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South East Queensland Waterways, Land Use and Slope Analysis

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GLOSSARY OF TERMS

AHD	Australian Height Datum, standard datum for elevation mapping in Australia
Bilinear	Two reference lines, for instance co-ordinates
Catchment	Land area, where run-off drains to a common point
Co-ordinate system	Used to locate objects, to measure location of objects on a map, data is described by x and y locations, for instance latitude, longitude.
DEM	Digital Elevation Model, gridded, attributed cells of elevation of a land area
DNRW	Department of Natural Resources and Water
Ecosystem	Collection of living things, and the environment they live in
Ephemeral	Lasting for a short time
GIS	Geographic Information Systems
Grid	Evenly spaced square cells (pixels) over a region. Each cell has a value.
Land Use	Category describing what that section of land is used for, or potentially used for
LIDAR	Light Detection and Radar, a method of remotely sensing elevation of the earths surface
Projection system	Allows objects on the earths surface to be located on a flat map
Pit Filled Grid	DEM grid, processed to remove pits and hollows
OUM	Office of Urban Management
Raster	Raster images are made up from a series of pixels, that represent objects/areas. Co-ordinates/attributes may be associated with the objects, GIS programs use raster and vector data
SEQ Catchments	South East Queensland Catchments
SEQ	South East Queensland
SEQHWP	SEQ Healthy Waterways Partnership
Shire	Local Government Area
Slope	Deviation from the horizontal
Stream Order	Measure of size of waterway, in SEQ from the smallest, 1st order to largest, 8th order, the Brisbane and Logan Rivers
Survey Data	Measurement, recording of data about the earths surface
TIN	Triangulated Irregular Network, attributed triangles joining areas of elevation
Waterway	Stream, river, canal, body of water
Vector	Objects with coordinates and attributes

See section 3.4.8 for data naming protocols.

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 institution, except where specifically stated.

Bruce Robert Harris

Student Number: W0069997

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Signature

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Date

ABSTRACT

A rapid population increase in South East Queensland (SEQ) has placed extra demands on the ecosystem of the region. This has led to an increase in the need to understand what's happening within the landscape, in particular the need to understand more about the health of waterways and catchments. Therefore, there is a requirement for more information relating to waterways and catchments.

Information about waterways and catchments has become more important than ever before. Catchment groups, waterways managers, Local Governments and State Government departments all valuing any data about waterways and catchments. This information assists them manage the health and remediation of these systems.

Any data that assists with planning and the continued maintenance of healthy ecosystems is highly sought after. Managing waterways to ensure environmental values are maintained while allowing for continued economic development is major challenge facing many areas of Australia (Newham et al. 2004).

It has been identified by planners and users of the existing waterways data that there is a need for knowledge of lengths of streams in land use types, for existing and future land use. Identification of lengths of stream order in land use types would enable better management of these waterways and assists with planning change, or lack of change for an area. This study provides information on the lengths of waterways in existing and future land use categories.

There was also a need for more information about SEQ waterways with regard their relationship with the slope of the land over which they lie. Slope analysis of waterways assists in the estimation of sedimentation run-off and transport of pollutants through waterways. It also assists with such things as identifying nutrient export 'hot spots' that require treatment. Knowledge of slope of the land over which waterways flow can assist characterise land, and therefore help with the planning process. This study supplies information on the lengths of waterways in slope categories.

This study addresses the identified waterway, land use and slope requirements for the eastward draining (mostly into Moreton Bay) catchments and shires of SEQ. The project builds on previous waterways and catchments data created by the author through a project at BMT WBM. This project created stream ordered waterways information of the region for the SEQ Healthy Waterways Partnership (SEQHWP).

A Digital Elevation Model (DEM) created for the previous work is used in this new project as the basis to create categories of slope for SEQ. From the slope categories, lengths of stream ordered waterways are derived for each catchment and shire in the region. The waterways are also analysed with both existing and future land use categories. Finally, information about lengths of stream order within land use areas for each SEQ catchment and shire is provided.

Lengths of waterways are already available for catchments, but not for the shires, and not for land use and slope categories for catchments or shires. So, while the project defines these waterway lengths in land use and slope categories, it also delivers another benefit in that it supplies areas of land use (existing and future) for the catchments and shires. It also delivers areas of slope categories for each of the catchments and shires in SEQ.

A major implication from this study is that it has become apparent that there is a straight forward, simplistic way to work out lengths of waterways, and indeed lengths of stream ordered waterways (see Figure 1-3 for explanation of stream ordered waterways) within catchments and land use areas (and any other large land area). This can be done without the need for detailed DEM construction and processing. It was found that for every square kilometre of catchment or land use there is approximately two kilometres of waterways. Also, for every square kilometre of land use there is approximately one kilometre of stream order one waterways. Stream order two waterways are half the length of stream order one waterways. Stream order three waterways are approximately half the length of stream order two waterways, and so on.

The accompanying hard copy A3 Drawing addendum gives details for all catchments (Levels 1, 2 and 3) and shires, or parts of shires within the SEQ catchments area, detailing lengths of waterways within the various land use and slope categories.

Information from this study will be of use to a large number of organisations in SEQ, being delivered in various formats, from Geographic Information Systems (GIS) data through to the A3 hard copy output. Any available resources for waterway management may be better utilised with an improved knowledge of those waterways. To the authors knowledge, this is the first time this type of information has been created over such a large area, and over so many catchments and shires.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank all those who have contributed to the completion of this dissertation. The following pages are a representation of the largest project I have ever worked on, from the initial creation of the DEM, catchments and waterways, through to the work described in this dissertation and the accompanying A3 Drawing addendum. The project could not have been achieved without the assistance and support of the following people and organisations.

Firstly, thanks to my family, Sheena, James and Sarah for allowing me to put "a million hours" of time into the project. Thanks for putting up with me being a little grumpy whilst I was attempting to sort out methodologies for the project, and then allowing me the time to process the data to achieve this result.

Also, thanks to Dr Michael Barry, a respected colleague, who was of great assistance as a sounding board and supplier of good advice during the creation of this dissertation.

To my Supervisor, Dr Badri Basnet, your time and advice has been greatfully received over the last eight months.

Thanks to my employer BMT WBM for supplying the software and hardware to allow the dissertation to be created and printed.

And finally, thanks to those that supplied and/or allowed use of data for the project, SEQ Healthy Waterways, SEQ Catchments, Office of Urban Management and the Department of Natural Resources and Water. I hope the results from this dissertation will be of use to you and many other organisations.

1 INTRODUCTION

There is a requirement in South East Queensland (SEQ) for more consistent, regional scale information relating to the waterways and catchments of region.

SEQ waterways and catchments are under enormous and increasing pressure. More than 2.5 million people live within 50 kilometres of the coast. The region has one of the fastest growing populations in Australia. The population is expected to grow from a total of 2.73 million in mid-2006 to four million people or more in 2026 (SEQHWP, 2008).

This rapid growth will result in increased demands for reliable supplies of drinking water and increased recreational pressure on natural areas such as Moreton Bay and inland waterways. There will be greater demands for roads, housing, shopping centres and industrial estates. Without careful management, this will lead to further degradation of the SEQ waterways (SEQHWP, 2008).

Some of the consequences of declining waterway health, if nothing was done to improve management of the waterways, are:

- Increased risks of algal blooms affecting areas of SEQ. Algal blooms can be dangerous, sometimes fatal, to livestock, wildlife, marine animals and humans (Nova, 2008). Algal blooms can also affect the tourism industry, SEQ waterways are a major drawcard for international tourists,

- Reduced production from commercial and recreational fisheries, and aquaculture industries,

- Negative impacts on segments of SEQ's agricultural sector, and,

- Loss of biodiversity including seagrass beds, which relies on water quality and waterway health (SEQHWP, 2008).

A report card on SEQ waterways SEQHWP was released in October, 2008. It shows that some upstream rivers have improved health from last year. However, some freshwater streams in the lower river catchments could barely sustain marine life. The SEQHWP reported that increasing population and climate change were big threats to the health of the SEQ waterways, and called for action (Heger, U. 2008).

The necessity for enhanced management of these waterways and catchments has led to the need for an improved knowledge of the ecosystem. Any accurate information regarding waterways and catchments can assist with the management, health and remediation of those waterways. Therefore, any data that assists with this planning and continued maintenance of healthy ecosystems is highly valued.

It has been identified by planners and users of the existing waterways data that there is a need for information regarding of lengths of streams in existing and future land use types. Identification of lengths of stream order in land use types would enable better management of these waterways and assists with planning change, or lack of change for an area. This study provides valuable information on the lengths of waterways in land use categories. This information also allows for easier identification of waterways potentially in need of remediation (and easier costing of remediation), based on whether they lie within areas such as non-vegetated/urban (costs high) or grass/vegetated areas (costs lower).

There is also a need for more information about SEQ waterways with regard their relationship with the slope of the land over which they lie. Slope analysis of waterways assists in the estimation of sedimentation run-off and transport of pollutants through waterways. It also assists with such things as identifying nutrient export 'hot spots' that require treatment. Knowledge of slope of the land over which waterways flow can assist characterise land, and therefore help with the planning process. This study supplies information on the lengths of stream ordered waterways in newly devised slope categories.

Through this research project, information is created about waterways and catchments that was not previously available at a consistent, regional scale. Its aim was to extract lengths of stream ordered waterways with regard land use and slope, at a consistent regional scale, for the catchments shires of SEQ. This project derives the length and location of waterways throughout SEQ in various land use types along with length of waterways in various slope categories.

The detailed information in this project, such as areas of land use in catchments/shires, lengths of stream ordered waterways and areas of slope within catchments/shires will assist with the management of the waterways and catchments in the region. The information in this project builds on existing waterways data created by the author in a previous project for the SEQHWP.

1.1 Background

In 2005 BMT WBM was commissioned to undertake a Geographic Information System (GIS) based study for the SEQHWP. All of the major work, including project management, was undertaken by the author. The SEQHWP was established in July 2001 and is collaboration between government, industry, researchers and the community. These Partners work together to improve catchment management and waterway health of the eastward-draining waterways of South East Queensland, most of these waterways flowing into Moreton Bay (See Figure 1-1, Study Area Locality Map).

C:\BRH\USQ\ENG4111-2 Research Project\DRG\GIS_014_080826 Locality.wor Layout 2
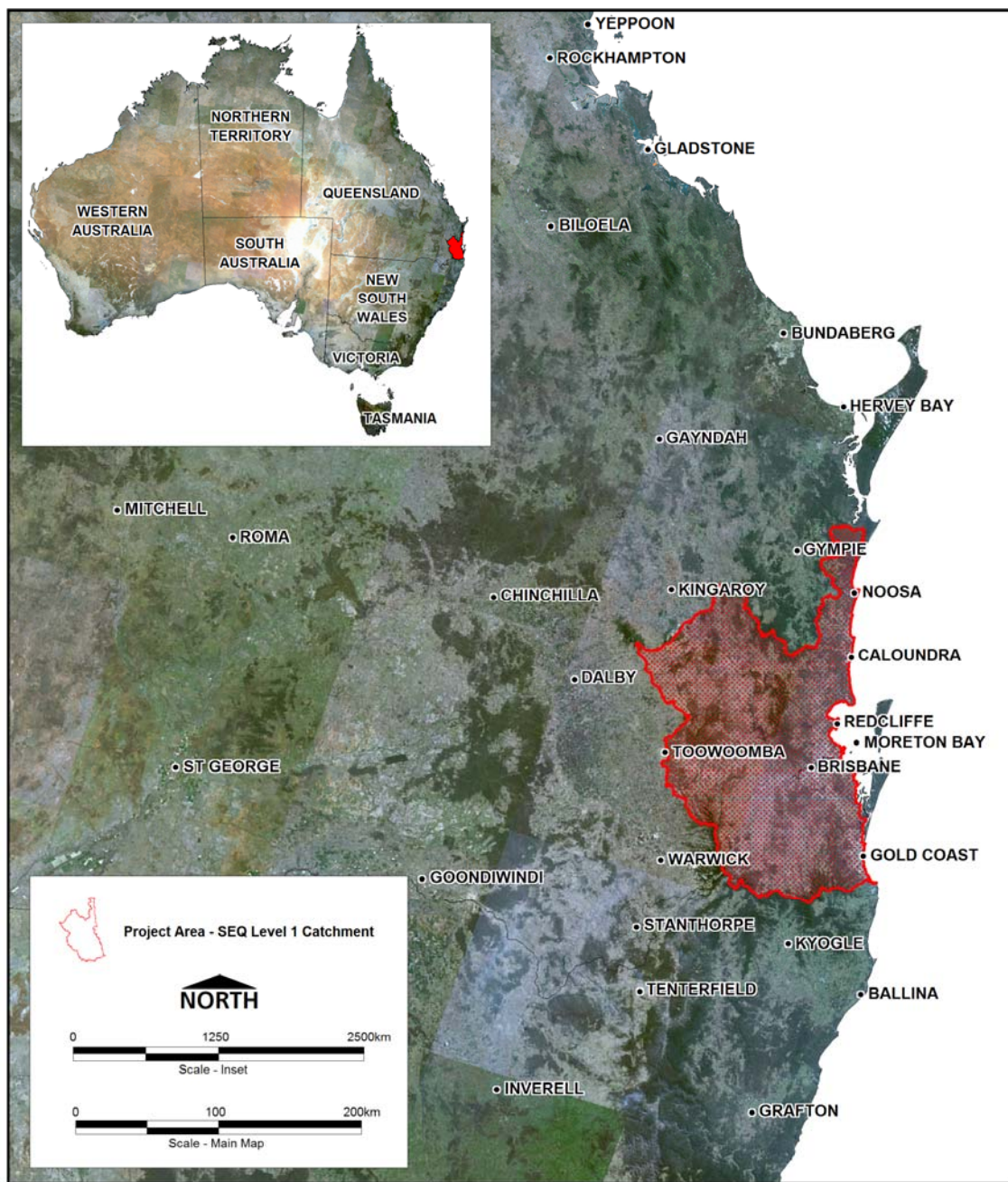
Figure 1-1   Study Area Locality Map

The scope of the previous commission was to create an attributed waterways and catchments network of SEQ (See Figure 1-2, Study Area Catchments). Amongst others, the attributes of the waterways included Stream Order, which is a classification based on stream size and location within a network. Specifically, headwater streams are deemed first order, second order streams commence at the junction of two or more first order streams, and so on (See Figure 1-3, Stream Order Classification). Figure 1-4, Example Stream Orders displays examples of waterways that fall into stream order categories. In SEQ the largest rivers (Brisbane and Logan) are stream order eight.
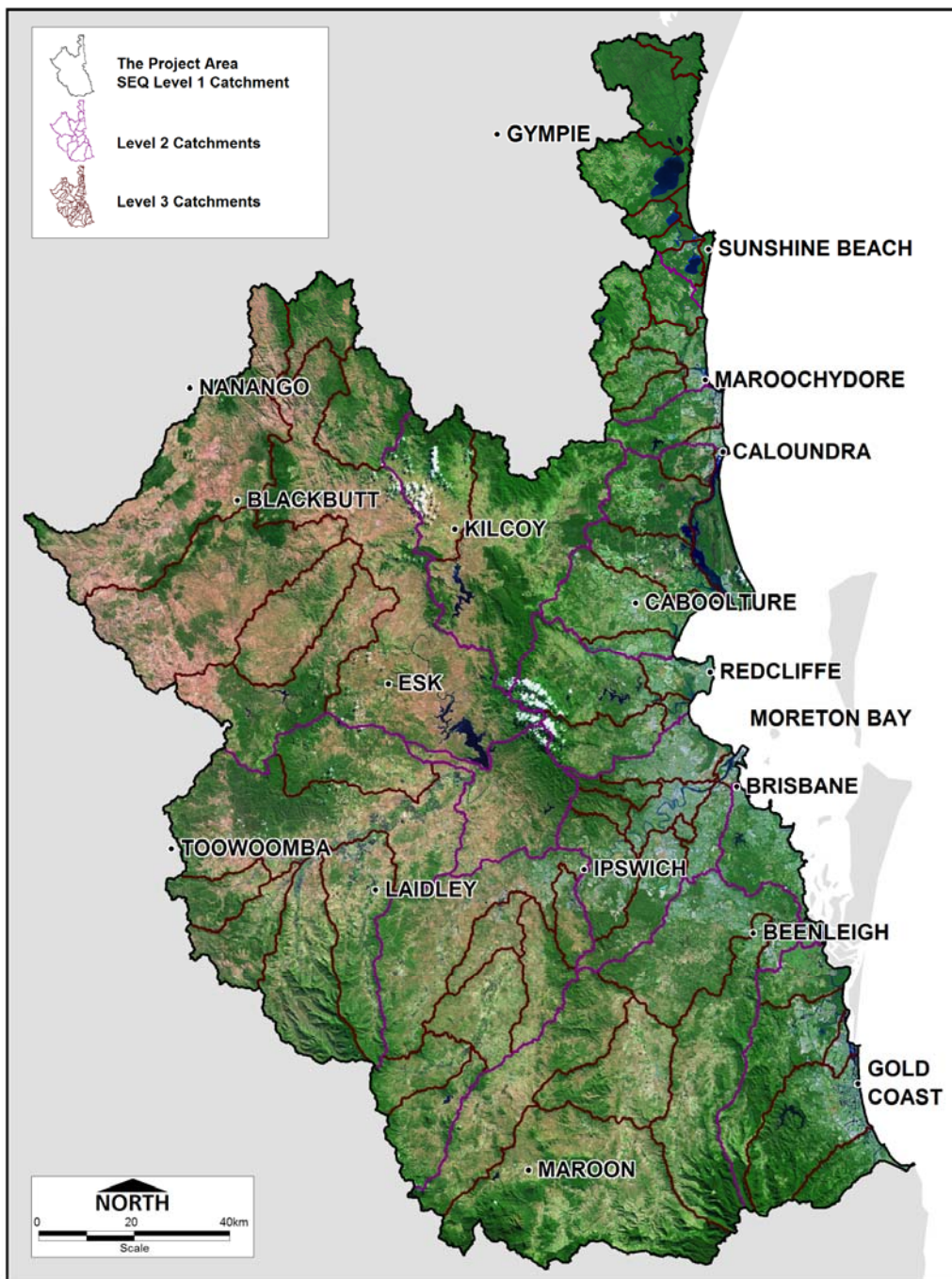
Figure 1-2   Study Area Catchments
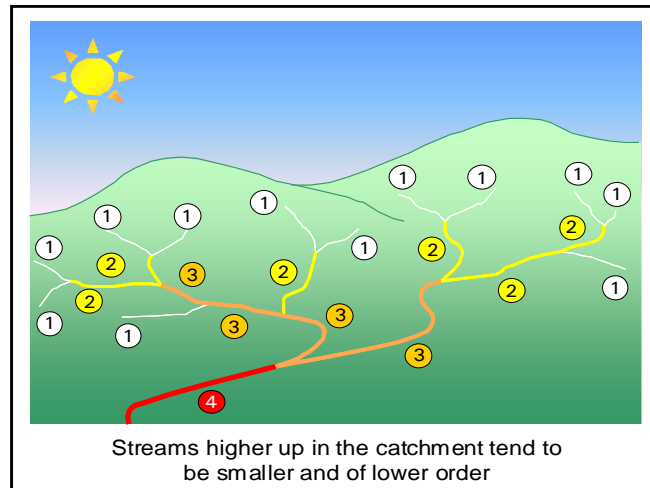
(Harris, 2005)

Figure 1-3   Stream Order Classification

Until the creation of this data, there was no consistent, attributed, broad scale GIS information for waterways and catchments network over SEQ, and therefore any existing GIS and hard copy data was limited in value. In contrast, the new data has wide use in assisting natural resource managers by providing a consistent waterway classification with greater detail and coverage than previously available for the region. This data is now used widely throughout SEQ by organisations such as catchment groups and Local Governments.

Stream Order 1   Stream Order 2   Stream Order 4

(Catchments Up Close, 2005)

Figure 1-4   Example Stream Orders

This work was entirely created the author of this study (other than some initial testing of software that was not used in the project, some field work to check results and some manual waterway creation in some flat areas where the DEM was unsuitable). The author was involved in every stage of the original project, from the gathering of raw data through to the final digital and hard copy outputs. For this current study, catchment waterways and DEM images from the previous study were updated and redrawn. This was mainly because of the availability of more recent information such as satellite imagery, but also, to ensure they conform with new images created for this study (See Appendix B – Drawings).

A thorough process testing various software and procedures was entered into for the original waterways and catchments project. This process allowed for the creation of the accurate DEM that is also used in this study. The DEM covers SEQ in the project area and was created from best available raw data. The data was sourced from Local and State Government departments and includes information such as; survey data, photogrammetry and LIDAR data through to Department of Natural Resources and Water (DNRW) 5 metre contours in rural areas. The DEM (See Figure 1-5, Study Area DEM) is still the best available covering the whole region. The DEM, and the waterways and catchments data created for the previous study are being used as the basis of this project, **South East Queensland Waterways - Land Use and Slope Analysis.** Also used in this study is newly sourced and created land use and slope data (See section 3.3.1).
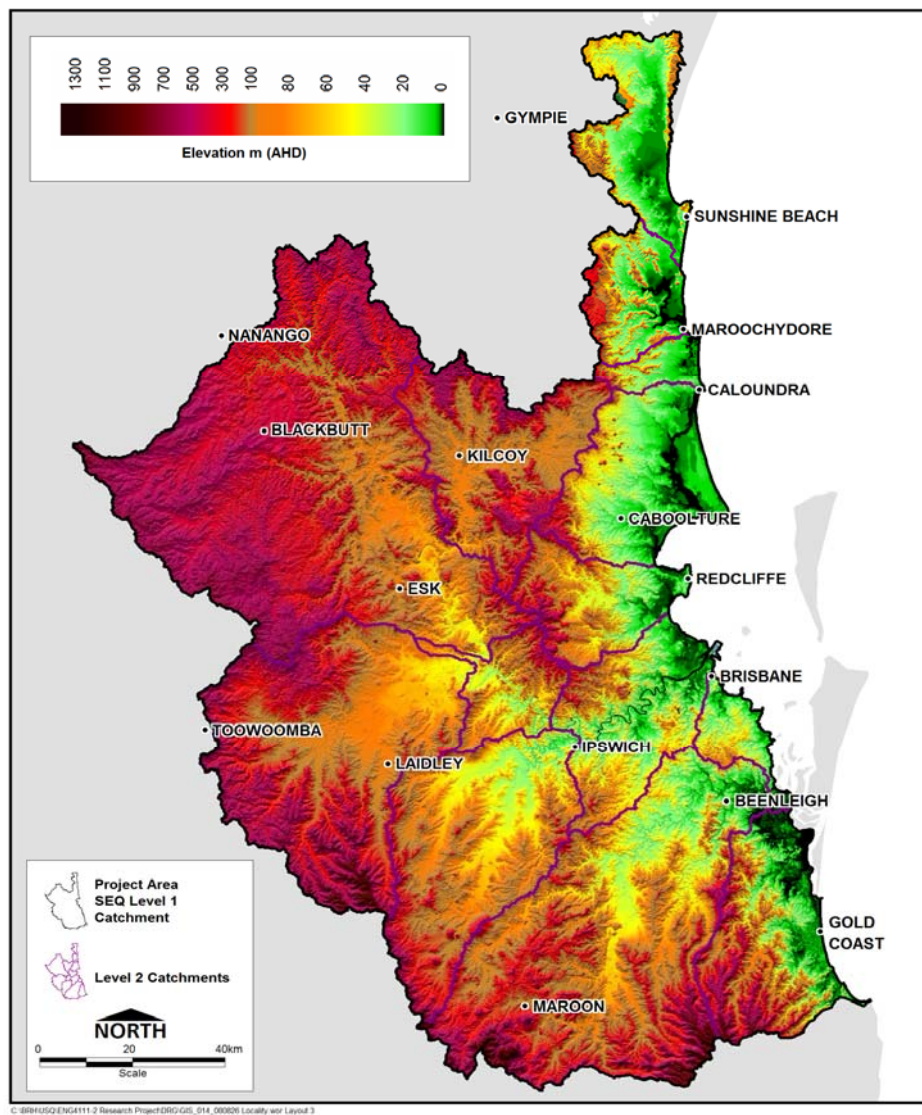
Figure 1-5   Study Area DEM

The information from the previous study is used widely throughout SEQ, but there is always a need for more information for the waterways and catchments of the region.

1.2 The Problem

Whilst the data created for the previous project has been of use to many organisations, there is always room for improvement. It became obvious that the more information that could be created for catchments and waterways, the better they can be managed. Planners and users of this data, such as catchment modellers, have identified waterways within land use categories (existing and future) and waterways within slope categories as areas requiring more detailed information.

Despite there being ample data sets of waterways, catchments, land use and DEM data in SEQ, they mostly cover just single (outdated) shire boundaries. They were created randomly with dissimilar (or no) attributes and at varying scales. There is a DEM of the region created by DNRW from 1:250,000 contour information, but it unsuitable for the creation of a detailed waterways and catchment information. Therefore, it is also less than suitable for creating new slope data for SEQ.

There has never been attributed data that covers all of SEQ at a similar scale (other than the waterways information created for the previous study), that allowed for detailed analysis and modelling of the area. Also, previous data did not allow for comparison of data between areas, or within areas such as catchments and shires.

