University of Southern Queensland

Faculty of Engineering and Surveying

3D TERRAIN VISUALISATION AND VIRTUAL FLY-THROUGH FOR TOURISM CONSERVATION USING GEOGRAPHIC INFORMATION SYSTEMS (GIS)

A dissertation submitted by

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ABSTRACT

Environmental protection and conservation of tourism hot-spots can be controlled through management planning, zoning and permitting. This methodology will allow government bodies and agencies to assess natural and cultural values of a selected area consistently. A common approach to management and control of conservation areas within a tourist hot-spot is through the use of a visualisation and spatial analysis techniques within a Geographic Information System (GIS) environment.

Visualisation has been the foundation of scientific progress throughout history and with current technology GIS has advanced these visualisation techniques to develop powerful three-dimensional graphical computing environments.   This type of GIS planning methodology involves the identification of a range of environmental, social and economic issues that have an influence on a specific tourist location or study area.

The general objective of this project is to strengthen tourism planning and conservation through GIS applications such as visualisation, 3D fly-through and spatial analysis. GIS can be regarded as providing a toolbox of techniques and technologies of wide applicability to the achievement of sustainable tourism development (Giles, 2003, p.2). These objectives will be achieved through providing examples of how GIS visualisation and analysis techniques were used within the Currumbin Valley study area, Examples include:

- Research and identify suitable and relevant spatial data sets for GIS analysis and modelling ie. Major roads, dwellings, soil coverage, contour data and regional ecosystems;
- Use a Global Positioning System (GPS) to identify existing walking tracks;
- Develop a 3D model to include a DEM and digital aerial photography of the study area, and;
- Create a virtual fly-through that will display existing natural and man-made features, landscape sensitivities, terrain analysis and conservation assessment for an existing tourism area.

These visualisation techniques provide GIS users with tools to develop a higher level of thinking and problem solving which in turn will give a better understanding for decisions not only in the tourism and conservation industries but a wide range of planning, environment and engineering projects.

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ENG4111 & ENG4112 *Research Project*

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CERTIFICATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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                              Signature

__28th October 2004_____
                               Date

ACKNOWLEDGEMENTS

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GLOSSARY OF TERMS

Abbreviation	Description
2D	Two-dimensional
3D	Three-dimensional
DEM	Digital Elevation Model
ESRI	Environmental Systems Research Institute
GCCC	Gold Coast City Council
GHD Pty Ltd	Gutteridge, Haskins and Davies Pty Ltd
GIS	Geographic Information System
INCA	Infrastructure Corridor Assessment
RE	Regional Ecosystem
TIN	Triangular Irregular Network
USQ	The University of Southern Queensland

Chapter 1
Introduction

1.1 Introduction

Australia is a country that thrives on tourism industries by contributing approximately $70 billion to our economy (Queensland Ecotourism Plan, 1997, p.17). A key part of the Australian tourism industry is centred around natural areas that are unique and known worldwide.   The state of Queensland provides tourists with a wide range of natural protected areas to visit. A key component to the nature based tourism industry is conservation management and sustainability of ecosystems and natural surrounds.

It is essential to identify tourism destinations that contain areas of high natural and cultural value. This identification will ensure environmental protection and management strategies are imposed to all natural areas visited by tourists.

Environmental protection and conservation of tourism hot-spots can be controlled through management planning, zoning and permitting. This methodology will allow government bodies and agencies to assess natural and cultural values of a selected area consistently.

A common approach to management and control of conservation areas within a tourist hot-spot is through the use of a visualisation and spatial analysis techniques within a Geographic Information System (GIS) environment. A Geographical Information System can be defined as a system for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referenced (Hearnshaw and Unwin, 1994, p.xiii). Visualisation has been the foundation of scientific progress throughout history and with current technology GIS has advanced these visualisation techniques to develop powerful three-dimensional graphical computing environments.   This type of GIS planning methodology involves the identification of a range of environmental, social and economic issues that have an influence on a specific tourist location or study area.

1.2 Statement of the Problem

This project will assess new GIS visualisation techniques that can be used to represent tourist values within a chosen study area. Although widely used in environmental planning, GIS use in tourism has been slow. This is because tourism planning involves a wide range

of inconsistent and restrictive spatial and non-spatial data that are yet to be linked for the tourist by the relevant tourist body ie. Local Government Authority.

GIS is capable of bridging this gap through spatially linked databases that contain information about particular tourist spots that can assist with future tourism planning and conservation. The power of GIS not only lies in spatially related databases but also in the ability to visualise these spatial relationships. Three-dimensional (3D) visualisation techniques provide users with the ability to display together digital aerial photography and Digital Elevation Models (DEMs) through an interactive interface that can assist tourism planning and conservation. In addition, a series of analysis functions involving grid calculations within a GIS environment can assist in identifying landscape sensitivity areas through viewshed analysis and terrain classification and evaluation. These grids can then visualise a conservation assessment within a chosen study area for inclusion within a 3D model or virtual fly-through.

These visualisation techniques provide GIS users with tools to develop a higher level of thinking and problem solving which in turn will give a better understanding for decisions not only in the tourism and conservation industries but a wide range of planning, environment and engineering projects.

1.3 Significance of the Study

The term 'Ecotourism' describes tourism conservation and management strategies by recognising ecological sustainability, local community support and provide visitor satisfaction.

Ecotourism represents a specialised role within the tourism industry, for example; National parks, which cover 3.8 percent of Queensland, are a natural focus for ecotourism. Ecotourism highlights the importance of environmental aspects by controlling and understanding human impacts. This is achieved by developing State-wide guidelines on permissible activities and sustainable use levels. In addition, relationships formed between the physical environment and tourism can be described through:

- Features of the physical environment are attractions for tourists;
- Tourism development and tourist use of an area generate environmental impacts, and;
- Tourism is often developed in environmentally fragile and vulnerable areas, such as small islands, coastal and mountainous areas.

The foundation of this study will aim to achieve a balance for the conservation of current and future tourism areas through the use of GIS software that will analyse and visualise spatially related data. These practices can then assist ecotourism procedures by achieving sustainable development and limiting tourist usage impacts.

1.4 Objectives

The general objective of this project is to strengthen tourism planning and conservation through GIS applications such as visualisation, 3D fly-through and spatial analysis. GIS can be regarded as providing a toolbox of techniques and technologies of wide applicability to the achievement of sustainable tourism development (Giles, 1994, p.2).

These objectives will be achieved through providing examples of how GIS visualisation and analysis techniques were used within the Currumbin Valley study area including:

- Research and identify suitable and relevant spatial data sets for GIS analysis and modelling ie. Major roads, dwellings, soil coverage, contour data and regional ecosystems;
- Use a Global Positioning System (GPS) to identify existing walking tracks;
- Develop a 3D model to include a DEM and digital aerial photography of the study area, and;
- Create a virtual fly-through that will display existing natural and man-made features, landscape sensitivities, terrain analysis and conservation assessment for an existing tourism area.

1.5 Scope and Limitations of the Study

The scope of work undertaken for this study was based on the available data sets provided by the University of Southern Queensland (USQ), Gold Coast City Council (GCCC) and GHD Pty Ltd. It was determined that numerous spatial data sets were necessary to achieve the visualisation required for a 3D model and virtual fly-through compulsory. The primary data sets included a DEM, digital aerial photography and satellite imagery.

The Currumbin Valley study area was selected on the basis that the spatial datasets were readily available to complete the following tasks successfully:

- Identification and collation of the readily available spatial data necessary to address the environmental issues associated with tourism in the Currumbin Valley;

- Analysis of the data in preparation for grid analysis, eventually displaying varying levels of environmental suitability, for example, a terrain assessment can identify areas suitable for walking tracks and will therefore assist with impact control measures;

- Development of a 3D model and virtual flythrough of the Currumbin Valley area to provide the viewer with a realistic outlook of the existing tourist usage and environmental assessment;

- Implement the GIS model to provide an example of how to improve current and future tourism sustainability within a natural environment, and;

- Market the principles of GIS capabilities within the tourism industry ie. increase awareness.

Further visualisation analysis and modelling could have been performed, for example, grid querying of additional environmental data sets such as detailed soils data. This will be discussed further in chapter 6. It was determined that additional detailed data sets and analyse of such data would increase the time constraints for this study. In addition, other factors that limited the depth of this study included:

- Limitations to the availability of GIS hardware and software provided at restricted hours by GHD Pty Ltd ie. weekends only;

- Hardware and software memory problems whilst running the 3D model within ESRI 3D Analyst.

- Data quality issues included availability of spatial data sets at a small scale only;

- GPS data recording of additional walking tracks within the study area would have been beneficial, but proved to be time consuming, and;

- Digital aerial photography was not obtained for the whole study area ie. a small section to the north of the study area does not contain photography, and;

1.6 The Organisation of the Dissertation

This dissertation has been organised into six chapters and also includes ancillary pages and appendices. This section will provide a brief outline of the content of each chapter.

Chapter one provides an introduction to the dissertation detailing problems, significance of the study, project objectives and scope and limitations of the project.

Chapter two consists of a literature review detailing background information on GIS and visualisation techniques and tourism studies previously utilising GIS capabilities.

Chapter three is a significantly important chapter. It outlines and details the study area's geographical location and bio-physical and socio-economic aspects. In addition, it also describes the data capture and acquisition techniques for all spatial data sets used in this study. The data pre-processing and analysis techniques are also described.

Chapter four displays the grid calculation results discussed in Chapter three. Chapter five provides a detailed discussion and interpretation of the results and how they may be of benefit to the tourism industry.

Chapter six discusses both a conclusion and future recommendations determined from this research project with general reference to analysis results and visualisation techniques employed to achieve a desired outcome.

Chapter 2
Literature Review

2.1 Introduction

This chapter is divided into four sections. The first section provides a brief background explanation on GIS concepts, systems and software. The second section briefly discuses relationship between GIS and visualisation, including developments in this discipline and advancements in 3D visualisation. The third section details and provides an example of a grid based modelling application. The fourth section details GIS and its current uses for the tourism industry (including tourism management and planning) and provides an example of how GIS and the tourism industry have been effectively used to date.

2.2 GIS Concepts, Systems and Software

A Geographic Information Systems (GIS) is a computer based tool or program used for mapping and analysing natural or man-made phenomena that exist on earth. GIS technology integrates common database operations such as query and statistical analysis whilst portraying a unique visualisation of geographic information for analysis through maps or virtual models. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining procedures, predicting outcomes and planning strategies.

Map making and geographic analysis was once performed through manual methods. GIS has now replaced these manual techniques and is now widely in a vast range of industries including educational purposes, science and engineering.

Detailed in Table 2.1 below are specific components required to successfully manage a GIS system. In addition, Table 2.2 provides examples of tasks used in GIS processes.

Table 2.1 – Components of a GIS

Type	Description
Hardware	• Hardware is the computer on which a GIS operates. • Today, GIS software runs on a wide range of hardware types, from centralised computer servers to desktop computers used in stand-alone or networked configurations.
Software	GIS software provides the functions and tools needed to store, analyse and display geographical information, key software components are; • Tools for the input and manipulation of geographic information; • A database management system (DBMS) • Tools that support geographic query, analyse and visualisation; • A graphical user interface (GUI) for easy access to tools.
Data	• The most important component of a GIS is the data. • Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. • A GIS will integrate spatial data with other data resources and can even use DBMS to organise and maintain their data.
People	• GIS technology is of limited value without the people who manage the system and develop plans for applying it to real world problems. • GIS users range from technical specialists who design and maintain the system to those who use it to help them perform their everyday work.
Methods	• A successful GIS operates according to a well designed plan and business rules, which are the models and operating practices unique to each organization.

Table 2.2 – GIS Tasks

GIS Tasks	Description
1. Input	• Before geographic data can be used in a GIS, the data must be converted into a suitable digital format. • The process of converting data from paper maps into computer files is called digitising. • Today many types of geographic data already exist in GIS compatible formats.
2. Manipulation	• It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make them compatible with your system. • Before spatial information can be integrated, it must be transformed to the same scale and projection. • GIS technology offers many tools for manipulating spatial data.

3. Management	•	Stored as simple files or in a DBMS management system connected to the GIS by a unique ID or common field.
	•	DBMS can store large amounts of data.
4. Query & Analysis	•	GIS provides both simple point and click query capabilities and sophisticated analysis tools to provide timely information examples include proximity analysis eg. Buffers and overlay analysis eg. Integration of different spatial data layers.
5. Visualisation	•	GIS provides new and exciting tools to extend the art and science of cartography.
	•	Map displays can be integrated with reports, three-dimensional views, photographic images and other output such as multimedia.

Spatial data technology (incorporating GIS software) is considered to be pivotal for optimising the operational and administrative functions of the planning, environmental and engineering divisions. This can be achieved through the use of specific GIS software such as ESRI's ArcGIS Version 8.3, 3D Analyst and Spatial Analyst.

2.3 GIS and Visualisation

Visualisation in a GIS environment focuses on the use of computer software and graphics for acquiring an understanding of specific spatial data. This methodology allows for the generation and interaction of realistic images, for example, digital aerial photography and a digital elevation model.

Developments in GIS visualisation techniques have been driven by the progress of powerful and sophisticated software that incorporate high-end analysis and display functionality. These systems are rapidly changing to 3D visualisation techniques that provide a descriptive and analytical virtual methodology. These methods can be applied as a number of visualisation types, for example (Cartwright, Miller and Pettit, 2004):

- Animations;
- Temporal mapping;
- Environmental modelling, and;
- Spatial modelling.

The abovementioned visualisation techniques can be achieved by using:

- New media;

- Multimedia;
- The web;
- Mobile computing;
- Virtual reality, and;
- GIS.

The increase of GIS technologies since the early 1990s has seen the delivery of desktop GIS products such as Arcview and Mapinfo that have made geographical information more accessible. Since the introduction of desktop GIS there has been an explosion of supporting tools including on-line, location-based, dynamic database, 3D visualisation and decision support tools (Cartwright, Miller and Pettit, 2004).

2.3.1 GIS and 3D Visualisation

It can be acknowledged that GIS provides options for a diverse range of geographical visualisation techniques. The primary focus of visualisation techniques over the past 10 years was to communicate an understanding of spatial information (Cartwright, Miller, Pettit, 2004).

In the past 5 years, the spatial industry has witnessed advancements in 3D GIS software visualisation techniques which are providing a distinction between reality and general cartography representation. Creating snapshots of spatial analysis and modelling results in a 3D environment, provides for a more realistic landscape that can depict various scenarios that reflect certain environmental, social or economic objectives, for example, sequencing a series of snapshots will animate movement through the landscape, or through time when coupled with a simulation model such as vegetation growth (Berry, Buckley and Ulbricht, 1998).

To illustrate the more recent use of GIS and 3D visualisation, an example is discussed in this section. An application whereby a 3D model and virtual fly-through using GIS techniques was used to determine a visual assessment of a proposed Weather Watch Radar Facility.

The objective of the proposed Weather Watch Radar Facility was to derive a maximum performance benefit from the radar and to satisfy the operational objectives (S1, p.6, 2004). A 3D visual assessment was performed to represent a realistic view of the radar tower from specific locations such as major roads and existing dwellings. ESRI's ArcScene was employed to create the 3D model from a DEM and digital aerial photography. Figure 2.1 represents a snapshot from an existing road. In this scenario vegetation was included to

depict how the radar tower will appear without clearing. Figure 2.2 represents an aerial view of the proposed tower and provides a view of how the tower will appear if the surrounding vegetation is cleared. In addition, a virtual fly-through was developed providing viewers with a realistic view of landscapes and surrounds. The virtual fly-through was exported to a video file format which enables geographical visualisation to be viewed using multimedia tools. This research project will employ the functionalities used to create the virtual fly-through techniques established during this project.

Figure 2.1 – 3D model snap-shot of the proposed radar site from an existing road, with vegetation (2004)

Figure 2.2 - 3D model aerial snap-shot of the proposed radar site, with no vegetation (2004

2.4 Grid Based Modelling Application

GIS software can be used as a planning and suitability tool by utilising and applying mathematical operators to raster base spatial data sets. In general terms, GIS is able to identify constraints, sensitivities or suitability relevant to a specific project. This section will focus on a type of software called Infrastructure Corridor Assessment or INCA (GHD Pty Ltd, 2004). The spatial analysis completed for this research project will employ similar methodologies to that of INCA's described below.

The INCA planning approach involves quantitatively assessing and evaluating complex environmental and social issues that have an influence on the location of infrastructure within a selected study area, for example, soils, dwelling locations and vegetation. The process of corridor selection within INCA employs mathematical operators such as addition and multiplication analytical techniques whereby the identified issues and their perceived importance are reflected in the assigned ratings and weightings.

In general terms, ratings are applied to primary and secondary data, such as soils, vegetation and visual impact, to reflect the sensitivity of the resource to the routing of a corridor. These data sets and their assigned ratings are represented by sensitivity maps.

The sensitivity maps can be weighted to reflect the perceived importance of the resource in the overall planning study, for example, vegetation may be of more significance then soil type. The various weighted sensitivity maps are then combined to produce a composite sensitivity map. This map is then used for the selection of corridor alternatives (Refer to Figure 2.2).

The methodology used by INCA software provides a number of distinct advantages over traditional methods of corridor selection, advantages include:

- Large quantities of data can be collected, stored and effectively managed to solve complex analytical problems associated with corridor selection, and;

- Assumptions and weightings assigned to specific parameters can be changed in response to further information and public comment.

Figure 2.3 – INCA Modelling Overview (GHD Pty Ltd, 2004)
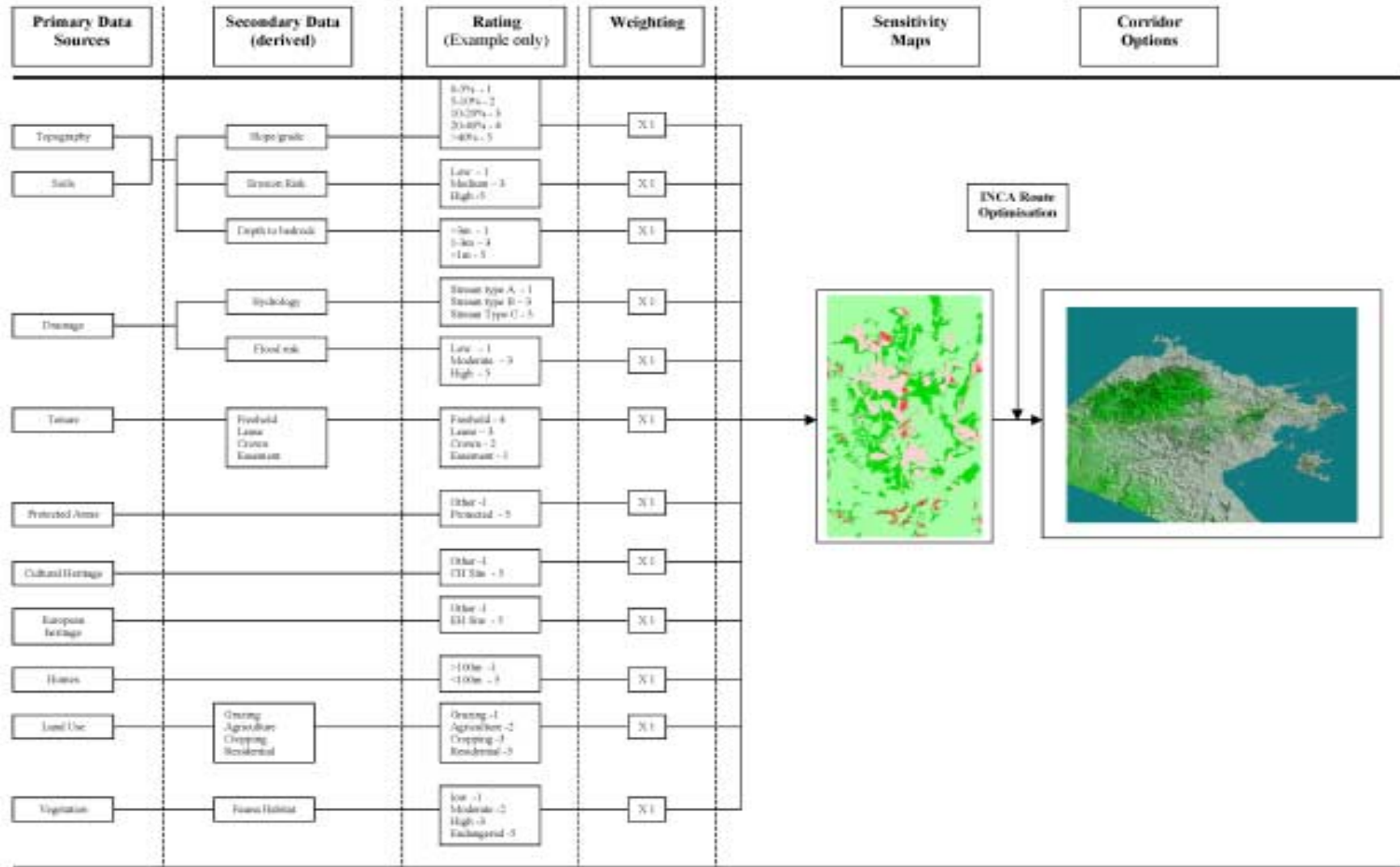
2.5 GIS Applications and the Tourism Industry

To date, both Tourism and GIS have been applied to a multiple of disciplines and interests such as (Giles, 2003, p.2):

- Geography and geographers;
- Environmental studies and environmental scientists, and;
- Planning and town planners.

GIS is recognised as providing an effective tool for managing, analysing and visualising spatial datasets for various planning and environmental scenarios. Tourism planning is dependent on identifying these scenarios or constraints to achieve sustainable tourism developments, for example, a proposed tourist wilderness park should consider planning and environmental constraints of the following spatial layers:

- Social constraints such as noise and visual assessment;
- Population of neighbouring suburbs;
- Flora and fauna species, and;
- Environmentally fragile areas.

GIS technology, such as overlay analysis, could consider each of the abovementioned layers by identifying areas that are least sensitive and therefore assist in determining a decision for the most suitable development site.

So far applications of GIS in tourism has been limited to recreational facility inventory, tourism based land management, visitor impact assessment, recreation wildlife conflicts, mapping wilderness perceptions, tourism information management system and decision support systems (Giles, 2003, p3). The information contained in Table 2.3 and 2.4 and related issues are described by Giles (2003, p.4) as illustrating the functional capabilities of GIS and relevant applications in tourism and the range of issues and potential applications of GIS. It can be observed from both these information tables that GIS can provide and assist with a multiple of decision-making and planning capabilities that are currently being under utilised in the tourism industry.

Table 2.3 – Capabilities of GIS

Functional Capabilities of a GIS	GIS Basic Questions		Tourism Applications
Data entry, storage and manipulation	Location	What is at?	Tourism resource inventories
Map production	Condition	Where is at?	Identify most suitable locations for development
Database integration and management	Trend	What has changed?	Measure tourism impacts
Data queries and searches	Routing	Which is the best route?	Visitor management/flows
Spatial analysis	Pattern	What is the pattern?	Analyse relationships associated with resource use
Spatial modelling	Modelling	What if…?	Assess potential impacts of tourism development
Decision support			

Source: Giles, 2003, p4.

Table 2.4 – Common tourism-related issues and GIS applications

Problem	GIS Application
Benchmark/database	Systematic inventory of tourism resources
Environmental management	Facilitating monitoring of specific indicators
Conflicts	Mapping recreational conflicts: recreation-wildlife; user conflict
Tourism behaviour	Wilderness perceptions
Carrying capacity	Identify suitable locations for tourism/recreation development
Prediction	Simulating and modelling spatial outcomes of proposed tourism development
Data integration	Integrating socio-economic and environmental datasets within a given spatial unit
Development control and direction	Decision support systems

This research project will focus on techniques that aim to bridge the gap between GIS and the tourism industry by considering applications that were mentioned in Table 2.3 and 2.4, for example, using spatial analysis to analyse relationships associated with resource use.

2.5.1 Example GIS and a Tourism Related Project

In 1999 the country of Nepal conducted a GIS project whereby the mapping effects of visitor use on mountain trails were identified. The number or visiting tourists, predominately trekkers to the region was increasing significantly and therefore high level impacts were degrading the existing trails.

GIS was employed to map trail impacts and determine the relationships between impacts and environmental features. Trail specific information was collected and included (Giles, 2003, p.6):

- Soil erosion;
- Vegetation loss along train transects;
- Trail braiding;
- Bedrock exposure;
- Train displacement;
- Muddy and wet trails were mapped and integrated with visitor use data such as visitor density along different sections of the trail;
- Packstock density, and;
- Density of lodge accommodation.

To complete the required spatial relationship and final analysis, environmental features were also included to the GIS database and including the following spatial layers:

- Trail locations and positions;
- Site specific vegetation types;
- Trail slope;
- Altitude;
- Soil type; and;
- Site specific hazards such as landslides.

Finally, the GIS software namely ArcGIS was employed to map and analyse the abovementioned spatial information. The final map displayed combined information of trail

specific impact types and the relationship with use levels and environmental features (Giles, 2003, p.7). This project established that GIS systems and software can be used to identify what type of site constraints contribute to specific trail damage and provide an effective means to create guidelines to reduce resource degradation and design sustainable future trails.

2.6   Conclusion

This chapter has introduced background knowledge of GIS concepts, systems and software by providing explanations and examples of what type of components are required to successfully manage a GIS. It has also provided an outline of what type of tasks are used in GIS processes.

This chapter has also provided an example of existing GIS techniques and scenarios that will form the basis of this study.   It has also detailed important background developments in 3D visualisation techniques and grid based modelling applications.

As detailed in this chapter, it can be determined that GIS and its current uses for tourism management and planning are limited. This research project will aim to achieve and open opportunities to form an additional relationship between tourism and GIS systems.

Chapter 3
Research Methods

3.1 Introduction

This chapter describes the most important component and issues related to this dissertation, namely research methods for:

- The study area, outlining geographic location and biophysical and socio-economic descriptions;
- Data capture and acquisition methods, and;
- Data pre-processing and analysis techniques used to determine final results.

3.2 The Study Area

The Gold Coast is located in the south-eastern corner of the State of Queensland, south of the city Brisbane (Refer to Figure 3.1). Gold Coast City is presently home to approximately 425,481 people and hosts over 78,000 domestic and international visitors everyday, therefore tourists represent approximately 15 per cent of all people in Gold Coast City on any given day (Gold Coast City Council (GCCC), 2004). The total area of Gold Coast City is approximately 1404 square kilometres.

