CONSTRUCTION TECHNIQUES FOR SEDIMENT POLLUTION CONTROL

EPA
Victoria

May 1991

P R E F A C E

State Environment Protection Policies specify a range of requirements aimed at protecting the many beneficial and indeed vital features of Victoria's waterways. These requirements are legally binding and must be complied with by all Victorians engaged in activities that impact on surface water environments.

Activities of concern include many common construction projects such as building site preparation, bridge and road works, drainage and dam works and other similar engineering works. These changes to the physical environment often result in significant off-site environmental damage and reduced amenity.

The Environment Protection Authority has the role of pursuing and acting against those that pollute the environment, but it recognises that prevention is better than cure. These guidelines and the associated EPA video Green Engineering - Simple Solutions to Pollution Control have been produced to assist planners and construction organisations by providing information about simple but effective solutions to these problems.

I would encourage the responsible planning and construction organisations to incorporate these guidelines in all relevant permits, contract specifications and internal guidelines in order to entrench good environmental practice in regular engineering undertakings.

Brian Robinson
Chairman
Environment Protection Authority

C O N T E N T S

1. INTRODUCTION

Aquatic ecosystems are easily damaged by eroded soil and other contaminants from construction sites, land subdivisions and other areas where soil is exposed. Water is a scarce resource and it is important to prevent it being polluted by muddy sediment wherever possible.

(a) Use of this booklet

This booklet has been prepared for the use of land development companies, civil engineering consultants, authorities involved with land use planning, departments involved with land use controls and any other interested groups.

With careful planning, the application of the techniques outlined in this booklet can help protect the environment at the same time as increasing construction efficiencies and reducing land development costs (references 19 and 24).

The quantity of sediment discharged from a site can often be minimised by a few simple techniques which have many on-site benefits. Many of these techniques, however, are easily overlooked. Techniques such as early revegetation often receive a low priority when there are many other problems to be solved.

One way to help reduce these problems is to include definitive pollution controls in construction site specifications, planning permit conditions, and. controls by the relevant Government authorities. The techniques listed in this booklet provide a basis for such controls.

To increase the chances of success, it is suggested that financial incentives such as bonuses and financial bonds or assurances be provided for adequately completing erosion and sediment controls.

Detailed design information, such as drainage works dimensions for different water flow rates, have been left to the province of more specialised books and manuals. A key publication for this purpose is Guidelines for Minimising Soil Erosion and Sedimentation from Construction Sites in Victoria (reference 22) available from the Department of Conservation and Environment.

(b) Advantages of Erosion & Sediment Control

With careful pre-planning, erosion and sediment control usually result in many on-site advantages in addition to protecting the environment.

Environmental benefits include:

- reduced risk of damage to aquatic ecosystems,
- improved appearance of the site and downstream waters,
- reduced water treatment costs,
- reduced blockage of drains,
- less mud dropped or washed onto roads.

On-site benefits typically include:

- less risk of works being undermined by erosion or buried by sediment,
- improved drainage and reduced site wetness as a result,
- less dust problems,
- improved working conditions,
- reduced downtime after rain,
- less stockpile losses,
- reduced dean-up costs,
- earlier works completion,
- earlier land sales,
- less chance of complaints by neighbours.

(c) Water pollution

Soil washed from land development sites is usually deposited as sediment in streams. This process can greatly increase the concentration of materials suspended and dissolved in streams and the durations and frequencies for which downstream waters remain turbid.

Water which flows or is pumped from land disturbance sites can be contaminated by suspended, dissolved, floatable and settleable soil materials, oils, detergents, litter, fertilisers, alkaline cement materials and other chemicals.

Soil nutrients and chemical pollutants become attached to and are transported by sediment particles as a result of soil erosion, dewatering of trenches, washing of vehicles, cleaning of concrete supply equipment, careless waste disposal and other similar incidents. Heavy metals and disease organisms also become attached to, protected by and transported on sediment particles.
These pollutants reduce the usefulness and enjoyment of the water environment to people downstream and damage aquatic life in streams, lakes and estuaries (references 4, 5 and 7).

Muddy sediment can smother stream beds where aquatic animals live, reproduce and obtain nourishment. Muddy material suspended in water can choke and abrade aquatic organisms and their eggs. Suspended material can also reduce visibility and the ability of many fish and other organisms to capture prey. Suspended and coloured materials can block sunlight and prevent the growth of aquatic plants (reference 4).

Sediment can fill dams and block waterways and drains, thereby increasing removal or dredging costs. Siltation of streams can reduce their capacities to carry flood waters and increase the risk of flooding as a consequence.

Muddy material in water can also degrade its aesthetic appearance.

(d) State Environment Protection Policy

To protect the quality of surface waters, the State Environment Protection Policy (Waters of Victoria) has been declared by Government (reference 44).

Under this Policy, controls are needed for construction and other land disturbance sites to protect the following beneficial uses of water from pollution:

- natural aquatic ecosystems and associated wildlife,
- recreation (swimming, boating and aesthetic enjoyment),
- agriculture (stock watering and irrigation),
- potable town water supplies,
- production of molluscs for human consumption,
- edible fish and crustaceans,
- industrial water uses.

The State Environment Protection Policy (Waters of Victoria) specifies water quality objectives and provisions to help achieve these objectives. These provisions include the minimisation of erosion on construction sites and along roads, streams and drainage lines. Acts of Parliament which are relevant to achieving such provisions include the Environment Protection Act 1970, the Soil Conservation and Land Utilisation Act 1958, the Planning and Environment Act 1987, the Local Government Act 1958 and other Acts which relate to land use and management.

(e) Other pollution problems

Many air, land and noise pollution problems are often considered at the same time as erosion and sediment control on land disturbance sites.

Soil stabilisation, for example, can reduce both sediment discharge and the generation of wind blown dust. Litter screens are often installed as important components of sediment traps. Construction activities can result in noise and land contamination problems.

For these reasons, many relevant aspects of air, land and noise pollution are outlined in this booklet. More detailed information about the control of these problems, however, can be obtained in the references listed at the end of this booklet.

2. STANDARDS

The State Environment Protection Policy (Waters of Victoria) requires that land disturbance activities be carefully controlled and soil conservation measures undertaken to minimise soil erosion and subsequent run-off of suspended, dissolved, floatable and settleable matter (reference 44).

Fine soil particles such as clays tend to remain suspended in water and are difficult to remove or settle out. Soil erosion can therefore result in streams being polluted by muddy sediment for long distances.

Environmental and engineering needs are usually interrelated. Structural stability of sediment trap dams, for example, is needed to ensure their long term safety and effectiveness; downstream sediment pollution can occur if the dams fail (references 2, 8 and 31).

For effective control of soil erosion, sediment discharge and associated problems, it is therefore important to use the best management practices available, commonly available technology and high environmental, safety and engineering standards.

(a) Suspended solids & turbidity

The State Environment Protection Policy (Waters of Victoria) specifies water quality objectives for light penetration or turbidity, suspended solids and settleable matter such as sediment (reference 44).

Figure 1. Eroded embankment and driveway which have not been stabilized during early stages in a housing subdivision area

Figure 2. This sediment from a roadside drain blocks stormwater pipes and can pollute rivers and creeks further downstream.

A major objective written into this Policy is the minimisation of soil erosion and the runoff of suspended, dissolved, floatable and settleable matter such as sediment.

To help achieve these objectives, it is suggested that runoff from land disturbance sites not be allowed to increase suspended solids concentrations in streams by more than 10% or 10 milligrams per litre, whichever results in the highest figure. Similarly, water turbidity should not be increased by more than 10 percent or 10 NTU's (see Glossary), whichever results in the highest figure. These water quality limits are suggested where a high level of protection is needed.

Other allowable increases in suspended solids concentrations and turbidity would need to be chosen on the basis of factors such as relative catchment areas, water runoff rates and the environmental qualities of the waters involved (references 5 and 29).

Water samples and tests to measure suspended solids increases would typically need to be taken along a stream just upstream and downstream of a location where contaminated runoff enters the stream. Water sampling within any one hour period could be specified in contract specifications, permits, notices etc. to provide sufficient sampling time.

In areas where waters have a good or excellent environmental quality (references 5 and 29), it may be necessary to prevent any land disturbance activities which increase sediment discharge rates. The State Environment Protection Policy (Waters of Victoria), for example, specifies no variation in water quality from background levels in aquatic reserves.

It should be noted that, under the Environment Protection Act 1970, the Environment Protection Authority may impose specific waste discharge quality limits on any premises, particularly those which are scheduled under the Environment Protection (Scheduled Premises and Exemption) (Amendment) Regulations: (reference 48).

(b) Water pH

Wastewaters from construction sites are often alkaline (ie: a high pH) where cement and lime are used. Schedule E of the State Environment Protection Policy (Waters of Victoria) requires that all waste discharges are maintained in the pH range of 6.0 to 9.0 pH units (reference 44).

It should be noted that Schedule B of this Policy requires that water pH in general surface waters is not altered from seasonal background levels by more than 1.0 pH value and 0.5 pH values for waters in parks, forests, estuaries and coastal areas.
No variation of pH from background values is allowed in aquatic reserves.

(c) Other pollutants

It is important to ensure that no scum, foam, grease, toxic substance, litter, visible oil or floating material flows from land disturbance sites (Sections 15 to 18).

3. GENERAL CONSTRUCTION PRINCIPLES

This section outlines some of the most important principles for erosion and sediment control on construction sites. By including these principles in contract specifications, planning conditions and other such requirements, the environment can be protected in addition to reducing land development costs.

(a) Land Use Intensities

Water pollution can be minimised or avoided by simply reducing or preventing an increase in land use intensities. This typically involves the planting or preservation of trees and other vegetation. Minimising the areas of land disturbed for residential development, roads and other facilities can protect the environment in addition to reducing development costs (references 24, 33 and 53).

(b) Early drainage

Soil erosion along drainage lines where water becomes concentrated is a major source of sediment which can flow unhindered into downstream waters. Works such as stormwater drainage pipes therefore need to be installed as quickly as possible and the exposed soil stabilised.

Such works should preferably be undertaken during dry seasons when there is least water flowing into drainage lines.

If deadline dates are not specified, a typical contract specification might be:

> Functionally connect stormwater drainage pipes and completely stabilize all drains, drainage lines, creeks, streams and river banks within thirty days of soil being exposed in such locations.

Shorter time limits may be needed for waters of 'good' or 'excellent' environmental quality (references 5 and 29). Even if drainage features are to be reconstructed at a later date, temporary stabilization is better and more cost effective than allowing long term erosion and sediment pollution.

Periods of soil exposure longer than thirty days may be acceptable if the water is diverted to more stable locations.

(c) Early stabilization

In many cases, the most significant reductions in sediment discharge can be achieved by a contract specification such as:

> Completely vegetate, pave, cover or stabilize all areas of exposed and unstabilized soil or loose material within 180 days of soil being mechanically or manually exposed in such locations.

Shorter time limits may be needed for waters of 'good' or 'excellent' environmental quality (references 5 and 29). Early stabilization can also help prevent problems such as dust hazards and weed invasion of exposed land. Where schedules are known, it may be possible to specify deadline dates for works to be stabilized.

Longer time periods may be acceptable if extraneous run-off water is diverted away from areas of exposed soil and sediment is trapped in large dams or broad densely vegetated areas.

In any situation, it is desirable for contract specifications to require soil stabilization works to be undertaken as soon as final surface contours are achieved.

Figure 3. Drainage line which has not been stabilized early.

(d) Water diversion

It is important to divert water along stable diversion drains, banks or bunds around or away from exposed areas of soil or loose material (see Section 12). This is often one of the easiest and cheapest ways of preventing erosion and sediment runoff.

(e) Sediment and litter control

To prevent sediment and other matter flowing into drainage systems, sediment and litter traps may be needed. Such structures should be constructed from heavy duty materials in accordance with Sections 13 and 15. Sediment trap dams and basins should also be constructed, wherever practicable, downstream from and prior to earthworks operations.

(f) Delegation

It is important that developers and construction site workers are aware of all relevant erosion and pollution control objectives and techniques. Knowledge and skills in these aspects should be increased as much as possible, by providing training sessions and accurate plans and specifications. Ideally, a specialist person or group with relevant training or experience should be provided to plan, advise, supervise, install and maintain erosion and pollution control works.

(g) Maintenance

All pollution control works should be inspected on a regular basis and maintained or repaired to ensure their ongoing effectiveness. At these times, reassess their operation and improve their effectiveness wherever possible.

4. EARLY PLANNING

Consideration of erosion and sediment controls during early planning stages is important to minimise their cost and maximise their effectiveness.

(a) Prior planning

Erosion and sediment control plans, specifications and schedules for development sites should be prepared prior to the commencement of works and submitted to the relevant groups.

Relevant information about the area such as soil characteristics, geology and land capability maps should be obtained at the earliest stages.

When planning finance and labour needs, it is important to allow for erosion and sediment controls <u>additional</u> to usual contingency allowances.

Figure 4. Drainage line and hillside which have been stabilized during early construction stages.

(b) Avoid sensitive areas

Wide buffer areas of dense vegetation need to be provided along the margins of streams, drainage lines and other surface water features (Section 6). Excavations or earthworks should be confined to land with gradients less than 20% (5:1 horizontal: vertical) and preferably less than 8% (reference 33). Avoid works which increase landslip risks and avoid disturbing environmentally sensitive areas.

Maps showing land capability ratings, vegetation types, stream values etc. can help to identify sensitive areas (see references).

(c) Site plans

Site plans of the 'premises should be drawn to scale showing existing and proposed works, site gradients, closely spaced contour lines, drainage systems, easements, boundaries, direction, permanent survey marks, scale(s) and other relevant features, prior to undertaking works.

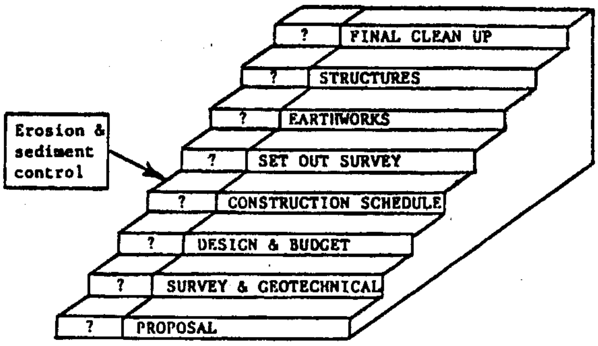


Figure 5. Erosion and sediment control plans should be part of every construction phase.

(d) Catchment plans

Location plans should be prepared or aerial photographs marked to show the premises, catchment boundaries, gradients, land uses, soil types, landslip risks, flood zones and other relevant features prior to undertaking works.

(e) Tenders & Permit Applications

There are many topics relevant to erosion and sediment control which are not included in this booklet, which should be outlined in project specifications, planning permit applications, tenders etc. It is suggested that the following sections be considered for inclusion in such applications:

- project description,
- schedules,
- location plans,
- land capability,
- erosion & sediment controls,
- noise control,
- flora, fauna & aquatic life,
- maintenance & waste disposal,
- financial budgets & bonds,
- training & supervision
- plans showing –

  allotments & easements existing & proposed works existing & proposed contours site drainage & gradients land capabilities & soil types landslip risks existing & proposed vegetation catchment characteristics buffer areas & nearby landuses earthworks, stockpiles etc erosion & sediment controls,
- works cross sectional drawings,
- water discharge calculations.

(f) Subdivisions & works layout

Developments should ideally be designed to conform to existing land contours in ways which minimise soil exposure and potential soil erosion and sediment discharge rates.