There was also no consistent regional information about lengths of stream ordered waterways within the old (pre 2008) SEQ shire boundaries. Therefore, there was no consistent regional waterways information within any of the newly revised (2008) shire boundaries (See Figure 1-6, SEQ Shire Boundaries within SEQ Catchments Area).

Management of catchments at a catchment level is simpler than managing areas of catchment that sit within various shires. The relationship between the two is often unapparent, shires are defined by population values and development patterns whilst catchments are defined by geographical conditions. Different shires within a catchment may have varying policies for land use and waterway management but may have waterways flowing into the same rivers (Lee, Toonkel and Ilany, 2004). For this project area, they mostly flow into Moreton Bay. A better understanding of the waterways at a regional scale may assist co-operation between shires (Lee et al. 2004).
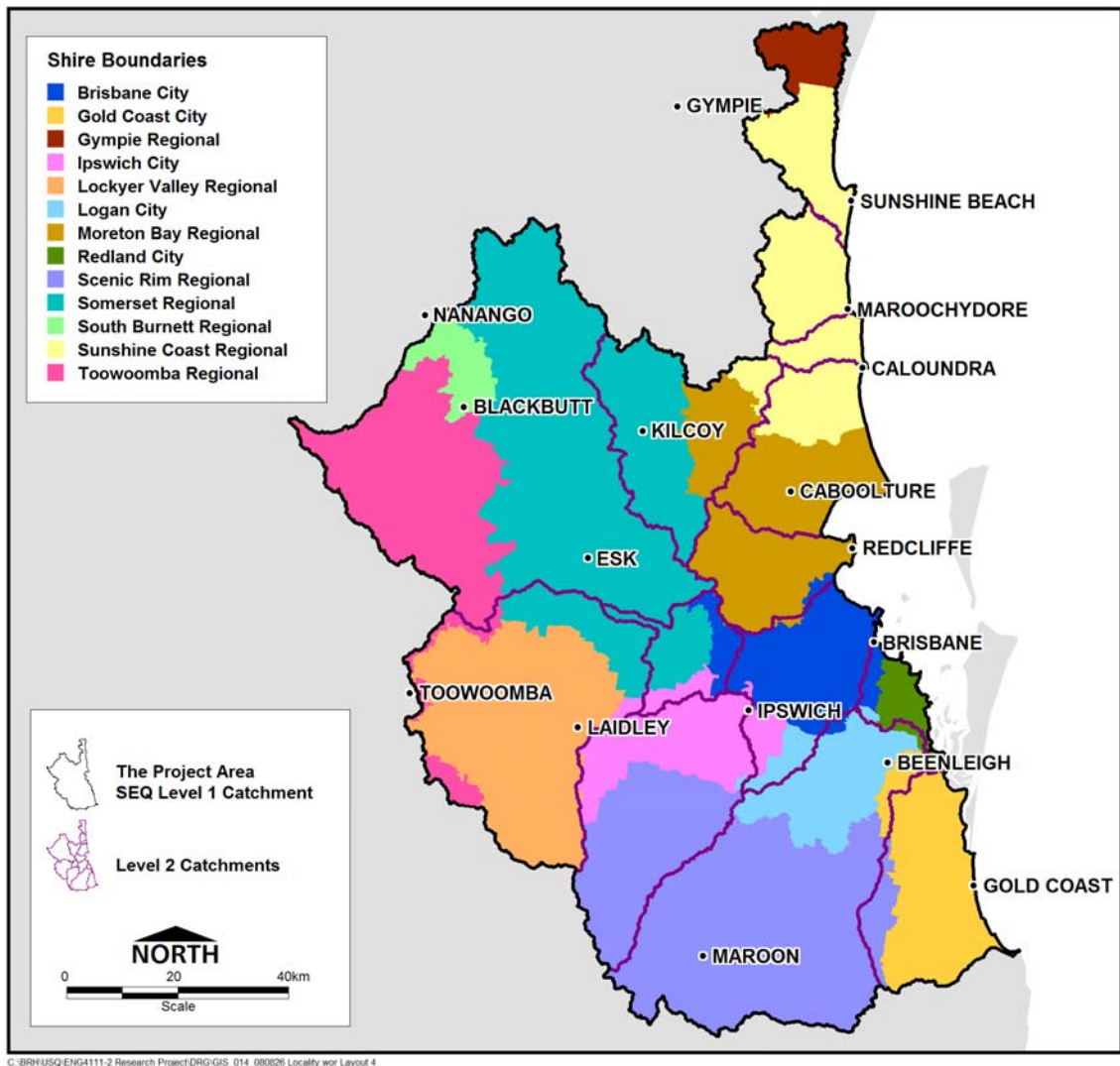
Figure 1-6   SEQ Shire Boundaries within SEQ Catchments Area

There has not, until now, been any analysis of waterways and catchments within land use and slope categories at a regional scale. There are several existing land use layers for SEQ, but there is no layer showing possible future a land use at a scale suitable for analysis with the waterways and catchments data.

Previously, there has not been a method to define or predict lengths of waterways within a catchment or shire, nor has there been a method of predicting the length of stream ordered waterways within land use categories.

Other than the previously described stream and catchments data, there has not before been waterways and catchments data for SEQ that anyone can pick up and study in hard copy format, or study via GIS at a regional scale (such as that in Appendix B – Drawings).

Identifying the problem to be researched led to the need to need to set out research/project objectives.

1.3 Research/Project Objectives

This research project identified what data/information would be of use in SEQ, and then researched procedures and techniques to process and analyse that data, along with creating new data as required. The last objective of the project was to present that data in a fashion for widespread use.

There has not been any waterway data gathered at a consistent scale covering all of SEQ other than the waterways and catchments created for the SEQHWP (2005). Therefore, the broad outline of this research project was to derive land use (existing and future) and slope information for SEQ, and then apply that consistent information to the waterways throughout the shires and catchments of the region.

The information derived for the SEQHWP provided lengths of stream order for each of the catchments in SEQ, but there is no information about length of waterways for each of the shires. Therefore one of the tasks of the project was to document the length of each stream order for each of the newly revised shire boundaries, which became available (from DNRW) in digital format in May, 2008.

The Major Objectives of this project were to:

- **Determine lengths of stream ordered waterways within existing and future land use categories in SEQ, and,**

- **Determine lengths of stream ordered waterways within slope categories in SEQ, and,**

- **Present (make available) the data for widespread use.**

To achieve the major objectives, the project also involved some other tasks, they included:

- Researching, requesting and seeking permission to use available data suitable for project,

- Identifying methodology and procedures to enable the project,

- Researching suitable software for each component of the project,

- Identifying classifications of land use, and classifications for slope analysis,

- Creating new GIS data sets as and when required, such as slope data and future land use data (based on projected land uses),

- Defining areas of land use categories in each catchment and shire. Defining areas of slope categories within each catchment and shire, and,

- Creating new hard copy drawings (See Appendix B – Drawings), that includes new data about the waterways and catchments of SEQ. Also included is previously known information such as catchment boundaries and total length of waterways. The drawings cover all SEQ catchments and the newly revised shire boundaries.

To present and discuss the tasks and objectives this research project is divided into six main parts, they are:

1. Chapter 2 - Literature Review, which reviews relevant literature that relates to the project,

2. Chapter 3 - Research Methodology, defines the data available, sourced, used and created for the project and then describes the methodology used in creation of the results, how the data was analysed and trends in the data,

3. Chapter 4 – Results and Discussion, gives some results for the project, and discusses the project and its implications. Appendix B, Drawings, displays detailed results for the project,

4. Chapter 5 - Conclusions, discusses achievements of the project,

5. Chapter 6 - Recommendations, discusses possible future options and work that could evolve from this project, and,

6. The project has a second major component, Appendix B – Drawings. It displays (in images) and describes (in tables) results from the project.

An important part of the project is researching methodologies used by others and reviewing available literature that may assist understand and improve techniques and procedures for the project.

2 LITERATURE REVIEW

There is an element of difficulty in any work that has not been attempted before and this project was no exception. It is particularly true in this project due to large coverage of the area (i.e. all of SEQ, and its catchments and shires) and the involvement of a large number of extensive datasets. There are difficulties in deciding methodologies, researching which data to include, deciding which software to use for the project and working out their capabilities.

Not only is the number and size of the data sets and the method of processing important, but also critical is the improved knowledge of the types of data, method of derivation etc. Therefore, any knowledge gained from available literature is valuable to assist understand these issues. This study starts with the review of literature to understand basic concepts such as slope and land use.

2.1 Slope Definition

Slope is a measurement of the steepness of a grid cell or area in three-dimensional space and is therefore is used on elevation surfaces, such as raster grids used in this project. Slope (in raster format) is calculated by averaging the slopes of the eight triangle faces that are formed from the surrounding nodes (MapInfo, 2008). (See Figure 2-1, Slope Calculation).
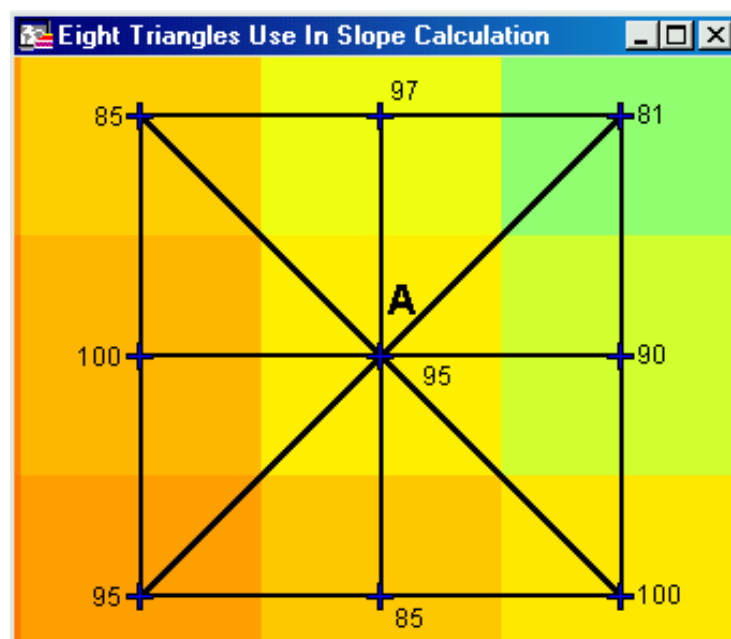
(MapInfo, 2008)

Figure 2-1   Slope Calculation

Slope identifies downhill slope for a location on a surface (A in Figure 2-1). Slope is calculated for each triangle in TINs (Triangulated Irregular Networks) and for each cell in rasters (ESRI, 2008). For a TIN, this is the maximum rate of change in elevation across each triangle. For rasters (as used in this project), it is the maximum rate of change in elevation over each cell and its eight neighbours (ESRI, 2008). Slope analysis takes an input surface raster (DEM) and calculates an output raster containing the slope at each cell. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain (ESRI, 2008). The output slope raster for this project was calculated as percentage slope.

When the slope angle equals 45 degrees, the rise is equal to the run. Expressed as a percentage, the slope of this angle is 100 percent. As the slope approaches vertical (90 degrees), the percentage slope approaches infinity (ESRI, 2008). (See Figure 2-2, Slope Definition).

Degree of Slope = θ Percent of Slope = $\dfrac{\text{Rise}}{\text{Run}}$ x 100

$\tan\theta = \dfrac{\text{Rise}}{\text{Run}}$

Rise

Run

Degree of Slope = 30   = 45
Percent of Slope = 58   = 100

(ESRI, 2008)
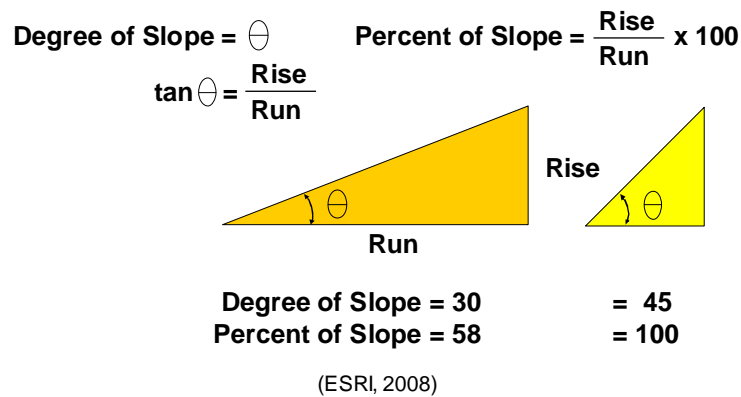
Figure 2-2   Slope Definition

Slope analysis is used on elevation datasets, as displayed in Figure 2-3, DEM, Slope Grid and Slope Contours (from the Brisbane River Catchment). The DEM represents elevation, the slope grid is slope of each cell (red steepest, blue flattest) and the slope contours are the slope grid divided up into categories (dark green is the steepest, light green flattest).

DEM (grid)   Slope (grid)   Slope (contours)
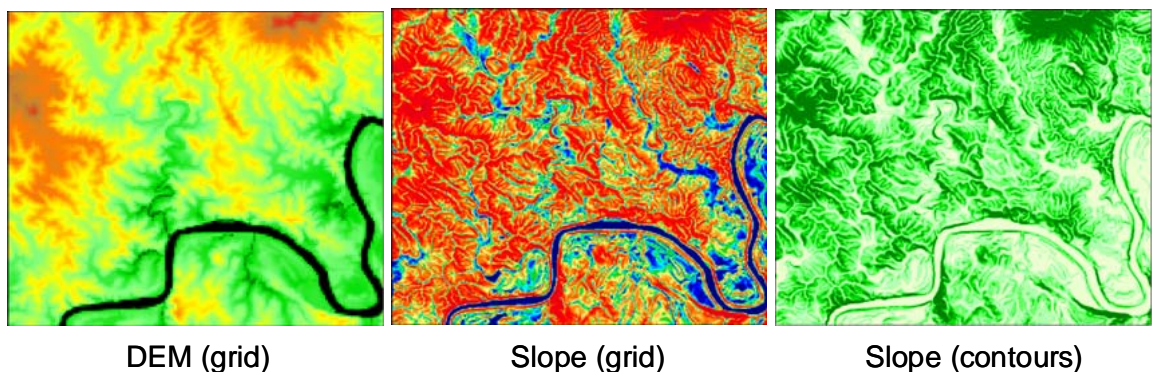
Figure 2-3   DEM, Slope Grid and Slope Contours

2.2 Land Use Definition

Land use is based on the functional dimension of land for different human purposes or economic activities. Typical categories for land use (used in this study) are non-vegetated, impervious road surface, crops and native forest. (Organisation for Economic Co-operation and Development (OECD), 2008).

Land use classification is a classification providing information on land cover, and the types of human activity involved in land use (SEQ Existing Land Use, 2007). It may also facilitate the assessment of environmental impacts on, and potential or alternative uses of land (OECD, 2008), such as SEQ Future Land Use. See Figure 2-4, SEQ Existing and Future Land Use (from the Brisbane River Catchment), this figure shows the impact of potential future land use, particularly in the red coloured areas (non-vegetated), and the lemon coloured areas (grassland).

Land Use (existing)   Land Use (future, 2026)
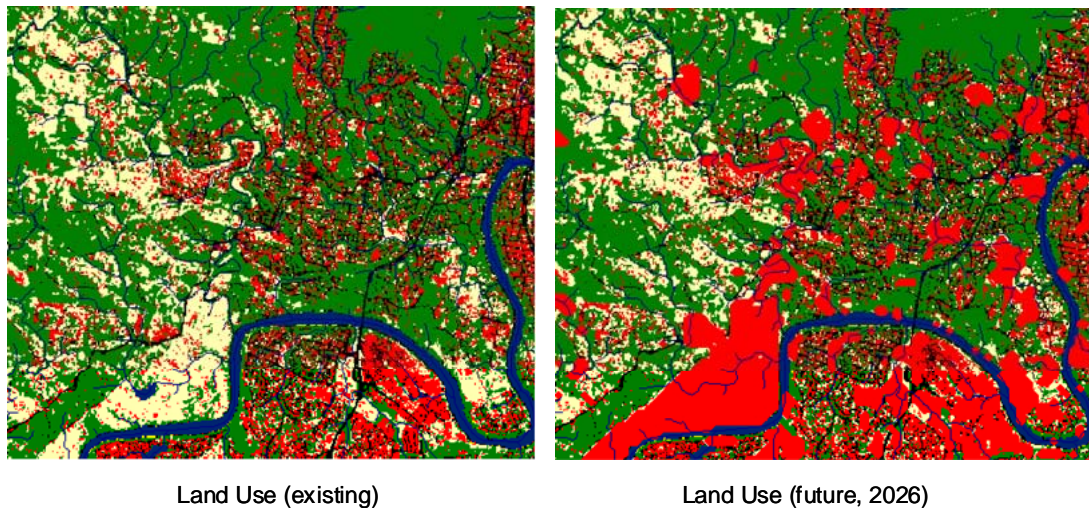
Existing land use (Terranean Mapping Technologies, 2007).
Future land use (Terranean Mapping Technologies, 2007 and BMT WBM/Office of Urban Management, 2008).

Figure 2-4   SEQ Existing and Future Land Use

For this study, land use and slope data are an important component. This data was required for analysis with the waterways and catchments of the region, to define more information for those waterways.

2.3 Importance of Analysing Waterways and Catchments

The waterways of SEQ are an important component of our environment and contribute to the character of the region. Waterways are made up of a broad combination of forms, including both ephemeral and continuously flowing headwaters. They meander and can have channelled sections, permanent and temporary freshwater wetlands, estuarine wetlands and estuaries (Logan City Council, 2008).

In addition to their environmental value as habitat for a wide variety of native plant and animal species (ranging from algae through to rainforest trees, from microscopic organisms and invertebrates to fish, birds and mammals), our waterways link directly with our major rivers and Moreton Bay. This linkage with downstream receiving waters, including Moreton Bay, means that chemicals, pollutants and other contaminants that find their way into drains and waterways influence the capacity of the waterways to support flora and fauna. This includes recreational and commercially valuable fish species, turtles and dugongs (Logan City Council, 2008). Run-off from land uses can have different effects on catchments and waterways, SEQ waterways in upstream areas health improved in 2007-2008 with rain and run-off from land. That same rain damaged areas of waterways downstream, by depositing picked-up sediment and pollution from non-vegetated land use areas such as industry and urban development (Greenfield, 2008).

Some of our waterways are not what they used to be, development of the surrounding catchments for housing, industry and transport, and changes to the amount and quality of run-off from rainfall, has reduced the capacity of our waterways to support the wide variety of wildlife that previously existed here (Logan City Council, 2008). The decline of the platypus is one example, the deep, shaded in-stream pools with high banks for burrows, which are the preferred habitat of the platypus, have mostly been filled by sediment. This sediment transported to the waterways by run-off from developed areas in the surrounding catchments (Logan City Council, 2008). In addition, reduced water quality and available food continue to make it difficult for our waterways to support these animals in any significant numbers (Logan City Council, 2008). A knowledge of land use areas through which waterways pass can assist identify sources of pollutants (Lee et al. 2004).

Knowing more about our waterways, and the surrounding land use, can assist improve the management of the waterways. This can also lead to improved identification of areas in need of remediation within land use areas.

2.3.1   Importance of Analysing Waterways and Land Use Categories

Land use and land management practices have a major impact on natural resources including waterways, soil, nutrients, plants and animals. Waterways, attributed with land use information can be used to assist develop solutions for natural resource management issues such as salinity and water quality. For instance, water bodies in a region that has been deforested or having erosion will have different water quality characteristics than those in areas that have been forested (Wikipedia, 2008). Vegetation gives protection to waterways from erosion, it can reduce the velocity in the waterway and assists to reduce erosion by binding the soil together (DNRW, 2004).

Identification of natural resources within a catchment is important in understanding the characteristics of the catchment and waterways. For instance, forested areas are typically the most benign of all land uses and provide shade, and therefore a greater potential for biodiversity. This can have regenerative effects on waterways. On the other hand, irrigated crop and pasture, where there is use of fertilisers and pesticides, presents a threat to waterways and can cause limitations to aquatic life and algal blooms. Land with no development, typically has impervious areas of around zero percent, at this level there is potential for healthy waterway life. However, agricultural land use also has impervious areas of around zero percent, but pesticides can be used. At a very low ratio of impervious conditions (around 10-15%) there is a noticeable drop in aquatic life diversity, and an increase in pollutants and flow fluctuation (Lee et al. 2004). These reasons give a better understanding of the need for an improved knowledge of waterways and the land use areas through which they flow.

Waterways with higher stream orders are larger, and often less accessible and have greater and more diverse conditions, and therefore greater potential for biodiversity and ability to potentially dilute pollutants. Lower ordered (headwater) waterways are often more accessible, and have fragile natural conditions. However, no waterways (in SEQ) can be assumed to be isolated from the impacts of development such as urbanised areas with their greater imperviousness and wastewater runoffs (Lee et al. 2004).

Wastewater runoff management can be assisted with more knowledge about waterways and the slope of the land over which they meander.

2.3.2 Importance of Analysing Waterways and Slope Categories

Polluted run-off from land is a major problem in waterways. Assessing the amount of waterways in various slope categories of the land can assist with techniques to manage that land. Valuable topsoil can be eroded from poor land management of sloping land, and this top soil, along with nutrients, fertilisers and pesticides are carried into the waterways that cut through the land, leading to poor water quality and less productive land. The runoff from the land (often into the headwaters, i.e. stream orders one and two) eventually has a major impact on our waterways and therefore also effects water quality in areas such as Moreton Bay.

Slope analysis of waterways can assist with improved management of land areas, helping to identify areas to prevent erosion and run-off and help identify lengths of waterways that may need remediation. This can then assist with planning any changes in land use to the area. Waterways in steeper areas are more likely to erode, therefore knowing more about the amount of waterways in slope categories can assist maintain and manage those waterways, reducing the risk of erosion. Slope is considered to be a most important factor on waterways due to its influence on soil characteristics (Newham et al. 2004).

The potential for surface runoff and soil erosion on sloping ground is strongly affected by land use and cultivation. Therefore the modeling of slope and land use changes is important with respect to the prediction of soil degradation and its on-site and off-site consequences. During periods of increasing pressure on the land, forests are cleared mainly on areas with low slope gradients and favourable soil conditions. In times of decreasing pressure, land units with steep and unfavourable soil conditions were taken out of production (Wiley, 2008).

Possible future land use needs to be considered with the slope of an area and therefore the impacts on the waterways of the area. Any analysis of waterways and slope categories can assist with the protection and management of waterways.

Studies that analyse slope and waterways are described in the following chapter.

2.4 Studies Using Similar Techniques

Whilst this project is somewhat unique, it does have similarities to some existing literature, including a section of a document from Miami Township, Clermont County, Ohio in the United States of America. This literature is called the Miami Township Comprehensive Plan (Rucker, et al. 2005). The Comprehensive Plan is designed as a guide for the town's preferred future direction and this is partly achieved by allowing the understanding of existing characteristics of the town.

The section of the Miami Township Comprehensive Plan with context to this project is called Existing Conditions (see Appendix E). It describes the physical characteristics of the town such as land use, waterways and slope of the land (See Figure 2-5, Miami Township Slope).
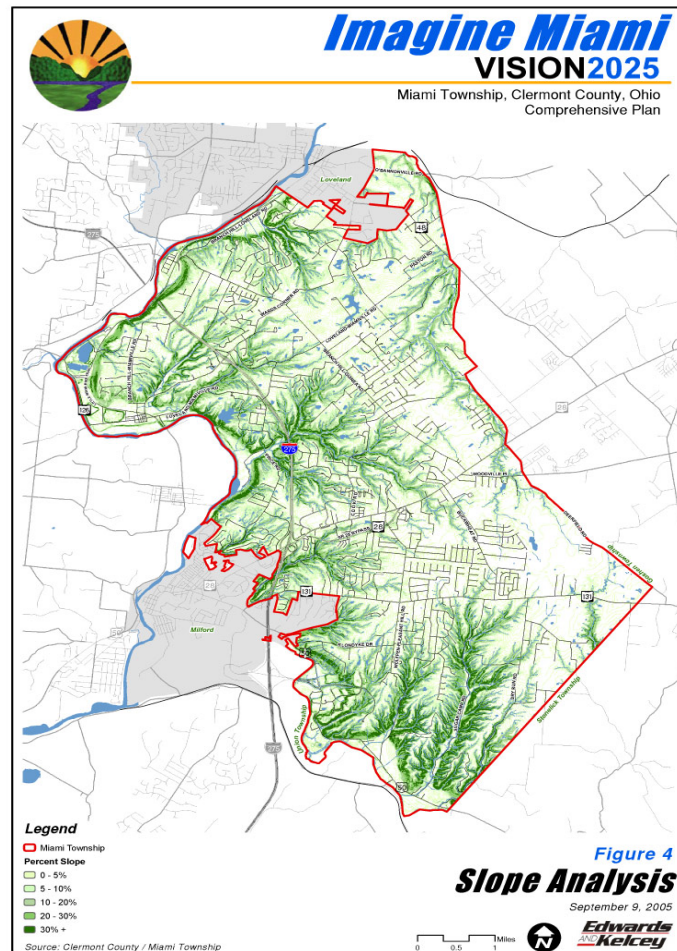
(Rucker et al. 2005)

Figure 2-5   Miami Township Slope

Another project with similarities to this project was a study undertaken in New South Wales, Australia. The On-site Risk Assessment System (OSRAS) by Chapman et al. (2004) (Appendix F: Slope Classification – Land Use) also has analysis of water run-off over land (in this instance with sewerage) within categories of slope. OSRAS is a management information system that accepts, processes and generates GIS-based datasets. Its intended users are catchment managers and local government. OSRAS allows the systematic identification and evaluation of the relative cumulative risks that decentralised systems of sewage management pose to downstream sensitive receptors. It integrates spatial, natural resource, infrastructure and operational data relevant to the performance of common on-site sewage management systems. It provides a framework for a cumulative, spatial assessment of sanitation risks, the setting of strategic sewage management goals and standards, and land capability planning (Chapman et al. 2004).