The Currumbin Valley study area is situated to the south west of the coastal suburb of Currumbin and approximately a 40 minute drive from Coolangatta airport along Currumbin Creek Road. Currumbin Valley has been heavily cleared in the coastal reaches and upper plains, while the steep mountainous areas are largely untouched (Refer to Figure 3.1). Mount Cougal is located on the fringe of Springbrook National Park, or otherwise known as the Gold Coast Hinterland. Mount Cougal's twin peaks overlook the picturesque Currumbin Valley and protect a subtropical rainforest, Cougal's Cascades and Currumbin Creek.
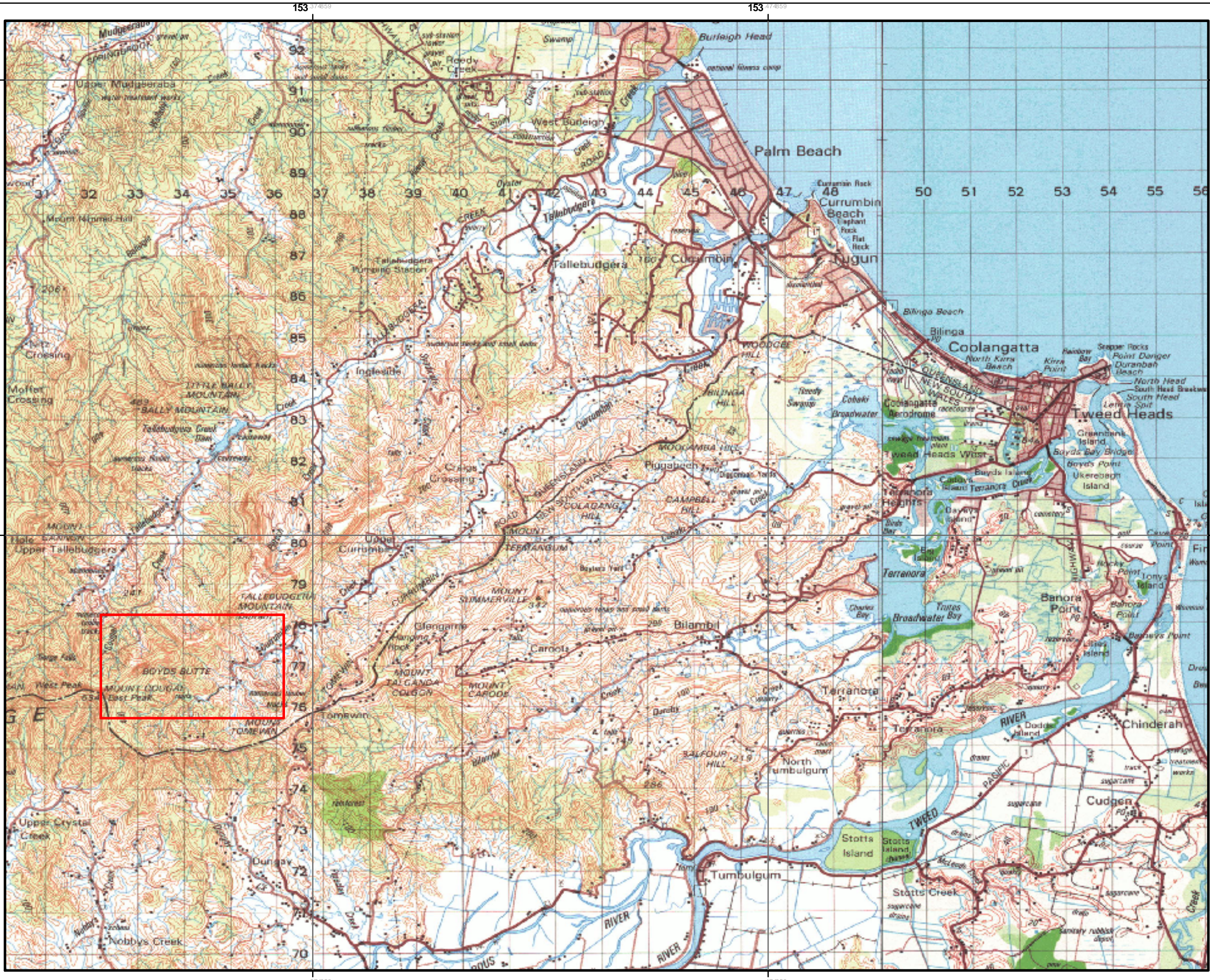
CURRUMBIN VALLEY
TOURISM CONSERVATION
STUDY

Location Map

FIGURE 3.1

Legend

☐ Study Area

N

0 0.375 0.75   1.5   2.25   3
Kilometers

1:85,000

Source Information: Geoimage
Projection: Geographic AGD 84
Date Printed: 18/05/04

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Figure 3.2 – Photograph of Currumbin Valley, looking west to Mount Cougal (2004)

3.2.1 History

Both Indigenous and European populations have had a long association with the Currumbin Valley and Mount Cougal area. The Yugambeh Aboriginal people lived in this valley for at least 6000 years and still have a close connection with the national park.

Conservation of the Currumbin and Tallebudgera Creek areas began in 1938 with 142 hectares set aside to protect the rainforest headwaters. Additions over the years brought the Currumbin Valley conservation area to 811 hectares before it was amalgamated with the adjoining Springbrook National Park in 1990 (GCCC, 2004).

European communities primarily used Currumbin Valley for timber production and banana plantations. A bush sawmill was established in 1943 and continued till 1954 (GCCC, 2004).

The sawmill remains are partly restored and are located at the end of the walking tracks near Cougal's Cascades.

3.3　Existing Land Use within the Study Area – Biophysical Attributes

The following presents an assessment of the existing environmental and potential biophysical attributes for the chosen study area. There are many levels of impacts that have been identified. Minor environmental impacts are classed as having no long term impact on physical, biological or human environment, moderate environmental impacts are classed as being manageable by imposing appropriate practices and will not have any long term environmental impacts and major environmental impacts are classes as having a significant effect on the environment.

3.3.1 Topography

The topography of the Study Area is dominated by coastal lowlands near Currumbin and low-lying valleys leading into Currumbin Valley along Currumbin Creek to the Cougal's Cascades and picnic area (Refer to Figure 3.3). The elevation of land from Currumbin Valley heading west to the Mount Cougal generally increases from a minimum of 110 AHD to a maximum 670m AHD at the mountain's East Peek. The study area primarily starts at slope category of less than 15 percent within Currumbin Valley and along Currumbin Creek leading to Mount Cougal's East Peek. The slope north and south of Currumbin Valley generally increases to approximately 20 to 50 percent, with the highest slope located at Mount Cougal (Refer to Figure 3.4).

3.3.2 Regional Ecosystems and Rare and Threatened Species

A Regional Ecosystem can be defined as 'vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil (Environmental Protection Agency Queensland (EPA), 2004).

The Regional Ecosystem Description Database lists the status of regional ecosystems as gazetted under the Vegetation Management Act 1999 (EPA's Vegetation Management Status) and the EPA Biodiversity Status as recognised by the Environmental Protection Agency. The specific criteria used to assess the Vegetation Management Act 1999 Status and Biodiversity Status of regional ecosystems are given in Table 3.1 below. (EPA, 2004)
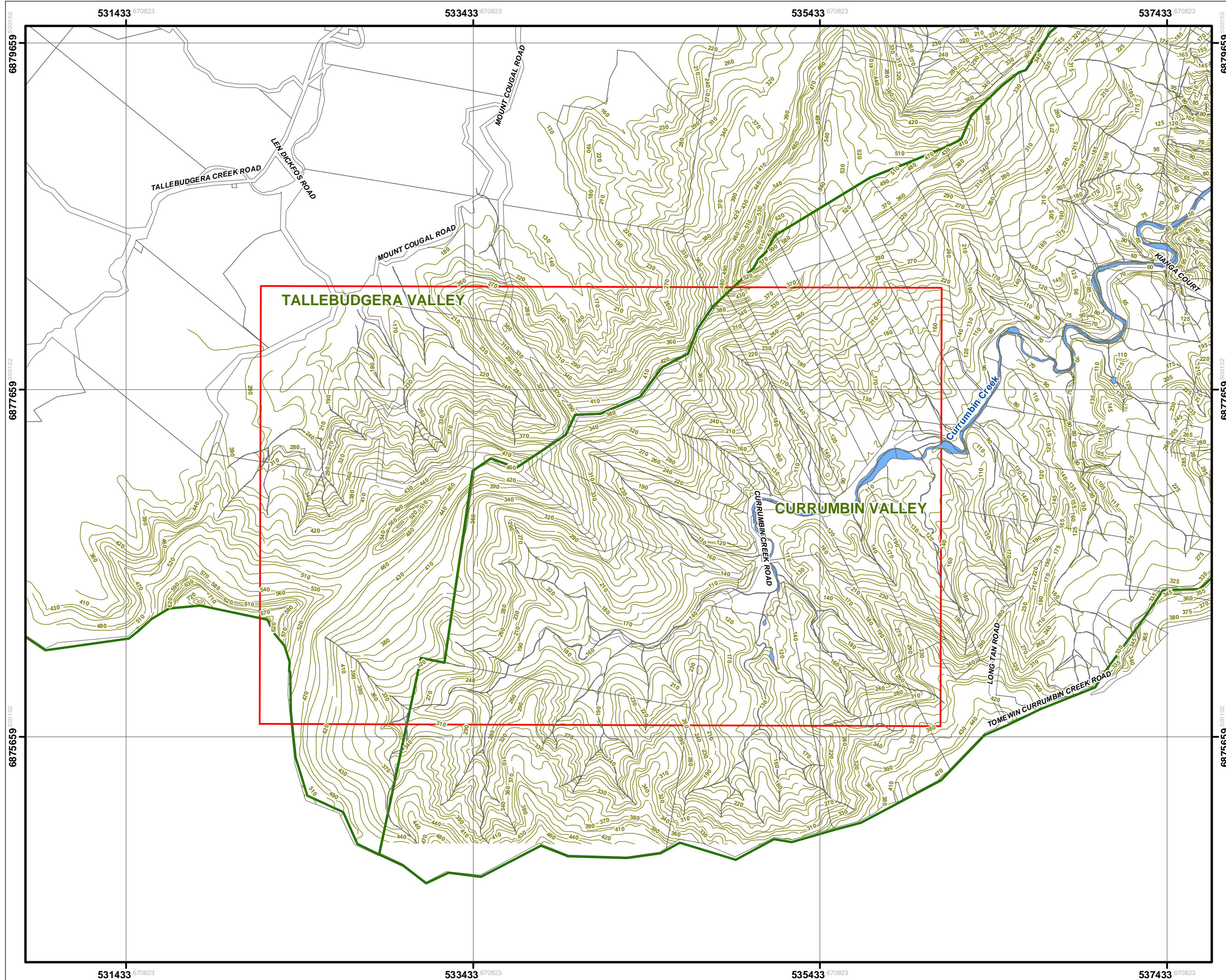
CURRUMBIN VALLEY TOURISM CONSERVATION STUDY

Topography

FIGURE 3.3

Legend
- Study Area
- Suburb Boundary
- 5m Contour

N

0 62.5 125 250 375 500 Meters

1:20,000

Source Information: GHD Pty Ltd
Projection: GDA 94, MGA Zone 56
Date Printed: 18/05/04

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TALLEBUDGERA VALLEY

CURRUMBIN VALLEY

Currumbin Creek

TALLEBUDGERA CREEK ROAD

LEN DICKFOS ROAD

MOUNT COUGAL ROAD

MOUNT COUGAL ROAD

CURRUMBIN CREEK ROAD

LONG TAN ROAD

TOMEWIN CURRUMBIN CREEK ROAD

KIANGA COURT

CURRUMBIN VALLEY
TOURISM CONSERVATION
STUDY

Slope Analysis

FIGURE 3.4

Legend
Study Area
Suburb Boundary
Slope %
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50

N

062.5125   250   375   500
Meters

1:20,000

Source Information: EPA
Projection: GDA 94, MGA Zone 56
Date Printed: 18/05/04

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Table 3.1 – Vegetation Management Status

Vegetation Management Status	Description	Located within Study Area
Endangered	• Less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss; or • 10-30 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or • It is a rare regional ecosystem subject to a threatening process.	Currently no endangered areas are located within the Study Area.
Of Concern	• Remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 30 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares. • In addition to the criteria listed for an of concern regional ecosystems under the *Vegetation Management Act 1999*, for biodiversity planning purposes the Environmental Protection Agency also classifies a regional ecosystem as of concern if: 10-30 per cent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.	There are currently two classes of Concern areas within the Study Area. Firstly, Of Concern Dominant areas are located north-west of Currumbin Creek Road and south of Mount Cougal Road. Secondly, a small area containing Of Concern Sub-dominant status is located north of Currumbin Creek Road. Particular caution may be needed for tourism activities.
Not of Concern	• Remnant vegetation is over 30 per cent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and; • The degradation criteria listed above for endangered or of concern regional ecosystems are not met.	The Study Area is currently partial to half the area of Not of Concern vegetation management status. Therefore this status type will not impact on any part of tourism activities.

(Source: EPA, 1997)

Refer to Figure 3.5 for Regional Ecosystem Mapping.

In addition to Regional Ecosystem identification, the EPA has also created a database containing the spatial location of rare and threatened species. The Currumbin Valley study area includes one location that contains a rare and threatened species. The description of this species will be detailed at a later date.

CURRUMBIN VALLEY
TOURISM CONSERVATION
STUDY

Regional Ecosystems &
Wildnet Rare & Threatened
Species

FIGURE 3.5

Legend
☐ Study Area
☐ Suburb Boundary

VMS_SHADE
☐ Clear
☐ Of Concern - Dominant
☐ Of Concern - Sub Dominant
☐ Not of Concern
★ Wildnet Rare & Threatened Species
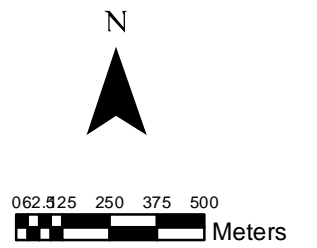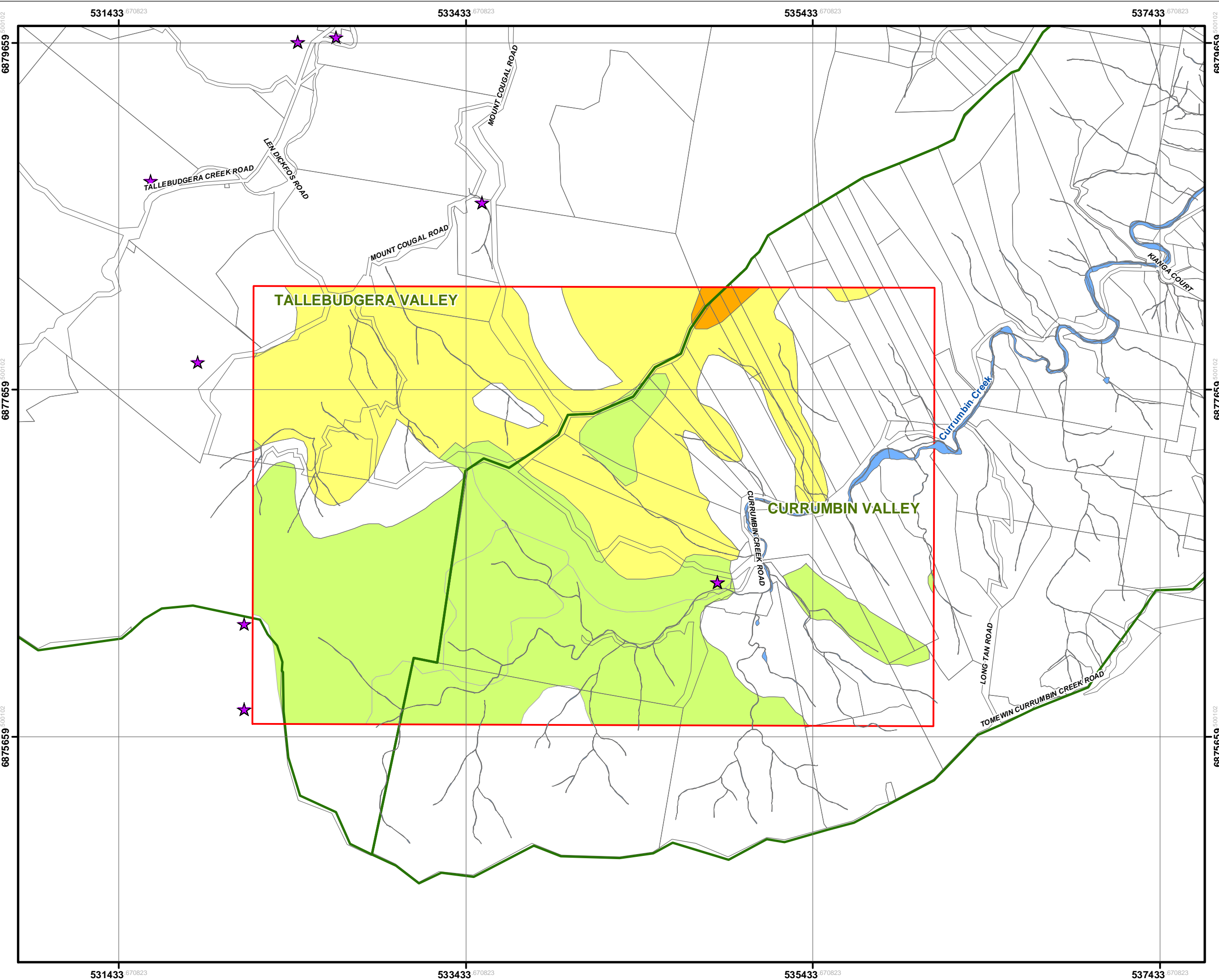
N

062.5125 250 375 500
Meters
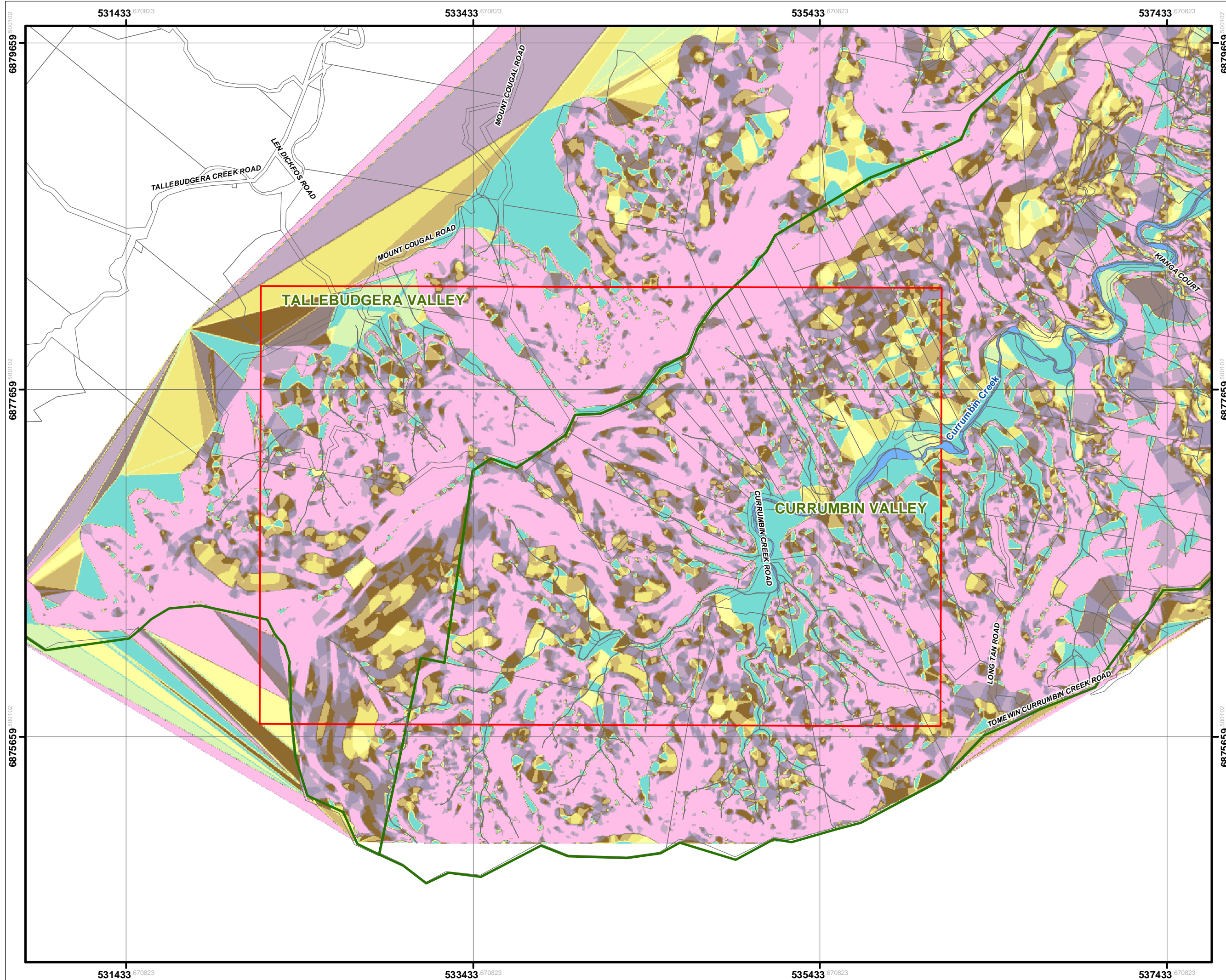
1:20,000

Source Information: EPA
Projection: GDA 94, MGA Zone 56
Date Printed: 18/05/04

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TALLEBUDGERA VALLEY

CURRUMBIN VALLEY

Currumbin Creek

LEN DICKFOS ROAD
TALLEBUDGERA CREEK ROAD
MOUNT COUGAL ROAD
MOUNT COUGAL ROAD
CURRUMBIN CREEK ROAD
LONG TAN ROAD
TOMEWIN CURRUMBIN CREEK ROAD
KIANGA COURT

3.3.3 Flora and Fauna

The chosen study area and surrounds is predominantly covered by sub tropical to warm temperate rainforest found mostly on the cooler and moist south and east facing slopes and along wet gullies and creeks. The second most dominant vegetation species is Moist Eucalypt Open Forest found on the north and east facing slopes with Rainforest Understorey and White Mahogany and Grey Gum contained in open woodland. In addition, there is small open forest complexes located to the central-west of the study area that are vegetated by New England Blackbutt, Tallowwood and Scribbly Gum. Mount Cougal is completely surrounded by a wide sheathe of rainforest and giant spear lilies can be found at the east peak.

Currumbin Valley and Mount Cougal are home to a wide range of fauna species, significant species include:

- Lamington Spiny Cray;
- One of the world's largest skinks, the land mullet;
- Platypus;
- Eastern water dragons;
- Sooty owls;
- Water-rats;
- Brushtail possums;
- Brush turkeys, and;
- Logrunners.

3.3.4 Geology and Soil

Over 300 million years ago this area was covered by deep oceanic waters and was the scene of massive and widespread deposition of sedimentary material derived from an ancient volcanic mountain chain to the west. These deep water sediments were subsequently compressed by major movements of the crustal plates, folded and slightly recrystallised. Eventually they were thrust up above sea level, probably to form mountainous terrain. These rocks, known as the Neranleigh-Fernvale beds, occur below 300m altitude. After a long period of stability and erosion a major volcano erupted 23 million years ago. This was centred on what is now Mount Warning, 20km to the south in NSW. Pouring out a

series of highly mobile basalt lava flows and less mobile rhyolite lava, it formed a broad, gently sloping shield, burying the rocks of the older landscape (EPA, 2004).

Figure 3.6 - Graphical representation of rocks within the study area (2004)

A description of current geological and soil types and their location within the study are listed in Table 3.2 below and graphically shown in Figure 3.7 and 3.8.

