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Corangamite Catchment Management Authority

Erosion Risk Management

Background Report for the Corangamite Soil
Health Strategy.

EMO Implementation Project for The City of
Greater Geelong

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1. Introduction

The Corangamite Catchment Management Authority (CCMA) is developing a Soil Health Strategy (CSHS) as a sub-strategy of the Corangamite Regional Catchment Strategy. The development of the CSHS is being managed by the Department of Primary Industries (DPI) and will provide the basis for investment in regional soil health over the next decade. The CSHS addresses a number of soil issues of which landslides and erosion are of particular interest to both the CCMA and the City of Greater Geelong (CoGG). A brief overview of land degradation within the Corangamite region is detailed in Appendix A whilst some photographic examples within the region are shown in Appendix B.

As part of the overall implementation process within the CCMA region, a pilot study was commenced with the City of Greater Geelong (CoGG) to address key elements involved in the development and implementation of an Erosion Management Overlay (EMO) within the CoGG planning scheme under the Victorian Planning Provisions. Phase 1 of the pilot study included the establishment of a standalone data handling and management system compatible with CoGG's existing GIS system. In addition a series of preliminary susceptibility hazard maps relating to a various land degradation processes and accompanying preliminary guidelines and management procedures were produced (GHD, 2004).

Whilst the initial phases of the EMO implementation project for the CoGG yielded significant progress, a number of limitations were also recognised associated with both the data sets and the preliminary guidelines. In particular it was recognised that further mapping and ground truthing of land degradation occurrences was required to complete and verify the initial database. This aspect of the Phase 1 work has since been addressed as part of ongoing commitment by CCMA and includes an erosion and landslide database compiled using high resolution mapping from ortho-corrected aerial photographs by the University of Ballarat. Field verification of the database has been assisted by various Landcare Groups, Catchment Coordinators, and Soil Extension Officers within the CCMA region.

As defined in the initial study, land degradation was taken to include landslides, erosion and costal erosion processes. Whilst risk management techniques have been successfully applied to assessment and management of the landslide hazard, the study identified the lack of suitable methods of risk management for erosion and coastal erosion processes. As a result, this report aims to develop a suitable method of erosion hazard identification, risk estimation, risk evaluation and risk treatment which is to be collectively referred to as Erosion Risk Management.

It should be noted that this report only refers to a risk management methodology for erosion, as a well-established method of risk management for landslides already exists.

The proposed methodology has been based on the overall approach developed in the Australian Standard on Risk Management AS/NZS 4360:2004. In addition the methodology and format of the report has been intentionally aligned with the risk management concepts and guidelines developed for landslides by the Australian Geomechanics Society (AGS) (AGS 2000).

2. When is Erosion Risk Management Applicable?

Erosion risk management should be conducted:

- For any land identified as potentially susceptible to any forms of erosion.
- Where erosion hazards which impact a site have been identified.
- Where a history of erosion activity has been identified.
- Where the site, development of the site, or construction upon the site, may produce erosion hazards which have the potential to impact on the site and areas beyond the site boundaries.

Erosion susceptibility mapping such as that conducted at a regional scale by Primary Industries Research Victoria (PIRVic) for the CCMA in the recent Corangamite Land Resource Assessment Study (Robinson et al. 2002) has been used in the development of this erosion risk management process in order to initiate a site specific erosion risk assessment and identify any associated risk treatment and management options.

Extensive aerial photographic mapping of the occurrences of erosion and landslides recently completed by the University of Ballarat (Feltham 2005) has also greatly added to the ability to carry out meaningful erosion risk management throughout the CCMA area. This study has resulted in 4175 land degradation features being identified within the region.

As such, the process of erosion risk management can be used in:

- Planning and design of a proposed development.
- Reduction of risk in existing developments.
- Design of erosion rehabilitation and remediation works.

3. Erosion Risk Management Process

3.1 The Risk Management Process

The process of risk management is best described by reference to the following definitions contained in the Australian Standard on Risk Management AS/NZS 4360:2004

Risk Management: The culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects.

Risk Management Process: The systematic application of management policies, procedures and practices to the tasks of communicating, establishing the context, identifying, analysing, evaluating, treating, monitoring and reviewing risk.

The main elements of risk management are shown in Figure 1 which is taken from AS/NZS 4360:2004.

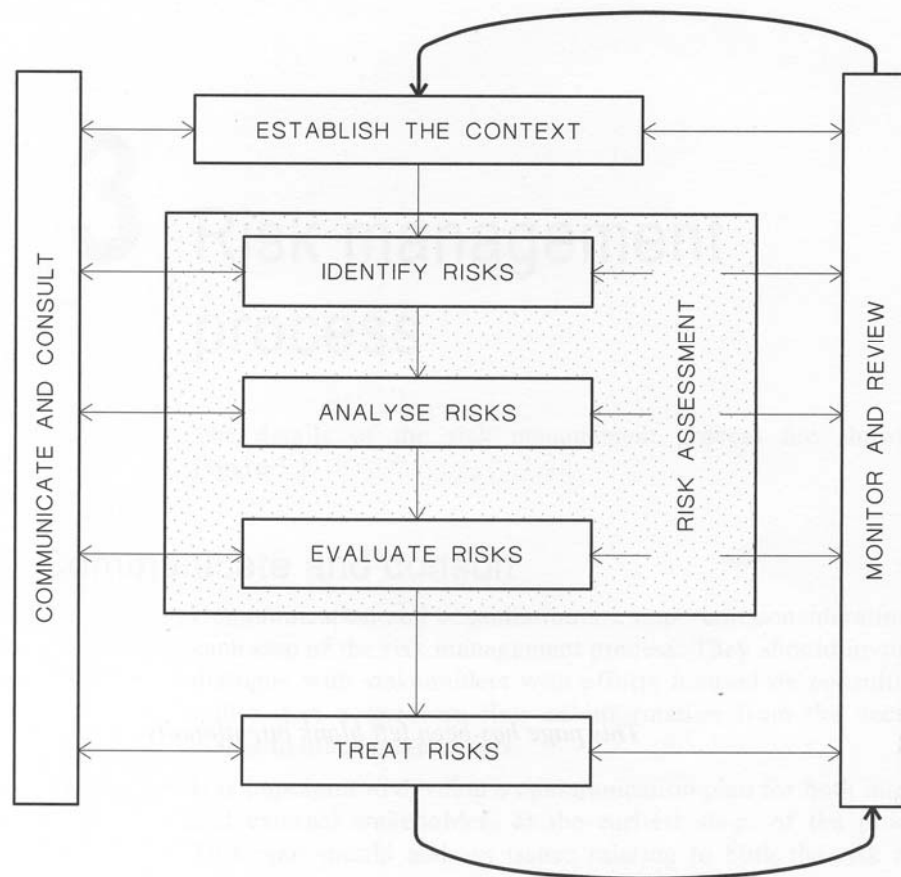


Figure 1 Risk Management Overview

The risk management process proposed for erosion has been based on the approach taken in the Australian Geomechanics Society's (AGS) Landslide Risk Management Guidelines and Concepts (AGS 2000) which also draws heavily on the Australian Standard. The process for landslide risk management from the AGS document is detailed in Appendix C. As such, the risk management process can be described as comprising three main components:

- Risk Analysis (incorporating Hazard Identification, Frequency Analysis, Consequence Analysis and Risk Estimation).
- Risk Evaluation.
- Risk Treatment.

In essence the process involves answering the following questions:

- What might happen? (Assess the likely modes of land degradation).
- How likely is it? (Assess the probability of occurrence).
- What impact, damage or injury may result? (Assess the consequence of the hazard).
- How important is it? (Assess the significance of the impact in relation to the regulatory criteria and public opinion).
- What can be done about it? (Assess treatment options including management and mitigation options).

Details from the draft submission on Guidelines for the Development of Sites Prone to Landslide to the Australian Building Controls Board (ABCB) (ABCB 2004) are also included in Appendix C. These guidelines detail processes involved in both the investigation phase and the design/ verification phase for landslide risk management. It is the intent of this report to replicate both the overall process and the stages for both investigation and design of developments in areas prone to erosion.

The proposed process for erosion risk management is presented in Figure 2. The main elements of risk management are summarised in the following sections.

3.2 Risk Analysis

The context of the assessment is established whereby the scope of the assessment, the nature of the methodology and the criteria against which risk is to be evaluated are to be defined and fully communicated at the start of the assessment.

Hazard identification identifies what, why and how things can arise as the basis for further analysis. The identification process should be broad so that all possible risks, no matter how small, are considered.

Risk analysis is undertaken after hazard identification and involves the estimation of both hazard and likelihood (in this case a probability based likelihood and the consequence of occurrence). The combination of these two elements provides an estimation of the level of risk i.e.

Risk=Function (Likelihood and Consequence).

FLOWCHART FOR EROSION RISK MANAGEMENT

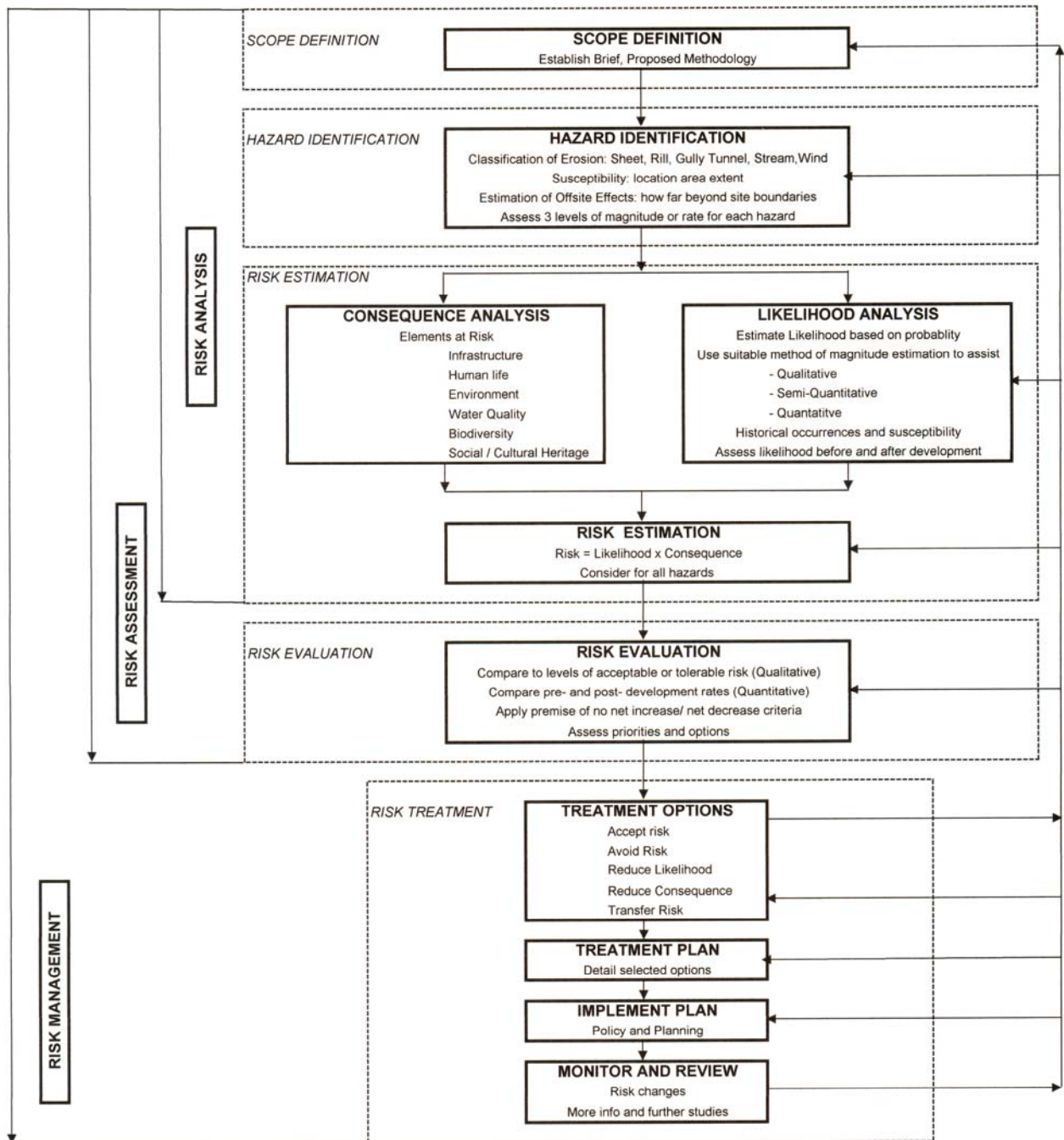


Figure 2 Proposed Method of Erosion Risk Management

3.3 Risk Evaluation

The levels of estimated risk are compared against pre-established criteria. Criteria may be in terms of qualitative criteria for a qualitative approach or may involve a numerical level of risk against criteria which may be expressed as a specific number.

Risks can then be ranked so as to identify management priorities.

3.4 Risk Treatment

If levels of risks are low they may fall into the acceptable category and require no further treatment. However, if risk levels are moderate or higher, they will require some degree of risk treatment and/or risk mitigation. In these cases, specific management plans may be required to be developed and implemented.

In some cases levels of risks may be of such a degree that the proposed development is unacceptable and may not proceed.

In addition, other important elements of the risk management process present at all times of the assessment include monitoring and review of the performance of the risk management process and communication and consultation with stakeholders during appropriate stages of the assessment.

4. Risk Management Terminology

Whilst risk management is a well established and accepted technique, there is still some confusion in the use of risk terminology and vocabulary due in part to the diverse range of activities the methodology has been applied to. In addition the use of risk management in erosion assessment is a relatively new innovation and as such there is little precedent for terminology usage or meaning.

The terminology in this report has been adapted from the Australian New Zealand Standard AS/NZS 4360:2004 for Risk Management. These definitions are detailed in Appendix D and should be explained in any erosion risk assessment (ERA) report by either the inclusion of the attached list or by re-defining appropriate key terms in the text of the report.

In particular, important definitions for use in this document include:

Hazard: A source of potential harm.

Likelihood: Used as a general description of probability or frequency (expressed either qualitatively or quantitatively).

Consequence: The outcome or impact of an event.

Risk: The chance of something happening that will have an impact upon objectives. (expressed in terms of the combination of likelihood and consequence).