Rucker et al. (2005) use of categories of slope distribution in the Miami Township document is interesting, there seems to be no data (and therefore no land) within the area that falls into the 5–10% category (see Appendix E: Slope Classification – Land Use). This is interesting, since all of the data processed in the SEQ slope classification has slopes that fall within that category. In the Miami Township document the total of the percentage column adds up to 100%, but one would have to suspect an error in the data, or an error in their DEM and/or processing technique. A map in another part of the document shows a different category distribution to those in the document, and it includes land in the 5-10% category in the legend. Overall, there is inconsistency between the mapping and the reporting.

The distribution of categories in 5% groupings in the Miami document is reasonable. It is easier reading than 6 – 6 – 8 – 5 % class divisions used for OSRAS (See Figure 2-5, OSRAS Slope Hazard Class, Table 2-2, OSRAS Slope Classifications and Appendix F: Table 4.3). The classification system in OSRAS is based on class values cited in another document, however no supporting information was provided. Chapman et al. (2004) in OSRAS also say that 0-10% was used as a division by the Department of Land and Water Conservation in 1996. The 0-10% grouping potentially misses valuable information in finer groupings.

The groupings decided for this current study, the **South East Queensland Waterways - Land Use and Slope Analysis** project are a combination of the two studies, the 5% groupings of the Miami Township document (See Table 2-1, Miami Township Slope Categories) and divisions names similar to those described for the OSRAS document (See Figure 2-5 OSRAS Slope Hazard Class and Table 2-2, OSRAS Slope Classifications).

Slope groupings for this study are described in Table 3-2, Slope Classification and in the maps in the accompanying Appendix B - Drawings.

Slope Category Distribution	
Slope	**Percentage**
0-6%	69.6%
10-16%	12.9%
15-20%	8.4%
20-25%	10.0%
25% +	9.1%
Total	100.0%

(Rucker et al. 2005)

Table 2-1   Miami Township Slope Categories

SLOPE HAZARD CLASS

- CLASS 5 - GREATER THAN 25%
- CLASS 4 - 20% TO 25%
- CLASS 3 - 12% TO 20%
- CLASS 2 - 6% TO 12%
- CLASS 1 - LESS THAN 6%
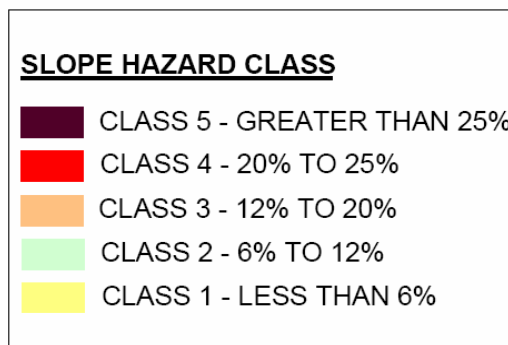
(Chapman et al. 2004)

Figure 2-6   OSRAS Slope Hazard Class

	Slope classification				
Limitation type	1 Little	2 Minor	3 Moderate	4 High	5 Severe
Slope %	<6%	6–12%	12–20%	20–25%	>25%

(Chapman et al. 2004)

Table 2-2   OSRAS Slope Classifications

The Miami Township and OSRAS documents are similar to this project in that both used the natural landscape (a DEM) as the basis for their slope analysis, and in the case of the Miami Township, they also considered land use as part of their planning. Both Miami Township and OSRAS used their researched GIS data to assist with decision making for the future, it is assumed that data from this project will be used in a similar fashion in SEQ.

Of concern with this SEQ project was the availability of suitable future land use data. Therefore, of note is the Miami township document which makes no attempt to predict future land use. "Land uses that may be planned for the future do not necessarily reflect the existing land use" (Rucker et al. 2005). Future land use information was deemed suitable for this SEQ project, with the rider that future land use is less reliable and predictive only, and will probably change as time goes by. OSRAS makes no mention of specific land use in the calculation of its results. This was because OSRAS was a study of contaminant release from on-site sewage treatment facilities and therefore land use would not be as important because these devices would mostly be focused in areas of one land use specification.

Methodologies of the Miami Township and OSRAS projects are similar to this project in that they both use GIS slope data to assist develop an outcome in conjunction with other GIS layers. This SEQ project, did not take into consideration soils data, as in the Miami and OSRAS documents.

The knowledge gained from the Miami Township Comprehensive Plan and OSRAS supports the methodology used in this study, justifying the need for, and the intentions of this project. Both of the reviewed documents were about researching data and creating outcomes, partly based on existing data sets. Like this research project, the results they created did not exist until the new project was completed. Both studies showed that an increased understanding of the characteristics of an area assist with the management of that area. The techniques used in these studies assist define the methods used and the need for data created in this study, allowing for a comparison with aspects of this study.

Neither of these studies considered methods of defining stream order, or length of stream ordered waterways within slope or land use categories.

2.5 Stream Order Length

Chow, Maidment and Mays (1988) discuss that Horton (1945) and Strahler (1964) were the first people to define methods of defining stream order. The main purpose of this work was to discover holistic stream properties from the measurement of various stream attributes (PhysicalGeography.net, 2008).

One of the first attributes to be quantified was the hierarchy of stream segments according to an ordering classification system (See Figure 1-3, Stream Order Classification). In this system, channel segments were ordered numerically from a stream's headwaters to a point somewhere down stream. Numerical ordering begins with the tributaries at the stream's headwaters being assigned the value one. A stream segment that resulted from the joining of two first order segments was given an order of two. Two second order streams formed a third order stream, and so on (Chow et al. 1988). Maidment (1992) discusses that, in general efforts to establish relationships between stream flow and network structure have not been very successful.

Whilst Horton, Strahler and Maidment discussed and defined methods for ordering stream networks, and defined relationships between stream orders, they do not discuss a methodology for defining actual lengths of waterways or their relationship to catchment, land use or slope areas. The Horton, Strahler and Maidment literature is about the relative size of waterways to one another. No literature was discovered regarding methods of defining waterway lengths (distance) within known areas.

To effectively manage data sets such as those described, there is a need to understand issues such as data storage, data manipulation and data processing. Standards and procedures for data management are required.

2.6 Setting Standards for Procedures for Data Management

This project had to deal with some very large data sets. Approximately 40GB of data was gathered, processed, created and stored. Strict processing, storage and naming protocols needed to be set early in the project. Foote and Huebner (1996) said that no matter what the project, standards should be set from the start. Standards should be established for both spatial and non-spatial data. For instance, naming conventions should apply for all data, and directories that store that data, such as this document and the many GIS data sets gathered and created for this project.

Issues to be resolved include the accuracy and precision to be invoked as information is placed in the project, conventions for naming geographic features, criteria for classifying data, and so forth. Such standards should be set both for the procedures used to create the dataset and for the final products (Foote and Huebner, 1996). The recognition of the value of this local data should also create pressure for its consistent collection and storage, helping to address difficulties of comparison over space and time. GIS has an important role to play in ensuring consistency and providing a means for the storage and display of local knowledge (Centre for Advanced Spatial Analysis (CASA), 2002).

Standards are not arbitrary; they should suit the demands of accuracy, precision, and completeness determined to meet the demands of a project. Regular checks and tests should be employed through a project to make sure that standards are being followed (Foote and Huebner, 1996). Data gathered at a regional scale should be noted and potential users need to be advised of any limitations in the data.

Standards for procedures and data should always be documented in writing or in the dataset itself. Data documentation should include information about how data was collected and from what sources (Foote and Huebner, 1996). For this project, metadata was created, it describes the project data (See Appendix D – Metadata).

Selection and acquisition of data for this project also required a considerable amount of study.

2.7 Data Selection/Acquisition

Sourcing appropriate data is in itself a major task. Data availability, accuracy, scale, attributes and formats can lead to the smooth processing of that information with accurate, reliable outputs.

Major issues common to all GIS projects, which must be allowed for to support decision making:

• Are the data available?

• Are they of sufficient quality?

• Can they be mapped in a GIS?

• Are they of the correct spatial resolution?

• Is the choice of indicators more dependent on data availability than relevance? (CASA, 2002).

For a project such as this, data availability was an issue. Local knowledge assists with data collection and collation. It is of crucial importance that the data are of as high a quality as possible. The ways in which they are collected are also significant in determining their usefulness in contributing to the analysis. Even data which are known to exist and to be of high quality may not be made available for use in a project. The scale of analysis and the format of the data are issues of concern for the application of a GIS. Some data are only available at relatively coarse spatial scales (CASA, 2002). Fortunately for this study, all data owners were pleased to supply their information, and some of that data was considered suitable for this project.

A GIS is a useful way of incorporating large quantities of data into a single analysis. This presents the cumulative picture for the chosen landscape, in a pragmatic, highly visual way. This aids understanding and decision-making among both expert and non-expert users. The reliability of these insights provided by a GIS depends to a large degree upon the quality, quantity and spatial scales of the available data, and the suitability of the methodologies and analyses applied. Environmental sustainability priorities may also be strongly related to physical geographic features, the potential impacts on which can be mapped in a GIS (CASA, 2002).

Use of the chosen data for a study such as this also required choosing the correct GIS software for processing of that information into the required outputs.

2.8 Software Selection

Software plays a crucial role in any major GIS project, selection of that software can allow for a timely and accurate delivery of that project. Software, and in particular, GIS software can be used for assembling and analysing large, multiple data sets. A GIS platform (or platforms) for a project such as this must provide all the capabilities necessary to support the project (GIS.com, 2008), such as:

- Geographic database to store and manage all geographic objects,

- Possibility of a Web-based network for distributed geographic information management and sharing,

- Desktop and server applications for:

  - Data compilation,

  - Information query,

  - Spatial analysis and geoprocessing,

  - Cartographic production,

  - Image visualisation and exploitation,

  - GIS data management.

- A comprehensive GIS platform that meets all geographic requirements (GIS.com, 2008).

Long-term flexibility and compatibility of software are also key considerations for a project such as this. Data must be created in a fashion that will allow future use for as many potential users as possible (Burke, 1995).

Software selection should also take into account local experience and existing digital data (if any), in addition to short-term needs of the project and long-term goals of the GIS information (Burke, 1995).

In summary, software selection literature (and all the literature reviewed) during the creation of this project assist justify methodologies used for the project. They also prove that there is value creating new data, such as that created for this project. The literature also shows that the data created for this project, if created in an appropriate fashion, could be of use long into the future. Therefore, it could also possibly be of assistance in future studies.

3 RESEARCH METHODOLOGY

3.1 Introduction

A large portion of this project involved deriving and delivering new data sets. There was difficulty in attempting something not attempted before, deciding on methodologies for a project such as this. Research was required to decide which data to include, deciding which software may best suit tasks within the project, working out capabilities of each of the software and to also research any existing studies, literature and data sets.

This project involved working with very large data sets and some software was found to be more suitable for some of the tasks than others, software was tested to find which was the most suitable for the project. Planning for the project also involved testing raw data to ascertain what processing times might be like.

Due to the size of the datasets, data was split into smaller areas to allow processing to proceed at an acceptable rate. For instance land use and slope data could not be processed at a regional (SEQ) scale, they needed to be split into smaller catchment areas. Previous work on Catchments Up Close (SEQHWP, 2005), proved splitting the large sets was the only way to process them at a suitable scale.

Dividing data into known boundaries such as catchments also assists with data storage, and for the straight forward creation of larger regional areas, by combining the smaller data sets. Some data sets were approximately 1GB each at all of SEQ scale, and therefore difficult to process, even for the fastest of desktop PC's.

This research project was divided into two parts. The first part of the project involved deriving the length and location of stream ordered waterways throughout SEQ in various existing and future land use categories.

The second part of the project derives the length of stream ordered waterways in various slope categories.

The creation of these data sets enables a comparison of the stream ordered lengths of waterways within land use types (existing and future), and also lengths of waterways within categories of slope of the land over which they lie. This comparison of data within catchments and shires is something that was not previously available, as there was no data to compare.

The project involved sourcing, seeking permission to use, analysing and creating GIS data. Data from the project is delivered via hard copy (see Appendix B – Drawings) and digital formats (See Appendix C – Electronic Copies of Dissertation). The project methodology needed to include how to process the data in the catchments for the area covered by the SEQHWP as well as each of the shires (areas within SEQ catchments) within the region. Any existing data (waterways and catchments information) was for catchments only. This study used the newly merged shire boundaries of SEQ which became available soon after the project commenced in early 2008. A plan was put into place to commence the project. Listed below is a summary of tasks that were involved in planning methodology for this project:

- Defining methodology for all proposed sections of the project, and timeframes for each task,

- The process of sourcing and creating data used for the project,

- Software research, testing data in different software,

- Choosing which software is best suited for each of the tasks, from initial land use and slope analysis, through to final presentation of data,

- The project planning involved researching available existing land use data and creating future land use data,

- Defining slope, percentage slope or degrees slope?

- Defining categories for slope analysis,

- Defining the type of data sets to use (vector or raster),

- Defining a process to analyse the results of the data development process,

- Comparing results of the project with other data created using the same technique,

- Describe how the data was developed and processed,

- Defining the final formats of output data,

- Creating drawings in Appendix B, and,

- Creating data graphs showing results of the project, including, waterways, catchments, land use (existing and future) and slope.

This is a very large study area for a project of this nature, so, a thorough understanding of the study area was required.

3.2 The Study Area

The study area for this project was the eastward draining (into Moreton Bay and the South Pacific Ocean) catchments of SEQ (See Figure 3-1, The Study Area). This area is over 23,000 km² and ranges in elevation from 0 m to almost 1400 m. There is almost 48,000 km of waterways in the region, and they are spread over 78 (Level 1, 2 and 3) catchments (See Figure 1-2, Study Area catchments). In turn, the catchments are spread over 13 shires in SEQ (See Figure 1-6, SEQ Shire Boundaries within SEQ Catchments Area).
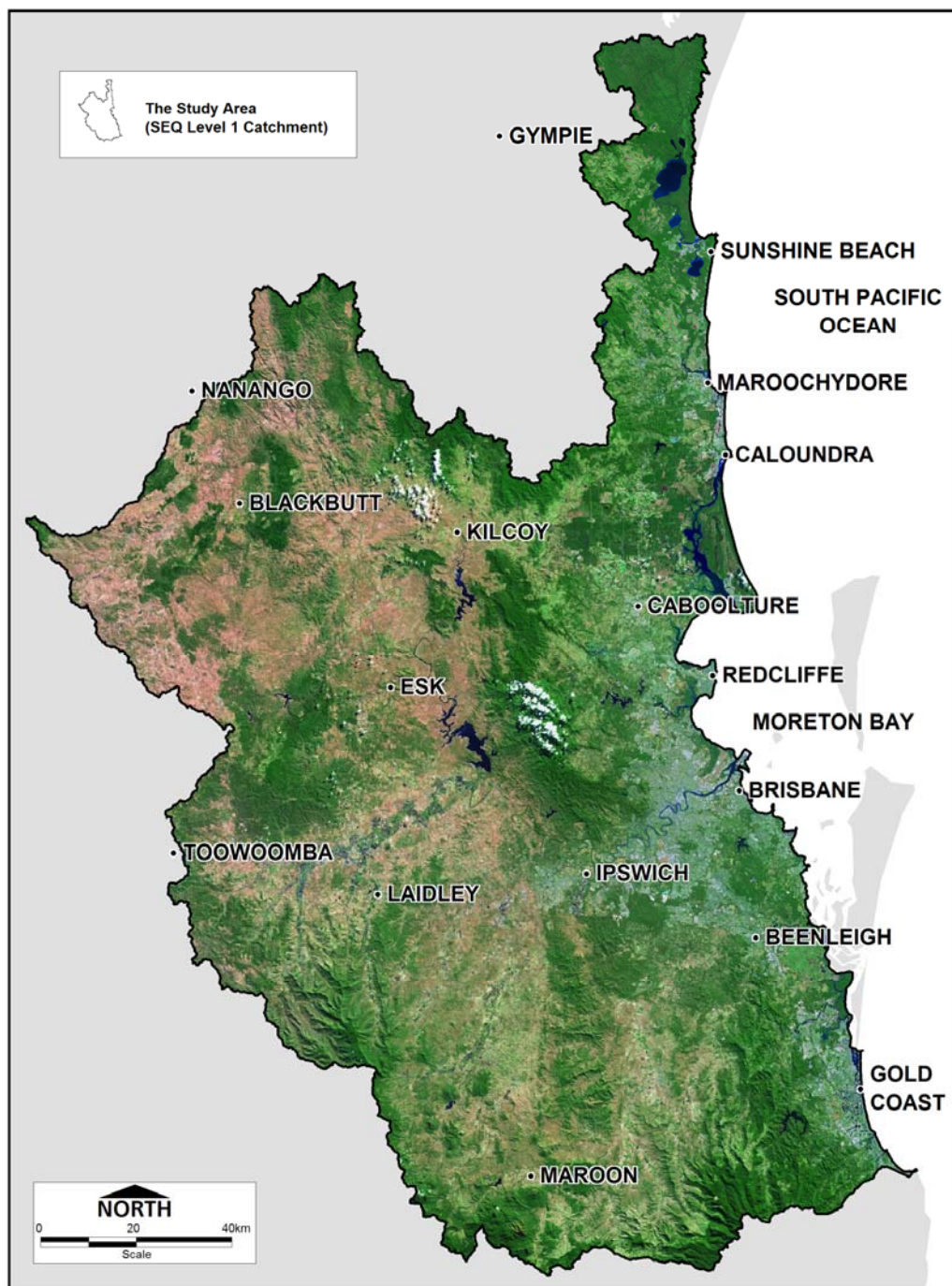
Figure 3-1   The Study Area

Acquiring suitable, accurate data at consistent scale for the study area was a major task for this study.

3.3 Data Acquisition

3.3.1 Data Source

The project involved sourcing and seeking permission to use available data, along with analysing and creating GIS data sets. Permission to use existing data such as the DEM, waterways, catchments, cadastre and satellite imagery was sought and granted from the appropriate bodies.
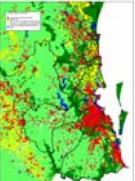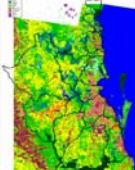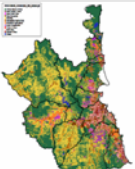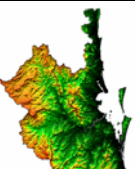
All known and researched sources of data were approached to supply data. Table 3.1 lists where the data used for analysis was from sourced from. It also lists data not used in the final processing/mapping. Some data was involved in initial analysis to test its suitability for the project.

There was no reluctance with data delivery from relevant owners of any of the data sought, as any newly derived data from this project will be of use to each of the existing data owners. They were pleased to supply their data and requested access to any newly created data.

Data was supplied from the following organisations:

- SEQ Healthy Waterways Partnership,

- Office of Urban Management,

- SEQ Catchments,

- Department of Natural Resources and Water, and,

- BMT WBM.

Table 3-1, Resource Analysis - Data Source, describes data accessed/created for this project.

Data	Data description	Data from	Data accuracy	Mapped from	Data date	Date received	Permission to use data	Data agreement signed	Suitable for use in final project
	Queensland Land Use Mapping Program (QLUMP) Land Use data	Department of Natural resources and Water (DNRW)	Statewide/ Broadscale Mapping, 80% accuracy	MODIS satellite imagery, PRIMARY attributes	2001	03/2008	Yes	Yes	No
	QLUMP Land Use data	DNRW	Statewide/ Broadscale Mapping, 80% accuracy	MODIS satellite imagery, SECONDARY attributes	2001	03/2008	Yes	Yes	No
	Office of Urban Management Land Use data (Current)	Office of Urban Management (OUM)	25 metre cells, mapped from 1999 DNR SLATS Data	1999 DNR SLATS Data	2001 – 2002	2002	Yes	No	No
	Office of Urban Management Land Use data (Future, 2026)	Office of Urban Management (OUM)	100 metre cells, mapped from 1999 DNR SLATS Data	1999 DNR SLATS Data with additional data added by BMT WBM and OUM	2001 – 2002, 2005	2005	Yes	No	Yes
	SEQ Catchments Land Use data	SEQ Catchments (SEQ Catchments)	10 metre cells	2.5m Spot Imagery, LC_TYPE attributes	2007	04/2008	Yes	Yes	Yes
	SEQ Catchments Land Use data	SEQ Catchments	10 metre cells	2.5m Spot Imagery, PMY_Class attributes	2007	04/2008	Yes	Yes	No
	SLATS Land Use data	DNRW	30 metre cells	Landsat 30m satellite Imagery	2007	04/2008	Yes	Yes	No
	SEQ Digital Elevation Model (DEM)	Bruce Harris, BMT WBM	20 metre cells	Various data, including data from Local Councils and DNRW	2004	04/2008	Yes	Yes	Yes
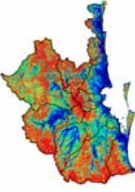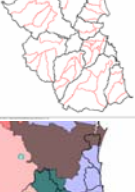
Data	Data description	Data from	Data accuracy	Mapped from	Data date	Date received	Permission to use data	Data agreement signed	Suitable for use in final project
	SEQ Slope Grid (Degrees)	Bruce Harris, created for project	Data accuracy	SEQ Digital Elevation Model	March, 2008	N/A	Yes	No	No
	SEQ Slope Grid (Percentage)	Bruce Harris, created for project	Data accuracy	SEQ Digital Elevation Model	March, 2008	N/A	Yes	No	Yes
	20 metre Satellite Imagery	(SEQ Catchments)	20 metre cells	2.5m Spot Imagery	2007	04/2008	Yes	Yes	Yes
	10 metre Satellite Imagery	(SEQ Catchments)	10 metre cells	2.5m Spot Imagery	2007	04/2008	Yes	Yes	Yes
	SEQ Waterways	Bruce Harris, BMT WBM	Created from 20m SEQ DEM	SEQ DEM	2004	2004	No	Yes	Yes
	SEQ Level 2 and level 3 Catchment Boundaries	Bruce Harris, BMT WBM	Created from 20m SEQ DEM	SEQ DEM	2004	2004	No	Yes	Yes
	SEQ Shire Boundaries (Note, image shown is	DNRW	N/A	DNRW data	2008	Expected in June 2008	Yes	Yes	Yes
	SEQ Cadastral Boundaries	DNRW	Varies	DNRW data	2005	2005	Yes	Yes	Yes

Table 3-1   Resource Analysis - Data Source

After compiling/creating relevant data for the project, a data pre-processing/data development process needed to be defined.

3.4 Data Pre-processing

3.4.1 Data Development Process

The process of data development for this project is illustrated in Figure 3-2, Data Development Process. It describes the process of data development, including how raw elevation data can be developed into many useful data sets such as catchment extent, waterways and slope. It also describes the process to use and create land use and slope data for this project.
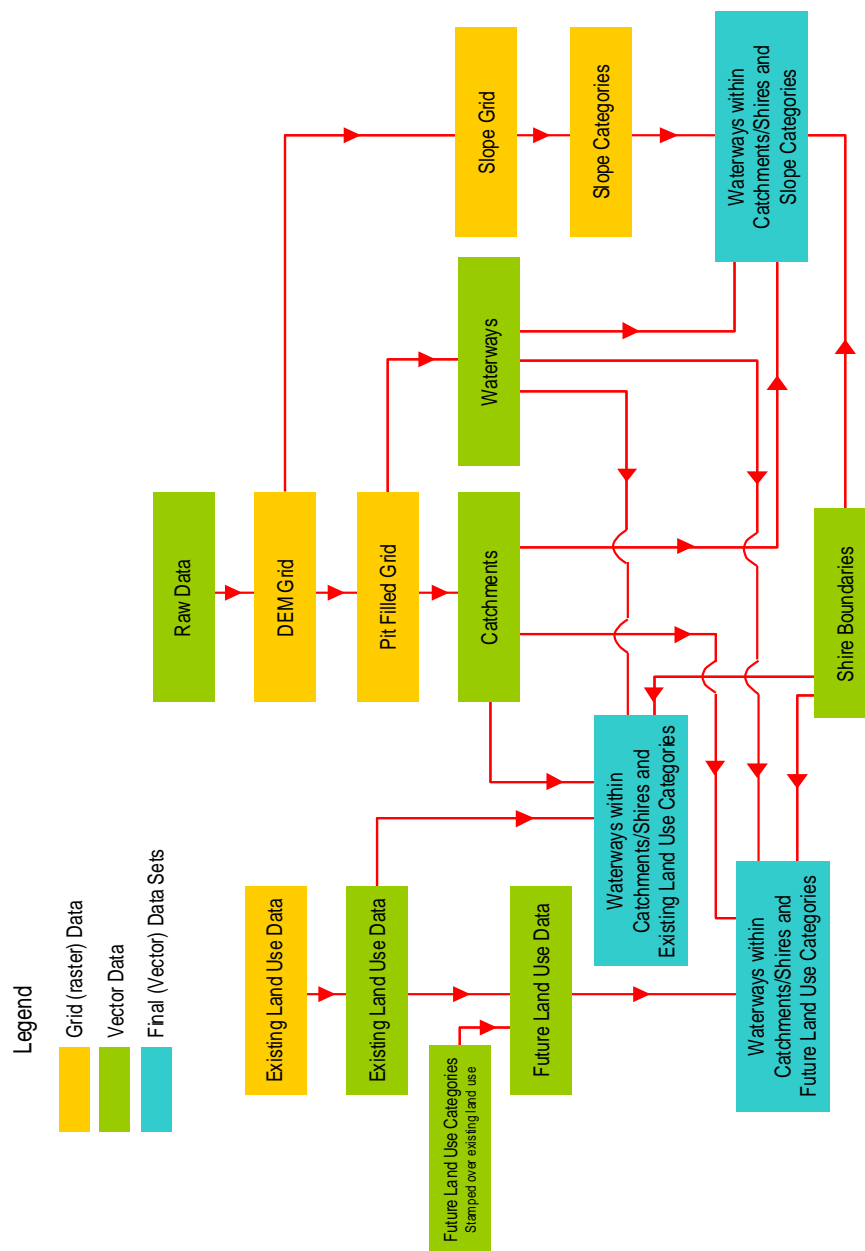
Figure 3-2   Data Development Process

Following data acquisition and creation of the data development process, general software suitable for the project needed to be chosen. This software selection is partly based on availability.