Table 3.2 – Geological and Soil Types

Location	Geology Code	Name	Soil Description
Predominately located north-west and south-east of the study area	DCf	Metasediments and Neranleigh-Fernvale beds	Arenite, mudstone, shale, chert, jasper, basic metavolcanics, pillow lava and conglomerate.
Scattered throughout study area	TQcb	Colluvium Basalt	Soil, clay, cobbles and boulders.
Located either side of Currumbin Creek	Qha	Alluvium – active channels and low terraces	Clay, silt, sands, gravels and cobbles.
Located at Mount Cougal and Boyds Butte	Tlr	Binnaburra Rhyolite	Rhyolitic tuffs and lavas.
Located at Boyds Butte	Tlb	Beechmont Basalt	Olivine basalt

CURRUMBIN VALLEY
TOURISM CONSERVATION
STUDY

Geology

FIGURE 3.7

TALLEBUDGERA VALLEY

CURRUMBIN VALLEY

TALLEBUDGERA CREEK ROAD

LEN DICKFOS ROAD

MOUNT COUGAL ROAD

MOUNT COUGAL ROAD

CURRUMBIN CREEK ROAD

Currumbin Creek

KIANGA COURT

LONG TAN ROAD

TOMEWIN CURRUMBIN CREEK ROAD

531437 .983809
533437 .983809
535437 .983809
537437 .983809

6879662 .03683
6877662 .03683
6875662 .03683

N

062.5 125 250 375 500
Meters

1:20,000

Source Information: GHD Pty Ltd
Projection: GDA 94, MGA Zone 56
Date Printed: 18/05/04

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Legend

Study Area

Suburb Boundary

Geology Formation

DCf - Metasediments : Neranleigh-Fernvale beds : arenite, mudstone, shale, chert, jasper, basic metavolcanics, pillow lava, conglomerate

Qha - Alluvium : active channel and low terraces : clay, silt, sands, gravels and cobbles

TQcb - Colluvium basalt : soil, clay, cobbles and boulders

TQw - Colluvial fans : slope wash, clay, scree, soil

Tfa - Albert Basalt : olivine basalt

Tlb - Beechmont Basalt : olivine basalt

Tlr - Binnaburra Rhyolite : rhyolitic tuffs and lavas

Tls - Springbrook Rhyolite : rhyolite

CURRUMBIN VALLEY TOURISM CONSERVATION STUDY

Soils

FIGURE 3.8

TALLEBUDGERA VALLEY

CURRUMBIN VALLEY

N

0 62.5 125 250 375 500 Meters

1:20,000

Source Information: GHD Pty Ltd
Projection: GDA 94, MGA Zone 56
Date Printed: 18/05/04

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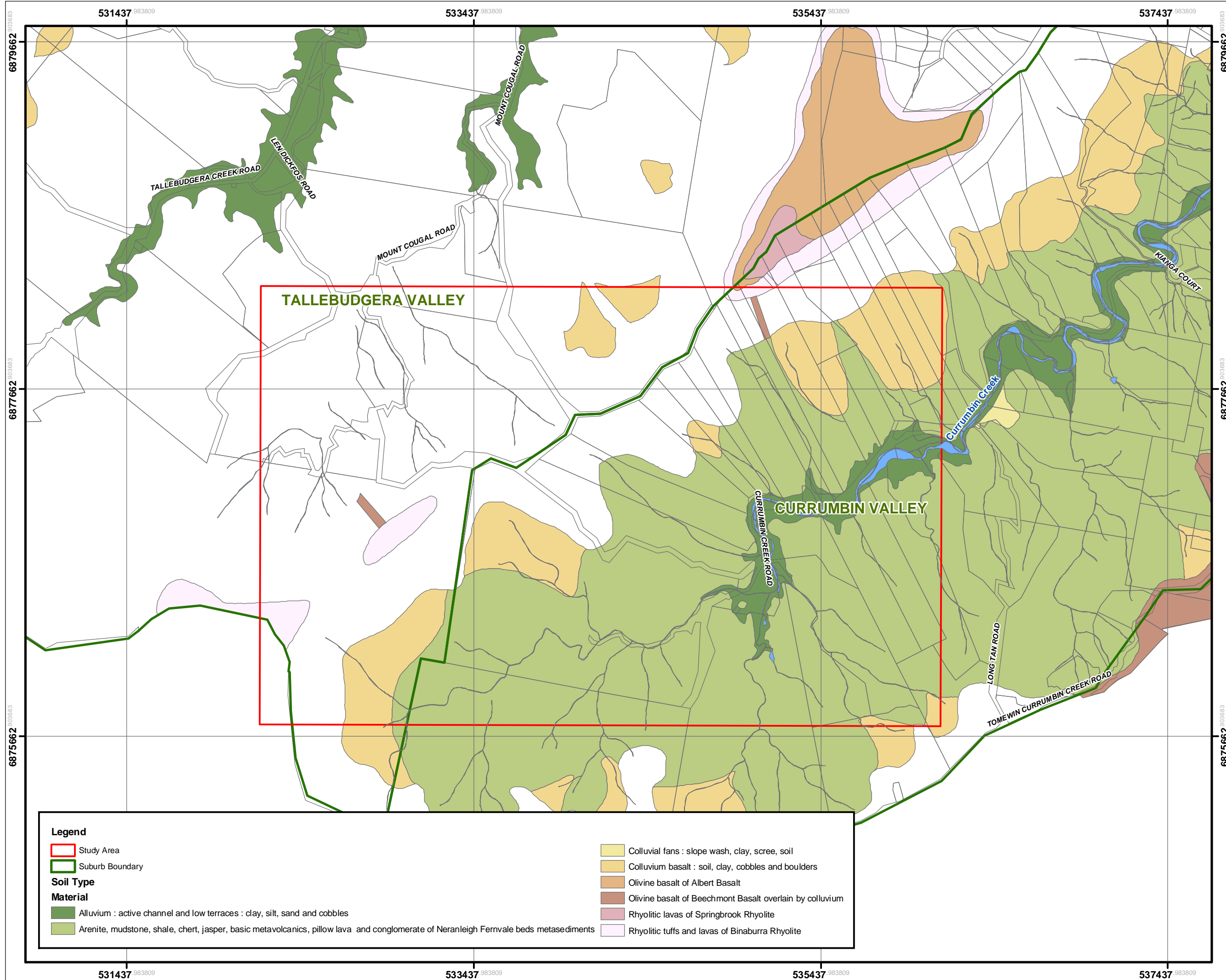
Legend

☐ Study Area
☐ Suburb Boundary

Soil Type
Material

☐ Alluvium : active channel and low terraces : clay, silt, sand and cobbles
☐ Arenite, mudstone, shale, chert, jasper, basic metavolcanics, pillow lava and conglomerate of Neranleigh Fernvale beds metasediments

☐ Colluvial fans : slope wash, clay, scree, soil
☐ Colluvium basalt : soil, clay, cobbles and boulders
☐ Olivine basalt of Albert Basalt
☐ Olivine basalt of Beechmont Basalt overlain by colluvium
☐ Rhyolitic lavas of Springbrook Rhyolite
☐ Rhyolitic tuffs and lavas of Binaburra Rhyolite
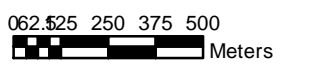
3.3.5 National Parks and Conservation Areas

The eastern area of Currumbin Valley and Mount Cougal is contained within Springbrook National Park. Springbrook National Park has an approximate area of 3000 hectares and is classified as part of the Central Eastern Rainforest Reserves World Heritage Area. In addition, Tomewin Conservation Park is located to the east, outside the study area along Tomewin Currumbin Creek Road.

3.3.6 Currumbin Catchment and Creek

Currumbin Creek is located within the Currumbin Valley Catchment and is approximately 24km in length. The upper catchment is located within the Mt Cougal National Park, where runoff flows narrowly and shallow through Currumbin Creek and is separated with deeper pool areas. This area of the Currumbin Valley has been extensively cleared for a variety of agricultural practices including banana plantations and dairy farming (GCCC, 2004). The lower catchments has predominately been cleared for urban residential development, leading to lose of riparian vegetation.

Currumbin Creek flows into the Pacific Ocean at Currumbin Beach. Both the estuaries and the freshwater bodies contain dissolved oxygen levels and pH values (acidity or alkalinity of the water). High levels of Chlorophyll-a and phosphorus concentrates are have been located towards the mid estuary areas. This indicates that nutrients are entering Currumbin Creek at the mid reaches generally through stormwater drains and catchment runoff (EPA, 2004). Two distinct sites have been located by the EPA as being slightly impacted.
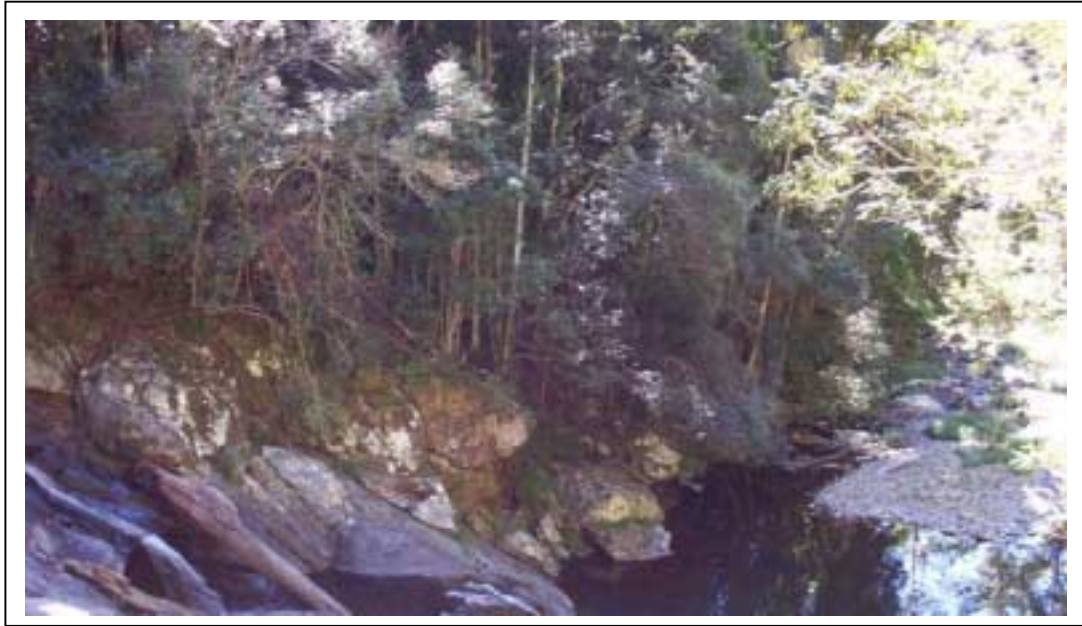
Figure 3.9 – Currumbin Creek and Rock Pools (2004)

3.3.7 Climate

Currumbin Valley is situated within the sub-tropical humid coastal belt of Queensland. The summer months from December to February bring long hot days, which often produce thunderstorms towards late afternoon. The average temperature and rainfall during the summer months as recorded from the Mount Tamborine weather station is 26 degrees and 209mm of rain (Bureau of Meteorology Australia (BOM), 2004). The winter months from June to August are normally dry, fine and cool at night and mornings particularly at the head of the valley where cold air drifts down the rocky creek. Winter can also see occasional frosts in the open flats. The average temperature and rainfall during the winter months is 18 degrees and 80mm or rain (BOM, 2004).

3.4 Data Capture and Acquisition

During this study several different types of spatial data sets were used. This section will discuss the processes of data input and acquisition procedures. The study area was chosen due to the contrasting terrain of the valley and mountains. In addition, the study area was a common destination for tourists whilst visiting the Gold Coast.

Table 3.3 below lists all spatial data sets that are used for this research project and relevant source information. In addition, Table 3.3 also lists the importance of the data set, ie. Primary data set is a data set that has been used for modelling and/or analysis and will be described in detail later in this section. A Secondary data set is one that has been used for cartographic figure representation for biophysical attributes only.

Table 3.3 – Spatial Data

Data Type	Source	Importance
Digital Aerial Photography	Gold Coast City Council, 2004	Primary Data Set
5m Contour Data	GHD Pty Ltd	Primary Data Set
Walking Track	GPS Field Survey	Primary Data Set
Existing Dwellings	Aerial Photography	Primary Data Set
Queensland Major Roads	QSIS	Primary Data Set
Soils Data	Digital Atlas of Australian Soils	Primary Data Set
Regional Ecosystems	Environmental Protection Agency, Qld	Primary Data Set
1:100,000 Digital Topographic Map	Geoimage	Secondary Data Set
Digital Cadastral Database (DCDB)	GHD Pty Ltd	Secondary Data Set
Satellite Imagery	GHD Pty Ltd	Secondary Data Set
Geology Data	Department of Natural Resources and Mines, Qld	Secondary Data Set
Vegetation Data	GHD Pty Ltd	Secondary Data Set
Wildnet Data	Environmental Protection Agency, Qld	Secondary Data Set
Conservation and National Park Data	Environmental Protection Agency, Qld	Secondary Data Set

The digital aerial photography was acquired in April 2004 from Gold Coast City Council (GCCC). The digital aerial photography supplied by GCCC arrived via CD-ROM and was

previously geo-referenced to GDA 94, Zone 56. The format supplied was ERMapper's ECW file rasters.

The walking track layer was derived from a field investigation of Currumbin Valley. An ESRI GPS unit was used. ArcPad enabled constant GPS recording of a vector polyline shape file whilst walking. ArcPad is a system similar to ESRI's ArcGIS, although the functions are a limited version.

The dwellings layer was digitised from the aerial photography. A new shape file was created to a point file and dwellings were recognised through visually identifying settlement patterns on the aerial photography.

The soils layer originated from the Bureau of Rural Sciences after Commonwealth Scientific and Industrial Research Organisation (1991). The soils layer is available via the internet http://www.brs.gob.au/data/datasets and is referenced to the *Digital Atlas of Australian Soils.* The digital vector file was mapped at a scale of 1:2,000,000. The soils layer details the following information (contained in separate fields):

- Association;
- Material, and;
- Source.

The Regional Ecosystems (RE) layer forms part of information reported in 1999 from the "Conservation Status of Queensland's Bioregional Ecosystems" produced by the Environmental Protection Agency Queensland. The report describes the Regional Ecosystem data as the primary basis for planning and conservation of biodiversity, particularly at the landscape level (EPA, 1999). In addition, the RE data provides the *Vegetation Management Act (VMA)* status which provides a legislative outline for different levels of conservation management status eg. Endangered. The *VMA* is the primary information that was used for this study.

3.5 Data Pre-processing and Analysis

This section will discuss and describe pre-processing for all primary data sets and the grid analysis involved to achieve the required results. There are two main pre-processing areas

that were completed, firstly the grid analysis pre-processing and secondly the 3D model pre-processing. The analysis element involved the grids only and not the 3D Model.

3.5.1 Software and Hardware

There was one individual hardware system used for all analysis and modelling, this system incorporated the following specifications and was located at GHD Pty Ltd Brisbane:

- Dell Precision 360 workstation;
- 1GB RAM;
- Video card;
- Windows XP, and;
- Hewitt Packard laser jet 8550 printer.

There is two primary software systems that was used to complete this study. This system required the use of several extensions for different functions and is listed in Table 3.4 below.

Table 3.4 – Software and Extensions

Software	Required For
ArcGIS Version 8.3	Preparation of all maps and general GIS tasks.
Spatial Analyst extension	Required for all grid compilation, analysis and calculations.
3D Analyst extension	Required for creation of 3D model and fly-through.
ArcToolbox	Required for defining projections and re-projecting spatial data sets.
Mapinfo Version 7.5	Universal Translator was used to transfer Mapinfo tab. Files to ESRI shape.
ArcPad GPS System	Required for field investigation to record all GPS vector files.

3.5.2 Datum and Initial Layer Preparation

The preferred projection used for this project and spatial data sets was Geocentric Datum of Australia 1994 (GDA94), Zone 56. Initially most data sets were defined to spatial projection Australian Grid Datum (AGD84), Zone 56 or Geographic AGD84, with exception to the digital aerial photography that was defined at GDA94, Zone 56. Using ArcGIS's "ArcToolbox" the data sets were all re-projected into the common datum GDA94, Zone 56.

The study area was defined using a vector polygon feature. The applicable data sets, which were all vector files, were then clipped to the study area extent using ArcGIS's "Geo-processing Wizard". The clipping feature in ArcGIS acts as a "cookie cutter" by using the study area polygon layer to clip for example, a vector contour layer. A new layer is then contains a geographic subset of the original layer. The attributes of the clipped layer remain the same as the original layer (Refer to Figure 3.10). This step was completed to limit the file size of the data sets in preparation for vector-raster conversion and especially for the creation of the Triangular Irregular Network (TIN) and Digital Elevation Model (DEM).

Figure 3.10 – ArcGIS's "Geoprocessing Wizard – Cookie Cutter" Function
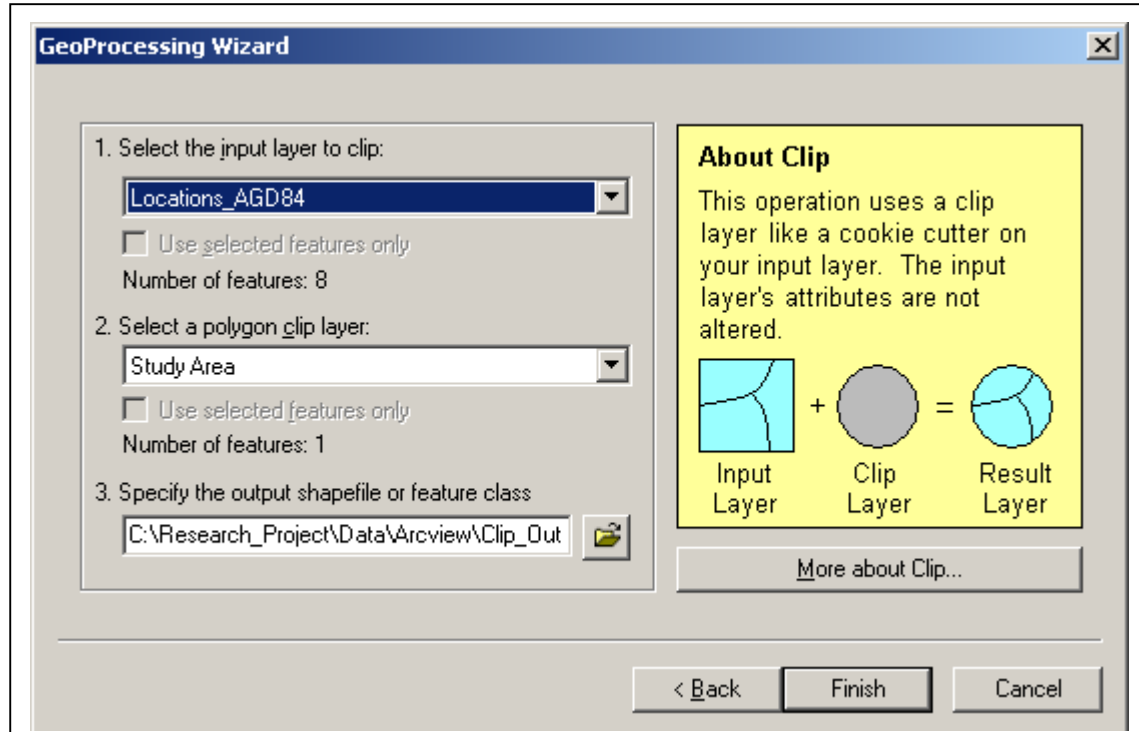
3.5.3 Pre-processing of the Contour Layer

The 5m contour vector file was originated from a Mapinfo tab file. Mapinfo's "Universal Translator" was used to transfer the tab file to ESRI shape file format. The shape file was then added to ArcGIS. The 5m contour data set is the primary source for creation of all viewshed analysis, terrain analysis, 3D models and fly-through and is therefore extremely important for this research project (Refer to Figure 3.11).

As previously mentioned, the 5m contour layer was clipped to the polygon study area boundary using ArcGIS's "Geoprocessing Wizard". The next phase involved creation of the Triangular Irregular Network (TIN) file. A TIN file can be defined as a process for grid generation that is most commonly applied to data such as elevation readings. The creation of a TIN file involves a process whereby all original vector data, typically points or polylines are connected in space by a network of triangular faces. The points or polylines are connected based on a nearest neighbour relationship, which enables the accuracy of topographic features (Refer to Figure 3.12).

Figure 3.11 – 5m Contour Data
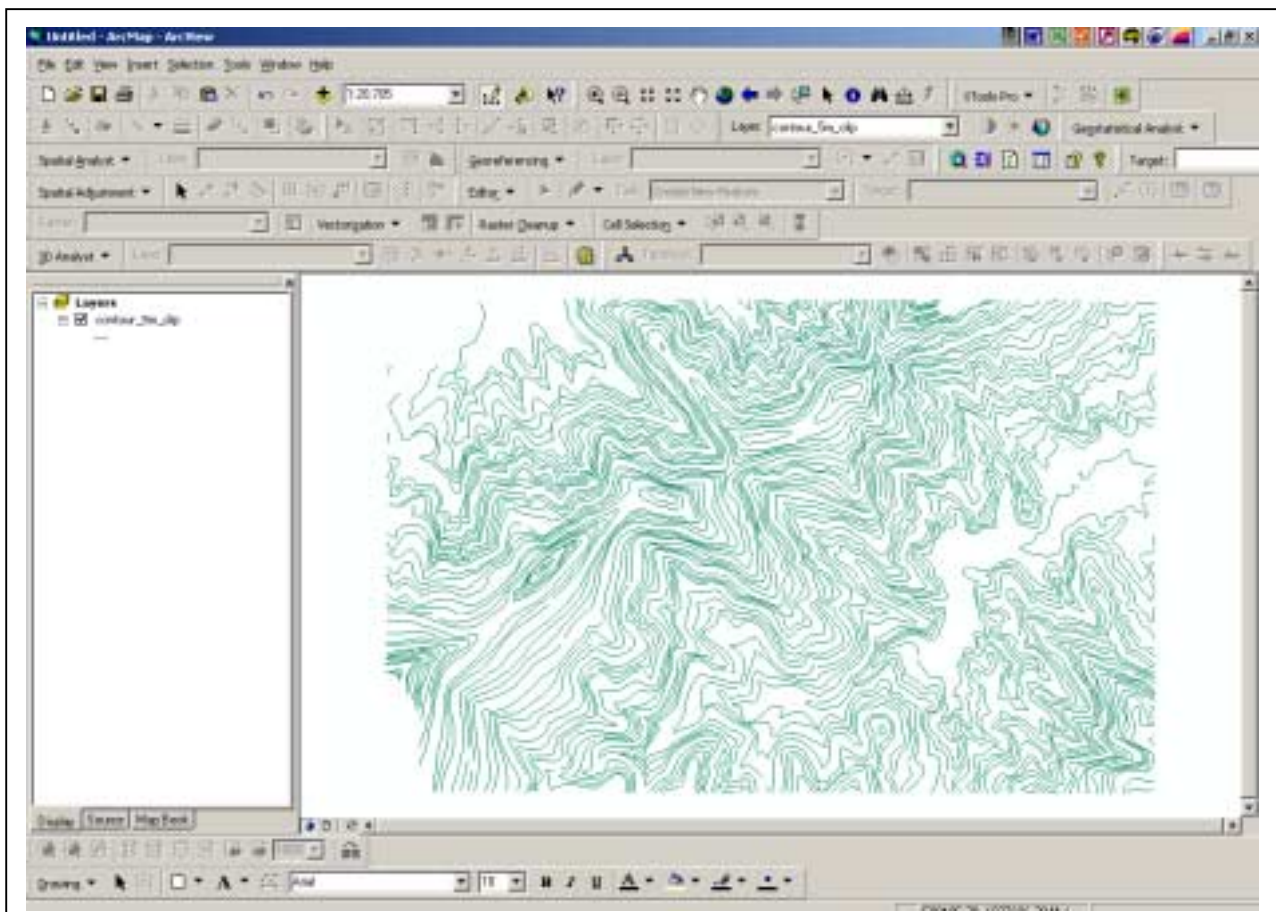
Figure 3.12 – TIN Methodology
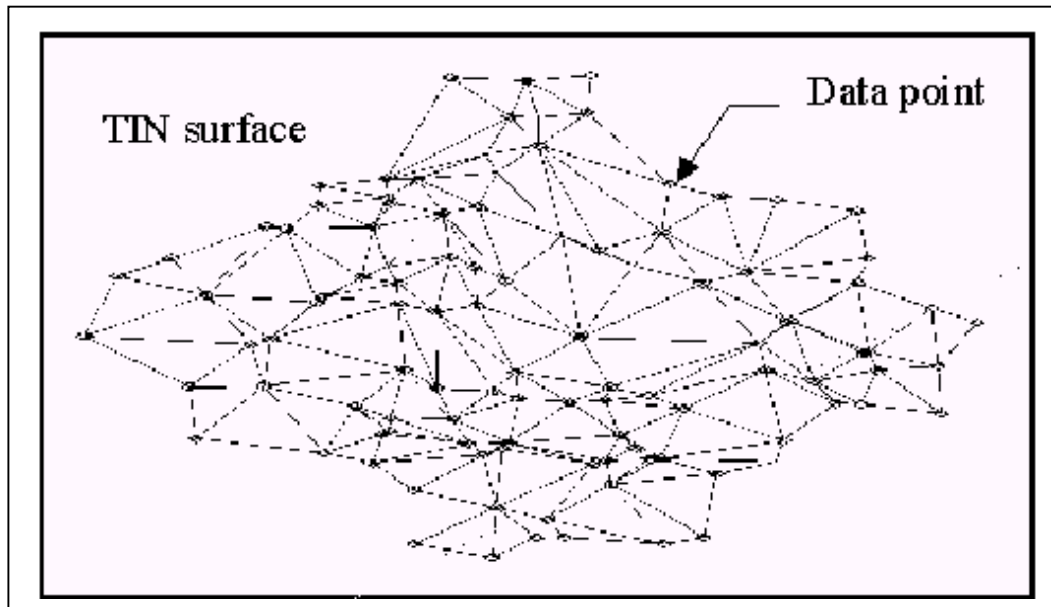
Source: Vertical Mapper 2.6 (2004)

The "3D Analyst" extension for ArcGIS was used to create the TIN from the vector 5m contour layer. Building a TIN involves the following steps:

- Choose the function "Create TIN from Features" under the 3D Analyst extension toolbar;
- Select the vector file from which the TIN will be built ie. 5m contour layer, and;
- Generally all input features should contain a z-value, which relates to the Height Source – choose your Height Source field within the 5m contour layer.

The next phase in TIN creation involves how the features should be incorporated into the TIN ie. mass points or breaklines. The mass points selection ensures more mass points are in areas where the surface is highly variable and few in places where the surface is less variable (ESRI, 2004). The next feature choice in TIN creation is breaklines. Breaklines represent natural features such as creeks or ridgelines and built features such as roads. There are two types of breaklines. Firstly hard breaklines that represent and capture sudden changes in surface and generally improve a TIN's display and furthermore analysis. Secondly soft breaklines, which enable the use to add, for example, a study area boundary to capture linear features without affecting the shape of the surface (ESRI, 2004).

For the purposes of this research study, hard breaklines were incorporated into the TIN creation (Refer to Figure 3.13).

Figure 3.13 – TIN output based on the 5m contour data set
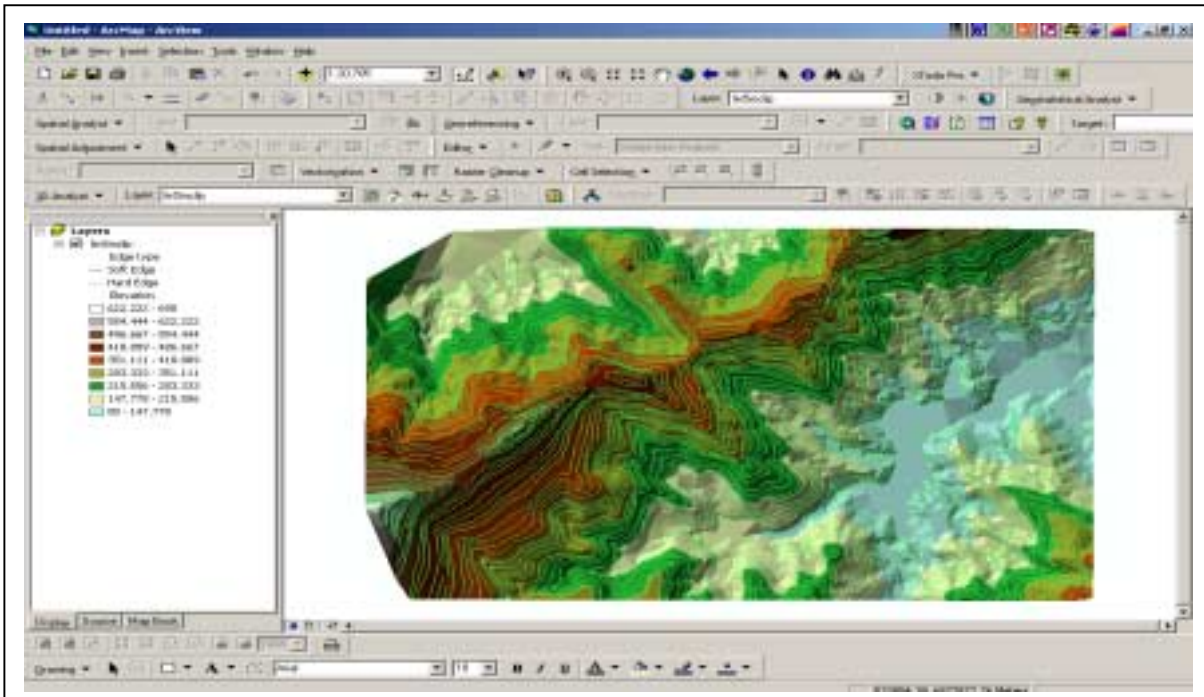
The next phase involved creation of the Digital Elevation Model (DEM) from the TIN file. A TIN file was converted to a raster (DEM) for use in:

- Slope analysis;
- Viewshed analysis;
- 3D terrain modelling, and;
- Virtual fly-through.

