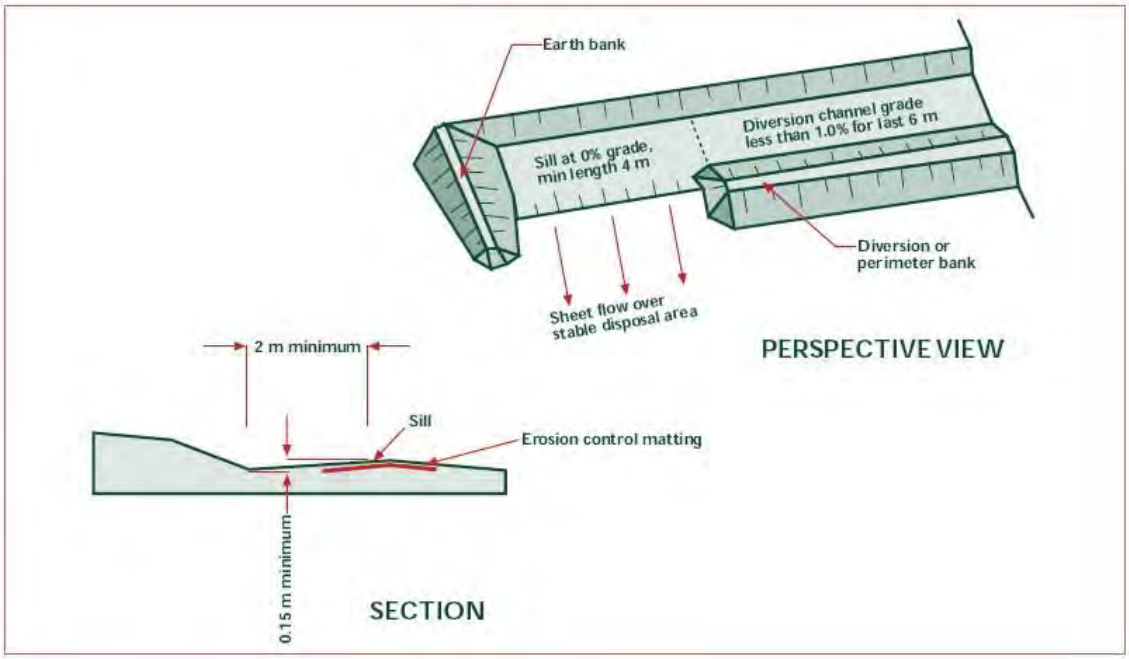

Figure 2: Example level spreader installation method

4.1.4 Vegetative Stabilisation

After any clearing or earthworks, one of the most effective means of minimising or preventing erosion is for vegetation to be re-established. It is important that the overall planning and timing of any works is carefully considered to ensure that they can be completed and vegetation successfully re-established before heavy winter rains.

Prior to stripping topsoil, vegetation should be removed and shredded to form mulch for later use. Because the topsoil is required later in the revegetation process, subsoil must not be mixed with topsoil stockpiles. Topsoil should be stripped from the site and stockpiled away from drainage lines in a way that erosion of the stockpiles does not occur. Sediment fencing is required downslope of stockpiles in order to intercept any sediment, and upslope runoff should be diverted away from stockpiles. The maximum topsoil stockpile height should be 2m in order to preserve micro-organisms within the topsoil, which can be lost due to compaction and lack of oxygen. Topsoil should not be stripped or stockpiled if it is wet, as compaction may result.

In order to allow rehabilitation of cut and fill batters, batter slopes should be a maximum of 18° or (1:3, vertical: horizontal). The height (or length) of any batter slope should be minimised. It is recommended that all exposed batters at a site be rehabilitated to the following minimum requirements:

- Respread topsoil over batter areas (minimum thickness as per original profile);
- Deep rip the slope on the contours (nominal spacing 2m) using a dozer;
- Seed, fertilise and mulch the disturbed batter areas as required; and
- The use of coir fibre matting products, and weed-free hay should be considered for rehabilitation in order to assist vegetation to become established without significant erosion occurring.

In addition, prior to the vegetation becoming established, various techniques such as the use of mulches can reduce soil loss from a site by approximately 90% (dependent on the erodibility of the original soil).