Wherever practicable, roads and buildings should be located on gently sloping land along or near ridgelines or where there is least risk of soil erosion. Locating roads so they follow actual land contours can also minimise earthworks and erosion risk.

Wherever possible, roads should not be located along drainage lines where the risks of soil erosion and sediment pollution are high. In general, steep land with terrain that requires such road locations should not be chosen for subdivision development.

Allotment boundaries should coincide with streamside buffer boundaries and allow easy access to streams in case erosion controls or other such works are needed in the future. Subdivision boundaries across drainage lines and streams should also be prevented or minimised to provide easy access for erosion controls if needed in the future.

(g) Water discharge calculations

To minimise the risk of drainage works being overtopped by water and soil being eroded, it is important to calculate peak water flow rates and velocities.

These should be calculated for standard design stormwater recurrence intervals for all drainage and sediment control works. The recurrence intervals needed depend on the situations and may vary from about one year for temporary works where there are low environmental risks to 100 or more years for permanent works in areas with high environmental risks. References 22 and 25 list typical recurrence intervals.

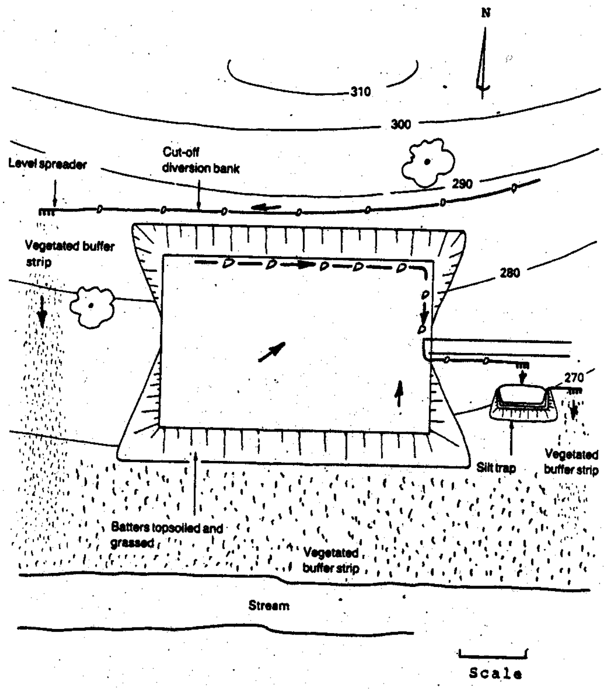
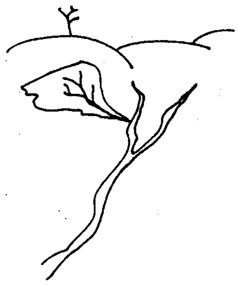


Figure 6. Typical construction site plan showing erosion and sediment controls.

Table 1. Summary of erosion and sediment controls: water erosion in general, sheet and rill erosion.

Definitions	Main Causes	Typical Solutions	Key Sections (in this booklet)
Water erosion in general Erosion is defined as the detachment or wearing away of materials such as soil. Water erosion can occur in various forms such as sheet, raindrop splash, rill, gully, channel side and channel bed erosion. Tunnel erosion and landslips are also relevant. These can occur in varying combinations with one form predominating. More detailed information is contained in Tables 2 to 5. 	The forces imposed by flowing water which increase as water velocities or flow rates increase.	Reducing or preventing an increase in land use intensities. Reductions in water flow rates or velocities such as by: • diversion of water to stable locations, • increasing water infiltration into the soil by deep ripping or revegetation, • increasing water use in catchments by growing vegetation, or • conversely, by minimising • the area which is hard paved, • providing wide buffer areas of • dense vegetation alongside • streams & other water features, • installing flood detention dams. Well supported retaining walls, subsurface drains &/or tree planting to hold steep land such as occurs along hillside cuttings. Protection of exposed soil with dense vegetation or material such as crushed rock or pavement Sediment trap dams or structures Water treatment or filtration	1 to 10, 12 to 18
Sheet & rill erosion Sheet erosion is the relatively uniform removal of soil or material from an area without conspicuous channel formation. Rills are eroded channels less than 300 mm deep.	Water flowing across & removing exposed soil. Rates of sheet & rill erosion are increased by the turbulence created by rainfall. Raindrop splash also dislodges & transports soil downhill.	Establishment of dense vegetation. Other solutions as listed above.	6 to 9

5. CLEARING OF VEGETATION

Many erosion and sediment control problems can be avoided by maximising the areas of vegetation retained and by careful clearing techniques.
Such strategies should be considered during early planning stages.

(a) Clearing controls

Under planning schemes and other government legislation, the clearing of vegetation may not be possible without permits, licences or approvals from the responsible government authorities.

A permit may need to be obtained from the local municipal council, for example, for the clearing, removal, destruction or lopping of native vegetation. Controls may also be required under the Flora and Fauna Guarantee Act 1998, the Code of Forest Practices for Timber Production and the Timber Harvesting Regulations 1989 (references 9, 50 and 51). The preparation of clearing, revegetation and environment protection plans, outlines and schedules may assist in the provision of appropriate permits or approvals to clear vegetation.

(b) Minimise or prevent clearing

To minimise the risk of soil erosion and sediment pollution, existing vegetation should be retained wherever feasible.

The preservation of vegetation is particularly important on steep land or in buffer areas along drainage lines where the risks of soil erosion are greatest. Vegetation needs to be protected in and around environmentally significant waterbodies such as wetlands. Vegetation may also need to be preserved in catchments to streams of high or excellent environmental value to protect aquatic ecosystems (references 5 and 293.

If it is necessary to clear vegetation; the area cleared at any one time should be minimised.

(c) Windrows

Windrows of cleared vegetation should be placed along the contour rather than directly up and down slopes. This approach tends to assist in the trapping of sediment.

(d) Burning off

Wherever possible, convert cleared vegetation into mulch or sawn logs rather than burning it on the premises. If burning materials on the premises, abide by local municipal laws and EPA guidelines.

(e) Rough cultivation

After clearing vegetation, it may be desirable to leave the soil surface in a rough condition or cultivate so as to leave large clods of soil. This will increase the infiltration of water into the soil and reduce water runoff and soil erosion as a result. Contour or across-slope ripping can also reduce water run-off rates.

6. BUFFER AREAS OF VEGETATION

Wide buffer areas of dense vegetation around development sites and along streams can significantly reduce water, air and noise pollution.

(a) Premises boundaries

The planting of appropriate types of trees in buffer areas preferably wider than 30 metres around the boundaries of premises can often improve visual appearances in addition to controlling sediment and dust pollution.

(b) Drainage features

Wherever possible, establish and maintain buffers of dense grasses or ground cover vegetation at least 30 metres wide alongside drainage lines and other surface water features. Such buffer areas can help prevent soil erosion in addition to trapping sediment and other pollutants.

Streamside buffer areas may not be possible for some high intensity landuses such as urban development. In such areas, stable drainage works should be completed as early as possible.

In pristine areas such as dense natural bushland, it may not be possible to prevent damage to aquatic ecosystems if buffer areas are less than 100 or even several hundred metres wide. To protect streams of high or excellent environmental value (references 5 and 29), it may be desirable to prevent any increases in land use intensities throughout the catchments to these streams.

(c) Mark vegetation boundaries

Boundaries for buffer areas and areas for vegetation establishment or protection are often difficult to identify during works operations. This can be overcome by using painted pegs, rip lines, fences, signs, coloured ribbons, spray paint lines or other obvious markers about which site workers have been previously advised.

7. ESTABLISHING VEGETATION

Establishing or preserving dense vegetation is often the cheapest way of preventing soil erosion and sediment pollution. Checking on the range of different plants available and assessing their growth requirements can greatly improve the chances of success.

(a) Vegetation requirements

The establishment requirements of plants need to be identified prior to commencing site works. Relevant factors include local climate, soil nutrient levels, site wetness and soil pH.

(b) Topsoil & mulch

Plants grow better in loamy topsoil than clayey subsoil. To assist plant establishment, spread loamy topsoil on all exposed areas of subsoil where vegetation is to be established and soil amelioration is not planned to be used. The subsoil should be contour ripped or scarified to assist plant establishment.

(c) Minimise fertilisers

If fertilisers are used, they should be applied at the minimum rates required, and mixed or combined with the surface layers of soil or mulch. Prevent the drift of fertilisers across streams, drains or other locations where water pollution may result. Along streambanks, high application rates of appropriate seed types and resowing if and when needed, can often compensate for a lack of fertiliser.

The need for nitrogen fertilisers can be avoided by sowing nitrogen fixing legumes such as clovers to assist grass establishment. Additional information about plant nutrition can be found in references 3, 6 and 10.

Figure 7. Grass has fibrous roots to hold the soil and flexible leaves to absorb rain impact.

(d) Temporary vegetation

When a temporary cover of vegetation is required, consider the use of a cereal cover crop for rapid establishment. Resow or undersow cover crops with suitable plant species where soil protection is required for more than one year. Use vigorous growing but non-competitive plant species where a temporary cover of vegetation is required prior to establishing native plant species.

(e) Establish vegetation early

Establish dense vegetation as soon as practicable on all areas of exposed soil for which other stabilization techniques or sediment trap devices are not completed.

As a "rule of thumb", dense vegetation should be established, even if temporary, within 180 days of soil being exposed and not further excavated or covered (see Section 1).

Longer establishment times may be required for native vegetation. Even so, cereal cover crops can be used to provide temporary soil protection while undersown native plants become established.

If areas becomes too boggy for mechanical sowing or planting techniques, it should be noted that manual techniques are often possible.

Grass sods or sprigs, irrigated during dry periods, can provide an immediate cover of vegetation.

(f) Irrigation

Areas which are newly sown to grass or planted with seedlings should be irrigated during excessively dry periods to help achieve dense plant growth.
This can help to provide a protecting soil cover prior to possible erosive rainstorms and is particularly important on steep land or wherever water run-off becomes concentrated. This approach can reduce the need for resmoothing of rifled surfaces after rainstorms and the use of expensive mulch and netting. It can also avoid expensive resowing if rainstorms wash away unprotected seed and fertiliser.

Irrigation from dams, streams, springs or truck water tankers may be possible if reticulated water is not otherwise available. A water tanker holding 20,000 litres of water, for example, can irrigate one hectare to a depth of 2mm. Four or so irrigations can provide the equivalent of a gentle rainfall of 8mm. Pumps and rotating spray irrigators attached to water tankers are commercially available.

(g) Trees and bushes along gullies

When trees or bushes are used to stabilize eroded gullies, they usually need to be planted alongside each other on each side of the gully.

This helps prevent water being deflected around individual trees and initiating gully side erosion.

(h) Plant damage

Trees and bushes are easily killed by soil excavation or deposition. Excavations or fill material can alter water drainage patterns and water table heights. This can result in waterlogging or soil drying and death of the plants.

Soil compaction, oil or chemical spillages and direct damage to trunks, branches or roots can also result in plant death. Solutions to these problems are outlined in references 13, 22 and 41.

8. MULCH

Thin layers of mulch are needed to conserve soil moisture and assist plant growth. Thick layers of mulch material can be useful where needed to suppress weed or other plant growth and to help protect soil from erosion.

(a) Mulch types

Mulch materials include straw, hay, gravel, paper mache fibres, wood fibres in plastic mesh, sugar cane fibre matting, chipped tree branches, coarse wood shavings and tan bark. Thin layers of mulch are particularly needed where vegetation is to be established but topsoil is absent from soil surfaces or where batters are steeper than 3:1 (horizontal:vertical).

(b) Mulch stability

Thin layers of mulch can be displaced by wind or stormwater. This can be prevented by holding down the mulch by a material such as plastic mesh or possibly by crimping the mulch into topsoil with cleated rollers or bulldozer tracks.

Bitumen is sometimes useful for holding down mulch. If bitumen or other adhesive liquids are used, they should be applied in ways which do not pollute water, drift onto neighbouring properties or cause a public nuisance.

Plastic mesh can be useful to hold down mulch until plants become established because it breaks up under the influence of sunlight. Steel mesh, however, can become a safety hazard when loose and rusted. If steel mesh is used to hold down mulch, it should be removed when grass becomes established to allow the growth of trees without trunk damage.

Loose mulch should have gentle surface gradients to prevent it being washed away during heavy rainstorms. Wherever possible, divert extraneous water around or away from mulched areas to prevent the mulch being washed away.

(c) Mulch storage

Avoid storing mulch in thick layers to prevent decomposition and resultant heat build up and the risk of spontaneous combustion. Decomposition and combustion of mulch materials can result in fire risks, offensive odours and air pollution. Keeping the mulch dry can also help to prevent these problems. Typical solutions include the use of tarpaulins and enclosed composting bins.

Figure 8. Chopped straw and bitumen being blown onto a batter. Care is needed to prevent bitumen drifting onto nearby property.

9. EARTHWORKS

In general, earthworks should be stabilized as early as possible to minimise the risk of soil erosion and sediment pollution.

(a) Protect exposed soil

The following controls are needed where sediment trap structures are not available and soil is to remain exposed for more than a few months or vegetation is difficult to establish:

- divert extraneous water runoff away from exposed soil,
- contour plough or deep-rip so as to leave a rough cloddy surface,
- provide protective covers, and/or
- construct gently sloping diversion banks at frequent intervals (see Section 12h).

(b) Dry season work

Whenever possible, confine earthworks operations, particularly those along drainage lines, to months which have least average rainfall and hence, lowest risks of soil erosion.

(c) Wet season work

During winter months, confine earthworks to locations where there is a low risk of soil erosion and sediment discharge from the premises. This approach can also avoid waterlogging problems.

(d) Staged earthworks

Wherever practicable, work in staged sections so that no more than a specified area of soil is disturbed or exposed at any one time.

(e) Soil testing & treatment

Soil tests are often advisable to assess the erodibility of soil and its suitability for establishing vegetation. Agricultural lime, for example, may be needed for effective plant establishment if the soil is acidic. Poorly structured clayey soil may need gypsum or suitable organic matter to make it more friable.

Slaked lime may need to be carefully mixed into subsoil to reduce soil erodibility and improve its engineering characteristics. Cement can also be mixed into soil to reduce its erodibility and to provide a more solid surface. Pollution of runoff water should be prevented, such as by thoroughly mixing lime and cement into soil, adding water then compacting the soil to good standards.

(f) Batters

Batters (see Glossary) need to be constructed at stable gradients to prevent land slip. The slippage of steep land into drains can be a major source of sediment pollution. Stable gradients depend on soil types, batter heights and subsurface drainage and vary from 1:1 to less than 4:1 (horizontal:vertical). The gradients and design of dam embankment batters are detailed in references 22 and 31.

Gently sloping berms or benches are often needed to increase the stability of batters higher than about six metres. Berms or benches should be free draining and not contain depressions where water ponds. Pondage of water can result in landslip or tunnel erosion. Soil compaction and paved drains may also reduce these problems.

The advice of geotechnical consultants may be needed for batters higher than about six metres or batters in dangerous or difficult situations.

(g) Topsoil

Plants grow better in loamy topsoil than in clayey subsoil with little organic matter. Exposed subsoil should be contour ripped or scarified to assist plant establishment and to reduce topsoil slippage or erosion. Where practicable, spread topsoils from areas being excavated directly onto previously completed earthworks. This can reduce costs, reduce damage to plant seeds in the topsoil and result in earlier stabilization. Otherwise stockpile or transport topsoils separately from subsoils for later respreading or use.

(h) Topsoiling batters

Rip, scarify, step or otherwise roughen earthen batters which are to be stabilized with vegetation and are steeper than 3:1 (horizontal:vertical). This is needed to increase the penetration of plant roots and help prevent topsoil slipping downhill. Spread loamy topsoil 70 to 100 millimetres thick on such batters. Thicker layers of topsoil tend to slip off steep batters.

