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EROSION AND SEDIMENT CONTROL MANUAL FOR THE DARLING RANGE, PERTH WESTERN AUSTRALIA





UPPER CANNING/SOUTHERN WUNGONG CATCHMENT TEAM

Edited by Brian Lloyd and Ron Van Delft

June 2001

Cover photos

Photo 1	Photo 2		Photo 3
Photo 4		Photo 5	

1. Lack of a stormwater drop structure causes erosion down a steep slope in a Foothills subdivision.
2. Sediment-laden stormwater mixes with clean water in Bickley Brook.
3. A drainage line in the Hills is contaminated by sediment resulting from soil being disturbed right up to the waters edge by earthworks.
4. Sheet erosion from a new subdivision in the Foothills washes directly into stormwater drains.
5. A rock flume outlet on Neerigen Brook, Armadale, not only forms the main feature of a park, but also safely conveys water down from one level to another.

The Darling Range area, directly to the east of Perth, is continuing to experience development as the population of the city expands. This development may be in the form of new subdivisions, single building developments and/or infrastructure provision or maintenance (e.g. roads, telephone, etc.). Such activities require disturbances of the soil. In the Hills and Foothills areas, there is a significant risk of erosion and sedimentation from soil disturbances, each with a variety of inherent problems. The costs are not only to individuals, but also to the community and the environment. It is believed that the majority of sediment loadings in the Canning River (contributing to algal blooms, etc.) may originate in the 'Hills' areas of the catchment.

Perth will continue to grow, as will the number of developments. It is essential to ensure that activities to prevent, or at least minimise erosion and sedimentation become standard practice in all sectors involved in such development. Preventing the problem in the first instance is far more efficient and cost-effective than attempting to fix problems later.

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Steering Committee for this Manual

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Brian Lloyd - Development Officer with Agriculture Western Australia, based at the Midland District Office.

Ron Van Delft - Environmental Officer with the City of Armadale and also a member of the UCSW Catchment Team.

The Manual was based on a report prepared by:

Soil & Rock Engineering Pty Ltd
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Word processing and layout courtesy of Document Support Centre, Agriculture Western Australia, South Perth.

All photos in this Manual were taken by Brian Lloyd.

Diagrams in Appendix E are reproduced with permission from NSW Department of Housing (1998). *Managing Urban Stormwater: Soils and Construction*, 3rd edn. NSW Department of Housing, Sydney.

FOREWORD

The Upper Canning/Southern Wungong Catchment Management Plan identifies erosion and sedimentation as a major issue relating to the health of the Canning and Southern/Wungong Rivers. Erosion and siltation has also been identified as a problem in many other waterways throughout the State, and is recognised as a key issue in Western Australia's State of the Environment Report.

Many deep pools become silted up and weeds find the silt an excellent growing medium in the summer during the reduced flow. The sediment also carries nutrients off site, which leads to algal bloom problems downstream in the Canning and Swan Rivers.

This Manual has been prepared by a sub-committee of the Catchment Team with assistance from Agriculture Western Australia, the City of Armadale and a representative from the Urban Development Institute of Australia. It is based on a report prepared for the Catchment Team by Soil and Rock Engineering Pty Ltd.

The Manual gives the opportunity for local governments, developers and builders to recognise erosion issues in proposing developments throughout the Darling Range and to build in appropriate measures to tackle them. Local governments are encouraged to use the draft Planning Policy at the rear of this Manual to link into their Town Planning Schemes.

The draft Manual was circulated widely to key stakeholders for their input and information. The stakeholders consulted, their comments and the Team's response to those comments appear as Appendix A to this document.

It has taken a great deal of commitment by those involved and special mention must be made of Ron Van Delft (City of Armadale) and Brian Lloyd (Agriculture WA, Midland) for their strong drive in seeing this Manual through to completion. Peter Bowyer (representing the Urban Development Institute of Australia) also shared his depth of experience in trying to ensure erosion at development sites is minimised.

To those of us in the Armadale and Gosnells communities who are helping care for our precious waterways it is a successful outcome for something we have been wanting for a long time.

Pat Hart
ACTING CHAIR
UPPER CANNING/SOUTHERN WUNGONG CATCHMENT TEAM

8 June 2001

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1. INTRODUCTION

1.1 About the Manual

This Manual provides guidelines to assist in the minimisation of land degradation and water pollution due to land development. The focus is on the minimisation of erosion resulting from runoff and the prevention of sediment movement off site during land development. It is hoped that the Manual will be an invaluable resource for local government staff, contractors and other stakeholders to assess erosion risk and apply suitable control measures. Diagrams of structures in this Manual can, for example, be photocopied and given to field staff to ensure their correct construction.

The focus of this Manual's recommendations is on temporary measures rather than permanent works required as part of a wider stormwater management strategy. However, after establishment, many developments still impact on sloping environments due to runoff from shedding surfaces, etc. Such situations should also be identified at the planning stage and permanent erosion and sediment control (ESC) devices (e.g. rock mattresses, concrete flumes) need to be budgeted for and installed. This is **in addition** to temporary ESC devices to minimise risks of erosion and sedimentation associated with disturbances during the construction phases. Erosion risks may also be greatly minimised by planning the timing of soil disturbances to avoid, for example, the period of heavy winter rains, and having revegetation works completed in time to take advantage of the opening autumn rains.

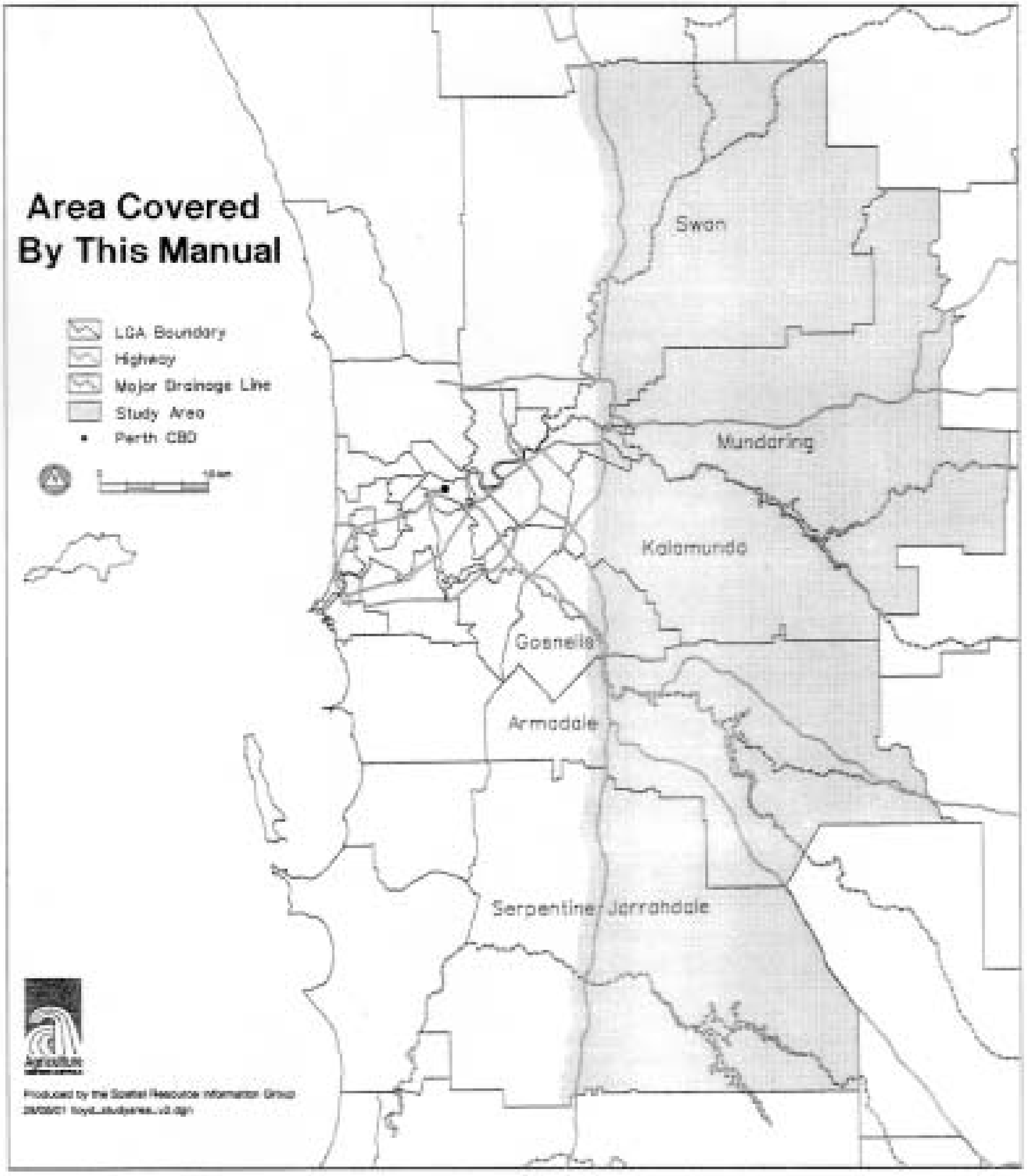
The control measures presented are considered to be cost-effective best management practices at the time of writing of this Manual. The recommendations in this Manual are not intended to preclude the use of judgement based on an assessment of risk and consequence or the use of innovative techniques or appropriate technologies. Calculations used to formulate specifications in various tables in this Manual are shown in Appendix B.

The study area for which this Manual was written comprises the Perth Metropolitan Darling Range region east of the coastal plain and west of the State Forest reserves. It stretches from the northern boundary of the City of Swan south to the southern boundary of the Shire of Serpentine-Jarrahdale (refer map). Caution should be used if the Manual is utilised to assess erosion risk and control measures outside the study area. Although also relevant in the study area, erosion due to wind and erosion due to agricultural land practices (i.e. over-stocking) are not the focus of this Manual.

1.2 Government regulation

The Soil and Land Conservation Act (1945) is the principal Western Australian Act relating to the control of soil erosion. It should be noted that 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.

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


Area Covered
By This Manual
LGA Boundary
Highway
Major Drainage Line
Study Area
Perth CBD
Swan
Mundaring
Kalamunda
Gosnells
Armadale
Serpentine Jarrahdale
Produced by the Spatial Resource Information Group

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

- Environmental Protection (Swan and Canning Rivers) Policy (1999) - requires that 'drainage systems should be designed, constructed and operated in accordance with best management practices' and 'in order to prevent and mitigate land degradation' such as erosion.
- Local Government Act (1995) - local law provisions.
- Swan River Trust Act (1988) - waters, parks and recreation areas covered by this Act.
- Environmental Protection Act (1986) - land development proposals that are likely to have a significant effect on the environment.
- WA Planning Commission Act (1994) - subdivision approvals.
- Town Planning Development Act (1928) - planning approvals.
- Waterways Conservation Act (1976).
- Wildlife Conservation Act (1976).

1.3 Impacts of erosion

Soil erosion and sedimentation is a major cause of land and watercourse degradation and is also a non-point source of pollution. Soil erosion leads to a decrease in water quality of the receiving waters due to increases in turbidity and bedload, the transport of nutrients with eroded soil particles and siltation of river pools.

The rate of soil formation varies according to several factors, such as parent material and climate. These factors influence the rate of weathering, biological activity, and the impact of water and wind. However, the process of soil formation is invariably slow, and in Western Australia, soil formation in the order of one millimetre per 100 years would be a broad order of magnitude (Schoknecht, N. 2001, pers. comm., 1 May). Consequently, when soil erosion occurs, it is not replaced in any timeframe relevant to today's developments.

It is more efficient and more cost-effective to minimise erosion in the first place, rather than to attempt clean up measures, most of which are expensive and not practical without other significant adverse environmental impacts. Inadequate management of erosion effectively transfers some of costs of the development to the community at large, either as direct dollar costs or more intangible costs to the environment. As illustrated in this Manual, erosion prevention costs relatively little.

The main consequences of soil erosion and sedimentation are:

- Increase in turbidity of receiving waters leading to:
    - decrease light penetration in water, affecting aquatic flora and fauna;
    - deceasing aesthetic appeal of the water body.
- Siltation upslope of watercourses leading to:
    - degradation of local ecosystems (i.e. smothering of lower storey vegetation).

- Siltation of watercourses leading to:
  - impeding of flow;
  - increased frequency of and damage caused by flooding;
  - siltation of river pools that would otherwise function as drought refuges for aquatic fauna and waterbirds.
- Degradation of local ecosystems (i.e. weed invasion, fish habitats, smothering of benthic environments).
- Increases in nutrient load, leading to algal growth and hence:
  - decrease light penetration in water, effecting aquatic flora and fauna;
  - reduced suitability for recreation, etc. due to toxic algae.
- Increased cost of maintenance of stormwater systems due to:
  - removal of sediment from drainage structures;
  - repair of erosion damage due to increased flooding downstream.
- Infrastructure damage such as undermined roads, destroyed fences, etc.
- Increased 'lost time' for contractors/developers following rainfall events causing erosion and sedimentation and thus repair and delays.
- Reduced value of land in terms of reduced ability to use the land, accessibility, land capability and aesthetic value (Photo 1).
- Safety aspects to the community, e.g. flooded or undermined roads, etc.

Erosion and sedimentation risk is greatest during the construction/development stage. Studies of Lake Illawarra in NSW indicate that sediment pollution levels associated with new urban developments can be 5 to 20 times greater than those from developed urban areas (NSW Dept. of Housing 1998, Section 6.3).

Further information on the impacts from suspended solids that result from erosion can be found in Section 2.4.2 of the Water and Rivers Commission *A Manual for Managing Urban Stormwater Quality in Western Australia* (Water and Rivers Commission 1998). The Water and Rivers Commission manual includes a number of best management practices that deal with sediment-laden water once it reaches the stormwater system. However, this Manual for the Darling Range deals with preventing sediment-laden stormwater in the first instance.

1.4 Types and causes of erosion

The risk of erosion and sedimentation is a direct consequence of exposure of soil to rainfall droplets and stormwater runoff. Vegetation and other materials can cover the soil and absorb raindrop energy and retard overland flow. The risk of erosion is directly proportional to the amount of soil exposed to water (and wind). Slope is also a major determining factor of erosion risk. Erosion by water occurs by a process of raindrop detachment of soil particles, transport and flow, and sedimentation. The transport and attachment of the soils occurs at a point when the rainfall no longer soaks into the soil, but runs off.

Water erosion causes two main problems. It not only leaves a gully where soil is washed away from, but there is also sedimentation, where this eroded soil is deposited elsewhere, often causing problems. These problems can be obvious such as a blocked drain, or less

Photo 1: Severe gully erosion on a Hills subdivision, caused by inadequate erosion control.

Photo 2: Sections of U-shaped concrete channel provide a safe delivery of roadside stormwater.

Photo 3: Correctly installed and maintained sediment fencing stops particles leaving a construction site.

obvious such as eutrophication (nutrient enrichment of water bodies). This leads to problems like algal blooms on the Swan and Canning Rivers because of nutrients attached to the eroded soil particles.

The loss of vegetation can occur due to land development, inappropriate use of land or as a consequence of bush fires, etc.

The main forms of erosion by water are:

Sheet erosion	The removal of a relatively uniform layer of soil (generally, the most fertile topsoil layer) from the land surface, without leaving obvious channels.
Rill erosion	Numerous small channels or rills develop where sheet flow becomes concentrated into small streamlets, often on newly disturbed ground. Rill erosion is a consequence of the development of these streamlets and increased flow velocities. It results in very small multiple gullies that cumulatively, are very significant in terms of volumes of soil lost and associated problems.
Gully erosion	Occurs as a consequence of concentrated flows entailing large volumes of water and increased velocities. A gully develops by erosion of exposed and erodible soil down to an erosion resistant material (i.e. caprock). The gully erosion tends to continue to erode in an upslope direction. Gully erosion can also occur in natural drainage lines when they are disturbed.
Channel erosion	Occurs when the channel velocity exceeds the threshold velocity of the materials forming the channel.