If cut or fill slopes are steepened above 18°, additional measures should be taken to minimise the potential of erosion (such slopes would be difficult to rehabilitate using the procedures outlined above). These additional measures include:

- Benching of a cut slope consisting of materials prone to erosion, to break the slope and allow planting on benches;
- Stone pitching; and
- Retaining wall systems such as rock gabions.

If possible, timing of the whole project should also allow the rehabilitation phase to be completed by mid April, prior to the onset of winter rains. This not only ensures an early establishment of rehabilitation plants, but also minimises the time that disturbed or reshaped slopes are exposed and vulnerable to erosion.

4.2 Sedimentation Control Measures

Measures described in this section are small-scale devices for use on construction sites to remove sediment from site runoff. Most of the measures would normally be temporary in nature, being required only until the disturbed surfaces in the catchment they serve have become permanently stabilised, usually by revegetation.

The appropriate controls, or combination of controls, should be selected based on the expected rate of sediment export and the duration of the construction works. All sediment control structures will require regular inspection and periodic maintenance and/or replacement. Care must be exercised to ensure that the sediment removed from the structures during maintenance operations is not allowed to be remobilised and exported from the site.

4.2.1 Stabilised Site Access

Temporary construction site exits should be installed at any point where traffic will be leaving a construction site. The function of the construction site exits is to minimise the transportation of sediment from construction sites onto public roads or adjacent properties via the wheels, chassis and sides of vehicles. Removal of soil from the site on the tyres of vehicles can lead to sediment entering drainage systems and hence it is necessary to provide measures to prevent it.

Temporary construction exits consist of an elevated pad of coarse gravel overlaying a geotextile fabric. A timber or metal shaker ramp is often located on top of the gravel pad. All drainage from the exit pad must be directed to a sediment pad. The following recommendations are suggested regarding site access:

- Access to single lot building sites should be restricted to one location;

- Construct a stabilised site access at the entrance to the building site;
- Access points to subdivision construction sites should be kept to a minimum and be well delineated. Drivers must be informed of these access points;
- Access to work areas should only be by defined roads. The number and location of access roads should be designed to minimise the area of disturbance at the site and should be generally located where future permanent roads are to be located;
- Roads should be sheeted with erosion resistant material where appropriate. Where access is via temporary roads, such roads would require the sheeting to be removed and the area rehabilitated; and
- Contractors/developers must ensure all employees and sub-contractors are aware of the above requirements.

(See Construction note SD 5-7 Appendix B)

4.2.2 Sediment Traps

Sediment traps such as sediment fences are temporary measures constructed during land development activities in order to minimise sediment movement off-site. These traps aim to firstly retain sediment close to where it originates and secondly, to separate sediment from 'dirty water' runoff from disturbed areas. It should be noted that these traps generally only retain coarse sediment (coarser than 0.2mm). Recommended temporary sediment control measures include:

- Weed-free hay bales;
- Sediment fence; and
- Inlet filters at drainage structure inlets.

(See Construction Note SD 6-7 Appendix B)

4.2.3 Weed-free hay bales

Hay bale barriers are constructed from bales of hay positioned so as to intercept sediment-laden runoff. The primary purpose of the hay bale barrier is to reduce runoff velocities and filter runoff, thus causing the deposition and removal of silt. Hay bale barriers may be place across minor drainage lines to filter runoff from small catchment areas of up to 0.5ha in size. They may also be used as a temporary perimeter bank around disturbed areas preventing runoff from leaving the disturbed area without being treated.

Hay bale barriers are inexpensive and are easy to install, however the bales only have roughly a three month life span and therefore require regular inspection, repair and replacement. Bales used on development sites can be utilised as mulch when their useful life as a barrier is finished, however it is important to ensure that the hay bales do not contain any potential pest plants.

Experience has shown that most hay bale barrier failures are related to the following installation and related problems:

- Bales not staked firmly into the ground;
- Bales not embedded into the ground;
- Bales not butted tightly end-to-end;
- Insufficient space provided for sediment entrapment;
- Access for cleaning not provided;
- Bales displaced by site operations or equipment and not restored to their original position at the end of the working day;
- Barrier not located in the centre of, and perpendicular to, the flowpath;
- Bales providing habitat for vermin; and
- Care should be taken when using hay bales on sites prone to vandalism as they may be subject to arson attacks.

