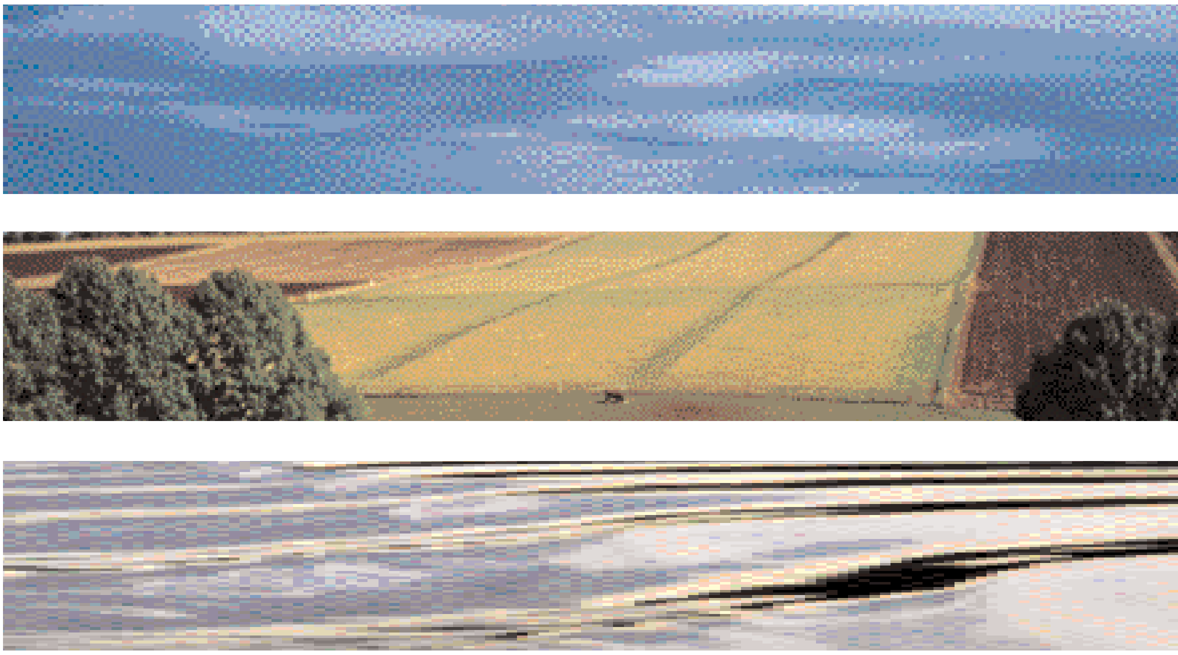
COOPERATIVE RESEARCH CENTRE FOR **CATCHMENT HYDROLOGY**

MODELLING OF RUNOFF, SEDIMENT AND NUTRIENT LOADS FOR THE MAROOCHY RIVER CATCHMENT USING EMSS

TECHNICAL REPORT
Report 05/08

June 2005

Ross Searle



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[1]Queensland Department of Natural Resources and Mines, Bundaberg, Qld, 4670

Preface

The Cooperative Research Centre (CRC) for Catchment Hydrology has always had a strong focus on producing outputs that have practical application. In late 2002 as part of the Communication and Adoption Program (Program 7) it was decided to instigate a series of Development Projects in each of the CRCs focus catchments. The aim of these Development Projects was to take some of the tools being developed within the CRC for Catchment Hydrology and apply them to real life situations within the focus catchments. This way the tools could be tested by CRC for Catchment Hydrology staff who could provide feedback on their application to the tool developers. In addition another major component of the Development Project was to enhance the capacity within the agency partners of model use. This report outlines the results of the development of a local EMSS model for the Maroochy River Catchment.

This Development Project was much more than a simple application of the CRC for Catchment Hydrology's EMSS model to a specified location. The project brought together a very disparate team representing community groups, local authorities as well as state agencies and local universities. Representatives from these stakeholder groups had varying experiences and abilities in applying such numeric models. In addition, the stakeholders had a wide-ranging need for the application of such models. The level of understanding of what modelling could produce and of what scales was not particularly high. This community based group, affectionately called "Maroochy Catchment Community Modelling Team" oversaw the development of the local EMSS model for their own Maroochy Catchment. More importantly the group then went on to use the model in their local area and to make management decisions on how the catchment could be managed. This partnership between the various stakeholders was built on a foundation of mutual trust and willingness to learn from one another. The vehicle where this learning occurred was a series of workshops in which a shared understanding of the models capabilities was gained and, based on local input, the model was developed.

This report outlines the mechanics of the model development, its application and a preliminary assessment of the results produced. In addition to the local application of the results the modelling exercise has allowed the development of increased capacity within a range of stakeholders in the use of this and similar models. This local exercise has been the precursor to the application of similar models throughout the catchments of coastal Queensland.

David Perry, Program Leader
Communication and Adoption Program
CRC for Catchment Hydrology

Acknowledgements

The development of the Maroochy Catchment EMSS model has been a collaborative effort involving a great many individuals. Those in the Maroochy Catchment Community Modelling Team who have directly contributed to the development of the model include:

Jon Burgess (Queensland Department of Natural Resources and Mines)

Steve Dudgeon (Maroochy Shire Council)

Cerran Fawns (Maroochy Water Watch)

Gwyn Griffith (Maroochy Landcare)

Bill McFarlane (Queensland Environmental Protection Agency)

John Muir (Queensland Department of Primary Industries)

Peter Oliver (Queensland Department of Natural Resources and Mines)

Mark Sallaway (Queensland Department of Natural Resources and Mines)

Andrew Todd (Maroochy Water Watch)

Tony Weber (WBM Oceanics)

Belinda Wedlock (Maroochy Shire Council)

Jacki Williams (Maroochy Landcare)

The efforts of Sandra Griffith (Maroochy Landcare) and Esma Armstrong (Maroochy Landcare) in setting up and supporting the project are gratefully acknowledged.

Robin Ellis (Queensland Department of Natural Resources and Mines) provided a great deal of assistance in data preparation and analysis.

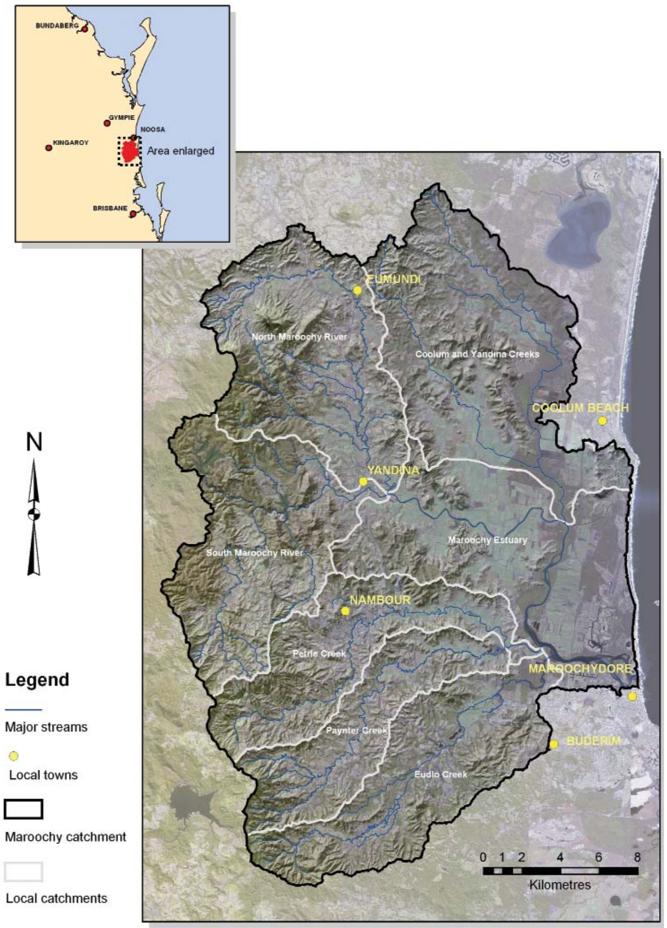
The project would have not been possible without the generous support of the Cooperative Research Centre for Catchment Hydrology through its Development Project. In particular the work of Joel Rahman and Shane Seaton in providing training and technical support is gratefully acknowledged.

Report editors Dr Tony Ladson (Monash University), Andrew Biggs (Queensland Department of Natural Resources and Mines) and Mark Silburn (Queensland Department of Natural Resources and Mines) are gratefully acknowledged for their invaluable assistance in reviewing this report.

Project Summary

Where Was The Project?

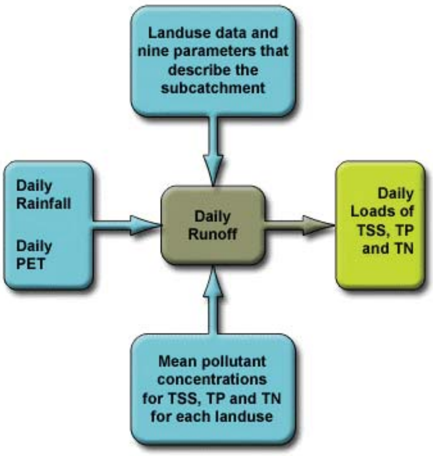
The project was undertaken in the Maroochy Catchment in South East Queensland.



What Was Done?

A catchment water quality model produced by the Cooperative Research Centre for Catchment Hydrology, called the Environmental Management Support System (EMSS), was implemented in the Maroochy Catchment. EMSS predicts daily flow and pollutant loads for a catchment. EMSS estimates loads for:

- Total Suspended Sediment (TSS)
- Total Nitrogen (TN) and
- Total Phosphorous (TP).



Why Was It Done?

- The Maroochy Catchment is currently experiencing a range of land use pressures.
- Since the inception of the Environmental Health Monitoring Program (EHMP) “Report Card”, the Maroochy Catchment “health” has declined.
- The release of the broad scale South East Queensland EMSS model commissioned by the Moreton Bay Partnership generated a lot of community interest.
- There was a desire within the community to develop an understanding of catchment models and how they can be applied.

Who Did It?

The project was undertaken by a group of stakeholders with interests in land management and water quality within the Maroochy Catchment.

The group was called "The Maroochy Catchment Community Modelling Team".

The team consisted of members from Maroochy Landcare, Maroochy Water Watch, Maroochy Shire Council, the Environmental Protection Agency (EPA), the Queensland Department of Primary Industries (DPI), Moreton Bay Waterways and Catchments Partnership and the Queensland Department of Natural Resources and Mines (NR&M).

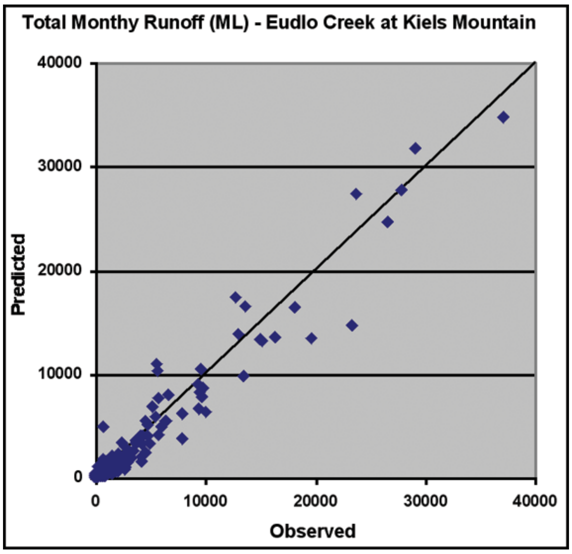
Model Inputs

- Daily rainfall
- Monthly potential evapotranspiration
- Daily runoff from gauging stations
- Landscape erosion hazard surface
- Land-use
- Point sources pollutants
- Storages descriptors
- Event mean concentrations (EMC) and dry weather concentrations (DWC) of pollutant runoff for each land-use*

Model Outputs

Hydrology

The model does a good job at simulating the hydrology of the Maroochy Catchment. The chart below shows modelled vs observed flows for one of the four gauges used in the calibration.

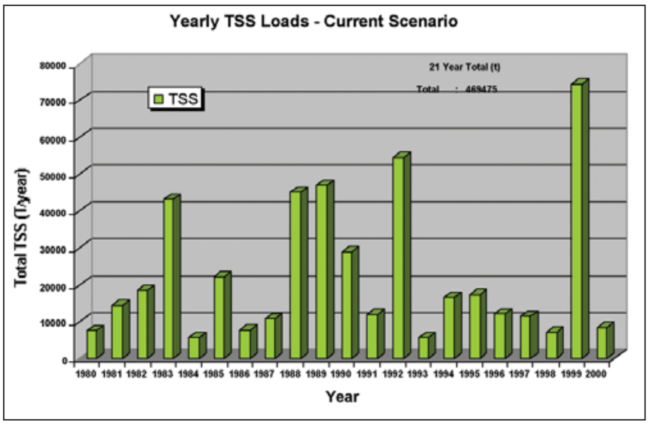


Pollutants

Over the 21 year model period EMSS predicts that the Maroochy Catchment generates on average:-

- 22,350 tonnes sediment / year
- 420 tonnes nitrogen / year
- 11 tonnes phosphorus / year.

The three following charts show the total annual loads predicted by the model for TSS, TN and TP.



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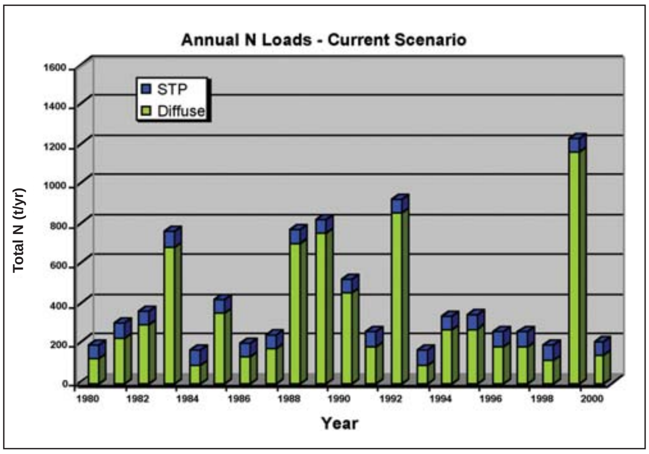
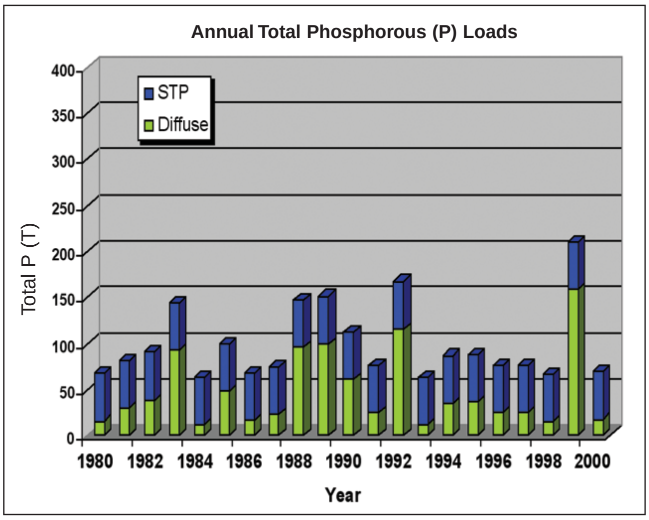
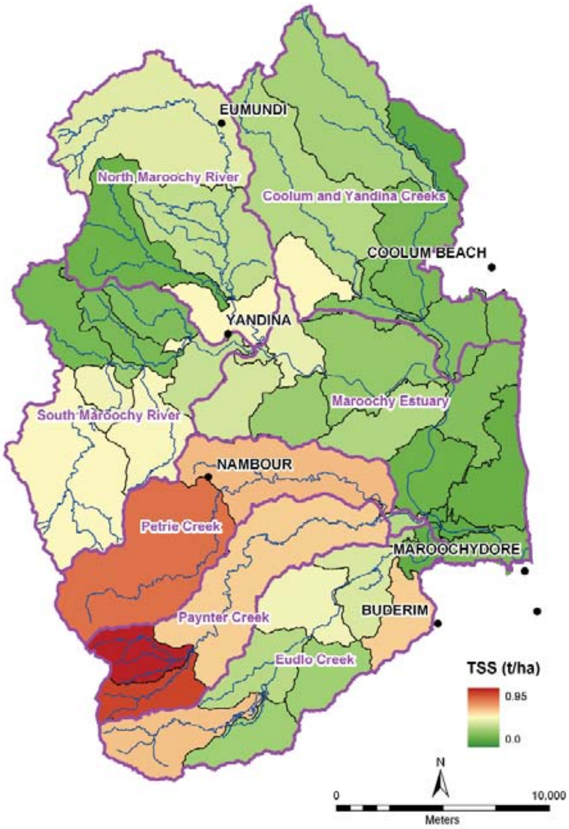
*Please refer to the "Series on Model Choice" in particular #2 for an explanation of EMC/DWC - http://www.toolkit.net.au/modelchoice (Grayson, 2005)





The map below shows the spatial distribution of sediment generation within the catchment.



Comments

- Diffuse or landscape generated loads dominate the total pollutant loads from the catchment.
- There is a significant difference in pollutant loads between years.
- The model will be a useful planning tool for land and water quality management within the Maroochy Catchment.

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1. Introduction

1.1 Background

The Maroochy Catchment is currently experiencing a range of land-use pressures. Along with other areas in South East Queensland (SEQ), the Maroochy Catchment is experiencing significant urban and rural residential development pressure. In 2003 the Moreton Sugar Mill ceased production, meaning that sugar production is no longer a viable industry for Maroochy cane farmers. Hence, there is potentially about 10,000 ha of land that will change use in the short term. At the same time there are a range of governmental land-use planning schemes and policies being implemented. These planning instruments will have significant impacts on potential future land-uses within the Maroochy Catchment.

The Moreton Bay Waterways and Catchments Partnership (MBWCP) has established an Ecosystem Health Monitoring Program (EHMP) in SEQ. Every year this program produces a “Report Card” which describes and rates the “health” of catchments within SEQ. Since the inception of the EHMP the Maroochy Catchment health has declined.

In 2001 the National Land and Water Resources Audit (NLWRA) produced a national scale SedNet model (Prosser *et al*., 2001). This model covered the majority of the Australian coastal regions. The SedNet model predicts long term annual pollutant loads exported from catchments. While this model was useful at the national scale there was a need for finer scale models to assist in understanding regional water quality issues.

In 2002, the Cooperative Research Centre (CRC) for Catchment Hydrology was commissioned by the MBWCP to develop an Environmental Management Support System (EMSS) to simulate runoff and pollutant movement across the entire SEQ region, including the Maroochy catchment (Chiew *et al*., 2002). The model produced was based on broad scale data sets and the outputs generated were appropriate for use on a broad scale.

After the public release of the SEQ EMSS, there was much interest amongst sectors of the Maroochy Catchment community pertaining to the EMSS model. Members of the Maroochy Catchment community felt the EMSS may be a useful tool to assist in addressing some of the issues in the catchment, if the model could be implemented at a finer scale.

At the same time the CRC for Catchment Hydrology was aiming to increase the use and understanding of its modelling tools within the wider community. To facilitate this process the CRC for Catchment Hydrology and its partners including the Department of Natural Resources and Mines embarked on a training and support programme for EMSS.

With the convergence of these circumstances an opportunity arose at the end of 2003 to develop a project to produce an EMSS for the Maroochy Catchment, using the best available natural resource data. Inspired by Maroochy Landcare, a community based group called the “Maroochy Catchment Community Modelling Team” was formed to undertake the EMSS modelling for the Maroochy Catchment.

1.2 The Maroochy Catchment Community Modelling Team

The team consisted of members from Maroochy Landcare, Maroochy Water Watch, Maroochy Shire Council (MSC), Environmental Protection Agency (EPA), Queensland Department of Primary Industries (DPI), Moreton Bay Waterways and Catchments Partnership (MBWCP) and the Queensland Department of Natural Resources and Mines (NR&M).

Through a series of workshops the team was able to collectively source, rigorously analyse and integrate the most appropriate currently available data into the model. Throughout the period of model development the team was also involved in learning about and analysing the concepts and assumptions on which the model was based. The team also provided peer review of the model at each stage of development.

1.3 Project Objectives

The objectives of this project were to:

- build an EMSS model for the Maroochy Catchment using the best available data;
- build understanding between people of diverse backgrounds regarding catchment models that may be of use for natural resource management in the Maroochy Catchment at a range of scales;
- identify weaknesses and strengths of these catchment models;
- identify weaknesses and strengths of Maroochy Catchment water quality, water flow, land-use and soil data available to run these models;
- collect data to address these weaknesses; and
- communicate these outcomes to others interested in the use of catchment models as an aid to improved natural resource management in the Maroochy Catchment and elsewhere.

2. Biophysical Resources of the Maroochy Catchment

2.1 Location

The Maroochy Catchment (Figure 1) covers an area of over 60,000 ha on the Sunshine Coast in SEQ and is located approximately 100 kilometres north of Brisbane. It is centred on the city of Nambour and includes the towns of Yandina, Eumundi and Maroochydore. The Maroochy Catchment is contained almost entirely within the Maroochy Shire.

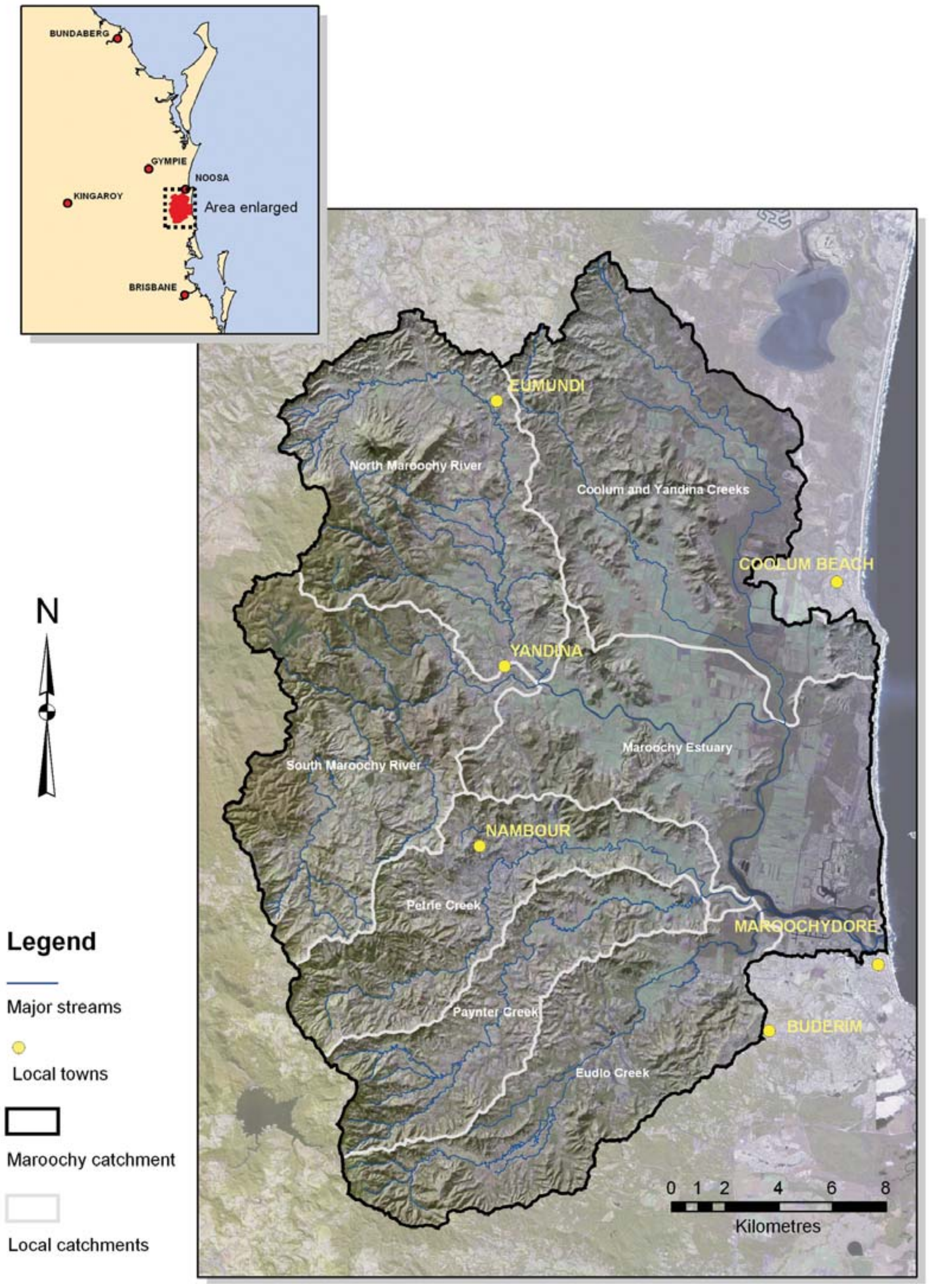

Figure 1. Location of the Maroochy Catchment.

There are seven locally recognised catchments within the Maroochy River Catchment. These are, Eudlo Creek, Paynter Creek, Petrie Creek, South Maroochy River, North Maroochy River, Maroochy Estuary and Coolum and Yandina Creek (Figure 1). The river mouth is located approximately 1 km north of Maroochydore. There are three main regulated storages used for water supply within the catchment, Cooloolabin, Wappa, and Poona.

