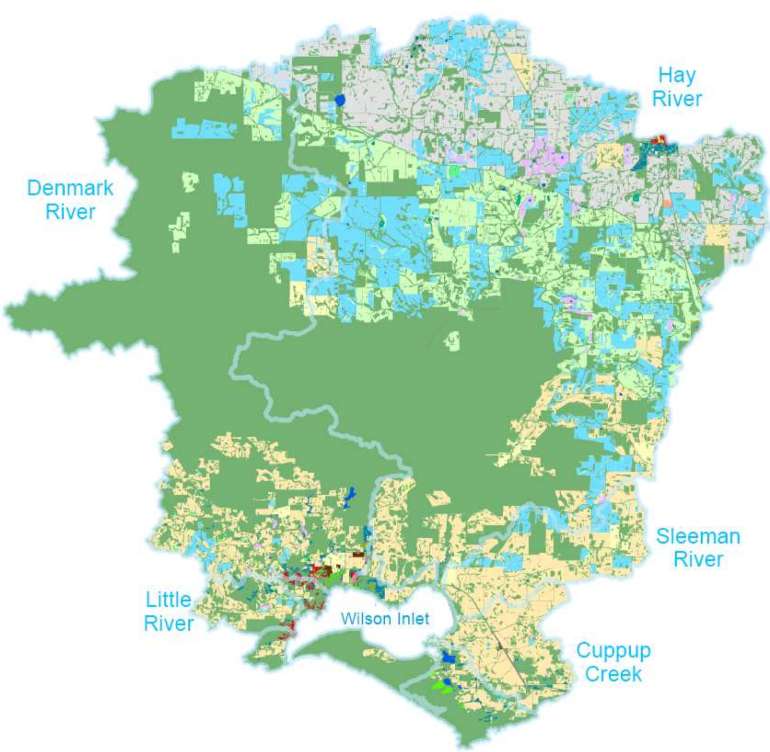
Report to the Wilson Inlet Catchment Committee

Consultancy to Provide Land Use and Nutrient Hazard Mapping for the Wilson Inlet Catchment



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1 Background & Introduction

This report has been produced as part of a contract let in December 2007 - Consultancy to provide land use and nutrient hazard mapping in the Wilson Inlet catchment.

The Tender is part of review being conducted by the Wilson Inlet Catchment Committee of the Wilson Inlet Nutrient Reduction Action Plan (WINRAP).

1.1 Project Objective

The Tender specifies that this project must:

- Produce a land use map for the Wilson Inlet catchment.
- Conduct nutrient hazard mapping for the Wilson Inlet catchment, comprising N and P nutrient hazard mapping, identified at source and at the Wilson Inlet.
- Produce maps of these.

1.2 Project Limitations

Note that this project and the SSPND modelling are targeted at rural land and were bound to 2001/2003 land use:

- No provision was made for climate change.
- Land use is taken from 2001 & 2003 aerial photography (although checked to some degree with the present).
- Urban land use is included in base export modeling but only to a limited degree.

1.3 Report Disclaimer

Nutrient exports, landuses and catchment hydrology exhibit characteristics and properties which vary from place to place and can change with time. The preparation of this Report involved gathering and assimilating facts and other information—including opinions—about these characteristics and properties, in order to carry out the brief. The facts and opinions reported in this document have been obtained by surveys and sampling, and interpretations of these using a variety of mathematical models. They are directly relevant only to the catchments and waterways and management practices at, about or for which the surveys and sampling were carried out, and are believed to be reported accurately. The mathematical models used are intended to provide indicative results only, and are dependent on input parameters. Any interpretation or recommendation given in this document is based on judgment and experience, and not on greater knowledge of the facts that the reported investigations may imply. The interpretations and recommendations are opinions provided for the sole use by the Wilson Inlet Catchment Committee, in accordance with a specific Tender Brief. Ecotones does not represent that the information or interpretation contained in this document address completely all issues relating to nutrient management in the CCI catchments. The responsibility of Ecotones is solely to its client, the Wilson Inlet Catchment Committee. It is not intended that this report be relied upon by any third party. Ecotones accept no liability to any third party.

1.4 Acknowledgements

The work detailed in this report has been carried out by the author and Ecotones & Associates staff: Bronwyn Neville carried out the landuse mapping, and Julian Neville conducted the hydrology mapping.

The SSPND framework and approach to nutrient modelling has been a collaborative effort between the author and David Weaver from the Department of Agriculture and Food, WA, with assistance from Rob Summers, Nardia Keipert, Rebecca Ovens and others from the Department of Agriculture and Food, WA. Dennis Van Gool from the Department of Agriculture and Food assisted in constructing the P & N loss frameworks, based on work from the Department's land resource mapping program (see Neville, 2008). He also calculated P & N Loss risk indexes based on landform and soils (the map unit database).

Our thanks to all of these people.

2 Landuse Mapping

2.1 Datasets Used

- Two digital aerial photography mosaics: Denmark (dated 16/07/01) and Albany_Mt_Barker_Manypeaks (dated 05/09/03). Desk-top landuse identification was based on these.
- Available digital data on landuse locations was supplied by WICC.
- Cadastre provided the landuse base polygons (approx 2007).
- Digital remnant vegetation mapping was used to ID vegetation cover (DAF 2008).

2.2 Methodology

The mapping process used has been applied in other catchments by Ecotones & Associates, including Torbay (see Neville, 2006), Bremer Bay, Lake Warden and the Vasse-Geographe. The land uses mapped include the following:

- Intensive agriculture – dairies, feed lots, piggeries, by location where information on locations is provided.
- Intensive (annual) horticulture – market gardens, potato farms – identified from air photos, or by location where information on locations is provided
- Perennial Horticulture – orchards, vineyards, olive groves – identified from air photos, or by location where information on locations is provided
- Grazing– sheep and cattle grazing as identified from air photos, or separated where information on locations is provided.
- Plantations - blue gums, pines– identified from air photos
- Industry/commercial areas – identified from air photos
- Urban Residential areas– identified from air photos
- Peri-Urban – lifestyle blocks & Rural residential– identified from air photos
- Remnant vegetation– identified from air photos

Cadastre was intersected with remnant vegetation to produce a base map. Identifiable landuse types within cadastral parcels (such as areas of horticulture) were digitized and separate polygons created.

Resultant polygons were attributed with landuse type in the following order:

- From remnant vegetation & plantation maps;
- On the basis of digitising (eg horticultures);
- From digital landuse data (eg lists of farms with location numbers for landuses such as dairy farming or specific grazing);;
- On the basis of aerial photography (eg landfills, dams, rural residential and lifestyle blocks);
- On the basis of cadastral size & aerial photography (urban areas).
- Where no landuse is ascribed from the above steps, land was classified as grazing, varying by geographic location between cattle for beef, mixed grazing and sheep. This was done in consultation with WICC staff.