"Rounding off" batter crests and toes can further reduce the chance of erosion and makes mowing easier.

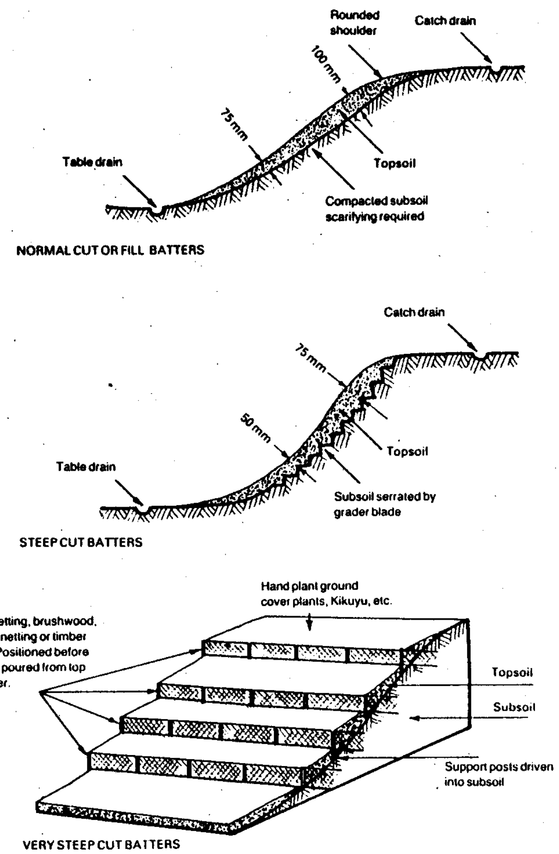


Figure 9. Techniques for retaining topsoil on batters.

Table 2. Summary of erosion and sediment controls: tunnel erosion & landslips.

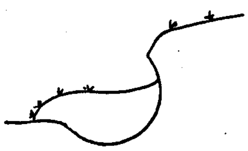
Definitions	Main Causes	Typical Solutions	Key Sections (in this booklet)
Tunnel erosion Tunnel erosion is the removal of subsoil by water while the surface soil remains intact. 	Concentrations of water flowing through holes or cracks in the subsoil. Concentrations of subsoil water can result in the progressive sloughing or sapping of subsoil which creates a tunnel progressively eroding uphill.	Ripping and compaction of soil into tunnels plus water diversion to stable locations. Impermeable barriers such as compacted clay plugs may be needed to prevent water flowing along large tunnels. These should be deeply entrenched into the tunnel sides & floor. Diversion drains or banks should be check surveyed at completion to ensure that water does not pond & cause more tunnel erosion. Paving of diversion drains may also reduce this problem. Control of burrowing animals such as rabbits	7. 9, 12
Landslip or mass movement Collapse or downhill slippage or movement of soil, rock, or other material. This can be a significant source of sediment pollution when the material collapses into streams or other drainage lines. 	Land or embankments with gradients steeper than their natural angle of repose. Concentrations of subsoil moisture which lubricate the soil & exert increased water pressures within soil pores and cracks. Undermining which results in material collapse due to gravity.	Deep rooted vegetation. Subsoil drainage. Well buttressed or entrenched retaining walls with subsurface drainage works. (Sloping of retaining walls uphill can resist downhill movement). Diversion of surface waters to stable locations. Batter gradients less steep than their natural angle of repose. Pavement above embankments may help divert water & prevent water infiltration into slip prone material.	9. 12

Figure 10. Batter scarified across-slope to trap topsoil and assist grass establishment

(i) Steep batters

It is usually difficult to retain topsoil on batters steeper than 2:1 (horizontal:vertical). On steep batters, topsoil can be retained by installing horizontal boards, mesh, branches, logs or other suitable material held and secured by vertical stakes, rods or other methods. Fibre mesh or mulch pinned firmly onto batters can also help to trap topsoil.

(j) Retaining walls

Retaining walls need to be constructed to good engineering standards with adequate drainage and foundation or buttress support. This is particularly important where batters are higher than about two metres and steeper than 2:1 (horizontal vertical), or otherwise unstable and not stabilized by deep rooted vegetation or other appropriate means. Construction of retaining walls higher than about one metre may need a building permit from the responsible planning authority.

(k) Avoid water jetting

Use mechanical excavation, scraping or sweeping rather than water jetting techniques to remove soil or loose material from pipes and other such locations. Water jetting tends to produce discharges which are highly polluted with suspended and dissolved materials. If it is necessary to drill through soil using water rather than rotary boring or other mechanical techniques, then large sediment traps, settlement areas or filters will be needed. Eductor or vacuum tankers can sometimes be used to remove sediment from pipes and drainage pits.

10. STOCKPILES

Stockpiles of topsoil, sand and building materials are valuable commodities. Preventing their erosion can help prevent pollution, prevent the spread of weed seeds and save money.

(a) Location

Place all stockpiles of soil, sand, fertiliser, cement or other fine loose material in locations away from drainage lines, roadside channels and culverts unless adequately protected from erosion by diversion drains, bunds or similar works.

(b) Temporary uses

Stockpiles of soil can often be used for the construction of small sediment trap dams and diversion banks, provided they are adequately compacted and stabilised. The soils used should have characteristics suitable for the particular job and water flow rates involved.

(c) Topsoil stockpiles

Stockpile topsoils separately from subsoils. Don't mix topsoils and subsoils during excavation or fill operations. This will assist plant establishment and reduce soil settlement and surface drainage problems.

Where practicable, avoid stockpiling large depths of topsoil for more than a year to maintain the virility of plant seeds and soil organisms.

(d) Protective Covers

Where possible, contain all stockpiles of loose erodible material in storage bins or cover them with tarpaulins or dense vegetation. This is particularly important if stockpiles remain in place for more than about six months and would otherwise contribute to sediment discharge from the premises.

(e) Stockpile Removal

Remove any stockpiles which cannot be stabilized or protected from erosion and treat, use or relocate them in a way that does not result in sediment discharge from the premises.

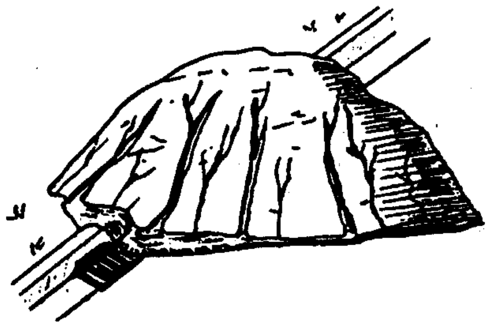


Figure 11. Stockpiles of loose material should be located away from drains

11. DUST CONTROL

Wind blown dust is a major nuisance on many construction sites and adjoining properties during dry seasons. Many techniques to control soil erosion by water can also prevent wind erosion. Dust control can improve working conditions, reduce vehicle maintenance needs and reduce the chance of neighbour complaints.

a) Exposed areas

Dust from exposed soil or stockpiles can often be minimised by one or a combination of the following techniques:

i) establishing vegetation;
ii) cultivating or ripping soil and leaving it rough, cloddy or furrowed;
iii) applying a surface cover such as gravel or a mulch of water and paper mache fibres;
iv) covering exposed material with tarpaulins or woven membranes such as geotextiles;
v) surface stabilizations using lime or cement plus water;
vi) regular spraying with water;
vii) installing semi-permeable wind breaks.

Windbreaks with about 50% permeability are needed to minimise wind turbulence. They should be of a height equal to one tenth of the horizontal distance of exposed land to be protected.

If dust suppressants such as those containing latex or wetting agents are used, they should be applied away from water channels or any place liable to result in pollution.

(b) Roads and tracks

Dust blown from unpaved roads and tracks can be reduced by covering them with a pavement such as compacted gravel, by stabilization using cement followed by compaction when moist, or by the regular spraying of water. Other dust suppressants must not themselves cause environmental pollution.

(c) Building dust

Dust from stone, pavement, metal, plastic or wood cutting or shaping operations can become a nuisance to the public and an environmental hazard. It can be controlled by the use of wet sawing, grinding or smoothing techniques or adequate dust extraction systems. Extraction and clean-up systems include filter bags, cyclone separators and wet vacuuming equipment. Wastewater from such operations must not be disposed to the stormwater system but disposed at appropriately licenced facilities.

Table 3. Summary of wind erosion controls.

Dust Source	Main Causes	Typical Solutions
Wind erosion Wind erosion is the detachment and transport of loose material such as soil by wind. 	Removal of vegetation Removal of windbreak or poor location of windbreaks which results in funnelling or other concentration of wind. Import and placement of material which is not protected from wind. Dust caused by construction vehicles.	Establishment of dense vegetation or early placement of pavement or other coverings where appropriate. Covering exposed surfaces with mulch such as paper mache or straw held in place by plastic mesh or bitumen. Leaving surfaces in a rough cloddy condition Covering exposed surfaces with thick layers of rock or gravel Installing semi-permeable wind breaks which are less likely to cause wind turbulence than solid barriers. Care may be needed to prevent wind funnelling between wind breaks & other barriers. Frequent water spraying to dampen exposed surfaces.

12. DRAINS, DIVERSIONS & STREAMS

Rates of soil erosion are often greatest where runoff water becomes concentrated along drainage lines and streams. Erosion controls in these locations can therefore have a major effect in reducing the risk of downstream sediment pollution.

(a) Protect drainage lines & surface waters

Wherever possible, avoid exposing or depositing soil or loose material in or along drainage lines or other surface water features.

(b) Buffer areas

Establish and maintain wide buffer areas of dense vegetation along the margins of streams, drainage lines and other water features (Section 6).

(c) Discharge rates

Peak stormwater discharge rates should be calculated and drainage works designed to cope with these discharge rates.

Discharge rates and works dimensions can be calculated on the basis of references 22, 25 and 40 listed at the end of this booklet. This is particularly important if water discharge rates are likely to increase when catchments become hard paved. Channel capacities should include an allowance for dense vegetation which is often needed to prevent soil erosion and sediment pollution.

(d) Water discharge reduction

Wherever practicable, reduce the rates of water discharge which may increase the rates of downstream erosion and sediment pollution.
This can sometimes be done by the use of flood detention basins, gravel filled seepage pits, porous or perforated pavement over drainage underlays and drains lined with crushed rock. Contour ripping or revegetation of catchment areas can also reduce water runoff rates.

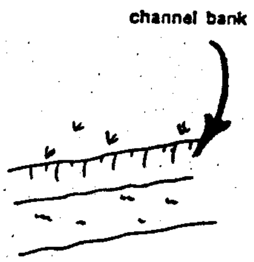
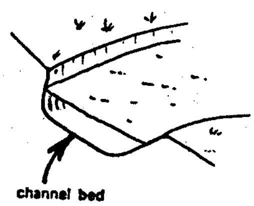
(e) Legal discharge

Undertake all works in ways compatible with the requirements of local drainage Authorities. Obtain approval to discharge water to a drain or drainage system vested in or under the control of any person or body.

Table 4. Summary of erosion and sediment controls: gully head erosion.

Definitions	Main Causes	Typical Solutions	Key Sections
Gully head erosion Erosion of the upstream end of a gully or other drainage line, usually as a vertical face or steeply sloping channel. Gullies are eroded channels 300 mm or more deep.	Soil scouring by increased water velocities or turbulence. Mobilisation & removal of soil by groundwater seepage. Soil slippage or collapse due to undermining.	Water drop structures or chutes. These typically need: • erosion resistant materials, • sufficient capacities, • stable channel gradients & works to prevent undermining, • downstream stilling basins, • wing walls & anti-seepage barriers of sufficient widths & depths, • soil filter layers or membranes (if well supported impermeable barriers are not used), • drains or barriers to prevent hydrostatic water uplift. Diversion of water to stable locations. This may permit the filling of minor gullies with compacted soil. Topsoiling & grassing complete the process. Devices or techniques to allow fish migration or passage may be needed	12, 13

Table 5. Summary of erosion and sediment controls: channel bank and bed erosion.

Definitions	Main Causes	Typical Solutions	Key Sections (in this booklet)
Channel bank erosion Erosion of the sides of a gully, creek, stream, river or other drainage line. 	Soil scoured by high water velocities such as occur at the outside bend of river meanders. Other factors as listed for gully head erosion above.	Soil protection such as by: • dense vegetation, • anchoring brush or timber against banks, • groynes to deflect water away from banks, • realignment of channels using heavy gauge fencing, vegetation, placing river stone etc., • removal or re-alignment of timber snags, • large diameter rocks over soil filter layers, • paving or piping. The particular technique should be chosen on the basis of the beneficial uses of the channel such as protection of aquatic ecosystems (including fish passage), recreation, potable water supply, commercial fishing, aesthetic requirements etc. Other solutions as listed in Table 4	12
Channel bed erosion Erosion of the floor of a gully, creek, stream, river or other drainage line. 	Factors as listed for gully head & channel bank erosion above.	Reduction in channel gradients by increasing channel length or by installing water drop structures or chutes. Other solutions as listed above.	12

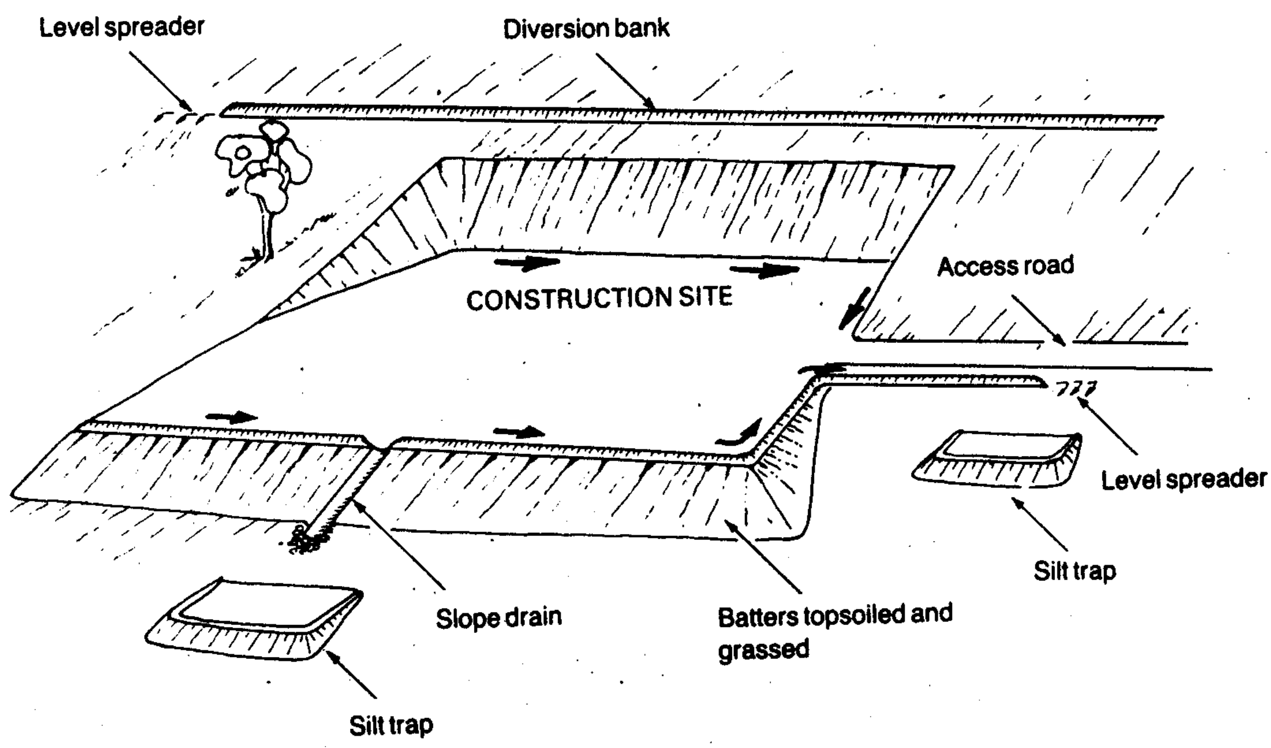


Figure 12. Typical drainage works to minimise soil erosion and sediment pollution.