5. Erosion Risk Analysis –Scope Definition

5.1 Scope Definition

It is important that any assessment clearly state the scope of works and define the terms of reference under which the assessment has been undertaken. It is also very important that the assessment address any regulatory requirements imposed by the responsible authority initially requesting the information.

To ensure the assessment addresses the relevant issues, the following issues are to be clearly stated in the report:

- The exact nature of the study site, being the primary area of interest.
- The geographic and physiographic boundaries that may be involved in the processes both affecting the site and upon which development at the site may impact.
- The elements at risk and the major asset classes which are to be considered in the assessment. (It is strongly recommended that methodology for erosion risk management take into account not only damage to property and injury or loss of life but also the impact on the receiving environment and in particular, the health of waterways, wetlands and river courses).
- The extent and nature of the investigations to be conducted.
- The type of analysis undertaken and the results.
- The basis for acceptable and tolerable risks (The recommended methodology for erosion risk is to incorporate a minimum policy of no net increase for low and moderate risk sites and a net decrease for high risk sites. In all cases risks should be reduced to levels as low as reasonably practical within appropriate resource limitations.).

These issues must be clearly defined in the report and must be consistent with the requirements of each municipality and/or local government authority.

5.2 Stakeholders

There are a number of stakeholders involved in the process of erosion risk management. These include:

- Property owner/developer (with recognition of future owners).
- Property occupier.
- Owners and developers of adjacent properties whose land may impact the study site or be impacted by the study site.
- The regulatory authority involved in statutory decision making (municipality and/or State or Federal Government Authority).
- Government authorities involved in strategic direction setting (catchment authorities, water boards or State authorities).

- The broader community, including special interest groups.
- Any referral authority involved in decision making.
- The consultant preparing the erosion risk assessment report.
- The tradesmen, builders or developers involved in construction, installation, establishment or completion of the proposed development.

5.3 Consultant Qualifications

An erosion risk assessment (ERA) should be prepared by professionally qualified consultants with an appropriate level of experience and competency in the field of soil conservation, geological and geomorphological hazards, natural resource management and land rehabilitation. Such practitioners may include:

- Soil scientists (pedologists).
- Agricultural scientists with experience in pedology and erosion management.
- Environmental scientists with experience in pedology and erosion management.
- Soil conservation and extension officers.
- Engineering geologists.
- Geotechnical engineers.

The assessment may be prepared by independent consultants or staff from appropriate government agencies (such as DPI, CCMA, and EPA).

NOTE. One of the main issues highlighted in landslide risk assessment in the last few years has been the requirement that the assessment is undertaken by appropriately qualified personnel with specific expertise and understanding of the process of risk assessment and the nature of geological and geomorphological hazards. The same requirement for suitably qualified professionals to undertake the assessment is seen as an equally important element of a successful process for erosion risk assessment.

6. Erosion Risk Analysis – Hazard Identification

6.1 Hazard Identification

The standard definition of hazard as per the Australian /New Zealand Standard on Risk Management (AS/NZS 4360:2004) is as follows:

Hazard: A source of potential harm.

Erosion hazard identification in particular requires an understanding of the various erosion processes and their inter-relationship with such as (but not limited to) geomorphology, geology, landscape evolution, physiography, hydrology, climate, vegetation, soil parameters, land capability and land use. From such an understanding it should be possible to:

- Classify the types of potential and active erosion at a site.
- Assess the susceptibility of the study site and adjacent sites to the different types of erosion.
- Assess the physical extent of each potential erosion type being considered including the location, areal extent, distance of impact from the source and volume of soil loss.
- Assess the likely initiating events such as rainfall, storm surges or human activity at a site.
- Identify increasing or decreasing trends over time by reference to historical data and observations.
- Assess the impacts of proposed management and development strategies.
- Assess interim or temporary circumstances which may arise during development or construction.

A plan and section of the site drawn to an appropriate scale can be extremely useful in representing possible hazards at a site. In particular key features should be identified which may include the locations of the proposed development, buildings, structures, roads, landscaping elements, drainage provisions and water supply (both man made and natural) and all natural and environmental features with a potential to be impacted upon.

6.2 Methodology Considerations in Hazard Identification

The method of hazard identification is critical to the overall risk assessment. An understanding of “what might happen” is essential to enabling all possible or potential hazards to be assessed. As discussed previously, erosion may occur in a number of forms; however it is also important to remember that more than one form of erosion can occur at any one site. In addition, other forms of erosion may be initiated off-site due to the proposed activities so it is vital that a full range of hazards (ranging from small, high frequency events to large low frequency events) be included in the analysis.

Numerous and varied methods may be utilised in the process of erosion hazard identification. For example the use of geological mapping, geomorphological mapping, terrain classification, gathering of historical information on occurrences of erosion in similar topography, geology and climate, soil units studies, landform and land units studies and GIS based methodologies can all be incorporated into the identification of hazards for a particular study site.

Another vital element of hazard identification is the assessment of the impact that the proposed development will have on a site in the future. It is possible that a proposed development will initiate a new form of erosion and not just exacerbate an existing problem. Hence soil erosion may occur in locations where it has never been previously observed or at rates that are several times greater than those existing in the natural or current situation. This is particularly the case where surface drainage has been modified by the construction of paved surfaces resulting in the redirection of runoff into channels.

As such, a list of all possible or potential erosion hazards must be prepared as the initial step of the risk assessment. The list of hazards must include those generated both on-site and off-site which may be initiated as part of the proposed development.

It is vital that persons with suitable training and experience be involved with this initial step of hazard identification as omission and under/over estimation of the effects of the development on different hazards will control the outcomes of the overall risk assessment.

Guidance on erosion types to be considered and sources of information on observed occurrences and postulated susceptibility is provided in the following sections.

6.3 Potential Types of Erosion

The process of erosion is facilitated firstly by the detachment of soil particles from the parent material and its subsequent transport and re-deposition at a point distant from the source material. In accordance with the previous study conducted for the City of Greater Geelong (GHD 2004), the following potential modes of erosion (i.e. hazards) should be considered in the erosion risk assessment:

- *Sheet: Removal of a uniform layer of surface material from a land surface by continuous sheets of water rather than concentrated channels.*
- *Rill: Type of water erosion in which storm runoff is conducted through channels that are narrow and open and less than 0.3 m deep. Rills can develop into gullies if runoff is persistent enough.*
- *Gully: Type of water erosion in which storm runoff is conducted through channels that are narrow and open and greater than 0.3 m deep.*
- *Tunnel: Hydraulic removal of subsurface soil resulting in the formation of underground channels. Tunnelling can develop into gullies if the surface collapses.*
- *Wind: Movement or bouncing of soil particles across the soil surface occurring when the force of the wind exceeds the resistance of the soil surface.*
- *Stream Bank Erosion: Removal of soil from the sides of an existing watercourse and deposition of sediment to waterways through loss of riparian vegetation.*

- *Coastal Dune, Beach and Foreshore Erosion: Includes degradational changes to the dunes, beaches to the high water mark and foreshore area but generally restricted to terrestrial impacts. The process of change may include one or more of the previous erosion types such as wind or landslide*

The process of coastal erosion can extend beyond the dune and foreshore areas and out into the littoral zones. As such coastal processes are currently dealt with under a variety of strategies, acts and plans. It is not the intent of this document to include such processes. The discussion is only intended to include terrestrial processes at the coast such as wind erosion of dunes or impact on coastal foreshore areas by land based processes such as landslides at coastal cliffs.

Further general discussion and information on the potential modes or forms of erosion is provided in Appendix E.

6.4 Proposed Levels of Magnitude for Erosion Hazards.

The magnitude or rate at which erosion may occur is related not only to the susceptibility of the landscape to erosion but also to the nature of the initiating or triggering events. In many cases the rate of erosion may be episodic or only become significant on an infrequent basis. In addition, the magnitude or rate of erosion may be significantly altered by the development and as such the same hazard may be present both pre- and post-development but at a significantly different magnitude.

In order to ensure all possible combinations of the hazard type and the potential range of rates at which that hazard may occur are considered, it is proposed that 3 levels of magnitude be assessed for each and every potential hazard type or mode. The recommended levels are shown in Table 1.

<i>Level</i>	<i>Descriptor</i>	<i>Description</i>
1	Significant	Significant to very significant volumes of sediment and/or a high to very high rates of occurrence are expected.
2	Moderate	Nominal to moderate volumes of sediment and/or medium to medium-high rates of occurrence are expected.
3	Minor	Insignificant or negligible volumes of sediment and/or low rates of occurrence are expected.

Table 1 Proposed magnitude levels to be assessed for each hazard.

6.5 Information Resources for the CCMA Region

Susceptibility to erosion and the rate at which it occurs depends on many factors including geology, geomorphology, climate, soil texture, soil structure, nature and density of vegetation and land management practices.

A number of previous studies have been conducted within the CCMA region that address issues of erosion susceptibility and land capability on a regional scale. Whilst different methods of assessment and evaluation have been used in individual studies, they provide extremely valuable insight and understanding into the potential occurrence of erosion in landscapes, landform units or soil units.

A list of useful studies and research reports relating specifically to erosion processes applicable to the CCMA region is detailed in Appendix F. The list should not be viewed as either a complete or comprehensive compendium of the available resource material but is intended to serve as a useful starting point in understanding the current spatial extent and severity of erosion within the CCMA region.

An extremely useful information source on land degradation in the CCMA region is the DPI Victorian Resources Online (VRO) which provides access to a wide range of natural resource maps and associated information. Information is available at both State-wide and Regional levels across Victoria. The website for the VRO home page is as follows:

<http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/vrohome>

Additional information is also currently being compiled by the CCMA in a series of geo- and environmental bibliographies. Further information can be obtained from the CCMA Website:

<http://www.ccma.vic.gov.au/>

6.6 Estimation of Off-site Effects and Impacts

The nature and spatial extent area affected by the occurrence of erosion is an important consideration which must be included in the risk assessment process. Whilst sheet, rill, tunnel and gully erosion will primarily occur in areas susceptible to these types of erosion, the impacts may be felt some distance away due to transport of sediment within streams and rivers. An estimation of how far down stream or downslope of the primary source is critical to understanding what elements are at risk and the overall consequence of the occurrence.

For example, wind erosion has significant off-site effects but this will vary depending on the magnitude and direction of the transporting agent, in this case the wind. As such, considerations of typical wind speeds and directions and the likely time of suspension for a particular soil type are critical to a full understanding of the likely consequence of the occurrence.

7. Erosion Risk Analysis – Risk Estimation

7.1 Likelihood

7.1.1 Definition of Likelihood for Erosion Risk Management

The standard definition of likelihood and probability as per the Australian /New Zealand Standard on Risk Management (AS/NZS 4360:2004) is as follows:

Likelihood: Used as a general description of probability or frequency.

Probability: A measure of the chance of occurrence expressed as a number between 0 and 1.

The earlier standard (AS/NZS 4360:1999) described probability as the likelihood of a specific event or outcome, measured by the ratio of specific events or outcomes to the total number of possible events or outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible event or outcome and 1 indicating an event or outcome is certain.

The related term frequency is described as follows:

Frequency: A measure of the rate of occurrence of an event expressed as the number of occurrences of an event in a given time.

The estimation of the likelihood of an event or hazard is generally the most difficult part of the risk assessment process when complicated or inter related natural processes are involved.

For example in landslide risk assessment considerations, the likelihood of the hazard (i.e. the landslide) is expressed in terms of an annual probability of occurrence such as a probability of 0.01 per annum. This expression of probability is the inverse of the more commonly used Average Recurrence Interval (ARI) which is used in rainfall, storm and flood estimation (e.g. 1 in 100 year flood).

However, erosion differs somewhat from this concept due to the fact that erosion is an ongoing process (albeit somewhat episodic in nature) and one which is not readily described only by the observation of a single or a few discrete events over a finite time period. This fact reinforces the need to consider not only the type of the hazard but also the range of magnitudes at which the hazard can occur.

As a result, the risk management process for erosion is to be facilitated by the consideration of hazard type, its associated range of magnitudes and a probability based estimate of likelihood for each combination. In many cases the likelihood will be linked to the likelihood of the triggering event but other changes due to the development or land use processes may significantly alter pre- and post-development likelihoods.

Based on the key processes involved, it is proposed that the likelihood of erosion (based on the concept of probability) can be described as a function of two separate factors as follows:

- *Preparatory Casual Factors (Susceptibility)*: those factors such as geology, terrain, slope length, soil type, erosivity that create an opportunity for occurrence. This is alternatively also referred to as *susceptibility*.
- *Triggering Causal Factors (Triggers)*: those factors such as rainfall, and anthropogenic actions (land use and management) that produce an effect. Such events are often described as *triggers*.

Hence for the purposes of this report and methodology it is proposed that the likelihood of erosion be defined as follows:

$$\text{Likelihood} = \text{Function (Susceptibility and Triggering Events)}$$

7.1.2 Qualitative Descriptors for Likelihood

In general terms, likelihood describes a condition of being likely or probable and an example of a qualitative measure of likelihood is shown in Table 2.

Level	Descriptor	Description
A	Almost Certain	Is expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur at some time
D	Unlikely	Could occur at some time
E	Rare	May occur only in exceptional circumstances

Table 2 Example of qualitative descriptors for likelihood.

A five-level qualitative system of likelihood assessment based on a probability scale approach has been developed in accordance with the principles of the companion document to the risk standard (Risk Management Guidelines. HB436:2004). The proposed system is shown in Table 3. The likelihoods are to be applied to each combination of hazard type and magnitude. The probability of occurrence significant depends on the susceptibility of the site to generate the erosion and the nature of the triggers.

IMPORTANT NOTE: It is extremely important that the likelihood be estimated for each of the three levels of magnitude for every hazard. The estimation of likelihood must be completed for pre-development and post-development conditions. As a result, consequences can be estimated for the different levels of magnitude and risks can be evaluated for all possible hazards on a basis of pre- and post-development conditions.

Level	Descriptor	Description
VH	Probable (Very High)	Erosion and/or sedimentation is expected to occur in most circumstances.
H	Likely (High)	Erosion and/or sedimentation will probably occur in most circumstances.
M	Possible (Moderate)	Erosion and/or sedimentation might occur at some time.
L	Unlikely (Low)	Erosion and/or sedimentation could occur at some time.
VL	Improbable (Very Low)	Erosion and/or sedimentation may occur only in exceptional circumstances.