A draft digital copy of this map (PDF file) was produced, and a single round of edits made after checking by WICC staff.

2.3 Results

The final map has been exported as a high resolution .pdf file, and is available as a feature class in Wilson Inlet geodatabase (supplied to WICC).

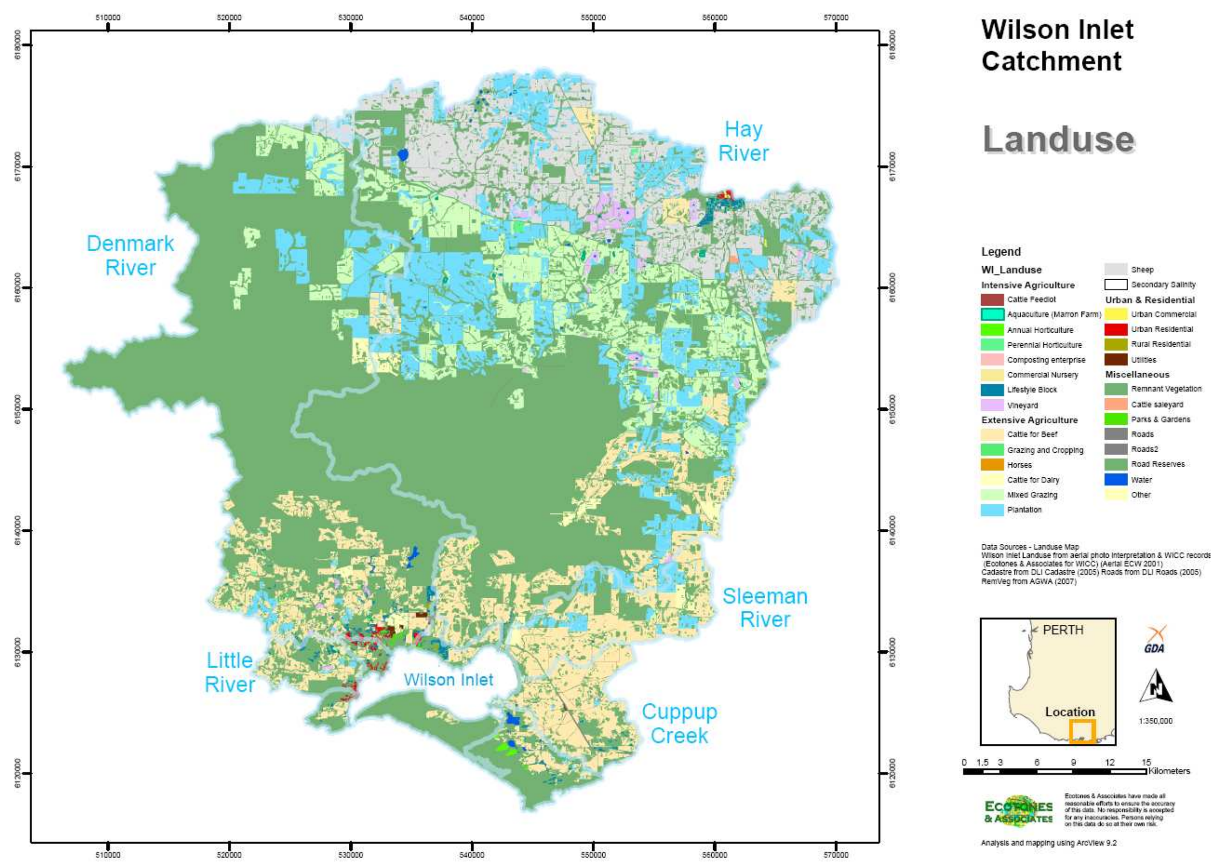

Figure 1. Wilson Inlet Catchment Landuse Map

3 Nutrient Hazard Modeling

3.1 Introduction

The nutrient hazard mapping combines the landuse map with hydrology and subcatchment maps, P & N loss risk mapping (Van Gool, 2005) and landuse-based nutrient export information from DAF surveys from other WA catchments (Neville, 2004, 2007, Ovens, 2008). The combined mapping uses a simplified SSPND model (see Neville, 2008) as used for the Torbay catchment in 2006 (Neville, 2006).

3.2 Hydrological Mapping

Datasets used

- Digital hydrology (‘wa_watercourses’, supplied by DOW)
- Digital elevation model – 10m cell size (WA Land monitor).

Methodology

1:250,000 scale hydrology mapping was checked and matched to aerial photography, with significant editing where necessary, notable to remove in-paddock drains. All streamlines were correctly segmented, joined, and flow direction checked. Stream order attribution was carried out (Strahler).

Hydrological sub-catchments were created and attributed. Sub-catchment routing was created, and sub-catchment nutrient assimilation figures estimated for each subcatchment.

