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Department of **Water**

Hydrological and nutrient modelling of the Swan Canning coastal catchments

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Hydrological and nutrient modelling of the Swan-Canning coastal catchments

Coastal Catchment Initiative project

By

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Department of Water

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The Swan and Canning estuaries cover an area of approximately 40 km^2 and extend approximately 60 km upstream from Fremantle to the confluence of Ellen Brook with the Swan River, and 11 km upstream from the Canning Highway Bridge to the Kent Street Weir on the Canning River. The catchment area comprises the Avon River catchment with an area of approximately 124 000 km^2 and 30 smaller catchments which drain approximately 2090 km^2. These smaller catchments are mostly located on the Swan Coastal Plain, and will be referred to as the Swan-Canning coastal catchments.

The health of the rivers and estuaries is in decline: over the few past decades they have been displaying increasing signs of eutrophication including fish kills, cyanobacterial blooms, red tides and accumulation of organic matter in the bottom sediments. Algal blooms, which generally occur in the upper reaches of the Swan and Canning estuaries, are driven by the nutrients in catchment inflows, or nutrients that have built up in the sediments and re-mobilised under anoxic conditions.

The quantity of nutrients exported from catchments to receiving waterbodies depends primarily on land use, but is modified by environmental attributes such as soil type, geology, slope, rainfall, drainage density, catchment size and land management practices.

In this study the Streamflow Quality Affecting Rivers and Estuaries (SQUARE) model is used to estimate the flow, and the nitrogen and phosphorus loads from the Swan-Canning coastal catchments to the rivers and estuaries. The flow and loads from the Avon River have been calculated using data collected at site 616011 (Swan River, Walyunga).

The relative areas, average annual flows and loads (1997–2006) of nitrogen and phosphorus contributing to the Swan and Canning estuaries are:

Catchment	Area (km^2)	Average annual flow (GL)	Average annual nitrogen load (tonnes)	Average annual phosphorus load (tonnes)
Avon	123 900	254	575	20
Coastal catchments	2 090	190	250	26

Although on average the Avon River contributes more flow and nitrogen load to the estuaries than the coastal catchments, in most years it contributes less – because in wet years its flow volume is disproportionately larger than in dry years. The coastal catchments generally contribute more phosphorus to the estuaries than the Avon River, on both an annual and monthly basis.

The average annual flow in the Avon River for the period 1997 to 2006 was 35% less than the average for the preceding 22 years. This decrease in flow volume means that the estuaries are less well flushed, more saline and the flows from the coastal catchments have greater impact than previously. Climate predictions indicate a drying climate in the south of

Western Australia, which will further decrease Avon River flows relative to those from the coastal catchments.

The timing and distribution of rainfall, as well as catchment characteristics are very important. The urban catchments, which have large impervious areas, have significant flows in summer and autumn when the Avon River, Ellen Brook and several of the other rural catchments have small or no flows. As the conditions in summer and autumn are often favourable for algal blooms, targeting nutrient reduction in the urban catchments may significantly decrease the likelihood of algal blooms. However, nitrogen and phosphorus that is not flushed out to sea builds up in the sediments, and can become available to fuel algal growth (particularly under anoxic conditions). All nutrient inputs to the Swan-Canning estuary need to be addressed.

The coastal catchments with the greatest nutrient inputs per unit area are generally the urban catchments which are closest to the estuaries. Ellen Brook and Southern River catchments also contribute significant phosphorus inputs in terms of load per cleared area. The main sources of nitrogen in terms of land use (for 1997–2006) for the coastal catchments were residential (26%), farms (23%), septic tanks (16%) and recreation (13%). Recreation (golf courses and fertilised parks and gardens) only occupies 2% of the catchment area. The pattern is slightly different for phosphorus: the main contributions (1997–2006) came from farms (33%), residential (22%), recreation (12%) and septic tanks (8%). Farming land use dominates phosphorus export because it occupies large areas in the Ellen Brook catchment.

The SQUARE modelling of the coastal catchments supports the *Swan Canning water quality improvement plan* (SCWQIP) of the Swan River Trust. The prime aim of the SCWQIP is to reduce nitrogen and phosphorus pollution to the Swan and Canning rivers and estuaries. The water quality objectives for the SCWQIP are winter median total nitrogen (TN) and total phosphorus (TP) concentration targets. As nutrient concentrations are directly influenced by runoff, and the runoffs of the coastal catchments range from approximately 15 mm to 350 mm depending on the imperviousness of the catchment, concentration targets were defined in terms of water yield as shown below:

Average annual runoff	TN concentration target	TP concentration target
< 100 mm	1.0 mg / L	0.1 mg / L
100 to < 200 mm	0.75 mg/L	0.075 mg/L
≥ 200 mm	0.5 mg / L	0.05 mg / L

For the purposes of the SCWQIP, average annual maximum acceptable pollutant load targets corresponding to the concentration targets were specified. The average annual **maximum acceptable load target** is the maximum load that may prevail in a stream that enables the stream to just meet its median concentration target. For streams that are meeting their concentration target currently, the maximum acceptable load target is given as the current load. The load reductions required to achieve the maximum acceptable load targets will be used to guide the scale of remediation.

The current annual nitrogen load from the 30 coastal catchments to the Swan and Canning rivers and estuaries is approximately 250 tonnes. If all catchments were meeting their concentration targets the nitrogen load would be approximately 130 tonnes (a 49% reduction). The catchments that are meeting their targets for nitrogen (at catchment equilibrium)[1] are Ellis, Perth Airport South, and Upper Canning. The urban catchments generally require greater percentage load reductions than the rural catchments. However, Ellen Brook and Saint Leonards catchments, which have predominantly rural land, also require large percentage load reductions (60–70%).

The current annual phosphorus load from the coastal catchments is 26 tonnes. If all the catchments were meeting their water-quality targets, the phosphorus load to the rivers and estuaries would be approximately 14 tonnes (a 46% reduction). Seven of the 30 coastal catchments meet their targets for phosphorus (at catchment equilibrium)[1]. However, most of the required load reduction (8 tonnes) is from Ellen Brook catchment, which is the largest catchment and has poor nutrient-retaining soils. Southern River, which requires a load reduction of about 50% (1 tonne), is responsible for about half the nutrient inputs to Kent Street Weir pool.

Scenarios related to future urban development, climate change and management interventions were modelled in the coastal catchments to determine their impacts on flows and nutrient loads to the estuaries. The management scenarios included point source control, removal of septic tanks, fertiliser management, application of soil amendments, artificial wetlands and in-stream interventions (zeolite/laterite filters).

The A2 (pessimistic) climate change scenario predicted decreases of flow, nitrogen and phosphorus loads of 30%, 15% and 31% respectively from the coastal catchments. However, the nutrient concentrations are generally expected to increase. The Avon River, which generally has better water quality than the coastal catchment inflows, will have proportionately greater decreases in flow than the coastal catchments with less rainfall, thus reducing its diluting and flushing function.

The future urban development in the coastal catchments was estimated to comprise about 130 000 new dwellings, with estimated increases in average annual flow of about 5%, nitrogen load of about 47 tonnes (18%) and phosphorous load of about 7 tonnes (25%). The percentage changes are expected to be greatest in the Henley, Munday-Bickley, Saint Leonards, Southern, and Blackadder catchments. However, the greatest absolute load increases are expected in Ellen Brook and Southern River.

Of the management scenarios modelled, *Fertiliser action plan* implementation predicted the greatest decreases in phosphorus load. If implemented in urban and rural areas, the reduction in load to the estuaries is estimated to be 25% – with 20 catchments achieving their phosphorus targets. For nitrogen the greatest improvement modelled was the 50% reduction in urban fertilisation scenario, which has the potential to produce a 22% load reduction – with 13 catchments achieving their nitrogen load targets.

[1] Note: In some catchments, nutrient yields are not in equilibrium with respect to recent land use changes due to the buffering by soil and vegetation.

1 Introduction

1.1 The problem

The Swan and Canning rivers and estuaries are vitally important natural resources of the Perth metropolitan area. The estuaries are the scenic and recreational heart of the city. Yet the health of Swan-Canning river system is in decline: over the past few decades it has shown increasing signs of eutrophication including fish kills, cyanobacterial blooms (Hamilton 2000), red tides (Hamilton et al. 1999) and accumulation of organic matter in the bottom sediments (Douglas et al. 1997; Smith et al. 2007). The most visible sign of the decline in health is the increasing frequency and extent of low oxygen or anoxic events. Algal blooms, which generally occur in the upper reaches of the Swan and Canning estuaries, are driven by nutrients in catchment inflows, or nutrients that have built up in the sediments and re-mobilised under anoxic conditions.

Besides nutrient pollution, the rivers and estuaries are also adversely affected by non-nutrient contaminants (Nice et al. 2009) and large volumes of gross pollutants in the form of litter and debris (Environmental Advisory Services 1999). The drying climate in Western Australia, and the state's increasing population, are expected to exacerbate these problems.

The Swan and Canning estuaries (Figure 1.1) cover an area of approximately 40 km^2 and extend approximately 60 km upstream from Fremantle to the confluence of Ellen Brook with the Swan River, and 11 km upstream from the Canning Highway Bridge to the Kent Street Weir on the Canning River. The lower Swan Estuary comprises the main basin of Melville Water, Freshwater Bay and the narrow channel from Blackwall Reach to Fremantle. The city of Perth is adjacent to Perth Water in the middle Swan Estuary.

The Swan and Canning estuaries have a catchment area of approximately 126 000 km^2 (Figure 1.2) comprised of the Avon River catchment, with an area of approximately 124 000 km^2, and 30 smaller catchments, which drain approximately 2090 km^2 (Figure 1.3). These smaller catchments are mostly located on the Swan Coastal Plain, and will be referred to as the Swan-Canning coastal catchments. Following European settlement in Western Australia, the area that drains to the estuaries, through the coastal catchments, has been decreased by water supply dams on the Helena, Canning and Wungong rivers and Bickley and Churchman brooks, as well as the artificial drainage network that directs some flows to the ocean.

Over three-quarters of the Swan Coastal Plain is characterised by sandy soils; the rest has alluvial clays and silts (Guildford Formation) and lacustrine deposits. Many low-lying areas are waterlogged or inundated in winter. An extensive artificial drainage network has been introduced in some low-lying areas to enable the development of land for agricultural and urban use. The rural catchments are generally further from the estuaries than the urban catchments, and have ephemeral streams and fewer artificial drains. The urban catchments have a high density of artificial drains, many of which flow all year round, driven by groundwater and garden watering using imported mains water.

The nutrients required to sustain algal blooms – carbon, nitrogen, phosphorus, sulfur, potassium and many more – are washed from the catchment into the rivers with rainfall. Of these nutrients, only a few are required in relatively large amounts, while at the same time being limited by their natural availability. Of these, nitrogen and phosphorus are the most important for plant and algal growth. Other major nutrients, such as carbon and sulfur, are usually in plentiful natural supply.

The natural and human sources of nutrients in river catchments include:

- atmospheric deposition
- phosphorus from the weathering of rocks
- decaying plant and animal matter
- nitrogen fixation by leguminous plants
- fertilisers from both rural and urban land use
- sewage effluent
- animal faeces and urine
- phosphorus from detergents.

Nitrogen and phosphorus exported from catchments to rivers and estuaries occur in both soluble and particulate form (adhered to soil particles) and may be transported in either surface runoff or groundwater discharge. Nitrogen occurs in the environment in several forms, including nitrogen gas, organic nitrogen, ammonium, nitrate and nitrite. Chemical processes cause transformations between these forms. Denitrification is important as it provides a pathway by which excess nitrogen in soils may be released into the atmosphere. Studies indicate that soils with high levels of dissolved organic carbon, pH range of 5 to 7 and low redox potential, generally promote denitrification. Bassendean Sands, which are prevalent on the Swan Coastal Plain, have these characteristics and are generally observed to have low levels of nitrate. The plant-preferred form of nitrogen is generally nitrate, which is highly soluble and thus readily leached from the soil profile by water.

In contrast to nitrogen, the phosphorus cycle in soils is relatively simple. Phosphorus occurs as ortho-phosphate in soils and is generally, except in sandy soils, strongly bound to soil particles. Phosphorus is lost from the soils in particulate form by surface erosion, and is leached in soluble form.

Large point sources of nutrients, such as discharge from sewage treatment plants or industry, are generally easy to locate and quantify. Diffuse sources, such as nutrient export from broadscale agriculture or urban areas, are more difficult to quantify. For this reason catchment models such as the Streamflow Quality Affecting Rivers and Estuaries (SQUARE) model are used to quantify the sources and fate of nutrients in the environment (Zammit et al. 2005; Hall 2009).

1.2 SQUARE modelling

In this study SQUARE is used to estimate the flow and nitrogen and phosphorus loads from the Swan-Canning coastal catchments to the rivers and estuaries. The flow and loads from the Avon River have been calculated using data collected at site 616011 (Swan River, Walyunga).

The quantity of nutrients exported from catchments to receiving waterbodies depends primarily on land use, but is modified by environmental attributes such as soil type, geology, slope, rainfall, drainage density, catchment size and land management practices. SQUARE, which the Department of Water developed for Western Australian water catchments, conceptualises the flow of water and nutrients across and through the soil profile (taking into account the physical processes that occur) to give the yields of water, nitrogen and phosphorus. The conceptualisation, physical processes modelled, structure, and calibration procedure of the SQUARE model are discussed in Section 3.

1.3 The *Swan Canning water quality improvement plan*

In 2006, the Australian Government's Coastal Catchment Initiative (CCI) identified the Swan-Canning river system as a coastal 'hotspot'. The SQUARE modelling of the Swan-Canning coastal catchments was done to support the Swan River Trust's *Swan Canning water quality improvement plan* (SCWQIP) (SRT 2009). The plan's focus is to reduce nitrogen and phosphorus inputs to the Swan and Canning rivers and estuaries. The SCWQIP will guide investment during the next seven years, identifying cost-effective management actions to limit transport of nitrogen and phosphorus from the catchment to the estuaries and coastal waters. The management measures identified include:

- use of water sensitive design in all new urban developments
- structural nutrient interventions
- fertiliser management
- application of soil amendments to low nutrient-retaining soils
- management of point sources, primarily septic tanks.

1.4 This report

A brief description of the Swan-Canning coastal catchments is given in Section 2. The SQUARE model is described in Section 3.1 and the input data requirement, which is large, is discussed in Section 3.2. SQUARE is calibrated against observed flow and nutrient data. The flow and nutrient calibration procedure is described briefly in Section 3.3 and expanded upon in Appendix A.

Section 4 discusses the water-quality objectives for the Swan-Canning coastal catchments, which have been specified in terms of median total nitrogen (TN) and total phosphorus (TP) concentrations. The average annual maximum acceptable loads and load reduction targets are defined.

In Section 5 the SQUARE modelling results are presented. The current catchment condition is discussed in terms of average annual loads and timing of delivery of nitrogen and phosphorus from the Avon River, Ellen Brook and the other coastal catchments. The sources of nutrients in relation to location and land use are presented. Similar data for each of the 30 catchments are presented in Appendix B.

Several climate and land-use scenarios have been modelled and are presented in Section 6, including:

- B1 and A2 future climate scenarios
- future urban development
- removal of septic tanks
- removal of point sources
- *Fertiliser action plan* implementation
- application of soil amendments
- constructed wetlands
- zeolite and laterite nutrient filters in waterways.

A discussion of environmental flows for the tributaries of the Swan and Canning estuaries was a requirement of the project. However, specification of ecological water requirements (EWRs) and environmental flow provisions (EFPs) is a long and involved process, beyond the time frame of this project. Sustainable diversion limits (SDLs) based on the stream hydrology have been deduced for some streams, as discussed in Section 7.

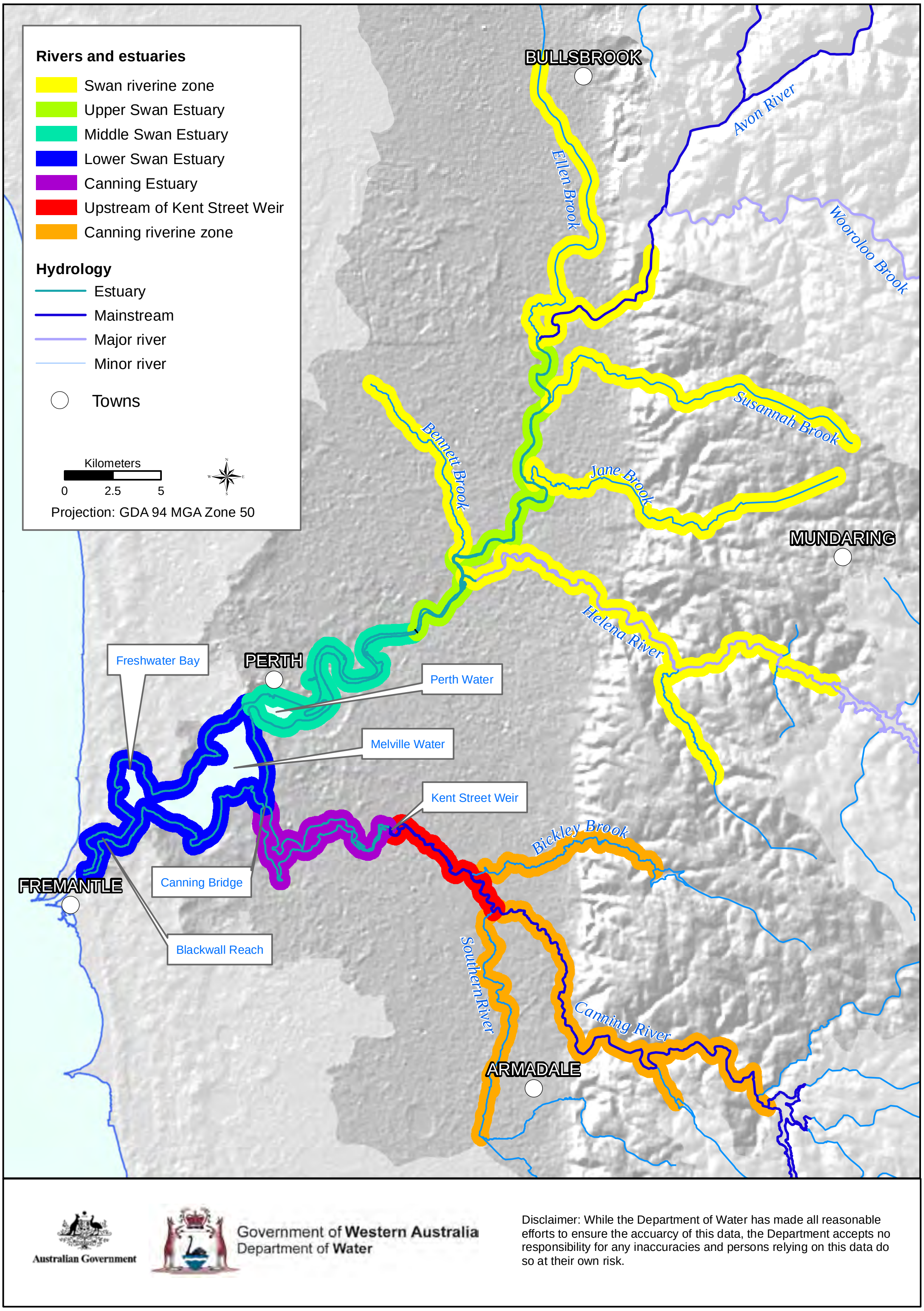


Figure 1.1 The Swan and Canning estuaries

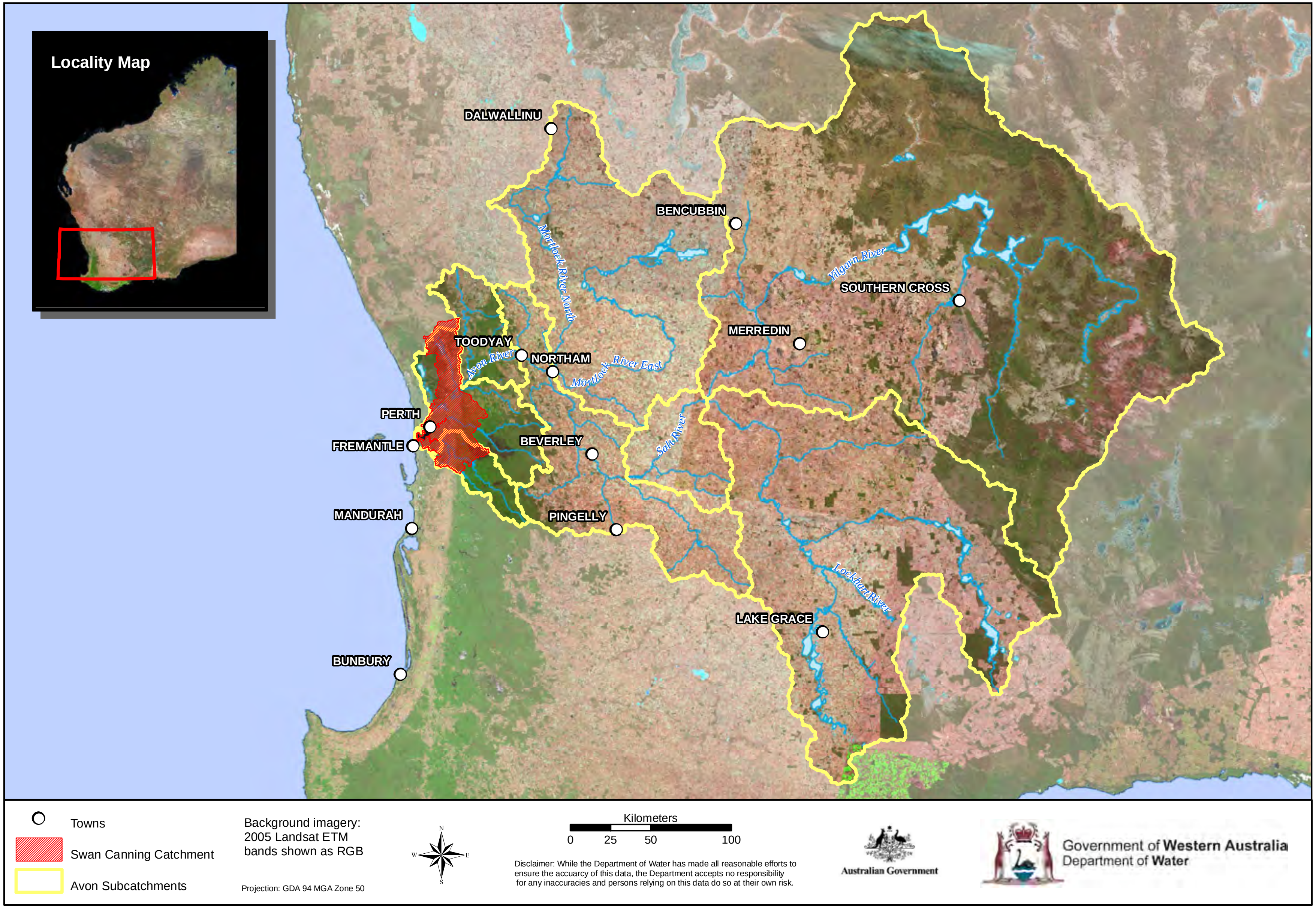


Figure 1.2 The catchment of the Swan and Canning estuaries

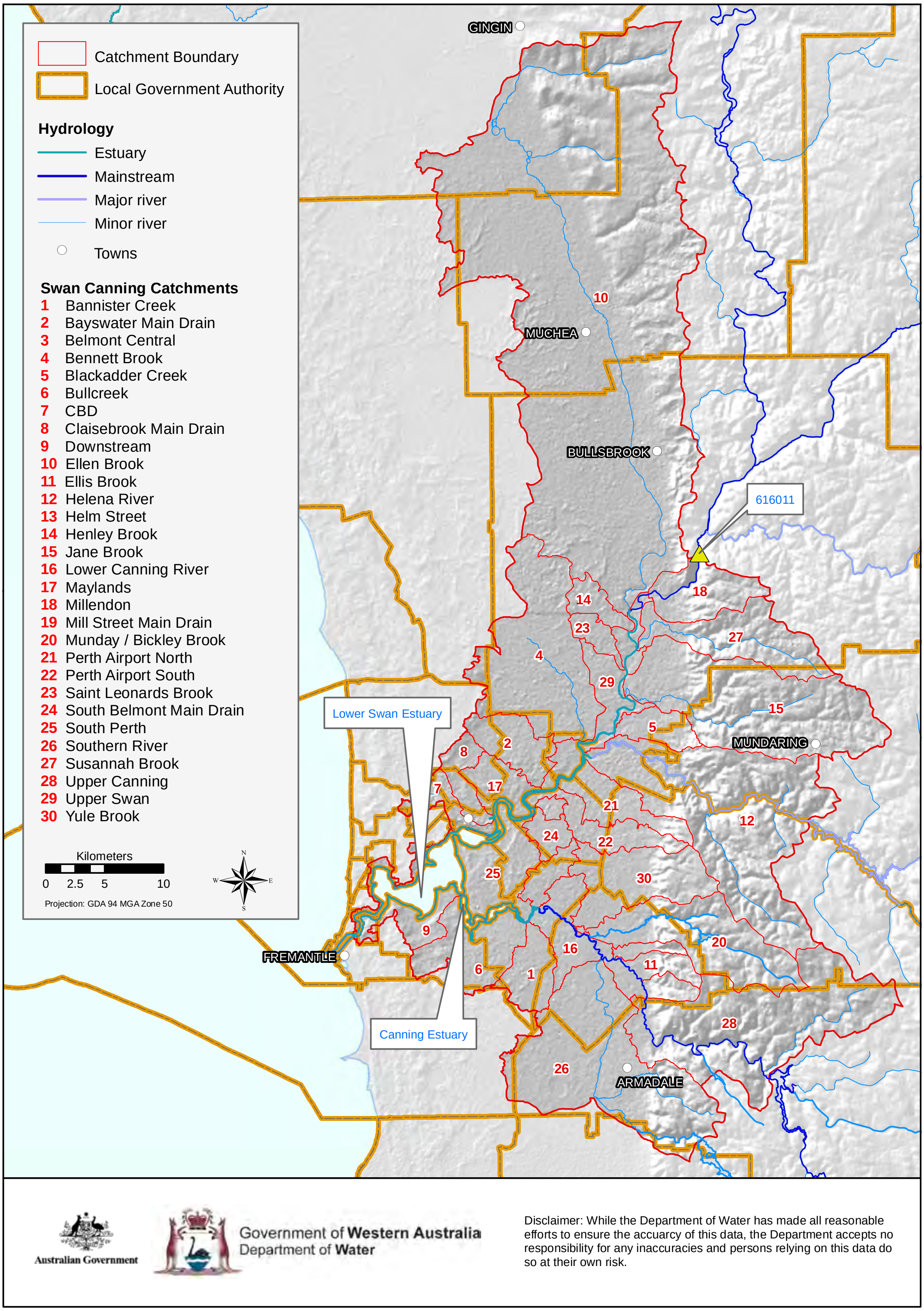


Figure 1.3 The Swan-Canning coastal catchments

2 Catchment description

2.1 Location

The Swan and Canning estuaries are located adjacent to Western Australia's west coast in the Perth metropolitan area (Figure 1.1). The catchment area is approximately 126 000 km^2 and includes the Avon River catchment (124 000 km^2) and 30 smaller coastal catchments mostly located on the Swan Coastal Plain (2090 km^2) (Figure 1.2). This report discusses modelling of these smaller coastal catchments (Figure 1.3), which are defined as the Swan-Canning coastal catchments. The flows and nutrient inputs from the Avon River have been calculated from data from site 616011 (Swan River, Walyunga).

The Swan-Canning coastal catchments contain the city of Perth, much of the Perth metropolitan area, and the regional/suburban centres of Muchea, Bullsbrook, Mundaring and Armadale (Figure 1.3). Twenty-nine local government authorities overlap the coastal catchments. In June 2007 the estimated population of Perth was 1.6 million (ABS 2008), with the number of residents in the Swan-Canning coastal catchments estimated to be 550 000.

2.2 Climate

The Swan-Canning coastal catchments have a Mediterranean climate with cool, wet winters (June–August) and hot, dry summers (December–March). The long-term average annual rainfall varies from about 800 mm on the coast to 1300 mm on the Darling Scarp in the south-east of the catchment area. About 90% of the rain falls in the April to October period. The average annual potential evaporation (Class A pan evaporation) varies from approximately 1800 mm in the south to 2000 mm in the north (in Ellen Brook catchment). The long-term rainfall and evaporation contours are shown in Figure 2.1. The monthly average maximum daily temperature varies from 17°C to 30°C, with the hottest months being January and February. The monthly average minimum daily temperature varies from 9°C to 18°C, with the coldest months being July and August.

The south of Western Australia is experiencing a drying climate. Since 1974 there has been a noticeable decrease in rainfall in Perth. The long-term average annual rainfall, from Bureau of Meteorology stations 9034 (Perth regional office) and 9225 (Perth metro), was 878 mm for the period 1889 to 1974 (Figure 2.2). For the period 1975 to 1996 the average annual rainfall was 795 mm, and for the period 1997 to 2006 it was 732 mm – a decrease of 17% from the 1889 to 1974 average.

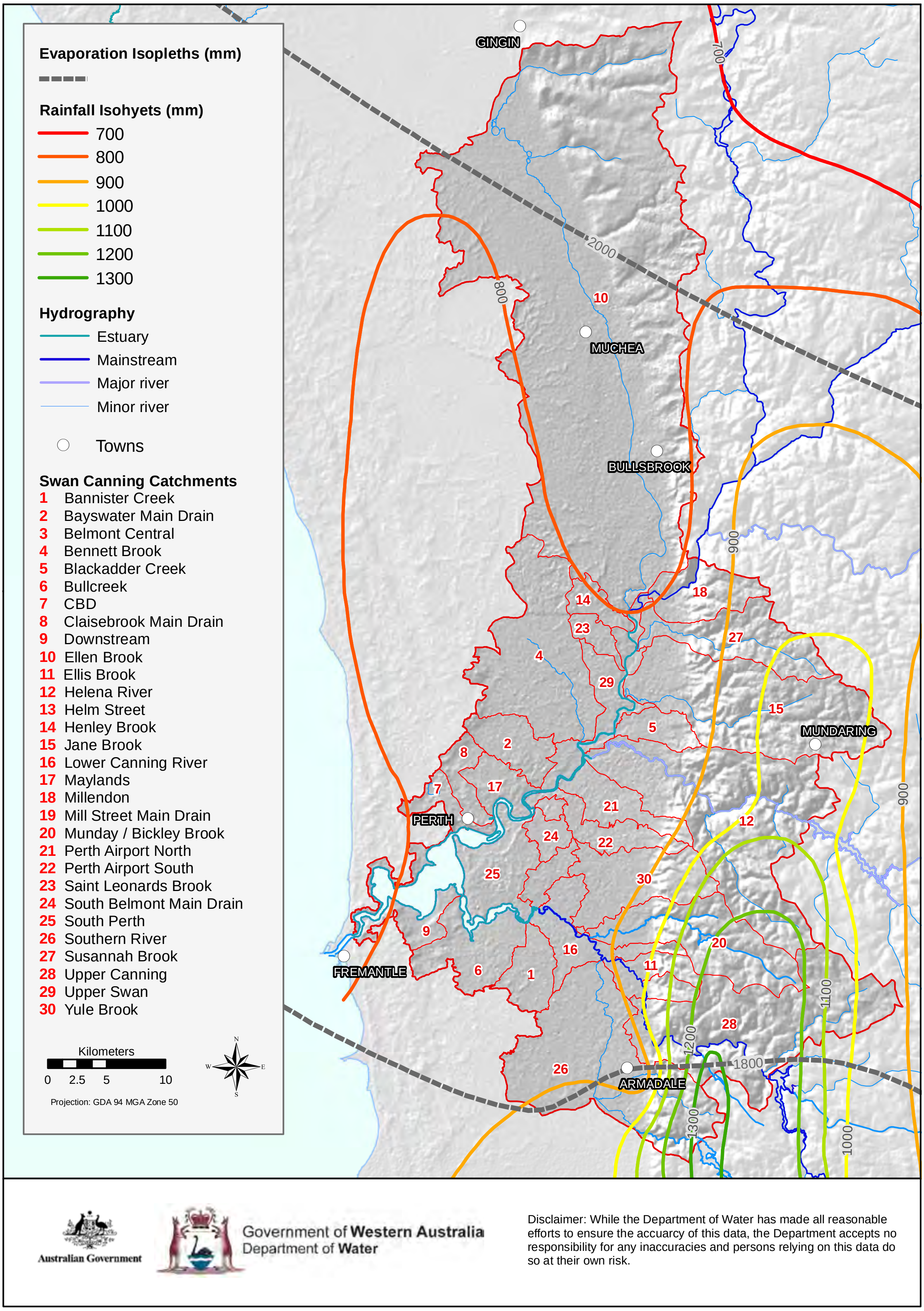


Figure 2.1 Long-term average annual rainfall and evaporation for the Swan-Canning coastal catchments

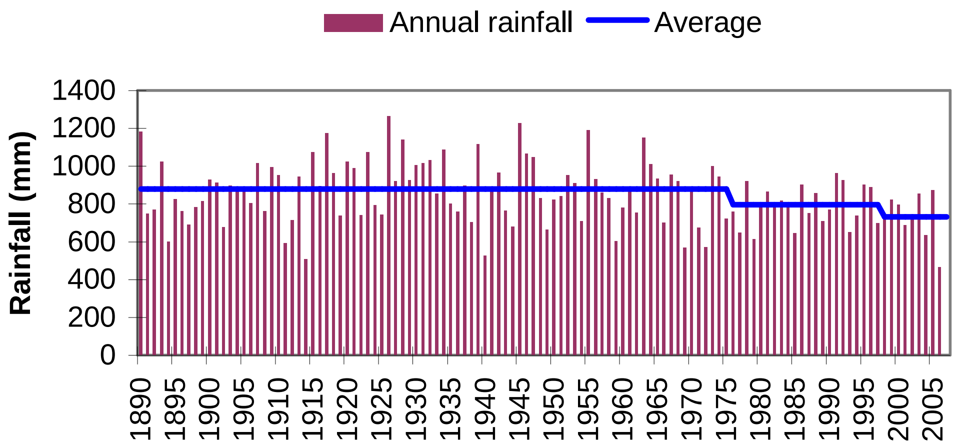


Figure 2.2 Annual Perth rainfall (combined data from rainfall gauges 9034 and 9225)

2.3 Geology, geomorphology and soils

Geology

The Swan-Canning coastal catchments lie on the Swan Coastal Plain, the Dandaragan Plateau to the north-east and the Darling Plateau to the east (Figure 2.3). The Darling Plateau is located on the Archaean basement rocks of the Yilgarn Craton. The Swan Coastal Plain lies on the Perth Basin, and the Dandaragan Trough is a major structural subdivision within the basin. The sedimentary succession in this part of the Perth Basin is 12 000 m thick and separated from the crystalline rocks of the Yilgarn Craton by the Darling Fault (Davidson 1995).

The Perth Basin was formed during periods of rifting and sagging along the continental margin of south-western Australia that culminated in separation from the rest of Gondwana during the Early Cretaceous. These events resulted in a faulted sedimentary sequence, which is bounded to the east by the Darling Fault and overlain by comparatively undeformed, mid-Neocomian and younger sediments deposited during the tectonically quiet period following separation. Before the breakup, continental sedimentation (predominantly fluvial) prevailed through to the Late Jurassic and into the Cretaceous. During the Neocomian and following the breakup, marine incursion resulted in periods of continental, paralic and marine sedimentation. By the Albian Stage of the Cretaceous, marine sedimentation dominated and thick sequences of glauconitic shale and greensand were deposited.

Over most of the Perth region the Cretaceous sediments are concealed below a veneer of late Tertiary–Quaternary sediments (discussed below). However, on the Dandaragan Plateau, between the Gingin Scarp and the Darling Fault, Cretaceous units outcrop in some of the valleys and deeply incised drainages. The Cainozoic sediments range from Tertiary marine carbonate deposits, occupying deeply eroded channels, to relatively flat-lying Quaternary shoreline and coastal-dune deposits, with more recent alluvial and colluvial deposits associated with the present drainages and escarpment (Davidson 1995). A detailed description of the stratigraphy of the Perth Basin in this region is given in Davidson (1995) and the surface geology is shown in Figure 2.3.

Geomorphology and soils

The Swan Coastal Plain consists of a series of geomorphic elements formed in the late Tertiary–Quaternary period, which lie approximately parallel to the coastline. Soil mapping from the Department of Agriculture and Food WA (DAFWA) has a hierarchical system for classification based on these geomorphic elements (or soil-landscape systems) which are described below (from west to east) (Figure 2.4). Within the soil-landscape systems the soils are mapped at greater detail and the phosphorus retention indices (PRIs) – which is a measure of the soil's ability to retain phosphorus through adsorption to soil particles (McPharlin et al. 1990) – are shown (Figure 2.5). Generally the soils of the coastal plain and much of the Dandaragan Plateau have low PRIs (less than 10) whereas the soils of the Darling Plateau have high PRIs (greater than 10). Within each soil-landscape unit there is a range of PRIs, as shown in Figure 2.5.

- **Quindalup Dunes**/Safety Bay Sand. This most westerly dunal system flanks the ocean west of the Swan-Canning coastal catchments. It consists of wind-blown lime and quartz beach sand forming dunes or ridges that are generally orientated parallel to the present coast. (PRIs range from 5 to 50.)
- **Spearwood Dunes**/Tamala Limestone. The Spearwood Dunes consist of slightly calcareous aeolian sand remnant from leaching of underlying limestone. It is overlain by variable depths of yellow or brown sands. (PRIs generally 0 to 9.)
- **Bassendean Dunes.** The Bassendean Dunes form a gently undulating aeolian sand plain about 20 km wide, with the dunes to the north of Perth generally having greater topographical relief than those to the south. The low hills of highly permeable siliceous sand are interspersed with extensive areas of poorly drained soils or seasonally waterlogged flats (palusplains). (PRIs generally negative to 5.)
- **Pinjarra Plain** (or Guilford Formation) (**Pinjarra Zone** in Figure 2.4). This is a piedmont and valley-flat alluvial plain at an altitude of approximately 40 m above sea level, consisting predominantly of clayey alluvium that has been transported by rivers and streams from the Darling and Dandaragan plateaux. (PRIs range from negative to 140.)
- **Ridge Hill Shelf.** The Ridge Hill Shelf (or Darling Scarp) is the most easterly landform of the coastal plain. It comprises the colluvial slopes that form the foothills of the Darling Plateau and represents the dissected remnants of a sand-covered, wave-cut platform. (PRIs range from 2 to 90.)

At the eastern margin of the Swan Coastal Plain, the Gingin and Darling scarps rise steeply to more than 200 m above sea level. The scarps represent the eastern boundary of the marine erosion that occurred during the Tertiary and Quaternary periods, although at many locations the Darling Scarp is a fault scarp.

Dandaragan Plateau. The Dandaragan Plateau is a wedge between the Gingin and Darling scarps in the north-east of Ellen Brook catchment. The plateau is a sand- and laterite-covered plateau overlying the Cretaceous sediments of the Perth Basin. It has a regional average elevation of about 250 m AHD (Australian Height Datum) and is generally gently undulating. The Quaternary sand cover of the plateau is unrelated to the sand of the coastal plain, is thin (commonly less than 10 m thick) and derived from the underlying Cretaceous sediments. Many brooks and streams rise on the plateau and flow in a westerly direction onto the coastal plain. The plateau is bounded to the west by the Gingin Scarp, which resulted from fluvial and marine erosion in the Late Tertiary or early Pleistocene, and is not fault controlled as is the Darling Scarp. (PRIs generally 0 to 17.)

Darling Plateau (Western Darling Range). The eastern-most landform of the catchment area is the Darling Plateau. The plateau is a gently undulating area of Pre-Cambrian gneisses and granites overlain by laterite ridges with sands and gravels in shallow depressions. The plateau has a regional average elevation of about 350 m AHD and in the catchment area is dissected by the Swan River and numerous streams. The plateau is bounded to the west by the Darling Scarp, which follows the Darling Fault (Playford & Low 1972; Playford et al. 1976). (PRIs generally 15 to 45.)

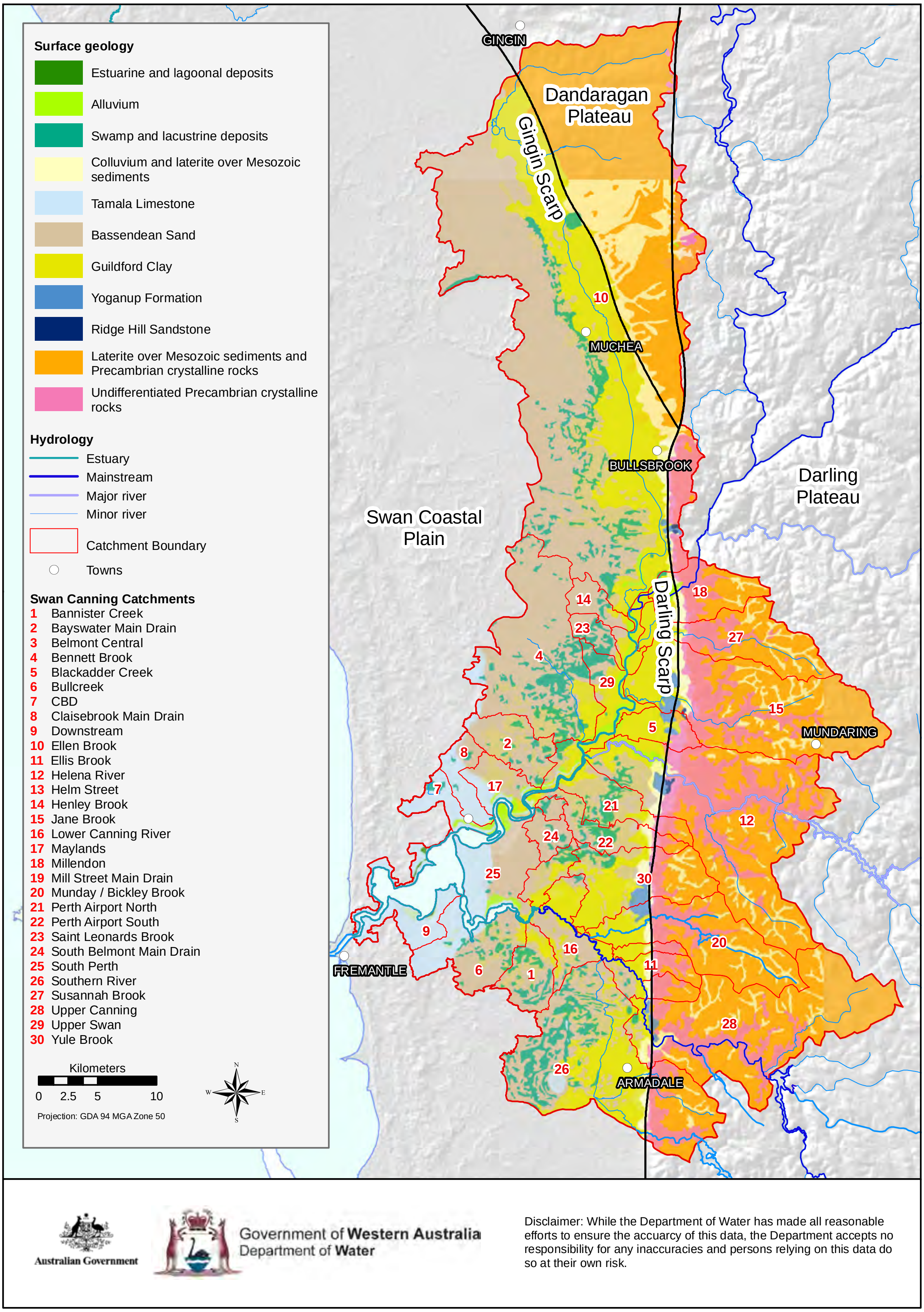


Figure 2.3 Surface geology

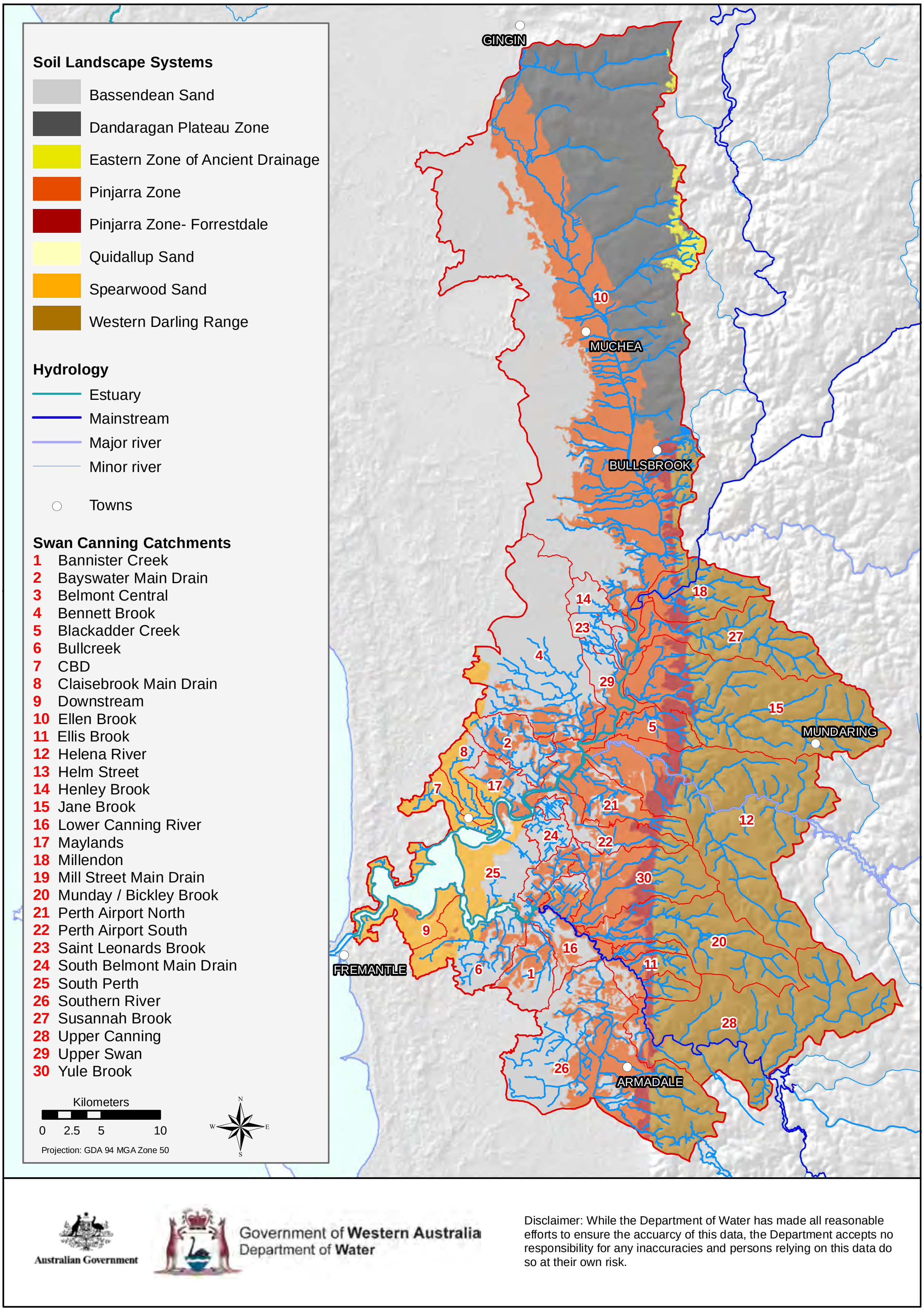


Figure 2.4 Soil-landscape systems of the Swan-Canning coastal catchments

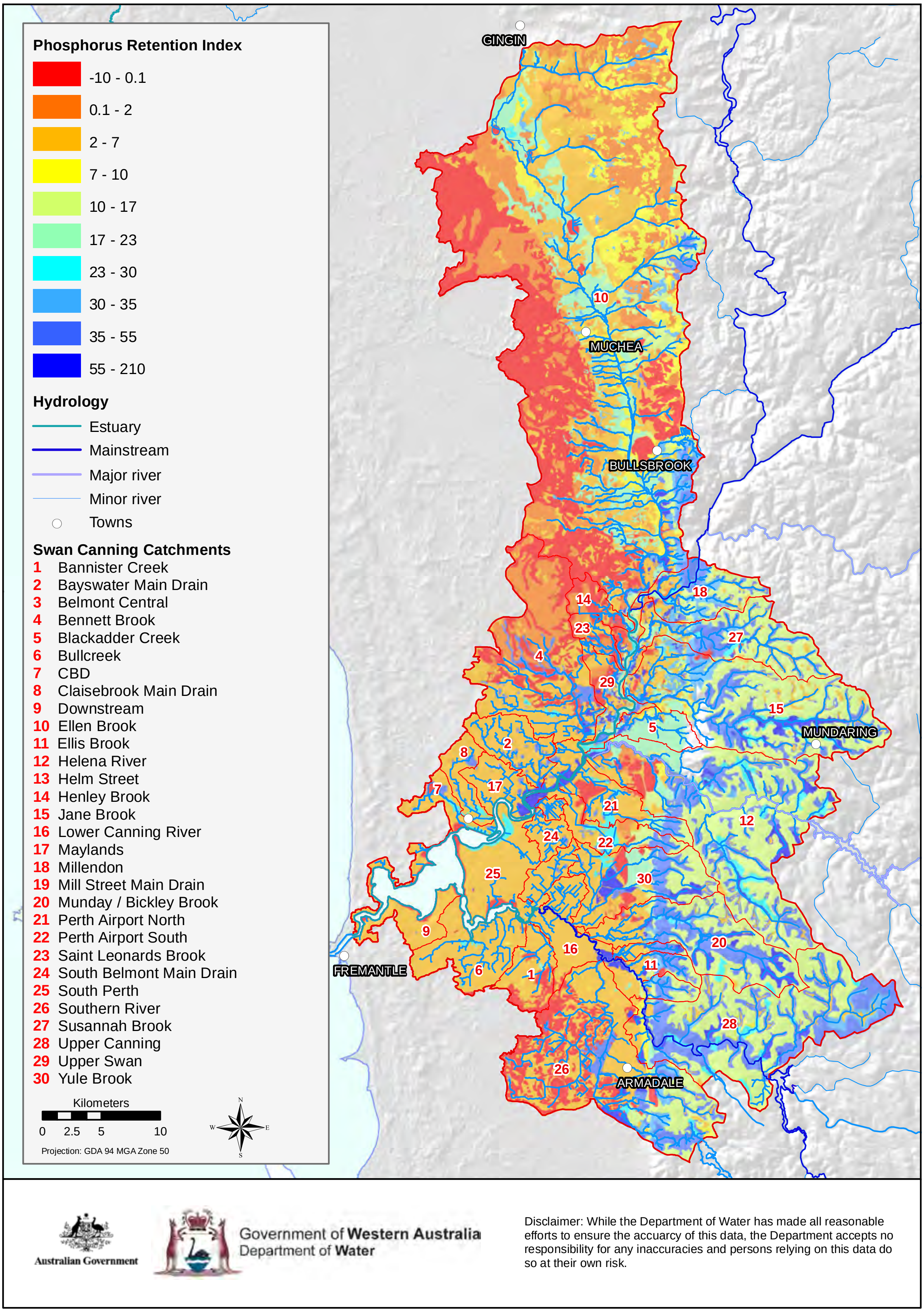


Figure 2.5 Soil phosphorus retention indices

2.4 Hydrogeology

Groundwater pervades the superficial and underlying formations beneath the Swan Coastal Plain. Perth relies on groundwater for up to 60 per cent of its potable water supply (depending on annual dam inflows) and many industries use large amounts of groundwater (Table 2.1) (Davidson & Yu 2006). Large volumes of groundwater are used for watering of private gardens and public open space, such as parks, playing fields and golf courses. Licensed private users and the Water Corporation use water from the Superficial, Mirrabooka, Leederville and Yarragadee aquifers. Unlicensed bore owners (householders) draw water from the Superficial aquifer. Groundwater abstraction has been steadily increasing over recent years (Table 2.2). The total annual abstraction was 487 GL in 2004, of which 360 GL was drawn from the Superficial aquifer.

Table 2.1 Groundwater use in Perth for 2004 (Davidson & Yu 2006)

Aquifer	Licensed private use		Water Corporation		Unlicensed home garden use		Total	
	Use (GL/yr)	%	Use (GL/yr)	%	Use (GL/yr)	%	Use (GL/yr)	%
Superficial	185	85	63	40	112	100	360	74
Mirrabooka	2	1	5	3			6	1
Leederville	19	9	42	27			61	13
Yarragadee	11	5	48	30			60	12
Total	217		158		112		487	

Table 2.2 Groundwater use (Davidson & Yu 2006)

Use Category		1980 Use	1985 Use	1992 Use	2001 Use	2002 Use	2003 Use	2004 Use
Bore type	Use type	(GL/yr)	(GL/yr)	(GL/yr)	(GL/yr)	(GL/yr)	(GL/yr)	(GL/yr)
Licensed private bore	Self supply	113	108	127	196	206	210	217
Water corporation bore	Scheme supply	58	62	81	134	154	158	158
Unlicensed garden bore	Home garden use	60	78	77	104	107	109	112
Total		231	248	285	434	467	477	487

Note:

1980 data are from Allen (1981), Groundwater resource of the Swan Coastal Plain near Perth, Western Australia.

1985 data are from Cargeeg et al. (1987), Perth urban water balance study.

1992 data are from Davidson (1995), Hydrogeology and groundwater resources of the Perth Region, Western Australia. Usage/allocation ratio = 0.8

2001–2004 data are from Davidson & YU (2006). Usage/allocation ratio = 0.92.

Water Corporation data are based on fiscal year while the licensed private use data are based on calendar year.

Many groundwater-dependent ecosystems on the Swan Coastal Plain, such as lakes and wetlands, are being adversely affected by groundwater abstraction (particularly from the Superficial aquifer). Drawdown from the Gnangara Mound is subject to a ministerial condition (*Ministerial Statement 687*, Government of Western Australia 2005) and monitored for compliance. However, in recent years groundwater levels have been lower than desired because of the drying climate and the amount of abstraction. Falling groundwater levels can also activate acid sulfate soils, which can damage the environment and surrounding infrastructure.

2.4.1 Description of the hydrogeology

The Superficial aquifer is a major unconfined aquifer comprising the Quaternary–Tertiary sediments of the coastal plain – Safety Bay Sand and Becher Sand, Tamala Limestone, Bassendean Sand, Gnangara Sand, Guildford Clay, Yoganup Formation, and Ascot Formation. The groundwater in the Superficial aquifer ranges in age from the present at the watertable to about 2000 years at the base of the aquifer (Thorpe & Davidson 1991). The aquifer has a saturated thickness of about 10 to 40 m in the coastal catchments.

The upper surface of the saturated Superficial aquifer is the watertable, which varies in depth depending mainly on topography but also on the hydraulic conductivity (permeability) of the sediments and location within the groundwater flow system. Over much of the central area of the Bassendean Dunes and beneath the low-lying areas of the Spearwood Dunes, the watertable intersects the surface, as indicated by the many lakes and swamps and the large areas of groundwater inundation during winter. As a consequence of the varying hydraulic conductivities, the watertable fluctuates seasonally by about 3 m in areas of clay adjacent to the Darling Fault and Gingin Scarp; by about 1.5 m in the central sandy area; and by less than 0.5 m in limestone along the coast. The watertable is highest during September to October and lowest during April to May. The watertable contour configuration is dominated by the presence of two major groundwater mounds: the Gnangara Mound (east of Ellen Brook catchment) and Jandakot Mound (south of the Canning River) (Davidson 1995). The presence of these mounds is determined mainly by the regional topography, and partly by the drainage pattern and the hydraulic characteristics of the sediments.

Discharge from the Superficial aquifer is an important component of the hydrology of the coastal catchments. However, the groundwater regime has been affected by human activity such as clearing of bushland for agriculture and urban development, drainage, and groundwater abstraction. The clearing of bushland has facilitated rainfall recharge and caused rising groundwater levels. As a result, large areas become inundated during winter and require drainage. Impervious surfaces in urban developments induce additional rainfall recharge and some of the naturally occurring seasonal lakes are now permanently inundated. In other areas, such as close to the Gnangara Mound, the watertable has been lowered by groundwater abstraction and some of the naturally occurring lakes and swamps have become permanently dry or contain water for shorter periods of the year.

Along the foothills of the Gingin and Darling scarps, where the Guildford Clay is commonly present, there may be some recharge from minor ephemeral streams debouching from the

Dandaragan and Darling plateaux and dissipating on the coastal plain. The area is characterised by the shallow watertable with many wetlands. The watertable can also be seasonally ‘perched’ above the Guildford Clay.

Groundwater recharge rate and volume depend on geology, drainage and land use. In areas of Guildford clays, the recharge volume ranges from 5 to 20 per cent of annual rainfall; whereas in areas of Bassendean sands with no confining layers, recharge volumes can be as high as 60 per cent. The average over most of the coastal catchments is 15 per cent of the annual rainfall (Davidson & Yu 2006).

Some recharge to the Superficial aquifer also occurs by upward leakage and discharge of groundwater from the underlying aquifers. Within the urban areas, recharge also occurs as a result of garden and parkland irrigation of imported (scheme) water or water obtained from the deeper aquifers.

The rate of groundwater flow through the Superficial aquifer ranges from less than 50 m/year to more than 1000 m/year depending on geological location; it is greatest in the Tamala Limestone and least in the Guildford Clay (Davidson & Yu 2006). Groundwater in the Superficial aquifer discharges through natural and constructed drainages into wetlands, the estuaries and the ocean, and at springs. Groundwater is a major component of the hydrology of the coastal plain’s streams and rivers.

The underlying semi-confined and confined aquifers include the Kings Park, Mirrabooka, Leederville, Parmelia Sand and Yarragadee aquifers (in order of depth), which are described in detail in Davidson and Yu (2006) (Figure 2.6).

The Mirrabooka aquifer comprises the Poison Hill and Molecap greensands and the Mirrabooka Member. The Poison Hill greensands aquifer is predominantly on the Dandaragan Plateau, but extends onto the coastal plain to the north-east of the Swan River (Davidson & Yu 2006).

The Leederville aquifer, which comprises the Leederville Formation (Pinjar Member, Wanneroo Member and Mariginiup Member) and Henley Sandstone Member of the Osborne Formation, is continuous under most of the coastal plain section of the study area – except in the north near the Swan Estuary (cross-section DD' in Figure 2.6), where the Leederville Formation has been eroded out before deposition of the Kings Park Formation (Davidson & Yu 2006), and in the south-east corner, where the superficial formations rest directly on the Cattamarra Coal Measures.

The Parmelia Sand aquifer underlies the eastern portion of Ellen Brook catchment (Davidson & Yu 2006). The Parmelia Sand aquifer was included in the Yarragadee aquifer in Davidson (1995). The Yarragadee aquifer is a major confined aquifer underlying the Perth region and extending to the north and south within the Perth Basin. It is a multi-layered aquifer more than 2000 m thick. The aquifer consists of the Jurassic Yarragadee Formation and the Cretaceous Gage Formation over most of the study area, but in the south-eastern area, the Cattamarra Coal Measures is the major component of the aquifer.

The Mirrabooka, Leederville and Yarragadee aquifers are used for potable water supply and for industry (Table 2.1). The deeper aquifers have limited connectivity with the Superficial aquifer and thus little impact on the hydrology of the coastal catchments.

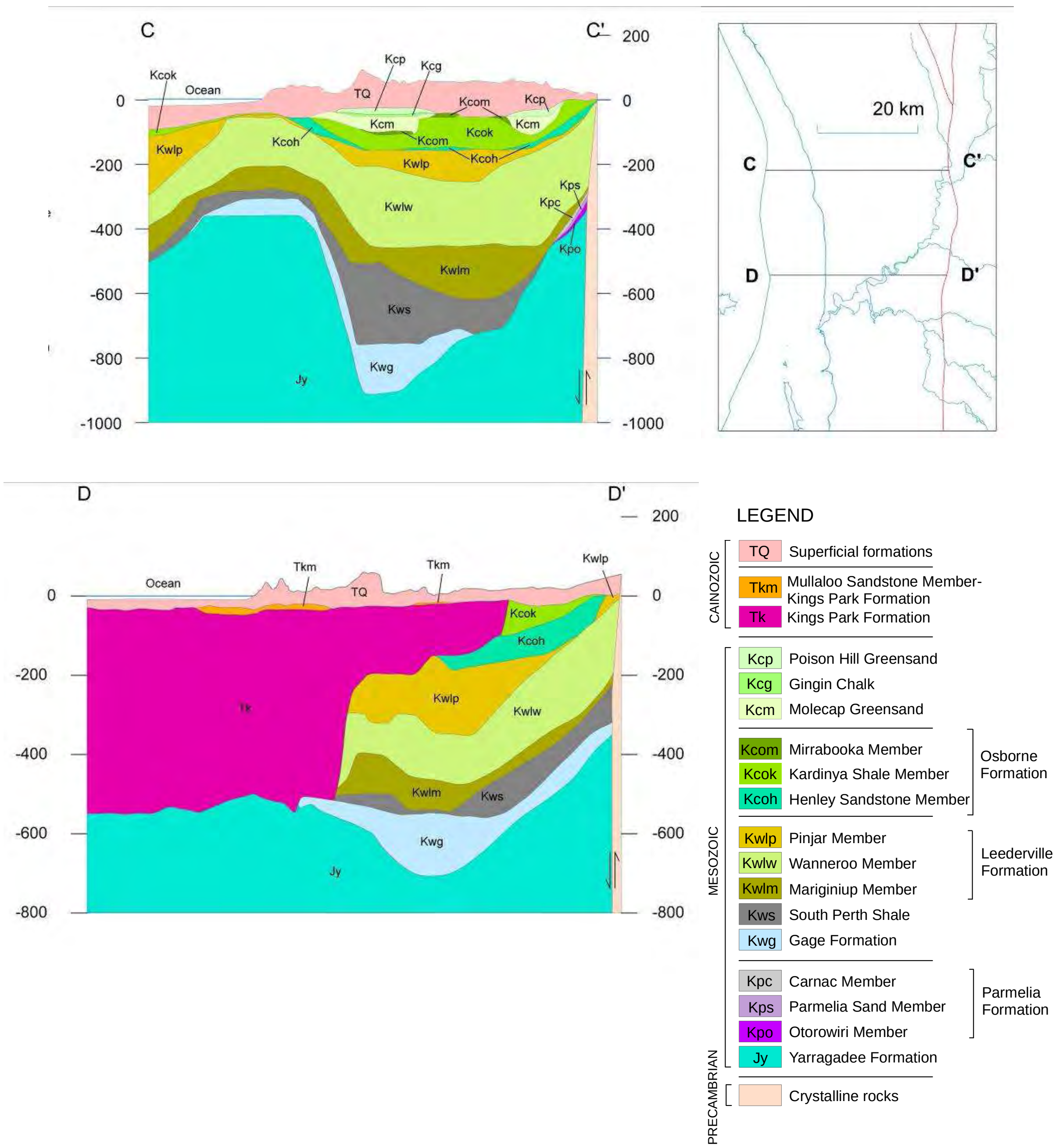


Figure 2.6 Stratigraphy of the geological formations (from Davidson & Yu 2006)

2.4.2 Ellen Brook hydrogeological study

As part of the Coastal Catchments Initiative (CCI) project, a hydrogeological investigation of the Ellen Brook catchment (Barron et al. 2010) was undertaken. Ellen Brook catchment constitutes about one-third of the area of the Swan-Canning coastal catchments, and it contributes large loads of nitrogen and phosphorus to the Swan River and Estuary. The main aim was to determine the amount of water, nitrogen and phosphorus in groundwater inputs to Ellen Brook. The project investigated groundwater recharge and discharge areas, as well as the sources of water (i.e. surface or ground) and areas of the catchment that contributed to the flow. Chlorofluorocarbon (CFC) dating was used to date the groundwater flowing into the brook. The main findings of the study were:

- Drainage densities (which give an indication of infiltration capacity) are approximately:
  - Bassendean sands: 0.2 km/km^2
  - Guildford clays: 3 km/km^2
  - Sand over clay (duplex Yanga soils): 1.7 km/km^2
  - Darling and Dandaragan plateaux: 1.3 km/km^2.
- On an annual basis, baseflow accounts for (on average) 44% of stream discharge. (Baseflow is defined as flow of 20 L/sec or less). Baseflow is derived from groundwater discharge and the slow drainage of water stored in local wetlands.
- The contribution of groundwater discharge to streamflow is significant in two areas:
  - 80% of groundwater discharged to streams in the catchment occurs on the Dandaragan Plateau
  - 5% of the catchment's groundwater discharge occurs downstream of gauge 616189 (Ellen Brook, Almeria Parade).
- Groundwater discharge to the brook in the southern half of the catchment (between site 616100 and 616189) is low and likely to be less than potential evaporative losses (estimated at 5000 ML/day during the spring baseflow period of 2007). This confirms that the occurrence of Guildford clays provides a regional confining layer restricting groundwater discharge from the deeper Superficial aquifer to Ellen Brook and its tributaries.
- Landsat 7 imagery was used to identify discharge zones, which were widely distributed in the catchment. In some areas of continuous groundwater expression (springs or damplands), discharge rates are not large enough to sustain continuous flow in streams. Yet the permanent presence of water supports flourishing flora and fauna, which then influences the biological and chemical processes within the hyporheic zones and maintains an environment where organic matter and nutrient accumulation occurs. Areas of permanent groundwater supply also attract human settlements and agricultural activities. These areas include:
  - the upper reaches of the western tributaries that receive groundwater discharge from the Gnangara Dunes

  - the break in the slope areas along the foothills of the Dandaragan Plateau.

  Groundwater fluxes in these areas promote primary productivity, influence sediment microbial activity and affect organic matter decomposition. This explains the high concentrations of dissolved organic carbon and total organic nitrogen in the creeks downstream from these areas.

- Nutrient concentrations in baseflows are generally lower than during stormflows. Nitrogen and phosphorus in baseflows may be derived from the different sources, as high concentrations of nitrogen are associated with high concentrations of dissolved organic carbon, whereas phosphorus concentrations are not closely related to dissolved organic carbon concentrations.

- Nutrient concentrations in the regional groundwater are generally low. The regional groundwater residence time is greater than 30 to 40 years and groundwater quality is unlikely to be significantly influenced by current land-use activities.

- Shallow groundwater in areas of Bassendean sand is likely to have high concentrations of phosphorous and organic nitrogen.

- High nitrate concentrations are detected in the Lennard Creek but not in the Ellen Brook. This indicates that denitrification is occurring in the waterlogged areas (characterised by high organic carbon and anaerobic conditions) in the catchment’s north.

2.5 Hydrology

The Avon River drains an area of approximately 124 000 km^2 consisting of the Mortlock, Salt, Yilgarn and Lockhart river catchments (Figure 1.2). The Avon River has little flow during summer (generally), but can contribute large volumes of water to the estuaries in winter. The catchments of the tributaries are gently undulating and the rivers in the upper reaches are slow flowing with many lakes. Depending on the timing, distribution and amount of rainfall, different areas of the catchment will contribute flow to the Avon River at different times. Thus, there is a large variability in flow from year to year. This is discussed further in Section 5.1.

Besides the Avon River, which becomes the Swan River at its confluence with Wooroloo Brook in Walyunga National Park, there are 10 major streams (Bennett Brook, Ellen Brook, Jane Brook, Susannah Brook, Helena River, Yule Brook, Bickley Brook, Canning River, Southern River and Bannister Creek) and several smaller creeks and drains (such as Bayswater, Mills Street and South Belmont main drains) which flow into the Swan and Canning estuaries. For the purposes of this study, the estuaries' coastal catchment has been divided into 30 catchments, defined as the Swan-Canning coastal catchments (shown in Figure 2.7 and listed in Table 2.3). These coastal catchments abut the Moore River catchment to the north, the Peel-Harvey catchment to the south and the Avon catchment to the east. The areas to the west of the coastal catchments drain directly to the ocean.

The coastal catchments have been modified extensively since European settlement in Western Australia in 1829. Much of the area (58%) has been cleared for agricultural and urban uses and an extensive artificial drainage network has been introduced to limit flooding and efficiently convey water to the ocean or the estuaries. A large area to the north of the lower Swan Estuary, which naturally drained to the estuary, now flows to the ocean through the Subiaco and Herdsman main drains.

There are five major water supply dams that affect flows to the Swan-Canning coastal catchments – the Mundaring, Victoria, Canning, Churchmans Brook and Wungong dams (Figure 2.7). There are also pump-back dams on Helena River and Bickley Brook. The capacities of the dams are given in Table 2.4. The water supply dams limit inflow into the rivers downstream because they rarely overflow (Table 2.4). However, the Water Corporation releases water periodically, and the Department of Water recently established environmental water provisions (EWPs) for the Canning River that mandate releases of set amounts of water (Radin et al. 2009).

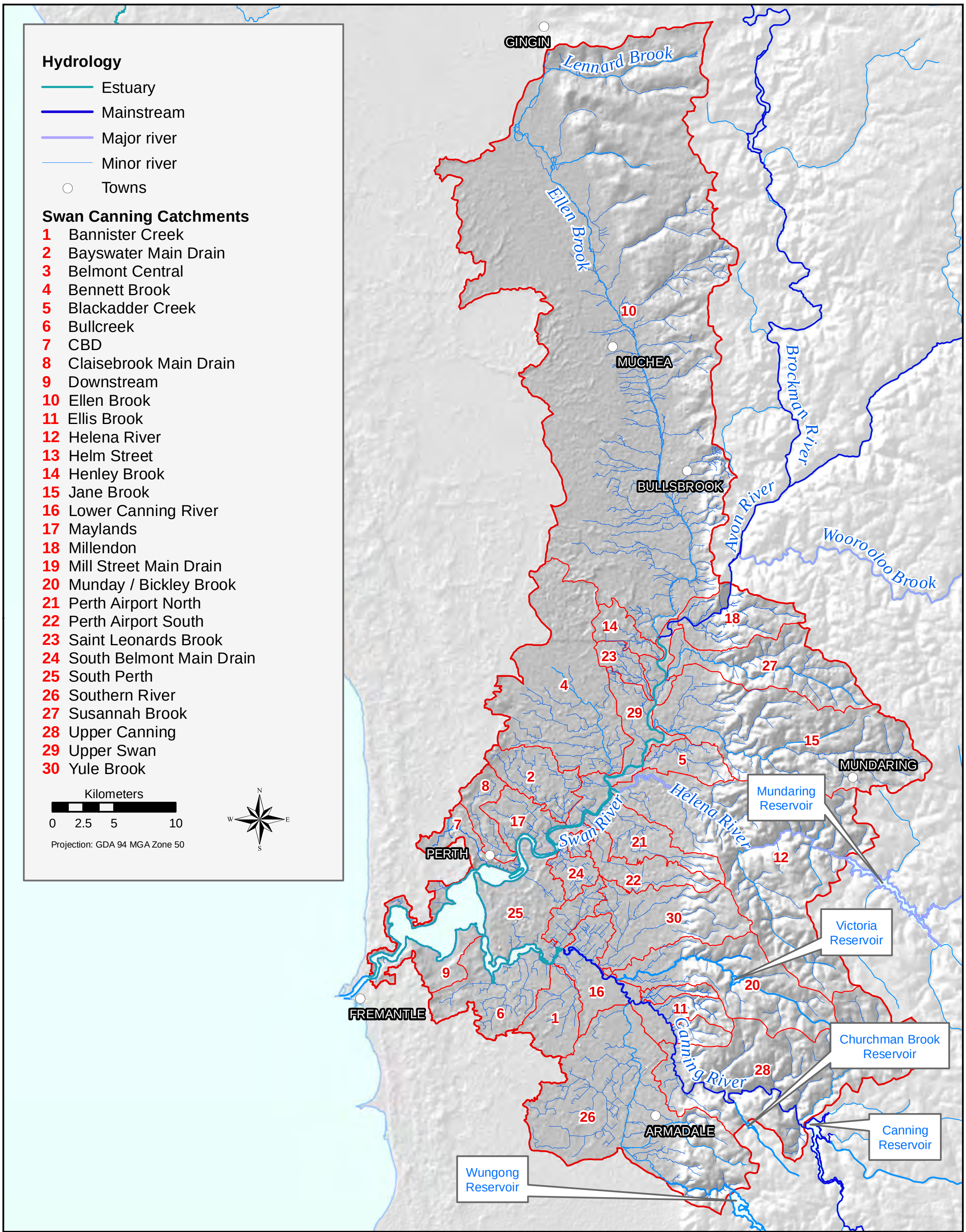
The Avon River was not used for water supply because it was naturally salty. However clearing of the Avon catchment for agricultural land uses has increased the flows in the Avon River, as well as raising the water table height. Much of the catchment is now prone to salinisation and large areas are unproductive. The Avon River is much saltier today than in pre-European times.

Table 2.3 Catchments of the Swan and Canning estuaries used for reporting of results

Catchment	Area (km^2)	Cleared area (km^2)	Cleared area (%)
Bannister	23.6	20.2	86
Bayswater	27.2	26.4	97
Belmont Central	3.6	3.2	90
Bennett	113.1	74.6	66
Blackadder	17.1	13.6	80
Bullcreek	42.5	39.3	92
CBD	13.7	12.7	93
Claisebrook	16.1	15.8	98
Downstream	26.2	24.1	92
Ellen	716.4	387.4	54
Ellis	11.7	4.2	36
Helena	175.7	63.1	36
Helm Street	6.0	3.4	57
Henley	12.6	8.0	64
Jane	137.7	66.9	49
Lower Canning	44.3	32.8	74
Maylands	18.7	18.0	96
Mills Street	12.3	11.7	96
Millendon	35.2	18.5	53
Munday & Bickley	73.7	26.3	36
Perth Airport N	28.1	25.3	90
Perth Airport S	24.6	18.3	74
Saint Leonards	9.8	5.6	57
South Belmont	10.5	10.2	97
South Perth	40.5	38.1	94
Southern	149.5	89.0	60
Susannah	54.7	35.9	66
Upper Canning	148.9	36.6	25
Upper Swan	40.5	33.5	83
Yule	55.7	43.5	78
Coastal catchments	2 090	1 206	58

Table 2.4 Dams on the tributaries of the Swan and Canning rivers

Dam	River	Storage capacity (ML)	Built	Overflows
Canning	Canning River	90 353	1940 (upgraded 1998)	Never
Churchman Brook	Curchman Brook	2 241	1929	Never
Mundaring	Helena River	63 597	1903 (upgraded 1951)	3 times
Lower Helena pumpback	Helena River	133	1971	Regularly
Victoria	Munday Brook	9 463	1891 (upgraded 1991)	Never
Bickley Brook pumback	Bickley Brook	60	1921	Regularly
Wungong	Wungong Brook	59 796	1979	5 times



Disclaimer: While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Figure 2.7 Rivers, drains and reservoirs

2.6 Land use

The Swan-Canning coastal catchments contain the city of Perth and much of the Perth metropolitan area (Figure 1.3). Approximately 1.6 million people live in Perth and surrounding suburbs (ABS 2008), while about 550 000 live in the coastal catchments.

Although large areas of the catchments have native vegetation, such as the national parks on the Darling Plateau and an area in Ellen Brook catchment's west, they have mostly been developed for agricultural and urban land uses (58%). Ellen Brook catchment, which is 716 km^2 in area (about one-third of the study area), has mostly rural land uses including cattle grazing, horse properties, poultry farming, hobby farms and vineyards. The catchments on the coastal plain are predominantly urban, and the catchments that originate on the plateau have a mixture of native vegetation, rural and urban land uses. The Swan Valley supports a wine-growing industry (mostly in the Upper Swan, Jane, Susannah, Millendon, Ellen and Henley catchments). The land-use map is shown in Figure 2.8 and Table 2.5 gives the area of each land use.

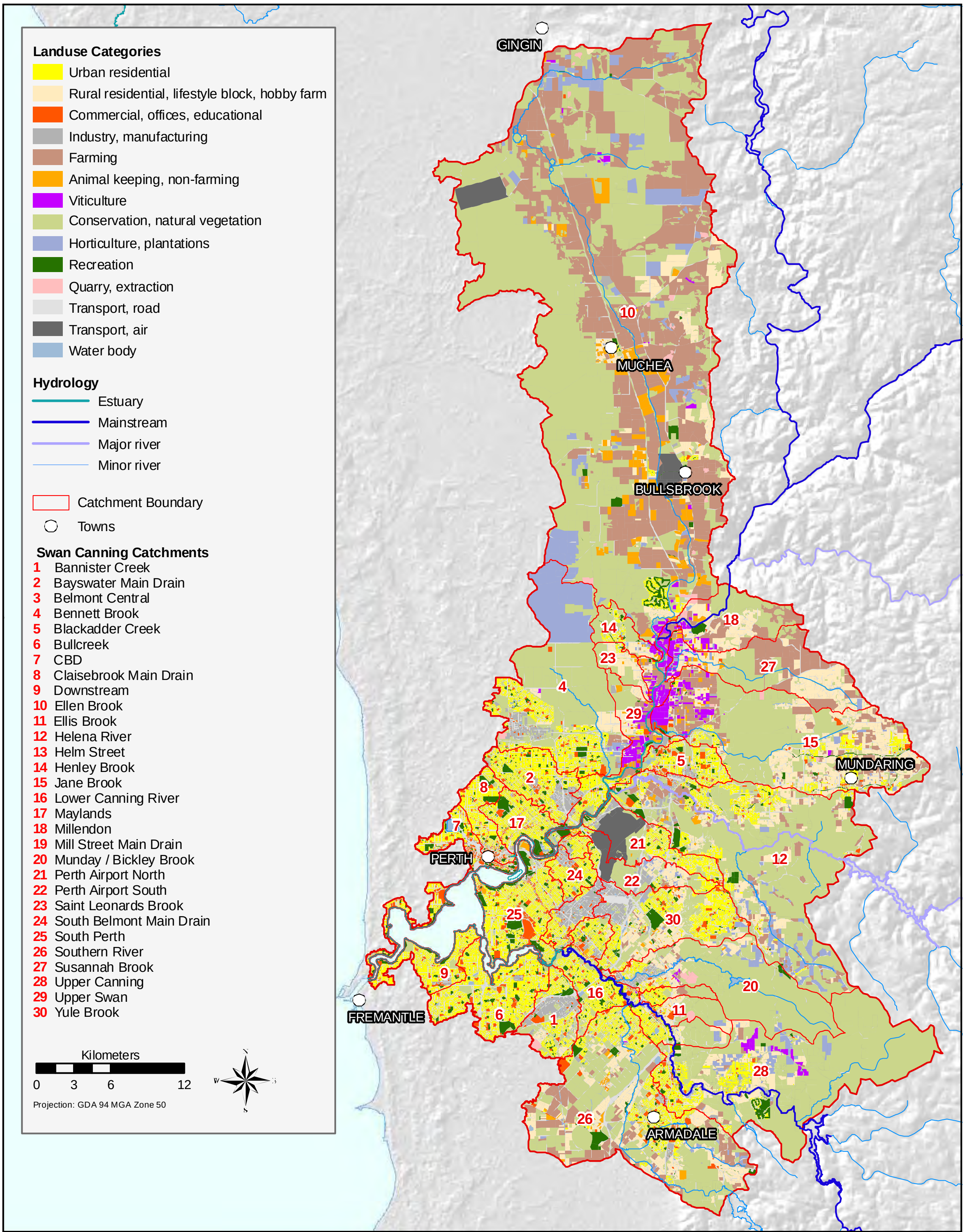


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Figure 2.8 Land-use map

Table 2.5 Land-use areas in the Swan-Canning coastal catchments

Land Use	Area (km$^{2)}$	%
Residential	214	10
Horticulutre & plantation	86	4
Recreation	50	2
Viticulture	23	1
Horses	37	2
Farm	339	16
Lifestyle block/ hobby farm	104	5
Offices, commercial & education	40	2
Conservation & natural	924	44
Industry, manufacturing & transport	273	13
Total	2 090	100

3 The **S**treamflow **Qu**ality **A**ffecting **R**ivers and **E**stuaries model

3.1 Description

The **S**treamflow **Qu**ality **A**ffecting **R**ivers and **E**stuaries (SQUARE) model was developed by the Water Science Branch of the Department of Water. SQUARE is a physically-based conceptual model with a daily timestep. The basic building blocks are subcatchments organised around a river network. The model architecture is similar to its predecessor – Large Scale Catchment Model (LASCAM) – which was developed by Viney and Sivapalan (1996). All hydrological and water-quality processes are modelled at the subcatchment scale; the resultant flows and loads are aggregated via the stream network to yield the response of the catchment at the main outlet, and at any of the subcatchment outlets in the stream network (Figure 3.1).