Table 3 Likelihood (Probability Scale).

7.1.3 Methods of erosion estimation and their use.

In order to assist with the estimation of the likelihood of each of the three levels of magnitude, an estimate of the magnitude of the hazard using a representative set of site parameters can be undertaken.

The estimation of the magnitude and rate of erosion can be undertaken using qualitative, semi-quantitative or quantitative techniques which can be described as follows:

- *Qualitative (Subjective)*: Inspection and observation based on experience and expert knowledge. Such assessments can be based on observed relationships between land attributes and erosion. Whilst they can be very accurate when undertaken by experienced personnel, discrepancies and unreliability can be introduced when the assessment is undertaken by inexperienced users or when the system is extrapolated into area and environments different from those where the system was originally developed.
- *Semi- Quantitative (Objective)*: An objective assessment is based on specified criteria that can be applied to a range of environments. Whilst the criteria are not necessarily quantitative they can produce reliable results if they are well defined. Susceptibility maps and ratings based on land capability mapping, landform and land system studies can be an example of an objective system where limited detailed soil data is available but a well defined system of ranking is used based on geological or geomorphological units and expert knowledge.

- *Quantitative*: such methods involve a mathematical calculation of expected soil loss. Estimates of process rates from published methods such as USLE and its derivatives utilising automated GIS developments and algorithms have been widely reported within literature.

Generally a qualitative measure of likelihood should be used initially as a screening tool, when the level of risk does not justify the time and effort for a full analysis or when insufficient data exists to allow either a semi-quantitative or full quantitative assessment of process rates of erosion. However when time and resources are available or the perceived risks are high, semi quantitative and quantitative estimates of process rates should be undertaken.

Numerous methods used to estimate of the magnitude and rate of the various forms of erosion have been published in the scientific literature. These methods are varied in their sophistication and applicability and due to the limited timeframe and resources available within the current project it is not the aim of this risk assessment methodology to differentiate between methods. Fundamentally, the choice of method of estimation lies with the assessor or consultant undertaking the assessment.

Some of the available methods applicable to each mode or form of erosion are tabulated in Appendix G. The list is not exhaustive and should serve as a guide only. It must be noted that the methods use different approaches and terminology and are not readily comparable. Each method should be evaluated on its merits and be used in accordance with the method guidelines and the specific circumstances to which it is to be applied.

When a detailed assessment of the factors involved in these quantitative equations is undertaken, it becomes apparent that the range of values for various input parameters around Australia will produce different threshold or limits for each of the magnitude levels described in section 6.4. As a guide, values for some forms of erosion based on Australian continental averages have been presented in Appendix H.

It should be noted that further refinement is strongly recommended to establish appropriate values for the CCMA region and no definitive criteria can be provided at this point in time for the CCMA region.

7.2 Consequence Analysis

7.2.1 Definitions

The standard definition of consequence as per the Australian /New Zealand Standard on Risk Management (AS/NZS 4360:2004) is as follows:

Consequence: The outcome or impact of an event.

The earlier standard ((AS/NZS 4360:1999) described consequence as the outcome of an event expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain. There may be a range of possible outcomes associated with an event.

Another useful term is impact which can be described as follows:

Impact, A strong or powerful effect or impression.

An estimate of the consequence from an event is required to assess the nature and magnitude of the outcomes of the event, should it occur. Other elements involved in consequence may also include vulnerability to occurrence, temporal and spatial considerations.

Consequence may be determined using statistical analysis and calculations. Alternatively where no past data is available, subjective estimates may be made which reflect an individual's or group's degree of belief that a particular event or outcome will occur.

Other important considerations in consequence analysis for erosion include defining all potential elements at risk, different types of land use prior and post development and on-site and off-site effects and impacts. These are discussed in detail in the following sections.

7.2.2 Elements at Risk

Previously the elements at risk within the landslide risk assessment framework have focused on property, infrastructure and people. Such elements have included:

- Property, which may be divided into portions relative to the hazard being considered.
- People, who either live work or may spend time in the area affected by landsliding.
- Services such as water supply or drainage or electricity supply.
- Roads and communications facilities
- Vehicles on roads, subdivided into categories, (cars, trucks and buses).

In addition, landslide risk assessment has also been regularly applied to forestry applications.

Whilst the assessment of erosion may have an effect on all these elements, the above list is by no means complete and should also be extended to also consider the five asset classes commonly assessed as part of the CCMA core strategy. These include:

- Water quality.
- Agricultural land and activity.
- The environment including flora, fauna and biodiversity.
- Infrastructure (adequately described above).
- Cultural and heritage issues.

7.2.3 Land Use Considerations

The assessment of the impact a particular development may have on a site, will be intrinsically related to the prior and post development land use. Whilst the susceptibility of a particular site may remain unchanged, erosion magnitudes and rates may alter significantly following development depending on land use on part or the entire site.

A list of potential land uses to be considered in a full erosion risk assessment is detailed in Appendix I.

7.2.4 On-site and Off-site Effects and Impacts

In assessing consequences or impact, the assessor should consider both on-site and off-site effects. The former Soil Conservation Authority (SCA) guidelines for minimising soil erosion and sedimentation from construction sites in Victoria provides an extensive list of impacts and effects which should be considered. These have been reproduced in Appendix J.

7.2.5 Qualitative Descriptors for Consequence

The use of qualitative descriptors of consequence is related to the type of hazard and the elements at risk. As such, the development and application of qualitative terms to specific hazards should be completed at the time of the assessment and be tailored to reflect the individual nature of the hazard and element at risk.

In order to assist with the overall development of qualitative terms of consequence, a five-level qualitative system of generic terms for consequence is proposed in Table 4.

<i>Level</i>	<i>Descriptor</i>	<i>Detail Description</i>
V	Catastrophic	Momentous, sudden, tragic, unexpected, extensive, notable disaster or event of extreme severity, greatest or primary in importance, size rank or degree
IV	Major	Very serious or significant, notable in effect or scope, considerable, greater in importance, size, rank or degree
III	Moderate	Not extreme or excessive, within due or reasonable limits, of average in quality , amount degree or extent
II	Minor	Inferior, lesser or secondary in size, rank, amount, extent, importance or degree, not serious
I	Insignificant	Having little or no importance, small or inadequate, almost or relatively meaningless not distinctive in character, inconsequential very small in size, amount or number

Table 4 Example of generic qualitative descriptors of consequence.

As a further possible guide to the application of the generic terms to specific examples, qualitative measures of consequence have been developed for a number of elements at risk. The sample descriptors are detailed in Appendix K.

Additional examples are also provided in Table 6.2 in the companion document to the risk standard (Risk Management Guidelines. HB436:2004).

7.3 Risk Estimation

7.3.1 Definition

The level of risk is determined by combining estimates of likelihood and consequence such that in its simplest form:

$$\text{Risk} = \text{Function (Likelihood and Consequence)}$$

For the purposes of this assessment and in accordance with the principles underlying the AGS Landslide Risk Management Guidelines and Concepts (AGS 2000), it is assumed that the level of risk is proportional to each of its two components (i.e. Likelihood and Consequence). As a result the risk function is essentially a product whereby:

$$\text{Risk} = \text{Likelihood} \times \text{Consequence}$$

It must be recognised that this simple relationship does not take account of complicating factors such as non linear relationships between the occurrence of the hazard and the value of consequence. The assessment of a more complicated inter-relationship is currently beyond the capabilities of the proposed methodology and is duly acknowledged.

Based on the above premise and its inherent limitations, the use of a risk matrix allows for a simple method of estimation of the level of the risk. An example of a possible risk matrix is presented in Table 5

Likelihood (Probability Scale)	Consequence				
	V Catastrophic	IV Major	III Medium	II Minor	I Insignificant
Probable	VH	VH	H	H	M
Likely	VH	H	H	M	L
Possible	H	H	M	L	L
Unlikely	H	M	L	L	VL
Improbable	M	L	L	VL	VL

Table 5 Risk estimation matrix.

The top left hand corner of the matrix produces combinations of very high risk whilst the corresponding lower right hand corner produces estimates of very low risk. The degree of symmetry is reflected about the diagonal of the matrix.

Implications associated with different levels of risk may differ depending on the nature and extent of the hazard, the elements at risk and the severity of the anticipated consequence or impact. An example of possible risk implications is presented in Appendix L as a starting point for discussion for the specific erosion assessment.

7.3.2 Uncertainty

The process of risk analysis provides a standardised framework with which to manipulate data relating to likelihood and consequence of a potential hazard or hazards in order to estimate the level of risk associated with that occurrence. By inference it implies a formalised relationship and a degree of accuracy attached to the outcomes.

However risk is characterised by uncertainty and difficulties will always exist where insufficient or inadequate input data exists. For example:

- We may know or assume the range of possible likelihoods and outcomes of a hazard but the specific value within each range is not known.
- We may not know all the possible outcomes or the likelihoods of each outcome or both.
- Causal chains and effects may be uncertain or indeterminate.

Further information may reduce the level of uncertainty but it is important the effort required to obtain such information does not exceed the value to the final decision making process. Hence the staged use of progressively more sophisticated assessment methods (i.e. qualitative, semi quantitative and quantitative) can provide a cost effective approach to the prioritisation of risk but the assessment must always record and explain the methods adopted, the level of uncertainty and its effect on the analysis.

The use of available information such as erosion susceptibility maps and ERA reports based on a consistent framework performed by suitably qualified professionals (notwithstanding the inherent limitations of the data) is seen as the first critical step in assessing and analysing levels of risk associated with erosion within the CCMA region.

8. Erosion Risk Assessment - Risk Evaluation

Risk evaluation involves comparing the level of risk or risks found during the assessment with previously established risk criteria. In addition, it is desirable that the risk analysis and the criteria against which risks are compared in the evaluations are considered on the same basis i.e. qualitative level of risk evaluated against qualitative criteria.

Risk evaluation involves making judgements about the significance and acceptability of the estimated risk. Evaluation may not only include consideration of issues such as environmental effects but also issues of public reaction, politics business or public confidence and fear of litigation.

Whilst the owner, client and consultant are involved in the risk management process it seems increasing likely that the regulatory authority will need to establish a set of criteria against which risk is evaluated. However such criteria are yet to be developed and ratified and as such, the assessor or consultant should clearly define and document the evaluation criteria used in the overall evaluation of risk.

Some guidance on evaluation criteria is provided in Appendix M.

It is strongly recommended that the overall aim of the evaluation process should result in the following outcomes:

- For *low levels* of risk a premise of no net increase in the extent, degree or amount of erosion should occur when comparing pre-development conditions with post-development conditions
- For *moderate levels* of risk a premise of no net increase in the extent, degree or amount of erosion must apply when comparing pre-development conditions with post-development conditions and must be combined with risk treatment plans to maintain or reduce risks. However where at all possible, it is preferable that the extent, degree or amount of erosion be reduced.
- For *high and very high* levels of risk a premise of a net decrease in the extent, degree or amount of erosion must apply when comparing pre-development conditions with post-development conditions,. In addition the level of risk must be reduced to acceptable levels and be combined with both rigorous and effective risk treatment and risk mitigation plans.

The approach above includes the principle of reducing risk wherever possible commonly known as the ALARP concept or “As Low As Reasonably Possible”. As defined in the companion document (HB 436:2004) to the Australian Risk Management Standard, the concept of the ALARP principle includes the ideas of practicality (Can something be done?) as well as the cost and benefits of action or inaction (is it worth doing something in the circumstances?). However it should be emphasised that risks should be reduced wherever possible and economical to do so, no matter what the level of the perceived or estimated risk.

9. Erosion Risk Management - Risk Treatment

9.1 Treatment Options

Risk treatment is the final stage of risk management. In summary risk treatment involves identifying the range of options for treating risk, assessing those options, preparing risk treatment plans and implementing them.

Options for the treatment of risk may include the following:

- *Accept the Risk*

This would usually require that the level of risk to be considered to be in acceptable limits. Levels of risks deemed to be tolerable may also be accepted in combination with appropriate treatment plans.

- *Avoid the Risk*

This would involve not proceeding with the proposed development or seeking an alternative site or form of development which would result in acceptable risks. Such a decision may have adverse effects in the future due to failure to treat a risk or deferring decisions which may be best handled in the present.

- *Reduce the Likelihood*

This would require stabilisation methods to control the preparatory causes or the initiating circumstances. Such treatments could involve increased vegetative cover, roughening surfaces, surface treatments, chemical additives and bonding.

- *Reduce the Consequence*

This may involve defensive stabilisation methods, siltation collectors, interceptor or separator structures, improved management strategies.

- *Transfer the Risk*

This may involve requiring another party or authority to bear or share some part of the risk through mechanisms such as contracts and insurance arrangements. Whilst this may reduce the risk to the client or consultant it may not diminish the overall level of risk to society.

- *Postpone the Risk*

This may involve the deferment or postponement of a decision due to insufficient data and non-availability of information to make an appropriate decision. As such further assessment and investigation would be required and the situation should only be viewed as a temporary one.

9.2 Treatment Plans

Treatment plans should be included for each treatment option and should demonstrate how each option is to be implemented. The plans should include the extent and nature of the works required, performance measures and expected outcomes and the responsibilities of those involved.

Recommendations on planning for runoff and sediment control during development and construction phases of a development must be included in the treatment plans. Guidance on important aspects of erosion treatment plans is included in Appendix N.

9.3 Monitoring and Review

It is necessary to monitor treatment plans and risk to ensure the plan is effective and that changes in circumstances do not alter risks. Ongoing review is essential for the risk management process as factors effecting likelihood and consequences may change.

It is recommended that the responsible authority adopt an active and ongoing system of data collation ensuring the progressive update of stored information. Such data should be made available to the public and consultants in order to ensure all appropriate information is used in the determination of erosion risk for any development.

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(Courtesy of Peter Dahlhaus, University of Ballarat)

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Appendix A

Background Information on Land Degradation in the CCMA

Occurrence of Land Degradation Processes in the CCMA Region.

Erosion can be found throughout the entire Corangamite Catchment Management Authority (CCMA) region. The processes of land degradation have been persistent throughout geological time and continue to be active although they are generally episodic in nature.