A site visit report within the study area, along with laboratory test results of samples are documented in Appendix C.

2. EROSION RISK ASSESSMENT

2.1 Key definitions

Erosion risk assessment	The process of identifying the potential for adverse erosion effects.
Control measure	Procedures designed to minimise the severity of erosion and sedimentation.

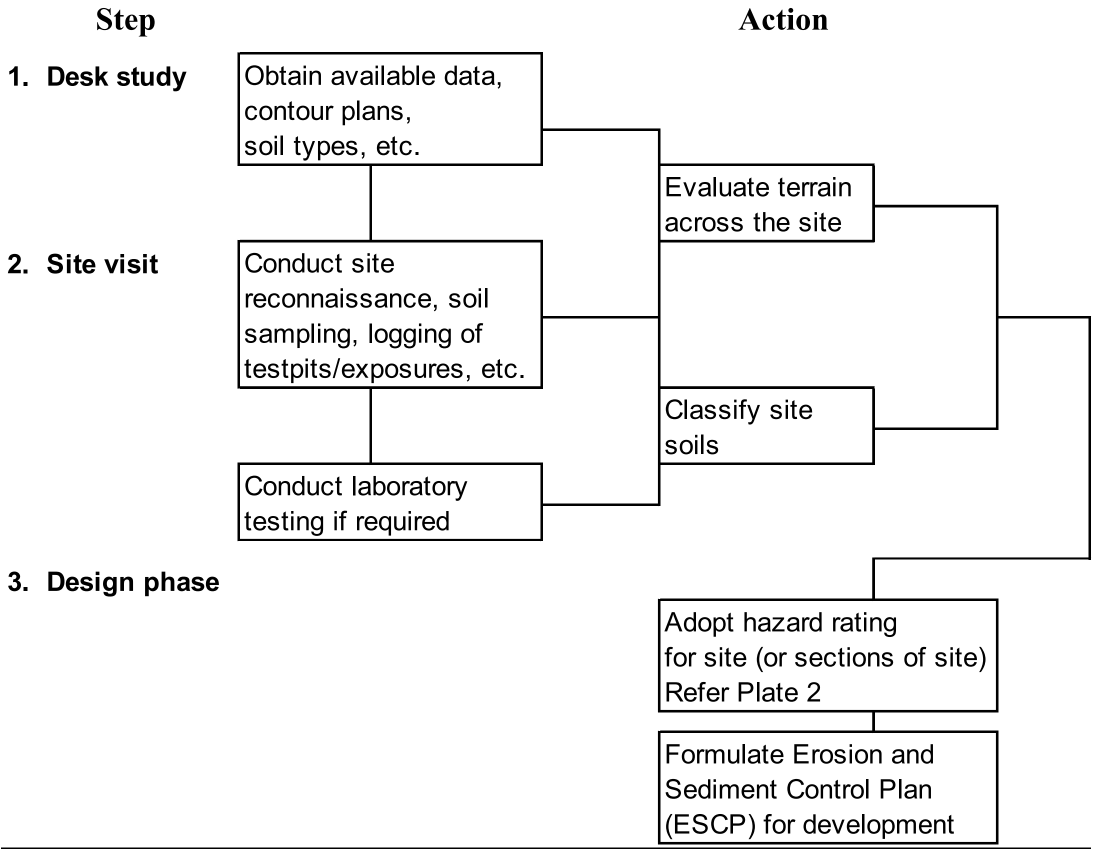
Note: A comprehensive list of definitions can be found in the Glossary at the rear of this Manual.

2.2 General

The site erosion risk assessment process outlined in the section below is a simplified approach, based on the use of tables and the determination of a hazard rating based on the estimation of a soil loss class. The soil erodibility potential of the soils likely to be exposed at the site is assessed using Table 1 in accordance with AS 1726-1993 (Standards Australia 1993). This characterisation of the soils can be done on a visual basis or by submitting samples for laboratory testing.

The soil loss class (hazard rating) is estimated for the site based on an estimate of the general slope across the site and the soil erodibility potential as determined in Table 1. A work sheet that can be copied for field use is provided as Appendix D in this Manual and a flow sheet below will assist users of this Manual in the assessment process.

Risk Assessment Flow Sheet



Alternatively, a more rigorous approach as presented in Appendix A of *Managing Urban Stormwater: Soils and Construction* (NSW Department of Housing 1998) can be adopted.

2.3 Soil characterisation

The potential erodibility of a soil type (as distinct from its situation, e.g. slope) is related to its structure and dispersivity (stability of aggregates/peds). Soils having a high proportion of silt and fine sand generally have a greater potential for erosion than soils with a lower proportion of silt and fine sand. In addition, dispersive clay soils have a greater potential for erosion than non-dispersive soils. Soil erodibility is also related to runoff potential, which is related to surface roughness and surface storage.

Table 1 presents a comparison between soil erodibility potential, soil description as classified in accordance with AS 1726-1993 (Standards Australia 1993) and Emerson Class Number.

Table 1. Soil erodibility potential

Soil erodibility potential	Soil description	Group symbol	Emerson class no.
Low	Sandy gravels	GP	> 2
Moderate	Non-dispersive and slightly dispersive clays and clayey sands, clayey gravels, silty gravels, sands	CH, CL, CI, SC, GC, GM, SP	> 2
High	Silts silty sands, fine sands, dispersive clays and clayey sands, water repellent sands	ML, SM, CH, CL, CI, SC	1, 2

Please note that the above table is a general guide. Soils within the above groupings will vary in erodibility due to differences in fine sand and silt content, aggregate dispersivity and the gradient of the slope.

2.4 Terrain evaluation

In addition to the soils at the site, assessment of the site for the development should take into account the following items (as a minimum):

- Potential area of disturbance at the site.
- Length of time of disturbance.
- Catchment area upslope of the site and upslope catchment characteristics (for assessment of runoff potential).
- Past land use (influence on runoff potential).
- The slope length and gradient of the site (remembering that slope gradients may be changed by works at the site).
- Other features such as the natural drainage lines, existing soil erosion, etc.

Slope measurement can be obtained by using a clinometer, a level or from skilled interpretation of detailed site contour plans.

2.5 Erosion risk assessment

Assessment of erosion risk of a site can be performed by classifying the site in terms of a Soil Loss Class. Soil loss can be estimated using the Revised Universal Soil Loss Equation - RUSLE (described in NSW Dept. of Housing 1998, Appendices A1 & A2). This method considers soil erodibility, terrain, rainfall erosivity and cover (vegetation or stabilisation).

Soil Loss Classes as defined in accordance with Institute of Engineers, Australia, Queensland Division (1996), are as follows:

- Class 1 < 300 t/ha/annum, with no control measures (< 25 mm nominal depth per annum).
- Class 2 > 300 t/ha/annum and < 900 t/ha/annum, with no control measures (between 25 mm and 70 mm nominal depth per annum).
- Class 3 > 900 t/ha/annum, with no control measures (> 70 mm nominal depth per annum) (not expected in the Study Area).

Note that approximately 1.3 tonne of soil is equivalent to one cubic metre.

Table 2 provides the estimated Soil Loss Class for a site within the study area for varying slope gradients and soil erodibility potential.

Table 2. Erosion risk assessment by Soil Loss Class

Soil erodibility potential (as defined in Table 1)	Site slope 5%-10%	Site slope 10%-20%	Site slope > 20%
Low	1	1	1
Moderate	1	1	2
High	1	2	2

Assumptions: (i) *A maximum slope length at the site of 80 m.*
(ii) *An estimated Average Rainfall Erosivity Factor (R) for the study area of 1225.*

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

(i) Soil loss is normally greater during winter than summer. However intense rainfall events 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.

(ii) 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.

(iii) Erosion control measures are still important for sites which have a Soil Loss Class 1.

(iv) Construction staging and progressive rehabilitation of disturbed areas is especially important for Soil Loss Class 2 sites. Table 3 summarises development approaches for both Soil Loss Class 1 and 2 sites. Rehabilitation should be finished within 14 days after completion of the construction phase.

(v) The extent of the disturbance will influence the risk and consequences of erosion at a site.

Table 3. Development approaches

Development approaches	**Soil Loss Class**	
	1	**2**
	Action	**Action**
Planning of control measures as part of an Erosion and Sediment Control Plan (ESCP)	Recommended	Required
Implement control measures in Section 3 where appropriate	Required	Required
Staged Construction and Progressive rehabilitation	Consider	Required
Divert runoff around the site	Consider	Required

3. CONTROL MEASURES

The following general principles relate to the planning and implementation of an Erosion and Sediment Control Plan (ESCP) 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 site needs.
- Minimise the area that is disturbed in the development (better to minimise erosion in the first place rather than attempting to minimise damage by installing sediment control measures).
- Minimise the time the disturbed areas are exposed without stabilisation or cover.
- Conserve and safely stockpile topsoil (e.g. away from 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.
- Institute a maintenance program for both the temporary and permanent erosion and sediment control measures that have been adopted.

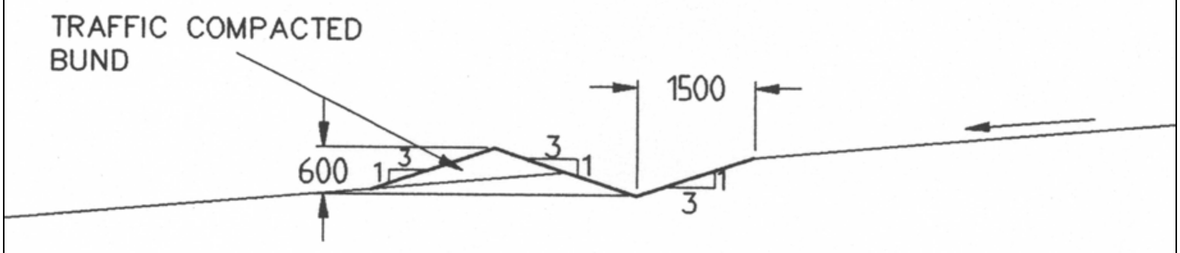
Design drawings should indicate the area of site disturbance for the land development. Any areas where vegetation is to be retained (i.e. vegetation strips) should be clearly identified on maps, on the ground and to the workers, so it is not accidentally disturbed.

3.1 Diversion drains

Diversion drains should be provided in order to divert runoff from upslope areas around the site of disturbance. Such measures are particularly important for Soil Loss Class 2 sites. Diversion drains are also required in areas upslope of cuts in order 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.

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 as estimated using the Rational Method (Institute of Engineers, Australia 1987) Typical construction details are presented in Figure 1.



NOTES:

1. DRAIN TYPICALLY FORMED USING GRADER (MOST PRACTICAL METHOD).
2. ROCK PROTECTION OR SIMILAR TO BE PROVIDED WHERE AVERAGE DRAIN VELOCITIES ARE >0.7m/s (GRADE, >0.5%). REFER TO TABLE IN APPENDIX B. NOTE DRAIN AVERAGE VELOCITY DEPENDENT ON GRADE OF DRAIN.
3. MAXIMUM CATCHMENT AREA UPSLOPE OF DRAIN EG, 3.7ha, JARRAH FOREST (NO CLEARING), OR 0.7ha, 100% CLEARED PASTURE.

TYPICAL SECTION – DIVERSION DRAIN
NOT TO SCALE

Figure 1. Diversion drain construction details.

3.2 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. An example of a permanent drop structure for roadside stormwater is shown in Photo 2.

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). Typical construction details are presented in Figure 2. A flow sheet detailing steps for the design of drop structures is provided in Appendix E.

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.

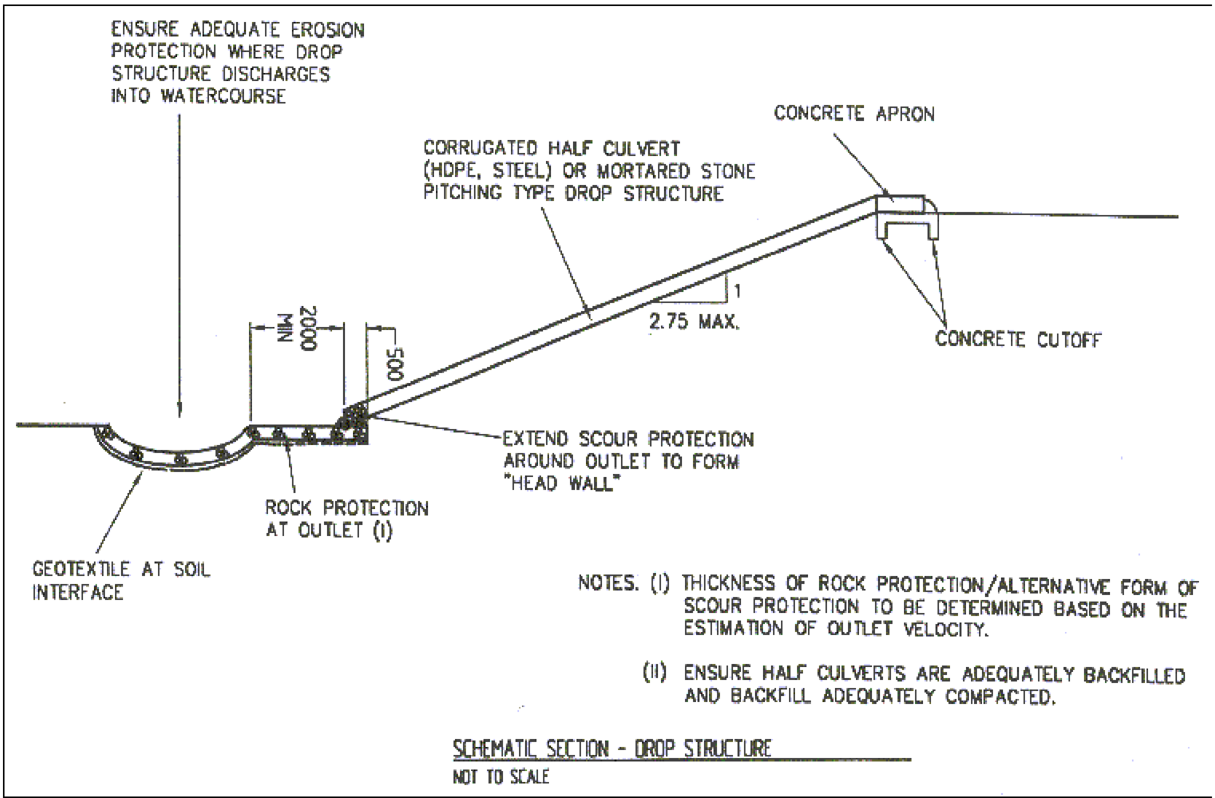


Figure 2. Drop structure construction details.

3.3 Stabilised site access

It should be noted that removal of material from site on the tyres of vehicles can lead to sediment entering drainage systems and hence it is necessary to provide measures to prevent such an occurrence. In order to minimise erosion the following recommendations are made regarding site access:

- Access to building sites (i.e. single lots) should be restricted to one location.
- Construct a stabilised site access at the entrance to the building site (refer to Appendix E for construction details).
- 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 were appropriate. Where access is via temporary roads, such roads would require the sheeting to be removed and the area rehabilitated (refer to Section 3.5).
- Contractors/developers to ensure all employees and sub-contractors are aware of the above requirements.

3.4 Sediment traps

Sediment traps 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 0.2 mm). Recommended temporary sediment control measures include:

- weed-free hay bales;
- sediment fences (Photo 3);
- inlet filters at drainage structure inlets (Photos 4, 5 and 6).

Construction details for the above control measures are provided in Appendix E. The maximum spacing between sediment traps (weed-free hay bales, earth banks and sediment fences) should be approximately at a slope length of 80 m. The maximum recommended slope length (i.e. spacing between sediment traps) should be varied for the slope grade (refer to Table 4).

Table 4. Recommended sediment trap spacing

Site slope	Recommended spacing (m)
< 5%	80 m
> 5% < 10%	60 m
> 10% < 20%	40 m
> 20%	30 m

In order to assess construction staging and progressive rehabilitation requirements, etc. Table 5 provides estimates of the design life of temporary sediment traps for varying site slopes and Soil Loss Classes.