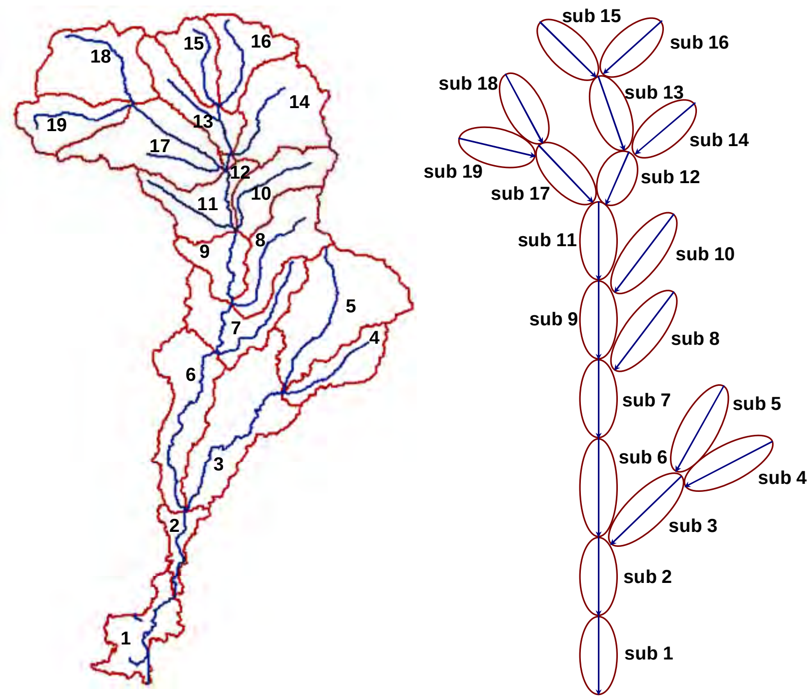
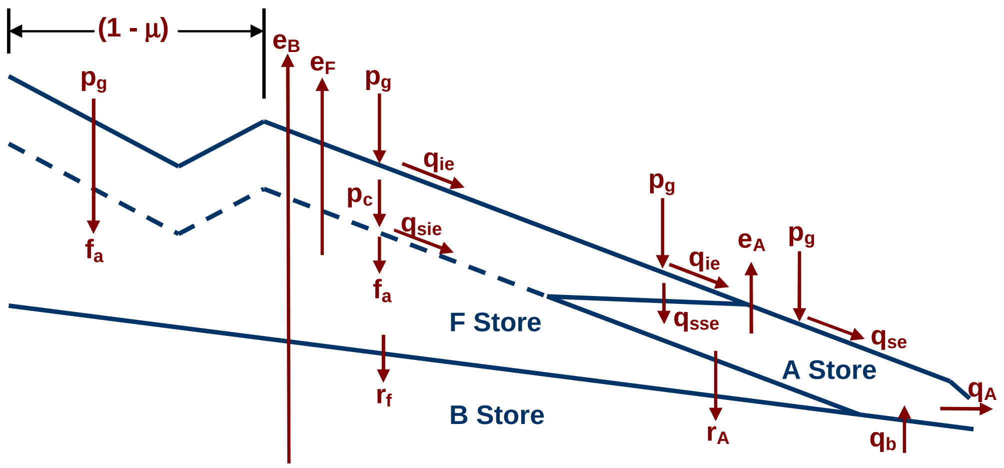


Figure 3.1 Subcatchment organisation (i.e. surface connection) based on a river network of 19 subcatchments

Calculation of the daily fluxes of water, nutrient and sediment through the soil and discharge to the stream is based on three soil-moisture stores representing the near-stream perched aquifer, or shallow ephemeral groundwater (the A store), the permanent deep groundwater system (the B store), and the intermediate unsaturated zone (the F store) (Figure 3.2). In addition, daily fluxes of nutrients through the soil are represented by the U store, which can be conceptualised as the root zone of shallow-rooted vegetation (Figure 3.3).



Symbol	Definition
e_A	Evaporation from A store
e_B	Evaporation from B store
e_F	Evaporation from F store
q_A	A store discharge to stream
q_B	B store discharge to A store
q_{se}	Saturation excess surface runoff
q_{ie}	Infiltration excess surface runoff
q_{sie}	Infiltration excess subsurface runoff
q_{sse}	Saturation excess subsurface runoff
p_g	Throughfall
p_c	Surface infiltration
f_a	Subsurface infiltration
r_A	Recharge from A store to B store
r_F	Recharge from F store to B store
μ	Upslope perching factore

Figure 3.2 Schematic of a hill-slope cross-section, water fluxes and stores assumed in SQUARE, (Viney & Sivapalan 2001).

Phosphorus and nitrogen are modelled in both dissolved and particulate forms. The soluble component of nitrogen is further discriminated into nitrate/nitrite-nitrogen, ammonium-nitrogen and dissolved organic nitrogen. For each subcatchment, a set of physically-based constitutive relations is used to direct water, soluble phosphorus, total phosphorus (TP), nitrate/nitrite, ammonium, dissolved organic nitrogen and total nitrogen (TN) between stores and to distribute rainfall either into the stores or directly into the stream (Figure 3.3).

The physical processes represented in SQUARE include hydrological processes such as canopy interception of rainfall, infiltration-excess and saturation-excess runoff, infiltration, interflow, evaporation and evapotranspiration; as well as the processes that occur in the nitrogen and phosphorus cycles, such as mineralisation, immobilisation, denitrification, volatilisation, fixation by leguminous plants, atmospheric deposition, nutrient uptake by vegetation, decomposition of plant residues and crop harvest.

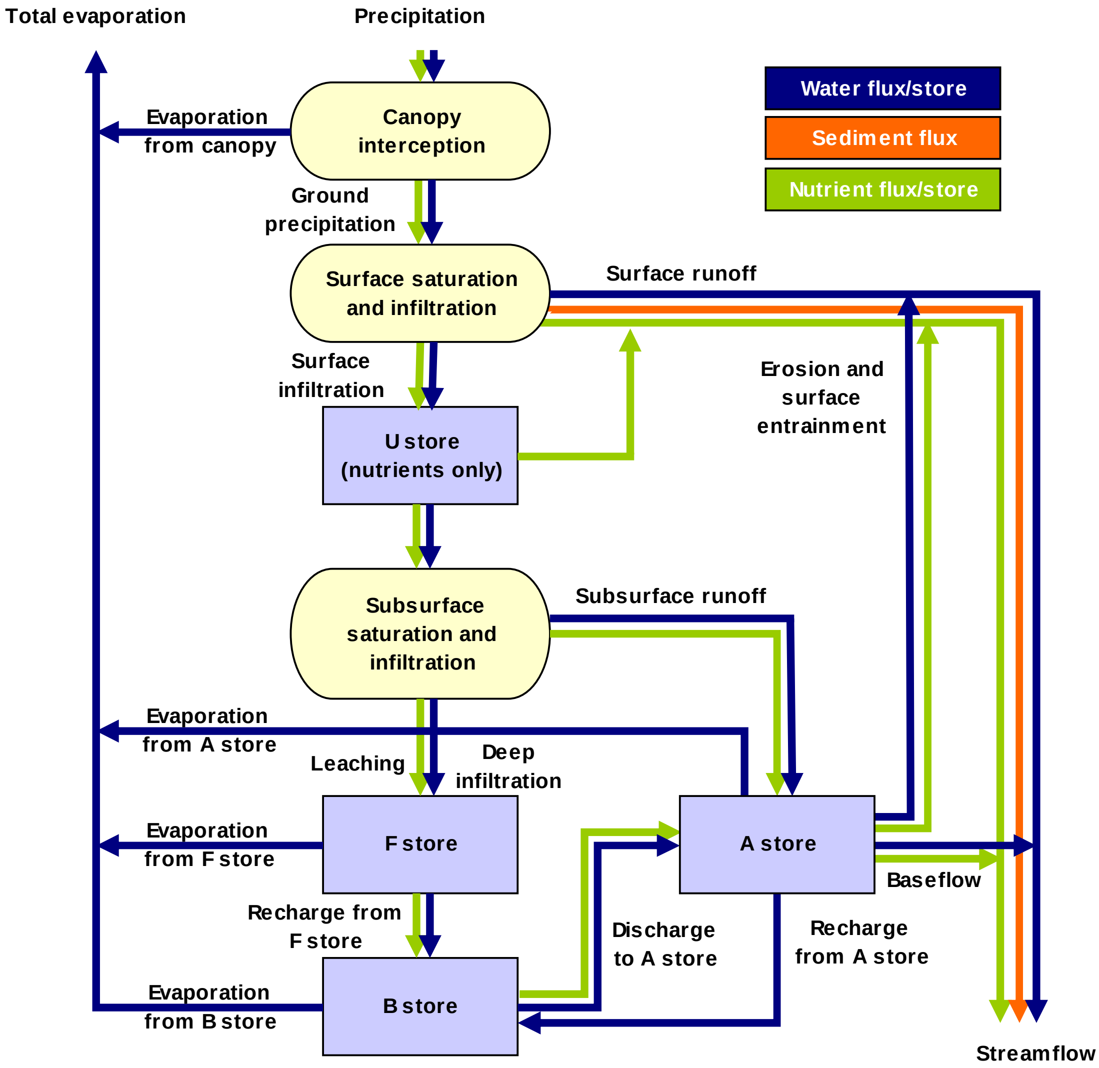


Figure 3.3 Small catchment model (building block model) in SQUARE for water, sediments and nutrients (Zammit et al. 2005).

SQUARE has several other features that make it a very powerful model:

- The riparian zone vegetation is differentiated from the non-riparian zone vegetation, and the hill-slope sediment transport model allows interception of particulate phosphorus and organic nitrogen in the riparian zone. These two features allow modelling of riparian zone rehabilitation.
- The leaf-area index changes with time to reflect seasonal changes. It also may be changed to reflect vegetation stress due to the drying climate.
- Soil characteristics can change with time to reflect application and rundown of soil amendments.
- Sources and sinks of surface water and groundwater can be included. This enables the model to receive inputs from upstream catchments, thus reducing the modelled

area. This also enables irrigation inputs and extraction from surface water and ground water to be included.

- The impact of point sources of nutrient pollution (such as wastewater treatment plants) and septic tanks can be modelled.

The water, sediment and nutrient balance models have 92 parameters. The model is calibrated using a Shuffled Complex Evolution algorithm (Duan et al. 1993) to optimise an objective function relating one or more pairs of observed and predicted fluxes.

Calibration of the hydrological component is undertaken initially and independently from the nutrient modules. The hydrological component has 32 parameters that are calibrated against data extracted from flow-gauging stations. When the hydrological calibration is complete, the sediment model is then calibrated (six parameters), followed by the models for phosphorus (16 parameters) and nitrogen (38 parameters). The modelled fluxes are calibrated against observed sediment and nutrient data. The Nash-Sutcliffe estimator (McCuen et al. 2006; Appendix A3) is used to determine the efficiency of the calibrations, and each calibration produces a suite of results containing the highest efficiencies. The greatest mathematical efficiency does not necessarily correspond to the most physically-correct model, and a suite of 20 sets of parameters are analysed for each calibration to determine the most appropriate, if any, to be used for scenario modelling and presentation of results.

Verification of the modelled data is undertaken by loading the modelled and observed data into a series of Matlab™ scripts for visualisation and statistical analysis. Daily, monthly, annual and cumulative series are compared (Figure 3.4) with particular care taken to meet the total water balance for the hydrological model. If satisfactory time-series results are obtained, the soil-store time-series are analysed, and the B-store values are verified against annual rainfall or nearby superficial-groundwater-bore signals. The flux paths and statistics are then analysed, not only to determine if the effect of over-cycling patterns is evident in the model, but also to check if evaporation, evapotranspiration and groundwater fluxes are physically plausible. If a satisfactory calibration is derived, the set of parameters is used for modelling scenarios and analysis of results. If not, inputs are investigated and changed if necessary, parameters are adjusted and the model is recalibrated.

The methodology for verification of the nutrient calibrations includes two additional criteria. Firstly, the modelled winter median TN and TP concentrations are closely matched to the observed winter median concentrations. Secondly, at sites where annual loads have been calculated using a locally-estimated scatterplot smoothing (LOESS) technique (Cleveland 1979; Helsel & Hirsch 1992), the SQUARE-modelled loads are checked against these. Model calibration is discussed further in Section 3.3 and Appendix A.

If a catchment does not contain a flow-gauging station or a sampling point, a comparison of the geophysical, climatic and land-use attributes is undertaken with adjacent catchments that contain calibrated models, and the set of parameters from the most similar nearby catchment is adopted.

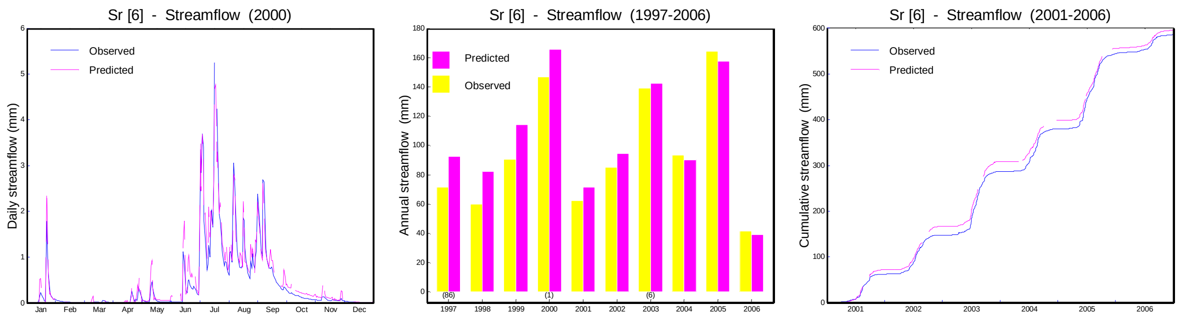


Figure 3.4 Examples of modelled and observed daily, annual and cumulative streamflow data from Southern River used in model verification.

3.2 Input data

The SQUARE model requires meteorological inputs, spatial inputs and observed data for calibration. Meteorological inputs describe the rainfall and evaporation. The spatial inputs describe the soil and land-use attributes (impervious area, deep-rooted vegetation area, leaf-area index and fertilisation rates). The observed data includes daily streamflow and nutrient-sampling data, which are used for calibration and validation as discussed above.

As mentioned in Section 3.1, SQUARE is a semi-distributed model and all information is ‘lumped’ at a subcatchment level. The 30 Swan-Canning coastal catchments were divided hydrologically into 1034 subcatchments (Figure 3.5).

The process of ‘lumping’ involves the area-weighting of land-coverage component values within each subcatchment, so that each subcatchment is given a single, unique value for a particular input. This information is pre-processed to the required data format, and comprises the catchment-modelling-input dataset.

3.2.1 Meteorological data

Distributed daily rainfall

Rainfall is a fundamental driver of the SQUARE model, and rainfall data are required at a daily timestep. Rainfall data from 1970 to 2006 were extracted from the Bureau of Meteorology and Department of Water rainfall gauges (Figure 3.6).

Each subcatchment is given a daily rainfall value for each day of the simulation using the ‘makerainf.exe’ program, which is one of the suite of SQUARE pre-processing programs. The program ‘makerainf.exe’ assigns a daily rainfall value to the centroid of each subcatchment using inverse-square distance weighting of data from the nearest five rain gauges.

Daily potential evaporation

SQUARE avoids the need to have continuous daily pan evaporation or potential evaporation measurements (these are typically unreliable, inaccurate and sparse). Instead, it assumes that the daily potential evaporation values follow a sinusoidal trend in time according to a predetermined harmonic distribution. The daily potential evaporation values are calculated using a mean annual potential evaporation value for each subcatchment, and parameters relating to the amplitude and phase of the curve. Daily evapotranspiration is calculated based on the potential daily evaporation, leaf-area index, deep-rooted vegetation area, and the availability of water in the A, B and F stores.

Mean annual potential evaporation and rainfall

Mean annual rainfall (mm) for each subcatchment is used to adjust initial storage values to some approximate equilibrium value. Mean annual potential evaporation (mm) is used as a scalar for the daily evaporation calculation from each store in each subcatchment. The accuracy of their absolute values is not critical – only reasonable representations of their spatial variability are required.

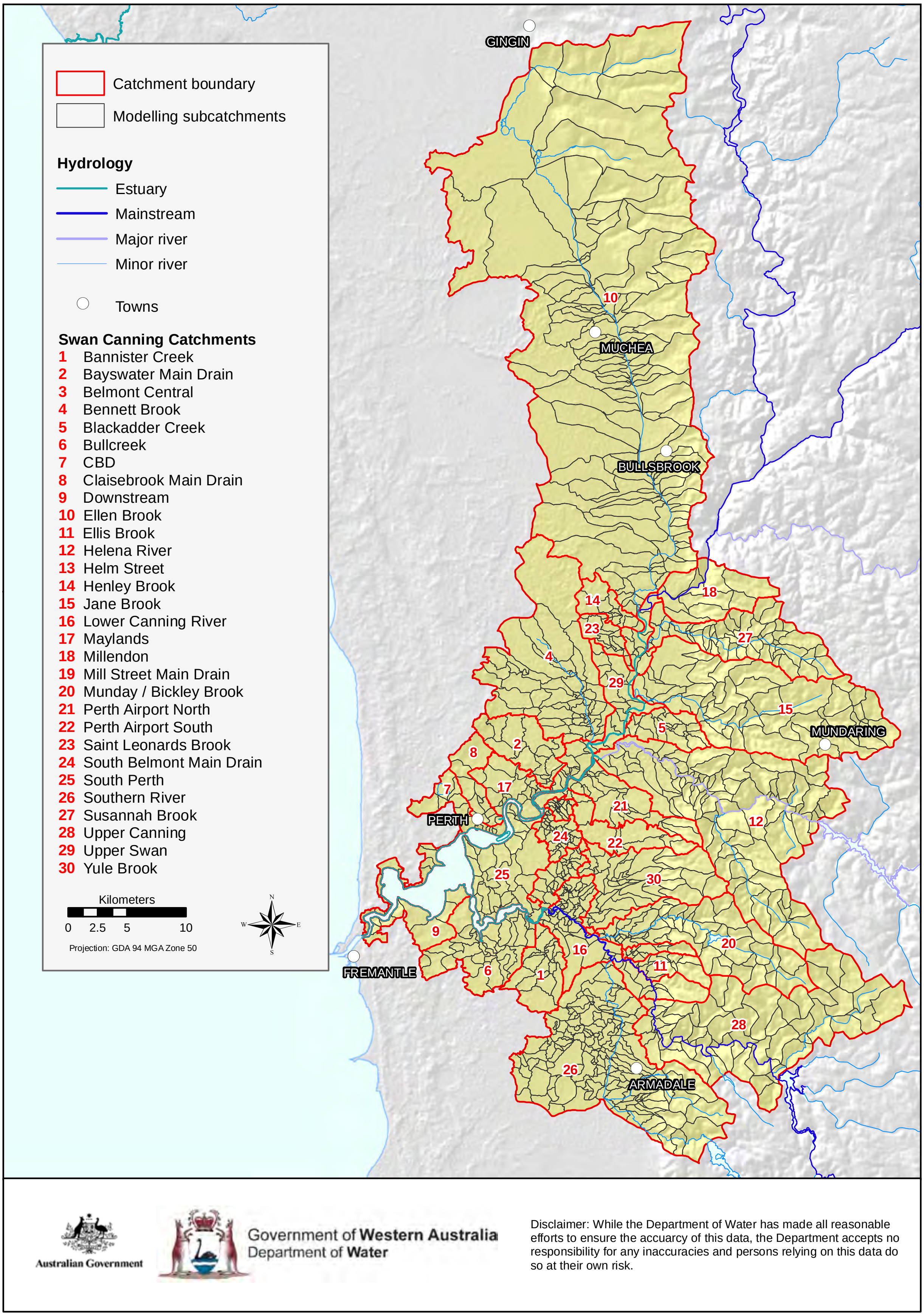


Figure 3.5 SQUARE modelling subcatchments

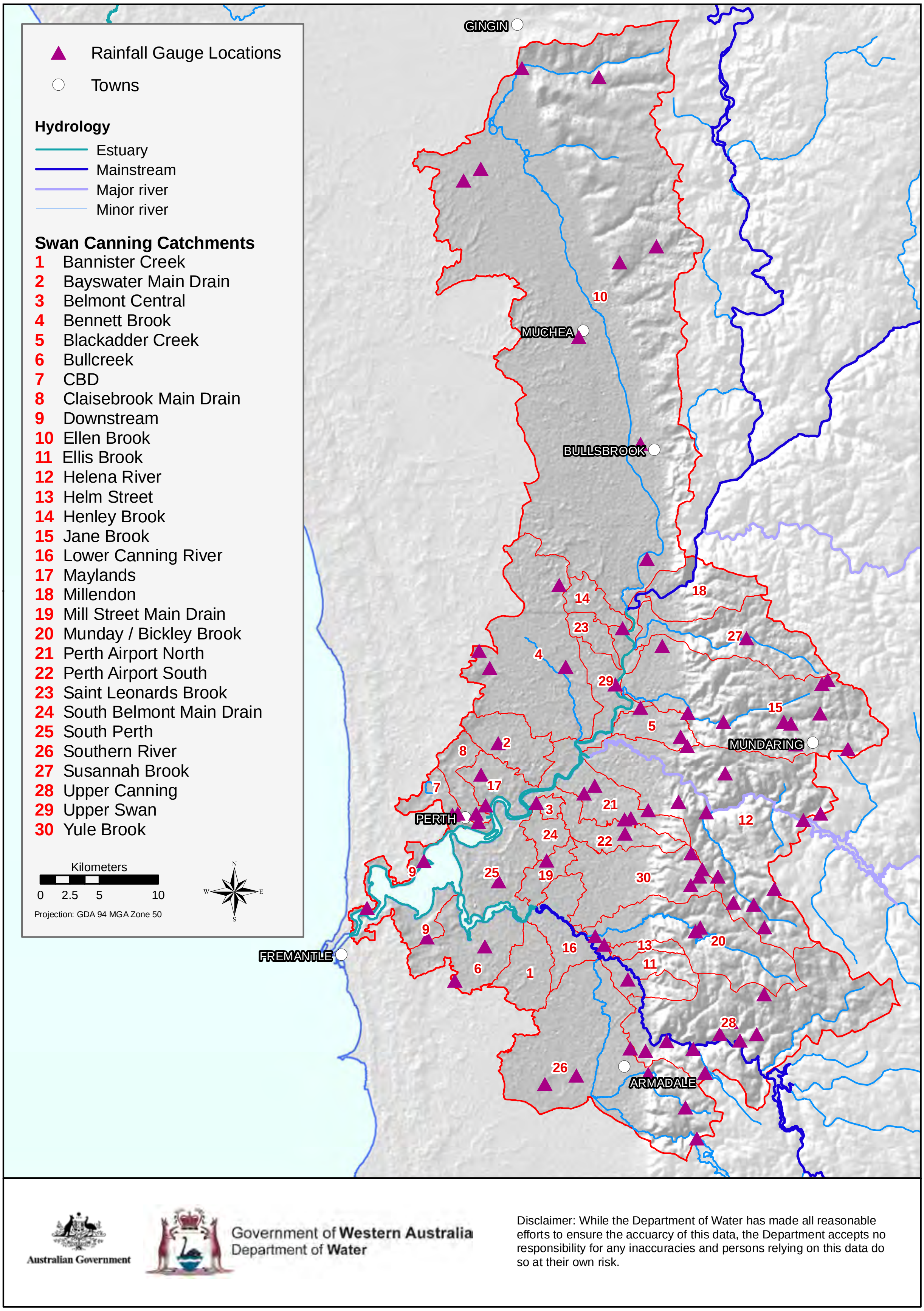


Figure 3.6 Rainfall gauge locations

3.2.2 Spatial data

The spatial coverages that contribute to the SQUARE input data files include:

- leaf-area indices (LAI)
- deep-rooted vegetation areas
- impervious areas
- soil phosphorus retention indices (PRI)
- nutrient input (fertilisation) rates
- nutrient point source locations
- septic tank locations.

These data are required for each year modelled; that is, 1970 to 2006 inclusive.

Leaf-area index, deep-rooted vegetation area and impervious area

At the start of the project accurate land-use mapping at the cadastral-parcel scale was unavailable, so the Water Science branch's modelling team created accurate maps. This took approximately 24 people-months, and the number of cadastral parcels mapped was approximately 2.2 million.

Land uses were mapped from aerial photography for the years 2000, 2003 and 2005. For Ellen Brook the rural land-use mapping was supplied by DAFWA. The 2005 land-use map (Figure 2.8) was ground-truthed in urban and rural areas. For years before 2000, the Perth urban footprint (Jarvis 1986) was used to create land-use maps for 1974, 1984 and 1995.

Values for LAI, deep-rooted vegetation percentage, and impervious area percentage were assigned to each land-use class, based on literature and satellite imagery studies, as listed in Table 3.1 and Table 3.2 for the Ellen Brook catchment and Swan-Canning 'urban' catchments respectively.

Subcatchment inputs for LAI, deep-rooted vegetation percentage and impervious area percentage were determined by calculating area-weighted averages of each characteristic (from the land-use mapping) in each subcatchment. For the years with no mapping, the values were derived by linear interpolation from the data for the years with mapping.

Table 3.1 Leaf-area indices (LAI), percentage impervious area and percentage deep-rooted vegetation for land uses in the Ellen Brook catchment

Land use	LAI	Percentage deep-rooted vegetation	Percentage impervious area
Airport	0.9	5	5
Cattle	0.5	5	0
Cattle for beef	0.5	5	0
Cattle for beef and horses	0.5	5	0
Cleared land - unused	1.0	0	0
Commercial	0.2	5	20
Conservation reserve	1.8	100	0
Drain reserve	1.2	80	0
Effluent treatment	0.5	8	10
Floriculture	1.3	5	0
Glasshouses	1.5	50	5
Golf course	1.2	15	0
Government facility	0.8	10	0
Government facility - education	0.8	20	2
Horses	0.5	10	0
Horticulture	1.3	50	2
Lifestyle block > 20.0000ha	1.2	20	0
Lifestyle block 10.0000 - 20.000	1.2	20	1
Lifestyle block 5.0000 - 10.0000	1.2	20	2
Light industrial	0.0	0	50
Livestock - alpaca	0.5	5	0
Native forest	1.8	100	0
Pasture for hay	1.2	5	0
Pasture for seed	1.2	5	0
Perennial horticulture - trees	1.6	80	0
Peri-urban < 0.5000ha	1.2	20	10
Peri-urban 0.5000 - 2.0000ha	1.2	20	5
Peri-urban 2.0000 - 5.0000ha	1.2	20	3
Plant nursery	1.5	10	5
Poultry	0.5	5	0
Public access way	0.6	10	50
Quarry	0.0	0	0
Railway reserve	0.8	30	0
Recreation reserve	1.0	5	0
River or stream reserve	1.2	50	0
Road reserve	1.8	10	50
Rural residential	1.4	80	5
Sand mine	0.0	0	0
Sheep	0.5	5	0
Tree plantation	1.9	100	0
Turf farm	1.2	0	0
Uncleared land - unused	1.8	100	0
Urban	0.5	10	20
Utility	0.0	0	0
Viticulture	1.2	0	0
Wetland	1.8	100	0
Bare soil	0.0	0	0
Grass	1.2	0	0
Trees	1.9	100	0

Table 3.2 Leaf-area indices (LAI), percentage impervious area and percentage deep-rooted vegetation for land uses in the Swan-Canning coastal catchments

Land use	LAI	Percentage deep-rooted vegetation	Percentage impervious area
Animal keeping - non-farming	0.5	10	0
Commercial / service - centre	0.0	0	50
Commercial / service - residential	0.2	5	20
Community facility - education	0.8	20	0
Community facility - non-education	0.5	10	10
Drainage	0.5	0	0
Farm	0.9	20	0
Garden centre / nursery	1.5	10	5
Horticulture	1.3	50	2
Landfill	0.0	0	0
Lifestyle block / hobby farm	1.2	20	2
Manufacturing / processing	0.0	0	20
Office - with parkland	0.5	10	0
Office - without parkland	0.0	0	20
Plantation	1.9	100	0
Quarry / extraction	0.0	0	0
Recreation - grass	1.0	5	0
Recreation - turf	1.2	15	0
Recreation / conservation - trees / shrubs	1.8	95	0
Residential - aged persons	0.5	10	20
Residential - multiple dwelling	0.1	0	20
Residential - single / duplex dwelling	0.5	10	20
Residential - temporary accommodation	0.1	0	20
Rural residential / bush block	1.4	80	2
Sewage - non-treatment plant	1.0	0	0
Sewage - treatment plant	0.5	8	10
Storage / distribution	0.0	0	100
Transport / access - airport	0.9	5	10
Transport / access - non-airport	0.6	10	50
Turf Farm	1.2	0	0
Unused - cleared - bare soil	0.0	0	0
Unused - cleared - grass	1.0	0	0
Unused - uncleared - trees / shrubs	1.8	95	0
Unused - uncleared - tree / shrub cover	1.8	95	0
Utility	0.0	0	0
Viticulture	1.2	0	0
Water body	0.0	0	0
Yacht facilities	0.5	0	0

Phosphorus retention index (PRI)

In SQUARE, the soil is characterised by its phosphorus retention index (PRI) (McPharlin et al. 1990) – a measure of the soil's ability to retain phosphorus through adsorption to soil particles. Many of the sandy soils on the Swan Coastal Plain have a low PRI, and hence a low capacity to adsorb phosphorus. The soil PRI was determined from DAFWA mapping units (Figure 2.5).

Nutrient input (fertiliser) rates

Each land use is assigned a monthly nutrient fertilisation rate (in kg/ha). Data were taken from DAFWA's fertiliser surveys of rural properties and the Department of Water's 2006 urban nutrient survey (Kelsey et al. 2010). The DAFWA fertiliser surveys covered rural or semi-rural properties in the Ellen Brook, Geographe Bay and Peel-Harvey catchments (Ovens et al. 2008; Weaver et al. 2008). Rural and semi-rural properties in the Swan-Canning coastal catchments that had a fertiliser survey undertaken were assigned the actual fertiliser rate calculated from the survey. Properties that did not complete a fertiliser survey were assigned the median fertiliser rate of properties with similar land use. Median fertiliser rates were taken from the Ellen Brook survey dataset where there were sufficient samples to obtain a plausible result, otherwise the medians were taken from the entire fertiliser dataset of DAFWA's surveys. Urban properties were given the median fertilisation rates from the urban nutrient survey.

Median annual fertilisation rates assigned to each land-use category for the urban catchments are listed in Table 3.3, and the monthly breakdown of the application is in Table 3.4. The median annual fertilisation rates and timing of application for Ellen Brook are listed in Table 3.5 and Table 3.6 respectively. The spatial representation of nitrogen fertilisation rates are shown in Figure 3.7 and the phosphorus fertilisation rates are shown in Figure 3.8. Fertiliser nutrient input is one of three nutrient-input datasets required by the SQUARE model. Other nutrient datasets include point sources and septic tanks, which are described below.

Table 3.3 Annual nitrogen and phosphorus fertilisation rates for the urban catchments

Land use	Nitrogen fertiliser rate (kg/ha)	Phosphorus fertiliser rate (kg/ha)
Animal keeping - non-farming	37.4	10.2
Commercial / service - centre	5.0	2.5
Commercial / service - residential	109.5	26.2
Community facility - education	109.5	26.2
Community facility - non-education	54.8	13.1
Farm	71.0	9.7
Garden centre / nursery	28.7	5.3
Horticulture	142.6	126.9
Lifestyle block / hobby farm	49.2	3.4
Manufacturing / processing	5.0	2.5
Office - with parkland	54.8	13.1
Office - without parkland	5.0	2.5
Plantation	5.0	2.5
Recreation - grass	175.0	35.0
Recreation - turf	350.0	70.0
Residential - aged persons	109.5	26.2
Residential - multiple dwelling	54.8	13.1
Residential - single / duplex dwellin	109.5	26.2
Residential - temporary accommodation	5.0	2.5
Sewage - non-treatment plant	5.0	2.5
Sewage - treatment plant	5.0	2.5
Transport / access - non-airport	5.0	2.5
Turf Farm	432.8	14.5
Viticulture	23.5	25.4

Table 3.4 Monthly fertilisation application in the Swan-Canning urban catchments as a percentage of annual amount

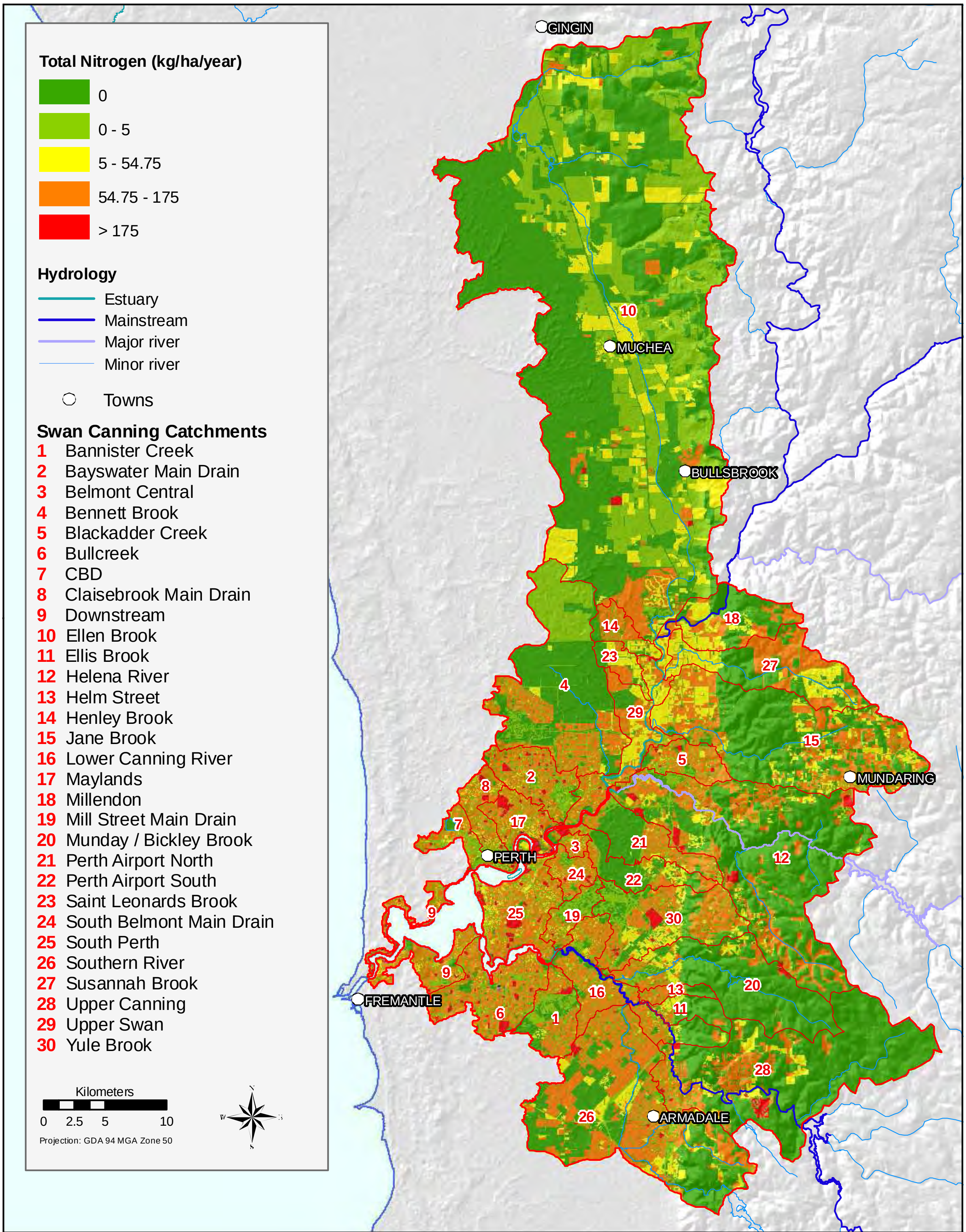
Land use	*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*
Animal keeping - non-farming	0	0	0	50	0	0	0	50	0	0	0	0
Commercial / service - centre	23	0	18	0	0	13	0	0	46	0	0	0
Commercial / service - residential	23	0	18	0	0	13	0	0	46	0	0	0
Community facility - education	23	0	18	0	0	13	0	0	46	0	0	0
Community facility - non-education	23	0	18	0	0	13	0	0	46	0	0	0
Farm	17	10	3	10	12	11	0	16	9	11	0	0
Garden centre / nursery	18	4	3	0	24	12	19	0	9	3	4	4
Horticulture	18	4	3	0	24	12	19	0	9	3	4	4
Lifestyle block / hobby farm	5	4	4	11	12	10	10	5	18	11	7	4
Manufacturing / processing	23	0	18	0	0	13	0	0	46	0	0	0
Office - with parkland	23	0	18	0	0	13	0	0	46	0	0	0
Office - without parkland	23	0	18	0	0	13	0	0	46	0	0	0
Plantation	0	0	0	0	0	0	0	0	50	50	0	0
Recreation - grass	23	0	18	0	0	13	0	0	46	0	0	0
Recreation - turf	23	0	18	0	0	13	0	0	46	0	0	0
Residential - aged persons	23	0	18	0	0	13	0	0	46	0	0	0
Residential - multiple dwelling	23	0	18	0	0	13	0	0	46	0	0	0
Residential - single / duplex dwelling	23	0	18	0	0	13	0	0	46	0	0	0
Residential - temporary accommodation	23	0	18	0	0	13	0	0	46	0	0	0
Sewage - non-treatment plant	23	0	18	0	0	13	0	0	46	0	0	0
Sewage - treatment plant	23	0	18	0	0	13	0	0	46	0	0	0
Transport / access - non-airport	23	0	18	0	0	13	0	0	46	0	0	0
Turf Farm	18	4	3	0	24	12	19	0	9	3	4	4
Viticulture	18	4	3	0	24	12	19	0	9	3	4	4

Table 3.5 Annual fertiliser rates for non-surveyed diffuse land uses in the Ellen Brook catchment.

Land use	Nitrogen fertiliser rate (kg/ha)	Phosphorus fertiliser rate (kg/ha)
Cattle	3.9	7.1
Cattle for beef	3.9	7.1
Cattle for beef and horses	3.9	7.1
Floriculture	142.6	126.9
Glasshouses	39.2	6.9
Golf course	24.7	0.5
Commercial / government facility	109.5	26.2
Government facility - education	109.5	26.2
Horses	37.4	10.2
Horticulture	142.6	126.9
Lifestyle block	2.8	1.0
Livestock - alpaca	4.2	5.9
Mixed grazing	3.9	7.1
Pasture for hay	4.2	5.9
Pasture for seed	4.2	5.9
Perennial horticulture - trees	16.2	11.6
Peri-urban < 0.5000ha	109.5	26.2
Peri-urban 0.5000 - 2.0000ha	2.8	1.0
Peri-urban 2.0000 - 5.0000ha	2.8	1.0
Plant nursery	39.2	6.9
Recreation - grass	175.0	35.0
Sheep	1.3	2.5
Tree plantation	16.2	11.6
Turf farm	432.8	14.5
Urban < 0.1000ha	109.5	26.2
Urban 0.1000 - 0.2000ha	109.5	26.2
Urban 0.2000 - 0.5000ha	109.5	26.2
Viticulture	23.5	25.4

Table 3.6 Monthly fertilisation application in Ellen Brook catchment as a percentage of annual amount

Land use	January	February	March	April	May	June	July	August	September	October	November	December
Cattle	3	9	14	17	16	12	6	7	9	3	4	0
Cattle for beef	3	9	14	17	16	12	6	7	9	3	4	0
Cattle for beef and horses	3	9	14	17	16	12	6	7	9	3	4	0
Floriculture	18	4	3	0	24	12	19	0	9	3	4	4
Glasshouses	18	4	3	0	24	12	19	0	9	3	4	4
Golf course	23	0	18	0	0	13	0	0	46	0	0	0
Government facility	23	0	18	0	0	13	0	0	46	0	0	0
Government facility - education	23	0	18	0	0	13	0	0	46	0	0	0
Horses	0	0	0	50	0	0	0	50	0	0	0	0
Horticulture	18	4	3	0	24	12	19	0	9	3	4	4
Lifestyle block	5	4	4	11	12	10	10	5	18	11	7	4
Livestock - alpaca	17	10	3	10	12	11	0	16	9	11	0	0
Mixed grazing	17	10	3	10	12	11	0	16	9	11	0	0
Pasture for hay	17	10	3	10	12	11	0	16	9	11	0	0
Pasture for heed	17	10	3	10	12	11	0	16	9	11	0	0
Perennial horticulture - trees	18	4	3	0	24	12	19	0	9	3	4	4
Peri-urban < 0.5000ha	5	4	4	11	12	10	10	5	18	11	7	4
Peri-urban 0.5000 - 2.0000ha	5	4	4	11	12	10	10	5	18	11	7	4
Peri-urban 2.0000 - 5.0000ha	5	4	4	11	12	10	10	5	18	11	7	4
Plant nursery	18	4	3	0	24	12	19	0	9	3	4	4
Recreation reserve	23	0	18	0	0	13	0	0	46	0	0	0
Sheep	17	10	3	10	12	11	0	16	9	11	0	0
Tree plantation	0	0	0	0	0	0	0	0	50	50	0	0
Turf farm	23	0	18	0	0	13	0	0	46	0	0	0
Urban < 0.1000ha	23	0	18	0	0	13	0	0	46	0	0	0
Urban 0.1000 - 0.2000ha	23	0	18	0	0	13	0	0	46	0	0	0
Urban 0.2000 - 0.5000ha	23	0	18	0	0	13	0	0	46	0	0	0
Viticulture	18	4	3	0	24	12	19	0	9	3	4	4



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Disclaimer: While the Department of Water has made all reasonable efforts to ensure the accuarcy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Figure 3.7 Nitrogen input rates for the Swan-Canning coastal catchments

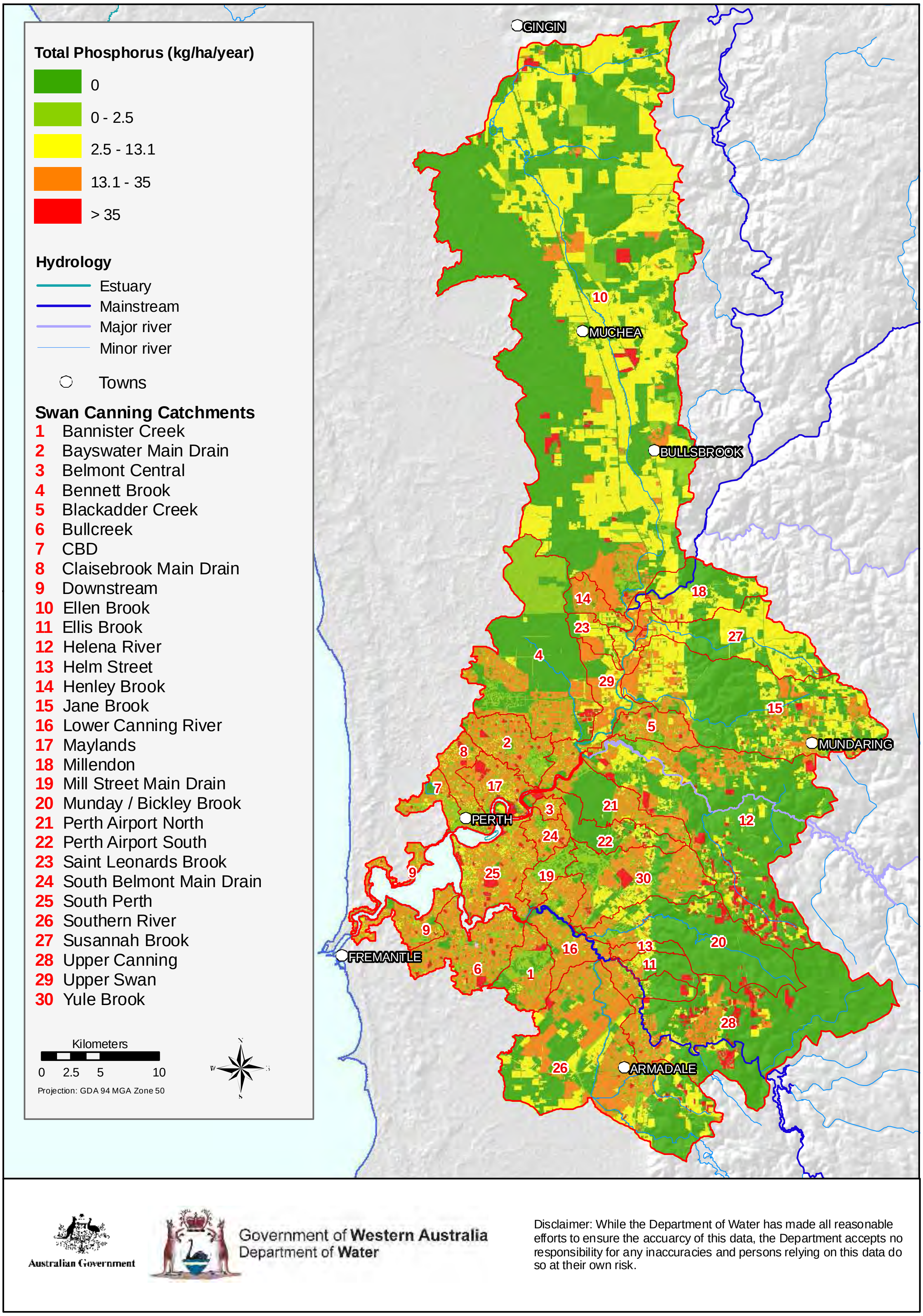

Figure 3.8 Phosphorus input rates for the Swan-Canning coastal catchments

Nutrient point source data

Potential point sources of nutrient pollution were investigated using the Australian Government's National Pollutant Inventory (NPI), Department of Water's Legacy database and the Department of Environment and Conservation's Pollution Prevention System (PPS). Also the point source studies by Hirschberg (1991) and GHD (2007a) were reviewed and potential sites from these publications included. All potential sites are shown in Table 3.7 and mapped in Figure 3.9. GHD consulted with Natural Resource Management Sub Regional Group representatives in their desktop study, thus sites identified by this group are labelled NRMSRG in Table 3.7.

There are 59 sites listed in Table 3.7. Of these, the 17 piggeries and two of the poultry farms are no longer operating. However, nutrients stored in the soil profile may still be leaching to the waterways from these sites. In the 1990s the Australian Government deregulated the pork industry: this allowed pork to be imported primarily from Denmark and Canada, which adversely affected the local industry and caused many enterprises to close (Waite *pers. comm.* 2007).

The only landfill site included is the Ranford Road site, which reports emissions to the NPI. There are many abandoned landfill, animal burial, night soil and liquid waste disposal sites, as mapped by Hirschberg (1991), some of which are known to be polluting groundwater and surface waters (Hirschberg 1992, *pers. comm.* 2007; Evans 2009). It is impossible to estimate pollution from these sources without intensive monitoring and modelling at each site, thus they have not been included in this work. It is recommended that all historic landfill, animal burial, night soil and liquid waste disposal sites are mapped accurately and investigations are carried out to determine if nutrients and other contaminants are leaching from these sites for inclusion in future modelling.

Many sites housing large numbers of animals, such as poultry farms and feedlots, emit large volumes of ammonia to air. For example, the 13 poultry farms in Ellen Brook catchment that report to the NPI emit approximately 260 tonnes of nitrogen (as ammonia) per year. The ammonia emissions to air were included in the modelling, but caused the model to calibrate badly. This may be because the emissions are moved by the wind and do not impact in the subcatchment where the facility is located. That is, emissions to air may be 'smeared' over the whole catchment or blown inland away from the coastal catchments. The SQUARE model calibrated much better without the inclusion of the point sources in Table 3.7, which emit to air and land. Thus the only point sources included in the modelling are those that emit directly to water: a feedlot in Ellen Brook catchment close to the gauging station (616189) and the Ranford Road tip and Swan Brewery in Bannister Creek catchment, both of which report emissions to the NPI. The estimated average annual amounts of nitrogen and phosphorus emitted to water from these three sites for the period modelled (1970–2006) are shown in Table 3.8.

Table 3.7 Potential nutrient point sources in the Swan-Canning coastal catchments

Subcatchment	Destination[1]	Industry	Source	Start year	End year
Bannister	A/L/W	Beer and malt manufacturing	NPI	1979	-
Bannister	L/W	Landfill	NPI	1970's	-
Bennet	A	Poultry	NRMSRG	1970	-
Bickley	A	Poutry (meat)	NPI/Legacy	1975	-
Bickley	A	Poutry (meat)	NPI/Legacy	2004	-
Bickley	A	Poutry (meat)	NPI/Legacy	1975	-
Ellen	A	Poutry (meat)	NPI	2004	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	2004	2004
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	A	Poutry (meat)	NPI	1970	-
Ellen	L	Mineral sand mining	NPI	1992	-
Ellen	A/L	Abandoned piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1992
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1992
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1989
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1990	1995
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1992
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1992
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1991
Ellen	A/L	Piggery	Hirschberg/NRMSRG	1970	1995
Ellen	A/L	Feed lot	NRMSRG	2000	-
Ellen	A/W	Feed lot	NRMSRG	1990	-
Helena	A	Poutry (meat)	NPI	1975	2004
Helena	A	Poultry	NRMSRG	1970	-
Helena	A	Saleyard	Leagacy/ Hirschberg/PPS	1970's	-
Helena	A	Feedlot / sheep live export	Hirschberg/Legacy /PPS	1970's	-
Helena	L	Meat processing	NPI	1970's	-
Jane	A	Poutry (meat)	NPI/NRMSRG	1975	-
Jane	A	Poultry	NRMSRG	1970	-
Jane	A	Poultry	NRMSRG	1970	-
Jane	A	Poultry	NRMSRG	1970	-
Jane	A	Poultry	NRMSRG	1970	-
Jane	A	Poultry	NRMSRG	1970	-
Lower Canning	A	Poultry	Hirschberg/Legacy	1960	-
Southern	A	Poutry (meat)	NPI/Legacy	1975	-
Southern	A	Poultry	Hirschberg/Legacy	1977	-
Southern	A/L	Feedlot	Legacy/ Hirschberg	1970's	-
Susannah	A/L	Feedlot / sheep live export	Hirschberg	1970's	-
Upper Swan	A	Poutry (meat)	NPI	1975	-
Upper Swan	A	Poultry	NRMSRG	1970	-
Yule	A	Poutry (meat)	NPI	2004	-
Yule	A	Poutry (meat)	NPI	1975	-

[1] *A = Air, L = Land, W = Water*

Table 3.8 Average annual emissions for the period 1970 to 2006 for point sources included in the model

Catchment	Industry	Facility name	Average annual emission (tonnes/year)	
			Nitrogen	Phosphorus
Bannister	Beer and malt manufacturing	The Swan Brewery company	1.05	0.19
Bannister	Landfill	Ranford Road landfill	0.03	0.00
Ellen	Feed lot	Almeria Road	2.80	0.10

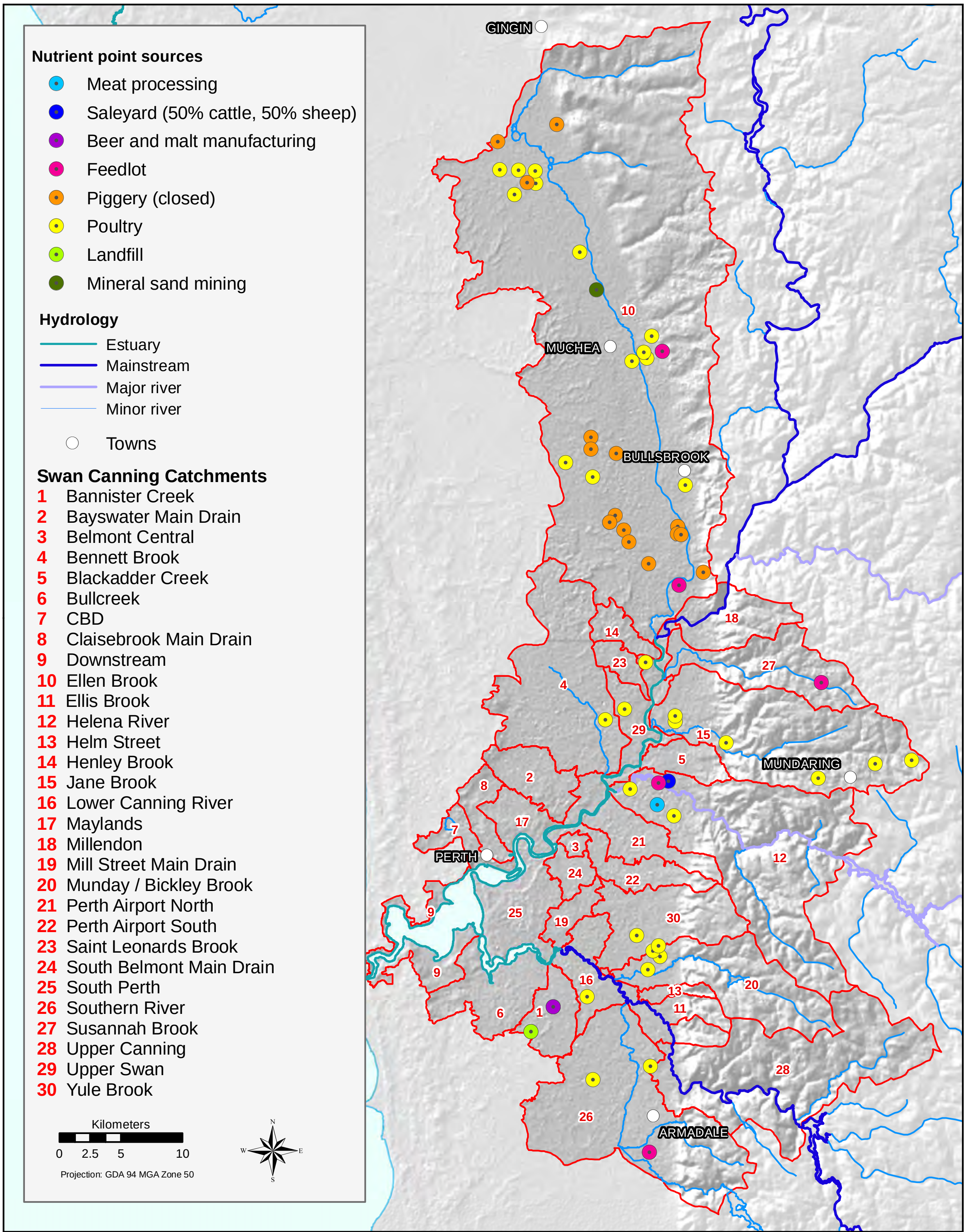

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Figure 3.9 Nutrient point sources in the Swan-Canning coastal catchments

Septic tanks

Septic tank mapping was created from the Department of Land Information's cadastral spatial coverages and deep-sewerage mapping supplied by the Water Corporation. All urban residential, rural residential and lifestyle blocks not included in the area of reticulated deep-sewerage are assumed to have septic tanks. The cadastral parcels thus selected were checked against aerial photography to confirm there was a dwelling on the property. The septic tank emissions were estimated following the research of Whelan and Barrow (1984a, 1984b) and Whelan et al. (1981) which attribute nitrogen and phosphorus emissions from septic tanks to be 5.5 and 1.1 kg/person/year respectively. Occupancy rates were estimated from Australian Bureau of Statistics census data (Table 3.9). For properties that were occupied during business hours, the estimated emission rates were reduced by a third to reflect the occupancy of these properties for approximately eight hours of the day. A connection rate to infill sewerage of 100% was assumed. The number of septic tanks and estimated average annual nitrogen and phosphorus emissions for each catchment are listed in Table 3.10 and the septic tank mapping is shown in Figure 3.10.

Table 3.9 Occupancy rates for properties in the Swan-Canning coastal catchments

Landuse category	Occupancy rate	Reference
Residential - single / duplex dwelling	2.43	ABS (2007)
Residential - multiple dwelling	2.43	ABS (2007)
Residential - aged persons[1]	1.22	ABS (2007)
Residential - temporary accommodation	71.1	ABS (*various dates*)
Rural residential / bush block	2.43	ABS (2007)
Lifestyle block / hobby farm	2.43	ABS (2007)
Manufacturing / processing[2]	19.9	ABS(2002)
Storage / distribution[2]	10.4	ABS(2002)
Commercial / service - centre[2]	10.1	ABS(2002)
Commercial / service - residential[2]	5.5	ABS(2002)
Office - with parkland[2]	7.4	ABS(2002)
Office - without parkland[2]	7.4	ABS(2002)
Community facility - education[2]	246.2	ABS(2006)
Community facility - non-education[2]	11.9	ABS(2002)
Recreation - turf[2]	11.9	ABS(2002)

[1] Occupancy rate of aged person's dwelling assumed to be one-half of Residential - single / duplex

[2] Occupancy rate multiplied by one-third to reflect business hour useage

Table 3.10 Estimated septic tank emissions for each catchment

Catchment	Number of septic tanks	Emissions from septic tanks (tonnes/year)	
		Nitrogen	Phosphorus
Bannister Creek	234	5.1	1.0
Bayswater Main Drain	428	13.9	2.8
Belmont Central	23	0.5	0.1
Bennett Brook	187	5.1	1.0
Bickley Brook	476	7.8	1.6
Blackadder Creek	629	9.5	1.9
Bullcreek	65	1.6	0.3
CBD	20	0.8	0.2
Claisebrook	107	2.9	0.6
Downstream	127	3.8	0.8
Ellen Brook	1 235	13.6	2.7
Ellis Brook	159	3.0	0.6
Helena River	5 700	88.5	17.7
Helm Street	56	1.3	0.3
Henley Brook	92	1.7	0.3
Jane Brook	4 429	64.7	12.9
Lower Canning	705	10.8	2.2
Maylands	55	1.7	0.3
Millendon	269	3.6	0.7
Mills Street	448	36.3	7.3
Munday Brook	49	0.7	0.1
Perth Airport North	2 041	29.5	5.9
Perth Airport South	756	10.8	2.2
Saint Leonards Creek	181	2.4	0.5
South Belmont	97	3.4	0.7
South Perth	398	7.3	1.5
Southern River	2 304	51.0	10.2
Susannah Brook	455	6.2	1.2
Upper Canning	3 559	51.0	10.2
Upper Swan	462	9.3	1.9
Yule Brook	5 349	83.8	16.8
Total	31 095	531	106

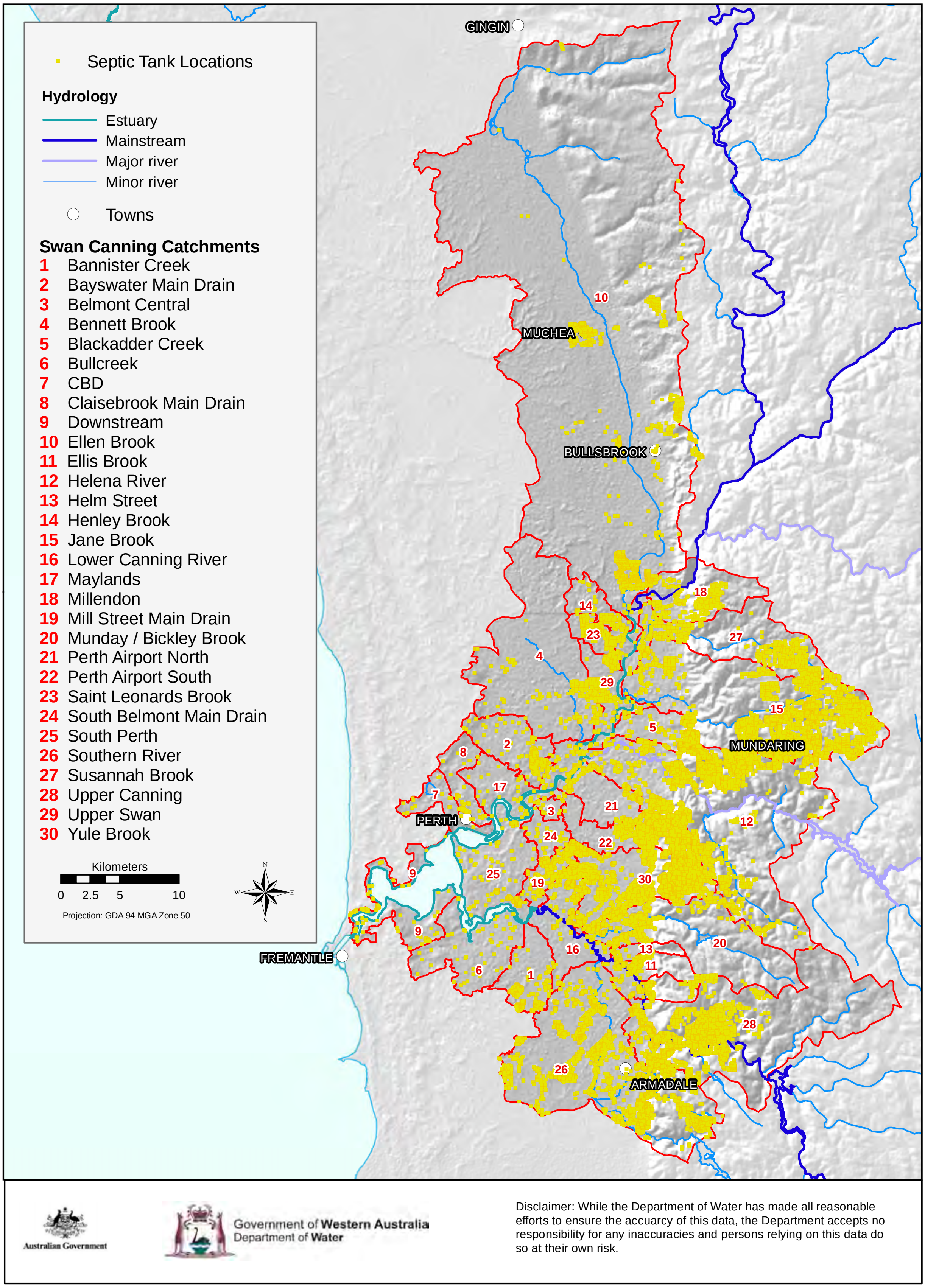


Figure 3.10 Septic tank locations

3.3 SQUARE calibration for the Swan-Canning coastal catchments

In the Swan-Canning coastal catchments, the Department of Water has monitored approximately 10 sites for flow and 16 for water quality for many years, which provides a long data time-series for model calibration. The Water Corporation also has flow data at some sites as indicated in Table 3.11. As part of the CCI project, nutrient data sampling was initiated at a further 17 sites. In total, data from 17 flow-gauging stations and 20 water-quality sampling sites were used for the hydrological and nutrient calibrations. A further six nutrient-monitoring sites, did not have sufficient data for calibration, but were used for validation of modelled nutrient concentrations.

Figure 3.11shows the flow and sampling sites used for calibration and validation. Table 3.11 and Table 3.12 contain the Nash-Sutcliffe efficiencies for the flow, TN and TP calibrations, and Table 3.13 contains nutrient sites that were used for validation. A detailed calibration report is presented in Appendix A and the Nash-Sutcliffe efficiency coefficient is defined and discussed in Section A3 of the appendix. The close match between the modelled and observed winter median concentrations of TN and TP is shown in Figure 3.12 and Figure 3.13 respectively.

Table 3.11 Daily, monthly and annual Nash-Sutcliffe efficiencies for flow calibrations

Catchment	AWRC Ref.	Daily	Monthly	Annual
Bayswater Main Drain	616082	0.52	0.75	0.64
Bennett Brook	616084	0.69	0.76	0.72
Bickley Brook[1]	616047	0.66	0.90	0.69
Munday Brook[1]	616232	0.66	0.90	0.69
Ellen Brook	616189	0.85	0.93	0.83
Helena River	616086	0.42	0.54	0.65
Jane Brook	616178	0.82	0.87	0.86
Jane Brook	616088	0.81	0.86	0.62
Maylands[1]	616045	0.30	0.79	0.45
Mills Street Main Drain[1]	616043	0.80	0.95	0.81
Perth Airport North[1]	616015	0.59	0.81	0.54
Southern River	616092	0.89	0.95	0.86
Southern River[1]	616044	0.73	0.85	0.12
Susannah Brook	616040	0.87	0.92	0.93
Susannah Brook	616099	0.85	0.96	0.84
Upper Canning	616027	0.73	0.91	0.85
Yule Brook[1]	616042	0.79	0.89	0.56

[1] Water Corporation gauge

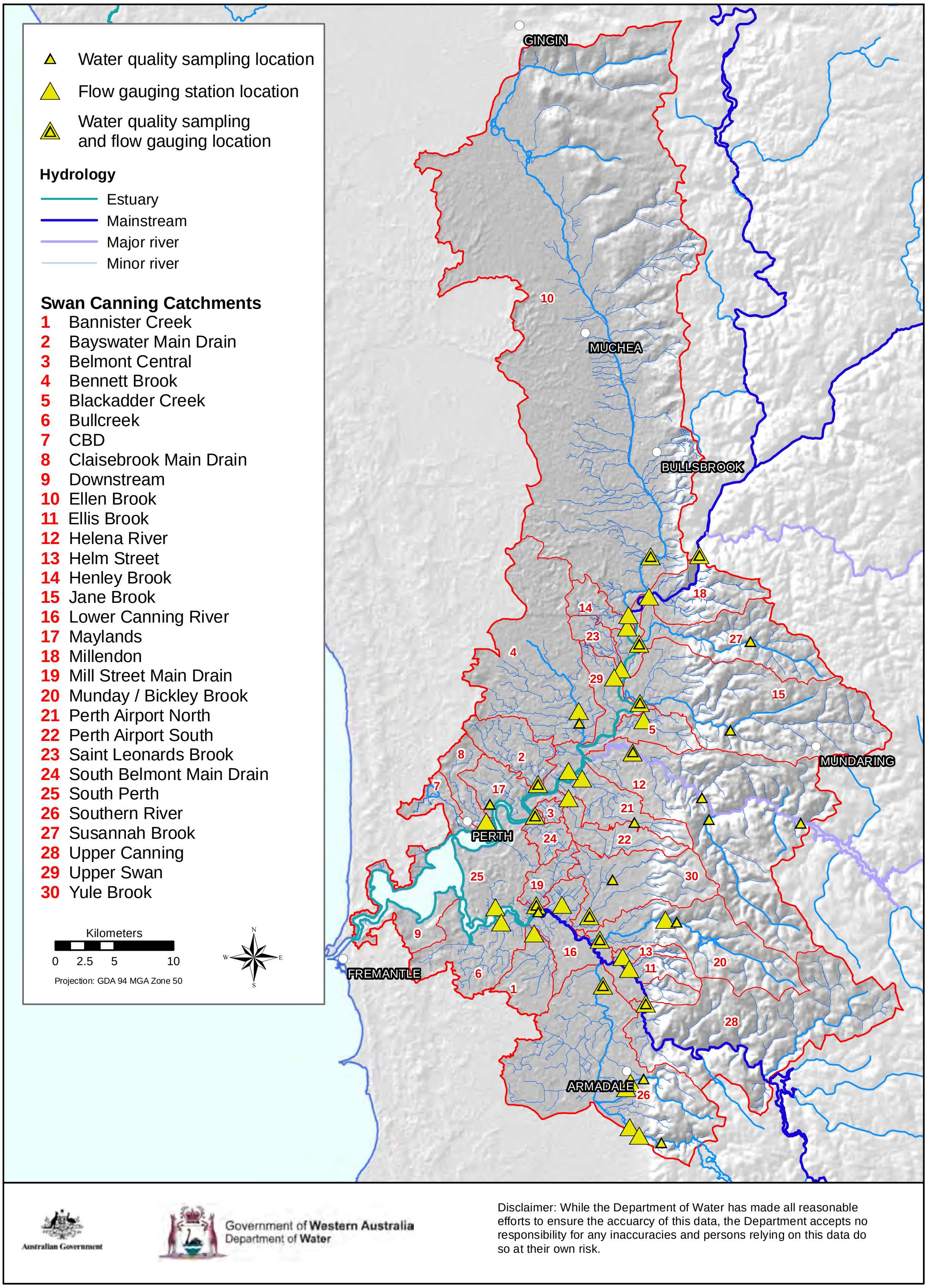


Figure 3.11 Flow-gauging and water-quality sampling sites in the Swan-Canning coastal catchments

Table 3.12 Nash-Sutcliffe efficiencies for TN and TP calibrations

Catchment	AWRC Ref.	TN Daily	TP Daily
Bannister Creek	616091	0.24	0.58
Bayswater	616082	0.37	0.10
Bennett Brook	6163143	0.57	0.03[1]
Blackadder	6162925	0.22	0.25
Bullcreek	6162311	0.74	0.42
Ellen	616189	0.60	0.42
Helena	616086	0.28	0.27
Helm Street	6162313	0.33	-0.08[1]
Henley	6161692	0.21	0.18
Jane	616088	0.47	0.64
Mills Street	616043	0.44	0.35
Millendon	616076	0.51	0.01[1]
Munday & Bickley	616047	0.48	0.52
Perth Airport North	6162318	0.71	0.75
Perth Airport South	6162317	0.90	0.71
South Belmont	616087	0.61	0.39
Southern	616092	0.86	0.55
Susannah	616099	0.51	0.51
Upper Canning	616027	0.52	0.23
Yule Brook	616042	0.10	0.12

[1] See Appendix A3

Table 3.13 Water-quality sampling sites used for validations of nutrient models

Catchments	AWRC Ref.	Name
Belmont Central	6160067	Centenary Park outlet
CBD	6161754	Mounts Bay Main Drain
Ellis Brook	6160690	Mills Road
Lower Canning	6162312	Cockhram Street Drain
St. Leonards	6162319	George Street
Upper Swan	6161696	Chapman Street Main Drain

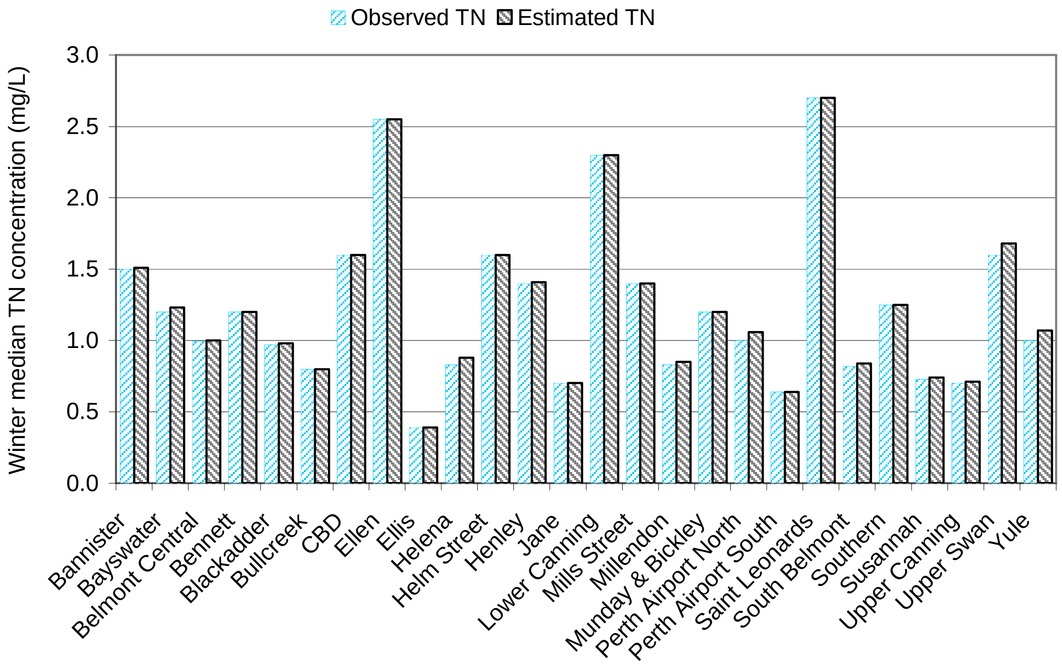


Figure 3.12 Observed and modelled winter median TN concentrations

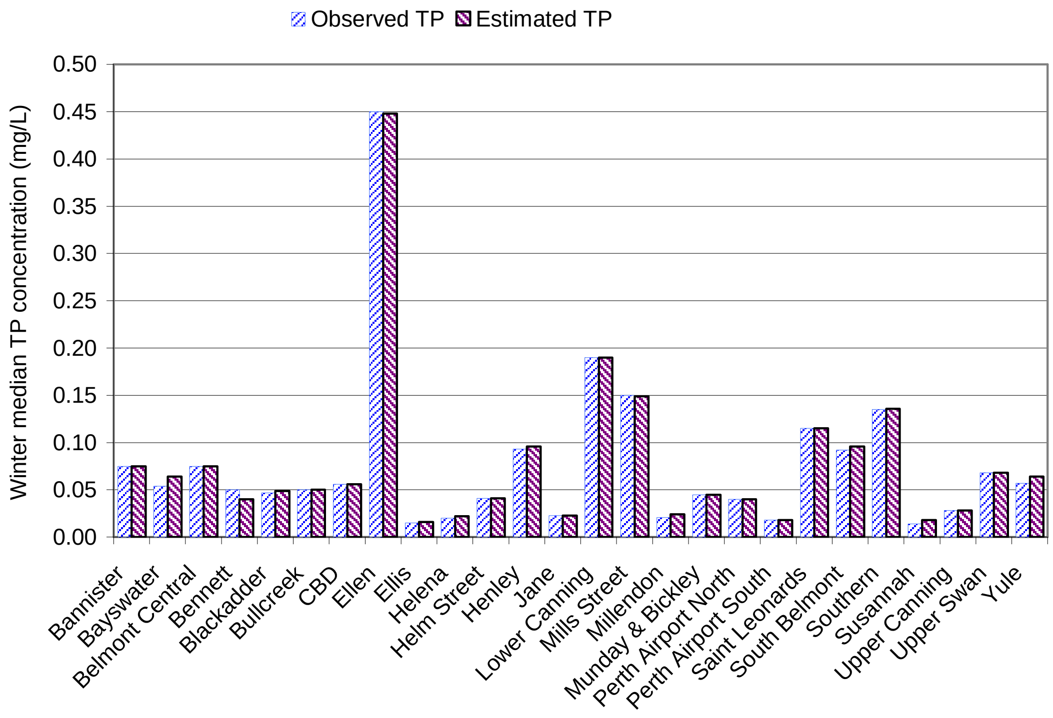


Figure 3.13 Observed and modelled winter median TP concentrations

3.4 Confidence assessment for modelling outputs

The accuracy of modelling outputs is largely determined by the data used to drive the models. Good modelling practice requires the modeller to evaluate confidence in the model, and assess the uncertainties associated with the modelling process and outputs.

One method to test the robustness of a model is to perform sensitivity analyses on the model parameters and/or inputs. Sensitivity analyses apportion the variation in the model's output to the variation in the model's parameters and inputs. The SQUARE model has 92 parameters and approximately 25 input datasets (depending on the subcatchment). As such, sensitivity analyses would be extremely onerous and not possible to pursue within the scope of this project.

A more qualitative approach has been adopted for the Swan-Canning modelling project, whereby factors affecting the quality of the flow and nutrient data used for calibration are scored for each of the reporting catchments (Table 3.14, Table 3.15 and Table 3.16). The scores are then added to provide a total score for the flow, nitrogen and phosphorus components of the model for each reporting catchment. The scores are interpreted, using the assessment scales in Table 3.17, to assess confidence in the modelled results based on the input data. A high score equates to a high confidence in the modelling results; the maximum score is 5.

The scores of 3, 4 and 5 in Table 3.14 indicate that the estimated flows at the outlets of the Ellen, Jane, Mills Street, Munday & Bickley, Southern, Susannah, Upper Canning and Yule catchments are accurate (high confidence). Flows at other points in the Jane, Southern and Susannah catchments are likely to be accurate because of the secondary flow gauges in these catchments. The catchments with scores 1 and 2 have reasonable flow estimations (medium confidence). However, five catchments have confidence scores of zero (low confidence). These are the urban catchments (Bullcreek, Downstream, Lower Canning, South Perth and Upper Swan) with multiple outlets to the estuaries and no flow gauging.

It should be noted that there are flow gauges at South Belmont (616087) and Millendon (616076) but data from these gauges were not of sufficient quality to use for calibration. The Bannister Creek flow gauge (616091) was not rated successfully and thus has no useful flow data. This gauge was replaced in March 2007 by gauge 616134, which should provide usable flow data in the future.

Table 3.14 Confidence scoring for flow calibrations (✓ = 1, x = 0)

Catchment	Flow gauge in catchment	Secondary flow gauge in catchment	Flow gauge in nearby catchment	Catchment hydrology is understood and documented	Hydrological calibration Nash-Sutcliffe monthly efficiency >0.8	Total
Bannister	x	x	✓	x	x	1
Bayswater	✓	x	✓	x	x	2
Belmont Central	x	x	✓	x	x	1
Bennett	✓	x	✓	x	x	2
Blackadder	x	x	✓	x	x	1
Bullcreek	x	x	x	x	x	0
CBD	x	x	✓	x	x	1
Claisebrook	x	x	✓	x	x	1
Downstream	x	x	x	x	x	0
Ellen	✓	x	✓	✓	✓	4
Ellis	x	x	✓	x	x	1
Helena	✓	x	✓	x	x	2
Helm Street	x	x	✓	x	x	1
Henley	x	x	✓	x	x	1
Jane	✓	✓	✓	✓	✓	5
Lower Canning	x	x	x	x	x	0
Maylands	✓	x	✓	x	x	2
Mills Street	✓	x	✓	✓	✓	4
Millendon	x	x	✓	✓	x	2
Munday & Bickley	✓	✓	✓	x	✓	4
Perth Airport N	✓	x	x	x	✓	2
Perth Airport S	x	x	✓	x	x	1
Saint Leonards	x	x	✓	x	x	1
South Belmont	x	x	✓	x	x	1
South Perth	x	x	x	x	x	0
Southern	✓	✓	✓	✓	✓	5
Susannah	✓	✓	✓	✓	✓	5
Upper Canning	✓	x	✓	✓	✓	4
Upper Swan	x	x	x	x	x	0
Yule	✓	x	✓	x	✓	3

Table 3.15 Confidence scoring for TN calibrations (✓ = 1, x = 0)

Catchment	Single outlet[1]	Nitrogen sampling in catchment	Nitrogen sampling record > 3 years	TN calibration Nash-Sutcliffe efficiency[2] > 0.4	Confidence score for flow estimations ≥ 3	Total
Bannister	✓	✓	✓	x	x	3
Bayswater	✓	✓	✓	x	x	3
Belmont Central	✓	✓	✓	-	x	3
Bennett	✓	✓	✓	✓	x	4
Blackadder	✓	✓	✓	x	x	3
Bullcreek	x (10)	✓	x	✓	x	2
CBD	x (7)	x[3]	x	-	x	0
Claisebrook[4]	✓	x[3]	x	-	x	0
Downstream	x (24)	x	x	-	x	0
Ellen	✓	✓	✓	✓	✓	5
Ellis	x (5)	✓	x	-	x	1
Helena	✓	✓	✓	x	x	3
Helm Street	✓	✓	x	x	x	2
Henley	✓	✓	x	x	x	2
Jane	✓	✓	✓	✓	✓	5
Lower Canning	x (28)	✓	x	-	x	1
Maylands	x (8)	x	x	-	x	0
Mill Street	✓	✓	✓	✓	✓	5
Millendon	✓	✓	✓	✓	x	4
Munday & Bickley	x (2)	✓	✓	✓	✓	4
Perth Airport N	x (6)	✓	x	✓	x	2
Perth Airport S	x (2)	✓	x	✓	x	2
Saint Leonards	✓	✓	x	-	x	2
South Belmont	✓	✓	✓	✓	x	4
South Perth	x (19)	x[3]	x	-	x	0
Southern	✓	✓	✓	✓	✓	5
Susannah	✓	✓	✓	✓	✓	5
Upper Canning	✓	✓	✓	✓	✓	5
Upper Swan	x (20)	✓	x	-	x	1
Yule	✓	✓	✓	x	✓	4

[1] the number refers to the number of outlets

[2] "-" means that no calibrations were done

[3] Data were collected as part of CCI project, but not suitable for model calibration

[4] Claisebrook has score of zero because no data suitable for model calibration

Table 3.16 Confidence scoring for TP calibrations (✓ = 1, x = 0)

Catchment	Single outlet[1]	Phosphorus sampling in catchment	Phosphorus sampling record > 3 years	TP calibration Nash-Sutcliffe efficiency[2] > 0.4	Confidence score for flow estimations ≥ 3	Total
Bannister	✓	✓	✓	✓	x	4
Bayswater	✓	✓	✓	x	x	3
Belmont Central	✓	✓	✓	-	x	3
Bennett	✓	✓	✓	x	x	3
Blackadder	✓	✓	✓	x	x	3
Bullcreek	x (10)	✓	x	✓	x	1
CBD	x (7)	x[3]	x	-	x	0
Claisebrook[4]	✓	x[3]	x	-	x	0
Downstream	x (24)	x	x	-	x	0
Ellen	✓	✓	✓	✓	✓	5
Ellis	x (5)	✓	x	-	x	1
Helena	✓	✓	✓	x	x	3
Helm Street	✓	✓	x	x	x	2
Henley	✓	✓	x	x	x	2
Jane	✓	✓	✓	✓	✓	5
Lower Canning	x (28)	✓	x	-	x	1
Maylands	x (8)	x	x	-	x	0
Mills Street	✓	✓	✓	x	✓	5
Millendon	✓	✓	✓	x	x	3
Munday & Bickley	x (2)	✓	✓	✓	✓	4
Perth Airport N	x (6)	✓	x	✓	x	2
Perth Airport S	x (2)	✓	x	✓	x	2
Saint Leonards	✓	✓	x	-	x	2
South Belmont	✓	✓	✓	x	x	4
South Perth	x (19)	x[3]	x	-	x	0
Southern	✓	✓	✓	✓	✓	5
Susannah	✓	✓	✓	✓	✓	5
Upper Canning	✓	✓	✓	x	✓	5
Upper Swan	x (20)	✓	x	-	x	1
Yule	✓	✓	✓	x	✓	4

[1] the number refers to the number of outlets

[2] daily or monthly efficiency, "-" means that no calibrations were done

[3] Data were collected as part of CCI project, but not suitable for model calibration

[4] Claisebrook has score of zero because no data suitable for model calibration

Table 3.17 Confidence in the modelled results based on the score obtained from the scoring table

Flow value	Confidence in results
5 (High)	High confidence that actual flows are well represented by modelled flows for the output of the catchments. Also confident that upstream and intermediate points have modelled flows that are accurate.
3/4 (High)	Modelled flows are likely to represent actual flows at the flow guage used for calibration and at the outlet of the catchment if the gauge is only a small way upstream from the catchment outlet. Less confidence in flows predicted at other places in the catchment.
1/2 (Medium)	Annual flows will be likely to have some error associated with them (plus or minus 30%), which will be compounded in annual nutrient load quantities. Priority actions in these catchments should be to improve the understanding and measurement of the flow. Daily and monthly flow quantities are likely to be associated with larger errors.
0 (Low)	Flow quantities are likely to be associated with large errors (plus or minus 50%), and priority in these catchments will be to improve the understanding of the flow, and to re-assess the flow estimation and consequently the load targets.
Nutrient value	**Confidence in results**
5 (High)	High confidence in modelled nutrient concentrations, and annual and seasonal loads at the catchment outlets. Where secondary gauges exist (Ellen, Munday & Bickley and Southern catchments) load estimations are likely to be accurate in other parts of catchment also.
3/4 (High)	Modelled annual loads are likely to have reasonable accuracy (plus or minus 30%) for catchments with one outlet. In the case of multiple outlets this accuracy will only apply to the subcatchment which has been sampled.
1/2 (Medium)	Some nutrient data available in catchment. Confidence in flow estimations are low, so errors in nutrient loads expected to be of the order of 50%. Priority actions in these catchments should be to extend the sampling regime, particularly in the catchments with more than one outlet.
0 (Low)	No nutrient data available for model calibration and validation. Water quality assumed to be similar to adjacent catchments with similar land use and soil types. Low confidence associated with nutrient loads and concentrations, and errors in annual loads are likely > 50%. Priority is to begin sampling in these

Eleven of the Swan-Canning coastal catchments have multiple outlets. Generally only one of the outlets is sampled and the data are used for calibration or validation. The variability of water-quality data across a catchment is apparent in the data collected at two outlets in the Upper Swan catchment – the winter median concentrations at 6161696 were TN 1.6 mg/L and TP 0.068 mg/L, whereas at 6162320 they were TN 2.65 mg/L and TP 0.215 mg/L. Whether catchments have single or multiple outlets is one of the scoring criteria in the nutrient-confidence-scoring tables.