2.2 Landscapes and Soils

The dominant landforms in the catchment include undulating low hills to very steep mountains on andesite and rhyolite in the north west of the catchment (Figure 2). The dominant soils of these landscapes include shallow lithosols (Stace *et al.,* 1968) on the steep slopes, red gradational and red and yellow podzolic soils and krasnozems. The south western fringe of the catchment is dominated by a gently inclined basaltic plateau overlain by krasnozems in the upper parts of the landscape and heavier clay soils including black earths and prairie soils in the lower parts of the landscape. The southern end of the catchment is predominantly undulating steep hills with dissected slopes on sandstones. The soils of this landscape tend to be coarse textured and the dominant soils include red and yellow earths, podzolics and lithosols. The uplands of the Maroochy Catchment drain onto an extensive level alluvial plain in the east. The soils of this landscape range from uniform coarse textured soils through to heavy cracking clay soils. The eastern part of the catchment is dominated by coastal dunes and a tidal estuary. The soils of this landscape include coarse textured humus podzols, deep siliceous sands and humic gleys. A comprehensive description of landscapes and soils of the Maroochy Catchment is given in Capelin (1987).

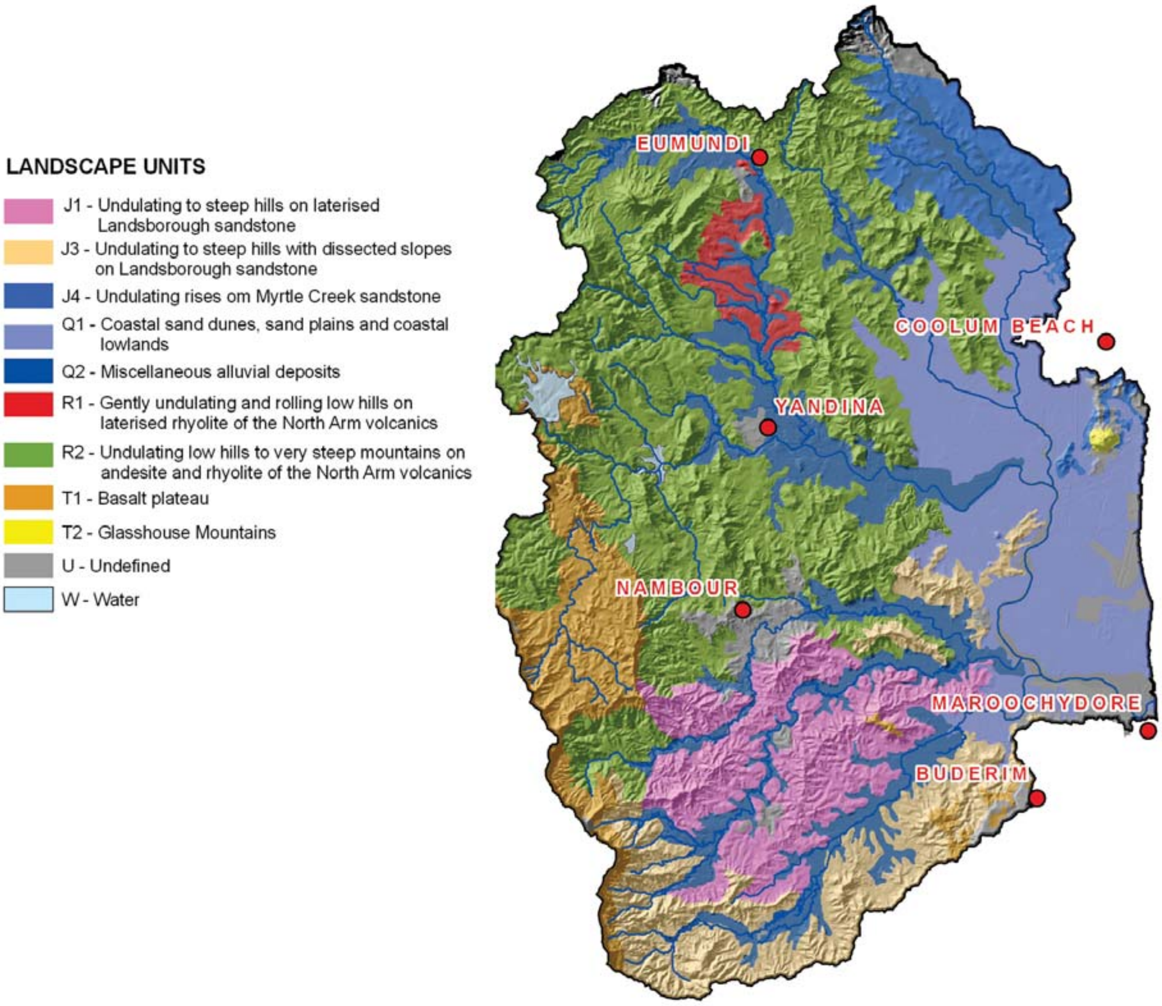

Figure 2. Landscapes of the Maroochy Catchment (Capelin, 1987)

2.3 Climate

The Maroochy Catchment has a coastal sub-tropical climate, with a summer dominant rainfall (Figure 3). The catchment receives approximately 1700 mm of rainfall a year with an annual actual evaporation of approximately 1430 mm. Storm events are common during the summer months, with approximately 15 rain days per month during the summer period and 8 rain days per month during the winter months.

At Nambour, the average monthly maximum temperatures range from 29.2ºC in January to 21.1ºC in July. Average monthly minimum temperatures range from 19.7ºC in February to 7.5ºC in July.

2.4 Land-use

The Maroochy Catchment has a broad range of land-uses including urban development, sand mining, light and heavy industry, grazing, agriculture and tourism. Urban development is dominant along the coastal strip and in the town of Nambour. The hinterland is dominated by rural industries, native forests and rural residential development. The majority of the population lives on the coastal strip.

Due to the closure of the Moreton Mill in 2003 and a number of government planning initiatives currently under consideration, the patterns of land-use within the Maroochy catchment may change considerably in the near future.

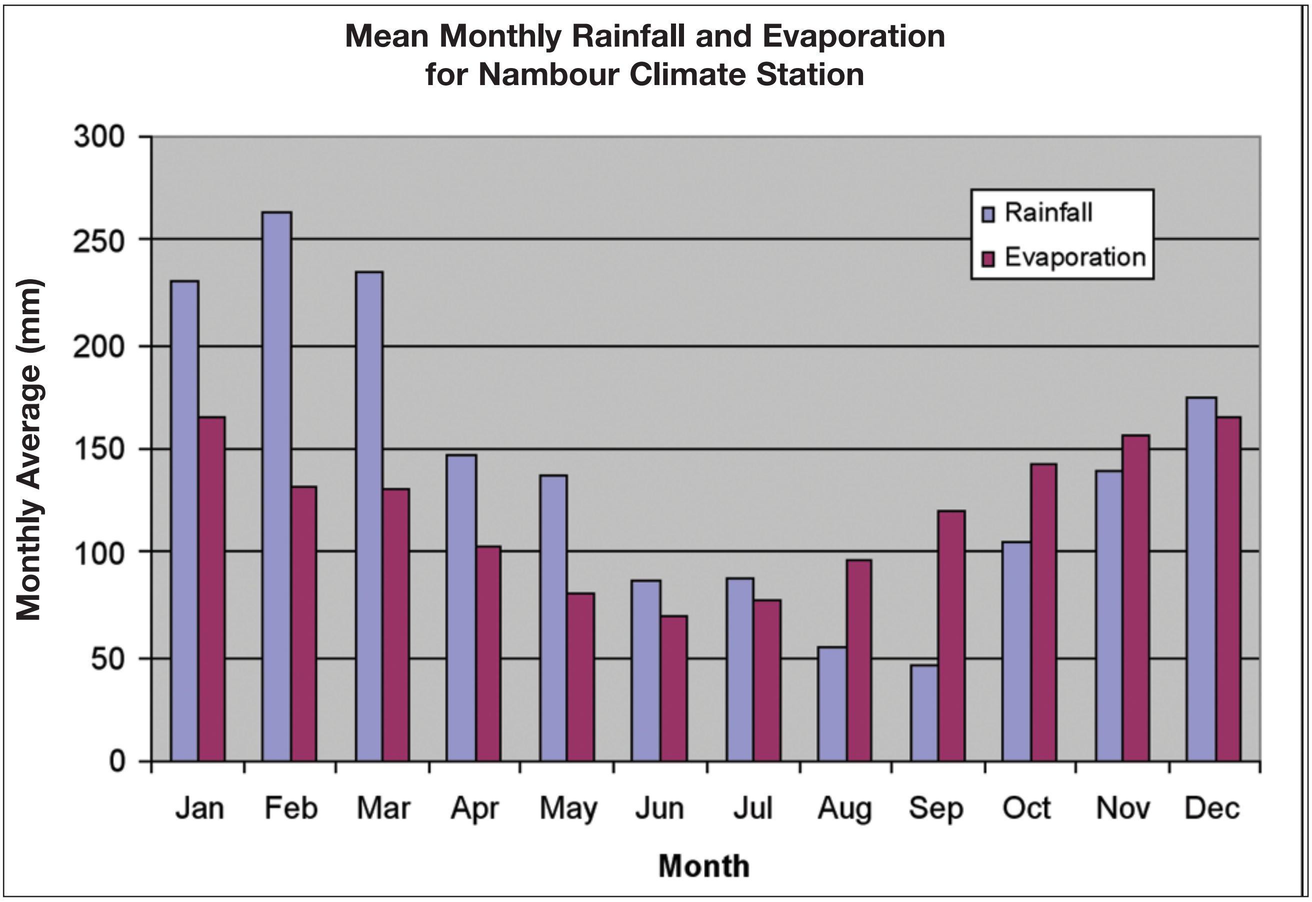

Figure 3. Mean Monthly Rainfall and Actual Evaporation for the Nambour Climate Station.

3. About the EMSS*

This section is derived from information contained in the SEQ EMSS Assistant (CRC for Catchment Hydrology, 2002). The EMSS is composed of three linked models. A runoff and pollutant export model (referred to as 'Colobus') operates on each sub-catchment, providing estimates of daily runoff (Q), and daily loads of total suspended sediment (TSS), total phosphorous (TP) and total nitrogen (TN). The sub-catchments are linked to one another using a 'node-link' system to represent the river network.

Flow and pollutant loads from sub-catchments are conveyed down through the river network using a routing model (referred to as 'Marmoset').

As a number of sections in the river are regulated by storages, a storage model (referred to as 'Mandrill') has been included in the EMSS. This model regulates river flows, traps pollutants, and accounts for evaporative losses.

A schematic representation of the EMSS models and objects and how they are interlinked, is shown in Figure 4.

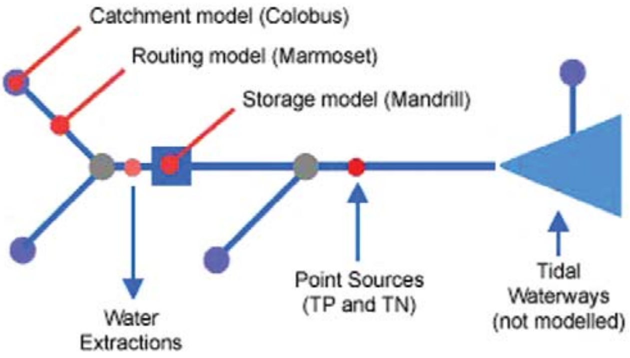

Figure 4. Schematic Diagram of the EMSS Model.

The physical system is represented as a series of:

Model Sub-catchments

There are 46 model sub-catchments that were automatically generated by the EMSS software, averaging 13 km^2 in area. The level of model sub-catchment detail is user controlled. The Maroochy Catchment Community Modelling Team considered 46 individual model sub-catchments to be approximately the appropriate level of detail. Individual model sub-catchments are grouped into seven local catchments in the EMSS. These local catchments represent the local drainage basins within the Maroochy Catchment.

Nodes

There is a node for each model catchment outlet, and nodes for storages, gauging stations, diversion points, and major pollutant point sources. Spacer nodes are also placed at various points along the river network.

Links

Nodes are connected by links, which may be thought of as segments of the river network. Runoff and pollutants are transferred along links using the Marmoset model. The river network represented in the EMSS is approximately 176 km long.

3.1 What is the Colobus Model?

The Colobus model is used in the EMSS to predict daily flows and pollutant loads from each of the model sub-catchments. A schematic representation of the model is presented in Figure 5.

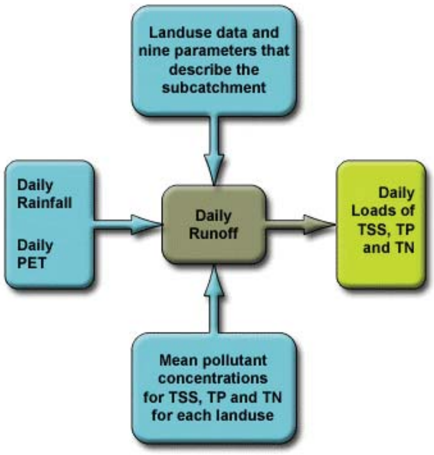

Figure 5. Schematic Representation of the Colobus Model.

Daily rainfall and potential evapotranspiration data are used to estimate daily runoff, which is partitioned into four different flow components. These flow components are multiplied by user-specified loading factors to estimate daily loads of total suspended sediment (TSS), total phosphorous (TP) and total nitrogen (TN).

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*EMSS has now been superceded by E2, a modelling platform that expands on the capability of EMSS.

Colobus is referred to as a ‘lumped-conceptual’ model. The term ‘lumped’ means that the model is applied as a single set of equations for a whole sub-catchment. In other words, the model does not recognize spatial variation in runoff or pollutant generation across the sub-catchment. The term ‘conceptual’ means that most of the input parameters and internal processes in the model have a quasi-physical meaning. Therefore, most of the input parameters cannot be measured in the field but have a physical basis.

The rainfall-runoff component of Colobus originates from a model called SIMHYD (Peel *et al.,* 2001) and precursors to that model.

3.2 What is the Marmoset Model?

This is the river network routing model. It “transports” the output from the sub-catchments down the river system.

The core of Marmoset is a flow routing model and pollutant transport model. It also manages linkages with the EMSS sub-catchment runoff model (Colobus) and the EMSS storage model (Mandrill).

The Colobus sub system produces values of flow, TSS, TN and TP for each node on a daily basis.

The “outputs” from the nodes are accumulated as one moves downstream. Point source pollutant contributions are added as necessary.

3.3 What is the Mandrill Model?

This is the storage and evaporation sub system which accounts for the effects of dams on the flow of water and pollutant loads.

Mandrill is a ‘bucket’ type model. Inputs are from the upstream links and rain on the reservoir. Outputs are evaporation, based on the potential evapotranspiration (PET) from the reservoir area, and releases from the dam on a daily basis.

4. Data Inputs

The EMSS has a range of input data requirements. Preparation of data for use in the EMSS can often involve complex manipulation and analysis. A detailed description of how each of the input data sets was developed is given in the following section. Details of the exact data formats required by EMSS are given in the EMSS User Guide (Cuddy and Murray, 2003).

4.1 Hydrologic Inputs

A digital elevation model (DEM) is used by EMSS to generate the node link network. The DEM for the Maroochy EMSS was developed from 1:25 000 (5 metre vertical interval) digital contour mapping and drainage originally supplied to Maroochy Shire Council by the Department of Natural Resources and Mines. Both contour and drainage vector coverages were originally digitised from aerial photography using standard photogrammetric techniques. The Maroochy Shire Council did a great deal of data cleansing work to prepare these two data sets for input into DEM creation software. Contour height attributes were checked and drainage lines were edited so that all arcs were pointing downstream. Using Ikonos (Space Imaging) satellite imagery as a backdrop, the drainage lines were also edited to produce a continuous network draining to a single outlet for the catchment.

The Maroochy EMSS could not directly use the DEM produced by the Maroochy Shire Council as a small portion of the northern end of the catchment was not included in that surface, because it is not within the Maroochy Shire. Data for this area were added and a new surface generated specifically for this model.

The software package ANUDEM (Hutchinson, 1989) was used to produce the hydrologicaly correct DEM. It is important to have a hydrologicaly correct DEM for use in EMSS as the various routines in EMSS have to be able to generate sensible representations of the sub-catchments and stream networks. ANUDEM allows the vector stream lines to inform the surface generation algorithm as to where to place the stream lines in the output surface.

The DEM (Figure 6) produced for the model had a 10 m pixel size and had dimensions of 2624 cells by 3711 cells, with an elevation range of -0.1 m to 435.6 m AHD.

Due to problems with EMSS resolving drainage lines in very flat areas, a slight modification of the DEM was undertaken. All stream lines were "burnt in" to a depth of 10 cm, i.e. every cell on a drainage line as represented by the corrected vector drainage coverage had 10 cm subtracted from its original elevation.

The large areas of very low slope in the Maroochy DEM also cause problems for EMSS in trying to resolve flow directions. To overcome these issues the DEM produced from ANUDEM was pit filled and the flow directions calculated using TAUDEM (Tarboton, 1997). The resulting flow direction surface was used as the input to the EMSS hydrologic routines. Model sub-catchments and the node link network were generated using a minimum flow accumulation area of 750 ha. Five gauging locations (Figure 11) were also added during the stream network definition process. Based on these parameters a total of 46 model sub-catchments were automatically generated (Figure 7 and Table 1) for use in the model. The node link network generated by EMSS is shown in Figure 8.

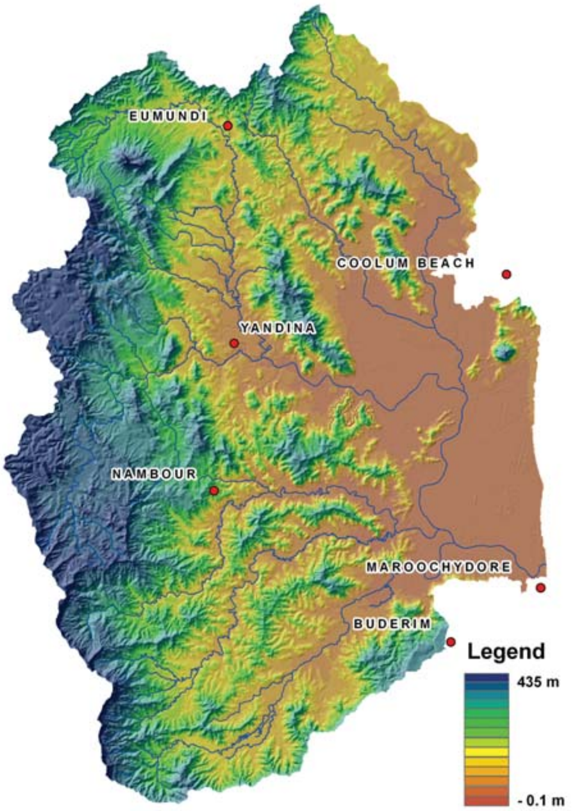

Figure 6. An Elevation Shaded Depiction of the Maroochy Catchment Digital Elevation Model.

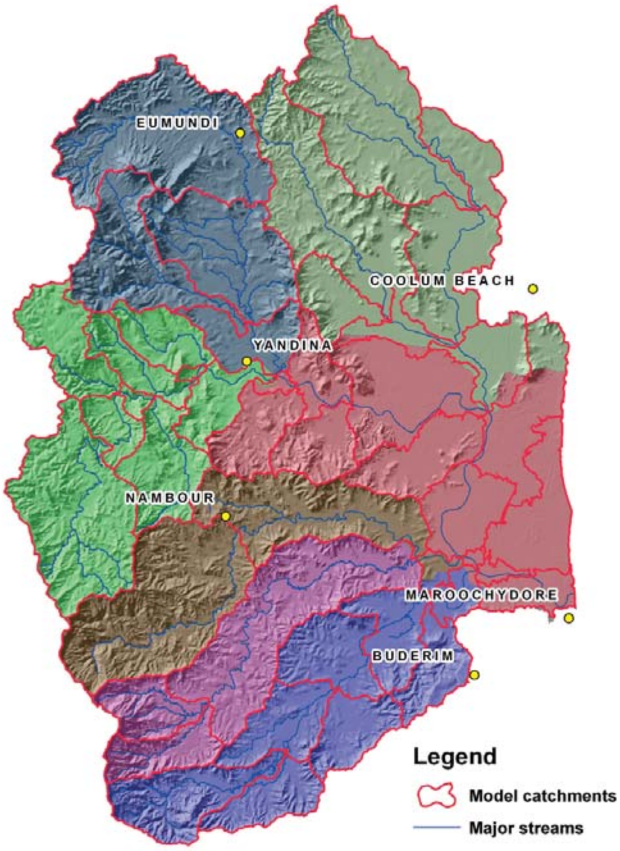

Figure 7. Model Sub-catchments used in the Maroochy EMSS.

Figure 8. Node Link Network used in the Maroochy EMSS.

Table 1. Number of Model Sub-Catchments per Local Catchment within the Maroochy River Catchment.

	Local Catchments	Number of Model Sub-catchments
1	Eudlo Creek	8
2	Paynter Creek	3
3	Petrie Creek	3
4	Maroochy Estuary	12
5	South Maroochy River	9
6	North Maroochy River	4
7	Coolum and Yandina Creeks	7
	Total	**46**

4.2 Rainfall

Rainfall inputs for EMSS were derived from the NR&M Silo Data Drill database (Silo, 2004). The Silo Data Drill accesses grids of data derived by interpolating the Bureau of Meteorology's (BoM) station records. The data are supplied as a series of individual files of interpolated daily rainfall totals on a roughly 5 km grid (Figure 9). Interpolations are

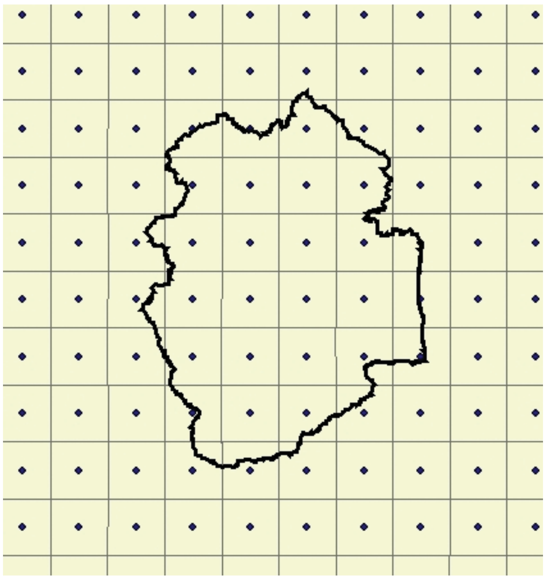

Figure 9. Silo Database Point Locations over the Maroochy Catchment.

calculated by splining and kriging techniques. These data are all synthetic; there are no original meteorological station data left in the calculated grid fields. However, the Data Drill does have the advantage of being available for any set of coordinates in Australia.

Silo rainfall files were collated for input into the EMSS for the modelling period 1980 – 2000 for each of the 46 model sub-catchments.

4.3 Areal Potential Evapotranspiration (PET)

Evapotranspiration (ET) is a collective term for the transfer of water, as water vapour, to the atmosphere from both vegetated and unvegetated land surfaces. It is affected by climate, availability of water and vegetation. (Wang, 2004)

Areal average potential ET is the ET that would take place, if there was an unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average. A full description of the methods used to generate this data can be found in Wang (2004).

The PET data is supplied by the Bureau of Meteorology (BoM) as a grid of average values at a 0.1 degree resolution for each month of the year. EMSS pre-processes these data grids to generate a file containing a daily PET value for each of the 46 model catchments over the 1980 – 2000 modelling period.

4.4 Land-Use

The EMSS considers 11 land-uses, broadly grouped into woody, agricultural and urban classes, plus one water category (Table 2). Each of these land-uses is assigned pollutant generation parameters (see Section 4.7.2). Three land-use maps were generated for the Maroochy EMSS to allow modelling of natural, current and future land-use conditions.

4.4.1 Current Land-Use

The current land-use information used in the Maroochy EMSS is derived from the Queensland Land-Use Mapping Program (QLUMP) (QLUMP, 2004) data supplied by NR&M. The QLUMP data is derived from automatic classification of 1999 Landsat TM satellite imagery refined by field checking. Based on the QLUMP mapping there are 34 unique land-uses within the Maroochy Catchment. A full description of the methods used to generate this data can be found at the NR&M website (QLUMP, 2004).

The 34 land-uses described by the QLUMP mapping were aggregated into the 11 land-uses (Figure 10) required by EMSS using the groupings defined in Table 3.

4.4.2 Future Land-Use

The land-use map used to represent a possible future land-use configuration within the Maroochy Catchment was derived from the Maroochy Shire Council Strategic Plan. The strategic plan describes

Table 2. EMSS Land-Use Groups.

Group	EMSS Land-Use Class	Description
Woody	National Park	An area of native vegetation preserved for conservation
	Managed Forest	An area of native vegetation preserved for later use, recreation or forestry
	Plantation	An area of vegetation specifically for forestry purposes
	Native Bush	Native vegetation that is not part of a National Park or State Forest
Agriculture	Grazing	Areas of grassland potentially used for grazing
	Broadacre Agriculture	Large areas of crops such as corn
	Intensive Agriculture	Crops such as sugarcane, may include areas of horticulture
Urban	Rural Residential	Rural areas with some settlement
	Future Urban	Areas that are flagged for conversion into urban areas by the year 2020
	Suburban Areas	Suburbs, with backyards and parks
	Dense Urban Areas	Built up urban areas with little or no vegetation

Table 3. EMSS Land-Use Groupings Applied to the QLUMP Mapping.