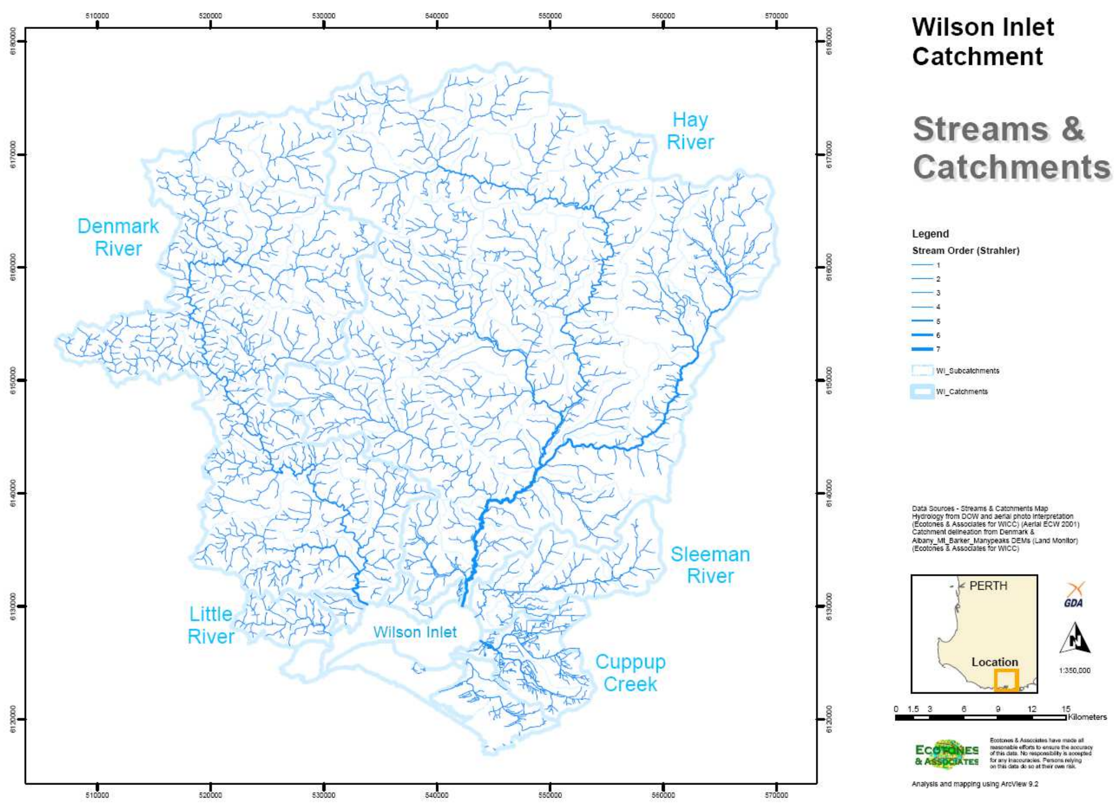

Figure 2. Wilson Inlet Streams & Catchments Map

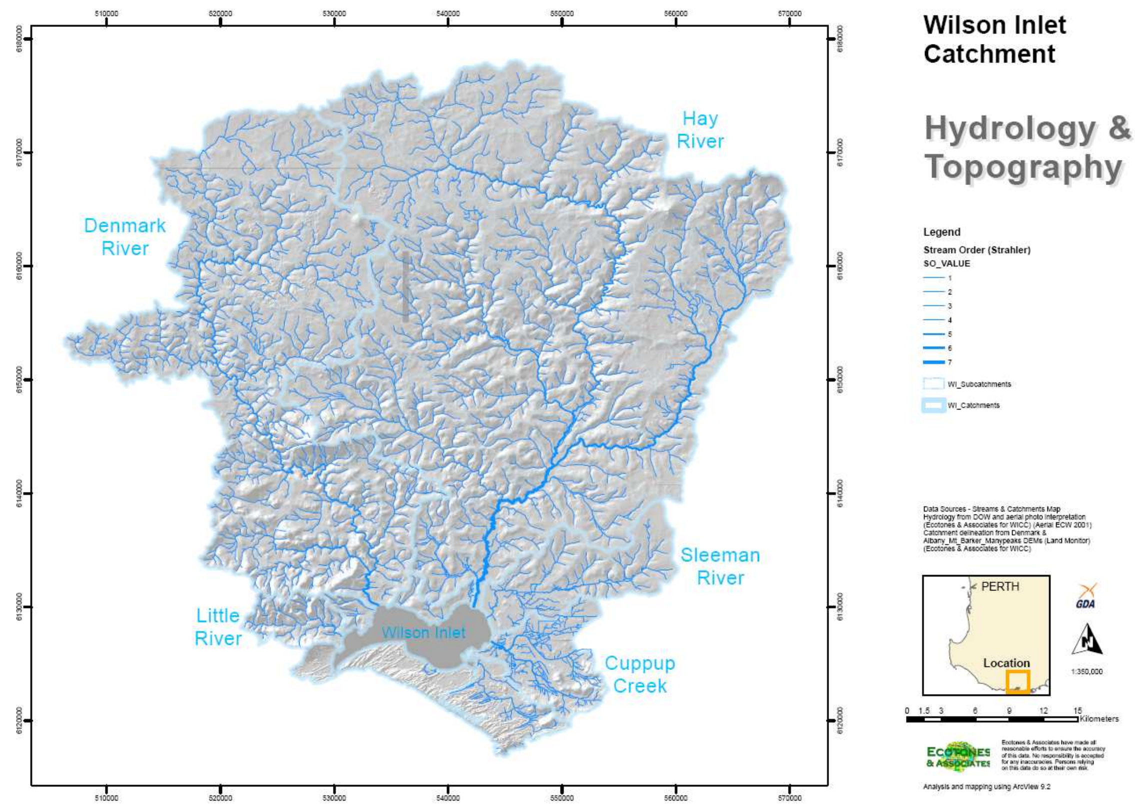

Figure 3. Wilson Inlet Hydrology & Topography Map

The final maps have been exported as high resolution .pdf files, and the datasets are available as feature classes in Wilson Inlet geodatabase (supplied to WICC).

3.3 Nutrient Hazard Modeling

Datasets used

- Landuse Map
- Subcatchment map
- Soils_subsystems mapping (DAF – van Gool et al 2005).

Risk Model Approach

The approach taken follows on from the PEWOC approach described by Weaver *et al*. (2003), which was in turn adapted to examine nutrient management scenarios for the Peel-Harvey catchment (Neville, 2005), to develop a tool called the Support System for Phosphorus Reduction Decisions (SSPRED).

The nutrient export model used in SSPRED is a modification of the P indicators tool of Heathwaite *et al*. (2003) which uses three model layers: loss potential, represented by nutrient inputs and soil mineralisation; transfer indicators (effective rainfall and erosion risk); and delivery indicators (land drainage or hydrological connectivity). These layers synthesise a number of existing modelling approaches in the UK. As we do not have other modeling approaches in the south west of WA to build on, this approach was adapted using local data and research.

While SSPRED was developed for Phosphorus, the underlying model can be used for Nitrogen as well, although a variation on the nutrient loss tables – suitable for N pathways – is used for nutrient delivery. In addition, assimilation coefficients are modified to reflect the lower levels of N assimilation in degraded waterways and drains.

The combined nutrient export model as developed – 'SSPND' – combines three layers:

- Nutrient Source: landuse related nutrient availability;
- Nutrient Delivery factors - based on susceptibility to nutrient loss from the most limiting soil/geomorphological factor (aka 'Nutrient Loss Risk'); and
- In-stream assimilation – based on sub-catchment characteristics (residence time, waterway depth) related to in-stream processing of nutrients or assimilation.