The confidence-scoring tables for the flow, TN and TP calibrations are summarised in Table 3.18 using the low, medium and high ratings. An overall rating is given for each catchment that is the least of the three ratings.

Table 3.18 Overall confidence scores

Catchment	Confidence			
	Flow	TN	TP	Overall
Bannister	Medium	High	High	Medium
Bayswater	Medium	High	High	Medium
Belmont Central	Medium	High	High	Medium
Bennett	Medium	High	High	Medium
Blackadder	Medium	High	High	Medium
Bullcreek	Low	Medium	Medium	Low
CBD	Medium	Low	Low	Low
Claisebrook	Medium	Low	Low	Low
Downstream	Low	Low	Low	Low
Ellen	High	High	High	High
Ellis	Medium	Medium	Medium	Medium
Helena	Medium	High	High	Medium
Helm Street	Medium	Medium	Medium	Medium
Henley	Medium	Medium	Medium	Medium
Jane	High	High	High	High
Lower Canning	Low	Medium	Medium	Low
Maylands	Medium	Low	Low	Low
Mills Street	High	High	High	High
Millendon	Medium	High	High	Medium
Munday & Bickley	High	High	High	High
Perth Airport N	Medium	Medium	Medium	Medium
Perth Airport S	Medium	Medium	Medium	Medium
Saint Leonards	Medium	Medium	Medium	Medium
South Belmont	Medium	High	High	Medium
South Perth	Low	Low	Low	Low
Southern	High	High	High	High
Susannah	High	High	High	High
Upper Canning	High	High	High	High
Upper Swan	Low	Medium	Medium	Low
Yule	High	High	High	High

SQUARE was used to deduce average annual current loads for the period 1997 to 2006 inclusive, maximum acceptable loads and load reduction targets (the difference between the current load and the maximum acceptable load) for each catchment.

Eight catchments have high confidence ratings (Ellen, Jane, Mills Street, Munday & Bickley, Southern, Susannah, Upper Canning and Yule). The absolute load calculations and load reduction targets are accurate in these catchments.

Although there are eight catchments that have low confidence ratings (Bullcreek, CBD, Claisebrook, Downstream, Lower Canning, Maylands, South Perth and Upper Swan) it should be noted that if SQUARE is, for instance, over-predicting for a particular catchment, then both the current and maximum acceptable loads will be over-predicted. Thus the error in the load-reduction target given as a percentage (of the modelled current load) will be much less than the errors in the absolute loads. In this case, confidence in the required percentage reduction in load to achieve the desired water quality is high, although confidence in the absolute loads (tonnes) is not.

The remaining 14 catchments (Bannister, Bayswater, Belmont Central, Bennett, Blackadder, Ellis, Helena, Helm Street, Henley, Millendon, Perth Airport N, Perth Airport S, Saint Leonards and South Belmont) have medium confidence ratings.

4 Water-quality objectives

A water-quality objective, as defined in *The framework for marine and estuarine water quality protection* and based on the Global Program of Action (Department of Environment, Water, Heritage and the Arts 2002) for the CCI program is:

'a numerical concentration limit or narrative statement that has been established to support and protect the environmental values of water at a specific site. It is based on scientific criteria or water-quality guidelines but may be modified by inputs such as social or political constraints'.

The water-quality objectives for the Swan-Canning CCI project are winter median total nitrogen (TN) and total phosphorus (TP) concentration targets. These are used to deduce annual load targets for guiding management actions.

4.1 Concentration targets

The Swan River Trust's Swan-Canning Cleanup Program (SCCP) (SRT 1999) was initiated as a key management strategy to improve the health of the Swan and Canning rivers and estuaries. The aim was to reduce the frequency and severity of algal blooms by reducing nutrient inputs and addressing the consequences of excess nutrient in the waterways.

The first *SCCP action plan* was launched in 1999, followed by the *SCCP II action plan* in 2006 and the *Healthy Rivers action plan (HRAP)* (SRT 2007) in 2008. Nutrient concentration targets for the tributaries of the Swan and Canning rivers (Table 4.1) were developed for the SCCP (SRT 1999). Compliance against the targets is tested using three years of nutrient data. The three-year timeframe is considered appropriate to minimise the effects of natural variations, and to collect enough data from weekly or fortnightly sampling regimes to enable robust statistical compliance testing.

Table 4.1 Swan-Canning Cleanup Program targets (now HRAP targets) for median TN and TP concentrations in catchment tributaries of the Swan-Canning river system

Target	**TN concentration**	**TP concentration**
Short term	2.0 mg / L	0.2 mg / L
Long term	1.0 mg / L	0.1 mg / L

However, examination of TN and TP concentrations in the urban waterways of the Swan-Canning river system reveals that concentrations are being diluted by the increased runoff from the highly impervious catchments. For example, semi-rural catchments such as Saint Leonards Brook have an average annual runoff of approximately 60 mm, whereas an urban catchment such as Bayswater Main Drain has an average annual runoff of approximately 300 mm; that is, five times more flow from similar annual rainfalls.

As the SCCP/HRAP targets were derived from comparison with data in natural rivers (pervious catchments), they are not directly applicable to the highly impervious urban catchments. The Swan-Canning coastal catchments were examined in terms of the following characteristics:

- percentage of impervious area
- average annual runoff (mm)
- summer flow percentage
- average annual yields of TN and TP per unit area
- observed stream concentrations of TN and TP.

These characteristics are shown in Table 4.2 below.

Table 4.2 Characteristics of the Swan-Canning coastal catchments

Catchment	Area (km^2)	Impervious area (%)	Average annual runoff (mm)*	Summer+ flow (%)	Observed TN median conc** (mg/L)	Nitrogen load/area (kg/ha)	Observed TP median conc** (mg/L)	Phosphorus load/area (kg/ha)
Bennett	113.1	9	14	12	1.2	0.63	0.053	0.04
Helena	175.7	5	35	2	0.83	0.33	0.02	0.01
Ellen	716.4	1	38	0	2.55	1.00	0.45	0.14
Munday & Bickley	73.7	2	45	0	1.4	1.32	0.05	0.06
Henley***	12.6	9	54	5	1.4	0.64	0.09	0.04
Saint Leonards***	9.8	5	61	11	2.7	1.43	0.12	0.14
Upper Canning	148.9	3	73	7	0.7	0.50	0.03	0.03
Perth Airport S***	24.6	17	82	3	0.64	0.45	0.02	0.07
Ellis	11.7	2	85	1	0.39	0.60	0.02	0.02
Millendon	35.2	2	90	2	0.83	0.74	0.02	0.04
Upper Swan***	40.5	27	100	12	1.65	2.12	0.07	0.50
Perth Airport N***	28.1	16	101	3	1.0	0.71	0.04	0.07
Jane	137.7	5	103	1	0.7	0.80	0.02	0.04
Southern	149.5	8	106	3	1.3	1.42	0.14	0.15
Helm Street***	6.0	7	113	6	1.6	2.83	0.04	0.12
Susannah	54.7	3	116	0	0.73	0.88	0.01	0.12
Lower Canning***	44.3	21	148	10	2.3	1.78	0.19	0.22
Blackadder	17.1	21	171	3	0.97	1.47	0.047	0.10
Yule	55.7	19	179	4	1.0	1.35	0.06	0.08
Maylands	18.7	24	208	17	-	5.82	-	0.16
CBD	13.7	28	211	17	-	3.80	-	0.18
Claisebrook***	16.1	26	211	17	1.7	2.88	0.056	0.19
Downstream	26.2	25	229	18	-	2.41	-	0.11
South Belmont	10.5	28	231	17	0.82	1.61	0.09	0.23
Belmont Central	3.6	29	251	17	1.0	1.98	0.075	0.17
Mills Street	12.3	37	278	10	1.4	5.79	0.15	0.64
Bayswater	27.2	27	304	14	1.2	3.60	0.054	0.22
Bullcreek***	42.5	25	347	11	0.8	2.61	0.050	0.28
Bannister	23.6	26	361	11	1.5	5.13	0.075	0.35
South Perth***	40.5	21	364	11	-	3.14	-	0.48

+Summer is defined as the months December, January, February and March

**Average annual runoff (mm) is from simple runoff modelling prior to completion of SQUARE modelling, so slightly different runoffs in rest of document.*

***Observed median concentrations for the period 1997 – 2006*

****Median concentration for 2007 only.*

The data in Table 4.2 are ordered by increasing runoff, which correlate well with increasing impervious area. Note that the percentage of summer flow, where summer is defined as the months of December, January, February and March, also increases with increasing impervious area. (Exceptions are Bennett Brook and Saint Leonards Creek, which have groundwater discharge from the Gnangara Mound or deeper aquifers; and the Lower Canning, which receives water from Canning Dam). In pervious catchments summer rainfall infiltrates and the catchment rarely becomes sufficiently saturated in summer to allow discharge to the stream. In impervious areas there is generally a good connection between the paved areas and the stream and increased flows will be observed after rainfall. In addition to this, urban catchments use imported water for irrigation and large drains may intercept the watertable.

The nutrient concentrations in a stream are a consequence of the land use and management, catchment area, hydrology and soil type. The highly impervious urban catchments have small areas and intensive land uses. It is expected that the nutrient loads to adjacent streams and waterways will be large relative to catchment size. This can be seen in the graph of catchment TN yields (load per unit area) versus runoff (a surrogate for urbanisation) in which a strong correlation is apparent (Figure 4.1a). However, there is no correlation between TN concentration and runoff (urbanisation) (Table 4.1b). The observed concentrations in highly impervious catchments are diluted by the large water yields from these catchments. That is, nutrient concentrations are determined as much by the catchment hydrology as the land use.

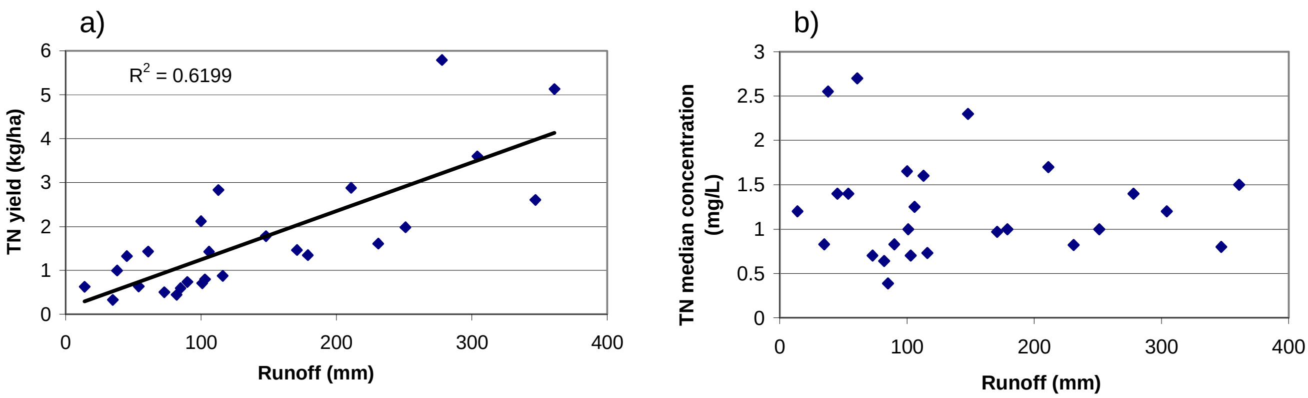


Figure 4.1 a) TN yield versus runoff and b) TN concentration versus runoff for the Swan-Canning coastal catchments

The impact of catchment hydrology on nutrient concentration is examined further in Figure 4.2. Figure 4.2a plots observed TN concentrations against TN yields and little correlation is apparent (correlation coefficient < 0.1). However, if the concentration is modified[2] to reflect the catchment runoff (Figure 4.1b) then there is a strong correlation between concentration and TN yield (correlation coefficient = 0.8). Similar behaviour is observed with respect to TP concentrations and yields.

[2] All catchments are assumed to have an average annual runoff of 200mm. Thus modified TN concentration = observed TN concentration*catchment runoff (mm)/200mm.

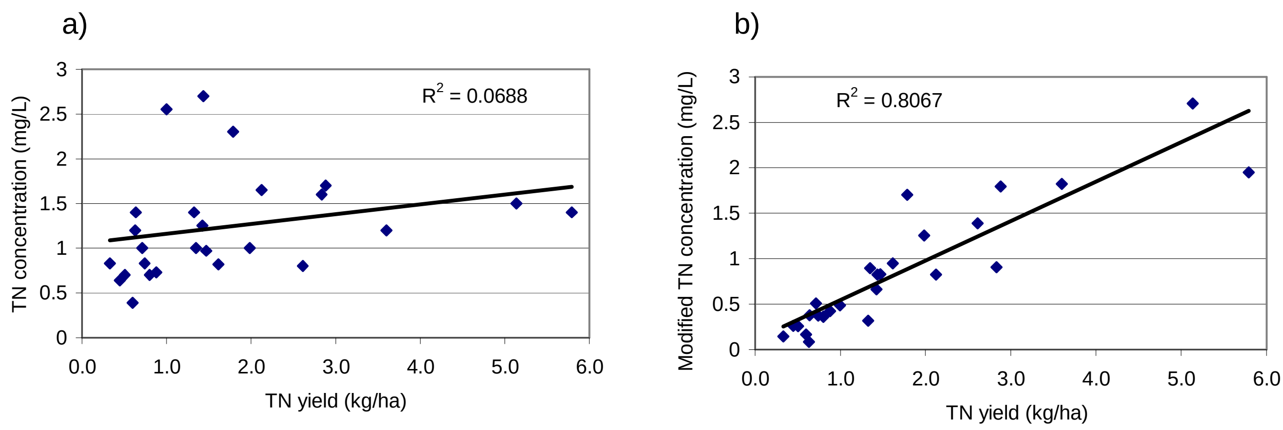


Figure 4.2 a) Winter median TN concentration as function of annual TN yield (kg/ha), and b) Winter median TN concentration modified for catchment water yield as a function of annual TN yield (kg/ha)

To allow for hydrological differences between urban and rural catchments, the concentration targets for the urban catchments were adjusted to allow for their greater runoffs, and were thus defined in terms of the catchment runoff. For catchments that are 'pervious' (those with annual runoffs of less than 100 mm) the targets for median TN and TP concentrations are the same as the HRAP targets: 1.0 mg/L and 0.1 mg/L respectively. For 'impervious' catchments (those with annual runoffs greater than or equal to 200 mm) the targets are 0.5 mg/L and 0.05 mg/L for TN and TP respectively. For moderately impervious catchments (those with annual runoffs of 100 to 200 mm) the targets are 0.75mg/L for TN and 0.075 mg/L for TP (Table 4.3). The concentration targets for each stream are given in Table 4.4.

Table 4.3 Adjusted targets for median TN and TP concentrations in tributaries of the Swan-Canning river system

Average annual runoff	**TN concentration**	**TP concentration**
< 100 mm	1.0 mg/L	0.1 mg/L
100 to < 200 mm	0.75 mg/L	0.075 mg/L
> = 200 mm	0.5 mg/L	0.05 mg/L

Table 4.4 Adjusted targets for median TN and TP concentrations for each tributary

Catchment	Area (km^2)	Impervious area (%)	Average annual runoff (mm)*	Summer flow (%)	TN target conc. (mg/L)	TP target conc. (mg/L)
Bennett	113.1	9	14	12	1.0	0.1
Helena	175.7	5	35	2	1.0	0.1
Ellen	716.4	1	38	0	1.0	0.1
Munday & Bickley	73.7	2	45	0	1.0	0.1
Henley	12.6	9	54	5	1.0	0.1
Saint Leonards	9.8	5	61	11	1.0	0.1
Upper Canning	148.9	3	73	7	1.0	0.1
Perth Airport S	24.6	17	82	3	1.0	0.1
Ellis	11.7	2	85	1	1.0	0.1
Millendon	35.2	2	90	2	1.0	0.1
Upper Swan	40.5	27	100	12	0.75	0.075
Perth Airport N	28.1	16	101	3	0.75	0.075
Jane	137.7	5	103	1	0.75	0.075
Southern	149.5	8	106	3	0.75	0.075
Helm Street	6.0	7	113	6	0.75	0.075
Susannah	54.7	3	116	0	0.75	0.075
Lower Canning	44.3	21	148	10	0.75	0.075
Blackadder	17.1	21	171	3	0.75	0.075
Yule	55.7	19	179	4	0.75	0.075
Maylands	18.7	24	208	17	0.5	0.05
CBD	13.7	28	211	17	0.5	0.05
Claisebrook	16.1	26	211	17	0.5	0.05
Downstream	26.2	25	229	18	0.5	0.05
South Belmont	10.5	28	231	17	0.5	0.05
Belmont Central	3.6	29	251	17	0.5	0.05
Mills Street	12.3	37	278	10	0.5	0.05
Bayswater	27.2	27	304	14	0.5	0.05
Bullcreek	42.5	25	347	11	0.5	0.05
Bannister	23.6	26	361	11	0.5	0.05
South Perth	40.5	21	364	11	0.5	0.05

**Average annual runoff (mm) is from simple runoff modelling prior to completion of SQUARE modelling, so slightly different runoffs in rest of document.*

4.2 Average annual load targets

For the purposes of the *Swan Canning water quality improvement plan* (SCWQIP), the average annual maximum acceptable pollutant load targets for achieving the water-quality objectives (i.e. the adjusted concentration targets discussed in Section 4.2) are required. The average annual **maximum acceptable load target** is the maximum load delivered by a stream that enables the stream to just meet its median concentration target. For streams that are meeting their concentration targets currently, the maximum acceptable load target is given as the current load.

The SCWQIP also requires load reduction targets for all the streams. The average annual **load reduction target** is the average annual current load minus the average annual maximum acceptable load target. For streams that are currently meeting their concentration targets, the load reduction targets are zero. The average annual maximum acceptable load targets and load reduction targets for TN and TP in the Swan-Canning coastal catchments deduced from the SQUARE modelling are discussed in Section 5 and shown in Table 5.6 and Table 5.7 respectively.

The load reduction targets will be used to guide management actions, as the effect of management actions are given in terms of loads. The necessary scale of catchment remediation will be determined by the load reduction targets.

The load targets have been derived using the climate sequence for the period 1997 to 2006. The loads, and thus load targets, would be different if deduced for a different period (i.e. different climate sequence) because of the dependence of load on rainfall. This needs to be considered when modelling future management options because of the drying climate in Western Australia. The drying climate must also be taken into consideration when assessing compliance with management targets.

5 SQUARE modelling results

5.1 Current catchment condition

5.1.1 Average annual flows and loads

As mentioned previously, SQUARE calculates daily flows and nutrient loads for each subcatchment of the model (Figure 3.5). Daily loads may be aggregated to produce monthly, seasonal or annual loads at any of the subcatchment outlets. In this study, the reporting catchments are the Swan-Canning coastal catchments shown in Figure 1.3. The average annual flow, nitrogen and phosphorus loads for the period 1997 to 2006 for the coastal catchments and the Avon River are shown in Table 5.1. Appendix B contains the annual loads for each year modelled (1997–2006) for each of the coastal catchments. The annual loads for the Avon River (Table 5.2) were calculated with a locally-estimated scatterplot smoothing load algorithm (LOESS 2009) using observed flow and TN and TP concentration data from site 616011 at Walyunga.

The 30 Swan-Canning coastal catchments and the Avon River deliver nutrients to the Swan River and Estuary, the Canning River above Kent Street Weir and the Canning Estuary below Kent Street Weir. The Avon River becomes the Swan River at its confluence with Wooroloo Brook in Walyunga National Park. The amount of nitrogen and phosphorus delivered to the various parts of the Swan-Canning estuary are highlighted in Table 5.1.

In an average year, 830 tonnes of nitrogen are delivered to the Swan-Canning estuary – 575 tonnes (70%) from the Avon and 250 tonnes (30%) from the coastal catchments; while 46 tonnes of phosphorus are delivered – 20 tonnes (43%) from the Avon and 26 tonnes (57%) from the coastal catchments. The flow volume for an average year is 443 GL – 254 GL (57%) from the Avon River and 189 GL (43%) from the coastal catchments (Figure 5.1).

The Avon River and the Swan River catchments on the coastal plain contribute almost equal amounts of phosphorus to the Swan Estuary: 20 and 18 tonnes respectively. The Avon contributes proportionally much greater amounts of nitrogen (575 tonnes) than the coastal plain catchments (170 tonnes). However, the timing of delivery is important. Much of the nitrogen from the Avon that comes in large winter flows goes directly to the ocean with little impact on the estuary (LOICZ 2000). On the other hand, some of the drains and smaller rural catchments of the Swan deliver large amounts of nutrients to the rivers and estuaries during summer and autumn when the conditions are best for algal blooms and neither Ellen Brook nor the Avon River are flowing. The seasonal delivery of nutrients is discussed further in Section 5.1.3.

The average annual nutrient inputs above the Kent Street Weir on the Canning River are approximately 50 tonnes of nitrogen and 4.3 tonnes of phosphorus. Although much of this is delivered in winter when the weir is open to the estuary, there are sufficient nutrients delivered in spring, summer and autumn or built up in the sediments to drive algal blooms in the Kent Street Weir pool when the weir boards are in place. The main contributor to the

Kent Street Weir pool is the Southern River catchment, which delivers about half the nutrients. Approximately 35 tonnes of nitrogen and 3.4 tonnes of phosphorus are delivered to the Canning Estuary below Kent Street Weir in an average year.

Table 5.1 Average annual loads of nitrogen and phosphorus to the Swan-Canning estuary for the period 1997 to 2006

Catchment	Area (km^2)	Average annual discharge (ML)	Annual average nitrogen load (tonnes)	Annual average phophorus load (tonnes)
Swan River and Estuary:				
Avon River	**123 900**	**253 900**	**575**	**20**
Swan coastal tributaries:				
Bayswater	27.2	8 267	9.8	0.60
Belmont Central	3.6	900	0.7	0.06
Bennett	113.1	4 997	7.1	0.42
Blackadder	17.1	2 993	2.5	0.17
CBD	13.7	2 413	5.2	0.24
Claisebrook	16.1	3 411	4.7	0.30
Downstream	26.2	5 852	6.9	0.30
Ellen	716.4	26 750	71	10
Helena	175.7	4 876	5.8	0.23
Henley	12.6	681	0.8	0.05
Jane	137.7	14 780	11	0.58
Maylands	18.7	3 726	11	0.27
Millendon	35.2	3 154	2.6	0.15
Perth Airport N	28.1	3 070	2.0	0.21
Perth Airport S	24.6	2 048	1.1	0.17
Saint Leonards	9.8	594	1.4	0.14
South Belmont	10.5	2 427	1.7	0.24
South Perth*	27.0	9 487	8.5	1.3
Susannah	54.7	6 207	4.8	0.65
Upper Swan	40.5	4 004	8.6	2.0
Subtotal (Swan coastal tributaries)	1 508	110 600	170	18
Canning River above Kent Street Weir:				
Ellis	11.7	1 427	0.7	0.02
Helm Street	6.0	765	1.7	0.07
Lower Canning	44.3	6 560	7.9	0.97
Munday & Bickley	73.7	3 343	2.9	0.14
Southern	149.5	16 040	21	2.2
Upper Canning	148.9	10 830	7.5	0.42
Yule	55.7	7 574	7.5	0.43
Subtotal	490	46 540	50	4.3
Canning Estuary below Kent Street Weir:				
Bannister	23.6	8 557	12	0.82
Bullcreek	42.5	14 444	11	1.2
Mills Street	12.3	4 418	7.1	0.78
South Perth*	13.5	4 743	4.2	0.65
Subtotal	91.9	32 160	35	3.4
Subtotal (coastal catchments)	**2 090**	**189 300**	**250**	**26**
Total	**126 000**	**443 200**	**830**	**46**

**South Perth delivers approximately 2/3 of its flow and nutrient yield to the Swan Estuary and the remainder to the Canning Estuary*

Table 5.2 Annual loads of nitrogen and phosphorus from the Avon River, site 616011 for the period 1997 to 2006.

Year	**Annual flow (GL)**	**Annual nitrogen load (tonnes)**	**Annual phosphorus load (tonnes)**
1997	184	248	7.7
1998	196	257	8.0
1999	589	1450	42
2000	576	2400	96
2001	91	116	3.9
2002	88	84	2.5
2003	278	428	14
2004	119	139	4.0
2005	305	458	16
2006	114	161	5.5
Average	**254**	**575**	**20**

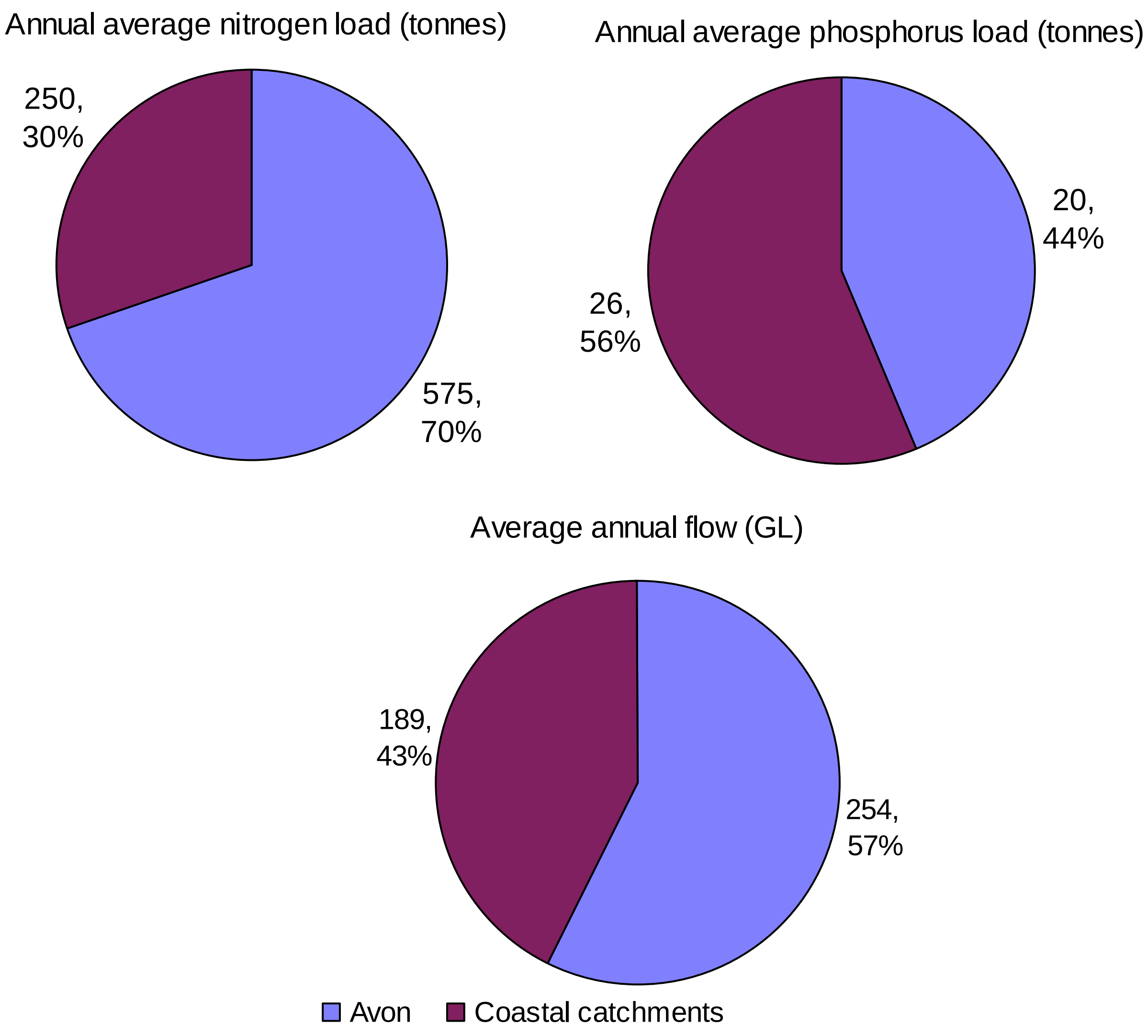


Figure 5.1 Average annual flow, nitrogen and phosphorus loads to the Swan-Canning estuary

5.1.2 Annual delivery of nutrients

Figure 5.2 displays the annual flows for the Avon River and the total annual flow for all the Swan-Canning coastal catchments for the period 1997 to 2006. In years of high rainfall, the Avon contributes annual flows greater than the flows from the coastal catchments; whereas in low rainfall years, the Avon contributes less annual flow than the coastal catchments. Even though on average (1997–2006) the Avon contributed 34% more flow than the coastal catchments, in the drier years of 2001 and 2002 it contributed only 63% and 55% of the coastal catchments' flow volume respectively.

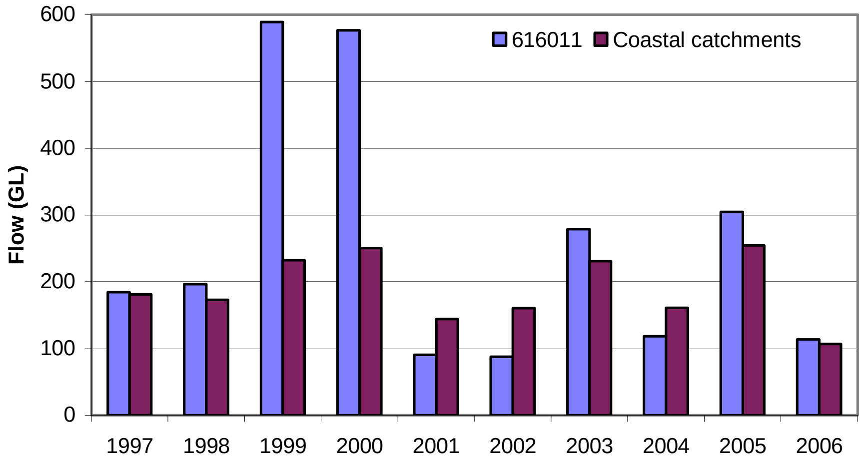


Figure 5.2 Annual flows (GL) from the Avon River (site 616011) and the coastal catchments

Figure 5.3 displays the annual nitrogen loads for the Avon River and the coastal catchments. The nitrogen loads for the low- and medium-flow years reflect the annual flow volumes; however, for the high-flow years of 1999 and 2000, the nitrogen loads from the Avon are disproportionately greater than those from the coastal catchments.

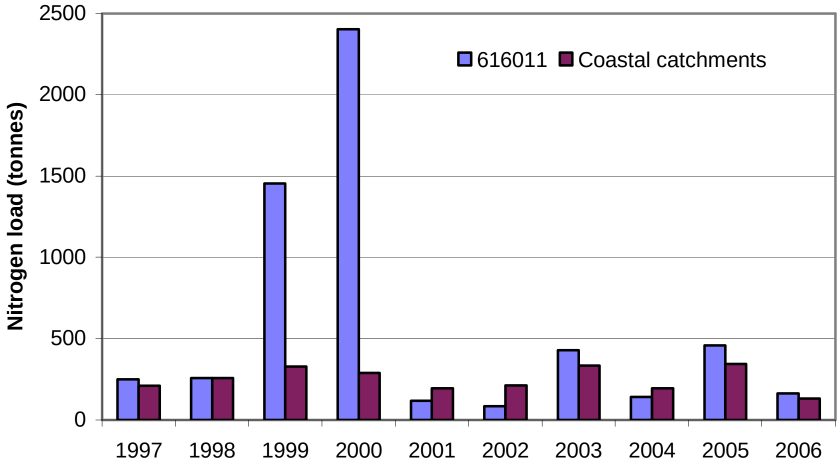


Figure 5.3 Annual nitrogen load (tonnes) from the Avon River (site 616011) and the coastal catchments

Similar to the annual nitrogen loads, the annual phosphorus loads from the coastal catchments (Figure 5.4) reflect the annual flow volumes. However, the phosphorus loads from the Avon are disproportionately smaller in low- and medium-flow years. This indicates a strong positive correlation between daily flow and concentration. Large amounts of phosphorus are mobilised in high-flow events and low flows have relatively low concentrations. This is particularly apparent in the extreme weather event of 2000 where 47% of annual flow and approximately 80% of annual nitrogen and phosphorus loads flowed into the estuary in the three-week period from 23 January following cyclonic rainfall.

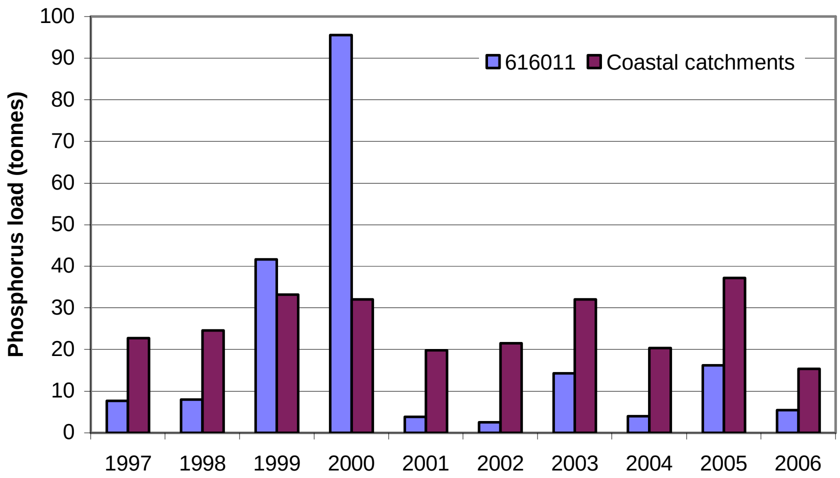


Figure 5.4 Annual phosphorus load (tonnes) from the Avon River (site 611011) and the coastal catchments

Historically, the Avon River has delivered more water to the estuary than for the period 1997 to 2006 as shown in Figure 5.5. The average annual flow from the Avon River was 392 GL for the period 1974 to 1996, whereas the average annual flow for the period 1997 to 2006 was 254 GL (35% reduction). This decrease in flow volume due to the drying climate in southern Western Australia means the estuaries are less flushed, more saline and the water quality of flows from the coastal catchments has a greater impact than previously. As well as having high nutrient loads, urban drains may contain metals, detergents, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, endocrine-disrupting chemicals and other pollutants typical of the urban environment (Nice et al. 2009).

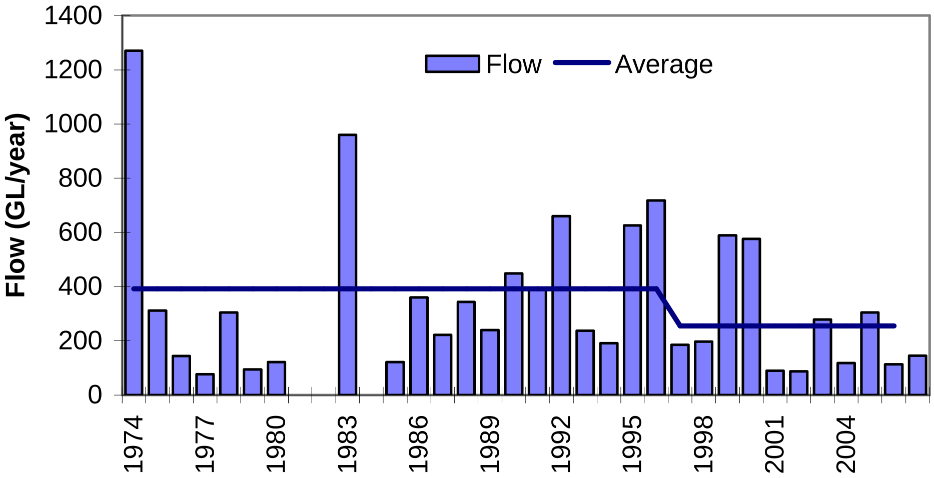


Figure 5.5 Annual flows (GL) from the Avon River (site 616011)

5.1.3 Seasonal delivery of nutrients

The timing of rainfall is important. Even though the annual flow from the Avon River had a similar volume for 1999 and 2000 (about 590 GL), the timing of the rainfall was different. In 1999 the flow from the Avon River followed a typical pattern of no flow in summer, flow starting with the onset of the winter rainy season, high flows in winter and then dropping off towards the end of the year (Figure 5.6). In 2000, however, the flow was dominated by a cyclonic event in January and the winter flows were similar to those of a typical year such as 2003. This unusual summer flow from the Avon River in January and February 2000 brought a large amount of nutrients into the estuary and caused a bloom of the toxic cyanobacteria *Microcystis aeruginosa,* which closed the Swan Estuary for recreation and fishing for 12 days due to the human health risk.

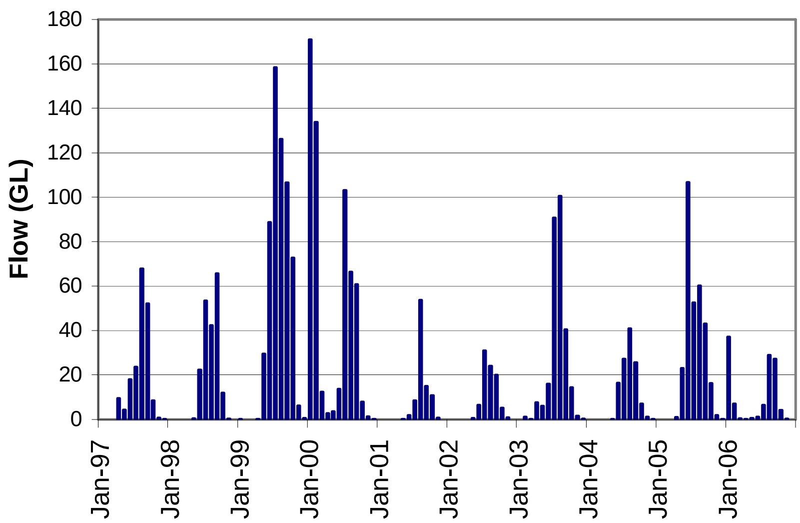


Figure 5.6 Monthly flows from the Avon River (site 616011)

The toxic bloom of February 2000 was unusual and unique. The *Microcystis aeruginosa* that bloomed, due to the fresh water, sunny conditions and plentiful nutrients was most likely brought into the estuary with the flow, as it had not been observed in the estuary previously. Generally, a regular cycle of algal growth occurs in the Swan-Canning estuary every year – usually from spring to autumn. The succession pattern of the blooms is affected by the timing of flows and nutrient inputs, sediment nutrient release and changes in salinity. Blooms of different species can occur concurrently. Figure 5.7 shows the general succession pattern for algal blooms in the Swan-Canning estuary (WRC 2005).

The impervious urban catchments have significant flows in summer when the Avon River, Ellen Brook and several other rural catchments have no or small flow volumes, as shown in Table 4.2. As the conditions in summer and autumn are often favourable for algal blooms, decreasing the nutrient inputs from the impervious urban catchments in this period may significantly improve the health of the Swan-Canning estuary.

The year 1997 was a fairly average year in terms of total flow volume in the coastal catchments and the Avon River, and the rainfall had the typical winter pattern (Figure 5.2 and Figure 5.6). The annual flow volumes and nitrogen loads from the Avon River and the coastal catchments were approximately equal, whereas the phosphorus load from the coastal catchments was approximately three-times that of the Avon River (Figure 5.4). The monthly flow volumes, nitrogen and phosphorus loads for the Avon River and coastal catchments for 1997 are shown in Figure 5.8, and the contributions for Ellen Brook are highlighted in Figure 5.9.

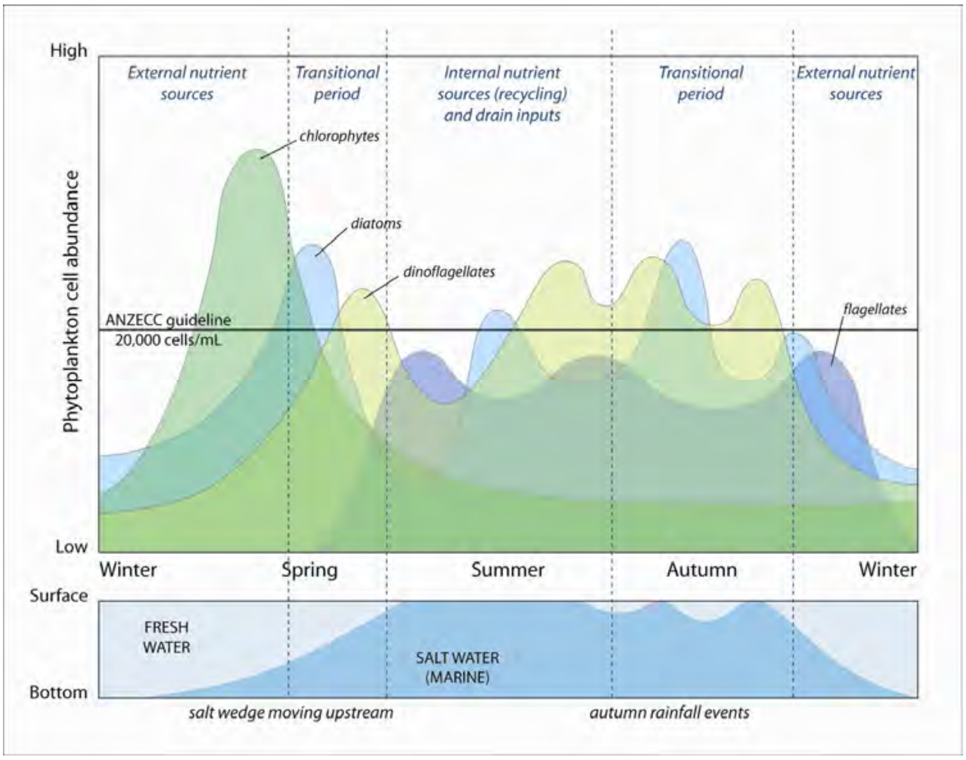


Figure 5.7 General succession of phytoplankton in the Swan-Canning estuary. Note that the vertical scale is arbitrary. Peaks in abundance are many times higher than background numbers (from River Science 3, WRC 2005)

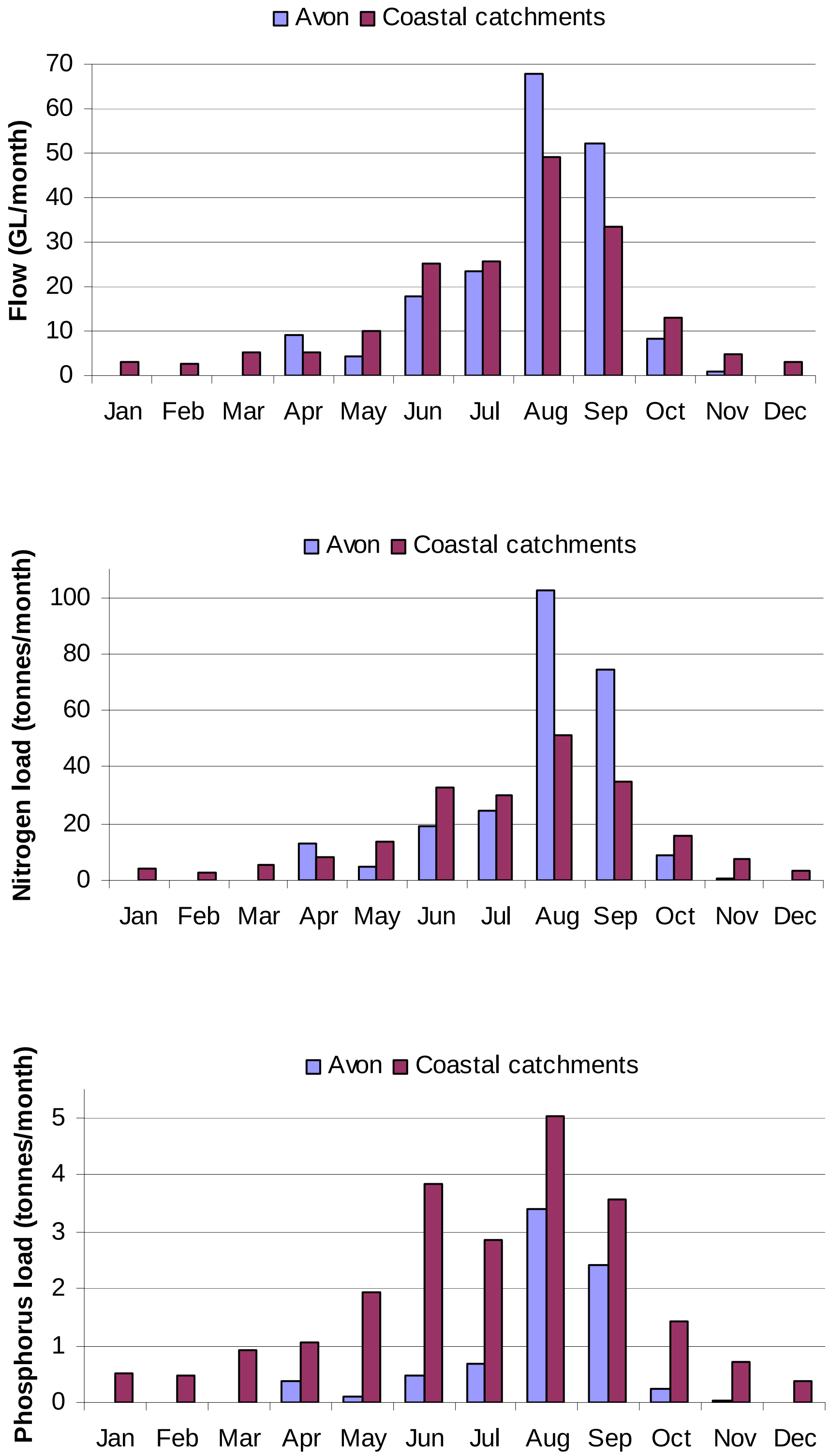
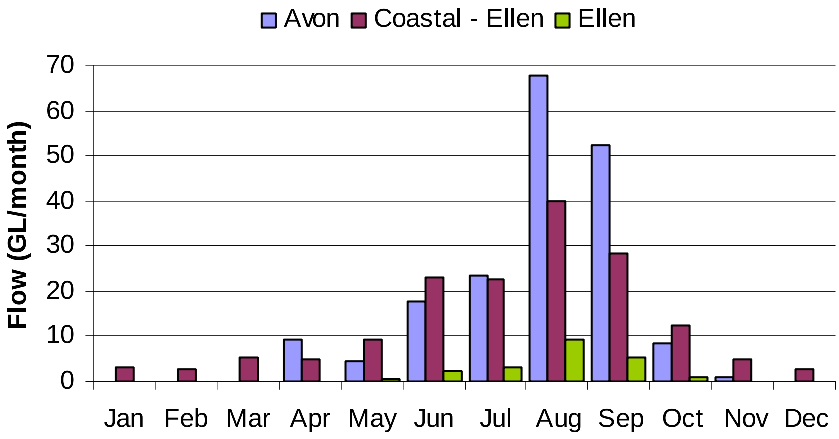
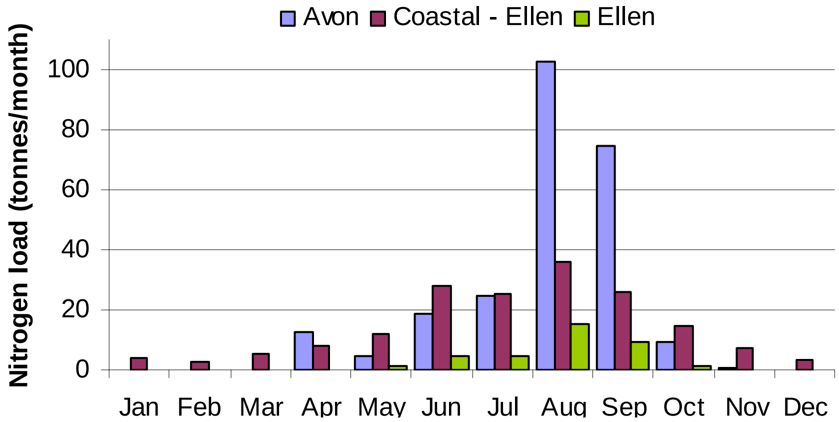


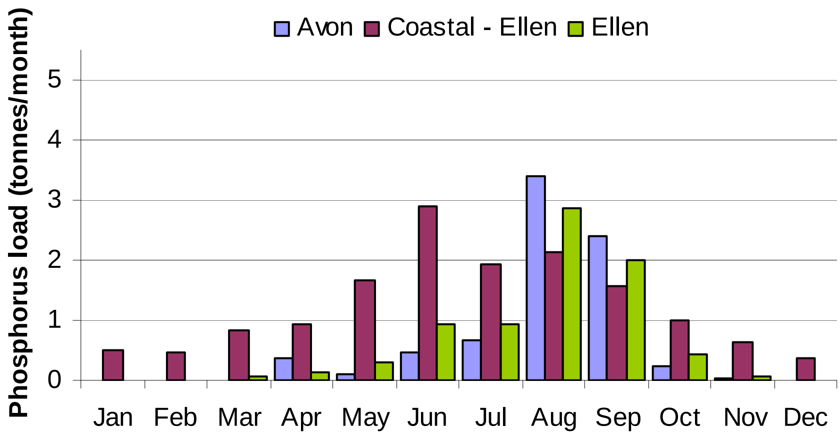
Figure 5.8 Monthly flows, nitrogen and phosphorus loads for the Avon River and coastal tributaries for 1997



Ellen Brook contributes 12% of the annual flow from the coastal catchments.



Ellen Brook contributes 15% of the annual nitrogen load from the coastal catchments.



Ellen Brook contributes 30% of the annual phosphorus load from the coastal catchments.

Figure 5.9 Monthly flows, nitrogen and phosphorus loads from the Avon River, the coastal tributaries not including Ellen Brook, and Ellen Brook for 1997. Ellen Brook catchment constitutes 34% of the catchment area of the coastal catchments.

Figure 5.8 shows that the monthly nitrogen loads correlate well with the monthly flow volumes. However, the high-flow months of August and September show a relative decrease in nitrogen load compared with flow in the coastal tributaries and a relative increase in the Avon River. This indicates that nitrogen concentrations are diluted in high flows on the coastal plain, but the reverse is true in the Avon, where greater flows mobilise proportionally greater amounts of nitrogen. A 'first flush' nitrogen concentration increase can also be seen in the coastal tributaries, as the flow volume is less in June than July, although the nitrogen load is greater.

The total phosphorus loads from the coastal tributaries are much greater in all months of the year than those from the Avon River, and significant phosphorus input occurs during the dry season (from October to May) when there is little or no phosphorus input from the Avon River. The 'first flush' effect for phosphorus (the June load compared with the July load) in the coastal tributaries is greater than for nitrogen.

Figure 5.9 displays the monthly flows, nitrogen and phosphorus loads for the Avon River, coastal tributaries not including Ellen Brook, and Ellen Brook for 1997. The annual flow in Ellen Brook in 1997 was 12% of the flow from all the coastal tributaries even though it occupies 34% of the area of the coastal catchments. There was very little or no flow from Ellen Brook in January to April and October to December. The nitrogen inputs from Ellen Brook reflected the flow input with May to September being the months with significant nitrogen inputs. In 1997 Ellen Brook contributed 15% of the total nitrogen input of the coastal catchments.

The phosphorus inputs from Ellen Brook for 1997 were more significant and constituted 30% of the inputs from the coastal catchments. This indicates, on an annual basis, that Ellen Brook is contributing its 'share' of phosphorus input – as it constitutes approximately 34% of the catchment area. The timing of delivery is important – Ellen Brook has small or no phosphorus inputs in a typical year (such as 1997) from November to April when the conditions are favourable for algal blooms. In 1997, the total monthly phosphorus inputs from all the other coastal tributaries were much greater than those from Ellen Brook, except in the wettest months of August and September. This is because many of the tributaries (drains) in the urban areas flow all year, and the impervious nature of the urban catchments means that even small rainfall events produce significant flows.

The total phosphorus load from Ellen Brook is huge (approximately 70 tonnes in an average year) when compared with the other coastal catchments (next-largest contributor is Southern River with approximately 20 tonnes). As most of the Ellen Brook nutrient load is delivered in the large winter flows, little impact on the loads will be made through management actions that address nutrient delivery in low flows (such as zeolite and laterite filters and wetlands). To address the nutrient inflows from Ellen Brook, either management actions that decrease the nutrient inputs to the catchment or large-scale engineering interventions that treat the winter flows are required. The scenario modelling for Ellen Brook included in Appendix B shows the results of several management scenarios.

5.2 Sources of nutrients

5.2.1 Nutrient loads by subcatchment

For the coastal catchments and the Avon River, the average annual loads and the average annual loads per unit cleared area for nitrogen and phosphorus are listed in Table 5.3. ‘Cleared area’ is used to normalise the catchment exports because it gives a better indication of the intensity of nutrient exports from developed land than normalisation by total catchment area. The coastal catchments’ loads and loads per cleared area are shown in Figures 5.10, 5.11, 5.12 and 5.13. The load per unit cleared area for the Avon is low because of its low-intensity land use, and also because in most years flow from the catchment’s upper reaches does not reach the Swan River.

Table 5.3 Average annual flow, nitrogen and phosphorus loads and loads per unit cleared area for the Avon River and coastal catchments for 1997 to 2006

Catchment	Area (km^2)	Cleared area (km^2)	Cleared area (%)	Average annual discharge (ML)	Average annual nitrogen load (tonnes)	Nitrogen load per cleared area (kg/ha)	Average annual phosphorus load (tonnes)	Phosphorus load per cleared area (kg/ha)
Avon	123 891	107 785	87	254 000	575	0.53	20	0.019
Bannister	23.6	20.2	86	8 560	12	5.99	0.82	0.41
Bayswater	27.2	26.4	97	8 270	9.8	3.72	0.60	0.23
Belmont Central	3.6	3.2	90	900	0.7	2.21	0.06	0.19
Bennett	113.1	74.6	66	5 000	7.1	0.95	0.42	0.06
Blackadder	17.1	13.6	80	2 990	2.5	1.84	0.17	0.13
Bullcreek	42.5	39.3	92	14 400	11	2.83	1.2	0.31
CBD	13.7	12.7	93	2 410	5.2	4.09	0.24	0.19
Claisebrook	16.1	15.8	98	3 410	4.7	2.95	0.30	0.19
Downstream	26.2	24.1	92	5 850	6.9	2.86	0.30	0.12
Ellen	716.4	387.4	54	26 800	71	1.84	10	0.26
Ellis	11.7	4.2	36	1 430	0.7	1.65	0.02	0.05
Helena	175.7	63.1	36	4 880	5.8	0.92	0.23	0.04
Helm Street	6.0	3.4	57	765	1.7	4.99	0.07	0.21
Henley	12.6	8.0	64	681	0.8	0.96	0.05	0.06
Jane	137.7	66.9	49	14 800	11	1.65	0.58	0.09
Lower Canning	44.3	32.8	74	6 560	7.9	2.41	0.97	0.30
Maylands	18.7	18.0	96	3 730	11	6.18	0.27	0.15
Mills Street	12.3	11.7	96	4 420	7.1	6.04	0.78	0.66
Millendon	35.2	18.5	53	3 150	2.6	1.41	0.15	0.08
Munday & Bickley	73.7	26.3	36	3 340	2.9	1.10	0.14	0.05
Perth Airport N	28.1	25.3	90	3 070	2.0	0.79	0.21	0.08
Perth Airport S	24.6	18.3	74	2 050	1.1	0.60	0.17	0.09
Saint Leonards	9.8	5.6	57	594	1.4	2.50	0.14	0.25
South Belmont	10.5	10.2	97	2 430	1.7	1.67	0.24	0.24
South Perth	40.5	38.1	94	14 200	13	3.33	1.9	0.51
Southern	149.5	89.0	60	16 000	21	2.39	2.2	0.25
Susannah	54.7	35.9	66	6 210	4.8	1.34	0.65	0.18
Upper Canning	148.9	36.6	25	10 800	7.5	2.05	0.42	0.11
Upper Swan	40.5	33.5	83	4 000	8.6	2.56	2.0	0.60
Yule	55.7	43.5	78	7 570	7.5	1.73	0.43	0.10
Coastal catchments	2 090	1 206	58	189 000	250	2.09	26	0.21

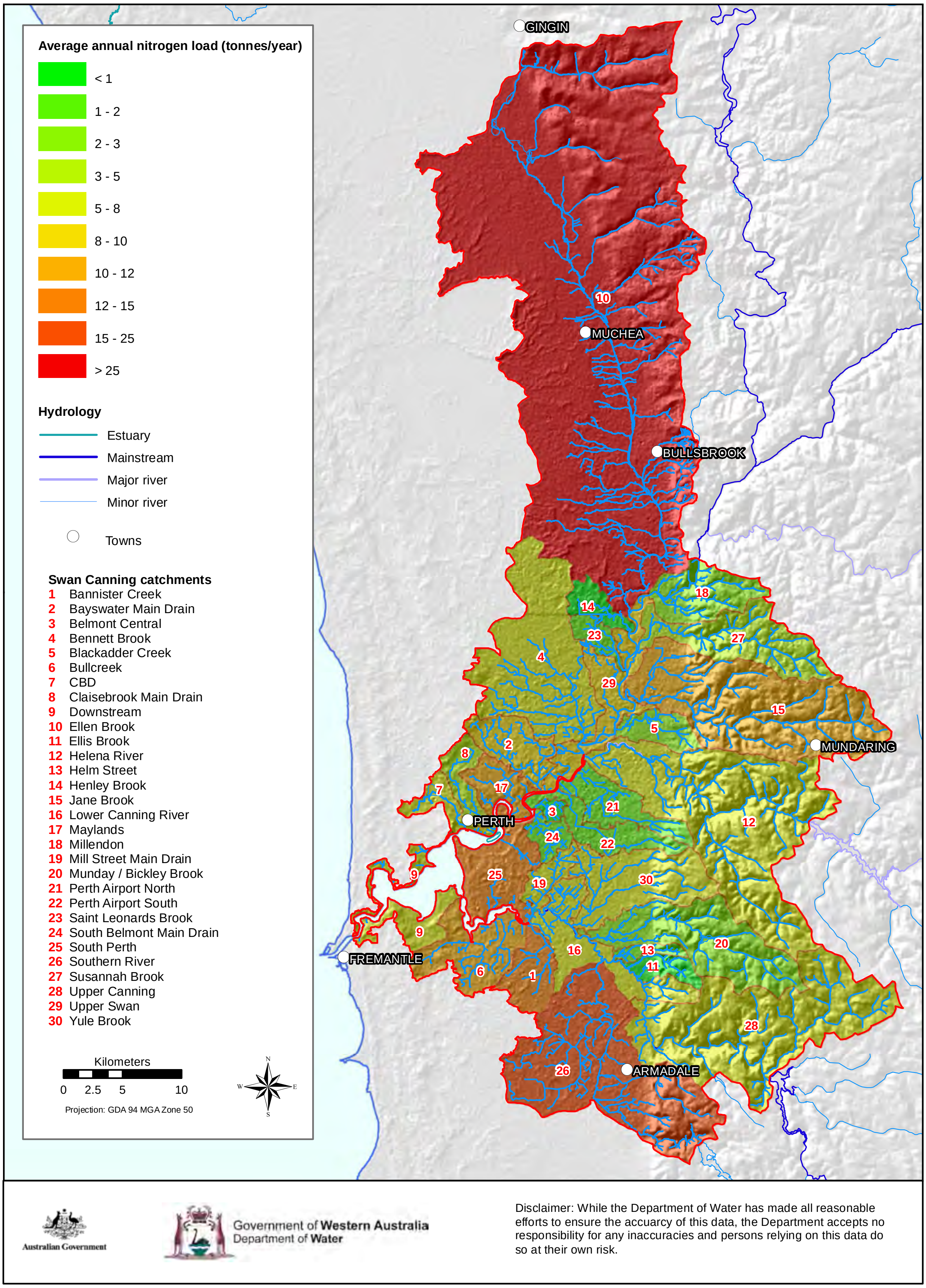


Figure 5.10 Average annual nitrogen export (tonnes) from the coastal catchments

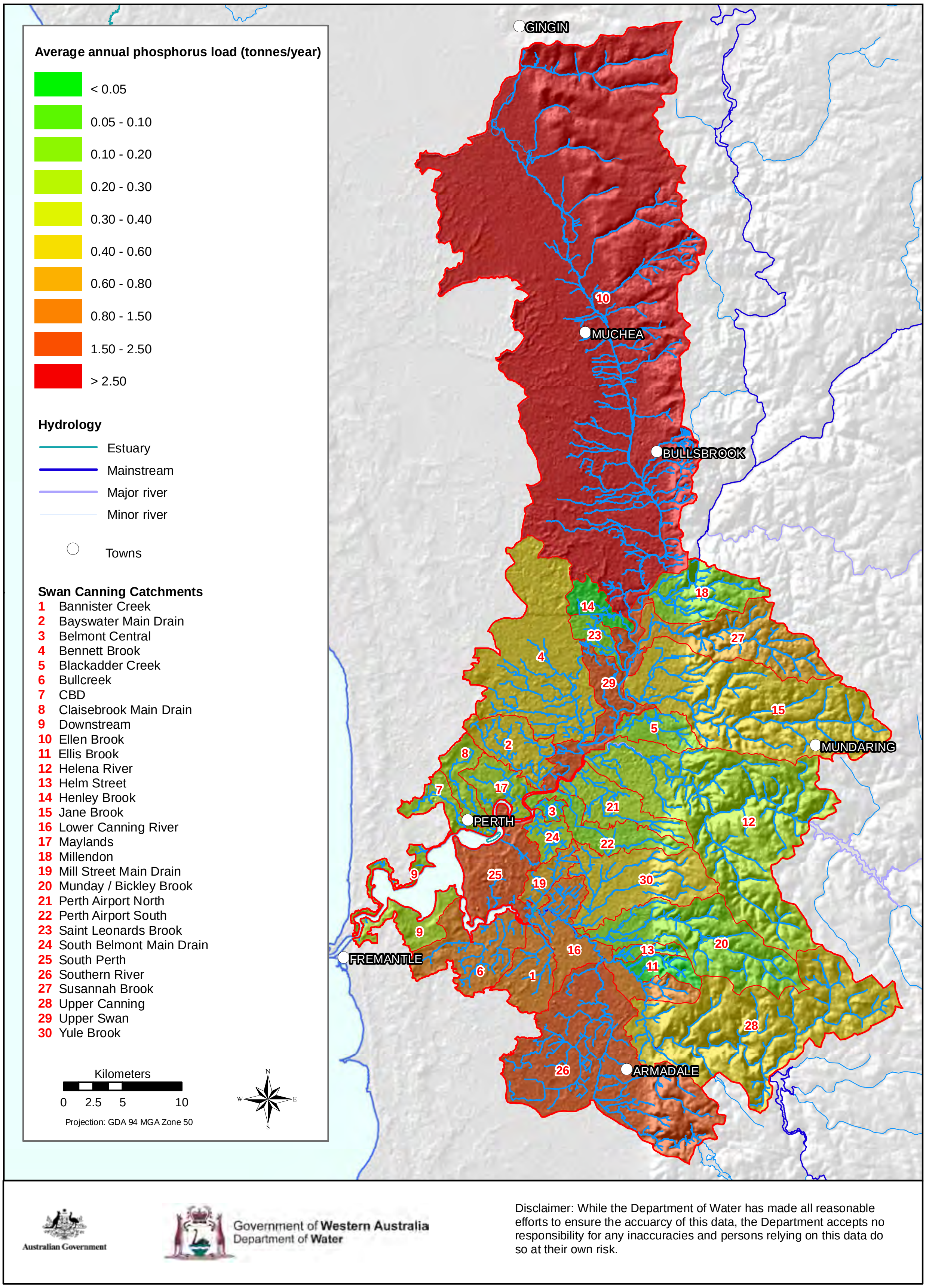


Figure 5.11 Average annual phosphorus export (tonnes) from the coastal catchments

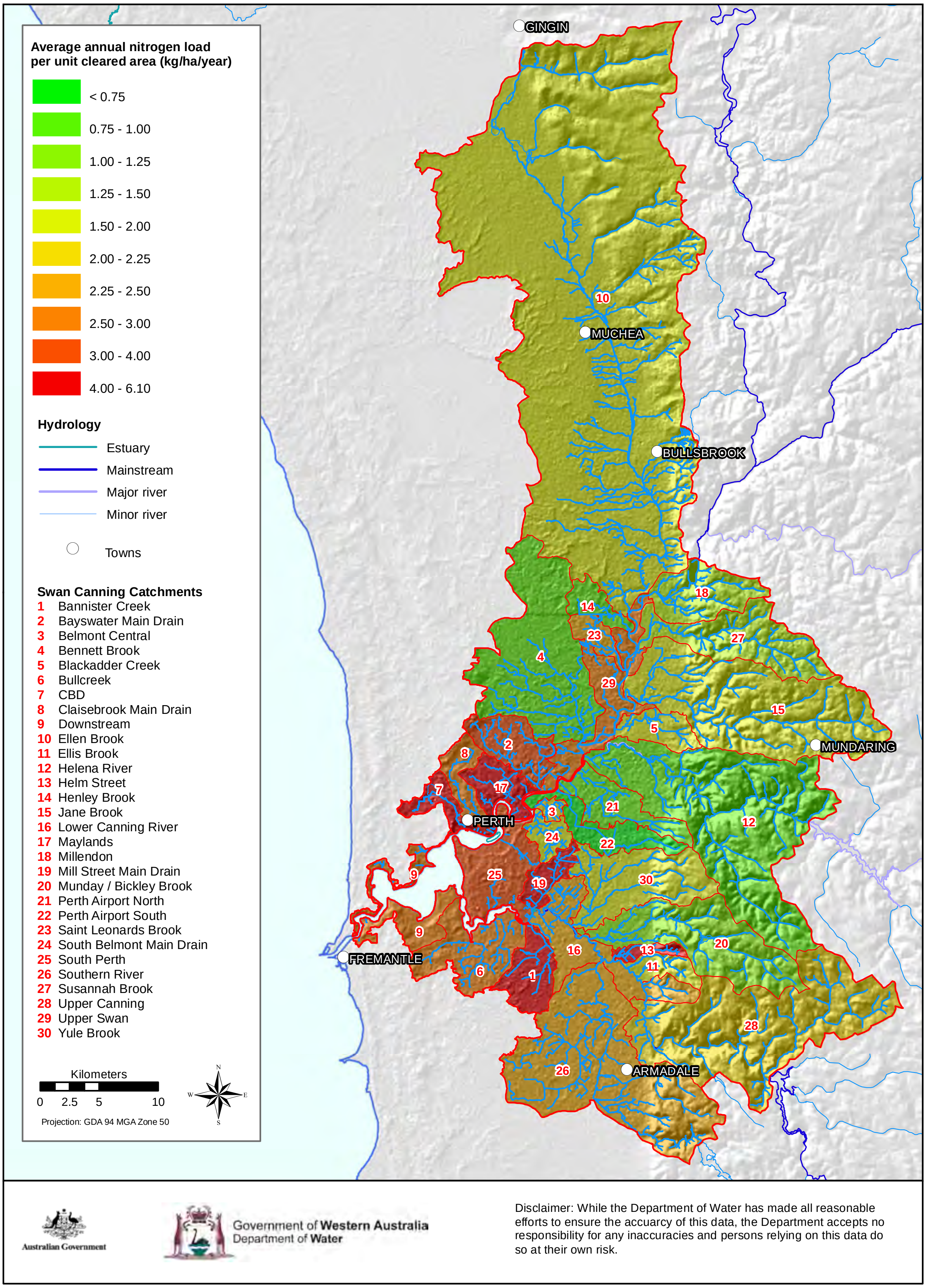


Figure 5.12 Average annual nitrogen export per unit cleared catchment area (kg/ha) for the coastal catchments

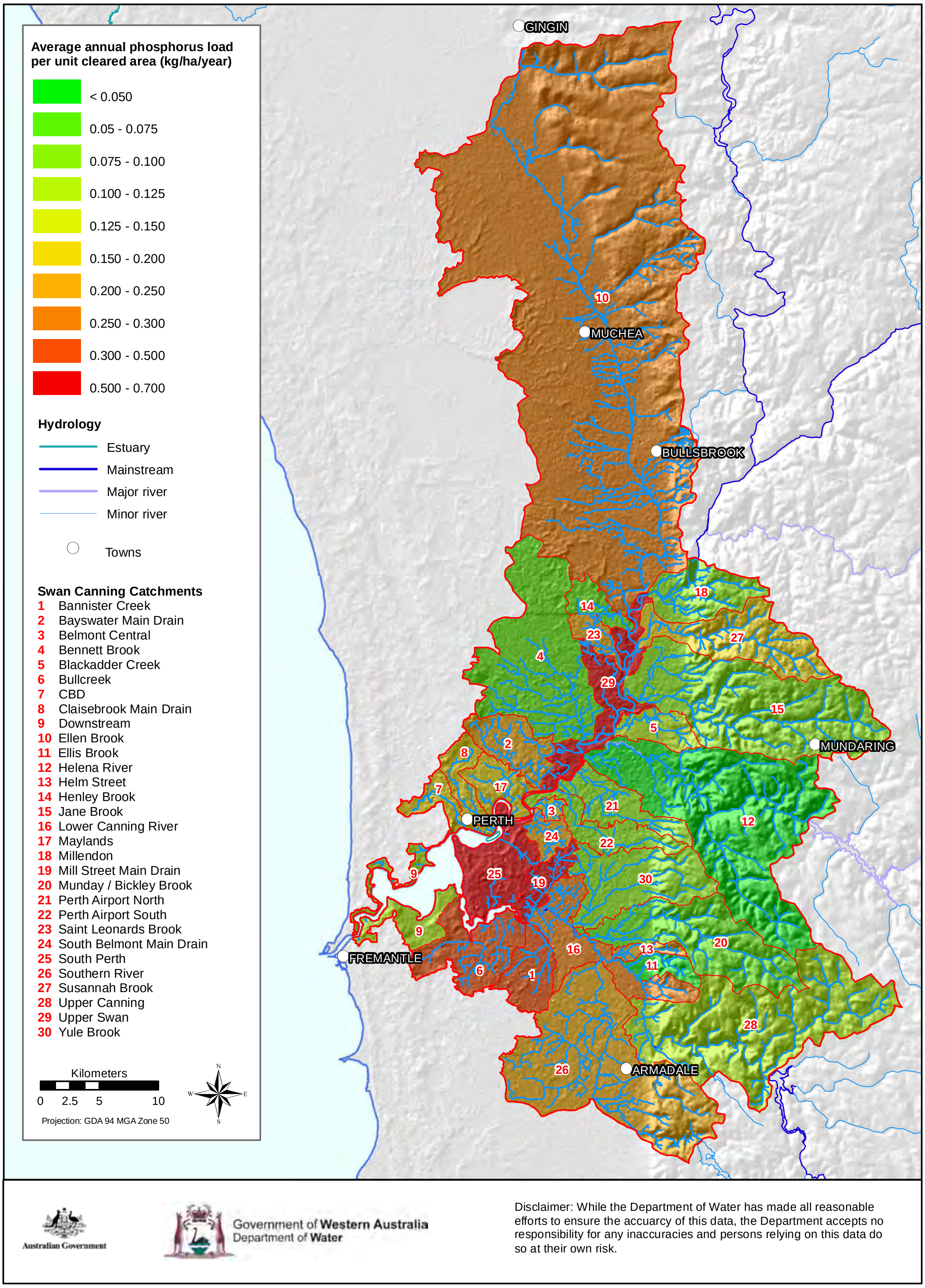


Figure 5.13 Average annual phosphorus export per unit cleared catchment area (kg/ha) for the coastal catchments

Mills Street Main Drain catchment has intensive land uses and exports approximately 6 kg/ha/year of nitrogen and 0.66 kg/ha/year of phosphorus from its developed areas (a large contribution is from septic tanks). Maylands and Bannister Creek catchments export about 6 kg/ha/year of nitrogen from the cleared land; and the Upper Swan and South Perth catchments have high phosphorus exports – 0.6 and 0.5 kg/ha/year respectively. All of these catchments have large percentages of cleared area (> 83%).

Ellen Brook is the greatest nutrient exporter because of its large size: 71 tonnes of nitrogen and 10 tonnes of phosphorus per year. Its nitrogen export rate of 1.84 kg/ha/year is less than the median value of 2.13 kg/ha/year, but its phosphorus export rate of 0.26 kg/ha/year is much greater than the median value of 0.18 kg/ha/year – although less than the export rates from six urban catchments (Lower Canning, Bullcreek, Bannister, South Perth, Upper Swan and Mills Street) which have export rates ranging from 0.30 kg/ha/year to 0.66 kg/ha/year) (Table 5.3).

The Upper Canning catchment has the 15th highest nitrogen and 11th highest phosphorus export rates per cleared area of the 30 coastal catchments (2.05 kg/ha/year and 0.11 kg/ha/year). Despite this, it has very good water quality (median TN 0.72 mg/L and median TP 0.03 mg/L) because 75% of its area is forested.

5.2.2 Nutrient export by land use (source separation)

The land-use map for the coastal catchments is shown in Figure 2.8. The SQUARE modelling of the Swan-Canning coastal catchments did not include the Avon catchment, so the nutrient sources within the Avon catchment have not been identified.

The SQUARE modelling encompassed the land uses listed in Table 3.1 and Table 3.2, which have been grouped into 10 categories for reporting purposes (Table 5.4). Table 5.5 contains the areas of each of the land-use categories and their average annual nitrogen and phosphorus exports for the Swan-Canning coastal catchments. The relative areas and exports are also shown in Figure 5.14. Similar pie charts are given for each catchment in Appendix B.

Table 5.4 Land-use groupings

SQUARE land use	Land use categories
Residential - single / duplex dwelling Residential - aged persons Residential - multiple dwelling Residential - temporary accommodation	Residential
Garden centre / nursery Horticulture Plantation Turf Farm	Horticulture & plantation
Recreation - grass Recreation - turf	Recreation
Viticulture	Viticulture
Animal keeping - non-farming Horses	Horses
Farm	Farm
Lifestyle block / hobby farm	Lifestyle block / hobby farm
Commercial / service - centre Commercial / service - residential Office - with parkland Office - without parkland Community facility - education Community facility - non-education	Commercial & education
Drainage Recreation / conservation - trees / shrubs Rural residential / bush block Unused - cleared - grass Unused - uncleared - trees / shrubs Unused - uncleared - tree / shrub cover Water body	Conservation & natural
Landfill Manufacturing / processing Quarry / extraction Sewage - non-treatment plant Sewage - treatment plant Storage / distribution Transport / access - airport Transport / access - non-airport Unused - cleared - bare soil Utility Yacht facilities	Industry, manufacturing & transport

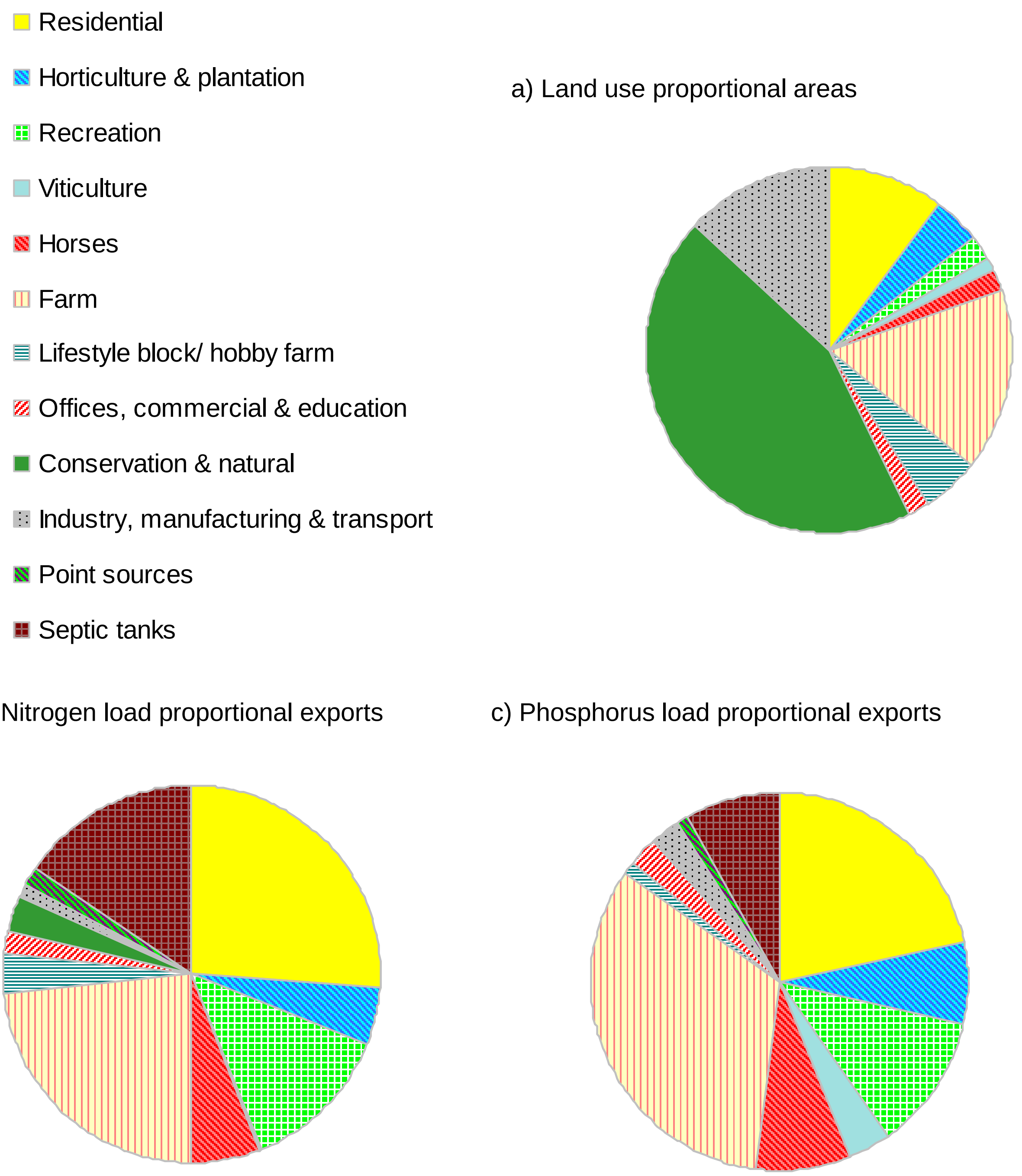


Figure 5.14 Source separation for the Swan-Canning coastal catchments

Table 5.5 Land-use areas and nitrogen and phosphorus exports for the coastal catchments

Land Use	Area		Nitrogen Export		Phosphorus Export	
	(km^2)	%	(tonnes)	%	(tonnes)	%
Residential	214	10	66	26	5.6	22
Horticulture & plantation	86	4	12	5	1.8	7
Recreation	50	2	32	13	3.0	12
Viticulture	23	1	0.9	0	0.92	4
Horses	37	2	14	6	2.1	8
Farm	339	16	59	23	8.4	33
Lifestyle block/ hobby farm	104	5	7.9	3	0.29	1
Offices, commercial & education	40	2	5.2	2	0.70	3
Conservation & natural	924	44	7.5	3	0.00	0
Industry, manufacturing & transport	273	13	3.1	1	0.61	2
Point sources			3.9	2	0.29	1
Septic tanks			39	16	2.1	8
Total	2090	100	250	100	26	100

Point sources contribute approximately 2% of the nitrogen and 1% of the phosphorus exports from the coastal catchments. However, it should be noted that data for nutrient emissions from small point sources are difficult to obtain. Only three point sources that discharge directly to water were included: Swan Brewery, Ranford Road tip and a feedlot in Ellen Brook catchment (see Section 3.2). Further investigation of nutrient exports from point sources on the Swan Coastal Plain is warranted, particularly for historic landfill and liquid waste disposal sites.

Septic tanks contribute a further 16% of the nitrogen and 8% of the phosphorus. Farming, mainly in the Ellen Brook catchment, is the greatest contributor of phosphorus load at 33%. This is followed by residential areas, which contribute 22% of the phosphorus load but are the biggest contributors of nitrogen at 26%. The other land uses that are significant contributors are ‘recreation’ which includes golf courses and fertilised playing fields – 13% of the nitrogen and 12% of the phosphorus load – and ‘horses’ (predominantly in Ellen Brook catchment) – 6% of the nitrogen and 8% of the phosphorus load. Note that ‘recreation’ contributes relatively large loads of nitrogen and phosphorus compared with its area (2%). Horticultural land uses have high fertilisation rates but as their area is relatively small, they only contribute approximately 5% of the nitrogen and 7% of the phosphorus load to the estuaries.