QLUMP Land-Use	EMSS Land-Use
Natural feature protection	National Park
National park	National Park
Other conserved area	National Park
Other minimal uses	National Park
Production forestry	Managed Forest
Plantation forestry	Plantation
Marsh/wetland - conservation	Native Bush
Aquaculture	Native Bush
Marsh/wetland	Native Bush
Remnant native cover	Native Bush
Recreation and culture	Grazing
Airports/aerodromes	Grazing
Grazing natural vegetation or grazing modified pastures	Grazing
Cropping	Broadacre Agriculture
Waste treatment and disposal	Intensive Agriculture
Irrigated seasonal horticulture	Intensive Agriculture
Dairy	Intensive Agriculture
Irrigated modified pastures	Intensive Agriculture
Irrigated perennial horticulture	Intensive Agriculture
Tree fruits	Intensive Agriculture
Sugar	Intensive Agriculture
Perennial horticulture	Intensive Agriculture
Intensive animal production	Intensive Agriculture
Research facilities	Intensive Agriculture
Intensive horticulture	Intensive Agriculture
Rural residential	Rural Residential
Residential	Suburban
Mining	Dense Urban
Commercial services	Dense Urban
Manufacturing and industrial	Dense Urban
Services	Dense Urban
Reservoir	Water
River	Water
Lake	Water

distribution of 10 broad land-use categories within the shire which may eventuate in the future, based on current shire planning provisions.

These 10 categories were matched with compatible EMSS land-uses to generate the future land-use input map used in the Maroochy EMSS.

4.4.3 Natural Conditions Land-Use

The natural land-use map used in the Maroochy EMSS is based on the assumption that before humans had an impact on the landscape, the whole of the catchment would have been covered in native vegetation. Hence a land-use map of just one category ie. ‘native bush’, was used as an input to the EMSS to model natural conditions.

4.5 Stream Flow Data

Daily flow time series data are needed for the calibration of the SIMHYD rainfall-runoff model. The flow gauging data was provided by NR&M. Daily flow data is collected at sites all over QLD and stored in the NR&M HYDSIS database.

From the state wide database, five gauging stations were suitable for use in the Maroochy EMSS modelling (Table 4). Gauging station 141004 was not suitable for use in the SIMHYD calibration as it is situated below a major storage. Results of this calibration process are given in Section 7.1. The locations of the gauging stations are shown in Figure 11.

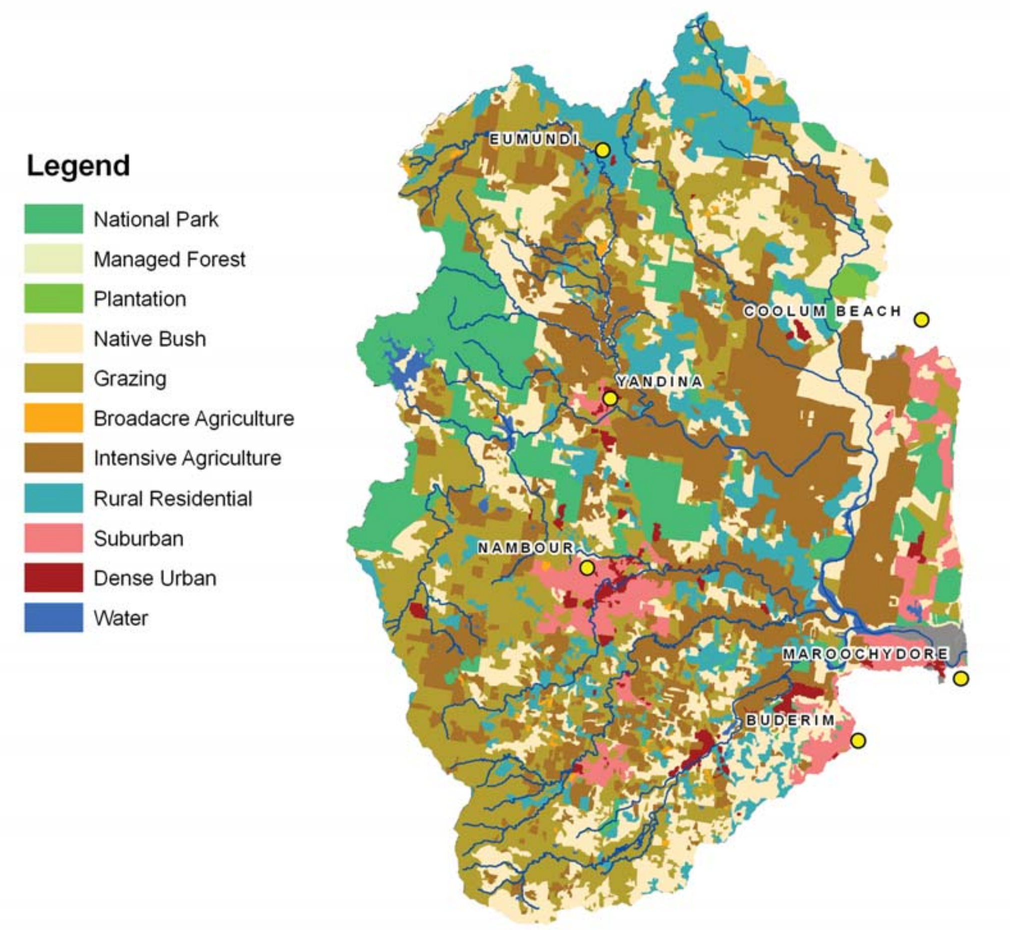

Figure 10. EMSS Current Land-Use Map Derived from the QLUMP Data.

Table 4. Location and Description of Gauging Stations used in the Maroochy EMSS. (Projection : MGA 94, Zone 56)

Easting	Northing	Gauge ID	Location
490340	7058810	141001	South Maroochy River at Kiamba
495756	7055164	141003	Petrie Creek at Warana Bridge
493842	7061872	141004	South Maroochy River at Yandina
501738	7050824	141008	Eudlo Creek at Kiels Mountain
496065	7069359	141009	North Maroochy River at Eumundi

4.6 Storages

EMSS requires the location, average surface area and the storage depth to volume relationship (storage curve) for each storage. The three major storages of Poona, Wappa and Cooloolabin were used in the model (Figure 12).

As part of the Maroochy Shire water supply normal operating environment, water is transferred between the various storages. These transfers of water have not been accounted for in this version of the model, as EMSS does not allow for complex storage management. This is not considered to be a major source of error as the inter storage transfers are a relatively minor component of the total catchment hydrology.

There were numerous smaller storages such as farm dams within the catchment. These were not modelled as they are deemed not to have a significant impact on the overall hydrology of the catchment modelled at this scale. The storage curve relationship was developed by using dam wall height to volume functions generated from the DEM. A series of volume to surface area values were generated by taking slices through the DEM from the bottom to the top of each of the individual dam walls (Figures 13 to 15).

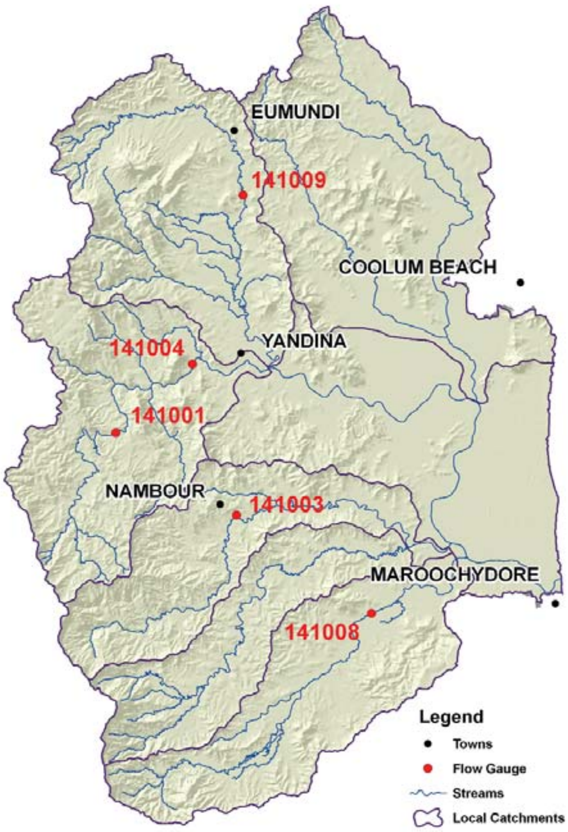

Figure 11. Gauging Station Locations in the Maroochy Catchment.

Figure 12. Locations of Modelled Storages (blue) within the Maroochy Catchment.

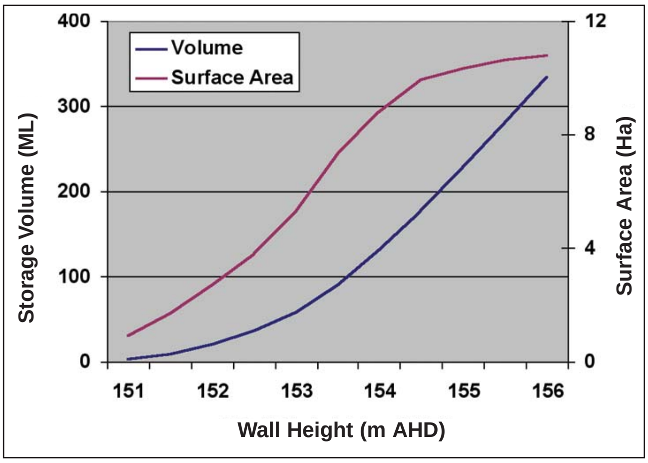

Figure 13. Storage Curve for the Poona Storage.

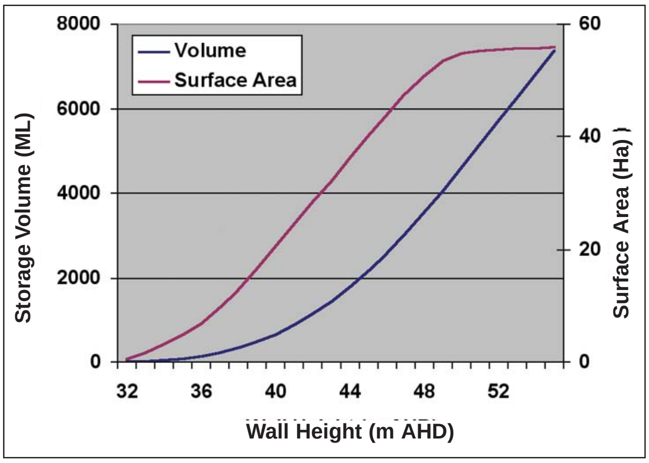

Figure 14. Storage Curve for the Wappa Storage.

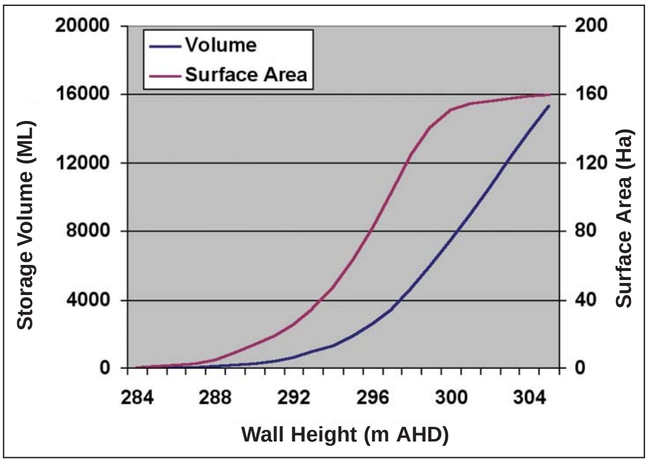

Figure 15. Storage Curve for the Cooloolabin Storage.

4.7 Pollutant Inputs

4.7.1 Point Source Pollutants

Figure 16 shows the location of the sewage treatment plants within the Maroochy Catchment.

Current TN and TP loads generated by each of the STPs were obtained from Maroochy Water Services (Table 5). These loads were applied as a constant rate over the 21 year modelling period. The three Maroochy Shire sewage treatment plants (STPs) were the only point source pollutant contributors considered in this version of the model.

Sewage treatment plant loadings have been estimated by Maroochy Water Services for the year 2015 (Table 6). These estimated values were used as input to the 'Future Conditions Scenario'.

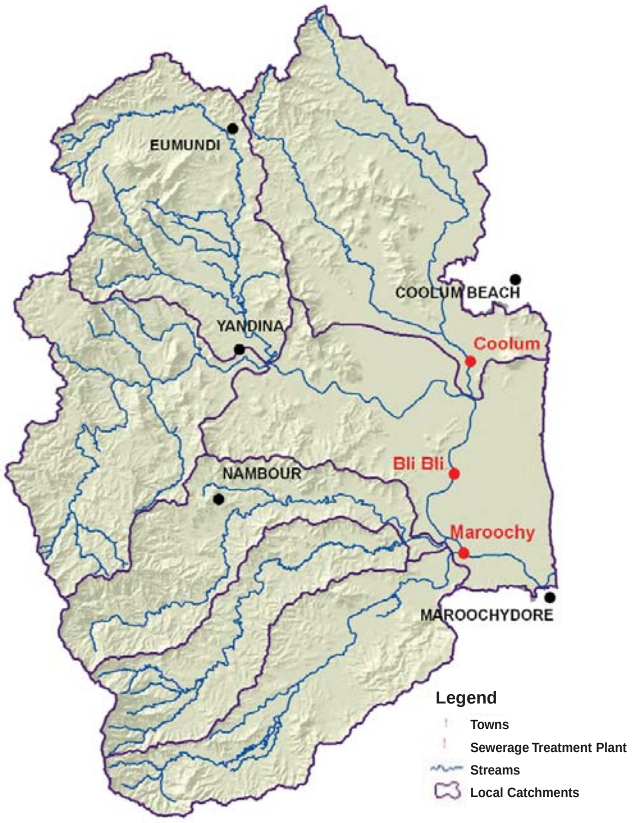

Figure 16. Sewage Treatment Plant Locations.

Table 5. Current Sewage Treatment Plant Loads for the Maroochy Catchment.

STP	TN Load (t/yr)	TP Load (t/yr)	TN Load (kg/day)	TP Load (kg/day)
Maroochydore	51.2	38.2	140.3	104.7
Coolum	5.0	3.5	13.7	9.6
Bli Bli	5.2	2.4	14.2	6.6

4.7.2 Diffuse Source Pollutant Concentrations

EMSS requires two pollutant concentration values for each land-use considered i.e. the Event Mean Concentration (EMC) and the Dry Weather Concentration (DWC). An upper and a lower limit is also required to allow EMSS to moderate these diffuse pollutant concentrations based on soil erosion hazard at any given location (refer section 4.8).

Table 6. Predicted Future Sewage Treatment Plant Loads for the Maroochy Catchment.

STP	TN Load (t/yr)	TP Load (t/yr)	TN Load (kg/day)	TP Load (kg/day)
Maroochydore	73.6	54.9	201.7	150.5
Coolum	10.9	7.6	29.9	20.9
Bli Bli	7.5	3.5	20.4	9.5

Table 7 lists the pollutant concentrations used in the Maroochy EMSS. These are the default values used by EMSS. They differ slightly from the values reported by Chiew and Scanlon (2002) that were used in the SEQ EMSS. These values are based on an extensive review of the currently available literature.

Table 7. Pollutant Concentration Values used in the Maroochy EMSS.

Landuse	Range	Total Suspended Sediment (mg/L)		Total Nitrogen (mg/L)		Total Phosphorous (mg/L)	
		DWC	EMC	DWC	EMC	DWC	EMC
National Parks	Lower	3	8	0.3	0.4	0.02	0.55
	Median	7	20	0.4	0.8	0.03	0.2
	Upper	14	90	0.5	2.0	0.06	0.4
Managed Forests	Lower	3	8	0.3	0.4	0.02	0.05
	Median	7	20	0.4	0.8	0.03	0.2
	Upper	14	90	0.5	2.0	0.06	0.4
Plantations	Lower	3	8	0.3	0.4	0.02	0.05
	Median	7	20	0.4	0.8	0.03	0.2
	Upper	14	90	0.5	2.0	0.06	0.4
Natural Bush	Lower	3	8	0.3	0.4	0.02	0.05
	Median	7	20	0.4	0.8	0.03	0.2
	Upper	14	90	0.5	2.0	0.06	0.4
Grazing	Lower	5	40	0.5	0.9	0.03	0.12
	Median	10	140	0.7	1.6	0.07	0.28
	Upper	23	380	0.9	4.6	0.14	0.72
Broadacre Agriculture	Lower	5	40	0.5	0.9	0.03	0.12
	Median	10	140	0.7	2.1	0.07	0.36
	Upper	23	490	0.9	5.9	0.14	1.1
Intensive Agriculture	Lower	5	40	0.5	0.9	0.03	0.12
	Median	10	140	0.7	2.1	0.07	0.36
	Upper	23	490	0.9	5.9	0.14	1.1
Rural Residential	Lower	5	40	0.5	0.9	0.03	0.12
	Median	10	140	0.7	1.6	0.07	0.28
	Upper	23	380	0.9	4.6	0.14	0.72
Future Urban	Lower	5	40	0.9	0.9	0.05	0.12
	Median	7	130	1.5	1.6	0.11	0.28
	Upper	27	380	2.8	4.6	0.28	0.72
Suburban	Lower	5	40	0.9	0.9	0.05	0.12
	Median	7	130	1.5	1.6	0.11	0.28
	Upper	27	380	2.8	4.6	0.28	0.72
Dense Urban	Lower	5	40	0.9	0.9	0.05	0.12
	Median	7	130	1.5	1.6	0.11	0.28
	Upper	27	380	2.8	4.6	0.28	0.72

4.8 Erosion Hazard

EMSS uses an erosion hazard surface as an input to weight landscape pollutant generation rates within land-uses. This erosion hazard surface is normally a combination of a hillslope erosion hazard surface and a gully erosion hazard surface. After consultation with a range of experts familiar with the landscapes of the Maroochy Catchment, it was decided that as the contribution of gully erosion to the total amount of sediment generated was minimal, it could be ignored in the Maroochy EMSS. Therefore only a hillslope erosion hazard surface needed to be produced.

The generation of the hillslope erosion hazard surface for use in EMSS is based on the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). The average annual soil loss (t/ha/yr) generated from the USLE is used as the erosion hazard surface input to EMSS. The USLE is an empirical relationship designed to calculate long term average soil losses from sheet and rill erosion under specified conditions. A newer and more accurate method for calculating the effect of slope steepness and slope length (Rosewell, 1993), the revised USLE (RUSLE) is used. The equation takes the form

$$A = R \times K \times L \times S \times C \times P$$

where:

A = the annual average soil loss (t/ha/yr),

R = the rainfall erosivity factor (MJ mm ha/hr/yr), a measure of the erosive power of the rain,

K = the soil erodibility factor, a measure of the resistance of soil to erosion,

L = the slope length factor,

S = the slope steepness factor,

C = the crop and cover management factor,

P = the support practice factor, a measure of the effect on erosion of soil conservation measures such as contour cultivation and bank systems (Rosewell, 1993).

In order to represent the model spatially, each of the terms in the equation is generated as a raster surface and combined in GIS. The method described by Lu *et al.,* (2001) with a number of minor modifications as described below was used to generate each of the component layers.

4.8.1 Rainfall Erosivity (R)

Rainfall erosivity (Figure 17) is defined as the mean annual sum of individual storm erosion index values, EI30, where E is the total storm kinetic energy and I30 is the maximum 30 minute rainfall intensity (Lu *et al.,* 2001). Given there was no short time interval rainfall data available in the Maroochy Catchment from which to directly derive this surface, there was a need to develop a surrogate.

The surface was obtained from the National Land and Water Resource Audit website. The map was generated by using the models proposed by Yu and Rosewell (1996). Rainfall surfaces at 0.05 degree (approx. 5 km) resolution were interpolated from daily rainfall data from 1980-1999, obtained from the Silo database (NR&M). The final result was re-gridded to 9" (approx 250 m) resolution.

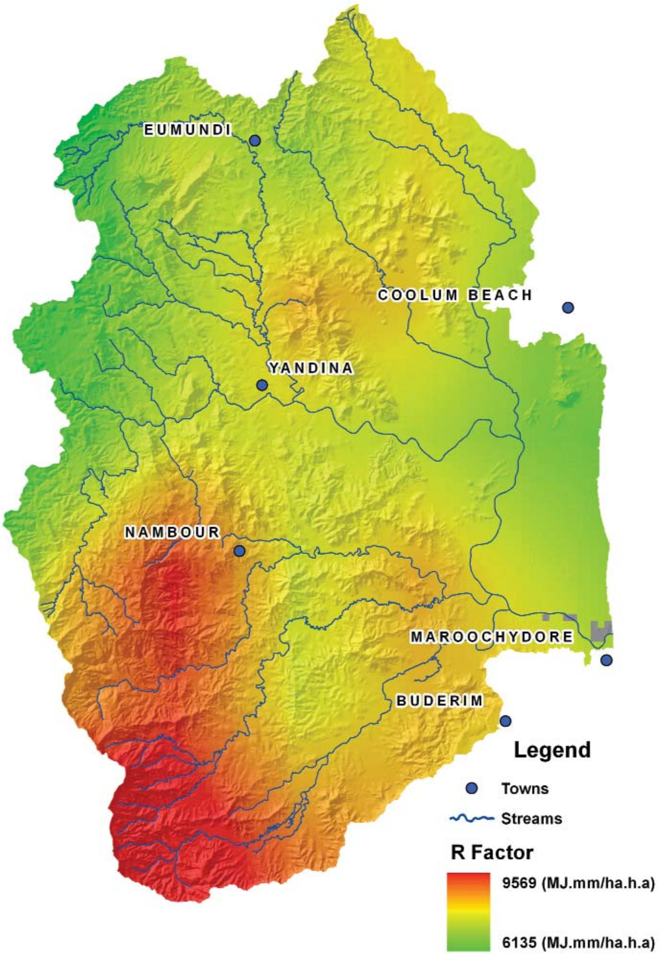

Figure 17. Rainfall Erosivity Surface (R).

4.8.2 Soil Erodibility (K)

Soil erodibility (Figure 18) is the average soil loss per unit area for a particular soil in cultivated, continuous fallow with an arbitrarily selected slope length of 22 m and slope steepness of 9%. K is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute.

The value of K can be calculated using an empirical equation developed by Littleboy (1997):

$$K = (2.77 \text{ x } M^{1.14})\text{x}(10^{-7}\text{x}(12-OM)+4.24\text{x}10^{-3}\text{x}(SS-2)+3.29\text{x}10-3)\text{x}(PR-3)$$

where:

K = USLE soil erodibility factor

M = Particle size parameter

OM = Organic matter (%)

SS = Soil structure code

PR = Soil permeability rating

This is a slightly modified form of the USLE nomograph (Wischmeier and Smith, 1978) in which the particle size term has been adapted to account for Australian conditions.

The values for each of the terms in the equation are derived from a 1:100 000 scale land resource survey (Capelin, 1987). Each individual principal profile form (PPF), (Northcote, 1974) described by Capelin, was statistically analysed against the NR&M Soil and Land Information (SALI) database to derive mean values for each of the four terms in the modified USLE nomograph equation.

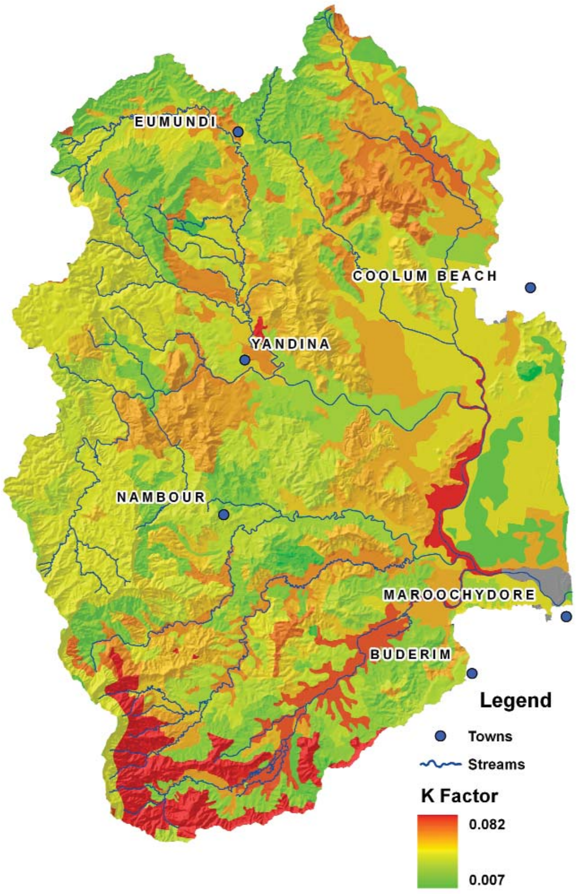

Figure 18. Soil Erodibility Factor Surface (K).

4.8.3 Slope Steepness (S)

The slope steepness factor (Figure 19) is defined as the ratio of soil loss from the field slope gradient to that from a 9% slope under otherwise identical conditions. The slope steepness factor is calculated using the equations:

$$S = 10.8\text{x}\sin\theta + 0.03 \qquad \sigma \le 9\%$$

$$S = 16.8\text{x}\sin\theta + 0.03 \qquad \sigma > 9\%$$

where: θ is the angle of slope and σ is the slope gradient in percentage (McCool *et al.,* 1989). The slope values are generated from the DEM using the standard ArcGIS (ESRI, Redlands) algorithm.

4.8.4 Slope Length (L)

The slope length factor (Figure 20) is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins, or the runoff water enters a well defined channel that may be part of a drainage network.