(f) Subsurface drainage

Subsurface drainage systems include gravel filled (dutch) drains, slotted or perforated pipes along gravel filled trenches and thick filter membrane materials. Subsurface drains can greatly increase the stabilities of steep batters. Site wetness problems can also be reduced by subsurface drains.

Drains may also be needed to intercept contaminated water seeping from storage dams and other sources for diversion or pumping to secure facilities (see also Sections 14 and 18).

(g) Water diversion

It is important to divert water along stable diversion drains or banks around or away from exposed areas of soil or loose material. This is often one of the easiest and cheapest ways of preventing erosion and sediment runoff.

Works along streams often require water to be diverted around the work site. Such diversions are often excavated as vertical trenches. If these are excavated into highly erodible soils or are to remain for more than about thirty days, they should be protected by temporary membranes or other works listed in sections (i) to (k) below.

(h) Construction of earthen diversion banks.

Earthen diversion banks can be used to intercept and divert water away from erosion prone sites to stable locations.

Earthen diversion banks can be constructed by pushing soil downhill into a long mound (a “cut and fill” diversion bank) or by pushing soil uphill (an “all fill” diversion bank).

To avoid diversion bank channels becoming eroded, they need to be surveyed at gradients no steeper than about 05%, unless they are stabilized prior to the occurrence of rainstorms (see pages 181 to 220 of reference 22).

To prevent soil slippage, diversion banks and their channels need to be constructed with stable side gradients, typically no steeper than 2:1 (horizontal:vertical).

Good soil bonding, compaction and revegetation are needed to prevent diversion banks becoming rill or tuned eroded. Surface vegetation and at least 50mm of topsoil should be stripped from below diversion bank areas, exposed soil furrowed and the bank compacted in thin layers when moist. It may be necessary to add water to enable effective soil compaction.

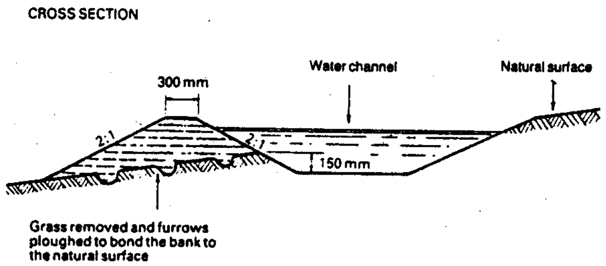


Figure 13. Cross section of a “cut & fill” diversion bank

Final check surveying is needed to ensure that water does not pond in depressions along diversion banks and cause tunnel erosion or landslips.
Soil compaction and paving of drains can also reduce these problems. Topsoil should then be respread on exposed subsoil and grass established as early as possible to prevent erosion damage.

If a diversion bank diverts water onto a vegetated hillside, its outlet should be horizontal and spread water in a thin sheet to minimise water velocities and resultant erosion risk. It is important that outlet areas be densely vegetated and maintained on an ongoing basis to prevent rill erosion. (See Section i below).

(i) Channel stabilization

One or a combination of the following techniques can be undertaken to prevent soil erosion along drainage lines, streams and other channels. The techniques needed will depend on factors such as channel gradients and water velocities, and should be selected on the basis of publications referenced at the end of this booklet (particularly references 7, 22 and 25).

All the beneficial uses of streams should be considered when planning works, including the maintenance of aquatic ecosystems. Deep pools and submerged logs, for example, may be needed for the survival of some fish and crustaceans. Timber snags, however, may need to be removed along some streams for the protection of canoeists and boats.
A variety or combination of treatments along different parts of streams may provide sufficient variety for a range of aquatic life and other uses.

Final stabilization works should be completed in as short a time as possible to minimise the risk of erosion and resultant sediment pollution. In some cases, it may be possible to complete stabilization works progressively or in sections to minimise the area of soil exposed at any one time.

Any techniques chosen should be in accord with the requirements of the responsible drainage authorities.

i) Grass:

Where peak water velocities are no more than about 2 metres per second, dense grass or pasture can often be used to protect the soil from erosion (references 22, 25 and 40).

The grass should be grown in topsoil 50 mm to 70 mm thick over roughened or surface-scarified subsoil. Thicker layers of topsoil or hard layers of subsoil may not allow plant roots to penetrate the subsoil and result in topsoil erosion or slippage.

Soil can be eroded or vegetation killed where outlet areas are steep or water flows for long durations.
To prevent soil erosion in these situations, water should be directed down trickle flow pipes or paved drains. Water loving plants such as sedges may be suitable to stabilize channels in some cases.

Figure 14. Stream banks stabilized by dense native vegetation.

Drains should have broad flat “spoon” shaped floors with sides no steeper than 2:1 (horizontal:vertical), rather than narrow “V” shapes, to minimise water velocities and erosion risk.

Grass downstream from eroded areas can be killed by the long term abrading and smothering effect of sediment. In such cases, the eroded areas should be stabilized Otherwise structural erosion and sediment controls will be needed along the drains.

ii) Mulch matting

To protect grass seed and topsoil applied along minor or intermittent drainage lines, use a cover such as dense sugar cane fibre matting covered with a protective plastic mesh, entrenched and pinned down (reference 21). Thickly woven jute mesh might also be used in such locations (reference 32).
Light duty mulch, such as straw or wood fibres held under mesh, is seldom effective along drainage lines because soil particles, grass seed and fertilisers are easily washed from below and through gaps within such materials

iii) Other plants

Appropriate species of sedges, cane grass, shrubs and trees with deep fibrous roots may be suitable for the stabilization of stream banks and waterlogged locations. Such plants are often combined with and are longer lasting than many structural stream stabilization works.

iv) Fences:

Fences along streamside and other buffer zones are needed to prevent damage to stabilizing vegetation by livestock, vehicles or people. Warning signs may also help in come cases

v) Rock armouring

A surface armouring or beaching of rocks can be used to protect channel beds and banks from erosion. However, the rocks need to be large enough to resist dislodgement by peak water flows (references 22, 24 and 40). Otherwise heavy gauge steel mesh may be need to be placed over the rocks to prevent them being dislodged by flood waters.

The most economic and environmental approach along channel banks may be to install rock to a height no more than that required to prevent bank erosion. Dense vegetation could then be used to stabilise higher portions of the bank.

A soil filter underlay is needed to prevent the rocks from being undermined. Soil filter underlays typically consist of crushed rock with average diameters of about 60mm or synthetic geotextile filter membranes. Small diameter rocks may not be needed to filter soil if the surface layer of rocks is thick enough and precautions are made to prevent tunnel erosion in erodible soils (reference 22).

Figure 15. Thick layer of rocks with a large size range

It should be born in mind that geotextile filter membranes tend to prevent the growth of plants. This may be an advantage where uninterrupted water flows are required but a disadvantage along stream banks where it is desired to promote the growth of vegetation. Topsoil interspersed amongst rocks can assist in establishing vegetation.

Figure 16. A few large rocks by themselves are seldom adequate to prevent side scour.

Rocks need to be shaped to form a channel large enough to prevent side scour by storm waters. Crushed rocks should be compacted to form an erosion resistant pavement.

It is worth noting that crushed rock along roadside drains in residential areas can help improve the quality of runoff water in addition to controlling erosion. Rocks should be thick enough for water to trickle through the lowest layers where microbes help break down pollutants. The base of such drains should be evenly graded to prevent water ponding and becoming stagnant.

vi) Gabions

Rock in steel mesh gabions or mattresses are sometimes used to protect stream banks. Soil filter underlays and seepage barriers are needed to prevent undermining of such gabions or mattresses. Other comments in the above section on rock armouring are also applicable.

viii) Pipes:

Subsurface stormwater or trickle flow pipes may be needed below or beside densely vegetated channels to prevent vegetation damage. This may be particularly needed where stormwater runoff rates are increased by the hard paving of urban areas. Stormwater pipes with safety grills may also be needed for public safety reasons.

When installing pipes, use the correct pipe class and connection types for the water pressures and in-service stresses involved.

Where temporary protection of minor drains is needed, it may be possible to butt pipes end-on-end prior to final positioning. Flexible pipes can sometimes be used for temporary drainage in steep locations.

Anti-seepage collars may be needed around pipes where there is a risk of side scour or tunnel erosion along the pipelines. Headwalls and inlet structures are usually needed to direct water into pipes and prevent water flowing down and eroding soil alongside the pipes. Midstream alignment of pipe outlets and energy dissipators may be needed to prevent bed and bank erosion immediately downstream.

Where water discharge rates are not high, it may be possible to maintain or construct natural open channels to preserve aesthetic and environmental values. Other stabilization techniques listed in this section may be needed for such channels.

Figure 17. Crushed rocks of about 60 millimetres diameter need to be compacted into a rounded “spoon drain” shape.

viii) Structures:

Water drop or chute structures can be used to reduce channel gradients and water velocities.
Structures should be made to good engineering standards from durable materials such as pipes, rock or concrete. Typical construction standards are listed in Section 13.

ix) Soil stabilizers:

It is sometimes useful to reduce the erodibility of soil with gypsum, lime or cement. After thoroughly mixing these materials into soil, the soil should be moistened and compacted to good engineering standards. This is needed to prevent alkaline water discharges.

x) Gully filling:

Eroded channels or gullies can sometimes be stabilized by filling them with soil and diverting water by dams or diversion banks away from fill material to stable locations. Soil used to fill gullies should be compacted in thin layers and finally covered with topsoil originally stripped from gully sides.

Construction standards equivalent to those needed for dam construction, such as through compaction of soil in thin moist layers, are needed where diversion banks cross gullies to prevent tunnel erosion in fill material.

xi) Pavement

Channels can often be protected by pavement materials such as compacted asphalt, reinforced concrete with well sealed expansion gaps or interlocking blocks over a soil filter layer. Drainage pipes or layers may be needed below pavements or membranes to prevent hydrostatic uplift and underlying material being weakened by accumulations of water.

xii) Temporary stabilization

Some construction projects may require temporary erosion controls along drains and streams while construction works are in progress.

Exposed soil could be protected by temporary membranes such as tarpaulins, geotextile filter cloths, rubber sheeting or thick polythene.

The upstream edges of such membranes should be well secured to prevent them being washed away should unexpected flood flows occur. Membranes could be held down by large stakes, deep edge entrenchment or heavy material such as large rocks.

Sand or soil filled bags can sometimes be used for surface armouring, barriers or cutoff walls if placed close together. If soil is used to fill bags, it should have a low clay content or be stabilized with a small proportion of cement to prevent water turbidity problems.

However, the risk of bags splitting and their difficulty of removal can make other techniques more applicable for large streams. Other works such as carefully anchored logs may provide temporary protection in some cases.

Figure 18. Steep river bank stabilised by a thick layer of rock near a roadway.

It should be noted, however, that membranes or filter material are needed under materials such as tree branches and car tyres with open gaps to prevent underlying soil being removed by water turbulence.

Temporary soil binding agents such as asphalt or glues should not be used where there is a risk of environmental pollution.

xiii) Other techniques:

Other stream stabilization techniques include:

- diversion of water to stable locations,
- groynes to deflect water from channel banks,
- realignment using heavy gauge fences, rock placement etc.,
- removal or alignment of timber snags,
- anchoring of timber or brush against banks.

Such methods are detailed in reference 7.

(j) Channel gradients

For most of the channel stabilization techniques listed above, it is usually necessary to excavate channel banks to gradients no steeper than 2:1 (horizontal:vertical). More gentle channel banks may be needed where they are prone to slippage or undercutting. Excavated material should be disposed of in stable locations. Do not pollute drainage lines or streams by pushing soil straight into the water.

To prevent the erosion of unpaved channel beds, their longitudinal gradients need to be no steeper than about 0.5%. To achieve stable gradients, it may be necessary to re-align channels or install water drop structures (see Section 13).

(k) Vehicle Crossings

Considerable erosion and sediment pollution problems can result where vehicles and earthmoving machinery cross streams. Stable crossings need to be installed in such locations. Construction techniques for stream crossings are listed in Section 17.

(l) Livestock & public access

If livestock are allowed access to streams for drinking purposes, they damage protective vegetation and stir up mud in the water. Livestock manures also reduce water qualities. Stable stock watering and crossing points can sometimes be provided along streams. To prevent water pollution, however, livestock should be excluded from streams and drainage lines as much as possible and provided with off-stream drinking locations. This is particularly important in Proclaimed Water Supply Catchments.

To ensure livestock and public safety, fences may be needed alongside channels with steep sides or which experience high water flow rates. (See Section 6).

Figure 19. River bank stabilized by cane grass.

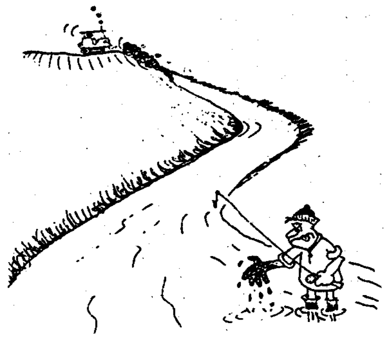


Figure 20. Soil pushed directly into streams results in water pollution. This can usually be avoided by careful planning based on the techniques listed in this booklet.

13. WATER DROP OR CHUTE STRUCTURES

Water drop or chute structures are needed to prevent soil erosion and sediment pollution wherever water flows from one level down a steep incline to a lower level. Such drops in water level may also be needed to provide stable stream gradients between the structures.

Water drop and chute structures should typically be built from materials Listed in the previous Section 12(i) "Channel stabilization".

No matter whether the structures are large or small they should be designed and constructed to good engineering standards, such as:

(a) water discharge rate calculations, site survey, subsurface investigations and soil tests to good engineering standards;

(b) construction materials and stabilisation techniques which ensure that the structure functions effectively for its design life (see Glossary);

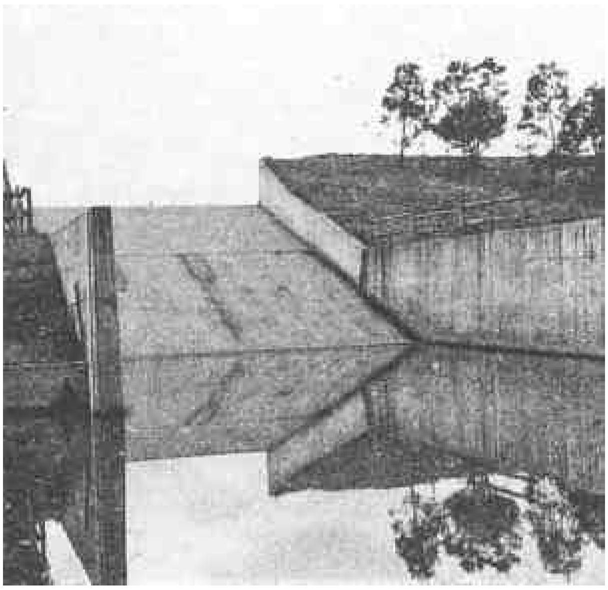


Figure 21. Large water drop structure with deep seepage barriers and wing walls.