(See Construction Note SD 6-6 Appendix B)

4.2.4 Sediment Fences

Sediment fences are used to reduce runoff velocities and cause the deposition of silt. They are usually placed to intercept sheet flow from disturbed areas, or around the toe of stockpiles. The fences are relatively quick and easy to install, and may be moved from location to location as required. The fences are constructed from an approved geotextile filter fabric with the bottom 150mm buried to prevent soil washing under the fence.

(See Construction Note SD 6-7 Appendix B)

4.2.5 Stormwater Inlet Filters

Stormwater inlet filters are temporary devices used to prevent sediment from entering stormwater drainage pipes during construction or maintenance works. Care should be taken when installing these devices to ensure that total blockage of the approach to the inlet pit does not create the risk of flooding adjacent properties or roads.

Two basic types of inlet pit traps can be used, one for drop inlets, and the other for side entry inlets. Both are constructed from heavy gauge wire netting or mesh that supports a geotextile filter fabric. The filter fabric is protected and held in place by being covered with a 50-75mm layer of gravel, preferably prewashed. A semi-portable version consists of a long ‘sausage’ manufactured from the wire netting, filter fabric and gravel. It can be laid around the approach to both types of inlets or used as a series of interceptors laid diagonally across road gutters.

The small scale of these devices means they need to be frequently cleaned to remain effective for long periods. They are ideal for use during short-term maintenance projects.

(See Construction Note SD 6-8 / 6-9 Appendix B)

4.2.6 Vegetated Buffers

Vegetated buffers take the form of a strip of undisturbed or established vegetation, left to intercept sediment laden sheet flow. The buffers remove the silt from runoff by trapping soil land sediment particles. It is essential that the buffer is continuous. Vegetated buffers are most

effective where the flow is shallow and spread over a large area. Buffer strips may also be used within swales to intercept and filter the runoff. Grassed roadside swales are one example of such an application.

Vegetation strips may become degraded due to sediment deposition and hence vegetation strips should be used in conjunction with the sediment control measures outlined above. The use of turf strips adjacent to roadways etc. as the sole sediment control measure is not considered feasible given the Mediterranean-type climate of the Swan Coastal Plain.

4.3 Comparison of Control Measures

Table 2 below compares the advantages and disadvantages of various control measures and their approximate cost. The table has been taken drawn from the *Erosion and Sediment Control Manual for the Darling Range, Perth Western Australia* (2001) prepared by the Upper Canning/Southern Wungong Catchment Team (UCSWCT). The unit costs provided are approximate and should be used for comparison purposes only. The actual costs of installation will depend on the extent of the works required, access restrictions, market forces at the time of tender, etc. Unit costs exclude all supervision, design costs, etc. The cost will also depend on the volumes ordered.

4.4 Summary of Control Measures

In summary, the following are the general principles that relate to the planning and implementation of erosion and sediment control measures where land will be disturbed due to a land development project:

- Plan erosion and sediment control measures (i.e. draft an ESCP) based on erosion potential at the design/construction planning stage. Incorporate both temporary (i.e. during construction) and permanent erosion and sediment control structures according to the sites needs;
- Minimise the area that is to be disturbed in the development. It is better to minimise erosion in the first place rather than attempting to minimise damage by installing sediment control measures;
- Any areas where vegetation is to be retained (i.e. vegetation strips) should be clearly identified on maps, on the ground, and to workers so it is not accidentally disturbed;
- Minimise the time the disturbed areas are exposed without stabilisation or cover;
- Conserve and safely stockpile topsoil (e.g. away from the drainage lines), for later distribution;
- Divert upslope runoff around the works or site (i.e. separate ‘clean’ water from sediment-laden water), and safely dispose of in a stable area;
- Rehabilitate disturbed areas progressively; and
- Institute a maintenance program for both the temporary and permanent erosion and sediment control measures that have been adopted.