A diverse range of landscapes and soil units exist within the CCMA region and when combined with highly variable climatic conditions across the region, resulting in annual rainfall ranging from 430 mm to in excess of 1250 mm, almost all types and forms of erosion are possible.

As discussed the main processes of land degradation within the CCMA include:

- Landslides (or mass wasting).
- Sheet and rill erosion.
- Gully and tunnel erosion.
- Wind erosion.
- Streambank and waterway erosion.
- Coastal erosion processes.

The susceptibility of the Corangamite landscapes to these processes has been investigated in a number of studies over the years and includes investigations carried out by the former Soil Conservation Authority and subsequent government bodies (see Bibliography). The recent Corangamite Land Resource Assessment (LRA) study completed by the Department of Primary Industries (DPI) empirically assigned ratings to landform units to provide the most up to date assessment of land degradation processes within the region.

The LRA study concluded significant areas of the CCMA region were highly susceptible to various forms of land degradation and has highlighted the need for ongoing study and investigation.

Early studies including those conducted by the Geological Survey of Victoria focused on mapping occurrences of landslides throughout the region. A recent study completed as part of a pilot project in the City of Greater Geelong (GHD 2004) began the process of mapping and capturing incidences of landslide and erosion within the city's local government area. This work has since been extended by the University of Ballarat and the CCMA to include the entire CCMA region and has established a region wide database detailing the results of mapping carried out from high resolution ortho-corrected aerial photographs.

As a result, these early studies mapped over 1480 landslides throughout the Corangamite region. An additional 38 landslides were added to this from the recent CoGG study and it is estimated thousands more exist within the region which are yet to be added to the database.

Major areas of landslide susceptibility and activity within the CCMA include the northern coast of the Bellarine peninsula, The Otway Ranges and coast, the dissected plains of the Heytesbury Region and the flanks of the major river valleys including the Barwon, Moorabool and Leigh Rivers.

Incidences of erosion have been less well defined until recently. The initial CoGG study mapped 8 instances of erosion (various forms) and 25 instances of coastal erosion within the city's local government area. The work carried out in 2005 by the University of Ballarat under direction from the CCMA has since significantly expanded the erosion database within the CCMA region.

The CCMA erosion and landslide database (Feltham, 2005) now contains 4673 records, with the breakdown by type as tabulated below:

	Gully erosion	Sheet and rill erosion	Stream erosion (beds and banks)	Landslides	Other soil degradation sites
Certain	626	993	209	1924	423
Uncertain	70	318	32	328	218
Total	696	1311	241	2252	641

The distribution of erosion and landslides varies across the CCMA landscape zones. The vast majority of gully erosion occurs in the three catchments in the north of the CCMA – the Woody Yaloak River catchment (40%), the Leigh River catchment (23%) and the Moorabool River catchment (22%) – with the worst affected areas around Cape Clear, Illabarook, Bamganie and Morrisons. Sheet and rill erosion is more widespread, with the greatest number of sites mapped in the Moorabool River catchment (25%) followed by the Woody Yaloak River catchment (17%) and the Leigh River catchment (15%). Rokewood Junction, Meredith, Anakie, and the You Yangs ranges are areas where sheet erosion is most conspicuous. By comparison, the majority of landslides occur in the southern CCMA region, with the Gellibrand (30%), Curdies (24%), Otway Coast (22%), Upper Barwon (11%) and Aire (7%) drainage basins being the most affected.

Whilst the current compilation is a significant achievement and represents the best available 'state of nature' database, it cannot address issues of temporal occurrence and trends. As such it is not possible at this point in time to estimate rates of occurrence and change for land degradation within the CCMA region.

Such assessment may be possible through a re-examination of historical aerial photographs and current field verification trials being carried out by the DPI in association with local Landcare groups. Whilst such information will be vital in the future to ongoing assessment of the problem throughout the region, the current database highlights the prevalence and significance of land degradation processes throughout the entire CCMA region.

Appendix B

Examples of Erosion Types within the CCMA Region.

Examples of Erosion Types within the CCMA Region.

1. GULLY EROSION.



Figure B 1 Gully erosion in the Williamsons Creek catchment near Elaine.



Figure B 2 Gully erosion (active) in the Leigh River catchment near Shelford.



Figure B 3 Gully erosion near the Rokewood-Cressy Rd, Rokewood.



Figure B 4 Deeply incised gully at Clifton Springs/Drysdale.

2. SHEET AND RILL EROSION.



Figure B 5 Sheet and rill erosion on coastal cliffs on the Bellarine Peninsula at Drysdale.



Figure B 6 Sheet and rill erosion below Beacon Pt Rd, Clifton Springs.



Figure B 7 Sheet erosion in the City of Ballarat (Peady Street Reserve).



Figure B 8 Sheet erosion of cropping paddock near Dean (Note the depth of erosion by the step at the fence line).

3. TUNNEL EROSION.



Figure B 9 Collapsed tunnel forming hole at the surface at Separation Creek.



Figure B 10 Tunnel erosion on the hill slopes at Wongarra.



Figure B 11 Tunnel and gully erosion near Irrewillipie.



Figure B 12 Tunnel and gully erosion in a road cutting at Rokewood Junction.

4. STREAMBANK EROSION.



Figure B 13 Streambank erosion at Bruce's Creek at Bannockburn.



Figure B 14 Streambank erosion at Bruce's Creek at Bannockburn.



Figure B 15 Stream erosion north east of Rokewood.



Figure B 16 Streambank erosion and sedimentation near Bacchus Marsh Rd, Anakie.

5. COASTAL EROSION.



Figure B 17 Coastal foreshore erosion and degradation at Clifton Springs.



Figure B 18 Coastal erosion at Jan Juc.

Appendix C

Examples of Risk Management Process from Landslide Risk Management Guidelines

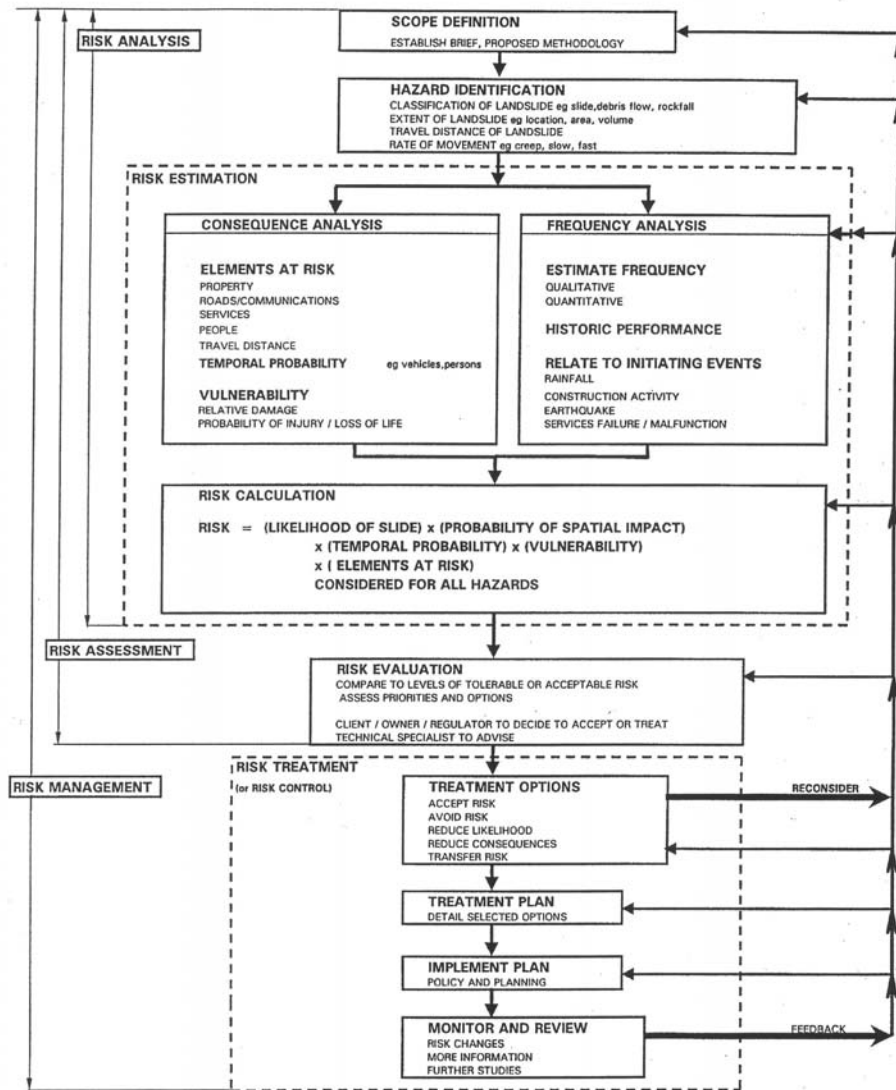


Figure 1: Flowchart for Landslide Risk Management

This figure is an extract from LANDSLIDE RISK MANAGEMENT CONCEPTS AND GUIDELINES as presented in Australian Geomechanics, Vol.35, No.1, 2000, which discusses the matter more fully.

Figure C 1 Extract from AGS 2000 Landslide Risk Management Concepts and Guidelines.

LANDSLIDE RISK ASSESSMENT & MANAGEMENT
INVESTIGATION PHASES

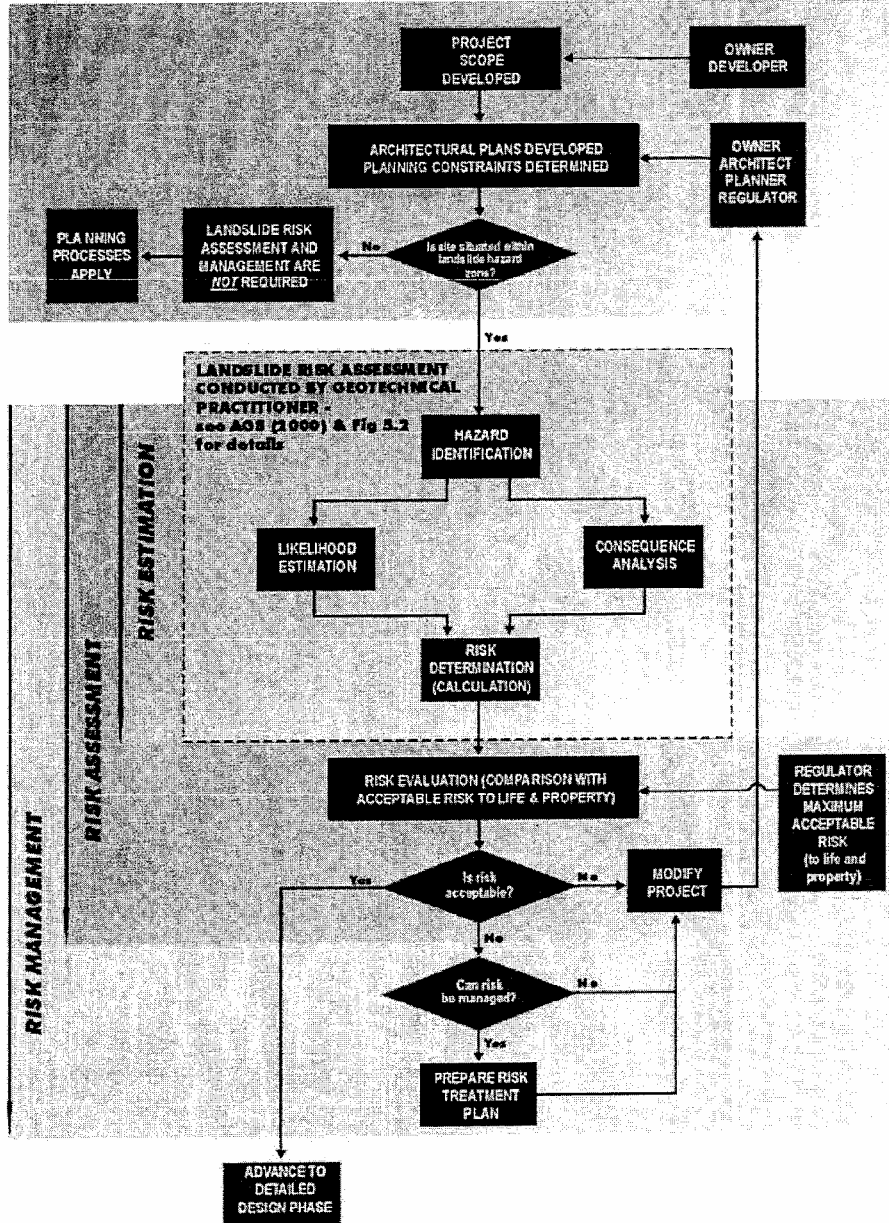


Figure 4.1 Flow Chart demonstrating the process involved in the investigation phase of Landslide Risk Management

Figure C 2 Extract from ABCB 2004 Draft guideline Sites Prone to Landslide Hazard.