Table 5. Sediment trap estimated minimum design life

Soil loss class	Site slope 5%-10%	Site slope 10%-20%	Site slope > 20%
1	6 months	1.6 months	1.2 months
2	Not applicable	1.1 months	0.5 months

Assumptions: (i) Slope length between structures at the site of 80 m, sediment trap height 0.5 m nominal.
(ii) An estimated average Rainfall Erosivity Factor (R) for the study area of 1225.

Table 5 emphasises the point that construction staging and progressive rehabilitation of disturbed areas is especially important for Soil Loss Class 2 sites.

Permanent detention basins can be constructed in the early stages of a project to assist as temporary sediment control measures. These will need cleaning at the end of the post-construction phase.

Retention of vegetation strips adjacent to roads and watercourses is important in order to reduce the area of disturbance and minimise the potential for sediment entering drainage systems and watercourses. The Environmental Protection Authority (EPA) provides

Photo 4: A Filter Fabric Drop Inlet Sediment Trap is both cost effective and efficient in keeping sediment out of stormwater systems.

Photo 5: A Filter Fabric 'sausage' is very effective in settling coarse particles from stormwater.

Photo 6: A Stone Mattress Sediment Trap stops sediment entering a stormwater drain. These traps are more durable during construction phases.

guidelines on the width of vegetation buffers (strips) adjacent to watercourses on private land and these recommendations are summarised below:

- Watercourses with permanent water 50 metres
- Seasonally flowing watercourses 30 metres
- Watercourses which flow in response to specific rain events 10 metres

The EPA document, 'Guidelines for Environment and Planning' (1997), discusses further environmental issues regarding vegetation buffers adjacent to watercourses.

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 a sediment control measure is not considered feasible given the Mediterranean-type climate in the study area.

3.5 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 the stripping of topsoil, vegetation should be removed and stockpiled for shredding to form mulch for later use, if appropriate. Because the topsoil is required later in the revegetation stages, subsoil must **not** be mixed with topsoil in 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 2 m 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 will occur.

In order to allow rehabilitation of cut and fill batters, batter slopes should be a maximum of 18^{o} 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 2 m) using a dozer.
- Seed, fertilise and mulch the disturbed batter areas as required.
- The use of Geocell®, 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 in order 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 non-competent materials (i.e. prone to erosion), to break the slope and to allow planting on benches (Photo 7);
- stone pitching;
- retaining wall systems (including rock gabions - Photo 8).

If possible, timing of the whole project should also be such that the rehabilitation phase is completed by mid-April, prior to the commencement of the growing season opening rains (approximately early to mid-May in Darling Ranges east of Perth). This not only ensures an early establishment of rehabilitation plants, but also minimises the time that disturbed or reshaped slopes are exposed without growing vegetation.

3.6 Comparison of control measures

Table 6 compares the advantages and disadvantages of various control measures and their approximate cost. 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 be dependent on the volumes ordered.

Table 6. Comparison of control measures

Control measure	Approx. unit cost	Advantages	Disadvantages
Weed free hay bales	\$4 to \$8/m	- Inexpensive. - Ease of installation by semi-skilled labour.	- Requires removal at completion of work. - Requires periodic clean out and disposal of sediment.
Sediment fence	\$10/m	- Inexpensive. - Ease of installation by semi-skilled labour.	- Requires removal at completion of work. - Requires periodic clean out and disposal of sediment.
Level bank (Sediment Trap - Level)	\$5 to \$10/m	- Low cost. - Local materials may be able to be used.	- Requires removal at completion of work. - 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.

Control measure	Approx. unit cost	Advantages	Disadvantages
Mulching (with seed)	\$0.20 to \$0.25/m^2	- Low cost. - Suitable for slopes with limited slope length.	- Unsuitable for erosion prevention of concentrated flows. - Requires specialised equipment. - May not be able to be used on steep sites due to access restrictions 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. - Can be used in conjunction with grasses in the early stages of stabilisation. - Ease of installation by semi-skilled labour.	- Unsuitable for medium to high velocities (in channel applications).
Geocell®-type products	From \$10/m^2 (excluding landscaping and site earthworks)	- Designed to be used in conjunction with landscaping on slopes. - Ease of installation by semi-skilled labour.	- Higher cost than Geomats.
Rip-Rap type drain lining 300 mm thick (Permanent)	\$30/m^2 (excluding site earthworks)	- Effective for medium flow velocities. - Local materials may be able to be used (should be underlain with a filter fabric). - Ease of installation by semi-skilled labour.	- Higher cost than Geomats. - Access for construction may be a problem. - Higher risk of failure than rock mattresses, etc.
Reno Mattresses, 300 mm thick (Permanent)	\$45/m^2 (excluding site earthworks)	- Effective for high flow velocities. - Local materials may be able to be used (i.e. rocks) (should be underlain with a filter fabric). - Ease of installation by semi-skilled labour.	- High cost. - Access for construction may be a problem. - Greater energy dissipation than revetment mattresses.
Revetment mattresses, 80 mm thick (Permanent)	\$32 to \$38/m^2 (excluding site earthworks)	- Effective for high flow velocities.	- High cost. - Access for construction may be a problem. - Requires specialised equipment and specialised labour.
Rock gabions (Permanent)	\$150/m^3 (excluding site earthworks)	- Effective retaining wall system. - Local materials may be able to be used (should be underlain with a filter fabric). - Ease of installation by semi-skilled labour.	- High cost. - Access for construction may be a problem. - May require tie backs (i.e. soil reinforcement).

Photo 7: A benched embankment roadside cutting to minimise erosion.

Photo 8: Rock gabions stabilise a slope adjacent to a road.

Photo 9: Sediment fencing stopping soil movement off a construction site.

4. STORMWATER QUALITY MANAGEMENT

The Water and Rivers Commission (1998) document describes Best Management Practices (BMPs) to reduce nutrient inputs to stormwater drainage and provides guidelines for the incorporation of water sensitive design principles in urban planning and design. This document should be consulted for the design of sediment control measures prior to discharge of stormwater into watercourses (e.g. sediment basins, constructed wetlands).

It should be remembered that sediment basins are typically designed to retain coarse sediment (particle size > 0.2 mm) and hence basins in catchments with clayey soils will have a low sediment entrapment efficiency. In such catchments, a form of constructed wetland should be considered. However, it is important to note that these measures deal with the sediment problem after it has occurred and **preventing it occurring is far more cost-effective and efficient.**

5. IMPLEMENTATION OF CONTROLS

5.1 Vegetation removal

Minimum site disturbance for the shortest possible time is a key principle of erosion and sediment control. Prior to the commencement of large scale vegetation removal, the control measures summarised in Section 3 should be considered and put in place. Vegetation should not be removed from sites just for 'aesthetics' or 'saleability'. For subdivision development the construction of sediment basins and constructed wetlands should be undertaken in the preliminary stage of the development. When construction delays lead to exposure of the site for an extended period of time (refer to Table 5 for nominal sediment trap design lives) stabilisation using techniques such as the use of mulches will need to be considered.

5.2 Subdivision development

The recommended approach to subdivision development, Pre-construction, Construction and Post-construction activities is summarised below.

Pre-construction

- Designers to formulate ESCP.
- Include permanent erosion control measures in design, including measures to reduce runoff and increase infiltration. Measures could include lined drains, drop structures, diversion drains, etc.
- Include permanent and temporary sediment control measures in design, remembering that different measures have different pollutant removal efficiencies. Measures could include sediment fences, grass swales, filter strips, infiltration basins and trenches, sand filters, detention basins, constructed wetlands, sediment traps/basins, etc. (refer to Water and Rivers Commission 1998).
- Include a requirement for the allowance of temporary and permanent erosion and sediment control measures by the construction contractor in the contract documents.
- Contractor to formulate an ESCP, including maintenance and program the ESC works into the overall development timetable.

Construction

- Contractor to implement ESCP.
- Induct all workers and sub-contractors in ESCP.
- Haul roads and access tracks are to be located to minimise erosion (refer Section 3.3).
- Locate an 'Equipment Lay Down' area in order to minimise erosion and sedimentation.
- Implement control measures to minimise pollution from spills (e.g. oil), etc.
- Undertake drainage works prior to topsoil stripping operations (refer Section 5.1).
- Ensure adequate supervision of construction activities to ensure compliance with ESCP.
- Ensure regular maintenance of control measures undertaken (refer Section 5.7).
- Review adequacy of ESCP.
- Clean up site and remove all rubbish, etc.

Post-construction

- Maintain permanent control measures (clean out sediment traps, etc.).
- Ensure vegetative stabilisation continues to perform (institute irrigation or tanker watering, if required).
- Consider leaving key sediment fences on site until vegetation cover is established.

The following are considered examples of inadequate or 'poor' land development practices:

- Excavation of cut to fill building pads at the subdivision stage (well before construction of houses) **unless** temporary (and permanent where necessary) ESC devices in relation to the cut and fill are addressed in the Erosion and Sediment Control Plan.
- Site accessways across drains without the provision of culverts (the fill at any culverts should be scour-resistant gravels, adequately compacted).

Figures 4 and 5 provide typical plans, showing the use of various control measures applicable to the subdivision development.

5.3 Building sites

Building sites typically have limited space and therefore control measures are more difficult to implement. The recommended approach to residential development, Pre-construction, Construction and Post-construction is summarised below.

Pre-construction

- Include permanent erosion and sediment control measures in site design, including measures to increase infiltration of runoff at the source (i.e. drainage from roofs and carpark areas). Measures could include porous and modular pavement, sediment fencing, grass swales, infiltration trenches, sand filters (refer Waters and Rivers Commission 1998).

Construction

- Direct clean water around the site.
- Manage materials, as appropriate.
  - Limit the amount of materials on site at any time, and store within the building envelope (if applicable).
  - Cover material stockpiles prior to rain and locate away from drains.
  - Erect sediment fences around material stockpiles.
- Erect sediment fencing at downslope boundary (Photo 9).
- Protect downstream drainage pit entry from sediment (refer Section 3.4).
- Limit entry and exit to one point and stabilise it. Do not use earth against kerbs for access - use solid materials instead (e.g. wood) or install a concrete drop access in the kerb (if necessary) where the driveway will eventually be. Ensure adequate site access for fill delivered to site (refer Section 3.3).
- Reschedule material deliveries in wet weather, as appropriate.
- Provide bins for concrete slurry, paints, etc.

- Ensure adequate supervision of construction activities.
- Instigate maintenance of control measures undertaken (refer Section 5.7).
- Compact all trench lines when back filling (refer Section 5.6).

Post-construction

- Ensure stabilisation and revegetation continues to perform (institute irrigation, if required).
- Consider leaving key sediment fences on site until vegetation cover is established.

Figure 3 provides a typical plan of a residential land development showing the use of various control measures documented in Section 3.

The following are considered examples of inadequate or ‘poor’ land development practices:

- Use of concrete raft slab construction on Soil Loss Class 2 sites (consider pier and beam type construction in order to minimise earthworks).
- Earth ramps over kerbs at site entrances.
- Site accessways across drains without the provision of culverts (the fill at any culverts should be scour resistant gravels, adequately compacted).
- Soil being tracked onto roads, etc. due to multiple site accesses, inappropriate base material for access tracks, etc.

5.4 Road construction and maintenance

The following principles relate specifically to the planning and implementation of an Erosion and Sediment Control Plan for a road construction project.

- Clearing should be limited to the width required to accommodate the earthworks, drainage and miscellaneous areas such as topsoil stockpiles, service corridors, etc.
- Road works should be programmed such that only chainages where earthworks are currently proceeding are cleared (i.e. minimum disturbance).
- Designed drainage measures (e.g. culverts and diversion drains) should be installed before general clearing (if that is impractical, before topsoil stripping).
- Topsoil stockpiles should be located in order to minimise clearing, as well as the risk of erosion, especially into drainage lines.
- Erosion of the topsoil stockpiles should not occur. Sediment traps below (refer Section 3.4) and diversion drains above should be adopted.
- Earthworks batters should be rehabilitated progressively.
- If possible, timing of the project should aim to coincide the completion of rehabilitation works with the break of the season (i.e. early to mid-May).

It is important to note that route selection will affect the erosion risk of a project. At the planning stage of a project various road routes are typically examined. Erosion and sedimentation issues should be considered at this stage of a project and may form part of a geotechnical investigation of the route(s).

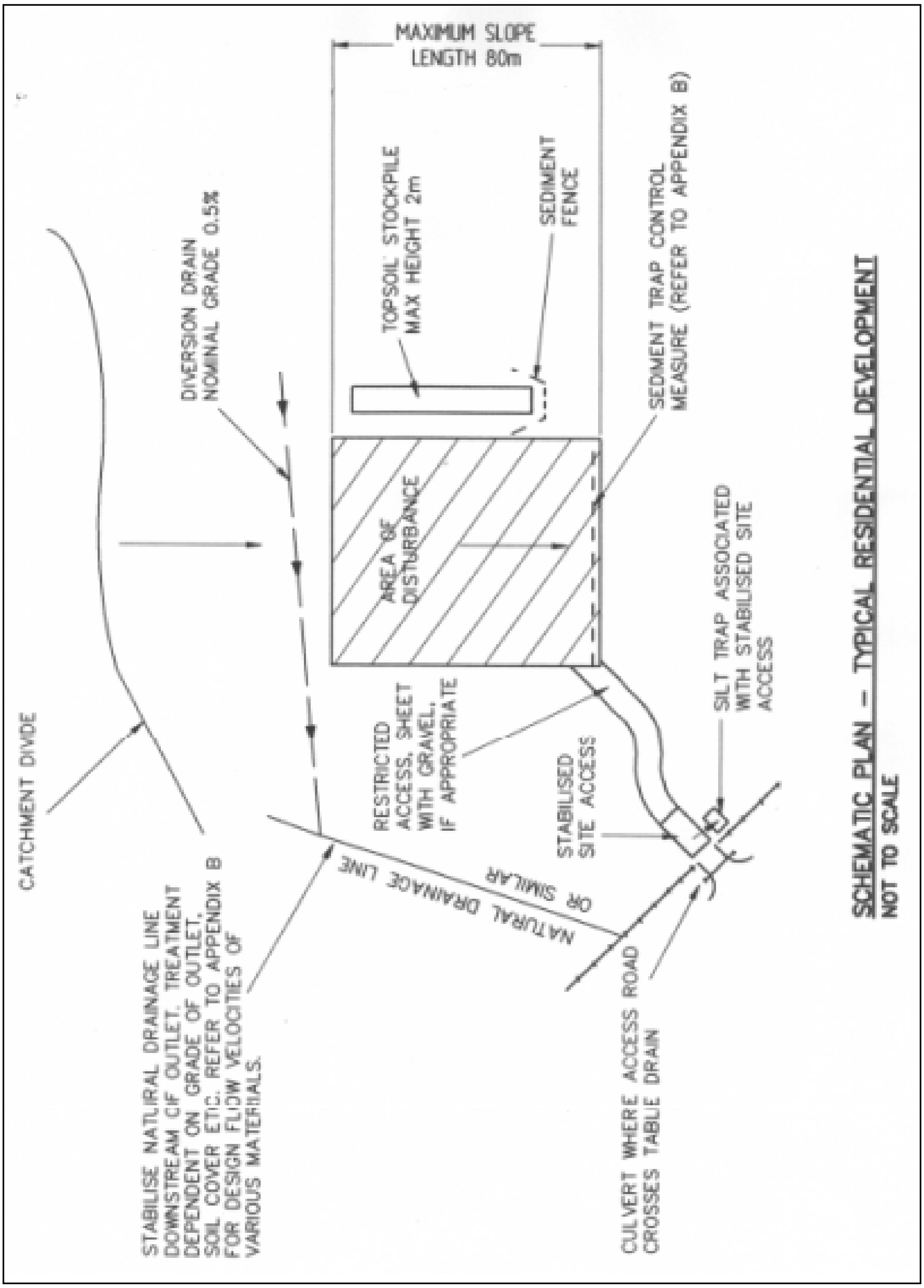


Figure 3. Sample of control measures used on a typical residential development site.