The "Creating raster from a TIN" function was applied under the 3D Analysis extension. This process involved choosing the newly created TIN file for raster conversion whilst selecting the appropriate cell size, in this instance a 5 metre cells size was adopted. It can be seen in Figure 3.14 that areas representing low elevation are coloured yellow and areas represented by high elevation are coloured brown.

Figure 3.14 – DEM created from the TIN file
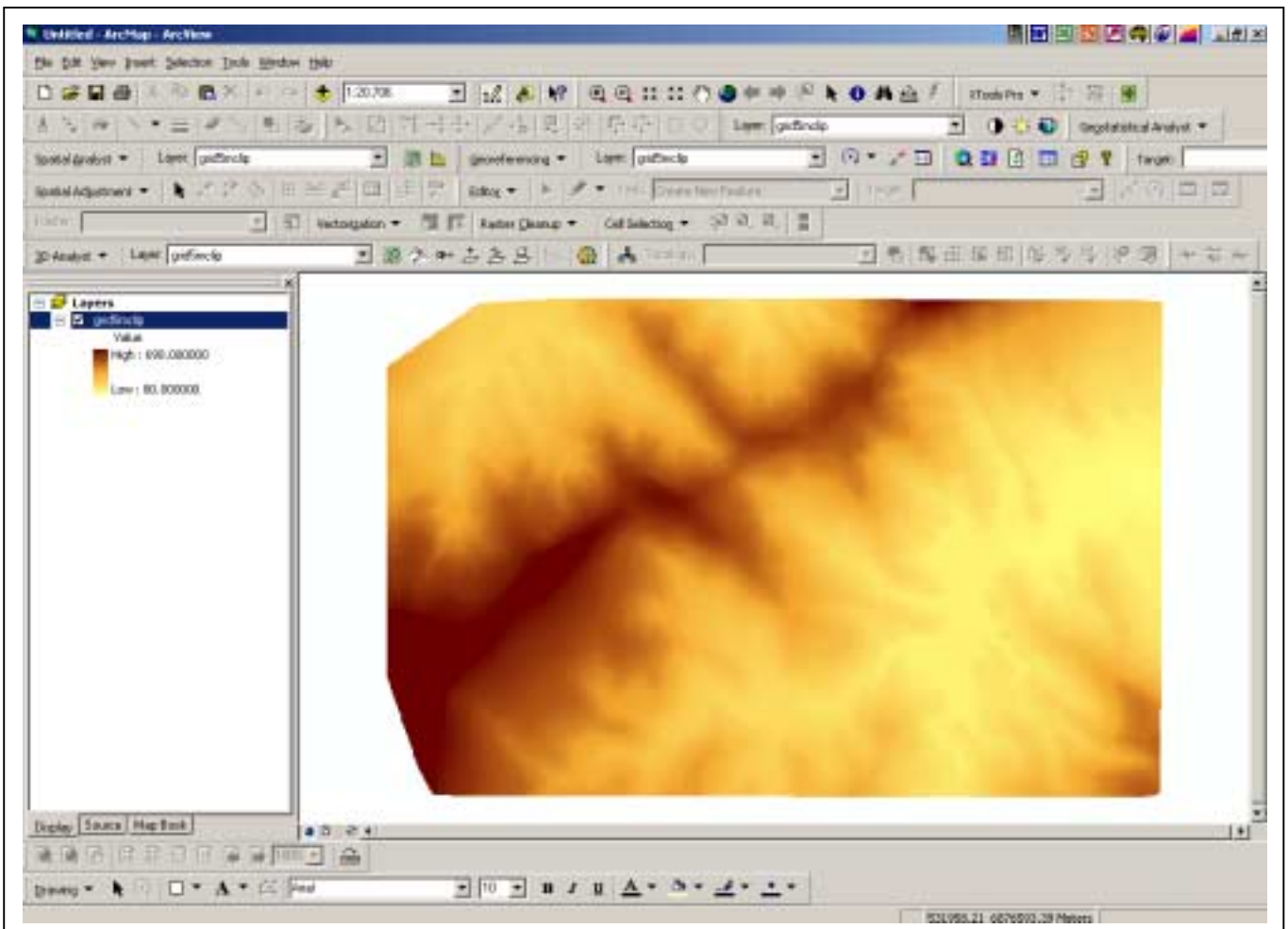
3.5.4 Pre-processing of the Tourist Walking Track, Roads and Dwelling Layers

As previously mentioned, the walking track layer was derived from using ArcPad GPS unit. The walking track was recording as a continuous line through GPS readings. The layer was then transferred from the GPS unit, in shape file format to ArcGIS.

In preparation for a viewshed analysis, the walking track polyline layer was divided into points using ArcGIS's "Dividing lines with points" function. The divide command enables points to be created from a polyline a number ways, for example:

- Specify the number of points along the line segment, and;
- Choose a specified interval along the polyline.

The walking track layer was divided into points using the second method at 100m intervals. In addition, the roads polyline layer was also divided into points using 100m intervals in preparation for a viewshed analysis.

The dwellings point layer originated from the digital aerial photography. The point layer was created by digitising and creating points for existing dwellings visualised by eye within the study area (Refer to Figure 3.15). This process was also in preparation for a viewshed analysis.

Figure 3.15 – Tourist Walking Track, Major Roads and Dwelling Layers
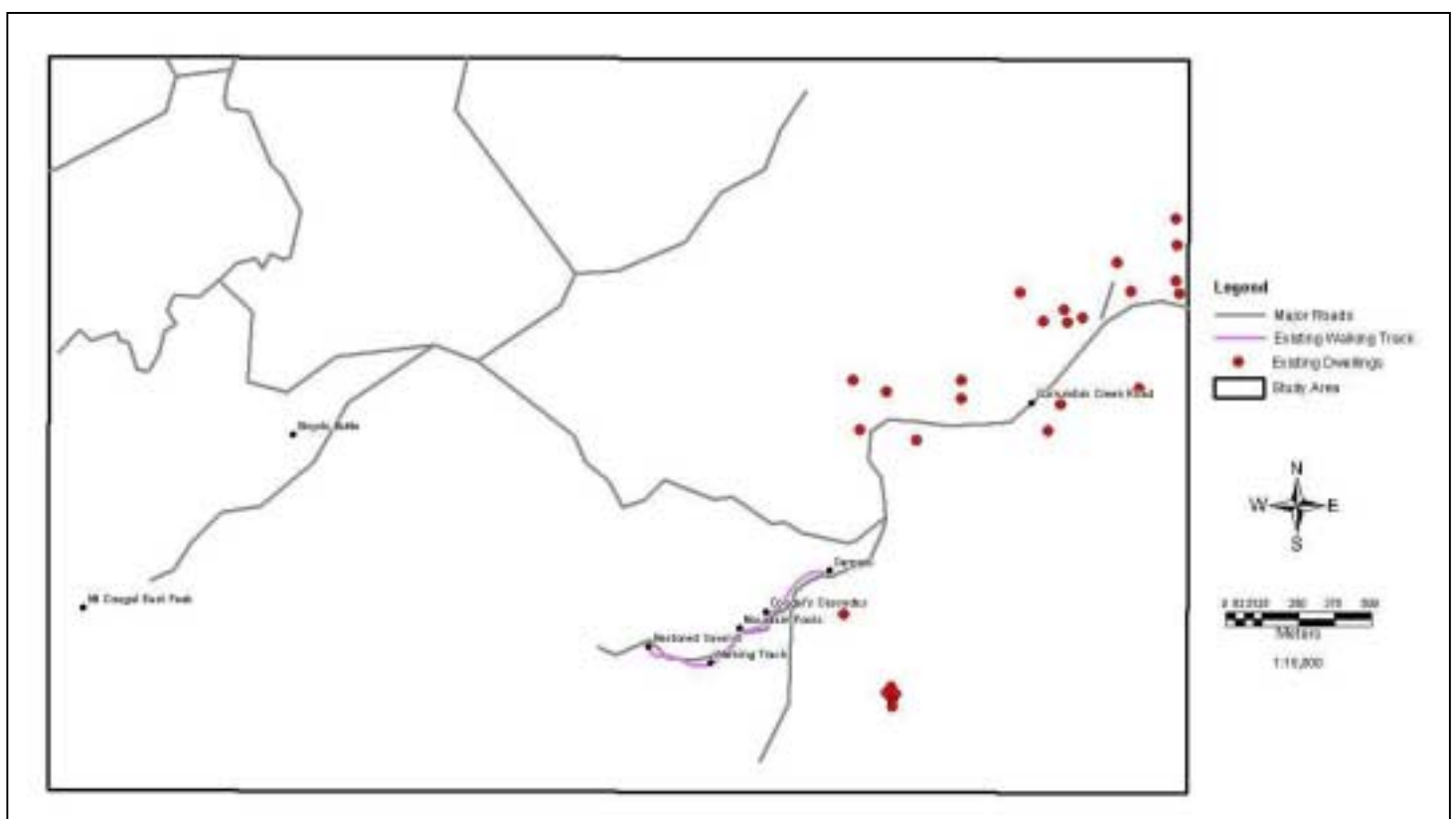
3.5.5 Pre-processing of the Soils Layer

One of the major tourist interests today is bushwalking. Due to human impact, bushwalking degrades the top layer of the earth's soil which can trigger erosion. Poor conservation practices within a tourist area may also cause soil erosion that can eventually lead to vegetation loss. The soils layer used for this study and the relevant attribute data ie. soil type, forms an essential part to assessing the terrain and erosion risks (Refer to Figure 3.16).

Figure 3.16 – Soil Layer of study area
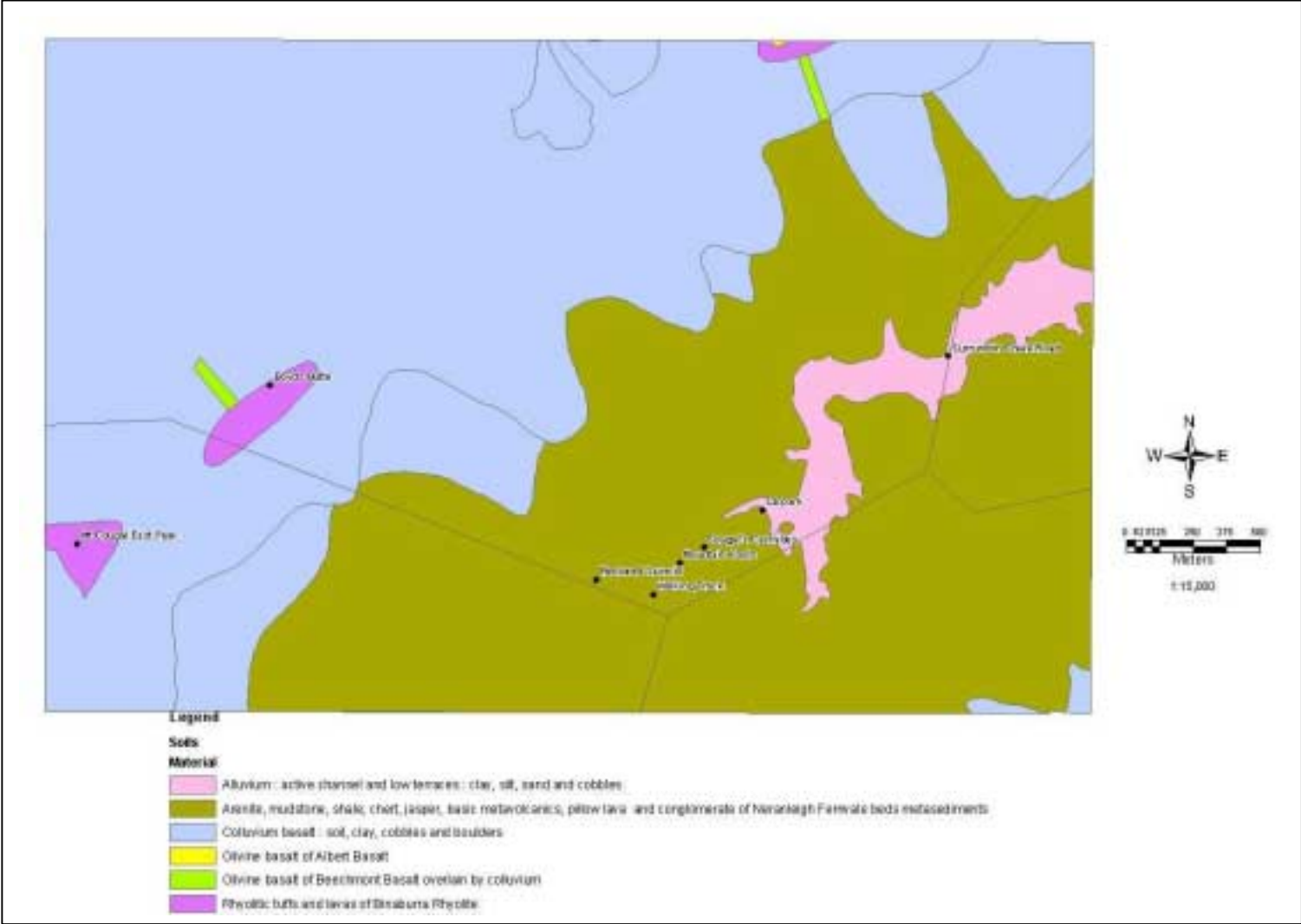
In preparation for a terrain assessment, the soils data set and each soil type was categorised into an erosion risk and rated appropriately. These specified erosion risks were determined using the Digital Atlas of Australian Soils and with the expert knowledge of a Geologist. Table 3.5 depicts the different soil types within the study area and the appropriate erosion risk and ratings that were applied.

Table 3.5 – Soil erosion risk and ratings

Soil Type	Description	Erosion Risk	Rating
Alluvium	Clay, silt, sand and cobbles.	High	4
Arenite	Mudstone, shale, chert, jasper.	Low to Medium	2
Colluvium Basalt	Soil, clay, cobbles and boulders.	Medium to High	3
Olivine Basalt	Of Albert Basalt.	Low	1
Olivine	Basalt of Beechmont Basalt overlain by colluvium.	Medium	3
Rhyolitic	Tuffs and labas of Binaburra Rhyolite	Low to Medium	2

The rating of the soils data employed the approach to reflect the sensitivity of each soil type. It can be seen in Figure 3.17 that a rating 4 is represented by red colour and are equal to the highest erosion risk and that a rating 1 represented by yellow is equal to the lowest erosion risk. The next process involved converting the soils vector layer to a grid file using Spatial Analyst "Convert features to grid". The vector file was converted using a 5-metre cell size, whilst including the new "Rating" field as the primary data classification. The new soil grid file will be used for further analysis with procedures and results detailed later in this report.

Figure 3.17 – Soils Grid File
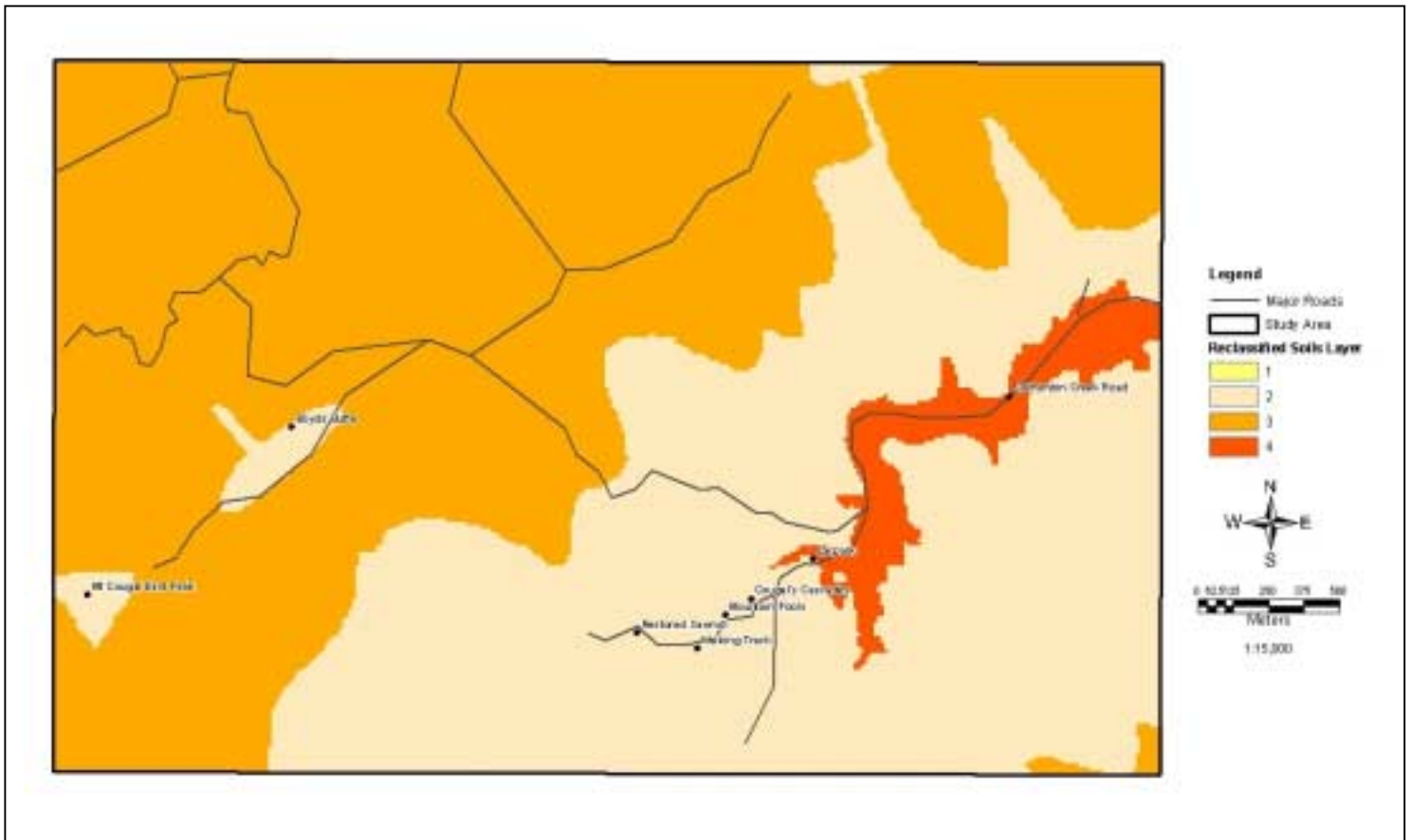
3.5.6 Pre-processing of the Slope Layer

Like soils, slope is also an important factor when completing a terrain assessment. A slope layer is derived from a DEM and enables the visualisation of the steepness of terrain based on a grid cell in three-dimensional space.

The slope layer was created using the "Surface Analysis - Slope" function of Spatial Analyst. The output grid was based on measurement units as percentages.

Figure 3.18 displays the slope analysis for the study area with blue colours representing low sloped areas and red colours representing high sloped areas. It should be noted that there are significantly high sloped percentages ie. > 200% within the study area. This is due to high mountainous terrain.

Figure 3.18 – Slope Analysis
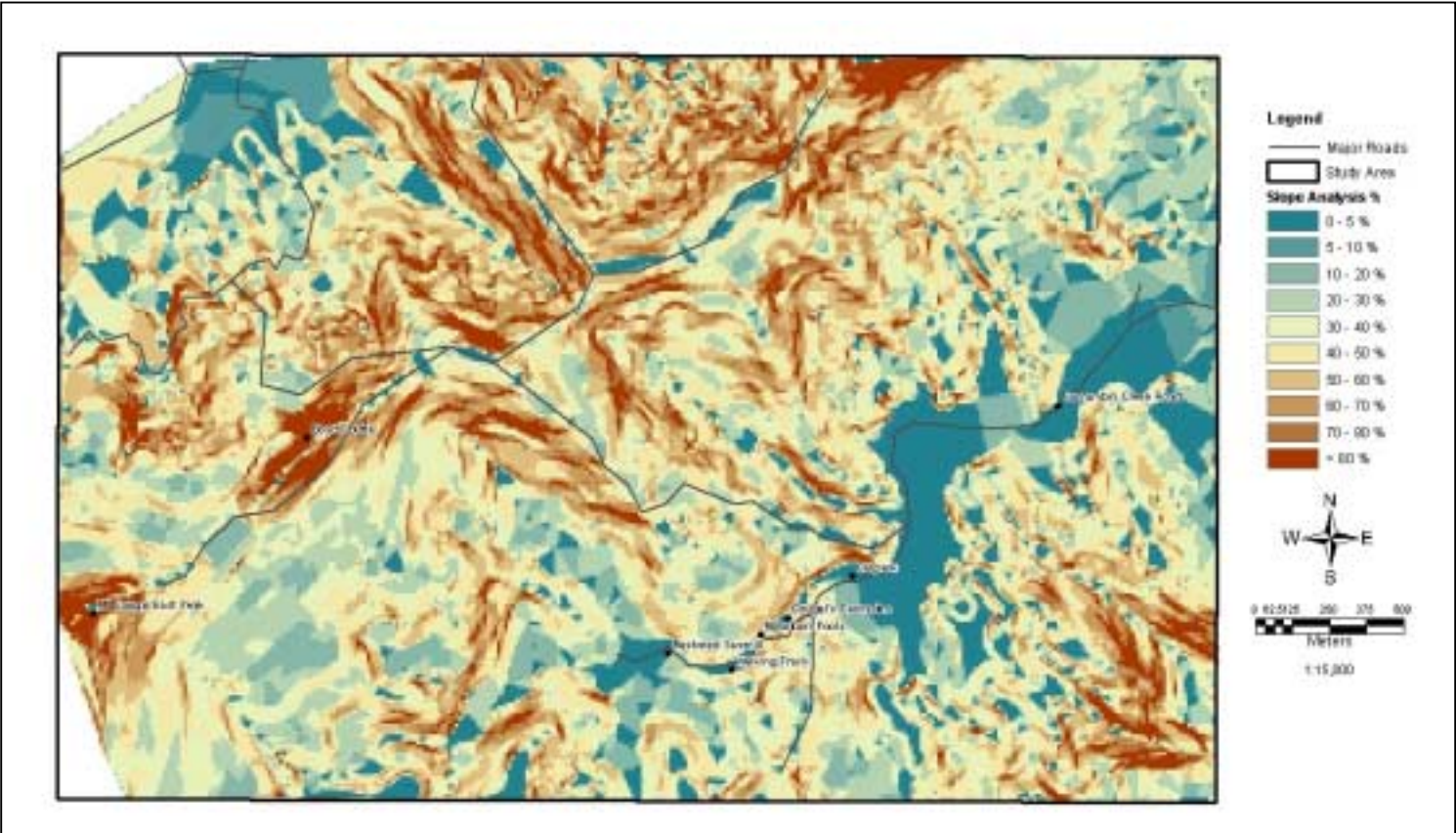
3.5.7 Pre-processing of Regional Ecosystem Layer

The Regional Ecosystems (RE) layer is used as primary information for the planning biodiversity conservation. The significance of RE data for this study is essential to conduct analysis and assessment for conservation (as detailed later in this section). RE data can determine whether of not an area contained endangered ecosystems (Refer to Figure 3.19).

Figure 3.19 – Regional Ecosystems within the Study Area
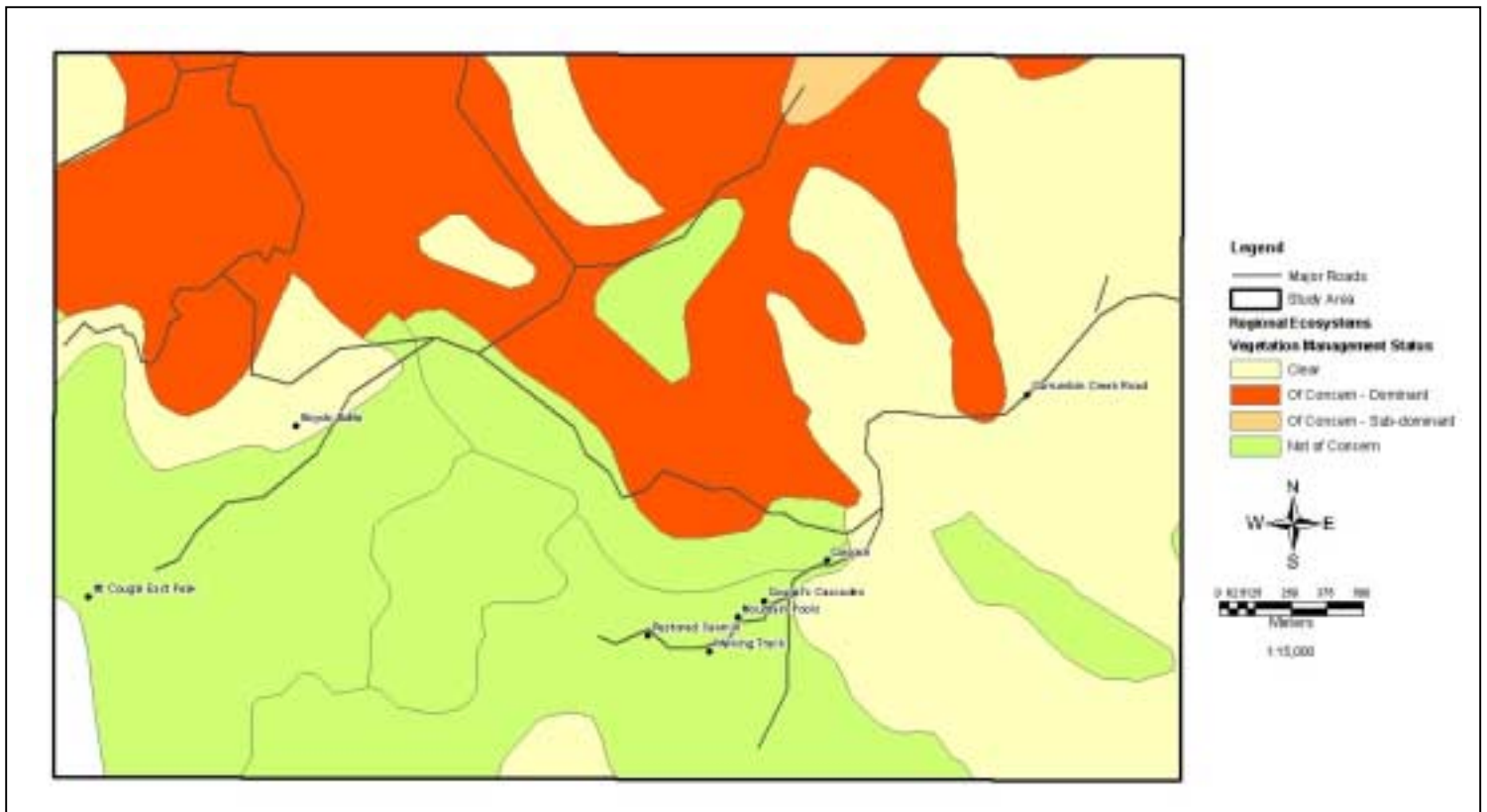
In preparation for the conservation assessment, the RE layer was thematically mapped based on the "Vegetation Management Status" field. The "status" enables the application of appropriate ratings. Table 3.6 depicts the different status types within the study area and the appropriate conservation ratings that were applied.