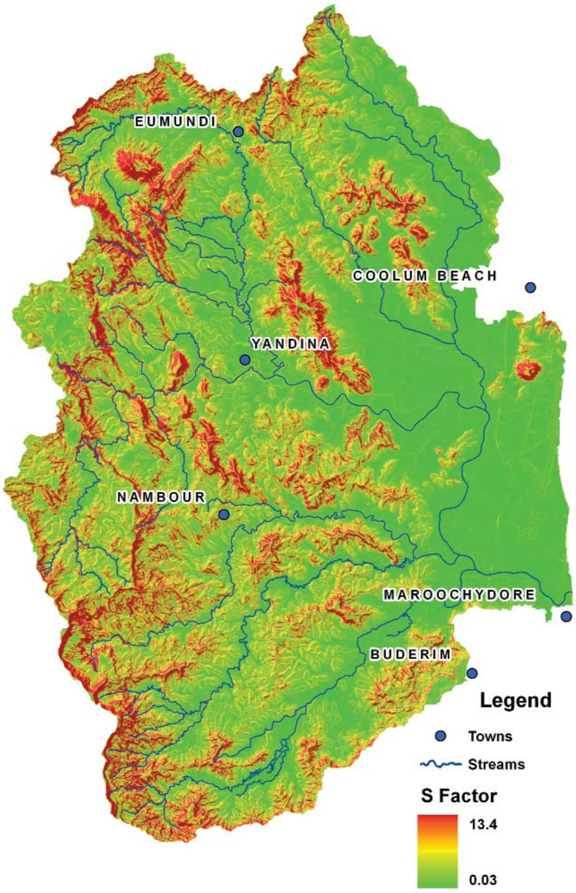

Figure 19. Slope Steepness Factor Surface (S).

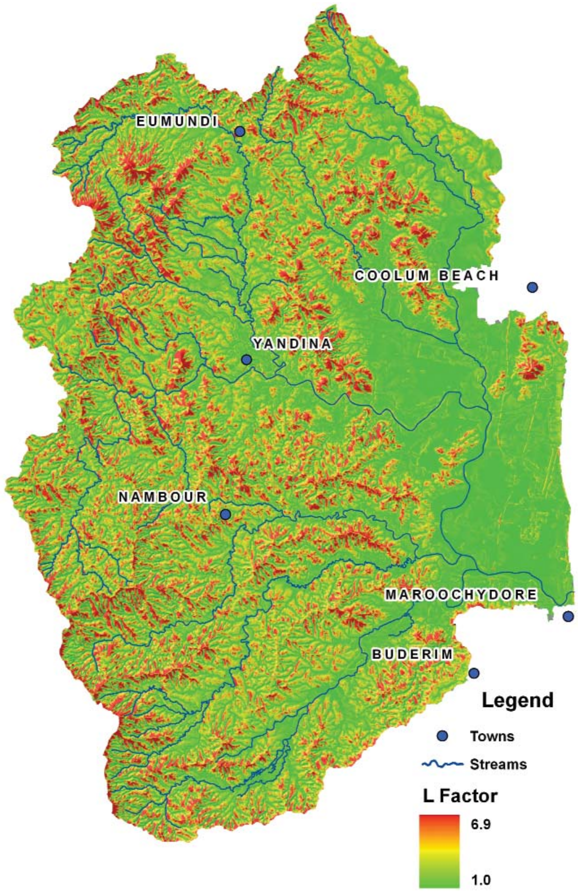

Figure 20. Slope Length Factor Surface (L).

The slope length factor is evaluated using the equations in the RUSLE (McCool *et al.,* 1989). The slope length component of the slope length factor is calculated from the DEM using the drainage network as the slope length cut off point. An ArcGIS flow path length algorithm was used to generate the surface.

The maximum flow length valid in the USLE is 300 metres. This was set as the upper limit for the flow length raster. There are a number of steeply sloping areas within the Maroochy Catchment. It was assumed that it would be unlikely for planar sheet flow to occur over a total length of 300 m in these areas. As the USLE assumes planar sheet flow or non concentrated flow a number of adjustments were made to the initial flow length output. On slopes greater than 5 percent, maximum flow length was set to 100 m and on slopes greater than 10 percent, maximum flow length was set to 50 m.

4.8.5 Crop and Cover Management (C)

The crop and cover management factor is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss. The C factor is a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land.

The C factor can be considered to be land-use specific. The QLUMP land-use mapping was categorised as per Table 8 and C values assigned from a review of the literature, using locally determined values where possible, and also taking into account local land management techniques.

4.8.6 Support Practice Factor (P)

The support practice factor reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The P factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most common locally used supporting cropland practices are cross slope cultivation, contour farming and contour banks.

It was considered that there was sufficient information to apply P factors to only a limited number of land-uses. For this reason the majority of the P factors were set to one. Table 9 shows the P factors applied to each land-use.

Table 8. C Factor Values used in the Maroochy EMSS and their Source

Land-Use	C Factor	Literature Source
Cropping	0.40	Stone and Hilborn (2000)
Grazing	0.01	Rosewell (1993)
Improved Pasture	0.01	Rosewell (1993)
Manufacturing	0.05	Estimate
Mining	0.90	Wischmeier (1978)
Native	0.00	Rosewell (1993)
Perennial horticulture	0.30	Estimate
Plantation forestry	0.14	Wischmeier (1978)
Residential	0.10	Estimate
Rural residential	0.10	Estimate
Sugar	0.09	Sullivan and Sallaway (1994)
Tree fruits	0.04	Wischmeier (1978)

Table 9. P Factor Values used in the Maroochy EMSS

Land-Use	P Factor
Cropping	1
Irrigated seasonal horticulture	1
Grazing natural vegetation or Grazing modified pastures	1
Dairy	1
Recreation and culture	1
Airports/aerodromes	1
Other minimal uses	1
Intensive animal production	1
Waste treatment and disposal	1
Irrigated modified pastures	1
Manufacturing and industrial	0.5
Commercial services	0.5
Intensive horticulture	0.5
Mining	1
Remnant native cover	1
Natural feature protection	1
Other conserved area	1
National park	1
Marsh/wetland - conservation	1
Production forestry	1
Marsh/wetland	1
Perennial horticulture	1
Irrigated perennial horticulture	1
Plantation forestry	1
Residential	0.5
Services	0.5
Rural residential	0.9
Sugar	0.5
Tree fruits	1
Research facilities	1
River	1
Lake	1
Reservoir	1
Aquaculture	1

4.8.7 Annual Average Erosion Surface

The final annual average erosion surface was generated by multiplying each of the individual raster input layers together as depicted in Figure 21. The value generated for each cell is the expected long term annual average sheet and rill erosion rate in t/ha/yr (Figure 22). This surface is used as the erosion hazard input for EMSS.

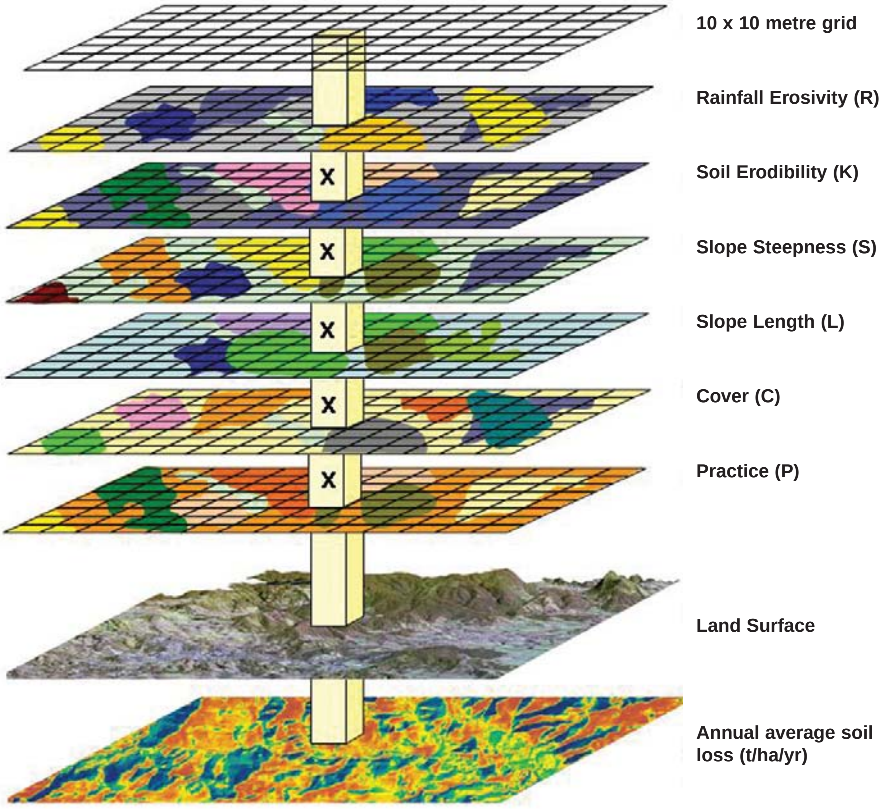

Figure 21. Schematic Representation of how the Annual Average Soil Loss Surface is Generated.

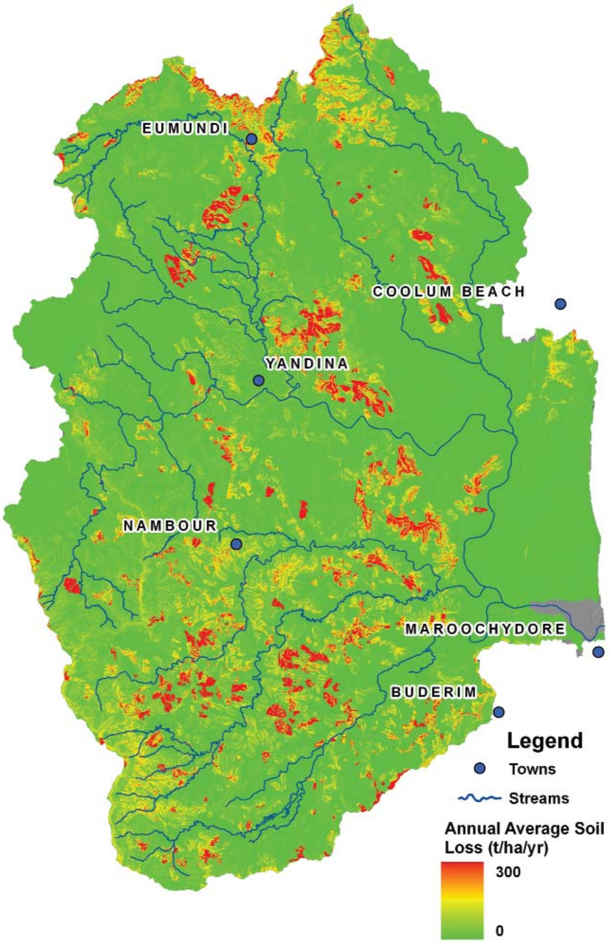

Figure 22. Annual Average Soil Loss Surface Generated using the USLE Method.

5. Hydrologic Calibration

Prior to running EMSS the rainfall-runoff component of the model, Colobus, must be calibrated to derive the required input parameters for runoff generation within EMSS. The SIMHYD_PS and Regional_SIMHYD programs (Chiew, *pers. comm.*) were used in the calibration process. A detailed description of the calibration process can be found in Chiew *et al.,* (2002).

The SIMHYD_PS calibration program takes daily rainfall, daily PET and total monthly runoff from each gauged catchment and produces a set of seven optimised SIMHYD parameter values for each individual gauge. Modelled daily flows are summed for each month to calibrate against the total monthly flows for each gauge.

To achieve optimum parameter estimates the gauges used in the calibration should be in unregulated reaches of the catchment. Four of the available five gauges within the Maroochy Catchment are in unregulated sections of the catchment and hence were suitable for use in the calibration process. All of the available stream flow data for each gauge was used in the calibration. The contributing catchment to each of the gauging stations was generated from an analysis of the DEM (Figure 23).

SIMHYD also requires the percentage of forested, non forested and impervious areas within each of the gauging station catchments. These figures were derived from the QLUMP mapping.

The model was calibrated for each of the gauges separately using an automatic pattern search optimisation routine coded into SIMHYD_PS. The seven model parameters were optimised to minimise an objective function termed the coefficient of efficiency (E) (Nash and Sutcliffe, 1970). The coefficient of efficiency expresses the proportion of variance of the recorded runoff that can be accounted for by the model and provides a direct measure of the ability of the model to reproduce recorded flows, with E=1.0 indicating that all the estimated flows are the same as the recorded flows (Chiew *et al.,* 2002).

The Regional_SIMHYD program was then used to estimate one single set of SIMHYD parameters, from the individual calibrations, for use in the Colobus model.

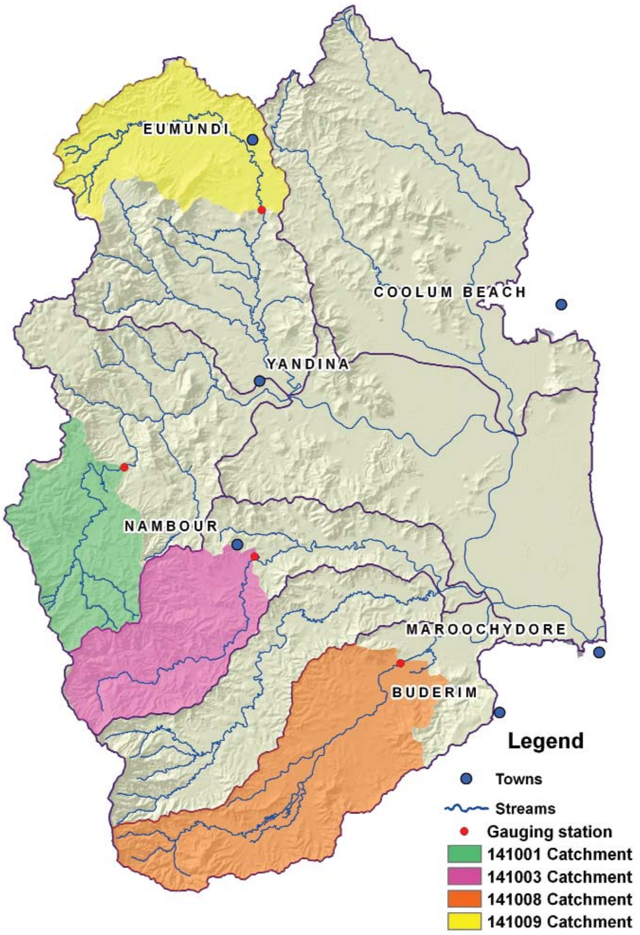

Figure 23. Contributing Catchment (coloured) for each of the Gauging Stations used in the SIMHYD Calibration.

6. Model Scenarios

Ten individual precompiled scenarios were included with this version of the model. The types of scenarios generated are based on the ideas and needs of the Maroochy Catchment Community Modelling Team. The concepts and details of the scenarios are described below. Details of the results of each scenario run are given in Appendix 1.

1. Current Conditions

This scenario reflects current conditions in the Maroochy Catchment.

The use of the term "current" to describe this scenario may be misleading, given that the scenario uses land-use data derived from 1999 satellite imagery, STP loads from 2002/2003 and the rainfall record for the period 1980-2003.

Keeping in mind that the model is only designed to predict long term average loads, it is appropriate to use input data that "represent" current conditions.

2. Natural Conditions

This reflects conditions in the Maroochy Catchment before European influences were imposed on the catchment.

- No storages are used in this scenario.
- All of the catchment is covered by native vegetation.
- There are no point source inputs.

All other inputs remain the same as those in the ‘Current Conditions’ scenario.

3. Future – Maroochy Shire Council Strategic Plan

This reflects conditions in the Maroochy Catchment if the land-use distribution proposed in the Maroochy Shire Council Strategic Plan was to occur.

The land-use mapping was changed to reflect the predicted patterns of land-use in the Strategic Plan.

The sewage treatment plant inputs were increased based on predictions for loads in 2015 made by Maroochy Water Services.

All other inputs remain the same as those in the ‘Current Conditions’ scenario.

4. Cane Lands Converted to Rural Residential Land-Use

This reflects conditions in the Maroochy Catchment if all the land that is currently used for sugar cane production was developed as rural residential housing blocks.

This scenario is based on the ‘Current Conditions’ scenario. That is, model inputs remain the same as the ‘Current Conditions’ scenario except land that was previously mapped as ‘Sugar Cane’ is now mapped as ‘Rural Residential’.

5. Cane Lands Converted to Suburban Land-Use

This reflects conditions in the Maroochy Catchment if all the land that is currently used for sugar cane production was developed as suburban housing blocks.

This scenario is based on the ‘Current Conditions’ scenario. That is, model inputs remain the same as the ‘Current Conditions’ scenario except that land previously mapped as ‘Sugar Cane’ is now mapped as ‘Suburban’. The sewage treatment plant inputs were increased based on the proportionate increase in suburban area.

6. Grazing Generation Reduced by 50 Percent

This reflects conditions in the Maroochy Catchment if an unspecified management practice was applied to all current grazing land to reduce pollutant generation by 50 percent of the current levels.

This scenario is based on the ‘Current Conditions’ scenario. That is, model inputs remain the same as the ‘Current Conditions’ scenario except that a 50 percent reduction in pollutant generation from grazing lands is applied.

7. Stream Buffers Increased by 25 Percent

This reflects conditions in the Maroochy Catchment if 25 percent of the streams in the catchment had a vegetated buffer of approximately 5 m.

The concept of a vegetated buffer in this scenario is that of a permanent grass filter strip of high percentage ground cover (Lovett and Price, 1999).

This scenario is based on the 'Current Conditions' scenario. That is, model inputs remain the same as the 'Current Conditions' scenario except that stream buffers are applied to 25 percent of all streams in the catchment.

8. Stream Buffers Increased by 50 Percent

This reflects conditions in the Maroochy Catchment if 50 percent of the streams in the catchment had a vegetated buffer of approximately 5m.

The concept of a vegetated buffer in this scenario is that of a permanent grass filter strip of high percentage ground cover.

This scenario is based on the 'Current Conditions' scenario. That is, model inputs remain the same as the 'Current Conditions' scenario except that stream buffers are applied to 50 percent of all streams in the catchment.

9. Stream Buffers Increased by 75 Percent

This reflects conditions in the Maroochy Catchment if 75 percent of the streams in the catchment had a vegetated buffer of approximately 5 m.

The concept of a vegetated buffer in this scenario is that of a permanent grass filter strip of high percentage ground cover.

This scenario is based on the 'Current Conditions' scenario. That is, model inputs remain the same as the 'Current Conditions' scenario except that stream buffers are applied to 75 percent of all streams in the catchment.

10. Stream Buffers 100 Percent Buffers for First Order Streams

This reflects conditions in the Maroochy Catchment if 100 percent of all the Strahler (1957) first order streams in the catchment had a vegetated buffer of approximately 5 m.

The concept of a vegetated buffer in this scenario is that of a permanent grass filter strip of high percentage ground cover.

This scenario is based on the 'Current Conditions' scenario. That is, model inputs remain the same as the 'Current Conditions' scenario except that stream buffers are applied to 100 percent of all first order streams in the catchment.

7. Results

7.1 Hydrology

The relationship between observed and predicted total monthly flows for each of the gauges used is shown in Figures 24 to 27. All of the gauges used for calibration in the Maroochy Catchment had a strong relationship between observed and predicted monthly flows.

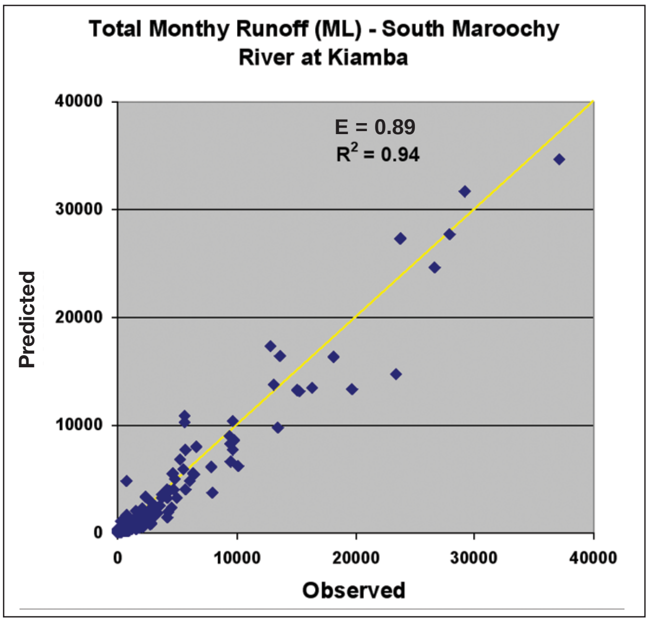

Figure 24. Observed Vs Predicted Flows for Gauge 141001.

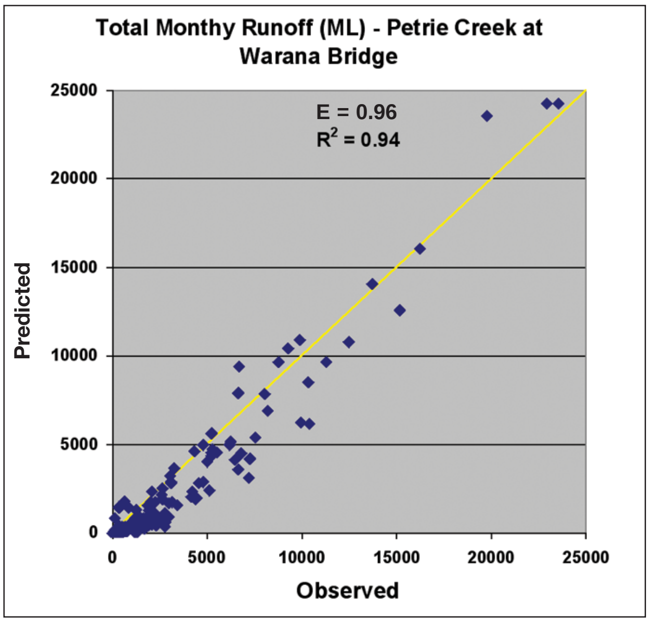

Figure 25. Observed Vs Predicted Flows for Gauge 141003.

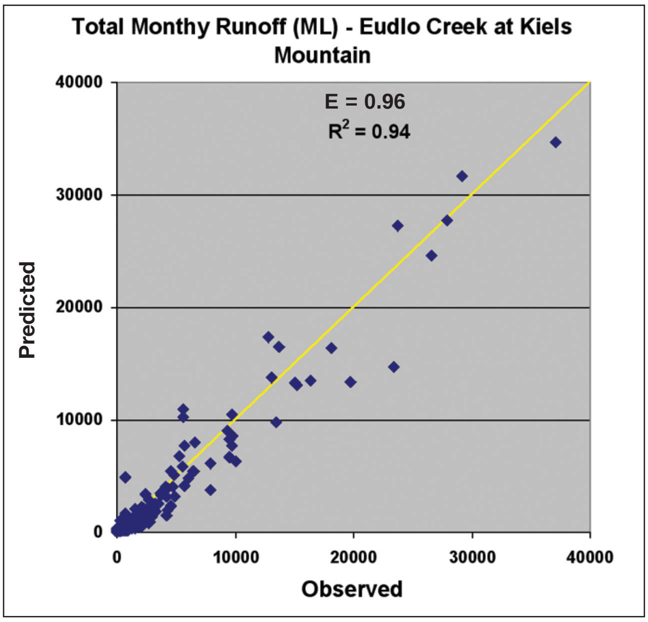

Figure 26. Observed Vs Predicted Flows for Gauge 141008.

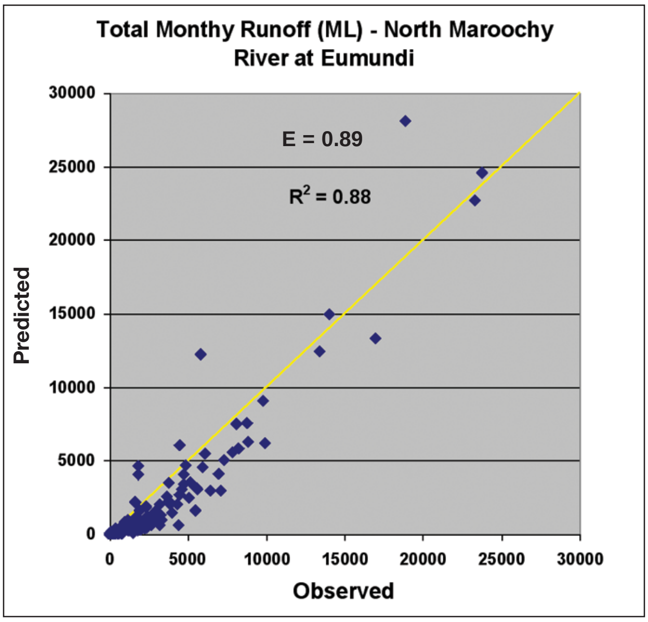

Figure 27. Observed Vs Predicted Flows for Gauge 141009.

EMSS allows grouping of areas of similar hydrologic characteristics within a catchment into separate lumped hydrologic regions, in order to simplify the application of the Colobus model. This hydrologic grouping is generally based on an analysis of landscape characteristics such as slope, soil permeability and rainfall intensity, to name a few, along with the results of the individual calibrations. An analysis of these factors within the Maroochy Catchment showed no significant unique groupings to be apparent within the catchment; hence only one hydrologic region was used in the model.

Table 10. Colobus Parameters used in the Maroochy EMSS.

