APPENDIX II

Notes on Assessment of Susceptibility of Land Types to Deterioration

Introduction

The need to maintain and improve the productivity of soil is being increasingly recognised. For soil conservation to be achieved, however, land uses and management practices must be within the capability of the land to support them, and past degradation must, if possible, be repaired. An assessment of land capability (including susceptibility of the land to degradation) and determination of management practices which will at least maintain, and ideally improve, productivity require a knowledge of the natural resources of an area and an understanding of the processes operating.

It is also necessary to understand how land management practices affect landscape characteristics and hence processes. Ideally land characteristic and land process relationships need to be quantified. Among other things, this allows the effects of different managements and land uses on a land type, or of the same management and land use on different land types, to be compared. Considerable research is devoted to developing hydrology and erosion models which allow quantitative prediction of processes from measured values of critical parameters. Unfortunately, current models are too data intensive to be used to provide assessments useful for this report and other methods have had to be employed.

This appendix outlines the methodology used and provides some of the background information on which the method is based. Firstly, however, descriptions of the basic processes and land characteristics involved in land deterioration are given.

Processes of Soil Deterioration and Land Characteristics Involved

There are many forms of land deterioration. These differ in the mechanisms involved and soil properties affected. They include:

Mechanism	**Form of degradation and on-site effect**
Water erosion *Sheet and rill* *Gully* *Tunnel* *Scour* *Streambank* *Wind erosion* *Mass movement*	Loss of soil and associated nutrients
Chemical deterioration	Loss of nutrients Acidification
Physical deterioration	Decline in structure
Biological deterioration	Loss of humus, and soil fauna flora

Considered here are mass movement and the different forms of water erosion. These processes involve sediment transport and affect water quality in Dartmouth Dam and Lake Hume, a primary reason for this survey.

Definitions of these forms of deterioration are given below. The definitions, with the exception of that for scour erosion, are followed by tables which set out the processes involved, the associated land characteristics, and the management practices that modify the land characteristics. The aim of these tables is to help those unfamiliar with processes of deterioration to understand them and the way they are linked to the land and hence are affected by land management. The definitions and tables are from Aldrick *et al.* (1988).

Sheet (inter-rill) and rill erosion

Sheet erosion is the removal of relatively even layers of soil from the land surface, resulting primarily from the effects of raindrop impact and the transport of detached soil particles by splash and thin-film runoff.

It occurs after the protective cover of plants and litter has been reduced, exposing the soil surface. Rill erosion is the removal of soil within small channels where runoff water concentrates and develops sufficient velocity and turbulence to detach soil by hydraulic shear. Rills are channels which can be obliterated by tillage. These forms are summarised by Fairbridge and Finkl (1979).

Sheet and rill erosion are considered together because runoff usually does not take place as thin-film flow for great distances, but tends to channelise due to irregularities in the shape and nature of the soil surface. Thus sheet and rill erosion tend to be inextricably interwoven.

Land characteristics and management factors involved in sheet and rill erosion

Processes	Land characteristics affecting processes	Factors affected by land characteristics	Management factors that modify land characteristics
Sheet and rill erosion occur when the forces due to rainfall, flowing water and gravity overcome the cohesion and weight of the soil particles/aggregates Processes involved are: detachment of exposed soil by: - raindrop impact - surface flow Transport by - rain splash - surface flow Deposition Surface flow occurs on any sloping surface when the rainfall rate exceeds the infiltration rate Off-site effects include increased sedimentation in streams and on lower lands	Vegetation - structure, percent surface cover (including litter) - leaf area, rooting depth and perenniality	• Exposure of surface soil • Intensity of rain drop impact • Infiltration/runoff ratio • Velocity of surface flow • Transpiration and hence infiltration rate and volume of surface flow	All aspects of the vegetation are affected by selection of species and control of biomass by practices such as: cultivating clearing trafficking fertilising grazing trampling harvesting burning
	Climate - rainfall intensity/duration - seasonal rainfall/ evapotranspiration regime	• Intensity of raindrop impact • Volume of water exceeding infiltration rate and hence volume of surface flow • Soil water content and hence infiltration rate and volume of surface flow	
	Geology - permeability of rock or unconsolidated sediments	• Soil water content and hence infiltration rate and volume of surface flow	
	Topography - microrelief - slope degree and length - slope and landform shape - position in landscape	• Infiltration/runoff ratio • Velocity of surface flow • Volume and velocity of surface flow • Tendency to concentrate surface flow • Volume of run-on	Contour cultivating, contour banking and strip cropping reduce slope length and affect microrelief
	Soil - profile permeability - depth and water-holding capacity - size/weight of surface particles/aggregates - cohesion of surface particles/aggregates, including tendency to slake and disperse - tendency to surface seal and hydrophobicity - percent stone cover	• Infiltration rate and hence volume of surface flow • Infiltration/runoff ratio • Detachment and transport • Detachment • Infiltration rate and hence volume of surface flow • Infiltration/runoff ratio and velocity of surface flow	The above management practices controlling biomass affect soil organic matter content, which in turn affects all listed soil characteristics except surface rock Direct soil compaction and disruption by trampling, trafficking and cultivating affect soil permeability, water holding capacity and size/weight and cohesion of aggregates