LANDSLIDE RISK ASSESSMENT & MANAGEMENT
DESIGN & VERIFICATION PHASES

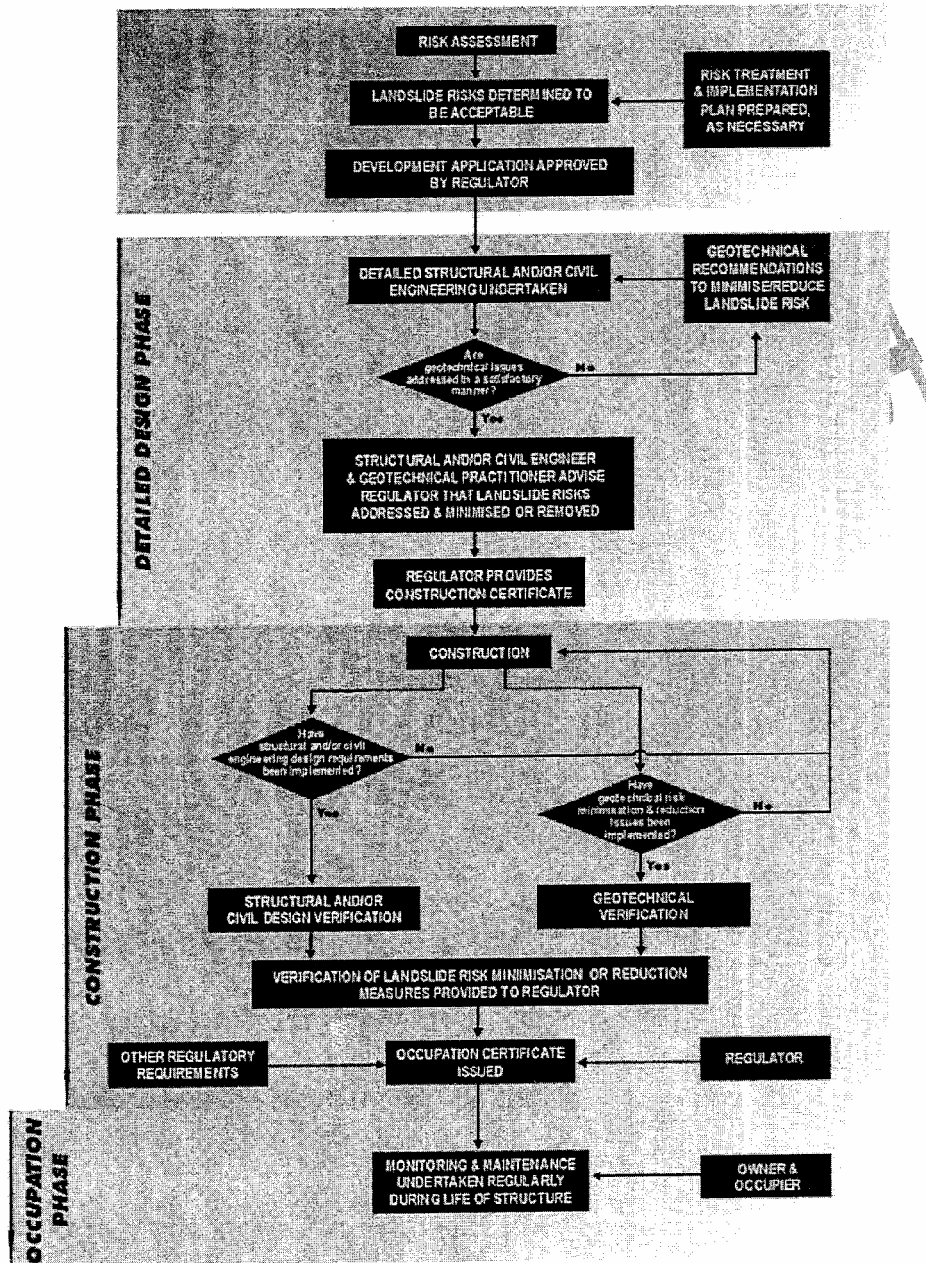


Figure 4.2 Flow Chart demonstrating the process involved in the design and verification phases of Landslide Risk Management

Figure C 3 Extract from ABCB 2004 Draft guideline Sites Prone to Landslide Hazard.

Appendix D

Risk Management Terminology

- pro-active rather than re-active management;
- more effective allocation and use of resources;
- improved incident management and reduction in loss and the cost of risk, including commercial insurance premiums;
- improved stakeholder confidence and trust;
- improved compliance with relevant legislation; and
- better corporate governance.

1.3 Definitions

For the purpose of this Standard, the definitions below apply.

1.3.1 Consequence

outcome or impact of an **event** (1.3.4)

NOTE 1: There can be more than one consequence from one event.

NOTE 2: Consequences can range from positive to negative.

NOTE 3: Consequences can be expressed qualitatively or quantitatively.

NOTE 4: Consequences are considered in relation to the achievement of objectives.

1.3.2 Control

an existing process, policy, device, practice or other action that acts to minimize negative risk or enhance positive opportunities

NOTE: The word 'control' may also be applied to a process designed to provide reasonable assurance regarding the achievement of objectives.

1.3.3 Control assessment

systematic review of processes to ensure that **controls** (1.3.2) are still effective and appropriate

NOTE: Periodic line management review of controls is often called 'control self assessment'.

1.3.4 Event

occurrence of a particular set of circumstances

NOTE 1: The event can be certain or uncertain.

NOTE 2: The event can be a single occurrence or a series of occurrences.

(ISO/IEC Guide 73, in part)

1.3.5 Frequency

A measure of the number of occurrences per unit of time.

Figure D 1 Extract from AS/NZ 4360:2004

- 1.3.6 Hazard**
a source of potential harm
(ISO/IEC Guide 51, in part)
- 1.3.7 Likelihood**
used as a general description of probability or frequency
NOTE: Can be expressed qualitatively or quantitatively.
- 1.3.8 Loss**
any negative **consequence** (1.3.1) or adverse effect, financial or otherwise
- 1.3.9 Monitor**
to check, supervise, observe critically or measure the progress of an activity, action or system on a regular basis in order to identify change from the performance level required or expected
- 1.3.10 Organization**
group of people and facilities with an arrangement of responsibilities, authorities and relationships
EXAMPLE: Includes company, corporation, firm, enterprise, institution, charity, sole trader, association, or parts or combination thereof.
NOTE 1: The arrangement is generally orderly.
NOTE 2: An organization can be public or private.
NOTE 3: This definition is valid for the purposes of quality management system standards. The term 'organization' is defined differently in ISO/IEC Guide 2.
(AS/NZS ISO 9000)
- 1.3.11 Probability**
a measure of the chance of occurrence expressed as a number between 0 and 1
NOTE 1: ISO/IEC Guide 73 defines probability as the 'extent to which an event (1.3.4) is likely to occur'
NOTE 2: ISO 3534-1:1993, definition 1.1, gives the mathematical definition of probability as 'a real number in the scale 0 to 1 attached to a random event'. It goes on to note that probability 'can be related to a long-run relative frequency of occurrence or to a degree of belief that an event will occur. For a high degree of belief, the probability is near 1.'
NOTE 3: 'Frequency' or 'likelihood' rather than 'probability' may be used in describing risk (1.3.13).
- 1.3.12 Residual risk**
risk (1.3.13) remaining after implementation of **risk treatment** (1.3.26)
NOTE: See ISO/IEC Guide 51 for safety related applications.

Figure D 2 Extract from AS/NZ 4360:2004

1.3.13 Risk

the chance of something happening that will have an impact on objectives

NOTE 1: A risk is often specified in terms of an event or circumstance and the consequences that may flow from it.

NOTE 2: Risk is measured in terms of a combination of the consequences of an event (1.3.4) and their likelihood (1.3.7).

NOTE 3: Risk may have a positive or negative impact.

NOTE 4: See ISO/IEC Guide 51, for issues related to safety.

1.3.14 Risk analysis

systematic process to understand the nature of and to deduce the level of risk

NOTE 1: Provides the basis for risk evaluation and decisions about risk treatment.

NOTE 2: See ISO/IEC Guide 51 for risk analysis in the context of safety.

1.3.15 Risk assessment

the overall process of **risk identification** (1.3.19), **risk analysis** (1.3.14) and **risk evaluation** (1.3.18), refer to Figure 3.1

1.3.16 Risk avoidance

a decision not to become involved in, or to withdraw from, a **risk** (1.3.13) situation

1.3.17 Risk criteria

terms of reference by which the significance of **risk** (1.3.13) is assessed

NOTE: Risk criteria can include associated cost and benefits, legal and statutory requirements, socioeconomic and environmental aspects, the concerns of **stakeholders** (1.3.27), priorities and other inputs to the assessment.

1.3.18 Risk evaluation

process of comparing the level of **risk** (1.3.13) against **risk criteria** (1.3.17)

NOTE 1: Risk evaluation assists in decisions about risk treatment.

NOTE 2: See ISO/IEC Guide 51 for risk evaluation in the context of safety.

1.3.19 Risk identification

the process of determining what, where, when, why and how something could happen

1.3.20 Risk management

the culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects

Figure D 3 Extract from AS/NZ 4360:2004

1.3.21 Risk management process

the systematic application of management policies, procedures and practices to the tasks of communicating, establishing the context, identifying, analysing, evaluating, treating, monitoring and reviewing **risk** (1.3.13)

1.3.22 Risk management framework

set of elements of an **organization's** (1.3.10) management system concerned with managing **risk** (1.3.13)

NOTE 1: Management system elements can include strategic planning, decision making, and other strategies, processes and practices for dealing with risk.

NOTE 2: The culture of an organization is reflected in its risk management system.

1.3.23 Risk reduction

actions taken to lessen the **likelihood** (1.3.7), **negative consequences** (1.3.1), or both, associated with a **risk** (1.3.13)

1.3.24 Risk retention

acceptance of the burden of loss, or benefit of gain, from a particular **risk** (1.3.13)

NOTE 1: Risk retention includes the acceptance of risks that have not been identified.

NOTE 2: The level of risk retained may depend on **risk criteria** (1.3.17).

(ISO/IEC Guide 73, in part)

1.3.25 Risk sharing

sharing with another party the burden of loss, or benefit of gain from a particular **risk** (1.3.13)

NOTE 1: Legal or statutory requirements can limit, prohibit or mandate the sharing of some risks.

NOTE 2: Risk sharing can be carried out through insurance or other agreements.

NOTE 3: Risk sharing can create new risks or modify an existing risk.

1.3.26 Risk treatment

process of selection and implementation of measures to modify **risk** (1.3.13)

NOTE 1: The term 'risk treatment' is sometimes used for the measures themselves.

NOTE 2: Risk treatment measures can include avoiding, modifying, sharing or retaining risk.

(ISO/IEC Guide 73, in part)

Figure D 4 Extract from AS/NZ 4360:2004

Appendix E

General Information on Erosion Types

General Information on Erosion Types.

1. LANDCARE NOTES - STATE OF VICTORIA, DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT.



What is soil degradation?

David Cummings, Melbourne

December 1999

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Soil degradation occurs where our activities (either directly or indirectly) cause it to become less vigorous or less healthy. The ultimate degradation is the removal or loss of its physical components.

Acidification, salinity, organic depletion, compaction, nutrient depletion, chemical contamination, landslides, and erosion are all forms of soil degradation that can be brought about by inappropriate land use practices.

But what is an inappropriate land use practice? The answer is very much dependant on the robustness of the land and its climate. Soil degradation results if we push production to levels beyond the ability of land to support it. If production is carefully matched to the robustness of the land (land capability), then we have sustainable land use.

Soil degradation is undesirable. It results in our land being less useful and less productive. The soil becomes less able to support plant and animal growth as there is a decline in levels of available moisture, available nutrients, and biological activity.

As soil degradation develops, land can become unsuitable for particular uses. In extreme cases it can stop nearly all plant growth (eg salt pans and areas of severe sheet erosion). In less extreme (and less visible) cases it will restrict production (eg compaction reducing plant growth and grain yields). It may even prohibit specific activities (eg acidification preventing sub-clover growth).

Perhaps we should remember that the collapse of the Mesopotamian and the Roman Empires is often blamed on degradation of their grain growing soils.

A soil can degrade in 3 ways:

- a. Physical, chemical or biological run-down causing a reduction in vigour. This can result from excessive product removal (depleting soil nutrients), reduction in plant growth, lowered organic cycling, increasing soil temperatures, leaching, compaction and surface crusting.
- b. Reduction in mass and volume through erosion. This reduces the physical size of the soil ecosystem.
- c. Accumulation of specific soil chemicals to levels that detrimentally effect plant growth. Such materials include: soluble salts (causing salinity); hydrogen ions (causing acidification); and, some chemicals from

industrial, mining and agricultural activities (chemical contamination).

The underlying table presents more specific information on the major forms of degradation, how they effect our environment, and what land management practices can help to contain and control them.

Implementation of better land management practices is strongly influenced by economic pressures and social pressures. It is important that our economic and social systems acknowledge the need to maintain and enhance our soil. Soil should never be regarded as an unlimited and indestructible resource. Soil is not a commodity. Soil should be our partner in production.

Clearly soil degradation is not just a problem for our time. A lot of it is inherited from past activities. Further, anything we do now will consequentially effect future generations. We must avoid compromising future land use potential.

We need to learn from the past, apply current solutions and protect the future.

Further information

Chisholm A. and Dumsday R. (Eds.) (1987) *Land Degradation: problems and policies*. Cambridge University Press

McTainsh G. and Boughton W.C. (Eds.) (1993) *Land Degradation Processes in Australia*. Longman Cheshire.

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Forms of soil degradation

FORMS	DEFINITION	CONSEQUENCES	CONTROL OF CAUSES
Sheet and Rill Erosion	Rain drops and surface flows causing shallow stripping of soil.	Results in loss of the most productive part of the soil profile. Reduced plant growth. Deposition of eroded material frequently causes damage. Catchment water quality, stream habitat and water storages affected.	A good vegetative cover over catchment lands is essential. Minimize cultivation and land disturbance. Maintain strong cycling of organic materials by having vigorously growing vegetation.
Gully Erosion	Concentrated flows of water scouring along flow routes causing sharp sided entrenched channels deeper than 0.5 m	Land is physically dissected, limiting access. Excess draining and drying of depressions. Damage to roads and other public utilities.	Reduce runoff from catchment lands using the same methods as outlined for sheet and rill erosion.
Tunnel Erosion	Scouring of pipes and tunnels through susceptible subsoils because of excessive quantities of water moving through the soil and concentrating along cracks, root channels and animal burrows.	Physical disruption of soil. Loss of productive capacity. Deposition of inhospitable soil material on lower lying lands. Dispersed clay material readily moves to streams.	Develop and maintain strong vegetative cover to increase plant water use. May need soil conditioners to decrease susceptibility of soil in bad areas.
Wind Erosion	Where wind has direct access to bare dry soil and causes soil detachment and removal. Fine material can be transported long distances. Coarser material moves only locally by bouncing and rolling.	Dust days affecting aircraft, environment and clothes washing. Loss of nutrients from topsoil in dust. Accumulation of sand on roads, railway lines and water supply channels.	Reduce the amount of soil bared through reduced cultivation, stubble retention, minimization of stock damage to vegetation and soil surfaces. Maximize organic matter on the soil surface through strategic crop rotations and grazing management.
Coastal Dune Erosion	Reactivation of sand movement because of loss of surface cover through uncontrolled and/or excessive recreational activity.	Loss of coastal amenity and damage to adjacent areas due to sand drift.	Careful retention of vegetation in sensitive areas. Restriction of foot and vehicular traffic on sensitive areas.
Land Slips	Where sloping soils become unstable and slip downhill. Usually brought about by increase in soil mass because of excess moisture in the soil. Can also result from construction activities.	Causes damage to private and public assets, restricts access and can add sediment loads to streams.	Minimize adverse changes to soil hydrology in susceptible areas. Minimization of physical disturbance. Stabilization of slippage areas using vegetation and physical structures.
Stream Bank Erosion	Where streams begin cutting deeper and wider channels as a consequence of increased peak flows or the removal of local protecting vegetation.	Increase in stream sediment and suspended material. Loss of stream habitat values.	Manage stream flows as much as possible through broadscale catchment management practices. Manage stream frontage areas to retain adequate vegetation. Minimize need for direct animal access for watering.
Dryland Salinity	Where saline groundwater rises towards soil surface and interferes with plant growth. Primarily due to interference with hydrologic cycle.	Loss of productivity from land with surface close to saline groundwater surfaces. Contamination of surface flows of water. Loss of stream and wetlands habitat.	Increase the vigor and plant water use in catchment to groundwater systems.
Acidification	Where the acid level of soil progressively increases and interferes with plant growth. Associated with nitrate leaching, product removal and fertilizer practice.	Reduce plant production. Problems with rhizome nodulation of sub-clovers. Acidification of streams.	Use deep rooted species to maximize nutrient and water cycling in the plant root zone. Liming.
Soil Compaction	Where productivity of soil is reduced because of physical changes to the nature of soil. Frequently associated with surface crusting, plough pans, dispersive clays, excessive cultivation and stock trampling.	Poor water and air movement in and through soils causing a lowering of biological activity.	Reduced mechanical disturbance via cultivation and trafficking. Careful selection of cropping/ley rotations. Maximize organic cycling to maximize biological activity.