Table 2. Comparison of control measures

Control measures	Approx. unit cost	Advantages	Disadvantages
Weed free hay bales	$4 to $8/m	Inexpensive	Requires removal at completion of work
		Ease of installation by semi-skilled labour	Requires periodic clean out and disposal of sediment
Sediment fence	$10/m	Inexpensive	Requires removal at completion of work
		Ease of installation by semi-skilled labour	Requires periodic clean out and disposal of sediment
Level bank (Sediment Trap – Level)	$5 to $10/m	Low cost	Requires removal at completion of work
		Local materials may be able to be used	Requires periodic clean out and disposal of sediment
			May be difficult to use on steep slopes due to access for equipment
			Erosion of a breached bank may contribute to some soil loss from site
			Licensed operator required for equipment
Vegetative Swales	$2.50/$m^2$ (Grass swale) to $20/$m^2$ (Rolled turf)	Low cost	May become degraded due to sediment deposition
		High sediment removal	Requires frequent maintenance in first few months
Vegetative Buffers	$3.50/$m^2$ (Turf buffer strip) to $20 – $50/$m^2$ (Native grasses and Shrubs)	High sediment removal	May become degraded due to sediment deposition
			Requires frequent maintenance in first few months
			Higher cost than swales
Mulching (with seed)	$0.20 to $0.25/$m^2$	Low cost	Unsuitable for erosion prevention of concentrated flows
		Suitable for slopes with limited slope length	Requires specialised equipment
			May not be able to be used on steep sites due to access restriction for equipment
			Batters of limited length can be mulched if equipment can gain access
			Growing season may not be favourable, watering may be required
Geomat® - type products	$3 to $5/ m^2 (excluding site earthworks)	Inexpensive	Unsuitable for medium to high velocities (in channel applications)
		Can be used in conjunction with grasses in the early stages of stabilisation	
		Ease of installation by semi-skilled labour	
Geocell® - type products	From $10/ m^2 (excluding site earthworks)	Designed to be used in conjunction with landscaping on slopes	Higher cost than Geomats
		Ease of installation by semi-skilled labour	
Rip-Rap type drain lining 300mm thick (Permanent)	$30/ m^2 (excluding site earthworks)	Effective for medium flow velocities	Higher cost than Geomats
		Local materials may be able to be used (should be underlain with a filter fabric	Access for construction may be a problem
		Ease of installation by semi-skilled labour	Higher risk of failure than rock mattresses, etc.
Reno mattresses 300mm thick (Permanent)	$45/ m^2 (excluding site earthworks)	Effective for high flow velocities	High cost
		Local materials may be able to be used (i.e. rocks) (should be underlain with a filter fabric)	Access for construction may be a problem
		Ease of installation be semi-skilled labour	Greater energy dissipation than revetment mattresses
Revetment mattresses, 80mm	$32 to $38/ m^2 (excluding site	Effective for high flow velocities	High cost
			Access for construction may be a problem

thick (Permanent)	earthworks)		Requires specialised equipment and specialised labour
Rock gabions (Permanent)	$150/ m^2 (excluding site earthworks)	Effective retaining wall system	High cost
		Local materials may be used (should be underlain with a filter fabric)	Access for construction may be a problem
		Ease of installation by semi-skilled labour	May require tie backs (i.e. soil reinforcement)

5 REFERENCES and FURTHER READING

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6 APPENDICES

6.1 Appendix A

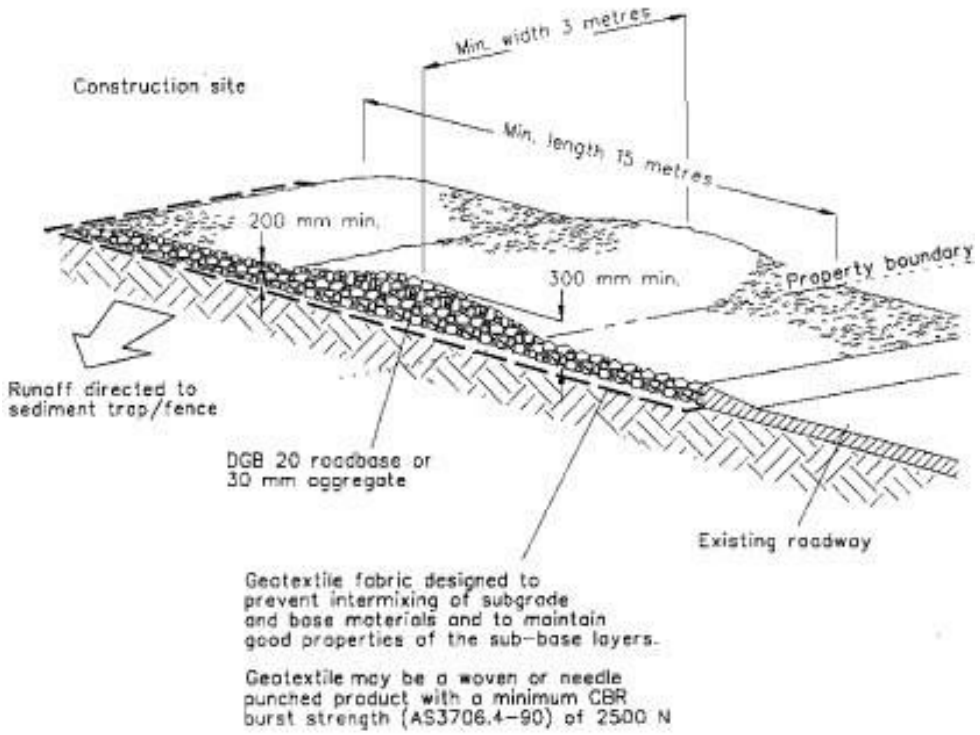
Erosion and Sedimentation Control Checklist