Methodology

The modelling is carried out for a set of unique map units for each catchment, derived from an intersection of each of the model layers Landuse, subcatchments and soil_subsystems maps were intersected to provide a composite mapping unit map – the 'mulusu' map. This map is attributed with nutrient surplus values, loss risk estimates and nutrient assimilation values as follows:

- Landuse-based N and P **surplus values** are based on farm-gate nutrient balance surveys conducted in the Vasse-Geographe catchment, as these are the most appropriate values available.
- **Soil loss risk** was calculated using an existing framework for P loss risk for WA soils (Van Gool *et al*. 2005) which uses soil and landform qualities (susceptibility to water erosion, flood risk and specific landforms/landscape location, soil PRI and water-table depth) to represent loss risk as weighted percentages for land units. This loss risk simulates the ability of the soil to store P or to lose P through leaching, surface runoff, loss of soil particles (Neville, 2004B). A framework for N loss risk for WA soils uses soil and landform qualities (susceptibility to water erosion, flood risk and specific landforms/landscape location, soil waterlogging and water-table depth). This loss risk simulates the ability of the soil to store N or to lose N through denitrification, volatilisation, leaching, surface runoff and loss of soil particles. Each nutrient risk framework produces a nutrient export susceptibility risk (Low to Extreme) for each soil group. In the digital datasets developed by the Department of Agriculture and Food, WA, soil occurrence is represented as a percentage for each landscape mapping units, rather than being mapped directly. We therefore have to derive an area-weighted risk factor for each mapping unit. This area-weighted risk factor is based on an estimate of probable P or N loss (a value ranging from 0% – no losses to 100% loss) for each P or N export susceptibility risk class.
- Nutrient **assimilation** values are calculated on the basis of subcatchment attributes [including min and max height, flow length, stream type, calculated residence time] (see Simmons and Cheng, 1985). They use assimilation coefficients based on the Bransby-Williams formula for each sub–catchment using a modification of the method of Davis *et al.* (1996). Flow times as used in this formula (based on catchment length, slope and area) were modified according to the proportion of catchment drainage which is artificial drains rather than natural waterways. The manning coefficient of these two types of channel was used to estimate an increased speed of flow in drains. We calculated an assimilation value (ie a % reduction) for flows from each sub-catchment, and another value for flows passing through subsequent sub-catchments, as the two pathways are frequently different in length, slope and order. Variations were made to the assimilation functions for N based on the expectation that N processing is poorer in degraded streams.

Calibration

Calibration was not specified in the project tender, in part as the as the SSPND model is an annualised lumped catchment model, intended to provide "relative and indicative" results. However we have carried out calibration to better provide results, and during this process modified assimilation indexes to better represent processes in the Wilson Inlet catchments. The single calibration year used is 1999, which is the last average rainfall year for which load estimates are available (Neville, 2002).

Calibration is undertaken in two ways: by modifying P and N assimilation strength separately for both originating and subsequent catchments, and by modifying global values for the % loss from different soil/landform loss risk classes.

Station	Monitoring Results		Modeling Results		Modeling Results as a % of Monitoring	
	TN	**TP**	**N**	**P**	**N**	**P**
Denmark	49.42	1.32	30.83	1.9	62%	144%
Hay	59.62	1.3	60.13	1.2	101%	92%
Cuppup	25.11	2.02	31.04	1.98	124%	98%
Little R	8.64	0.8	9.45	0.764	109%	96%
Sleeman	25.05	3.58	24.73	0.983	99%	27%
Total	**167.8**	**9.0**	**156.2**	**6.8**	**99%**	**91%**

Table 1. Catchment Calibration load estimates

The table above shows the load estimates from the monitoring data and the post-calibration, and indicates a very good fit with the 1999 year loads for N (R^2 = 0.79). The fit for P is also good with the exception of the Sleeman River, and excluding this the R^2 is 0.697. Clearly there are processes at work in the Sleeman that we cannot account for, which are providing a monitored load estimate of over 300% of the model load. We note that the landuse surplus rates used have not been derived locally, which may account in some part for this large error. Alternatively, drainage processes in the Sleeman may be contributing to the large P loads; alternatively the process used to derive the estimated loads may be in error.

Estimated Landuse Exports

Estimated P & N exports (loads) have been grouped by landuse for all catchments draining into Wilson Inlet, and are shown in Table 2 below. Native vegetation accounts for over 50% of the total area as shown in Table 3, but contributes a very small amount of N and P. Cattle for Beef is by far the largest contributor of both N (68.6%) and P (66.8%) even though covering only 12% of the catchment area. Mixed grazing is the second largest contributor of N (18.5%), although its estimated P exports are small. Annual horticulture is estimated to be the second largest producer of P at 13% of the total, closely followed by Urban & Residential at 10.1%.

	Area (ha)	N export (T)	P export (T)
Annual Horticulture	130	0.60	1.13
Cattle for Beef	26,886	117.21	5.83
Cattle for Dairy	1,742	9.83	0.51
Lifestyle Block	1,016	4.40	0.13
Mixed Grazing	38,416	31.65	0.10
Native Vegetation	127,060	0.36	0.01
Other	570	0.50	0.03
Perennial Horticulture	219	0.03	0.02
Plantation	24,727	0.91	-
Roads	989	0.02	0.00
Urban & Residential	546	4.60	0.89
Vineyard	1,359	0.68	0.08
Total	223,659	170.79	8.73

Table 2. N & P exports by Landuse.

	Area (%)	N Export (%)	P Export (%)
Annual Horticulture	0.1%	0.4%	13.0%
Cattle for Beef	12.0%	68.6%	66.8%
Cattle for Dairy	0.8%	5.8%	5.8%
Lifestyle Block	0.5%	2.6%	1.5%
Mixed Grazing	17.2%	18.5%	1.1%
Native Vegetation	56.8%	0.2%	0.1%
Other	0.3%	0.3%	0.3%
Perennial Horticulture	0.1%	0.0%	0.2%
Plantation	11.1%	0.5%	0.0%
Roads	0.4%	0.0%	0.0%
Urban & Residential	0.2%	2.7%	10.1%
Vineyard	0.6%	0.4%	0.9%

Table 3. N & P Landuse exports as %.

3.4 Hazard Map Results

All final maps have been exported as high resolution .pdf files, and are available as feature classes in the Wilson Inlet geodatabase (supplied to WICC).

Terms

Loss –the estimated P or N delivered to streams, *before* accounting for assimilation.

Export – the estimated P or N exported to the Wilson Inlet, *after* accounting for assimilation.

Intensity – P or N loss/export per hectare aggregated at the subcatchment scale. Intensity maps are shaded to reflect the relative intensity.

Contribution – P or N loss/export summed for each subcatchment. Contribution maps are coloured according to a 'natural breaks' classification[1], which best illustrates the relative importance of each subcatchments' contribution.

Types of nutrient hazard map.