3.4.2 Project Software/Hardware

Software/Hardware used in this project, and/or used in the earlier stream order/catchment definition project includes:

- AutoCAD, (Computer Aided Drafting, CAD)

- MapInfo, (GIS)

- TAU DEM (GIS)

- Vertical Mapper, (GIS)

- 12D, (Civil Design)

- ArcGIS, (GIS)

- Adobe Photoshop, (Graphics)

- Adobe Illustrator, (Graphics)

- Corel Photopaint, (Graphics)

- Microsoft Word, (Documents)

- Microsoft Powerpoint, (Graphics)

- Microsoft Excel, (Spreadsheets)

- UltraEdit, (Data cleaning), and,

- BMT WBM desktop PC's, BMT WBM colour laser printers.

Following data acquisition and development of the data development process, and deciding on the chosen software for the project, detailed research was required for the chosen data, including land use data:

3.4.3 Land Use Data

There was a need for knowledge of lengths of waterways in land use types, for existing and if possible, future land use. Research was required into the available land use information, the data collection methods, data quality and the classification of land use categories.

Existing land use data for the project was obtained from various sources (see table 3-1, Resource Analysis – Data Source). After investigating the multiple data sets available for the project, it was decided that the land use data to be used was the information from SEQ Catchments. This data was found to be the most suitable, and importantly is the most recent (2007). It was created at the best scale (10 metre) and had the most applicable, recently decided, land use categories. Using this data will assist in take-up and on-going use of the data derived from this project.

The land use data for the future (2026) required further collaboration with the relevant authorities to decide its relevance to the project. Future land use data was not currently available at a scale suitable for this project. Land use data has been collected from the Office of Urban Management (OUM) at 100 m resolution. It shows 2026 land use, attributed with different land use categories to that of the data being used for the existing land use section of the project. Of concern was that the 2026 data was at 100 m resolution, and that did not allow the quality of output that was achieved with the resolution of the existing land use data. It was possible to 'group and stamp' future 100 m land use categories over the existing land use data, but some testing was required to ensure it was relevant, and that both data sets could be considered to be acceptable, at the new 'consistent scale'. (See Figure 2-4, SEQ Existing and Future Land Use).

Reclassification was required for the future land use data to ensure both existing and future land use represent the same classification types. Recording of this process and other information created during this project was of value, no metadata has been created for future land use data. This was an opportunity to create up to date metadata that was based on ANZLIC guidelines (ANZLIC, 2007).

Project outcomes allow for comparison of lengths of waterways in existing (and future) land use within shires and catchments in the study area. The next stage of the project involved creating slope data and defining lengths of waterways within slope categories.

3.4.4 Slope Data

There was also a need for more information about SEQ waterways with regard their relationship with the slope of the land over which they lie. Slope analysis of waterways assists in the estimation of:

- The relative amount of sedimentation and run-off in various areas throughout the catchments and shires, particularly when compared with land use information,

- The likely transport of these pollutants through streams,

- Prioritisation of remedial catchment works,

- Understanding of stream morphological evolution, and,

- Identifying nutrient export 'hot spots' for treatment.

There is no slope analysis data for the SEQ region at the scale of this project (20 m). The existing 20 m DEM is the basis for the slope analysis of the waterways. Slope data for this study could be created in two ways, they are:

Percentage Slope or Degrees Slope

Research was conducted into the type of slope analysis best suited for this project. For instance; should slope be percentage (%) slope or degrees slope. Most users of slope data refer to slope percentages, 1%, 5% etc. or as 1 in 100 (a 1% slope), therefore this project defined waterways compared with percent slope.

Once type of slope was decided, the next task was to decide categories of slope for the project. This enabled waterways to be divided into the defined slope categories:

Slope – Categories

Categories of slope to use for the project required further research, i.e. 1-5% slope, 5-10% slope, 10%-15%........., what would best assist potential users of the data.

Research, see Chapter 2 – Literature Review, experience and consultation with colleagues suggests 5% increments in slope would best suit this project, ensuring a valid data set would be delivered at the end of the project. Therefore, waterway slopes are divided into six categories, as described in table 3-1, Slope classification. However, of note, is that whilst <5% slope is considered to be little or low for a study such as this, 1% slope is considered to be steep in other forms of engineering studies such as River Hydraulics (Caddis, B. 2008, Pers. Comm.).

Slope Classification						
	1	2	3	4	5	6
Slope category	Little	Minor	Moderate	High	Very High	Severe
Slope %	<5%	5% - 10%	10% - 15%	15% - 20%	20% - 25%	> 25%

Table 3-2 Slope Classification

Based on: Table 2-1, Miami Township Slope Categories and Figure 2-6, OSRAS Slope Hazard Class.

After deciding on percentage slope and the categories for slope definition, testing was required to decide the most suitable software for slope analysis for the project:

Slope – Software

Research was conducted into which software best suits the creation of slope grids for the region. Tests showed that the difference between ARCGIS and MapInfo/Vertical Mapper to be minimal, both in output and the time taken to translate.

Therefore, MapInfo/Vertical Mapper was the software used for this project. The available DEM and the original waterways and catchments data were created in that format. Therefore, the use of MapInfo/Vertical Mapper saved time in data translation to ARCGIS format. Data sets of this size take a long time to process, so any time savings are of value.

This also suits the land use section of the project as that data is also available in MapInfo format. Figure 3-3, shows minimal difference in a cross section, A-A1, taken from ARGIS (red line) just visible in a couple of places below the Vertical Mapper cross section (green line).
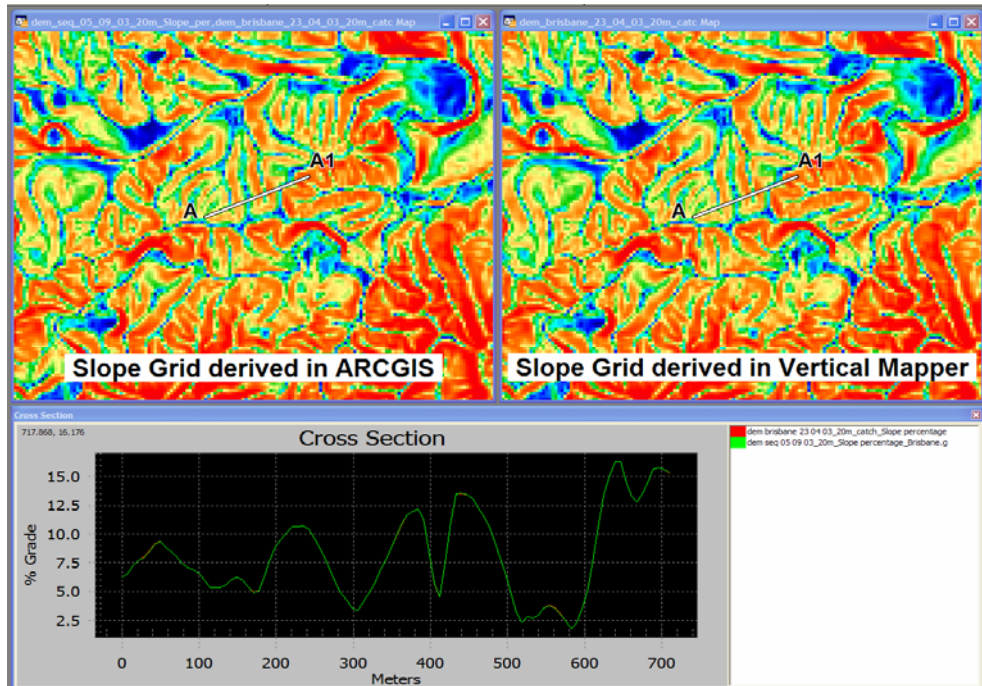
Figure 3-3   Slope Comparison

Project outcomes deliver length of waterways in SEQ within the defined slope classifications for all shires and catchments in the study area. After defining land use and slope data a detailed procedure, listing steps to create slope and land use data and their relationship to waterways information also needed to be defined.

3.4.5 Data Creation Methodology

Pre-processing for the project also required a general methodology for land use and slope data creation, due to size and complex nature of the task. Methodology was tested and from that the process was split into the following categories (each of the categories briefly discusses the process involved in that section of the project):

Slope Creation

- Create Slope grid from DEM of SEQ.

- Cut slope grid into manageable (enabling data to be processed) sized grids, mostly based on Level 2 and 3 catchments (bigger catchments such as the Upper Brisbane and Logan Albert were cut into smaller Level 3 areas),

- Contour (vector polygons) smaller slope grids into slope categories,

- Add area column to slope data,

- Populate slope area column (km²).

Land Use Information

- Decide on which land use data for project,

- Resize grids (see chapter 3.4.6),

- Create future land use from existing land use information, and future land use layers, ensuring consistency between data sets,

- Cut land use into manageable sized files (as with slope, based on catchments),

- Add area column to land use data,

- Populate land use area column (km²).

Waterways

- Save one copy for slope analysis and two for land use analysis (one for existing, and one for future land use),

Chapter 3.5.2, Waterway Data Analysis Methodology describes process to update/create waterways data with pre-processed land use and slope data.

An issue discovered at this stage of the project was that it would be impossible to process the land use data (at the available 10 m resolution) in the time prescribed for this study. The data would need to be resized.

3.4.6 Resizing Land Use Data

Following initial experimentation with the chosen land use data it was found that to process, classify and present the data within the time period prescribed for this project the data would need to be processed in smaller parcels and at a 20 m resolution.

The data could not be processed (with the exception of the Redlands and Mid Brisbane catchments) at a level 1 or 2 catchment level, ARCGIS and MapInfo/Vertical Mapper, along with high end PCs did not have the capacity to process the data at that level. Therefore, the majority of the catchments were processed at the level 3 catchment level and which was then pieced together to create the level 2 data and subsequently the level 2 data joined into level 1 information.

The process to create a test area for the 10 m to 20 m conversion was identified. It needed to be an area of reasonable size and with varying land use categories. The Maroochy Level 2 catchment was chosen and the data was resized in grid format and re-contoured into vector format.

Table 3-3, Information from 10 and 20 m land use shows the Maroochy land use information processed with the waterway information. This result showed that processing the data at 20 m resolution had little effect on the length of waterways within land use categories, therefore the 20 m data was used for this project. Resizing the land use information enabled processing of the data to proceed at a rate suitable for the project. It took two (and sometimes three) very quick PC's to process data for this project. Approximately 5000 hours of computer processing time, spread over more than 3 months.

Data was transformed in ARCGIS (MapInfo/Vertical Mapper would not translate the data) by, resizing the 10 m resolution grid to 20 m. This reduces the file size by a factor of 4 with minimal impact on the resulting output. The resolution of a grid is the size of the cells, the grids used in this project have square cells. The smaller the grid, the higher the resolution (it has more detailed the information depicted). The appropriate resolution depends on the application (MapInfo, 2008), in this project resizing the grid from 10 m to 20 m had little impact (See Table 3-3, Information from 10 and 20 m Land Use and Figure 3-4, 10 and 20 m Land Use Grids). Other data sets for the project such as the DEM and therefore, slope are based on 20m grids.

Whilst a very high resolution grid file is suitable for modelling and high quality output, a lower resolution version of the same file is often adequate for generating contour lines or regions/polygons (as used in this project). When the cell size of an existing grid is resized, a new value must be interpolated for every cell in the new grid. The original smaller cell grid is basically a network of evenly spaced nodes, and the new grid overlays this network by creating a new network consisting of more widely spaced nodes. The value at the new grid node is calculated using a bilinear interpolation (rectangular interpolation) of the four nearest nodes of the underlying, more closely-spaced grid (MapInfo, 2008).

Existing Land Use Information - Maroochy (MAR) Level 2 Catchment										
		Stream Order (km)								
Land Use Type	Land Use Area (km²)	1	2	3	4	5	6	7	8	Total
Canal	0.6	1.6	2.6	1.9	1.7	0	0	0	0	7.8
Cloud	0	0	0	0	0	0	0	0	0	0
Dryland Crop	0	0	0	0	0	0	0	0	0	0
Grass	147	120	59.6	31.8	8.9	1.7	0	0	0	222
Impervious Road Surface	18.6	12	5.8	3.1	1.6	3.5	0	0	0	26
Irrigated Crop and Pasture	77.5	88.5	59.2	20	10.5	3.7	0	0	0	181.9
Mine/Quarry	1	1.1	0.3	0.2	0.4	0	0	0	0	2
Native Forest	302.3	408.7	212.8	114.7	92.6	29.7	2.7	0.4	0	861.6
Natural Rock/Cliff	0.1	0	0	0	0	0	0	0	0	0
Non-forest Native Vegetation	5.7	4	2.6	0.4	1.2	0.4	0.2	0	0	8.8
Non-vegetated	54.3	39.7	21.9	9.9	3.8	1.7	0	0	0	77
Ocean	0.1	0	0	0	0	0	0	0	0	0
Plantation	0.9	1.2	0	0	0	0	0	0	0	1.2
Sand/Mud Bank	0.8	0.1	0.1	0.4	0.3	2	0	0.2	0	3.1
Tree Crop	17	22.3	9.1	4.6	2	0	0	0	0	38
Unclassified	0	0	0	0	0	0	0	0	0	0
Waterbody	9.7	14.7	11	6.5	3.7	11.2	13.9	14.2	0	75.2
Total Area of Land Use (km²)	635.6									
Total length of Waterways (km)		713.9	385	193.5	126.7	53.9	16.8	14.8	0	1504.6

Information from resized 20 m land use data

Existing Land Use Information - Maroochy (MAR) Level 2 Catchment (from 10m grid)									
		Stream Order (km)							
Land Use Type	Land Use Area (km²)	1	2	3	4	5	6	7	8
Canal	0.6	1.5	2.6	1.9	1.7	0	0	0	7.7
Cloud	0	0	0	0	0	0	0	0	0
Dryland Crop	0	0	0	0	0	0	0	0	0
Grass	147	118.9	60.4	32.5	8.9	1.32	0	0	222.02
Impervious Road Surface	17.95	11.6	5.5	2.9	1.5	3.3	0	0	24.8
Irrigated Crop and Pasture	77.9	89.9	59.7	20.5	10.5	3.9	0	0	184.5
Mine/Quarry	1	1.1	0.3	0.2	0.5	0	0	0	2.1
Native Forest	304.3	410.2	212.6	114.8	92.8	30	2.7	0.3	863.4
Natural Rock/Cliff	0.1	0	0	0	0	0	0	0	0
Non-forest Native Vegetation	5.7	4	2.6	0.5	1.2	0.4	0.1	0	8.8
Non-vegetated	52.3	37.9	21.1	9	3.8	1.6	0	0	73.4
Ocean	0	0	0	0	0	0	0	0	0
Plantation	0.9	1.2	0.1	0	0	0	0	0	1.3
Sand/Mud Bank	0.9	0.1	0.1	0.3	0.3	2	0.1	0.1	3
Tree Crop	17	22.1	9	4.5	2	0	0	0	37.6
Unclassified	0	0	0	0	0	0	0	0	0
Waterbody	9.7	14.6	11	6.5	3.7	11.4	13.9	14.3	75.4
Total Area of Land Use (km²)	635.35								
Total length of Waterways (km)		713.1	385	193.6	126.9	53.92	16.8	14.7	1504.02

Information from original 10 m land use data

Table 3-3   Information from 10 and 20 m Land Use
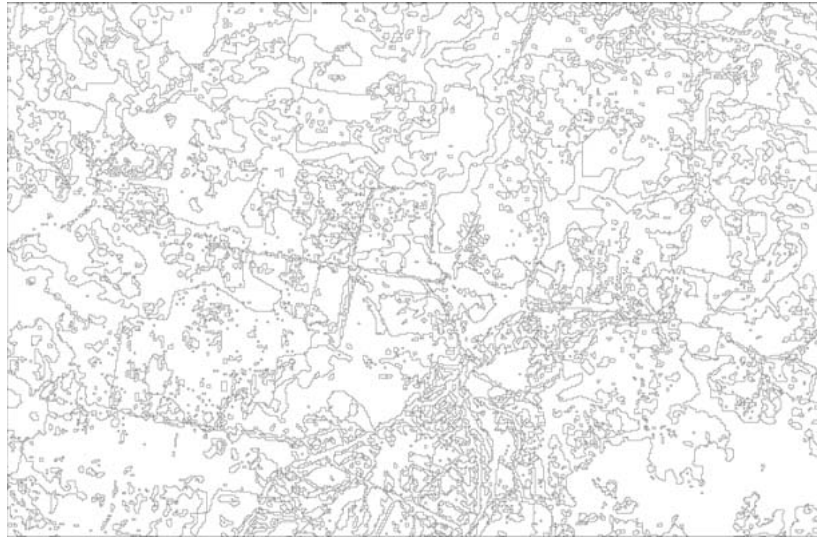
10 m Land Use
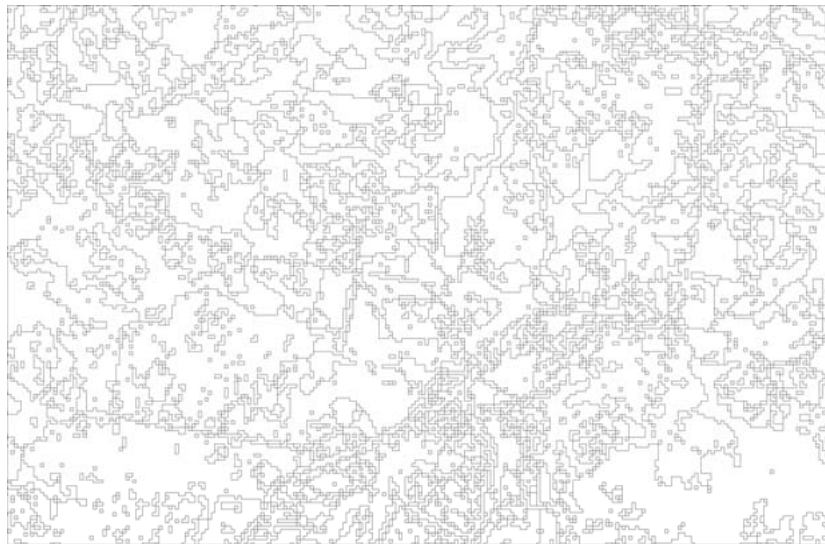
20 m Land Use

Figure 3-4   10 and 20 m Land Use Grids

Also required for the project was a layer of information defining future land use. This data did not exist at a scale suitable for the project and had to be created.

3.4.7 Future Land Use Creation

Research methodology pre-processing involved how to best create future land use information for the project. The future land use data was created for this project, and was based on the existing land use information collected from SEQ catchments (See Appendix G: Land Use Report).

Future land use information was supplied by BMT WBM/Office of Urban Management and included the categories high density urban, future urban, future industrial and new rural residential data. These data differed from the SEQ Catchments in the defined categories of land use and was reclassified to ensure a match in land use types. These data sets have been overlayed (stamped, removing any underlying data) on the existing land use layer. High density urban, future urban, future industrial were classed as non-vegetated, rural residential was classed as grass. The high density urban, future urban and new rural residential data sets are based on population projections created as part of the SEQ regional plan.

The future industrial data is less reliable, as it is a collection all potential future industrial land as proposed by the Department of State Development in 2006. This less accurate (broader scale) information accounts for the small loss of areas such as impervious road surfaces and waterbodies in the future land use information.

Figure 2-4, SEQ Existing and Future Land Use, shows an example of the future land use categories with their categories aligned to match the existing land use, and the resulting land use information. Appendix B – Drawings shows (and describes) future land use for all the SEQ catchments and shires.

Developing data sets, such as future land use, for the project enhanced the need to also define a process for naming and storage of the many data sets used.

3.4.8 Data Naming Protocols/Metadata

Whilst researching methodology for the project, it was decided, principally due to the large amount (in volume and file size) of data, and the possible on-going use of that data, to adopt data naming protocols. Naming conventions are of little interest to most readers, but they very important to users of the data. In particular, future users of the digital sets from this study will benefit from the naming protocols used. The following section outlines the naming structure for all spatial data and drawings created and entered into the project that may have on-going use. This includes naming conventions for regions (catchments and shires) and data types, for instance slope and land use.

All drawings in Appendix B - Drawings display a complete file path in the lower portion of the image.

All new and entered data for the project have metadata describing the data.

Data Naming Protocols

Spatial data is named according to the convention below. The convention aims to name data so that:

- It uniquely names the data item, and,

- It is easily identifiable by region and type.

The naming convention for data is:
<Region ID>.<Data Type ID>.<Catchment Level ID>.<Date ID>.<Ext ID>
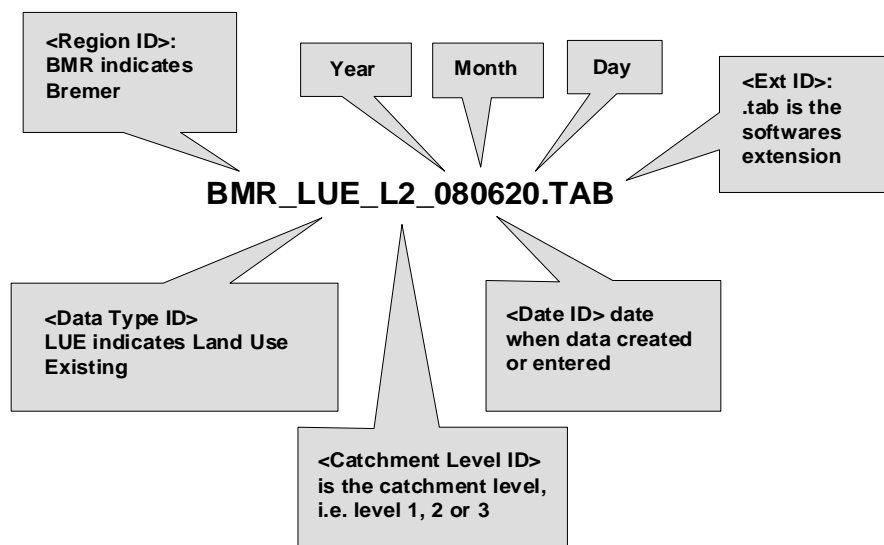
Figure 3-5   Data Naming Protocols

- If required, extra information was added to data title as shown below,

- The first four sections of title must remain as per protocols.

<Region ID>.<Data Type ID>.<Catchment Level ID>.<Date ID>.<Extra Information>.<Ext ID>
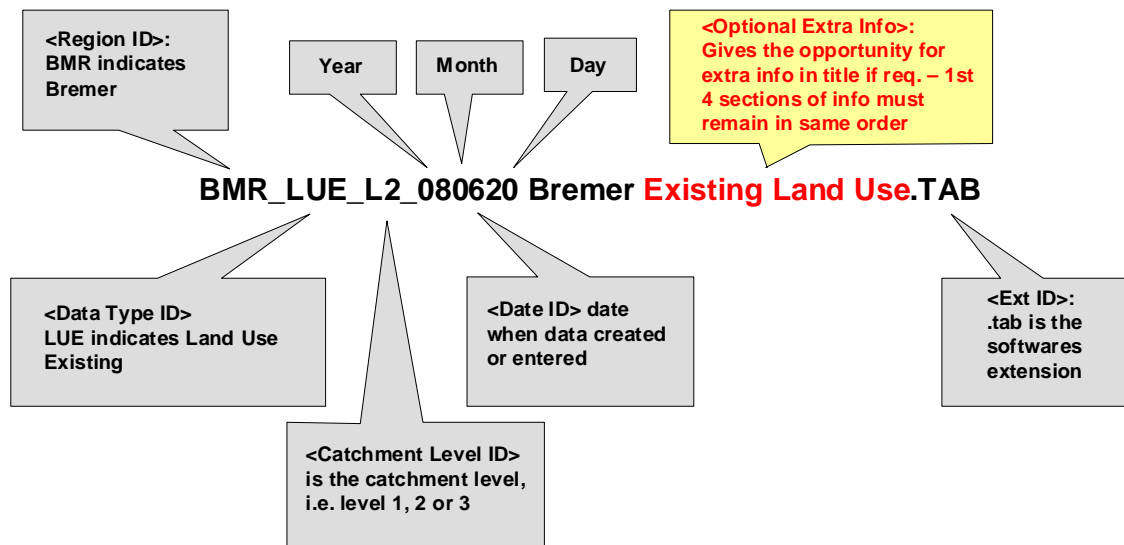
Figure 3-6   Data Naming Protocols (Extra Information)

Drawing Naming Protocols

Drawings are named according to the convention below. The convention aims to name drawings so that:

- It uniquely names the drawing,

- Identifies subject drawing created for, and,

- The drawing is identifiable by area.