Topic	Section
Site Assessment – erosion risk evaluation • Slope • Soil • Area of disturbance • Extent of remnant vegetation down slope of disturbance • Distance of building site to existing drains/water courses • Land capability, based on available land information	2.2.1
Erosion and Sedimentation Control Plan Map • 1:500 scale or greater showing locality, north point • Property boundaries • Existing contours and direction of fall • Construction site /disturbance area boundary • Access points • Erosion potential ratings • Location, details and dimensions of all permanent and temporary sediment control structures • Location of existing vegetation to be retained and location of vegetation protection fences or belts • Location of vegetation to be removed and method of removal • All existing watercourses and/or drainage structures • Details of the sites catchment area • Temporary and permanent stormwater management measures • Material stockpile areas • Staging of works, including erosion/sedimentation control • Maintenance schedule • Site rehabilitation including vegetation techniques and final contours	2.2.2

Supporting Information A brief description of the overall sediment control strategy for the site including: • Brief description of the existing site conditions such as soils, proposed works, impact on the site and adjacent areas • Description of any areas within the site that have the potential for serious erosion and or sedimentation, together with their proposed management details • The construction sequence over the duration of the works. This may include a chart outlining the sequence of works, including erosion and sedimentation control measures and their maintenance • Brief description of the overall site rehabilitation program • A maintenance strategy for all control measures, including the nomination of responsibility • Estimation of 1:5 year rainfall event • Estimation of peak flows	2.2.3
Construction Details • Design criteria and calculations used to size controls should be shown. • Construction drawings or written specifications should be provided on each type of structural erosion and sedimentation control measure proposed. • Specifications for all rehabilitation and vegetation components of the plan should include volume and rates or materials used (seeding, fertilising and mulch) and methods of application. • The use of local native vegetation should be used to stabilise and revegetate the area. (See Appendix B for Construction Notes)	2.2.4
Implementation	4.4
• Erosion and Sedimentation Control Plan approved by Local Government	
• ESCP communicated with contractors by proponent	
• Maintenance program for both temporary and permanent erosion and sediment control measures by proponent	

6.2 Appendix B

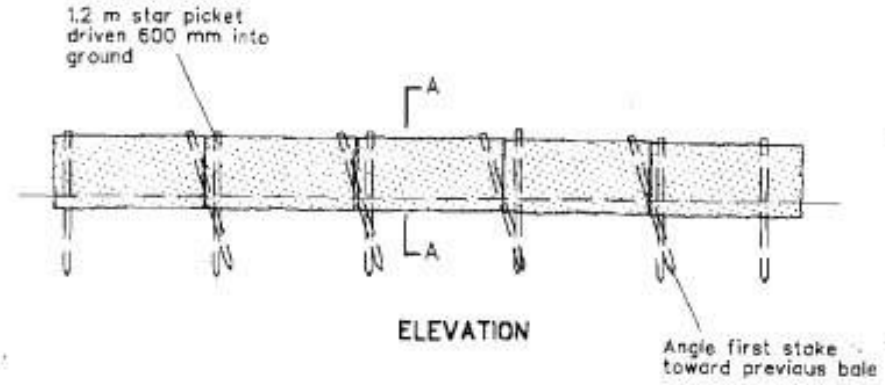
Construction Notes for Erosion and Sediment Control Measures