Even though ‘conservation and natural’ land uses make up a large area of the catchment (44%), outputs from these areas are estimated to be small – less than 0.1% for phosphorus and 3% for nitrogen. Estimations of nutrient loads to the estuaries for pre-European times have not been made, as the hydrology has been altered so greatly that pre-European flow estimations are difficult. However under natural conditions the nutrient concentrations would be at least an order of magnitude less (compared with those in the pervious catchments); thus pre-European nutrient loads would be expected to be an order of magnitude less than the current loads.

5.3 Load reduction targets

The annual maximum acceptable loads for each subcatchment were deduced by progressively reducing the fertilisation inputs in the SQUARE model until the estimated TN and TP concentrations in the streams agreed with the median winter concentration targets for TN and TP (Table 4.4). For streams that are already meeting the concentration targets, the maximum acceptable loads are the current loads.

The average annual maximum acceptable loads and the average annual current loads for the period 1997 to 2006 for nitrogen and phosphorus are shown in Table 5.6 and Table 5.7 and Figures 5.15 and 5.16. The average annual load reduction target, defined as the average annual current load minus the average annual maximum acceptable load, is also listed.

Table 5.6 Nitrogen current loads, load reduction targets and maximum acceptable loads for the period 1997 to 2006

Catchment	Current load (1997–2006) (tonnes/ year)	Load reduction target (tonnes/ year)	Maximum acceptable load (tonnes/ year)	Current winter median conc (mg/L)	Target winter median conc (mg/L)	% Load reduction
Bannister	12	8.2	3.9	1.51	0.5	68
Bayswater	9.8	5.8	4.0	1.22	0.5	59
Belmont Central	0.7	0.4	0.3	0.92	0.5	58
Bennett	7.1	2.3	4.8	1.46	1.0	32
Blackadder	2.5	0.4	2.1	0.91	0.75	16
Bullcreek	11	6.2	4.9	1.07	0.5	56
CBD	5.2	3.5	1.7	1.60	0.5	67
Claisebrook	4.7	3.4	1.3	1.70	0.5	72
Downstream	6.9	3.4	3.5	1.20	0.5	49
Ellen	71	49	22	2.73	1.0	69
Ellis	0.7	0	0.7	0.46	1.0	0
Helena	5.8	2.2	3.6	1.20	1.0	38
Helm Street	1.7	1.2	0.5	2.34	0.75	71
Henley	0.8	0.1	0.6	1.63	1.0	18
Jane	11	0	11	0.71	0.75	0
Lower Canning	7.9	4.7	3.2	2.30	0.75	59
Maylands	11	6.0	5.1	1.89	0.5	54
Mills Street	7.1	4.5	2.6	1.56	0.5	63
Millendon	2.6	0	2.6	0.85	1.0	0
Munday/Bickley	2.9	0.6	2.3	1.43	1.0	21
Perth Airport N	2.0	0.7	1.3	1.01	0.75	35
Perth Airport S	1.1	0	1.1	0.65	1.0	0
Saint Leonards	1.4	0.9	0.5	2.70	1.0	64
South Belmont	1.7	0.7	1.0	0.83	0.5	41
South Perth	13	3.9	8.8	0.82	0.5	31
Southern	21	9.9	11	1.32	0.75	46
Susannah	4.8	0	4.8	0.74	0.75	0
Upper Canning	7.5	0	7.5	0.72	1.0	0
Upper Swan	8.6	2.5	6.1	1.68	0.75	30
Yule	7.5	1.9	5.6	1.06	0.75	25
TOTAL	250	120	130			49

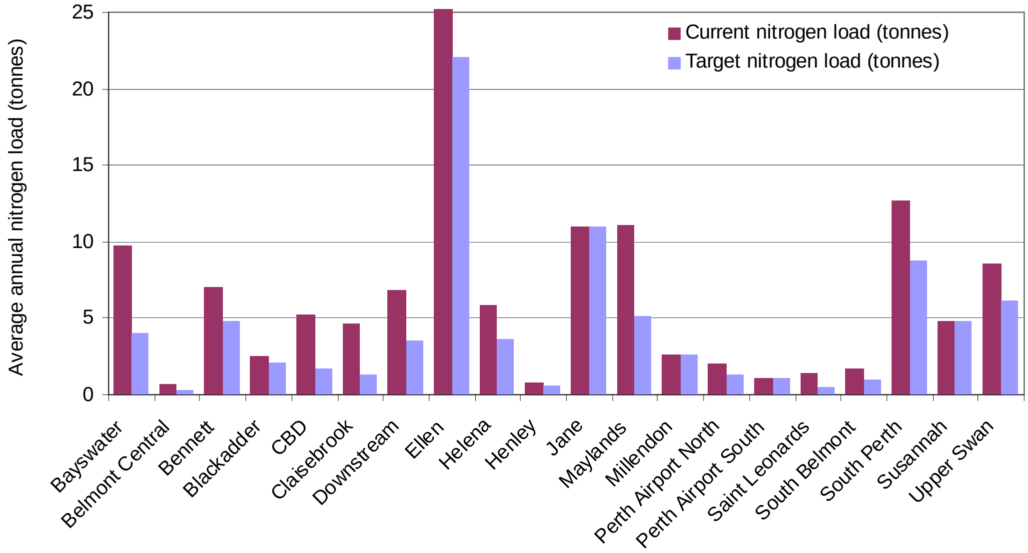
Table 5.7 Phosphorus current loads, load reduction targets and maximum acceptable loads for the period 1997 to 2006

Catchment	Current load (1997–2006) (tonnes/ year)	Load reduction target (tonnes/ year)	Maximum acceptable load (tonnes/ year)	Current winter median conc (mg/L)	Target winter median conc (mg/L)	% Load reduction
Bannister	0.82	0.27	0.55	0.08	0.05	33
Bayswater	0.60	0.16	0.44	0.06	0.05	27
Belmont Central	0.06	0.02	0.04	0.06	0.05	33
Bennett	0.42	0	0.42	0.05	0.1	0
Blackadder	0.17	0	0.17	0.04	0.075	0
Bullcreek	1.20	0.19	1.01	0.06	0.05	16
CBD	0.24	0.03	0.21	0.06	0.05	13
Claisebrook	0.30	0.06	0.24	0.06	0.05	20
Downstream	0.30	0	0.30	0.05	0.05	0
Ellen	10	7.9	2.1	0.46	0.1	79
Ellis	0.02	0	0.02	0.02	0.1	0
Helena	0.23	0	0.23	0.02	0.1	0
Helm Street	0.07	0.02	0.04	0.11	0.075	29
Henley	0.05	0	0.05	0.12	0.1	0
Jane	0.58	0	0.58	0.02	0.075	0
Lower Canning	0.97	0.47	0.50	0.19	0.075	48
Maylands	0.27	0.00	0.27	0.04	0.05	0
Mills Street	0.78	0.51	0.28	0.14	0.05	65
Millendon	0.15	0	0.15	0.02	0.1	0
Munday/Bickley	0.14	0	0.14	0.04	0.1	0
Perth Airport N	0.21	0	0.21	0.04	0.075	0
Perth Airport S	0.17	0	0.17	0.03	0.1	0
Saint Leonards	0.14	0.04	0.10	0.11	0.1	29
South Belmont	0.24	0.11	0.13	0.10	0.05	46
South Perth	1.94	0.19	1.76	0.06	0.05	10
Southern	2.21	1.06	1.15	0.14	0.075	48
Susannah	0.65	0	0.65	0.02	0.075	0
Upper Canning	0.42	0	0.42	0.03	0.1	0
Upper Swan	2.01	0.72	1.29	0.17	0.075	36
Yule	0.43	0	0.43	0.07	0.075	0
TOTAL	26	12	14			46

Removal of point sources of nutrient pollution generally cause immediate improvement in stream nutrient concentrations; however, the full impact of management or land-use changes are often not evident for several years. This is due to the buffering effect of soil and vegetation nutrient stores. SQUARE has been used to estimate the time it would take to achieve the concentration targets in each catchment, given an immediate reduction in nutrient inputs. The time required depends on the magnitude of the reduction, and catchment size and characteristics. The estimated times required to achieve the nitrogen and phosphorus load reduction targets for each catchment are included in Appendix B.

The current nitrogen load from the 30 coastal catchments to the Swan and Canning rivers and estuaries is approximately 250 tonnes. If all catchments were meeting their water-quality targets, the nitrogen load to the rivers and estuaries would be approximately 130 tonnes, which is a reduction of 120 tonnes or 49%. There are 24 catchments not meeting their median concentration targets for TN and the required reductions in these catchments range from 16% for Blackadder to 72% for Claisebrook. The catchment requiring the largest absolute reduction is Ellen Brook; that is, a load reduction of 49 tonnes (69%). The catchments meeting their concentration targets for TN are Ellis, Jane, Millendon, Perth Airport South, Susannah and Upper Canning. These catchments have only small areas of residential land use.

a) Swan catchments (note: Ellen Brook current load = 71 tonnes is ‘off’ the chart)



b) Canning catchments

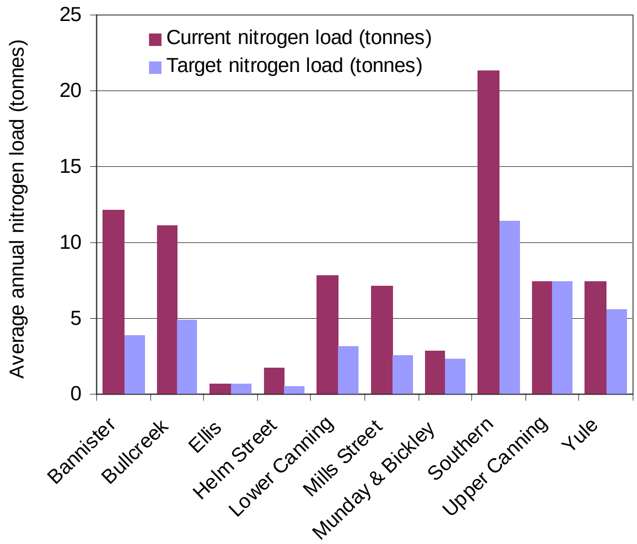
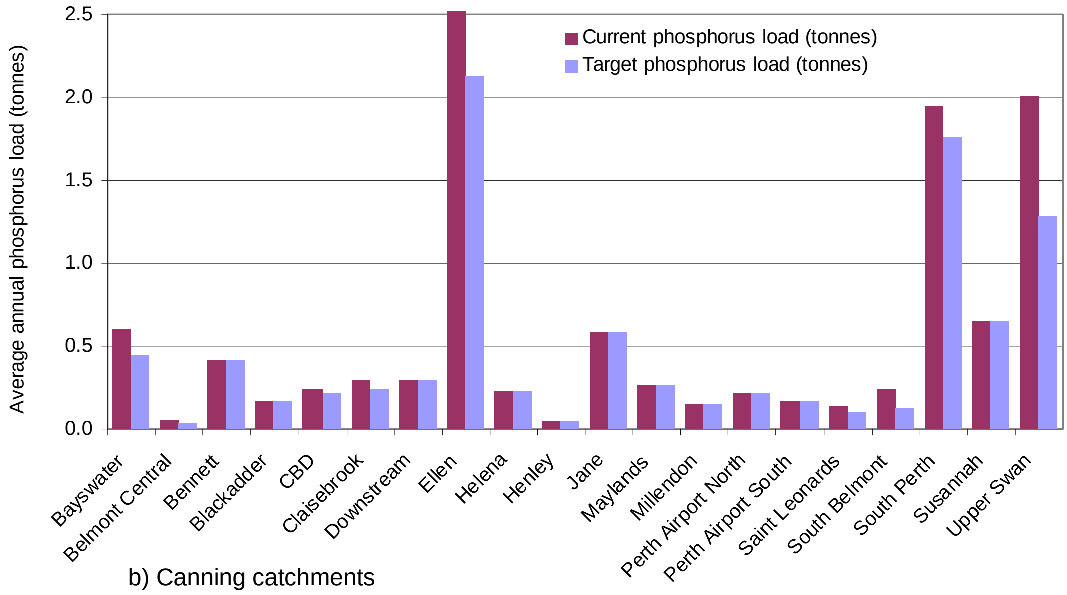


Figure 5.15 Current nitrogen loads (1997–2006) and maximum acceptable loads

The current phosphorus load to the rivers and estuaries from the coastal catchments is approximately 26 tonnes. If all the catchments were meeting their water-quality targets, the phosphorus load to the rivers and estuaries would be approximately 14 tonnes, a reduction of 12 tonnes or 46%. Fifteen of the 30 coastal plain catchments are exceeding their median concentration targets for TP. However, most of the required load reduction (in absolute terms) is from Ellen Brook, which is the largest catchment. Ellen Brook has Bassendean sands and duplex Yanga (sand over clay) soils. The Bassendean sands have very low PRIs.

The Yanga soils have low PRIs in their upper horizon and become waterlogged in winter, promoting export of applied nutrients to the stream, particularly phosphorus. Ellen Brook needs a phosphorus load reduction of 79% or 7.9 tonnes to achieve its water-quality targets.

a) Swan catchments (note: Ellen Brook current load = 10 tonnes is 'off' the chart)



b) Canning catchments

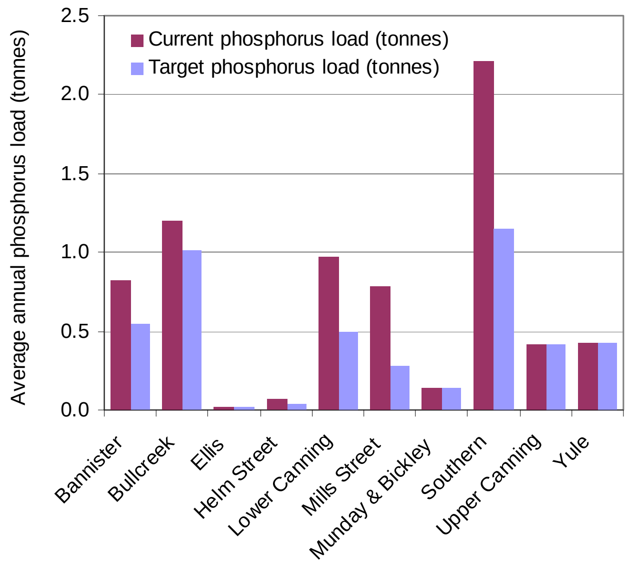


Figure 5.16 Current phosphorus loads (1997–2006) and maximum acceptable loads

In summary, all the Swan-Canning coastal catchments with more than very small areas of 'residential' land use require reductions to their nitrogen exports. Source separation for these catchments (Appendix B) also highlights sources such as recreation (fertilised parks and gardens), septic tanks (primarily in Mills Street and Bayswater catchments) and the point sources in Bannister Creek catchment.

Because of the ability of soils to bind phosphorus, the catchments requiring phosphorus load reductions are generally those with low phosphorus-retaining soils and intensive land uses such as Ellen Brook, Southern River and some of the highly-urbanised catchments such as Mills Street and Lower Canning. Ellen Brook requires a phosphorus load reduction of 7.9 tonnes, which is 71% of the total load reduction for all the coastal catchments. Southern River, which requires a 1.1 tonne load reduction, is responsible for about half the nutrient inputs to Kent Street Weir pool.

Urban development is progressing rapidly in many of the Swan-Canning coastal catchments such as Southern River, Saint Leonards Brook and Ellen Brook. As such, appropriate development that minimises fertiliser inputs and processes applied nutrients on-site, is required.

The timing of nitrogen and phosphorus loads to the Swan-Canning estuary was discussed in Section 5.1.3 for 1997, which was considered a typical year. Ellen Brook was seen to contribute large amounts of nutrients in the wet months of May to September. Although, the nutrient contributions from Ellen Brook during summer and autumn, considered to be the ‘algal bloom season’, are small, it is believed that phosphorus from the Ellen Brook winter inflows that is precipitated into the sediments of the upper Swan River is readily re-mobilised and available to fuel algal growth during summer and autumn. However, algal blooms in the upper Swan River are generally nitrogen limited. Nutrient limitation bioassays at different times of the year would inform on whether blooms are nitrogen, phosphorus, sulfur, salt, heat or light limited. This would enable greater understanding of the relative importance of the various nutrient sources for fuelling algal growth at different times of the year.

That is, the relative importance of the nutrient inflows from Ellen Brook (in winter) and from the urban drains (all year round) for fuelling algal growth, needs to be further investigated, particularly with respect to the changes that are occurring due to the drying climate. Because many urban drains flow all year, nutrient reductions in these may have a greater impact on the estuary’s health than nutrient reductions in the inflows from the ephemeral catchments.

To determine appropriate management actions that will have the greatest short-term impact in the various reaches of the Swan-Canning estuary; that is, upper Swan Estuary, middle Swan Estuary, Canning Estuary above Kent Street Weir, Canning Estuary below Kent Street weir and the Swan Estuary downstream of the Narrows and Canning Highway bridges, many factors need to be considered, including:

- the magnitude and timing of nutrient inputs from the upstream catchments
- groundwater inputs
- potential for nutrient sediment releases
- the timing and conditions that promote nutrient sediment releases, such as stratification and low dissolved oxygen at depth
- the limiting factors for algal blooms (nutrients, salinity, light and heat).

Detailed discussion of appropriate management actions in each of the reaches of the estuary is beyond the scope of this report. However, the calibrated SQUARE model presented here is available for future scenario modelling to guide management decisions in all areas of the catchment, and determine impacts on the estuary.

6 Scenario modelling

6.1 Introduction

A half-day workshop was held on 18 October 2007 to formulate the scenarios that would be modelled by SQUARE and the Support System for Phosphorus and Nitrogen Decisions (SSPND) (Ecotones 2008) for the Vasse-Geographe and Swan-Canning water quality improvement plans. The Department of Water, Department of Agriculture and Food WA (DAFWA), Swan River Trust and Geographe Bay Catchment Council contributed. SSPND is a nutrient management decision-support tool that DAFWA developed for use in the Ellen Brook and Geographe Bay catchments.

The scenarios modelled by SQUARE for the Swan-Canning coastal catchments include climate change, urban expansion and various interventions and management actions listed in Table 6.1. The scenario modelling implementation is discussed in Section 6.2, the climate change scenarios in Section 6.3, the urban expansion scenario in Section 6.4 and the management and intervention scenarios in Section 6.5.

Table 6.1 Scenarios modelled for the Swan-Canning coastal plain catchments

1. Climate change
   - B1 scenario
   - A2 scenario
2. Urban expansion
   - no best practices included
   - soil amendments applied to all new developments
3. 100% infill of septic tanks
   - reticulated sewerage system to all urban areas
4. Removal of all point sources of nutrient pollution
5. *Fertiliser action plan*
   - 100% implementation in urban only
   - 100% implementation in rural only
   - 100% implementation in urban and rural areas
6. Fertiliser modification
   - reduction of urban fertilisation by 50%
7. Soil amendment in rural land use
8. Drainage changes
   - wetlands (similar to Liege St) at bottom of catchments
9. In-stream interventions
   - zeolite/laterite nutrient filters in waterways

6.2 Scenario modelling implementation

Scenario modelling involves modelling a climate or land-use change into the future. For management or land-use change scenarios, to enable comparison with the current catchment condition, the future climate sequence for the scenario modelling is the climate for the period 1997 to 2006 inclusive repeated six times, that is until 2066. For all the scenarios modelled, by 2066 the average annual loads of nitrogen and phosphorus over the 10-year climate sequence had stabilised. That is, the catchment is in equilibrium with respect to the new catchment land use or management practice. For several of the scenarios the catchment reached equilibrium before 2066.

However, the nutrient loads from the Swan-Canning coastal catchments are not in equilibrium with respect to their current land uses due to recent changes. If the climatic conditions of 1997 to 2006 and current land uses (2006) prevail, the total nutrient exports will increase slightly in the future – the average annual nitrogen load will increase to 266 tonnes (compared with 251 tonnes currently) and the average annual phosphorus load to 27 tonnes (compared with 26 tonnes currently). The current average annual loads for the period 1997 to 2006 and the estimated future average annual loads (called 'current climate loads') for the Swan-Canning coastal catchments are listed in Table 6.2. Note that in some catchments the average annual loads are expected to decrease in the future. The catchments that display decreases at catchment equilibrium are Bayswater, Claisebrook, Helena, Helm Street, Lower Canning, Mills Street, Perth Airport South, South Belmont, South Perth, Southern River and Upper Canning. The decreases are mostly due to the infill sewerage program.

The average annual flow at catchment equilibrium (assuming 2006 land uses) and the average annual flows for the period 1997 to 2006 are shown in Table 6.3. The increase in flow at catchment equilibrium in Henley Brook is due to the urban development undertaken during 2005 and 2006.

The land-use change and management scenarios will be assessed by comparing the predicted average annual nitrogen and phosphorus loads with the 'current climate loads' and the maximum acceptable loads shown in Table 6.2. Data for individual years for each catchment are included in Appendix B.

For the climate change scenarios the 2006 land use was used to model into the future, with a future climate sequence (representing the B1 or A2 scenarios) to determine the impact of the changing climate given no land use or management changes. The average annual nitrogen and phosphorus loads for the new climate (once the catchments had reached a new equilibrium) may be compared with the current climate equilibrium loads shown in Table 6.2. However, it is inappropriate to compare the average annual nutrient loads from the climate change scenarios with the maximum acceptable loads. The maximum acceptable loads were derived using the current climate sequence and the water-quality objectives (concentrations) discussed in Section 4. As stream nutrient concentrations depend on both land use and climate, the maximum acceptable loads would be different under a different climate regime.

Note that for the period 1997 to 2006, 24 catchments have average annual nitrogen loads and 15 catchments have average annual phosphorus loads greater than their maximum acceptable loads. Whereas once the catchments have reached equilibrium with respect to the current (2006) land uses (‘current climate loads’ in Table 6.2), there are 27 catchments with greater than the desired nitrogen loads and 23 catchments with greater than the desire phosphorus loads.

Table 6.2 Average annual nitrogen and phosphorus loads (tonnes) for 1997 to 2006, at catchment equilibrium (current climate load) and maximum acceptable load

Catchment	Current nitrogen load (1997–2006) (tonnes/ year)	Current Climate nitrogen load (tonnes/ year)	Maximum acceptable nitrogen load (tonnes/ year)	Current phosphorus load (1997–2006) (tonnes/ year)	Current Climate phosphorus load (tonnes/ year)	Maximum acceptable phosphorus load (tonnes/ year)
Bannister	12.1	12.8	3.9	0.82	0.70	0.55
Bayswater	9.8	7.5	4.0	0.60	0.50	0.44
Belmont Central	0.7	0.6	0.3	0.06	0.06	0.04
Bennett Brook	7.1	5.7	4.8	0.42	0.60	0.42
Blackadder	2.5	2.4	2.1	0.17	0.17	0.17
Bullcreek	11.1	10.2	4.9	1.20	2.60	1.01
CBD	5.2	4.2	1.7	0.24	0.27	0.21
Claisebrook	4.7	3.3	1.3	0.30	0.24	0.24
Downstream	6.9	7.6	3.5	0.30	0.30	0.30
Ellen	71.4	92.8	22.1	10.04	10.55	2.13
Ellis	0.7	0.7	0.7	0.02	0.01	0.02
Helena	5.8	4.9	3.6	0.23	0.22	0.23
Helm Street	1.7	1.6	0.5	0.07	0.06	0.04
Henley	0.8	0.8	0.6	0.05	0.18	0.05
Jane	11.0	11.6	11.0	0.58	0.67	0.58
Lower Canning	7.9	6.9	3.2	0.97	0.91	0.50
Maylands	11.1	11.7	5.1	0.27	0.26	0.27
Mills Street	7.1	6.1	2.6	0.78	0.75	0.28
Millendon	2.6	2.9	2.6	0.15	0.15	0.15
Munday & Bickley	2.9	2.6	2.3	0.14	0.16	0.14
Perth Airport North	2.0	2.0	1.3	0.21	0.20	0.21
Perth Airport South	1.1	0.5	1.1	0.17	0.16	0.17
Saint Leonards	1.4	0.7	0.5	0.14	0.14	0.10
South Belmont	1.7	1.4	1.0	0.24	0.21	0.13
South Perth	12.7	10.9	8.8	1.94	1.93	1.76
Southern	21.3	19.5	11.4	2.21	1.94	1.15
Susannah	4.8	8.6	4.8	0.65	0.72	0.65
Upper Canning	7.5	6.5	7.5	0.42	0.38	0.42
Upper Swan	8.6	11.6	6.1	2.01	1.79	1.29
Yule Brook	7.5	7.5	5.6	0.43	0.46	0.43
Total	252	266	129	26	27	14

Table 6.3 Average annual flow for the Swan-Canning tributaries for 1997 to 2006 and at catchment equilibrium (2057–2066)

Catchment	Flow 1997-2006 (ML/yr)	Flow catchment equilibrium (ML/yr)	
Bannister	8 560	8 740	2%
Bayswater	8 270	8 160	-1%
Belmont Central	900	874	-3%
Bennett	5 000	5 070	2%
Blackadder	2 990	2 990	0%
Bullcreek	14 400	14 400	0%
CBD	2 410	2 500	4%
Claisebrook	3 410	3 360	-1%
Downstream	5 850	5 780	-1%
Ellen	26 800	25 400	-5%
Ellis	1 430	1 410	-1%
Helena	4 880	4 560	-6%
Helm Street	765	746	-3%
Henley	681	960	41%
Jane	14 800	14 900	1%
Lower Canning	6 560	5 810	-11%
Maylands	3 730	3 680	-1%
Mills Street	4 420	4 380	-1%
Millendon	3 150	3 160	0%
Munday/Bickley	3 340	3 410	2%
Perth Airport North	3 070	3 040	-1%
Perth Airport South	2 050	2 090	2%
Saint Leonards	594	519	-13%
South Belmont	2 430	2 390	-2%
South Perth	14 200	14 200	0%
Southern	16 000	15 900	-1%
Susannah	6 210	6 280	1%
Upper Canning	10 800	9 200	-15%
Upper Swan	4 000	3 340	-17%
Yule	7 570	7 590	0%
Total	189 300	184 900	-2%

6.3 Climate change scenarios

The Intergovernmental Panel on Climate Change (IPCC) attributes most of the global warming observed over the past 50 years to greenhouse gases released by human activities. To estimate future climate change, the IPCC (2000) prepared 40 greenhouse gas and sulfate aerosol emission scenarios for the 21st century that combine a variety of assumptions about demographic, economic and technological driving forces likely to influence such emissions in the future. For this project two of the emission scenarios are considered:

- **B1 scenario:** The population peaks around 2050 and declines thereafter. There is an emphasis on global solutions to economic, social, and environmental sustainability, including the introduction of clean efficient technologies. This is an optimistic scenario.

- **A2 scenario:** The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge slowly, leading to steadily increasing population and per capita economic growth. Technological changes are more fragmented and slower than in other scenarios. The A2 scenario is the highest emission option (pessimistic scenario) with continued high rates of greenhouse gas emissions which reach 1.7 times current levels by 2090.

By incorporating these scenarios into climate models (General Circulation Models [GCMs]) predictions of future rainfall and temperature are made. The Department of Water and CSIRO undertook a project in 2005 in which the GCMs Mk3 and Mk3.5 were run for climate change scenarios A2 and B1 respectively; for the south coast of Western Australia, and for scenario A1 for the south west of Western Australia (Cleary 2008). A statistical downscaling technique was used to attribute GCM outputs to local areas. This allowed the downscaling of 1997 to 2006 rainfall values to represent potential future rainfall regimes for the B1 and A2 scenarios for the Swan-Canning coastal catchments. The percentage changes in rainfall for each of the seasons for the B1 and A2 scenarios are shown in Table 6.4. The decrease in annual rainfall is 1.8% for the B1 climate, with decreases in summer and autumn rainfall, a small decrease in winter rainfall and a small increase in spring rainfall. For the A2 scenario the annual decrease in rainfall is 11.9%, with the biggest percentage decrease in rainfall occurring in autumn. That is, there is a later start to the rainy season.

Table 6.4 Percentage change in rainfall for the B1 and A2 climate scenarios

Season	B1 (Mk3.5 model)	A2 (Mk3 model)
Summer	-8.5%	-7.7%
Autumn	-6.3%	-25.2%
Winter	-0.3%	-10.5%
Spring	0.9%	-7.4%
Annual	-1.8%	-11.9%

How climate change scenarios were modelled in this study

- *The catchment was modelled with the current land use (2006) and the current climate sequence (1997–2006) successively repeated until the catchment reached equilibrium (current climate loads in Table 6.2). This baseline was then used for comparison of model outputs for the future climate scenarios.*
- *B1 – optimistic scenario: The catchment was modelled with the 2006 land use and the 10-year climate sequence representative of 1997 to 2006 rainfall downscaled to represent a B1 climate. The climate sequence was successively repeated until catchment reached equilibrium. Evapotranspiration inputs were not modified.*
- *A2 – pessimistic scenario: The catchment was modelled with the 2006 land use and the 10-year climate sequence representative of 1997 to 2006 rainfall downscaled to represent an A2 climate. The climate sequence was successively repeated until the catchment reached equilibrium. Evapotranspiration inputs were not modified.*

The changes to the average annual flows for each catchment are given in Table 6.5 and shown in Figure 6.1. The nitrogen and phosphorus load changes are given in Table 6.6 and shown in Figure 6.2.

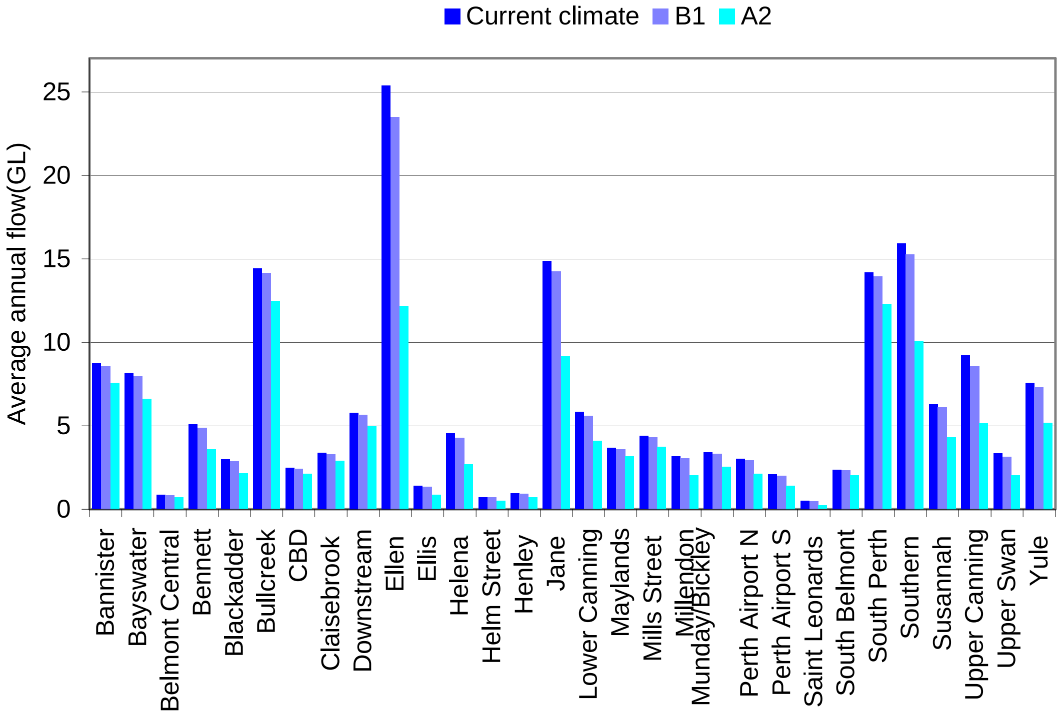


Figure 6.1 Current climate flows and flows for B1 and A2 climate change scenarios

Table 6.5 Average annual current climate flows and flows for the B1 and A2 climate change scenarios

Catchment	Current climate flow (ML/yr)	B1 climate change scenario (ML/year)		A2 climate change scenario (ML/year)	
Bannister	8 740	8 590	-2%	7 570	-13%
Bayswater	8 160	7 960	-3%	6 630	-19%
Belmont Central	874	857	-2%	857	-15%
Bennett	5 070	4 860	-4%	3 580	-29%
Blackadder	2 990	2 880	-4%	2 140	-28%
Bullcreek	14 400	14 200	-2%	12 500	-13%
CBD	2 500	2 450	-2%	2 130	-15%
Claisebrook	3 360	3 300	-2%	2 890	-14%
Downstream	5 780	5 670	-2%	4 980	-14%
Ellen	25 400	23 500	-7%	12 200	-52%
Ellis	1 410	1 350	-4%	880	-38%
Helena	4 560	4 260	-7%	2 680	-41%
Helm Street	746	716	-4%	716	-33%
Henley	960	933	-3%	933	-24%
Jane	14 900	14 200	-4%	9 200	-38%
Lower Canning	5 810	5 600	-4%	4 100	-30%
Maylands	3 680	3 610	-2%	3 150	-14%
Mills Street	4 380	4 300	-2%	3 760	-14%
Millendon	3 160	3 050	-4%	2 030	-36%
Munday/Bickley	3 410	3 310	-3%	2 560	-25%
Perth Airport N	3 040	2 930	-3%	2 120	-30%
Perth Airport S	2 090	2 010	-4%	1 430	-32%
Saint Leonards	519	474	-9%	474	-54%
South Belmont	2 390	2 340	-2%	2 040	-15%
South Perth	14 200	13 900	-2%	12 300	-13%
Southern	15 900	15 300	-4%	10 100	-37%
Susannah	6 280	6 090	-3%	4 310	-31%
Upper Canning	9 240	8 570	-7%	5 150	-44%
Upper Swan	3 340	3 150	-6%	2 050	-39%
Yule	7 590	7 310	-4%	5 190	-32%
Total	184 900	177 700	-4%	129 800	-30%

Table 6.6 Average annual nitrogen and phosphorus loads (at catchment equilibrium) for the current (1997–2006) climate and for the B1 and A2 climate scenarios

	Nitrogen					Phosphorus				
Catchment	Current climate load (tonnes/ year)	B1 climate (tonnes/year)		A2 climate (tonnes/year)		Current climate load (tonnes/ year)	B1 climate (tonnes/year)		A2 climate (tonnes/year)	
Bannister	12.8	12.8	0%	12.9	1%	0.70	0.68	-2%	0.62	-11%
Bayswater	7.5	7.4	-2%	6.6	-12%	0.50	0.49	-2%	0.46	-8%
Belmont Central	0.6	0.6	7%	0.6	7%	0.06	0.06	-2%	0.06	-2%
Bennett	5.7	5.6	-1%	4.9	-13%	0.60	0.60	0%	0.56	-7%
Blackadder	2.4	2.3	-5%	1.8	-26%	0.17	0.17	-1%	0.16	-7%
Bullcreek	10.2	10.2	0%	10.0	-2%	2.60	2.6	-1%	2.45	-6%
CBD	4.2	4.2	1%	4.4	5%	0.27	0.27	-1%	0.27	-1%
Claisebrook	3.3	3.3	-1%	3.3	-1%	0.24	0.24	-1%	0.21	-13%
Downstream	7.6	8.2	8%	8.9	17%	0.30	0.30	1%	0.28	-6%
Ellen	93	86	-7%	73.2	-21%	10.5	9.6	-9%	5.22	-51%
Ellis	0.7	0.6	-8%	0.5	-23%	0.01	0.01	1%	0.01	1%
Helena	4.9	4.6	-6%	3.3	-33%	0.22	0.22	-1%	0.18	-19%
Helm Street	1.6	1.6	1%	1.3	-18%	0.06	0.06	5%	0.04	-30%
Henley	0.8	0.7	-8%	0.5	-34%	0.18	0.17	-3%	0.13	-26%
Jane	11.6	11.4	-1%	9.0	-22%	0.67	0.61	-9%	0.32	-52%
Lower Canning	6.9	6.8	-2%	5.7	-17%	0.91	0.88	-3%	0.73	-19%
Maylands	11.7	11.8	1%	12.6	7%	0.26	0.26	0%	0.25	-4%
Mills Street	6.1	6.1	0%	6.0	-1%	0.75	0.74	-1%	0.69	-8%
Millendon	2.9	2.9	-2%	2.2	-25%	0.15	0.15	-2%	0.12	-21%
Munday/Bickley	2.6	2.5	-5%	1.6	-39%	0.16	0.16	-2%	0.10	-38%
Perth Airport N	2.0	2.0	2%	1.8	-8%	0.20	0.20	-2%	0.19	-7%
Perth Airport S	0.5	0.5	-3%	0.4	-23%	0.16	0.15	-3%	0.12	-23%
Saint Leonards	0.7	0.7	-2%	0.4	-44%	0.14	0.13	-7%	0.07	-50%
South Belmont	1.4	1.4	3%	1.4	3%	0.21	0.21	-2%	0.20	-7%
South Perth	10.9	10.9	0%	10.9	0%	1.93	1.89	-2%	1.70	-12%
Southern	19.5	19.3	-1%	16.1	-17%	1.94	1.89	-3%	1.41	-27%
Susannah	8.6	8.3	-3%	6.6	-23%	0.72	0.69	-5%	0.53	-27%
Upper Canning	6.5	5.9	-9%	3.5	-46%	0.38	0.36	-4%	0.26	-31%
Upper Swan	11.6	11.1	-5%	8.9	-24%	1.79	1.72	-4%	1.20	-33%
Yule	7.5	7.4	-1%	6.1	-19%	0.46	0.44	-3%	0.32	-30%
TOTAL	266	257	-3%	225	-15%	27	26	-5%	19	-31%

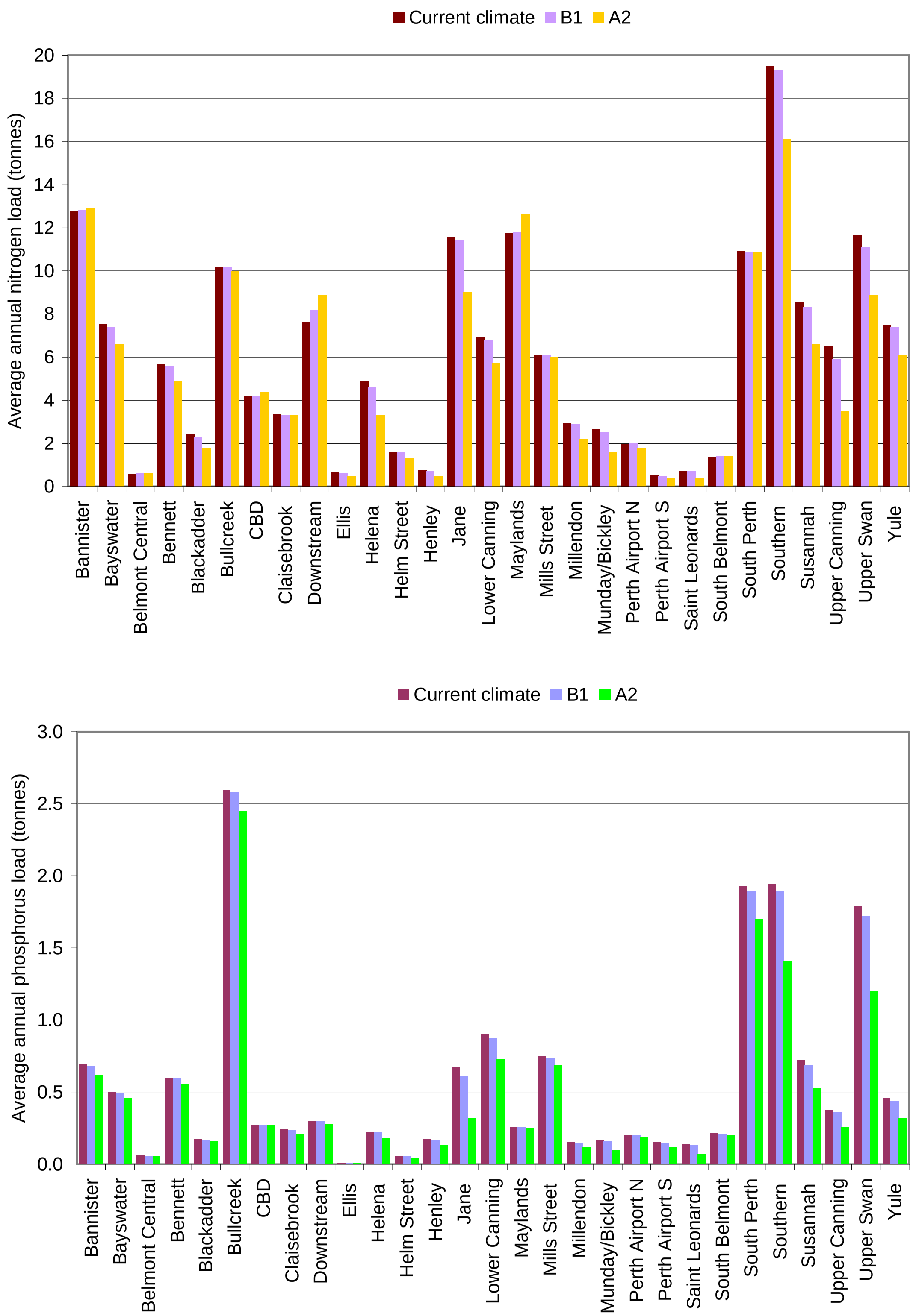


Figure 6.2 Nitrogen and phosphorus loads for the current climate and B1 and A2 climate change scenarios (excluding Ellen Brook)

In pervious catchments water is used by plants and absorbed into the soil profile: water loss due to evaporation and evapotranspiration is high; water yield is low. In highly-impervious urban catchments, there is less opportunity for evaporation and evapotranspiration and water is conveyed efficiently to receiving waterbodies through open and piped drainage systems. Many urban catchments also have a significant portion of flow from septic tanks, garden watering and industrial washdown. Thus, decreased rainfall will cause a greater relative decrease in flows in pervious catchments than in highly impervious catchments, as can be seen in Figure 6.1.

Under the A2 (pessimistic) climate scenario, the flow from Ellen Brook is expected be less than half its current volume and the average annual flow volume would be similar to flows from some of the large urban catchments such as Bullcreek and South Perth, even though the timing of delivery would be different. Ellen Brook rarely flows during summer and autumn, but many of the urban drains do (as discussed in Section 5). Note that Ellen Brook has an area of about 715 km^2, whereas Bullcreek and South Perth have areas of 42.5 km^2 and 40.5 km^2 respectively. Large decreases in flow volume under the A2 scenario are also seen in other pervious catchments such as the Jane (-38%), Southern (-37%) and Upper Canning (-44%), whereas highly urbanised catchments such as Bannister (-13%), Bullcreek (-13%) and Claisebrook (-14%) have smaller percentage decreases in annual flow volume.

The 1.8% decrease in annual rainfall under the B1 (optimistic) scenario has only a small effect on flow and nutrient loads (Table 6.5 and Table 6.6). This is even more apparent in Figure 6.3, which displays the total flow and loads to the estuaries.

The changes in nitrogen and phosphorus loads (Figure 6.2) are similar (relatively) to the changes in flow, except for in some of the urban catchments such as Bannister, Downstream and Maylands. In these catchments, even though the annual flows and phosphorus loads have decreased with less rainfall, the nitrogen loads have increased. This means the TN concentrations have increased, as a consequence of less denitrification due to a drier catchment.

In summary, the decreased rainfall (1.8% annually) under the B1 scenario is predicted to decrease the annual flow and loads from the coastal catchments by: flow 4%, nitrogen load 3% and phosphorus load 6%. The A2 scenario (decrease in annual rainfall of 11.9%) is predicted to decrease annual flow and loads by: flow 30%, nitrogen load 15% and phosphorus load 8%.

Under a drying climate the flows from the Avon River will be greatly reduced (see Section 5), thus the estuaries will be less flushed and more salty. The decreased rainfall will cause the greatest reductions in flows and loads from the pervious (more rural) catchments. The inflows to the estuaries will be dominated by the highly impervious urban catchments and a greater proportion of the flow will be in spring, summer and autumn (algal bloom season). With the drying climate the concentrations will tend to increase, even though the loads will generally decrease. In some of the urban catchments there may also be increased nitrogen loads due to less denitrification occurring.

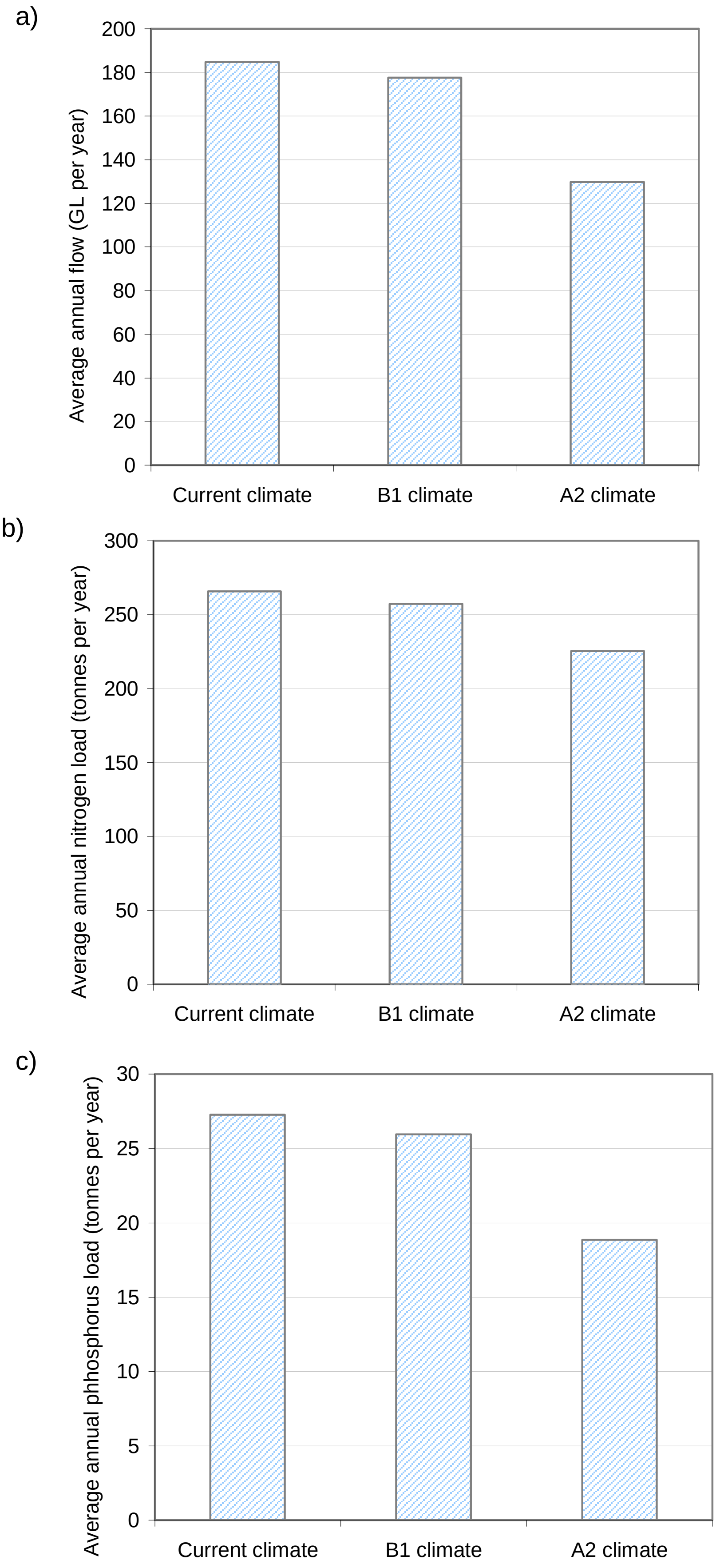


Figure 6.3 Total annual average a) flows and b) nitrogen and c) phosphorus loads to the Swan and Canning estuaries under current and future climate scenarios

6.4 Future urban development

Although the Australian Bureau of Statistics (ABS) predicts that Perth's population will grow enormously over the next 50 years, most of the residential growth will not be in the Swan-Canning coastal catchments. The ABS (2008) gives several population forecasts based on various assumptions. With the current trends in fertility, life expectancy at birth, net overseas migration and net interstate migration, the population of Perth would increase from 1.6 million people in June 2007 to 2.3 million in 2026, and to 3.4 million in 2056 (116% increase). The ABS's conservative estimates are for an increase to 2.1 million by 2026 and 2.8 million by 2056. However, these estimates assume conditions similar to the past, and as water and other resources become more scarce, they are likely to be revised.

The future urban developments modelled in this study, included the areas within the Swan-Canning coastal catchments designated as 'urban deferred' or 'urban residential' in the current Metropolitan Regional Scheme (2005), which had not already been developed with urban land uses. This does not take into account the large growth forecast of the ABS. The estimated number of new dwellings is approximately 130 000, which would house approximately 270 000 people (Table 6.7).

How future urban development was modelled in this study

The future urban development was based on the Metropolitan Regional Scheme (MRS 2005) (Department of Planning 2009). All areas in the MRS designated 'urban residential' or 'urban deferred' which had a rural or peri-urban land use in the 2006 land-use map were changed from their current land use to 'residential – single duplex dwelling'. The rural and peri-urban land uses that were reclassified as residential are listed in Table 6.8. The numbers of new 'residential – single/duplex dwellings' in each catchment are listed in Table 6.7.

The future urban development was modelled with:

1) *no best management practices (BMPs) included in the development*
2) *soil amendments applied to the areas with low PRI soils; that is, all the developed areas that had a soil PRI of less than 10 were given a PRI of 10.*

No other BMPs were modelled, as the effectiveness of the various urban BMPs on the Swan Coastal Plain have not been quantified. The scenario without soil amendments gives the estimated nutrient yields for urban development similar to current existing residential areas in Perth. This is thought to be the worst-case scenario.

The change from rural land use to urban is generally accompanied by a decrease in vegetation and an increase in impervious area. This means that the catchment will have a greater and 'flashier' water yield. Table 6.9 contains the average annual flows for each subcatchment pre- and post-development, which are also plotted in Figure 6.4. Estimated nitrogen and phosphorus loads and concentrations are shown in Table 6.10 and Table 6.11 respectively, and plotted in Figure 6.5 (excluding Ellen Brook). Table 6.11 includes the estimated phosphorus loads and concentrations with and without soil amendments for future urban developments. Note that even though soil amendments may increase the waterholding capacity of the soil and decrease the leaching of nitrogen fertilisers, these properties and related processes are not included in the SQUARE conceptualisation. Thus, application of soil amendments changes only the phosphorus yields and has no effect on water and nitrogen yields.

Table 6.7 Number of new 'residential – single/duplex dwelling' properties in the Swan-Canning coastal catchments

Catchment	Number of new residential properties	Population increase
Bannister	3 608	7 577
Bayswater	861	1 809
Belmont Central	888	1 865
Bennett	6 439	13 521
Blackadder	3 437	7 217
Bullcreek	885	1 859
CBD	421	885
Claisebrook	609	1 279
Downstream	1 276	2 680
Ellen	17 770	37 318
Ellis	591	1 242
Helena	5 544	11 642
Helm Street	747	1 568
Henley	6 063	12 733
Jane	8 165	17 147
Lower Canning	5 596	11 752
Maylands	683	1 434
Mills Street	783	1 645
Millendon	0	0
Munday/Bickley	2 644	5 553
Perth Airport N	2 506	5 263
Perth Airport S	1 609	3 379
Saint Leonards	2 667	5 601
South Belmont	715	1 502
South Perth	2 368	4 974
Southern	37 290	78 309
Susannah	554	1 164
Upper Canning	2 479	5 205
Upper Swan	6 993	14 685
Yule	4 882	10 252
Total	129 075	271 058

Table 6.8 Land uses within the Metropolitan Regional Planning Scheme footprint which were reclassified to 'residential – single/duplex dwelling' for future urban development. Note that land-use classifications are different in the Ellen Brook catchment

Land use	Ellen Brook land use
Horticulture	Cattle for beef
Plantation	Cleared land – unused
Viticulture	Horses
Animal keeping – non-farming	Commercial
Farm	Lifestyle block 5.0000–10.0000 ha
Lifestyle block / hobby farm	Light industrial
Rural residential / bush block	Mixed grazing
Quarry / extraction	Peri-urban 0.5000–2.0000 ha
Unused – uncleared – trees/shrubs	Peri-urban 2.0000–5.0000 ha
Garden centre / nursery	Tree plantation
Manufacturing / processing	Uncleared Land – unused
Storage / distribution	
Unused – cleared – bare soil	
Unused – cleared – grass	

Table 6.9 Changes to average annual flows following urban development proposed in the Metropolitan Regional Planning Scheme

Catchment	Current equilibrium Flow (GL/yr)	Future urban Flow (GL/yr)	% change
Bannister	8.7	8.9	1%
Bayswater	8.2	8.2	0%
Belmont Central	0.9	0.9	0%
Bennett	5.1	5.6	10%
Blackadder	3.0	3.4	13%
Bullcreek	14.4	14.4	0%
CBD	2.5	3.0	19%
Claisebrook	3.4	3.3	-1%
Downstream	5.8	5.8	0%
Ellen	25.4	27.0	6%
Ellis	1.4	1.5	5%
Helena	4.6	4.8	5%
Helm Street	0.7	0.8	7%
Henley	1.0	1.4	49%
Jane	14.9	15.5	5%
Lower Canning	5.8	6.5	12%
Maylands	3.7	3.7	0%
Mills Street	4.4	4.6	5%
Millendon	3.2	3.2	0%
Munday/Bickley	3.4	3.5	2%
Perth Airport N	3.0	3.1	2%
Perth Airport S	2.1	2.1	3%
Saint Leonards	0.5	0.8	49%
South Belmont	2.4	2.3	-2%
South Perth	14.2	14.2	0%
Southern	15.9	17.9	12%
Susannah	6.3	6.3	0%
Upper Canning	9.2	10.4	13%
Upper Swan	3.3	3.9	16%
Yule	7.6	7.9	5%
Total	185	195	5%

Table 6.10 Average annual nitrogen loads and median concentrations and percentage changes following urban development proposed in the Metropolitan Regional Planning Scheme

Catchment	Current equilibrium		Future urban			
	Nitrogen load (tonnes/yr)	TN conc. (mg/L)	Nitrogen load (tonnes/yr)	% change	TN conc. (mg/L)	% change
Bannister	12.8	1.5	15.8	24%	1.94	28%
Bayswater	7.5	0.9	7.8	4%	0.97	4%
Belmont Central	0.6	0.8	0.7	30%	1.04	30%
Bennett	5.7	1.2	6.3	11%	1.18	0%
Blackadder	2.4	0.9	4.6	88%	1.57	73%
Bullcreek	10.2	1.1	10.3	2%	1.09	0%
CBD	4.2	1.2	4.2	1%	1.24	2%
Claisebrook	3.3	1.3	3.5	4%	1.32	6%
Downstream	7.6	1.3	8.4	10%	1.38	4%
Ellen	92.8	3.2	115.4	24%	4.72	46%
Ellis	0.7	0.4	0.9	36%	0.36	0%
Helena	4.9	1.4	5.4	10%	1.44	5%
Helm Street	1.6	2.3	1.6	0%	2.40	6%
Henley	0.8	1.2	1.8	141%	2.07	73%
Jane	11.6	0.8	12.3	6%	0.80	7%
Lower Canning	6.9	1.8	7.9	14%	2.07	13%
Maylands	11.7	2.3	12.0	2%	2.37	3%
Mills Street	6.1	1.3	6.0	-1%	1.19	-11%
Millendon	2.9	1.0	2.9	0%	0.97	0%
Munday/Bickley	2.6	1.1	3.9	49%	1.65	47%
Perth Airport N	2.0	1.0	2.0	3%	1.02	1%
Perth Airport S	0.5	0.3	0.5	3%	0.28	0%
Saint Leonards	0.7	1.5	1.7	138%	2.37	54%
South Belmont	1.4	0.7	1.4	6%	0.75	7%
South Perth	10.9	0.6	11.4	4%	0.69	10%
Southern	19.5	1.3	25.5	31%	1.44	14%
Susannah	8.6	1.1	9.2	8%	1.14	2%
Upper Canning	6.5	0.7	6.8	5%	0.73	1%
Upper Swan	11.6	1.2	14.4	23%	3.07	150%
Yule	7.5	1.1	8.1	8%	1.09	3%
Total	266		313	18%		5%

Table 6.11 Average annual phosphorus loads and median concentrations, and percentage changes in load and concentration, following proposed urban development implemented with and without soil amendment

Catchment	Current equilibrium		No soil amendment				With soil amendment			
	Phosphorus load load (tonnes/yr)	TP conc. (mg/L)	Phosphorus load (tonnes/yr)		TP conc. (mg/L)		Phosphorus load (tonnes/yr)		TP conc. (mg/L)	
				% change		% change		% change		% change
Bannister	0.70	0.06	0.86	23%	0.08	22%	0.86	23%	0.08	22%
Bayswater	0.50	0.05	0.53	5%	0.06	6%	0.52	5%	0.06	6%
Belmont Central	0.06	0.07	0.07	18%	0.08	17%	0.07	14%	0.08	11%
Bennett	0.60	0.07	0.76	27%	0.07	12%	0.76	26%	0.07	9%
Blackadder	0.17	0.04	0.24	41%	0.05	21%	0.24	41%	0.05	21%
Bullcreek	2.60	0.14	2.66	2%	0.14	1%	2.66	2%	0.14	1%
CBD	0.27	0.06	0.28	3%	0.07	5%	0.28	3%	0.07	5%
Claisebrook	0.24	0.05	0.25	2%	0.05	2%	0.25	2%	0.05	2%
Downstream	0.30	0.05	0.31	4%	0.05	0%	0.31	4%	0.05	0%
Ellen	10.55	0.50	13.64	29%	0.66	32%	13.04	24%	0.63	27%
Ellis	0.01	0.01	0.01	18%	0.01	0%	0.01	12%	0.01	0%
Helena	0.22	0.03	0.25	10%	0.03	3%	0.24	10%	0.03	3%
Helm Street	0.06	0.10	0.07	20%	0.11	12%	0.07	18%	0.11	10%
Henley	0.18	0.31	0.54	207%	0.65	109%	0.46	163%	0.56	81%
Jane	0.67	0.02	0.85	27%	0.03	29%	0.85	27%	0.03	29%
Lower Canning	0.91	0.17	1.06	18%	0.21	20%	1.02	12%	0.16	-6%
Maylands	0.26	0.04	0.27	3%	0.04	3%	0.27	3%	0.04	3%
Mills Street	0.75	0.14	0.85	14%	0.14	6%	0.83	11%	0.14	4%
Millendon	0.15	0.02	0.15	0%	0.02	0%	0.15	0%	0.02	0%
Munday/Bickley	0.16	0.05	0.32	97%	0.11	94%	0.24	46%	0.07	26%
Perth Airport N	0.20	0.04	0.25	23%	0.05	17%	0.25	23%	0.05	17%
Perth Airport S	0.16	0.02	0.18	16%	0.03	17%	0.18	16%	0.03	17%
Saint Leonards	0.14	0.15	0.32	132%	0.23	52%	0.27	96%	0.19	27%
South Belmont	0.21	0.08	0.23	9%	0.09	12%	0.23	9%	0.09	11%
South Perth	1.93	0.06	2.00	4%	0.06	9%	1.93	0%	0.06	5%
Southern	1.94	0.13	3.17	63%	0.18	43%	2.06	6%	0.11	-10%
Susannah	0.72	0.02	0.85	17%	0.02	0%	0.85	17%	0.02	0%
Upper Canning	0.38	0.03	0.40	5%	0.04	6%	0.40	5%	0.04	6%
Upper Swan	1.79	0.07	2.31	29%	0.08	19%	2.07	16%	0.08	17%
Yule	0.46	0.07	0.48	6%	0.07	0%	0.47	4%	0.07	-1%
Total	27		34	25%		12%	32	17%		6%

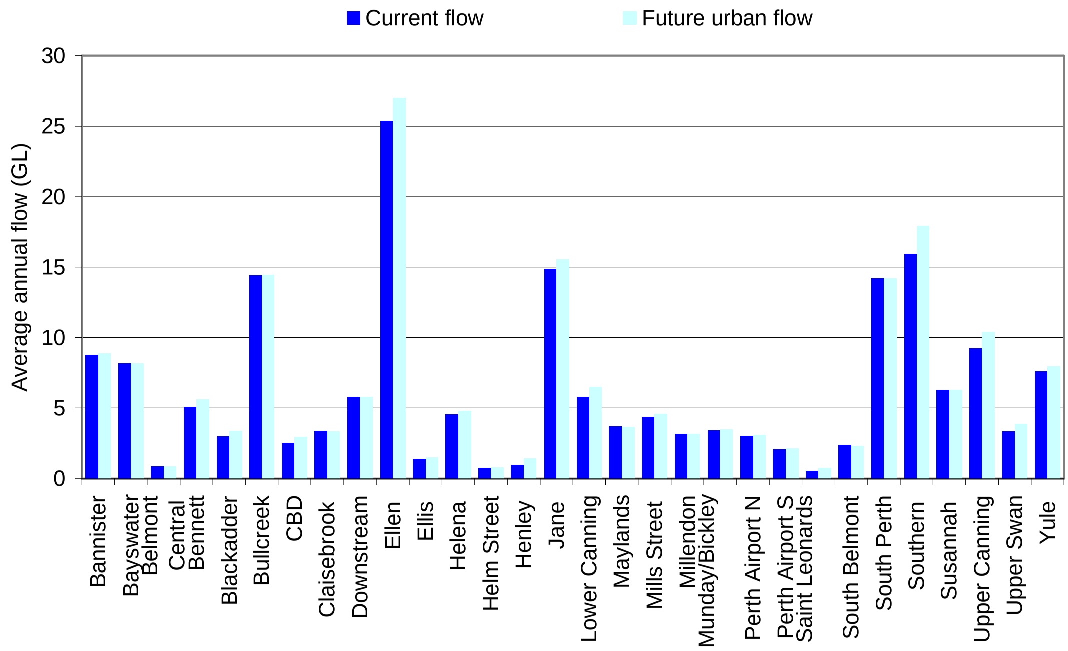
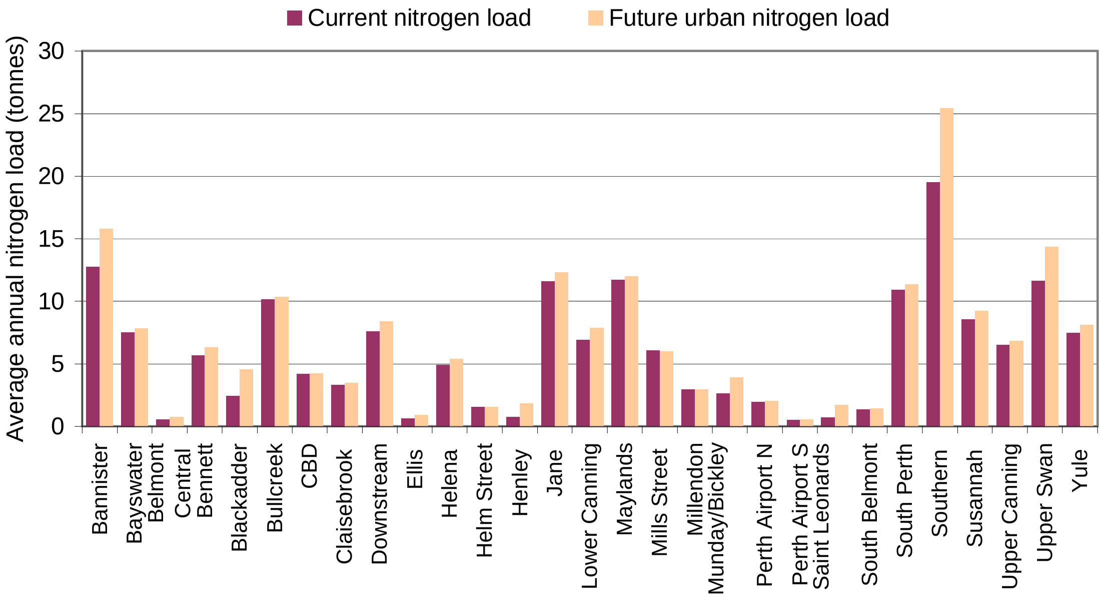


Figure 6.4 Estimated average annual flows following future urban development



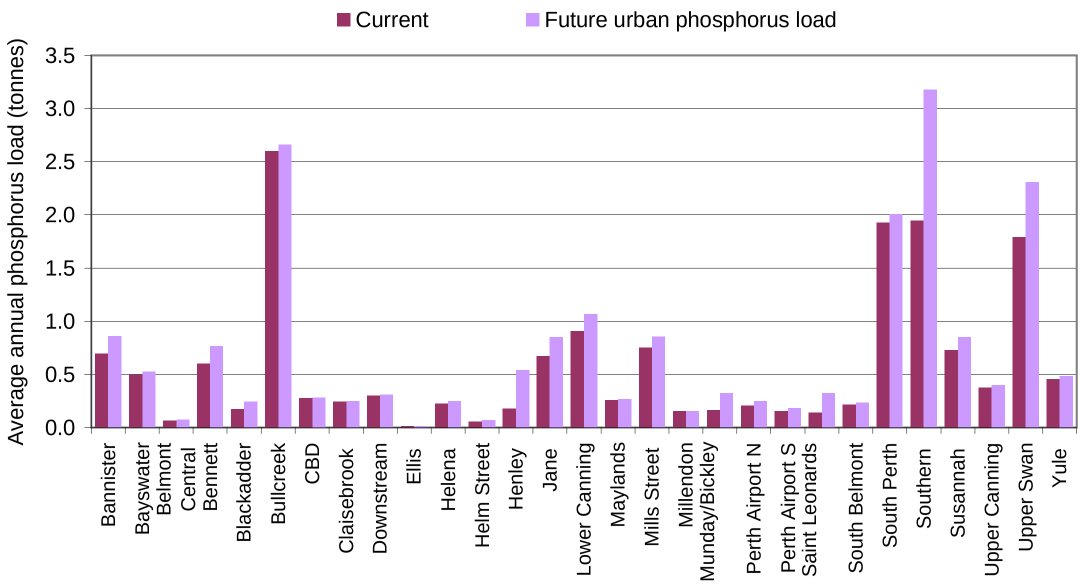


Figure 6.5 Current nitrogen and phosphorus average annual loads at catchment equilibrium and estimated average annual loads following future urban development (without soil amendment)(excluding Ellen Brook)

In summary, three catchments (Ellis Street, Perth Airport North and Upper Canning) are currently meeting their water-quality objectives for nitrogen (at catchment equilibrium) (Table 6.12). Future urban development would mean Ellis Street no longer achieves its water-quality objectives for nitrogen, and would cause an increase in average annual nitrogen load in all but seven catchments (CBD, Helm Street, Mills Street, Millendon, Perth Airport North, Perth Airport South and South Belmont). The nitrogen load to the estuaries is estimated to increase by 18% from 266 to 313 tonnes (estimated load increase in Ellen Brook is 23 tonnes).

The phosphorus input to the estuaries is exceeding its target by a similar percentage to the nitrogen input (93% and 106% respectively). However, much of the phosphorus input is due to Ellen Brook, and the urban catchments generally have lower percentage exceedences for phosphorus than nitrogen. At catchment equilibrium there are seven catchments meeting their water-quality objectives for phosphorus (Table 6.12); however, with future urban development in place, the number meeting their water-quality objectives is expected to be only three (Ellis Street, Maylands and Upper Canning). The average annual phosphorus load exported to the estuaries is estimated to increase by 25% from 27 to 34 tonnes (with estimated load increase in Ellen Brook of 3.1 tonnes). This is the worst-case scenario. If soil amendments are used in the new urban developments, the estimated increase in phosphorus load to the estuaries is 17% to 32 tonnes.

Soil amendments make very little difference in catchments that have naturally high PRI soils. However, there are 10 catchments with low PRI soils where the load increases associated with urban developments would be about 25% less with soil amendments (Belmont Central, Ellis, Henley, Lower Canning, Mills Street, Perth Airport North, Munday-Bickley, Saint Leonards, Southern, Upper Swan and Yule). This is most apparent in the Southern River catchment where the estimated average annual phosphorus load increase for the future urban development is 1.2 tonnes without soil amendments and 0.11 tonnes with soil amendments. Clearly soil amendments should be used in urban developments in this catchment, and all other catchments with low PRI soils.

Table 6.12 Average annual maximum acceptable loads, current climate loads and estimated future urban loads and percentage difference between future urban loads and maximum acceptable loads for nitrogen and phosphorus for the Swan-Canning coastal catchments

	Nitrogen:					Phosphorus:						
Catchment	Maximum acceptable load	Current climate load		Future urban		Maximum acceptable load	Current climate load		Future urban with soil amendment		Future urban without soil amendment	
	tonnes	tonnes	%	tonnes	%	tonnes	tonnes	%	tonnes	%	tonnes	%
Bannister	3.9	12.8	227	15.8	304	0.55	0.70	26	0.86	56	0.86	56
Bayswater	4.0	7.5	88	7.8	96	0.44	0.50	13	0.52	19	0.53	19
Belmont Central	0.3	0.6	87	0.7	143	0.04	0.06	53	0.07	75	0.07	80
Bennett	4.8	5.7	18	6.3	31	0.42	0.60	43	0.76	81	0.76	82
Blackadder	2.1	2.4	16	4.6	118	0.17	0.17	1	0.24	43	0.24	43
Bullcreek	4.9	10.2	107	10.3	111	1.01	2.60	157	2.66	163	2.66	163
CBD	1.7	4.2	146	4.2	149	0.21	0.27	30	0.28	33	0.28	33
Claisebrook	1.3	3.3	157	3.5	167	0.24	0.24	1	0.25	2	0.25	3
Downstream	3.5	7.6	117	8.4	140	0.30	0.30	-1	0.31	3	0.31	3
Ellen	22.1	92.8	320	115	422	2.13	10.5	395	13.0	512	13.6	540
Ellis	0.7	0.7	-7	0.9	27	0.02	0.01	-51	0.01	-45	0.01	-42
Helena	3.6	4.9	36	5.4	50	0.23	0.22	-3	0.24	6	0.25	7
Helm Street	0.5	1.6	216	1.6	216	0.04	0.06	43	0.07	69	0.07	71
Henley	0.6	0.8	27	1.8	206	0.05	0.18	251	0.46	822	0.54	976
Jane	11.0	11.6	5	12.3	12	0.58	0.67	16	0.85	47	0.85	47
Lower Canning	3.2	6.9	116	7.9	146	0.50	0.91	81	1.02	103	1.06	113
Maylands	5.1	11.7	130	12.0	135	0.27	0.26	-13	0.27	-1	0.27	-11
Mills Street	2.6	6.1	134	6.0	130	0.28	0.75	168	0.83	197	0.85	205
Millendon	2.6	2.9	13	2.9	13	0.15	0.15	2	0.15	2	0.15	2
Munday/Bickley	2.3	2.6	14	3.9	71	0.14	0.16	16	0.24	69	0.32	129
Perth Airport North	1.3	2.0	51	2.0	56	0.21	0.20	-3	0.25	19	0.25	19
Perth Airport South	1.1	0.5	-53	0.5	-52	0.17	0.16	-9	0.18	6	0.18	6
Saint Leonards	0.5	0.7	44	1.7	242	0.10	0.14	40	0.27	173	0.32	224
South Belmont	1.0	1.4	36	1.4	43	0.13	0.21	65	0.23	80	0.23	80
South Perth	8.8	10.9	24	11.4	29	1.76	1.93	10	1.93	10	2.00	14
Southern	11.4	19.5	71	25.5	123	1.15	1.94	69	2.06	79	3.17	176
Susannah	4.8	8.6	78	9.2	92	0.65	0.72	11	0.85	30	0.85	30
Upper Canning	7.5	6.5	-13	6.8	-9	0.42	0.38	-11	0.40	-6	0.40	-6
Upper Swan	6.1	11.6	91	14.4	135	1.29	1.79	39	2.07	61	2.31	79
Yule	5.6	7.5	34	8.1	44	0.43	0.46	6	0.47	10	0.48	12
TOTAL	129	266	106	313	143	14	27	93	32	126	34	141

% = percentage difference with respect to Maximum acceptable load

- (green) Meets water quality objectives
- (yellow) Exceeds *Maximum acceptable load* by 0–50%
- (purple) Exceeds *Maximum acceptable load* by 50–100%
- (red) Exceeds *Maximum acceptable load* by more than 100%

6.5 Management scenarios

The scenarios related to land management (Table 6.13) are discussed in detail in the following sections (6.5.1–6.5.6). A summary of the results of these scenarios is given in Section 6.5.7.

Table 6.13 Land management scenarios for the Swan-Canning coastal catchments

1. 100% infill of septic tanks
   – reticulated sewerage system to all urban areas
2. Removal of all point sources of nutrient pollution
3. *Fertiliser action plan*
   – 100% implementation in urban only
   – 100% implementation in rural only
   – 100% implementation in urban and rural areas
4. Fertiliser modification
   – reduction of urban fertilisation by 50%
5. Soil amendment in rural land use
6. Drainage changes
   – wetlands similar to Liege St at bottom of catchments
7. In-stream interventions
   – zeolite/laterite nutrient filters in waterways

6.5.1 Removing septic tanks and point sources of nutrient pollution

Point sources

Only three point sources of nutrient pollution which discharge directly to water have been included in the modelling (as discussed in Section 3.2): the Swan Brewery and the Ranford Road tip in Bannister Creek catchment, and a feedlot in Ellen Brook catchment. The effect of removing these point sources is shown in Table 6.14. Removal of the two point sources in Bannister Creek catchment would reduce the catchment's nitrogen load by about 9% and the phosphorus load by about 26%, which would enable Bannister Creek to achieve its phosphorus load reduction target. Removal of the feedlot in Ellen Brook catchment would reduce its nitrogen load by 3% and its phosphorus load by 1%.

Table 6.14 Impact of removing nutrient point sources

Catchment	Nitrogen				Phosphorus			
	Current climate load (tonnes/ year)	Point source contributions (1997–2006) (tonnes/year)	No point sources (tonnes/year)		Current climate TP load (tonnes/ year)	Point source contributions (1997–2006) (tonnes/year)	No point sources (tonnes/year)	
Bannister	12.8	1.1	11.7	-8.6%	0.70	0.18	0.52	-26%
Ellen	92.8	2.8	90.0	-3.0%	10.5	0.1	10.4	-1.0%
Total (whole catchment)	**266**	**3.9**	**262**	**-1.5%**	**27**	**0.29**	**27**	**-1.1%**

Septic tanks

How septic tank removal was modelled this study

- *Remove all septic tanks; that is, infill all urban areas with a deep-sewerage system with a connection rate of 100% or install zero-emission onsite septic systems.*

The impact of septic tanks is examined by modelling into the future (until the catchment is at equilibrium) with septic tanks and without septic tanks. This estimates the potential reductions in nutrient loads if all septic tanks in urban areas were replaced with reticulated sewerage or zero-emission onsite septic systems.

In Table 6.15 and Table 6.16 the estimated *Contribution from septic tanks (1997–2006)* includes the average annual loads from existing septic tanks, as well as the residual nutrients from recently decommissioned septic tanks still leaching from the soil profile; whereas the *Contribution from septic tanks (2057–2066)* includes only contributions from existing septic tanks. The residual nutrients in the soil profile from septic tanks decommissioned before 2007 will have leached from the soil profile by 2057. Thus the difference between *Contribution from septic tanks (1997–2006)* and *Contribution from septic tanks (2057–2066)* is the decreases in nutrient loads that are still to occur as a result of the recent infill sewerage program. That is, the expected future decreases to average annual nitrogen and phosphorus loads from the current infill sewerage program are 17 and 0.38 tonnes respectively. If all remaining septic tanks were removed, the potential additional decrease in annual loads would be 22 and 1.72 tonnes of TN and TP respectively.

Table 6.15 Average annual nitrogen loads from all sources and from septic tanks (1997–2006) and at catchment equilibrium (2057–2066)

Catchment	Average annual nitrogen load (tonnes)					
	Current load (1997–2006)	Contribution from septic tanks (1997–2006)		Equilibrium load (2057–2066)	Contribution from septic tanks (2057–2066)	
Bannister	12	0.5	4%	12.8	0.5	4%
Bayswater	9.8	2.5	26%	7.5	0.6	8%
Belmont Central	0.7	0.1	14%	0.6	0.0	0%
Bennett	7.1	1.5	21%	5.7	0.0	0%
Blackadder	2.5	0.0	0%	2.4	0.0	0%
Bullcreek	11	1.1	10%	10.2	0.1	1%
CBD	5.2	0.9	17%	4.2	0.4	11%
Claisebrook	4.7	1.7	37%	3.3	0.2	5%
Downstream	6.9	0.8	12%	7.6	0.0	0%
Ellen	71	1.6	2%	93	1.6	2%
Ellis	0.7	0.1	14%	0.7	0.1	15%
Helena	5.8	2.6	45%	4.9	2.0	40%
Helm Street	1.7	0.3	18%	1.6	0.1	6%
Henley	0.8	0.1	13%	0.8	0.1	11%
Jane	11	5.2	47%	11.6	5.2	45%
Lower Canning	7.9	0.9	11%	6.9	0.4	6%
Maylands	11	2.3	21%	11.7	0.4	3%
Mills Street	7.1	3.6	50%	6.1	2.5	42%
Millendon	2.6	0.0	0%	2.9	0.0	0%
Munday/Bickley	2.9	0.2	7%	2.6	0.0	0%
Perth Airport N	2.0	0.9	45%	2.0	0.7	38%
Perth Airport S	1.1	0.9	82%	0.5	0.4	73%
Saint Leonards	1.4	0.0	0%	0.7	0.0	0%
South Belmont	1.7	0.3	18%	1.4	0.1	4%
South Perth	13	2.7	21%	10.9	1.0	9%
Southern	21	0.7	3%	19.5	0.7	4%
Susannah	4.8	0.1	2%	8.6	0.1	1%
Upper Canning	7.5	4.0	53%	6.5	2.1	33%
Upper Swan	8.6	1.7	20%	11.6	1.2	10%
Yule	7.5	1.8	24%	7.5	1.2	16%
Total	252	39	16%	266	22	8%

Table 6.16 Average annual phosphorus loads from all sources and from septic tanks (1997–2006) and at catchment equilibrium (2057–2066)

Catchment	Average annual phosphorus load (tonnes)					
	Current load (1997–2006)	Contribution from septic tanks (1997–2006)		Equilibrium load (2057–2066)	Contribution from septic tanks (2057–2066)	
Bannister	0.82	0.02	2%	0.70	0.02	3%
Bayswater	0.60	0.15	25%	0.50	0.04	8%
Belmont Central	0.06	0.01	17%	0.06	0.00	2%
Bennett	0.42	0.03	8%	0.60	0.00	0%
Blackadder	0.17	0.02	12%	0.17	0.01	5%
Bullcreek	1.20	0.09	8%	2.60	0.05	2%
CBD	0.24	0.00	0%	0.27	0.00	0%
Claisebrook	0.30	0.06	20%	0.24	0.00	1%
Downstream	0.30	0.02	7%	0.30	0.01	2%
Ellen	10.0	0.11	1%	10.5	0.46	4%
Ellis	0.02	0.00	0%	0.01	0.00	0%
Helena	0.23	0.03	13%	0.22	0.03	13%
Helm Street	0.07	0.01	14%	0.06	0.00	3%
Henley	0.05	0.00	0%	0.18	0.01	3%
Jane	0.58	0.09	16%	0.67	0.09	14%
Lower Canning	0.97	0.15	15%	0.91	0.04	5%
Maylands	0.27	0.02	7%	0.26	0.00	1%
Mills Street	0.78	0.49	63%	0.75	0.45	60%
Millendon	0.15	0.01	7%	0.15	0.01	4%
Munday/Bickley	0.14	0.01	11%	0.16	0.00	0%
Perth Airport N	0.21	0.06	29%	0.20	0.04	20%
Perth Airport S	0.17	0.03	18%	0.16	0.01	7%
Saint Leonards	0.14	0.01	7%	0.14	0.01	8%
South Belmont	0.24	0.05	21%	0.21	0.01	5%
South Perth	1.94	0.10	5%	1.93	0.05	3%
Southern	2.21	0.16	7%	1.94	0.11	6%
Susannah	0.65	0.02	3%	0.72	0.02	3%
Upper Canning	0.42	0.05	12%	0.38	0.03	9%
Upper Swan	2.01	0.18	9%	1.79	0.10	6%
Yule	0.43	0.11	26%	0.46	0.10	22%
Total	26	2.10	8%	27	1.72	6%

On a catchment-by-catchment basis, removal of septic tanks would cause five catchments – with current equilibrium nitrogen loads greater than their maximum acceptable loads – to have loads that are less than their maximum acceptable loads (Blackadder Creek, Helena River, Jane Brook, Millendon and Perth Airport North). For phosphorus, removal of septic tanks will allow Blackadder, Claisebrook, Jane, Millendon and Yule to achieve their phosphorus targets. In Mills Street septic tanks contribute approximately 60% of the phosphorus load and their removal almost achieves the phosphorus target in this catchment. The equilibrium average annual nitrogen and phosphorus loads with and without septic tanks are shown in Figure 6.6 and Figure 6.7 respectively – for all catchments except Ellen Brook. The impact of septic tank removal in Ellen Brook catchment is not significant in terms of percentage reductions because most of its load is from farming enterprises. The estimated reductions in Ellen Brook are 1.6 tonnes (2%) for nitrogen and 0.46 tonnes (4%) for phosphorus.