Colobus Parameter	SIMHYD Parameter	Forested	Non-Forested	Unit
Rainfall interception storage capacity	INSC	5	4.8	mm
Infiltration coefficient	COEFF	200	200	mm
Infiltration shape	SQ	1.5	1.5	-
Soil Moisture storage capacity	SMSC	240	220	mm
Interflow coefficient	SUB	0	0.8	-
Recharge coefficient	CRAK	0	0.9	-
Baseflow coefficient	RK	0.3	0.09	-

To determine the optimal model parameters for this hydrologic region the outputs of the individual gauging station calibrations were then run through the Regional SIMHYD program. The set of parameters derived for use in the Maroochy EMSS is given in Table 10.

7.2 Pollutants

The following section summarises the pollutant results produced by the Maroochy Catchment EMSS for the 'Current Conditions' scenario. Given the quality of the input data, the assumptions and generalisations used in the model and the lack of sufficient suitable observed data to validate the model against, all absolute values produced by the model should be considered with caution. It is best to look at relative rather than absolute values when comparing scenarios.

Summary maps and charts for each of the scenarios in the current model are given in Appendix 1.

7.2.1 Total Suspended Sediment (TSS)

The model predicts an average of 22,300 tonnes of suspended sediment per year exported from the Maroochy River mouth. There is a large variation in the amounts of sediment produced each year (Figure 28). Approximately 94 percent of the sediment exported from the catchment occurs during high flow events i.e. periods when flow from the catchment is greater than 2 mm/day (refer section 8.1).

Individual sub-catchments within the Maroochy Catchment vary significantly in their contribution to the total annual average TSS load. Figure 29 shows that the upper reaches of Petrie Creek and Paynter Creek have the highest TSS generation rates per hectare within the catchment. The Maroochy River floodplain and the upper reaches of the North and South Maroochy Rivers have the smallest contribution per hectare to the total load from the catchment.

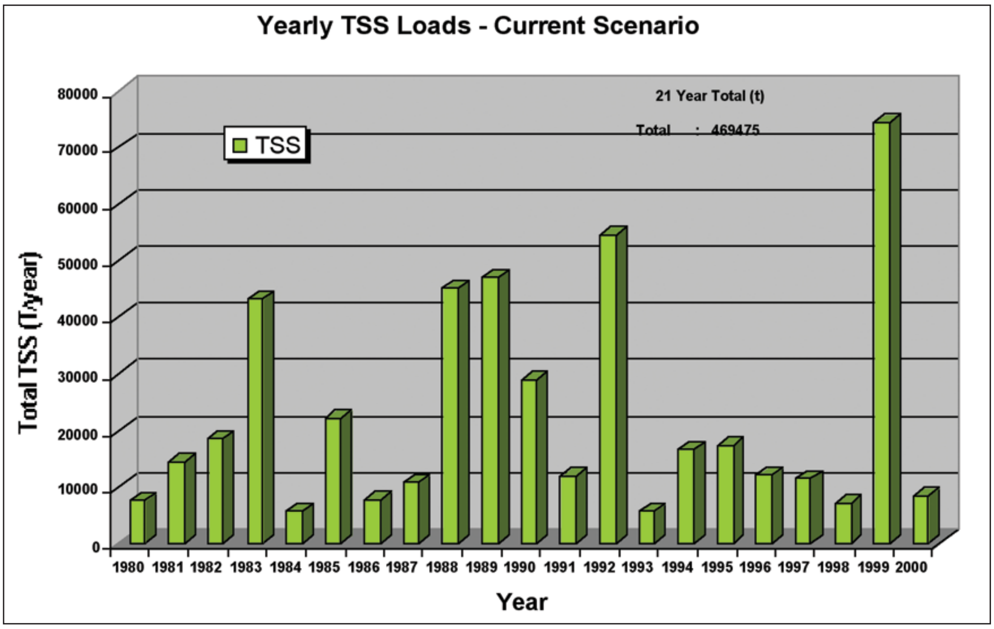

Figure 28. Predicted Annual Total Suspended Sediment Export from the Maroochy Catchment.

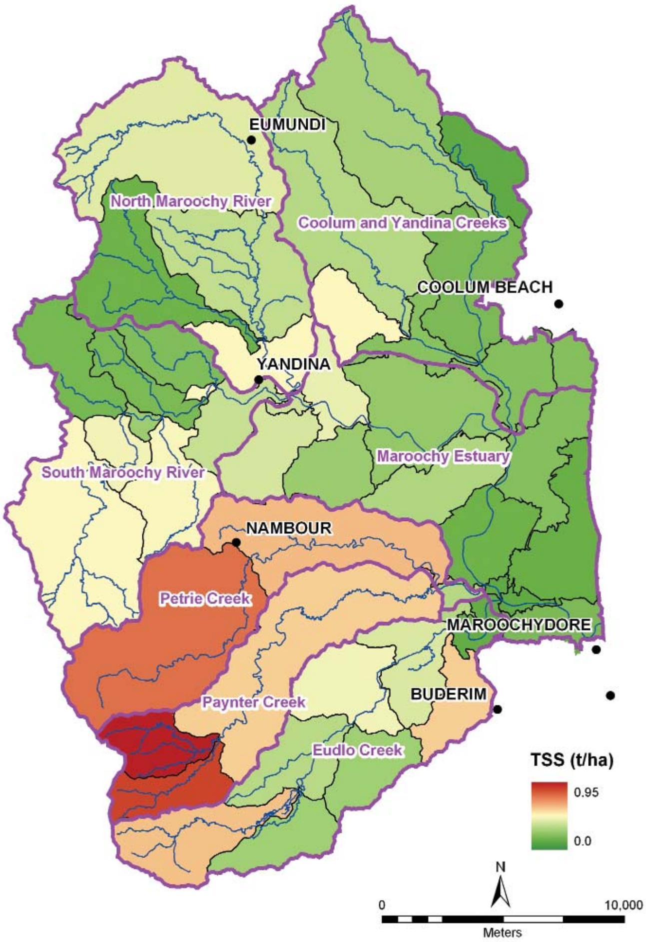

Figure 29. Average Annual Sediment Generation per Model Sub-catchment.

Whilst the upper reaches of Petrie Creek and Paynter Creeks have moderate to high slopes they are by no means the only regions within the catchment where this is the case (Figure 30). The high sediment generation rates within these areas is due to the interaction of high slopes, soil types and land-use.

7.2.2 Nutrients – Total Nitrogen (TN) and Total Phosphorous (TP)

The model predicts an average of 424 t/yr of nitrogen and 111 t/yr of phosphorous exported from the Maroochy Catchment per year. Figure 31 shows the yearly total nitrogen loads predicted by the model.

Figure 32 shows the yearly total phosphorous loads predicted by the model.

As with TSS, the total of the nutrients generated from diffuse sources in any year has a strong relationship with the total annual rainfall. It is evident from the model predictions that the majority of the nitrogen entering the waterways is from diffuse sources. However, the sewage treatment plants within the catchment account for approximately half of the phosphorous entering the waterways. In dry years the sewage treatment plants can be by far the dominant sources of phosphorous.

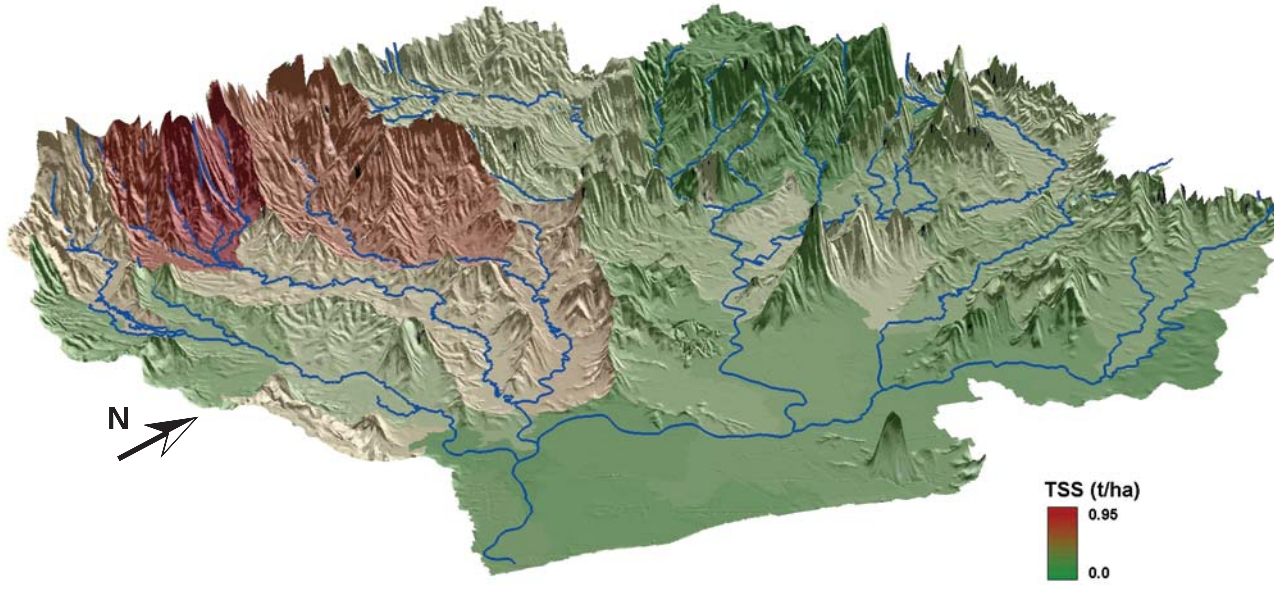

Figure 30. Average Annual Suspended Sediment Generation (t/ha) Draped over the DEM (vertically exaggerated).

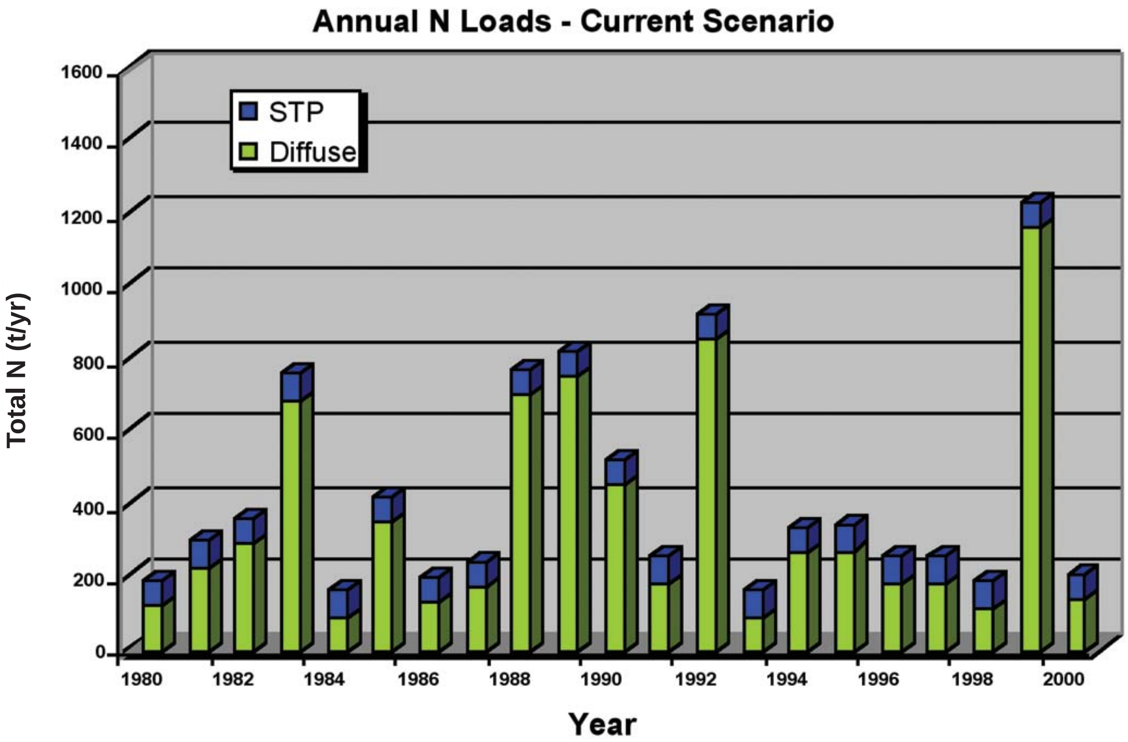

Figure 31. Total Yearly Nitrogen Loads at the Maroochy River Mouth.

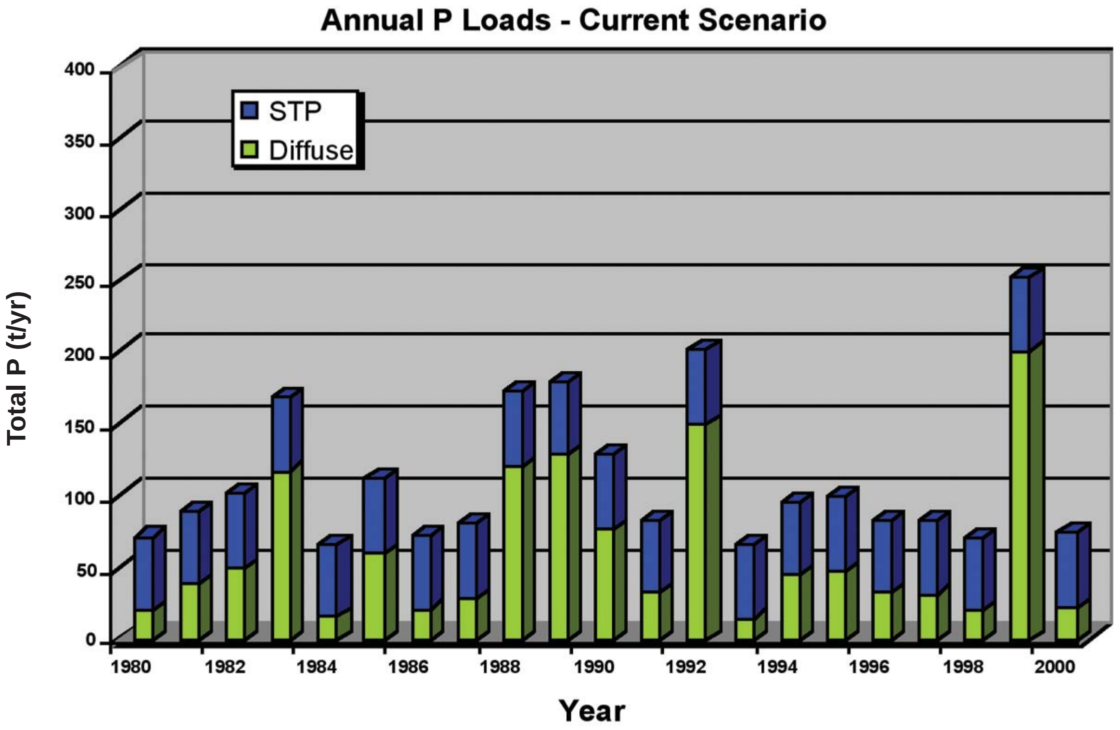

Figure 32. Total Yearly Phosphorous Loads at the Maroochy River Mouth.

8. Model Validation – Water Quality

With the available water quality sampling data within the Maroochy Catchment it is not possible to assess the validity of the modelled nutrient generation rates in a statistically rigorous manner. There is however, sufficient data to get a “feel” for how the model is performing in relation to its nutrient generation predictions.

8.1 Availability of Sample Data

Figure 33 shows the locations of all known water quality sampling locations within the Maroochy Catchment. There are approximately 53,000 individual samples for a wide range of analyses from 1962 to 2004. The data has been collected for a wide range of purposes, by a number of different organisations, including Maroochy Shire Council, Qld, NR&M, Environmental Protection Agency and Maroochy Water Watch.

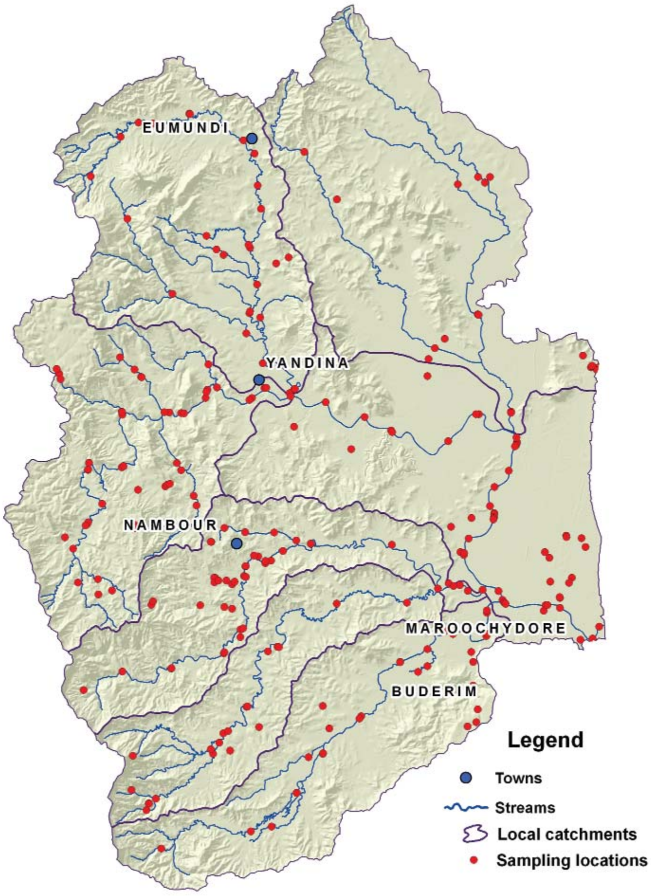

Figure 33. Water Quality Sampling Locations within the Maroochy Catchment.

From this existing data only a small subset was suitable for assessing against TSS, TN and TP predictions of the model. There were 1709 samples for TSS, 1341 samples for TN and 1628 samples for TP. Table 11 shows the number of samples for each stream order and Table 12 shows the number of samples per sub-catchment.

Table 11. Number of Pollutant Samples per Stream Order

Pollutant	Stream Order	Count
N	1	1
	2	40
	3	31
	4	186
	5	134
	6	357
	7	166
	8	372
P	1	1
	2	42
	3	31
	4	188
	5	140
	6	581
	7	166
	8	372
TSS	1	1
	2	42
	3	26
	4	187
	5	186
	6	629
	7	197
	8	328

Table 12. Number of Pollutant Samples per Sub-Catchment

Catchment	Pollutant	Count
Coolum and Yandina Creek	N	70
	P	70
	TSS	71
Eudlo Creek	N	96
	P	163
	TSS	197
Maroochy Estuary	N	468
	P	468
	TSS	420
North Maroochy River	N	67
	P	75
	TSS	121
Paynter Creek	N	15
	P	15
	TSS	14
Petrie Creek	N	94
	P	191
	TSS	225
South Maroochy River	N	477
	P	539
	TSS	548

This dataset was then split into event (high flow) and ambient (low flow) samples. From an analysis of the flow duration curves, based on daily runoff measured at the 4 gauges within the catchment, a value of 2 mm of flow was chosen as the cut off for a high flow event. Figure 34 shows an example of the flow duration curves from which this estimate was derived. Samples taken on days in which the flow exceeded 2 mm were considered to be event samples and samples taken on days in which the flow was 2 mm or less were considered to be ambient samples.

The available water quality samples were then averaged within each model sub-catchment for each individual day. Predicted values of flow and sediment load were then combined to give a sediment concentration value for each model sub-catchment for each day. These values were then compared with the averaged sample data for TSS for each day on which samples were available.

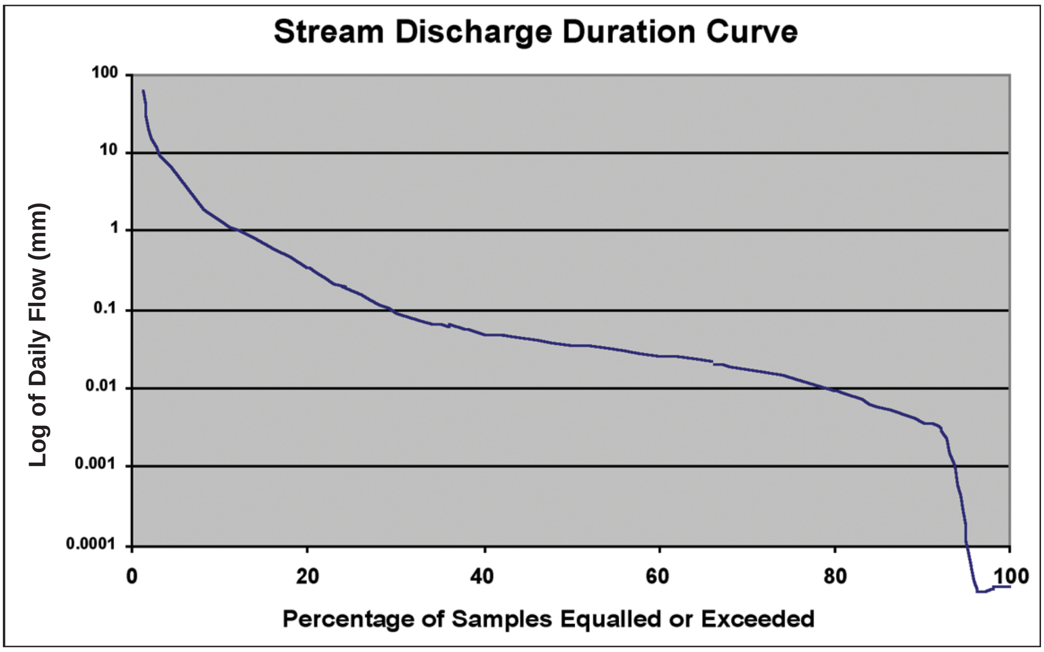

Figure 34. Flow Duration Curve for Gauge 141001 (8/11/1985-21/2/2005).

8.2 Analysis of High Flow Event Conditions

Figures 35 to 38 show the predicted TSS values versus the observed water quality sample values for selected local catchments within the Maroochy Catchment during high flow conditions ie. periods when average catchment flow is greater than 2 mm/day.

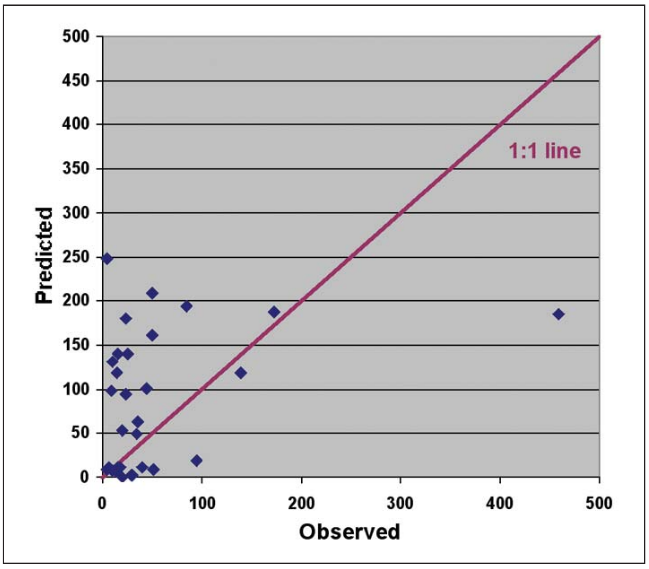

Figure 35. TSS Event Samples - Observed Vs Predicted Values for Petrie Creek (mg/L).

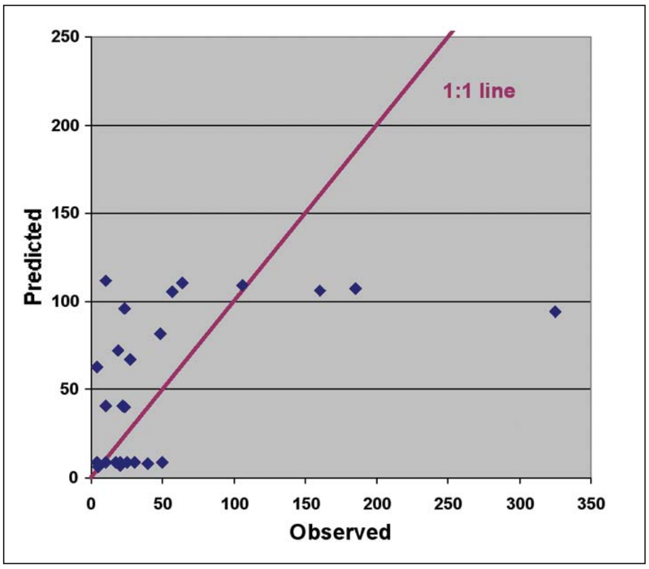

Figure 36. TSS Event Samples - Observed Vs Predicted Values for North Maroochy River (mg/L).

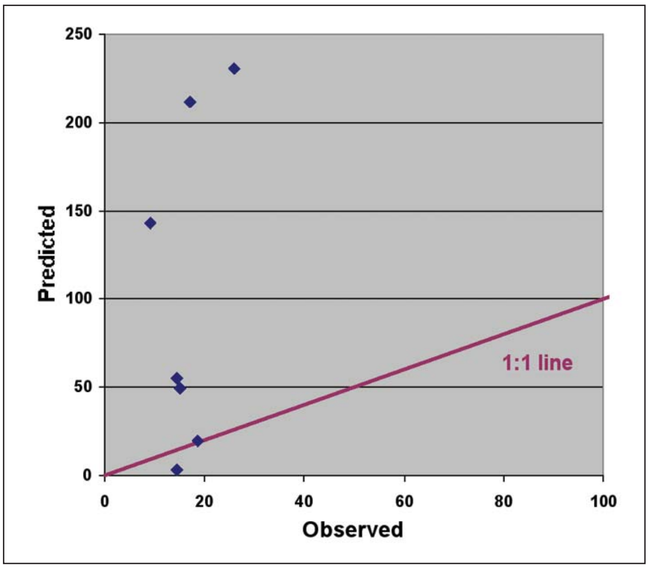

Figure 37. TSS Event Samples - Observed Vs Predicted Values for Maroochy Estuary (mg/L).