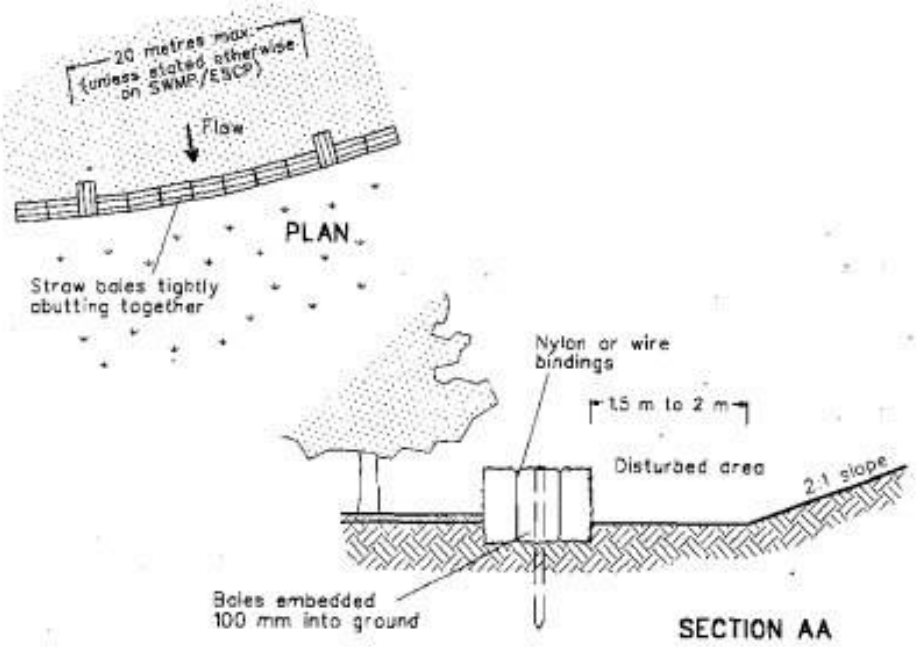


Construction Notes

1. Strip topsoil and level site.
2. Compact subgrade.
3. Cover area with needle-punched geotextile.
4. Construct 200 mm thick pad over geotextile using roadbase or 30 mm aggregate. Minimum length 15 metres or to building alignment. Minimum width 3 metres.
5. Construct hump immediately within boundary to divert water to a sediment fence or other sediment trap.