We have produced five different types of hazard map:

Map Unit scale

- N & P EXPORT Risk maps – these show loss intensity (kg/ha) at the Map Unit Level, with no aggregation. Use – base export data

Subcatchment scale

- N & P LOSS Intensity maps – show P or N loss per hectare aggregated at the subcatchment scale. *These indicate the estimated intensity of loss to waterways in each subcatchment, or where might we expect to see localised nutrient issues.*
- N & P EXPORT Intensity maps – show P or N export per hectare aggregated at the subcatchment scale. *These indicate the estimated intensity of export to Wilson Inlet, or which subcatchments are the most concentrated producers of nutrients entering Wilson Inlet.*
- N & P LOSS Contribution maps – show P or N loss for each subcatchment. *These indicate the estimated size of loss to waterways in each subcatchment, which may contribute to localised nutrient issues.*
- N & P EXPORT Contribution maps – show P or N export for each subcatchment. *These indicate the estimated size of export to Wilson Inlet, or which subcatchments are the largest producers of nutrients entering Wilson Inlet.*

[1] Classes are based on natural groupings inherent in the data. ArcMap identifies break points by picking the class breaks that best group similar values and maximize the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big jumps in the data values.

EXPORT Risk maps

Estimated N export risk is highest in areas closest to the inlet, notably to the east of the inlet, but moderate risk is also indicated in large areas of the catchment. The calibration requires that relatively low N assimilation exists, hence areas further away carry more risk than for P export.

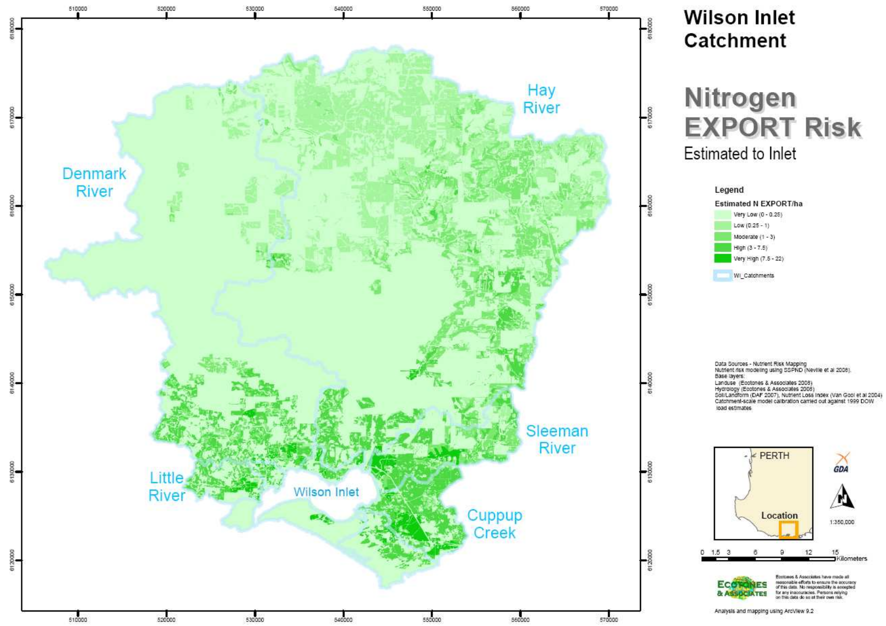

Figure 4. Nitrogen EXPORT Risk map

Estimated P export risk is again highest in areas closest to the inlet, notably to the east of the inlet, but risk falls off notably further upstream in major catchments.

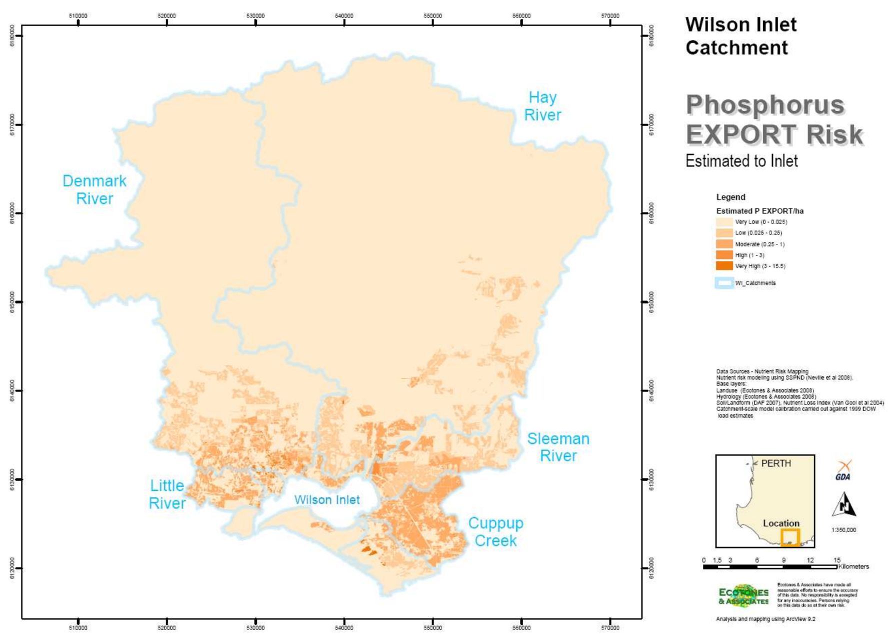

Figure 5. Phosphorus EXPORT Risk map

N & P LOSS Intensity Maps

N loss intensity is high in most of the subcatchments adjacent to the inlet, due to the more intensive land-uses practices there; particularly Sleeman, Cuppup, Little River and Scotsdale. Some catchments in the upper catchment also indicate high loss rates, which may be associated with subcatchment-scale nutrient issues. Subcatchments with high proportions of native vegetation or plantation show low intensity of loss.