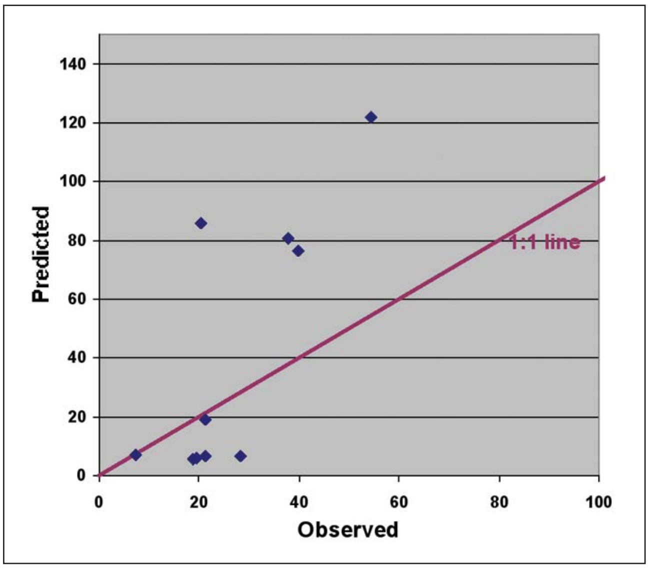

Figure 38. TSS Event Samples - Observed Vs Predicted Values for Coolum and Yandina Creeks (mg/L).

8.3 Analysis of Ambient Conditions

Figures 39 to 42 show the predicted TSS values versus the observed water quality sample values for selected local catchments within the Maroochy Catchment during ambient conditions i.e. periods when average catchment flow is less than 2 mm.

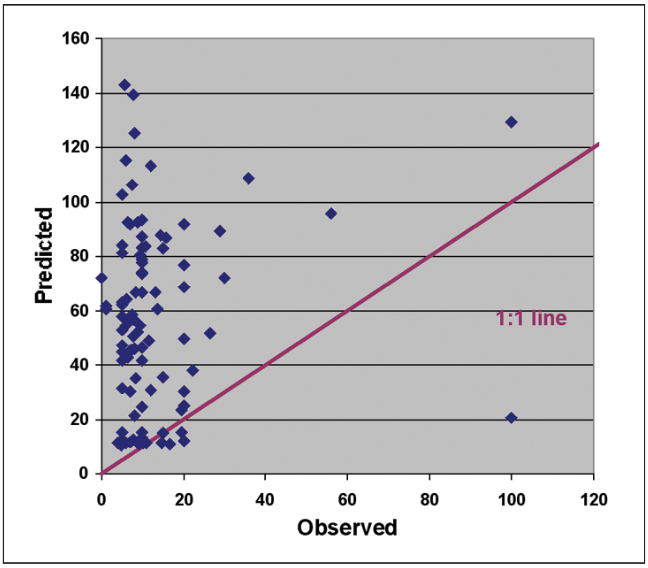

Figure 39. TSS Ambient Samples - Observed Vs Predicted Values for Petrie Creek (mg/L).

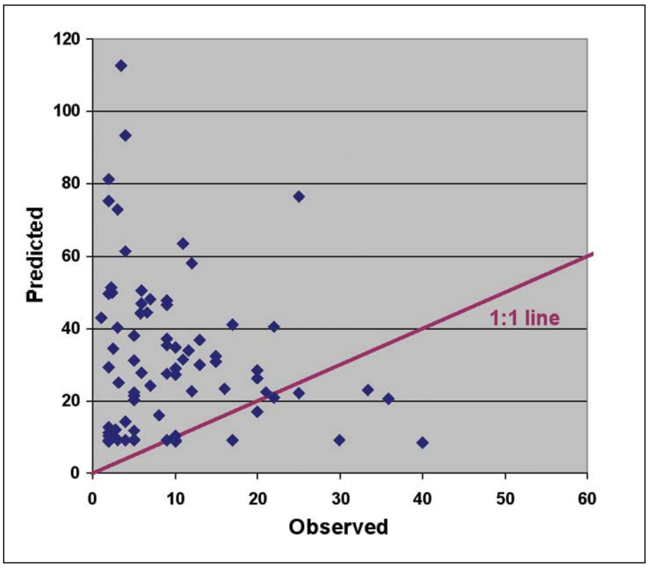

Figure 40. TSS Ambient Samples - Observed Vs Predicted Values for North Maroochy River (mg/L).

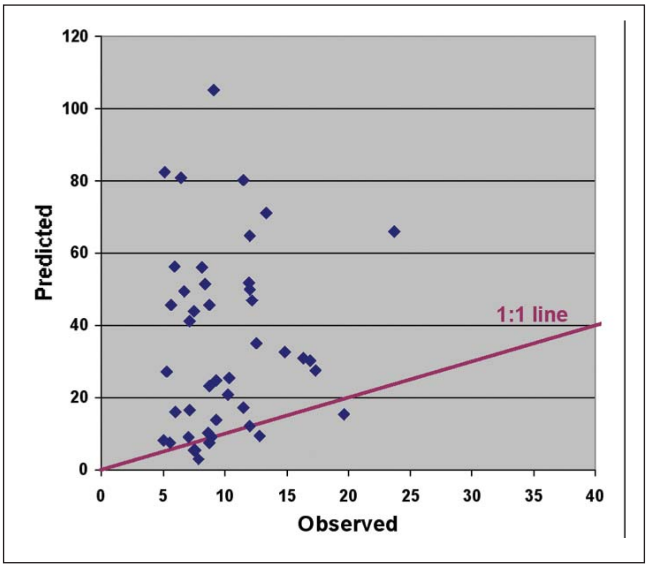

Figure 41. TSS Ambient Samples - Observed Vs Predicted Values for Maroochy Estuary (mg/L).

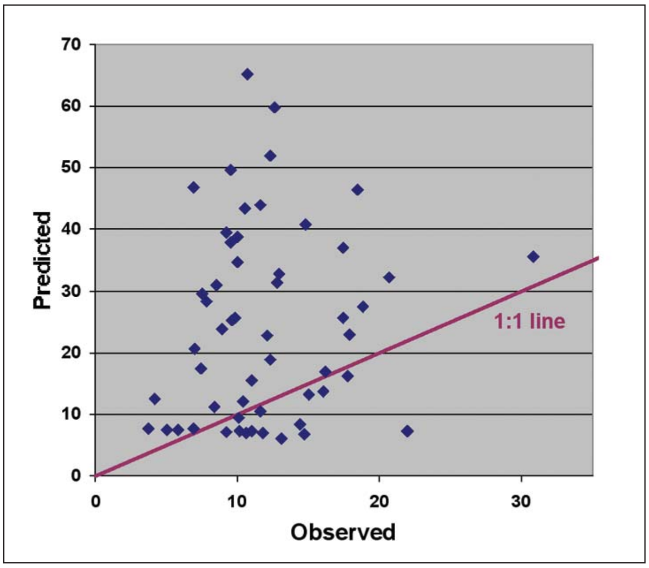

Figure 42. TSS Ambient Samples - Observed Vs Predicted Values for Coolum and Yandina Creek (mg/L).

9. Discussion

9.1 Hydrology

From the relationships between observed and modelled flows presented in Figures 24 to 27 it is evident that the model is well calibrated at the monthly time step. The stream flows are calibrated on a total monthly basis to allow for temporal aspects of rainfall-runoff processes that are not dealt with specifically by SIMHYD. For example, if heavy rainfall occurs at 11pm on a given day it would most likely not be recorded as flow at the relevant gauging station until the next day. This is due to the time lag it takes for water to move within the catchment. SIMHYD cannot account for this time lag in its daily time step calculations. Obviously the larger and flatter the catchment is, the bigger these types of effects will be. Figure 43 shows the difference between modelled and observed daily flows for a gauge in the Maroochy Catchment. The time lag effect described is clearly evident at this gauging station. Large modelled flows are generally closely followed by large measured flows.

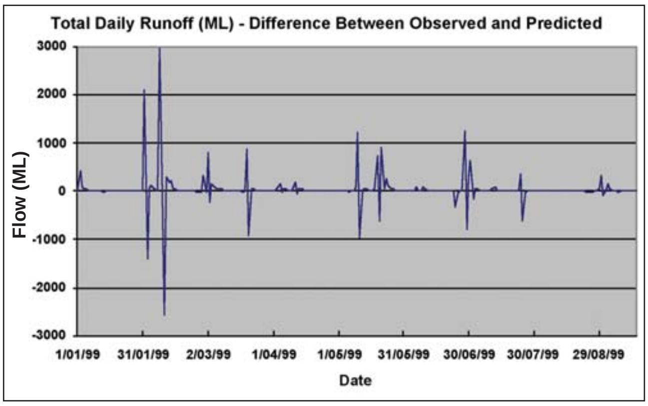

Figure 43. Difference between Observed and Predicted Daily Flows at Gauge 141001.

This same time lag effect is further evidenced by Figures 44 and 45. As we compare flows at increasingly finer time steps from monthly through to daily, the modelled vs predicted relationships become poorer. Comparisons of flows on a total weekly basis (Figure 44) still show a strong relationship between observed and predicted values but the relationship deteriorates significantly at the daily time interval (Figure 45).

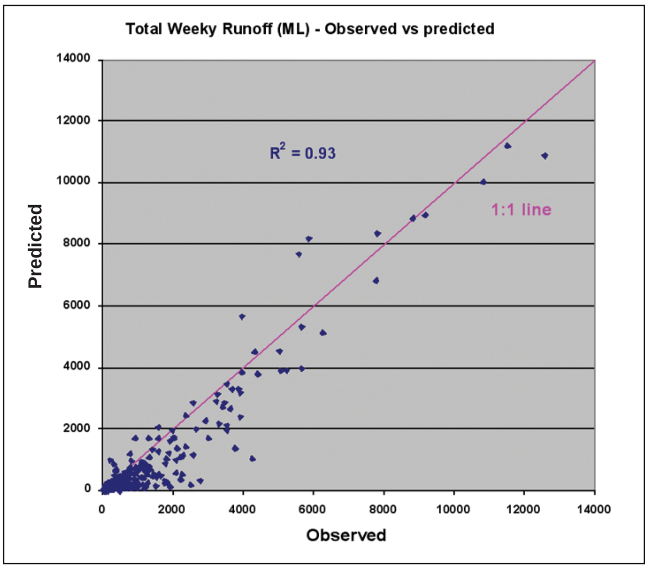

Figure 44. Total Weekly Observed Vs Predicted Flows for Gauge 141001.

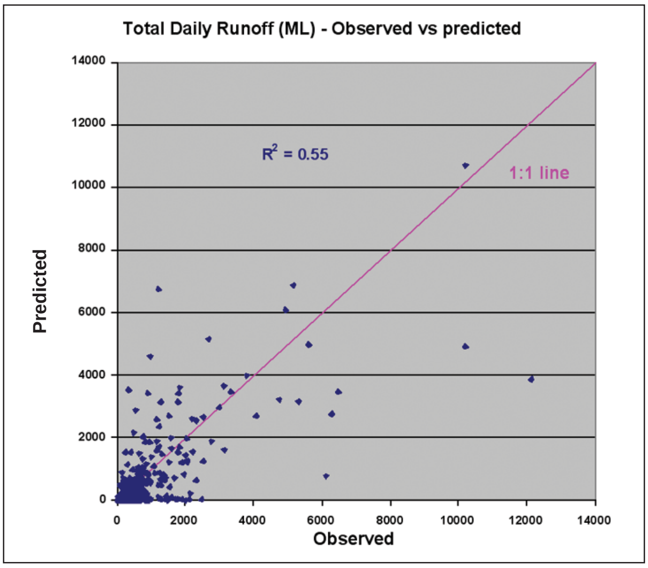

Figure 45. Total Daily Observed Vs Predicted Flows for Gauge 141001.

It is also important when assessing the quality of hydrologic predictions to visually compare the hydrographs for observed and modelled flows. Particularly when calibrating on a total monthly flow basis, there is potential for significant errors in how well the model is representing high and low flow. The model may give the correct monthly totals but for the wrong reasons. Take an example where a small constant flow is observed in a particular month to give a total flow of 70 ML. The model may also be predicting a monthly flow of 70 ML but representing this flow as the result of one big event at the start of the month and then no flow at all. This situation would result in a coefficient of efficiency of 1.0 but would not be representing reality. It is therefore an essential part of the hydrologic calibration process to visually assess observed and predicted flows.

Figure 46 shows a portion of the hydrograph for one of the gauging stations in the Maroochy Catchment. It is evident there is a good match between observed and modelled flows. The other gauges used in the calibration showed similar matches.

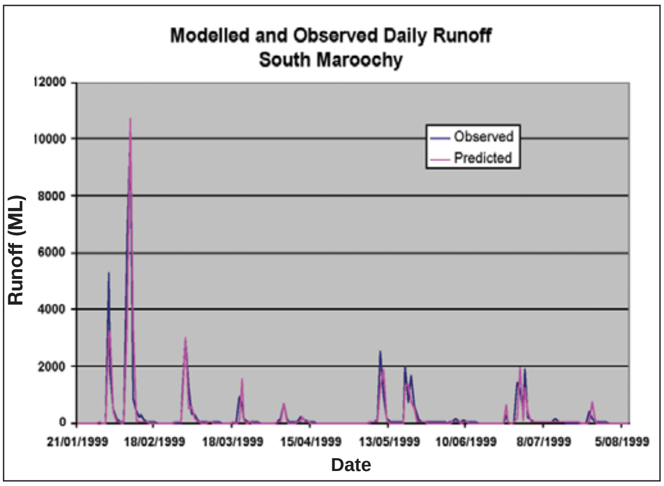

Figure 46. Observed and Modelled Daily Flows for Gauge 141004.

From analysis of the modelled flows it can be seen that EMSS is doing a good job of simulating catchment hydrology. The high flow events tend to be a little underestimated by the model while the low flows are slightly overestimated.

The strong relationship between observed and predicted flows is to be expected in a catchment such as the Maroochy. The catchment is relatively small and has a lot of short, steep slopes. The short steep slopes help to rapidly concentrate the overland flow so that most runoff moves through the landscape quickly and is recorded as runoff within a short time period. The proportionately high number of gauges relative to the catchment size also assists in obtaining a good calibration.

9.2 Pollutant Load Predictions

There is currently no definitive way to assess the accuracy or the validity of the pollutant components of EMSS model in the Maroochy Catchment. To do so would require access to long term continuous monitoring data at strategic locations within the catchment. There are however a number of reasons to believe that the absolute values of sediment and nutrient generation that the model is predicting are reasonable. The following discussion is mostly related to total suspended sediments, as this is the pollutant for which there is the most available observed data on which to base comments.

If the annual average predicted sediment load exported from the catchment was spread out evenly over the entire 60,000 ha of the catchment, the depth of sediment would be roughly 0.015 mm. This is within the accepted rates of formation of soils within Australia (McKenzie *et al.,* 2004), thus suggesting the soil removal rates that would be required to produce the amount of exported sediment predicted, could in fact be sustained without gross landscape degradation and hence the rates of sediment generation could conceivably be occurring. This argument assumes uniform soil removal over the whole catchment and doesn't account for re-deposition of sediments within the landscape. However, it does support the idea that the model predictions for sediment export are not grossly overestimating the sediment generation capacity of the catchment.

The SEQ EMSS model (Chiew *et al.,* 2002) is another source of possible validation or cross checking for the Maroochy EMSS model. The SEQ model uses much coarser scale data inputs than the Maroochy model. The sediment generation inputs for the SEQ model are mostly derived from the National Land and Water Resources Audit continental scale data sets. The SEQ model predicts an annual average sediment export in the order of 12,000 t/yr, compared to 22,300 t/yr predicted by the Maroochy EMSS. Whilst it is not possible to make a direct comparison between the two models, as the catchments defined in each do not exactly match, it can be seen that the Maroochy model is predicting roughly twice the amount of sediment export as the SEQ model.

The fact that the predictions of the two different versions of the model are within the same order of magnitude can give us some faith that at least the computational aspects of the model are consistent. Although it is not appropriate to use one model to validate another model, as the absolute values they both predict could be wildly wrong, it is encouraging that they produce similar end of catchment numbers. Interestingly the spatial distribution of sediment sources varies significantly between the two models. The higher values for the Maroochy model are not unexpected. As the level of detail of the data inputs increases there is better potential to spatially represent the erosion processes. This finer resolution can often lead to higher rates of generation as the level of averaging decreases. The default EMSS pollutant concentration values (EMC and DWC) used in the Maroochy model in general tend to be slightly higher than those used in the SEQ EMSS. This would also contribute to the explanation of the higher export predictions of the Maroochy EMSS.

9.3 Uncertainties in Measured Water Quality Data

Probably the most useful means of estimating the level of confidence to be placed in the model is to look at the results presented in the validation section. However this should be done with caution particularly for water quality data. This analysis can not give definitive results about the usefulness of the model outputs for a range of reasons.

There is a range of water quality sampling data available within the Maroochy Catchment, however there are a number of issues that need to be considered before this data can be used in model validation. Firstly, there is uncertainty about exactly when during an event the samples were collected. Given that sediment concentrations vary widely throughout the course of a flow event, the exact time of sampling can have a big impact when compared against model predictions. Most people involved in sample collection tend not to enjoy the tribulations of sampling during severe storms so manually collected samples typically tend to be biased towards the falling stage of flow events.

How a sample was taken and subsequently analysed may have a big impact. The differences between a sample collected using a bucket with a rope attached and thrown into the stream or being collected by an automated pumping sampler can significantly affect the values obtained. What part of the stream the sample is collected from can also bias the result. Was the sample collected in a fast flowing section of the channel or was it just a grab sample from the side of the channel? Sediment concentrations vary widely within different sections of the channel, hence the sampling position within the channel is important. Management of samples from time of collection to the time of analysis can also affect the values. In particular, for nutrient samples refrigeration is often required to ensure accurate results.

Few of the available samples had flow information recorded at the time of collection. This means that we have to rely on flow data from the four gauging stations within the catchment to determine if a sample is a high flow or low flow sample. Given the relatively small size of the catchment and the quick hydrologic response times this assumption is probably not too bad but it does introduce another source of variability.

The model only predicts one sediment load value on a given day for each of the 46 individual model sub-catchments i.e. there is no spatial discrimination within model sub-catchments. The samples may be collected from anywhere within these sub-catchments, leading to issues with physical characteristics of each sampling location. As an example a sample may be taken within a sub-catchment just below a quarry with very high sediment generation rates, occupying only a very small fraction of the total area of the catchment. If we were to use this sample in validation we would be comparing this very biased sample with prediction for the entire catchment.

9.4 Pollutant Load Validation

With these limitations in mind it is still useful to compare the modelled data with the available sample data. The comparison is broken into two distinct data sets. Given the model predicts that 94 percent of the total sediment is generated during high flow events it is important to be able to distinguish between high flow and ambient conditions. As with most water quality sampling data, in the Maroochy Catchment the number of samples is heavily biased towards to those taken during ambient or low flow periods, leaving us only relatively few samples to use for high flow event analysis.

Figures 35 to 38 show the predicted values of sediment concentration during high flow events tend to be higher than the observed values but typically well within an order of magnitude. Given the previously stated limitations it is difficult to make a comment about these discrepancies but one might infer that the model is over estimating the level of sediment generation within the model sub-catchments and resultantly over estimating sediment export from the Maroochy Catchment.

There is also great deal of variability between observed and predicted low flow TSS values (Figures 39 to 42). Predicted ambient values in general are higher than observed values, but once again the values are typically well within the same order of magnitude. Given the previously discussed limitations of the sample data and the fact that only 6 percent of the modelled total pollutant load is generated during low flow periods, the overall model results are not heavily impacted by these less than perfect predictions.

With the lack of appropriate data, it is difficult to specifically ascertain how well the model is performing with respect to predicting pollutant loads. It would be possible to recalibrate the pollutant load values to make the model more accurately match the observed data, but without any confidence in the validity of the observed data, this may be inappropriate. One of the most useful outcomes of the modelling process has been to highlight data deficiencies in the available water quality data. The learnings and the framework provided by the modelling will be a useful guide in implementing future water quality monitoring programs within the catchment.

9.5 General Model Considerations

There are a number of important model concepts and data issues that should be considered before trying to use the results from the Maroochy EMSS modelling.

The model does not account for stream bank erosion processes. Local opinion within the Maroochy Catchment Community Modelling Team suggested that stream bank erosion may contribute significantly to total sediment loads. The broad scale SedNet modelling undertaken by the NLWRA (Prosser *et al.,* 2001) predicts that streambank erosion accounts for 29% of the sediment supply within the catchment. There is currently no quantitative values for sediment loads from stream bank erosion available within the catchment, thus is it difficult to know exactly how important this sediment source is. However, the available evidence would suggest that the lack of stream bank sediment generation is a significant limitation in applying EMSS in the Maroochy catchment. Finer scale SedNet modelling may help to more accurately estimate the contribution of stream bank erosion to total sediment export from the catchment.

Gully erosion is not accounted for in this version of the model. This was a considered decision of the Maroochy Modelling Group. Local expert opinion suggested that gully erosion would not make a significant contribution to total sediment loads due to the high level of ground cover and the general landforms in the catchment. Local experts were not aware of any currently active areas of significant gully erosion. This assumption is also supported by the available soils mapping (Capelin, 1987). Only approximately one percent of the catchment is covered by soils with sodic subsoils, the type that would tend to promote the formation of gullies.

The EMSS model does not account for flood plain deposition of sediment. Given the flood plain covers approximately 20 percent of the catchment, there is potential for flood plain deposition to have a considerable impact on sediment loads delivered to the river mouth. The fact that 94 percent of the sediment is exported in high flow events, which would potentially inundate the flood plain, suggests that there is potential for sediment loss via this process. The NLWRA SedNet modelling (Prosser *et al.,* 2001) predicts that only 57 percent of the sediment supplied to the river is exported to the river mouth. Given the available evidence it is possible that the lack of flood plain process modelling within EMSS is a potential significant limitation. Further flood modelling and finer scale application of SedNet modelling may help assess the impacts of flood plain deposition.

The large flood plain/estuary within the Maroochy Catchment also poses problems for predicting sediment and nutrient loads at the mouth of the river, as EMSS does not account for estuary processes such as mixing, flushing or re-entrainment. The location of all of the Maroochy sewage outfalls within estuary reaches of the catchment also introduces processes that EMSS is not designed to model. Realising these limitations, the Maroochy Shire Council have commissioned a Mike11 model (DHI Software) to deal with the estuary dynamics (Beling, 2004). Results of this modelling work should help to more closely describe the temporal aspects of the catchment outlet loads.

9.6 Scenario Comparisons

The ten scenarios (see Appendix 1) developed for this project were designed to address the needs of the Maroochy Community Modelling Team. As such, the scenarios presented provide information relevant to the management issues being faced by a range of groups involved in natural resource management within the catchment.

The 'Current Conditions' scenario shows that the upper Petrie and Paynter Creeks provide the largest amount of sediment per hectare. Based purely on sediment generation considerations alone, on-ground works to reduce sediment would best be targeted in these areas. Nitrogen loads at the catchment mouth (see Figure 32) are dominated by inputs from diffuse sources while phosphorous loads (see Figure 32) are reasonably evenly split between sewage treatment plant inputs and diffuse inputs. Reducing sewage treatment plant outputs of P would be beneficial for reducing phosphorous export but reduction of nitrogen exports from the catchment would be best achieved by addressing catchment management practices to reduce diffuse runoff.

Any potential reductions in pollutant export should be examined in the context of the pollutant exports under the modelled 'Natural Conditions'. TSS under 'Natural Conditions' is predicted to be approximately 20 percent of 'Current Conditions' while N and P are approximately 40 percent of 'Current Conditions'. From this, it is evident that it is not feasible to reduce the exports of any of the modelled pollutants to zero levels. The best that could ever be achieved would be around the levels of the modelled 'Natural Conditions'.

The 'Future' Scenario' based on the Maroochy Shire Council Strategic plan, shows a very minor increase in pollutant loads. This scenario takes into account an increase in population, leading to a commensurate increase in STP loads. When this is factored in to the total loads of the 'Future scenario' there is actually a slight decrease in the overall modelled diffuse loads of N and P.

One potentially significant land-use change which may happen in the near future in the Maroochy Catchment, is the alienation of the current cane lands. Due to the recent closure of the Moreton Sugar Mill there is significant pressure on cane farmers to leave the industry. A lot of this cane land could become rural residential, not withstanding current planning regulations. The 'Cane lands to Rural Residential' scenario shows that this would potentially increase sediments loads in the order of 15 percent. Diffuse loads of nitrogen and phosphorous would increase by about 10 percent. This is probably contrary to most people's first assumption that a decrease in cane farming would help reduce sediment loads within the catchment.

Another potential use for the current cane lands is more intensive suburban development. The 'Cane Lands Converted to Suburban Land-Use' scenario predicts significant increases in N and P export. This is a direct result of the increased population and resultant inputs from the STPs. Obviously such a massive increase in population would put significant pressure on the health of the Maroochy Catchment and effective management of the sewage effluent would be critical.