Figures 4 and 5 provide typical plans of a rural road showing the use of various control measures documented in Section 3.

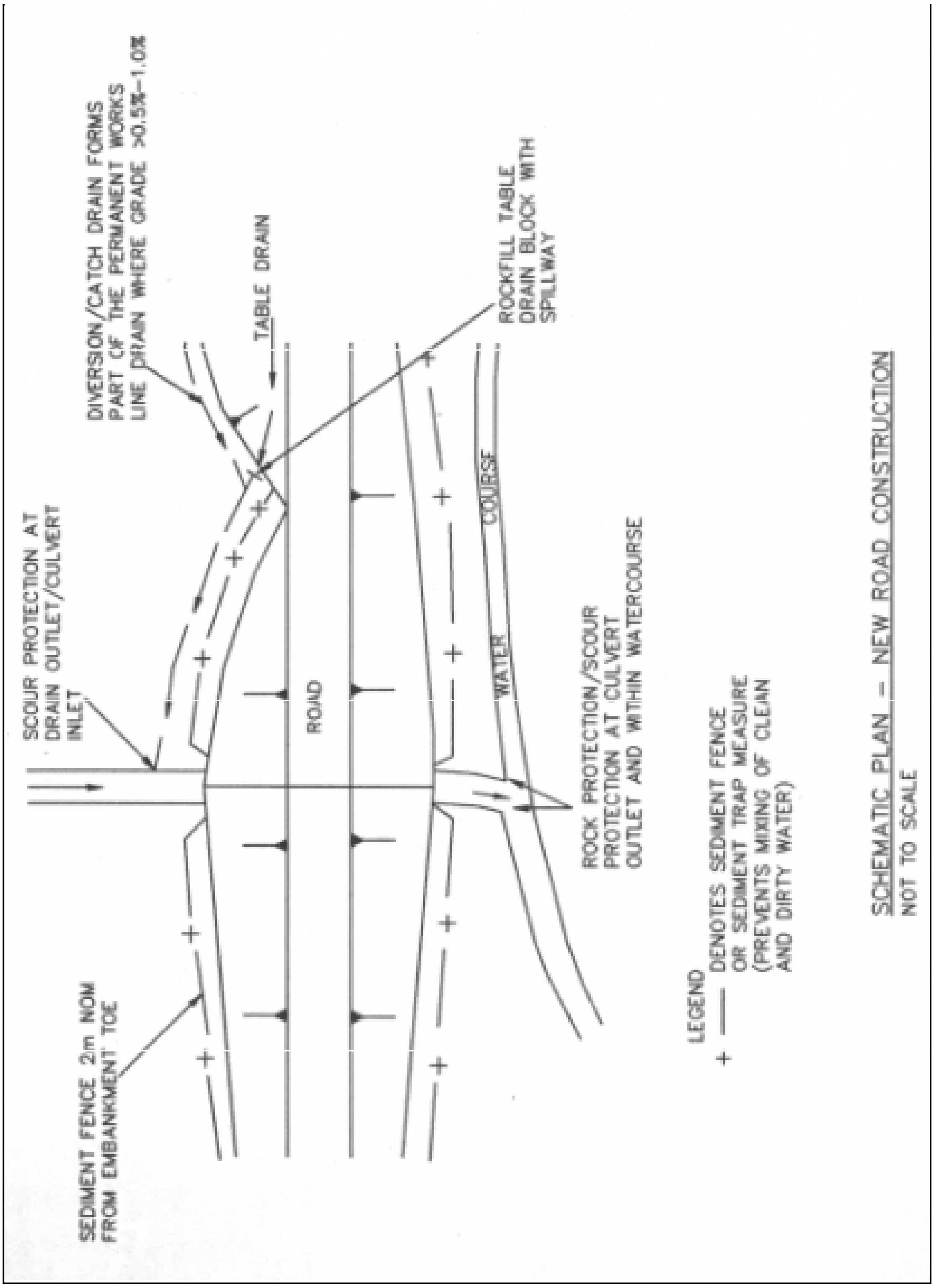


Figure 4. Sample of control measures used on a new road construction site.

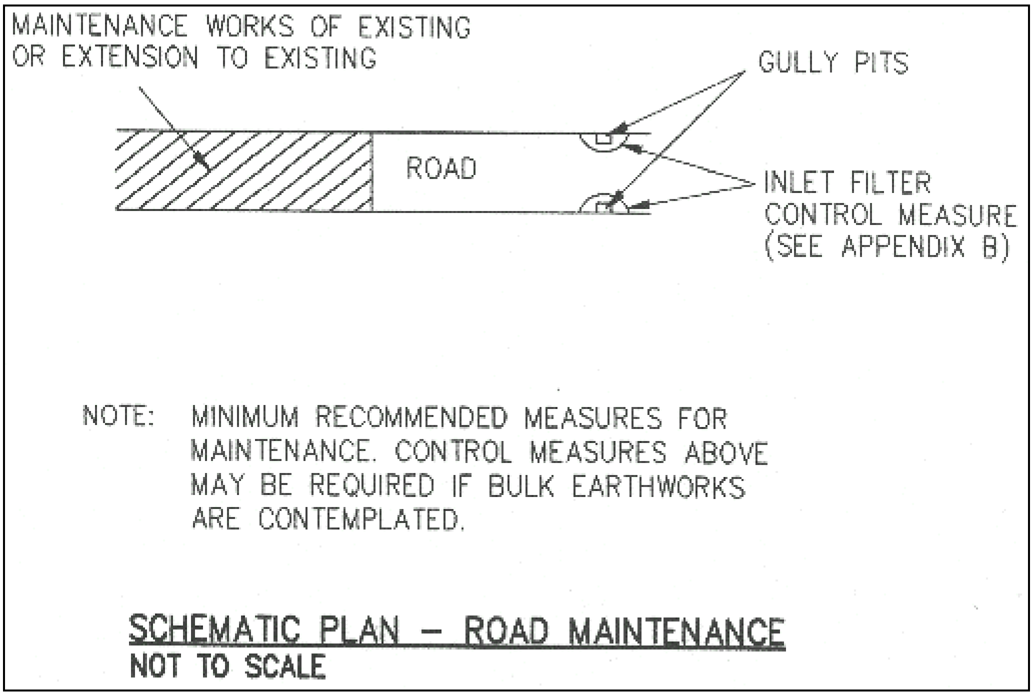


Figure 5. Sample of control measures used on a road maintenance site.

5.5 Firebreaks

It is preferable that firebreaks follow contours, however where a firebreak proceeds down a steep slope, regular cross-drains/compacted trafficable bunds should be provided in order to divert water away from the firebreak and minimise erosion. The recommended spacing of the cross drains/trafficable bunds is 80 m for slopes less than 10% and 35 m for slopes greater than 10%.

Firebreaks should be constructed in such a manner that there is minimal depth of disturbance to the soil profile (use of disc ploughs is not recommended). Locate firebreaks where possible along ridgelines or across slopes (preferably downslope of diversion drains, etc.). Consideration should be given to using a combination of slashing and herbicides for firebreaks (as approved by the Local Government Authority) rather than mechanical methods that disturb soil. The use of strategic firebreaks should also be discussed with the Local Government Authority, to avoid, for example, ripping a firebreak along a boundary, where it crosses a watercourse.

5.6 Infrastructure - Service trenches

Materials that are not compacted have a greater potential for erosion. In relation to trenches to install or maintain infrastructure such as telephone, power and water, the following recommendations are made:

(i) All trenches containing services should be backfilled and compacted. The level of compaction should be to a density at least matching the density of undisturbed in situ materials. Bedding, backfilling and trench widths should also be in accordance with AS/NZS 2566.1:1998 (Standards Australia/NZ 1998), with backfilling material normally comprising the original excavated material.

(ii) Where backfilling is performed behind kerbing, the materials should be compacted such that the material, when compacted, is in a medium dense condition (minimum relative density 35%). Where possible, common trenching of services should be utilised. Stockpiles of excavated material should be positioned such that they do not spill onto roads/drains, etc. and allow sediment to be transported to drainage structures.

5.7 Inspection and maintenance

Inspection and maintenance of the erosion and sediment control measures is necessary in order to ensure their adequate performance. All control measures should be maintained until all earthworks and landscaping activities have been completed and all disturbed areas remaining at the site have been rehabilitated. Inspections should be performed on a weekly basis and following major storm events, by a site manager or the equivalent and would include the following:

(i) Check the performance of diversion drains. Are drains of an adequate size and flowing at non-erosive velocities?

(ii) Is there evidence of erosion of cut and fill batters, drainage structure inlets and outlets?

(iii) Are sediment traps functional? If sediment traps have reached their design capacity, new traps will be required or sediment will need to be removed and taken for disposal at appropriate sites. Clean up spilled sediment and ensure spillage from traps does not encroach on drains.

(iv) Do permanent sediment basins, etc. have adequate capacity? If not why? Is maintenance required, including sediment removal?

(v) Check the progress of regrowth on areas of progressive rehabilitation. Are irrigation systems operational or is watering from tankers been done? If measures are not successful, the use of fibre-matting and Geocell®-type products or additional seeding and mulching may be warranted.

(vi) Have discarded/used construction materials (i.e. paints, cement, plaster, etc.) been disposed of in an appropriate manner? Bins should be regularly removed from site.

(vii) Do the ESCPs require modification due to changes in the project requirements, work practices or site conditions revealed by the works?

If inspections reveal remedial works are required, such remedial works should be carried out as soon as possible. Sediment removed from control devices should be disposed of in Council approved sites or respread on site if not contaminated, such that the sediment does not enter watercourses or drainage structures. The monitoring and maintenance requirements for various permanent sediment control devices are provided in the Water and Rivers Commission (1998) document.

Project-specific checklists can be generated based on the items (i) to (vii), detailed above. Such checklists should be signed off by a site manager or the equivalent.

5.8 Erosion repair

Prior to the repair of erosion gullies, etc. an assessment should be made of the cause of the erosion and whether control measures are adequate. Runoff should be diverted away from the area of the erosion scar using diversions drains prior to attempting to repair the erosion scar.

If deep, subsoil should be used to fill the gully, then compacted before topsoil is spread. Erosion scars should be backfilled with compacted fill and then stabilised using vegetative stabilisation (refer to Section 3.5). Alternatively, drop structures could be installed at the location of major erosion scars as appropriate.

5.9 Emergency stabilisation of erosion

A site with an adequately designed and implemented Erosion and Sediment Control Plan, using an appropriate, ARI should rarely need an emergency strategy. However, should the ARI be exceeded, site managers should have, as part of the ESCP, an emergency strategy ready to be activated. This will minimise further damage and any consequent problems.

An emergency situation will need **immediate** attention of the site manager. The site manager needs to visit the site as soon as possible (provided it is safe to do so) and ascertain the extent of damage. They then need to determine what actions need to be taken to stabilise the site, prioritise these actions and implement them.

To be prepared for emergencies, site managers need to have:

- regularly updated weather reports, (particularly at high risk stages of the project) so as to be aware of any storm warnings or the likelihood of other adverse events;
- an after-hours source of weed-free hay bales, filter fabric, star pickets, wire, flocculant (to settle particles prior to emptying a full detention basin) and other sediment trapping materials, with after hours contacts for suppliers;
- after-hours access to experienced labour (with appropriate safety clothing and tools) to repair structures; and
- after-hours access to whatever plant was used to construct the structures (e.g. grader), so maintenance of the temporary (and permanent if necessary) erosion and sediment control structures can be done, to renew their originally designed capacity as soon as possible.

Any storm deposited material, as far as practicable, needs to be removed and, if possible, returned to its original site, and reshaped and compacted to the original profile (allowing for about a 10% settlement).

6. EROSION PREVENTION AND SEDIMENT CONTROL POLICY - FOR TOWN PLANNING SCHEMES

Policy outline

6.1 Operation of this Local Planning Policy

(a) This local planning policy [has been] prepared in accordance with Part 2 of the Town Planning Amendment Regulations 1999.

(b) 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.

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

- (i) Environmental Protection (Swan and Canning Rivers) Policy 1998, the Environmental Protection Policy prevails; or
- (ii) The [Name of Council] Town Planning Scheme, the Scheme prevails.

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

6.2 Statement of intent

Elsewhere in Australia, the adverse impacts from sediment deposited in waterways is well recognised as a primary contributor to the degradation of waterways and water quality. 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 particularly in the Darling Range, there is increased evidence of adverse impacts from sediment deposition in waterways. 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.

The causes of these impacts are related to the export of sediment, for example from turbid water reaching the watercourse, which results in weed growth on nutrient-rich sediment, and consequent loss of river pools and deep water habitat through siltation. In almost all cases, these processes are exacerbated by land development.

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

The Environmental Protection (Swan and Canning Rivers) Policy 1998 requires that local government, when making decisions, ensures that drainage systems are designed 'in order to prevent and mitigate land degradation' (Clause 17 (a) (ii)).

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 in the Darling Range.

The Upper Canning Southern Wungong Catchment Team, which covers the Cities of Armadale and Gosnells, has prepared an Erosion and Sedimentation Control Manual for the Darling Range, Western Australia. The Manual reviews best practice in eastern Australia and provides recommendations for best management practice 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.

6.3 Definitions

'Best management practice' means best management practices developed under Clause 11 of the Environmental Protection (Swan and Canning Rivers) Policy 1998 or identified in the Upper Canning Southern Wungong Catchment Team's Erosion and Sedimentation Control Manual for the Darling Range, Perth Western Australia. In the event of an inconsistency, best management practices defined under the Environmental Protection (Swan and Canning Rivers) Policy 1998 prevails.

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

6.4 Policy objectives

(a) Assist in protecting the beneficial uses of the Swan and Canning Rivers and watercourses, consistent with the requirements of the Environmental Protection (Swan and Canning Rivers) Policy 1998. In particular, beneficial uses of the Swan and Canning Rivers and waterways to be protected under this policy are their use:

- (i) as a habitat for:
  - (i) locally indigenous fauna, including migratory and threatened species; or
  - (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;
- (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

6.5 Application of the policy

6.5.1 Local structure plans/outline development plans

Local structure plans/outline development plans in the Darling Range 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 in the Darling Range:

- (i) The erosion risk should be assessed using the Work Sheet reproduced as Attachment 1 to this policy (*as Appendix D in this Manual*).
- (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 80 m for slopes of less than 10% or 35 m for slopes greater than 10%.
- (v) The location of existing or 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.

6.5.2 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’ 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 subdivider’s 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 Sedimentation Control Manual for the Darling Range, Perth Western Australia* published by the Upper Canning Southern Wungong Catchment Team 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 Work Sheet reproduced as Attachment 1 to this policy.

(b) The soil stabilisation plan has been prepared consistent with the development approaches identified in Table 3 of the Work Sheet reproduced as Attachment 1 to this policy; and

(c) Erosion and sedimentation control measures described in Section 5.2 of the *Erosion and Sedimentation Control Manual for the Darling Range, Perth Western Australia* have been considered and applied where appropriate and practical.

6.5.3 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 Section 5.3 of the *Erosion and Sedimentation Control Manual for the Darling Range, Perth, Western Australia.*

7. REFERENCES

Agriculture Western Australia (1999). *The Land is in Your Hands: A Practical Guide for Owners of Small Rural Landholdings in Western Australia*. Misc. Pub. 58/99. Agriculture Western Australia, Perth.

Environmental Protection Authority (1997). *Policy Guidelines and Criteria for Environmental Impact Assessment: No. 33 - Guidelines for Environment and Planning* (draft). Department of Environmental Protection, Perth.

Institute of Engineers, Australia (1987). *Australian Rainfall and Runoff: A Guide to Flood Estimation*. Revised edn, ed. D.H. Pilgrim. The Institution of Engineers, Australia, Barton, ACT.