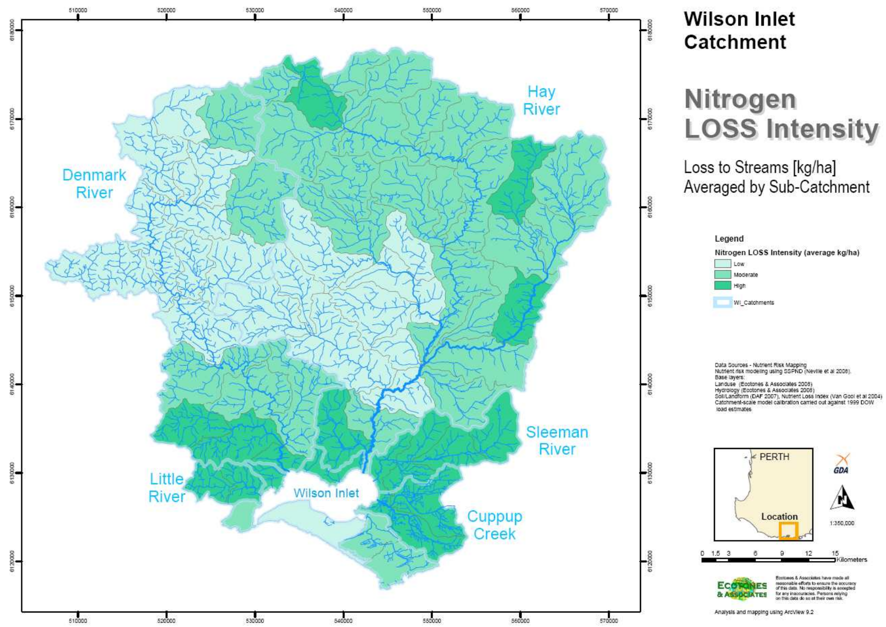

Figure 6. Nitrogen LOSS Intensity Map

High P loss rates are mainly found in southern catchments, notably Sleeman, Cuppup, Little River and lower Scotsdale. Subcatchment-scale nutrient issues are more likely to be found in these areas.

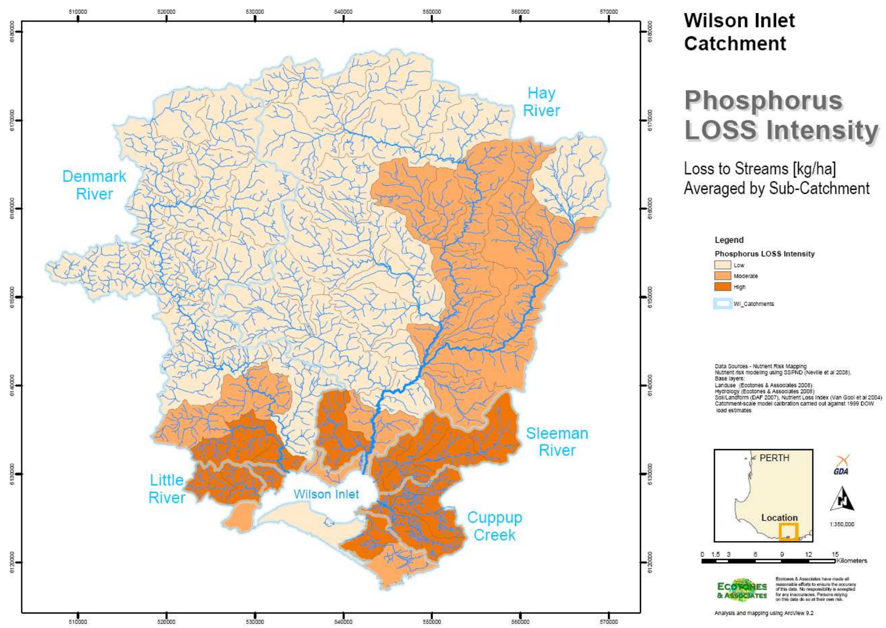

Figure 7. Phosphorus LOSS Intensity Map

N & P EXPORT Intensity Maps

N export intensity is highest in a small number of subcatchments adjacent to the inlet, due to the more intensive land-uses practices there; the Cuppup Creek, the lower Sleeman River, and small catchments adjacent to Denmark town.

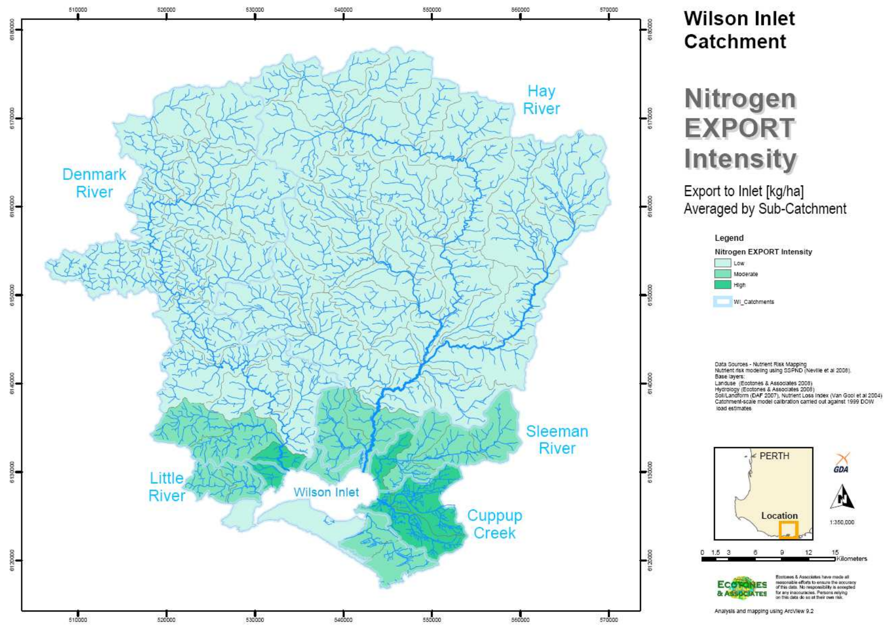

Figure 8. N EXPORT Intensity Map

P export intensity is highest in the same subcatchments adjacent to the inlet – the Cuppup Creek, the lower Sleeman River, and small catchments adjacent to Denmark town – and also in the lower Little River and lower Lake Saide catchments.

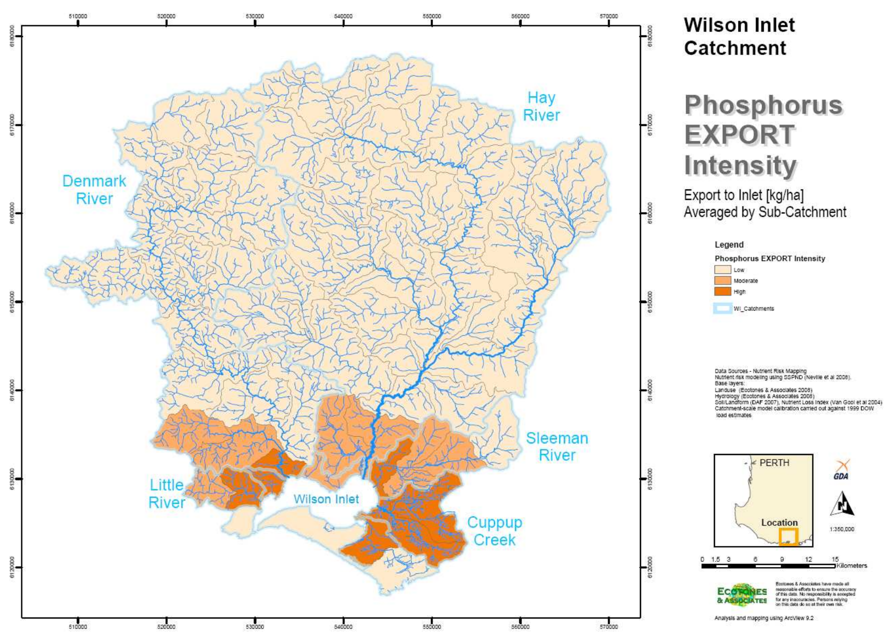

Figure 9. P EXPORT Intensity Map

N & P LOSS Contribution maps

N loss contributions (the amount of N lost to streams in each subcatchment) are high in much of the Hay catchment, the Sleeman River and Cuppup Creeks, the Scotsdale and Sunny Glen catchments.