STABILISED SITE ACCESS SD 5-7

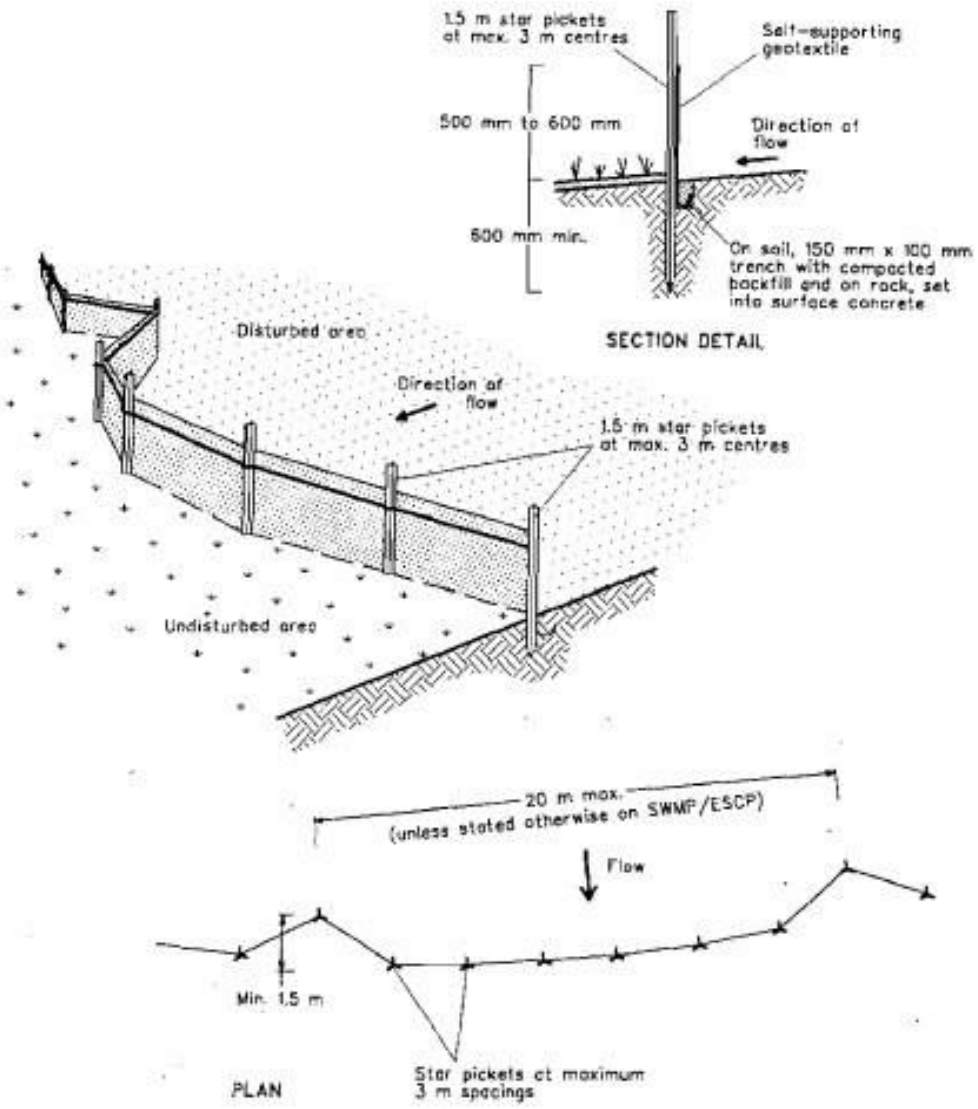




Construction Notes

1. Construct straw bale filter as close as possible to parallel to the contours of the site or at the toe of a slope.
2. Place bales lengthwise in a row with ends tightly abutting. Use straw to fill any gaps between bales. Straws to be placed parallel to ground.
3. Maximum height of filter is one bale.
4. On soft materials, embed each bale in the ground 75 mm to 100 mm and anchor with two 1.2 metre star pickets. Angle the first stake in each bale towards the previously laid bale. Drive stakes 600 mm into the ground and flush with the top of the bales.
5. Where a straw bale filter is constructed downslope from a disturbed batter the bales should be located 1.5 to 2 metres downslope from the toe of the batter.

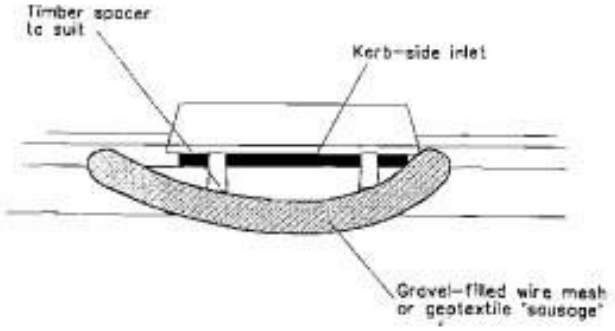
STRAW BALE FILTER SD 6-6

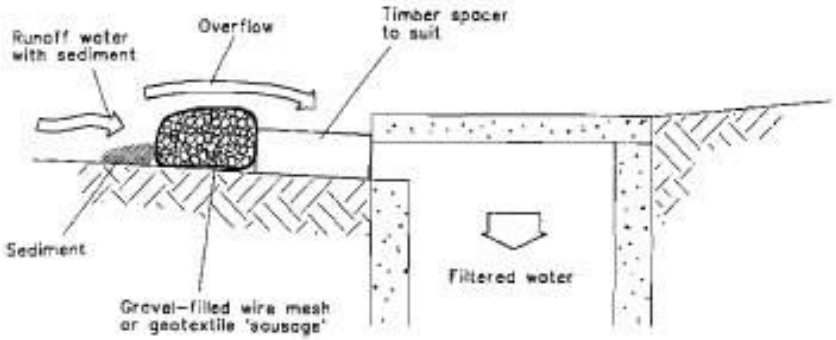


Construction Notes

1. Construct sediment fence as close as possible to parallel to the contours of the site.
2. Drive 1.5 metre long star pickets into ground, 3 metres apart.
3. Dig a 150 mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.
4. Backfill trench over base of fabric.
5. Fix self-supporting geotextile to upslope side of posts with wire ties or as recommended by geotextile manufacturer.
6. Join sections of fabric at a support post with a 150 mm overlap.