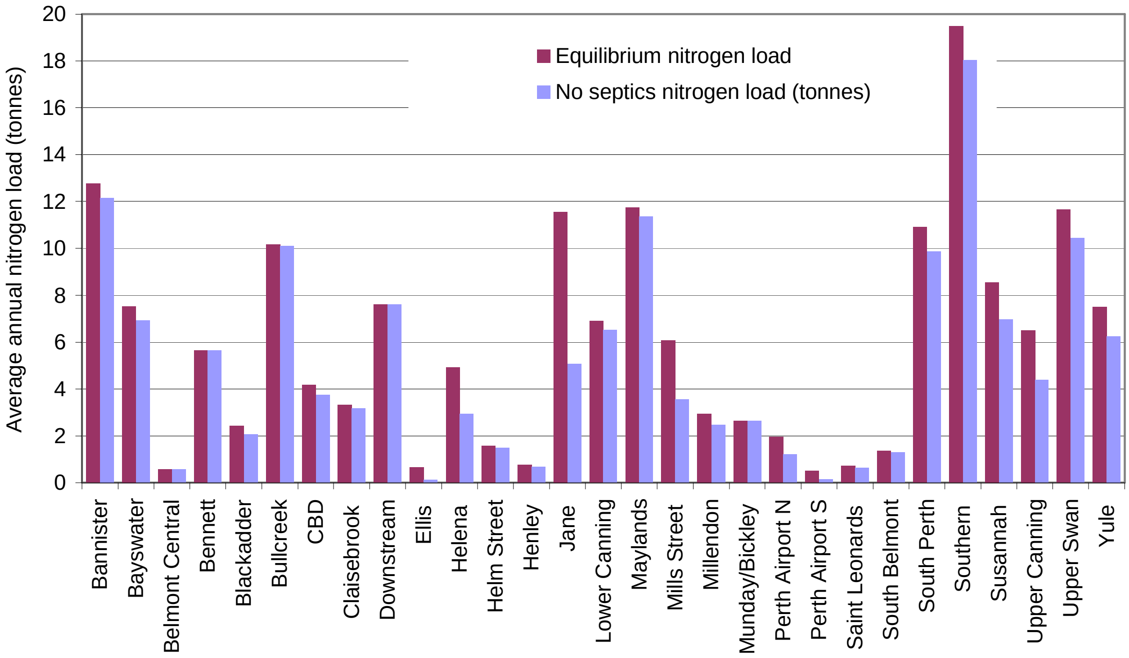


Figure 6.6 Average annual nitrogen loads with and without septic tanks at catchment equilibrium (excluding Ellen Brook)

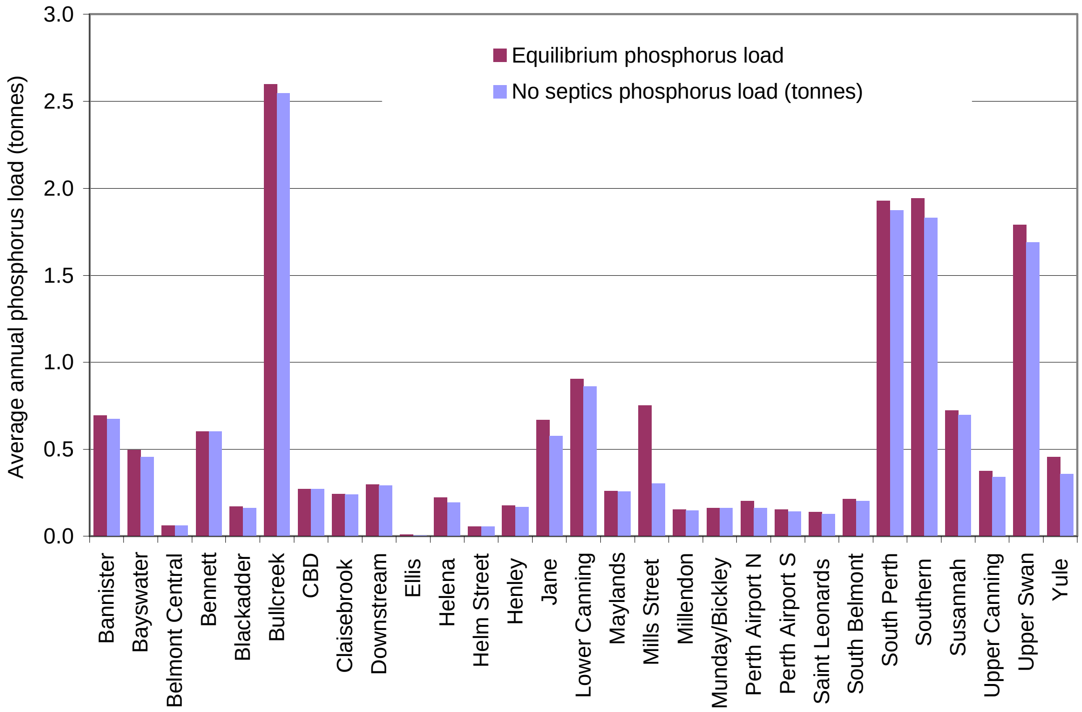


Figure 6.7 Average annual phosphorus loads with and without septic tanks at catchment equilibrium (excluding Ellen Brook)

6.5.2 Fertiliser action plan

The *Fertiliser action plan* (JGFIWP 2007) has been invoked to reduce leaching of phosphorus from fertilisers to waterways. The plan aims to phase out the use of highly water-soluble phosphorus fertilisers on the low PRI soils of the coastal plain (McPharlin et al. 1990). The water-soluble phosphorus fertilisers (80 to 100% soluble) will be replaced by fertilisers with low water solubility (40% or less). The plan’s implementation zone includes the Scott Coastal Plain and the Swan Coastal Plain from the Leeuwin-Naturaliste Ridge at Dunsborough to the Moore River catchment boundary in the north. In the Swan-Canning coastal catchments the area of implementation is from the coast to the Darling Scarp. Requests for continued use of highly water-soluble phosphorus fertilisers will be determined through a consultation process; and will need to be accompanied by a nutrient management plan that demonstrates low environmental risk from phosphorus application and loss, and that no low water-soluble fertiliser is an acceptable replacement. Although the details of the *Fertiliser action plan* are still to be finalised, it is proposed that fertiliser management will occur through the Fertiliser Industry Federation of Australia’s Fertcare program. This program will also provide guidance on nitrogen fertilisation.

The *Fertiliser action plan* will mandate maximum highly water-soluble phosphorus content of non-bulk (bagged) fertilisers for urban use to be 1% for lawn fertilisers and 2.5% for general garden fertilisers. These will be the only changes that result from the plan in urban areas.

In 2006 the Department of Water’s Water Science branch surveyed nutrient application in urban areas. Nutrient application rates for urban areas with different ages and densities were derived from the data supplied by approximately 12 000 respondents. The median phosphorus fertiliser application rate in urban areas is 26 kg/ha/year. If the phosphorus content of bagged fertilisers is reduced to 1% for lawn fertilisers and 2.5% for garden fertilisers, and gardeners apply the same products (with the reduced phosphorus contents) in the same quantities (mass) as previously, the median phosphorus fertiliser application rate will reduce by about 30%.

An unexpected finding of the urban nutrient survey was the large amount of organic fertiliser being applied. The *Fertiliser action plan*, as it stands, has no influence on the use of organic fertilisers in urban areas.

DAFWA has been a lead agency for this initiative, and its research in broad-acre agriculture, indicates that the phosphorus fertilisation requirement will decrease by approximately 30%. Furthermore, plant uptake will increase by about 10% because the fertiliser will reside in the soil profile for longer due to its reduced solubility (Summers et al. 2000; Summers, *pers. comm.* 2008). DAFWA estimates the impact of this initiative will be a 30% reduction in phosphorus leaching on a catchment scale.

How the* Fertiliser action plan *was modelled in this study

- *30% reduction in phosphorus fertiliser application to all fertilised land uses within the Fertiliser action plan implementation zone.*
- *10% increase in SQUARE plant uptake parameter in areas where Fertiliser action plan is implemented.*

The impact of the *Fertiliser action plan* has been examined by modelling three scenarios:

1. Application of *Fertiliser action plan* in urban areas.
2. Application of *Fertiliser action plan* in rural areas.
3. Application of *Fertiliser action plan* in rural and urban areas concurrently.

The predicted phosphorus load reductions to the estuaries following *Fertiliser action plan* implementation in urban areas, rural areas and both rural and urban areas are 3.8 tonnes (-14%), 3.4 tonnes (-12%) and 6.8 tonnes (-25%) respectively (Figure 6.8 and Figure 6.9). (The non-linearity is due to in-stream processing of phosphorus.)

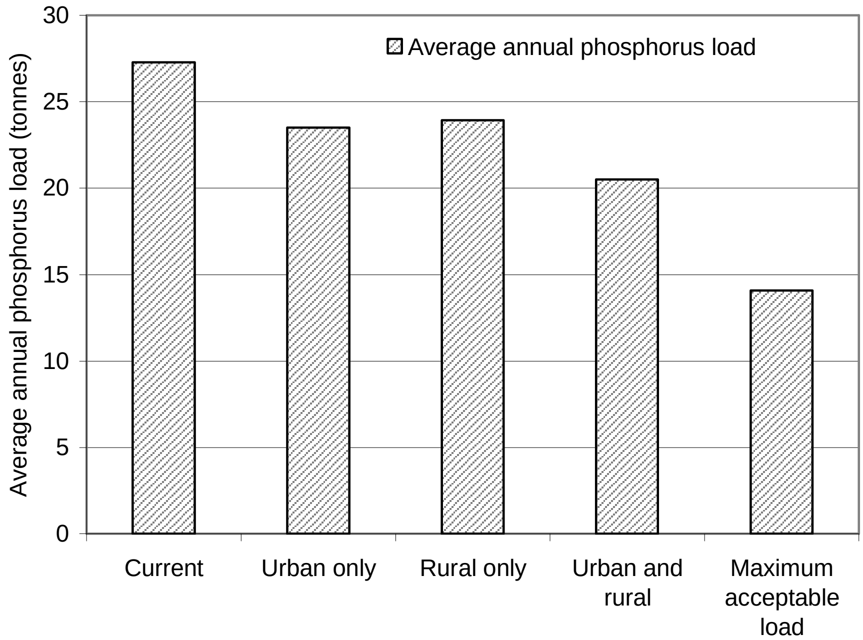


Figure 6.8 Phosphorus percentage load changes due to Fertiliser action plan *implementation in urban, rural, and both urban and rural areas*

Millendon, Susannah and Jane catchments have few or no fertilised areas on the coastal plain, so are relatively unaffected by *Fertiliser action plan* implementation (Table 6.17). Some other catchments such as Bayswater, Blackadder, Upper Canning and Yule Brook have small percentage reductions in phosphorus load because of contributions from septic tanks or small areas of fertilised land use on the coastal plain. The other catchments have percentage reductions ranging from 21% to 38%.

The predicted phosphorus load reduction in Ellen Brook following *Fertiliser action plan* implementation in both urban and rural areas is 2.4 tonnes (22%). The predicted load reductions for each of the catchments, except Ellen Brook, are shown in Figure 6.9. Of the 23 catchments for which the current climate loads (equilibrium loads) are greater than the maximum acceptable loads given in Table 6.2, *Fertiliser action plan* implementation causes 13 to have phosphorus loads less than their maximum acceptable loads. The *Fertiliser action plan* will also improve the water quality of catchments that are currently meeting their targets.

Table 6.17 Predicted average annual phosphorus loads and median TP concentrations following the implementation of the Fertiliser action plan

Catchment	Current climate phosphorus load	FAP urban only phosphorus load		FAP rural only phosphorus load		FAP urban + rural phosphorus load		Maximum acceptable phosphorus load
	(tonnes)	(tonnes)	% change	(tonnes)	% change	(tonnes)	% change	(tonnes)
Bannister	0.70	0.50	-28	0.70	0	0.50	-28	0.55
Bayswater	0.50	0.45	-10	0.50	0	0.45	-10	0.44
Belmont Central	0.06	0.04	-35	0.06	0	0.04	-35	0.04
Bennett	0.60	0.42	-30	0.54	-11	0.40	-33	0.42
Blackadder	0.17	0.15	-14	0.17	0	0.15	-14	0.17
Bullcreek	2.60	1.95	-25	2.60	0	1.95	-25	1.0
CBD	0.27	0.17	-36	0.27	-1	0.17	-36	0.21
Claisebrook	0.24	0.15	-36	0.24	-1	0.15	-36	0.24
Downstream	0.30	0.19	-38	0.30	1	0.19	-38	0.30
Ellen	10.5	10.3	-3	8.3	-21	8.2	-22	2.1
Ellis	0.01	0.01	-21	0.01	-19	0.01	-32	0.02
Helena	0.22	0.19	-16	0.20	-11	0.17	-26	0.23
Helm Street	0.06	0.04	-33	0.06	0	0.04	-33	0.04
Henley	0.18	0.12	-33	0.16	-11	0.11	-36	0.05
Jane	0.67	0.67	0	0.61	-9	0.61	-9	0.58
Lower Canning	0.91	0.60	-34	0.81	-10	0.59	-35	0.50
Maylands	0.26	0.17	-36	0.26	0	0.17	-36	0.27
Mills Street	0.75	0.60	-20	0.75	0	0.60	-20	0.28
Millendon	0.15	0.15	-2	0.15	-2	0.15	-2	0.15
Munday/Bickley	0.16	0.11	-31	0.15	-10	0.11	-34	0.14
Perth Airport North	0.20	0.16	-20	0.18	-9	0.16	-21	0.21
Perth Airport South	0.16	0.12	-21	0.14	-10	0.12	-22	0.17
Saint Leonards	0.14	0.10	-26	0.12	-16	0.09	-34	0.10
South Belmont	0.21	0.14	-35	0.21	0	0.14	-35	0.13
South Perth	1.93	1.37	-29	1.93	0	1.37	-29	1.8
Southern	1.94	1.77	-9	1.67	-14	1.30	-33	1.2
Susannah	0.72	0.72	0	0.72	0	0.72	0	0.65
Upper Canning	0.38	0.34	-10	0.38	1	0.34	-10	0.42
Upper Swan	1.79	1.39	-22	1.37	-24	1.14	-36	1.3
Yule	0.46	0.43	-7	0.40	-12	0.40	-12	0.43
Total	27	24	-14	24	-12	21	-25	14

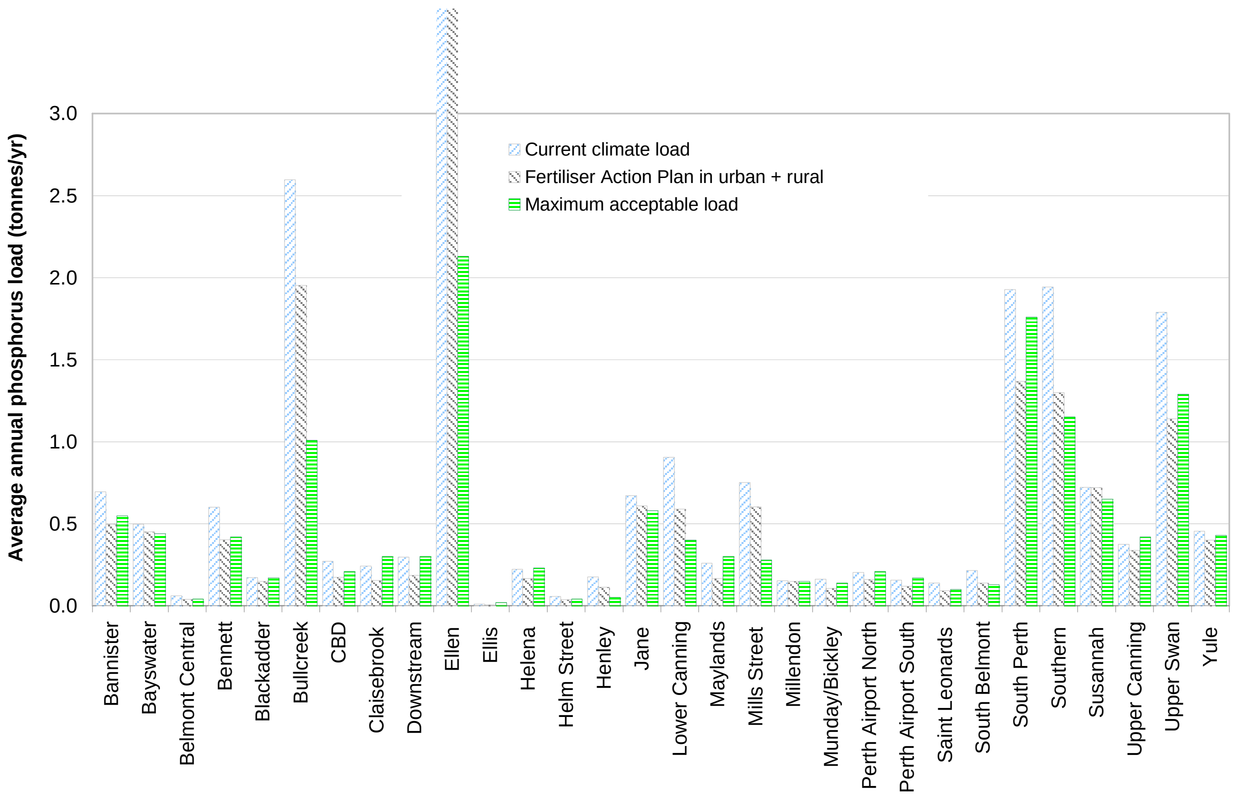


Figure 6.9 Phosphorus loads following Fertiliser action plan *implementation in both urban and rural areas (Ellen Brook current climate load and* Fertiliser action plan *load is off the graph)*

In summary, the current climate phosphorus load for all the catchments (at equilibrium) is estimated to be 27 tonnes. Following *Fertiliser action plan* implementation the load is expected to be approximately 21 tonnes, which represents about half the required reduction to meet the maximum acceptable load target of 14 tonnes. Of the 23 catchments with equilibrium loads greater than their maximum acceptable loads, 13 achieve their load target following *Fertiliser action plan* implementation. The plan's implementation in Ellen Brook causes the phosphorus load to decrease from 10.6 to 8.2 tonnes (22% reduction). (The maximum acceptable load in Ellen Brook is 2.1 tonnes.)

6.5.3 Urban fertiliser reduction

The effectiveness of education programs on gardening habits has not been studied. As such, possible reductions in fertiliser applications due to education programs are impossible to estimate. A 50% reduction was modelled to determine whether or not urban fertiliser reduction could substantially decrease nutrient inflows to the estuaries.

How urban fertiliser reduction was modelled in this study

- *50% reduction in nitrogen and phosphorus fertiliser application to the current urban land uses listed in Table 6.18.*

Table 6.18 Urban and rural land-use classifications for the Swan-Canning coastal catchments

Urban land use	**Rural land use**
Residential - single / duplex dwelling	Horticulture
Residential - aged persons	Plantation
Residential - multiple dwelling	Turf farm
Residential - temporary accommodation	Viticulture
Garden centre / nursery	Animal keeping - non-farming
Recreation - grass	Farm
Recreation - turf	Lifestyle block / hobby farm
Commercial / service - centre	Drainage*
Commercial / service - residential	Recreation / conservation - trees / shrubs*
Office - with parkland	Rural residential / bush block*
Office - without parkland	Water body*
Community facility - education	Landfill*
Community facility - non-education	Quarry / extraction*
Manufacturing / processing	Unused - uncleared - trees / shrubs*
Sewage - non-treatment plant	
Sewage - treatment plant	
Storage / distribution*	
Transport / access - airport*	
Transport / access - non-airport	
Utility*	
Yacht facilities*	
Unused - cleared - bare soil*	
Unused - cleared - grass*	

** Unfertilised land use*

Fertiliser action plan implementation only affects phosphorus fertilisation, whereas this scenario models a decrease in both nitrogen and phosphorus fertilisation to urban land uses. The average annual nitrogen and phosphorus loads that would result from the 50% fertiliser reductions are listed in Table 6.19 and shown in Figure 6.10.

Table 6.19 50% reduction to nitrogen and phosphorus fertilisation on urban land uses

	Nitrogen load (tonnes/year)				Phosphorus load (tonnes/year)			
Catchment	Current climate	50% urban fertiliser reduction		Maximum acceptable load	Current climate	50% urban fertiliser reduction		Maximum acceptable load
Bannister	12.8	7.1	-45%	3.9	0.70	0.39	-44%	0.55
Bayswater	7.5	2.7	-64%	4.0	0.50	0.27	-46%	0.44
Belmont Central	0.6	0.3	-48%	0.3	0.06	0.03	-47%	0.04
Bennett	5.7	3.6	-36%	4.8	0.60	0.36	-39%	0.42
Blackadder	2.4	0.8	-68%	2.1	0.17	0.09	-47%	0.17
Bullcreek	10.2	5.3	-48%	4.9	2.60	1.66	-36%	1.01
CBD	4.2	3.4	-19%	1.7	0.27	0.14	-50%	0.21
Claisebrook	3.3	1.4	-58%	1.3	0.24	0.12	-50%	0.24
Downstream	7.6	4.2	-45%	3.5	0.30	0.15	-51%	0.30
Ellen	93	89	-4%	22.1	10.5	10.3	-2%	2.13
Ellis	0.7	0.4	-33%	0.7	0.01	0.01	-20%	0.02
Helena	4.9	3.8	-22%	3.6	0.22	0.16	-30%	0.23
Helm Street	1.6	0.9	-42%	0.5	0.06	0.03	-43%	0.04
Henley	0.8	0.5	-32%	0.6	0.18	0.10	-42%	0.05
Jane	11.6	11.1	-4%	11.0	0.67	0.54	-20%	0.58
Lower Canning	6.9	2.8	-59%	3.2	0.91	0.40	-56%	0.50
Maylands	11.7	7.7	-34%	5.1	0.26	0.13	-49%	0.27
Mills Street	6.1	4.8	-21%	2.6	0.75	0.60	-20%	0.28
Millendon	2.9	2.9	0%	2.6	0.15	0.15	0%	0.15
Munday/Bickley	2.6	2.0	-23%	2.3	0.16	0.10	-38%	0.14
Perth Airport N	2.0	1.4	-28%	1.3	0.20	0.13	-37%	0.21
Perth Airport S	0.5	0.5	-12%	1.1	0.16	0.10	-33%	0.17
Saint Leonards	0.7	0.6	-16%	0.5	0.14	0.10	-31%	0.10
South Belmont	1.4	0.7	-47%	1.0	0.21	0.11	-47%	0.13
South Perth	10.9	6.0	-45%	8.8	1.93	1.00	-48%	1.76
Southern	19.5	15.0	-23%	11.4	1.94	1.25	-36%	1.15
Susannah	8.6	8.6	0%	4.8	0.72	0.72	0%	0.65
Upper Canning	6.5	5.1	-21%	7.5	0.38	0.24	-36%	0.42
Upper Swan	11.6	9.5	-18%	6.1	1.79	1.39	-23%	1.29
Yule	7.5	5.2	-31%	5.6	0.46	0.38	-17%	0.43
Total	266	207	-22%	129	27	21	-22%	14

For the 27 catchments with current climate nitrogen loads greater than their maximum acceptable loads, reducing the nitrogen fertilisation in urban areas by 50% causes 10 to have loads less than their maximum acceptable loads. The overall load reduction for nitrogen is 59 tonnes (22%) from 266 to 207 tonnes, which is still 79 tonnes above the maximum acceptable load of 129 for all the catchments (Table 6.19, Figure 6.10, Figure 6.11).

For the 23 catchments with current climate phosphorus loads greater than their maximum acceptable loads, reducing the phosphorus fertilisation in urban areas by 50% causes 15 to have loads less than their maximum acceptable loads. The overall load reduction is 6.1 tonnes (22%) from 27 to 21 tonnes. The maximum acceptable phosphorus load from all catchments is 14 tonnes. This scenario has a very small impact in the Ellen Brook catchment because of the relatively small area of urban land use compared with the agricultural land uses.

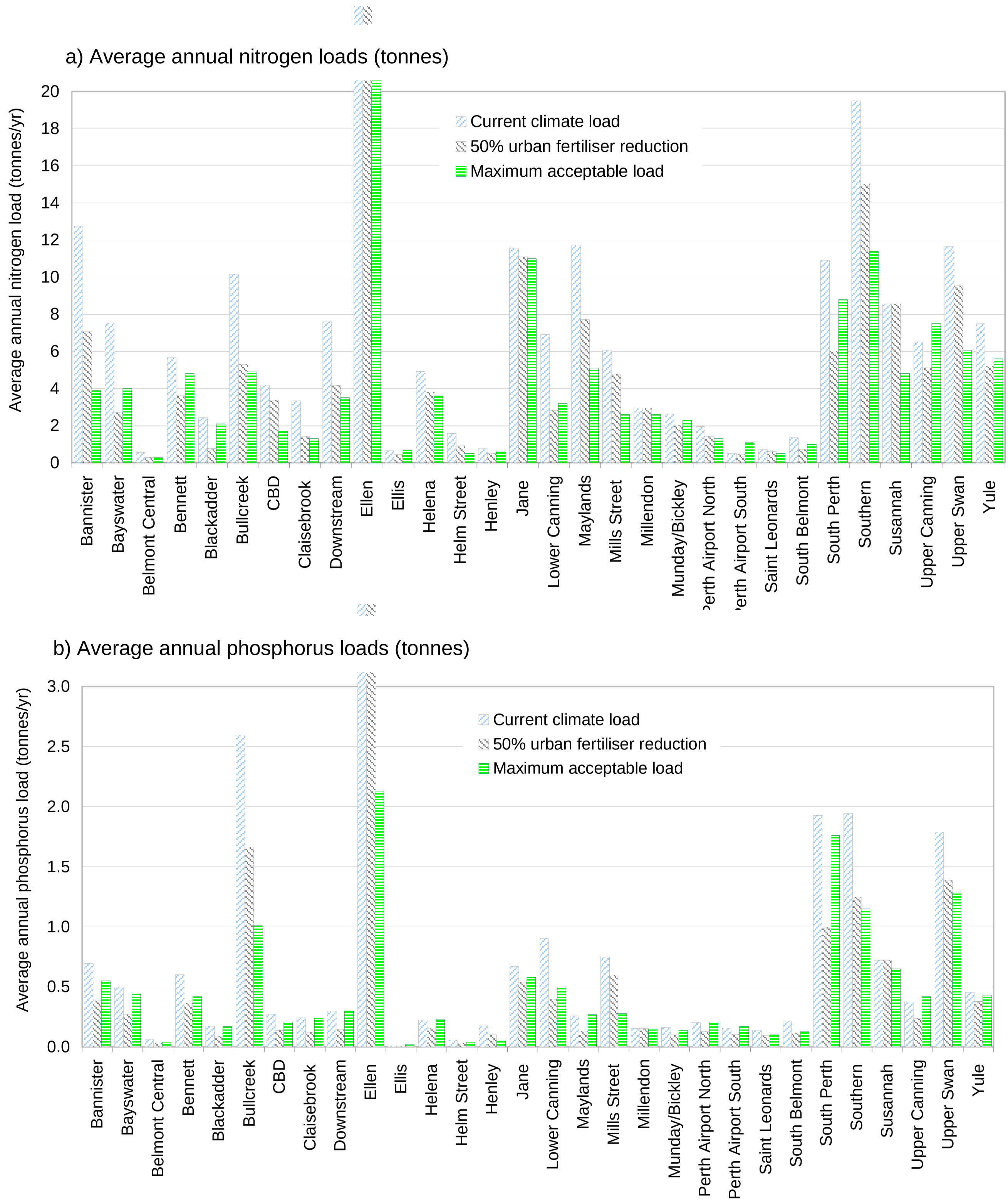


Figure 6.10 Current climate load, load with fertilisation reduced by 50% in urban areas and maximum acceptable loads for a) nitrogen and b) phosphorus (note: Ellen Brook is 'off' the graph)

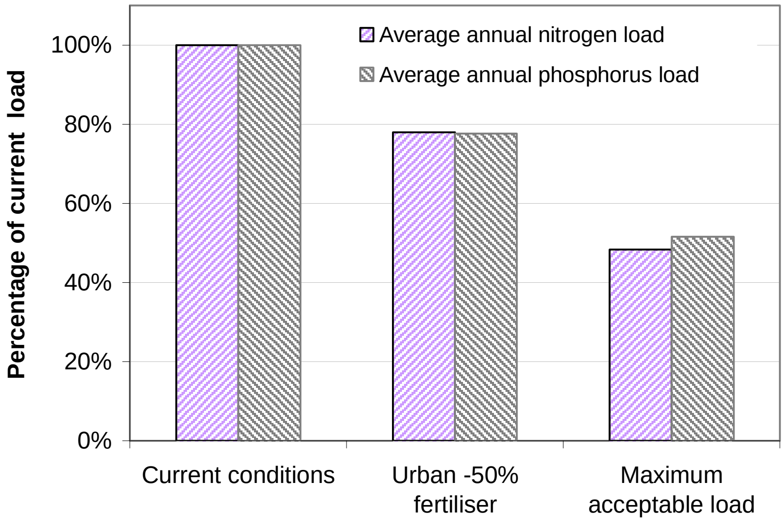


Figure 6.11 Percentage reduction in phosphorus and nitrogen exports for urban fertilisation reduction scenario for all catchments

6.5.4 Soil amendments in rural land uses

Several studies have demonstrated the effectiveness of soil-amendment application to decrease phosphorus leaching in areas with poor sandy soils (Summers et al. 2002). The amendments include bauxite residues and by-products from the refining of mineral sands (neutralised used acids). Generally the soil amendments are tilled into the soils to increase their PRI. Increasing soil PRI decreases phosphorus leaching from fertilisers, which allows greater plant uptake. Plant productivity is increased and the phosphorus fertilisation requirement is decreased (economic benefit). The increased plant productivity may also contribute to less nitrogen leaching, but this has not been included in the SQUARE model conceptualisation.

The rural land uses in the Swan-Canning coastal catchments other than Ellen Brook are listed in Table 6.18. The land-use mapping for Ellen Brook catchment has different classifications: the rural land-use classes for Ellen Brook are listed in Table 6.20.

Table 6.20 Rural land uses in Ellen Brook for which soil amendments may be applied

Land use
Cattle
Cattle for beef
Cattle for beef and horses
Floriculture
Glasshouses
Horses
Horticulture
Livestock - alpaca
Mixed grazing
Pasture for hay
Pasture for seed
Plant nursery
Sheep
Turf farm

How soil amendments in rural land uses was modelled this study

- *All fertilised rural land uses listed in Table 6.18 and Table 6.20 with PRIs of less than 10 were given a PRI of 10.*
- *Did not increase plant uptake parameter.*

In reality, the increase in soil PRI will depend on the type and quantity of soil amendment applied. This scenario indicates the possible benefits of soil amendments with respect to phosphorus leaching.

Soil-amendment application in rural land uses with low PRI soils reduces the phosphorus load to the estuaries from 27 to 24 tonnes (12% reduction) (Figure 6.12). There are eight catchments with sufficient areas of rural land use on low PRI soils for which this scenario demonstrates significant (>5%) reductions in phosphorus export (Ellen, Ellis, Helena, Lower Canning, Munday-Bickley, Saint Leonards, Southern and Upper Swan) (Table 6.21 and Figure 6.13). Two of these catchments (Ellis and Helena) do not require phosphorus load reductions. Soil-amendment application in all rural land uses on low PRI soils would allow Upper Swan, Saint Leonards Brook and Munday-Bickley catchments to achieve their load targets.

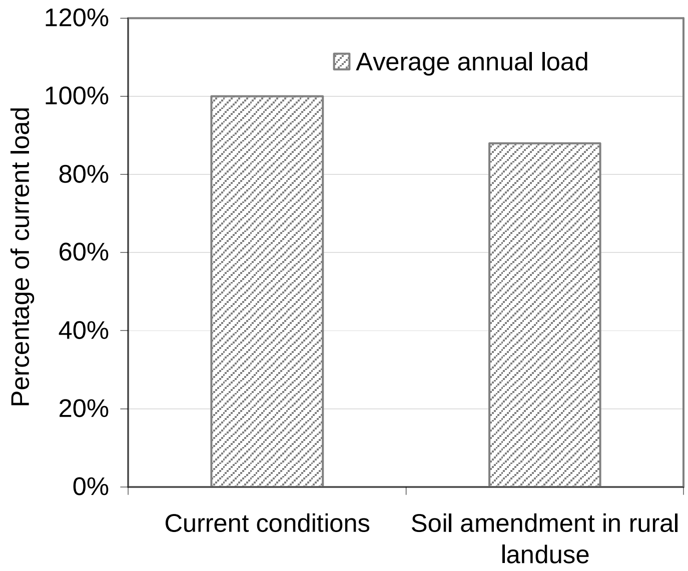


Figure 6.12 Percentage change in phosphorus export for soil amendment application in rural land uses

Ellen Brook has a current climate phosphorus load of 10.5 tonnes and a maximum acceptable load of 2.1 tonnes; thus it requires the greatest phosphorus load reduction of all catchments in absolute terms (8 tonne load reduction) and as a percentage (79% reduction). This scenario decreases the phosphorus load by about 2 tonnes – a quarter of the required reduction in Ellen Brook. Soil-amendment application in strategic locations in rural areas has a significant role in decreasing phosphorus leaching.

Table 6.21 Impact of soil-amendment application in rural land uses with low PRI soils

Catchment	Current climate phosphorus load (tonnes/year)	Soil amendment in rural landuse phosphorus load (tonnes/year)		Maximum acceptable phosphorus load (tonnes/year)
Bannister	0.70	0.70	0%	0.55
Bayswater	0.50	0.50	0%	0.44
Belmont Central	0.06	0.06	-0.5%	0.04
Bennett	0.60	0.60	-0.2%	0.42
Blackadder	0.17	0.17	-0.1%	0.17
Bullcreek	2.60	2.60	0%	1.01
CBD	0.27	0.27	0%	0.21
Claisebrook	0.24	0.24	0%	0.24
Downstream	0.30	0.30	0%	0.30
Ellen	10.55	8.53	-19%	2.13
Ellis	0.01	0.01	-13%	0.02
Helena	0.22	0.21	-7%	0.23
Helm Street	0.06	0.06	-1%	0.04
Henley	0.18	0.17	-2%	0.05
Jane	0.67	0.64	-4%	0.58
Lower Canning	0.91	0.72	-20%	0.50
Maylands	0.26	0.26	0%	0.27
Mills Street	0.75	0.75	0%	0.28
Millendon	0.15	0.15	0%	0.15
Munday/Bickley	0.16	0.13	-18%	0.14
Perth Airport North	0.20	0.20	0%	0.21
Perth Airport South	0.16	0.16	0.2%	0.17
Saint Leonards	0.14	0.10	-28%	0.10
South Belmont	0.21	0.21	0%	0.13
South Perth	1.93	1.86	-3%	1.76
Southern	1.94	1.71	-12%	1.15
Susannah	0.72	0.72	0%	0.65
Upper Canning	0.38	0.37	-0.2%	0.42
Upper Swan	1.79	1.14	-36%	1.29
Yule	0.46	0.45	-1%	0.43
Total	27	24	-12%	14

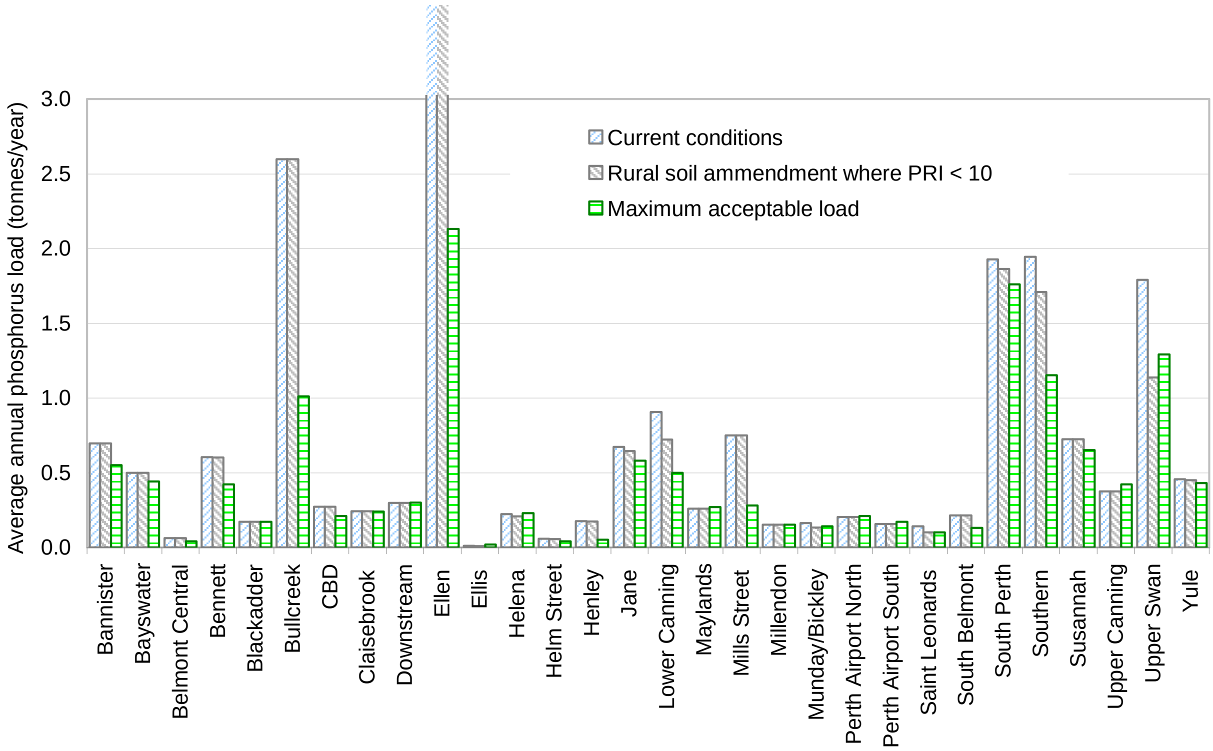


Figure 6.13 Soil amendment in rural land use (Ellen Brook current climate load and load with soil amendments applied are both 'off' the graph)

6.5.5 Artificial Wetlands

Construction of the Liege Street wetland, which constitutes 0.8% of the area of its contributing catchment, began in April 2004 (GHD 2007b). Planting was conducted from June 2004 to 2006 and monitoring began in November 2004. GHD (2007b) analysed the data collected from November 2004 to March 2007 to determine if the wetland was meeting SCCP targets (as discussed in Section 4.1) and Australian and New Zealand Environment Conservation Council guidelines (ANZECC & ARMCANZ 2000). GHD (2007b) also determined dry-season reduction efficiencies for nitrogen and phosphorus of 27% and 45% respectively. These efficiencies and the efficiencies given in the *Water sensitive urban design engineering procedures* (WSUD Engineering Procedures 2005) were used to derive relationships for nitrogen and phosphorus removal as a function of wetland size (given as a fraction of the catchment size) (Figure 6.14).

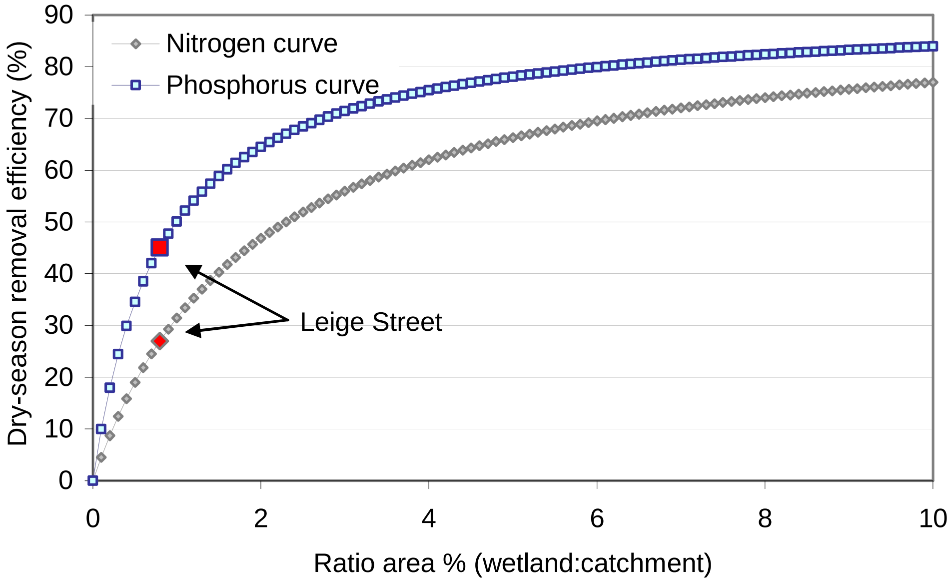


Figure 6.14 Dry-season removal efficiency curve for perennial wetlands

Liege Street wetland flows all year. Its ability to remove nitrogen and phosphorus in winter is small and most nutrient removal occurs in summer when the water resides for longer, plants are growing and higher temperatures promote denitrification. Perennial wetlands are assumed to only remove nutrients during dry season flows: the removal rates for the dry season are shown in Figure 6.14.

To deduce the annual removal efficiencies for wetlands that only flow in winter, load reductions for Liege Street for the dry season were calculated and an annual percentage reduction was deduced assuming the nutrient was removed in all flow regimes. Thus for a seasonal wetland of the same size as Leige Street, the estimated removal annual efficiencies are 11% for nitrogen and 21% for phosphorus. This is most likely an overestimation because nutrient removal in the cooler winter months will be reduced by plant and microbe dormancy. The annual nutrient removal efficiency curves for seasonal wetlands are given in Figure 6.15.

Fisher and Acreman (2004) examined and summarised data from 57 wetlands from around the world. Of the 54 wetlands with nitrogen data, 80% decreased, 13% increased and 7% showed no change in observed nitrogen concentrations. For phosphorus, 49 wetlands were studied and 84% decreased, 5% increased and 3% showed no change in concentrations. It should also be noted that studies over more than a few years, or which involved frequent sampling during high-flow events, were more likely to indicate that the wetland increased nutrient loadings.

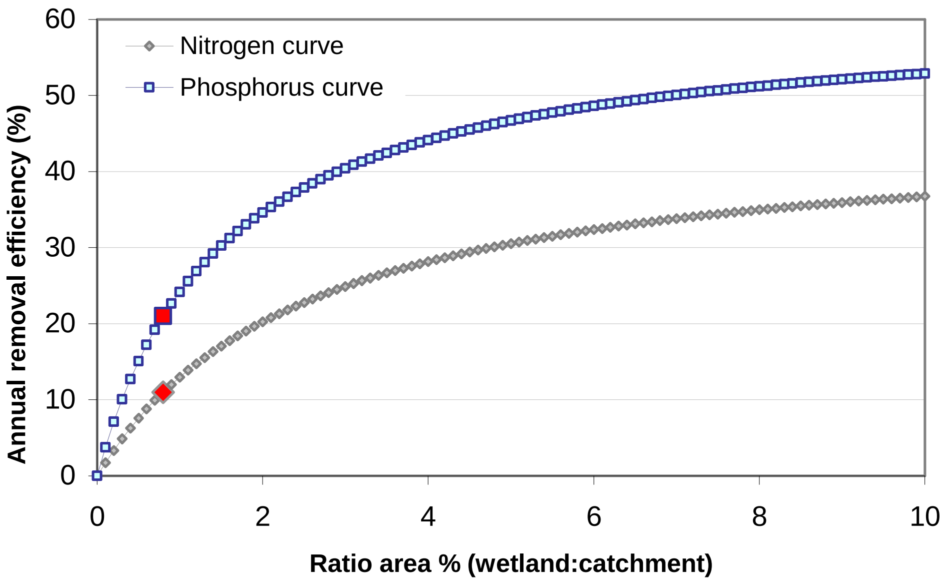


Figure 6.15 Removal efficiency curve for seasonal wetlands

The removal efficiencies used here were based on data from one wetland on the Swan Coastal Plain, taken over a short period when the wetland was establishing. This is the time in a wetland's lifecycle when uptake is expected to be greatest because the plants are growing rapidly and absorbing nutrients. More studies on the removal efficiencies of wetlands on the Swan Coastal Plain need to be undertaken to verify these estimates, and the potential for wetlands to become sources of nutrients should not be ignored.

How wetlands were modelled in this study

- *If the wetland was established in a waterway that flowed all year, the nitrogen and phosphorus removal efficiencies were taken from the graph in Figure 6.14. If the waterway ceased to flow in summer, the removal efficiencies were taken from Figure 6.15.*

The Swan River Trust selected the potential wetland sites and specified the wetland sizes. The potential wetlands and their sizes are listed in Table 6.22. No wetland sites were identified in the Claisebrook, Downstream, Henley, Jane, Millendon, Saint Leonards, Susannah or Upper Canning catchments. Two wetlands were specified for Lower Canning, Maylands, South Perth and Upper Swan.

Table 6.22 Potential wetlands, areas in hectares and area as a percentage of draining catchment

Catchment	Catchment area (ha)	Draining area (ha)	Wetland area (ha)	Ratio (wetland: draining catchment)
Bannister	2 357	2 357	21.8	0.9%
Bayswater MD	2 725	2 725	24.8	0.9%
Bennet	11 310	11 310	180	1.6%
Bickley	7 372	7 372	3.6	0.0%
Blackadder	1 705	1 705	25.7	1.5%
Bullcreek	4 255	1 938	29.5	1.5%
CBD	1 370	1 170	9.7	0.8%
Central Belmont	358	358	3.5	1.0%
Ellen Brook	71 642	71 625	71.6	0.1%
Ellis	1 174	769	4.8	0.6%
Helena River	17 566	17 566	20.7	0.1%
Helm Street	600	600	4.8	0.8%
Lower Canning - northern urban	4 430	654	8.5	1.3%
Lower Canning - rest of catchment		918	17.2	1.9%
Maylands - Inglewood	1 872	1 117	1.5	0.1%
Maylands - Walters Brook		249	3.3	1.3%
Mills Street	1 226	1 226	15.6	1.3%
Perth Airport North	2 812	2 361	11.1	0.5%
Perth Airport South	2 461	2 461	3.1	0.1%
South Belmont	1 055	1 055	0.7	0.1%
South Perth - Vic Park	4 047	915	3.8	0.4%
South Perth - Waterford		987	24.0	2.4%
Southern	14 950	14 949	15.6	0.1%
Upper Swan - Ashfield flats	4 050	164	22.4	13.7%
Upper Swan - Guildford		201	0.8	0.4%
Yule	5 568	5 568	18.4	0.3%

The potential load reductions for the constructed wetlands are listed in Table 6.23 and shown in Figure 6.16, Figure 6.17 and Figure 6.18. For nitrogen, the introduction of constructed wetlands causes a significant decrease (more than 5%) in loads in 10 catchments and a large decrease (more than 10%) in five catchments (Bannister, Bennett, Blackadder, CBD and Mills Street). The impact on phosphorus export is even greater, with 15 catchments displaying more than a 5% decrease in load, and seven catchments displaying more than a 15% decrease. This is a reflection of the annual removal efficiencies for phosphorus being greater than those for nitrogen (Figure 6.14 and Figure 6.15). As mentioned previously, these removal efficiencies were derived from Liege Street wetland data for the period after the wetland was established and vegetation was growing rapidly. For established wetlands (no net increase in total vegetation), the removal efficiencies for phosphorus may be less. Particulate phosphorus, which is deposited in the wetland in low flows, may become mobilised during large flows. More data needs to be collected on wetland efficiencies on the coastal plain.

Table 6.23 Potential load reductions from constructed wetlands in the Swan-Canning coastal catchments

	Nitrogen load (tonnes/year)				Phosphorus load (tonnes/year)			
	Current climate load	Wetland implementation load		Maximum acceptable load	Current climate load	Wetland implementation load		Maximum acceptable load
Bannister	12.8	11.5	-10%	3.9	0.70	0.56	-19%	0.55
Bayswater	7.5	6.8	-9%	4.0	0.50	0.40	-19%	0.44
Belmont Central	0.6	0.5	-9%	0.3	0.06	0.05	-20%	0.04
Bennett	5.7	4.7	-18%	4.8	0.60	0.41	-31%	0.42
Blackadder	2.4	1.8	-27%	2.1	0.17	0.12	-30%	0.17
Bullcreek	10.2	9.9	-3%	4.9	2.60	2.48	-5%	1.01
CBD	4.2	3.7	-11%	1.7	0.27	0.21	-22%	0.21
*Claisebrook**	3.3	3.3	-	1.3	0.24	0.24	-	0.24
*Downstream**	7.6	7.6	-	3.5	0.30	0.30	-	0.30
Ellen	92.8	90.9	-2%	22.1	10.55	10.15	-4%	2.13
Ellis	0.7	0.6	-1%	0.7	0.01	0.01	-3%	0.02
Helena	4.9	4.8	-2%	3.6	0.22	0.21	-5%	0.23
Helm Street	1.6	1.5	-6%	0.5	0.06	0.05	-13%	0.04
*Henley**	0.8	0.8	-	0.6	0.18	0.18	-	0.05
*Jane**	11.6	11.6	-	11.0	0.67	0.67	-	0.58
Lower Canning	6.9	6.6	-4%	3.2	0.91	0.84	-8%	0.50
Maylands	11.7	11.6	-1%	5.1	0.26	0.25	-5%	0.27
Mills Street	6.1	5.1	-15%	2.6	0.75	0.57	-24%	0.28
*Millendon**	2.9	2.9	-	2.6	0.15	0.15	-	0.15
Munday/Bickley	2.6	2.6	0%	2.3	0.16	0.16	0%	0.14
Perth Airport North	2.0	1.8	-6%	1.3	0.20	0.18	-12%	0.21
Perth Airport South	0.5	0.5	-2%	1.1	0.16	0.15	-4%	0.17
*Saint Leonards**	0.7	0.7	-	0.5	0.14	0.14	-	0.10
South Belmont	1.4	1.3	-1%	1.0	0.21	0.21	-3%	0.13
South Perth	10.9	10.1	-7%	8.8	1.93	1.66	-14%	1.76
Southern	19.5	19.1	-2%	11.4	1.94	1.87	-4%	1.15
*Susannah**	8.6	8.6	-	4.8	0.72	0.72	-	0.65
*Upper Canning**	6.5	6.5	-	7.5	0.38	0.38	-	0.42
Upper Swan	11.6	11.4	-2%	6.1	1.79	1.74	-3%	1.29
Yule	7.5	7.1	-5%	5.6	0.46	0.41	-11%	0.43
Total	266	256	-4%	129	27	25	-7%	14

** no wetlands in this catchment*

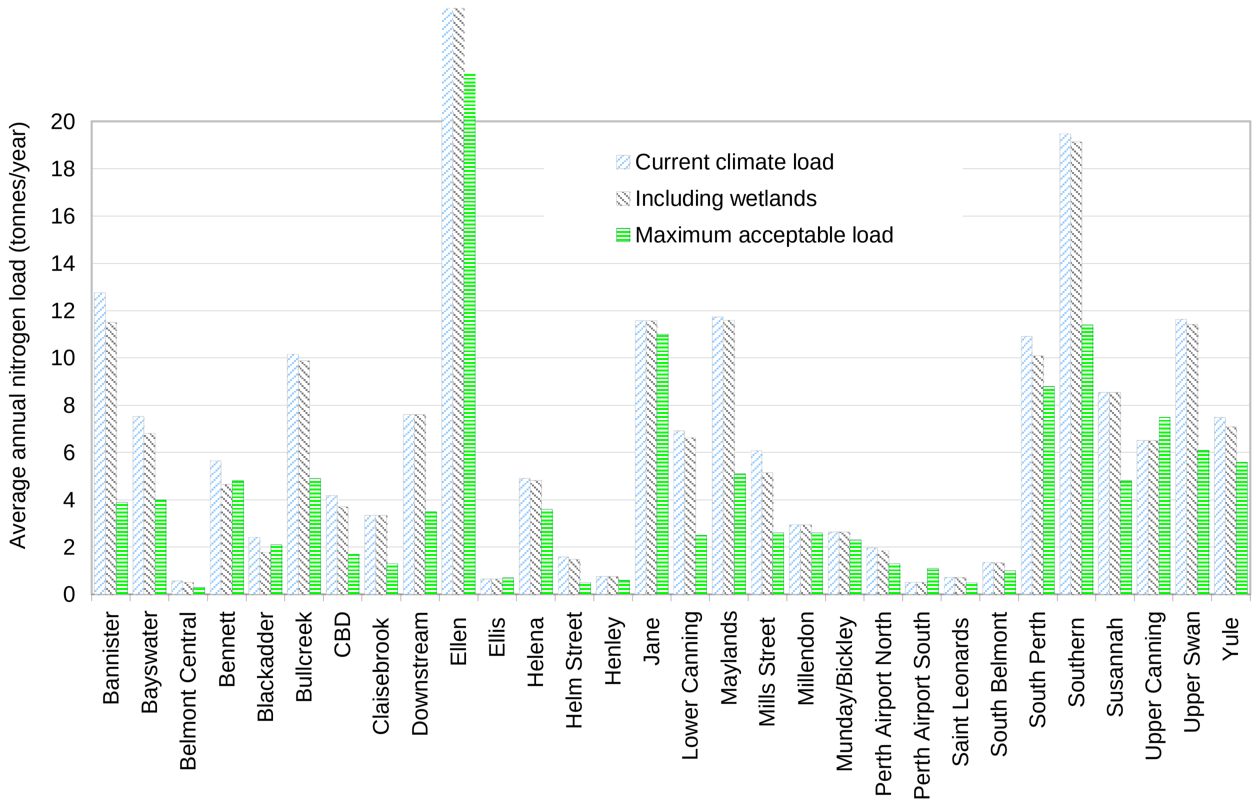


Figure 6.16 Current, potential and maximum acceptable nitrogen loads following construction of wetlands (Ellen Brook loads are 'off' the graph)

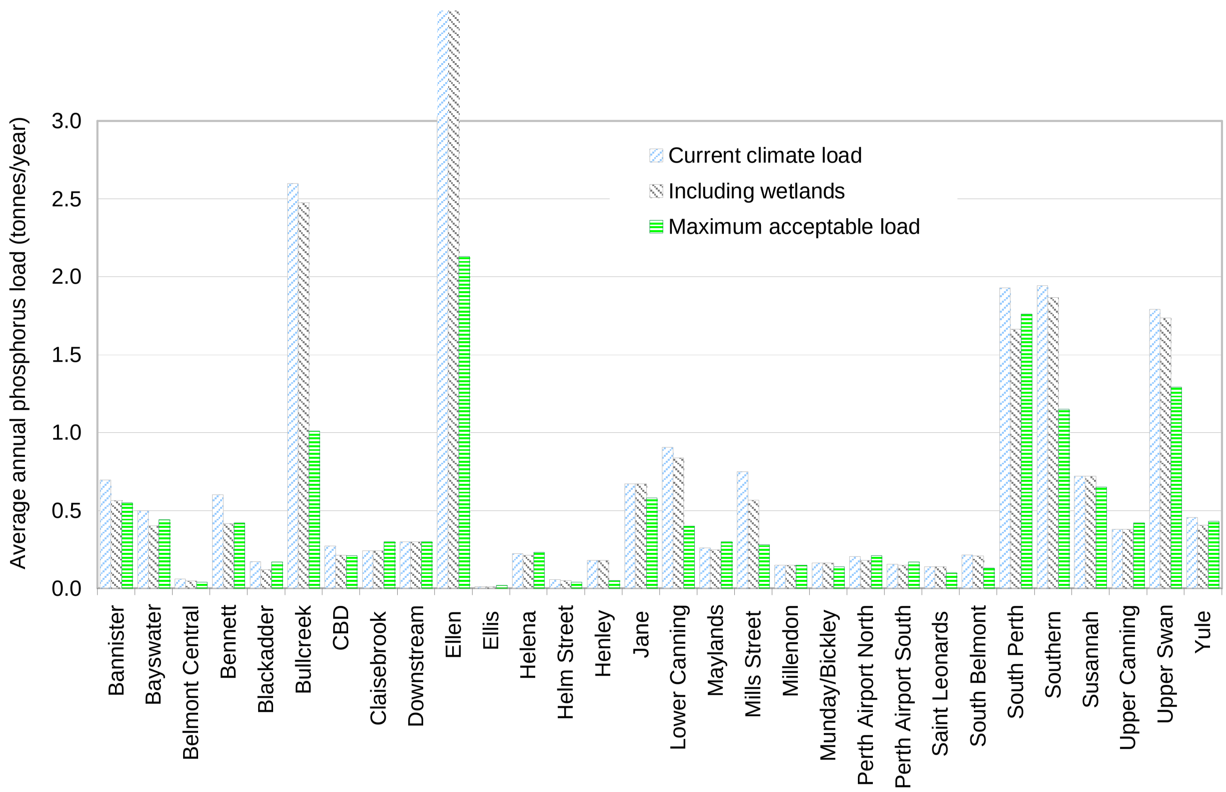


Figure 6.17 Current, potential and maximum acceptable phosphorus loads following construction of wetlands (Ellen Brook loads are 'off' the graph)

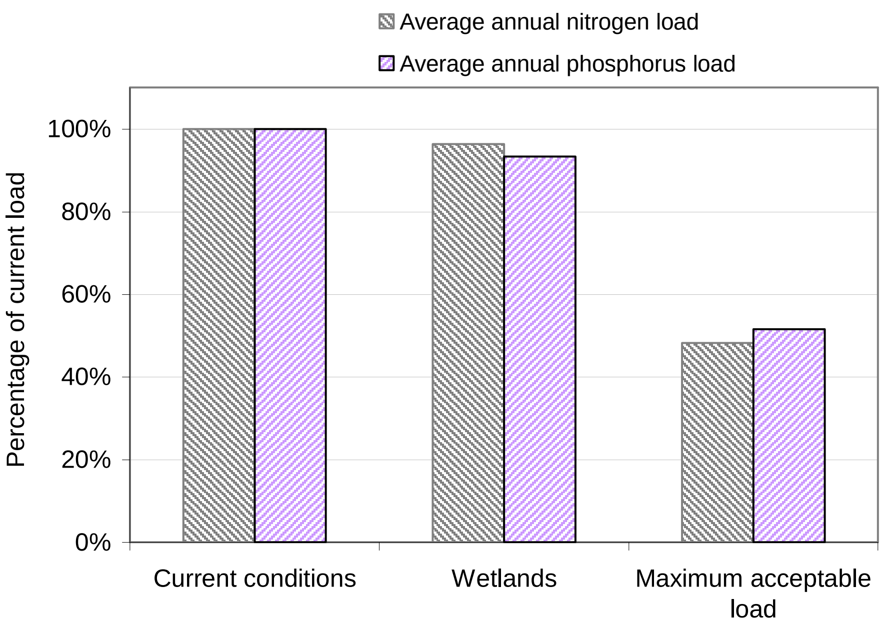


Figure 6.18 Percentage change in nitrogen and phosphorus loads to the estuaries following implementation of all wetlands

It should also be noted that the potential wetland sites supplied by the Swan River Trust were not examined for their suitability. Potential wetland locations need to be examined for risks such as acid sulfate soils and, if wetlands are sited on old landfill or industrial sites, release of contaminants. The non-nutrients contaminant program undertaken by the Department of Water (Evans 2009) examined contamination leaching from three historic landfill sites on the Swan and Canning rivers. Metal (lead, aluminium, chromium, copper, iron, zinc, arsenic, cadmium, manganese and nickel) concentrations in groundwater were observed to exceed ANZECC guidelines (ANZECC & ARMCANZ 2000). Numerous petroleum and polycyclic aromatic hydrocarbons were detected, of which naphthalene exceeded an ANZECC trigger value. However, trigger values are not available for many polycyclic aromatic hydrocarbons. Ammonia concentrations were also very high: one site had concentrations of up to 230 mg/L; the other two sites had concentrations of 4 mg/L and 46 mg/L respectively.

The proposed wetland near the outflow of Bayswater Main Drain incorporates the Eric Singleton Bird Sanctuary and an adjacent historic landfill site. A contaminated site rehabilitation program would be required before a nutrient-stripping wetland was built at this site. The Department of Environment (2004) advised that as well as being contaminated, the site had disturbed acid sulfate soils and should be approached with extreme caution.

6.5.6 Zeolite / laterite nutrient filters in waterways

GHD (2007c) modelled the removal of ammonium (NH_4) by zeolite adsorption and phosphate (PO_4) by laterite adsorption, for an in-stream structure in Ellen Brook for the period 1971 to 1997. The proposed structure consisted of approximately 500 m^3 of cracked pea laterite gravel with an 8 m^3 zeolite-filled gabion cage at the downstream end. Zeolite adsorption of NH_4 ranged from 2.8 to 5.7 kg N per year and laterite adsorption of PO_4 ranged from 28 to 55 kg P per year. On an annual basis, generally less than 1% of the NH_4 and PO_4 will be adsorbed to the intervention structure. The longevity of the system may exceed 70 years for the zeolite and 40 years for the laterite. The percentage removal efficiencies of the in-stream structure for varying flows are listed in Table 6.24 and plotted in Figure 6.19.

Table 6.24 Phosphate and ammonium removal efficiency for an in-stream structure consisting of 500 m³ of cracked pea laterite gravel with an 8 m³ zeolite-filled gabion cage at the downstream end

Flow Q (ML/day)	PO4 removal efficiency (%)	NH4 removal efficiency (%)
0.1	87%	100%
0.5	33%	33%
1	18%	17%
3	7%	6%
15	1%	1%

** From GHD (2007b), Page16*

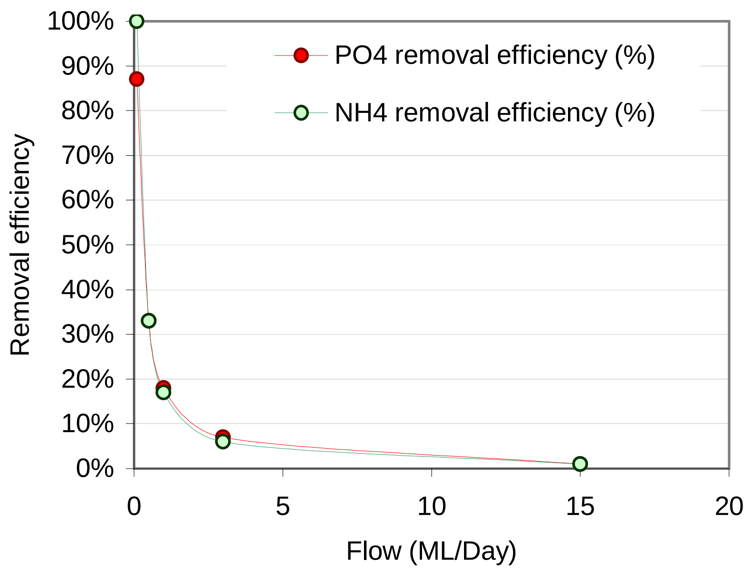


Figure 6.19 Plot of removal efficiencies of phosphate and ammonia for in-stream structure consisting of 500 m³ of cracked pea laterite gravel with an 8 m³ zeolite-filled gabion cage at the downstream end

The Swan River Trust requested scenario modelling of five in-stream nutrient filters: three in Ellen Brook catchment (two on tributaries and one on the Ellen Brook near the Brand Highway crossing at Muchea) and one in each of Mills Street Main Drain and Bannister Creek. The sizes of the nutrient filters are shown in Table 6.25. The removal efficiencies of the zeolite/laterite nutrient filters were taken from GHD (2007c) and scaled to allow for the size differences of the filters.

Table 6.25 Proposed nutrient filters in the Swan-Canning coastal catchments

Site	Catchment	Laterite volume (m^3)	Zeolite volume (m^3)
1	Ellen Brook	400	8
2	Ellen Brook	50	0.5
3	Ellen Brook	25	0.5
4	Mill Street Main Drain	500	8
5	Bannister Creek	500	8

The average annual nitrogen and phosphorus removals from these filters, as measured at the catchment outlets, for the 10-year modelling period are given in Table 6.26. The average annual nitrogen removals are 7 kg, 13 kg and 36 kg, and the average annual phosphorus removals are 22 kg, 5 kg and 12 kg for Ellen Brook, Bannister Creek and Mills Street Main Drain respectively. The predicted removals for Ellen Brook are similar to those estimated by GHD (2007c). The removal rates are all less than 1%, except for phosphorus removal in Mills Street Main Drain which is 1.6%.

Table 6.26 Nitrogen and phosphorus removal for in-stream interventions in Ellen Brook, Bannister Creek and Mills Street Main Drain catchments

Nitrogen:

	Current climate load (tonnes/ year)	Removal Sites 1, 4, 5 (tonnes/year)	Removal Site 2 (tonnes/ year)	Removal Site 3 (tonnes/ year)	Load with instream interventions (tonnes/year)	
Ellen Brook	93	0.005	0.002	0.000	93	-0.01%
Bannister Creek	13	0.013			13	-0.11%
Mill Street Main Drain	6.1	0.036			6.0	-0.59%

Phosphorus:

Catchment	Current climate load (tonnes/ year)	Removal Sites 1, 4, 5 (tonnes/year)	Removal Site 2 (tonnes/ year)	Removal Site 3 (tonnes/ year)	Load with instream interventions (tonnes/year)	
Ellen Brook	10.5	0.020	0.002	0.000	10.5	-0.21%
Bannister Creek	0.70	0.005			0.69	-0.70%
Mill Street Main Drain	0.75	0.012			0.74	-1.56%

In terms of all the Swan-Canning coastal catchments, removal of 56 kg of nitrogen from the estimated current climate load of 266 tonnes represents a 0.02% reduction, and removal of 39 kg of phosphorus from the current climate load of 27 tonnes represents a 0.14% reduction. Plots of the impact of the in-stream devices for the three catchments are given in Figure 6.20, Figure 6.21 and Figure 6.22.

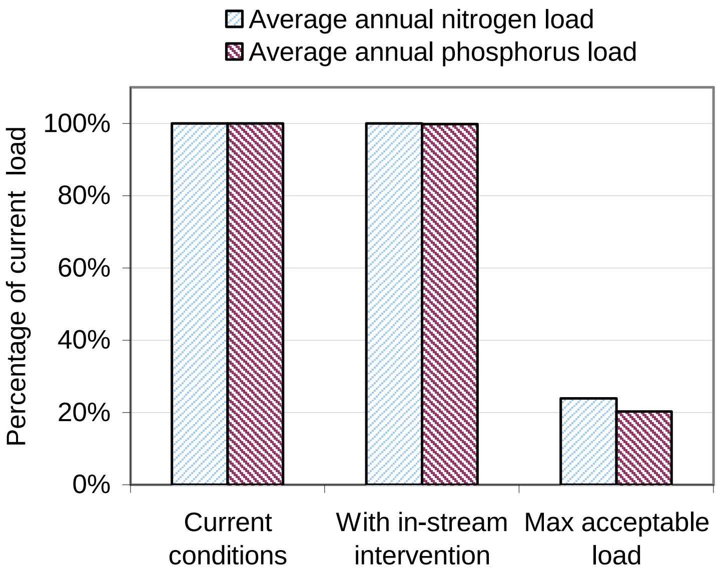


Figure 6.20 Predicted percentage reduction in nitrogen and phosphorus loads in Ellen Brook from installation of in-stream nutrient filters

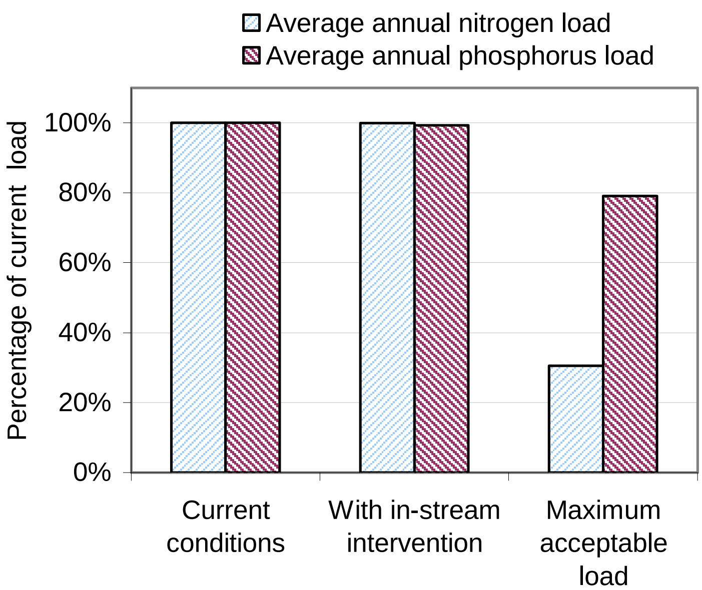


Figure 6.21 Predicted percentage reduction in nitrogen and phosphorus loads in Bannister Creek from installation of in-stream nutrient filter

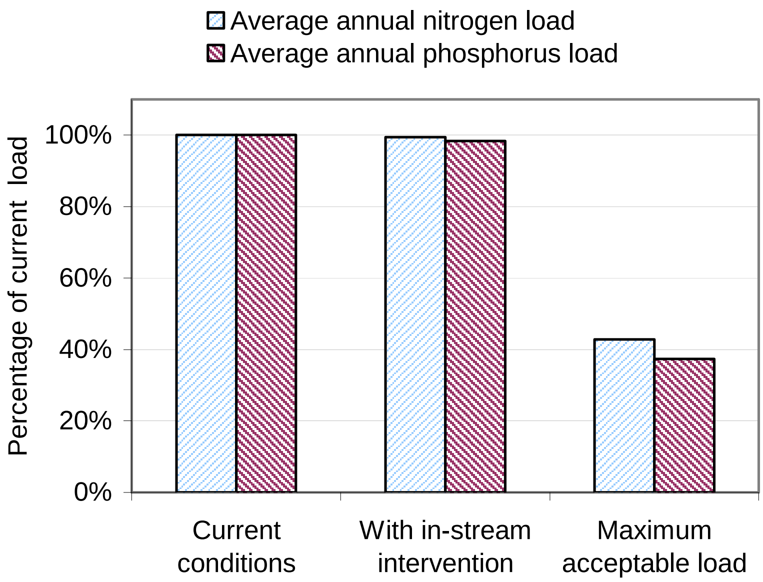


Figure 6.22 Predicted percentage reduction in nitrogen and phosphorus loads in Mills Street Main Drain from installation of in-stream nutrient filter

Examination of the removal efficiency curves (Figure 6.19) reveals that these structures are effective only at stripping nutrients during very low flows, and removal efficiencies are less than about 2% for flows greater than 10 ML/day. For a typical flow year such as 1997, the daily flow in Ellen Brook (at the catchment outlet) was greater than 10 ML/day from May to October, and there was no flow in January, February and December. Thus the structures in the Ellen Brook catchment are likely to be effective only in March, April and November. In 1997 in Bannister Creek, the daily flow volume was greater than 10 ML/day from March to November, and about 6 ML/day in January, February and December. In 1997 in Mills Street Main Drain, the daily flow was greater than 10 ML/day during May to October, and for the rest of the year the flow was generally greater than 3 ML/day.

The potential nitrogen and phosphorus removal by these structures is very small and the cost is of the order of hundreds of thousands of dollars. Thus, the cost in terms of dollars per kilogram of nitrogen or phosphorus removed is huge, and compares unfavourably with economic analyses of other possible remediations (Ecotones 2008).

6.5.7 Summary of management scenarios

This section summarises the management and intervention scenarios discussed in the previous sections, except for zeolite and laterite nutrient filters. Nutrient filters are not included because they were modelled in only three catchments and the potential impacts are less than 1% in most cases.

For each catchment Table 6.28 (nitrogen) and Table 6.29 (phosphorus) show the average annual loads for the current climate and land uses (that is, 2006 land use at catchment equilibrium, which is taken at 2057–2066), the maximum acceptable loads and the estimated loads following the management changes or interventions. The tables are coloured, depending on the magnitude of the percentage difference with respect to the maximum acceptable loads, as shown in Table 6.27. Loads less than the maximum acceptable load are green; loads which exceed the maximum acceptable load by between 0 and 50% are yellow and those which exceed the maximum acceptable load by between 50% and 100% are mauve; while loads more than 100% greater (double) than the maximum acceptable load are red. The loads and percentage changes relate to each scenario being implemented individually. No modelling has been done to trial the impact of combinations of scenarios.

Table 6.27 Colour coding for percentage difference between estimated load and maximum acceptable load

Meets water quality objectives
Exceeds *Maximum acceptable load* by 0–50%
Exceeds *Maximum acceptable load* by 50–100%
Exceeds *Maximum acceptable load* by more than 100%

The management scenarios presented in Table 6.28 and Table 6.29 include:

Scenario	**Implementation**	**Affects**
Remove point sources	Only 3 point sources included: 2 in Bannister Creek, 1 in Ellen Brook	Nitrogen, Phosphorus
Remove septic tanks	Assume no septic tank emissions in catchment	Nitrogen, Phosphorus
Wetlands	Construct wetlands in 22 catchments	Nitrogen, Phosphorus
Soil amendment in rural areas	Increase PRI of soils with rural land use	Phosphorus
Fertiliser action plan	Implementation of *Fertiliser action plan* in urban and rural areas	Phosphorus
50% urban fertiliser reduction	Decrease fertiliser application to urban land uses by 50%	Nitrogen, Phosphorus

Table 6.28 Average annual maximum acceptable loads, current climate loads and estimated scenario loads and percentage differences between scenario loads and maximum acceptable loads for nitrogen for the Swan-Canning coastal catchments

Catchment	Maximum acceptable load	Current climate load		Remove point sources		Remove septic tanks		Wetland		50% urban fertiliser reduction	
	tonnes	tonnes	%	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Bannister	3.9	12.8	227	11.7	200	12.2	212	11.5	195	7.1	81
Bayswater	4.0	7.5	88	7.5	88	6.9	73	6.8	71	2.7	-32
Belmont Central	0.3	0.6	87	0.6	87	0.6	87	0.5	71	0.3	-2
Bennett	4.8	5.7	18	5.7	18	5.7	18	4.7	-3	3.6	-25
Blackadder	2.1	2.4	16	2.4	16	2.1	-2	1.8	-15	0.8	-63
Bullcreek	4.9	10.2	107	10.2	107	10.1	106	9.9	102	5.3	8
CBD	1.7	4.2	146	4.2	146	3.7	120	3.7	118	3.4	99
Claisebrook	1.3	3.3	157	3.3	157	3.2	144	3.3	157	1.4	9
Downstream	3.5	7.6	117	7.6	117	7.6	117	7.6	117	4.2	19
Ellen	22.1	92.8	320	90	307	86.5	291	91	311	89	303
Ellis	0.7	0.7	-7	0.7	-7	0.1	-82	0.6	-8	0.4	-37
Helena	3.6	4.9	36	4.9	36	2.9	-18	4.8	34	3.8	6
Helm Street	0.5	1.6	216	1.6	216	1.5	197	1.5	198	0.9	83
Henley	0.6	0.8	27	0.8	27	0.7	13	0.8	27	0.5	-14
Jane	11.0	11.6	5	11.6	5	5.1	-54	11.6	5	11.1	1
Lower Canning	3.2	6.9	116	6.9	116	6.5	104	6.6	107	2.8	-12
Maylands	5.1	11.7	130	11.7	130	11.4	123	11.6	127	7.7	51
Mill Street	2.6	6.1	134	6.1	134	3.5	36	5.1	98	4.8	83
Millendon	2.6	2.9	13	2.9	13	2.5	-5	2.9	13	2.9	13
Munday/Bickley	2.3	2.6	14	2.6	14	2.6	14	2.6	14	2.0	-12
Perth Airport North	1.3	2.0	51	2.0	51	1.2	-7	1.8	42	1.4	9
Perth Airport South	1.1	0.5	-53	0.5	-53	0.1	-87	0.5	-54	0.5	-59
Saint Leonards	0.5	0.7	44	0.7	44	0.6	27	0.7	44	0.6	20
South Belmont	1.0	1.4	36	1.4	36	1.3	30	1.3	34	0.7	-28
South Perth	8.8	10.9	24	10.9	24	9.9	12	10.1	15	6.0	-32
Southern	11.4	19.5	71	19.5	71	18.0	58	19.1	68	15.0	32
Susannah	4.8	8.6	78	8.6	78	7.0	45	8.6	78	8.6	78
Upper Canning	7.5	6.5	-13	6.5	-13	4.4	-42	6.5	-13	5.1	-32
Upper Swan	6.1	11.6	91	11.6	91	10.4	71	11.4	87	9.5	56
Yule	5.6	7.5	34	7.5	34	6.3	12	7.1	27	5.2	-7
TOTAL	129	266	106	262	103	244	89	256	99	207	61

% percentage difference with respect to Maximum acceptable load

The catchments coloured red and mauve exceed their maximum acceptable loads by more than 50% and thus require the greatest percentage load reductions. For nitrogen these include all the highly urbanised catchments except South Belmont and South Perth. However, the predominantly rural catchment of Ellen Brook has exceeded the maximum acceptable load for nitrogen by the largest percentage – 320% – because of its intensive agricultural land uses and low nutrient-retaining soils.

Removal of the three point sources decreases the total nitrogen input to the estuaries by 3.9 tonnes (1.5%). Removal of septic tanks decreases the nitrogen input by 22 tonnes (8%) and causes five catchments – with current equilibrium nitrogen loads greater than their maximum acceptable loads – to have loads less than their maximum acceptable loads (Blackadder, Helena River, Jane Brook, Millendon and Perth Airport North). In Ellen Brook the impact of septic tank removal is not great (nitrogen reduction of 1.6 tonnes or 2%) because most of its load is from farming enterprises.

Wetlands in 22 catchments decrease the estimated average annual nitrogen loads to the estuaries by 10 tonnes (4%). Constructed wetlands cause a significant decrease (more than 5%) in nitrogen loads in 10 catchments and a large decrease (more than 10%) in five catchments (Bannister, Bennett, Blackadder, CBD and Mills Street). The wetlands in Bennett and Blackadder enable these catchments to achieve their water-quality objectives for nitrogen.

Of the scenarios modelled, the 50% reduction of fertiliser application in urban areas has the greatest impact with respect to nitrogen load reductions. The estimated average annual nitrogen load to the estuaries is reduced by 59 tonnes (22%). Under this scenario 13 catchments achieve their nitrogen load targets and only eight catchments exceed their targets by greater than 50%.

Two additional scenarios were included for phosphorus: soil amendments in rural areas and *Fertiliser action plan* implementation in urban and rural areas.

For phosphorus there are currently seven catchments achieving their desired water-quality objectives (at catchment equilibrium) (Downstream, Ellis, Helena, Maylands, Perth Airport North, Perth Airport South and Upper Canning). There are eight catchments exceeding their maximum acceptable loads by more than 50%. Of these, Bullcreek, Ellen Brook, Henley and Mills Street exceed their maximum acceptable loads by more than 100%.

Removal of point sources allows Bannister Creek to achieve its water-quality objective for phosphorus. Removal of septic tanks decreases the total phosphorus load to the estuaries by 1.72 tonnes (6%). In Mills Street catchment septic tanks contribute approximately 60% of the phosphorus load and their removal almost achieves the phosphorus target in this catchment. Removal of septic tanks allows the Blackadder, Claisebrook, Jane, Millendon and Yule Brook catchments to achieve their phosphorus targets. The impact of septic tank removal is not great in Ellen Brook (estimated phosphorus reduction is 0.46 tonnes or 4%) because most of its load is from farming enterprises.

Wetlands in 22 catchments decrease the estimated average annual phosphorus loads to the estuaries by approximately 2 tonnes. The constructed wetlands cause a significant decrease (more than 5%) in loads in 15 catchments, and a large decrease (more than 15%) in seven catchments. Five catchments that were exceeding their phosphorus targets, achieve them with the construction of wetlands at their outlets (Bayswater, Bennett, Blackadder, South Perth and Yule Brook).

Soil-amendment application in rural land uses with low PRI soils reduces the phosphorus load to the estuaries from 27 to 24 tonnes (12% reduction). There are eight catchments with sufficient areas of rural land use on low PRI soils for which this scenario demonstrates significant (more than 5%) reductions in phosphorus export (Ellen, Ellis, Helena, Lower

Canning, Munday-Bickley, Saint Leonards, Southern and Upper Swan). Soil-amendment application in all rural land uses on low PRI soils would allow the Munday-Bickley, Saint Leonards and Upper Swan catchments to achieve their load targets.