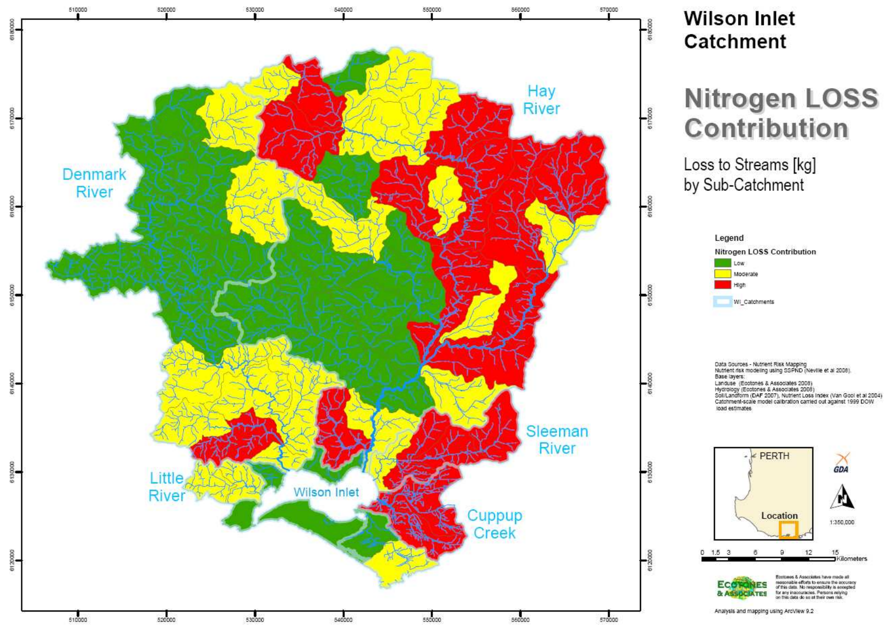

Figure 10. N LOSS Contribution map

N loss contributions (the amount of N lost to streams in each subcatchment) are high in much of the Hay catchment, the Sleeman River and Cuppup Creeks, the lowers Scotsdale and the Sunny Glen creek. The picture is similar for P.

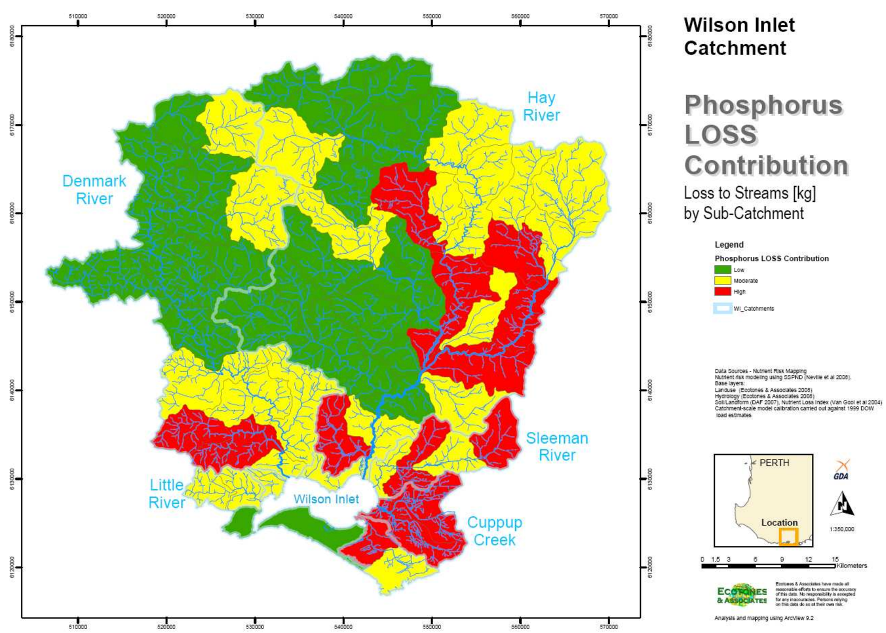

Figure 11. P LOSS Contribution map

N & P EXPORT Contribution maps

The export contribution maps are possibly the most significant maps from the Wilson Inlet perspective. They indicate the key subcatchments for loads into the inlet.

N export contribution is largest from the Cuppup Creek, and P export contribution from the Cuppup Creek, lower Lake Saide, and the lower Denmark river at Denmark town site.