Institute of Engineers, Australia (Queensland Div.) (1996). *Soil Erosion and Sediment Control: Engineering Guidelines for Queensland Construction Sites*. Eds G. Witheridge & R. Walker. Institute of Engineers, Australia, Queensland Division, Brisbane.

Moore, G. (1998). *Soil Guide: A Handbook for Understanding and Managing Agricultural Soils*. Bulletin 4343. Agriculture Western Australia, Perth.

NSW Department of Housing (1998). *Managing Urban Stormwater: Soils and Construction*, 3rd edn. NSW Department of Housing, Sydney.

Standards Australia (1993). *Geotechnical Site Investigations*. AS 1726-1993, 3rd edn. Standards Assoc. of Aust., Sydney.

Standards Australia/New Zealand (1998). *Buried Flexible Pipelines: Part 1: Structural Design*. AS/NZS 2566.1:1998. Standards Assoc of Australia/New Zealand, Sydney/Wellington.

Waters and Rivers Commission (1998). *A Manual for Managing Urban Stormwater Quality in Western Australia*. By Evangelisti & Associates *et al*. Waters and Rivers Commission, Perth.

Other relevant publications

Lloyd, B.A. (1997). *Report on Degradation in the Upper Canning Catchment.* Misc. Pub. 12/98. Agriculture Western Australia, Perth.

Lloyd, B.A. (1998). *Report on Degradation in the Southern River/Wungong Catchment, Perth, Western Australia*. Misc. Pub. 3/98. Agriculture Western Australia, Perth.

Upper Canning/Southern Wungong Catchment Team (1999). *Upper Canning/Southern Wungong Catchment Management Plan*. By Everall Consulting Biologist, Upper Canning/Southern Wungong Catchment Team, Perth.

8. GLOSSARY OF TERMS

Aggregates/Peds (of soil)	Aggregation of clay, silt and sand within a soil into larger units.
Bedload	Sediment that moves along the bed of a drainage line or watercourse by a sliding or rolling action.
Benthic environment	The habitat at the base of watercourses and waterbodies.
Dispersity	The tendency of the clay fraction in a soil to go into colloidal suspension in water.
Control measure	Procedures designed to minimise the severity of erosion and sedimentation.
Detention basin	A structure that temporarily stores large volumes of water after a storm event, that is designed to drain away at a controlled rate, so as to have the capacity to be ready for the next event.
Drop structure	A structure allowing water to fall from one level to another, normally including an inlet, a drop and an outlet. Depending on the expected velocity, the outlet may incorporate an energy dissipater.
Emerson class number	A soil classification system based on a soils coherence in water.
Energy dissipater	A device located usually at the outlet of pipes, spillways or drop structures, etc. for the purpose of interrupting discharged flows, dissipating their excess energy and thereby reducing the erosion potential.
Erosion risk assessment	The process of identifying the potential for adverse erosion effects.
Erosion and Sediment Control Plan (ESCP)	A plan that addresses erosion and sediment control during a construction phase. It does not usually address permanent control of stormwater quality.
Filter fabric	Synthetic material designed to allow water to pass through, but not soil particles, with the size of particle held back dependent on the fabric mesh size.
Gabion	A purpose-built rectangular box made from steel wire mesh with wire cross-ties, into which rocks are placed. They are used to stabilise embankments.
Hydromulching	Applying mulch, with or without seed and fertiliser, using a machine termed a hydromulcher. The hydromulcher sprays the mulch in slurry form under high pressure.
Level bank	A sediment trap formed by constructing an earth bund on the contour.

Mulching	The application of plant residues or other suitable materials to the land surface to conserve moisture, hold soil in place, aid in establishing plant cover, increase infiltration, and minimise temperature fluctuations.
Rainfall erosivity	This is a measure of the ability of rainfall to cause erosion and is dependent on total energy and rainfall intensity.
Rational method	A probabilistic method of estimating the design peak flows from a given catchment area (refer to Institute of Engineers, Aust. 1987).
Rock (or Reno) mattress	Similar to Gabion, in that it is a wire, rock-filled mesh box, but more a mattress shape. It used to line high-risk sections of drainage lines subject to substantial water flows.
Revetment mattress	A protective layer of erosion-resistant material placed along the banks of watercourses to prevent erosion. One type has grout pumped into a membrane cell to form a mattress conforming to the shape of the bank.
Sediment	Material that has been moved from its point of origin by erosive actions of wind, water or gravity.
Sediment (or silt) trap	A structure designed to collect coarse sediment, ideally as close to the point of origin as possible. Sediment traps need to be regularly checked and cleaned out if necessary.
Slope length	The slope length is the effective distance across a site between control measures.
Soil erodibility potential	For the purposes of this Manual, the susceptibility of a soil to detachment and transportation by water (related to soil properties taken in isolation).
Spillway	An open or enclosed structure used to safely convey outflow water from a storage structure, such as a dam, into a stable drainage line.

* * * * *

APPENDICES

APPENDIX A

Erosion and Sediment Control Manual - List of submitters

Organisation mailed a copy for comment	Submission received
Association of Consulting Engineers Australia (WA Division)	Would like briefing later
City of Armadale	Yes
City of Gosnells	Yes
City of Swan	
Civil Contractors Federation	
Eastern Metropolitan Regional Council	Letter of strong support
Housing Industry Association	
Institute of Municipal Engineering Australia (WA Division)	
Institution of Engineers Australia	
Master Builders	
Ministry for Planning	Commented during preparation
Ministry of Housing	Yes
Shire of Kalamunda	
Shire of Mundaring	
Shire of Serpentine-Jarrahdale	Yes
Urban Development Institute of Australia c/o Coffey Geosciences	Yes
Water & Rivers Commission	Supportive phone call
Western Australian Municipal Association	Yes

Erosion and Sediment Control Manual - Summary of submissions

No.	Sort	Comment	Response
1	General	The Manual may benefit by giving guidelines on acceptable sediment loads or some other indication that soil loss is not acceptable.	Measurement of sediment loads is difficult and expensive and is reliant upon monitoring happening during rainfall events or site specific measurements of sediment depth in water bodies. This Manual and policy therefore focuses on best practice, and it is suggested that sediment criteria would best appear in stormwater management policies based on the performance of best practice measures (e.g. continuous deflector units, which can remove sediment to 100 microns).
2	General	Advice may need to be included where unplanned erosion occurs (e.g. when exceptional storm events occur).	A new Section 5.9 'Emergency Stabilisation of Erosion' has been added.
7.2	General	Provide reference for RUSLE.	Reference has been included.
8	General	We should follow up on ability to charge developer for our works (e.g. 1.5% supervision fee).	A supervision fee for roads and drainage already applies for subdivisions.
10	General	Slope protection measures on Albany Highway Bedfordale are not Best Management Practice, so should not be used as an example in Photo 7.	This photograph was included to the show the use of possible measures. The caption has been altered to indicate this.
14	M1.1	Page 1 - Section 1.1 refers to temporary measures. There should be consideration to their replacement, in certain circumstances by permanent measures. If this is not addressed at the appropriate time by the developer, the local authority would have to come back in the future to solve this problem.	Section 1.1 has been amended to clarify that the Manual considers both temporary and permanent control measures.
9	M1.3	Formation and loss of topsoil should be carefully estimated and backed-up with proof.	Reference provided.
15	M2.2	Appendix D is not as stated.	Sentence re-worded.
4	M2.3	The source of Table 1 should be stated. Fells *et al*. (1992) 'Geotechnical Engineering of Embankment Dams' pg 306 states that 'The Emerson test ... does not provide a measure of erodibility'. It is curious that a soil with a class of 4 is regarded as having a lower erosion potential than a soil with a class of 5.	Table 1 has been re-considered and amended in response to this comment.

No.	Sort	Comment	Response
16	M3.3	Section 3.3, dot point 1, recommends limiting site access to one location. This needs qualification, as in many situations it would be difficult to restrict construction equipment working in the subdivision to one site access point only.	Agreed - text has been amended to clarify access points for subdivisions and for individual lots.
5	M3.6	It is not clear what length (of trench, of gully or of hay bales) is referred to in Table 6.	Table 6 refers to length of control measure.
6	M5.2	The statement that 'excavation of cut to fill building pads at the subdivision stage' is poor land development practice requires justification. The developer is more likely to have access to professional advice on erosion control than an individual landowner. Heavier compaction equipment and facilities for addition of water for compaction is also more likely during the land development stage.	This section has been amended to state that excavation of cut to fill building pads is only poor practice if this aspect of the subdivisional works is not covered in an Erosion and Sediment Control Plan.
7	P5.1	The requirement of Clause 5.1 (ii) (roads parallel to contours or on ridges) appears to be contradictory to Clause 5.1 (iv) (maximise boundary length along slopes and minimise boundary length down slopes to 35 m max if slopes >10%).	The intent of the guidelines was that roads should be aligned parallel or perpendicular to contours, rather than at oblique angles. The clauses are not considered to be contradictory because they are only guidelines. If the boundary length (as per Clause 5.1 (iv)) is more than 35m then a cross drain is recommended.
7.1	P5.1	A boundary length of 35 m max for slopes exceeding 10% hardly seems very practical.	See above.
3	Support	Both the Design Engineer & Environmental Officer endorse the draft.	Noted.
11	Support	WAMA does not have the resources to comment but recognises an urgent need to reduce sediment loads entering waterways and acknowledges UCSWCT efforts.	Noted.
12	Support	Supports initiatives, and please keep us informed.	Noted.
13	Support	Support document, but relevance limited because little construction activity in the hills. However Officers would support Council's consideration of the adoption of the final document.	Noted.

APPENDIX B

SOIL & ROCK ENGINEERING PTY. LTD. Consulting Geotechnical Engineers & Geologists	CLIENT: SWAN AVON INTEGRATED CATCHMENT MAN. PROJECT: EROSION & SEDIMENT CONTROL MANUAL		CALCULATION SHEET JOB No. 4916/1.0
DESIGNED BY: CW DATE: 18/2/2000	CHECKED BY: DATE:	REV: DATE:	PAGE No. 1 OF 3

Estimation of the Soil Loss for a 80m Slope length using the Revised Universal Soil Loss Equation, with no control measures.

Revised Universal Soil Loss Equation;
$A = R.K.LS.P.C$

where R = Rainfall erosivity factor, assume to be 1225 for the study area
K = soil erodibility factor (varies)
LS = slope length/gradient factor, varies see below.
P = Erosion Control Practice, assumed as 1
C = Cover Factor, assumed as 1.

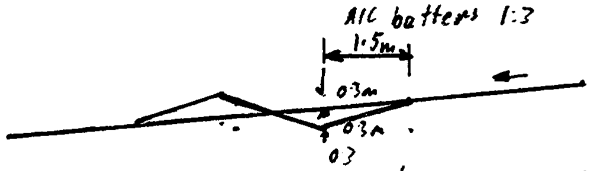
TABLE OF SOIL LOSSES (A)(in t/ha/ann)

Soil Erodibility Potential	K Factor	Slope 0-5% LS=0.53	5%-10% LS=1.90	10-20% LS=5.06	>20% LS>7.32
Low	0.02	13.0	46.5	124.0	179.3
Moderate	0.035	22.7	81.5	216.9	313.8
High	0.07	45.4	162.9	433.9	627.7

Notes: Slope Length assumed = 80m.

SOIL & ROCK ENGINEERING PTY. LTD. Consulting Geotechnical Engineers & Geologists	CLIENT .... PROJECT		CALCULATION SHEET / JOB No.
DESIGNED BY: DATE:	CHECKED BY: DATE:	REV: DATE:	PAGE No. 2 OF 3.

Consider Capacity of Proposed diversion drain:



drain nominal grade 0.5%,
drain characteristics:
$A = 0.27 m^2, P = 1.897 m$
$R_H = 0.142 m$
$n = 0.025$
$S = 0.005$ ✓

Estimate Drain Capacity using Manning's Formula

$Q = \frac{1}{n} A R_H^{\frac{2}{3}} S^{\frac{1}{2}}$

$= \frac{1}{0.025} \times 0.27 \times 0.142^{\frac{2}{3}}\ 0.005^{\frac{1}{2}}$

$= 0.2\ m^3/s$ ✓

$\simeq 200\ l/s$.

Average drain velocity $= \frac{0.2}{0.27} = 0.7\ m/s$. OK for most soils.

Rational method for a small catchment, 1 in 5 year 6min storm event.

$Q = \frac{C I A}{360}$

$I_{6min}^{5yr} = 97\ mm/hr$, Rainfall Intensity.

A = catchment area = ?

C = runoff coefficient.

Assume Jarrah forest with loamy soils

$C_{10} = 2.15 \times 10^{-1}\ 10^{0.0073 CL}$

$\frac{C_5}{C_{10}} = 0.8$

If 100% clearing of catchment
$C_5 = 0.9$ ✓

If 0% clearing of catchment
$C_5 = 0.2$

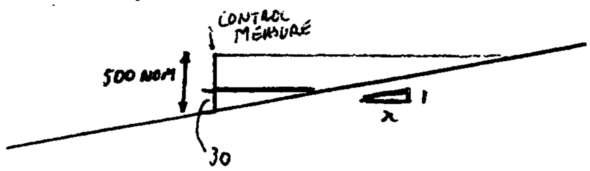
Estimate allowable catchment area for above, diversion drain

If 100% cleared $A = \frac{Q \times 360}{C I} = \frac{0.2 \times 360}{0.9 \times 97} = 0.8\ ha$ ✓

if 0% cleared $A = \frac{Q \times 360}{C \times I} = \frac{0.2 \times 360}{0.2 \times 97} = 3.7\ ha$.

SOIL & ROCK ENGINEERING PTY. LTD. Consulting Geotechnical Engineers & Geologists	CLIENT .... PROJECT		CALCULATION SHEET / JOB No.
DESIGNED BY: DATE:	CHECKED BY: DATE:	REV: DATE:	PAGE No.

Examine Silt traps.



Design criteria - maximum capacity 30%.
- Sediment density 1.3 t/m³.

- Silt Trap capacity per metre $= \frac{0.3 \times 0.5 \times 0.5x}{2}$
$= 0.0375x \ m^3/m$
$= 0.0488x \ t/m$

Slope	0-5%	5-10%	10-20%	>20%
Average % Slope	2.5	7.5	15	>20
1 : x , x =	40	13.3	6.67	5
Nominal Silt trap capacity t/m	1.95	0.65	0.32	0.24
Nominal Soil Loss/ann for a 80m slope length. Class 1 (t/m)	0.36	1.30	2.4	2.4
Class 2 (t/m)	-	-	3.47	5.02
Nom. Design Life Class 1	5.4 years	6 months	1.6 months	1.2 month.
Nom. Design Life Class 2			1.1 month	0.5 month.

APPENDIX C

EROSION AND SEDIMENTATION CONTROL MANUAL DESK STUDY, SITE VISIT AND SOILS TESTING DARLING RANGE

Report prepared for:

UPPER CANNING/SOUTHERN WUNGONG
CATCHMENT TEAM
PO BOX 51
ARMADALE WA 6992

Report prepared by:

SOIL & ROCK ENGINEERING PTY LTD
CONSULTING GEOTECHNICAL ENGINEERS
AND GEOLOGISTS
PO BOX 1346
OSBORNE PARK WA 6017

Ref: **ch4916_1_2000svrep.doc**
Date: **19 January 2000**

TABLE OF CONTENTS

Page no.

* * * * *

4916/1.0/CH 8 November 2000
ref: ch4916_1_2000svrep.doc

PROJECT: **EROSION AND SEDIMENTATION CONTROL MANUAL**

CLIENT: **UPPER CANNING/SOUTHERN WUNGONG CATCHMENT TEAM**

LOCATION: **DARLING RANGE**

SUBJECT: **DESK STUDY, SITE VISIT AND SOILS TESTING**

1. INTRODUCTION

This appendix presents the results of a desk study on the hydrology and the general soil types that can be expected to be found within the study area. In addition the appendix provides discussion relating to a study area visit by a representative of Soil & Rock Engineering and presents the results of laboratory testing on soil samples obtained from selected sites visited. The results of the laboratory testing were utilised in determinations as part of the production of the Manual.