Figure 22. Poorly designed structure which has been undermined and side scoured

c) sufficient channel and outlet notch capacities to prevent overtopping or side scour of the structures by design stormwater flows (references 2, 8, 22, 25 and 36);

(d) stable channel gradients or works to prevent soil erosion immediately upstream and downstream of the structures;

(e) designs and gradients to prevent long term sediment accumulation and excessive loss of water discharge capacity;

(f) midstream structure outlet alignments to prevent erosion of streambanks immediately downstream;

(g) stable downstream gradients (usually less than about 0.5%) to prevent streambed erosion and undermining of structures;

(h) correct water inlet and outlet levels to prevent the initiation of rill or gully erosion;

(i) stilling basins and energy dissipators of sufficient capacities and widths to prevent soil erosion and undermining of the structures;

(j) wing walls, headwalls and anti-seepage barriers extended to sufficient widths and depths (usually greater than 0.6 metres) to prevent overtopping and undermining or tunnel erosion;

(k) soil filter underlay layers or membranes, if well supported impermeable barriers are not used, to resist undermining or tunnel erosion;

(l) underdrainage, buttressing or sloping of barriers to resist hydrostatic water pressures;

(m) devices or designs to allow fish passage and migration.

The use of rock chutes over soil filter layers has increased in recent years. In some erodible soils, however, vertical anti-seepage barriers, similar to the core of a dam embankment, may be needed to prevent undermining.

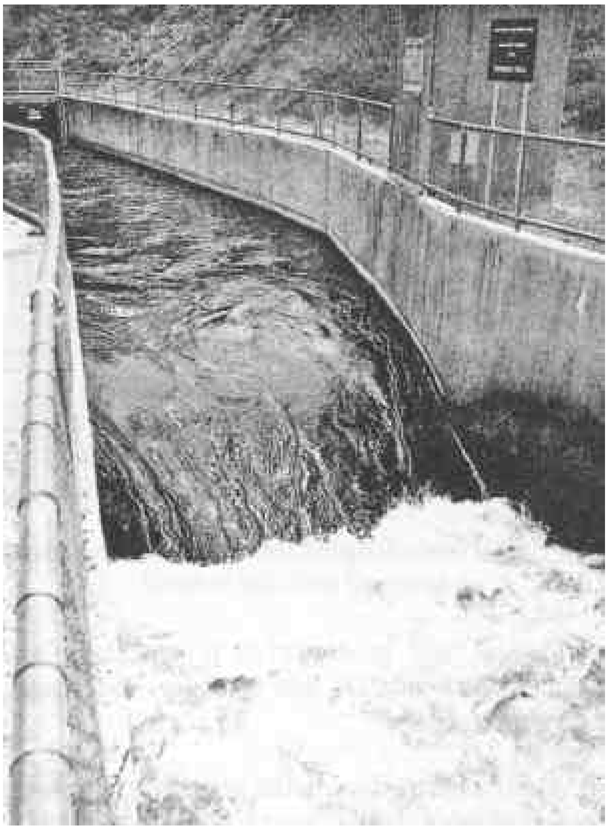


Figure 23. Stilling basin used to dissipate water energy.

Figure 24 Soil erosion has undermined this pipe outlet and contributes to sediment pollution.

Figure 25. Pipe outlet protected from erosion by a thick layer of rocks.

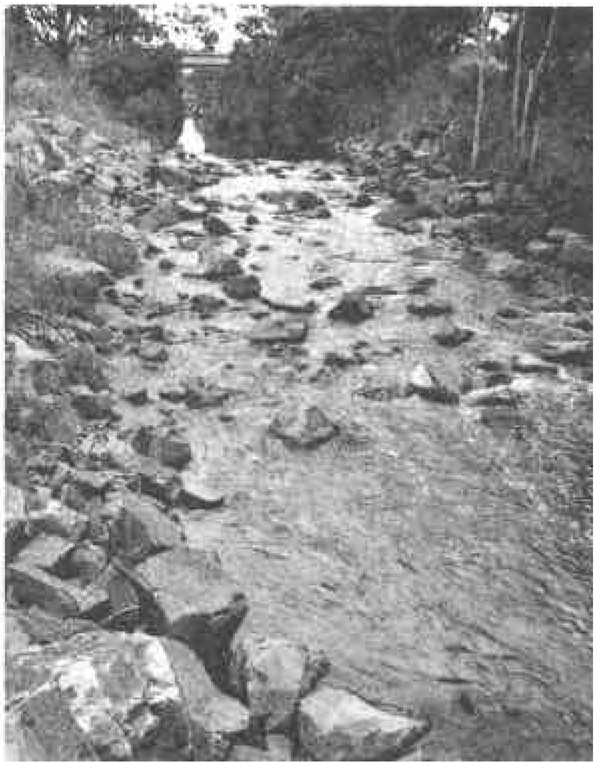


Figure 26. One of several rock chutes which enables fish passage along a creek.

14. DAMS & BASINS

Dams and basins are useful for trapping sediment, treating water pollutants and controlling flood discharge rates. They can also act as emergency traps in the event of accidental spillages of petroleum, che micals or other polluting substances. In addition, dams and basins can provide an aesthetically pleasing community resource.

In areas with existing residential development, however, it is often difficult to find a sufficiently large site with adequate soil types and land gradients for a sediment trap dam. In addition, the concerns of local residents need to be considered, such as water safety.

(a) Sediment trap dams and basins

Wherever feasible, install adequately sized, constructed and stabilized sediment trap dams downstream from areas of loose soil Such dams should be constructed prior to the commencement of project earthworks, particularly where soil is to remain exposed for more than about six months.

Where possible, construct dams or basins either singly or in combination, with both sediment trapping and flood detention functions. Dams with a flood detention function can reduce water velocities and thereby economise on downstream erosion and sediment control works. To maximise this effect, flood detenti on dams should have multi-stage outlets with small diameter outlets being placed at low levels.

Base flow outlet pipes should not be placed at the base of or upstream from sediment trap dams. Installing outlets in such locations can result in large quantities of sediment by-passing the dams or basins.

(b) Construction Standards

It is important to construct dams and basins to high standards to ensure their long term stability, effectiveness and safety. In Victoria inadequate soil compaction, poor seepage controls, embankments exposed to erosion and undersized spillways are common problems (reference 31 and personal communication, Nelson).

In the worst cases, embankments become tunnel eroded or breached; in other cases, dams have a greatly reduced life or require expensive maintenance. The failure of a dam embankment can result in significant sediment pollution in addition to damaging downstream areas and being hazardous to the public.

Figure 27. Sandy sediment trapped in a dam.

If a dam embankment is five metres or more high and its capacity at least 50 megalitres, or the embankment 10 metres or more high and its capacity at least 20 megalitres, it needs to be referred to the Office of Water Resources, Department of Conservation and Environment (references 2 and 8).

It is recommended that dams with embankments higher than about four metres or capacities greater than about ten megalitres be designed and their construction supervised by suitably qualified and experienced civil engineers. This should also be the case for dams built in hazardous or difficult locations.

The requirements of the responsible drainage authority should also be followed.

Additional information about dam design and construction is contained in references 22, 31 and 34 and their bibliographies.

(c) Site Investigations

Thorough investigation of soil and site conditions is important for adequate dam design and to avoid costly design changes if unpredicted features, such as permeable layers or hard rock are encountered.

A network of soil tests should be made at depths of at least two thirds the dam embankment height and deeper than the excavation depths.
Other investigations include contour surveys and water discharge rate calculations.

Figure 28. Dam embankment which has been breached by water as a result of poor soil compaction.

(d) Gradients

Construct dams or basins on land no steeper than 10% (10:1 horizontal vertical). Such locations are needed to minimise hillside excavation and resultant increased risks of landslip, soil erosion and sediment discharge.

In addition, earthen dams are difficult to construct to good engineering and safety standards on land steeper than 10% gradient. Vertical sided tanks and inlet chute structures may be better options in steep locations.

(e) Capacities

Wherever possible, sediment trap dams should be designed to trap the majority of sediment particles suspended in discharge waters.

The capacities of sediment trap dams can be calculated in different ways depending on factors such as water quality objectives, water discharge rates and settlement rates of suspended materials.

One or more of the following criteria could be chosen on the basis of information contained in the references at the end of this document. Capacities should be increased to allow for sediment accumulation and removal rates.

i) Recurrence interval

Construct sediment trap dams to retain the discharge of all average five year recurrence interval storms. This provides for the retention of runoff from heavy rainstorms.

ii) Yearly runoff

Construct sediment trap dams with capacities equivalent to average yearly rainfall runoff events (typically about 150 cubic metres per hectare). This provides for the retention of average runoff rather than heavy rainfall events.

iii) Silt retention

Construct sediment trap dams with minimum water storage areas of 4,000 square metres for every cubic metre per second of design maximum peak water flow. This usually results in retention of most silt and larger sized particles (0.02mm diameter Such particles are also trapped if the dam is designed to provide a one hour retention period for average five year recurrence interval stormwater flows.

iv) Clay retention

Most clay sized particles (less than 0.002 mm diameter), tend to be retained if the dam has a 10 hour retention period for average five year recurrence interval stormwater flows. This may require a dam of very large capacity. Some types of dispersible clay tend to remain in suspension for periods longer than 10 hours unless treated with a flocculant (Section 14).

v) Erosion rate.

Construct sediment trap dams with sufficient capacities to trap sediment calculated to result from average yearly erosion rates (references 22 and 24). This allows for the retention of a significant proportion of material eroded each year.

vi) Long term control

Access tracks to dams in steep terrain may themselves pose significant erosion and sediment pollution risks. In these situations, it may be desirable to avoid the construction of access tracks and build larger dams.

(f) Inlet baffles

Inlet baffles and islands can be used to spread sediment within water storage areas and maximise the volume of sediment trapped.

(g) Water depths

Construct the water storage areas of sediment trap dams with minimum water storage depths greater than 60 centimetres plus an allowance for sediment deposition. This is needed to help minimise sediment re-suspension.

If a dam is completed during a dry season, it may be desirable to fill it with enough water to keep the embankment moist and free from shrinkage cracks. Drying and cracking of a dam embankment can result in its failure when the dam is eventually filled with water (reference 31).

(h) Embankment sides (batters)

Sufficient widths need to be provided at the site for stable dam embankment and excavation gradients. Cross sectional drawings at appropriate scales can assist in this task.

High embankments may need horizontal berms and downstream toe drainage to increase their stability. Toe drains should be made from carefully graded and installed filter materials to prevent tunnel erosion. Additional information is provided in references 22, 31 and their bibliographies.

(i) Core trench & embankment foundation

It is important to remove all topsoil from below proposed dam embankment areas to provide for embankment stability and leakage control.

Excavate a core trench below the centre or the upstream portion of the embankment and at least 0.6 metres into impervious rock or solid clayey subsoil (references 22 and 31).

Surface scarify exposed subsoil clay to a depth of no more than 20mm to assist in embankment bonding. Water may leak through more deeply ripped layers.

These works are important if the embankment is higher than 1.5 metres, the site steeper than 5% gradient or wherever needed to prevent water seepage or improve dam safety. On the other hand, small dams in safe gently sloping locations could be designed to leak to assist in sediment trapping and de-watering.

(j) Soil type & compaction

Clayey soils with suitable engineering characteristics must be used for earthen dam embankments. Compact clayey embankment material in thin layers when moist according to standard engineering compaction tests and techniques. (See references 23, 31 and 38). This usually involves compaction of soil at optimum moisture contents when it is pliable or plastic, with a heavy sheepsfoot or padfoot roller.

The use of bulldozer tracks or rubber tyres alone to compact the soil is not recommended because they exert a low pressure on the ground and are relatively inefficient at compacting soils. Their use tends to result in horizontal layers of permeable soil which are prone to tunnel erosion and excess seepage and can result in structural failure of the embankment. Vibrating rollers can also cause horizontal layering in some cases.

Soil moisture contents and compaction densities should be assessed according to Australian Standards (reference 38). If the soil is not sufficiently moist, deep ripping and pre-irrigation may be needed. Additional water may need to be applied during hot weather to prevent the soil becoming too dry while it is being compacted.

Adequate soil compaction and sub-base preparation are important to prevent settlement cracks and other damage in day or membrane linings in dams.

(k) Soil treatment

Gypsum, slaked lime or cement may need to be incorporated into embankment and basin material where needed to reduce soil dispersibility, water turbidity or the risk of tunnel erosion. Soil tests can help to estimate the application rates needed. If soils are highly credible or permeable, the advice of a civil engineer with experience in dam design and construction should be obtained.

(l) Embankment crests

Crowning or side-sloping of embankment crests is needed to prevent water ponding on the crest and causing tunnel erosion within the embankment.

(m) Embankment surfaces

Exposed soil on dam embankments needs to be stabilised with dense grass growing in 50mm to 70mm of loamy topsoil unless stabilised by rock armouring over a soil filter underlay. Thicker layers of topsoil tend to slip off steep batters.

If embankments are composed of highly expansive (cracking) clay soils, spread a thick layer of surface stabilised sandy material to help minimise soil drying and cracking. This is needed to prevent embankments slipping or becoming tunnel eroded where water flows along shrinkage cracks (reference 31).

(n) Wave protection

Protect embankments from wave damage where this is likely to be excessive, by providing rock armouring or similar material over soil filter underlays. Aquatic plants such as cane grass can also prevent wave erosion. Floating breakwaters or booms may reduce wave erosion where wave heights are not high. Surface protection is particularly important for clay linings in dams.

(o) Outlet structures & freeboard

Sufficient outlet capacities and Freeboard should be provided to prevent water overtopping dam or basin embankments or structures during flood water flows.

Freeboard should include an allowance for wave action and extreme flood events (references 2, 8, 22 and 31). Several different types or combinations of outlet structures are possible for sediment trap dams. The particular design should be based on information contained in the previous Section about structures and references 2, 8, and 31.

If a sediment trap dam is also used for flood detention, the following designs are needed:

i) Ricer pipes

Install perforated or slotted riser pipes surrounded by small diameter crushed rock or equivalent filter material to allow gradual water discharge from sediment trap dams and basins;

OR

ii) Flexible pipes

Attach flexible outlet pipes to floats to allow gradual water discharge from sediment trap dams and basins;

AND/OR

Extra freeboard

Provide sufficient freeboard between the outlet pipe and the dam bywash or spillway for the dam to have adequate flood detention and sediment trapping capacities.

(p) Pipe tests

Undertake pipe pressure tests both before and after pipe trenches are filled with compacted soil to ensure that outlet pipes have not cracked and do not leak or fail.

(q) Pipe collars

Install anti-seepage cutoff collars of sufficient widths and at sufficient spacings along outlet pipes to prevent tunnel erosion along the pipe trenches (references 22 and 31).

Ensure that soil is well compacted in thin layers when moist by manual techniques along pipe trenches. Manual compaction is usually needed to protect the pipe from damage which can result from mechanical techniques.