Table 3.6 – RE; Vegetation Management Status and Ratings

Vegetation Management Status	Applied Rating
Clear	3
Not of Concern	4
Of Concern – Sub-dominant	23
Of Concern - Dominant	25

The rating of the RE layer employed the approach to reflect the sensitivity of the final "Landscape" grid calculations. This will be detailed in the "Analysis" section of this report. The next process involved convertin the RE vector layer to a grid file using Spatial Analyst "Convert Features to Grid". The vector file was converted using a 5-metre cell size, whilst including the new "Rating" field as the primary data classification. It can be interpreted through Figure 3.20 that areas of low sensitivity are represented by a light yellow colour and areas of high sensitivity are represented by red colour. The new RE grid file will be used for further analysis with procedures and results detailed later in this report.

Figure 3.20 – RE and New Applied Ratings
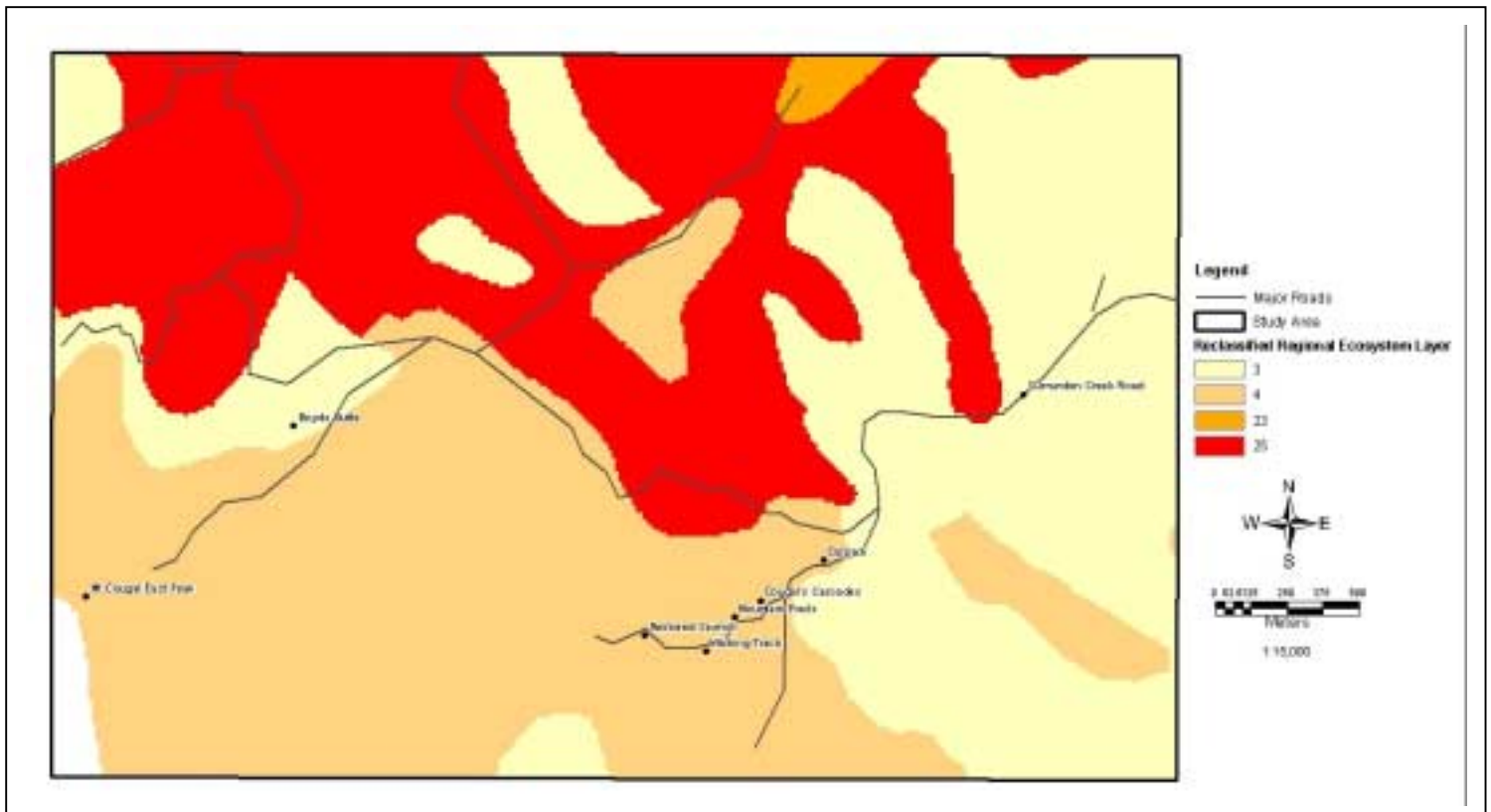
3.5.8 Pre-processing of 3D Model

Conservation of tourist areas can benefit by visualising realistic landscapes in a 3D environment. ArcGIS's "3D Analyst" or "ArcScene" enables viewing of multiple layers of 3D data. 3D Analyst can perform a vast range of tasks, for example (ESRI, 2004):

- Visualise data in three dimension;
- Find out what is visible from an observation point;
- Determine height at any location on a surface;

- View in pan and zoom mode as well as interactively tilt and rotate data, featuring fly-through simulation, and;
- Create 3D scenes into video files and two-dimensional (2D) image files.

This project will employ ArcScene's functionalities to visualise and create surface models and 3D fly-through from the primary data sets in this project.

The initial stage of this project involved creating a new 3D scene based on the following data sets (Refer to Figure 3.21):

- The new DEM was imported into ArcScene and used as a base height reference for all subsequent data sets;
- The digital aerial photography received from GCCC was imported and used as the base data for all 3D work;
- The major roads and walking track vector files were imported to aid with visualisation, and;
- Eventually the final analysis grids are added for visualising realistic conservation areas (to be discussed later in this report).

Importing vector files to a 3D scene requires the use of the "Offset" function. The Offset function is applied when the only height attribute for a theme is relative to a surface that is used to provide the base height ie. the DEM (ESRI, 2004). In this instance both the roads and track layer were offset by 2m relative to the DEM.

Figure 3.21 – Initial 3D Model
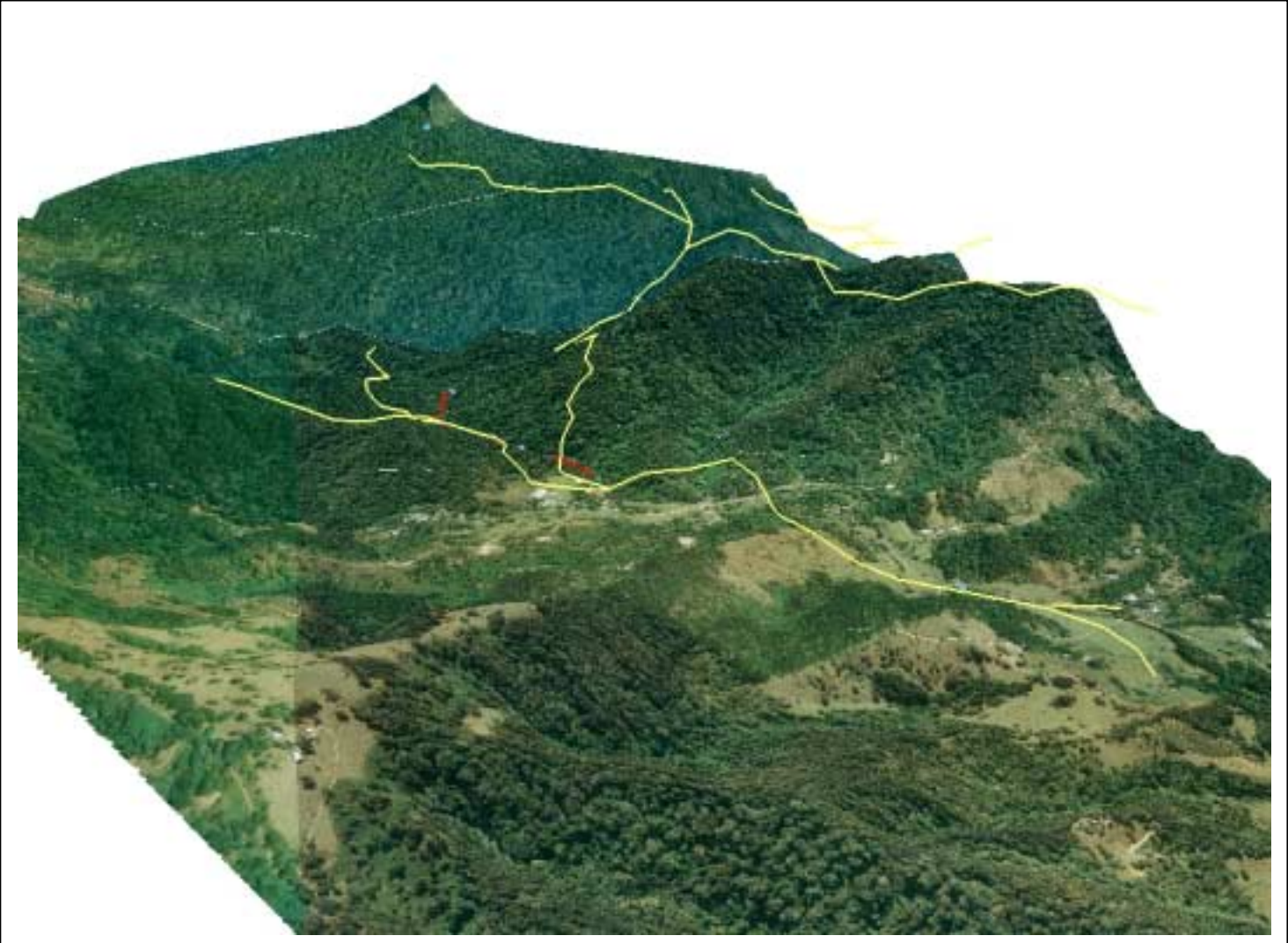
3.6 Grid Analysis

The general purpose of this section is to further apply, analyse and model the environmental and social grid based data sets mentioned in the previous section. This process involves creating viewshed analysis, reclassifying grids to relevant ratings and eventually using grid mathematical methods to calculate sensitivity and assessment grids.

The ratings applied to all primary data sets reflect the sensitivity or perceived importance of the resource or visual impact. In most instances, the ratings where applied to the primary grid files. This process was achieved by utilising Spatial Analyst's "Reclassification" function. The reclassify function enables the user to modify an input grid file by replacing the input cell values with new output cell values (ESRI, 2004) (Refer to Figure 3.22). The "Reclassification" function was adopted for this project to classify input values so that output values have the same common scale, for example, both the soils and slope grids where classified from 1 to 4. This function was used in preparation for use of ArcGIS's "Raster Calculator".

Figure 3.22 – Spatial Analyst Reclassification Utility
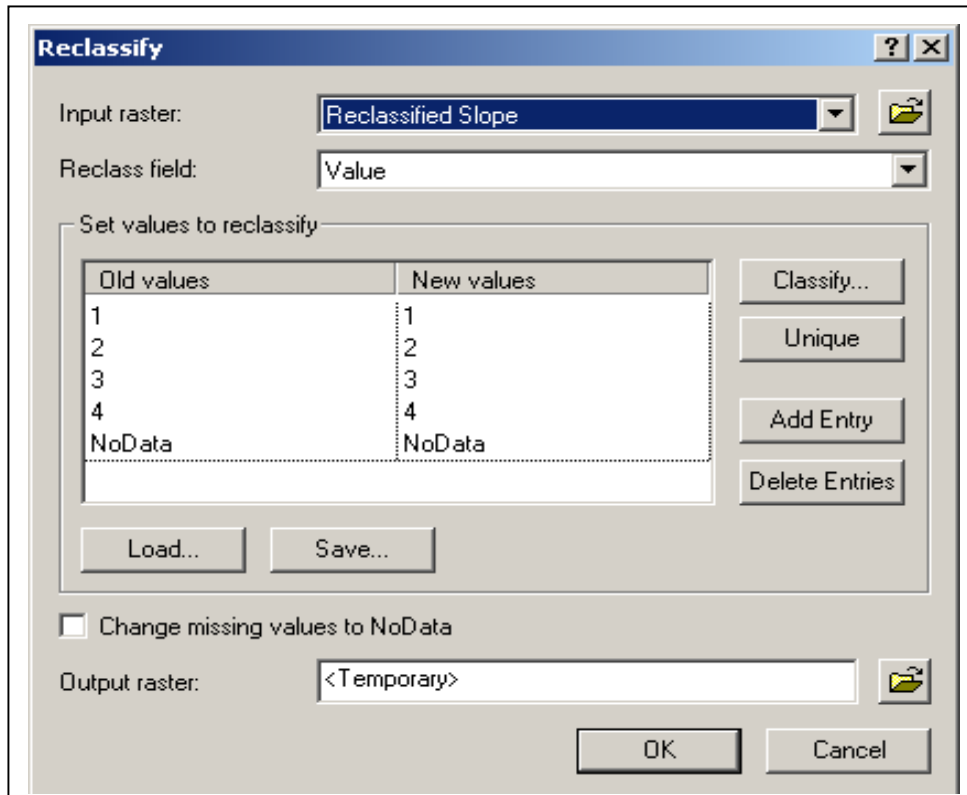
In the real world, rating data sets could be influenced by common sense or scientific knowledge. This project has employed both these methods to reclassify the primary grids based on the following three analysis categories listed in Table 3.7. Methodologies for each grid and analysis type will be detailed in this section.

Table 3.7 – Grid Analysis Categories

Analysis Type	Issue Type	Grids or Vector data used
Landscape Sensitivity	Social	Major Roads; Walking Track, and; Dwellings
Terrain Assessment	Environmental	Slope analysis, and; Soils.
Conservation Assessment	Social and Environmental	Landscape sensitivity analysis, and; Regional Ecosystems

3.6.1 Landscape Sensitivity

The purpose of the Landscape Sensitivity analysis is to identify the landscape units that are most valuable to people visiting the Currumbin Valley area. This can be achieved by deriving seen area analysis, namely Viewshed Analysis within a GIS environment.

The purpose of a Viewshed Analysis is to determine how visible a scene or objects are from a certain observer point, for example, to find out what the view will be like of surrounding topography from a road, house or walking track. The Viewshed methodology involves the input surface of a DEM and identifies the cells within the DEM that can be seen from one or more observation points (ESRI, 2004). Each cell within the DEM is assigned a value that specifies how many observer points can be seen from each location.

A Viewshed Analysis was created for primary data sets of major roads, walking tracks and existing dwellings within the study area. Figures 3.23, 3.24 and 3.25 depict a scenic value of orange colour representing "Visible" areas and yellow colour representing "Not Visible" areas.

Figure 3.23 – Viewshed Analysis from Major Roads within the Study Area
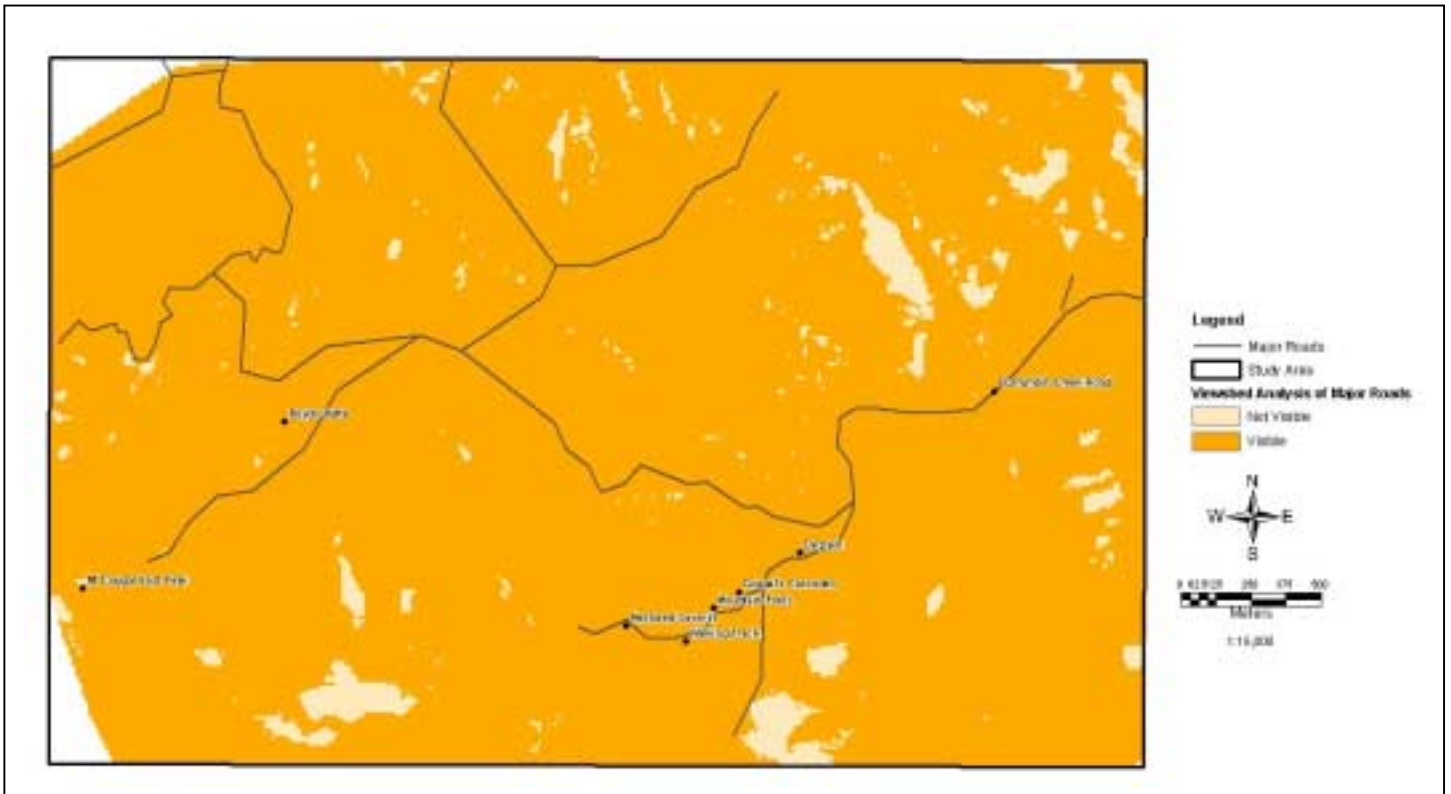
Figure 3.24 – Viewshed Analysis from Tourist Walking Track within the Study Area
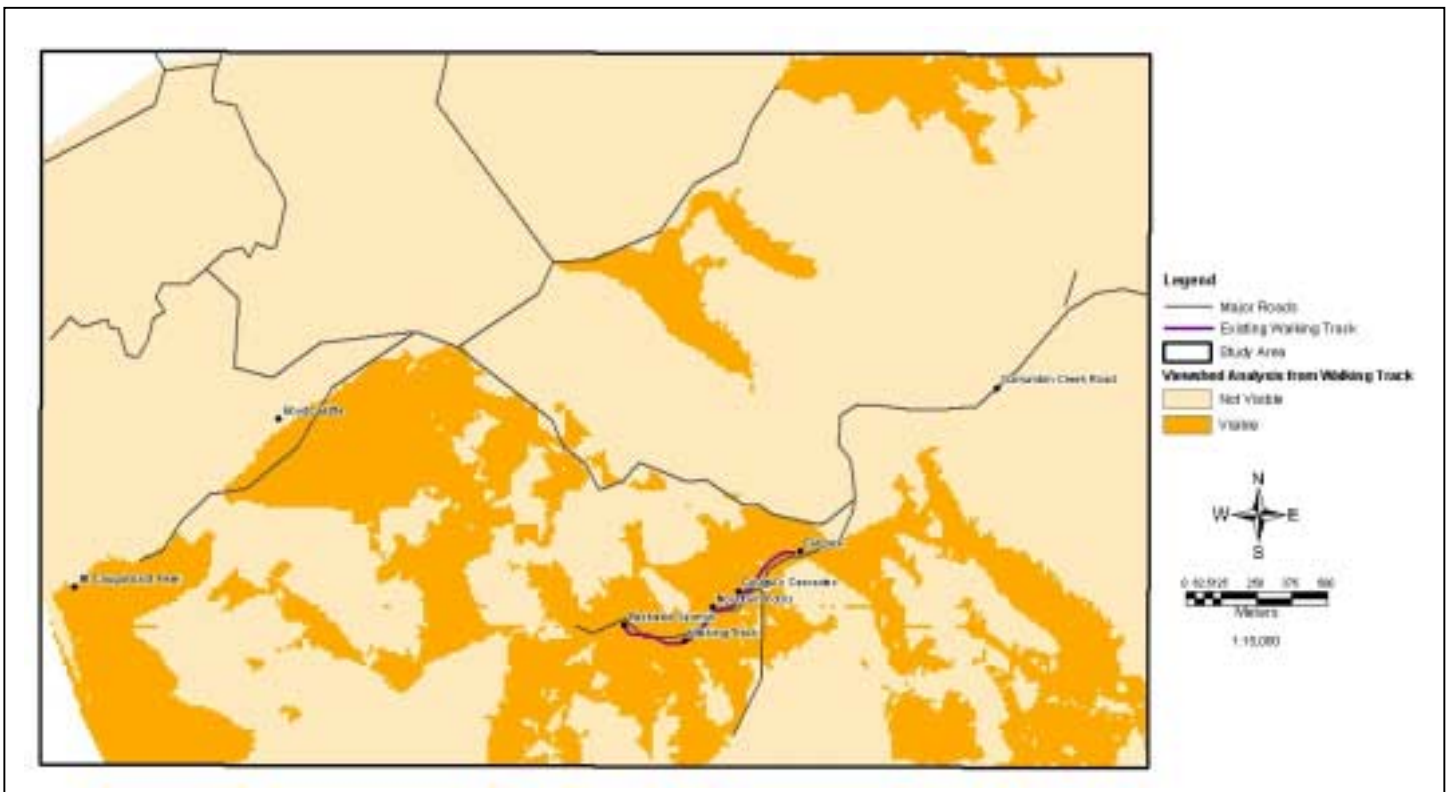
Figure 3.25 – Viewshed Analysis from existing Dwellings within the Study Area
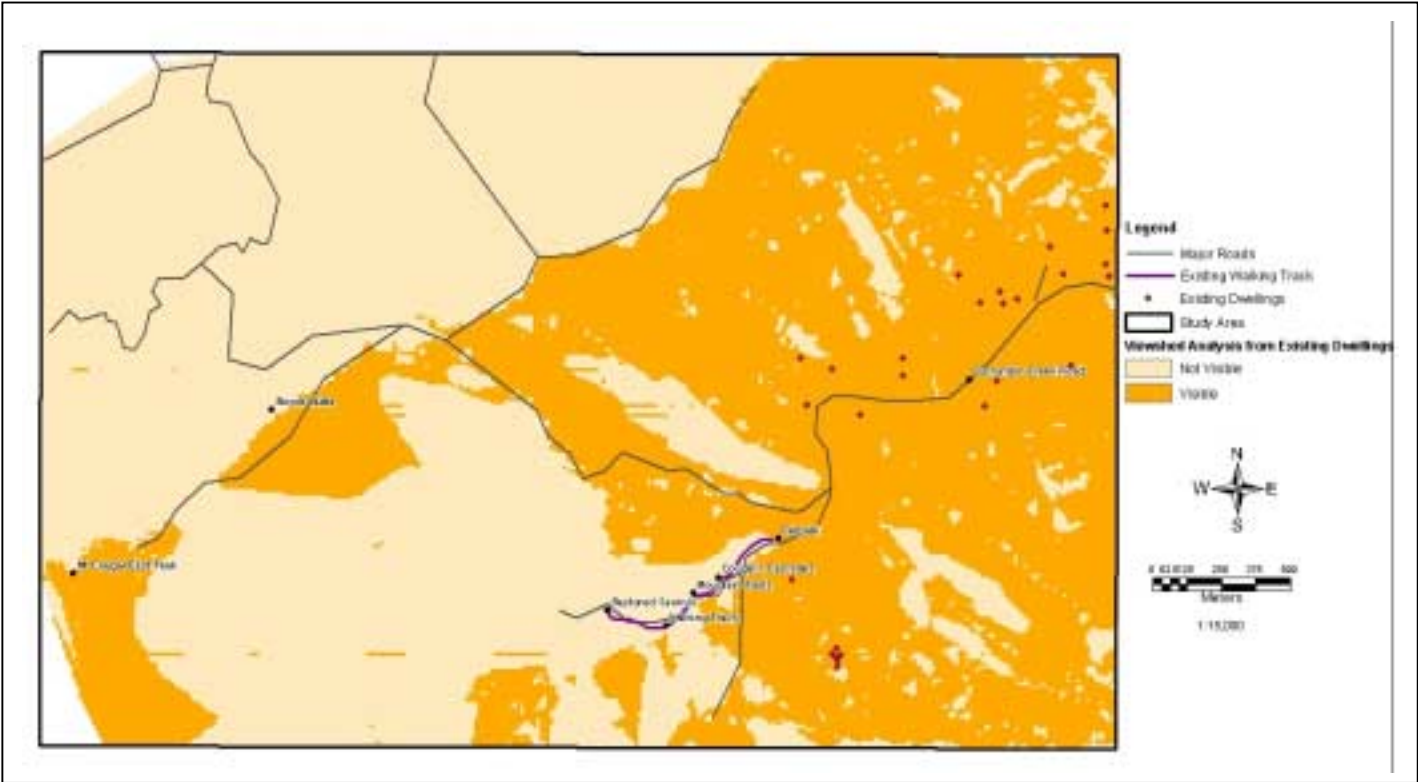
In preparation for the Landscape Sensitivity model, all Viewshed scenarios must be reclassified using the previous mentioned methods of the "Reclassify" function with Spatial Analyst. All three scenarios were reclassified from 1 to 10, with 1 being the least visible and 10 being the most visible from each different data set. Figure 3.26 displays the processes involved and reclassification of old values to new values

Figure 3.26 – Landscape Sensitivity processes – Including reclassification of viewshed analysis values to new values

Primary Data Sources	Secondary Data (derived)	Viewshed Analysis (grid)	Rating/ Reclassification of Viewshed
All Major Roads	Roads within Study Area only	Locate areas visible & not visible from roads	Assigned ratings: 0 – 5 = 1 (least visible) > 85 = 10 (highly visible)
GPS Field Investigation	Walking Tracks & Tourist Spots	Locate areas visible & not visible from walking tracks	Assigned ratings: 0-3 = 1 (least visible) > 27 = 10 (highly visible)
Digital Aerial Photography	Dwelling Locations	Locate areas visible & not visible from existing dwellings	Assigned ratings: 0-2 = 1 (least visible) > 22.5 = 10 (highly visible)

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3.6.2 Terrain Assessment

The purpose of a Terrain Assessment is to determine areas within the study area that are prone to erosion. This is achieved through the evaluation of different soil types and a slope analysis of the terrain. A Terrain Assessment can provide suggestions for current and future tourist facilities by providing an overlay map that will display erosion prone areas, for example, this may be of benefit for the development of future bushwalking tracks so that areas with high erosion are avoided.