Gully erosion

David Ziebell and Penny Richards (Leongatha)

November 1999

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What is gully erosion?

Gully erosion is the removal of soil along drainage lines by surface water runoff. Once started, gullies will continue to move by headward erosion or by slumping of the side walls unless steps are taken to stabilise the disturbance.

Repair work done in the early stages of newly formed gullies is easier and more economical than letting the problem go unchecked for too long. Large gullies are difficult and costly to repair.

What causes gully erosion ?

Gully erosion occurs when water is channelled across unprotected land and washes away the soil along the drainage lines. Under natural conditions, run-off is moderated by vegetation which generally holds the soil together, protecting it from excessive run-off and direct rainfall.

Excessive clearing, inappropriate land use and compaction of the soil caused by grazing often means the soil is left exposed and unable to absorb excess water. Surface run-off then increases and concentrates in drainage lines, allowing gully erosion to develop in susceptible areas.

Some of the problems caused by gully erosion include:

- dissection of the property causing access and management difficulties
- loss of productive land (gullies often occur in the most productive area of the catchment)
- reduced amenity and property values, including destruction of farm improvements, such as fences or tracks
- discolouration of water supply and sedimentation of waterways, dams and lower paddocks
- provides a harbour for vermin.

Control measures

To be effective, gully control needs to be tackled in two ways: by fixing the problems in the catchment and by stabilising the gully itself.

Catchment works

The object of catchment works is to reduce and divert the flow of water into stable drainage lines. This can be

achieved by increasing infiltration rates and water uptake by plants and by diverting and storing water.

A practical way to begin is to subdivide the catchment into appropriate land classes and then apply grazing and cropping practices most suited to each class. The development of a land management or whole farm plan is an ideal way of identifying these issues.

Strategies for stabilising the catchment include:

- co-operatively tackling the problem by the formation of a landcare group could be the most effective method where the source of the problem is spread over several properties
- diversion of water away from erosion prone gullies, thus dispersing the erosive power of the water over well vegetated areas. Diversion banks are a simple way of achieving this (see figure 1).
- contour cultivation where possible to slow down run-off and spread the water over a wide area
- maintaining farm tracks and culverts so that drainage is evenly dissipated and prevented from concentrating along any section.
- using trees and deep rooted perennial pastures to assist in both utilising excess water and reducing run-off. Again the development of a land management plan can be of assistance by identifying those areas which can be used for tree planting and pasture improvement.

Stabilising gullies

The object is to divert and modify the flow of water moving into and through the gully so that scouring is reduced, sediment accumulates and revegetation can proceed. Stabilising the gully head is important to prevent damaging water flow and headward erosion.

A variety of options can be used to get the water safely from the natural level to the gully floor. Improvements like grass chutes, pipe structures, rock chutes or drop structures can be installed to do this effectively.

Structures might also be required along gully floors since some grades can be quite steep and allow water to rush down under peak flows, ripping away soil and vegetation. These may take the form of rock barrages, wire netting or logs across gullies.

Sediments held in the water will then be deposited along the flatter grades as a result of slower water flow, allowing vegetation to re-establish.

If erosion control and revegetation work is undertaken, then damaged areas should be fenced off from stock, until restoration is complete. Further advice on how to build simple erosion control structures is available from the Department of Natural Resources and Environment (NRE) offices.

Dams can also be constructed to slow the flow of water into the gully head, but special care needs to be taken to get the overflow water back into the gully floor safely.

Preventing the problem

As with other forms of erosion, prevention is better than cure. In most cases gullies can be prevented by good land management practices aimed at maintaining even infiltration rates and a good plant cover.

Strategies for preventing gully erosion include:

- maintaining remnant vegetation along drainage lines and eliminating grazing from these areas
- increasing water usage by planting deep-rooted perennial pastures, trees, or an appropriate mixture of both thus maintaining healthy, vigorous levels of vegetation
- identifying drainage lines as a separate land class in which vegetation needs to be protected
- immediate stabilisation of sheet or rill erosion
- vermin control
- ensuring run-off from tracks is evenly distributed across paddocks to dissipate its energy
- maintaining high levels of organic matter in the soil
- avoiding excessive cultivation.

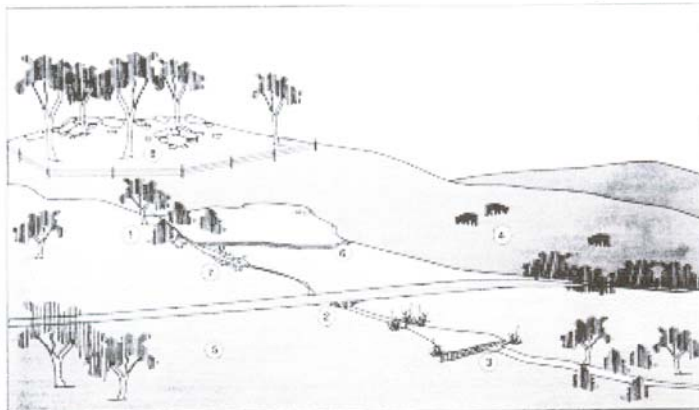


Figure 1. Farm management techniques to prevent gully erosion

General comments

Don't fill eroded gullies with solid objects such as old drums, car bodies or concrete. This only creates further erosion by directing water around such objects and removing more soil.

Financial and technical assistance may be available to individuals or Landcare groups with gully erosion problems. It is worth noting that this assistance is often more readily available to Landcare groups than it is to individuals.

Further information

This brochure is intended as a general guide only. For further advice and information about gully erosion and financial assistance schemes contact your nearest office of the Department of Natural Resources and Environment (refer to telephone directory for address and telephone number)

Acknowledgments

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1. Retain remnant vegetation along gullies and areas of recharge
2. Maintain tracks and culverts to minimise the erosive power of runoff water
3. Dam gullies to control flow with due consideration to spillways
4. Ensure a suitable stocking rate so that pasture is not damaged
5. Establish and maintain vigorous deep rooted perennial pastures
6. Divert water away from erosion prone areas using diversion banks
7. Build gully structures to reduce the force of water
8. Fence and manage the land according to its capability.



Stream bank erosion

David Ziebell, Leongatha

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Stream bank erosion occurs under natural conditions, particularly during peak storm flows and is part of an on-going cycle of sediment erosion and deposition within the stream system. However, large-scale changes to streams and their catchments since European settlement has greatly accelerated this process and many streams have become potentially unstable as they seek to find a new balance.

What causes stream bank erosion?

Increased run-off from cleared catchments has placed considerable erosive stress on streams, especially where the majority of the catchments have been cleared.

Clearing of stream-side vegetation and unrestricted stock access to streams are also significant causes of stream bank instability. Where local soils do not have the necessary strength to resist water erosion, the removal of protective vegetation can lead to extensive erosion.

In the past, many streams in Gippsland drained into wetland areas before entering the sea. These wetland areas were drained for agriculture and rivers often straightened and de-snagged. As a result, the water velocity tended to increase along the length of the stream. This kind of treatment heightens the potential for erosion - unless structures are introduced into the stream to slow the flow of water.

Other factors contributing to stream bank erosion include:

- direct access by vehicles and stock to the banks of streams
- rabbits, which can reduce plant cover and slow revegetation efforts by eating young seedlings and weaken banks by burrowing
- fallen logs and other obstacles which forces water to flow around them into the stream bank, causing undercutting
- willow trees, which often regenerate where they fall or lodge, thereby creating in-stream islands which again forces the flow of water into stream banks
- deepening of the stream bed, either through dredging or increased water velocity, can result in a steeper stream bank angle. This causes the stream bank to collapse at a later stage as the bank readjusts to a gentler, more stable angle.

What damage does stream bank erosion cause

Damage caused by stream bank erosion includes:

- loss of what is often regarded by landholders as the best agricultural land
- damage to roads, bridges and levee banks
- invasion by noxious weeds once native vegetation is depleted and soil is exposed.
- reduction of vegetated streamside verges and the subsequent loss of recreational and environmental values.

Managing stream bank erosion

The proper management of stock is most important in the protection of stream frontages. Where stock have unlimited access to the stream along the entire frontage, little can be done to preserve the stream frontage.

In most cases, fencing of the stream combined with well placed watering points may represent the best solution. A distance of 20m from the water's edge is usually considered the minimum required for bank protection. A simple, non-robust electrified fence is probably the best form of fencing as it offers least resistance during flooding and is easiest to re-establish should damage during flooding occur.

In areas where stock need to be excluded from damaged banks, concrete or gravelled walkways can allow stock access to water. Alternatively, off-stream water storage could be provided.

Where possible, remnant vegetation needs to be protected and maintained as flooding and access problems may make revegetation works difficult. Also, once the original vegetation has gone, costly erosion control structures may need to be built prior to embarking on revegetation works.

If revegetation work is necessary, then aim to re-establish a variety of indigenous plant species including grasses, sedges, shrubs and trees so that maximum ground cover and protection is achieved.

Avoid planting species such as willows and poplars which can significantly alter the ecology and physical structure of the stream. If a willow eradication program is considered necessary then it is preferable to either ringbark or poison the trees so that they decline gradually while native

vegetation is re-established. Removing the whole tree including roots in one operation will leave the banks vulnerable to erosion.

Indigenous vegetation

Some examples of indigenous stream bank vegetation found growing in South Gippsland include:

Trees:

<i>Acacia dealbata</i>	Silver Wattle
<i>Acacia melanoxylon</i>	Blackwood
<i>Bursaria spinosa</i>	Sweet Bursaria
<i>Eucalyptus ovata</i>	Swamp Gum
<i>Eucalyptus viminalis</i>	Manna Gum
<i>Eucalyptus radiata</i>	Narrow leaf Peppermint
<i>Melaleuca ericifolia</i>	Swamp Paperbark

Shrubs:

<i>Acacia verticillata</i>	Prickly Mosses
<i>Acacia mucronata</i>	Sallow Wattle
<i>Bauera rubiodes</i>	Wiry Bauera
<i>Coprosma quadrifida</i>	Prickly currant bush
<i>Goodenia ovata</i>	Hop Goodenia
<i>Hefichrysum, dendroideum</i>	Tree everlasting
<i>Hymenanthera dentata</i>	Tree Violet
<i>Leptospermum juniperinum</i>	Prickly Tea-tree
<i>Leptospermum phyllicoides</i>	Burgan
<i>Melaleuca squarrosa</i>	Scented Paperbark
<i>Olearia firata</i>	Snowy Daisy bush
<i>Olearia argophylla</i>	Musk Daisy bush
<i>Pittosporum bicolor</i>	Banyalla
<i>Pomadernis aspera</i>	Hazel Pomaderris
<i>Polyscias sambucifolia</i>	Elderberry Panax
<i>Prostanthera lasianthos</i>	Victorian Christmas bush
<i>Rapanea howittiana</i>	Muttonwood
<i>Viminaria juncea</i>	Golden Spray

Grasses and Sedges:

<i>Dianella tasmanica</i>	Tasman Flax Lily
<i>Dianella revoluta</i>	Black-anther Flax Lily
<i>Danthonia sp.</i>	Wallaby Grasses
<i>Gahnia sieberianna</i>	Red-fruit Saw sedge
<i>Lomandra sp.</i>	Mat Rushes
<i>Phragmites australis</i>	Common Reed
<i>Poa labillardieri</i>	Silver Tussock
<i>Themeda australis</i>	Kangaroo Grass

General comments

Stream frontage works will often involve several landholders, depending on the length of the stream and the extent of degradation. In this situation, local Landcare groups could be one way of tackling the problem and at the same time be a means of attracting technical and financial

assistance. There are already several successful examples of this occurring in Victoria.

Further information

In the case of major stream erosion, the relevant Catchment Management Authorities should be consulted, as the resources and knowledge required for the stabilisation works may be beyond that of individual landholders.

Advice and assistance on stream bank erosion and revegetation works can be obtained from your local Department Of Natural Resources & Environment office – Phone 136 186.

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General Information on Erosion Types.

2. AGRICULTURAL NOTES – STATE OF VICTORIA, DEPARTMENT OF PRIMARY INDUSTRIES.



Tunnel erosion occurs when the subsoil is eroded by water forming underground tunnels. It is often associated with soils that have a shallow hard-setting topsoil over a subsoil which may be stable when dry, but readily disperses when saturated.

Tunnels often start when water flows down rabbit burrows or old tree root lines.

Tunnel erosion is often difficult to detect. Often the only indication is small areas of silt around cracks or holes in the surface soil on lower slopes. As more subsoil is washed down the tunnels, fan shaped clay deposits form. Tunnels deepen and widen until the roof of the tunnel can no longer support its own weight and collapses forming holes. At this stage the problem is already well advanced. Eventually more tunnels collapse forming a gully (Figure 1).