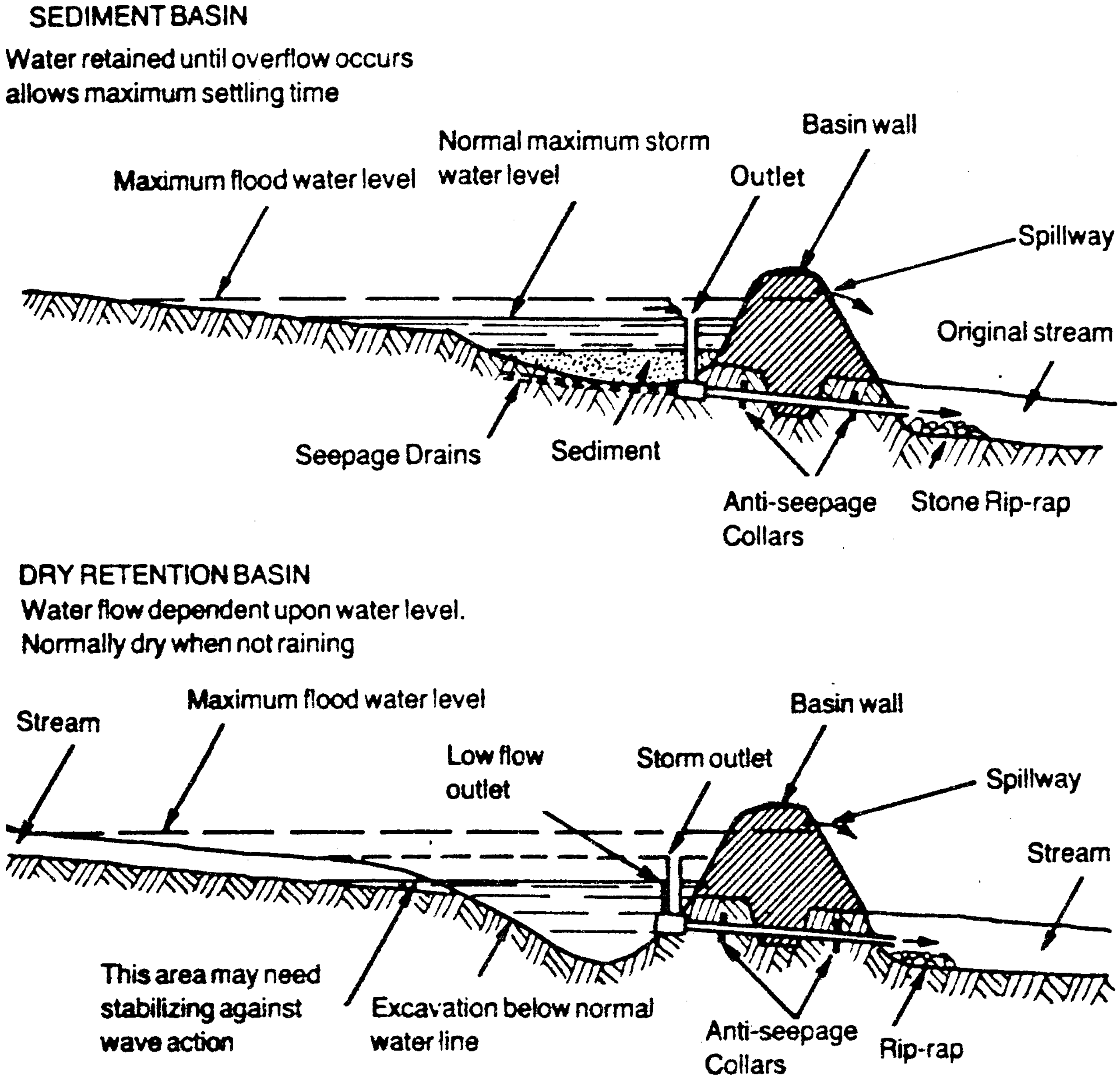


Figure 29. Cross sections of typical sediment trap and flood detention dams.

(r) Water hammer

Water hammer effects which can damage pipes and connections can result from the closing of valves, air entrapments and variations in water velocities. Broken or leaking pipes can result in soil erosion and contribute to sediment pollution.

Such problems can be avoided by installing air inlet pipes, curved pipe connections, pressure relief valves, water riser pipes and surcharge wells.

(s) Spillways

Erosion of dam spillways and bywashes can be avoided by installing works such as trickle water flow pipes, water drop or chute structures, or by undertaking other appropriate channel stabilization works (Sections 12 and 13).

(u) Control livestock

Prevent the access of livestock to dams or basins such as by installing stock proof fencing. This is needed to prevent the livestock muddying and fouling the water and trampling protective vegetation. Offstream stock water troughs are often a better alternative.

(v) Minor sediment traps

A small sediment trap dam or structure installed upstream from the main sediment trap dam can be useful for reducing the difficulty and cost of trapping and removing sediment (see also Section 15).

(w) Maintenance

Dams and basins should be regularly checked and repaired as needed.

Sediment needs to be removed from sediment trap dams, basins and structures at sufficient frequencies to maintain storage capacities and to ensure their ongoing effective operation. It may be desirable to specify a maximum depth of sediment deposition, typically no more than one third of total storage depth, before which sediment is to be removed. Excavated sediment should be deposited in stable locations and its surface stabilised.

It should be noted that mosquitoes can be controlled by stocking dams with predatory fish. It follows that control of sediment and related pollutants is needed to help protect such fish (references 4 and 16). Isolated pools of water without fish access may need to be removed to prevent the breeding of mosquitoes. Such considerations are needed to foster public support for sediment trap facilities.

(x) Leachate control

Dams are sometimes used to store leachate or contaminated water from mines, tips etc. To ensure that such leachate does not seep too far from a dam, it may be necessary to install monitoring bores, spear wells, intercept drains or additional dams near the main storage dam.

Dams and basins need to be constructed and maintained to high standards to ensure their long term stability, effectiveness and safety. Works such as fences, warning signs and buffer zones may be needed to ensure the safety of dams and basins to the public and to livestock.

15. SEDIMENT & LITTER TRAPS

Where there is insufficient space for sediment trap dams or basins, smaller sediment trap structures may be possible.

Sediment trap structures are often not large enough to trap more than a fraction of the sediment discharged from land disturbance sites. In such cases, it may be necessary to increase the number of sediment traps and decrease the catchment area to each trap.

Litter is a major pollutant of urban waterways and can often be controlled by the use of litter screens and floating booms combined with sediment traps or dams. Litter traps may also be needed to prevent drains becoming blocked if sediment trap materials such as hay bales fail and are washed downstream.

(a) Location

Sediment and litter traps should be installed at strategic locations such as premise boundaries or culvert pipe inlets and wherever needed to minimise the risks of downstream sediment and litter pollution. Litter and sediment traps are sometimes combined as gross pollution traps just upstream from lakes and wetlands (references 36, 37 and 39).

(b) Sediment trap materials

Sediment traps can be constructed from materials such as steel drums, gravel filled bags, cement stabilized sand bags, staked and entrenched hay bales, boards, concrete basins, earthen embankments, stones held under geotextiles, crushed rock, filter cloth fences, filter bags suspended on steel frames or filter membranes over steel drums (references 22, 24, 30, 36 and 37).

Heavy duty materials, such as closely spaced steel pylons with heavy gauge steel mesh supporting filter cloth membranes may be needed where high water flow rates are involved.

(c) Earthen embankment sediment traps

Earthen embankments or bunds can be used to both divert water and trap sediment. They should be built from soil compacted in thin layers when moist. Earthen embankments and their channels usually need to be stabilized with dense grass or a covering such as heavy duty edge entrenched geotextiles, membranes or mats.

(d) Sediment trenches & pits

Trenches and pits may be adequate to trap sediment where catchments and water flow rates are small, such as for individual house construction sites. Where soils are erodible and the land is steeper than about 3% gradient or the catchment greater than about 0.5 hectares, the trenches and pits usually need to be stabilized to prevent them being eroded and contributing to further sediment discharge.

e) Sediment trap design

To ensure their effectiveness, sediment traps, whether la rge or small, need to be designed according to the same principles listed for other hydraulic structures in Sections 13 and 14.

They should, for example, have erosion resistant spillways and storage areas to maximise the volumes of sediment trapped. Sedime nt trap fences such as hay bales and filter cloth membranes often need to be entrenched to resist undermining (reference 32 and 37).

Entrenched barriers such as metal sheets or piles may be needed to reinforce sediment traps, particularly where high water flow rates or erodible soils are involved. These should be driven into both the channel sides and the channel floor. Entrenchment depths typically need to be greater than 600 mm.

Figure 30 Sediment trap featuring litter screens to prevent pipe blockage and concrete and plastic aprons to prevent undercutting.

Sediment traps should be designed to allow easy sediment removal. The use of front end loaders to remove sediment, for example, may be possible if the sediment traps have sloping sides. This can be particularly useful for permanent concrete sediment trap structures.

Upstream "clean water" overflow outlets may be useful if water in sediment traps is pumped out or discharged on an ongoing basis. Grossly polluted water in such locations should be discharged as appropriate to land, sewer or mobile tankers for waste treatment.

(f) Gradients

Sediment traps by themselves are seldom effective along eroding drainage lines with gradients steeper than about 2%. Channel and catchment stabilizations works are needed as well.

(g) Capacities

Where sufficient space is available, sediment trap capacities should be designed according to the same criteria for dams and basins in Section 14(e) above.

(h) Stabilization of sediment traps

Materials used for sediment traps need to be sufficiently stable to resist peak water flows.

Stakes, geotextile covers, steel mesh and other such materials can be used to prevent sediment trap structures breaking up and causing litter problems and obstructions downstream. Litter screens located at or downstream from sediment traps can serve the same purpose.

Figure 31. This hay bale sediment trap has not been effective because the channel is steep and unstabilized. This has resulted in erosion along the channel and around the sides of the bales.

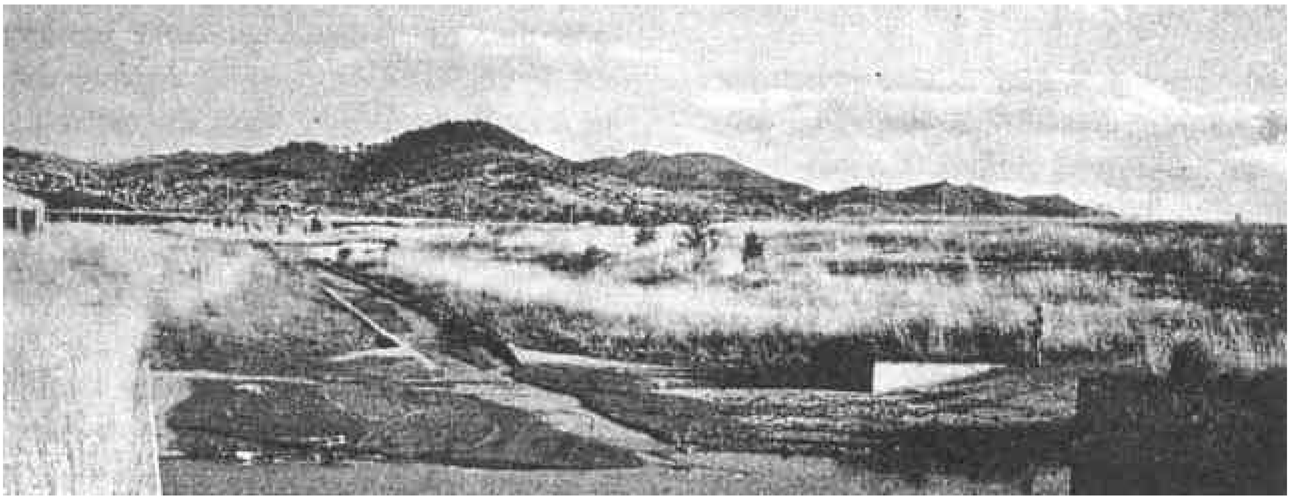


Figure 32. Sediment trap with a sloping concrete ramp to enable easy sediment removal.

Figure 33. Row of entrenched hay bales which traps sediment and diverts muddy water into densely grassed areas.

Crushed rock, entrenched membranes or other materials can be used to prevent undermining of structures or side scour.

Wherever possible, connect sediment trap structures in-line with gently sloping diversion banks. This will result in near level inlets and outlets and can help prevent the structures being undermined by storm waters.

(i) Litter screens & booms

Litter screens and floating booms are sometimes combined with sediment traps. Litter screens can be built from closely spaced steel bars, steel mesh supported on steel posts or other similar materials. They are typically located at culvert inlets, sediment trap dams or basins, and where drainage lines leave premise boundaries.

Litter screens made from steel bars can double as safety grids to prevent access by children and others to pipelines and drainage systems.

The size of openings in litter screens needs to be designed on the basis of the type of litter to be collected. Openings may need to be smaller than soft drink cans, for example. It may not be desirable, however, to use small circular openings which trap grass and leaves which may block the screen.

A stable emergency bywash around or over each litter screen is needed to prevent flooding problems should the litter screen become rapidly blocked with debris.

Litter screens should be constructed from heavy duty materials where high water velocities or depths are involved. Litter can be washed over the top of litter

screens during high stormwater flow events.
To reduce this problem, litter screens with discharge capacities equivalent to at least one year average recurrence interval storm discharges and preferably more than five year intervals are recommended.

Floating litter booms can also trap floating litter which would otherwise flow over the top of the screens.

However, floating booms may require more frequent repair than heavy duty litter screens.

Figure 34. Filter cloth sediment trap fence used to trap sediment from a small catchment.

(j) Maintenance

Regular repair and maintenance of sediment trap structures and litter screens, such as removal of trapped material after rainstorms, is needed to ensure their ongoing effectiveness. Removal of material when sediment traps are up to one third full may need to be specified in works programs to achieve this.

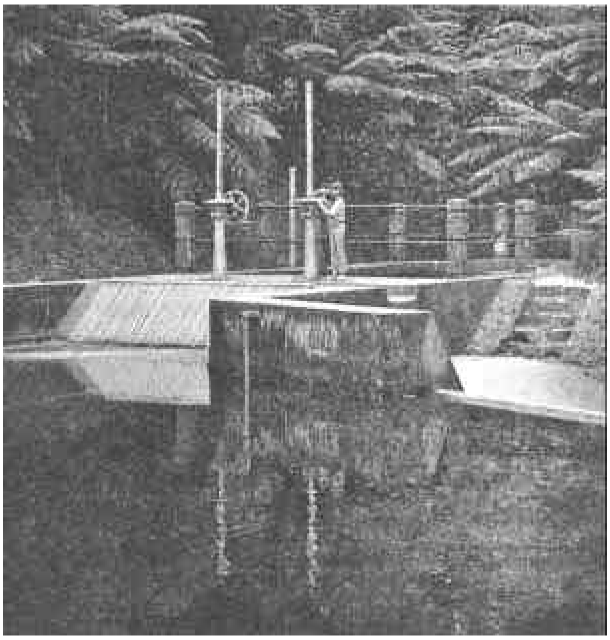


Figure 35 Sloping debri screen which allows easy debris removal. A floating boom upstream from the emergency spillway could be used in urban areas to trap additional litter

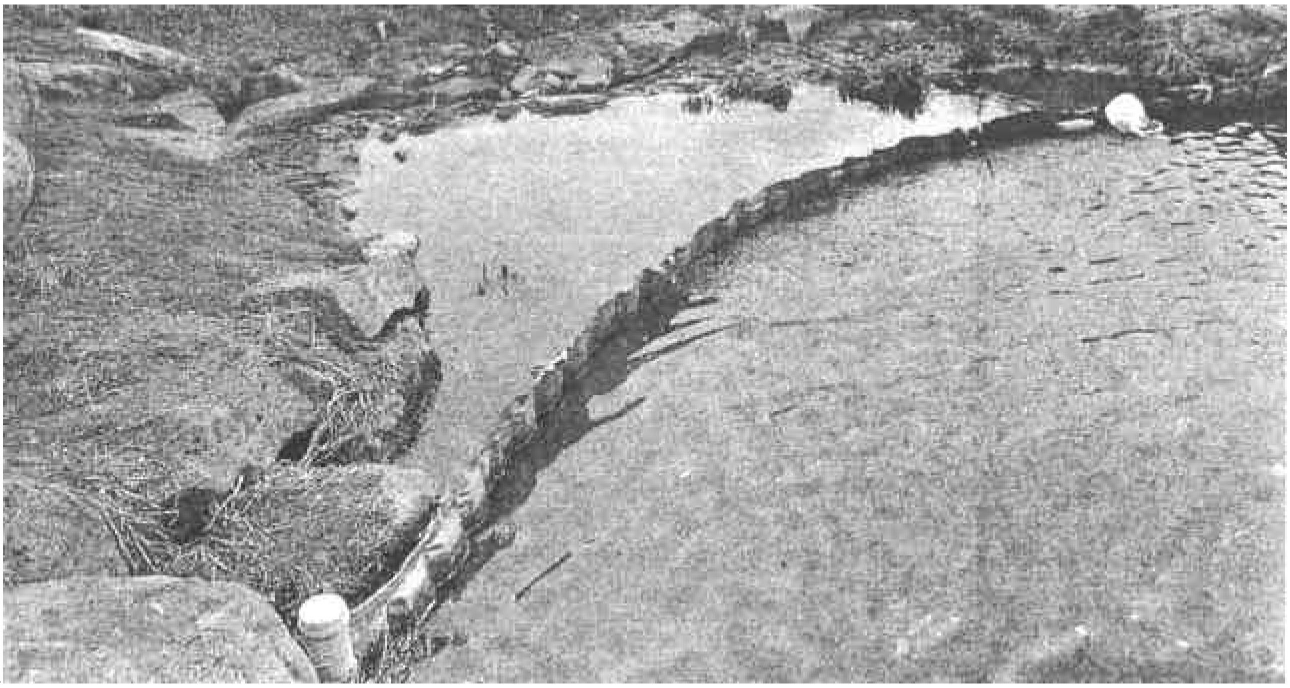


Figure 36. Floating litter boom in a sediment trap dam.