In preparation for the Terrain Assessment model, the slope analysis must be reclassified using the previous mentioned methods of the "Reclassify" function with Spatial Analyst. The reclassification of the slope grid is based on that of the soils scale ie. 1 to 4, to create a common scale of values for the terrain assessment. The slope grid was reclassified as detailed in Table 3.8 below. The reclassification can be justified by the representation of Figure 3.27 that displays yellow areas equal to rating 1 and low slope and orange areas equal to rating 4, high slope.

Table 3.8 – Slope reclassification

Slope Percentage	Reclassified Rating
0 – 5% Low Slope	1
5 – 10% Low to Moderate Slope	2
10 – 20% Moderate to High Slope	3
>20% High Slope	4

Figure 3.27 – Reclassified Slope Analysis
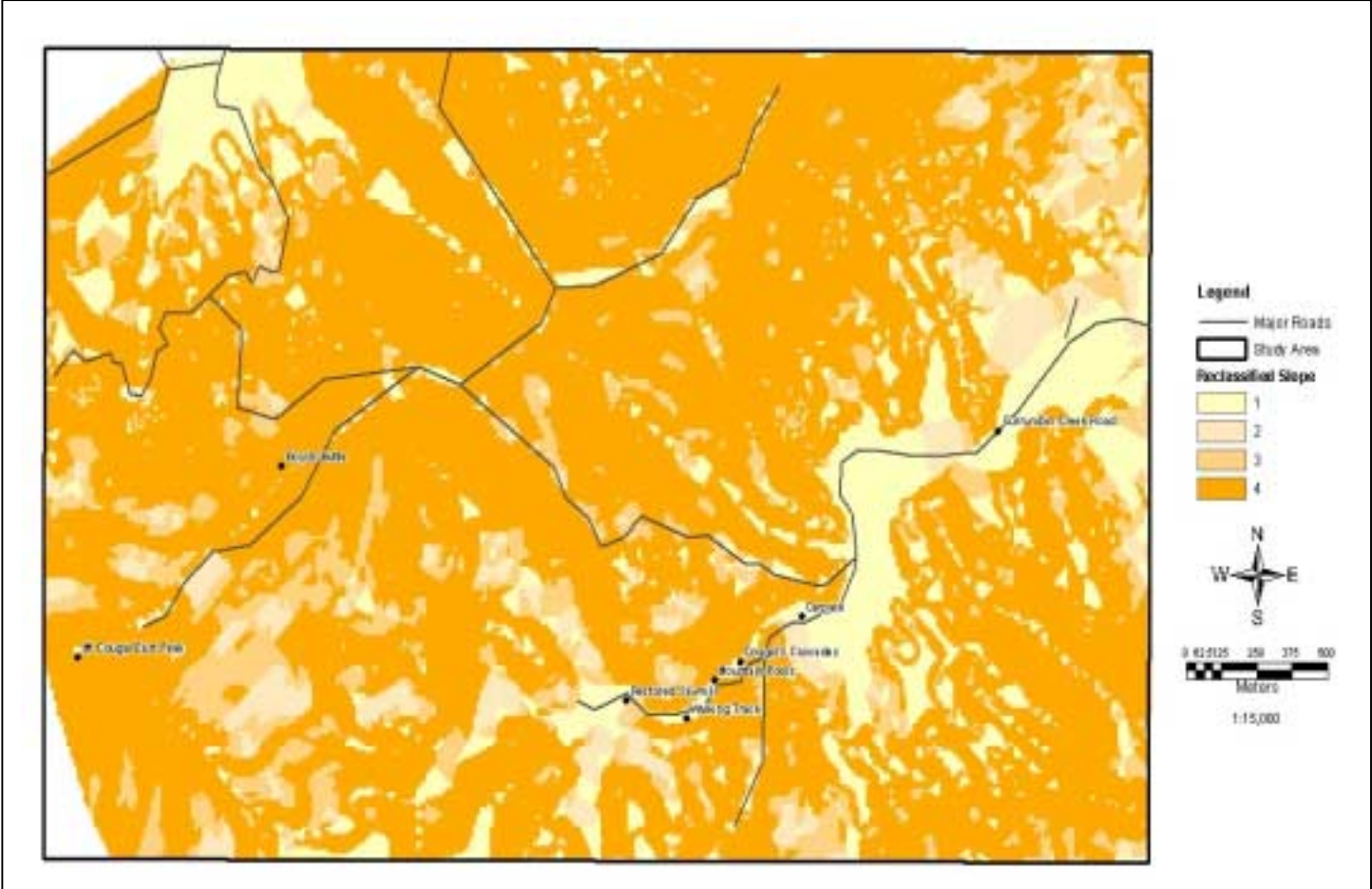
In the soil scenario, the soil data set has already been classified into erosion risks and rated appropriately. The rating of the soils data employed the approach to reflect the sensitivity of each soil type ie. 4 = Highest erosion risk and 1 = Lowest erosion risk. In addition, Figure 3.28 displays the processes involved and reclassification of old values to new values for the Terrain Assessment.

Figure 3.28 – Terrain Assessment processes – Including reclassification

Primary Data Sources	Secondary Data (derived)	Rating/ Reclassification
Topography	Slope/grade	0-5% = 1 5-10% = 2 10-20% = 3 >20% = 4
Soils	Erosion Risk	Low = 1 Low – Medium = 2 Medium – High = 3 High = 4
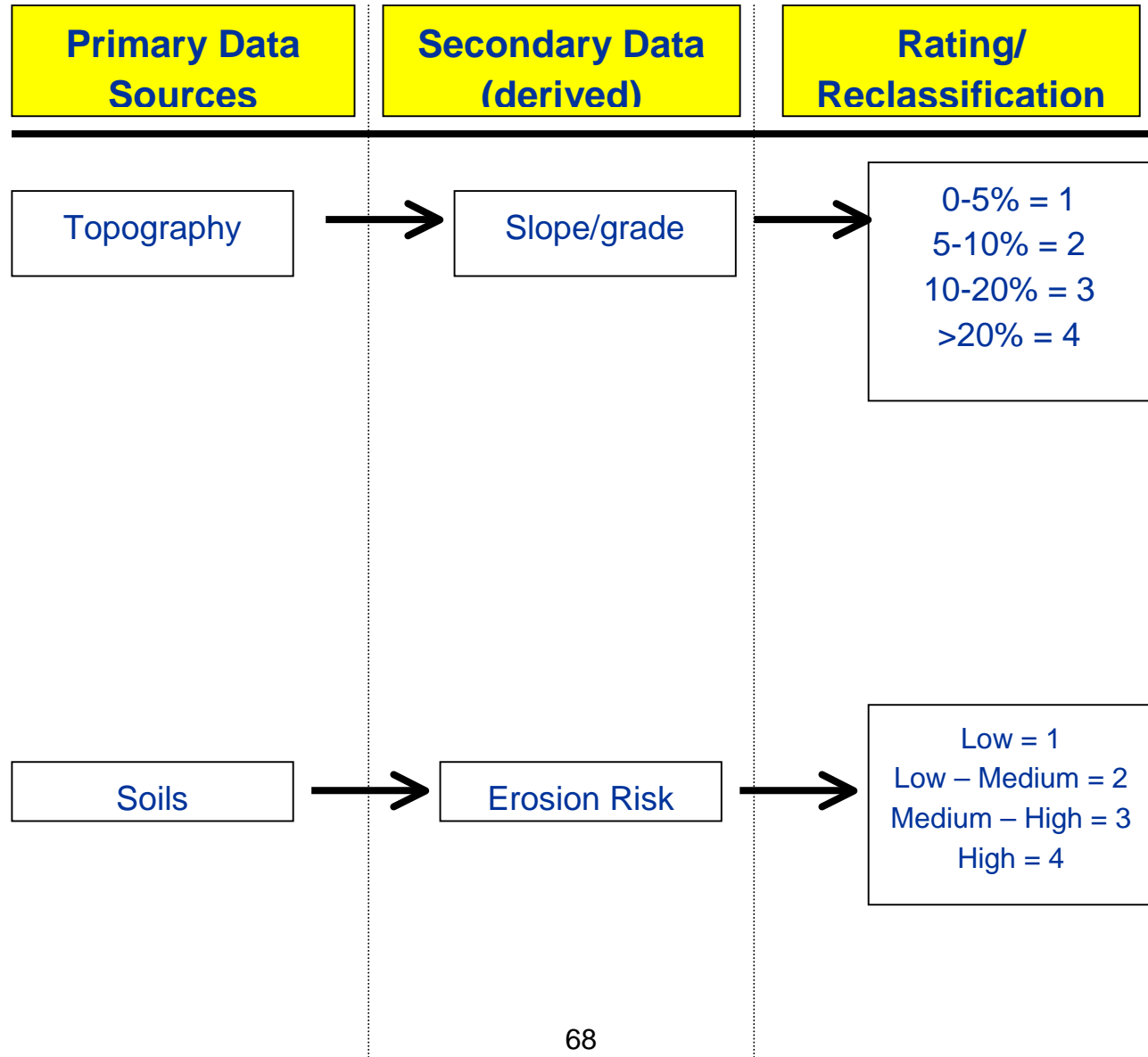
3.6.3 Conservation Assessment

The purpose of a Conservation Assessment is to identify areas that should be socially and environmentally protected to assist with future conservation of potential tourist areas through management and planning. There are many environmental constraints that can achieve this assessment type. This study will focus on the evaluation of two constraints:

- Social aspect – final Landscape Sensitivity model, and;
- Environmental aspect – regional ecosystem grid.

Including both social and environmental aspects will cover two types of tourist visitors to Currumbin Valley. Firstly visitors that enjoy the social aspect of nature based tourism ie. visual of natural surround via motor vehicle of picnic ground and secondly visitors who are interested in natural wilderness ie. flora and fauna.

As previously mentioned in the Data Pre-processing section of this report, the RE layer has been classified to reflect the final "Landscape" grid calculations. The "Landscape" and "Conservation" results will be details in the "Results" section of this report. Figure 3.29 displays the processes involved and reclassification of old values to new values for the Conservation Assessment.

Figure 3.29 – Conservation Assessment processes – Including reclassification

Primary Data Sources	Secondary Data (derived)	Rating/ Reclassification
Vegetation/ Ecosystems	Regional Ecosystems	Clear = 3 NOC = 4 OC-SD = 23 OC-D = 25
Final Landscape Sensitivity Grid		Grid Values – 3 to 26
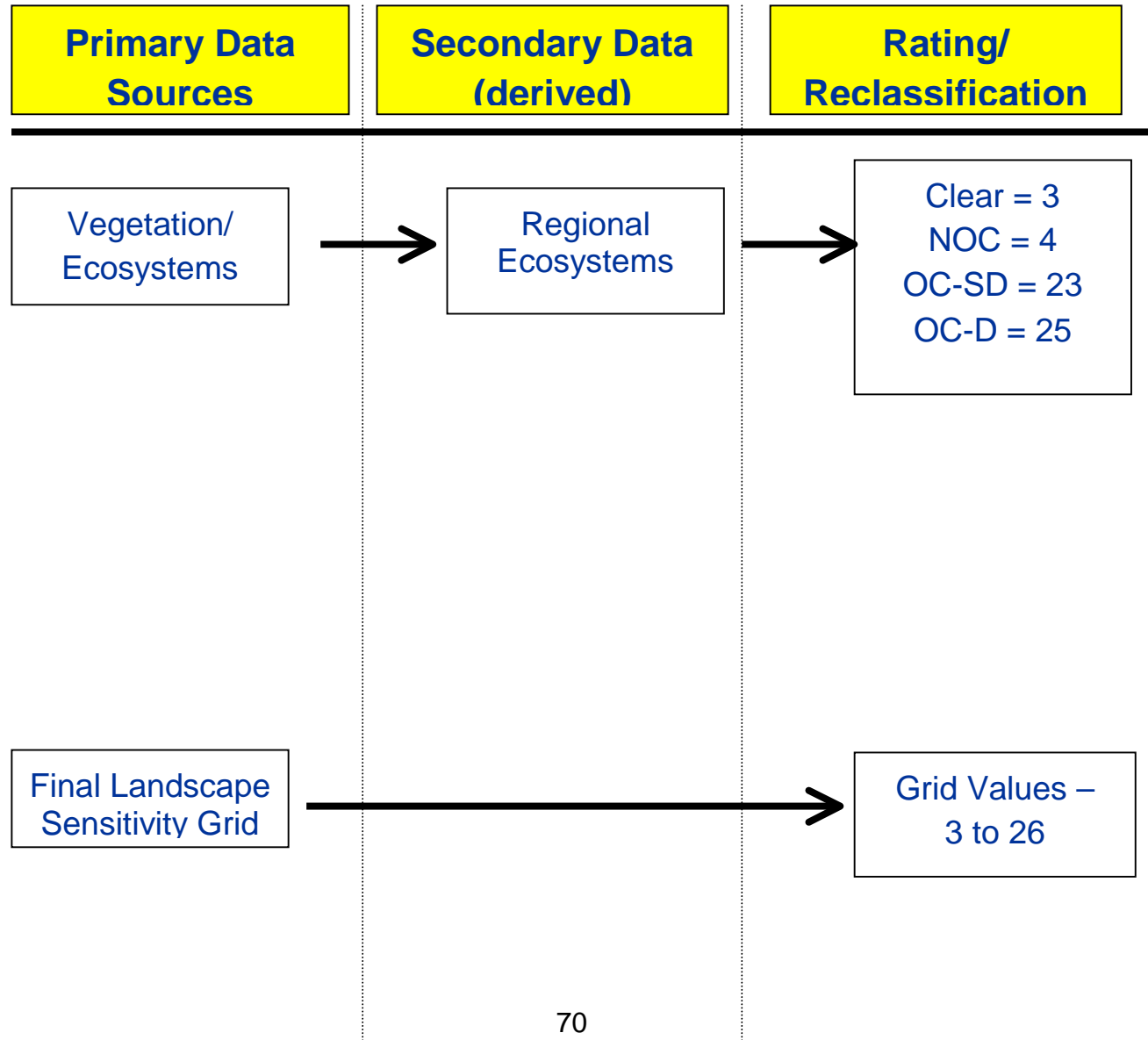
3.7 Summary

This chapter has introduced the geographical location, bio-physical and socio-economic factors for the Currumbin Valley study area. It has also provided an outline of all GIS software and hardware used for completion of the GIS analysis.

The data capture and acquisition section described techniques used to create the spatial data sets used in this study, methods included:

- External data sourcing ie. GCCC;
- Free internet spatial data sets;
- Digitising, and;
- GPS recordings

The data pre-processing section described methods used to prepare the spatial data sets for final grid analysis calculations. In addition, this section also provided explanations for why certain analysis techniques were adopted for landscape, terrain and conservation assessments.

Chapter 4
Results

4.1 Introduction

The objective of this chapter is to present the results depicted from the "Grid Analysis" as discussed in the previous chapter.   This chapter will also described the final "Raster Calculation" process that was performed to obtain the three final grids ie. Landscape Sensitivity and Terrain and Conservation Assessments.

This chapter will be divided into four sections. The first, second and third sections display and explain the final processes of the Landscape Sensitivity analysis, Terrain Assessment analysis and Conservation Assessment analysis respectively.

A full analysis and interpretation of all results will be detailed in Chapter 5.

4.2 Landscape Sensitivity

The "Raster Calculator" is utilised for this research project to combine grids using the "addition" mathematical operator (Refer to Figure 4.1). The objective of using the mathematical operator is to add the corresponding cell value for each grid to create a final output grid that will depict Landscape Sensitivity. Figure 4.2 depicts a graphical description of the arithmetic operator methodology.

ArcGIS's "Raster Calculator" is employed to combine the final three grids created from reclassified viewshed analysis ie. roads, walking tracks and existing dwellings. It can be seen from Figure 4.3 that for each grid, light colours represent low sensitive areas whilst areas containing high sensitivity are represented by darker colours.

The values calculated from the arithmetic operator methods are shown in Figure 4.4. It can be seen that the values range from a minimum of 3, which is displayed by light colour that represent landscape areas least visible by all three spatial layers ie. roads, track and dwellings. Whilst values equal to 26, displayed by dark colour, represent landscape areas most visible by all three constraints.   Further interpretation will be discussed in chapter 5.

Figure 4.1 – ArcGIS's "Raster Calculator"
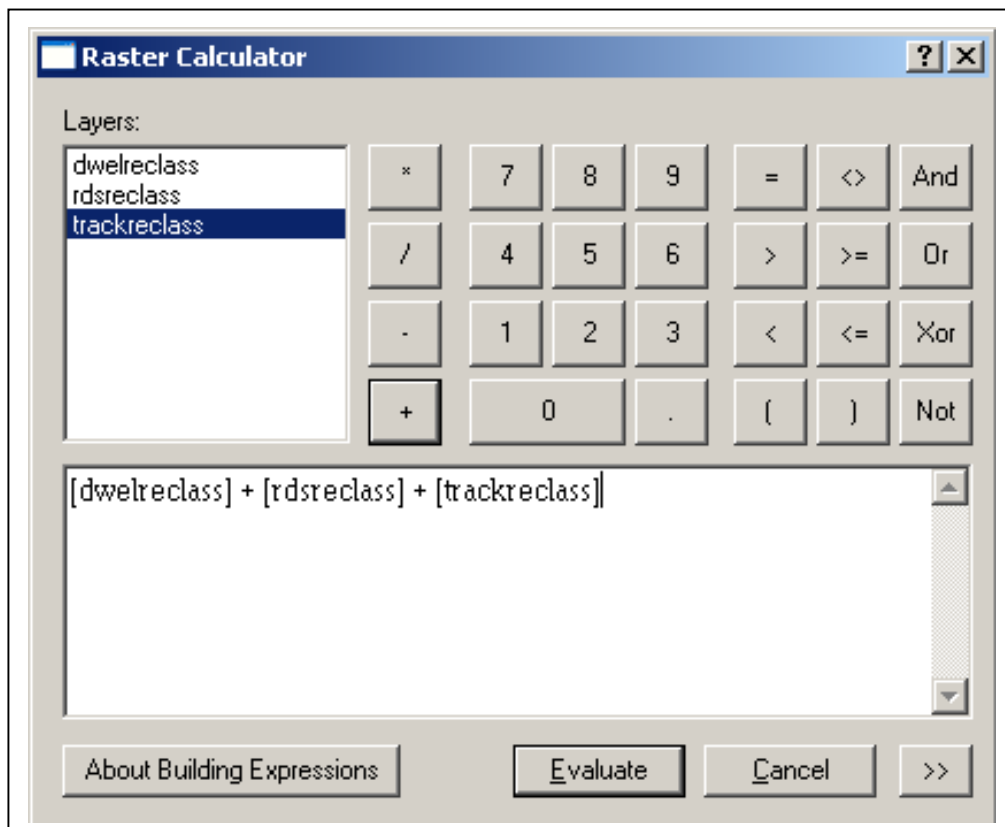
Figure 4.2 - Graphical description of the arithmetic operator methodology
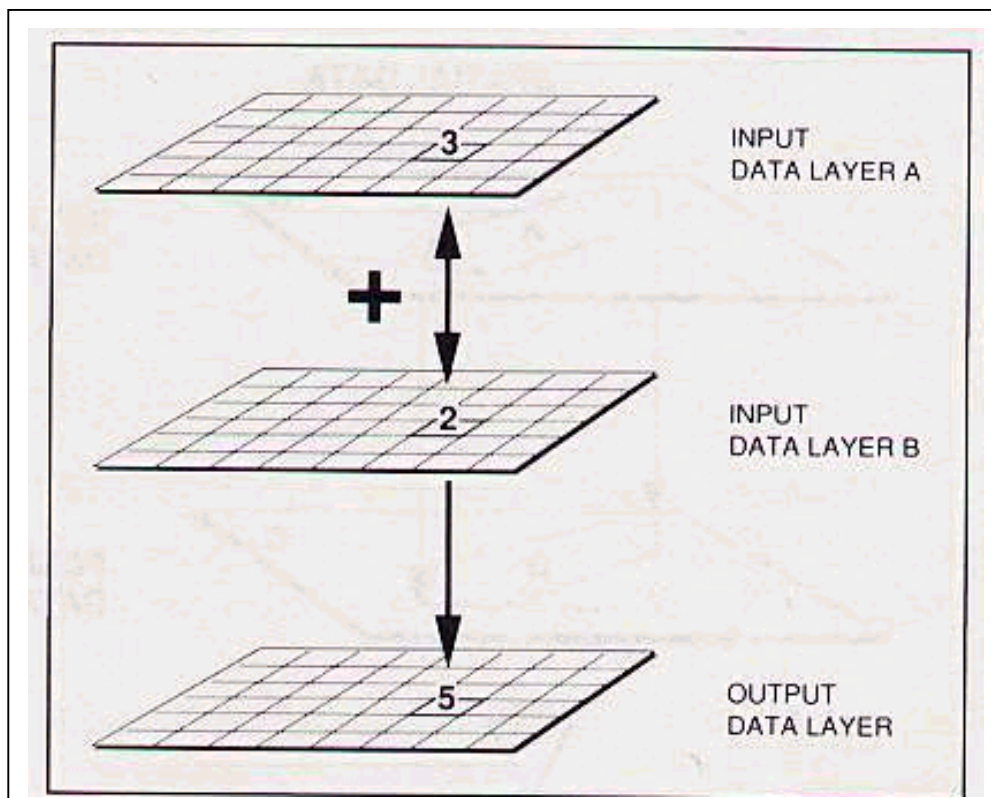
Figure 4.3 – Reclassified Viewshed Analysis Results - Landscape Sensitivity Input Grids

Roads within Study Area only

Walking Tracks & Tourist Spots

Dwelling Locations

74
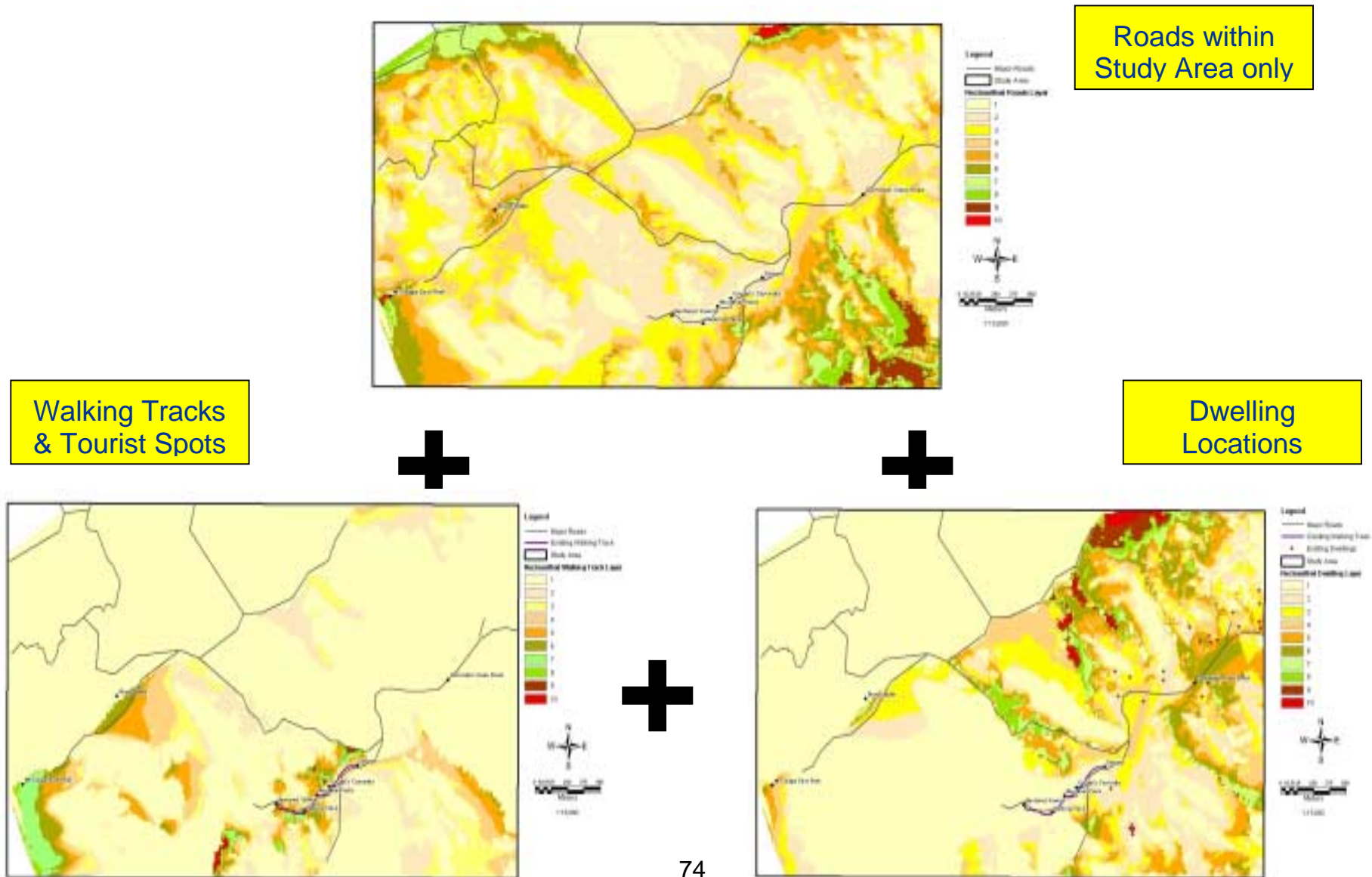
Figure 4.4 – Final Landscape Sensitivity Grid Result
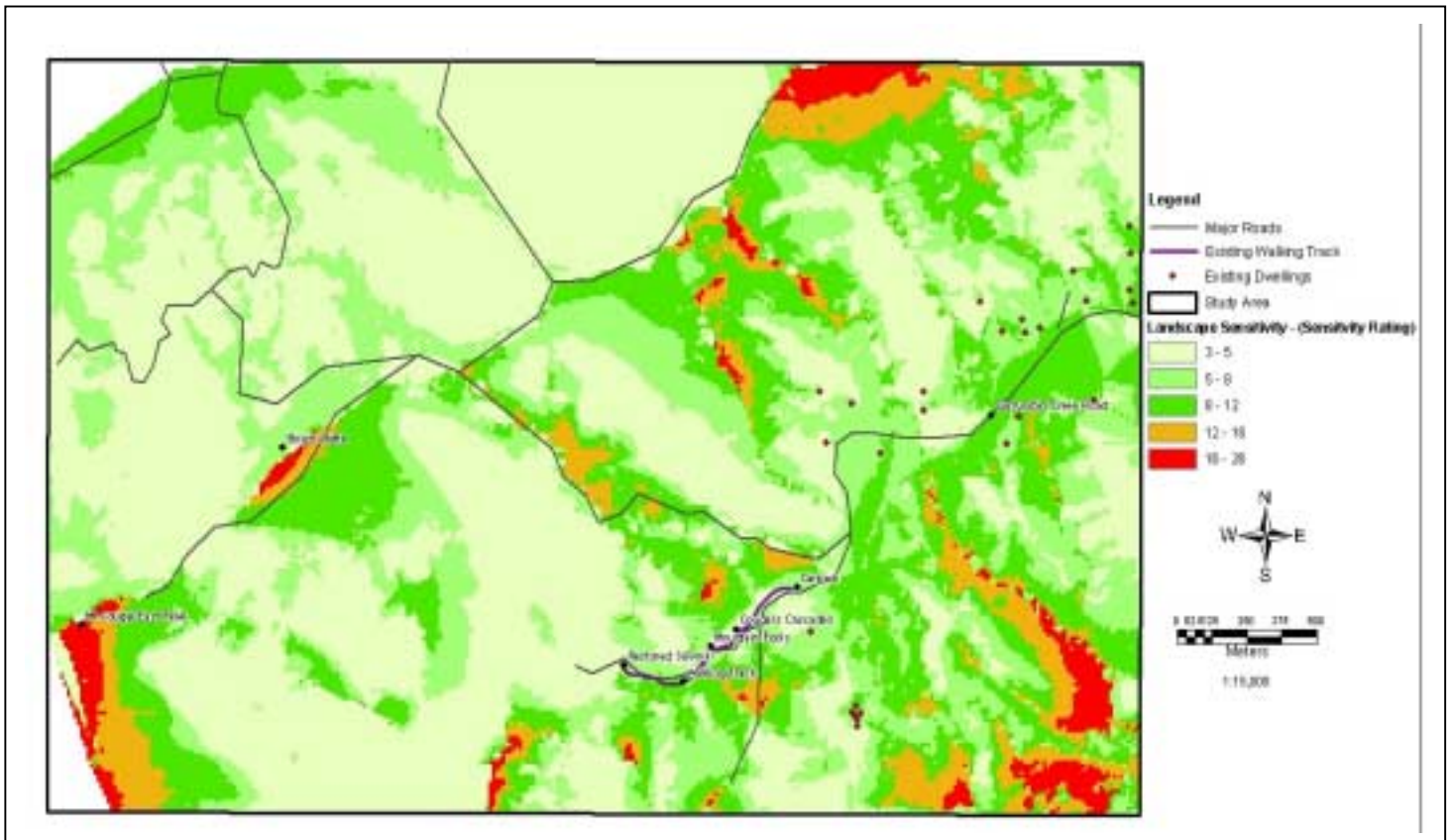
4.3 Terrain Assessment

ArcGIS's "Raster Calculator" is employed to combine the final two grids ie. slope and soils. The "Raster Calculator" is utilised for this research project to combine grids using the "addition" mathematical operator.