Gully and tunnel erosion

Gully erosion results in channels too large to be readily obliterated by tillage. In practical terms, channels with a depth of 0.5 m or more are considered gullies.

In Victoria, Milton (1971) classified gullies on the basis of formative mechanisms e.g. scouring, sapping, spalling, slumping.

Tunnel erosion is the removal of soil from subsurface seepage flow paths. The formation of tunnels has been described by Downes (1946) and Crouch (1980). It occurs when runoff is generated on a soil surface with a low infiltration rate and with interconnected cracks and other holes, such as old root channels and burrows. The water moves preferentially along these cracks and other voids in the subsoil, removing soil. As the tunnels enlarge the ceilings may collapse to form gullies.

Comments:

(i) lack of cohesion between particles is characteristic of soils with high sand and silt content and not cemented by agents such as carbonates, iron oxides or organic matter and of loose gravelly detrital materials with a fine earth matrix;

(ii) cracks and channels develop in soils with a high shrink-swell capacity;

Land characteristics and management factors involved in gully and tunnel erosion

Processes	Land characteristics affecting process	Factors affected by land characteristics	Management factors that modify land characteristics
Gully and tunnel erosion occur when the forces due to rainfall, flowing water and gravity overcome the cohesion and weight of the soil particles/aggregates	Vegetation - structure, percent surface cover (including litter) - leaf area, rooting depth and perenniality	• Exposure of surface soil to detachment • Intensity of raindrop impact • Velocity of channelised flow and hence particle detachment and transport • Transpiration and hence infiltration rate and volume of surface and subsurface flow	All aspects of the vegetation are affected by selection of species and control of biomass by practices such as: cultivating clearing trafficking fertilising grazing trampling harvesting burning
Processes involved are: detachment of exposed surface soil by: - raindrop impact - channellised overland flow - cracking	Climate - rainfall intensity/duration - seasonal rainfall/ evapotranspiration regime	• Intensity of raindrop impact • Volume of surface and subsurface flow • Volume of surface and subsurface flows via regulation of soil water content	
detachment of subsoil by - subsurface flow in permeable strata and along cracks and tunnels - cracking	Geology - perviousness of rock or unconsolidated sediments	• Soil water content and hence infiltration rate and volume of surface and subsurface flow • Lateral or vertical movement of water	
Transport of particles/ aggregates by - channellised overland flow - subsurface flow - gravity collapse Deposition	Topography - microrelief (both of channel and catchment to a site) - valley slope degree and length - position in landscape and catchment area - catchment slope degree and length - slope and landform shape	• Infiltration/runoff ratio • Velocity of surface flow • Volume of surface and sub-surface flows reaching site • Tendency to concentrate surface flow	Contour and diversion banking, strip cropping and contour cultivation reduce catchment slope length and catchment area; they also affect microrelief
Gully erosion is regarded as having occurred when the channel is too deep to be crossed or cannot be obliterated by tillage Off-site effects include increased sedimentation and run-on in streams and on lower lands	Soil - profile permeability - depth and water-holding capacity - size/weight of soil particles/aggregates - cohesion of particles/ aggregates, including tendency to crack, slake and disperse - differential permeability within a horizon due to the presence of cracks and channels - percent stone cover	• Infiltration rate and hence volume of surface and sub-surface flow • Lateral or vertical movement of soil water • Volume of surface and subsurface flow • Detachment and transport • Detachment • Movement of water along preferred channels • Infiltration/runoff ratio and velocity of surface flow	Type and amount of biomass production will affect soil organic matter content, which will in turn affect most listed soil characteristics Soil disruption and compaction by trampling, burrowing, cultivation and trafficking will affect profile permeability, water-holding capacity and size / weight and cohesion of soil particles/aggregates

Scour erosion

Scour erosion refers here to detachment and removal of soil by floodwaters from land beside rivers and creeks.