16. WATER TREATMENT

Muddy water trapped in dams, basins, trenches and sediment traps may need to be treated prior to discharge to meet State Environment Protection Policy water quality objectives (reference 44).

(a) Pumping out

Adequate qualities of pumped water can often be achieved by simply pumping from just below the water surface after suspended matter has been allowed enough time to settle. To help achieve this, flexible pipe inlets to pumps could be suspended on floats.

Pump inlet pipes should not be simply dropped onto the base of trenches where they can suck mud. Surrounding pump inlets with filter material such as coarse gravel or locating them over a membrane, baffle or board may also prevent the sucking of mud.

The use of screens on pump inlets which are located just below the water surface can minimise the risk of floating litter blocking the pump or being discharged.

(b) Flocculation

Wherever needed, clarify water in trenches or basins prior to pumping them out by the use of a minimum quantity of flocculent. Depending on water tests, fine grained gypsum (calcium sulphate) should be used as a flocculant in preference to filter alum (aluminium sulphate). Filter alum requires water pH to be adjusted using slaked lime (calcium hydroxide).
A water pH at or close to neutral (pH 7) should be achieved. (See Glossary and Section 2b).

Water tests should be undertaken prior to water treatment to assess the effectiveness of treatment and to calculate the minimum rates of chemical flocculants needed.

Flocculants can be useful as both a pre-dose by mixing them with soil in trenches or basins to be filled with water, and as a final dose before pumping water out. It may be possible to add flocculants with automatic dispensers at basin inlets. Otherwise, the use of pumps or propellers to mix the flocculent in the water may be needed.

Dragging a hessian bag full of flocculant through the water is another technique for spreading flocculant.

(c) Settling areas

If muddy water is not clarified prior to being pumped from trenches or basins, it should be pumped into broad hollows or densely vegetated areas to allow sediment to settle out. Alternatively, sediment trap dams or filters may be possible.

(d) Filters

In steep locations, it may be necessary to filter muddy water by one of the following devices.
It should be borne in mind that large quantities of sediment may need to be removed at regular intervals from such devices.

i) woven plastic filter bags on steel frames (such as used for waste paper),

ii) geotextile filter membranes suspended in or over steel drums or portable tubs,

iii) gravel or crushed rock bunds, covered with a filter cloth,

iv) well secured screens or permeable foam rubber plugs at the entrance of stormwater inlets (where flooding is not a problem if the filters become blocked),

v) reverse flush industria l filters or cyclone centrifuges.

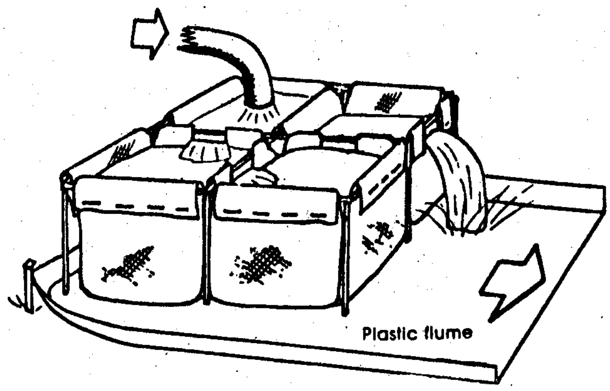


Figure 37. Woven plastic woolbale bags held on a steel frame can be useful for trapping sediment.

17. VEHICLES & ROADS

Eroding access tracks and areas disturbed by construction equipment are often a significant source of sediment pollution and wind blown dust. These problems often remain after construction activities have finished wherever roadside drains are not stabilized and adjacent areas are not revegetated.

It is particularly important to stabilize steep roads and drains from which muddy water flows directly into creeks and streams.

(a) Road and track stabilization

All road and track surfaces and side drains should be stabilized to minimise soil erosion and sediment discharge.

If gravel roads or tracks are involved, erosion and sediment discharges can be reduced by maintaining a well crowned or side sloped surface. This is often needed to prevent water flowing down and eroding tyre track depressions. Maintaining a hard surface of compact gravel can also reduce erosion and sediment discharge rates (reference 23).

An alternative approach is to provide frequent surface cross drains or roll-over bunds to minimise the distance that water flows along the road or track surfaces (references 22, 23 and 32).

Water runoff from gravel roads and tracks should be diverted into broad vegetated areas or sediment trap dams, structures or basins prior to its discharge into streams, rivers or other surface waters.

Roadside tabledrains should preferably be stabilized with dense grass to prevent erosion and to help trap water borne pollutants. Alternatively, crushed rock could be used to stabilise roadsides as shown in figure 17.

Even paved roadside tabledrains are better than no stabilization at all. Subsurface drainage works are often needed below paved tabledrains however, to prevent road surfaces becoming damaged and potholed by accumulated water. This is important for the provision of erosion and sediment control in the long term.

Where roadside tabledrains are not stabilized, frequent tabledrain outlets which divert water into stable locations are needed to minimise erosion and sediment discharge.

In some locations with low traffic densities, it may be possible to stabilize roadside shoulders with grass. Otherwise, paving road shoulders with asphalt or concrete may prevent erosion of shoulder material. This can greatly reduce maintenance costs and improve road safety.

Figure 38. Roadside tabledrain stabilized with grass.

(b) Restrict access

On construction sites, vehicles should be restricted to a minimum number of paved or stabilized access tracks and haul roads to minimise the area of soil disturbance and corresponding erosion and sediment discharge rates.

(c) Intercept Culverts

Muddy water can be prevented from flowing down tracks and out of premises by installing metal grid covered box culverts across the tracks and leading to sediment traps. Culvert sizes and designs should be used which allow easy sediment removal.

(d) Stream crossings

Use culvert pipes, rock pavements, logs or bridges to prevent the disturbance of streams and other drainage lines at vehicle crossing locations.
Soil erosion at such locations should be prevented by techniques outlined in Sections 12 and 13.
Soil erosion around culvert pipes may need to be prevented by installing vertical concrete headwalls or surrounding the pipes with geotextile filter cloths or soil filter material.

Bridges may be a feasible alternative to pipes and any other techniques which cause excessive disturbance of stream beds and banks. Works to prevent erosion undermining bridges may be needed at the outside bends of streams or where the channel is narrow and constricts water flow.

(e) Dirt on roads

Urban runoff is a major pollutant of many rivers and streams (reference 1). It is therefore important to remove soil and other loose material dropped, washed or blown onto roads at the earliest available times. This is needed because soil on hard pavements becomes readily mobilised by wind or rainwater runoff.

Techniques to remove soil and other loose material should be used which themselves minimise water runoff and the generation of air-borne dust. Simply hosing down streets and roads can generate large quantities of polluted water in addition to creating a slippery surface which can become a traffic hazard. Physical or manual removal of loose soil should be the first approach in all situations.

Figure 39. Eroded roadside tabledrain which contributes to sediment pollution.

(f) Minimise mud dropped on roads

Mud often becomes trapped between the dual wheels of trucks if they are driven across wet clayey sites. When mud or soil is dropped onto roads, it can become a dust nuisance and is readily washed into drains and streams. These problems can be reduced by restricting the passage of trucks to paved or stabilised roads and tracks wherever possible.

The quantity of mud deposited on roads can also be reduced by installing a recycled water vehicle washing facility. Alternatively, structures such as cattle grids or rows of railway sleepers can help trap mud. Covering exit tracks with a pavement such as compact crushed rock can also help to keep mud within the project area. Occasional reworking and compaction of crushed rock can help remove accumulations of muddy soil.

It should be noted that long grids designed to vigorously vibrate mud from truck tyres may not be acceptable if they contribute to vehicle wear and increase the risk of back injuries to truck drivers.

(g) Cleaning of vehicles and equipment

All vehicle washing facilities must comply with the Environment Protection Act 1970 and relevant regulations relating to vehicle wash facilities. These regulations require an EPA licence for vehicle wash facilities which are not used by the public for the washing of motor vehicles (reference 52).

The following controls can help to prevent water pollution resulting from the cleaning of vehicles and construction equipment.

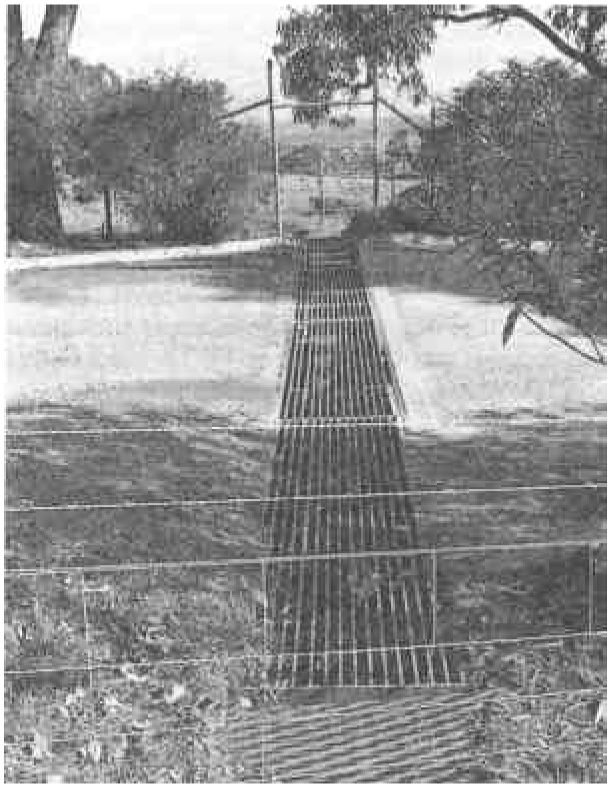


Figure 40. Grid covered intercept culvert.

i) Recycling

Water can be polluted by soil, alkaline cement products and other materials washed or dropped from construction vehicles and equipment.
This problem can be reduced by the use of a recycled water washing facility at the project site. Recycling

reduces the volume of water used, and assists in the later disposal of wastewater to appropriate disposal facilities.

ii) Waste minimisation

Wherever possible, brush or scrape soil and mud from vehicles and equipment prior to washing. This is needed to reduce the volumes of contaminated water produced. The use of gently sloping concrete wash bays can facilitate this process. Solid material should be shovelled or scraped from wash bays rather than hosed away.

To prevent wastewater discharges being increased by rainfall, it may be possible to install a roof over the facility. For both roofed and unroofed facilities, rainfall runoff should be diverted elsewhere, wherever possible, by diversion drains or bunds.

To further reduce the quantity of contaminated water, it is often possible to install a system of valves or pumps to separate rainfall discharges from wash waters. These systems are usually operated by float controls, water pressure sensors or water quality sensing devices.

iii) Pumps

To pump water which becomes gritty or muddy in vehicle wash facilities, centrifugal pumps are needed. Two such pumps should be installed in case one pump breaks down. The use of two pumps also enables both sides of a vehicle to be washed at the same time.

iv) Oil separation systems

To remove oil prior to wastewater recycling or disposal, an oil settlement and separation system, such as a gravity or parallel plate separator, can be useful. This will reduce the difficulty of wastewater disposal and the problem of spraying oily water onto vehicles.

v) Detergents

Do not use any detergents (surfactants) at the washing facility unless rainwaters are also prevented from entering the facility. This is needed to prevent the discharge of oils which can be emulsified by surfactants. Emulsified oils are very difficult to remove from wastewater.

vi) Concrete supply systems

Wash-out waters from concrete supply trucks and pumping systems should be recycled or collected to prevent alkaline discharges. This should occur even if these are only partially cleared of concrete. Steel drums, on-site sumps or other containers may be needed to recycle such wastewater. Wastewater for disposal should be transported to an appropriately licenced disposal facility. Such wastes can be useful to waste recycling companies to neutralise acidic wastes (Section 18).

18. MAINTENANCE & WASTE DISPOSAL

Some of the most important clauses in construction specifications and conditions relate to maintenance and waste control. Many works, such as sediment traps, require frequent maintenance and waste removal for them to operate effectively.

(a) Allocate personnel

All pollution control works should be maintained and repaired to ensure their ongoing effectiveness.
To achieve this, it is desirable to provide a person or group to specifically inspect sediment and other pollution control works on a frequent basis, particularly during installation and after rainstorms. At these times, the operation of these works needs to be assessed and their effectiveness improved wherever possible.

(b) Waste control

Many types of waste in addition to sediment are common at construction and other land disturbance sites. Under the Environment Protection Act 1970, waste includes any matter which is discarded, emitted or deposited in the environment and which can cause an alteration in the environment.

Typical contract specifications to help control waste could include:

Prevent litter, floating material, paper articles, plastic articles, drink cans, waste building products or any polluting material being washed, blown or deposited into streams or drainage lines from the premises; and

Ensure that no litter, refuse, chemical, oil or other polluting substance is left or buried at the premises at project completion.

The filling of erosion gullies and stream banks with loose waste materials such as fence wire, car bodies, paint tins, corrugated iron sheets, tree branches and car tyres, in an attempt to control erosion, is not permitted by the Litter Act 1987 and the Environment Protection Act 1970 (references 46 and 49). Water flowing around such obstructions without adequate soil filter membranes and seepage barriers, often increases the rates of erosion.

Hollows in loose material provide a harbour for vermin. If soil is pushed over loose waste, it often becomes tunnel eroded and presents a safety hazard to livestock and the public. In addition, the cost of long term erosion control, which may require removal of loose waste, is greatly increased.

(c) Spillages

Under the Environment Protection Act 1970 and the State Environment Protection Policy (Waters of Victoria) (references 44 and 46), it is essential to contain and collect accidental spillages of oils, fuels or chemicals and to prevent their discharge into drainage systems. Such spillages can typically be contained and collected by the use of earthen bunds, dams, structures, sand bags, soil filled bags, floating booms, suction tankers or the spreading of materials such as sawdust, topsoil or absorbent granules.

Bunds or dams should be installed upstream from environmentally sensitive areas where protection from accidental spillages is deemed necessary. Store pollution control equipment and materials, such as fuel absorbent mats or granules, in areas where there is a high pollution risk or environmental sensitivity.