Table 6.29 Average annual maximum acceptable loads, current climate loads and estimated scenario loads and percentage differences between scenario loads and maximum acceptable loads for phosphorus for the Swan-Canning coastal catchments

Catchment	Maximum acceptable load	Current climate load		Remove point sources		Remove septic tanks		Wetland		Soil amendment in rural land use		*Fertiliser action plan* urban + rural		50% urban fertiliser reduction	
		tonnes	%	tonnes	%	tonnes	%	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Bannister	0.55	0.70	26	0.52	-5	0.67	23	0.56	2	0.70	26	0.50	-9	0.39	-30
Bayswater	0.44	0.50	13	0.50	13	0.46	4	0.40	-9	0.50	13	0.45	2	0.27	-39
Belmont Central	0.04	0.06	53	0.06	53	0.06	50	0.05	22	0.06	52	0.04	-1	0.03	-19
Bennett	0.42	0.60	43	0.60	43	0.60	43	0.41	-1	0.60	43	0.40	-4	0.36	-13
Blackadder	0.17	0.17	1	0.17	1	0.16	-4	0.12	-29	0.17	1	0.15	-13	0.09	-46
Bullcreek	1.01	2.60	157	2.60	157	2.55	152	2.48	145	2.60	157	1.95	93	1.66	65
CBD	0.21	0.27	30	0.27	30	0.27	29	0.21	2	0.27	30	0.17	-17	0.14	-35
Claisebrook	0.24	0.24	1	0.24	1	0.24	0	0.24	1	0.24	1	0.15	-36	0.12	-49
Downstream	0.30	0.30	-1	0.30	-1	0.29	-3	0.30	-1	0.30	-1	0.19	-38	0.15	-52
Ellen	2.13	10.55	395	10.40	388	10.09	374	10.15	376	8.53	301	8.18	284	10.33	385
Ellis	0.02	0.01	-51	0.01	-51	0.00	-88	0.01	-52	0.01	-57	0.01	-66	0.01	-61
Helena	0.23	0.22	-3	0.22	-3	0.19	-16	0.21	-8	0.21	-10	0.17	-28	0.16	-32
Helm Street	0.04	0.06	43	0.06	43	0.06	38	0.05	24	0.06	42	0.04	-4	0.03	-19
Henley	0.05	0.18	251	0.18	251	0.17	240	0.18	251	0.17	245	0.11	126	0.10	103
Jane	0.58	0.67	16	0.67	16	0.58	-1	0.67	16	0.64	11	0.61	5	0.54	-7
Lower Canning	0.50	0.91	81	0.91	81	0.86	72	0.84	67	0.72	44	0.59	18	0.40	-20
Maylands	0.27	0.26	-4	0.26	-4	0.26	-5	0.25	-9	0.26	-4	0.17	-38	0.13	-51
Mill Street	0.28	0.75	168	0.75	168	0.30	8	0.57	103	0.75	168	0.60	116	0.60	114
Millendon	0.15	0.15	2	0.15	2	0.15	-2	0.15	2	0.15	2	0.15	0	0.15	2
Munday/Bickley	0.14	0.16	16	0.16	16	0.16	16	0.16	16	0.13	-5	0.11	-23	0.10	-28
Perth Airport North	0.21	0.20	-3	0.20	-3	0.16	-22	0.18	-15	0.20	-3	0.16	-24	0.13	-39
Perth Airport South	0.17	0.16	-9	0.16	-9	0.14	-15	0.15	-13	0.16	-9	0.12	-29	0.10	-39
Saint Leonards	0.10	0.14	40	0.14	40	0.13	28	0.14	40	0.10	0	0.09	-8	0.10	-4
South Belmont	0.13	0.21	65	0.21	65	0.20	56	0.21	60	0.21	65	0.14	7	0.11	-12
South Perth	1.76	1.93	10	1.93	10	1.87	6	1.66	-5	1.86	6	1.37	-22	1.00	-43
Southern	1.15	1.94	69	1.94	69	1.83	59	1.87	62	1.71	49	1.30	13	1.25	9
Susannah	0.65	0.72	11	0.72	11	0.70	7	0.72	11	0.72	11	0.72	11	0.72	11
Upper Canning	0.42	0.38	-11	0.38	-11	0.34	-19	0.38	-11	0.37	-11	0.34	-20	0.24	-43
Upper Swan	1.29	1.79	39	1.79	39	1.69	31	1.74	35	1.14	-12	1.14	-12	1.39	7
Yule	0.43	0.46	6	0.46	6	0.36	-17	0.41	-6	0.45	4	0.40	-7	0.38	-12
TOTAL	14	27	93	27	91	26	84	25	80	24	70	21	45	21	50

% percentage difference with respect to Maximum acceptable load

The current climate phosphorus load for all the catchments (at equilibrium) is estimated to be 27 tonnes. Following *Fertiliser action plan* implementation the load is expected to be approximately 21 tonnes (reduction of 6.8 tonnes or 25%), which represents about half the required reduction to meet the maximum acceptable load target of 14 tonnes. Of the 23 catchments with equilibrium loads greater than their maximum acceptable loads, 13 of them achieve their load target following *Fertiliser action plan* implementation. The plan's implementation in Ellen Brook causes the phosphorus load to decrease from 10.5 to 8.2

tonnes (22% reduction). Of all the scenarios modelled, the *Fertiliser action plan* causes the greatest decrease to the phosphorus load to the estuaries.

For 50% fertiliser reduction in urban areas, the estimated load reduction for phosphorus is 6.1 tonnes (22%) from 27 to 21 tonnes. Of the 23 catchments with current climate phosphorus loads greater than their maximum acceptable loads, reducing phosphorus fertilisation in urban areas by 50% causes 15 to have loads less than their maximum acceptable loads. This scenario has a very small impact in the Ellen Brook catchment because of the relatively small area of urban land use compared with the agricultural land uses.

7 Sustainable diversion limits

7.1 Ecological water requirements and environmental water provisions

The *Swan-Canning water quality improvement plan* identifies a range of environmental flow objectives to protect wetlands and floodplains (mimic natural inundation and drying patterns), and to minimise the effects of dams and extraction on water quality (mimic natural frequency, duration and seasonal flow) in streams, wetlands and the estuary.

Ecological water requirements (EWR) are descriptions of water regimes that maintain or restore ecological processes and protect the defined environmental values consistent with the *National principles for provision of water to the environment* (WRC 2000; ANZECC & ARMCANZ 2000). EWRs explicitly define quantitative flows that are required to achieve the environmental flow objectives. Water regime is a description of the variation of flow rate and volume (rivers, streams, drains) or water level (wetland, groundwater) over time, but may also include a description of water quality. When determining an EWR the ecosystem is considered as a whole. EWRs are based on the premise that particular flows perform specific ecological functions. For example, high flows following storms have the energy to scour the river channel, create diverse riverbed habitats and flood riparian vegetation. Similarly, early winter flows relieve summer stress (such as high water temperatures and low levels of dissolved oxygen), provide cues for breeding migrations of native fish, and provide habitat for a wide array of organisms such as water birds, micro-crustaceans, aquatic insects, in-stream vegetation and larval stages of terrestrial insects.

GHD (2008) identified environmental flow objectives for the Swan-Canning river system to protect a range of environmental attributes such as hydrology, channel morphology, aquatic and riparian vegetation, fish assemblages, macroinvertebrates, water birds, floodplains and water quality. In highly modified systems such as the Swan-Canning, these ecological parameters can differ greatly to those found in natural habitats.

Environmental water provisions (EWPs) are the water regimes put in place as a result of the water allocation process, taking into account ecological, social and economic impacts. In an ideal world EWPs maintain EWRs and environmental flow objectives; however, this is not always possible and EWPs may compromise environmental flow objectives.

Undertaking EWR studies and the subsequent translation of EWRs into EWPs by the Department of Water's Water Resource Use Division is an intensive process. Within the Swan-Canning river system, only the Canning River (between Canning Dam and the Kent Street Weir) has a completed EWR study (Radin et al. 2009). The EWRs for the Canning River require the maintenance of a continual flow of water in the lower Canning River in the summer months (summer baseflows) to maintain flow connectivity, pool depth and prevent oxygen concentrations becoming too low. Occasional additional flows to allow large fish passage in the summer months (fish pulse flows) are also a requirement. EWRs outside of the summer period include over-bank flows to inundate riparian vegetation and flows that provide additional habitat for fish spawning. These are met by rainfall and catchment runoff.

7.2 Sustainable diversion limit methodology

In the relatively unmodified streams of Western Australia's south-west, the Department of Water has adopted a sustainable diversion limit (SDL) approach. SDLs are deduced solely on the basis of discharge measurements using a methodology that the department has developed (Sinclair Knight Merz 2008). The intention is that the SDL is a conservative limit on water extraction that cannot be exceeded unless more detailed investigations, such as determination of EWRs, are completed. In this context the SDLs allow a first estimation of EWRs and EWPs. Because this method was developed for surface-water resources with low levels of use and modification, application to the Swan-Canning coastal catchments is problematic. Essentially the method comprises the following:

- Water may only be extracted from the stream during winter between 15 June and 15 October. This is referred to as the 'winterfill' period.
- During the winterfill period a 'minimum flow threshold' (MFT) is set, above which water may be extracted. The MFT is calculated as the maximum of either 0.3 times the mean daily flow or the 95th exceedance percentile of the annual median winterfill period daily flow.
- During the winterfill period a 'maximum extraction rate' (MER) is set for pumped extractions to maintain required flood peaks for geomorphological and riparian flood plain processes. The MER is calculated as the 25th exceedance percentile of the difference between the daily flow and the MFT for those days during the winterfill period when the MFT is exceeded.
- A sustainable diversion limit (SDL) or total extraction volume is calculated on the basis of an annual reliability of supply of 80%. In other words it is the 80th percentile of the annual discharge volume of the potential diverted flows derived from application of the MFT and MER rules, which generally equates to approximately 10% of the annual flow.

Inherent in this methodology are the following assumptions:

- The available record of discharge is greater than 10 years and is representative of the water regime that the waterway's ecology has adapted to. Maintenance of this ecological system can be achieved by extracting the SDL volume derived by this hydrological method.
- All discharge from October 15 to June 15 (i.e. spring through autumn) is retained in the system. This ensures the maintenance of sufficient flow for perennial waterways outside winter for macroinvertebrates, fish, water quality and pool depths.
- During the winterfill period (15 June to 15 October) the MFT must be defined to maintain baseflow ecological processes (macroinvertebrates, fish, water quality and pool depths) above which extraction is allowed.

- During winter the MER must be defined to maintain ecological processes depending on high flow rates such as fish passage from September to October, pool scouring, floodplain-waterway interactions and channel geomorphology processes.
- The SDL during the winterfill period provides an expected diversion volume for consumptive uses.

It should also be noted that SDLs need to be updated to include the consequences of the drying climate. They should also be reviewed regularly with respect to their impacts on the health of the rivers and estuaries.

7.3 Application of SDL methodology to the Swan-Canning tributaries

The Swan-Canning river system contains five major water supply dams in the Darling Scarp (Section 2.5) and many of the streams on the coastal plain have been modified to increase their drainage capacity. A large artificial drainage network has been established and many of the coastal plain's wetlands have been drained or filled to enable urban and agricultural land uses. The streams and drains of the Swan-Canning are highly modified and an SDL approach based on maintaining the existing modified flow regime is generally inappropriate. For highly modified streams, altering the existing flow regime (e.g. to improve summer baseflows) can provide a much-improved riverine environment.

The SDL approach also has considerable restrictions on when water can be taken (i.e. only during winter, as outlined above). In reality, water-licence holders take water throughout the year and are, in fact, more likely to take water during the summer period when rivers are most stressed.

The Department of Water licenses users for the extraction of surface water and groundwater in Western Australia. In the Swan-canning coastal catchments, it is generally the case that no more water can be diverted from the 'natural' tributaries (Bannister, Bennett, Blackadder, Ellen, Ellis, Helm, Henley, Jane, Saint Leonards, Susannah and Yule) or the tributaries with dams in their headwaters (Helena, Southern, Upper Canning, Lower Canning and Munday/Bickley).

Consequently the only Swan-Canning tributaries for which the SDL approach may be feasible are the artificial drains. However, the MER criteria for urban drains would most likely be different (larger), as geomorphological processes and riparian floodplain management are not relevant issues in drains. Decisions to extract water from drains would depend on the ecological values of the drains and whether it would improve or worsen downstream water quality. Extraction would need to be considered on a case-by-case basis.

The flow output from the SQUARE model was used to determine the SDLs for nine of the tributaries of the Swan-Canning river system: Bayswater, Belmont Central, CBD, Claisebrook, Maylands, Mills Street, Perth Airport North, Perth Airport South and South Belmont, listed in Table 7.1 and shown graphically for each catchment in Appendix B. The reasons for SDL calculations being inappropriate in the other 21 catchments are detailed below:

- SDLs were not be calculated in Bullcreek, Downstream, South Perth and Upper Swan because there are multiple small drains flowing to the estuary. In some cases there was more than one drain in a SQUARE subcatchment; and generally the confidence in the modelling results is not sufficient to report at such small scales.
- The Millendon catchment encompasses the area draining to the Swan River between Walyunga (site 616011) and the Great Northern Highway (site 616076). The main channel is the Swan River and determining SDLs for the Swan-Avon system was beyond the scope of this project.
- Water allocations in the 11 'natural' tributaries of Bannister, Bennett, Blackadder, Ellen, Ellis, Helm, Henley, Jane, Saint Leonards, Susannah and Yule have been exceeded and no more water may be diverted from these streams.
- There are five regulated catchments; that is, catchments with dams in their head waters. SDL calculations are impossible for these catchments because the rivers do not contain 'natural' flows. The Helena catchment is downstream of the Mundaring Reservoir, which last overflowed in 1996; the Munday-Bickley catchment contains Victoria Reservoir; and Southern River catchment is downstream of the Wungong Dam. The Upper Canning and Lower Canning catchments, which are downstream from the Canning Dam (and Churchman Brook Dam), have EWRs specified by the Department of Water which mandate dam releases to these catchments (Radin et al. 2009).

Table 7.1 Sustainable diversion limits (SDLs) for the Swan-Canning coastal catchments

Catchment	Minimum flow threshold (ML/day)	Maximum extraction rate (ML/day)	Average annual flow (1997-2006) (ML/year)	SDL (80% reliability) (ML/year)	SDL (%)
Bayswater	26.7	6.4	8 165	383	5%
Belmont Central	2.5	0.4	875	33	4%
CBD	6.4	1.0	2 160	64	3%
Claisebrook	10.2	1.5	3 411	101	3%
Maylands	6.8	1.1	2 296	77	3%
Mills Street	11.9	2.6	4 418	157	4%
Perth Airport North	6.6	5.7	2 468	432	17%
Perth Airport South	4.1	4.5	1 888	342	18%
South Belmont	6.8	1.2	2 427	95	4%
Total			28 108	1685	6%

8 Knowledge and data gaps

8.1 Data for model calibration and validation

8.1.1 Flow calibration

Sections 3.3 and 3.4 discuss the SQUARE calibration and confidence in the modelling results. Flow calibrations used data from 17 flow-gauging sites in 14 catchments. To model flow in the 16 ungauged catchments, parameters from the gauged (calibrated) catchments of similar character were used. The parameters from the flow calibration of 616045 (Mt Lawley Main Drain, Mt Lawley) in the Maylands catchment were used to model the flows in the South Belmont, Belmont Central, CBD, Claisebrook and Downstream catchments, even though this gauge calibrated with the lowest efficiencies (Table 3.11). Mt Lawley Main Drain has a highly impervious catchment similar to the catchments that used its flow-calibration parameters. Other catchments had better flow calibrations but were considered too pervious to transfer their flow parameters to these highly-impervious catchments. Thus, it is strongly recommended that good-quality flow data are obtained from some of these impervious catchments for future model calibration.

Generally the sites with flow data had better nutrient calibrations than those that used modelled flows. However this was not always the case, as high efficiencies were obtained for Bennett Brook, Perth Airport South and South Belmont, which used modelled flows; while relatively low efficiencies were obtained for Helena River and Yule Brook, which had flow data. This indicates that the flow data from 616086 (Helena River) and 616042 (Yule Brook) are most likely inaccurate, and these flow structures and ratings should be reviewed.

It is recommended that the flow gauging in the Swan-Canning coastal catchments is reviewed, and the following actions taken:

- Flow structures are upgraded where necessary.
- Rating curves are reviewed and regular ratings done for a large range of flows.
- One or more new gauges are installed, or existing gauges upgraded, to supplement 616045 (Mt Lawley Main Drain, Mt Lawley) in Belmont Central, South Belmont or Claisebrook catchments. Note that Belmont Central has a gauge close to the catchment outlet (616087), but data from this gauge were not of sufficient quality to use for calibration (HYDSTRA[3] quality code = 5).
- A recent urban development that includes water sensitive designs should be gauged to help determine the difference between the ‘hydrograph’ for flows from catchments with traditional urban form and those with recent urban developments. Water sensitive designs are specified in the *Stormwater management manual for Western Australia* (DoW 2007).

[3] HYDSTRA is the flow database used by the Department of Water

8.1.2 Nutrient calibrations

Four catchments had insufficient data to enable nutrient calibration or validation: Claisebrook, Downstream, Maylands and South Perth. Claisebrook, Downstream and Maylands used parameters from the Bayswater nutrient calibrations, and South Perth used parameters from the South Belmont calibrations. It is strongly recommended that nutrient data are collected in these catchments for at least one year to validate modelled concentrations in these catchments.

Eleven of the Swan-Canning coastal catchments have multiple outlets. Generally only one of the outlets is sampled, and the data used for calibration or validation. The variability of water-quality data across a catchment is apparent in the data collected at two outlets in the Upper Swan catchment: the winter median concentrations at 6161696 were TN 1.6 mg/L and TP 0.068 mg/L, whereas at 6162320 they were TN 2.65 mg/L and TP 0.215 mg/L. Whether catchments have single or multiple outlets is one of the scoring criteria in the nutrient confidence scoring tables.

It is recommended that a desktop study of the land uses in the catchments with multiple outlets is undertaken to determine the likelihood of varying water quality across each catchment. This should be coupled with ‘snapshot’ sampling of each of the outlets in the multiple-outlet catchments. This will guide the selection of sampling locations in these catchments to enable the nutrient sampling program to capture the variability between the different tributaries or drains in each catchment.

8.2 Wetland data

The construction of artificial wetlands in 22 catchments was modelled. However, the nutrient-removal efficiencies were based on data from one wetland – the Liege Street wetland – taken over a short period when the wetland was establishing. This is the time in a wetland’s lifecycle when uptake is expected to be greatest because the plants are growing rapidly and absorbing nutrients.

More studies need to be undertaken on the removal efficiencies of wetlands on the Swan Coastal Plain. At least two or three other wetlands should be monitored to determine their removal efficiencies, as these depend on the location and design of the wetland, which introduce great variability into wetland function. The potential for wetlands to become nutrient sources should not be ignored.

8.3 Monitoring of urban developments

There are many innovative water sensitive designs which are being incorporated into new urban developments, or retrofitted into established urban developments (DOW 2007), such as:

- rain gardens
- bio filtration systems

- living streams
- treatment basins
- water tanks.

However, on the Swan Coastal Plain, there has been very little study into the effectiveness of these measures. It is recommended that several of these structures in locations with varying characteristics in terms of hydrology and soil type are monitored to asses their nutrient-stripping capabilities.

There are many locations on the Swan Coastal Plain with high water table which have residential land use. The urban developments are enabled by using large amounts of fill and subsurface drainage to limit water table height. Sampling programs should be undertaken to determine the amount and quality of groundwater conveyed by subsurface drains under old and new urban developments. Locations with varying characteristics in terms of groundwater height, soil type, the characteristics of the soil fill and urban form should be investigated.

As discussed in Section 4, highly-impervious urban catchments have different flow characteristics to pervious rural catchments. Urban catchments generally have much greater water yields, more summer flow and 'flashier', higher-energy flows than rural catchments. Many urban areas have impervious surfaces directly connected to streams, that thus respond quickly to rainfall. Streams in rural locations will not flow until sufficient rain has fallen to 'wet' the catchment. The differences in hydrology in rural and urban catchments need to be quantified. As recent water sensitive urban designs focus on containment of the one-in-one year flows by infiltration (rain gardens; bio filtration systems) or capture (rain water tanks), differences between the hydrology of existing and new urban areas also need to be examined.

8.4 Urban stream health

There have been many studies of stream health in urban environments (Bernhardt & Palmer 2007; Meyer et al. 2005; Paul & Meyer 2001). *'Urban stream syndrome'* includes flashier hydrographs, altered channel morphologies, elevated concentrations of nutrients and contaminants, reduced biotic richness and dominance of tolerant species. Recent studies in the eastern states of Australia have linked the imperviousness of catchments to stream ecosystem degradation (Walsh et al. 2005).

The data collected during the modelling of the Swan-Canning coastal catchments provides descriptions of the catchments in terms of population, number of dwellings, area of impervious surface, area of roads, leaf-area index, area of deep-rooted vegetation and amount of fertiliser applied. These data may be compared to indicators of river health in the tributaries of the Swan and Canning rivers to determine the catchment characteristics most linked to ecological degradation of the streams and estuaries.

8.5 Point source data

The SQUARE modelling estimated point sources were contributing approximately 2% of the nitrogen and 1% of the phosphorus to the Swan-Canning waterways. However, it should be noted that data for nutrient emissions from small point sources are difficult to obtain, and that only three point sources discharging directly to water were included: Swan Brewery, Ranford Road tip and a feedlot (see Section 3.2). Further investigation of nutrient exports from point sources on the Swan Coastal Plain is warranted, particularly for historic landfill and liquid waste disposal sites.

The only landfill site included in the modelling was the Ranford Road site, which reports emissions to the National Pollutant Inventory (NPI). There are many abandoned landfill, animal burial, night soil and liquid waste disposal sites, as mapped by Hirschberg (1991), some of which are known to be polluting groundwater and surface waters (Hirschberg 1992, 2007; Evans 2009). It is impossible to estimate pollution from these sources without intensive monitoring and modelling at each site, thus they have not been included in this work. It is recommended that all historic landfill, animal burial, night soil and liquid waste disposal sites are mapped accurately and investigated to determine if nutrients and other contaminants are leaching from these sites for inclusion in future modelling.

Many sites housing large numbers of animals, such as poultry farms and feedlots, emit large volumes of ammonia to air. For example, the 13 poultry farms in Ellen Brook catchment that report to the NPI emit approximately 260 tonnes of nitrogen (as ammonia) per year. The ammonia emissions to air were included in the modelling, but caused the model to calibrate badly. This may be because the emissions are moved by the wind and do not impact in the subcatchment where the facility is located. That is, emissions to air may be 'smeared' over the whole catchment or blown away from the coastal catchments. The SQUARE model calibrated much better without the inclusion of the point sources in Table 3.7, which emit to air and land. Thus the only point sources included in the modelling were those that emit directly to water.

The effects of point sources that emit to air should be investigated, as poultry farms and cattle feedlots emit large amounts of nitrogen as ammonia. It may be appropriate to measure rainfall nutrient concentrations adjacent to these facilities for comparison with concentrations from other locations, such as urban areas and native forest.

8.6 Groundwater inflows

The Ellen Brook hydrogeological project (Barron et al. 2010) highlighted the contributions of flow and nutrients from groundwater discharge on the Dandaragan Plateau, and from the Gnangara Mound downstream of the Ellen Brook gauging station (616189). The brook falls 15 to 20 m between the gauging station and its confluence with the Swan River and cuts into the Superficial aquifer, thus Ellen Brook flows for most of the year at the confluence – even though flow ceases at gauge 616189 after the end of winter. These flows have not been estimated by SQUARE, because SQUARE was calibrated against data from gauge 616189, at which there is no flow in summer.

There are three catchments, besides Ellen Brook, that are likely to receive significant groundwater flows from the Gnangara Mound – as indicated by their estimated summer flow percentages (in brackets): Bennett (12%), Henley (5%) and Saint Leonards (11%) (Table 4.2).

It is recommended that a study be undertaken to quantify the groundwater flows and nutrient concentrations at each of these locations:

- Dandaragan Plateau portion of Ellen Brook catchment
- downstream of 616189 (Ellen Brook)
- Bennett Brook
- Henley Brook
- Saint Leonards Brook.

The age of the water and the nutrient sources – whether decaying native vegetation, animal manure, organic fertilisers, septic tank effluent or inorganic fertilisers – need to be established, as discussed in the next section.

8.7 Stable isotope analyses

Many factors need to be considered in determining the nutrient sources and their impact on the receiving waterway. For example, the source of dissolved organic nitrogen (DON) relates to its ability to be used by plants. DON from organic fertilisers (manures) is labile, whereas DON from decaying native vegetation is not. Different land uses leach different ratios of nitrogen species (DON, NH4-N, NOx-N) and have different sources of DON.

Stable isotope analyses have been used in botanical and plant biological investigations for many years (mostly carbon, nitrogen and oxygen). For instance N^{15} enrichment is used as a marker for sewage contamination (Dennison & Abal 1999).

Examination of the nutrient species and isotopic fractions to determine sources of nitrogen (and carbon) should be undertaken, that is to determine whether the nutrient is from:

- native vegetation
- animal manure
- organic fertiliser
- septic tank effluent
- inorganic fertilisers.

For instance, the proportion of septic tank effluent contributing to nutrient pollution in Mills Street Main Drain and the nutrient sources in a typical urban catchment (e.g. Bayswater or Maylands) should be investigated.

For groundwater investigations, the age of the groundwater should also be determined. For superficial groundwater (post 1950), this is commonly done using chlorofluorocarbon analyses (CFC-11 or CFC-12).

8.8 Water-quality objectives

Water-quality objectives for the SCWQIP (SRT 2009) and *Healthy Rivers action plan* (HRAP) (SRT 2007) in terms of TN and TP concentration targets were discussed in Section 4.1. The SCWQIP water-quality objectives specified for the tributaries of the Swan and Canning rivers were based on HRAP targets, but allowed for the increased flow from highly-impervious urban catchments. They were used for the estimation of average annual maximum acceptable load targets, and annual load reduction targets.

Thus, for the highly-impervious catchments, the concentration targets are lower than the HRAP targets currently used by the Swan River Trust to assess the heath of the Swan and Canning rivers and estuaries. It is strongly recommended that the hydrology of urban catchments be taken into account in any revision of the current HRAP targets.

8.9 Appropriate management actions

The timing of nitrogen and phosphorus loads to the Swan-Canning estuary was discussed in Section 5.1.3 for 1997, which was considered a typical year. Ellen Brook was seen to contribute large amounts of nutrients in the wet months of May to September. Although, the nutrient contributions from Ellen Brook during summer and autumn, considered to be the 'algal bloom season', are small or non existent, it is believed that phosphorus from the Ellen Brook winter inflows that is precipitated into the sediments of the upper Swan River is readily re-mobilised and available to fuel algal growth during summer and autumn. However, algal blooms in the upper Swan River are generally nitrogen limited. Nutrient limitation bio-assays at different times of the year would inform on whether blooms are nitrogen, phosphorus, sulfur, salt, heat or light limited. This would enable greater understanding of the relative importance of the various nutrient sources for fuelling algal growth at different times of the year.

That is, the relative importance of the nutrient inflows from Ellen Brook (in winter) and from the urban drains (all year round) for fuelling algal growth, needs to be further investigated, particularly with respect to the changes in rainfall volume and timing (more spring rainfall) that are occurring due to the drying climate. Because many urban drains flow all year, nutrient reductions in these may have a greater impact on the estuary's health than nutrient reductions in the inflows from the ephemeral catchments.

To determine appropriate management actions that will have the greatest short-term impact in the various reaches of the Swan-Canning estuary; that is, upper Swan Estuary, middle Swan Estuary, Canning Estuary above Kent Street Weir, Canning Estuary below Kent Street weir and the Swan Estuary downstream of the Narrows and Canning Highway bridges, many factors need to be considered, including:

- the magnitude and timing of nutrient inputs from the upstream catchments
- groundwater inputs
- potential for nutrient sediment releases

- the timing and conditions that promote nutrient sediment releases, such as stratification and low dissolved oxygen at depth
- the limiting factors for algal blooms (nutrients, salinity, light and heat).

Detailed discussion of appropriate management actions in each of the reaches of the estuary is beyond the scope of this report. However, the calibrated SQUARE model presented here is available for future scenario modelling to guide management decisions in all areas of the catchment, and to determine impacts on the estuary.

8.10 SQUARE model development

The SQUARE model of the Swan-Canning coastal catchments is a powerful tool, which may be used to model future scenarios of land use, management and climate, to support the implementation of the *Swan Canning water quality improvement plan* and *Healthy Rivers action plan*.

The model output allows comparison of nitrogen and phosphorus loads for the scenarios modelled. However, SQUARE does not incorporate economic analyses. It is recommended that a tool is developed, that can incorporate SQUARE scenario modelling results and economic data, so that the relative cost-benefits of the scenarios modelled can be determined.

9 Discussion

The Swan and Canning rivers and estuaries are vitally important natural resources of the Perth metropolitan area. The estuaries are the scenic and recreational heart of the city. Yet the health of the Swan-Canning river system is in decline: over the past few decades it has shown increasing signs of eutrophication including fish kills, cyanobacterial blooms, red tides and accumulation of organic matter in the bottom sediments. The most visible sign of the decline in health is the increasing frequency and extent of low oxygen or anoxic events. Algal blooms, which generally occur in the upper reaches of the Swan and Canning estuaries, are driven by the nutrients in catchment inflows, or nutrients that have built up in the sediments and re-mobilised under anoxic conditions.

The SQUARE catchment model was used to estimate flows and nitrogen and phosphorus loads from 30 coastal catchments of the Swan and Canning estuaries, and data from site 616011 (Swan River, Walyunga) were used to determine flows and loads from the Avon River. The relative areas, average annual flows and loads (1997–2006) of nitrogen and phosphorus contributing to the Swan and Canning estuaries are:

Catchment	Area (km^2)	Average annual flow (GL)	Average annual nitrogen load (tonnes)	Average annual phosphorus load (tonnes)
Avon	123 900	254	575	20
Coastal catchments	2 090	190	250	26

Although on average the Avon River contributes more flow and nitrogen load to the estuaries than the coastal catchments, in most years it contributes less – because in wet years its flow volume is disproportionately larger than in dry years. The coastal catchments generally contribute more phosphorus to the estuaries than the Avon River, on both an annual and monthly basis.

The average annual flow in the Avon River for the period 1997 to 2006 was 35% less than the average for the preceding 22 years. This decrease in flow volume means that the estuaries are less well flushed, more saline and the flows from the coastal catchments have greater impact than previously. Climate predictions indicate a drying climate in the south of Western Australia, which will further decrease Avon River flows relative to those from the coastal catchments.

Ellen Brook, which has a catchment area of 715 km^2 (about one-third of the area of the coastal catchments), contributes on average 12% of the annual flow, 15% of the annual nitrogen and 30% of the annual phosphorus loads from the coastal catchments. For its area this is not excessive; however, the TP concentrations (~ 0.4 mg/L) from Ellen Brook are much higher than those from other catchments (generally less than 0.2 mg/L). The high TP concentrations are due to the low catchment water yield because of its perviousness, coupled with poor phosphorus-retaining soils. The TN concentrations from Ellen Brook are high (~2.5 mg/L), but are comparable to some of the other catchments such as Lower Canning (~2.3 mg/L) and Saint Leonards Brook (~2.7 mg/L).

The timing and distribution of rainfall, as well as catchment characteristics, are very important. The impervious urban catchments have significant flows in summer and autumn when the Avon River, Ellen Brook and several of the other rural catchments have small or no flows. As the conditions in summer and autumn are often favourable for algal blooms, targeting nutrient reduction in these catchments may significantly decrease the likelihood of algal blooms. However, nitrogen and phosphorus that is not flushed out to sea builds up in the sediments, and can become available to fuel algal growth (particularly under anoxic conditions). All nutrient inputs to the Swan-Canning estuary need to be addressed.

Sources of nutrients

The coastal catchments with the greatest nutrient inputs per unit area are generally the urban catchments closest to the estuaries. Ellen Brook and Southern River catchments also contribute significant phosphorus inputs in terms of load per cleared area. The main sources of nitrogen in terms of land use (for 1997–2006) for the coastal catchments were residential (26%), farms (23%), septic tanks (16%) and recreation (13%). Recreation (golf courses and fertilised parks and gardens) only occupies 2% of the catchment area. The pattern is slightly different for phosphorus: the main contributions (1997–2006) came from farms (33%), residential (22%), recreation (12%) and septic tanks (8%). Farming land use dominates phosphorus export because it occupies large areas in the Ellen Brook catchment.

Load reduction targets

The water-quality objectives for the *Swan Canning water quality improvement plan* (SCWQIP) are winter median TN and TP concentration targets. As nutrient concentrations are directly influenced by runoff (mm), and the runoff of the coastal catchments range from approximately 15 mm to 350 mm depending on the imperviousness of the catchment, concentration targets were defined in terms of runoff as shown below:

Average annual runoff	**Water-quality objectives**	
	TN concentration	**TP concentration**
< 100 mm	1.0 mg / L	0.1 mg / L
100 to < 200 mm	0.75 mg/L	0.075 mg/L
> = 200 mm	0.5 mg / L	0.05 mg / L

For the purposes of the SCWQIP, the average annual maximum acceptable pollutant load targets corresponding to the concentration targets were specified. The average annual **maximum acceptable load target** is the maximum load that may prevail in a stream that enables the stream to just meet its median concentration target. For streams that are meeting their concentration targets currently, the maximum acceptable load target is given as the current load. The load reductions required to achieve the maximum acceptable load targets will be used to guide the scale of remediation.

The current nitrogen load from the 30 coastal catchments to the Swan and Canning rivers and estuaries is approximately 250 tonnes. If all catchments were meeting their water-quality targets the nitrogen load would be approximately 130 tonnes (a 49% reduction). The catchments that are meeting their targets for nitrogen (at catchment equilibrium) are Ellis, Perth Airport South, and Upper Canning. The urban catchments generally require greater percentage load reductions than the rural catchments. However, Ellen and Saint Leonards brooks, which have predominantly rural land use, require load reductions of 60 to 70%.

The current phosphorus load from the coastal catchments is 26 tonnes. If all the catchments were meeting their water-quality targets, the phosphorus load to the rivers and estuaries would be approximately 14 tonnes (a 46% reduction). Seven of the 30 coastal catchments meet their targets for phosphorus (at catchment equilibrium). However, most of the required load reduction (8 tonnes) is from Ellen Brook catchment, which is the largest catchment and has poor nutrient-retaining soils. Southern River, which requires a load reduction of about 50% (1 tonne), is responsible for about half the nutrient inputs to Kent Street Weir pool.

Scenario modelling

The scenarios modelled included future urban development, climate change and management interventions. The SQUARE modelling was only undertaken for the Swan-Canning coastal catchments; no land use or climate scenarios were investigated for the Avon catchment. The results discussed here refer only to the coastal catchments.

The A2 (pessimistic) climate change scenario predicted decreases of flow, nitrogen and phosphorus loads of 30%, 15% and 31% respectively from the coastal catchments. However, the model generally predicted increased concentrations with decreased rainfall. The Avon River, which generally has better water quality than the coastal catchment inflows, will have proportionately greater decreases in flow than the coastal catchments with less rainfall, thus reducing its diluting and flushing function.

The future urban development in the coastal catchments was estimated to comprise about 130 000 new dwellings, with estimated increases in average annual flow of about 5%, nitrogen load of about 47 tonnes (18%) and phosphorous load of about 7 tonnes (25%). The percentage changes are expected to be greatest in the Henley, Munday-Bickley, Saint Leonards, Southern, and Blackadder catchments. However, the greatest absolute load increases are expected in Ellen Brook and Southern River. These estimations assume the urban development will be similar to the current urban form, and water sensitive design principles will not be incorporated (worst-case scenario).

Several management scenarios, including point source control, removal of septic tanks, fertiliser management, soil-amendment application, artificial wetlands and in-stream interventions (zeolite/laterite filters) were modelled. The predicted percentage decrease of nutrient loads to the estuaries from the coastal catchments, and the number of catchments meeting their targets for the various scenarios, are shown in Table 9.1.

Table 9.1 Summary of impacts of management scenarios modelled

Scenario	**Decrease in load to estuary (%)**		**Number of catchments meeting target at equilibrium (#catchments = 30)**	
	Nitrogen	Phosphorus	Nitrogen	Phosphorus
Current conditions			3	7
Point source removal	1.5	1.1	3	8
Septic tank removal	8	6	8	12
Constructed wetlands (in 22 catchments)	4	7	5	12
50% reduction in urban fertilisation	22	22	13	22
Application of soil amendments in rural areas	-	12	-	10
Implementation of *Fertiliser action plan* in rural and urban areas	-	25	-	20
Zeolite and laterite filters (in three tributaries)	0	0	3	7

Removal of septic tanks and point sources is predicted to decrease nitrogen and phosphorus loads (at catchment equilibrium) to the estuaries by 9.5% and 7% respectively. At catchment equilibrium; that is, when the full impact of the recent infill sewerage program in Perth is apparent, it is predicted that several catchments will still have significant nutrient loads from septic tanks: Ellen, Helena, Jane, Mills Street and Upper Canning.

Although the estimated decrease in load to the estuaries following the construction of wetlands is 4% and 7% for nitrogen and phosphorus respectively, significant decreases are expected in the catchments for which large wetlands are proposed. However, the assumptions underlying the modelling of this scenario were derived from data from Liege Street wetland during its establishment phase, and these assumptions need to be refined when more data are available.

The scenario of 50% reduction of fertiliser application in urban areas indicates the effects of source control in urban areas. This scenario predicts a decrease in both nitrogen and phosphorus loads to the estuaries of 22%, which enables 13 catchments to achieve their nitrogen and 22 catchments to achieve their phosphorus targets.

Soil-amendment application and the *Fertiliser action plan* only affect phosphorus export. Soil-amendment application in rural land uses with low PRI soils is estimated to decrease the phosphorus load to the estuaries by 12% and 10 catchments would achieve their phosphorus targets. *Fertiliser action plan* implementation in both urban and rural areas is predicted to decrease phosphorus load to the estuaries by 25% and 20 catchments would achieve their phosphorus targets. This is the best result in terms of phosphorus reduction.

The four zeolite and laterite filters modelled in Ellen Brook, Bannister Creek and Mills Street Main Drain decreased nitrogen loads by 0 to 36 kg and phosphorus loads by 0 to 20 kg. The improvements in water quality at a catchment scale were generally less than 1% and were negligible in terms of load to the estuaries. Thus, use of zeolite and laterite filters for stream remediation is not recommended (large cost, small nutrient reduction).

Clearly there is no single management strategy that enables all the coastal catchments to achieve their water-quality objectives. The best results were achieved though fertiliser reduction and management and clearly the *Fertiliser action plan* should be implemented. Soil amendments in rural areas and septic tank removal in urban areas should be supported. Constructed wetlands of appropriate size and location are also an important management measure.

Under none of the scenarios did Ellen Brook achieve its load targets. Ellen Brook requires nitrogen and phosphorus reductions of 70 tonnes (76%) and 8 tonnes (80%) respectively (at catchment equilibrium). The best scenarios are *Fertiliser action plan* implementation and soil-amendment application, which both tackle phosphorus leaching from low PRI soils and predict an approximate 2-tonne decrease in phosphorus load in both cases. None of the scenarios that affect nitrogen export create much improvement in Ellen Brook; the best is urban fertiliser reduction which decreases nitrogen load by about 4 tonnes. The estimated increases in load due to future urban development (which includes a deep-sewerage system) are 23 tonnes of nitrogen and 3 tonnes of phosphorus. If urban development in Ellen Brook catchment is not connected to reticulated deep-sewerage, then the estimated increases in nutrient exports are likely to be much greater (i.e. approximately 70 tonnes of nitrogen and 10 tonnes of phosphorus). That is, the future load in Ellen Brook would be almost double the current load if new urban development is unsewered.

Future use of model

The SQUARE model of the Swan-Canning coastal catchments is a powerful tool, which may be used to model future scenarios of land use, management and climate, to support the implementation of the SCWQIP and HRAP. The model can be used to:

- evaluate the impact of proposed actions on local waterways and estuaries
- choose appropriate sites and scale of remediation
- estimate the impact of combinations of scenarios to determine options for achieving the water quality objectives of the tributaries
- guide future investment plans. That is, assess the impact of management actions so those with the greatest nutrient reductions in terms of cost of implementation can be pursued.

10 Conclusions

- The estimated nutrient loads from the 30 Swan-Canning coastal catchments are: 250 tonnes of nitrogen and 26 tonnes of phosphorus.
- The nutrient load reduction targets to achieve the desired water quality objectives, are 130 tonnes of nitrogen and 14 tonnes of phosphorus. That is, reductions of approximately 50 per cent of the current total loads are required.
- In ‘average’ years (such as 1997) the annual flow volumes and nitrogen loads from the coastal catchments and the Avon River are approximately equal, whereas the phosphorus load from the coastal catchments is approximately three-times greater than that from the Avon River.
- The highly-impervious urban catchments have significant flows in summer when the Avon River, Ellen Brook and several other rural catchments have no or small flow volumes. As the conditions in summer and autumn are often favourable for algal blooms, decreasing the nutrient inputs from the ‘urban’ catchments in this period may significantly improve the health of the Swan-Canning estuary.
- The drying climate in the south of Western Australia will cause a greater relative decrease in flows from the Avon River than from the streams and drains of the coastal catchments. This means that, in the future, the estuary will be less well flushed, more saline and the flows from the coastal catchments will have a greater impact than previously.
- Ellen Brook occupies one-third of the area of the coastal catchments. It contributes on average 12% of the annual flow, 15% of the annual nitrogen and 30% of the annual phosphorus loads. However the TP concentrations (~ 0.4 mg/L) in Ellen Brook are much higher than those in the other tributaries (generally less than 0.2 mg/L) due to its low water yield and poor phosphorus-retaining soils. The TN concentrations from Ellen Brook are high (~2.5 mg/L), but are comparable to some of the other catchments such as Lower Canning (~2.3 mg/L) and Saint Leonards Brook (~2.7 mg/L).
- The coastal catchments with the greatest nutrient inputs per unit area are generally the urban catchments closest to the estuaries. However, Ellen Brook and Southern River catchments also contribute large phosphorus inputs in terms of load per cleared area.
- Most of the nutrient comes from residential, farming and recreation land uses and septic tanks.
- Septic tanks contribute approximately 16% of the nitrogen and 8% of the phosphorus inputs to the estuary. Some catchments have large proportions of their nutrient inputs

from septic tanks, e.g. Mill Street (42% of nitrogen and 60% phosphorus) and Perth Airport North (38% of nitrogen and 20% phosphorus).

- Future urban development in the Swan-Canning coastal catchments, that includes reticulated deep-sewerage, is estimated to increase the flow, nitrogen and phosphorus loads to the estuary by 5%, 18% and 25% respectively. The greatest load increases are expected in the Southern River (6 tonnes of nitrogen, 1.3 tonnes of phosphorus) and Ellen Brook catchments (23 tonnes of nitrogen and 3.1 tonnes of phosphorus). These estimations assume that the new urban developments will have similar hydrology and nutrient exports to existing urban developments. Thus water sensitive urban designs that will mitigate these increased loads are required.

- If urban development in Ellen Brook catchment is not connected to reticulated deep-sewerage, then the estimated increases in nutrient exports are likely to be much greater (i.e. approximately 70 tonnes of nitrogen and 10 tonnes of phosphorus). That is, the future nutrient loads in Ellen Brook would be approximately double the current loads (of 71 tonnes nitrogen and 10 tonnes phosphorus) if new urban development is unsewered.

- No single management strategy will enable all of the 30 coastal catchment to achieve their water quality objectives for nitrogen and phosphorus. In many catchments several management actions will be required.

- Of the management actions modelled (point source and septic tank removal, constructed wetlands, fertiliser management, the application of soil amendments and zeolite and laterite filters in streams), fertiliser management showed the greatest decreases in nutrient loads. Clearly the *Fertiliser action plan* should be implemented and supported.

- Although the estimated decrease in load to the estuaries following the construction of wetlands in 22 catchments is 4% and 7% for nitrogen and phosphorus respectively, significant decreases are expected in the catchments for which large wetlands are proposed, such as Bennett, Blackadder and Mills Street catchments.

- Investigation of the effectiveness of water sensitive designs on the Swan Coastal Plain is required, particularly for areas of high water table where large amounts of fill and sub-surface drainage are required to enable urban development.

- It is recommended that all historic landfill, animal burial, night soil and liquid waste disposal sites are mapped accurately and investigated to determine if nutrients and other contaminants are leaching from these sites.

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Appendix A: Calibration report

A1 Flow calibration

The 17 gauges used to calibrate SQUARE flows are listed in Table A1.1. However, there are 16 catchments for which there are no flow data or data of insufficient quality to allow calibration. To estimate flows for these ungauged catchments, parameters from nearby catchments with similar characteristics were used, as displayed in Table A1.1. The daily, monthly and annual Nash-Sutcliffe efficiencies (McCuen et al. 2006; Section A3) for the calibrations are displayed in Table A1.2.

Table A1.1 Flow sites used for SQUARE calibration

AWRC Ref.	Context Name	Name	Catchment	Other catchments which used similar parameters
616082	Bayswater MD	Slade Street	Bayswater Main Drain	-
616084	Bennett Brook MD	Benara Road	Bennett Brook	St. Leonards, Upper Swan
616047	Bickley Brook	Austin Ave	Bickley Brook	Blackadder*
616232	Bickley Brook	Kumbaduru	Munday Brook	-
616189	Ellen Brook	Railway Parade	Ellen Brook	Henley*
616086	Helena River	Whiteman Road	Helena River	-
616178	Jane Brook	National Park	Jane Brook	Ellis Brook
616088	Jane Brook	Great Northern Highway, Road Bridge	Jane Brook	
616045	Mt. Lawley MD	Mt. Lawley	Maylands	South Belmont, Belmont Central, CBD, Claisebrook Main Drain, Downstream
616043	Mill Street MD	Palm Place	Mill Street Main Drain	Bannister Creek, Bull Creek, South Perth
616015	Poison Gully Creek	Littlefield Road	Perth Airport North	Perth Airport South*
616092	Southern River	Anaconda Drive	Southern River	Lower Canning, Helm Street
616044	Neerigen Brook	Abbey Road	Southern River	-
616040	Susannah Brook	Gilmours Farm	Susannah Brook	Millendon
616099	Susannah Brook	River Road	Susannah Brook	-
616027	Canning River	Seaforth	Upper Canning	-
616042	Yule Brook	Brixton Road	Yule Brook	-

* Modifications were made to adopted parameters

Table A1.2 Daily, monthly and annual Nash-Sutcliffe efficiencies (see Appendix A3 for definition) for flow calibrations

Catchment	AWRC Ref.	Daily	Monthly	Annual
Bayswater Main Drain	616082	0.52	0.75	0.64
Bennett Brook	616084	0.69	0.76	0.72
Bickley Brook[1]	616047	0.66	0.90	0.69
Munday Brook[1]	616232	0.66	0.90	0.69
Ellen Brook	616189	0.85	0.93	0.83
Helena River	616086	0.42	0.54	0.65
Jane Brook	616178	0.82	0.87	0.86
Jane Brook	616088	0.81	0.86	0.62
Maylands[1]	616045	0.30	0.79	0.45
Mills Street Main Drain[1]	616043	0.80	0.95	0.81
Perth Airport North[1]	616015	0.59	0.81	0.54
Southern River	616092	0.89	0.95	0.86
Southern River[1]	616044	0.73	0.85	0.12
Susannah Brook	616040	0.87	0.92	0.93
Susannah Brook	616099	0.85	0.96	0.84
Upper Canning	616027	0.73	0.91	0.85
Yule Brook[1]	616042	0.79	0.89	0.56

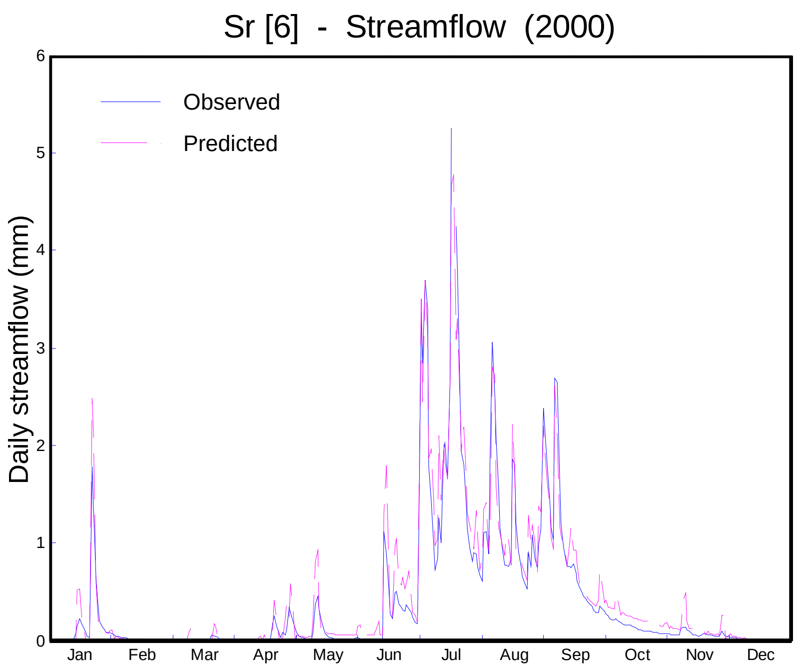
[1] Water Corporation gauge

The parameters from the flow calibration of 616045 (Mt Lawley MD, Mt Lawley), in the Maylands catchment were used to model the flows in the catchments: South Belmont, Belmont Central, CBD, Claisebrook and Downstream, even though this gauge calibrated with the lowest efficiencies. Mt Lawley MD has a highly-impervious catchment similar to the catchments that used its flow calibration parameters. Other catchments had better flow calibrations but they were considered too pervious, to transfer their flow parameters to these highly-impervious catchments. Thus it is strongly recommended that good-quality flow data are obtained from some of these 'impervious' catchments for future model calibration.

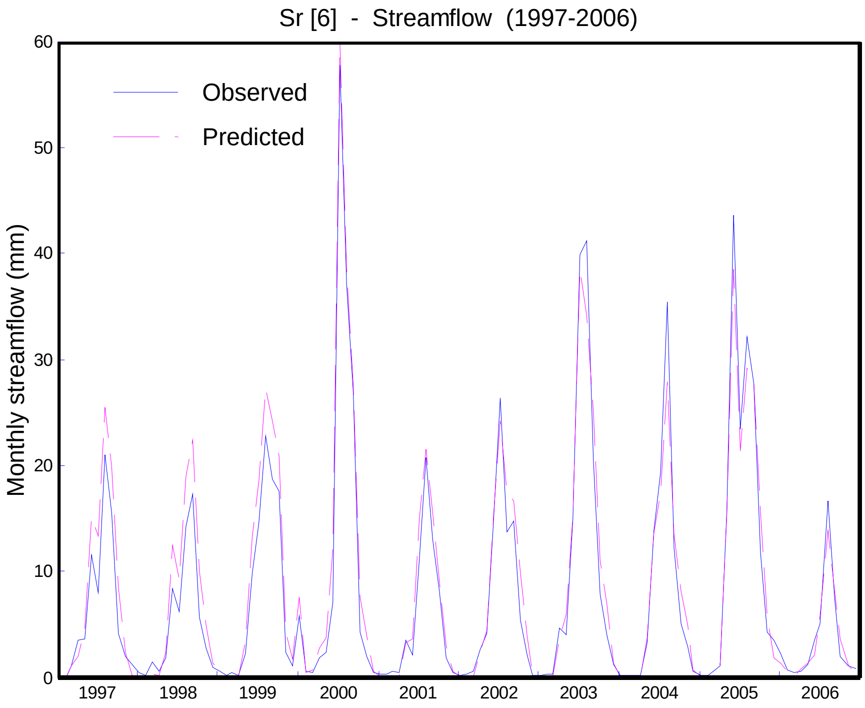
As an example, the results of the flow calibration for Southern River catchment are displayed below. The daily, monthly and annual efficiencies for the calibration of flows from 616092 (Southern River, Anaconda Drive) were 0.89, 0.95 and 0.86 respectively. The observed and predicted daily flows for 2000, the observed and predicted monthly and annual flows, and the cumulative flows for the period of the flow record (1997–2006) are displayed. The annual flows seem to over predict slightly at the beginning of the period and under predict towards the end. This is seen also in the cumulative flows. The monthly flows match very well and this calibration is considered appropriate. The three soil moisture stores which are displayed over the page behave in a stable manner. The change in the B-store between 1970 and 1978 is a feature of the "spin-up" of the model.

Southern River Flow Calibration:
616092 (Southern River, Anaconda Drive)
Efficiency:

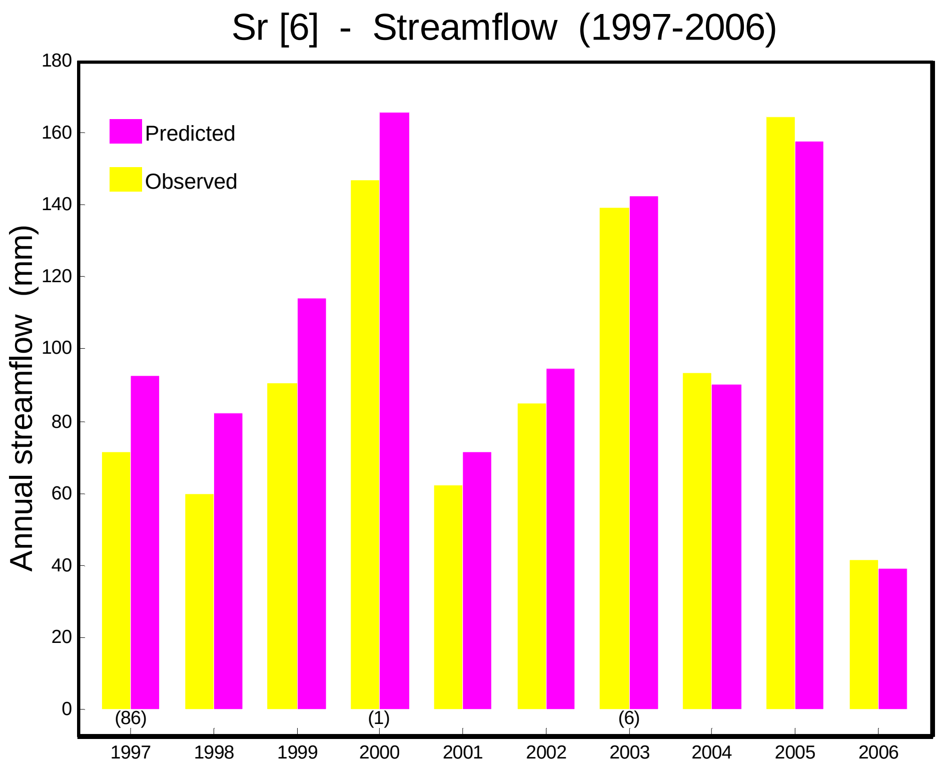
Daily = 0.89
Monthly = 0.95
Annual = 0.86



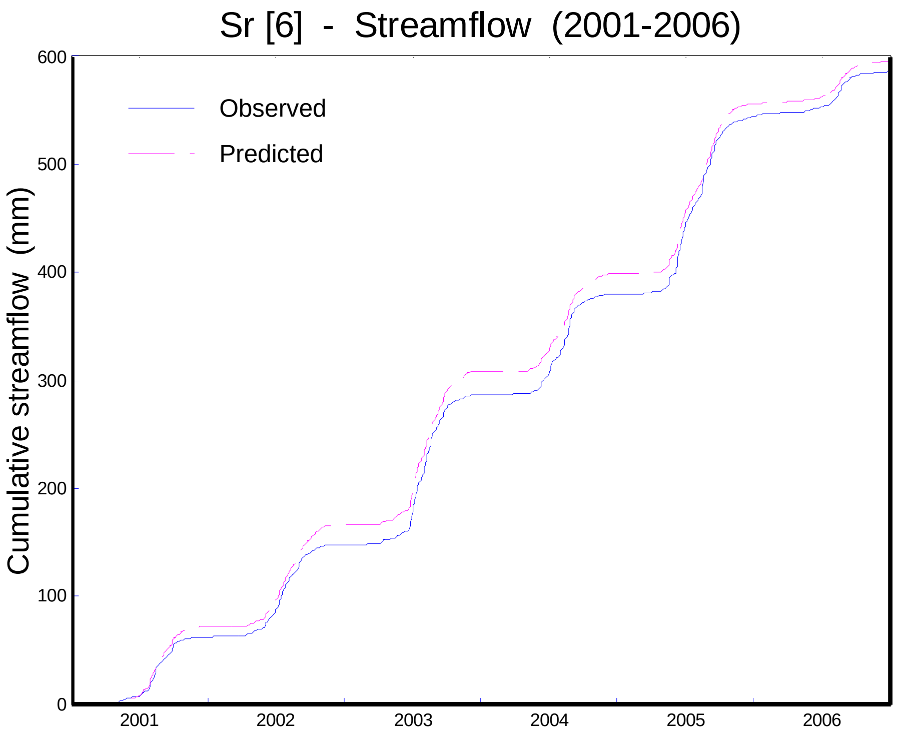
Observed and estimated daily flows for 2000



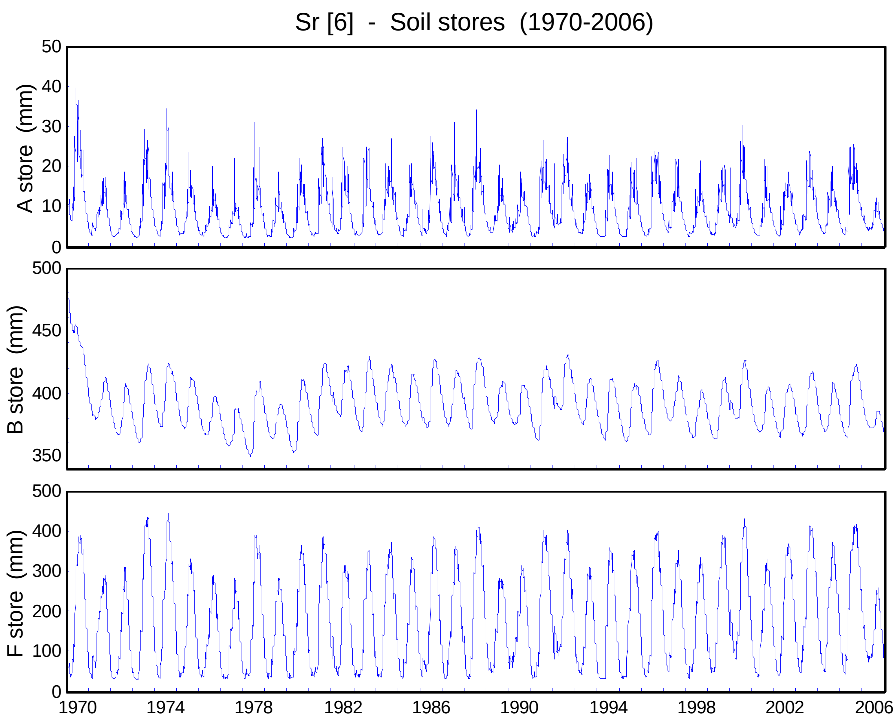
Observed and estimated monthly flows



Observed and estimated annual flows



Observed and estimated cumulative flow for the period 2001 to 2006



Soil moisture store values for subcatchment 6 (upstream 616092)

A2 Nutrient calibrations

The calibrations process discussed in Section 3.1 was undertaken at 20 sites with sufficient nutrient data. The Nash-Sutcliffe efficiencies for the total nitrogen (TN) and total phosphorus (TP) calibrations are given in Table A2.1. The Nash-Sutcliffe efficiency parameter is a stringent test of model fit, as discussed in Appendix A3, and nutrient calibrations achieved here are considered reasonable. The object of the calibrations was not only to achieve high efficiencies, but also to match closely the observed winter median concentrations for TN and TP, as well as the LOESS-calculated loads at some sites. Greater efficiencies would have been obtained if these criteria had not been included.

Table A2.1Nash-Sutcliffe efficiencies for TN and total phosphorus TP calibrations

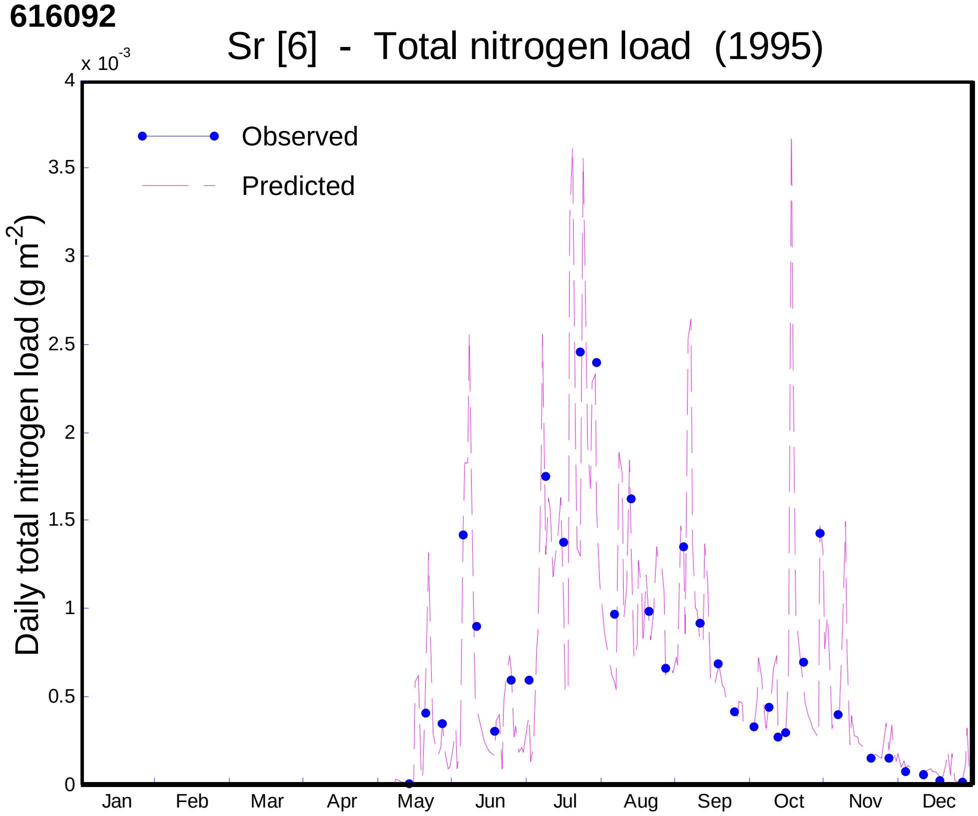
Catchment	AWRC Ref.	TN	TP
Bannister Creek	616091	0.24	0.58
Bayswater	616082	0.37	0.10
Bennett Brook	6163143	0.57	0.03
Blackadder	6162925	0.22	0.25
Bullcreek	6162311	0.74	0.42
Ellen	616189	0.60	0.42
Helena	616086	0.28	0.27
Helm Street	6162313	0.33	-0.08
Henley	6161692	0.21	0.18
Jane	616088	0.47	0.64
Mill Street	616043	0.44	0.35
Millendon	616076	0.51	0.01
Munday & Bickley	616047	0.48	0.52
Perth Airport North	6162318	0.71	0.75
Perth Airport South	6162317	0.90	0.71
South Belmont	616087	0.61	0.39
Southern	616092	0.86	0.55
Susannah	616099	0.51	0.51
Upper Canning	616027	0.52	0.23
Yule Brook	616042	0.10	0.12

Generally the sites which had flow data had better calibrations than those for which modelled flows were used to calculate the daily nutrient loads. However this was not always the case, as high efficiencies were obtained for Bennet Brook, Perth Airport South and South Belmont which used modelled flows, and Helena River and Yule Brook which have flow data had relatively low efficiencies. This indicates that the flow data from 616086 (Helena River) and 616042 (Yule Brook) are most likely inaccurate, and these flow structures and ratings should be reviewed.

Matlab™ plots of the observed and modelled daily TN and TP data at 616092 (Southern River, Anaconda Drive) for 1995 are displayed in Figure A2.1.

Catchment: Southern River

Site: 616092



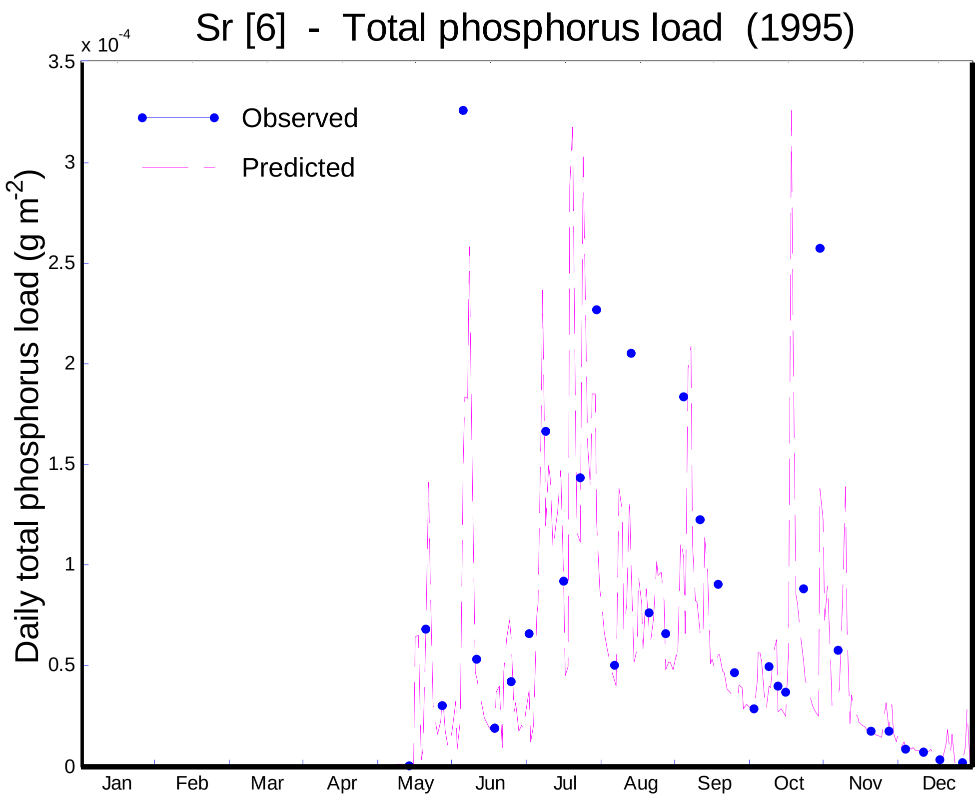


Figure A2.1 Plots of TN and TP data at 616092 (Southern River, Anaconda Drive)

Table A2.2 lists the sampling sites used for the nutrient calibrations, their catchments and the parameter sets used by the 10 catchments that did not have regular sampling programs. Six of the 10 ‘non sampled’ catchments had some nutrient data (generally collected as part of the CCI sampling program). For these catchments, if required, the parameters were “tweaked” so that the modelled winter median TN and TP concentrations closely matched the observed concentrations. These catchments, marked with an asterisk in Table A2.2, are described as validated. The sampling sites used for validation are listed in Table A2.3.

Table A2.2 Catchments for which nutrient calibrations were done, and the uncalibrated catchments that used parameters similar parameters

Sampling location	**Site Name**	**Calibrated Catchment**	**Catchment using similar parameters**
616091	Hybanthus Road	Bannister Creek	-
616082	Slade Street	Bayswater	CBD*, Claisebrook, Downstream, Maylands, *Upper Swan**
6163143	Brook Road	Bennett	*Saint Leonards**
6162925	Francis Street	Blackadder	-
6162311	Holmes Road	Bullcreek	-
616189	Railway Parade	Ellen	-
616086	Whiteman Road	Helena	-
6162313	Helm Street Drain	Helm Street	Ellis*
6161692	Brockman Road	Henley Brook	-
616088	Great Northern Highway	Jane	-
616043	Palm Place	Mill Street	Lower Canning*
616076	Upper Swan Bridge	Millendon	-
616047	Austin Ave	Munday & Bickley	-
6162318	Great Eastern Highway Bypass	Perth Airport North	-
6162317	Second Ave	Perth Airport South	-
616087	Abernethy Road, Great Eastern Hwy	South Belmont	Belmont Central*, *South Perth*
616092	Anaconda Drive	Southern	-
616099	River Road	Susannah	-
616027	Seaforth	Upper Canning	-
616042	Brixton Road	Yule Brook	-

**Modifications were made to parameters by comparison with data (mostly CCI)*

Table A2.3 Water quality sampling sites used for validation of model calibration

Catchment	**AWRC Ref.**	**Site name**
Belmont Central	6160067	Centenary Park outlet
CBD	6161754	Mounts Bay MD
Ellis Brook	6160690	Mills Road
Lower Canning	6162312	Cockhram Street Drain
St. Leonards	6162319	George Street
Upper Swan	6161696	Chapman Street Main Drain

There were four catchments with insufficient data to enable calibration or validation – Claisebrook, Downstream, Maylands and South Perth. Claisebrook, Downstream and Maylands used the parameters from the Bayswater calibrations, and South Perth used parameters from the South Belmont calibrations.

The observed and modelled winter median TN and TP concentrations for the calibrated and validated catchments are listed in Table A2.4 and plotted in Figure A2.2 and Figure A2.3. The nutrient calibrations were not accepted until the modelled TN and TP concentrations were with in the standard error of the observed data. However in most cases the modelled concentrations are equal to the observed concentrations.

Table A2.4 Observed and modelled TN and TP concentrations at the main sampling sites

Catchment	AWRC ref.	Observed TN winter median conc. (mg/L)	Modelled TN winter median conc. (mg/L)	Observed TP winter median conc.(mg/L)	Modelled TP winter median conc.(mg/L)
Bannister	616091	1.50	1.51	0.075	0.075
Bayswater	616082	1.20	1.23	0.054	0.064
Belmont Central	6160067	1.00	1.00	0.075	0.075
Bennett	6163143	1.20	1.20	0.050	0.040
Blackadder	6162925	0.97	0.98	0.047	0.049
Bullcreek	6162311	0.80	0.80	0.050	0.050
CBD	6161754	1.60	1.60	0.056	0.056
Ellen	616189	2.55	2.55	0.450	0.448
Ellis	6160690	0.39	0.39	0.015	0.016
Helena	616086	0.83	0.88	0.020	0.022
Helm Street	6162313	1.60	1.60	0.041	0.041
Henley	6161692	1.40	1.41	0.093	0.096
Jane	616088	0.70	0.70	0.023	0.023
Lower Canning	6162312	2.30	2.30	0.190	0.190
Mills Street	616043	1.40	1.40	0.150	0.149
Millendon	616076	0.83	0.85	0.021	0.024
Munday & Bickley	616047	1.20	1.20	0.045	0.045
Perth Airport North	6162318	1.00	1.06	0.040	0.040
Perth Airport South	6162317	0.64	0.64	0.018	0.018
Saint Leonards	6162319	2.70	2.70	0.115	0.115
South Belmont	616087	0.82	0.84	0.092	0.096
Southern	616092	1.25	1.25	0.135	0.136
Susannah	616099	0.73	0.74	0.014	0.018
Upper Canning	616027	0.70	0.71	0.028	0.028
Upper Swan	6161696	1.60	1.68	0.068	0.068
Yule	616042	1.00	1.07	0.057	0.064

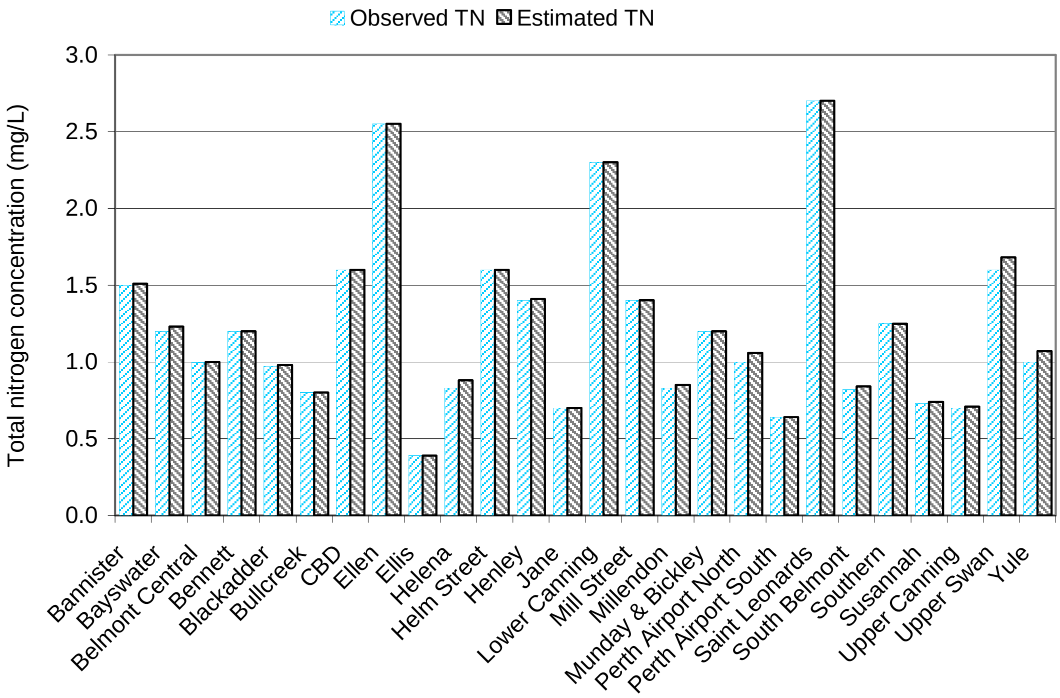


Figure A2.2 Observed and modelled winter median TN concentrations

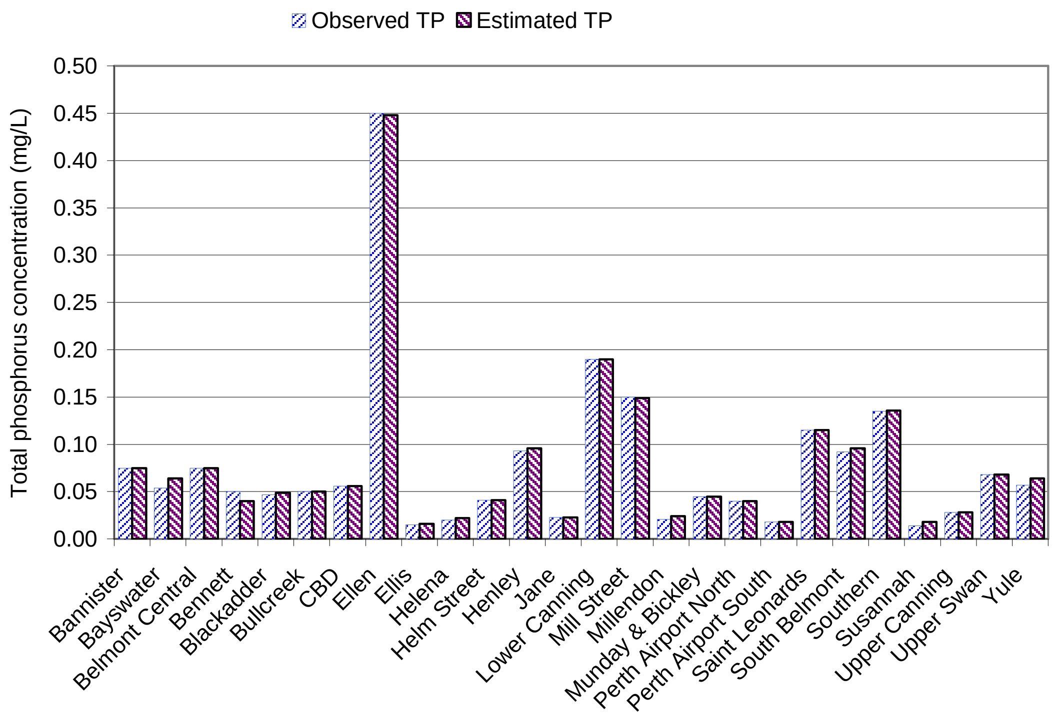


Figure A2.3 Observed and modelled winter median TP concentrations

A3 Nash-Sutcliffe efficiency coefficient

The Nash-Sutcliffe coefficient of efficiency, *E* (McCuen et al. 2006) is defined as

$$E = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2}$$

where

O_i be the individual observed values on day i,

$\overline{O}$ be the mean of observed values,

P_i be the individual modelled values on day i.

Nash–Sutcliffe efficiencies can range from −∞ to 1. An efficiency of 1 (*E* = 1) corresponds to a perfect match of modelled data to the observed data. An efficiency of 0 (*E* = 0) indicates that the model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero (*E* < 0) occurs when the observed mean is a better predictor than the model or, in other words, when the residual variance (described by the nominator in the expression above), is larger than the data variance (described by the denominator).

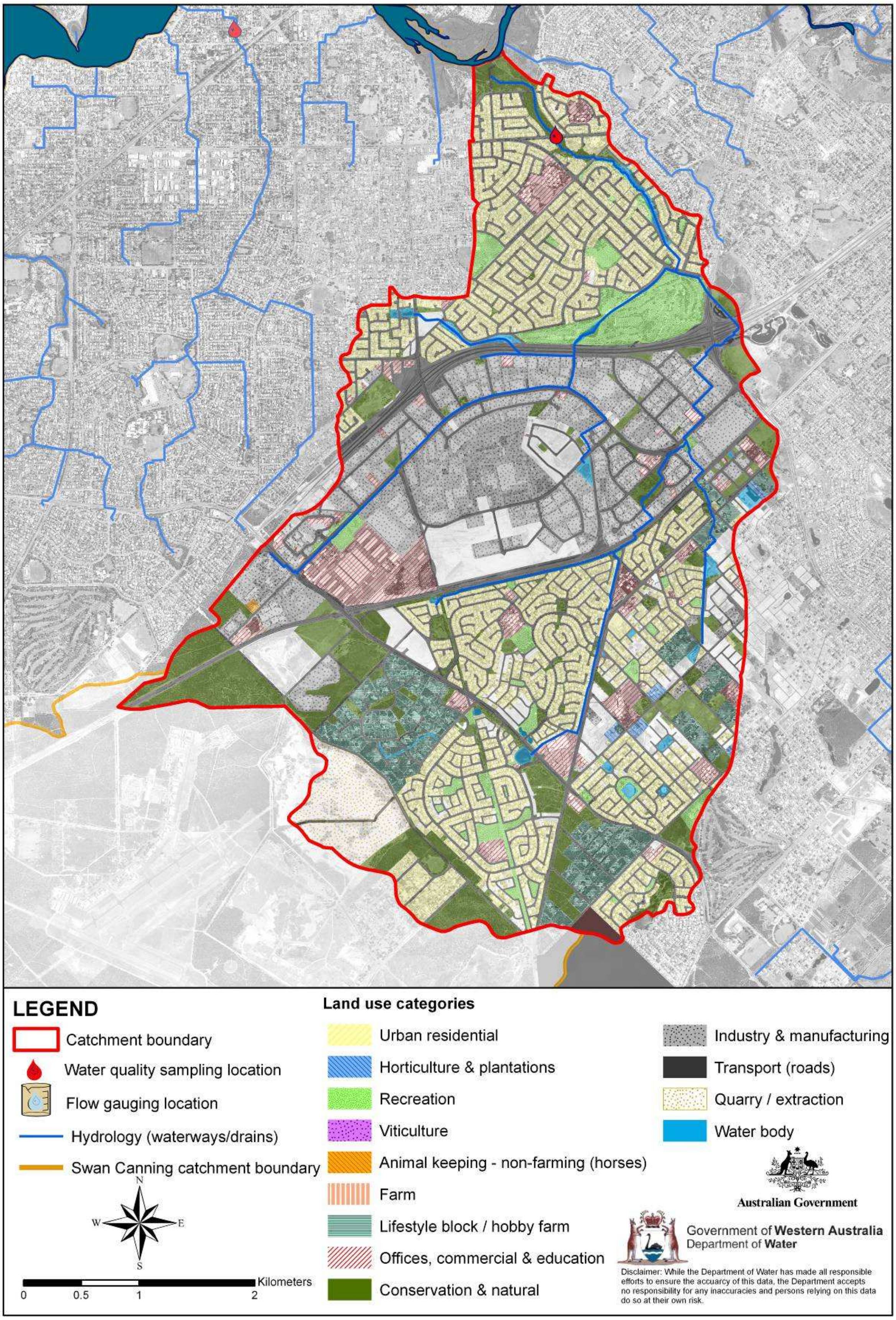
Essentially, the closer the model efficiency is to 1, the more accurate the model is.

Comment on nutrient calibration efficiencies

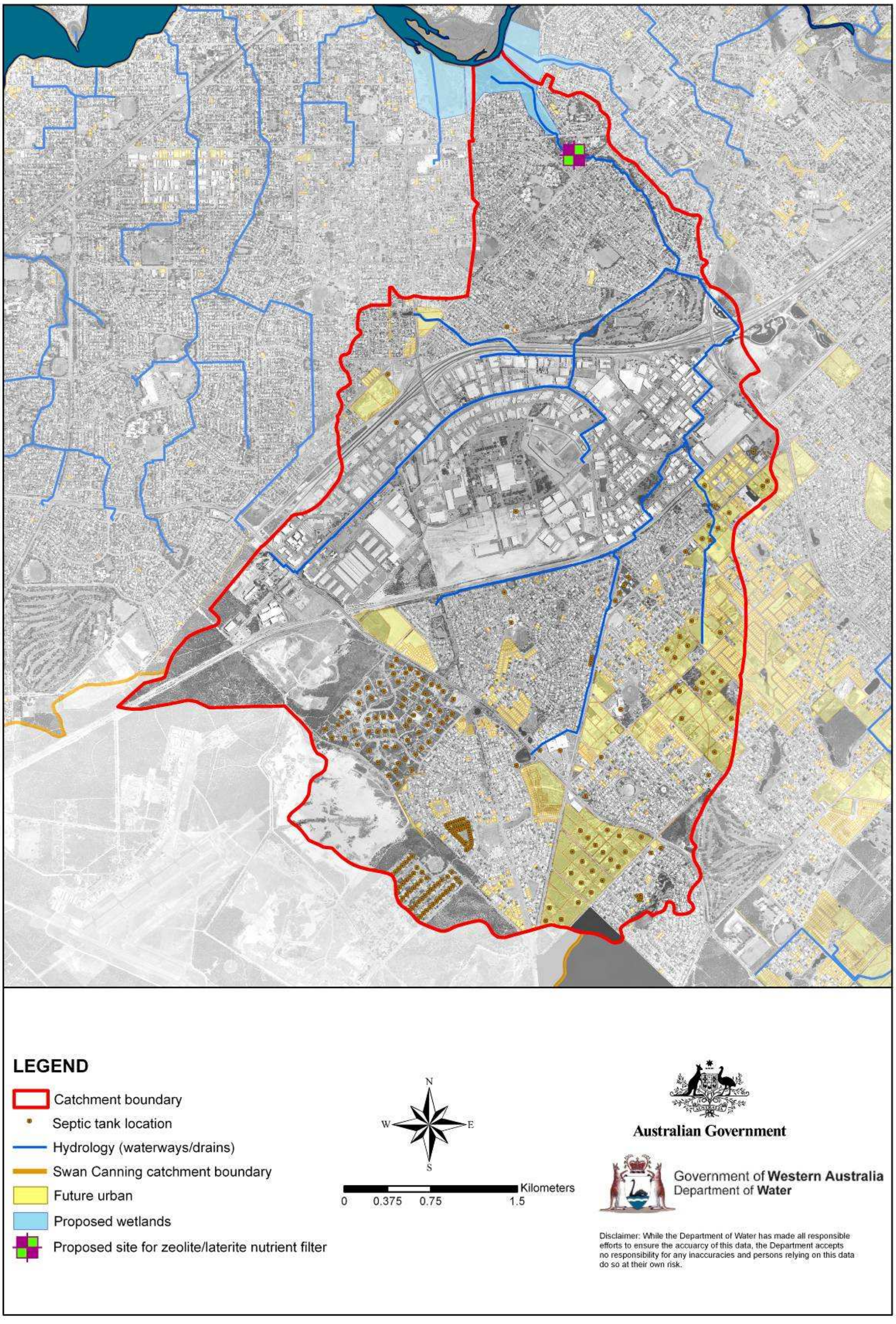
In the case of Nash-Sutcliffe efficiencies for nutrient calibrations, as all the data have equal weights, a few ‘spurious’ observations such as nutrient data collected from stagnant water, can produce a low efficiency, even though the concentrations during winter have been predicted well. In all the model calibrations, the predicted median winter concentrations of total nitrogen (TN) and total phosphorus (TP) were matched closely to the observed winter median concentrations, even when this produced a low efficiency coefficient. As most of the load is produced in winter a close match to the winter TN and TP concentrations was considered more important than a high efficiency.