The sites visited within the study area were as discussed in a meeting dated 1 December 1999 with the Upper Canning/Southern Wungong Catchment Team.

2. HYDROLOGY

Annual precipitation and rainfall intensity are factors that influence soil erodibility. Annual precipitation provides water for plant growth and provides moisture for soil cohesion/adhesion. Rainfall intensity determines the energy available to dislodge soil. It was noted that at the time of the site visit in January all the soil samples obtained were dry.

The annual precipitation within the study area varies from approximately 800 mm to 1,000 mm. Reference to maps of the study area in Rainfall and Runoff, Volume 2 indicates that rainfall intensity as indicated by isopleth lines is similar within the study area. The nominal rainfall intensity for a 1 in 2 year, 1 hour storm event is nominally 22.5 mm/hr south of Mount Helena and 20 mm/hr, north of Mount Helena.

Estimates of the Rainfall Erosivity Factor (R) (utilised in the Universal Soil Loss Equation, RUSLE) for the study area were undertaken using Rosewell and Turner (1992). The estimated Rainfall Erosivity Factor for the northern area of the study area was determined as 1064 and the estimated Rainfall Erosivity Factor for the southern area was determined as 1390. It should be noted that the Rainfall Erosivity Factor for major Australian cities varies from 330 in Adelaide to 16,590 for Cairns.

3. SOIL TYPES

It should be noted that soil types within the study area are largely related to terrain types. Table 1 below summarises the principal soil types associated with various terrain types.

Table 1. Soil types

Terrain type	Soil description#	USC*
Valley Slopes of the Darling Scarp (southern section of study area)	Red Earths, acid reaction trend	SC, CL, CH
Low and Hilly Terrain (northern section of study area)	Acidic yellow mottled soils and sandy acidic mottled soils which contain ironstone gravels	GC, SC
Moderate to steep valley sides (northern section of study area)	Hard neutral red soils	SC, CL, CH
Darling Plateau	Lateritic Gravels	GM, GP

Notes: # Soil descriptions in accordance with the Atlas of Australian Soils.
* Likely soil types in accordance with the universal soil classification system.

4. DESCRIPTION OF THE SITE VISIT

A site visit to the study area was undertaken on the 12 January 2000 by a Senior Civil Engineer from Soil and Rock Engineering. Ten (10) sites were visited and observations were made of the site, including assessment of terrain, soil types, evidence of erosion and erosion control measures utilised. In addition, five soil samples were taken from selected sites in order to perform laboratory tests and hence more accurately classify the soil types observed.

5. DESCRIPTION OF LABORATORY TESTING

Laboratory testing was carried out in accordance with the general requirements of the latest edition of AS 1289, by a NATA registered Testing Authority. The type of tests carried out to provide some of the parameters required for this study are presented in Table 2.

Table 2. Laboratory testing

Type of test	Abbreviation	Number
Particle Size Distribution	PSD	5
Plasticity Index, Plastic Limit, Liquid Limit	PI	5
Linear Shrinkage	LS	5
Emerson Class Number	ECN	4

Test certificates for the above mentioned tests are presented as Plates 1 to 8.

6. RESULTS OF THE LABORATORY TESTING

The results of the laboratory testing carried out on samples taken from selected sites are summarised below in Table 3.

Table 3. Laboratory testing results

Site no. (refer Table 4)	Sample ID	Soil type	% Passing 75 microns	Liquid limit (%)	Plasticity index (%)	Linear shrinkage (%)	Emerson class number
1	Turner Road/ Megisti Place	SC	28	29	17	5.5	3
2	Piers Park	GC	15	22	11	3.0	-
4	Scott Road	CH	70	62	38	14.0	4
5	Garland Road/ Viola Place	SC	34	33	16	5.5	4
7	Summit View/ Rise Court	SC	40	35	17	8.0	5

Based on the laboratory testing performed, the samples, obtained from Turner Road/Megisti Place and Garland Road/Viola Place, have been classified as low plasticity clayey sand (SC) with gravel. The Summit View/Rise Court sample, has been classified as a medium plasticity clayey sand (SC) with gravel. The Scott Road sample, has been classified as a high plasticity sandy clay (CH) with gravel. The Piers Park sample, has been classified as a low plasticity clayey gravel (GC).

Based on the soil erodiblility system presented in MRNSW (1984), materials with an Emerson Class Number of 3 or 5 are likely to have a moderate risk of erosion (that is the Turner Road/Megisti Place and Summit View/Rise Court samples) and materials with an Emerson Class Number of 4 are likely to have a low risk of erosion (that is Garland Road/Viola Place and Scott Road samples).

7. DISCUSSION

Table 4 below summarises the observations made during the visit to various sites within the study area.

Table 4. General observations during site visit

Site no.	Soil types	Comments	Sampling
1	SC	Turner Road Sub-division, Kelmscott Turner road is kerbed and the verges are grassed, no visible erosion is evident. There was material on the road adjacent to a construction site (appeared to be due to trafficking by vehicles). The construction site had an estimated slope of 5% to 10%. There was a creek line on the opposite side of the road, adjacent to the construction site.	PSD, PI, LS, ECN
2	GC	Piers Park, Kelmscott Only minor erosion was noted in a old gravel borrow pit opposite Piers Park. Minor erosion scars were also noted in a steep sided open channel near the Piers Park Entrance. West of Connell Avenue the Perth Coastal Plain commences (soil type SP).	PSD, PI, LS
3	GP	Versteeg Gr/Feldts Road, Martin Hilly terrain, slopes to nominally 10% slope. Erosion of laterite gravels in the table drains adjacent to the road was noted. Erosion is gully erosion to caprock.	
4	CH	Scott Road, Kelmscott Slope stabilisation using a gabion wall (utilising local materials). Land cleared upslope of the wall, no slope stabilisation by tree roots. Soil behind wall may be residual soil from a completely weathered Dolerite Dyke with no erosion scars noted.	PSD, PI, LS, ECN
5	SC	Garland Road/Viola Place, Roleystone At the time of the site visit, the roads within the sub-division were sealed and kerbed. The general site slope was > 10%. The full site was cleared and earthworks had been undertaken to form building pads by cutting into the slopes. Seeding of the verges, etc. had been performed, however, erosion scars were apparent on the steep batters of the building pads. It was noted that there was a basin downslope of the development with a spillway (lined with revetment mattresses) discharging into a watercourse.	PSD, PI, LS, ECN
6	GC, over Caprock	Henty Lookout (upper section), Roleystone Site viewed was largely cleared with grasses and small low trees, approximate slope 7.5% to 10%. Disturbance due to borrowing materials. Rill/gully erosion in areas of concentrated flow due to runoff from catchment areas upslope was noted (no contour banks used). Erosion in verge noted due to a lack of compaction of backfill.	
7	SC	Summit View/Rise Court, Armadale Both roads are sidling roads, terrain has a cross slope > 10%. Minor erosion scars were noted in completely weathered rock exposed in a cutting (Summit View). Erosion scars were noted on the sides of tracks at the end of Rise Court (scars down to 'rock'). Possible lack of compaction noted on verges backfilled with gravel.	PSD, PI, LS, ECN

Table 4 continued …

Site no.	Soil types	Comments	Sampling
8	SC	Richon Heights (upper section), Wungong Road grade nominally 10% (majority of road sidling). Minor rill erosion in road cut slopes (1:3) and retention basin slopes was noted from runoff from blocks upslope. A property access was a potential erosion source (in cut). Control measures utilised comprised rock lined table drains (with sealed shoulder), rock lined drop structures (from blocks) and 2 retention basins (which act as silt traps).	
9	GP	Off Admiral Road (Corner Wallangarra Dr), Bedfordale Gully erosion observed in old borrow pit (erosion to caprock). Slope 10 to 20%.	
10	GP, GC	Bungendore Park (northern entrance off Albany Highway), Bedfordale Minor rill erosion of track at northern entrance. Nominal slope 5%.	

8. CONCLUSIONS

It has been concluded that variations in annual rainfall and rainfall intensity, within the study area, have negligible effects on the variations in site erosion potential within the study area. Due to the size of the study area, climatic conditions can be assumed to be similar within the study area. In terms of soil loss from a site, soil loss in tonnes per hectare will be greater during winter than summer, however, assessment of the rainfall erosivity should recognise that intense rainfall events can occur during drier months. The estimated average Rainfall Erosivity Factor (R) for the study area of 1225 will be utilised in calculations using the RUSLE contained within the Manual.

Based on the results of the soil testing presented in Section 6, it has been concluded that the soil types within the study have low to medium risk potential for erodibility. Furthermore it is believed that there is no historic occurrence of highly dispersive (Emerson Class Numbers 1 and 2) materials within the study area.

The site assessments can be made using the RUSLE provided the results are critically assessed. This method considers soil erodibility, terrain, rainfall erosivity and cover (vegetation or stabilisation). Variations in site erosion within the study area will principally be due to soil type and terrain (i.e. slope length and grade). Variations in site erosion within the study area due to climatic and hydrological factors are considered negligible and hence the methodology presented in the attached Manual does not take into account such factors.

9. STANDARDS AND REFERENCES

The following standards and references were used in the preparation of this report.

(i) The Institution of Engineers, Australia, "Australian Rainfall and Runoff, A Guide to Flood Estimation", Volume 2, 1987.

(ii) CSIRO, "Atlas of Australian Soils, Perth-Albany-Esperance Area" (Sheet 5 and associated explanatory data), 1967.

(iii) Western Australian Department of Agriculture, Land Resources Series No. 3, "Darling Range Rural Land Capability Study", 1990.

(iv) AS 1726-1993 SAA Geotechnical Site Investigations.

(v) AS 1289 Method of Testing Soils For Engineering Purposes.

(vi) "Interim Guidelines for Control of Erosion and Sedimentation in Roadworks", Department of Main Roads, New South Wales, 1984.

* * * * *

SRC
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Telephone: (08) 9244 1199 Facsimile: (08) 9244 1457

TEST CERTIFICATE

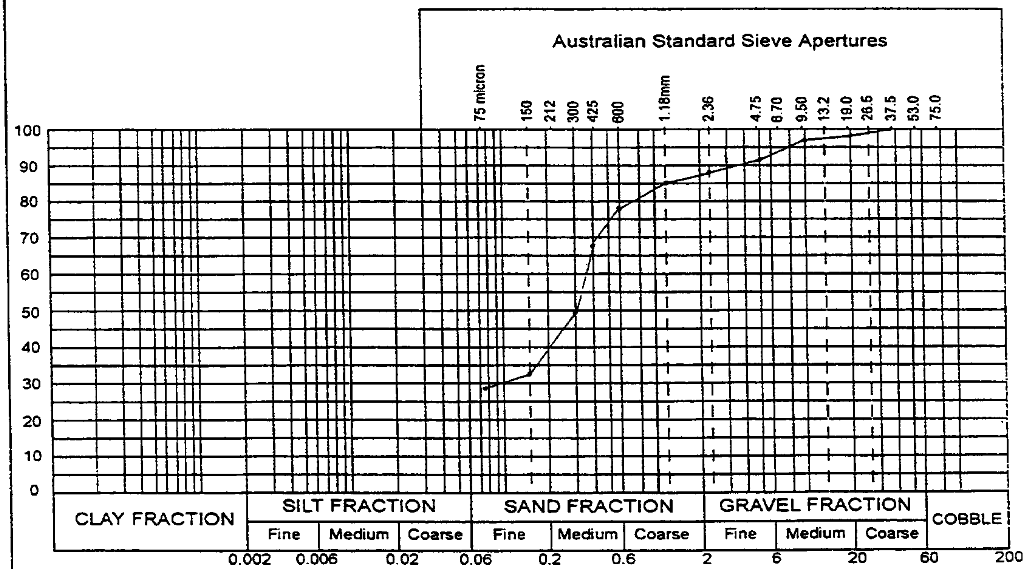
Client: SOIL & ROCK ENGINEERING PTY LTD
Project: SWAN AVON CATCHMENT MANAGEMENT EROSION AND SEDIMENTATION CONTROL, SRE JOB NO. 4916/1.0
Sample ID: TURNER ROAD / MEGISTI PLACE

Sheet No.: 2 OF 9
Job No.: S7290
Date Tested: 14 - 17.01.00

Particle Size Distribution of a Soil

Standard Method of Analysis by Sieving: AS 1289.3.6.1

Sieving				Sieving			
Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing
150.0mm		1.18 mm	85				
75.0mm		600 micron	78				
37.5 mm	100	425 micron	68				
19.0 mm	98	300 micron	49				
9.50 mm	97	150 micron	33				
4.75 mm	92	75 micron	28				
2.36mm	88						



Remarks: Sampling Method/s - Submitted by client

Approved: W Rozmianiec

Date: 26.11.99

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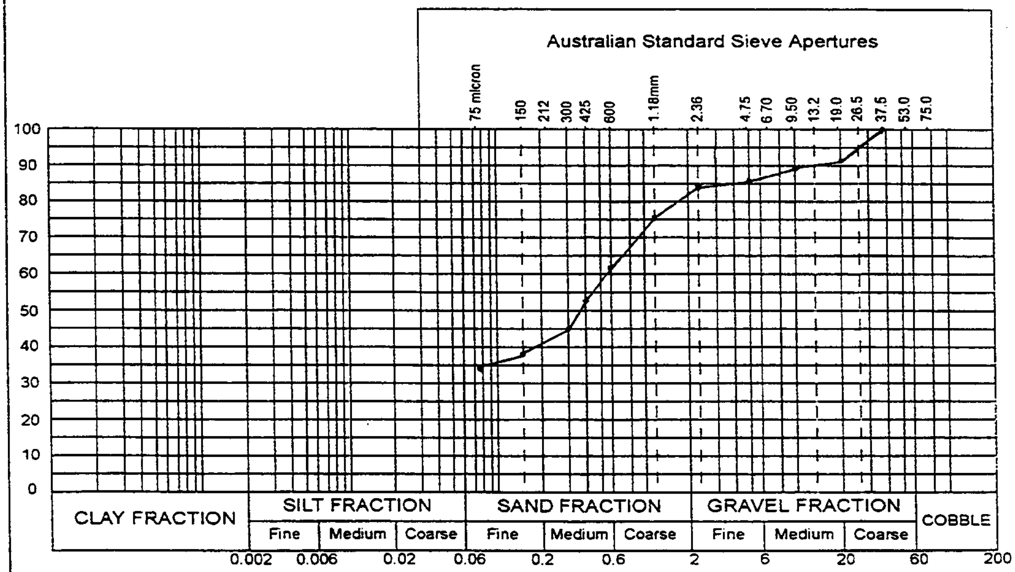
Client: SOIL & ROCK ENGINEERING PTY LTD
Project: SWAN AVON CATCHMENT MANAGEMENT EROSION AND SEDIMENTATION CONTROL, SRE JOB NO. 4916/1.0
Sample ID: GARLAND / VIOLA

Sheet No.: 3 OF 9
Job No.: S7290
Date Tested: 14 - 17.01.00

Particle Size Distribution of a Soil

Standard Method of Analysis by Sieving: AS 1289.3.6.1

Sieving				Sieving			
Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing
150.0mm		1.18 mm	76				
75.0mm		600 micron	62				
37.5 mm	100	425 micron	53				
19.0 mm	92	300 micron	45				
9.50 mm	89	150 micron	38				
4.75 mm	86	75 micron	34				
2.36mm	84						