Given that a significant proportion of pollutants from the catchment originate from diffuse sources, it is essential to implement land management actions to reduce generation from these sources. Stream buffers are one possible way to reduce pollutants entering the waterways. EMSS considers a stream buffer to be a grassed swale adjacent to the stream. The three levels of increased stream buffers modelled predict that significant reductions in pollutant export can be achieved by increasing the amount of stream buffers within the catchment. Interpretation of these scenarios requires caution. The increases in buffers described in these scenarios do not take into account existing buffers. Conceptually the reduction in sediment provided by existing buffers is accounted for by the EMCs used in the model. The scenarios only describe an increase in buffers. A particular catchment may have a high level of buffers in existence, e.g. 50 percent. It is therefore not possible to increase the buffers by 75 percent. The scenarios do not take this into account. An analysis of existing buffer percentages per catchment, and then only increasing the buffers accordingly would overcome this problem.

9.7 Potential Model Improvements

Before further investment in improving model predictions occurs, it would be important to undertake a sensitivity analysis of the EMSS data inputs. Substantial amounts of time and money may be saved by having an understanding of just how sensitive the model predictions are to improvements in the various input parameters. In the absence of this analysis, some potential areas of improvement are suggested.

As previously discussed, EMSS has a number of conceptual limitations in how it represents catchment water quality processes, such as the lack of stream bank erosion. As with any model, the level of sophistication of process representation has to match the level of data available to support the parameterisation of the mathematical functions used to represent those processes. Given that these models are continually evolving and improving, it is beneficial to examine how data may be improved within the Maroochy Catchment.

The most obvious data inputs that could be improved are the EMCs and DWCs. The values used in the current model were those developed from a review of data for the broader SEQ region. The model could be significantly improved by collecting water quality data specific to the Maroochy Catchment and the land-uses within it. Collection of high flow/flood data to develop complete pollutant hydrographs would be especially useful. Optimally, new data would be collected from subcatchments of predominantly single land-use. This would allow for collection of pollutant concentrations specific to a given EMC. At the time of publication, the Maroochy Shire Council was implementing a program to collect improved water quality data within the catchment.

Improved information for soil erodibility may significantly enhance model predictions. Current soil erodibility data are based on an interpretation of 1:100 000 scale soils mapping. Using this scale of data in the model is possibly pushing the data past its appropriate scale. At the time of publication, the Queensland Department of Natural Resources and Mines was conducting a finer scale soil survey of the Maroochy Catchment. Use of this data in future models is recommended.

A refined land-use map may also improve model predictions. As with the soil mapping, the QLUMP land-use mapping is possibly being pushed beyond its accuracy limits. Mapping land-use to specifically match the same categories as the EMC data would be advantageous. This would be possible for an area the size of the Maroochy given there is readily available fine scale aerial photography and Ikonos satellite imagery.

Sediment generation from unpaved roads within the catchment was an issue which the modelling team considered. Local experience in the Maroochy Catchment suggests that runoff from unpaved roads may be a significant contributor to sediment generation. Including roads as a specific land-use in the model was investigated. EMC values for an ‘Unpaved Roads’ land-use were determined from a review of the literature. However, unrealistically high sediment generation rates were predicted by the model when the ‘Unpaved Roads’ land-use was included. There may be a number of explanations for this. As unpaved roads tend to be a feature of most landscapes, their contribution to sediment generation may already be accounted for in the EMCs of the other land-uses. Also, the majority of the studies used in determination of EMC values for ‘Unpaved Roads’ were based in south eastern Australia. These values may not be appropriate for the Maroochy Catchment.

10. Conclusions

The work of the Maroochy Community Modelling Team has considerably improved estimates of sediment and nutrient loads within the Maroochy Catchment. As well, the spatial definition of where the loads are originating from has also been significantly improved.

The model predicts that diffuse sources are the most significant contributors to pollutant export from the catchment. The Upper Paynter and Upper Petrie Creek subcatchments produce the highest sediment loads in the Maroochy Catchment. Significant variations in annual export of pollutants occur, related to the amount of rainfall experienced.

The Maroochy Catchment Community Modelling Team worked together successfully to source the best available data and use it in the Maroochy EMSS model. In doing so, the group has developed an in-depth understanding of the EMSS and related models, and when and how it is appropriate to apply them. Given the high level of acceptance in the community of the model results, the Maroochy EMSS will provide a useful tool to address natural resource management issues in the Maroochy Catchment.

A number of data inputs to the Maroochy EMSS are currently being improved through collection of new data. As this data becomes available it can be used to refine the predictions of the model.

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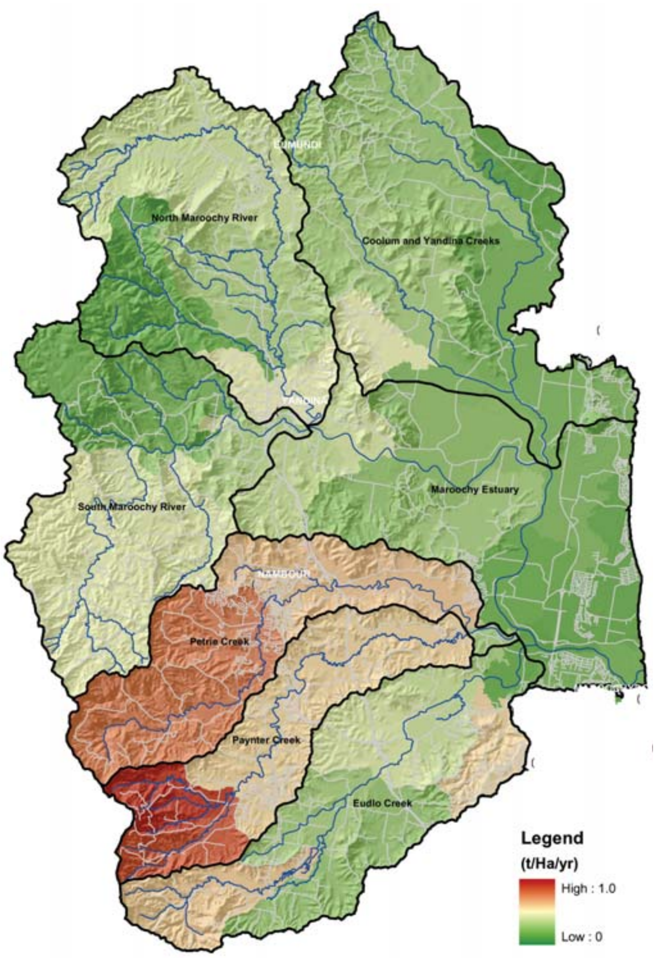
Appendix 1 - Model Scenario Results

1. Current Conditions

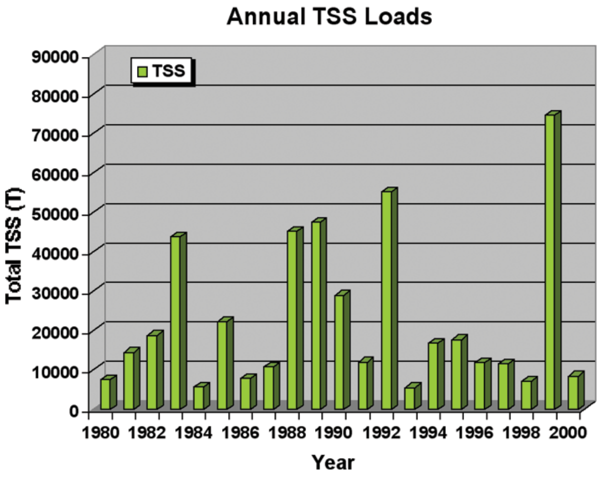
This scenario reflects current conditions in the Maroochy Catchment.

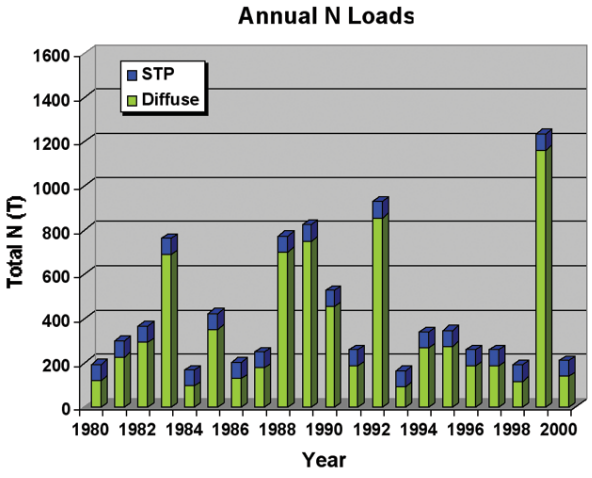
Annual Average Total Suspended Sediment for each Model Sub-catchment

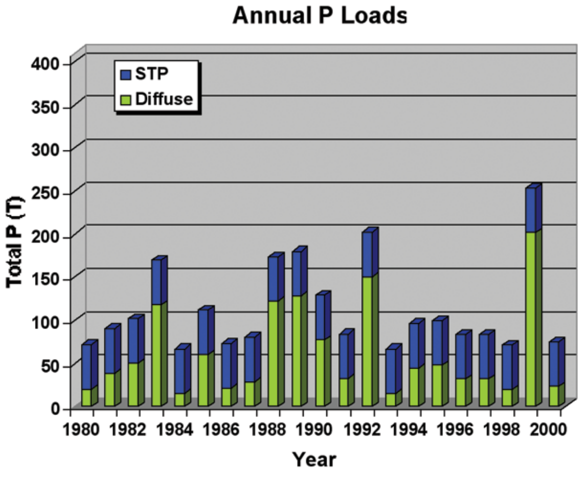


Average annual loads at the catchment outlet (t/yr):

TSS:	22476
Nitrogen:	427
Phosphorous:	112







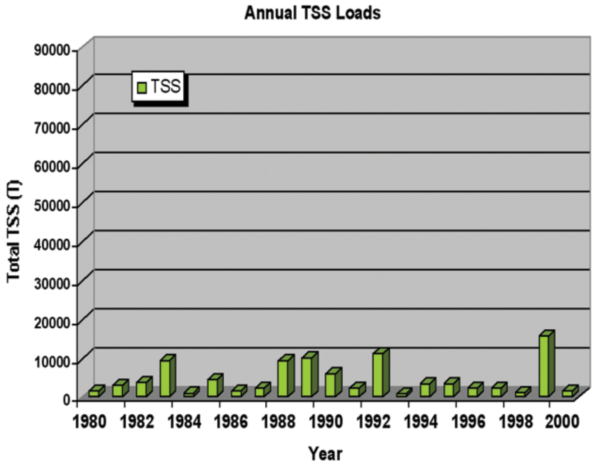
2. Natural Conditions

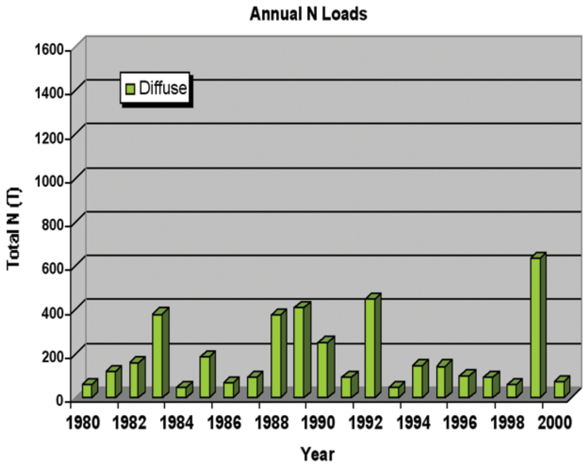
This reflects conditions in the Maroochy Catchment before European influences were imposed on the catchment.

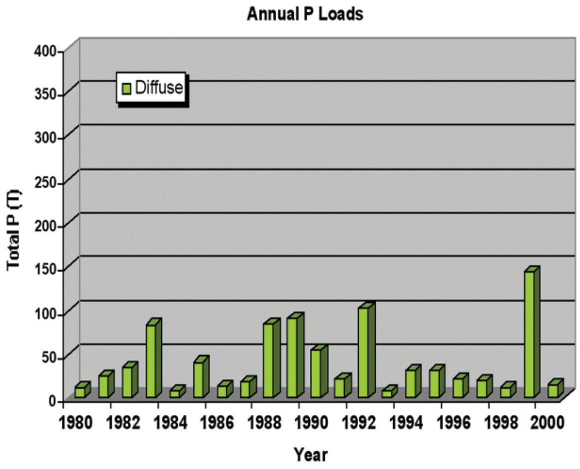
Annual Average Total Suspended Sediment for each Model Sub-catchment

Average annual loads at the catchment outlet (t/yr):

TSS:	4666
Nitrogen:	189
Phosphorous:	42



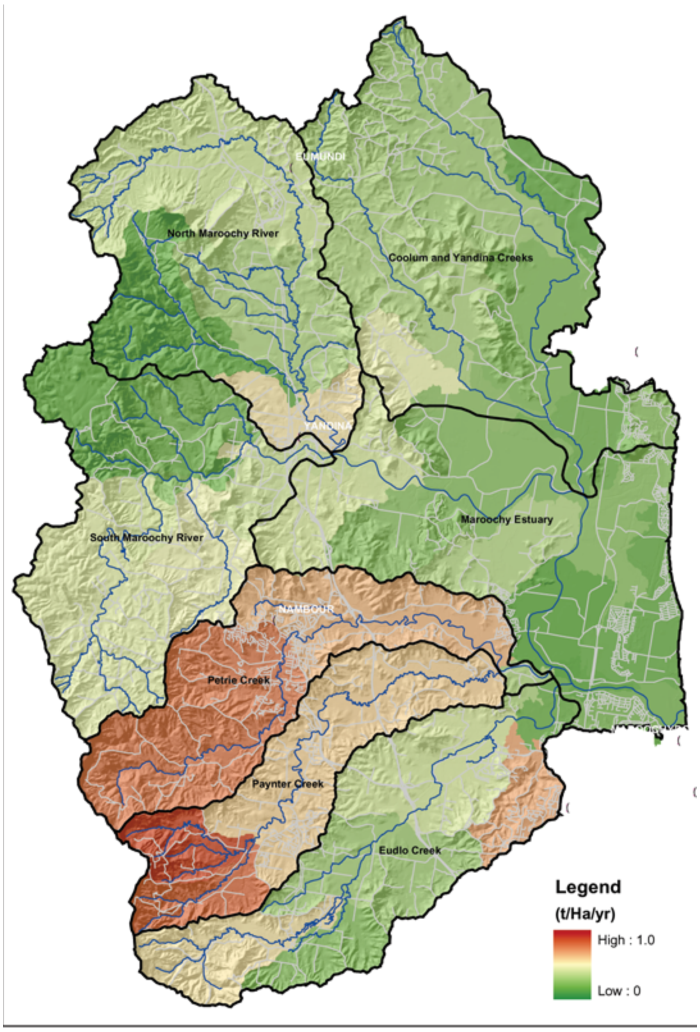




3. Future – Maroochy Shire Council Strategic Plan

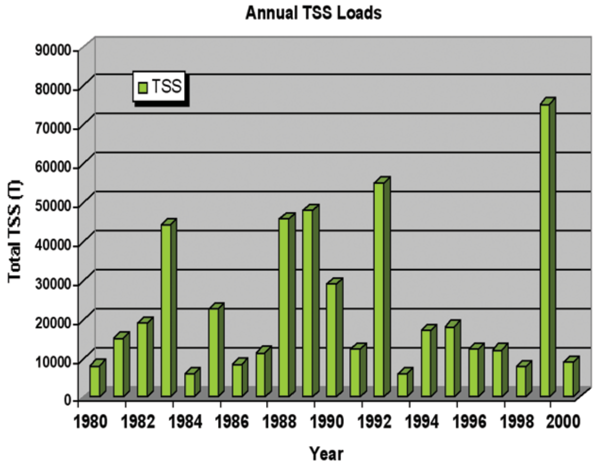
This reflects conditions in the Maroochy Catchment if the land-use distribution proposed in the Maroochy Shire Council strategic plan was to come to full fruition.

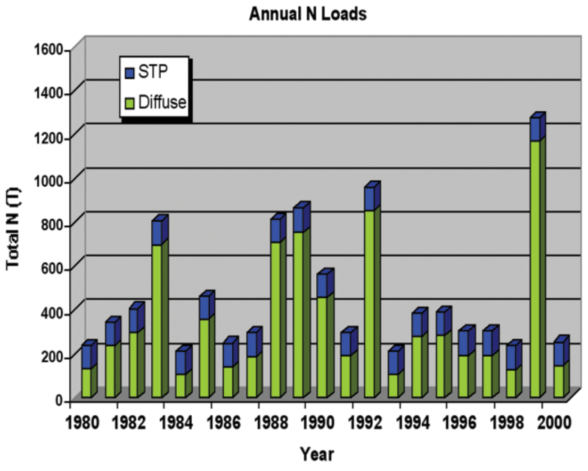
Annual Average Total Suspended Sediment for each Model Sub-catchment

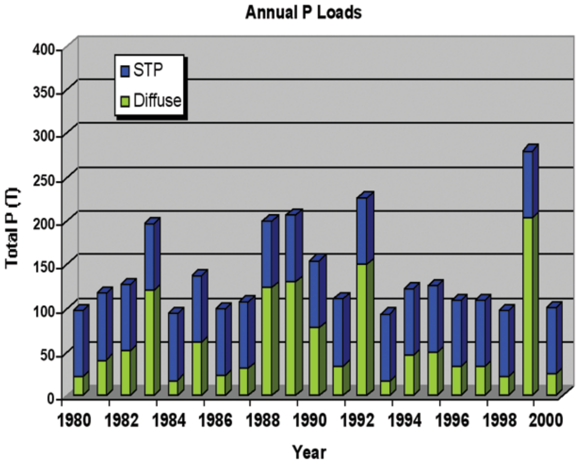


Average annual loads at the catchment outlet (t/yr):

TSS:	23032
Nitrogen:	470
Phosphorous:	139



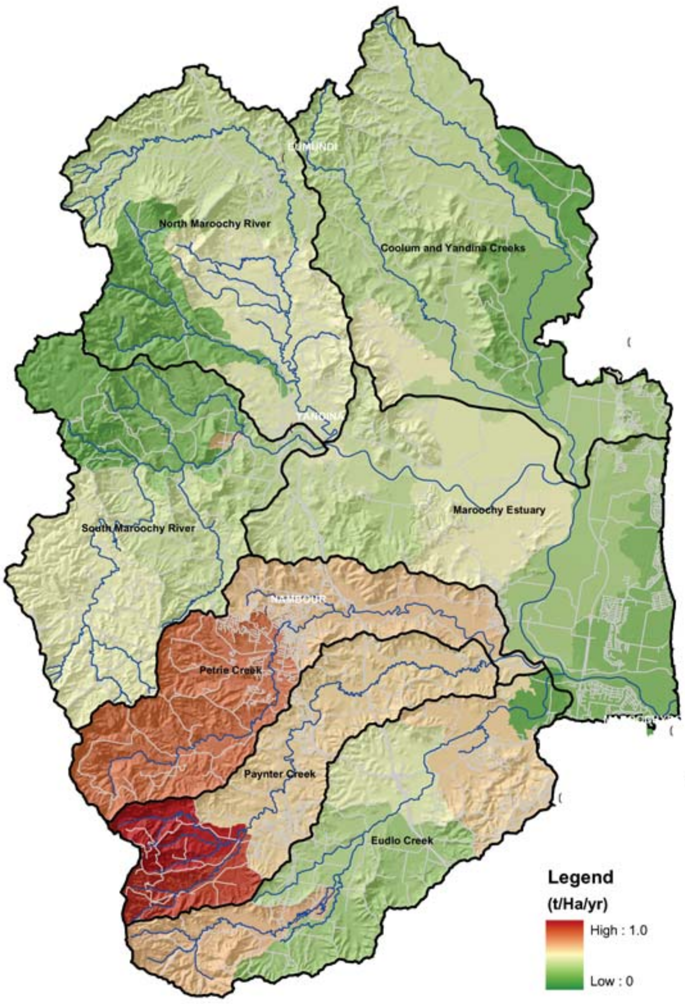




4. Cane Lands Converted to Rural Residential Land-Use

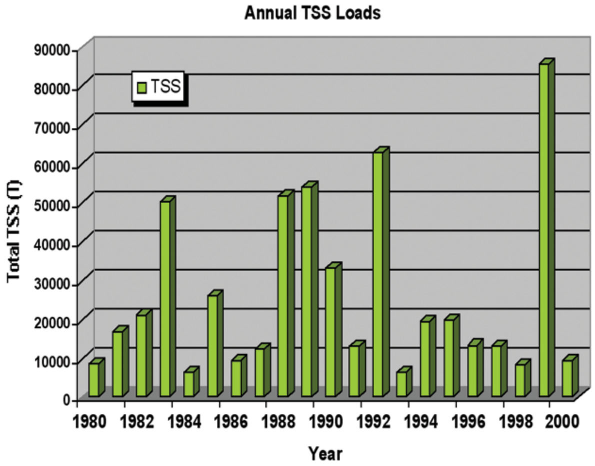
This reflects conditions in the Maroochy Catchment if all the land that is currently used for sugar cane production was developed as rural residential housing blocks.

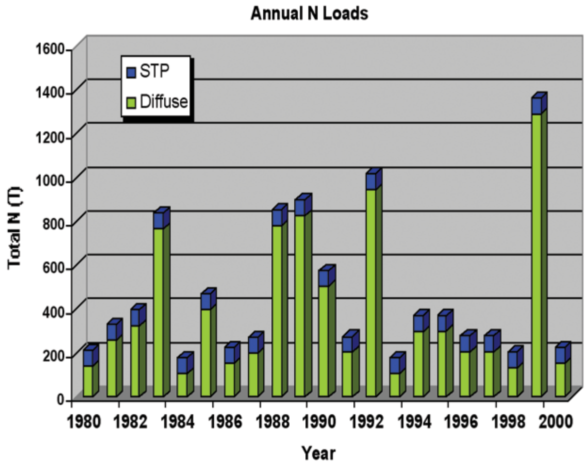
Annual Average Total Suspended Sediment for each Model Sub-catchment

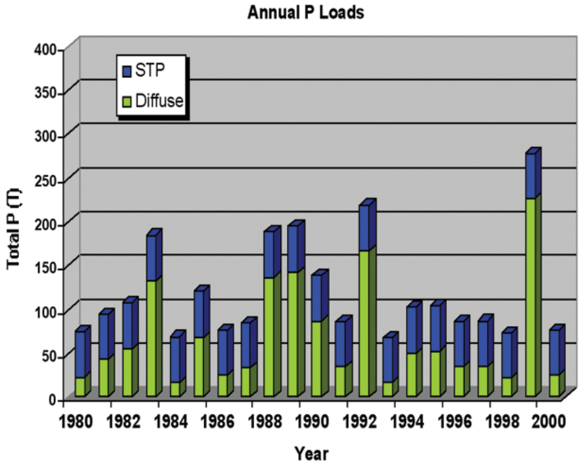


Average annual loads at the catchment outlet (t/yr):

TSS:	25780
Nitrogen:	466
Phosphorous:	120



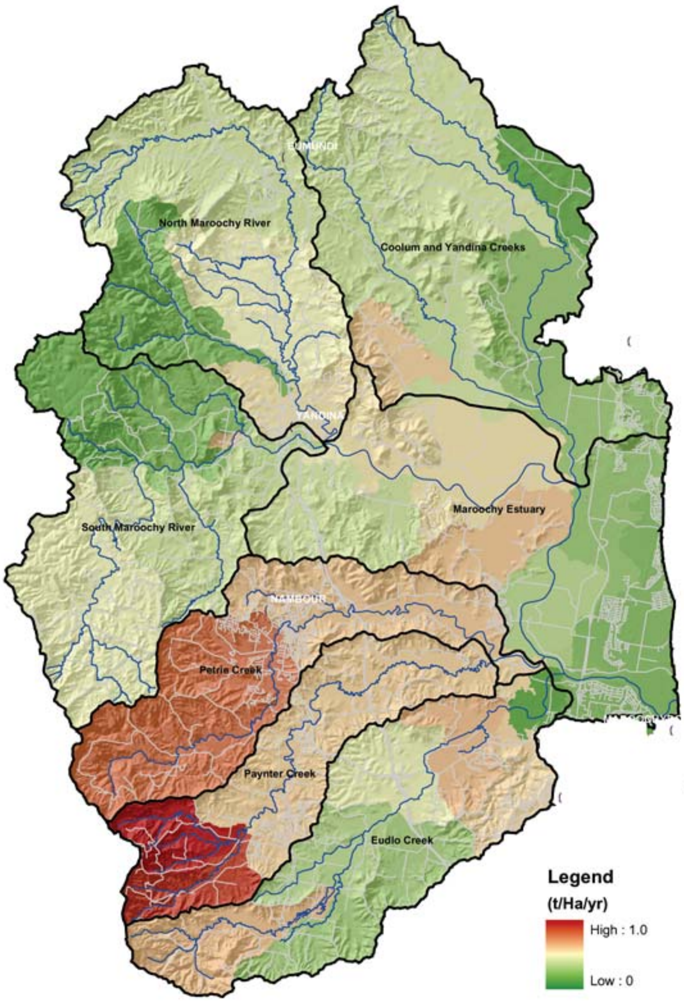




5. Cane Lands Converted to Suburban Land-Use

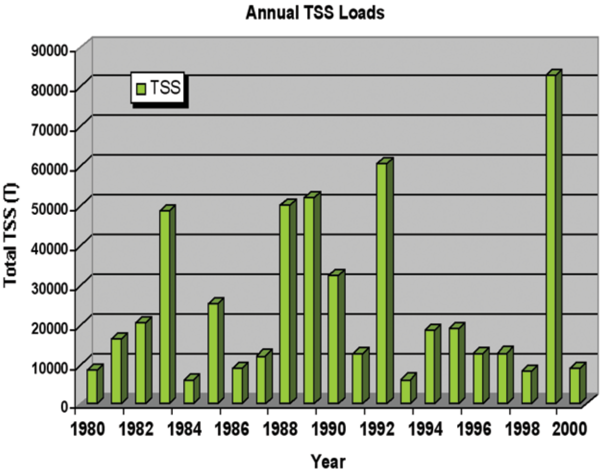
This reflects conditions in the Maroochy Catchment if all the land that is currently used for sugar cane production was developed as suburban housing blocks.