Appendix B: Modelling results for reporting subcatchments

Bannister Creek
Land use map



Locations of septic tanks, future urban development, proposed wetlands and zeolite/laterite filter



Bannister Creek - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616091		
	Current	22% Input Reduction		Current	22% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.74	0.49	*1997*	0.73	0.47
1998	0.78	0.52	*1998*	0.76	0.51
1999	0.84	0.57	*1999*	0.82	0.55
2000	0.88	0.61	*2000*	0.86	0.59
2001	0.76	0.51	*2001*	0.74	0.49
2002	0.83	0.56	*2002*	0.80	0.54
2003	0.90	0.62	*2003*	0.87	0.60
2004	0.77	0.50	*2004*	0.75	0.49
2005	0.99	0.66	*2005*	0.96	0.65
2006	0.68	0.41	*2006*	0.66	0.40
Average	**0.82**	**0.55**	**Average**	**0.80**	**0.53**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.08**	**0.05**	**SQUARE:**	**0.075**	**0.05**
Target:	**0.05**		**Target:**	**0.075**	
Load Target (t/yr)		**0.55**			
Load Reduction Target (t/yr)		**0.27**			
Required Reduction (%)		**33%**			
Time Required (yr)		**20**			

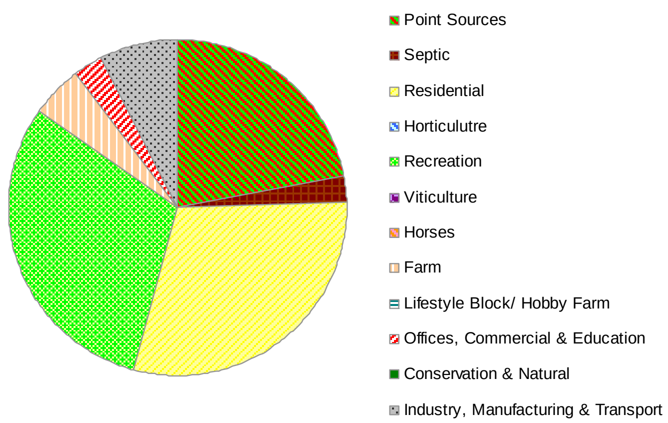
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616091		
	Current	47% Input Reduction		Current	47% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	10.6	3.8	*1997*	10.3	3.7
1998	11.7	4.1	*1998*	11.4	3.9
1999	13.1	4.4	*1999*	12.7	4.3
2000	12.9	4.3	*2000*	12.5	4.2
2001	11.2	3.6	*2001*	10.8	3.5
2002	12.1	3.9	*2002*	11.8	3.8
2003	13.5	4.3	*2003*	13.1	4.2
2004	11.6	3.5	*2004*	11.2	3.4
2005	14.3	4.4	*2005*	13.8	4.2
2006	9.8	2.9	*2006*	9.5	2.8
Average	**12.1**	**3.9**	**Average**	**11.7**	**3.8**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.51**	**0.50**	**SQUARE:**	**1.51**	**0.49**
Target:	**0.5**		**Observed:**	**1.50**	
Load Target (t/yr)		**3.9**			
Load Reduction Target (t/yr)		**8.2**			
Required Reduction (%)		**68%**			
Time Required (yr)		**60**			

Bannister Creek - Source separation

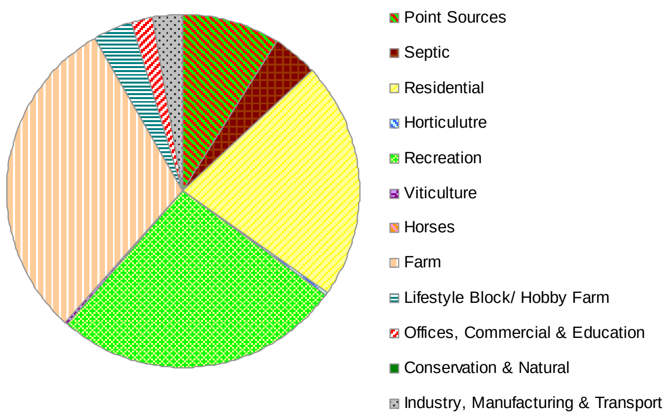
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.75	0.17	0.02	0.15	0.00	0.21	0.00	0.00	0.08	0.00	0.01	0.00	0.05
1998	0.78	0.17	0.02	0.17	0.00	0.22	0.00	0.00	0.08	0.00	0.01	0.00	0.06
1999	0.84	0.17	0.02	0.18	0.00	0.24	0.00	0.00	0.09	0.00	0.02	0.00	0.06
2000	0.88	0.17	0.02	0.21	0.00	0.27	0.00	0.00	0.06	0.00	0.02	0.00	0.06
2001	0.76	0.17	0.02	0.21	0.00	0.21	0.00	0.00	0.03	0.00	0.02	0.00	0.05
2002	0.83	0.17	0.02	0.24	0.00	0.24	0.00	0.00	0.02	0.00	0.02	0.00	0.06
2003	0.90	0.17	0.02	0.28	0.00	0.27	0.00	0.00	0.01	0.00	0.02	0.00	0.06
2004	0.77	0.17	0.02	0.25	0.00	0.20	0.00	0.00	0.01	0.00	0.02	0.00	0.05
2005	0.99	0.17	0.02	0.33	0.00	0.29	0.00	0.00	0.00	0.00	0.03	0.00	0.07
2006	0.68	0.17	0.02	0.23	0.00	0.16	0.00	0.00	0.00	0.00	0.02	0.00	0.05
Load (non adj)	0.82	0.17	0.02	0.22	0.00	0.23	0.00	0.00	0.04	0.00	0.02	0.00	0.06
Load (t/yr)	**0.82**	**0.18**	**0.02**	**0.24**	**0.00**	**0.25**	**0.00**	**0.00**	**0.04**	**0.00**	**0.02**	**0.00**	**0.06**
Load (%)	**100.0%**	**21.9%**	**2.6%**	**29.5%**	**0.1%**	**30.5%**	**0.0%**	**0.0%**	**5.1%**	**0.1%**	**2.6%**	**0.0%**	**7.6%**



Nitrogen (t/yr)

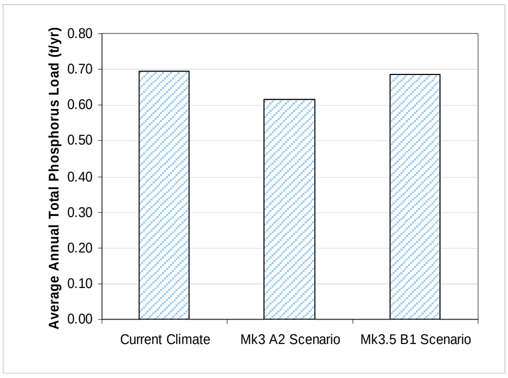
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	10.6	1.1	0.4	1.6	0.0	2.7	0.0	0.0	4.0	0.4	0.2	0.0	0.3
1998	11.7	1.1	0.5	1.9	0.0	3.0	0.0	0.0	4.3	0.4	0.2	0.0	0.3
1999	13.1	1.1	0.6	2.3	0.0	3.4	0.0	0.0	4.7	0.5	0.2	0.0	0.3
2000	12.9	1.1	0.6	2.4	0.0	3.4	0.0	0.0	4.4	0.5	0.2	0.0	0.3
2001	11.2	1.1	0.5	2.3	0.0	2.9	0.0	0.0	3.4	0.4	0.2	0.0	0.3
2002	12.1	1.1	0.5	2.7	0.0	3.3	0.0	0.0	3.5	0.5	0.2	0.0	0.3
2003	13.5	1.1	0.6	3.3	0.1	3.7	0.0	0.0	3.6	0.5	0.3	0.0	0.4
2004	11.6	1.1	0.5	3.0	0.0	3.1	0.0	0.0	2.9	0.4	0.3	0.0	0.3
2005	14.3	1.1	0.6	4.0	0.1	4.0	0.0	0.0	3.3	0.5	0.4	0.0	0.4
2006	9.8	1.1	0.4	2.8	0.0	2.6	0.0	0.0	2.0	0.4	0.2	0.0	0.3
Load (non adj)	12.1	1.1	0.5	2.6	0.0	3.2	0.0	0.0	3.6	0.4	0.2	0.0	0.3
Load (t/yr)	**12.1**	**1.1**	**0.5**	**2.6**	**0.0**	**3.2**	**0.0**	**0.0**	**3.6**	**0.4**	**0.2**	**0.0**	**0.3**
Load (%)	**100.0%**	**8.9%**	**4.2%**	**21.5%**	**0.4%**	**26.4%**	**0.1%**	**0.1%**	**29.9%**	**3.7%**	**1.9%**	**0.1%**	**2.7%**



Bannister Creek – Climate change

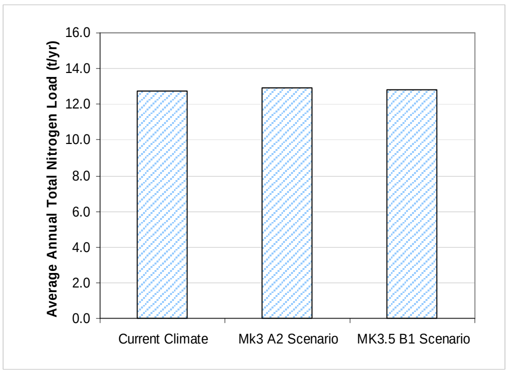
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.62	0.56	0.62
2058	0.67	0.60	0.66
2059	0.72	0.66	0.72
2060	0.78	0.68	0.76
2061	0.65	0.57	0.64
2062	0.71	0.64	0.70
2063	0.79	0.69	0.77
2064	0.64	0.57	0.63
2065	0.85	0.71	0.82
2066	0.53	0.48	0.52
Average Load for RF Sequence (t/yr)	**0.70**	**0.62**	**0.68**



Nitrogen

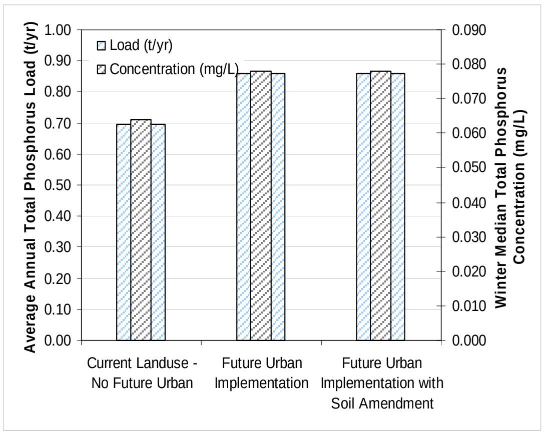
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	12.1	12.1	12.2
2058	13.1	13.2	13.1
2059	14.3	14.6	14.3
2060	13.9	14.3	13.9
2061	11.8	11.9	11.8
2062	12.7	12.9	12.8
2063	14.1	14.3	14.2
2064	11.7	11.9	11.7
2065	14.4	14.6	14.4
2066	9.5	9.6	9.5
Average Load for RF Sequence (t/yr)	**12.8**	**12.9**	**12.8**



Bannister Creek – Future urban

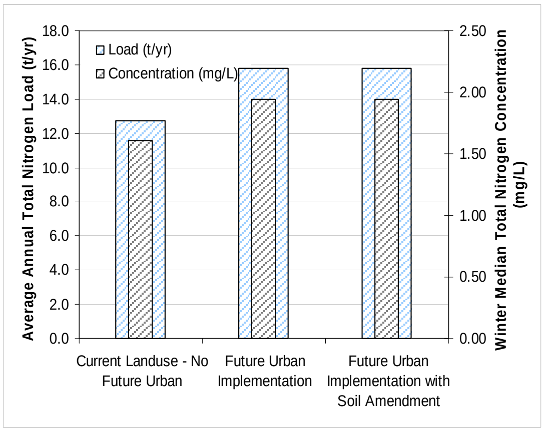
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.62	0.77	0.77
2058	0.67	0.83	0.83
2059	0.72	0.89	0.89
2060	0.78	0.95	0.95
2061	0.65	0.80	0.80
2062	0.71	0.88	0.88
2063	0.79	0.97	0.97
2064	0.64	0.79	0.79
2065	0.85	1.04	1.04
2066	0.53	0.66	0.66
Average Load for RF Sequence (t/yr)	**0.70**	**0.86**	**0.86**
Median Winter Concentration (mg/L)	**0.064**	**0.078**	**0.078**



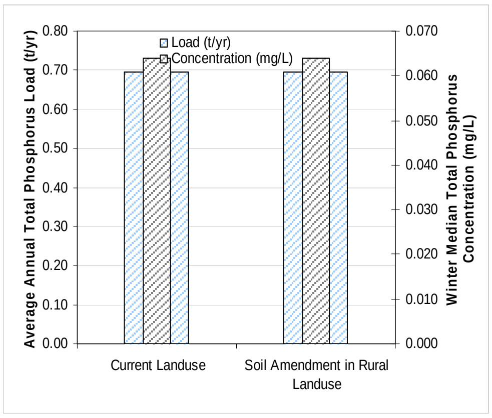
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	12.1	15.0	15.0
2058	13.1	16.2	16.2
2059	14.3	17.7	17.7
2060	13.9	17.2	17.2
2061	11.8	14.5	14.5
2062	12.7	15.7	15.7
2063	14.1	17.5	17.5
2064	11.7	14.4	14.4
2065	14.4	17.8	17.8
2066	9.5	11.7	11.7
Average Load for RF Sequence (t/yr)	**12.8**	**15.8**	**15.8**
Median Winter Concentration (mg/L)	**1.61**	**1.94**	**1.94**



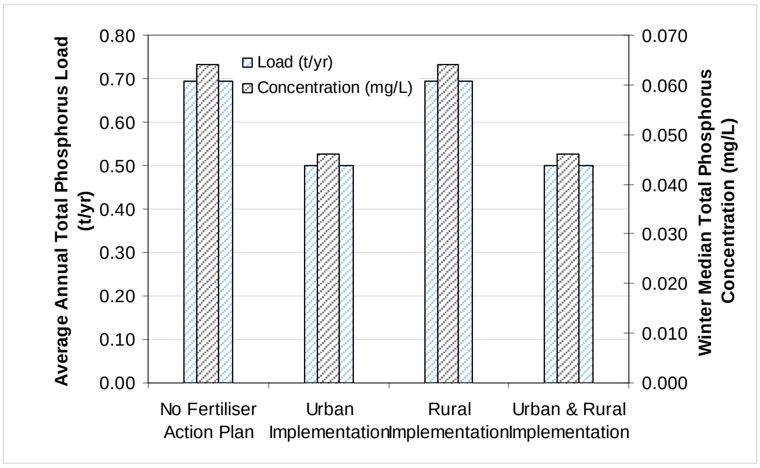
Bannister Creek – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.62	0.62
2058	0.67	0.67
2059	0.72	0.72
2060	0.78	0.78
2061	0.65	0.65
2062	0.71	0.71
2063	0.79	0.79
2064	0.64	0.64
2065	0.85	0.85
2066	0.53	0.53
Average Load for RF Sequence (t/yr)	**0.70**	**0.70**
Median Winter Concentration (mg/L)	**0.064**	**0.064**



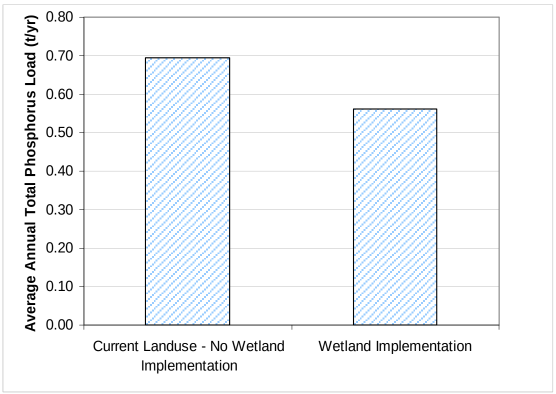
Bannister Creek – *Fertiliser action plan*

Phosphorus				
		At Catchment Outlet		
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.62	0.45	0.62	0.45
2058	0.67	0.48	0.67	0.48
2059	0.72	0.52	0.72	0.52
2060	0.78	0.56	0.78	0.56
2061	0.65	0.46	0.65	0.46
2062	0.71	0.51	0.71	0.51
2063	0.79	0.57	0.79	0.57
2064	0.64	0.46	0.64	0.46
2065	0.85	0.61	0.85	0.61
2066	0.53	0.38	0.53	0.38
Average Load for RF Sequence (t/yr)	**0.70**	**0.50**	**0.70**	**0.50**
Median Winter Concentration (mg/L)	**0.064**	**0.046**	**0.064**	**0.046**

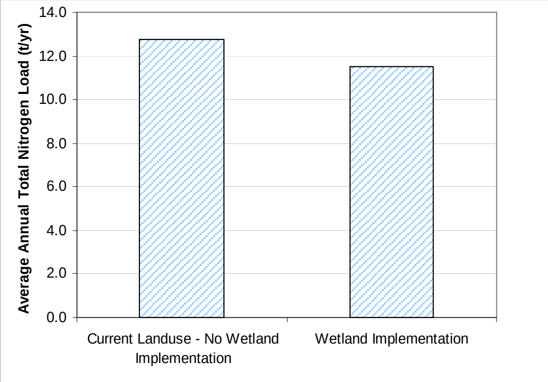


Bannister Creek – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	0.62	0.50
2058	0.67	0.54
2059	0.72	0.60
2060	0.78	0.64
2061	0.65	0.53
2062	0.71	0.58
2063	0.79	0.63
2064	0.64	0.52
2065	0.85	0.67
2066	0.53	0.42
Average Load for RF Sequence (t/yr)	**0.70**	**0.56**

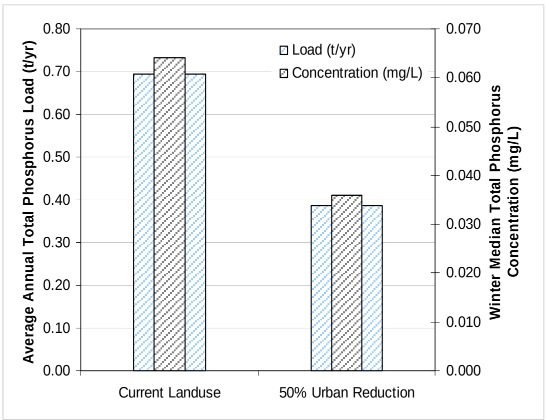


Nitrogen		
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	12.1	11.0
2058	13.1	11.9
2059	14.3	13.0
2060	13.9	12.3
2061	11.8	10.8
2062	12.7	11.5
2063	14.1	12.6
2064	11.7	10.7
2065	14.4	12.8
2066	9.5	8.5
Average Load for RF Sequence (t/yr)	**12.8**	**11.5**

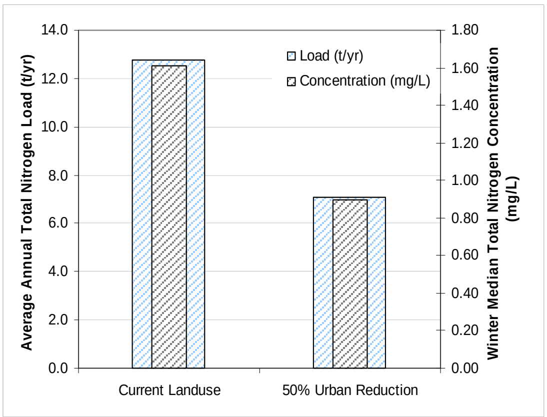


Bannister Creek – Urban 50% reduction

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.62	0.34
2058	0.67	0.37
2059	0.72	0.41
2060	0.78	0.43
2061	0.65	0.36
2062	0.71	0.40
2063	0.79	0.44
2064	0.64	0.35
2065	0.85	0.47
2066	0.53	0.29
Average Load for RF Sequence (t/yr)	**0.70**	**0.39**
Median Winter Concentration (mg/L)	**0.064**	**0.036**

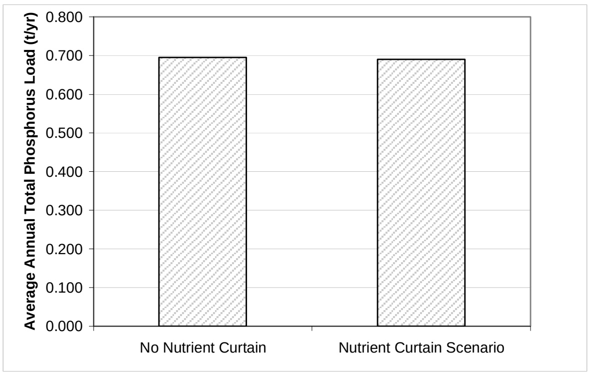


Nitrogen		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	12.1	6.8
2058	13.1	7.3
2059	14.3	8.0
2060	13.9	7.7
2061	11.8	6.5
2062	12.7	7.0
2063	14.1	7.8
2064	11.7	6.4
2065	14.4	8.0
2066	9.5	5.2
Average Load for RF Sequence (t/yr)	**12.8**	**7.1**
Median Winter Concentration (mg/L)	**1.61**	**0.90**

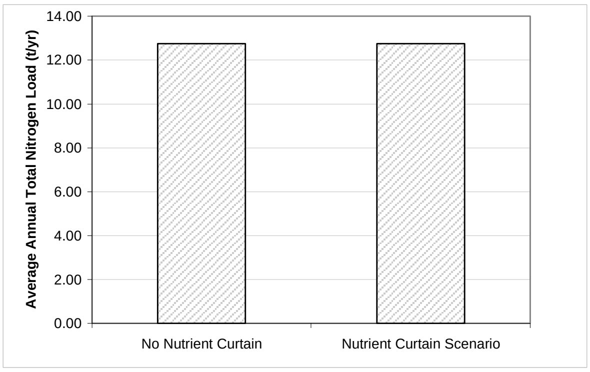


Bannister Creek – Zeolite/laterite nutrient filter

Phosphorus			
Year	No Nutrient Curtain Load (t/yr)	Phosphorus Removed - Main Stream (t/yr)	Nutrient Curtain Implementation (t/yr)
2057	0.623	0.005	0.617
2058	0.668	0.005	0.663
2059	0.725	0.005	0.720
2060	0.776	0.004	0.771
2061	0.648	0.005	0.643
2062	0.714	0.005	0.709
2063	0.787	0.005	0.782
2064	0.638	0.005	0.633
2065	0.847	0.005	0.842
2066	0.528	0.005	0.523
Average Load for RF Sequence (t/yr)	**0.695**	**0.005**	**0.690**



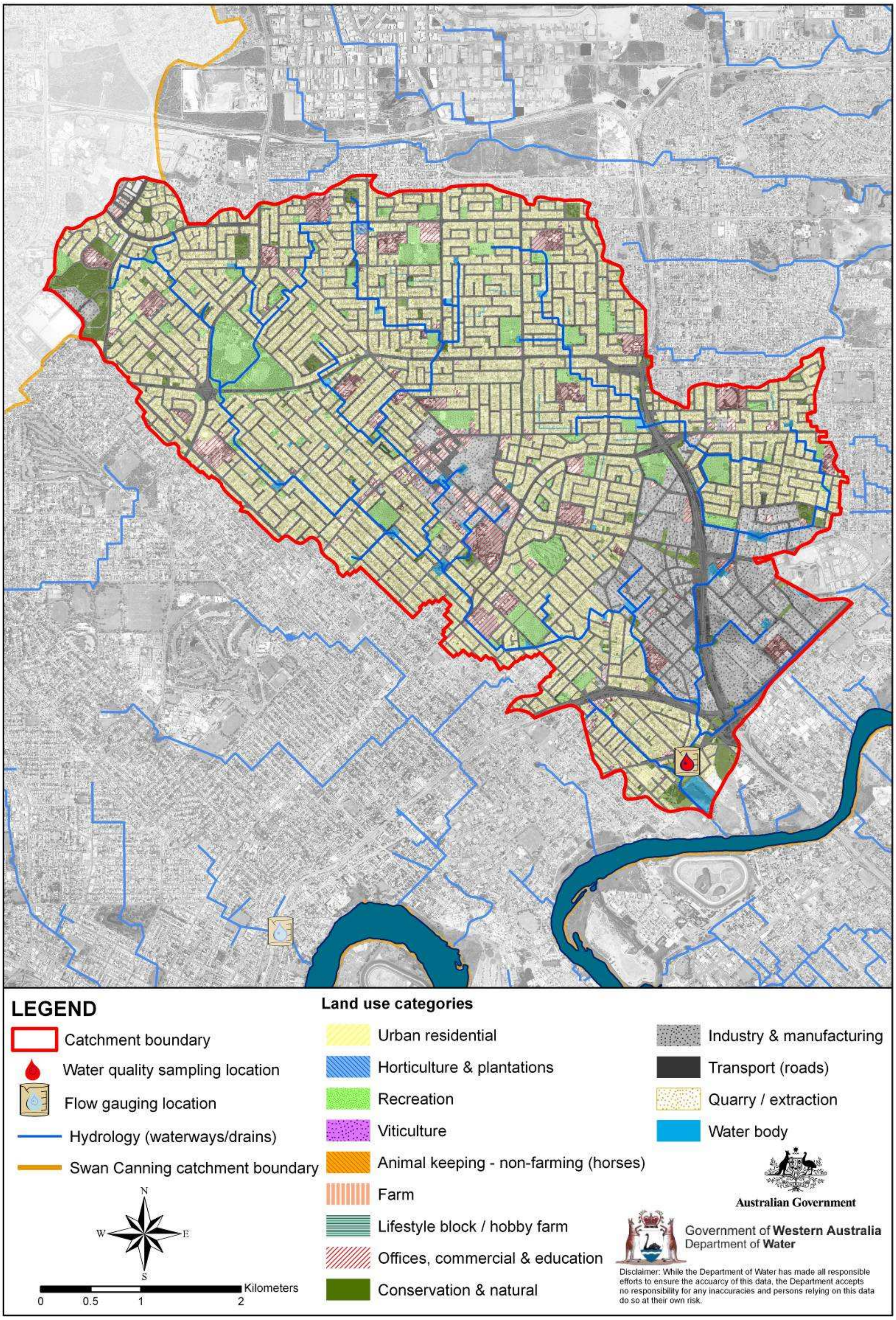
Nitrogen			
Year	No Nutrient Curtain Load (t/yr)	Nitrogen Removed - Main Stream (t/yr)	Nutrient Curtain Implementation (t/yr)
2057	12.13	0.01	12.12
2058	13.07	0.01	13.06
2059	14.31	0.02	14.29
2060	13.92	0.01	13.91
2061	11.76	0.01	11.75
2062	12.71	0.01	12.70
2063	14.13	0.01	14.12
2064	11.66	0.01	11.65
2065	14.42	0.01	14.41
2066	9.48	0.01	9.46
Average Load for RF Sequence (t/yr)	**12.76**	**0.01**	**12.75**



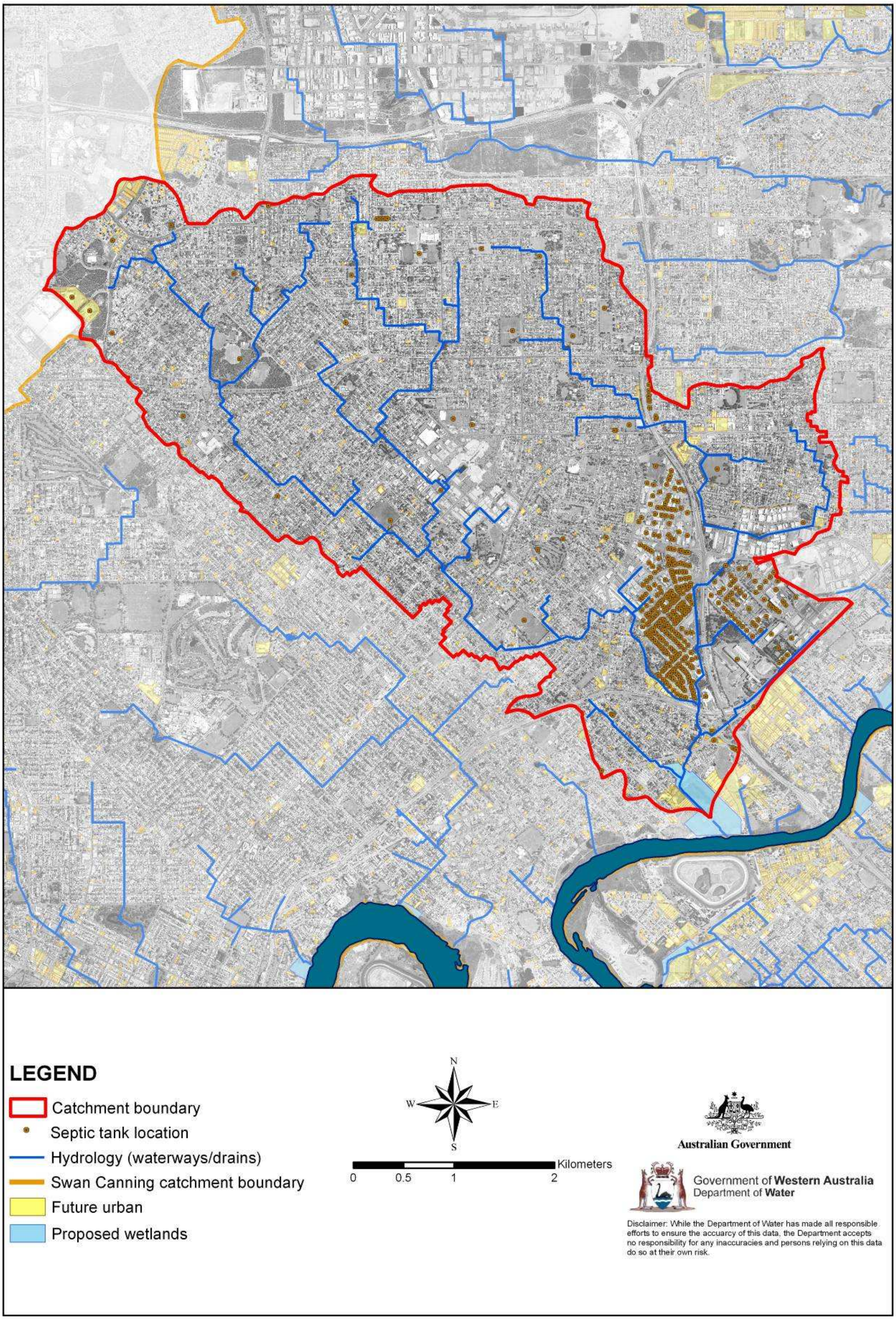
* Nutrient Curtain assumed to contain 500 cubic metres of Laterite and 8 cubic metres of zeolite

Bayswater Main Drain

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Bayswater Main Drain - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616082		
	Current	13% Input Reduction		Current	13% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.61	0.41	*1997*	0.58	0.38
1998	0.63	0.45	*1998*	0.60	0.42
1999	0.63	0.46	*1999*	0.60	0.42
2000	0.63	0.46	*2000*	0.60	0.43
2001	0.53	0.38	*2001*	0.50	0.36
2002	0.65	0.47	*2002*	0.61	0.44
2003	0.65	0.48	*2003*	0.61	0.45
2004	0.54	0.41	*2004*	0.51	0.38
2005	0.68	0.53	*2005*	0.64	0.49
2006	0.44	0.34	*2006*	0.41	0.31
Average	**0.60**	**0.44**	**Average**	**0.56**	**0.41**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.065**	**0.048**	**SQUARE:**	**0.064**	**0.046**
Target:	**0.050**		**Observed:**	**0.054**	
Load Target (t/yr)		**0.44**			
Load Reduction Target (t/yr)		**0.16**			
Required Reduction (%)		**27%**			
Time Required (yr)		**30**			

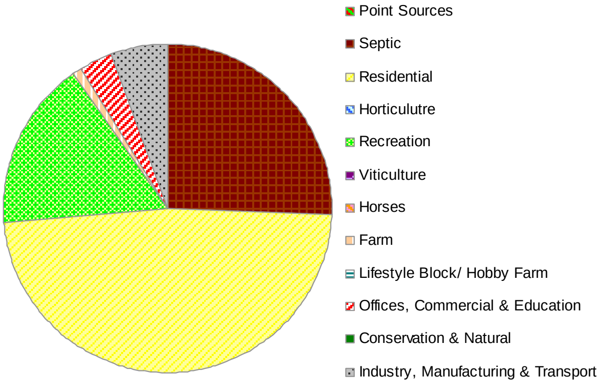
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616082		
	Current	36% Input Reduction		Current	36% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	10.9	3.6	*1997*	10.7	3.5
1998	10.0	3.9	*1998*	9.9	3.8
1999	12.5	4.8	*1999*	12.3	4.6
2000	12.1	4.7	*2000*	11.9	4.5
2001	8.8	3.6	*2001*	8.6	3.4
2002	9.4	4.0	*2002*	9.2	3.8
2003	10.7	4.7	*2003*	10.4	4.6
2004	7.5	3.5	*2004*	7.3	3.3
2005	11.0	5.3	*2005*	10.6	5.1
2006	5.0	2.5	*2006*	4.9	2.4
Average	**9.8**	**4.0**	**Average**	**9.6**	**3.9**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.22**	**0.50**	**SQUARE:**	**1.23**	**0.50**
Target:	**0.50**		**Observed:**	**1.20**	
Load Target (t/yr)		**4.0**			
Load Reduction Target (t/yr)		**5.8**			
Required Reduction (%)		**59%**			
Time Required (yr)		**30**			

Bayswater Main Drain – Source separation

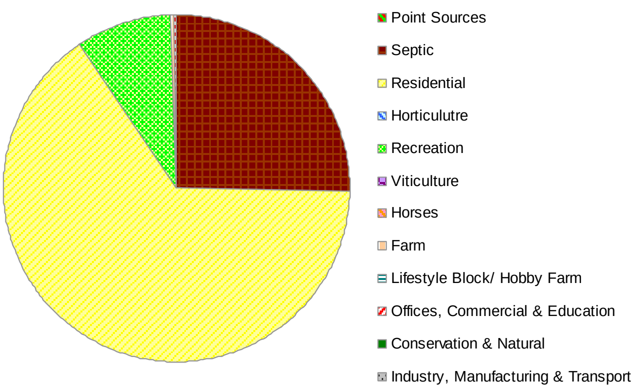
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.61	0.01	0.18	0.28	0.01	0.11	0.01	0.01	0.01	0.01	0.02	0.01	0.04
1998	0.63	0.00	0.18	0.30	0.00	0.10	0.00	0.00	0.01	0.00	0.02	0.00	0.04
1999	0.63	0.00	0.18	0.29	0.00	0.11	0.00	0.00	0.01	0.00	0.02	0.00	0.04
2000	0.63	0.00	0.17	0.29	0.00	0.11	0.00	0.00	0.01	0.00	0.02	0.00	0.04
2001	0.53	0.00	0.14	0.25	0.00	0.09	0.00	0.00	0.01	0.00	0.02	0.00	0.03
2002	0.65	0.00	0.17	0.31	0.00	0.11	0.00	0.00	0.01	0.00	0.02	0.00	0.04
2003	0.65	0.00	0.16	0.32	0.00	0.11	0.00	0.00	0.01	0.00	0.03	0.00	0.04
2004	0.54	0.00	0.13	0.27	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.03
2005	0.68	0.00	0.15	0.35	0.00	0.12	0.00	0.00	0.01	0.00	0.03	0.00	0.04
2006	0.44	0.00	0.09	0.23	0.00	0.08	0.00	0.00	0.00	0.00	0.02	0.00	0.03
Load (non adj)	0.60	0.00	0.16	0.29	0.00	0.10	0.00	0.00	0.01	0.00	0.02	0.00	0.04
Load (t/yr)	**0.60**	**0.00**	**0.15**	**0.29**	**0.00**	**0.10**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.00**	**0.03**
Load (%)	**100.0%**	**0.0%**	**25.6%**	**47.9%**	**0.0%**	**16.9%**	**0.0%**	**0.0%**	**0.7%**	**0.0%**	**3.4%**	**0.0%**	**5.5%**

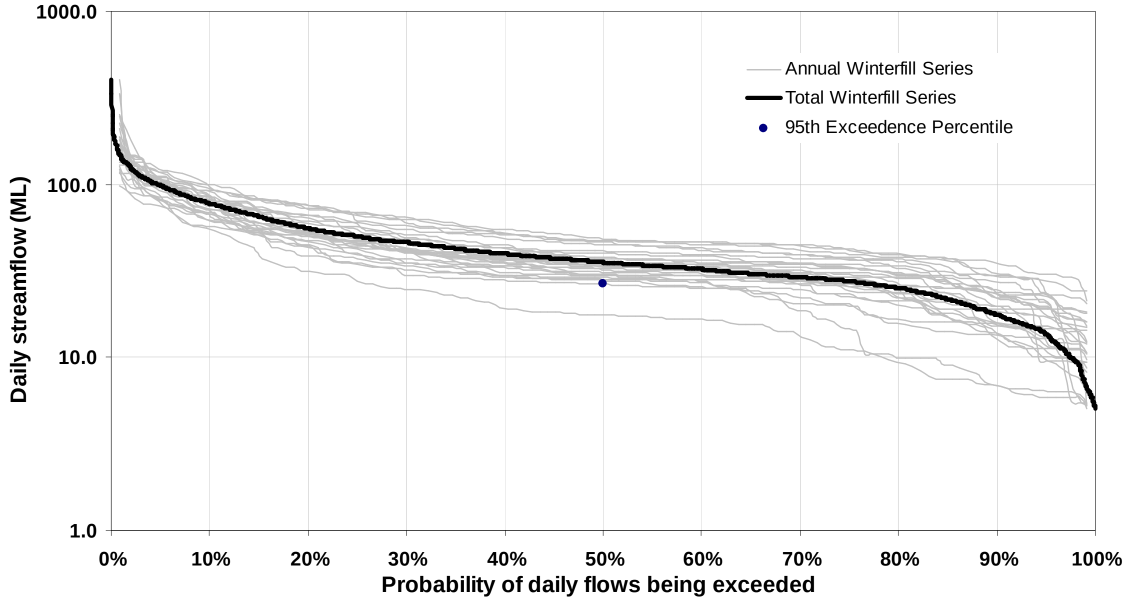


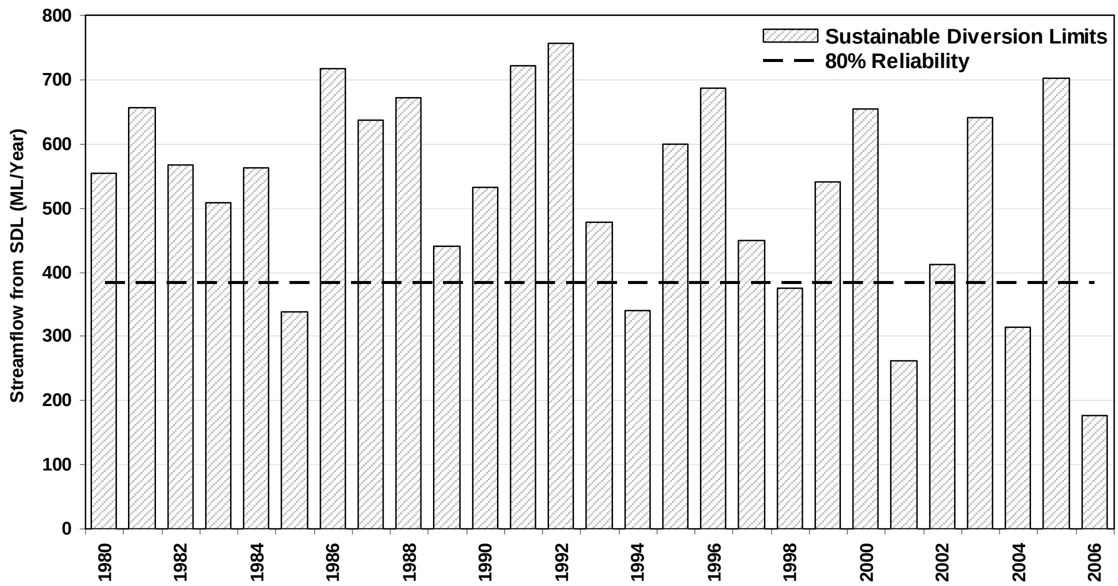
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	10.9	0.0	2.1	3.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	10.0	0.0	2.0	2.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	12.5	0.0	2.5	3.7	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	12.1	0.0	2.2	3.7	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	8.8	0.0	1.2	2.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	9.4	0.0	1.0	3.3	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	10.7	0.0	0.8	4.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	7.5	0.0	0.4	2.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	11.0	0.0	0.5	4.5	0.0	0.7	0.0	0.0	0.0	0.0	0.1	0.0	0.0
2006	5.0	0.0	0.2	2.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (non adj)	9.8	0.0	1.3	3.3	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (t/yr)	**9.8**	**0.0**	**2.5**	**6.4**	**0.0**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**25.1%**	**65.3%**	**0.0%**	**8.9%**	**0.0%**	**0.0%**	**0.1%**	**0.0%**	**0.3%**	**0.0%**	**0.1%**



Bayswater Main Drain – Sustainable diversion limits

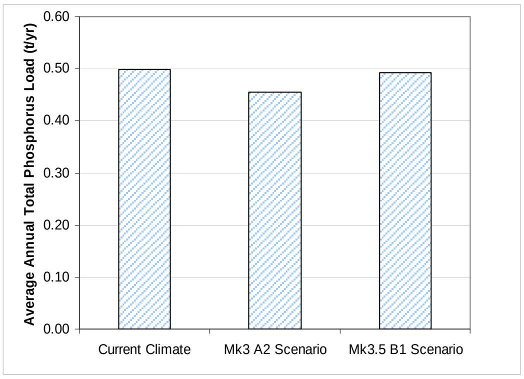




Bayswater Main Drain – Climate change

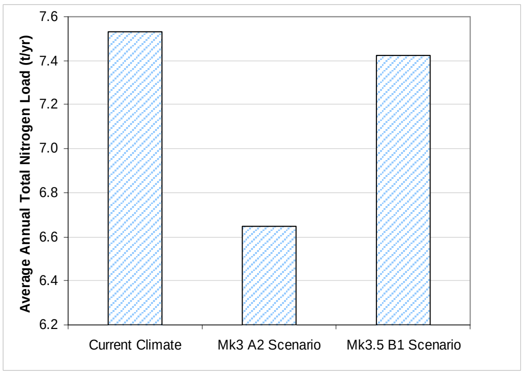
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.47	0.42	0.46
2058	0.51	0.47	0.51
2059	0.52	0.47	0.51
2060	0.52	0.48	0.51
2061	0.44	0.40	0.43
2062	0.54	0.49	0.53
2063	0.55	0.50	0.54
2064	0.46	0.42	0.46
2065	0.60	0.54	0.59
2066	0.38	0.36	0.38
Average Load for RF Sequence (t/yr)	**0.50**	**0.46**	**0.49**



Nitrogen

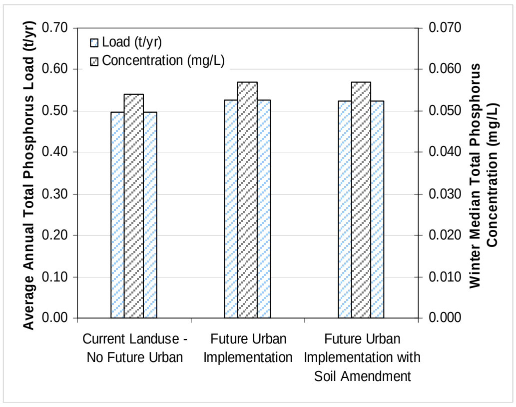
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	6.7	5.9	6.6
2058	7.3	6.4	7.2
2059	8.9	7.9	8.7
2060	8.7	7.9	8.5
2061	6.7	5.9	6.6
2062	7.4	6.5	7.3
2063	8.8	7.7	8.7
2064	6.5	5.7	6.4
2065	9.8	8.4	9.6
2066	4.6	4.2	4.5
Average Load for RF Sequence (t/yr)	**7.5**	**6.6**	**7.4**



Bayswater Main Drain – Future urban

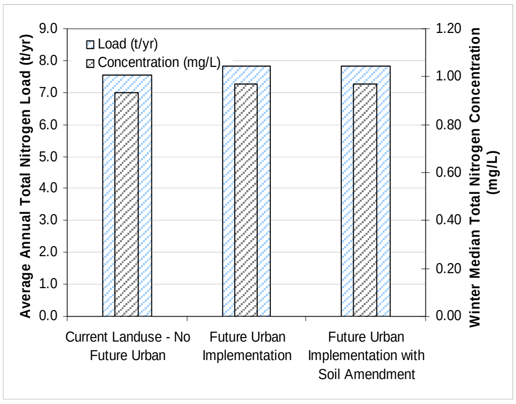
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.47	0.49	0.49
2058	0.51	0.54	0.54
2059	0.52	0.55	0.54
2060	0.52	0.55	0.54
2061	0.44	0.46	0.46
2062	0.54	0.57	0.56
2063	0.55	0.58	0.58
2064	0.46	0.49	0.49
2065	0.60	0.63	0.63
2066	0.38	0.40	0.40
Average Load for RF Sequence (t/yr)	**0.50**	**0.53**	**0.52**
Median Winter Concentration (mg/L)	**0.054**	**0.057**	**0.057**



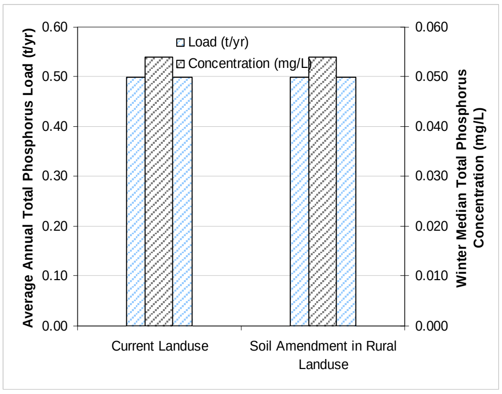
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	6.7	7.0	7.0
2058	7.3	7.6	7.6
2059	8.9	9.2	9.2
2060	8.7	9.0	9.0
2061	6.7	6.9	6.9
2062	7.4	7.7	7.7
2063	8.8	9.2	9.2
2064	6.5	6.7	6.7
2065	9.8	10.2	10.2
2066	4.6	4.8	4.8
Average Load for RF Sequence (t/yr)	**7.5**	**7.8**	**7.8**
Median Winter Concentration (mg/L)	**0.93**	**0.97**	**0.97**



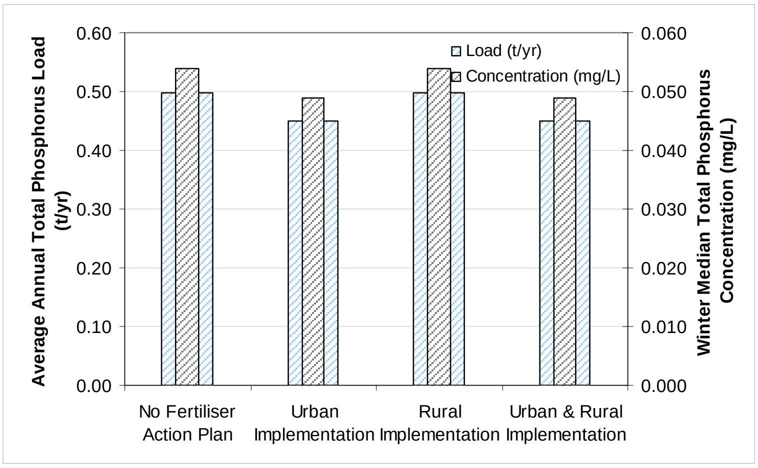
Bayswater Main Drain – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.47	0.47
2058	0.51	0.51
2059	0.52	0.52
2060	0.52	0.52
2061	0.44	0.44
2062	0.54	0.54
2063	0.55	0.55
2064	0.46	0.46
2065	0.60	0.60
2066	0.38	0.38
Average Load for RF Sequence (t/yr)	**0.50**	**0.50**
Median Winter Concentration (mg/L)	**0.054**	**0.054**



Bayswater Main Drain – *Fertiliser action plan*

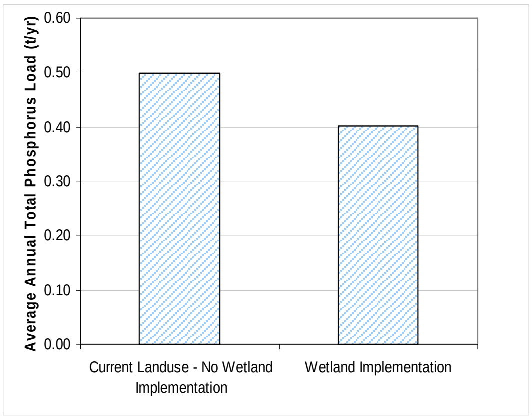
Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.47	0.42	0.47	0.42
2058	0.51	0.47	0.51	0.47
2059	0.52	0.47	0.52	0.47
2060	0.52	0.47	0.52	0.47
2061	0.44	0.39	0.44	0.39
2062	0.54	0.49	0.54	0.49
2063	0.55	0.50	0.55	0.50
2064	0.46	0.42	0.46	0.42
2065	0.60	0.54	0.60	0.54
2066	0.38	0.35	0.38	0.35
Average Load for RF Sequence (t/yr)	**0.50**	**0.45**	**0.50**	**0.45**
Median Winter Concentration (mg/L)	**0.054**	**0.049**	**0.054**	**0.049**



Bayswater Main Drain – Wetland implementation

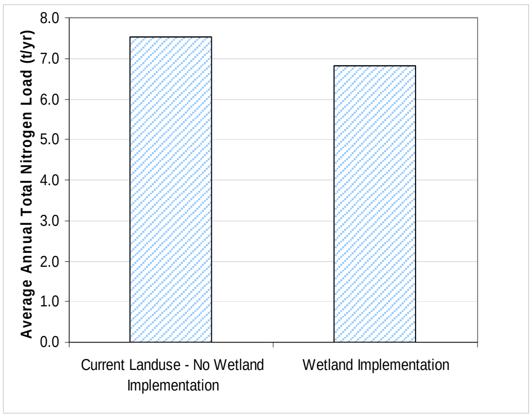
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	0.47	0.37
2058	0.51	0.42
2059	0.52	0.42
2060	0.52	0.43
2061	0.44	0.35
2062	0.54	0.43
2063	0.55	0.44
2064	0.46	0.38
2065	0.60	0.49
2066	0.38	0.30
Average Load for RF Sequence (t/yr)	**0.50**	**0.40**



Nitrogen

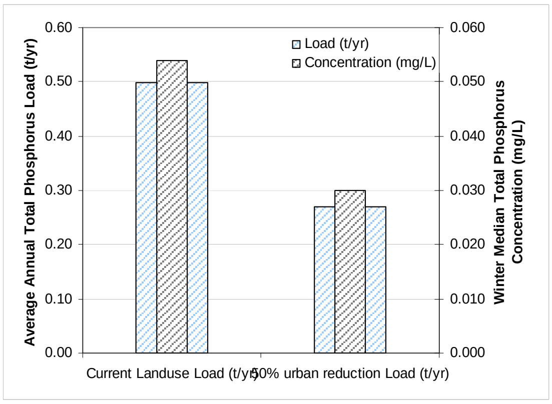
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	6.7	6.1
2058	7.3	6.6
2059	8.9	8.0
2060	8.7	7.8
2061	6.7	6.1
2062	7.4	6.7
2063	8.8	8.0
2064	6.5	5.9
2065	9.8	9.0
2066	4.6	4.1
Average Load for RF Sequence (t/yr)	**7.5**	**6.8**



Bayswater Main Drain – Urban 50% reduction

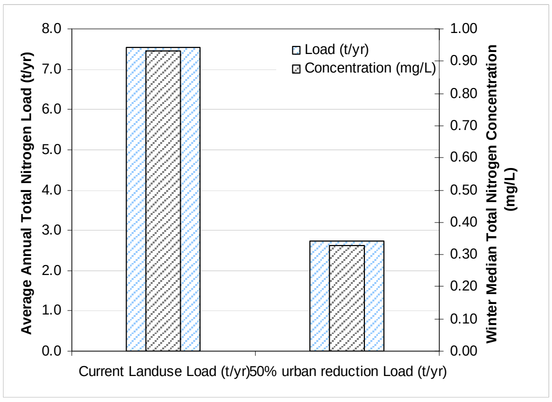
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.47	0.25
2058	0.51	0.28
2059	0.52	0.28
2060	0.52	0.28
2061	0.44	0.24
2062	0.54	0.29
2063	0.55	0.30
2064	0.46	0.25
2065	0.60	0.32
2066	0.38	0.21
Average Load for RF Sequence (t/yr)	**0.50**	**0.27**
Median Winter Concentration (mg/L)	**0.054**	**0.030**

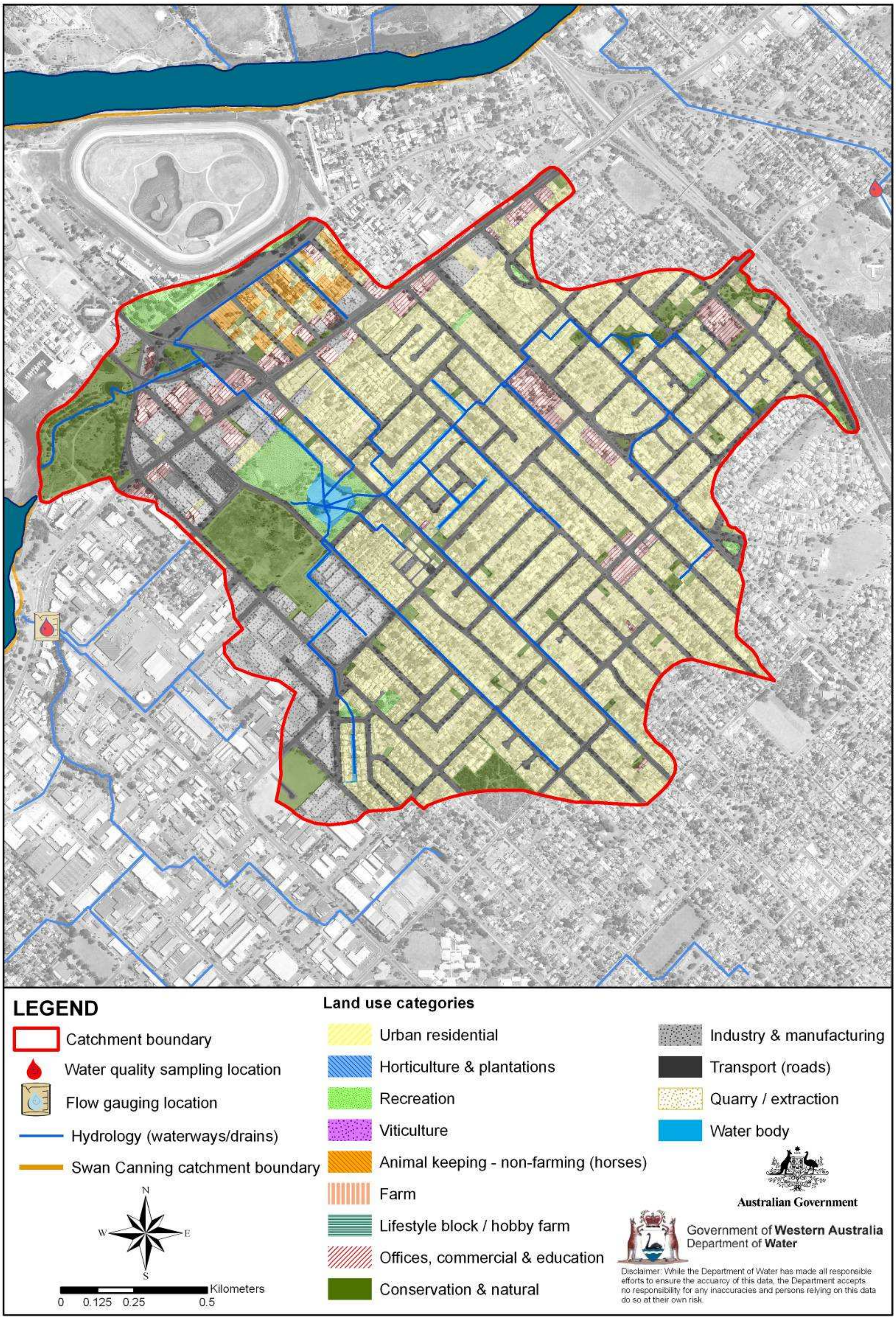


Nitrogen

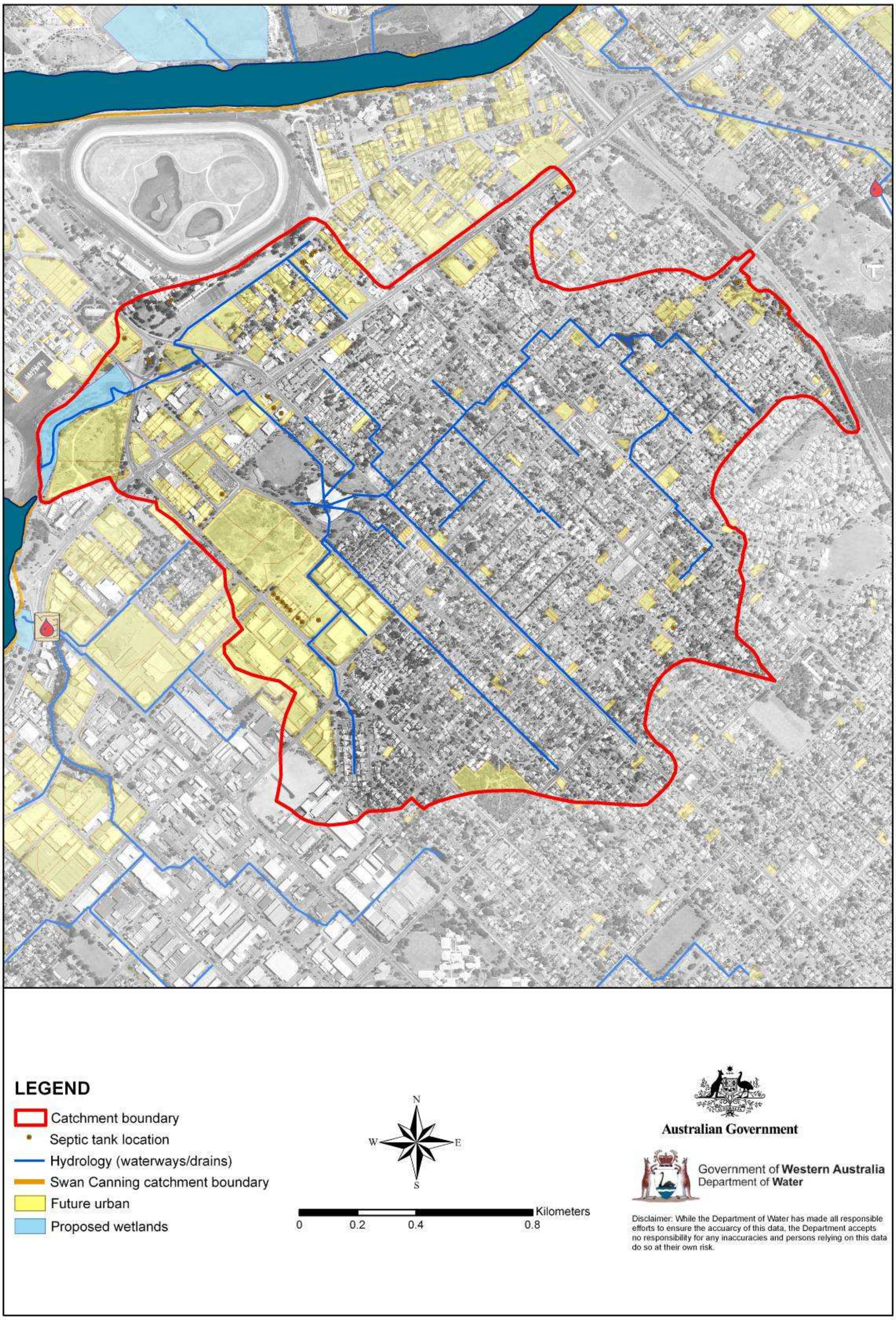
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	6.7	2.4
2058	7.3	2.6
2059	8.9	3.2
2060	8.7	3.1
2061	6.7	2.4
2062	7.4	2.7
2063	8.8	3.2
2064	6.5	2.3
2065	9.8	3.6
2066	4.6	1.6
Average Load for RF Sequence (t/yr)	**7.5**	**2.7**
Median Winter Concentration (mg/L)	**0.93**	**0.33**



Belmont Central
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Belmont Central - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Sampling Location 6160067		
	Current	31% Input Reduction		Current	31% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.06	0.04	*1997*	0.05	0.04
1998	0.06	0.04	*1998*	0.05	0.04
1999	0.06	0.05	*1999*	0.06	0.04
2000	0.06	0.05	*2000*	0.06	0.04
2001	0.05	0.04	*2001*	0.05	0.03
2002	0.06	0.04	*2002*	0.05	0.04
2003	0.07	0.05	*2003*	0.06	0.04
2004	0.06	0.04	*2004*	0.05	0.04
2005	0.06	0.05	*2005*	0.06	0.04
2006	0.05	0.04	*2006*	0.05	0.03
Average	**0.06**	**0.04**	**Average**	**0.06**	**0.04**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.064**	**0.049**	**SQUARE:**	**0.075**	**0.050**
Target:	**0.050**		**Observed:**	**0.075**	
Load Target (t/yr)		**0.04**			
Load Reduction Target (t/yr)		**0.02**			
Required Reduction (%)		**27%**			
Time Required (yr)		**40**			

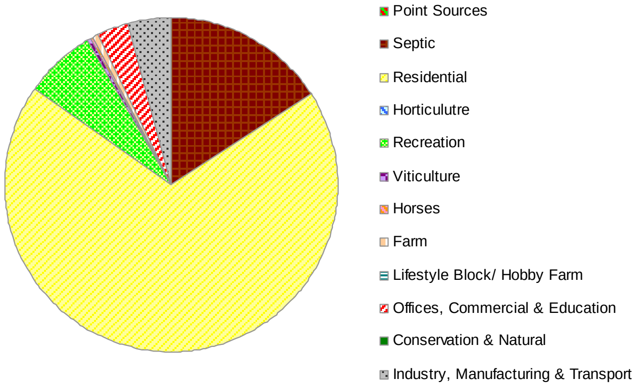
Nitrogen

At Outlet to Swan River Estuary			At Sampling Location 6160067		
	Current	41% Input Reduction		Current	41% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.7	0.3	*1997*	0.6	0.3
1998	0.8	0.4	*1998*	0.7	0.3
1999	0.8	0.4	*1999*	0.7	0.3
2000	0.8	0.3	*2000*	0.7	0.3
2001	0.6	0.3	*2001*	0.6	0.2
2002	0.7	0.3	*2002*	0.6	0.3
2003	0.8	0.4	*2003*	0.7	0.3
2004	0.6	0.3	*2004*	0.5	0.3
2005	0.7	0.4	*2005*	0.6	0.3
2006	0.5	0.3	*2006*	0.4	0.2
Average	**0.7**	**0.3**	**Average**	**0.6**	**0.3**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.92**	**0.48**	**SQUARE:**	**1.00**	**0.50**
Target:	**0.50**		**Observed:**	**1.00**	
Load Target (t/yr)		**0.3**			
Load Reduction Target (t/yr)		**0.4**			
Required Reduction (%)		**52%**			
Time Required (yr)		**40**			

Belmont Central – Source separation

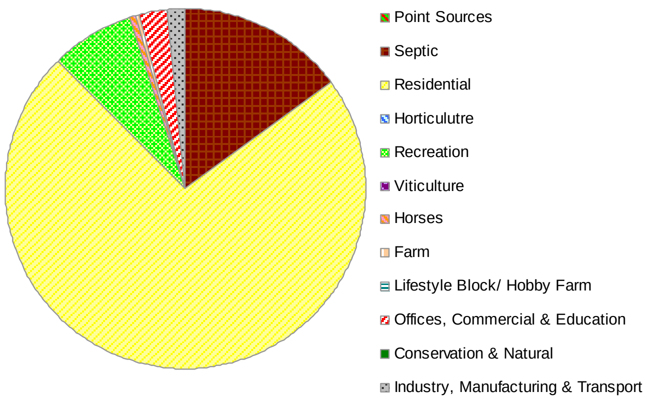
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.06	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.06	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.06	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.06	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.05	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.06	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.07	0.00	0.01	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.06	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.06	0.00	0.01	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	0.05	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Load (non adj)	0.06	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Load (t/yr)	**0.06**	**0.00**	**0.01**	**0.04**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**0.0%**	**15.9%**	**68.8%**	**0.1%**	**7.0%**	**0.1%**	**0.5%**	**0.5%**	**0.1%**	**2.9%**	**0.1%**	**4.2%**

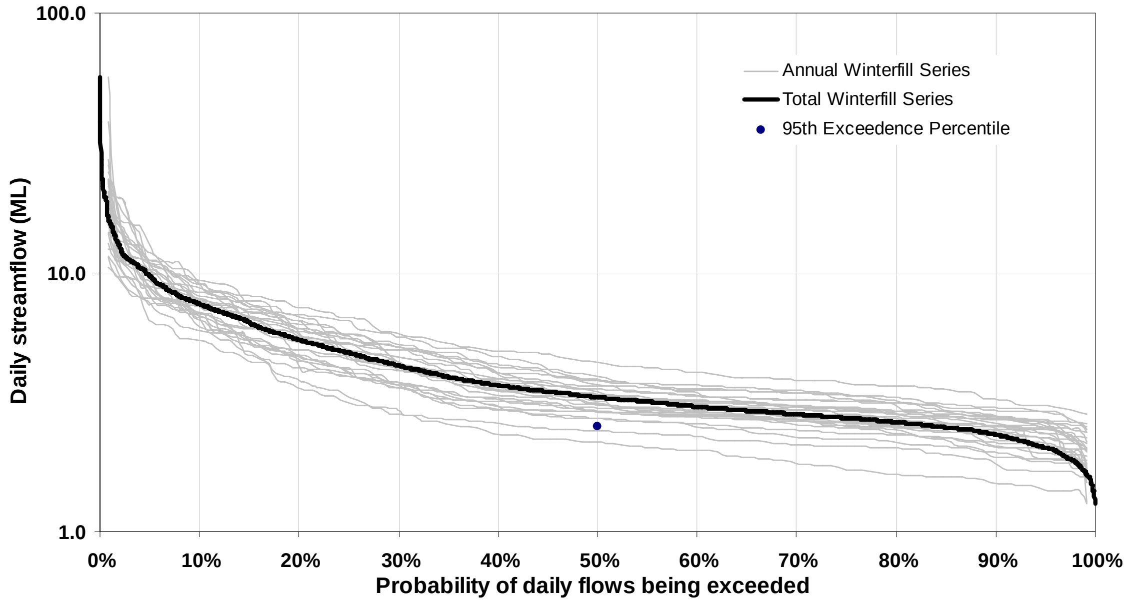


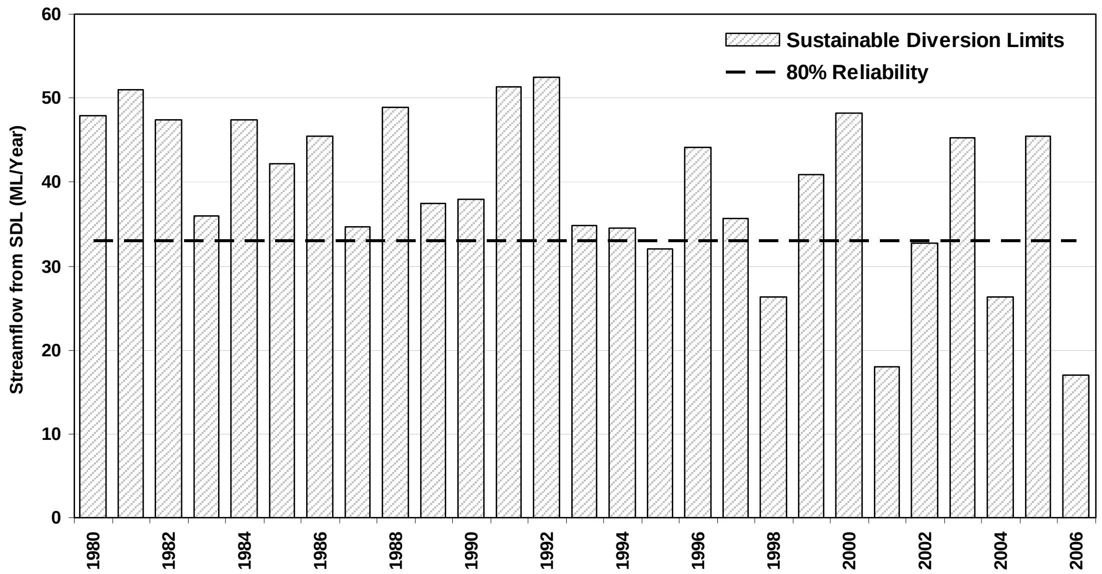
Nitrogen (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.7	0.2	0.3	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1998	0.8	0.2	0.3	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1999	0.8	0.2	0.3	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2000	0.8	0.1	0.2	0.6	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2001	0.6	0.1	0.2	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2002	0.7	0.1	0.2	0.5	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2003	0.8	0.1	0.2	0.6	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2004	0.6	0.1	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2005	0.7	0.1	0.2	0.6	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2006	0.5	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Load (non adj)	0.7	0.1	0.2	0.5	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Load (t/yr)	**0.7**	**0.0**	**0.1**	**0.5**	**0.0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**14.9%**	**72.0%**	**0.0%**	**7.4%**	**0.0%**	**0.6%**	**0.4%**	**0.0%**	**2.4%**	**0.0%**	**1.6%**



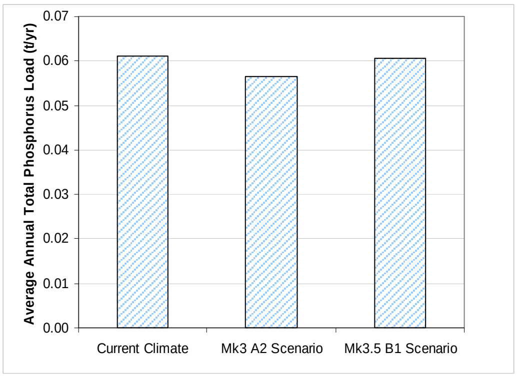
Belmont Central – Sustainable diversion limits



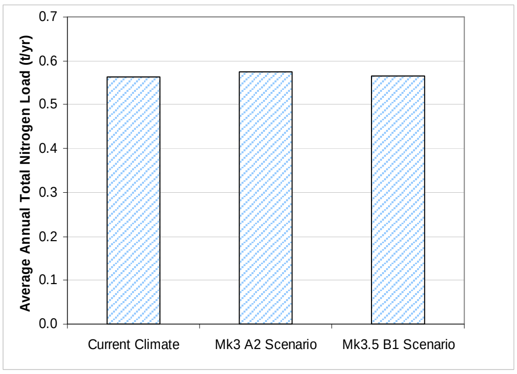


Belmont Central – Climate change

Phosphorus			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.06	0.05	0.06
2058	0.06	0.06	0.06
2059	0.07	0.06	0.07
2060	0.07	0.06	0.07
2061	0.05	0.05	0.05
2062	0.06	0.06	0.06
2063	0.07	0.06	0.07
2064	0.06	0.05	0.06
2065	0.07	0.06	0.07
2066	0.05	0.05	0.05
Average Load for RF Sequence (t/yr)	**0.06**	**0.06**	**0.06**

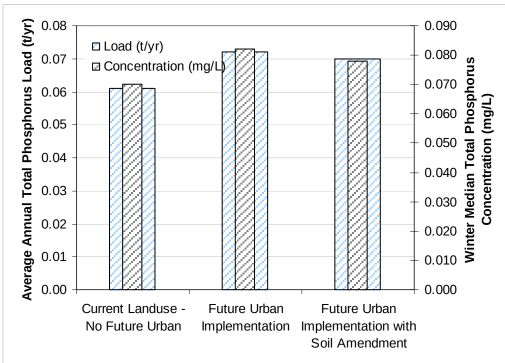


Nitrogen			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.6	0.6	0.6
2058	0.6	0.6	0.6
2059	0.6	0.7	0.6
2060	0.6	0.6	0.6
2061	0.5	0.5	0.5
2062	0.6	0.6	0.6
2063	0.6	0.6	0.6
2064	0.5	0.5	0.5
2065	0.6	0.6	0.6
2066	0.4	0.4	0.4
Average Load for RF Sequence (t/yr)	**0.6**	**0.6**	**0.6**

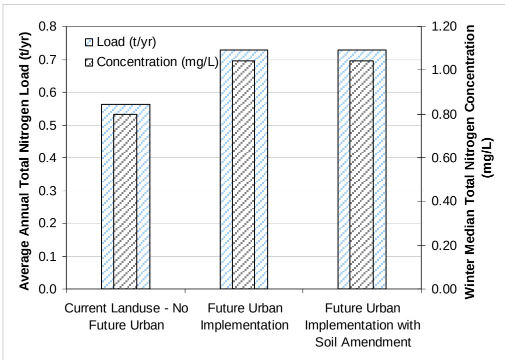


Belmont Central – Future urban

Phosphorus			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.06	0.07	0.06
2058	0.06	0.07	0.07
2059	0.07	0.08	0.08
2060	0.07	0.08	0.08
2061	0.05	0.06	0.06
2062	0.06	0.07	0.07
2063	0.07	0.08	0.08
2064	0.06	0.07	0.07
2065	0.07	0.08	0.08
2066	0.05	0.06	0.06
Average Load for RF Sequence (t/yr)	**0.06**	**0.07**	**0.07**
Median Winter Concentration (mg/L)	**0.070**	**0.082**	**0.078**

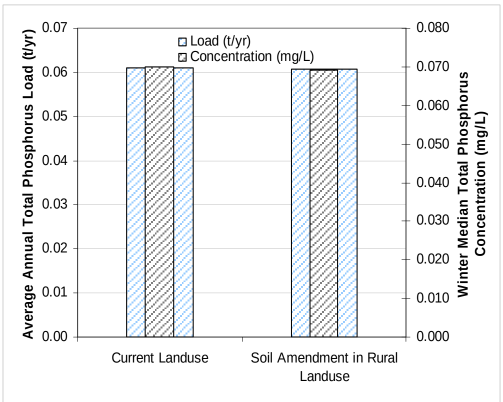


Nitrogen			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	
2057	0.6	0.7	0.7
2058	0.6	0.8	0.8
2059	0.6	0.8	0.8
2060	0.6	0.8	0.8
2061	0.5	0.6	0.6
2062	0.6	0.7	0.7
2063	0.6	0.8	0.8
2064	0.5	0.7	0.7
2065	0.6	0.8	0.8
2066	0.4	0.5	0.5
Average Load for RF Sequence (t/yr)	**0.6**	**0.7**	**0.7**
Median Winter Concentration (mg/L)	**0.80**	**1.04**	**1.04**



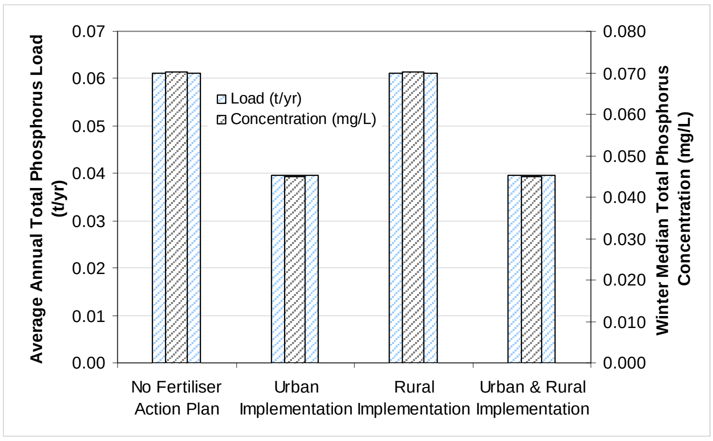
Belmont Central – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.06	0.06
2058	0.06	0.06
2059	0.07	0.07
2060	0.07	0.07
2061	0.05	0.05
2062	0.06	0.06
2063	0.07	0.07
2064	0.06	0.06
2065	0.07	0.07
2066	0.05	0.05
Average Load for RF Sequence (t/yr)	**0.06**	**0.06**
Median Winter Concentration (mg/L)	**0.070**	**0.069**



Belmont Central – *Fertiliser action plan*

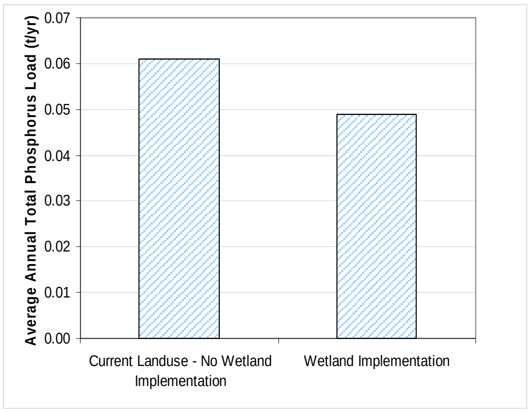
Phosphorus				
		At Catchment Outlet		
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.06	0.04	0.06	0.04
2058	0.06	0.04	0.06	0.04
2059	0.07	0.04	0.07	0.04
2060	0.07	0.04	0.07	0.04
2061	0.05	0.03	0.05	0.03
2062	0.06	0.04	0.06	0.04
2063	0.07	0.04	0.07	0.04
2064	0.06	0.04	0.06	0.04
2065	0.07	0.04	0.07	0.04
2066	0.05	0.03	0.05	0.03
Average Load for RF Sequence (t/yr)	**0.06**	**0.04**	**0.06**	**0.04**
Median Winter Concentration (mg/L)	**0.070**	**0.045**	**0.070**	**0.045**



Belmont Central – Wetland implementation

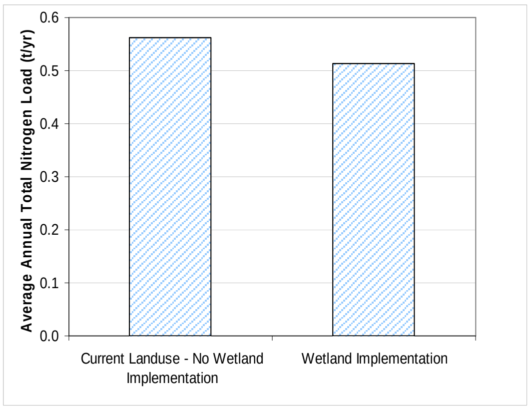
Phosphorus

	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.06	0.05
2058	0.06	0.05
2059	0.07	0.05
2060	0.07	0.05
2061	0.05	0.04
2062	0.06	0.05
2063	0.07	0.05
2064	0.06	0.05
2065	0.07	0.05
2066	0.05	0.04
Average Load for RF Sequence (t/yr)	**0.06**	**0.05**



Nitrogen

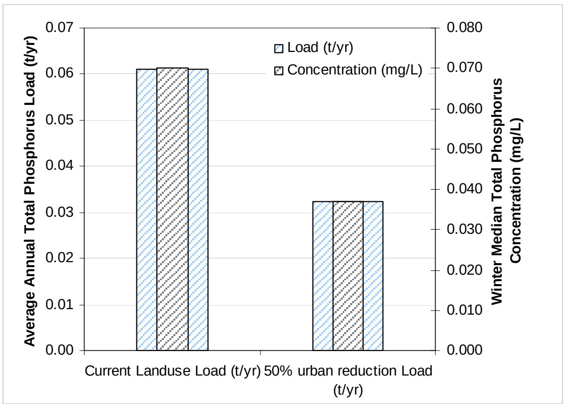
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.6	0.5
2058	0.6	0.6
2059	0.6	0.6
2060	0.6	0.5
2061	0.5	0.5
2062	0.6	0.5
2063	0.6	0.6
2064	0.5	0.5
2065	0.6	0.5
2066	0.4	0.4
Average Load for RF Sequence (t/yr)	**0.6**	**0.5**



Belmont Central – Urban 50% reduction

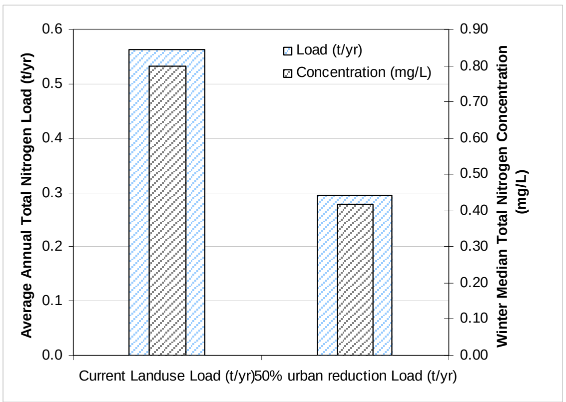
Phosphorus

	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.06	0.03
2058	0.06	0.03
2059	0.07	0.04
2060	0.07	0.04
2061	0.05	0.03
2062	0.06	0.03
2063	0.07	0.04
2064	0.06	0.03
2065	0.07	0.03
2066	0.05	0.03
Average Load for RF Sequence (t/yr)	**0.06**	**0.03**
Median Winter Concentration (mg/L)	**0.070**	**0.037**