It can be seen from the final reclassified slope input grid in Figure 4.5 that light colours represent low sloped areas and dark colours represent high sloped areas. In addition, Figure 4.5 displays the final soils input grid that can be interpreted through light colours representing low erosion prone soil types and dark colours representing high erosion prone soil types.

The "Raster Calculator" is now used to add corresponding cell values for each grid. The values calculated from the arithmetic operator methods are shown in Figure 4.6. It can be seen that values range from 2 to 8. Light coloured values represent landscape areas that are least likely to be erosion prone, whilst dark coloured values represent landscape areas

that are prone to erosion. Further interpretation of the final Terrain Assessment will be discussed in Chapter 5.

Figure 4.5 – Reclassified Soils and Slope Analysis Results - Terrain Assessment Input Grids
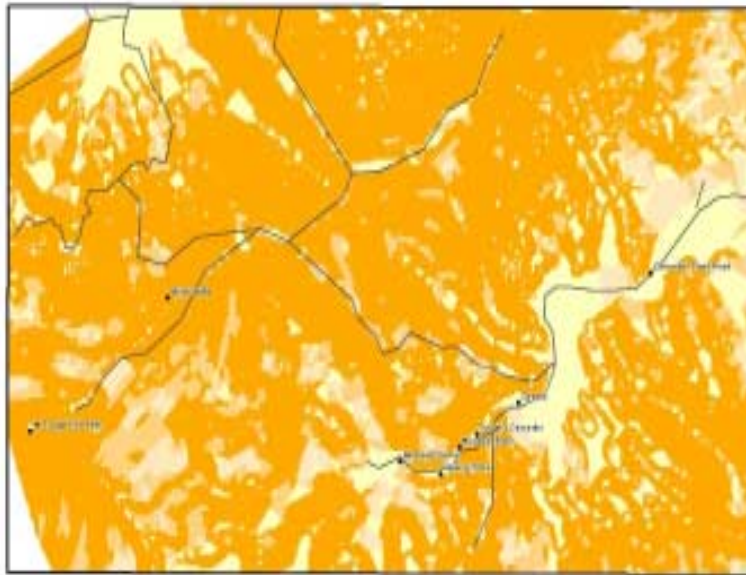
Slope Analysis - Input Grid

+

Soils - Input Grid

Figure 4.6 – Final Terrain Assessment Grid Result
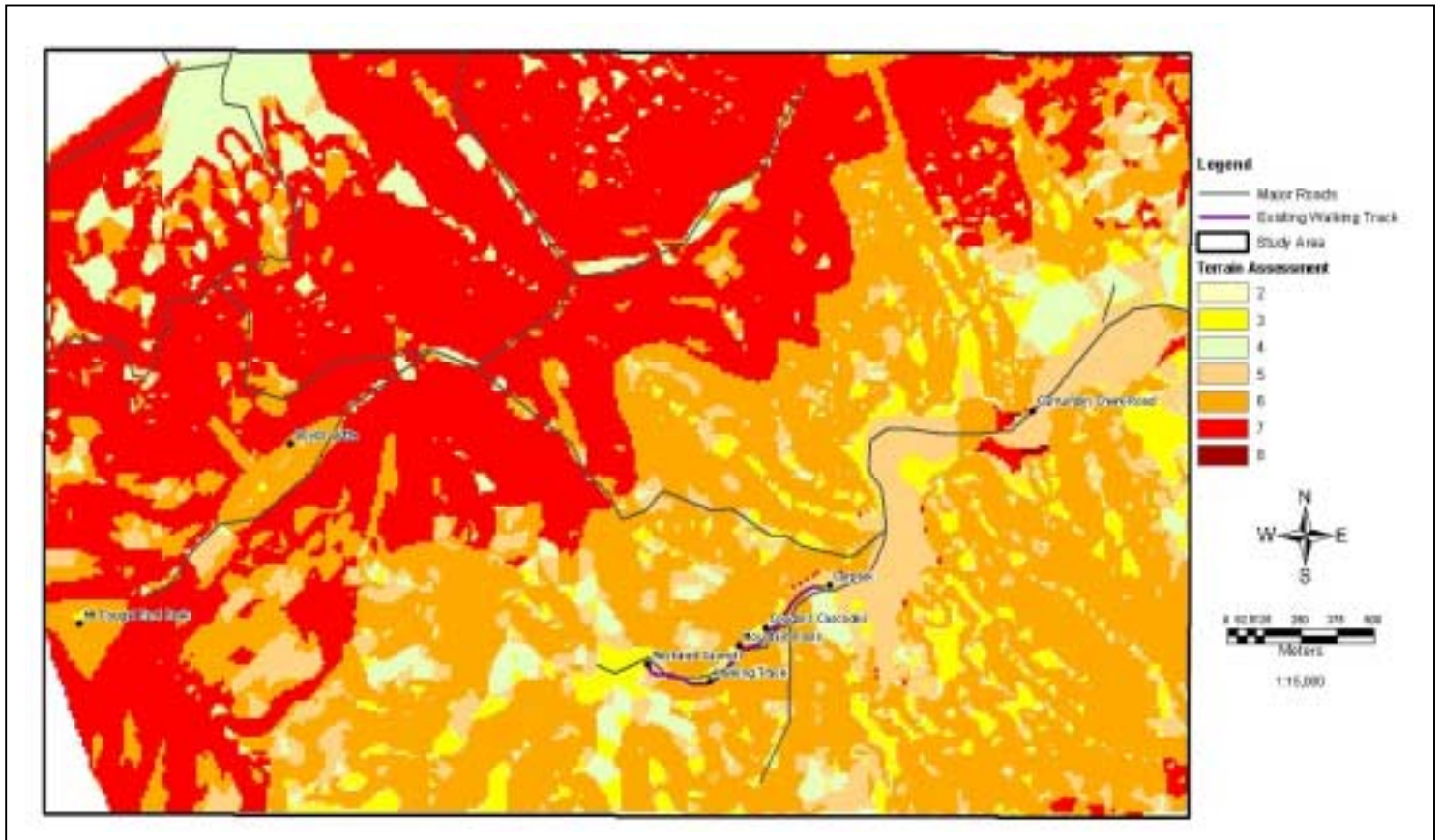
4.4 Conservation Assessment

ArcGIS's "Raster Calculator" was employed to combine the final two grids ie. RE and Landscape. The "Raster Calculator" is utilised for this research project to combine grids using the "addition" mathematical operator.

It can be seen from the final reclassified RE input grid in Figure 4.7 that light colours represent a vegetation management status value of "Not of Concern", whilst dark colours represent a status of "Of Concern". In addition, Figure 4.7 also displays the final "Landscape Sensitivity" grid. It can be seen that the values range from a minimum of 3, which is displayed by light colour that represent landscape areas least visible by all three spatial layers ie. roads, track and dwellings. Whilst values equal to 26, displayed by dark colour, represent landscape areas most visible by all three constraints.

The "Raster Calculator" is now used to add corresponding cell values for each grid. The values calculated from the arithmetic operator methods are shown in Figure 4.8.   It can be

observed that the final output values range from 6 to 48. The light coloured values represent areas of low conservation, whilst dark coloured values represent areas of high conservation. Further interpretation of the final Conservation Assessment in relation to social and environmental factors will be discussed in Chapter 5.

Figure 4.7 – Reclassified RE Grid and Final Landscape Sensitivity Results – Input Grids for Conservation Assessment

Regional Ecosystems - Input Grid

Terrain Assessment - Input Grid
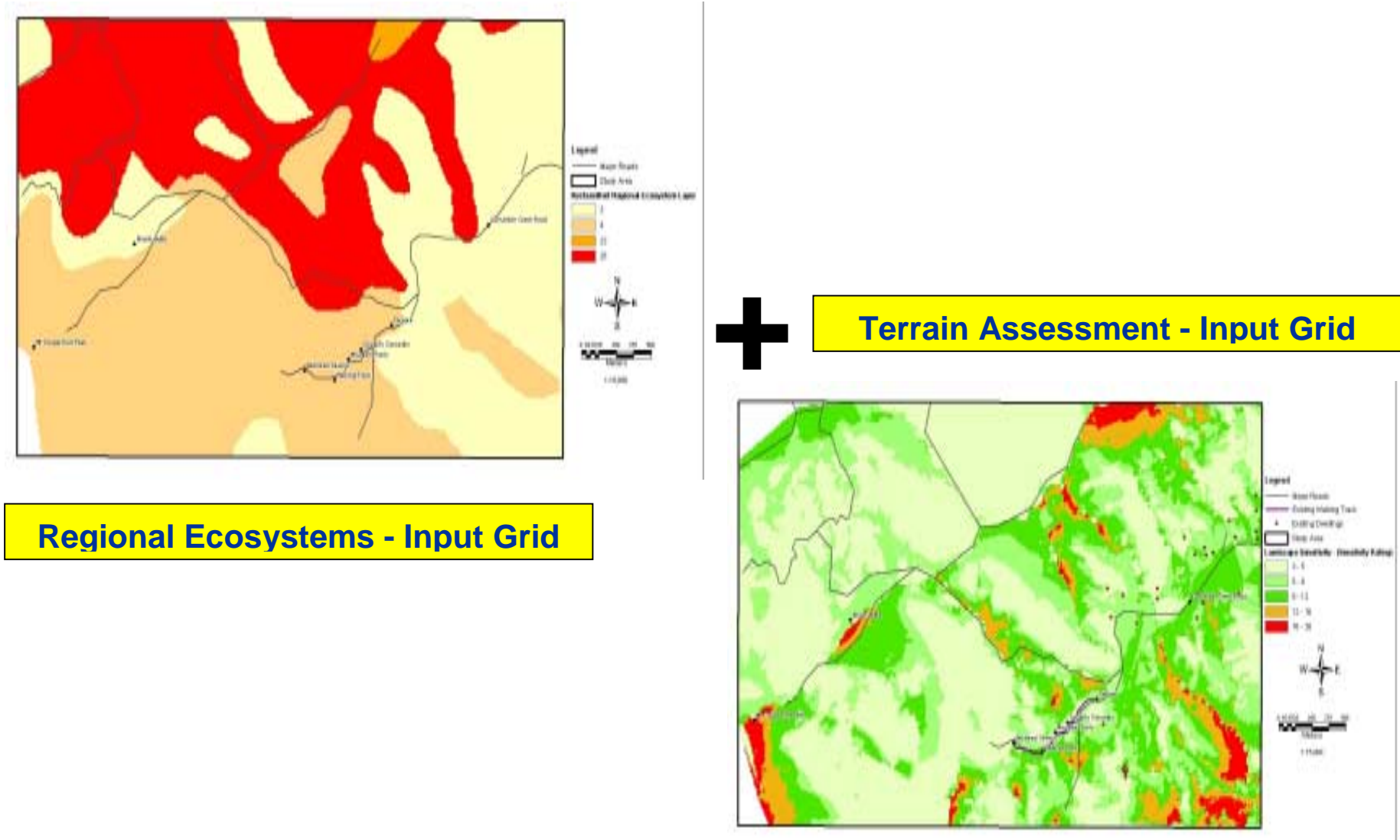
Figure 4.8 – Final Conservation Assessment Grid Result
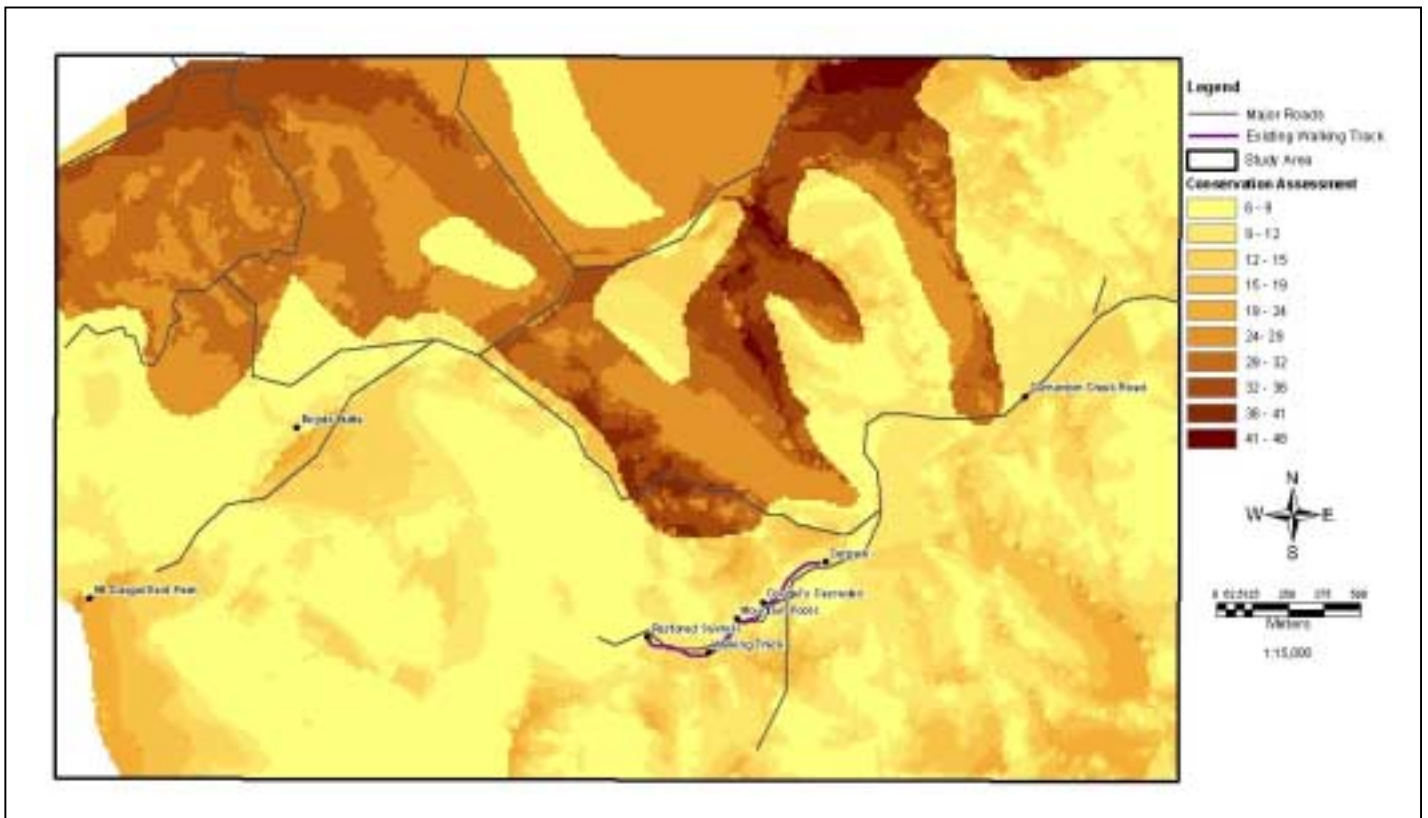
4.5 Summary

This chapter has presented and briefly described the output grids that were achieved by utilising ArcGIS's "Raster Calculator". This method was further described through the use of diagrams representing the methodology of mathematical grid operators.

The final display of grids and associated values for the Landscape Sensitivity and Terrain and Conservation Assessment where represented by light and dark colour shades.

Further interpretation and 3D representation of all three grid results will be discussed in Chapter 6.

Chapter 6
Discussions

5.1 Introduction

The aim of this chapter is to interpret a sound explanation of the results achieved from Chapter 4. The discussions will be focused on the study area and the relevance and detail of whether or not the results were normal or if there are any discrepancies or errors. In addition, this chapter will discuss if there are any problems interpreting the end result.

This chapter will be divided into four sections of discussions. The first section will interpret the social component of the analysis, namely the "Landscape Sensitivity" model. The second section will interpret the result from the "Terrain Assessment". The third section will discuss the "Conservation Assessment".

Finally, the last section will primarily focus on the final 3D visualisation developed in ArcScene and the representation of the highly sensitive areas from all three grid analysis.

5.2 Interpretation of the Landscape Sensitivity Model

As previously discussed, the purpose of the "Landscape Sensitivity" model was to visualise a type of social component for nature based tourism within Currumbin Valley. The social component for this study is defined as people that are interested in scenery from:

- Their motor vehicle ie. scenic driving;
- Tourist walking track ie. easy level walking tracks aimed for non-bushwalkers, and;
- Dwellings ie. scenic views from existing houses. Scenic views may be the reason why the house was initially purchased.

The primary focus of all three models was to identify landscape units that are most valuable to people from the abovementioned locations. This focus was initially achieved by creating seen area analysis, namely a "Viewshed" using Spatial Analyst extension.

5.2.1 Interpretation of the Reclassified Viewshed Analysis from Major Roads

Firstly a Viewshed analysis was performed from major roads within the study area. The pre-processing methods were discussed in Chapter 3. The viewshed analysis grid was then reclassified in Spatial Analyst using the "Reclassify" grid function as detailed in Chapter 4. The input viewshed grid was reclassified to 10 classes. The results display areas that were represented by darker colours ie. orange, green and red tones, locating areas " Most Visible" from all roads and beige and yellow colours locating areas "Least Visible" from all roads within Currumbin Valley. The results depict that the majority of the study area landscape can be seen from all major roads, with exception to small patchy areas scattered throughout. These low visible scenic areas are expected due to the absence of roads located in the north-east and south-west corner of the study area. In contrast, the highly visible orange areas are dominant. This result is expected due to the central location of the major roads.

Motor vehicles are the primary method for travel from one tourist spot to the next. It can therefore be appreciated the significance of conducting a viewshed analysis from all major roads within the study area.

5.2.2 Interpretation of Reclassified Viewshed Analysis from existing Walking Track

The existing walking track is located to the south of the study area. The track information was obtained from using a GPS during a field investigation. The walking track is situated parallel with Currumbin Creek and is the primary tourist interest within Currumbin Valley. The track creates access to rock pools that are used by tourists for swimming.

The pre-processing methods for the viewshed analysis from the walking track were discussed in Chapter 3. The viewshed analysis grid was then reclassified in Spatial Analyst using the "Reclassify" grid function as detailed in Chapter 4. The input viewshed grid was reclassified to 10 classes.

The results from the walking track viewshed analysis displayed through the representation of orange, green and red colours ie. values 4 to 10, identifying terrain areas that are "Most Visible" from the track and beige and yellow colours ie. values 1 to 3, identifying terrain areas that are "Least Visible" from the track. The results depict that the high visible areas are predominately located surrounding the track and in high elevated areas such as the east peak of Mount Cougal, Boyds Butte and adjacent ridges. This result can be considered in

two scenarios. Firstly, tourists interested in viewing mountains, cliffs and steep topography will find that the track provides this type of view. Secondly, tourist interested in viewing a rural outlook will be disappointed as this type of landscape is not visible from the walking track.

The "least visible" areas are the dominant feature in this viewshed analysis. It can be seen that areas situated behind the ridge and mountains are clearly not visible from the walking track. This result is expected due to the location of the track existing in a low terrain area, namely valley of Currumbin.

5.2.3 Interpretation of Viewshed Analysis from Dwellings

The dwelling locations are primarily located east within the study area. The dwelling layer was created through digitising from the digital aerial photography. The dwelling types consist of private domestic and rural homes and tourist accommodation facilities.

The pre-processing methods for the viewshed analysis from the dwellings were discussed in Chapter 3. The viewshed analysis grid was then reclassified in Spatial Analyst using the "Reclassify" grid function as detailed in Chapter 4. The input viewshed grid was reclassified to 10 classes.

The results from the dwelling viewshed analysis displayed through the representation of orange, green and red colours ie. values 4 to 10, identifying terrain areas that are "Most Visible" from the dwellings and beige and yellow colours ie. values 1 to 3 identifying terrain areas that are "Least Visible" from the dwellings. The results depict that the high visible areas are predominately located in the vicinity directly surround the dwellings and high elevated areas such as the east peak of Mount Cougal, Boyds Butte and adjacent ridges. The results present that the valuable features considered by most tourists ie. mountains and cliffs can be seen.

The areas classed "least visible" from dwelling locations are primarily below and behind the mountains and ridges. This result is expected due to the majority of dwellings located at a low elevation and therefore only having visible site to equal or high terrain within the study area.

5.2.4 Interpretation of Final Landscape Sensitivity Grid

As previously mentioned in Chapter 4, Spatial Analyst "Raster Calculator" was utilised to combine the three reclassified viewshed grids. The aim of this method is to add all corresponding grid values for each grid, to calculate and create a final grid that contains a combination value, for example, if a cell value in the roads grid was 3, a cell value in the track grid was 5 and a cell value in the dwelling grid was 2, then the final value for that cell in the new grid would be 10. This method aims to achieve a combined overall landscape sensitivity rating.

The final landscape sensitivity grid contains values from 3 to 26. The final grid is displayed through the use of five classification groupings.   Table 5.1 depicts each classified range, associated colour, visibility and location within the study area.

Table 5.1 – Landscape Sensitivity Classifications

Value Range	Colour	Visibility of Landscape	Location
3 – 5	Light Green	Least Visible	Primarily located behind the mountains and ridges and slope towards the valley.
5 – 8	Medium Green	Moderately Visible	Small areas are located behind the mountain and ridges, areas slightly lower than the mountain and ridges and scattered areas throughout Currumbin Valley.
8 – 12	Dark Green	Moderately Visible	Small areas are located behind the mountain and ridges, areas slightly lower than the mountain and ridges and scattered areas throughout Currumbin Valley.
12 – 16	Orange	Highly Visible	These areas are primarily located at high elevated landscape ie. mountains and ridges and sloping slightly to the valley and areas that are less elevated ie. less vegetated areas located in the south east corner of the study area.
16 – 26	Red	Highly Visible	These areas are primarily located at high

			elevated landscape ie. mountains and ridges and sloping slightly to the valley and areas that are less elevated ie. less vegetated areas located in the south east corner of the study area.

It can be interpreted through spatial visualisation and analysis techniques that the final landscape sensitivity grid represents scenic areas that are most visible from all three man-made features. It can be concluded that mountainous terrain is the most visible scene from all three characteristics.

This type of analysis has several practical applications in relation to tourism, examples include:

- Future development of tourist accommodation areas could benefit from this type of analysis by determining locations that have the best views of surrounding landscapes;
- Development of future roads may be based on the importance of scenic views ie. tourist ring roads and lookouts, and;
- Future tourist walking tracks may also be based on the importance of scenic views.

5.3 Interpretation of the Terrain Assessment Model

The purpose of the "Terrain Assessment" model was to identify and visualise areas that are prone to erosion within Currumbin Valley. This approach could provide suggestions for future investigations of nature based tourist activities, for example, a terrain assessment could help identify areas that are suitable for bushwalking tracks by avoiding areas that are prone to erosion.

This approach was achieved through the evaluation of different soil types and terrain slope within the study area. As previously mentioned in Chapter 4, the Spatial Analyst "Raster Calculator" was employed to combine both the reclassified soil and slope grids. This method used the arithmetic addition function to add all corresponding grid values for both grids to achieve a combined overall terrain assessment grid.

The final terrain assessment grid contains values from 2 to 8 ie. a total of 7 values. These values are displayed individually by a unique colour. Table 5.2 depicts each calculated new value, associated colour, erosion potential and risk for values within the study area. The "Erosion Potential" column is based on a scenario only. The situation is relevant to the development of uncontrolled bushwalking tracks, for example, bushwalking tracks that have been developed with no prior impact assessment or control.