Prevention and treatment are difficult, particularly when large proportions of the farm are prone to tunnel erosion and holes appear over wide areas.

Assess the situation on your farm

What proportion of your farm may be susceptible to tunnel erosion? Consider soil type and slopes.

- Tunnel erosion typically occurs in hill country in soils with shallow hard setting topsoil over subsoil which may be stable when dry, but erodes easily when very wet.
- Are there very steep areas with tunnel erosion where the best approach may be to fill the tunnels and plant down to trees and other vegetation? That is, take those areas out of pasture production.
- Are there small isolated areas which can be easily ripped and sown back to pasture? See below.
- Are there extensive areas where holes have developed from collapsing tunnels?
- The only practical way to deal with these areas may be to systematically rotate around the farm, treating the worst areas first in your pasture renovation program. Rip and fill tunnels prior to cultivation and sowing down. Plant trees in major drainage lines.
- Is the source of your tunnel erosion on a neighbouring farm? You may need to coordinate tunnel erosion works with other farmers. It may be appropriate to use a catchment or sub-catchment group or landcare group approach.

Whatever the situation, a whole farm plan will help you to identify the issues, set your priorities and plan how to address the relevant issues on your farm.

Treatment

Treatment generally involves reducing the amount of water entering the area (if practical), consolidation of the tunnelled area to interrupt the flow of water and planting trees to bind the soil, particularly in steep gully situations.

Deep rip the area up and down, then across the slope, in late Summer to early Autumn. A bulldozer will be required unless the tunnels are known to be shallow. Cultivate the area ready for pasture establishment.

Gypsum can improve the stability of dispersible subsoils. This can improve water infiltration and reduce tunnel erosion in susceptible soils.

Sow pasture including vigorous and productive perennial species and some quick establishing species. Use an adequate rate of fertiliser to encourage a quick vegetative cover. If subsoil is exposed, it may be low in essential nutrients, so a higher than normal application will be required.

Some subsoils also have lower pH levels than the overlying topsoil, so lime may also be required. Where possible remove the topsoil prior to earthworks, then spread it back over the area prior to cultivation.

Trees will also help to bind the soil. Non-suckering poplars, established as poles are showing promise in damp gully areas and areas where springs flow for most of the year.

Where possible, divert runoff from the area to a safe disposal site for at least 12 months to reduce surface scouring and to allow the vegetation to establish.

Fence the area out of production for 12 months and allow light grazing for the first 2 - 3 years to encourage strong development of the pasture.

In country which is too steep to cultivate, destruction of the tunnels and diversion of surface water may have to be done by hand. Trees on and above the site should be used to bind the soil and utilise excess water. This option will be impractical on a large scale. It may be better to fill holes with porous material such as hay to catch sediment, fence the area, plant trees and leave it as it is rather than fill in tunnels creating a depression or gully.

Maintaining restored areas

- Check for re-occurrence.
- Control rabbits and other burrowing animals.
- Continue regular topdressing to encourage pasture growth and increase soil organic matter.

- Regularly check the discharge points of diversion banks for possible erosion. Include these areas in your fertiliser program to ensure good grass cover.

General comments

Many farmers fill holes that form from the collapse of tunnels with lumps of concrete and other rubbish. This achieves the aim of preventing stock from falling into the holes. However solid objects in the tunnels may create further erosion by diverting water around them. As stated above, a material that catches sediment, but allows some water through may help to block the tunnels. Hay may be useful in this situation and it will not obstruct future ripping or earthworks in the area as wire netting or more solid materials would.

Further information

Contact the Department of Natural Resources and Environment Customer Service Centre on 136186.

Acknowledgments

This information was originally compiled by David Ziebell and Penny Richards, DCNR for the Farmcare project and adapted for dairyfarmers for the "Dairy Land Manager" project with advice from catchment specialists and dairyfarmer groups, February 1995. "Dairy Land Manager" is funded by the Dairy Research and Development Corporation and Agriculture Victoria.

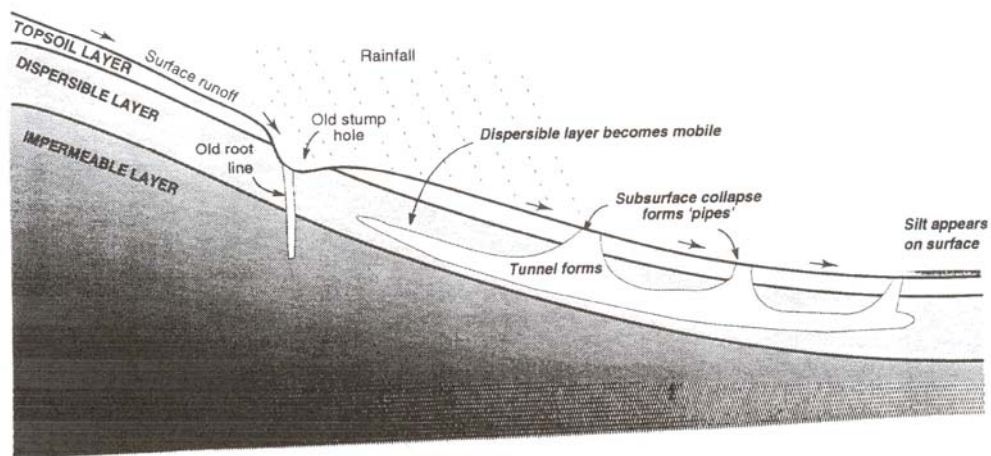


Figure 1. Formation of a tunnel

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Introduction

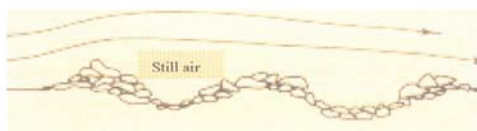
It is essential to minimise soil movement in the dry summer conditions ahead so that farms are in the best position for cropping next autumn. Besides causing the obvious damage to fences, tracks and public utilities, soil drift also destroys soil fertility and structure, therefore lowering productivity of future crops. Mechanical means are available to minimise soil drift.



Figure 1. Ridging operation to minimise the effects of wind erosion.

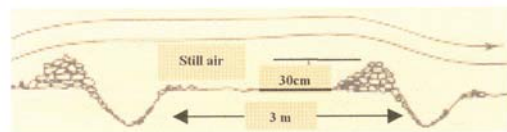
Minimising soil drift

The main need is to reduce wind speed at the soil surface so that drift does not occur. Roughening the soil surface will achieve this.



Heavier soils

Surface roughness, sufficient to stop soil movement can be achieved with a chisel plough or similar implement.



Lighter sandier soils

Where cloddy material can only be obtained from depth, north - south ridging is the only workable technique.

Deep sands

Where cloddy material is unavailable using a ridger or a chisel plough, the above mechanical measures do not apply. If ridging equipment does not uplift clod then the soil should **not** be disturbed.

Guidelines for ridging operation

Ridge height	Aim to get a ridge height of 30cm above natural surface - depth of furrow unimportant, 30-cm high ridge provides 3metres of protection.
Ridge material	Ridger must bring up cloddy material to ensure long life of ridge.
Spacing	Three metre maximum between each ridge (also allows for repeat operation in between, if found necessary).
Direction	North / South across majority of prevailing winds.
Extent	Whole of area drifting and likely to drift.
Starting point	Preferably at west side ie. at source of drift.
Timing	On susceptible areas before actual drifting occurs.

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Appendix F

List of Some Previous Land and Soil Information in the CCMA Region

Date of Publication	Organisation	Author	Title	Type of Study
1973	CSIRO Division of Applied Geomechanics	K Grant	Terrain Classification For Engineering Purposes of The Queenscliff Area. Victoria (Technical Paper No 12)	PUCE -
1977	Soil Conservation Authority	A.J.Pitt, A.W.Jakimoff and B.J.Evans	An interim report on land in the Heytesbury Settlement	
1979	Soil Conservation Authority Kew	J.P.Jeffrey and R.T.Costello	A study of land capability in the Shire of Ballan	Land capability
1979	Soil Conservation Authority Kew	J.P.Jeffrey, R.T.Costello and P.King	A study of land capability in the Shire of Bungaree	Land capability
1980	Soil Conservation Authority Kew	J.P.Jeffrey	A study of land capability in the Shire of Buninyong	Land capability
1981	Soil Conservation Authority Kew	J.P.Jeffrey and R.T.Costello	A study of land capability in the Shire of Bannockburn	Land capability
1981	Soil Conservation Authority	A.J.Pitt	A study of the Land in the Catchment of the Otway Ranges and Adjacent Plains (TC-14)	Land systems
May 1986	Ministry for Planning and Environment		The Rural Land mapping Project- Shire of Otway	Land capability
1987	State Chemistry Laboratory	J.M. Maher and J.J. Martin	Soil and landforms of south-western Victoria Part 1. Inventory of soils and their associated landscapes	Soil unit and Land system
2003	Department of Primary Industries (PIRVIC)	Robinson et al	A land Resource assessment of the Corangamite Region	Soil-landform units
Aug 2004	GHD	AS Miner	Erosion Management Overlay for the City of Greater Geelong	Historical instances (Erosion and
2005	University of Ballarat	W.Feltham and PG Dahlhaus	Corangamite Catchment Management Authority Landslide and Erosion Database. Version 2.	Historical instances (Erosion and

Table F 1 List of Some Previous Land and Soil Information for Erosion (Only) in the CCMA Region

Appendix G

Some Methods of Estimation of Magnitude and Rate of Erosion

Erosion Type	Estimation Technique	Method Identification	Originator Creator	Main Inputs	Main Outputs	Reference
<i>Sheet and Rill</i>	Qualitative / Semi- Quantitative	Van Zuidam Qualitative Methodology		Slope :steepness length form Soil/geology Vegetation/ landuse Erosion and mass movement activity	Ratings sum and class for erosion assessment	Van Zuidam (1986)
<i>Sheet and Rill</i>	Semi- Quantitative or Objective	QMR Erosion Risk Assessment	Queensland Main Road Department	Rainfall erosivity, Soil erodibility, Slope gradient and length, Vegetation cover	Peak and average erosion risk rating on a scale of 1-5	Road Drainage Design Manual QLD Main Roads
<i>Sheet and Rill</i>	Quantitative	Prediction of erosion from construction sites	Soil Conservation Authority VIC	R=Rainfall erosivity index K=Soil erodibility factor LS=Combined length/ slope factor C=Soil cover factor P=Soil practice factor	A=Computed soil loss in t/ha for a given storm period	Guidelines for Minimising Soil erosion and sedimentation from Construction sites in Victoria TC-13 SCA -1979

<i>Sheet and Rill</i>	Quantitative	Universal Soil Loss Equation USLE	VicRoads	R=Rainfall erosivity index K=Soil erodibility factor LS=Combined length/ slope factor C=Cover and Management Factor P= Surface Treatment factor	As= calculated average annual soil loss per unit area	Road Design Guidelines Part 7 Drainage VicRoads
<i>Sheet and Rill</i>	Quantitative	SOILOSS	NSW Soil Conservation Service			C.J.Rosewell (1993) SOILOSS: a program to assist in the selection of management practices to reduce erosion. Technical handbook no 11 (second Edition NSWSCS

<i>Sheet and Rill</i>	Quantitative	RUSLE2	USDA-ARS Washington	Ri=rainfall erosivity factor Ki=soil erodibility factor Li=soil length factor S=slope steepness factor Ci=cover management factor Pi=supporting practices factor All calculated on the ith day	Ai=average annual soil loss for the ith day of the year	DK McCool, GR Foster and DC Yoder The revised universal soil Loss Equation Version 2 ISCO 2004 13 th International soil conservation Organisation Conference Brisbane July 2004
<i>Gully Erosion</i>	Pseudo- Quantitative	Density Mapping Techniques	Ian Sargeant (VIC) or NLWA (AUST)	Density in km/km ²	Mean annual sediment yield (t/ha/yr) using approximations of gully age and volume	CSIRO Technical Report 26/01 AUG 2001
<i>Wind Erosion</i>	Quantitative	Wind erosion Equation WEQ	Natural Resource Conservation Service (USDA)	I= soil erodibility index K=soil ridge roughness factor C=climate factor L=unsheltered distance across a field V=equivalent vegetative cover	E= potential average annual soil loss	USDA –ARS WERU website Woodruff and Siddoway 1965

<i>Wind Erosion</i>	Quantitative	Wind Erosion Prediction System	USDA, EPA and BLM	Climate database Soils database Management database Crop and decomposition database	Soil loss on a daily basis	USDA –ARS WERU website
<i>Streambank Erosion</i>	Quantitative	SedNet (Sediment River Network Model)	National Land and water Audit	Riverbank erosion Tributary Supply Gully erosion	Mean annual sediment budget Downstream sediment yield	

Table G 1 Example methods for the estimation of erosion rate and magnitude

Note: A number of soil erosion hazard methodologies also exist as part of the framework for the management of Australian Forests. Detailed information on methodologies for erosion hazard assessment system in all Australian States as well as British Columbia (Canada) and Washington State (USA) is contained in the following document:

“Assessing soil hazard for Australian forest management”. Project No PN98.801. Published by Forest & Wood Products Research and Development Corporation. 2003.

[Web: http://www.fwprdc.org.au](http://www.fwprdc.org.au)

Appendix H

Examples of Potential Levels for Magnitude and Rate of Erosion.

An example matrix for different modes of erosion

Proposed Level	Proposed Descriptor	Detailed descriptors form other Methods	Description	Annual Erosion Rate t/ha/yr (Sheet and Rill)	Mean Annual Sediment Yield t/ha/yr (Gully)	Density of Gullying (km/km2) (Gully)	Suspended Sediment Load (t/ha/yr) (Streambank)
1	Significant	Very High	Very significant to extreme rates of erosion and/or sedimentation are expected	>10.0	> 5.25	> 3.5 >>0.5	>2.0
		High	Significant to very significant rates of erosion and/or sedimentation are expected	5.0-10.0	1.5-5.25	1.0-3.5 >0.5	1.0-2.0
2	Moderate	Moderate	Nominal to significant rates of erosion and/or sedimentation are expected	2.5-5.0	0.75-1.50	0.5-1.0 0.2-0.5	0.5-1.0
3	Minor	Low	Insignificant to nominal rates of erosion and/or sedimentation are expected	0.5-2.5	0.15-0.75	0.1-0.5 <0.2	0.1-0.5
		Very Low	Insignificant or negligible rates of erosion and/or sedimentation are expected	0-0.5	0-0.15	0-0.1 <<0.2	0-0.1

Table H 1 Example of potential levels of magnitude and rates of erosion

Values based on Australian Continental estimates from Water Bourne Soil Erosion. Land and Water Resource Audit 2001.