Land Characteristics involved in scour erosion

Erosion due to floodwaters depends on the volume and velocity of their flow. This is determined by:

(i) rainfall intensity and duration in the catchment

(ii) catchment area and topography

(iii) infiltration and water-holding capacities of soils in the catchment

(iv) stream channel size

(v) the gradient and microrelief of the flooded land

The soil characteristics influencing susceptibility are the same as those involved in the other forms of water erosion.

Streambank erosion

Streambank erosion is the collapse of streambanks and is usually caused by under-cutting of the banks by the stream. It is often exacerbated by trafficking by stock, people or vehicles, and tree clearing along streams.

Bank erosion occurs along river channels cut into colluvium and alluvium, particularly in meandering river systems. It is accelerated when the flow regime of a river is altered due to changes in the catchment, such as clearing, which increase the frequency and volume of peak flows. Straightening of stream channels also leads to more violent flooding and bank erosion due to increased stream velocities and decreased channel storage.

Land characteristics and management factors involved in stream-bank erosion

Processes	land characteristics affecting processes	Factors affected by land characteristics	Management factors that modify land characteristics
Streambank erosion occurs when forces due to water movement along a stream channel are sufficient to detach and remove soil material from the stream-bank	Vegetation - structure, percent surface cover (including litter) - leaf area, rooting depth and perenniality - structure, percent surface cover, leaf area, rooting depth and perenniality within the catchment	• Streambank stability • Transpiration and hence soil water content of banks • Volume and velocity of stream flow	Stabilise stream banks with trees, shrubs and grasses; restrict stock and vehicular access All aspects of catchment vegetation are affected by the selection of species and control of biomass by practices such as: cultivating clearing trafficking fertilising grazing trampling harvesting burning
Processes involved are: detachment of soil from streambank by: - slaking - undercutting - collapse of bank - transport by channel flow - deposition	Climate - rainfall intensity/duration in catchment - seasonal rainfall/ evapotranspiration regime within catchment	• Volume of water exceeding infiltration rate and hence volume of stream flow • Soil water content and hence infiltration rate, runoff and volume of stream flow	
	Geology - permeability of rock or unconsolidated sediments in the catchment	• Soil water content and hence infiltration rate, runoff and volume of stream flow	
	Topography - catchment slopes, degree and length	• Runoff and volume of stream flow	Contour cultivating, contour banking and strip cropping to reduce slope length
	Soil - permeability of soils within the catchment - depth and waterholding capacity of catchment soils - cohesion of soil particles /aggregates on stream bank, including tendency to slake and disperse - size/weight of stream bank particles/aggregates	• Infiltration rate and hence runoff and volume of river flow • Detachment • Detachment and transport	Restrict stock and vehicular access to streams

Mass movement - soil creep and landslide

Soil creep is the imperceptibly slow but significant downslope movement of a mass of soil; it does not require saturated conditions.

Landslides are sudden movements of soil or rock masses down a slope. Landslides (earth and mudflows) leave characteristic concave hollows with crescentric upper edges, whilst at their base the displaced material often has an irregular surface.