Remarks: Sampling Method/s - Submitted by client

Approved: W Rozmianiec

Date: 26.11.99

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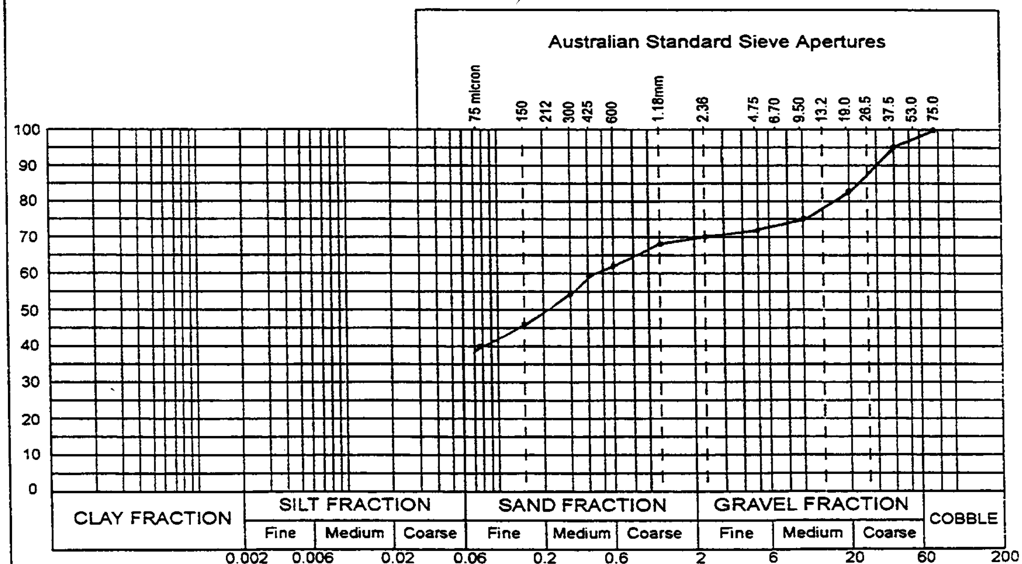
TEST CERTIFICATE

Client: SOIL & ROCK ENGINEERING PTY LTD
Sheet No.: 4 OF 9
Project: SWAN AVON CATCHMENT MANAGEMENT EROSION AND SEDIMENTATION CONTROL, SRE JOB NO. 4916/1.0
Job No.: S7290
Date Tested: 14 - 17.01.00
Sample ID: SUMMIT VIEW / RISE COURT

Particle Size Distribution of a Soil

Standard Method of Analysis by Sieving: AS 1289.3.6.1

Sieving				Sieving			
Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing
150.0mm		1.18 mm	68				
75.0mm	100	600 micron	62				
37.5 mm	95	425 micron	59				
19.0 mm	83	300 micron	54				
9.50 mm	75	150 micron	46				
4.75 mm	72	75 micron	40				
2.36mm	70						



Remarks: Sampling Method/s - Submitted by client

Approved:

W Rozmianiec

Date: 25.01.00

SRC RF-007 Issue 1

PLATE 3

SRC

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TEST CERTIFICATE

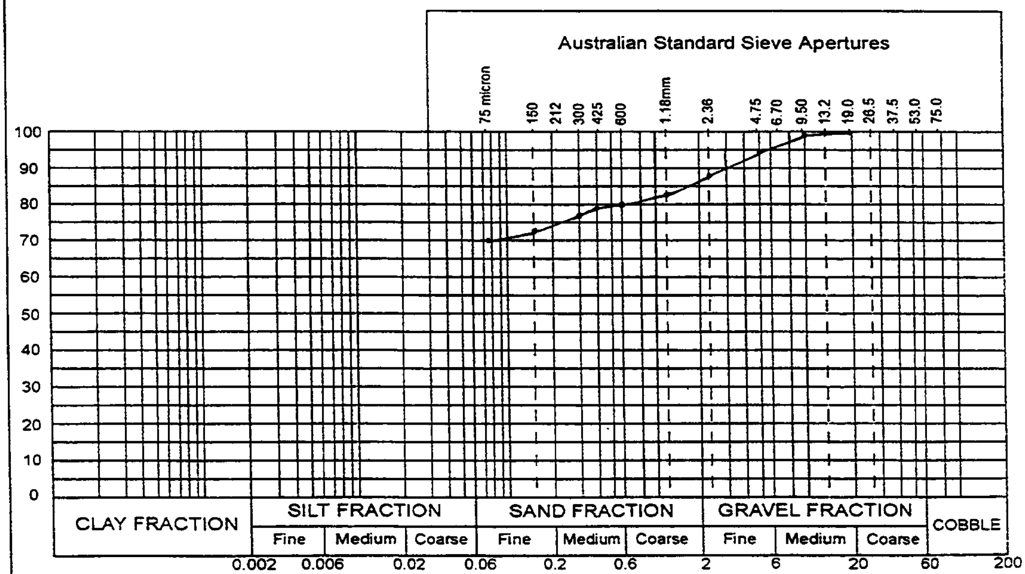
Client: SOIL & ROCK ENGINEERING PTY LTD
Project: SWAN AVON CATCHMENT MANAGEMENT EROSION AND SEDIMENTATION CONTROL, SRE JOB NO. 4916/1.0
Sample ID: SCOTT ROAD

Sheet No.: 5 OF 9
Job No.: S7290
Date Tested: 14 - 17.01.00

Particle Size Distribution of a Soil

Standard Method of Analysis by Sieving: AS 1289.3.6.1

Sieving				Sieving			
Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing
150.0mm		1.18 mm	83				
75.0mm		600 micron	80				
37.5 mm		425 micron	79				
19.0 mm	100	300 micron	77				
9.50 mm	99	150 micron	73				
4.75 mm	94	75 micron	70				
2.36mm	88						



Remarks: Sampling Method/s - Submitted by client

This laboratory is accredited by the National Association of Testing Authorities, Australia. The test(s) reported herein have been performed in accordance with its terms of accreditation. This document shall not be reproduced except in full.

Approved:

W Rozmianiec

Date: 25.01.00

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PLATE 4

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A Division of AMEC Engineering Pty Limited ACN 003 066 715
34 Walters Drive, Osborne Park WA 6017
Telephone: (08) 9244 1199 Facsimile: (08) 9244 1457

TEST CERTIFICATE

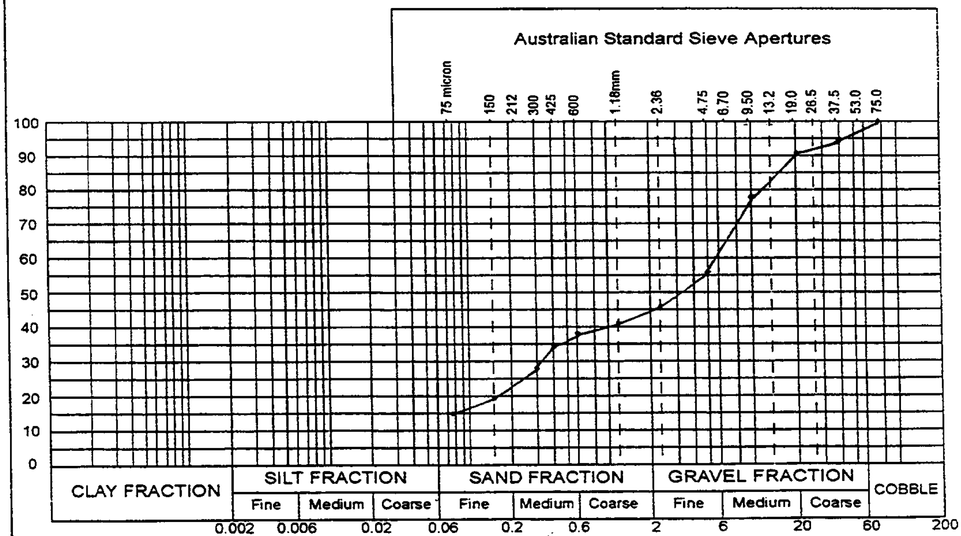
Client: SOIL & ROCK ENGINEERING PTY LTD
Project: SWAN AVON CATCHMENT MANAGEMENT EROSION AND SEDIMENTATION CONTROL, SRE JOB NO. 4916/1.0
Sample ID: PIERS PARK

Sheet No.: 6 OF 9
Job No.: S7290
Date Tested: 14 - 17.01.00

Particle Size Distribution of a Soil

Standard Method of Analysis by Sieving: AS 1289.3.6.1

Sieving				Sieving			
Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing	Sieve Size	% Passing
150.0mm		1.18 mm	41				
75.0mm	100	600 micron	38				
37.5 mm	94	425 micron	34				
19.0 mm	91	300 micron	28				
9.50 mm	78	150 micron	19				
4.75 mm	56	75 micron	15				
2.36mm	46						



Remarks: Sampling Method/s - Submitted by client

Approved:

W Rozmianiec

Date: 25.01.00

SRC RF-007 Issue 1

PLATE 5

SRC
A Division of AMEC Engineering Pty Limited ACN 003 066 715
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TEST CERTIFICATE

Client: SOIL & ROCK ENGINEERING PTY LTD
Project: SWAN AVON CATCHMENT MANAGEMENT EROSION AND SEDIMENTATION CONTROL, SRE JOB NO. 4916/1.0

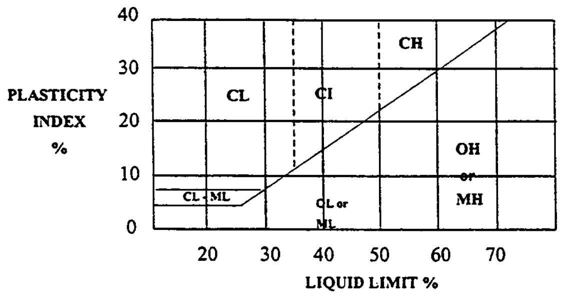
Sheet No.: 7 OF 9
Job No.: S7290
Date Tested: 14.01.00

Plastic Properties - Casagrande Method

AS 1289.3.1.1, .3.2.1, .3.3.1, .3.4.1, .2.1.1

Test No.		1	2	3	4
Sample ID		TURNER RD / MEGISTI PLACE	GARLAND / VIOLA	SUMMIT VIEW/ RISE COURT	SCOTT ROAD
Liquid Limit	%	29	33	35	62
Plastic Limit	%	12	17	18	24
Plasticity Index	%	17	16	17	38
Linear Shrinkage	%	5.5	5.5	8.0	14.0

PLASTICITY CHART: AS 1726



History of Sample: Cool Oven Dried
Method of Preparation: Dry Sieved
Remarks: Sampling Method/s - Submitted by Client

Length of Linear Shrinkage Mould: 250 mm
Nature of Shrinkage: Normal.

Approved:
W Rozmianiec

Date: 25.01.00

PLATE 6

SRC RF-003 Issue 2

SRC
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34 Walters Drive, Osborne Park WA 6017
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TEST CERTIFICATE

Client: SOIL & ROCK ENGINEERING PTY LTD
Project: SWAN AVON CATCHMENT MANAGEMENT EROSION AND SEDIMENTATION CONTROL, SRE JOB NO. 4916/1.0

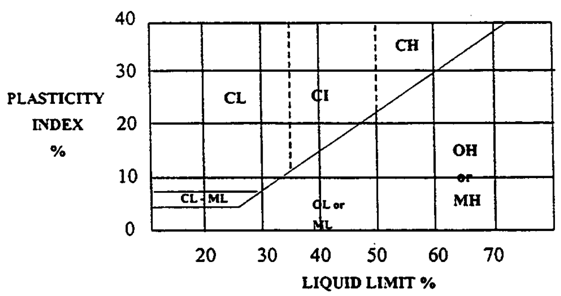
Sheet No.: 8 OF 9
Job No.: S7290
Date Tested: 14.01.00

Plastic Properties - Casagrande Method

AS 1289.3.1.1, .3.2.1, .3.3.1, .3.4.1, .2.1.1

Test No.		1
Sample ID		PIERS PARK
Liquid Limit	%	22
Plastic Limit	%	11
Plasticity Index	%	11
Linear Shrinkage	%	3.0

PLASTICITY CHART: AS 1726



History of Sample: Cool Oven Dried
Method of Preparation: Dry Sieved
Remarks: Sampling Method/s - Submitted by Client

Length of Linear Shrinkage Mould: 250 mm
Nature of Shrinkage: Normal.

Approved:
W Rozmianiec

Date: 25.01.00

PLATE 7

SRC RF-003 Issue 2

SRC

A Division of AMEC Engineering Pty Limited ACN 003 066 715
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TEST CERTIFICATE

Client: SOIL & ROCK ENGINEERING PTY LTD
Project: SWAN AVON CATCHMENT MANAGEMENT EROSION AND SEDIMENTATION CONTROL, SRE JOB NO. 4916/1.0

Sheet No.: 9 OF 12
Job No.: S7290
Date Tested: 14.01.00

Determination of Emerson Class Number of a Soil

AS 1289.3.8.1

Sample ID	Emerson Class No.	Type of Water used in testing	Temperature of Water used in testing °C
TURNER ROAD/ MEGISTI PLACE	3	De Ionised	25
GARLAND / VIOLA	4	De Ionised	25
SUMMIT VIEW/ RISE COURT	5	De Ionised	25
SCOTT ROAD	4	De Ionised	25

Remarks: Sampling Method/s - Submitted by client
Sample: Turner Road / Hegisti Place - some dispersion noticed over a period of 48 hours.

NATA

This laboratory is accredited by the National Association of Testing Authorities, Australia. The test(s) reported herein have been performed in accordance with its terms of accreditation. This document shall not be reproduced except in full.

Approved:

W Rozmianiec

Date: 25.01.00

SRC RF-012 Issue 2

PLATE 8

APPENDIX D

PROJECT: **EROSION AND SEDIMENTATION CONTROL MANUAL**

LOCATION: **DARLING RANGE**

SUBJECT: **WORK SHEET**

Site location (Lot No.)____________________ Shire____________

Proposed area of disturbance at the site ____________

Catchment area upslope of the site ____________

Upslope catchment characteristics (i.e. % cleared) ____________

Average gradient of the site ____________

(Note: Slope gradients may be changed by works at the site).