(Figures in red for Gully from I Sargeant's Victorian mapping project detailed on the VRO Website)

Appendix I
Land Use Categories

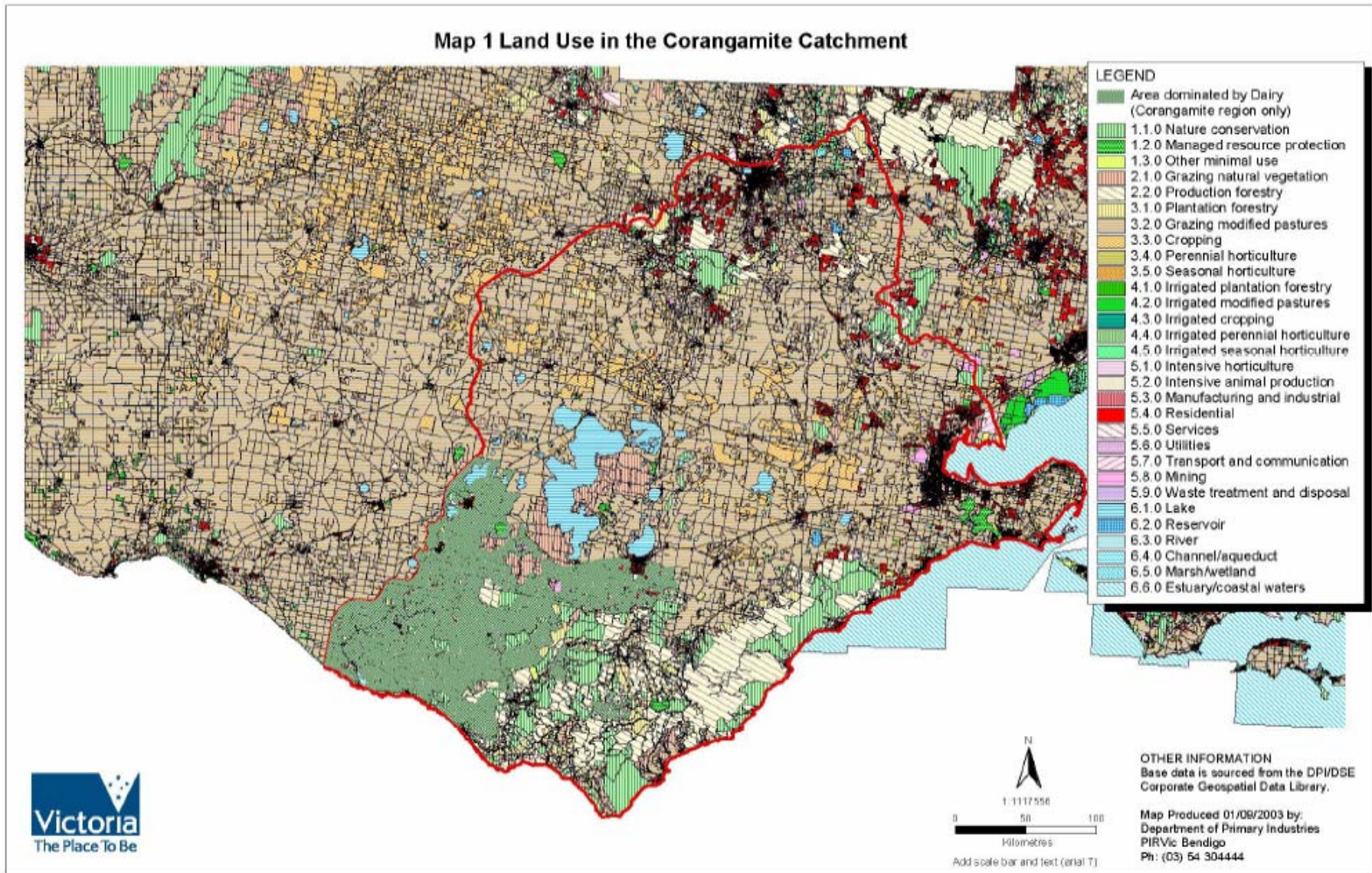


Figure I 1 Land Use categories within the CCMA region. (Extract from Draft CSHS 2004)

Appendix J

On-site and Off-site Effects and Impacts to be Considered in Consequence Analysis

Extract from “Guidelines for minimising soil erosion and sedimentation from construction sites in Victoria” published by Soil Conservation Authority. Document No. SCA TC 13

On-site and Off-site Effects and Impacts to be Considered in Consequence Analysis.

ON-SITE EFFECTS

Some on site effects associated with construction activity which should be considered may include but not be limited to:

1. Increased volumes of stormwater runoff and accelerated soil erosion caused by
 - Removal of existing protective vegetation cover
 - Exposure of underlying , more erodible or pervious soil horizons or geologic formations
 - Reduced capacity of soil to absorb water due to compaction by heavy equipment
 - Enlarged drainage areas caused by grading operations, diversions and subdivisions
 - Prolonged exposure of susceptible areas due to scheduling or delays
 - Shortened times of concentration of surface runoff caused by altering steepness, distance and surface roughness of stormwater facilities
 - Increased impervious surfaces associated with construction of streets, buildings paved areas, and parking lots
 - Concentration of runoff water in more defined channels with an increased potential to erode especially during construction
 - Increased energy in runoff discharges due to concentration and velocity
2. Alteration to groundwater regime which could effect drainage schemes, slope stability, survival of existing or new vegetation and water quality/salinity
3. Exposure of subsurface soils that may be unfavourable to quick and easy establishment of vegetation
4. Construction materials may be washed away with the stormwater runoff possibly introducing pollutants and causing blockages resulting in flooding and erosion
5. Waste water discharges from activities such as groundwater pumping, spraying and washing equipment, mining activities etc
6. Work carried out close to streams or drainage lines introducing sediment and accelerating bank erosion
7. Dust production
8. Accidental fires on construction sites

OFF-SITE EFFECTS

Some off site effects associated with construction activity which should be considered may include but not be limited to:

Stream Changes

1. Increased runoff and the related sediment load carried by the water may cause changes in stream alignment and gradient Particular effects may include:
 - Increased flooding frequency and volume of flow
 - Increased erosion of stream banks and beds
 - Possible change of stream route and loss of productive land
 - Transport and deposition of greater quantities of sediment downstream
 - Increase in water turbidity during peak flows resulting in greater uprooting of vegetation and destruction of aquatic life
 - Reduction in water quality during low flows due to increased quantities of decaying matter
 - Reduction in stream flow during low flow periods and the deterioration of water quality as a consequence of the lowered dilution and higher temperature
 - Local erosion problems at the point of discharge of drainage water from a site to the stream because of increased velocity and concentration

Environmental Effects

1. Increased Bed Load causing settleable solids to blanket the bed of water bodies, destroying sessile aquatic life and smothering breeding areas.
2. Increased suspended Solids load effecting certain forms of aquatic life particularly gill breathing fish
3. Increased turbidity reducing the amount of light penetrating water effecting the growth of fixed and suspended plant life
4. Pollutants carried by sediment which may be readily absorbed on to the surfaces of suspended or transported solids

Physical and Economic Effects

1. Specific damages that can be attributed to sediment deposition are
 - Increased flooding
 - Inconvenience ad cost of sediment removal
 - Loss in land values
 - Loss in agricultural productivity
 - Increased water treatment costs

Appendix K

Examples of Qualitative Measures of Consequence for Various Elements at Risk

<i>Level</i>	<i>Descriptor</i>	<i>Description</i>
V	Catastrophic	Total degradation and/or complete loss of beneficial uses of land, water, environment, toxic release off site with detrimental effects, total loss of stream water quality or habitat, complete loss of biodiversity
IV	Major	Extensive degradation and/or significant partial loss of beneficial uses of land, water, environment, off site release with some detrimental effects, extensive deterioration of stream water quality or habitat, major significance on biodiversity, loss of water supply
III	Moderate	Limited effect on the beneficial uses of land , water, environment up to acceptable limits of change and modification as per State and Federal legislation, on-site release contained with outside assistance, continuous significant change of stream water quality and habitat, noticeable effect on biodiversity and water quality
II	Minor	No significant effect on the beneficial uses of land , water, environment, on- site release immediately contained, seasonal or episodic elevated stream salinity in most years, minor impact on biodiversity and water quality,
I	Insignificant	No measurable effect on the beneficial uses of land , water, environment, gradual minor change to stream water quality or habitat, no measurable effect on biodiversity

Table K 1 An Example of a Qualitative Measure Of Consequence For The Environment.

<i>Level</i>	<i>Descriptor</i>	<i>Description</i>
V	Catastrophic	Structure completely destroyed or large scale damage requiring major engineering works for stabilisation, huge financial loss
IV	Major	Extensive damage to most of the structure or extending beyond site boundaries requiring significant stabilisation works, major financial loss
III	Moderate	Moderate damage to some structure or significant part of the site requiring large stabilisation works, moderate financial loss
II	Minor	Limited damage to small part of the structure or part of the site requiring some reinstatement or stabilisation, minor financial loss
I	Insignificant	Little damage ,low financial loss

Table K 2 An example of a qualitative measure of consequence for infrastructure.

<i>Level</i>	<i>Descriptor</i>	<i>Description</i>
V	Catastrophic	Almost certain fatality ,
IV	Major	Likely fatality, extensive injuries
III	Moderate	Possible fatality, medical treatment required
II	Minor	Unlikely fatality, first aid treatment minimal
I	Insignificant	Rare fatality, no injuries

Table K 3 An example of a qualitative measure of consequence effecting human life.

Appendix L

Example of Risk Level Implications

<i>Risk Level</i>	<i>Descriptor</i>	<i>Example Implication</i>
VH	Very High Risk	Extensive detailed investigation and research, planning and implementation of a state of the art treatment plans are mandatory. Unacceptable risks must be mitigated down to acceptable levels. Extensive modifications or complete abandonment to the project may be considered if sufficient safeguards and reduction of risk cannot be adequately demonstrated. Full consultation with all relevant government agencies DPI Shire Environmental Officer and EPA and possibly local interest groups is mandatory at all stages of the development. Detailed sediment and runoff control programs are mandatory.
H	High Risk	Detailed investigations, planning and implementation of treatment options are required to reduce risks to acceptable levels. High level of expertise is required and thorough investigation, pre planning and use of best available technology and methods are mandatory. Consultation with all relevant government agencies DPI, Shire Environmental Officer and EPA and possibly local interest groups is strongly recommended. Sediment and runoff control programs are mandatory
M	Moderate Risk	Comprehensive and thorough precautions required Tolerable provided treatment plans are implemented by experienced personnel to maintain risk as a minimum but preferable to reduce risks where possible. May require consultation at a planning stage with the DPI , Shire Environmental Officer and EPA
L	Low Risk	All reasonable precautions should be taken in accordance with normal good erosion control practices. Sediment control plan not normally needed. Runoff control plan may be needed. Treatment may be required to maintain levels
VL	Very Low Risk	Acceptable risk associated with the development and requires no specific treatment plans. Manage site in accordance with normal good erosion control practices

Table L 1 Example of risk level implications

Appendix M

Examples of Evaluation Criteria

Examples of Evaluation Criteria

QUALITATIVE CRITERIA

As erosion risk assessment is an emerging field there do not appear to be any published or established criteria against which to evaluate the level of risk estimated in the risk analysis phase. Guidance however can be sought from the AGS guidelines on Landslide risk management

As such the following concepts based on the AGS risk approach for landslides may be used as a starting point for evaluation of risk in a qualitative sense

- If risks fall into *very low or low* categories they may be deemed to be acceptable with minimal further treatment.
- If risk falls into a *moderate* category it may be deemed to be tolerable and must be treated with normal best practice
- If risk fall into *high and very high* categories they would be deemed to be unacceptable and risk treatment and mitigation options must be employed to reduce risks to acceptable levels. It must be noted that some risk levels may not be able to be mitigated to acceptable levels due to technical complexities or costs.

QUANTITATIVE CRITERIA

It is proposed that the provision of pre and post development scenario modelling be undertaken when using quantitative methods. The analysis should compare pre and post development values of estimated soils loss or sediment yield and comply with the following premises for evaluation

- *Low and very low* risk sites must show *no net increase* in soil loss or sediment yield
- *Moderate* risk sites must show *no net increase* in soil loss or sediment yield and preferably should indicate *a net decrease*.
- *High and very high* risk sites must show *a net decrease* soil loss or sediment yield in conjunction with risk treatment and mitigation measures which reduce risks to acceptable levels.

Appendix N

Guidance on Erosion Treatment Plans

Guidance on Preparation of Erosion Treatment Plans.

Invaluable information on planning for runoff and sediment control and principles of good practice to minimise erosion during development phases and beyond is contained in Chapters 5 and 6 of the following document:

“Guidelines for Minimising Soil Erosion and Sedimentation from Construction Sites in Victoria” Published by the former Soil Conservation Authority. TC-13 (1979)

Topics addressed include;

- Planning for runoff and sediment control
- Construction site practice and problem awareness
- Principles of good practice
- The role of the supervisor
- Control measures
- Minimising damage
- Preserving assets
- Protecting exposed surfaces
- Drainage
- Sediment traps

Similarly, valuable information on the preparation of erosion and sediment control plans (ESCP) can be obtained from the following document:

“Road Drainage Design Manual”

Published by the Department of Main Roads Queensland

A downloadable version of the manual can be found on the following website:

<http://www.mainroads.qld.gov.au/mrweb/prod/Content.nsf/fbadb90201547b374a2569e700071c81/c1decd6de87275fa4a256df3000c6214!OpenDocument&Highlight=0,erosion>

A further source of information on techniques for erosion and sediment control can be sourced from the following document:

“Construction Techniques for Sediment Pollution Control”

Published by EPA Victoria, May 1991

A downloadable version of the document can be found on the following website

<http://www.epa.vic.gov.au>