Table 5.2 – Terrain Assessment Classifications

Calculated Value	Colour	Erosion Potential	Erosion Risk
2	Light yellow	The combination of surface slope and soil erodability is such that no appreciable erosion damage is anticipated.	Low
3	Yellow	The combination of surface slope and soil erodability is such that no appreciable erosion damage is anticipated.	Low
4	Light Green	Localised minimal erosion may occur.	Low to Medium
5	Light Orange	Localised short-term erosions may occur.	Medium
6	Orange	Localised short-term erosions may occur.	Medium
7	Red	Short-term erosion is likely to occur due to the combination of slope and soil type and erodability factors	Medium to High
8	Dark Red	Soil losses are likely, due to steepness of slopes and a high soil erodability factor.	High

It can be interpreted through cartographic visualisation and analysis techniques that the areas with low slope, namely those situated around the walking track, are low to medium erosion prone areas. This can be seen as reassurance that the terrain surrounding the existing tourist areas of walking tracks and picnic spots are not in any danger of losing vegetation due to tourist impacts causing erosion.

In contrast, the areas cartographically represented as high slope, namely those situated around the mountains and ridges are medium to high erosion prone areas. The construction of future bushwalking tracks in these areas should be avoided due to the significant impact on soils which may lead to loss of vegetation.

It can be concluded that a more precise terrain assessment can be achieved through the use of additional data sets such as vegetation and drainage information. Due to data limitations and availability and time restrictions, this assessment criteria was simplified.

5.4   Interpretation of the Conservation Assessment Model

The purpose of the "Conservation Assessment" model is to identify and visualise landscape areas that require protection for both social and environmental reasons, for example, the identification of sensitive areas could provide protection of endangered ecosystems whilst preserving scenic values for tourists. In addition, landscape areas with no importance would be suitable for possible recreational activity.

This approach was achieved through the evaluation of two constrains. Firstly, the final Landscape Sensitivity model (social component) and secondly the regional ecosystem grid (environmental aspect). As previously mentioned in Chapter 4, the Spatial Analyst "Raster Calculator" was employed to combine both the landscape sensitivity grid and regional ecosystem grid. This method used the arithmetic addition function to add all corresponding grid values for both grids to achieve a combined overall conservation assessment grid.

The final conservation assessment grid contains values from 6 to 48. The grid is symbolised through the classification of 10 bands.   Table 5.3 depicts each band and a conservation management unit. The "Conservation Management Unit" is based on a scenario only. The units are based on the relevance of scenic views from the landscape sensitivity constraints ie. roads, track and dwellings and from the different regional ecosystem status as described in Chapter 3.

Table 5.3 – Conservation Management Units

Value Range	Conservation Management Unit
6 – 9	Areas suitable for future recreational activity, dependent on other constraints such as soil, geology and slope.
9 – 12	Areas suitable for future recreational activity, dependent on other constraints such as soil, geology and slope.
12 – 15	Areas suitable for future recreational activity, dependent on other constraints such as soil, geology and slope.
15 – 19	Maintain land use that is consistent with existing landscape.
19 – 24	Maintain land use that is consistent with existing landscape.
24 – 29	Maintain land use that is consistent with existing landscape.
29 – 32	Maintain land use that is consistent with existing landscape.
32 – 36	Full protection required with no human interference.
36 – 41	Full protection required with no human interference.
41 – 48	Full protection required with no human interference.

The interpretation of the final conservation assessment grid may seem a little confusing to some. It was initially recognised that both grids would depict common areas of high sensitivity in similar locations. This is may be due to tourist's interest in eye-catching vegetated landscapes.

In this instance a significant proportion of the areas rated "highly visible" match those classified as "of concern" for regional ecosystems. It can therefore be determined that areas represented by dark colours (values 32 – 48) on the conservation assessment grid, require full protection from human interference and are therefore not suitable for any type of tourist development or impact. These areas are primarily located on the mountainous terrain. Protection of these areas will ensure both scenic views remain intact for tourists from major roads, walking tracks and dwellings and "of concern" regional ecosystem values are protected.

In contrast, the areas cartographically represented by light colours (values 6 – 15) are presented in the scenario as having a conservation management unit suitable for future recreational activity, dependent on other constraints such as soil, geology and slope. These

areas can be described as having least visibility from the man-made landscape features and also containing a regional ecosystems status of "not of concern".

Finally, areas that are represented by medium toned colours (values 15 – 32) are described as having moderate visibility from the man-made landscape characters and featuring regional ecosystems that are "not of concern".

5.5   Interpretation of the 3D Model

As previously stated in Chapter 3, ArcScene was employed to create 3D models of the aerial photography using the base heights from the DEM. The 3D models will provide a specialised view of the realistic landscapes within Currumbin Valley. In addition, the sensitivity grids were imported as an overlay to represent each assessment type. Table 5.4 depicts each sensitivity and classes that were represented for each individual 3D image.

Table 5.4 – Sensitivities and associated grid values

Sensitivity	Grid Values Applied
Landscape Sensitivity grid	12 – 26
Terrain Assessment grid	7 and 8
Conservation Assessment grid	32 - 48

It was decided that values representing high sensitivities would only be included in the 3D images. This was because the representation became too crowded if all individual values were shown. Finally, the grids were converted to a feature polygon file using 3D Analyst "convert raster to feature" option and then imported into the ArcScene.

Importing vector files to a 3D scene requires the use of the "Offset" function. The Offset function is applied when the only height attribute for a theme is relative to a surface that is used to provide the base height ie. the DEM (ESRI, 2004). In this instance both the sensitivity polygons and track layer were offset by 5 metres relative to the DEM. In addition, all both vector and aerial photography data sets obtained their base heights from the 5 metre DEM. The three "high sensitivity" polygon features were each made transparent so that the aerial photography subsurface was visible underneath to compare and create a natural view of the landscape.

Unlike ArcGIS, ArcScene's label functionality enables only one vector file to be labelled during a scene. A vector point file was created to label certain features such as:

- Tourist locations, for example, walking track and picnic areas;
- Major roads such as Currumbin Creek Road, and;
- Mount Cougal.

The labels where created using Arial 45 black font, bill-boarded and with a height offset of 15 metres. The representation of these labels were notably absent when exporting the 3D scenes to 2D image files and video file. This discrepancy is due to a glitch within ArcScene.

It can be noted that the digital aerial photography coverage is limited to a small section of the study area situated north. This discrepancy will therefore display the three sensitivities vector file with no underlying aerial photography.

Two-dimensional "snap-shots" were taken to display in this report and through the export scene to 2D image functionality in ArcScene.

Figure 5.1 displays a 3D snap shot of the Landscape Sensitivity grid with representation of "high" sensitivity values only. This image can clarify the interpretation results from the final landscape grid. The areas represented by red are locations within the study area that are most visually seen from major roads, the walking track (represented by a red polyline) and dwellings. These area are predominately located on high elevated landscape ie. mountains and ridges and directly adjacent to the walking track.

Figure 5.1 – 3D representation of the "high" Landscape Sensitivity values
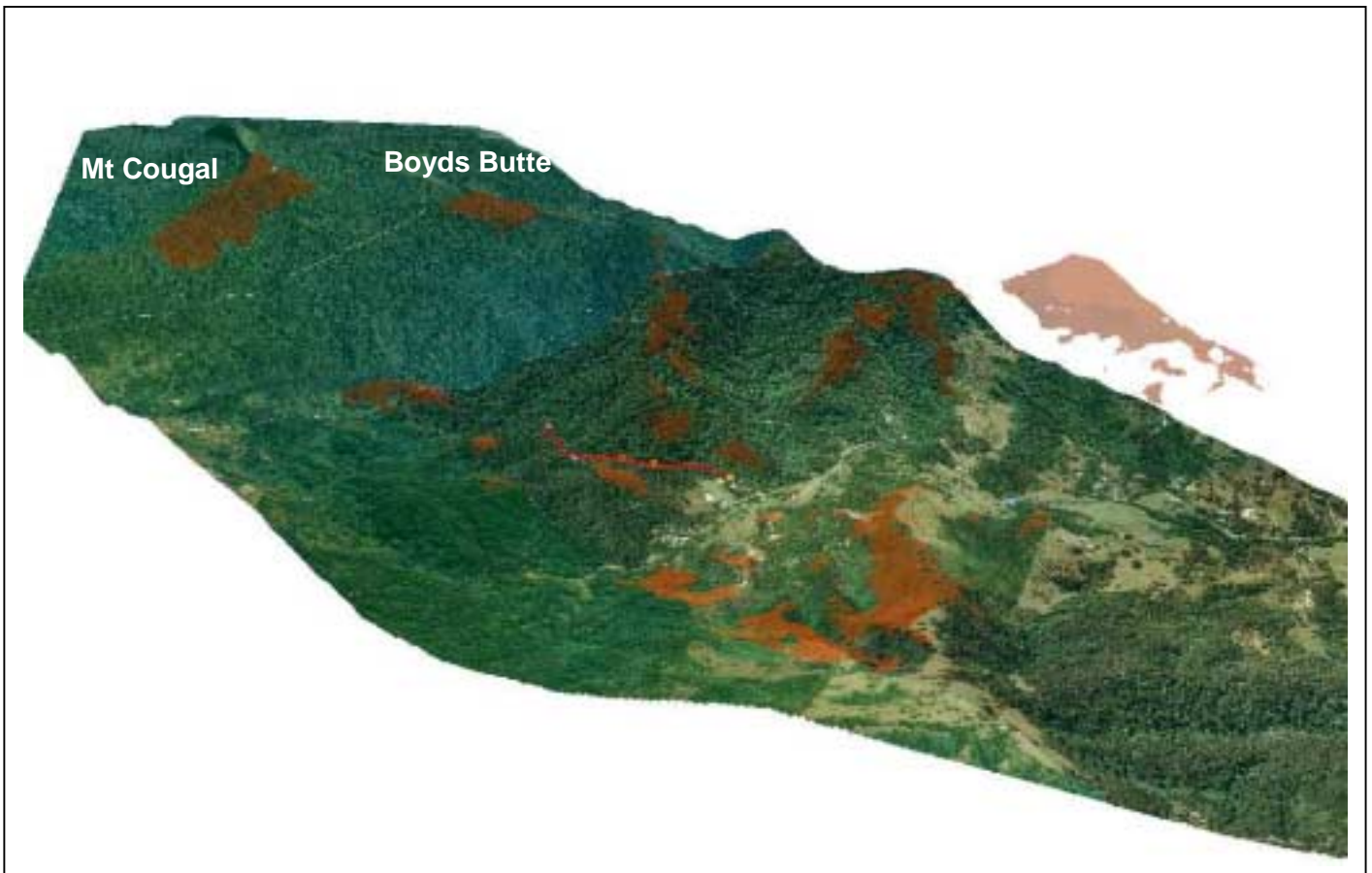
Figure 5.2 displays a 3D snap shot of the Terrain Assessment grid with representation of "high" sensitivity values only. This image can clarify the interpretation results from the final landscape grid. The areas represented by purple are locations within the study area that are most prone to erosion as analysed from the slope and soil grids. This visualisation represents that areas prone to erosion are predominately located on high-elevated landscape ie. mountains and ridges, sloping down into Currumbin Valley.

Figure 5.2 – 3D representation of the "high sensitivity" Terrain Assessment values

Mt Cougal
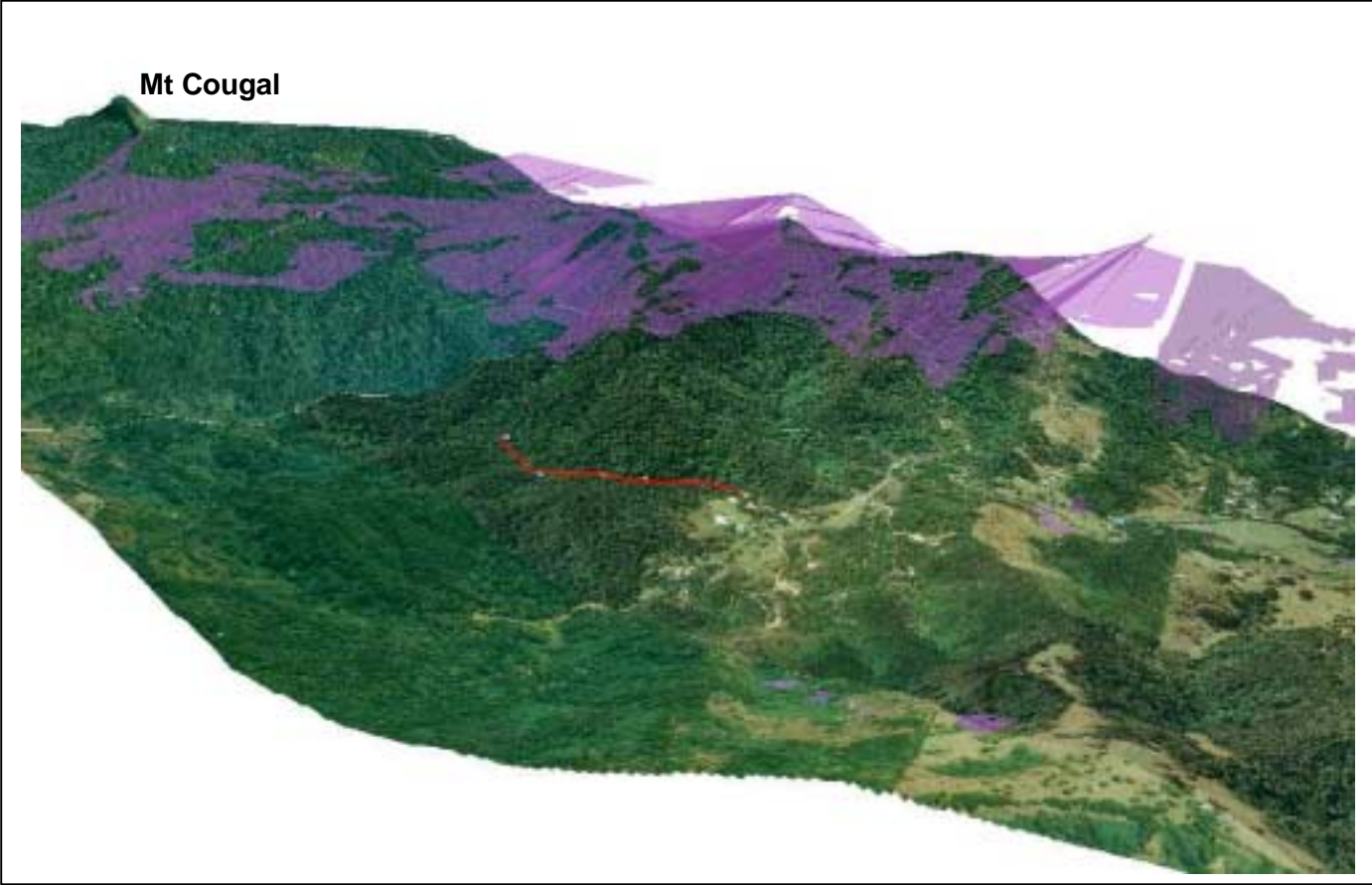
Figure 5.3 displays a 3D snap shot of the Conservation Assessment grid with representation of "high" sensitivity values only. This image can clarify the interpretation results from the final conservation grid. The areas represented by green are locations within the study area that may be considered for tourist conservation ie. these areas contain "Of Concern" ecosystems and are highly visible from major roads, the walking track and surrounding dwellings. These areas were determined from the final RE and Landscape grids. This visualisation represents conservation areas that are predominately located on high-sloped landscape adjacent and behind the walking track.

Figure 5.3 - 3D representation of the "high sensitivity" Conservation Assessment values

5.6 3D Virtual Fly-through

A virtual fly-through animation was created for this project using ArcScene. The animation functionality in ArcScene enables the user to compose animations using different methods. This project adopted the following techniques.

1. Firstly a group animation was created from individual layers within the scene.
2. Secondly, a series of keyframes was created to make up the camera track through navigating and taking snapshots of perspectives.
3. Thirdly, the animation manager was utilised to control the "Time View" of the tracks and their relationship to the keyframes. This functionality enabled the selection of "fading in" and "fading out" at a specific time during the animation of all three sensitivity vector files.
4. The animation was specified to run for 1 minute.
5. The animation was finally exported to a video file, opting for a high quality visualised output. This final video file size totalled 304MB.

There were several limitations whilst creating the virtual fly-through animation, for example:

- During the export to video file individual aerial photography layers would disappear due to hardware memory problems. This would create "white" gaps during animation;
- Export time for one video animation was 30 minutes;
- The hardware video card was not adequate for this project;
- Label features would not appear in the exported video file;
- The transparency of the sensitivity layers did not appear on the final video fly-through ie. appeared as solid colours.

The final 3D fly-through video file is saved to CD-ROM (Refer to Appendix C) together with an Adobe Acrobat file of this report. The video file begins with a general fly-through of the study area behind Mount Cougal. The fly-through navigates to the south of Currumbin Valley, eventually leading to the walking track area which is represented by a red vector line. The animation firstly displays the high "Landscape Sensitive" areas represented by the colour red. The fly-through navigates anticlockwise to display the "Terrain Assessment" erosion prone purple areas. To conclude, the fly-through navigates north-west whilst zooming out to display the "Conservation Assessment" represented by green high sensitive areas.

5.7 Summary

This chapter has discussed and interpreted the final results of the

The aim of this chapter is to interpret a sound explanation of the results achieved from Chapter 4.   The discussions will be focused on the study area and the relevance and detail of whether or not the results were normal or if there are any discrepancies or errors. In addition, this chapter will discuss if there are any problems interpreting the end result.

This chapter will be divided into four sections of discussions. The first section will interpret the social component of the analysis, namely the "Landscape Sensitivity" model. The second section will interpret the result from the "Terrain Assessment". The third section will discuss the "Conservation Assessment".

Finally, the last section will primarily focus on the final 3D visualisation developed in ArcScene and the representation of the highly sensitive areas from all three grid analysis.

Chapter 6
Conclusions & Recommendations

6.1 Introduction

This chapter discusses both conclusions and recommendations determined from this research project with general reference to analysis results and visualisation techniques employed. Recommendations for future enhancements will be made and suggestions on how these applications may be of benefit for future research or projects.

6.2 Conclusions

The GIS methods presented in this research project provides examples of how 2D and 3D visualisation and spatial analysis techniques can strengthen tourism planning and conservation. This methodology may be regarded as being significant to the tourism industry as it provides an example of how to identify areas of high nature value, which can then assist with future tourist developments, for example, a tourist accommodation development within Currumbin Valley.

GIS software and dataset processing techniques play an active role in examining existing environmental conditions, investigating the suitability of locations for proposed developments through visual assessments from existing man-made features, identifying suitable location of tourist based interest, for example, bushwalking tracks and modelling the relationships of these separate datasets. ESRI's ArcGIS, Spatial Analyst and ArcScene provide an effect means for achieving this type of grid based analytical result.

This study has identified that there is a need to monitor current and future nature based tourist destinations not only through the use of GIS spatial analysis and visualisation methods, but also through the improvement of tourist based GIS datasets, for example, a spatial database management system could control and identify tourism locations listing associated characteristics such as flora, fauna, walking tracks and picnic spots.

This study has also provided examples of how 3D terrain and virtual fly-through can assist in providing people with a realistic view of environmental and social sensitivities such as landscape views and existing tourist features such as walking tracks. Using 3D virtual environments in conjunction with digital aerial photography, it was anticipated that the final

landscape, terrain and conservation assessments grids could portray a realistic view of where these high sensitivities are located and perhaps inform people that these areas are to be conserved.

6.3   Recommendations for Practical Applications

The significance of this study can assist with GIS tourist applications and may be of benefit to a vast range of disciplines as listed in Table 6.1 below:

Table 6.1 – Future GIS tourist applications and associated disciplines

Discipline	Practical Applications
Nature based tourists	• Provide tourists with specific locations of flora and fauna species, for example, bird watching, and; • Providing tourists with a realistic 3D view of their proposed destination.
Scenic based tourists	• Provide tourists with locations that contain the best scene of a surrounding area, for example, a tourist lookout.
Environmental scientists	• Identify areas that contain endangered flora or fauna species, and; • Provide assistance for an Environmental Impact Assessment (if needed) through the use of GIS analysis and visualisation techniques to identify areas of conservation significance.
Property developers for tourism	• Assist with the identification of a suitable site for a tourist accommodation facility, by utilising GIS spatial analysis functions; • Identify areas within a nature based tourist location that contain the most scenic views of surrounding environments, and; • Provide developers with a 3D realistic

	landscape view of their proposed accommodation site and natural surrounds.
Local Authorities or Government bodies	• Assist Local Authorities with upgrading current and planning future nature based tourist destinations by assessing environmental and social sensitivities within a GIS environment, and; • Develop a virtual fly-through for a tourist location, for example, to be used to promote nature based tourism within Gold Coast region.

6.4 Recommendations for Future Research

This dissertation has provided a basis from which future research work may be investigated. Recommendations for future research improvements include:

- Upgrade of computer hardware memory and video card to reduce time for the development of 3D models and virtual fly-through;
- Upgrade of ArcScene 3D software to version 9, so that extra animation functionalities are available;
- Including additional datasets for the terrain and conservation assessments, for example, vegetation and climate information could provide for a more detailed conservation result;
- Upgrading current spatial datasets to a more detailed scale, for example, the soils dataset would have been more beneficial at a large scale for the terrain assessment;
- Extending the digital aerial photography coverage to include additional surrounding areas for the virtual fly-through, and;
- Extending the GPS field work to include a more detailed investigation of current tourist walking tracks and picnic spots within Currumbin Valley and eventually include these additions in the virtual fly-through.

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Vertical Mapper 2.6

APPENDIX A

Assessment of Consequential Effects -

Aspects of Sustainability

Ecological Sustainable Development (ESD) can be defined as:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Report 'Our Common Future', 1987).

This definition signifies that sustainable development and conservation is used as a means of preserving human well being through enhancing economic, social and environmental compatibilities whilst maintaining their potential conflicts in the short term. For example: To meet future needs, humans must maintain natural resources, prevent soil degradation and stop polluting.

I believe that my Research Project will implement and portray an appropriate example of sustainable development and conservation through the use of GIS.

Ecological sustainable development strategies play an essential part in maintaining our ecosystems. This is achieved by Local and State Government bodies developing compulsory guidelines and rules for future developments. This solution will prevent species extinctions, destruction of forests and bushland for agriculture and urban development.

Environmental laws and regulations now control approvals for potential developments or projects. These laws will prevent an environmental disaster from occurring by deciding what activities should be allowed to take place. This is achieved through land use regulations or an Environmental Impact Assessment (EIA). An EIA is now required by government law to ensure that all environmental impacts are considered before approval is given for developments and projects that are likely to have a detrimental affect on the environment. In addition, an EIA will describe in detail the proposed development or activity, by revealing all possible and certain effects. An EIA is also available for public viewing or comments.

Society's purpose is to progress towards further sustainable systems and positive changes that will provide support for social equity, human worth and ecological health.

Aspects of Ethical Responsibility

A selection of the Code of Ethics briefly detailed below is intended for GIS professionals to help them make suitable ethical choices. This information is sourced from the Urban and Regional Information Systems Association (URISA) web page (www.urisa.org). The points I have considered in my opinion are the most ethical.

Obligations to Society

- Provide full clear accurate information;
- Make data findings widely available, and;
- Admit when a mistake has been made and make corrections where possible.

Obligations to Employers and Funders

- Be qualified for the tasks accepted;
- Document work so that others can use it, this includes metadata and program documentation, and;
- Help develop security, backup, retention, recovery, and disposal rules.

Obligations to Colleagues and the Profession

- Cite the work of others whenever possible and appropriate;
- Work respectfully and capably with others in GIS and other disciplines, and;
- Support individual colleagues in their professional development.

Obligations to Individuals in Society

- Protect individual privacy, especially about sensitive information, and;
- Be especially careful with new information discovered about an individual through GIS-based manipulations (such as geocoding) or the combination of two or more databases.

APPENDIX B

Risk Assessment

GIS professionals work in limited situations usually inside an office and occasionally on site, therefore the section of this report will match the necessary safe work practices to the various workplaces.

This management system addresses all the requirements of AS/NZS 4801, "Occupational Health and Safety Management Systems", that apply to the knowledge-based service industry (this industry standard can be located through Standards Australia). The duty of care required under statute and common law needs to be well understood by all Engineering. Surveying and GIS professionals to ensure that all reasonable effort is made (through a systematic planning process) to secure and promote the health, safety and welfare of people at work

A risk management process consists of the following steps (Refer to the model below):

- Identification of hazards;
- Assessment of risks;
- Control of those risks identified by the risk assessment, and;
- Evaluation.

The risk management model forms part of the planning process and commences during proposal preparation. During this process the professional will make an assessment of the activities to be performed and the environment for the activities to be performed and the potential hazards.

The Risk Management Process

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WH&S Policy

The WH&S Policy is management's statement in writing off its commitment to Occupational Health and Safety. It details the organisation's intent with respect to health and safety, the roles of key parties, and the commitment of resources

↓

Office and Field WH&S Programs

The WH&S program is the process designed to fulfil the commitment outlined in the WH&S Policy. The core elements of the program are hazard identification, risk assessment, risk control and monitoring and review.

↓

Hazard identification	→	*Risk assessment*	→	*Risk control*
This is the process of examining every aspect of the workplace (including each work area and every task undertaken and identifying the hazards present)		This is the process of assessing the risk associated with each hazard identified. The risks are evaluated and prioritised based on their probability and consequence		This is the process of determining and implementing measures to control the risks from the risk assessment process

↘↖   ↓↑   ↗↙

Review and Audit

This involves ongoing monitoring of the hazard identification, risk assessment and risk control processes and reviewing them to ensure that they are working effectively. The impact of any changes in the workplace is thereby accounted for and any new (or previously overlooked) hazards are dealt with as they arise. The Office WH&S Committee ensures that this process is effectively planned and applied.

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Goal – A Safe and Healthy Workplace

Source: GHD Pty Ltd (2004)

Risk assessment is the process of assessing all of the foreseeable hazards associated with each process as identified during the hazard identification process. In assessing the risk, three essential steps are taken:

- Evaluation of the probability or likelihood of an accident occurring;
- Calculated severity of the potential consequences; and
- Assign priority for risk control through the use of a risk rating.

Generally the health and safety risks involved in the field of GIS are limited. Examples of office and field risks are detailed in Table B1 below.

Table B1 – Safety Risks associated with a GIS professional

Description of Health & Safety Hazard	Location	Risk Level	Risk Control
Skin Cancer caused by excessive exposure to the sun	Field Work	High	Broad rimmed hat, sunglasses, sunscreen and long sleave shirt.
	Field Work	Medium	Steel cap boots and safety vests.
Working at heights	Field Work	High	
Ergonomics ie. computer work	Office Work	Low	Ensure correct posture is maintained throughout the day and if required obtain an ergonomically safe mouse and keyboard.