(d) Bunding

Surround containers used for on-site storage of fuels, chemicals or similar materials with impermeable bunds to provide a storage capacity equal to the capacity of the largest tank plus 10% of the remaining tanks plus a 150 mm freeboard and an allowance for additional rainwater inflows. If fire sprinklers or extinguishing systems are installed, an additional volume allowance is needed for such systems.

Treat or pave the entire floor and sides of the bunded area so as to make it impermeable. Extraneous dean runoff water should be diverted around or away from areas subject to contamination.

Undertake all such works in accordance with the requirements and relevant guidelines of the Environment Protection Authority and departments involved with industrial safety.

(e) Waste removal

Where appropriate, remove any sediment washed from the premises and deposited in streams, drainage lines or culverts as soon as possible.

Prescribed industrial waste removed off the premises for disposal must be removed in accordance with the Environment Protection Act 1970 and relevant regulations relating to prescribed industrial waste (references 18 and 47). Prescribed industrial waste must be removed by vehicles using EPA permits and transport certificates to licensed disposal, treatment or recycling facilities. Transport waste in containers or vehicles appropriate to the type of waste.

(f) Contaminated water

Water flowing from construction sites can sometimes be contaminated by chemicals or other wastes prescribed under Environment Protection Regulations (references 18 and 47). Such water must be collected and disposed at licenced disposal or recycling facilities.

Water flowing from construction sites can be contaminated by alkaline cement and lime products. These are prescribed wastes (references 18 and 47) which can be useful to waste recycling companies for neutralising acidic wastes.

(g) Environment Protection

Abide by Environment Protection Regulations made under the Environment Protection Act 1970.
Obtain additional advice as required, about pollution control and waste disposal in Victoria, from the Environment Protection Authority.

GLOSSARY

Basin

A hollow or depression within which water can be contained.

Batter

The face of an embankment.

Buffer Area

An area, usually of dense vegetation, alongside and protecting a feature such as a stream from damage or pollution.

Capability

(See “Land Capability”)

Catchment

The area determined by landform within which falling rain will contribute to water runoff at a particular point being considered.

Channel

The bed and banks within which water flows along a ditch, drain, creek, stream or river. The bed and banks may be sharply defined as for an eroded gully or transitional as for a gentle depression.

Chute

An open channel with a steep gradient used to convey water to a lower level.

Compaction

The process of reducing the volume and increasing the density of a material such as by the use of a sheepsfoot or tamping roller or other machine.

Contour

A horizontal line, whether imaginary or marked, on the surface of the earth. Portrayed on maps as a drawn or plotted line of the same elevation.

Contour Ploughing

Ploughing horizontally on the contour.

Contour Wattling

The placing of closely spaced vertical branches of wattle to hold topsoil and vegetation on steep embankments. Also refers to horizontal boards, mesh or membranes held by vertical posts for the same purpose.

Cover Crop

Plants, particularly cereals, grown mainly to protect the soil on a temporary basis during or prior to the establishment of more protective plant cover.

Crest

The summit or top edge.

Culvert

Subsurface pipe or drain and its associated inlet and outlet.

Cyclone Centrifuge

Conical container within which a fluid such as air or water spirals to induce the separation of heavy particles from the bulk of the fluid.

Dam

A barrier or embankment which confines water.

Design Life

The period of time for which a structure or facility is expected to function effectively.

Discharge

For the purposes of this document, “discharge” includes any flow, emission, pumping or runoff, whether natural or otherwise, surface or subsurface, of water, eroded soil, suspended solids or other materials, whether deposited or carried by or in air or water.

Dispersible Soils

Soils which become easily dispersed and tend to remain suspended in water.

Diversion Bank

A low embankment used to divert or intercept water.

Drainage Line

A location where flowing water concentrates in a channel.

Drop Structure

A structure for conveying water vertically or down a steep incline to a lower level.

Dutch Drain

A drainage trench filled with gravel and rock to store and convey water downslope. Drainage capacities can be increased by incorporating a slotted or pervious pipe within dutch drains.

Embankment

Long mound of earth or the exposed face formed when soil is excavated or deposited.

Emergency Spillway

An outlet channel installed to convey excess water flows around a dam or structure.

Environment

The environment means the physical factors of the surroundings of human beings including the land, waters, atmosphere, climate, sound, odours, tastes, the biological factors of animals and plants and the. social factor of aesthetics.

Erodible

Able to be eroded.

Erosion

The detachment or wearing away of the earth's surface, particularly soil or loose material, by flowing water, wind or other geological agents.

Fill

Material, usually excavated soil or rock, deposited on an area

Flocculation

The coagulation of fine particles into aggregates of greater mass.

Freeboard (Hydraulic)

The vertical distance between the top of a dam embankment or structure and the high water level. Freeboard is provided to prevent water overtopping the structure or dam embankment.

Gabian

A rectangular box made from steel mesh and used to hold rocks. Gabians are assembled into many shapes for use as hydraulic structures.

Gabian Mattress

A gabian about 20 cm thick used to line channels to prevent erosion.

Geotextile (Geofabric or Filter Cloth)

A permeable membrane of woven, needle punched or loosely joined plastic filaments. Such membranes are used to filter soil from water, prevent soil being washed from under hydraulic structures and to increase the foundation stability of works such as roads.

Gradient

The slope or inclination of a surface. Gradients are usually expressed as a percentage of vertical rise divided by horizontal run or as degrees to the horizontal. They can also be expressed as the proportion x:1 where x is the horizontal distance and "1" is the equivalent unit vertical distance.

Gully

An eroded channel 300 mm or more deep.

Hydrostatic water pressure

The upward lifting pressure exerted by water on a surface equivalent to buoyancy.

Land Capability

Land capability is a system of interpreting and mapping land characteristics so as to assess the levels of land use management needed to maintain productivity and to preserve the environment. It is typically a three or five class system with each class describing the capability of the land to support a particular land use.

Mulch

A covering placed on the surface of soil to help protect it from erosion and/or to enhance soil characteristics such as water retention. Mulch is spread thinly to assist plant establishment or thickly to prevent weed growth.

Nephelometer Turbidity Units

Units of turbidity measured by comparing the intensity of light scattered by a water sample to a standard reference suspension under the same conditions (see "Turbidity"). Turbidimeters are usually calibrated using a standard formazin polymer solution of 40 Nephelometric units. This has an approximate turbidity of the now outdated 40 Jackson Turbidity Units, which were measured using the light from a candle.

pH

The number which is the logarithm (to the base power of 10) of the reciprocal of the hydrogen ion concentration in a water solution. The pH of pure water is 7. Higher values indicate an alkaline solution and lower values indicate an acidic solution. To reduce or alter the pH by one unit, the solution needs to be concentrated or diluted by pure water ten fold respectfully.

Polluted

Polluted means the condition of the environment described and referred to in the Environment Protection Act 1970.

Pollution

Contamination of air, water or land or the audible environment by an excessive concentration or level of any substance, chemical, noise or other alteration (see "polluted").

Recurrence Interval

The average time interval or frequency for which a particular event, such as a specific rate of water discharge or rainfall will occur.

Retaining Wall

Solid wall used to support a steep embankment or vertical land face.

Rill

A small eroded channel less than 300 mm deep.

Runoff

The surface discharge or flow of water or surface eroded soil.

Sediment

Mineral and organic material that has been eroded then deposited. "Suspended sediment" is sometimes used in reference to soil which has become suspended in water. Suspended solids are often expressed as concentrations in milligrams per litre (grams per cubic metre) of suspended solids.

Sediment Trap

A structure, barrier or filter to collect or trap sediment. It is usually designed to treat water from small catchments.

Sedimentation

The deposition of sediment from suspension in water.

Silt

Soil particles between 0.002mm and 0.02mm diameter.

Siltation

Technically, the deposition of silt. Sometimes used as an alternative to “sedimentation”.

Stable

Resisting erosion or movement.

Stabilization (Stabilisation)

For the purposes of this document, “stabilization” refers to the treatment of erodible material or provision of protective coverings so as to prevent erosion or reduce the rate or likelihood of erosion.

Stable

Enduring and resisting change such as by erosion.

Stockpile

A temporary pile or mound of loose material.

Surface Waters

Surface waters includes any river, stream, creek, drainage line, drain, reservoir, tank, billabong, anabranch, canal, spring, swamp, natural or artificial channel, lake, lagoon, waterway, dam, tidal water, coastal water, groundwater or other feature defined as such in the Environment Protection Act 1970.

Suspended Solids

Suspended solids refers to solid material such as soil or sediment which has become suspended in water.

Tunnel Erosion

Tunnel erosion is the removal of subsoil by water while the surface soil remains relatively intact.

Turbidity

The clarity or dearness of a liquid usually measured by passing a beam of white or infra-red light through a sample and measuring the amount of light scattered or transmitted with a light sensitive cell or diode (see “Nephelometer Turbidity Units”)

Waste

Under the Environment Protection Act 1970, waste includes any matter which is discarded, emitted or deposited in the environment in such volume, constituency or manner as to cause an alteration in the environment (see “pollution”).

Wing Wall

Extension of a vertical wall in an hydraulic structure to direct flows of water and to prevent water flowing around the side of the structure.

REFERENCES

1. Australian Environment Council, "Water Pollution Control Guide for Urban Runoff Quality Management", Report No. 23 (1988)

2. Australian National Committee on Large Dams, "Guidelines on Design Floods for Dams", (1986)

3. Board of Works, "Don't Forget the Soil!" - Leaflet No. 6

4. Cadwaller P L & Backhouse G N. "A Guide to the Freshwater Fish of Victoria", publ. Victorian Government Printing Office on behalf of the Dept Conservation & Environment (1983)

5. Commissioner for the Environment, "State of the Environment Report 1988 Victoria's Inland Waters", Government of Victoria (1988)

6. Department of Agriculture & Rural Affairs, Victoria, "Agnotes" and associated leaflets dealing with plants and plant requirements

7. Department of Conservation & Environment, Victoria, "Environmental Guidelines for River Management Works", (1990)

8. Department of Conservation & Environment, Victoria, "Inventory of Potentially Hazardous Dams", Water Victoria, Report No 43, (1989)

9. Department of Conservation & Environment, Victoria, "Code of Forest Practices for Timber Production", Revision No 1 (1989)

10. Department of Conservation & Environment, Victoria, "Tree Growing Notes", "Soil & Water Notes" and associated publications

11. Department of Conservation & Environment, Victoria, "Water Victoria. An Environmental Handbook", Water Resources (1989)

12. Department of Conservation & Environment, Victoria, "Water Victoria A Resource Hand book", Water Resources (1989)

13. Department of Planning & Housing, "Trees in Paved Areas", (revised 1990)

14. Department of Planning & Housing, "All Planning Schemes in Victoria Amendment S", Planning and Environment Act 1987 (1991)

15. Department of Planning & Housing, "Native Vegetation Clearance Controls", Planning and Environment Act 1987, Report of a Panel pursuant to Section 153 of the Act (1991)

16. Department of the Environment, Land and Planning, "Draft: Water Pollution Control Pond Design Guidelines", Interim Territory Planning Authority, ACT (1990)

17. Department of the Environment, Land and Planning, "Urban Erosion and Sediment Control Field Guide", (previously EPS, National Capital Development Commission) (1989)

18. Environment Protection Authority, "List of Treatment and Disposal Facilities - Prescribed Waste", Information Bulletin WM 8/88 (1988)

19. Environment Protection Authority, "Green Engineering" video produced by Film Victoria (1988)

20. Environment Protection Authority, "Recommended Water Quality Criteria" Publ. No. 165 (1983)

21. Finegan M, "Soil Stabilisation Assists Two Major Landscaping Projects in Canberra. ACT" Aust Jnl of Soil and Water Conservation, Vol 3 No 4, Nov 1990

22. Garvin R J, Knight M R, Richmond T J, "Guidelines for Minimising Soil Erosion and Sedimentation from Construction Sites in Victoria" Soil Conservation Authority, Victoria (1979), now available from the Department of Conservation & Environment, Victoria

23. Garden F, "Gravel Road Erosion Prevention Guidelines" publ. by the Department of Conservation and Environment, Victoria (1988)

24. Goldman S J, Jackson K, Bursztynsky P E, "Erosion and Sediment Control Handbook" McGraw-Hill Book Company Sydney (1986)

25. Institution of Engineers, Australia, "Australian Rainfall and Run off" (1987)

26. Koehn J D & O'Connor W G, "Biologicall Information for Management of Native Freshwater Fish in Victoria", Department of Conservation & Environment (1990)

27. Land Conservation Council, "Rivers and Streams. Special Investigation Report" Government of Victoria (1989)

28. Land Conservation Council, "Rivers and Streams - Special Investigation. Proposed Recommendations" Government of Victoria (1990)

29. Mitchell P, "The Environmental Condition of Victorian Streams", report for the Department of Water Resources, (1990), now part of the Department of Conservation & Environment, Victoria

30. National Capital Development Commission "Guidelines for Erosion and Sediment Control on Building Sites", (1989), now available from the Department of the Environment, Land and Planning, ACT

31. Nelson K D, "Design and Construction of Small Earth Dams" Inkata Press Melbourne (1985)

32. Ransom M J, "Control of Erosion on Construction Sites", Department of Conservation & Environment, Victoria (1987)

33. Rowe R K, Howe D F, Alley N F, "Manual of Guidelines for Land Capability Assessment in Victoria", Department of Conservation & Environment (1988)

34. Rural Water Commission of Victoria, "Guidelines for Consulting Engineers for the Construction of Private Dams on Watercourses", Government of Victoria (1990)

35. Rural Water Commission of Victoria, "Guidelines for Catchment Management" Standing Committee on River Management (1987)

36. Scott & Furphy Pty Ltd "Design Manual for Urban Erosion and Sediment Control – Guidelines", prepared for the National Capital Development Commission (1988), now available from the Department of the Environment, Land and Planning, ACT

37. Soil Conservation Service of New South Wales, "Urban Erosion & Sediment Control", Technical Handbook No. 2 (1978)

38. Standards Association of Australia - various "Australian Standards", engineering tests for dams, lagoons, earthworks etc.

39. State Pollution Control Commission, NSW, "Pollution Control Manual for Urban Stormwater" (1989)

40. Vic Roads, "Road Design Manual" (1985)

41. Vic Roads, "Roadside Management Guide" (1990)

42. Victoria Government Gazette, "State Protection Protection (The Air Environment)" No. 63 (1981)

43. Victoria Government Gazette, "State Environment Protection Policv (Waters of the Dandenong Valley)" No. S 12 (1988)

44. Victoria Government Gazette, "State Environment Protection Policv (Waters of Victoria)" No. S 13 (1988)

45. Victoria Government Gazette, "State Environment Protection Policv (Waters of the Yarra River and Tributaries)" No. 50 (1984)

46. Victorian Government Printing Office, "Environment Protection Act 1970" as amended

47. Victorian Government Printing Office, "Environment Protection (Prescribed Waste! Regulations", Statutory Rule No. 195 and Amendment No. 246, (1987)

48. Victorian Government Printing Office, "Environment Protection (Scheduled Premises and Exemptions) (Amendment) Regulations 1987) Statutory Rule No. 196, (1987)

49. Victorian Government Printing Office, "Litter Act 1987" No 54

50. Victorian Government Printing Office, "Flora and Fauna Guarantee Act 1988"

51. Victorian Government Printing Office, "Timber Harvesting Regulations 1989" Statutary Rule No 194 (1989)

52. Victorian Government Printing Office, "Environment Protection (Service Stations and Vehicle Wash) Regulations", Statutory Rule No. 253, (1980)

53. White L & Kelyneck J "Land Resource Data Atlas. Non Urban Areas", (including land capability information) Board of Works & Dept. Conservation & Environment (1985) available 'from the Department of Planning & Urban Growth, Victoria