Other features such as the natural drainage lines, etc. ____________________

____

Erosion Risk Assessment

Table 1. Soil erodibility potential

Soil erodibility potential	Soil description	Group symbol	Emerson class no.
Low	Sandy gravels	GP	> 2
Moderate	Non dispersive and slightly dispersive clays and clayey sands, clayey gravels, silty gravels, sands	CH, CL, CI, SC, GC, GM, SP	> 2
High	Silts, silty sands, fine sands, dispersive clays and clayey sands, water repellent sands	ML, SM, CH, CL, CI, SC	1, 2

Table 2. Erosion risk assessment by soil loss class

Soil erodibility potential (as defined in Table 1)	Site slope 5%-10%	Site slope 10%-20%	Site slope > 20%
Low	1	1	1
Moderate	1	1	2
High	1	2	2

Table 3. Development approaches

Development approaches	Soil loss class	
	1	2
	Action	Action
Planning of control measures as part of an ESCP	Recommended	Required
Implement control measures in Section 3 where appropriate	Required	Required
Staged Construction and Progressive rehabilitation	Consider	Required
Divert runoff around the site	Consider	Required

Site soil loss class (based on Tables 1 and 2) ____________

Proposed control measures ____________________

____

____

APPENDIX E

CH4916_1_2000DSFLOWSHT.xls
19/06/00

Subject: **Drop Structure Hydraulic Design (Simplified Approach)**

Assess Catchment Areas of Drop Structures. Max. Recommended Spacing 150m

Estimate the Peak Flows to each Drop Structure by the Rational Method*

Size Drop Structure entrance capacity using the Weir Formula, $Q=2LH^{3/2}$

Where: L=Weir Width
H=Flow Depth

A=Channel Area
Rh=Hydraulic Radius
S=Channel Slope
n=Manning's Coefficient

Estimate flow velocity down Drop Structure and for the channel downstream using Manning's Formula $Q=ARh^{2/3}S^{1/2}/n$

Assess Apron extents
Consider accelerated flow at inlet and energy dissipator at outlet**

Quantify Rock Protection thickness requirements at the inlet, outlets and within structure (refer critical velocity table below)

Detail Drop Structure based on the results of hydraulic analyses

Table of Recommended Maximum Design Velocities (m/s)
(Data from various sources)

	Soil Erodibility Potential		
	Low	Moderate	High
Bare Soil	0.7	0.5	0.3
Tussock Grasses	1.3	0.9	0.5
Couch Grass	2.0	1.8	1.4
Kikuyu Grass	2.5	2.2	1.9
Geomat Products	1.4	1.1	0.7

	Critical Velocity (m/s)
Loose Rip Rap, 300mm thick #, 200 nom stone size ##	2.5
Reno Matresses/Gabions, 300mm thick #, small stone size ##	4.5
Revetment Matresses, 100mm thick	4.0

Note: * For details of the Rational Method refer to Australian Rainfall and Runoff (1987)
** Table of rip rap requirements are provided for energy dissipators in NSW Department of Housing (1998) or product supplier information.
# Minimum recommended thickness, ## Stones competent igneous rock

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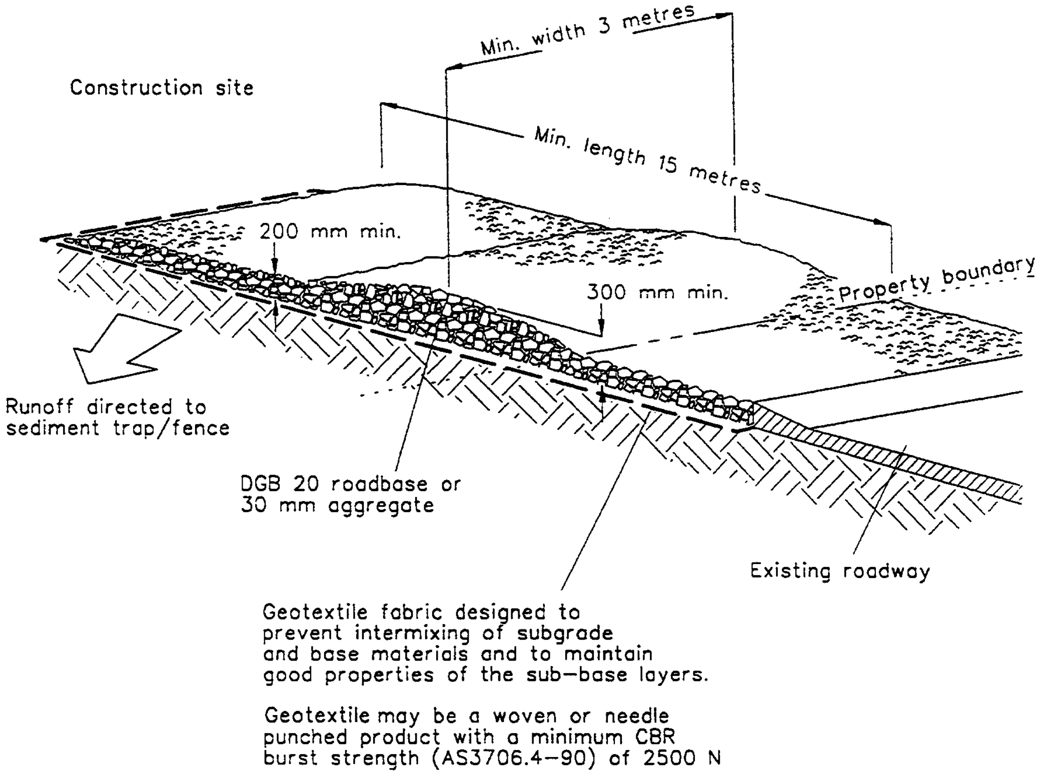
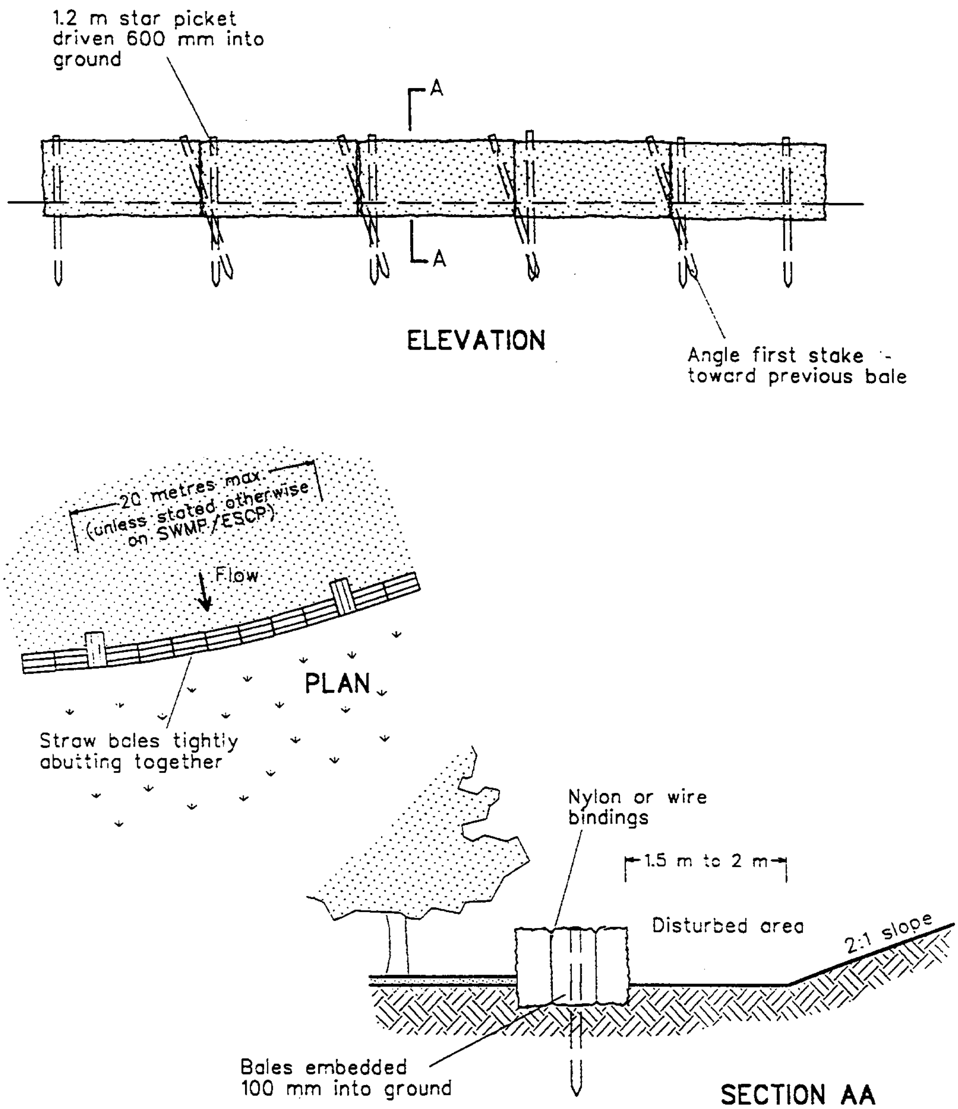


Construction Notes

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.

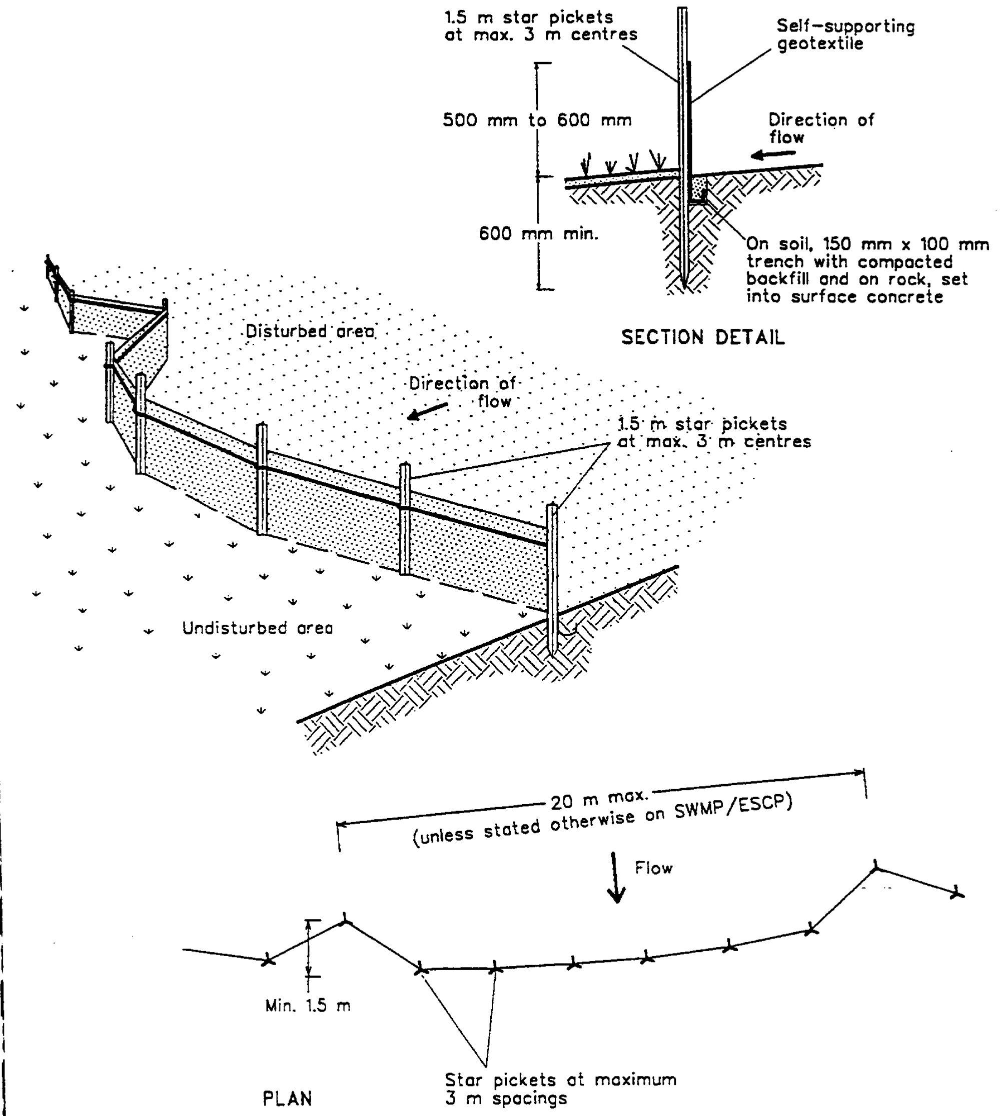
STABILISED SITE ACCESS SD 5-7



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.

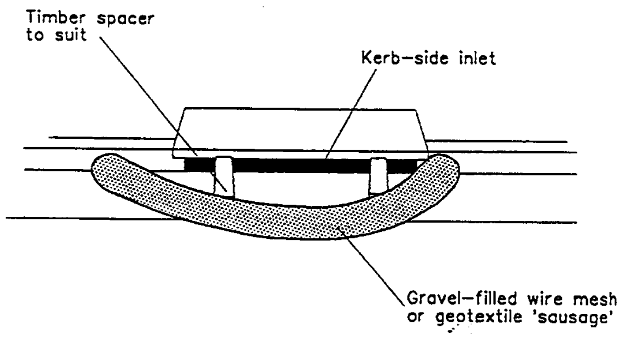
STRAW BALE FILTER **SD 6-6**

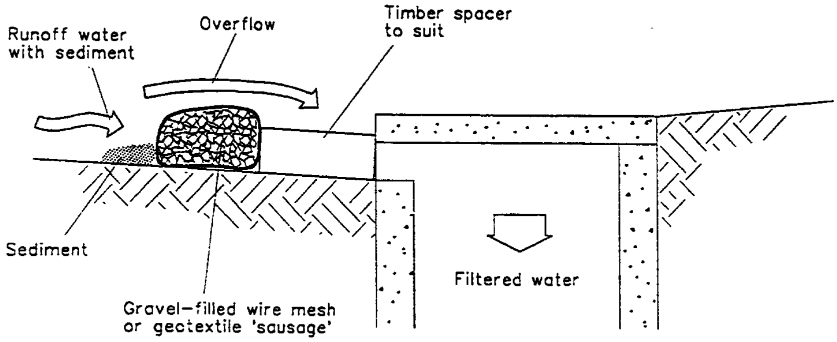


Construction Notes

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



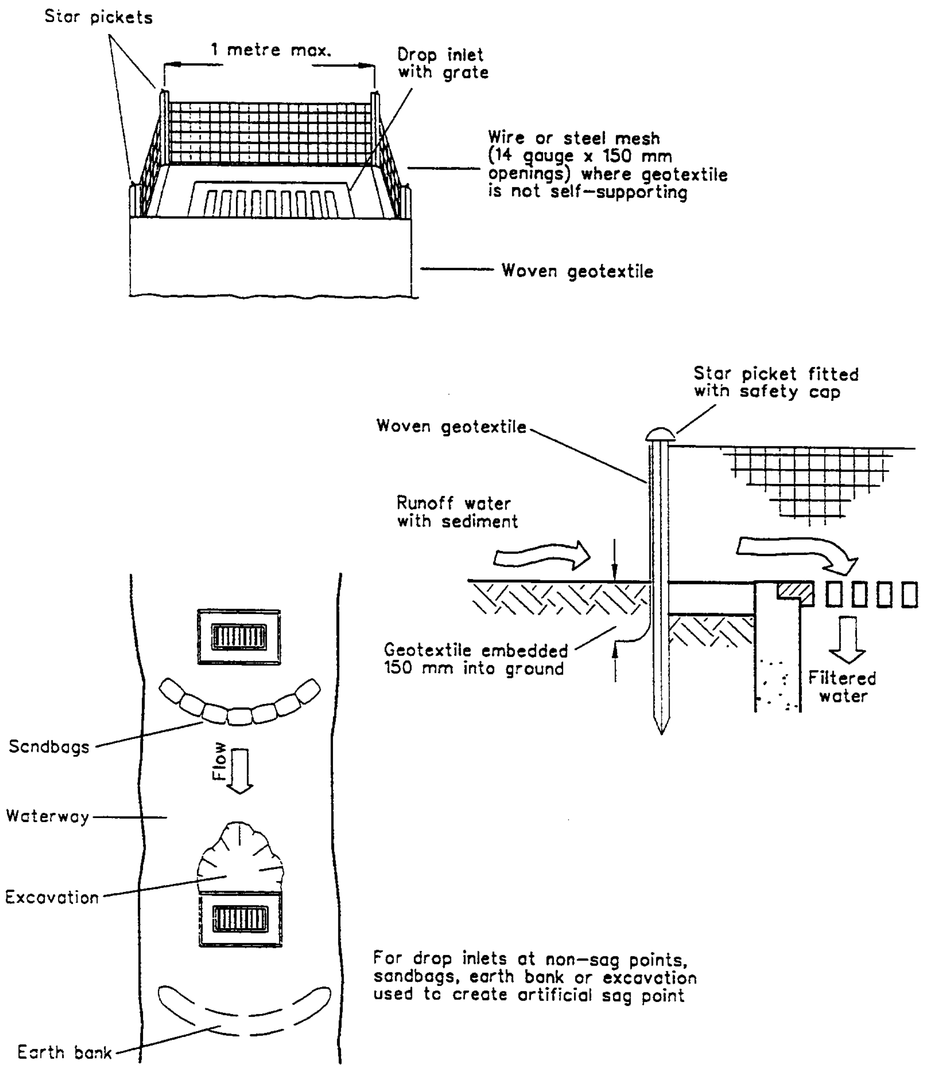


NOTE: This practice only to be used where specified in an approved SWMP/ESCP.

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

Agriculture
WESTERN AUSTRALIA

Upper Canning/Southern Wungong Catchment Team

AUSTRALIA

Natural Heritage Trust

A better environment for Australia
in the 21st Century

This report was prepared in conjunction with the Upper Canning/Southern Wungong Catchment Team as part of Agriculture Western Australia's contribution to the Natural Heritage Trust project 'Management Support for Ellen Brook and Southern River'