The naming convention is as follows:

<Subject ID >.<Drawing Number ID>.<Date ID>.<Area ID>.<Ext ID>
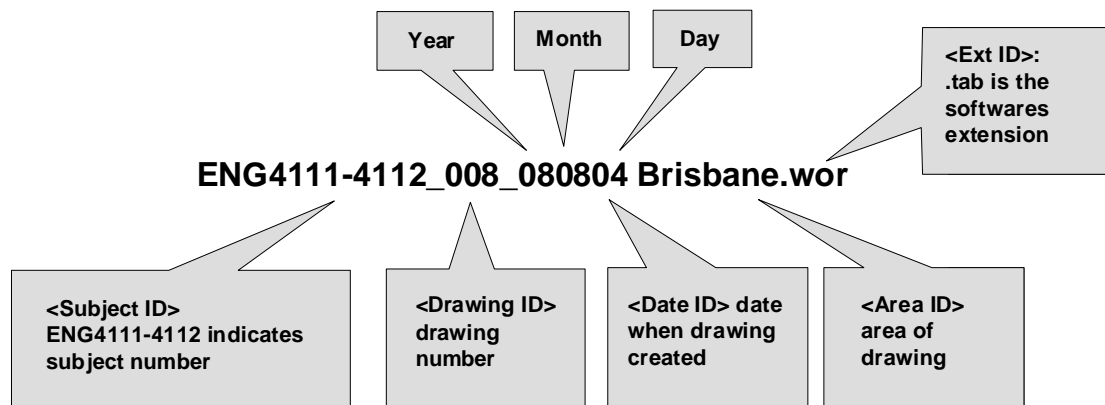
Figure 3-7   Drawing Naming Protocols

Region Identifiers

Region Identifiers (ID) are used in project data naming to define the area (catchment/shire) within which the data exists. Each ID consists of three letters relevant to the location of the data, for instance, 'TOO' for Toowoomba or 'BRI' for Brisbane. If data covers two or more catchments/shires, the data is stored with a three letter region identifier, for instance, 'SEQ' for South East Queensland.

These region identifiers also assist navigate through over 90 Microsoft Excel worksheets (See Appendix C – Electronic copies of Dissertation) that store the information created for this project about the waterways and catchments within SEQ (information shown on drawings in Appendix B – Drawings).

South East Queensland Catchments

Region Identifiers and Region

South East Queensland

SEQ	Level 1 South East Queensland

Bremer Catchments

BMR	Level 2 Bremer
BMC	Level 3 Bremer River
BDC	Level 3 Bundamba Creek
LWC	Level 3 Lower Warrill Creek
MWC	Level 3 Middle Warrill Creek
PCC	Level 3 Purga Creek
RCC	Level 3 Reynolds Creek
UWC	Level 3 Upper Warrill Creek

Brisbane River Catchments

BRI	Level 2 Brisbane River
BEC	Level 3 Brisbane Estuary
BCC	Level 3 Bulimba Creek
ECC	Level 3 Enoggera Creek
KCN	Level 3 Kedron Brook/Cabbage Tree and Nundah Creek
MCC	Level 3 Moggill Creek
NCC	Level 3 Norman Creek
OCC	Level 3 Oxley Creek
UBC	Level 3 Upper Brisbane

Lockyer Catchments

LOC	Level 2 Lockyer
BSC	Level 3 Buraraba and Spring Creek
FCC	Level 3 Flagstone Creek
LCC	Level 3 Laidley Creek
LCK	Level 3 Lockyer Creek
MMC	Level 3 Ma Ma Creek
TCC	Level 3 Tenthill Creek

Logan Albert Catchments

LGN	Level 2 Logan Albert
ACC	Level 3 Albert Creek
LLR	Level 3 Lower Logan River
MLR	Level 3 Middle Logan River
TBC	Level 3 Teviot Brook
ULR	Level 3 Upper Logan River

Maroochy Catchments

MAR	Level 2 Maroochy
CSC	Level 3 Coolum and Strummers Creek
EUC	Level 3 Eudlo Creek
MEC	Level 3 Maroochy Estuary
PPC	Level 3 Petrie and Paynter Creeks
UMC	Level 3 Upper Maroochy River

Mid Brisbane Catchment

MBR	Level 2 Mid Brisbane

Mooloolah Catchments

MLH	Level 2 Mooloolah
CTC	Level 3 Currimundi/Tooway Creek
MRC	Level 3 Mooloolah River

Nerang Gold Coast Catchments

NGC	Level 2 Nerang Gold Coast
BWC	Level 3 Broadwater Creeks
COO	Level 3 Coomera River
NER	Level 3 Nerang River
PIM	Level 3 Pimpama River
TAL	Level 3 Tallebudgera and Currumbin Creeks

Noosa Catchments

NSA	Level 2 Noosa
COA	Level 3 Coastal Creeks
CBH	Level 3 Lake Cooroibah
CKK	Level 3 Lake Cootharaba/Kin Kin
LWE	Level 3 Lake Weyba
NOO	Level 3 Lower Noosa
TEE	Level 3 Teewah Creek
UPN	Level 3 Upper Noosa

Pine Catchments

PNE	Level 2 Pine
NPR	Level 3 North Pine River
RED	Level 3 Redcliffe Peninsular
SPR	Level 3 South Pine River

Pumicestone Catchments

PUM	Level 2 Pumicestone
BEL	Level 3 Bells Creek
BRI	Level 3 Bribie Island
BUR	Level 3 Burpengary Creek
CAB	Level 3 Caboolture River
ELI	Level 3 Elimbah Creek
MEL	Level 3 Mellum Creek

Redlands Catchment

RDL	Level 2 Redlands

Stanley Somerset Catchments

SSO	Level 2 Stanley Somerset
KIL	Level 3 Kilcoy Creek
STA	Level 3 Stanley River

Upper Brisbane Catchments

UBR	Level 2 Upper Brisbane
BRC	Level 3 Brisbane River
CYA	Level 3 Cooya Creek
CRS	Level 3 Cressbrook Creek
EMU	Level 3 Emu Creek
MRG	Level 3 Marongi Creek
MON	Level 3 Monsidale Creek
UEB	Level 3 Upper East Brisbane

South East Queensland Shires (areas within SEQ Catchments)

Region Identifiers and Regions

BRS	Brisbane City
GCC	Gold Coast City
GMP	Gympie Regional
IPS	Ipswich City
LKY	Lockyer Valley Regional
LOG	Logan City
MBA	Moreton Bay Regional
RDL	Redland City
SCR	Scenic Rim Regional
SMR	Somerset Regional
SBR	South Burnett Regional
SCR	Sunshine Coast Regional
TOO	Toowoomba Regional

Table 3-4   Region Identifiers (Catchments and Shires)

Data Type Identifiers

Data Type Identifier (ID) refers to a designated three letter ID describing the type of data used in the project. The following table lists each ID for the data types used in the project.

Data Types and Data Type Id's

SLP	Slope Data
LUE	Existing Land Use
LUF	Future Land Use
CAT	Catchment
STR	Stream/Waterway
DEM	Digital Elevation Model

Table 3-5   Data Types and ID's

3.4.9 Metadata

Metadata was created for newly created datasets along with any other data entered into the project that may have future use (See Appendix D, Metadata).

3.5 Data Analysis

3.5.1 Project Methodology

Basic Methodology (and software used in that part of the project) for the project involved:

- Ensuring all data is in a common projection system that would suit the available software (ARCGIS/MapInfo/Vertical Mapper),

- Ensuring all data is in a common GIS software package (MapInfo/Vertical Mapper),

- Dividing land use data into catchment sized portions to enable processing (MapInfo),

- Creating future land use data at suitable resolution (ARCGIS/MapInfo/Vertical Mapper),

- Creating percentage slope grids for all of SEQ (ARCGIS/Vertical Mapper),

- Dividing percentage slope grids into catchment sized portions to enable processing (Vertical Mapper),

- Contour percentage slope grids into categories described in Waterway Slope Information, (Vertical Mapper),

- Define areas of existing and future land use categories in each catchment and shire (MapInfo),

- Define areas of slope categories within each catchment and shire (MapInfo),

- Analyse length of stream (based on stream order) within each land use category using queries, for all catchments and shires in SEQ (MapInfo),

- Analyse length of stream (based on stream order) within each slope category using queries, for all catchments and shires in SEQ (MapInfo),

- Create new land use and slope attributed streams data, defining length of each stream order in various existing and future land use and slope categories within all SEQ catchments and shires (MapInfo),

- Create database with results of results of streams in land use and slope categories (Microsoft Excel) (one tab for each catchment and shire),

- Reporting (Microsoft Word), and,

- Create Appendix B - Drawings (MapInfo, Vertical Mapper, Microsoft Excel, Adobe Illustrator, Adobe Photoshop, Microsoft Powerpoint).

After deciding on the basic methodology for the whole project, the next stage of the project was to define the procedure to analyse the project land use and slope data.

3.5.2 Waterway Data Analysis Methodology

Methodology for data creation using the project land use and slope data was split into the following categories:

Waterway Data Analysis, Existing and Future Land Use

- Trim/Split waterway data with land use vector data (See section 3.4.5),

- Update lengths of waterways column to allow for original data being cut be vector land use data (km),

- Add column to waterways data for land use type,

- Using GIS (MapInfo) query: Update waterways column land use type …..

- Query where column stream order = 1, 2, 3……. And column Land Use = Grass, Impervious Road Surface…….

- Calculate statistics, length of waterways (from query) based on waterway length column of waterways slope layer.

Waterway Data Analysis, Slope

- Trim/Split waterways with vector slope data (See section 3.4.5),

- Update lengths of waterways column to allow for original data being cut be vector slope data (km),

- Add columns to waterways data for slope categories type (i.e. Lower and Upper percentage categories),

- Update Lower and Upper slope columns in waterways layer with data from slope categories vector layer,

- Using GIS (MapInfo) query: Query where column stream order = 1, 2, 3……. and column Lower = 0%, 5%, 10%......

- Calculate statistics, length of waterways (from query) based on waterway length column of waterways slope layer.

Information from the Waterway Data Analysis, Land Use and Slope, then needed to be added to a spreadsheet.

Data Analysis, Land Use and Slope Data Spreadsheet

A spreadsheet, defining all SEQ catchments and shires in individual worksheets was created for the project, (See Appendix B – Drawings and for hard copy of each worksheet and Appendix C - Electronic copies of Dissertation for the electronic version of this data). Each worksheet in the Excel spreadsheet is split into categories that show:

- Area of each catchment/shire,

- Total length of waterways per catchment/shire,

- Maximum/minimum elevation of each catchment/shire,

- Area of each type of land use within each shire/catchment,

- Area of each category of slope within each shire/catchment,

- Length of waterway within each category of slope within each shire/catchment, (all stream orders),

- Length of waterway within each category of land use within each shire/catchment, (all stream orders),

- Total the length of waterways, based on all stream order categories within each catchment/shire for land use, and,

- Total the length of waterways, based on all stream order categories within each catchment/shire for slope.

See Chapter 4 – Results and Discussion, Figure 4-22, Typical Catchment/Shire Information on Drawings. This figure gives a detailed explanation of data available in the spreadsheets in Appendix C – Electronic copies of Dissertation.

4 RESULTS AND DISCUSSION

4.1 Waterways (Catchment, Land Use and Slope Areas) Data Results and Discussion

The initial goals of this project were to derive lengths of waterways within land use categories (existing and future) and slope categories.

The detailed results are mostly displayed in map and tabular formats in Appendix B – Drawings. The following pages show graphs that also represent results from the study, along with examples of the results displayed in the drawings appendix.

As the project studied over 90 catchments and shires, it gave the opportunity to compare results from these areas. The results show a clear pattern of waterway lengths in land area and land use category areas. Some interesting results were obtained from this study. The study successfully processed the length of waterways (and the length of stream ordered waterways) at various catchment levels, 1, 2 and 3.

The study found that it is possible to predict the length of waterways (See Figures 4-1, 4-2 and 4-3) and the length of waterways (See Figures 4-4, 4-5 and 4-6) within any known land area. The analysis of results of waterway lengths from this study revealed that there is a trend regarding lengths of waterways and their relationship with areas of land. The study developed procedures to:

- Predict the length of waterways within a catchment area,

- Predict the length of stream ordered waterways within a catchment,

- To predict the length of stream ordered waterways within any land use area, and therefore,

- It is also possible to predict the length of stream ordered waterways in any known area (these results are also discussed and confirmed in section 4.2, Validation of Key Findings).

In figures 4-7, 4-8 and 4-9 correlation analysis is used to measure the strength of association between the numerical variables. For this project, the lengths of waterways are correlated with areas of land. This measures the strength of association that exists between the numerical variables (Levine, Berenson and Stephan, 1998). Figures 4-7, 4-8 and 4-9 show that as the area of land increases, overall length of waterways also increases.

Figures 4-7, 4-8 and 4-9 also show that the length of stream order 1 waterways (km) are approximately equal to area of land (km²), length of stream order 2 waterways (km) equal to half the area of land (km²), and that stream order 3 waterways (km) are equal to one quarter of the area of land (km²). For clarity purposes, only stream order 1, 2 and 3 waterways are shown on the plots.

The data graphs in the following sections display typical results from the project, including information about waterways, catchments, land use (existing and future) and slope. Due to the amount of detailed results (lengths of waterways etc.) generated for the project, the majority of the results for the study are presented in Appendix B – Drawings.

See 'Figure 4-22, Typical Catchment/Shire Information on Drawings', and 'Figure 4-23, Typical Detailed Catchment Information on Drawings', for examples of results included in Appendix B.

The results and discussion in this section are divided into three categories, **Catchments, Land Use and Slope**:

4.1.1 Catchments, Results and Discussion**:**
- Length of Waterways in Catchments for:
  - Overall SEQ,
  - Typical Level 2 Catchment, and,
  - Typical Level 3 Catchment.
- Areas of Catchments/Length of Waterways for:
  - Overall SEQ,
  - Typical Level 2 Catchment, and,
  - Typical Level 3 Catchment.
- Areas of Catchments/Length of Stream Ordered Waterways for:
  - Overall SEQ,
  - Typical Level 2 Catchment, and,
  - Typical Level 3 Catchment.

4.1.2 Land Use, Results and Discussion**:**

- Areas of Land Use (Existing and Future) Categories in SEQ for:
  - Overall SEQ Existing Land Use,
  - Overall SEQ Future Land Use, and,
  - Overall SEQ Land Use (Existing and Future).
- Areas of Land Use Categories/Total length of Waterways for:
  - Overall SEQ.
- Land Use Categories/Lengths of Stream Ordered Waterways for:
  - Overall SEQ.

4.1.3 Slope, Results and Discussion**:**

- Areas of Slope in SEQ for:
  - Overall SEQ,
  - Level 2 Catchment, and,
  - Level 3 Catchment.
- Slope Categories/Lengths of Waterways for:
  - Overall SEQ.
- Areas of Slope/Lengths of Stream Ordered Waterways for:
  - Overall SEQ.

4.1.1 Catchments, Results and Discussion:

Lengths of Waterways in Catchments:
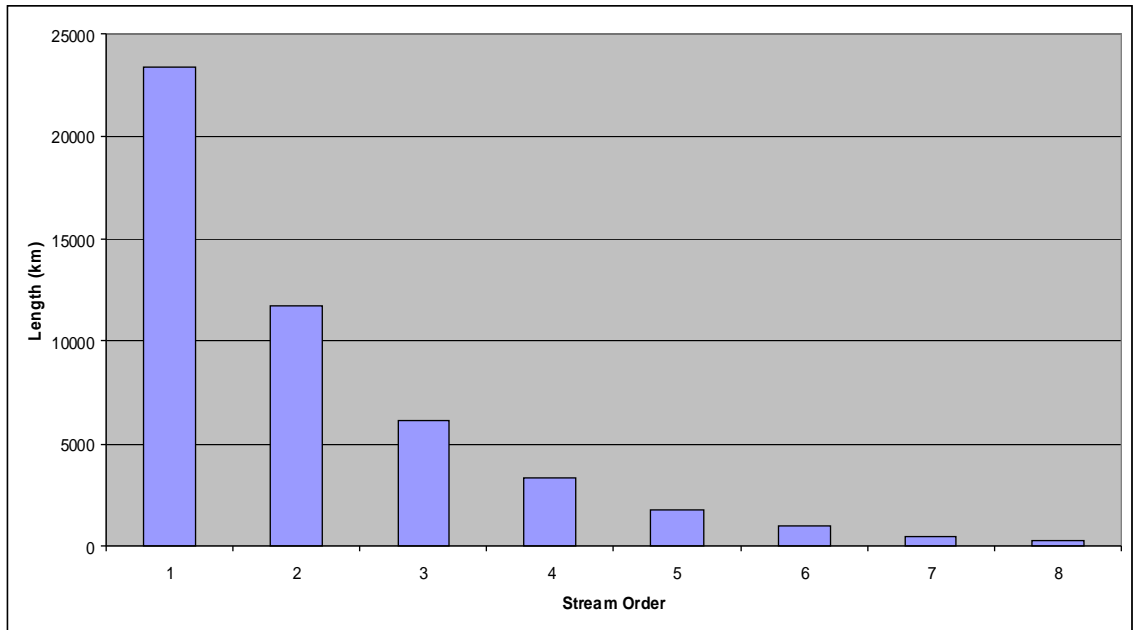
Figure 4-1   SEQ Level 1 Catchment, Lengths of Waterways

Figure 4-2   Logan Level 2 Catchment, Lengths of Waterways
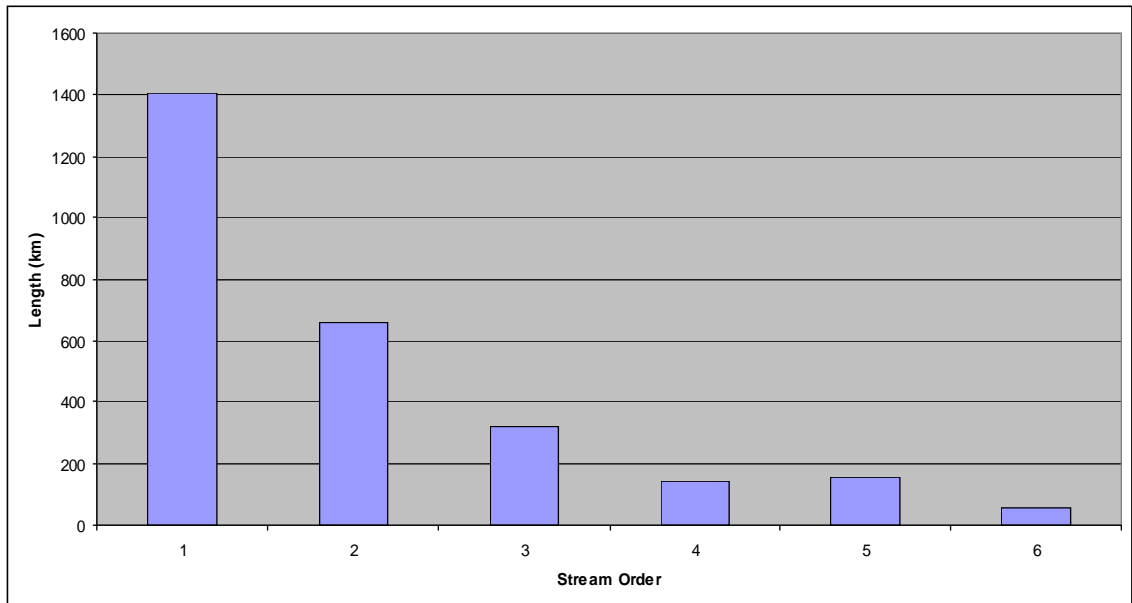
Figure 4-3   Upper Logan River Level 3 Catchment, Lengths of Waterways

Figures 4-1, 4-2 and 4-3 display lengths of waterways (km) and their relationship to each other, showing stream order (SO) 2 waterways are approximately half SO 1, and SO 3 being approximately half SO 2 waterways. Of note is the similar trend across the three different sized catchments, and the evenness of the decline in kilometres of the overall combined SEQ data, smoothing any anomalies in smaller Level 2 and Level 3 catchments.

Areas of Catchments/Length of Waterways:
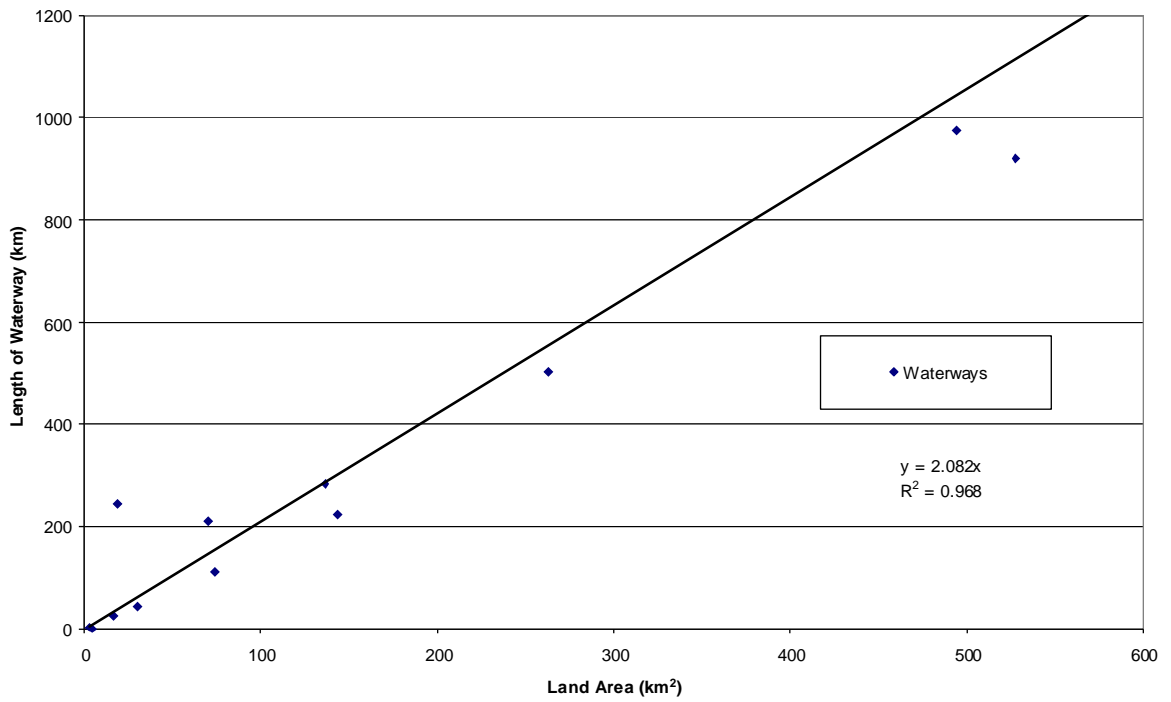
Figure 4-4   SEQ (Level 1 Catchment) Area of Catchment/Length of Waterways
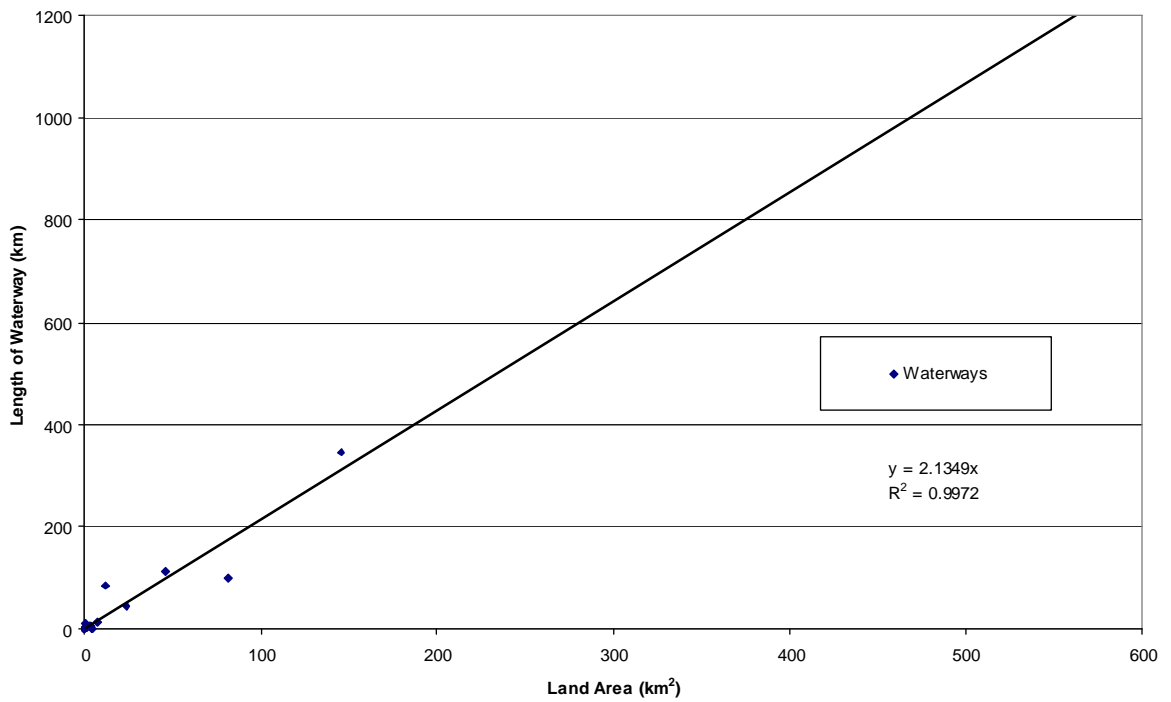
Figure 4-5   Logan (Level 2 Catchment) Area of Catchment/Length of Waterways
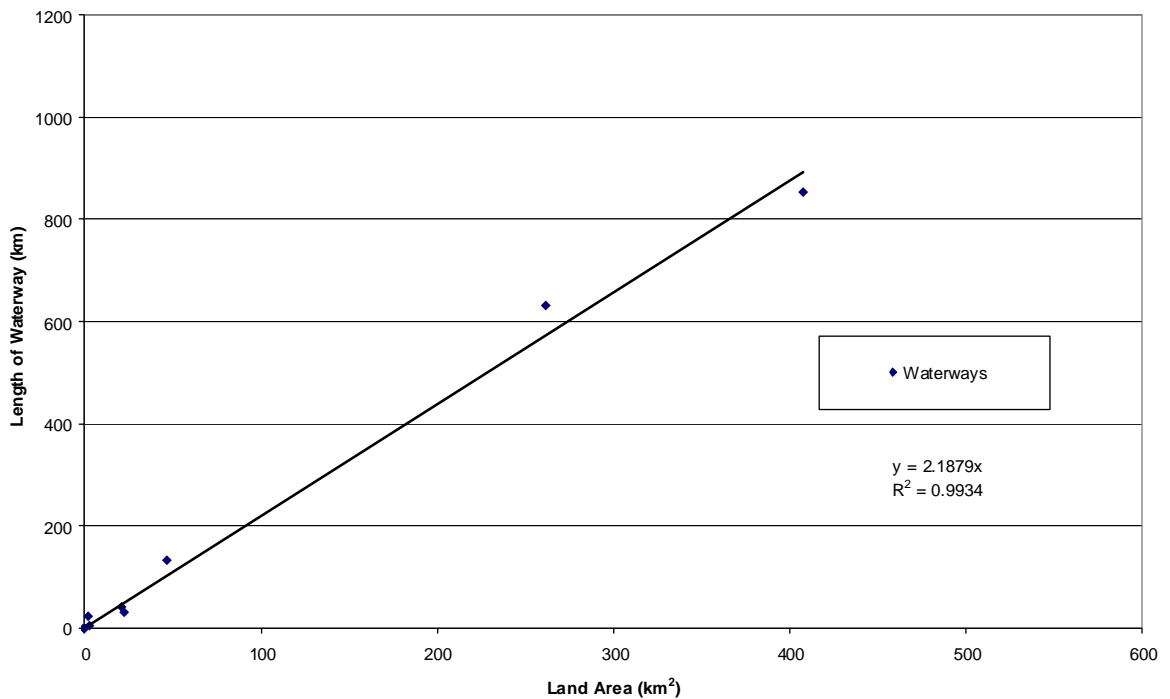
Figure 4-6   Bremer River (Level 3 Catchment) Area of Catchment/Length of Waterways

Figures 4-4, 4-5 and 4-6 display lengths of waterways and their relationship to land areas. Showing total length of waterways (km) being twice the land area (km²), with similar trends across all 3 catchment levels, from all of SEQ down to the small Bremer River level 3 catchment.