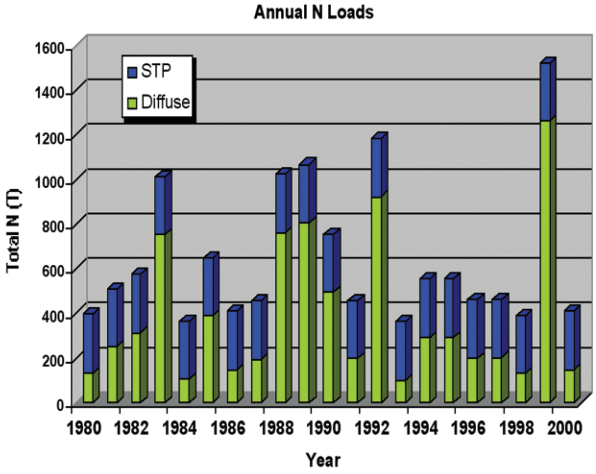
Annual Average Total Suspended Sediment for each Model Sub-catchment

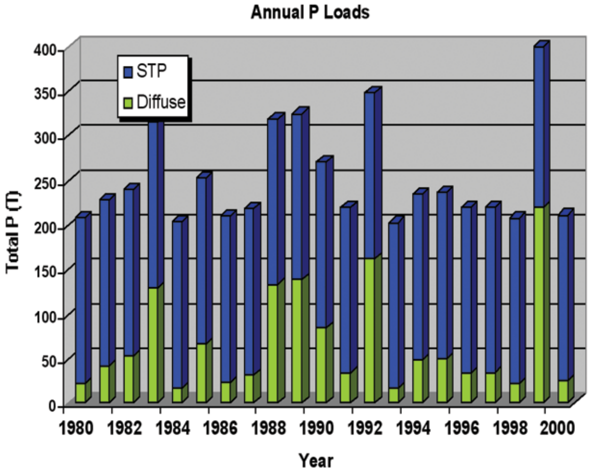


Average annual loads at the catchment outlet (t/yr):

TSS:	25003
Nitrogen:	646
Phosphorous:	252







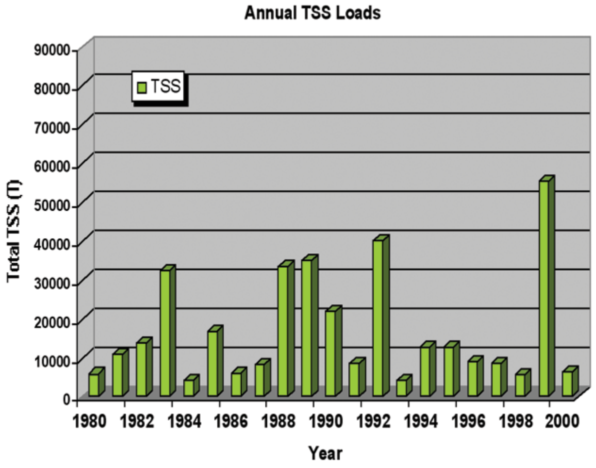
6. Grazing Generation Reduced by 50 Per Cent

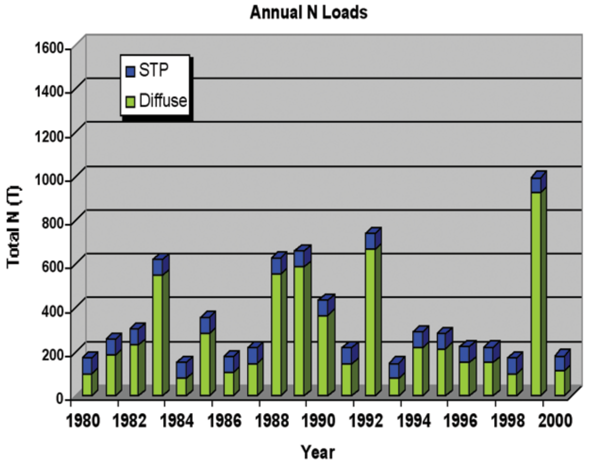
This reflects conditions in the Maroochy Catchment if an unspecified management practice was applied to all current grazing land to reduce pollutant generation by 50 percent of the current levels.

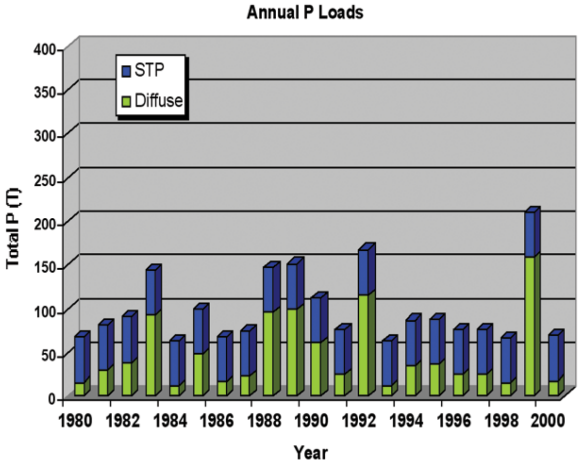
Annual Average Total Suspended Sediment for each Model Sub-catchment

Average annual loads at the catchment outlet (t/yr):

TSS:	16808
Nitrogen:	355
Phosphorous:	99



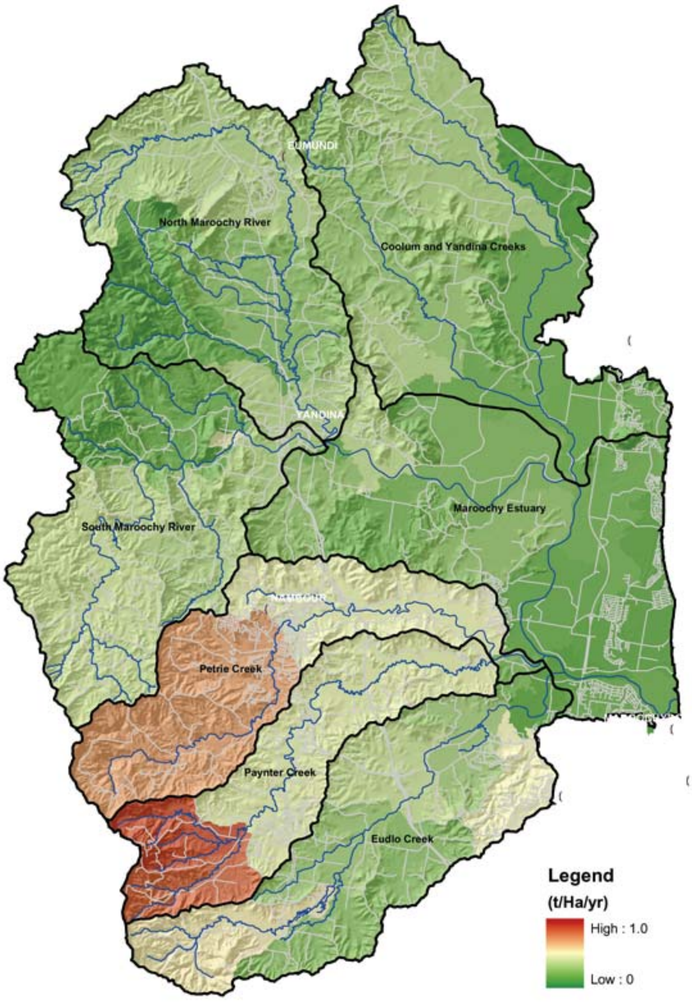




7. Stream Buffers Increased by 25 Per Cent

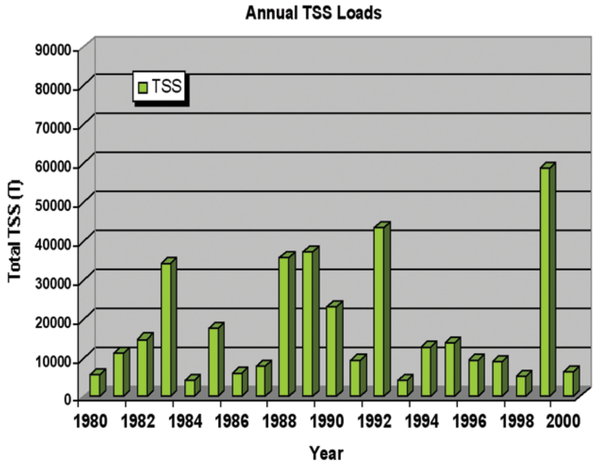
This reflects conditions in the Maroochy Catchment if 25 percent of the streams in the catchment had a vegetated buffer of approximately 5 metres.

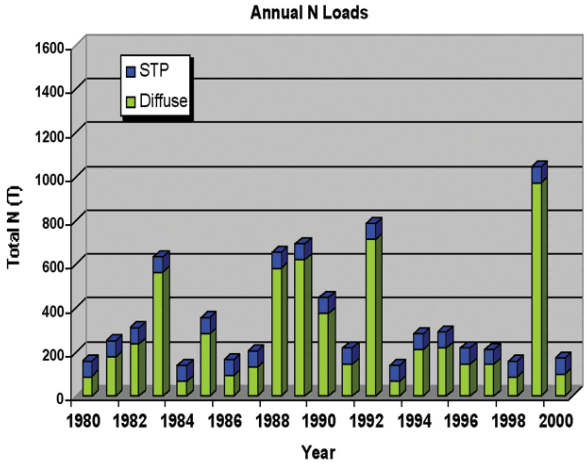
Annual Average Total Suspended Sediment for each Model Sub-catchment

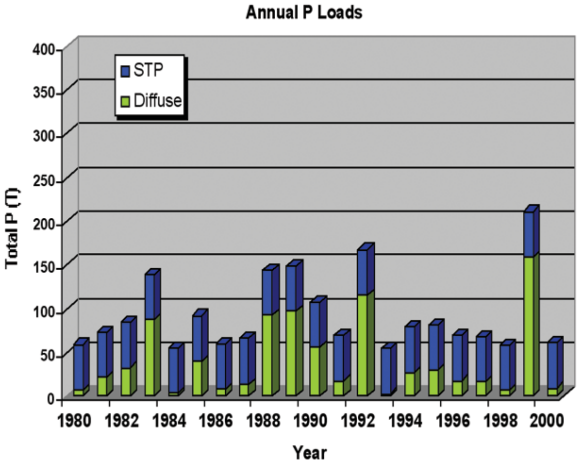


Average annual loads at the catchment outlet (t/yr):

TSS:	17640
Nitrogen:	358
Phosphorous:	93







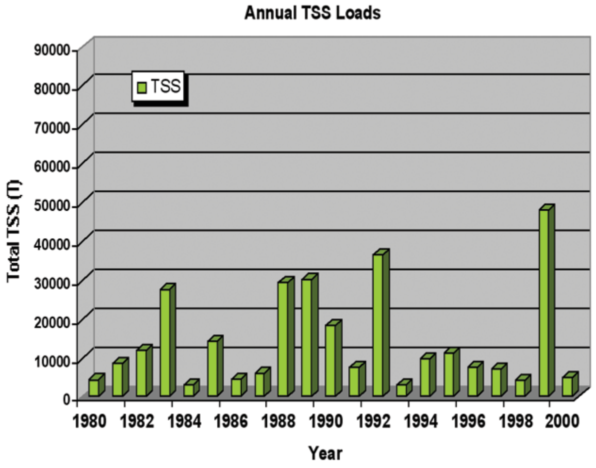
8. Stream Buffers Increased by 50 Per Cent

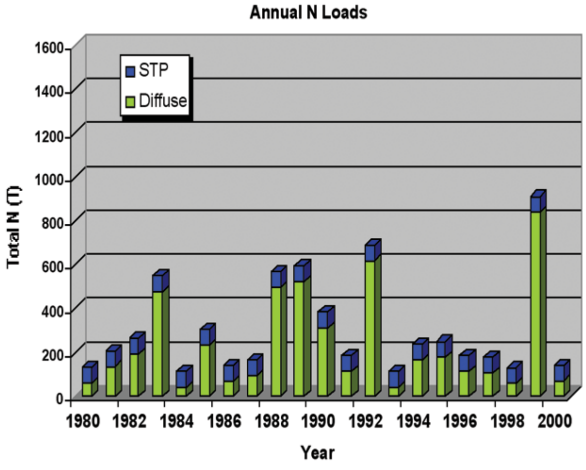
This reflects conditions in the Maroochy Catchment if 50 percent of the streams in the catchment had a vegetated buffer of approximately 5 metres.

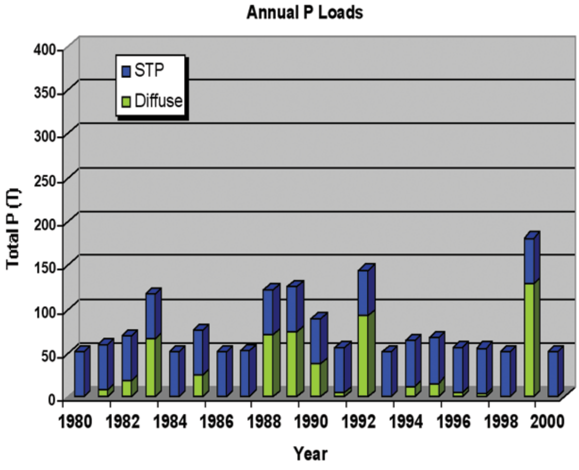
Annual Average Total Suspended Sediment for each Model Sub-catchment

Average annual loads at the catchment outlet (t/yr):

TSS:	14208
Nitrogen:	306
Phosphorous:	77







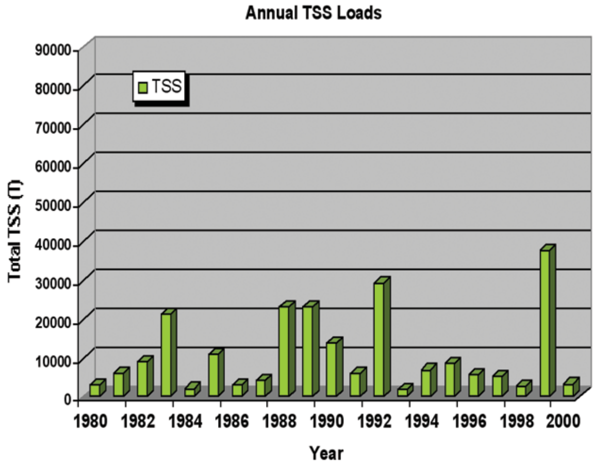
9. Stream Buffers Increased by 75 Per Cent

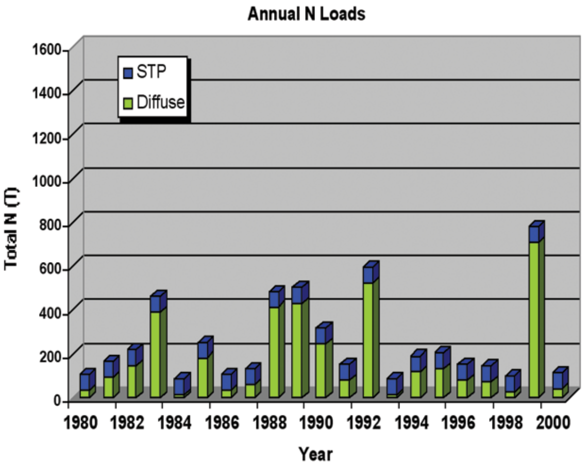
This reflects conditions in the Maroochy Catchment if 75 percent of the streams in the catchment had a vegetated buffer of approximately 5 metres.

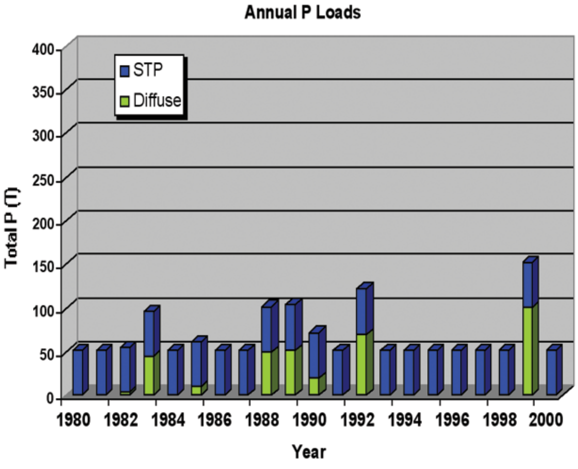
Annual Average Total Suspended Sediment for each Model Sub-catchment

Average annual loads at the catchment outlet (t/yr):

TSS:	10817
Nitrogen:	254
Phosphorous:	62



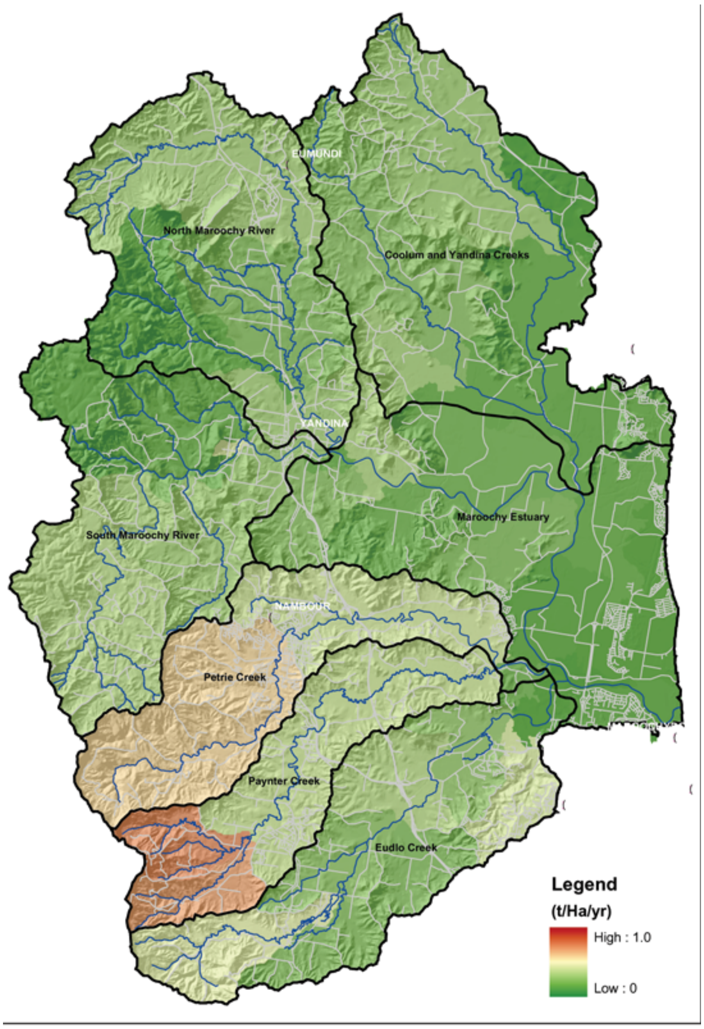




10. Stream Buffers 100% Buffers for First Order Streams

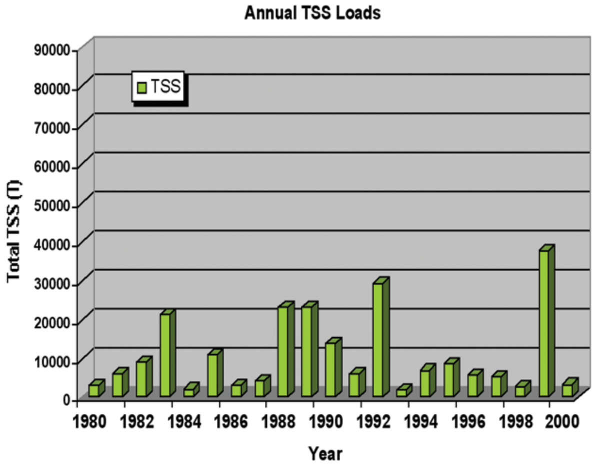
This reflects conditions in the Maroochy Catchment if 100 percent of all the first order streams in the catchment had a vegetated buffer of approximately 5 metres.

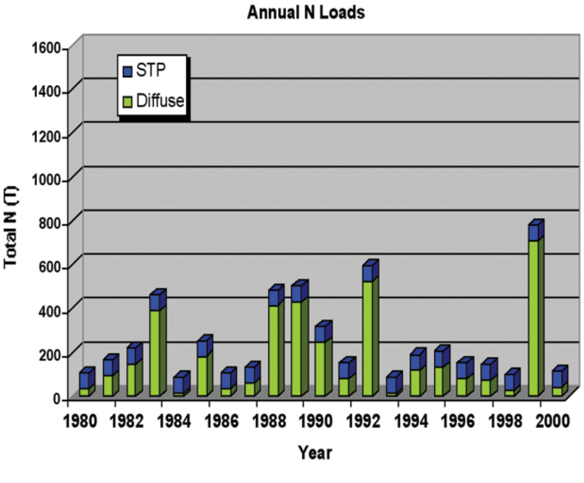
Annual Average Total Suspended Sediment for each Model Sub-catchment

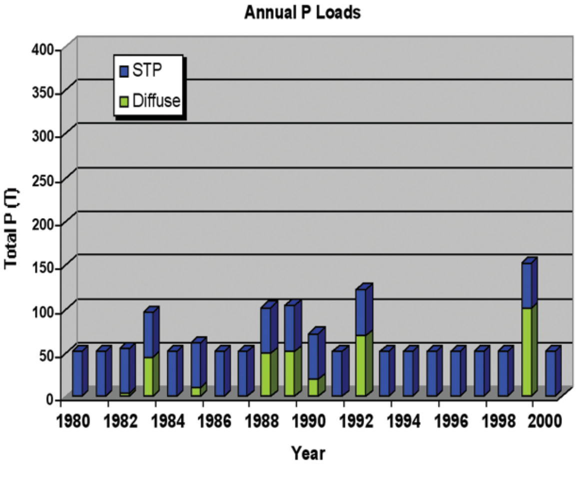


Average annual loads at the catchment outlet (t/yr):

TSS:	14816
Nitrogen:	312
Phosphorous:	78







Appendix 2. Abbreviations and Acronyms

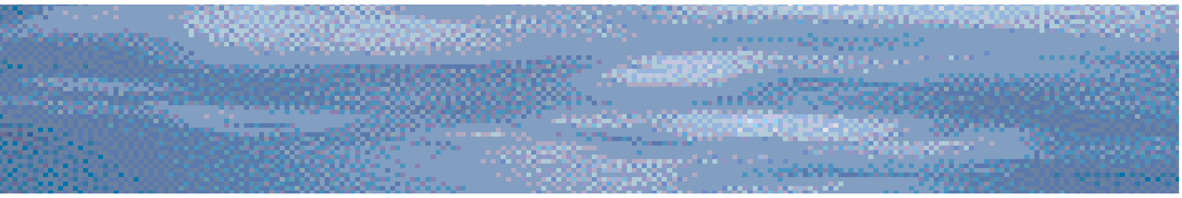
AHD	Australian Height Datum
ANUDEM	Digital Elevation Model generation software (Hutchinson, 1989)
ArcGIS	Geographic Information System software (ESRI, Redlands)
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
DPI	Department of Primary Industries - Queensland
DWC	Dry Weather Concentration
E	Coefficient of efficiency (Nash & Sutcliffe, 1970)
EHMP	Environmental Health Monitoring Program
EMC	Event Mean Concentration
EMSS	Environmental Management Support System
EPA	Environmental Protection Agency - Queensland
ET	Evapotranspiration
HYDSIS	Hydrological data management system
MBWCP	Moreton Bay Waterways and Catchments Partnership
Mike 11	River hydrology modelling software.
MSC	Maroochy Shire Council
NLWRA	National Land and Water Resources Audit
NR&M	Department of Natural Resources and Mines - Queensland
PET	Potential Evapotranspiration
PPF	Principal Profile Form (Northcote, 1974)
Q	Daily runoff
QLUMP	Queensland Land-Use Mapping Program (NR&M, 2004)
Regional_SIMHYD	Automated calibration software for the SIMHYD rainfall-runoff model
RUSLE	Revised Universal Soil Loss Equation
SALI	Soil and Land Information database (NR&M)
SEDNET	Catchment Water Quality Model (Prosser *et al.*, 2001)
SEQ	South East Queensland
SEQWQMS	South East Queensland Regional Water Quality Management Strategy
SIMHYD	Rainfall-runoff model (Peel *et al.,* 2001)
SIMHYD_PS	Automated calibration software for the SIMHYD rainfall-runoff model
STP	Sewage Treatment Plant
TAUDEM	Digital Elevation Model processing software (Tarboton, 1997)
TN	Total nitrogen
TP	Total phosphorous
TSS	Total Suspended Sediment
USLE	Universal Soil Loss Equation (Wischmeier and Smith,.1978).

COOPERATIVE RESEARCH CENTRE FOR **CATCHMENT HYDROLOGY**

CENTRE OFFICE

CRC for Catchment Hydrology
Department of Civil Engineering
Building 60
Monash University
Victoria 3800
Australia

Tel +61 3 9905 2704
Fax +61 3 9905 5033
email crcch@eng.monash.edu.au
www.catchment.crc.org.au



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