Land characteristics and management factors involved in landslides

Processes	Land characteristics affecting processes	Factors affected by land characteristics	Management factors that modify land characteristics
Landsliding occurs when the shear forces exceed soil/regolith strength; this generally occurs when soil/regolith strength is reduced by an increase in water Processes involved are: - Infilatration of water - wetting of basal plane - saturation of soil (mudflow) - Shearing and movement of soil mass by gravity Other processes that may be involved include: - loading of soil mass resulting in an increase in shear strength - removal of material from slope toe resulting in reduced slope support Types of landslides covered by this table are: - rock and earth slides - earth flow (downslope movement of unsaturated soil and weathered rock on a lubricated basal shear plane) - mudflow (movement of saturated soil and rock) - combination slide/flows	Vegetation - leaf area, rooting depth and perenniality - total leaf area and canopy type - root depth and mass	• Transpiration and hence soil water content • Volume of water held by canopy and hence volume available for infiltration • Anchorage of soil by roots	All aspects of the vegetation are affected by selection of species and control of biomass by practices such as: cultivating clearing trafficking fertilising grazing trampling clearing burning
	Climate - seasonal rainfall / evapotranspiration regime	• Soil water content	
	Geology - perviousness of rock or unconsolidated sediments - wet strength of rock/ regolith - angle of dip	• Soil water content • Shearing tendency	
	Topography - slope degree - microrelief and position in landscape	• Gravitational force • Run-on, site drainage and hence soil water content	
	Soil - topsoil permeability - presence of slowly permeable layer - cohesion of particles/ aggregates including tendency to slake and disperse - depth - clay mineralogy	• Infiltration/runoff ratio and hence soil water content • Water content of soil immediately above layer • Soil strength • Soil water content	Compaction and soil disruption by stock, vehicles and cultivation will affect profile permeability

THE SUSCEPTIBILITY OF LAND TO DETERIORATION

The concept of susceptibility

In order to consider the likely impact of land use/management on different land types, the concept of susceptibility of land to deterioration was developed. This concept was described in Aldrick *et al.* (1988); the discussion is repeated here for easy reference.

> The susceptibility of an area of land to a particular form of deterioration is related to the ease with which the associated processes can occur; it is related to the inherent properties of the land in question and is considered independently of land uses and severity of disturbance. For example, soil loss by sheet erosion involves particle detachment and transport by rain splash and surface flow. The susceptibility of the land to soil loss is therefore related to the land properties which influence resistance of the soil particles to detachment and transport, such as the size and weight of soil particles and their cohesion, and the volume and velocity of surface flows. Generation of surface flows is influenced by such factors as infiltration capacity of the topsoil, profile permeability and water holding capacity, slope of the land and rainfall intensity.
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> It is important that the concept of susceptibility to deterioration be distinguished from the concepts of magnitude of deterioration, tolerance to deterioration, and hazard of deterioration. The magnitude of a form of deterioration involves amount and aerial extent; for example, the amount of soil lost or the area of land waterlogged. It is determined by the severity and type of land disturbance as well as by the inherent susceptibility of the land.
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> The tolerance of the land to deterioration relates to the effects of deterioration on productivity. The hazard of deterioration involves the probability of deterioration occurring; this depends on land use and management, the magnitude and a real extent of disturbance, and inherent susceptibility.

Rating susceptibility

In order to compare the susceptibilities of different land types to particular processes of deterioration, susceptibility needs to be rated. This is difficult as:

(i) ideally it requires a quantified relationship between the different factors involved, for example, the slope gradient for different rainfall intensities that is necessary for overland flow to transport the surface particles of different soils.

(ii) some of the land characteristics important to particular degradational processes are known to be very variable within a land type or even land component. For example, Talsma and Hallam (1980) found that the saturated hydraulic conductivity of soils varied by up to two orders of magnitude over very short distances.

Methodology for rating susceptibility used in this report

A detailed rating of the susceptibility of the different land types to deterioration was not regarded as feasible due to the problems of rating susceptibility outlined and to the paucity of data available. Any such rating is likely to be misleading. Instead, the likely hydrology and its implications for erosion are discussed qualitatively for the different physiographic regions in Chapter 3. The aim is to provide an understanding of processes at a landscape as distinct from site level.

As there is a need, however, for some indication of the relative susceptibilities of the land types to sediment movement, land components have been given a broad rating, (low, moderate or high), to sheet, rill and gully erosion, and land slipping. These ratings are given in tabular form in Chapter 4, along with critical land characteristics.

To arrive at the ratings for sheet and rill erosion, and for gully erosion, weight has been given to probable soil infiltration rates, soil permeability, soil water storage capacity and rainfall. As no measurements were made for these characteristics for soils in the survey area, they have been assessed using the sources given in Appendix 1. Consideration has also been given to the method for rating the erodibility of soils in Charman (1984).