Results displayed in figures 4-4 to 4-6 show that assumptions can be made about waterway lengths in land areas.

Areas of Catchments/Length of Stream Ordered Waterways:
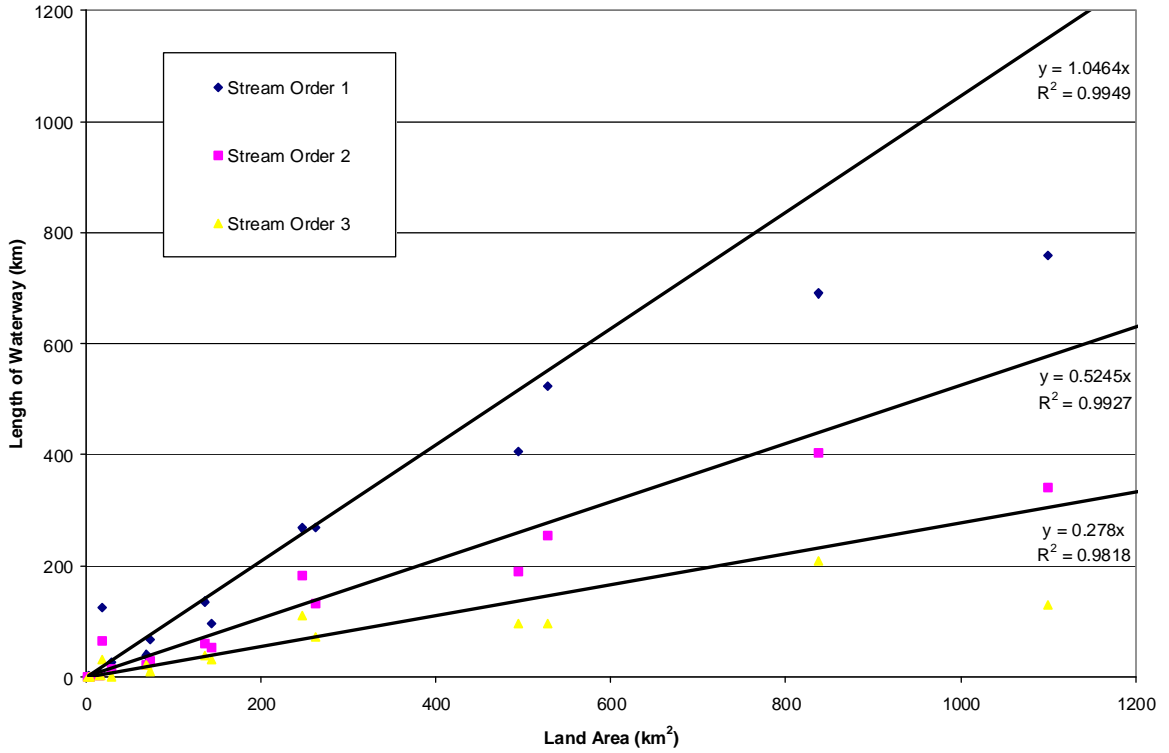
Figure 4-7   SEQ (Level 1 Catchment) Area of Catchment/Length of Stream Ordered Waterways
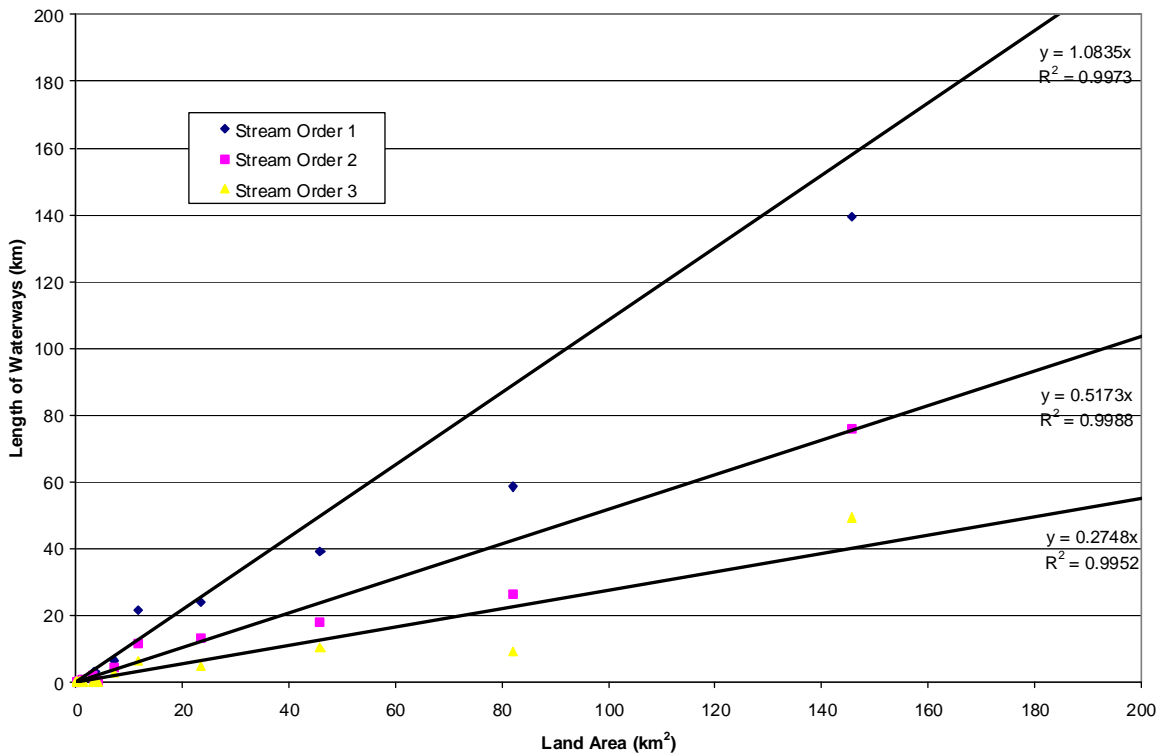
Figure 4-8   Logan (Level 2 Catchment) Area of Catchment/Length of Stream Ordered Waterways

$y = 1.138x$
$R^2 = 0.9985$

$y = 0.5962x$
$R^2 = 0.9957$

$y = 0.2287x$
$R^2 = 0.9861$
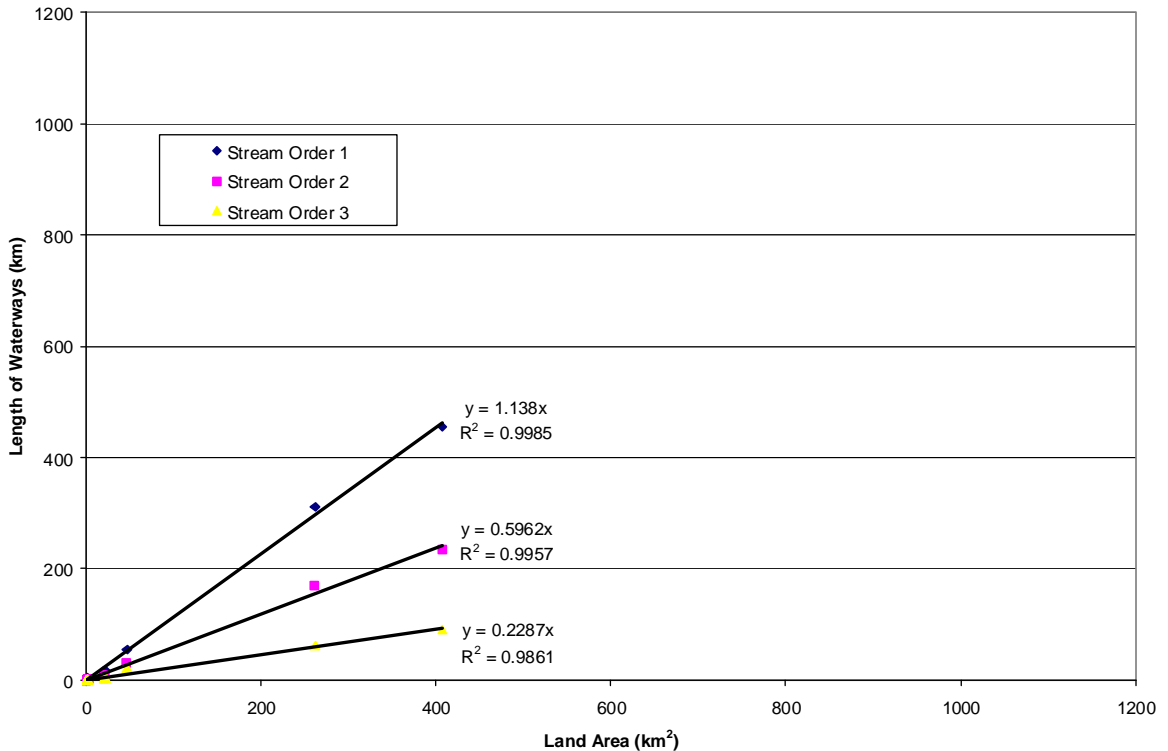
**Figure 4-9   Bremer River (Level 3 Catchment) Area of Catchment
/Length of Stream Ordered Waterways**

Figures 4-7, 4-8 and 4-9 display lengths of waterways and their relationship to land areas. Showing length of Stream Order (SO) 1 waterways (km) being approximately the same number as the land area (km²), SO 2 waterways (km) being approximately half SO1 (km), half the land area (km²), and SO 3 waterways (km) being half SO 2 (km²), (quarter land area). Similar trends exist across all 3 catchment levels, from all of SEQ down to the small Bremer River level 3 catchment.

Results in figures 4-7 to 4-9 display that it is possible to predict lengths of stream ordered waterways within catchments. From this, assumptions can be made about lengths of waterways in any areas without the need for detailed analysis.

For clarity purposes, only stream order 1, 2 and 3 waterways are shown on the plots.

4.1.2 Land Use, Results and Discussion:

Areas of Land Use (Existing and Future) Categories in SEQ:

Legend:

■ Canal	■ Cloud	□ Dryland Crop
□ Grass	■ Impervious Road Surface	■ Irrigated Crop and Pasture
■ Mine/Quarry	■ Native Forest	■ Natural Rock/Cliff
■ Non-forest Native Vegetation	■ Non-vegetated	■ Ocean
■ Plantation	■ Sand/Mud Bank	■ Tree Crop
■ Unclassified	■ Waterbody	
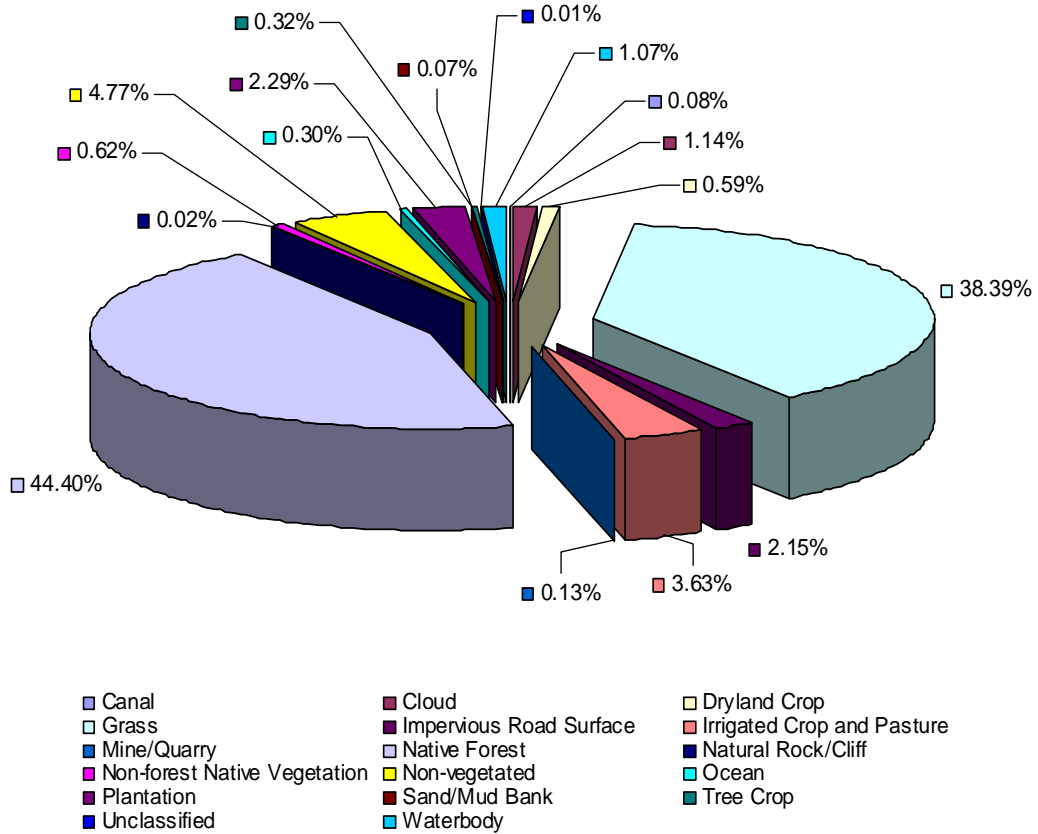
Figure 4-10   SEQ Existing Land Use
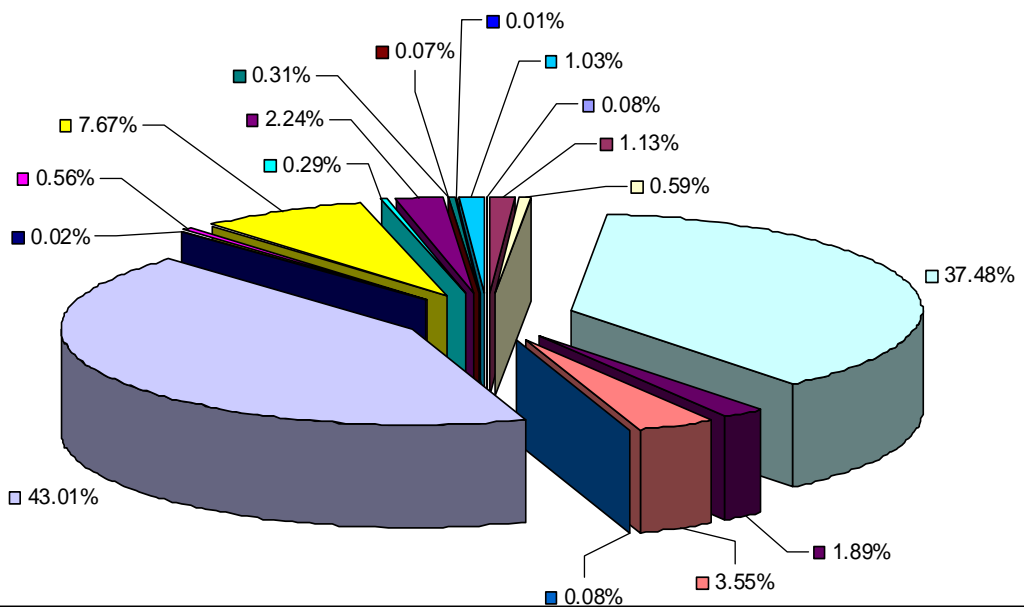
Figure 4-11   SEQ Future Land Use
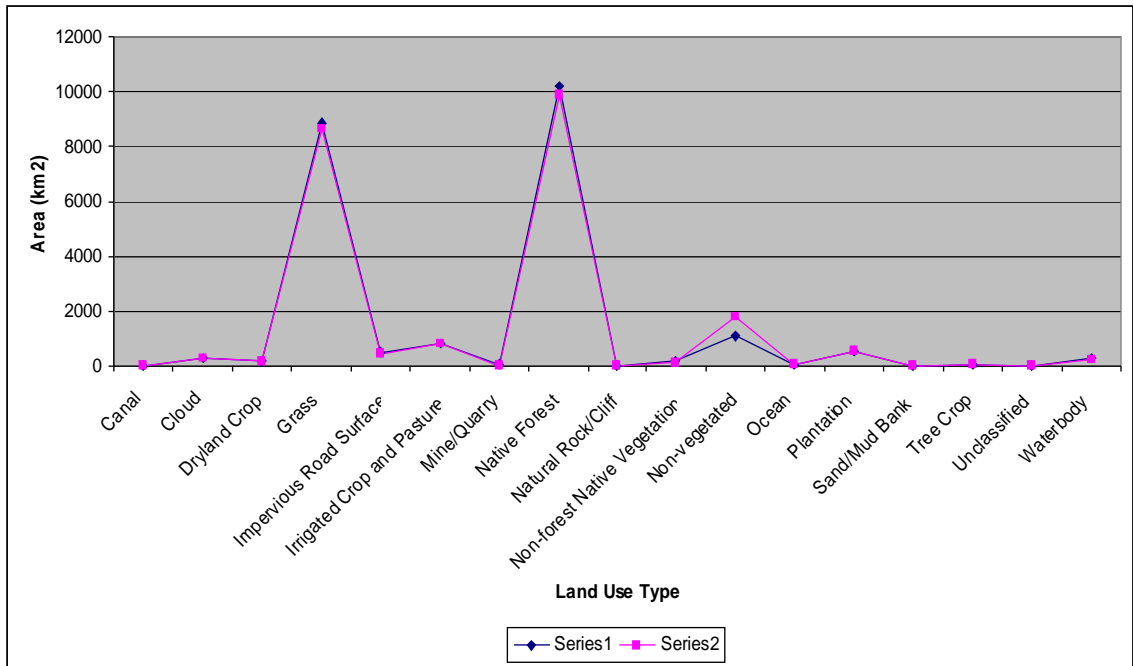
Figure 4-12   SEQ, Existing and Future Land Use Category Areas

Figures 4-10, 4-11 and 4-12 display, at a regional scale, that there is minimal difference in existing and future land use categories (km²). The exception being the increase in non-vegetated areas in future land use compared to existing land use.

Results show that there is no other major change in land use. Future increase in non-vegetated areas is contributed to by small losses from most categories of the existing land use information (mainly noticeable from approximately one percent losses in native forest and grass).

The land use category 'cloud' is derived from cloud cover on the satellite imagery the land use was derived from. Land use could not be categorised in these areas.

Areas of Land Use Categories/Total length of Waterways:
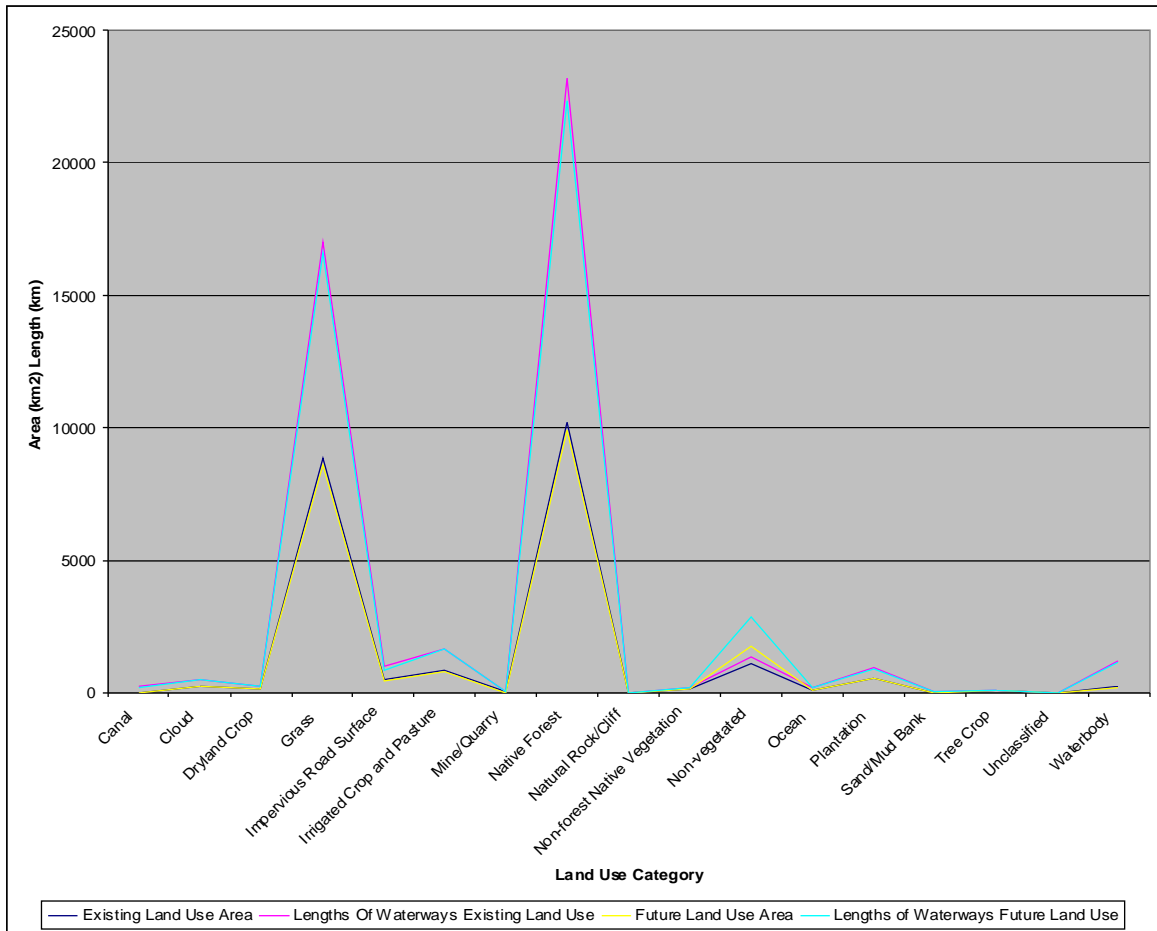
Figure 4-13   SEQ, Existing and Future Land Use, Waterway Lengths

Figure 4-13 displays that at a regional scale, there is minimal difference in existing and future land use categories (km²). The exception being the increase in non-vegetated areas in future land use compared to existing land use. Therefore, there is also a similar percentage increase in the length of waterways (km) in non-vegetated areas. See Appendix B – Drawings for detailed waterways lengths and land areas.