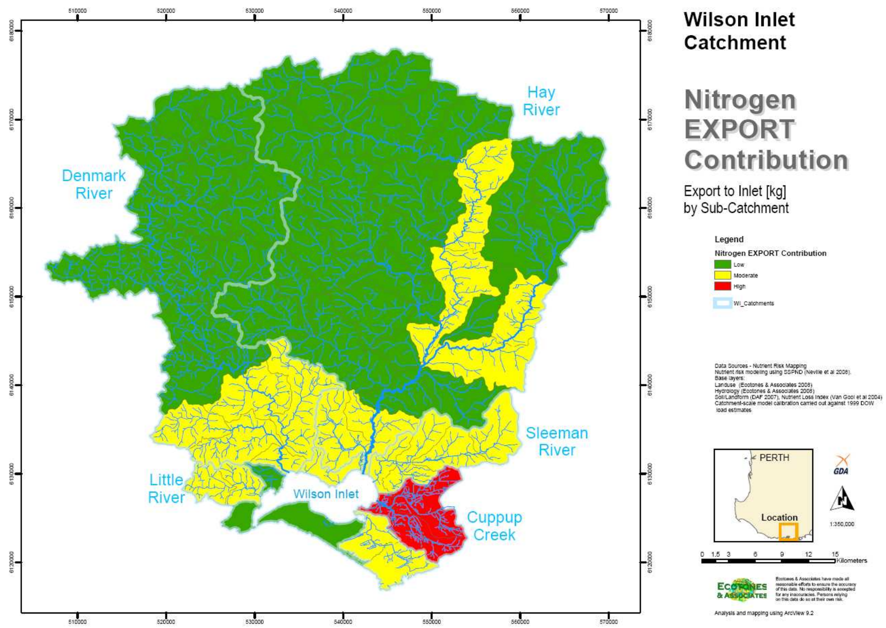

Figure 12. N EXPORT Contribution map

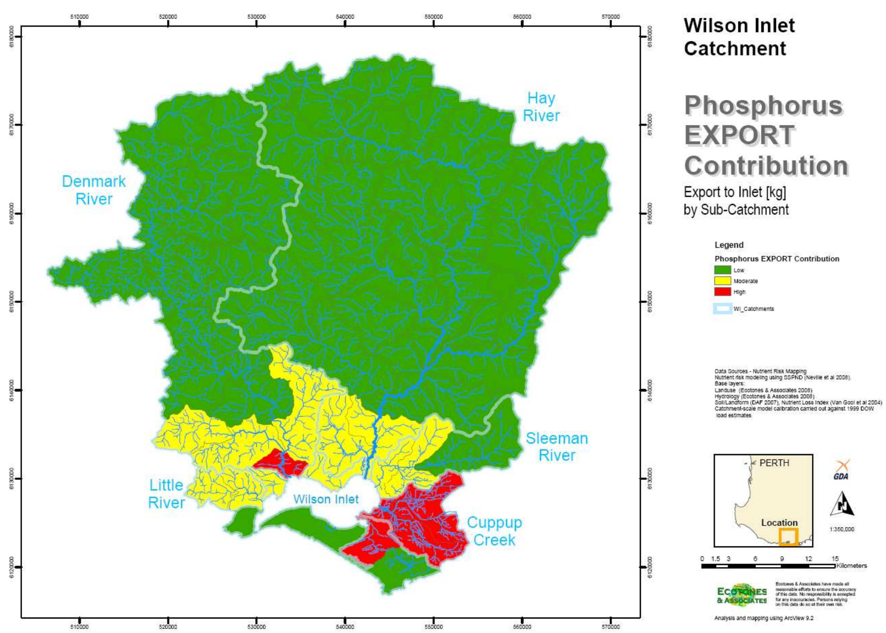

Figure 13. P EXPORT Contribution map

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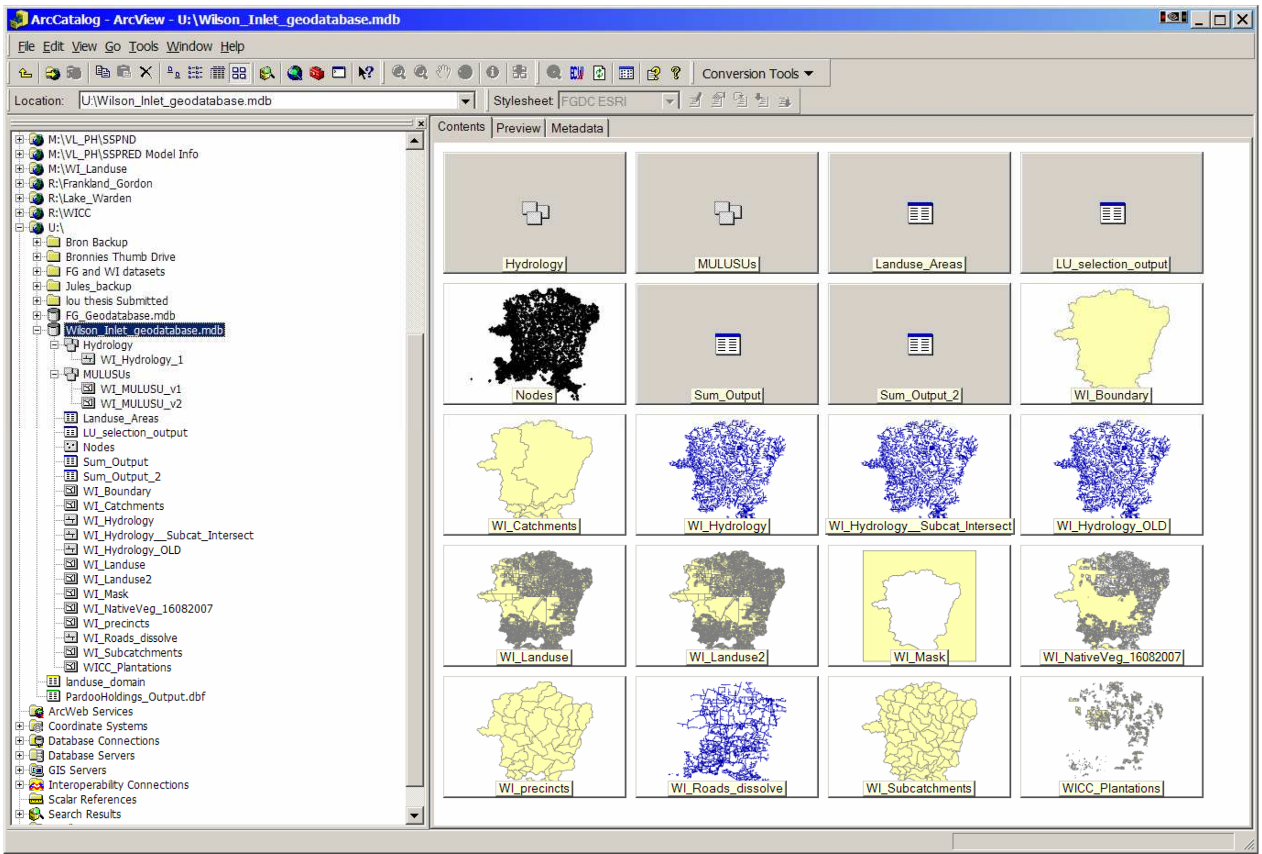
5 Appendices

5.1 Datasets & Project Files

Wilson Inlet Geodatabase

All of the new datasets produced are contained as feature classes within a Geodatabase – "Wilson_Inlet_Geodatabase". The geodatabase contains the features as follows:



Other Datasets

These are contained within the WICC folder which has been provided on DVD.

Map Document

An ArcView map document (WI_Landuse_Nutrient_Risk_Project.mxd) is provided which displays and provides legends for all of these datasets including all of the hazard maps, which are based on the WI_Subcatchments feature class. ArcView 9.2 is required to read this geodatabase.