SEDIMENT FENCE SD 6-7



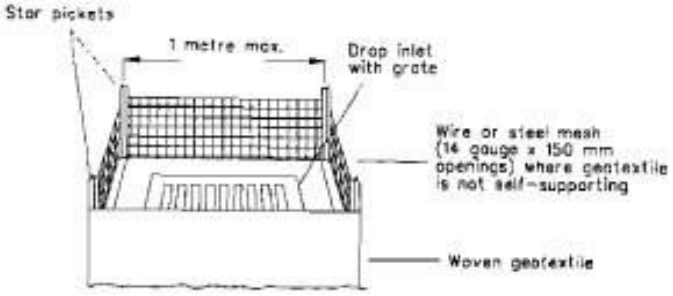


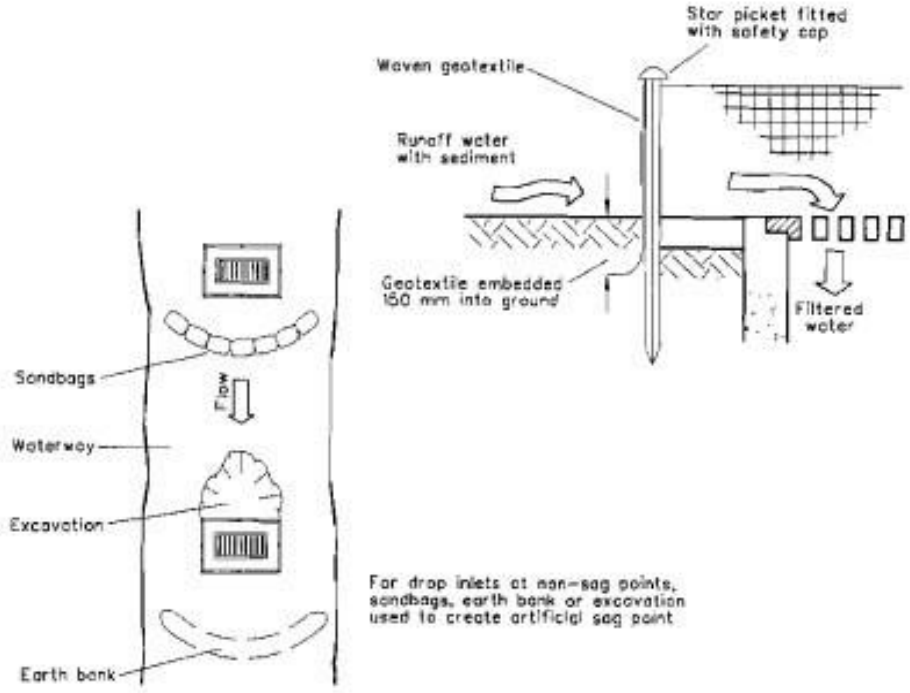
NOTE: This practice only to be used where specified in an approved SWMP/ESCP.

Construction Notes

1. Fabricate a sleeve made from geotextile or wire mesh longer than the length of the inlet pit.
2. Fill the sleeve with 25 mm to 50 mm gravel.
3. Form an elliptical cross-section about 150 mm high x 400 mm wide.
4. Place the filter at the opening of the kerb inlet leaving a 100 mm gap at the top to act as an emergency spillway.
5. Maintain the opening with spacer blocks.
6. Form a seal with the kerbing and prevent sediment bypassing the filter.
7. Fit to all kerb inlets at sag points.

MESH AND GRAVEL INLET FILTER SD 6-8





Construction Notes

1. Fabricate a sediment barrier made from geotextile or straw bales.
2. Support geotextile with mesh tied to posts at 1 metre centres.
3. Do not cover inlet with geotextile.
4. Construction details are similar to Standard Drawing 6-6 and Standard Drawing 6-7.

GEOTEXTILE INLET FILTER SD 6-9