The results in figure 4-13 show that (if future land use is adopted) there will be an increase in waterways in non vegetated areas. Run-off within these areas is more likely to contribute excessive sediment and pollutants to waterways. Therefore, there will be increased need for management of these extra kilometres of waterways.

Land Use Categories/Lengths of Stream Ordered Waterways:
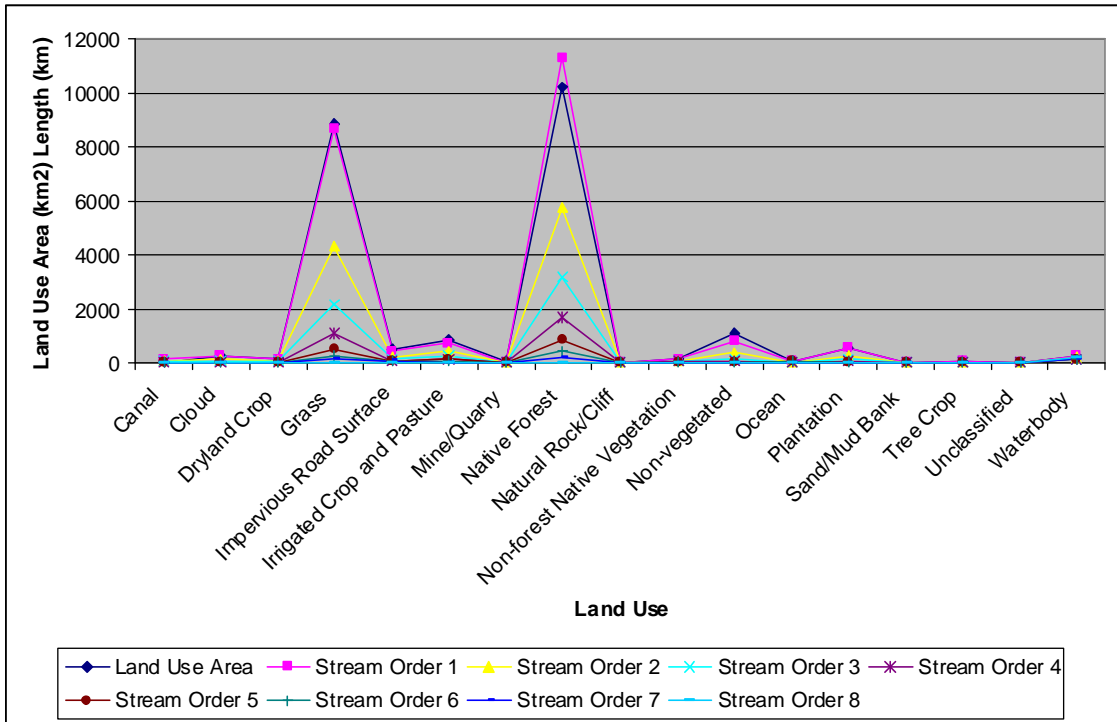
Figure 4-14   SEQ Land Use Area, Stream Order Lengths

Figure 4-14 displays, at a regional scale, the relationship between length (km) of stream ordered (SO) waterways and existing land use area (km²). Of note, is the similarity of land use area (km²) and SO 1 waterways (km), and the relationship of the SO waterways with one another and the land use areas.

The results in Figure 4-14 allows for assumptions to be made regarding lengths of stream ordered waterways within land use categories.

4.1.3 Slope, Results and Discussion:

Areas of Slope in SEQ:
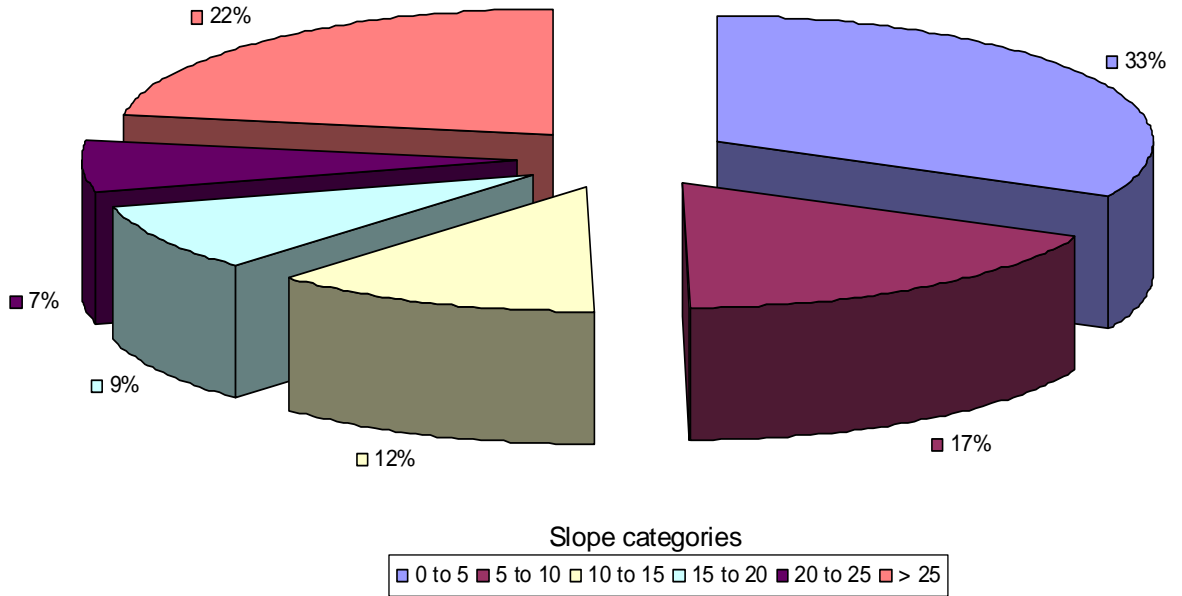
Figure 4-15   SEQ (Level 1 Catchment), Areas of Slope Categories
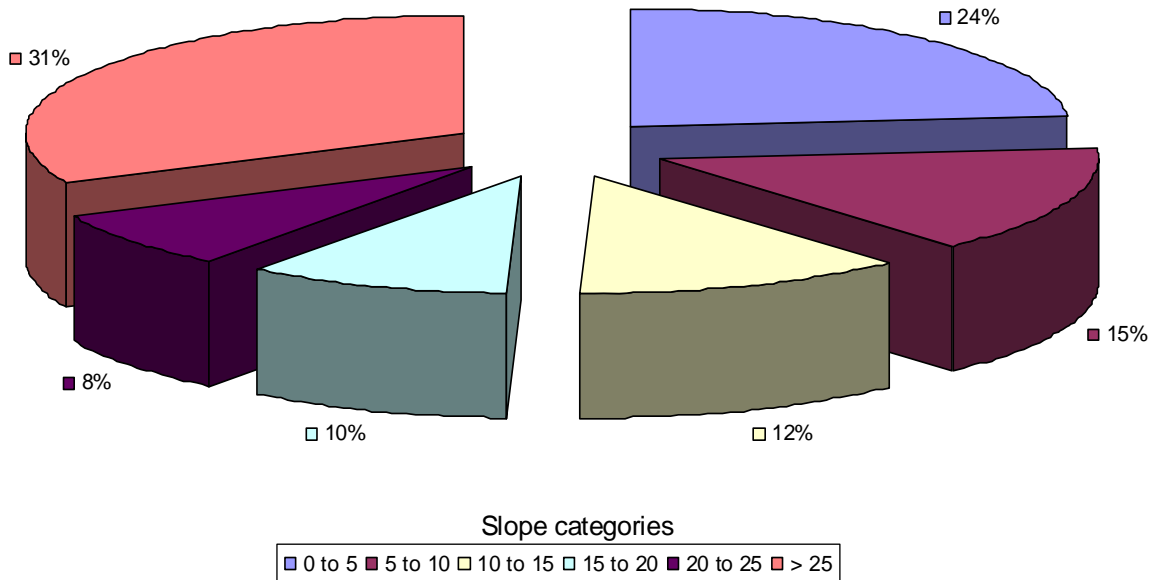
Figure 4-16   Stanley Somerset (Level 2 Catchment), Areas of Slope Categories

Slope categories

◻ 0 to 5 ◼ 5 to 10 ◻ 10 to 15 ◻ 15 to 20 ◼ 20 to 25 ◼ > 25
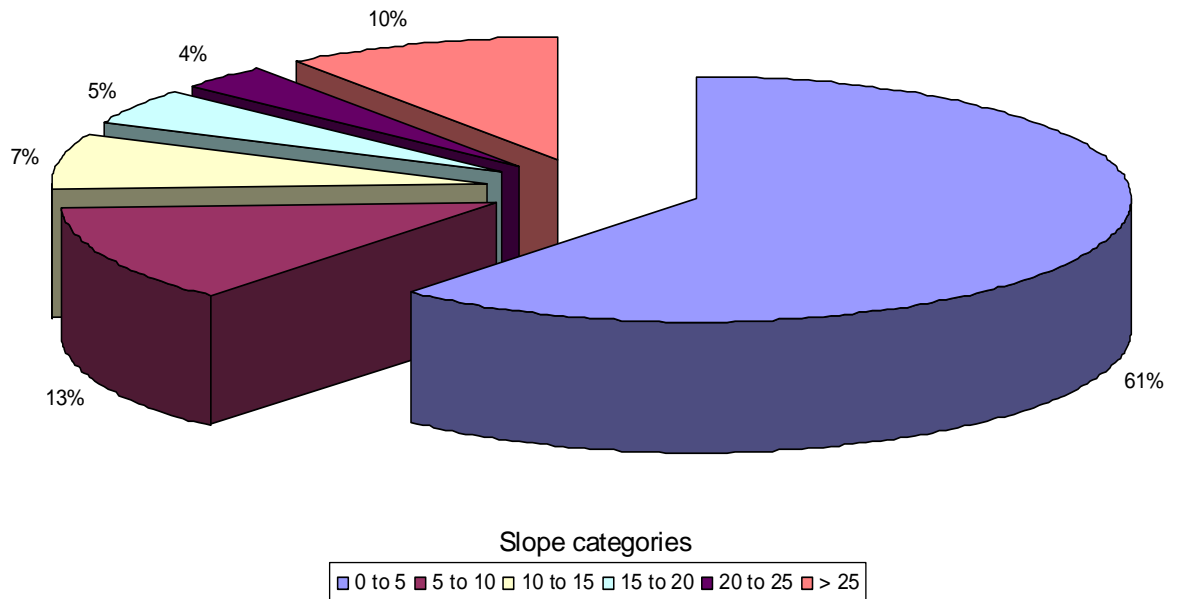
Figure 4-17   Pimpama River (Level 3 Catchment), Areas of Slope Categories

Figures 4-15, 4-16 and 4-17 display percentage of slope categories in Level 1, Level 2 and Level 3 catchment areas. Of note, is the change in percentage of the slope categories. The Level 2 and Level 3 catchments were chosen to show the change from inland (Level 2 Stanley Somerset) to coastal (Level 3 Pimpama River) catchments.

The Pimpama River level 3 coastal catchment has a much higher percentage of the 0-5% slope category. The Stanley Somerset level 2 catchment has a higher percentage of steep (20-25%) than the other catchments shown. The Stanley Somerset level 2 catchment is the sum of all Stanley Somerset level 3 catchments. The overall SEQ Level 1 catchment is the sum of all SEQ level 2 catchments. Because the SEQ information covers the varying terrain over all of SEQ the slope categories tend to even out.

Results in the drawings appendix show that the change in percentage of slope categories in the catchments is not reflected in the length of waterways (still similar lengths compared to land uses, and still double waterway length compared with catchment area) within catchment and land use areas, see Appendix B – Drawings:

Level 1 Catchment: Page 4, SEQ Catchment, Drawing SEQ-001,

Level 2 Catchment: Page 164, Stanley Somerset Catchment, Drawing SSO-001, and,

Level 3 Catchment: Page 110, Pimpama River Catchment, Drawing NGC-009.

Slope Categories/Lengths of Waterways:
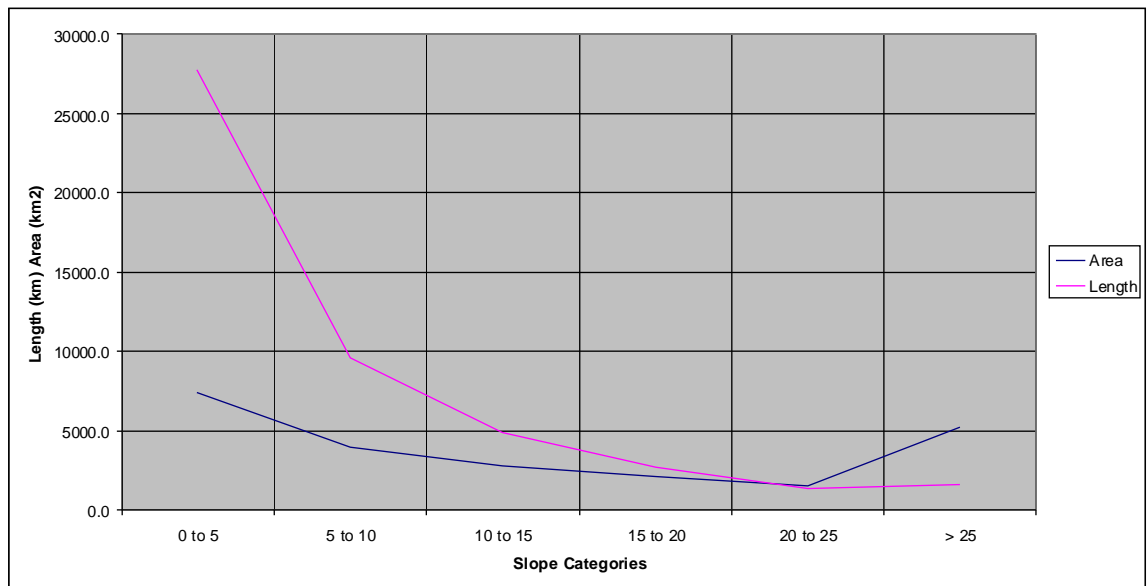
Figure 4-18   SEQ Stream Orders Lengths and Areas within Slope Categories

Figure 4-18 displays the length of waterways (magenta line) (km) within various slope categories in SEQ. It also displays the area (km²) of the various slope categories (blue line).

It shows that most waterways are in the flatter parts (lower slope categories) of the region, whilst the area of the region is greater in the flat and steeper categories of slope.

Areas of Slope/Lengths of Stream Ordered Waterways:
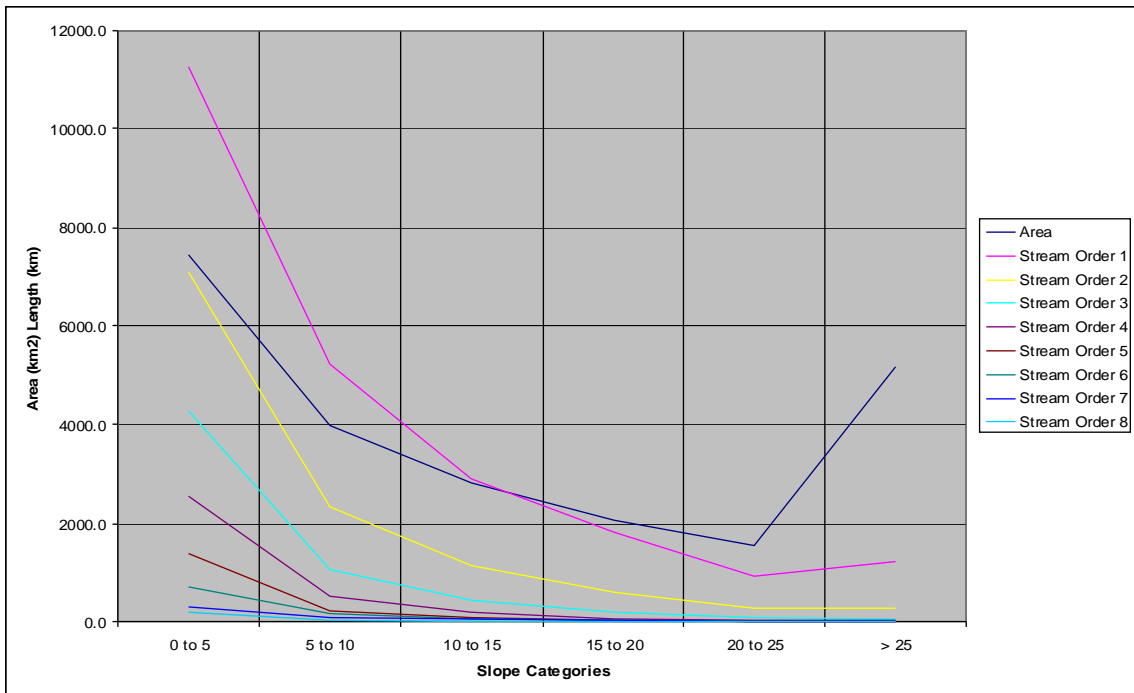
Figure 4-19   SEQ Areas (categories) of Slope compared with Lengths of Stream Ordered Waterways

Figure 4-19 displays the length of Stream Ordered (SO) waterways (km) within various slope categories in SEQ. It also displays the area (km²) of the various percentage slope categories (blue line). It shows the relationship between SO categories and that there is a general trend with land area within the slope categories with the exception of slope above 20%.

Results again show that most waterways are in the flatter parts (lower slope categories) of the region, whilst the area of the region is greater in the flat and steeper categories of slope.
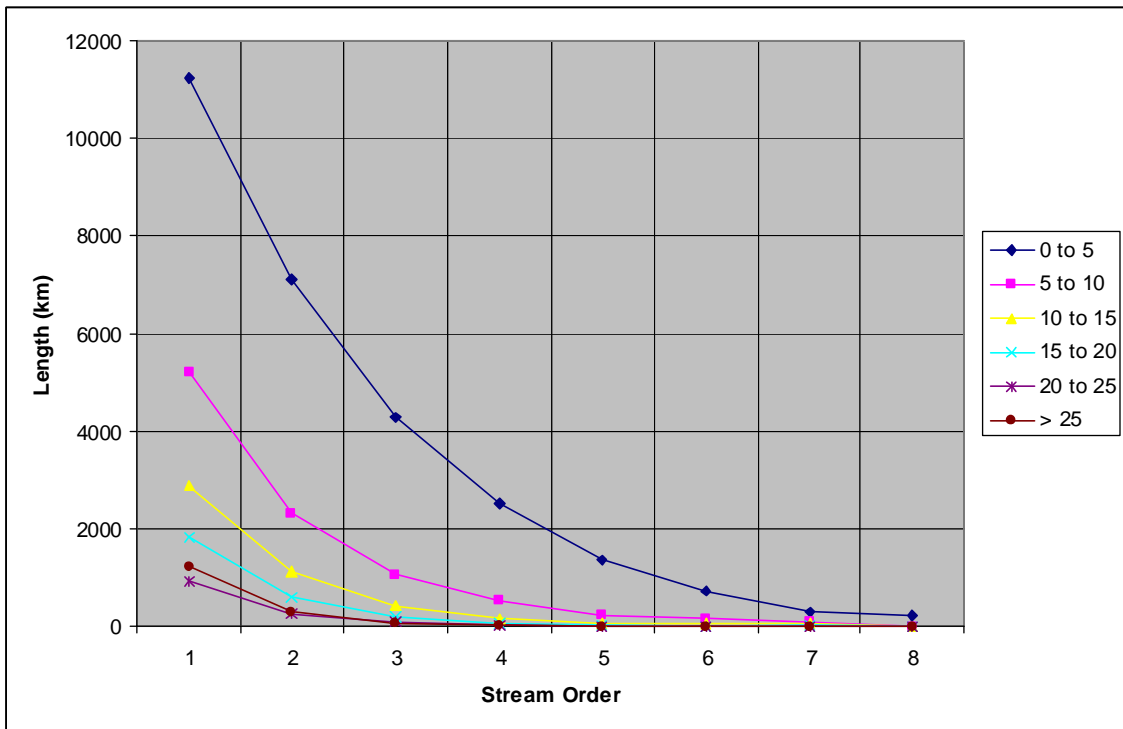
Figure 4-20   SEQ Categories of Slope compared with Lengths of Stream Ordered Waterways

Figure 4-20 displays the length (km) of percentage slope categories compared with Stream Ordered (SO) waterways in SEQ.

A general trend shows that most waterways are in the flatter parts of the region. It also shows a trend in lengths of waterways with SO 2 waterways being half SO 1, SO 3 waterways being half SO 2.

Figure 4-20 also shows that headwater streams (SO 1 and 2) are predominately in slope categories 0-5º and 5-10º, flatter areas that are more likely to be developed or attract potential development.

Appendix B – Drawings, displays detailed results for the items discussed. Due to results from the study showing a clear trend all over SEQ, it was decided to see if these results could be validated in another area of Australia, see section 4-2, Validation of Key Findings.

4.2 Validation of Key Findings

From the analysis of the data created for this study, it was found that:

- It is possible to predict the length of waterways within a catchment area just by knowing the size of the area (km²),

- It is possible to predict the length of stream ordered waterways within a catchment,

- It is possible to predict the length of stream ordered waterways within any land use area,

- It is possible to predict the length of waterways (km) in any known area (km²), and,

- Slope of the catchment does not have any effect on the length of waterways within an area (land use area, shire or catchment).

To test these theories, the same process used in all SEQ catchments was applied to another part of Australia. Access was gained to raw elevation data and land use information for a region to the east of Adelaide in South Australia (BMT WBM, 2008). (See Figure 4-21, South Australian Land Use and Slope Comparison).

The raw elevation data was processed into a DEM, from the DEM a catchment, an attributed (stream ordered) waterways network and slope data were created.

The results can be compared with any catchment/shire or land use area in SEQ and waterways (including stream ordered waterways) have a similar percentage of waterway per square kilometre or waterway per land use type.

The Lower Warrill Creek catchment (Pages 14 -15 in Appendix B – Drawings) in SEQ is one of the catchments in SEQ similar in size (approximately 150 km²) to the South Australian catchment. The land use types may be slightly different between the two catchments (South Australian land use data was renamed to conventions used in SEQ), but the land use types are inconsequential, the percentage length of waterways per area remains similar. Application of this theory to other catchments across Australia appears promising.

The results from the table on Figure 4-21 show that the same predictions can apply in another area of Australia, with the length of waterways having the same relationship with the catchment area and land use as those in SEQ (See Appendix B – Drawings), confirming that it is possible to predict lengths of waterways in catchment areas and land use areas just by knowing the areas in square kilometres.

Waterways and DEM **Slope** **Land Use**

Elevation (m AHD)

| 1300 |
| 1100 |
| 900 |
| 700 |
| 500 |
| 300 |
| 100 |
| 80 |
| 60 |
| 40 |
| 20 |
| 0 |

Slope (Percentage)

- 0 to 5 (Little)
- 5 to 10 (Minor)
- 10 to 15 (Moderate)
- 15 to 20 (High)
- 20 to 25 (Very High)
- > 25% (Severe)

Land Use

- Impervious Road Surface
- Cloud
- Ocean
- Mine/Quarry
- Waterbody
- Canal
- Native Vegetation
- Plantation
- Non-forest Native Vegetation
- Sand/Mud Bank
- Grass
- Tree Crop
- Irrigated Crop and Pasture
- Dryland Crop
- Natural Rock/Cliff
- Non-vegetated
- Unclassified
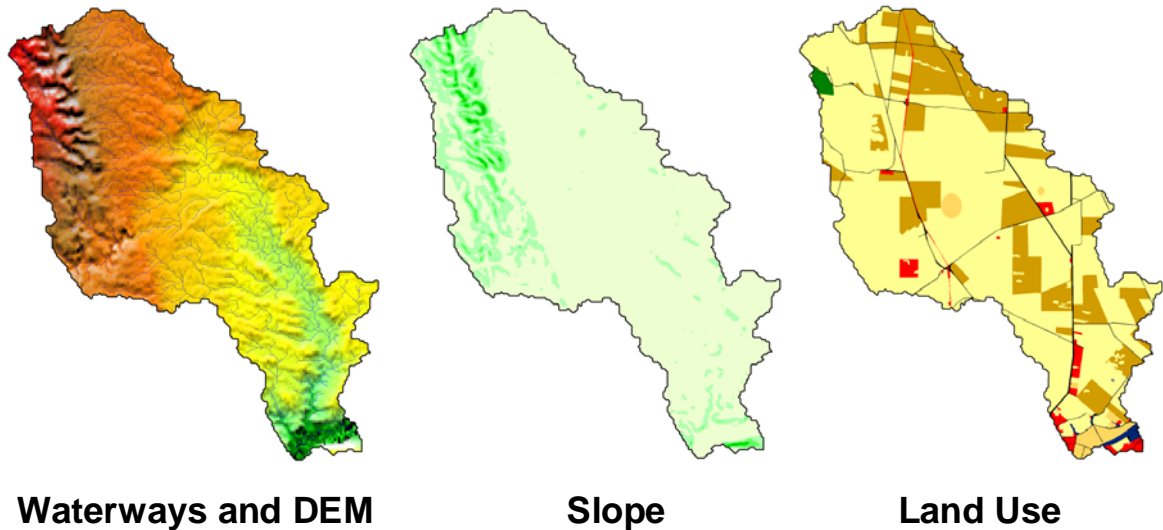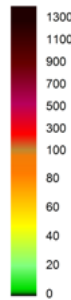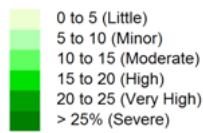
Total length of South Australian Catchment Waterways (km)	306.7	Catchment Maximum Elevation (m AHD)	270
Total area of South Australian Catchment (km²)	144.3	Catchment Minimum Elevation (m AHD)	0

Existing Land Use Information - South Australian Catchment

		Stream Order (km)								
Land Use Type	Land Use Area (km²)	1	2	3	4	5	6	7	8	Total
Canal	0	0	0	0	0	0	0	0	0	0
Cloud	0	0	0	0	0	0	0	0	0	0
Dryland Crop	31.1	31	24.2	12.6	5.6	4.5	0	0	0	77.9
Grass	102.9	92.9	54.2	31	15.9	12.1	0	0	0	206.1
Impervious Road Surface	2.8	2.5	1.8	1.1	0.7	0.4	0	0	0	6.5
Irrigated Crop and Pasture	2.9	2.2	2.6	1.6	0.4	1.4	0	0	0	8.2
Mine/Quarry	0.1	0	0	0	0	0	0	0	0	0
Native Forest	0.7	0.9	0.3	0	0	0	0	0	0	1.2
Natural Rock/Cliff	0	0	0	0	0	0	0	0	0	0
Non-forest Native Vegetation	0	0	0	0	0	0	0	0	0	0
Non-vegetated	3.1	3	0.9	0.8	0.4	0.9	0	0	0	6
Ocean	0	0	0	0	0	0	0	0	0	0
Plantation	0	0	0	0	0	0	0	0	0	0
Sand/Mud Bank	0	0	0	0	0	0	0	0	0	0
Tree Crop	0	0	0	0	0	0	0	0	0	0
Unclassified	0	0	0	0	0	0	0	0	0	0
Waterbody	0.6	0.4	0.4	0	0	0	0	0	0	0.8
Total Area of Land Use (km²)	144.2									
Total length of Waterways (km)		132.9	84.4	47.1	23	19.3	0	0	0	306.7

Slope Information - South Australian Catchment

		Stream Order (km)								
Percentage Slope	Slope Area (km²)	1	2	3	4	5	6	7	8	Total
0 to 5	119.2	122.2	80	44.3	23	19.4	0	0	0	288.9
5 to 10	17.9	9.9	4.3	2.7	0	0	0	0	0	16.9
10 to 15	4.6	0.9	0	0	0	0	0	0	0	0.9
15 to 20	1.1	0.1	0	0	0	0	0	0	0	0.1
20 to 25	0.1	0	0	0	0	0	0	0	0	0
> 25	0.0	0	0	0	0	0	0	0	0	0
Total Area of Slope (km²)	142.9									
Total length of Waterways (km)		133.1	84.3	47	23	19.4	0	0	0	306.8

Figure 4-21   South Australian Land Use and Slope Comparison

4.3 Results displayed on Drawings

The most efficient way of displaying the results from this project, to reach the widest possible audience is, at least initially, is in hard copy drawings. Appendix B – Drawings is a collection of new drawings to show that information.

Appendix B – Drawings is over 200 pages of project results and drawings of SEQ Catchments and Shires. That information includes:

- Waterways Map displaying Stream Order,

- Elevation,

- Shire Slope,

- Existing Land Use,

- Future Land Use,

- Locality Map,

- Length of waterways (Land Use, Existing and Future) – total waterways, individual stream order totals within the area and total length of waterways within land use categories,

- Length of waterways (Slope) – total waterways, individual stream order totals within the area and total length of waterways within slope categories,

- Total Area,

- Minimum and maximum elevation,

- Land use areas (total existing and future and for each land use type), and,

- Slope areas (total, individual stream orders and various categories).

See Figure 4-22, Typical Catchment/Shire Information on Drawings, and Figure 4-23, Typical Detailed Catchment Information, for examples of results to be found on each drawing in Appendix B – Drawings.
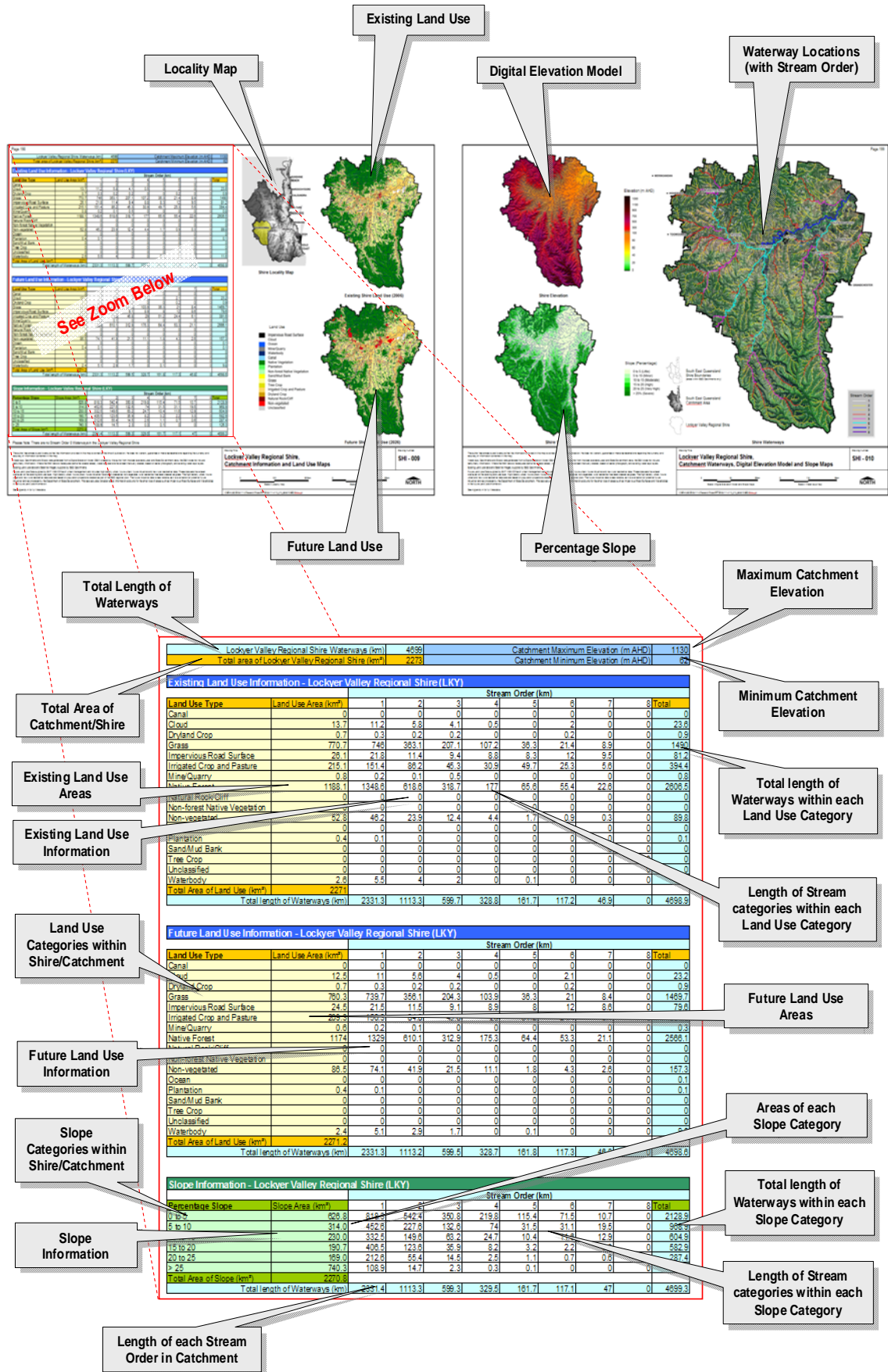
Figure 4-22   Typical Catchment/Shire Information on Drawings

(see Appendix B - Drawings)

South East Queensland Level 1 Catchment

Total length of South East Queensland Catchment Waterways (km)	47958	Catchment Maximum Elevation (m AHD)	1368
Total area of South East Queensland Catchment (km²)	23038	Catchment Minimum Elevation (m AHD)	0

Existing Land Use Information - South East Queensland(SEQ) Level 1 Catchment

Land Use Type	Land Use Area (km²)	Stream Order (km)								Total
		1	2	3	4	5	6	7	8	
Canal	18.8	125.6	64.9	30.7	23.3	0.2	0	0	0	244.7
Cloud	263.1	268.1	130.6	71.8	23.1	2.2	4	0.5	0.2	500.5
Dryland Crop	136	135.4	60.6	38.4	21.9	10.4	16.5	0	0	283.2
Grass	8843.7	8671.8	4281.2	2145.4	1081.3	455.9	246.9	117.1	2.6	17002.2
Impervious Road Surface	494.3	405.4	188.2	97	84.8	80.6	53.8	54.3	10.9	975
Irrigated Crop and Pasture	836.9	690.6	402.4	209.4	130	140.8	56.9	29.8	0	1659.9
Mine/Quarry	30	25.5	13.5	1.5	2.1	1	0.3	0	0	43.9
Native Forest	10229.9	11273.8	5706.3	3140.1	1699.5	814.8	405.3	152	26.6	23218.4
Natural Rock/Cliff	4.7	0.9	0.1	0	0	0.1	0	0	0	1.1
Non-forest Native Vegetation	143.8	95.7	53	31.4	33.9	7.8	0.6	0	0.1	222.5
Non-vegetated	1099.9	758.6	339.7	129.8	51.9	23.8	7.2	3.3	0.5	1314.8
Ocean	69.7	39.5	21.1	21.3	28.8	50.3	37.5	8.9	3.7	211.1
Plantation	527.8	522.5	253.7	95.1	41.4	6.4	1.4	0	0	920.5
Sand/Mud Bank	16.3	7.3	2.7	2.5	3.9	7.6	0.3	2.4	0.1	26.8
Tree Crop	73.9	66.9	28.3	10.5	3.6	0.1	0	0.2	0	109.6
Unclassified	2.9	1.8	0.8	0.2	0.3	0.3	0.1	0.2	0	3.7
Waterbody	247.1	267.8	181.4	110.4	120.7	121.3	124	101.6	193.3	1220.5
Total Area of Land Use (km²)	23038.8									
Total length of Waterways (km)		23357.2	11728.5	6135.5	3350.5	1723.6	954.8	470.3	238	47958.4

Future Land Use Information - South East Queensland (SEQ) Level 1 Catchment

Land Use Type	Land Use Area (km²)	Stream Order (km)								Total
		1	2	3	4	5	6	7	8	
Canal	17.5	121.2	62.1	28.6	21.8	0.1	0	0	0	233.8
Cloud	260.8	266.3	130.1	71.7	23	4.2	2	0.4	0.2	497.9
Dryland Crop	136	135.3	60.6	38.5	21.9	10.4	16.5	0	0	283.2
Grass	8633.8	8490.9	4185	2080.5	1051.4	442.1	246	115.4	2.5	16613.8
Impervious Road Surface	435.3	350.2	158.1	80.7	70.6	66.7	49.7	48.9	11.1	836
Irrigated Crop and Pasture	817.3	679.7	394.5	205.6	128.8	140.2	56.9	30.4	0.1	1636.2
Mine/Quarry	17.7	14.6	6.9	0.4	1.7	1	0.1	0	0	25.2
Native Forest	9908.2	10919.3	5482.7	2990.4	1629.7	780.4	391.7	142.9	25.1	22361.9
Natural Rock/Cliff	4.6	0.9	0.1	0	0	0.1	0	0	0	1.1
Non-forest Native Vegetation	129.7	82.2	46	26.2	31.9	7.2	0.7	0	0.1	194.3
Non-vegetated	1767	1429.9	732.5	380.6	176.7	92.1	34.8	31.8	9.2	2887.6
Ocean	67.7	33.1	19.7	20.5	28	49.2	33.7	7.7	3.6	195.5
Plantation	515.3	507.5	247.6	94.1	39.6	6.3	1.4	0	0	896.5
Sand/Mud Bank	15.8	5.8	2.2	2.1	3.9	7	0.4	1.6	0	23
Tree Crop	71.4	63.5	27.7	9.9	3.3	0.1	0	0.3	0	104.8
Unclassified	2.8	1.7	0.7	0.2	0.3	0.3	0.1	0.2	0	3.5
Waterbody	237.4	255.3	171.6	105.8	117.7	116.1	120.7	90.5	186	1163.7
Total Area of Land Use (km²)	23038.3									
Total length of Waterways (km)		23357.4	11728.1	6136	3350.3	1723.5	954.7	470.1	237.9	47958

Slope Information - South East Queensland (SEQ) Level 1 Catchment

Percentage Slope	Slope Area (km²)	Stream Order (km)								Total
		1	2	3	4	5	6	7	8	
0 to 5	7453.1	11234.2	7101.3	4273.5	2542.9	1364.6	715	294.3	217.4	27743.2
5 to 10	3980.1	5220.9	2333.5	1064.1	534.6	233.3	153.2	93.9	12.8	9646.3
10 to 15	2809.1	2906.4	1134.1	440.3	176.4	81.5	62.3	58.5	5.2	4864.7
15 to 20	2062.4	1832.2	599.2	199.1	57.3	27.3	14.9	18.4	1.3	2749.7
20 to 25	1557.6	934.7	277.4	84.5	20.6	10.9	5	4.8	0.7	1338.6
> 25	5175.8	1228.7	283.4	74.4	18.8	5.5	4.2	0.1	0.5	1615.6
Total Area of Slope (km²)	23038.0									
Total length of Waterways (km)		23357.1	11728.9	6135.9	3350.6	1723.1	954.6	470	237.9	47958.1

Figure 4-23   Typical Detailed Catchment Information on Drawings

(see Appendix B - Drawings)

4.4 Implications of the Project

Implications of the study are considerable. A large portion of the data defined within the study has not previously been available, data that was available (waterways) has not previously been split into shires within SEQ. Groups interested in waterway management will benefit considerably from results of this project. An increased understanding of waterways within the region allows for better planning and costing of works associated with the waterways.

People may not feel ownership or affinity with the catchment in which they live and may not have access to specific information relating to the area. Any information, in formats that everyone can access, allows any interested party to learn more about the catchments and waterways. This assists change understanding of an area, and therefore how the area is managed and used (Lee et al. 2004).

A better understanding of lengths of waterways within potentially changed land use areas will assist with the protection of waterways. Being able to identify the important headwater streams (levels 1 and 2) within land use and slope categories assists this process even more.

4.4.1   Consequential Effects and Ethical Responsibilities of the Project:

This project has created new, previously un-available data, using procedures new to the author. Because of the deliverables from the project, the output from the project is anticipated to receive widespread use throughout the SEQ region. It is provided for SEQ, as a whole, and has also been split into catchments and shires to aid specific area usage.

The data will assist with sustainability and protection of the environment because of the people using it, people such as Engineers and Planners through to catchment user groups and the general community.

The primary output of the project is the detailing length of waterways (in land use and slope categories) in each catchment and shire in SEQ. GIS data will also be supplied as required and approved to appropriate users. Appendix B – Drawings is the second major output of the study, it includes land use and slope data. A spreadsheet with all data for all SEQ Catchments and shires will also be of use in SEQ. This variety of output will assist with sustainability and protection of waterways and catchments in the region because it will be available to the widest possible amount of potential users of the information.

Potential users of all forms of data created by this project need to be made aware of the how the data was created, what data it was created from and the suitability of this data for their use. Metadata (data describing data) is a critical component of this project. As previously discussed, metadata has been created for all revised and newly created information. This includes the procedures used to create the data and the limitations of the data. The metadata includes the potential for errors because of the accuracy of the base information and limitations of the processing/creation of new data.

4.4.2 Risk Assessment

There is little in the way of safety risks from this project, other than the usual possibilities of people getting injured whilst sitting at their desks viewing the data on-screen or the risk of people being injured whilst using the data in the field.

The accuracy of the data could perhaps lead to some form of risk, someone could be using data in the field relying on locations from the data itself and end up in the wrong location, therefore, perhaps increasing risk to themselves. Accuracy of the digital data, when compared with local, more accurate digital data, could lead to the risk of misuse of the data. If data is compared with local data (not constructed at a regional scale such as the data from this project), there is the possibility of risk, the risk being that the output could be considered accurate at this new local scale when it was not intended to be.

As described in the previous section, metadata is crucial in a project such as this and a better understanding of the data being used could perhaps assist avoid potential misuse of the data created from this project.

Users need to be advised that this data was created at a regional, or catchment scale, and should be used as such, it is not considered accurate at a local allotment level. Again, the metadata should assist with this. The drawings include a disclaimer stating that every care was taken during the creation of the data, but there are no representations or warranties regarding its accuracy.

5 CONCLUSIONS

5.1 Conclusions

This project provides information about the waterways and catchments of South East Queensland. It also provides information on the waterways relationship with land use and slope over for the whole region.

A large amount of this data had not been previously defined. Therefore, this project delivers new information for SEQ waterways, catchments and shires. The data was researched and developed to a standard that is suitable for widespread use by organisations in SEQ.

The process to define waterways, catchments, land use, slope etc. is usually applied to individual areas, and, therefore, does not give an overall trend of waterways within catchments/shires/land use areas and slopes. This project studied over 90 individual areas, allowing for comparison of data, over catchments and shires. The results show a clear trend of waterway lengths in land and land use category areas. Therefore, this allows us to make assumptions about the lengths of waterways in the region (and for other regions) and also within land use types like no other study before.

The project delivers some major outputs that can be delivered to interested parties in hard copy, spreadsheet and GIS formats. The data created at a consistent, regional scale with consistent attributes.

5.2 Major Project Outputs

This project presents **new information** that was not previously available. The major outcomes of this project are as follows;

- Existing land use areas for catchments and shires,

- Future land use layer for SEQ,

- Future land use areas for SEQ, catchments and shires. Future land layers were available, but not at a scale, or with suitable attributes for a study such as this,

- A comparison of areas for existing and future land use,

- Slope layer for SEQ,

- Categorised slope data for SEQ, catchments and shires,

- Slope areas for catchments and shires,

- Comparison of slope data between level 1, 2 and 3 catchments, in steep and flat terrains,

- Lengths of stream ordered waterways for existing land use categories for SEQ, catchments and shires,

- Lengths of stream ordered waterways for future land use categories for SEQ, catchments and shires,

- Comparison of lengths of waterways from land use areas for existing and future land use, and,

- Lengths of stream ordered waterways for slope categories for SEQ, catchments and shires,

- A spreadsheet detailing length of stream ordered waterways in each catchment and shire in SEQ for existing and future land use and within slope categories,

- Hard copy drawings displaying results, Appendix B – Drawings. It has information about the catchments and shires in the region, and,

- Data from the project is available in GIS and spreadsheet formats.

5.3 Major Benefits of this Project

Major benefits of this project include identifying **procedures (methods) to predict**:

- The relationship (length) between stream ordered waterways, stream order. 1, 2, 3 and so on. If stream order 1 waterway length is known, stream order 1, 2 and 3 and so on can be predicted,

- The relationship between total waterways and land areas (i.e. catchment areas). If the area of land is known, the total length of waterways can be predicted,

- The relationship between stream ordered waterways and land areas (i.e. catchment areas). If the area of land is known, the length of stream ordered waterways can be predicted,

- The relationship between stream ordered waterways and land use areas. If the area of land use is known, the length of stream ordered waterways within that land use can be predicted.

From this study it was also found that:

- The slope of the land (catchment), did not have any effect on the length of waterways within a catchment, shire or land use area,

- The theory developed and applied to derive the above parameters in SEQ was equally applicable elsewhere in Australia.

As described in this project, the ability to be able to define lengths of (stream ordered) waterways within catchments or land use areas will be of assistance in the future. It will allow interested parties, just needing to know general lengths of waterways in an area, to know those lengths without necessarily needing to have a well defined DEM. They also may not need to be involved in a long and difficult process to produce this type of information, particularly over such a large area as SEQ and over so many catchments.

Being able to predict lengths of waterways within catchment and land use areas may be of use in regions where funds do not permit the creation of costly DEM data, permitting locals to estimate lengths of waterways types (stream ordered) within any defined areas.

On an 'as-needs' basis, it would now be quite a simple process to query extra information from the waterways, for instance:

> A shire may wish to know: The length of waterways, stream orders '3 to 5', within land use categories 'grass' and 'tree crop', with 'less than 10%' slope to assist assess finding potential areas for urban development, or,

> A catchment group may wish to know: The length of waterways, 'stream orders 1 and 2', within land use category 'irrigated crop and pasture' and with slope 'greater than 10%' to assess potential run-off from fertilisers, or,

> A farmer may like to find out: What category of land use their property sits within. For instance; what type (stream order) of waterways flow through or begin on their property, what catchment are they in, what is the slope of their land, what is the possible future land use category for the area.

6 RECOMMENDATIONS – FUTURE WORK

There are many recommendations for future work for a project such as this, there are a number of interesting ways that the project could evolve, these recommendations could be as single projects, or they could evolve as one very large project. Some recommendations are:

6.1 WebGIS

The project results, together with the waterways and catchments data previously created would be enhanced if delivered as a WebGIS output. Particularly if the WebGIS included other compatible information such aerial photography and/or satellite imagery. Cadastral boundaries, along with their relevant attributes such as lot number/plan number and street address would also be of use with type of delivery. This type of output would be even more suitable if some simple search functions were included, such as allowing individuals and groups to search properties, catchments and shires.

It would be desirable to many if Web GIS output was made available at some stage in the future. All data in this project was created with web delivery in mind, i.e. a common format, with the same attributes and naming conventions, in a common projection system.

6.2 Analysis with Additional Data Sets

It would also be desirable to analyse information, such as in this project, with other available data for a region that has strong environmental demands placed upon it. If applicable, in such a study, other data sets, such as rainfall, historical land use information and soils/geology could be added to the information and processes involved with this study, tailoring a data set suitable for the particular region.

6.3 Comparison of Areas

More analysis of areas may supply some interesting results for the waterways and their relationship with land use (comparing non vegetated and urban areas) and slope (steeper in hinterland areas than coastal areas). It would be interesting to do some more analysis of coastal zones compared with hinterland/inland areas and built-up areas compared with rural areas.

6.4 Further Analysis of Relationship between Land Areas and Waterways

It would also be desirable to perform some detailed technical analysis of how and why the results presented in this dissertation are what they are. Why is there double the amount of kilometres of waterway compared to a catchment area (km²)? Why is there a similar amount of stream order one kilometres to a particular land use area (km²)? Why is there approximately half the length of stream order two streams when compared with stream order one streams? Why do these results consistently appear over all of SEQ and the area tested in South Australia?

6.5 Rating System

Further analysis of GIS data of catchments and waterways could assist arrive at a rating system for catchment health. For instance, assessing the amount of headwater stream orders 1 and 2, existing land use and future land use (to assess a development ratio), catchment area (Lee et al. 2004), and slope within a buffer zone of waterways. This could be a way of defining a rating system for each catchment which could assist assess catchment groups/shires identify waterways in need of remediation, or perhaps those in danger of losing their healthy ecosystem.

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APPENDIX A: PROJECT SPECIFICATION

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **Bruce Robert HARRIS** (Student Number W0069997)

TOPIC: SOUTH EAST QUEENSLAND WATERWAYS, LAND USE
                AND SLOPE ANALYSIS

SUPERVISOR: Dr Badri Basnet

PROJECT AIM: To derive land use (existing and future) and slope information for
                South East Queensland (SEQ), then apply that information to the
                waterways throughout the shires and catchments of SEQ. To derive the
                length of waterways (based on stream order) in existing and future land
                use categories, and to also obtain length of waterways in various slope
                categories. The creation of this data will be used to assist facilitate
                advanced waterway management and planning.

PROGRAMME: (Issue A, 18th March, 2008)

  1. Identify methodology and procedures for the project.

  2. Research, request and seek permission to use available data suitable for project.

  3. Identify classifications for land use, and slope analysis.

  4. Research suitable software for each component of the project.

  5. Create new data sets as required, such as; land use, future land use (based on projected
     land uses) and slope data.

  6. Define areas of existing and future land use categories in each catchment and shire.
     Define areas of slope categories within each catchment and shire.

  7. Create new land use and slope attributed streams data, defining length of each stream
     order in various existing and future land use and slope categories within all SEQ
     catchments and shires.

  8. Create a new hard copy report covering SEQ catchments and newly revised shires.

  9. Submit an academic dissertation on the project.

AGREED:

.... (Student)   .... (Supervisor)

Date: 20 / 03 / 2008   Date: 26 / 03 / 2008

Examiner/Co-examiner: ....

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APPENDIX B: VOLUME 2, DRAWINGS

Please see A3 Drawing Folder

APPENDIX C: ELECTRONIC COPIES OF DISSERTATION

APPENDIX D: METADATA

APPENDIX E: SLOPE CLASSIFICATION – LAND USE
(FROM - EXISTING CONDITIONS - MIAMI TOWNSHIP COMPREHENSIVE PLAN)

APPENDIX F: SLOPE CLASSIFICATION – LAND USE (FROM - ON-SITE NATURAL HAZARD OSRAS - ON-SITE RISK ASSESSMENT SYSTEM)

APPENDIX G: LAND USE REPORT