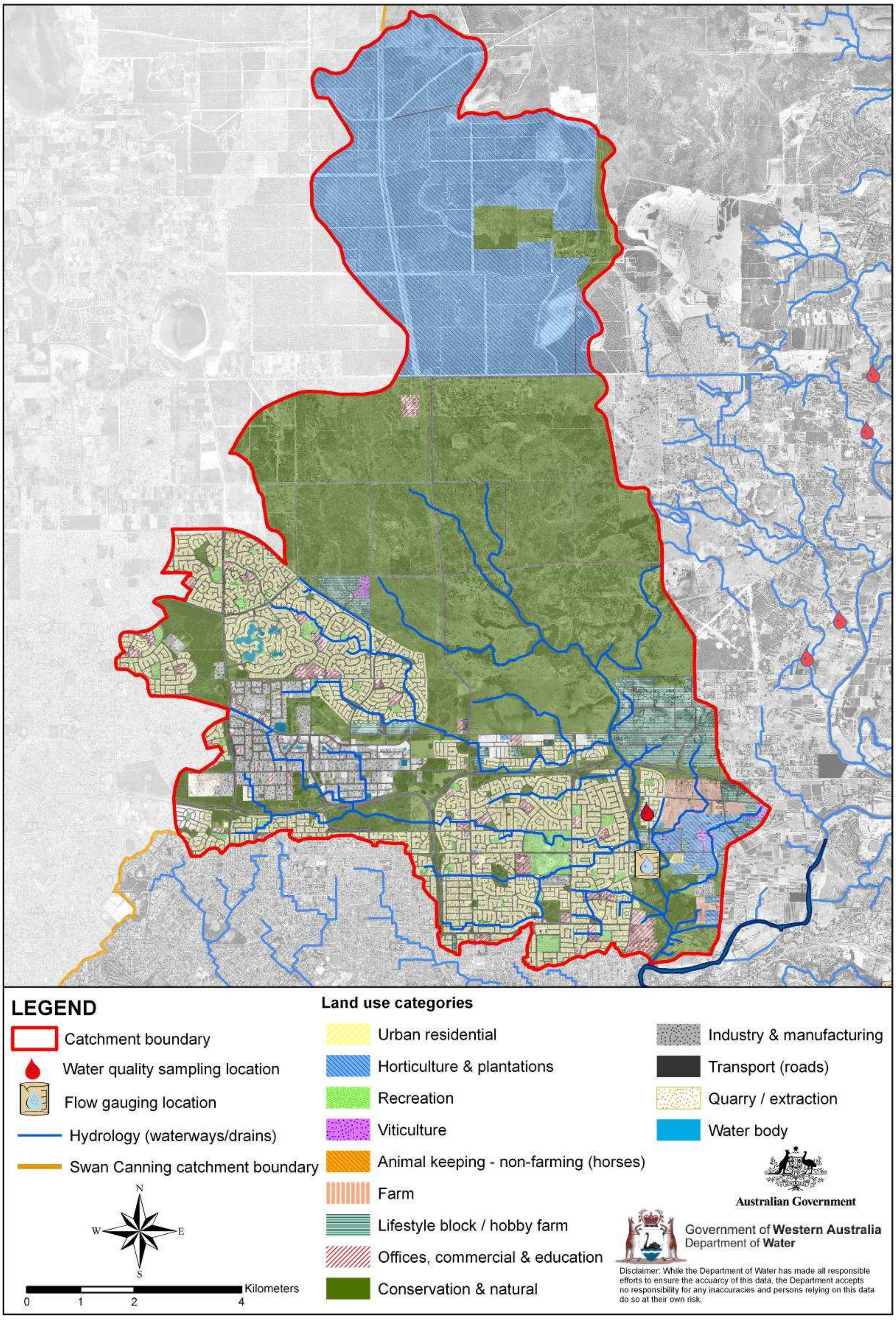


Nitrogen

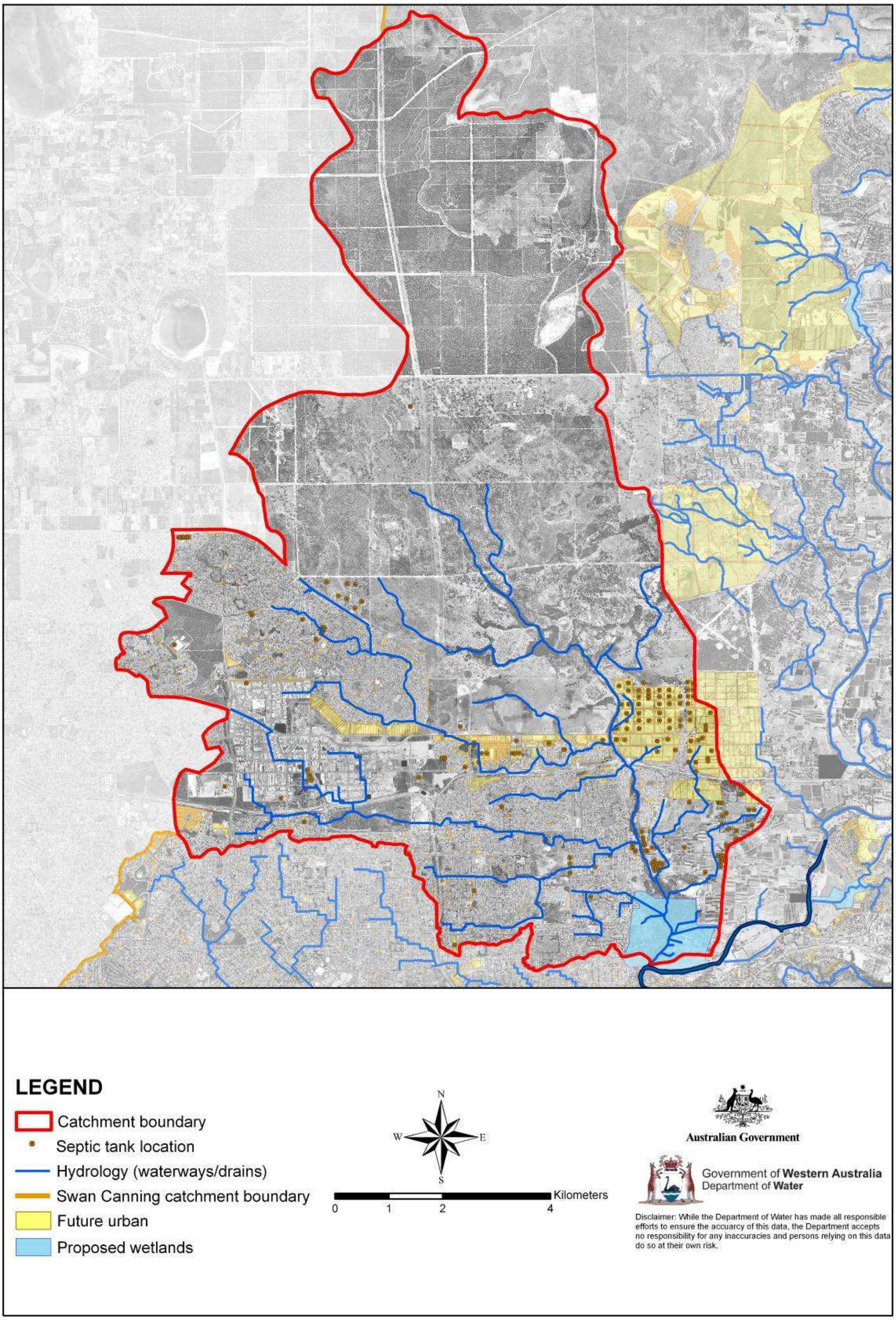
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.6	0.3
2058	0.6	0.3
2059	0.6	0.3
2060	0.6	0.3
2061	0.5	0.3
2062	0.6	0.3
2063	0.6	0.3
2064	0.5	0.3
2065	0.6	0.3
2066	0.4	0.2
Average Load for RF Sequence (t/yr)	**0.6**	**0.3**
Median Winter Concentration (mg/L)	**0.80**	**0.42**



Bennett Brook
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Bennett Brook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616084		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.35	-	*1997*	0.24	-
1998	0.38	-	*1998*	0.26	-
1999	0.41	-	*1999*	0.29	-
2000	0.43	-	*2000*	0.31	-
2001	0.37	-	*2001*	0.27	-
2002	0.43	-	*2002*	0.30	-
2003	0.49	-	*2003*	0.34	-
2004	0.42	-	*2004*	0.29	-
2005	0.53	-	*2005*	0.38	-
2006	0.37	-	*2006*	0.26	-
Average	**0.42**	**-**	**Average**	**0.29**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.05**		**SQUARE:**	**0.04**	**0.04**
Target:	**0.10**		**Observed:**	**0.05**	
Load Target (t/yr)		**0.42**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**-**			

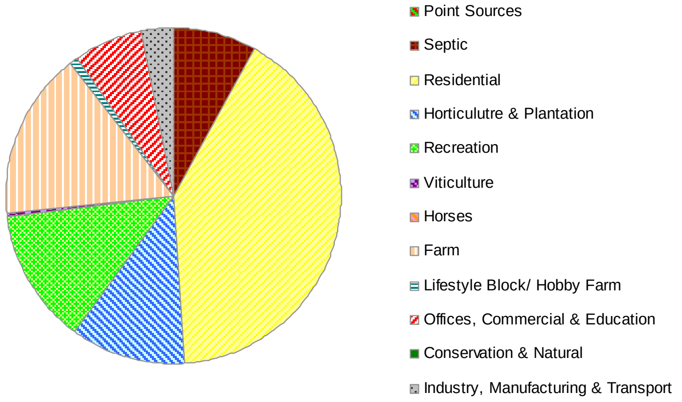
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616084		
	Current	16% Input Reduction		Current	16% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	6.8	4.4	*1997*	4.6	3.0
1998	7.1	4.7	*1998*	5.0	3.3
1999	8.3	5.5	*1999*	5.7	3.7
2000	8.0	5.4	*2000*	5.5	3.6
2001	6.8	4.6	*2001*	4.9	3.2
2002	6.9	4.6	*2002*	4.9	3.1
2003	8.0	5.5	*2003*	5.6	3.6
2004	6.2	4.4	*2004*	4.4	3.0
2005	8.1	5.9	*2005*	5.5	3.8
2006	4.9	3.5	*2006*	3.5	2.5
Average	**7.1**	**4.8**	**Average**	**5.0**	**3.3**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.46**	**1.00**	**SQUARE:**	**1.20**	**0.79**
Target:	**1.00**		**Observed:**	**1.20**	
Load Target (t/yr)		**4.8**			
Load Reduction Target (t/yr)		**2.3**			
Required Reduction (%)		**32%**			
Time Required (yr)		**30**			

Bennett Brook – Source separation

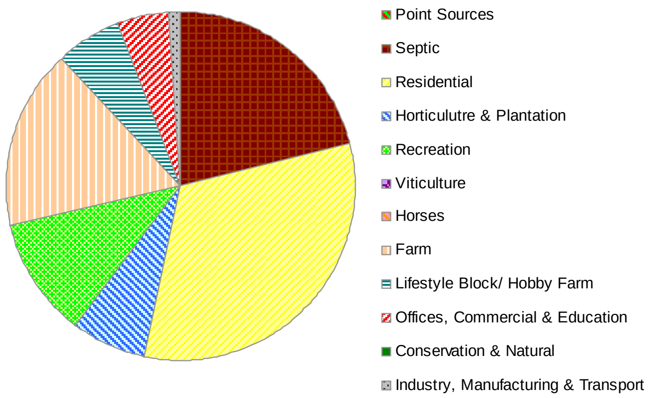
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre & Plantation	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.35	0.02	0.05	0.14	0.06	0.07	0.02	0.02	0.09	0.03	0.04	0.02	0.03
1998	0.38	0.03	0.06	0.16	0.07	0.07	0.03	0.03	0.09	0.03	0.05	0.03	0.04
1999	0.41	0.03	0.07	0.17	0.07	0.08	0.03	0.03	0.10	0.04	0.06	0.03	0.04
2000	0.43	0.05	0.09	0.20	0.10	0.10	0.06	0.05	0.12	0.06	0.08	0.05	0.07
2001	0.37	0.03	0.06	0.17	0.07	0.08	0.03	0.03	0.09	0.04	0.06	0.03	0.04
2002	0.43	0.02	0.05	0.19	0.06	0.07	0.02	0.02	0.08	0.02	0.05	0.02	0.03
2003	0.49	0.04	0.07	0.23	0.09	0.09	0.04	0.04	0.10	0.04	0.07	0.04	0.05
2004	0.42	0.02	0.05	0.19	0.06	0.07	0.02	0.02	0.07	0.02	0.04	0.02	0.03
2005	0.53	0.05	0.09	0.26	0.11	0.11	0.05	0.05	0.12	0.06	0.08	0.05	0.07
2006	0.37	0.01	0.03	0.18	0.05	0.06	0.01	0.01	0.06	0.01	0.03	0.01	0.02
Load (non adj)	0.42	0.03	0.06	0.19	0.07	0.08	0.03	0.03	0.09	0.03	0.06	0.03	0.04
Load (t/yr)	**0.42**	**0.00**	**0.03**	**0.17**	**0.05**	**0.05**	**0.00**	**0.00**	**0.07**	**0.00**	**0.03**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**8.1%**	**40.9%**	**11.0%**	**13.2%**	**0.2%**	**0.0%**	**16.1%**	**0.9%**	**6.4%**	**0.0%**	**3.2%**



Nitrogen (t/yr)

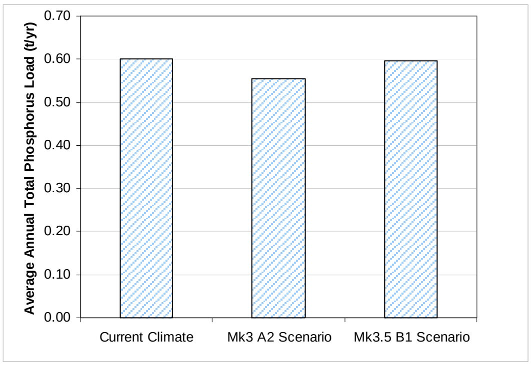
Year	Current	Point Sources	Septic	Residential	Horticulutre & Plantation	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	6.8	0.8	2.2	2.1	1.2	1.4	0.8	0.8	2.2	1.2	1.0	0.8	0.8
1998	7.1	0.8	2.3	2.4	1.2	1.5	0.8	0.8	2.2	1.2	1.1	0.8	0.9
1999	8.3	0.8	2.5	2.8	1.3	1.6	0.8	0.8	2.4	1.3	1.2	0.8	0.9
2000	8.0	0.8	2.4	2.8	1.3	1.5	0.8	0.8	2.2	1.3	1.1	0.8	0.9
2001	6.8	0.7	2.1	2.6	1.1	1.4	0.7	0.7	1.7	1.0	1.0	0.7	0.7
2002	6.9	0.8	2.1	2.8	1.2	1.5	0.8	0.8	1.6	1.1	1.1	0.8	0.8
2003	8.0	0.9	2.3	3.3	1.4	1.6	0.9	0.9	1.8	1.3	1.2	0.9	0.9
2004	6.2	0.7	1.7	2.8	1.0	1.3	0.7	0.7	1.3	1.0	1.0	0.7	0.7
2005	8.1	0.8	2.0	3.6	1.5	1.6	0.8	0.8	1.6	1.4	1.2	0.8	0.9
2006	4.9	0.5	1.2	2.4	0.8	1.1	0.5	0.5	0.9	0.7	0.8	0.5	0.6
Load (non adj)	7.1	0.8	2.1	2.8	1.2	1.5	0.8	0.8	1.8	1.2	1.1	0.8	0.8
Load (t/yr)	**7.1**	**0.0**	**1.5**	**2.3**	**0.5**	**0.8**	**0.0**	**0.0**	**1.2**	**0.4**	**0.3**	**0.0**	**0.1**
Load (%)	**100.0%**	**0.0%**	**21.1%**	**32.1%**	**7.0%**	**11.1%**	**0.1%**	**0.0%**	**16.5%**	**6.3%**	**4.7%**	**0.0%**	**1.1%**



Bennett Brook – Climate change

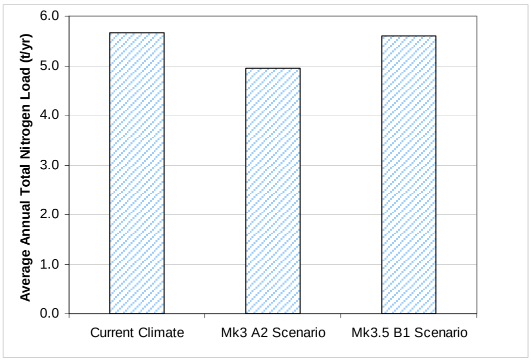
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.56	0.52	0.56
2058	0.60	0.55	0.59
2059	0.62	0.58	0.61
2060	0.63	0.58	0.62
2061	0.54	0.50	0.54
2062	0.62	0.57	0.61
2063	0.68	0.62	0.67
2064	0.58	0.54	0.57
2065	0.69	0.64	0.68
2066	0.50	0.46	0.50
Average Load for RF Sequence (t/yr)	**0.60**	**0.56**	**0.60**



Nitrogen

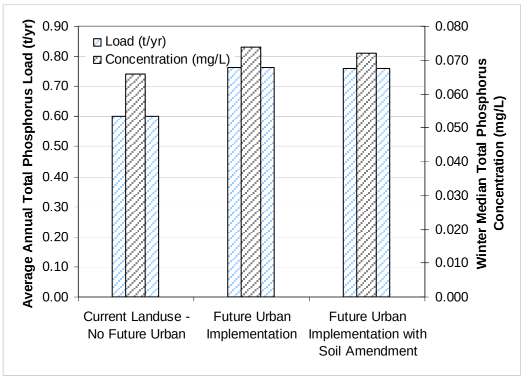
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	5.1	4.4	5.1
2058	5.5	4.7	5.4
2059	6.4	5.6	6.3
2060	6.3	5.8	6.2
2061	5.4	4.9	5.4
2062	5.3	4.5	5.3
2063	6.5	5.7	6.4
2064	5.1	4.4	5.1
2065	6.9	6.1	6.8
2066	4.1	3.4	4.0
Average Load for RF Sequence (t/yr)	**5.7**	**4.9**	**5.6**



Bennett Brook – Future urban

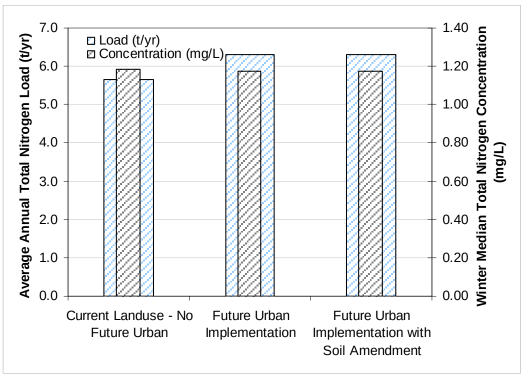
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.56	0.71	0.71
2058	0.60	0.76	0.75
2059	0.62	0.79	0.78
2060	0.63	0.79	0.79
2061	0.54	0.68	0.68
2062	0.62	0.79	0.79
2063	0.68	0.86	0.85
2064	0.58	0.74	0.73
2065	0.69	0.87	0.87
2066	0.50	0.65	0.65
Average Load for RF Sequence (t/yr)	**0.60**	**0.76**	**0.76**
Median Winter Concentration (mg/L)	**0.066**	**0.074**	**0.072**



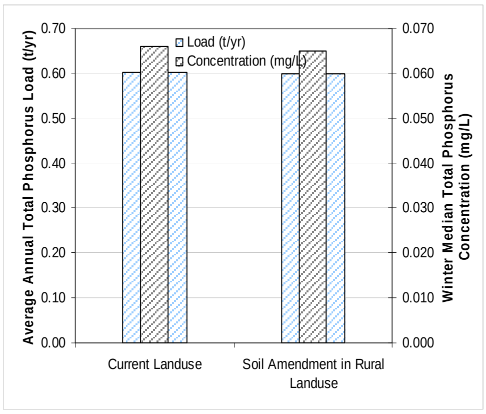
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	5.1	5.8	5.8
2058	5.5	6.2	6.2
2059	6.4	7.1	7.1
2060	6.3	6.8	6.8
2061	5.4	6.0	6.0
2062	5.3	6.1	6.1
2063	6.5	7.1	7.1
2064	5.1	5.8	5.8
2065	6.9	7.4	7.4
2066	4.1	4.7	4.7
Average Load for RF Sequence (t/yr)	**5.7**	**6.3**	**6.3**
Median Winter Concentration (mg/L)	**1.18**	**1.18**	**1.18**



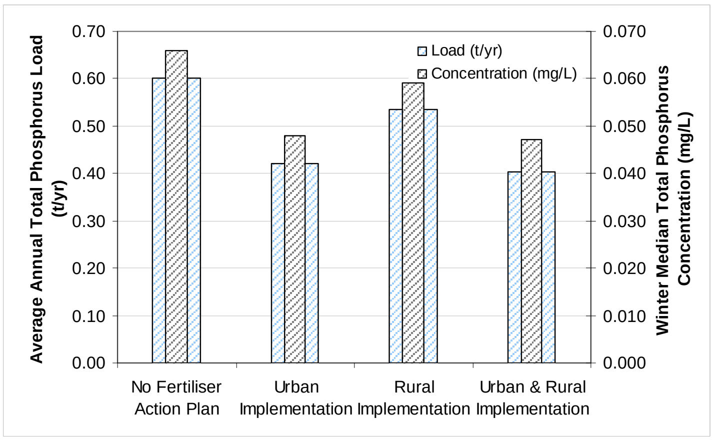
Bennett Brook – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.56	0.56
2058	0.60	0.60
2059	0.62	0.62
2060	0.63	0.63
2061	0.54	0.54
2062	0.62	0.62
2063	0.68	0.67
2064	0.58	0.58
2065	0.69	0.69
2066	0.50	0.50
Average Load for RF Sequence (t/yr)	**0.60**	**0.60**
Median Winter Concentration (mg/L)	**0.066**	**0.065**



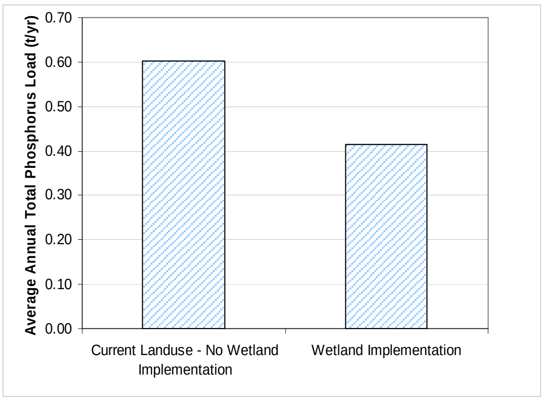
Bennett Brook – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.56	0.39	0.50	0.38
2058	0.60	0.42	0.53	0.40
2059	0.62	0.43	0.55	0.42
2060	0.63	0.44	0.56	0.43
2061	0.54	0.38	0.48	0.36
2062	0.62	0.43	0.55	0.41
2063	0.68	0.47	0.60	0.45
2064	0.58	0.40	0.51	0.38
2065	0.69	0.49	0.61	0.46
2066	0.50	0.35	0.45	0.33
Average Load for RF Sequence (t/yr)	**0.60**	**0.42**	**0.54**	**0.40**
Median Winter Concentration (mg/L)	**0.066**	**0.048**	**0.059**	**0.047**

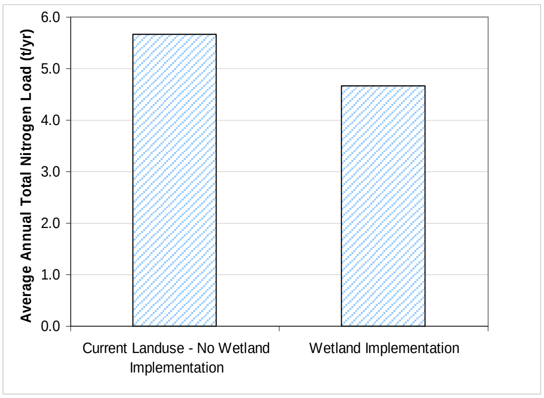


Bennett Brook – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	0.56	0.39
2058	0.60	0.41
2059	0.62	0.43
2060	0.63	0.43
2061	0.54	0.37
2062	0.62	0.43
2063	0.68	0.47
2064	0.58	0.40
2065	0.69	0.48
2066	0.50	0.35
Average Load for RF Sequence (t/yr)	**0.60**	**0.41**

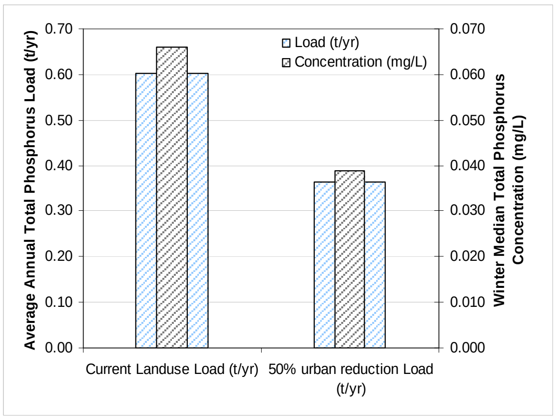


Nitrogen		
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	5.1	4.2
2058	5.5	4.5
2059	6.4	5.3
2060	6.3	5.2
2061	5.4	4.5
2062	5.3	4.4
2063	6.5	5.3
2064	5.1	4.2
2065	6.9	5.7
2066	4.1	3.4
Average Load for RF Sequence (t/yr)	**5.7**	**4.7**

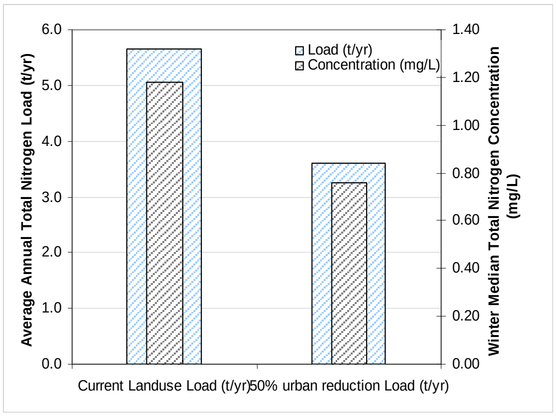


Bennett Brook – Urban 50% reduction

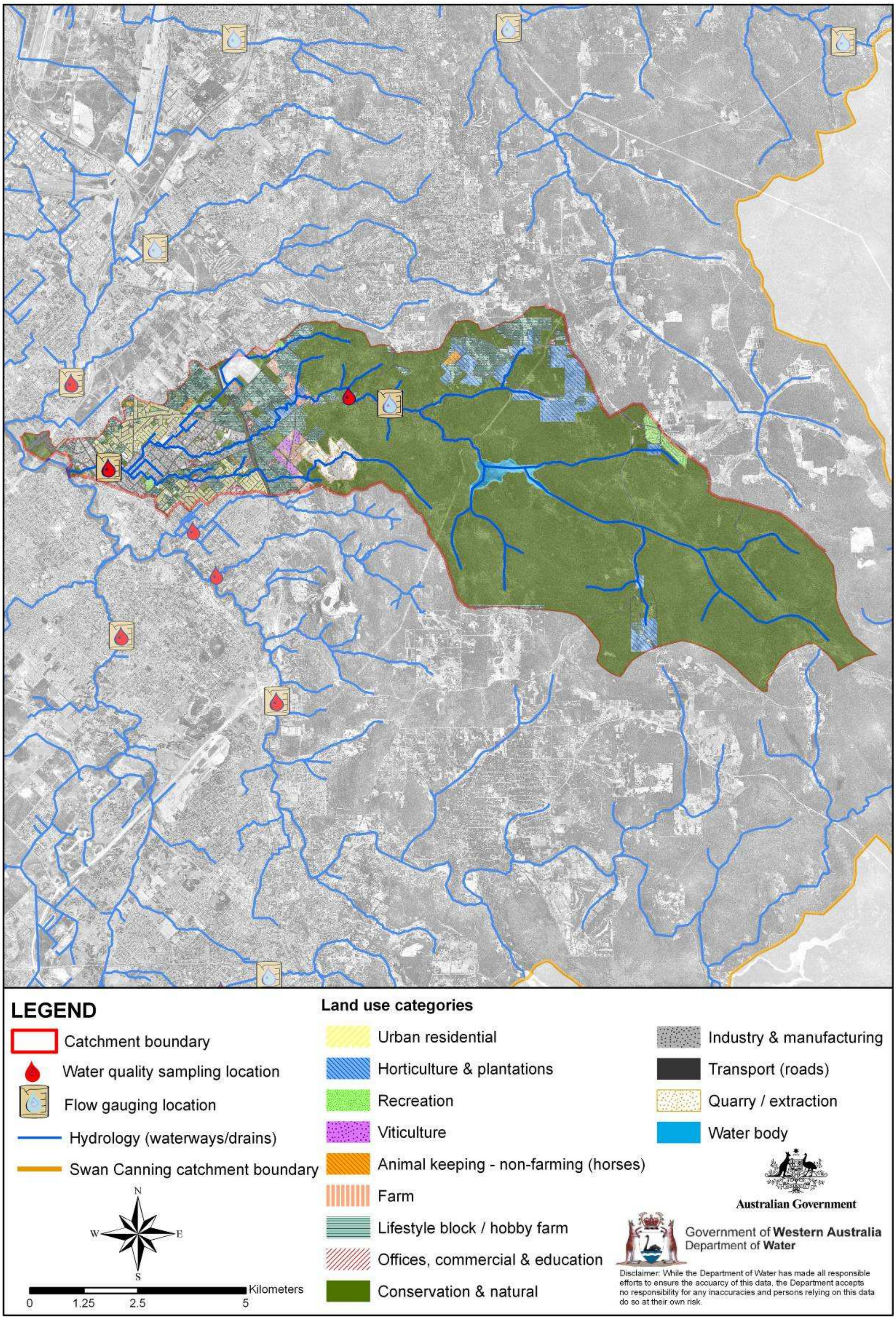
Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.56	0.34
2058	0.60	0.36
2059	0.62	0.38
2060	0.63	0.39
2061	0.54	0.33
2062	0.62	0.37
2063	0.68	0.41
2064	0.58	0.35
2065	0.69	0.42
2066	0.50	0.30
Average Load for RF Sequence (t/yr)	**0.60**	**0.36**
Median Winter Concentration (mg/L)	**0.066**	**0.039**



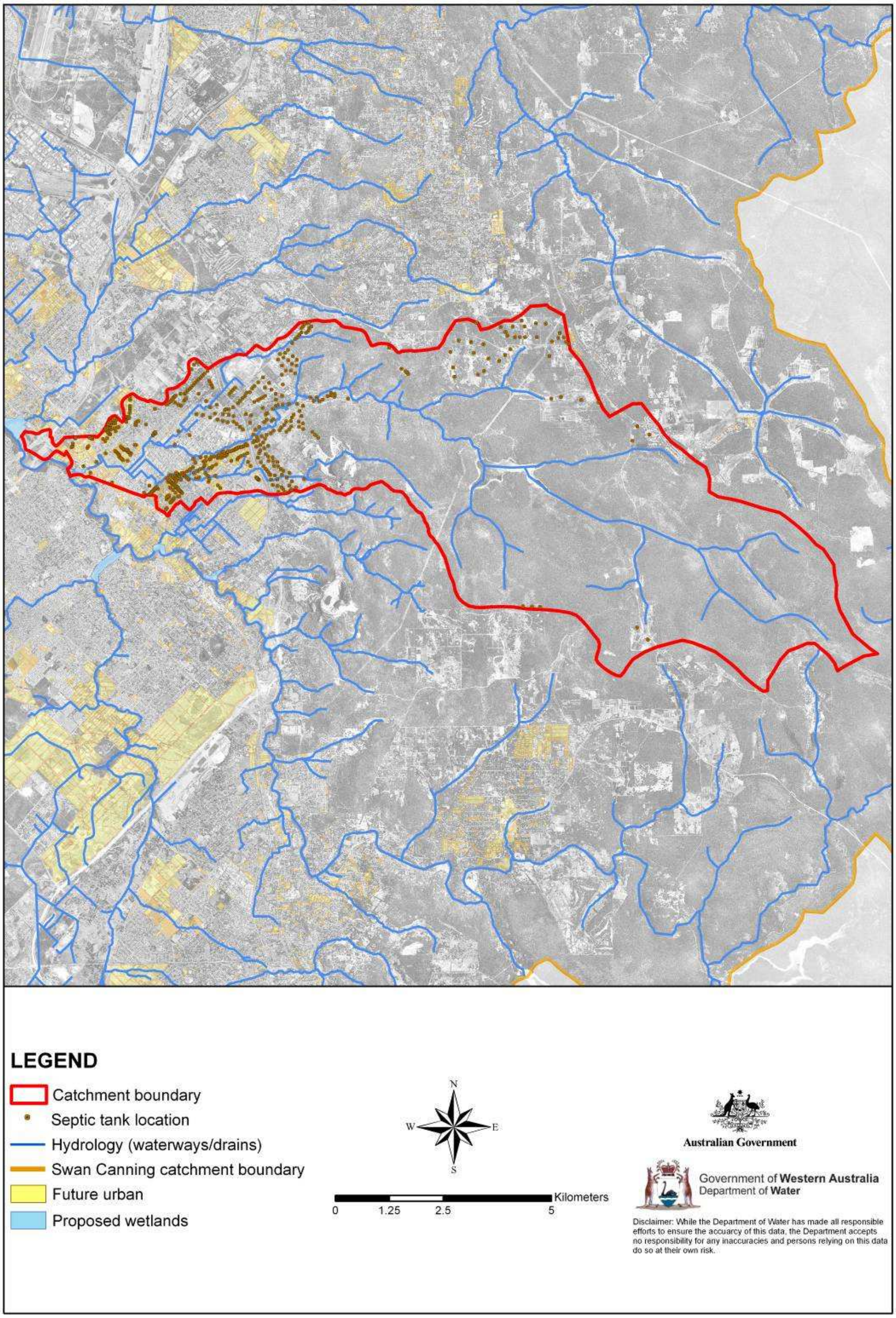
Nitrogen		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	5.1	3.2
2058	5.5	3.4
2059	6.4	4.1
2060	6.3	4.1
2061	5.4	3.4
2062	5.3	3.4
2063	6.5	4.2
2064	5.1	3.2
2065	6.9	4.5
2066	4.1	2.5
Average Load for RF Sequence (t/yr)	**5.7**	**3.6**
Median Winter Concentration (mg/L)	**1.18**	**0.76**



Bickley & Munday Brook
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Bickley & Munday Brook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616047		
	Current	No Reduction Required		Current	No Reduction Required
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	0.11	-	*1997*	0.09	-
1998	0.10	-	*1998*	0.08	-
1999	0.14	-	*1999*	0.12	-
2000	0.18	-	*2000*	0.16	-
2001	0.10	-	*2001*	0.09	-
2002	0.13	-	*2002*	0.11	-
2003	0.18	-	*2003*	0.15	-
2004	0.12	-	*2004*	0.10	-
2005	0.23	-	*2005*	0.19	-
2006	0.06	-	*2006*	0.05	-
Average	**0.14**	**-**	**Average**	**0.11**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.044**		**SQUARE:**	**0.045**	
Target:	**0.100**		**Observed:**	**0.045**	
Load Target (t/yr)		**0.14**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

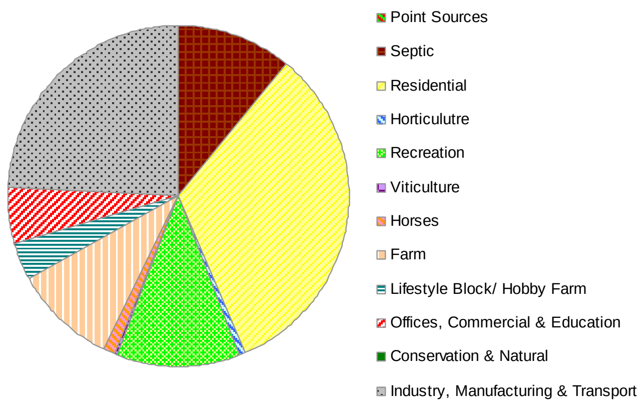
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616047		
	Current	13% Input Reduction		Current	13% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	2.9	1.4	*1997*	2.7	1.4
1998	2.3	1.6	*1998*	2.1	1.5
1999	3.4	2.5	*1999*	3.1	2.3
2000	4.3	3.6	*2000*	3.9	3.2
2001	2.0	1.7	*2001*	1.8	1.6
2002	2.9	2.5	*2002*	2.6	2.3
2003	3.6	3.2	*2003*	3.3	2.9
2004	2.3	2.1	*2004*	2.0	1.9
2005	4.2	3.6	*2005*	3.8	3.3
2006	0.9	0.8	*2006*	0.8	0.7
Average	**2.9**	**2.3**	**Average**	**2.6**	**2.1**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.22**	**1.00**	**SQUARE:**	**1.43**	**1.00**
Target:	**1.00**		**Observed:**	**1.40**	
Load Target (t/yr)		**2.3**			
Load Reduction Target (t/yr)		**0.6**			
Required Reduction (%)		**20%**			
Time Required (yr)		**10**			

Bickley & Munday Brook – Source separation

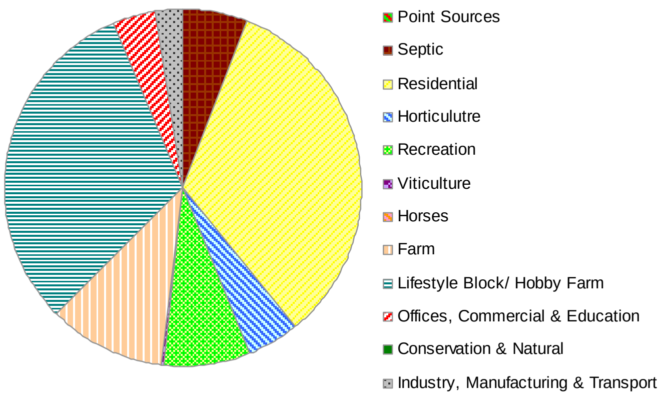
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.11	0.01	0.03	0.04	0.02	0.03	0.01	0.02	0.03	0.02	0.02	0.01	0.04
1998	0.10	0.01	0.02	0.04	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.03
1999	0.14	0.02	0.03	0.05	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.05
2000	0.18	0.02	0.04	0.07	0.02	0.04	0.02	0.02	0.04	0.03	0.03	0.02	0.06
2001	0.10	0.01	0.02	0.04	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.03
2002	0.13	0.01	0.03	0.05	0.01	0.03	0.01	0.01	0.02	0.02	0.02	0.01	0.04
2003	0.18	0.02	0.03	0.07	0.02	0.03	0.02	0.02	0.03	0.02	0.03	0.02	0.05
2004	0.12	0.01	0.02	0.05	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.04
2005	0.23	0.02	0.04	0.09	0.02	0.04	0.02	0.02	0.04	0.03	0.03	0.02	0.07
2006	0.06	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02
Load (non adj)	0.14	0.01	0.03	0.05	0.01	0.03	0.01	0.02	0.03	0.02	0.02	0.01	0.04
Load (t/yr)	**0.14**	**0.00**	**0.01**	**0.04**	**0.00**	**0.02**	**0.00**	**0.00**	**0.01**	**0.01**	**0.01**	**0.00**	**0.03**
Load (%)	**100.0%**	**0.0%**	**10.9%**	**32.6%**	**0.7%**	**11.6%**	**0.2%**	**1.2%**	**9.6%**	**3.8%**	**5.3%**	**0.1%**	**24.0%**



Nitrogen (t/yr)

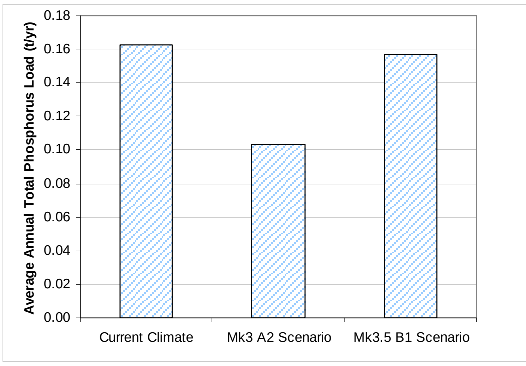
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	2.9	0.3	0.4	0.7	0.4	0.4	0.3	0.3	0.6	0.7	0.3	0.3	0.3
1998	2.3	0.3	0.3	0.6	0.3	0.3	0.3	0.3	0.5	0.6	0.3	0.3	0.3
1999	3.4	0.3	0.4	0.9	0.4	0.5	0.3	0.3	0.7	0.8	0.4	0.3	0.4
2000	4.3	0.4	0.5	1.2	0.5	0.6	0.4	0.4	0.6	1.1	0.5	0.4	0.4
2001	2.0	0.2	0.3	0.6	0.3	0.3	0.2	0.2	0.3	0.6	0.3	0.2	0.3
2002	2.9	0.3	0.4	0.9	0.4	0.4	0.3	0.3	0.4	0.8	0.4	0.3	0.3
2003	3.6	0.4	0.5	1.1	0.5	0.5	0.4	0.4	0.5	1.0	0.5	0.4	0.4
2004	2.3	0.3	0.3	0.7	0.3	0.4	0.3	0.3	0.3	0.7	0.3	0.3	0.3
2005	4.2	0.4	0.6	1.2	0.6	0.6	0.4	0.4	0.6	1.3	0.5	0.4	0.5
2006	0.9	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1
Load (non adj)	2.9	0.3	0.4	0.8	0.4	0.4	0.3	0.3	0.5	0.8	0.4	0.3	0.3
Load (t/yr)	**2.9**	**0.0**	**0.2**	**0.9**	**0.1**	**0.2**	**0.0**	**0.0**	**0.3**	**0.9**	**0.1**	**0.0**	**0.1**
Load (%)	**100.0%**	**0.0%**	**6.0%**	**33.2%**	**4.6%**	**7.8%**	**0.3%**	**0.1%**	**10.6%**	**31.0%**	**3.9%**	**0.0%**	**2.5%**



Bickley & Munday Brook – Climate change

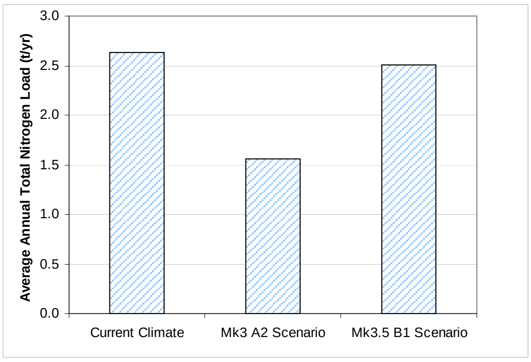
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.13	0.08	0.12
2058	0.12	0.08	0.12
2059	0.17	0.11	0.16
2060	0.23	0.15	0.22
2061	0.13	0.09	0.13
2062	0.16	0.10	0.15
2063	0.21	0.13	0.20
2064	0.15	0.09	0.14
2065	0.26	0.16	0.25
2066	0.07	0.05	0.07
Average Load for RF Sequence (t/yr)	**0.16**	**0.10**	**0.16**



Nitrogen

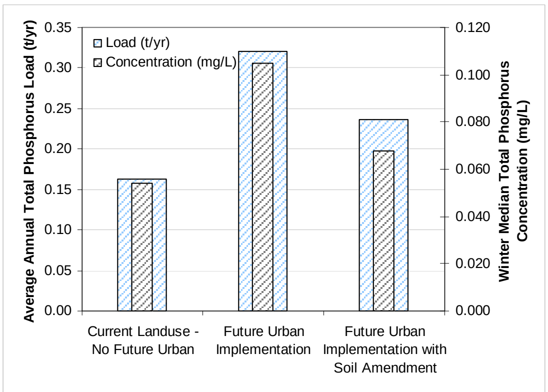
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	1.7	0.9	1.6
2058	1.8	1.0	1.7
2059	2.9	1.7	2.8
2060	4.1	2.7	3.9
2061	2.0	1.3	1.9
2062	2.8	1.4	2.7
2063	3.7	2.2	3.5
2064	2.4	1.3	2.2
2065	4.1	2.5	3.9
2066	0.9	0.5	0.8
Average Load for RF Sequence (t/yr)	**2.6**	**1.6**	**2.5**



Bickley & Munday Brook – Future urban

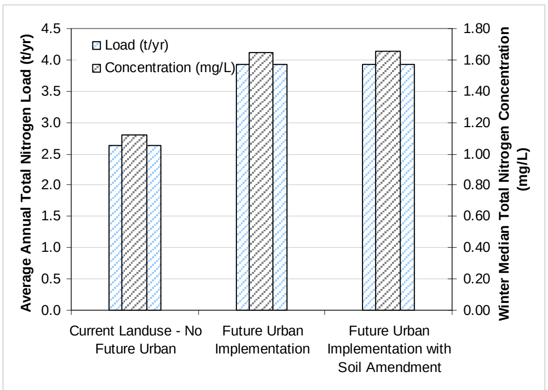
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.13	0.24	0.18
2058	0.12	0.24	0.18
2059	0.17	0.32	0.24
2060	0.23	0.45	0.34
2061	0.13	0.25	0.18
2062	0.16	0.32	0.23
2063	0.21	0.42	0.31
2064	0.15	0.30	0.22
2065	0.26	0.53	0.39
2066	0.07	0.14	0.11
Average Load for RF Sequence (t/yr)	**0.16**	**0.32**	**0.24**
Median Winter Concentration (mg/L)	**0.054**	**0.105**	**0.068**



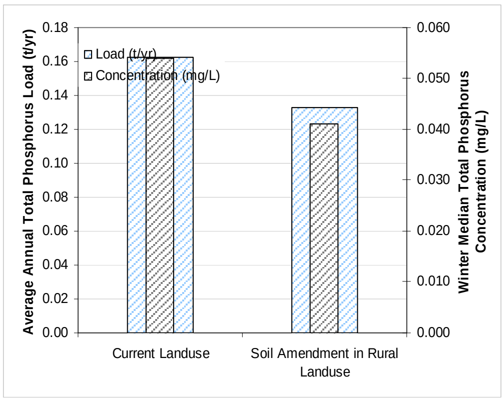
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	1.7	2.5	2.5
2058	1.8	2.7	2.7
2059	2.9	4.3	4.3
2060	4.1	6.2	6.2
2061	2.0	2.9	2.9
2062	2.8	4.4	4.4
2063	3.7	5.4	5.4
2064	2.4	3.6	3.6
2065	4.1	5.9	5.9
2066	0.9	1.5	1.5
Average Load for RF Sequence (t/yr)	**2.6**	**3.9**	**3.9**
Median Winter Concentration (mg/L)	**1.12**	**1.65**	**1.65**



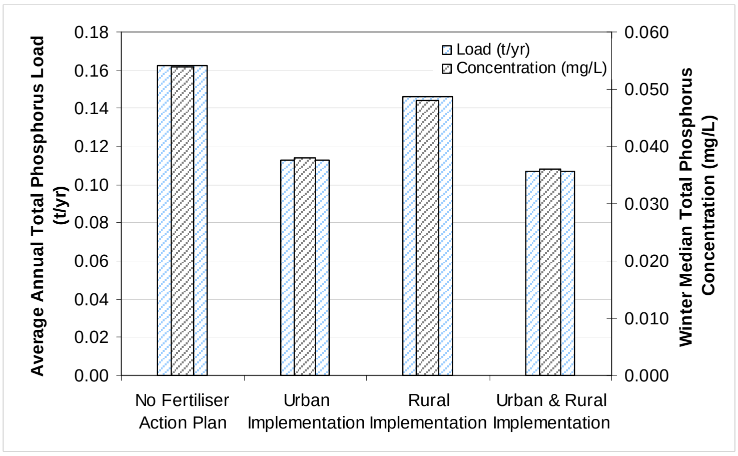
Bickley & Munday Brook – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.13	0.10
2058	0.12	0.10
2059	0.17	0.14
2060	0.23	0.19
2061	0.13	0.11
2062	0.16	0.13
2063	0.21	0.17
2064	0.15	0.12
2065	0.26	0.22
2066	0.07	0.06
Average Load for RF Sequence (t/yr)	**0.16**	**0.13**
Median Winter Concentration (mg/L)	**0.054**	**0.041**



Bickley & Munday Brook – *Fertiliser action plan*

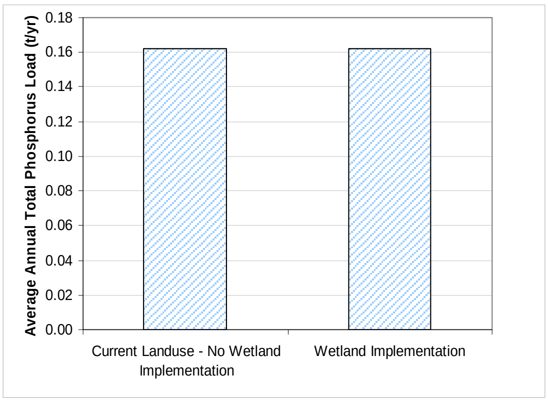
Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.13	0.09	0.11	0.08
2058	0.12	0.09	0.11	0.08
2059	0.17	0.12	0.15	0.11
2060	0.23	0.16	0.21	0.15
2061	0.13	0.09	0.12	0.08
2062	0.16	0.11	0.14	0.10
2063	0.21	0.15	0.19	0.14
2064	0.15	0.10	0.13	0.10
2065	0.26	0.18	0.24	0.17
2066	0.07	0.05	0.07	0.05
Average Load for RF Sequence (t/yr)	**0.16**	**0.11**	**0.15**	**0.11**
Median Winter Concentration (mg/L)	**0.054**	**0.038**	**0.048**	**0.036**



Bickley & Munday Brook – Wetland implementation

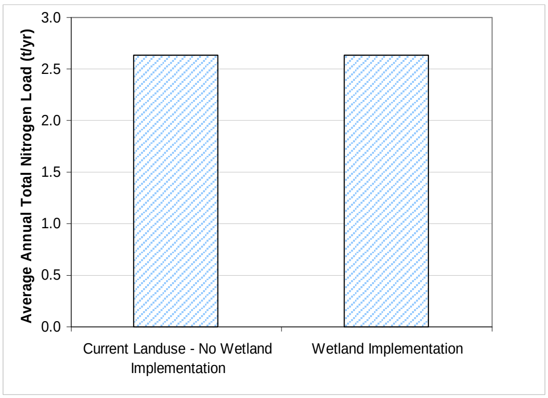
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	0.13	0.13
2058	0.12	0.12
2059	0.17	0.17
2060	0.23	0.23
2061	0.13	0.13
2062	0.16	0.16
2063	0.21	0.21
2064	0.15	0.15
2065	0.26	0.26
2066	0.07	0.07
Average Load for RF Sequence (t/yr)	**0.16**	**0.16**



Nitrogen

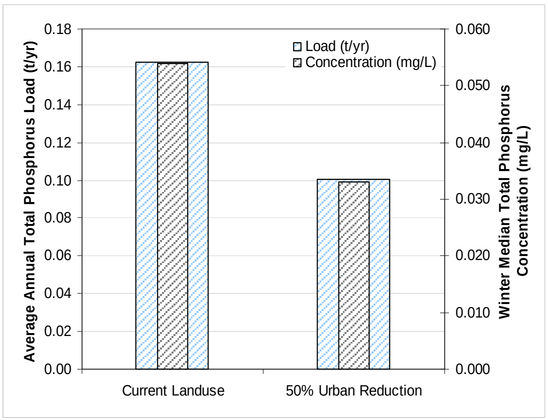
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	1.7	1.7
2058	1.8	1.8
2059	2.9	2.9
2060	4.1	4.1
2061	2.0	2.0
2062	2.8	2.8
2063	3.7	3.7
2064	2.4	2.4
2065	4.1	4.1
2066	0.9	0.9
Average Load for RF Sequence (t/yr)	**2.6**	**2.6**



Bickley & Munday Brook – Urban 50% reduction

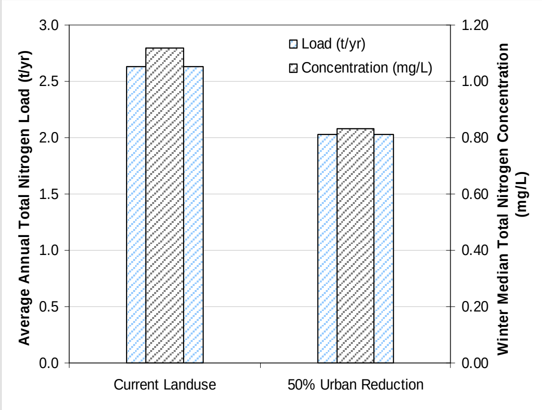
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.13	0.08
2058	0.12	0.08
2059	0.17	0.10
2060	0.23	0.14
2061	0.13	0.08
2062	0.16	0.10
2063	0.21	0.13
2064	0.15	0.09
2065	0.26	0.16
2066	0.07	0.04
Average Load for RF Sequence (t/yr)	**0.16**	**0.10**
Median Winter Concentration (mg/L)	**0.054**	**0.033**



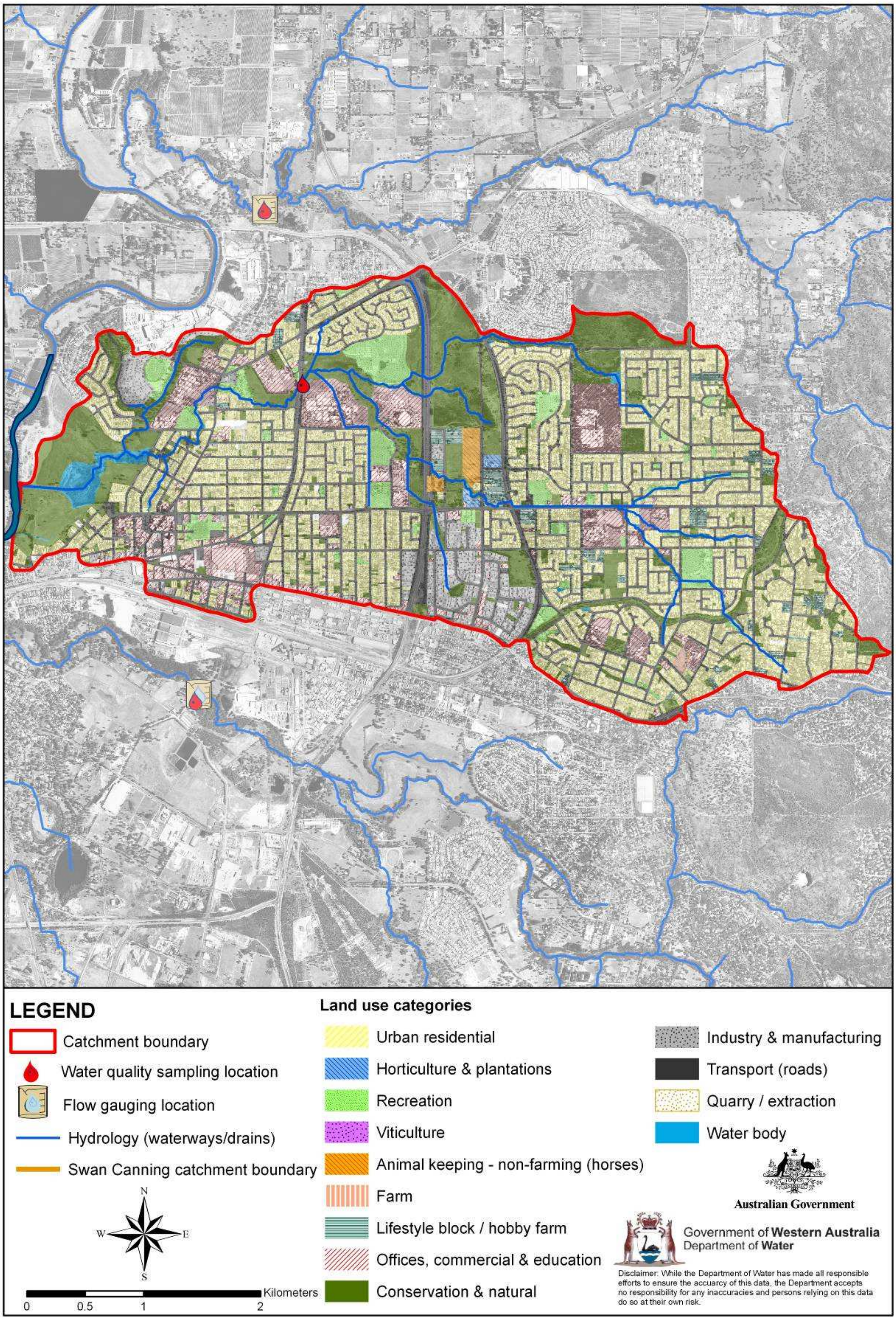
Nitrogen

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	1.7	1.3
2058	1.8	1.4
2059	2.9	2.2
2060	4.1	3.1
2061	2.0	1.5
2062	2.8	2.1
2063	3.7	2.8
2064	2.4	1.8
2065	4.1	3.3
2066	0.9	0.7
Average Load for RF Sequence (t/yr)	**2.6**	**2.0**
Median Winter Concentration (mg/L)	**1.12**	**0.83**

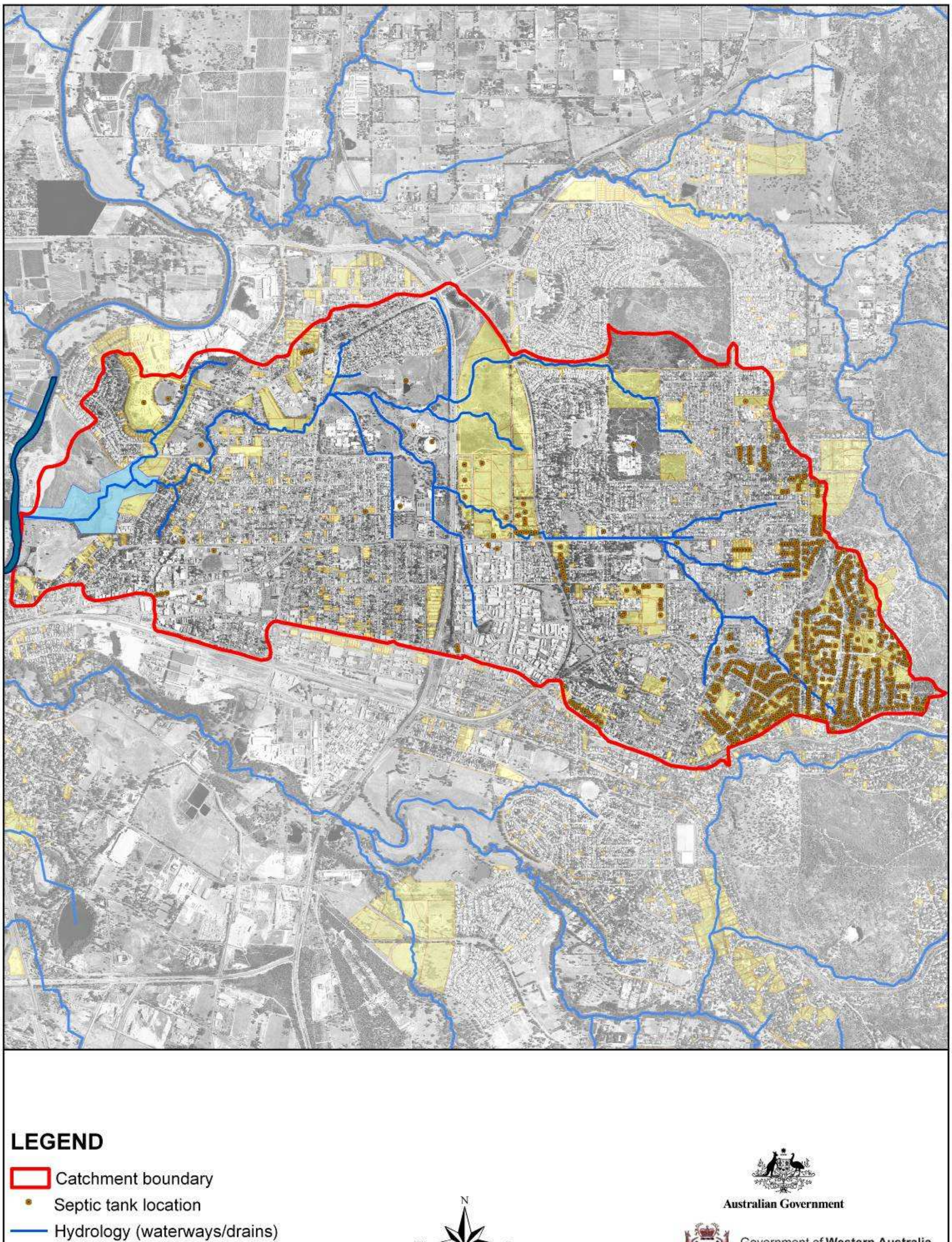


Blackadder Creek

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Blackadder Creek - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Sampling Location 6162925		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.17	-	*1997*	0.13	-
1998	0.18	-	*1998*	0.14	-
1999	0.19	-	*1999*	0.15	-
2000	0.19	-	*2000*	0.14	-
2001	0.15	-	*2001*	0.11	-
2002	0.17	-	*2002*	0.13	-
2003	0.20	-	*2003*	0.15	-
2004	0.16	-	*2004*	0.12	-
2005	0.21	-	*2005*	0.17	-
2006	0.13	-	*2006*	0.10	-
Average	**0.17**	**-**	**Average**	**0.13**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.043**		**SQUARE:**	**0.049**	**0.049**
Target:	**0.075**		**Observed:**	**0.047**	
Load Target (t/yr)		**0.17**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**-**			

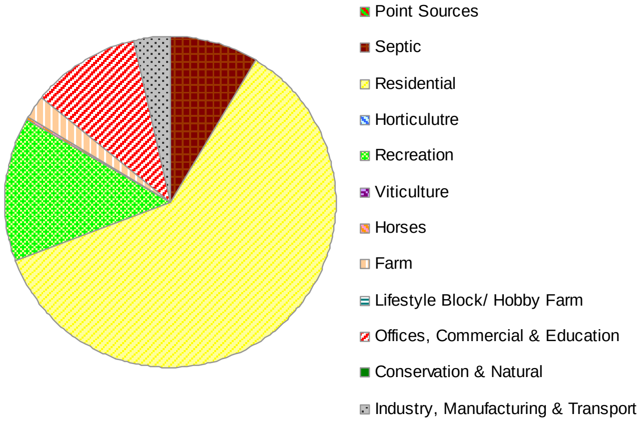
Nitrogen

At Outlet to Swan River Estuary			At Sampling Location 6162925		
	Current	7% Input Reduction		Current	7% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	2.5	1.5	*1997*	1.7	1.1
1998	2.4	1.8	*1998*	1.7	1.3
1999	3.4	2.5	*1999*	2.4	1.8
2000	3.3	2.8	*2000*	2.4	2.1
2001	1.3	1.1	*2001*	0.9	0.8
2002	2.4	2.0	*2002*	1.6	1.4
2003	3.1	2.8	*2003*	2.3	2.1
2004	1.9	1.8	*2004*	1.4	1.3
2005	4.0	3.7	*2005*	3.0	2.8
2006	0.9	0.7	*2006*	0.6	0.5
Average	**2.5**	**2.1**	**Average**	**1.8**	**1.5**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.91**	**0.74**	**SQUARE:**	**0.98**	**0.75**
Target:	**0.75**		**Observed:**	**0.97**	
Load Target (t/yr)		**2.1**			
Load Reduction Target (t/yr)		**0.5**			
Required Reduction (%)		**18%**			
Time Required (yr)		**20**			

Blackadder Creek – Source separation

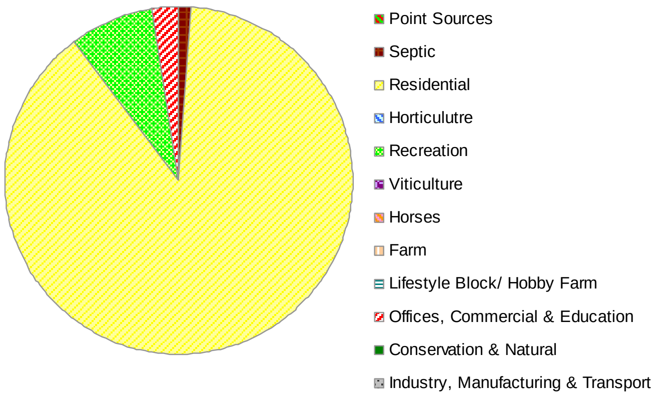
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.17	0.00	0.02	0.10	0.00	0.03	0.00	0.00	0.01	0.00	0.02	0.00	0.01
1998	0.18	0.00	0.02	0.10	0.00	0.03	0.00	0.00	0.01	0.00	0.02	0.00	0.01
1999	0.19	0.00	0.02	0.11	0.00	0.03	0.00	0.00	0.01	0.00	0.02	0.00	0.01
2000	0.19	0.00	0.02	0.11	0.00	0.03	0.00	0.00	0.01	0.00	0.02	0.00	0.01
2001	0.15	0.00	0.01	0.09	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2002	0.17	0.00	0.02	0.11	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2003	0.20	0.00	0.02	0.12	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2004	0.16	0.00	0.01	0.10	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2005	0.21	0.00	0.02	0.13	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2006	0.13	0.00	0.01	0.08	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Load (non adj)	0.17	0.00	0.02	0.11	0.00	0.03	0.00	0.00	0.01	0.00	0.02	0.00	0.01
Load (t/yr)	**0.17**	**0.00**	**0.02**	**0.11**	**0.00**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**8.7%**	**60.3%**	**0.0%**	**14.2%**	**0.0%**	**0.4%**	**2.3%**	**0.0%**	**10.4%**	**0.0%**	**3.6%**



Nitrogen (t/yr)

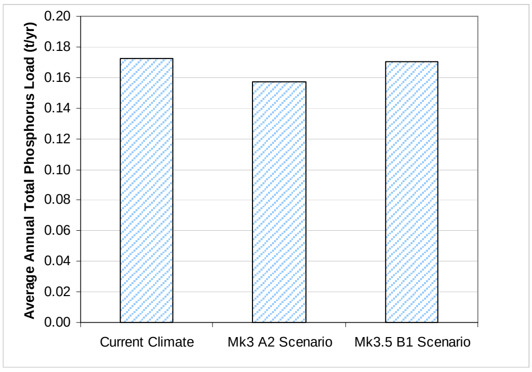
Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	2.5	0.1	0.2	0.7	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1
1998	2.4	0.1	0.1	0.6	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1999	3.4	0.2	0.2	0.9	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2000	3.3	0.2	0.2	1.0	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2001	1.3	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2002	2.4	0.1	0.1	0.7	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1
2003	3.1	0.2	0.2	1.1	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2004	1.9	0.1	0.1	0.7	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1
2005	4.0	0.3	0.3	1.8	0.3	0.5	0.3	0.3	0.3	0.3	0.4	0.3	0.3
2006	0.9	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Load (non adj)	2.5	0.2	0.2	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Load (t/yr)	**2.5**	**0.0**	**0.0**	**2.2**	**0.0**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**1.1%**	**88.6%**	**0.0%**	**7.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**2.4%**	**0.0%**	**0.0%**



Blackadder Creek – Climate change

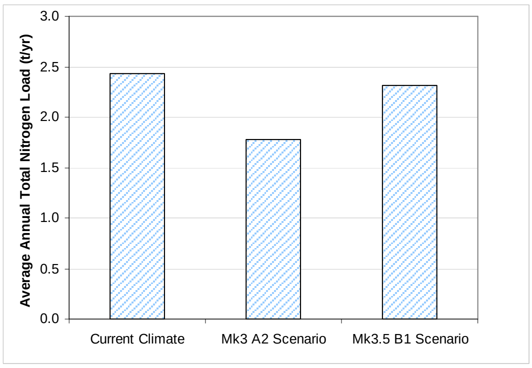
Phosphorus

	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.17	0.15	0.17
2058	0.17	0.16	0.17
2059	0.19	0.17	0.18
2060	0.18	0.17	0.18
2061	0.14	0.13	0.14
2062	0.17	0.15	0.17
2063	0.20	0.18	0.19
2064	0.16	0.14	0.16
2065	0.21	0.19	0.21
2066	0.13	0.12	0.13
Average Load for RF Sequence (t/yr)	**0.17**	**0.16**	**0.17**



Nitrogen

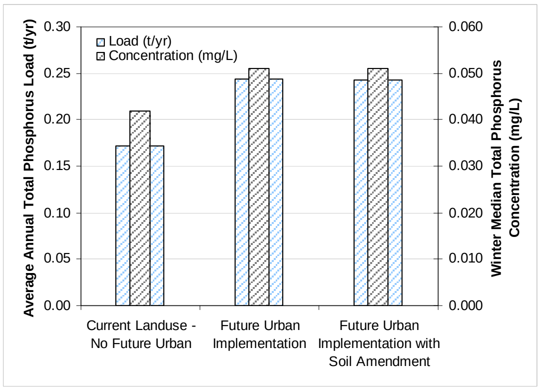
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	1.9	1.5	1.8
2058	2.1	1.6	2.0
2059	2.9	2.2	2.8
2060	3.2	2.3	3.0
2061	1.4	1.3	1.3
2062	2.3	1.6	2.2
2063	3.3	2.2	3.1
2064	2.1	1.5	2.0
2065	4.2	2.4	4.0
2066	0.9	1.0	0.8
Average Load for RF Sequence (t/yr)	**2.4**	**1.8**	**2.3**



Blackadder Creek – Future urban

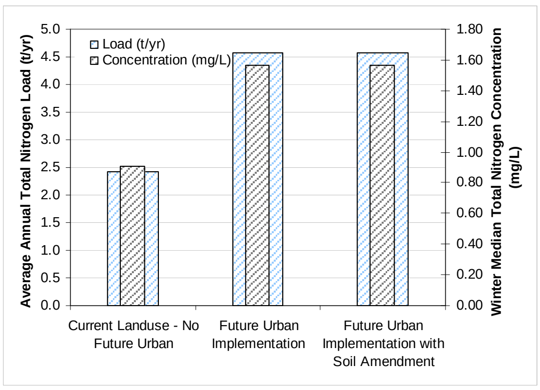
Phosphorus

	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.17	0.24	0.24
2058	0.17	0.25	0.25
2059	0.19	0.26	0.26
2060	0.18	0.25	0.25
2061	0.14	0.20	0.20
2062	0.17	0.24	0.24
2063	0.20	0.28	0.28
2064	0.16	0.23	0.23
2065	0.21	0.30	0.30
2066	0.13	0.19	0.19
Average Load for RF Sequence (t/yr)	**0.17**	**0.24**	**0.24**
Median Winter Concentration (mg/L)	**0.042**	**0.051**	**0.051**



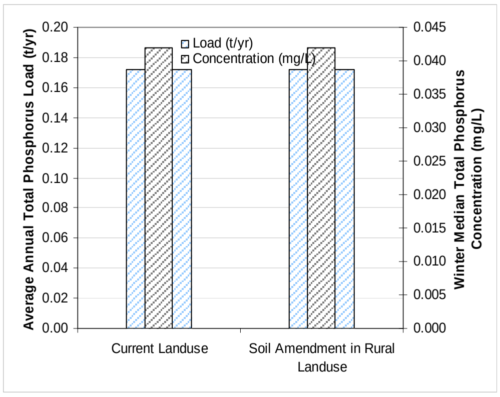
Nitrogen

	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	1.9	3.9	3.9
2058	2.1	4.3	4.3
2059	2.9	5.6	5.6
2060	3.2	5.7	5.7
2061	1.4	2.8	2.8
2062	2.3	4.5	4.5
2063	3.3	6.0	6.0
2064	2.1	4.0	4.0
2065	4.2	6.7	6.7
2066	0.9	2.1	2.1
Average Load for RF Sequence (t/yr)	**2.4**	**4.6**	**4.6**
Median Winter Concentration (mg/L)	**0.91**	**1.57**	**1.57**



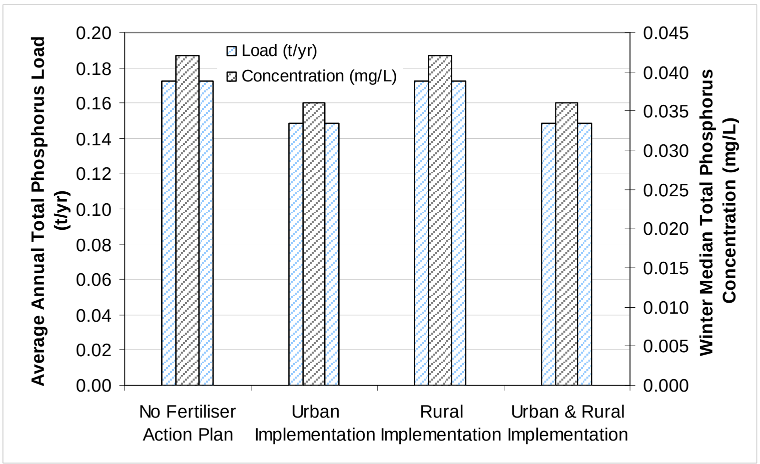
Blackadder Creek – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.17	0.17
2058	0.17	0.17
2059	0.19	0.19
2060	0.18	0.18
2061	0.14	0.14
2062	0.17	0.17
2063	0.20	0.20
2064	0.16	0.16
2065	0.21	0.21
2066	0.13	0.13
Average Load for RF Sequence (t/yr)	**0.17**	**0.17**
Median Winter Concentration (mg/L)	**0.042**	**0.042**



Blackadder Creek – *Fertiliser action plan*

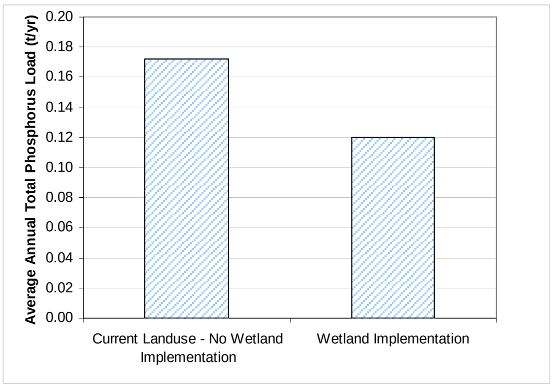
Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)*	Urban and Rural Implementation (t/yr)
2057	0.17	0.14	0.17	0.14
2058	0.17	0.15	0.17	0.15
2059	0.19	0.16	0.19	0.16
2060	0.18	0.16	0.18	0.15
2061	0.14	0.12	0.14	0.12
2062	0.17	0.15	0.17	0.15
2063	0.20	0.17	0.20	0.17
2064	0.16	0.14	0.16	0.14
2065	0.21	0.18	0.21	0.18
2066	0.13	0.11	0.13	0.11
Average Load for RF Sequence (t/yr)	**0.17**	**0.15**	**0.17**	**0.15**
Median Winter Concentration (mg/L)	**0.042**	**0.036**	**0.042**	**0.036**



Blackadder Creek – Wetland implementation

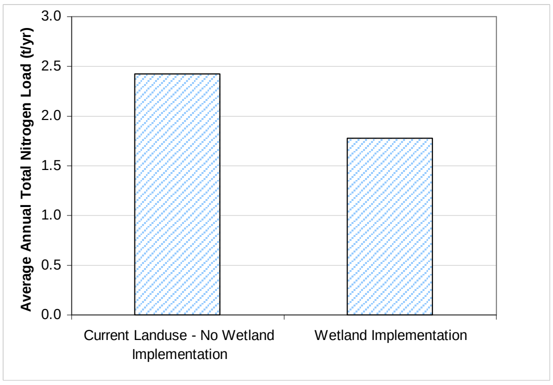
Phosphorus

	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.17	0.12
2058	0.17	0.12
2059	0.19	0.13
2060	0.18	0.12
2061	0.14	0.10
2062	0.17	0.12
2063	0.20	0.14
2064	0.16	0.11
2065	0.21	0.15
2066	0.13	0.09
Average Load for RF Sequence (t/yr)	**0.17**	**0.12**



Nitrogen

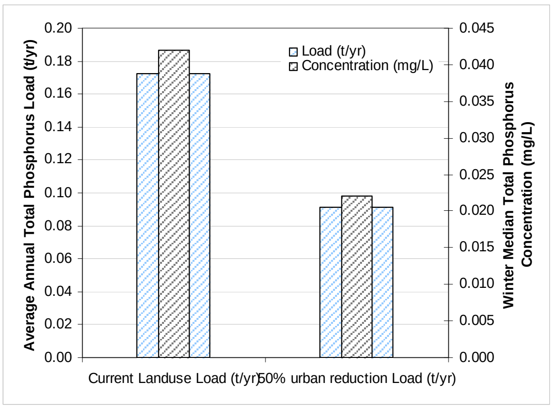
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	1.9	1.6
2058	2.1	1.7
2059	2.9	2.1
2060	3.2	2.2
2061	1.4	1.4
2062	2.3	1.7
2063	3.3	2.2
2064	2.1	1.6
2065	4.2	2.3
2066	0.9	1.1
Average Load for RF Sequence (t/yr)	**2.4**	**1.8**



Blackadder Creek – Urban 50% reduction

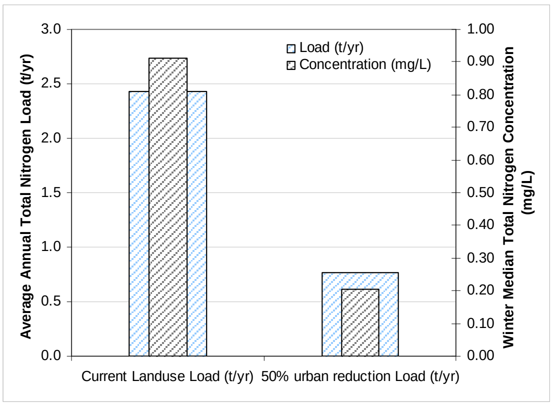
Phosphorus

	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.17	0.09
2058	0.17	0.09
2059	0.19	0.10
2060	0.18	0.09
2061	0.14	0.08
2062	0.17	0.09
2063	0.20	0.10
2064	0.16	0.08
2065	0.21	0.11
2066	0.13	0.07
Average Load for RF Sequence (t/yr)	**0.17**	**0.09**
Median Winter Concentration (mg/L)	**0.042**	**0.022**



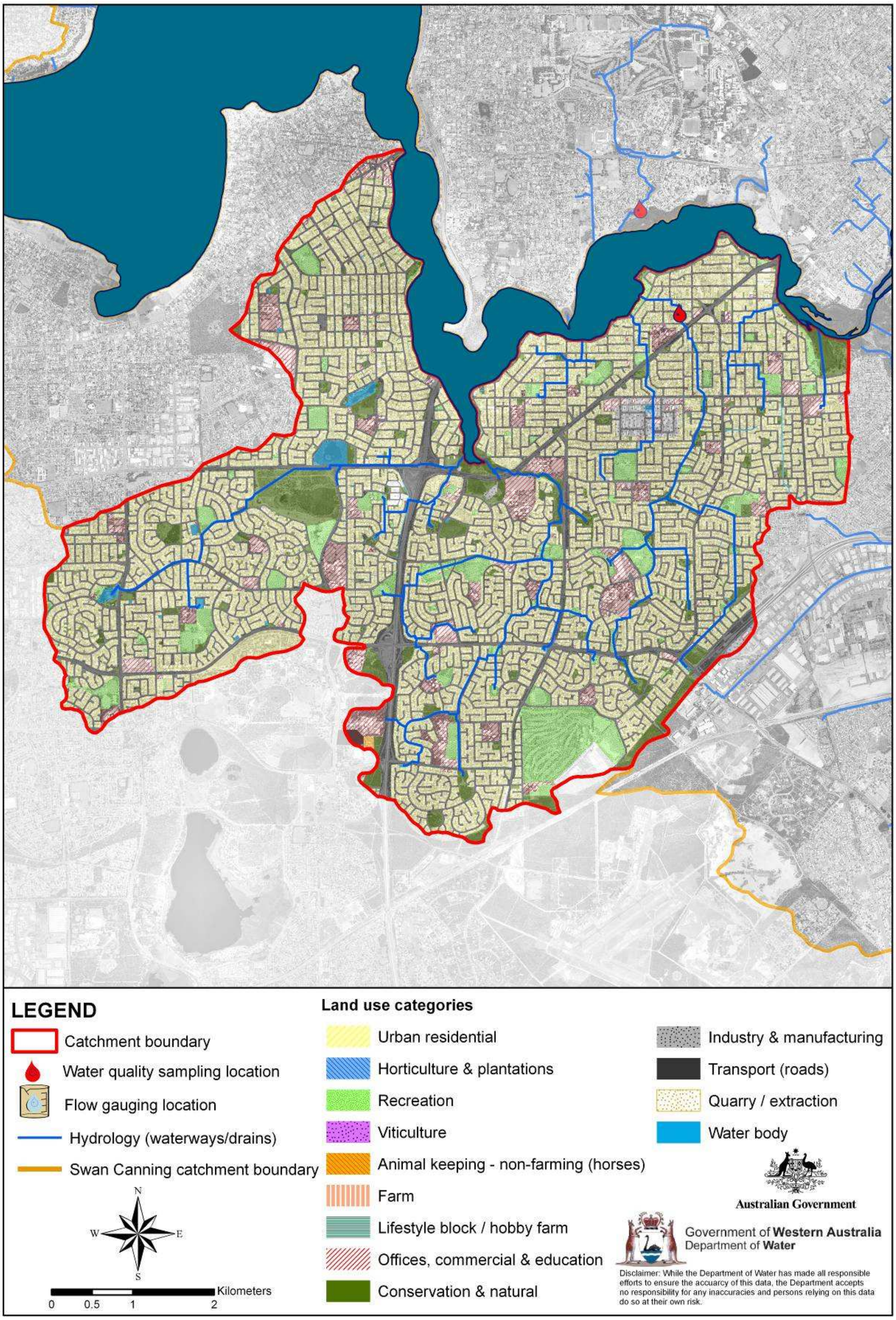
Nitrogen

	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	1.9	0.5
2058	2.1	0.6
2059	2.9	0.9
2060	3.2	1.0
2061	1.4	0.3
2062	2.3	0.7
2063	3.3	1.1
2064	2.1	0.7
2065	4.2	1.7
2066	0.9	0.2
Average Load for RF Sequence (t/yr)	**2.4**	**0.8**
Median Winter Concentration (mg/L)	**0.91**	**0.20**

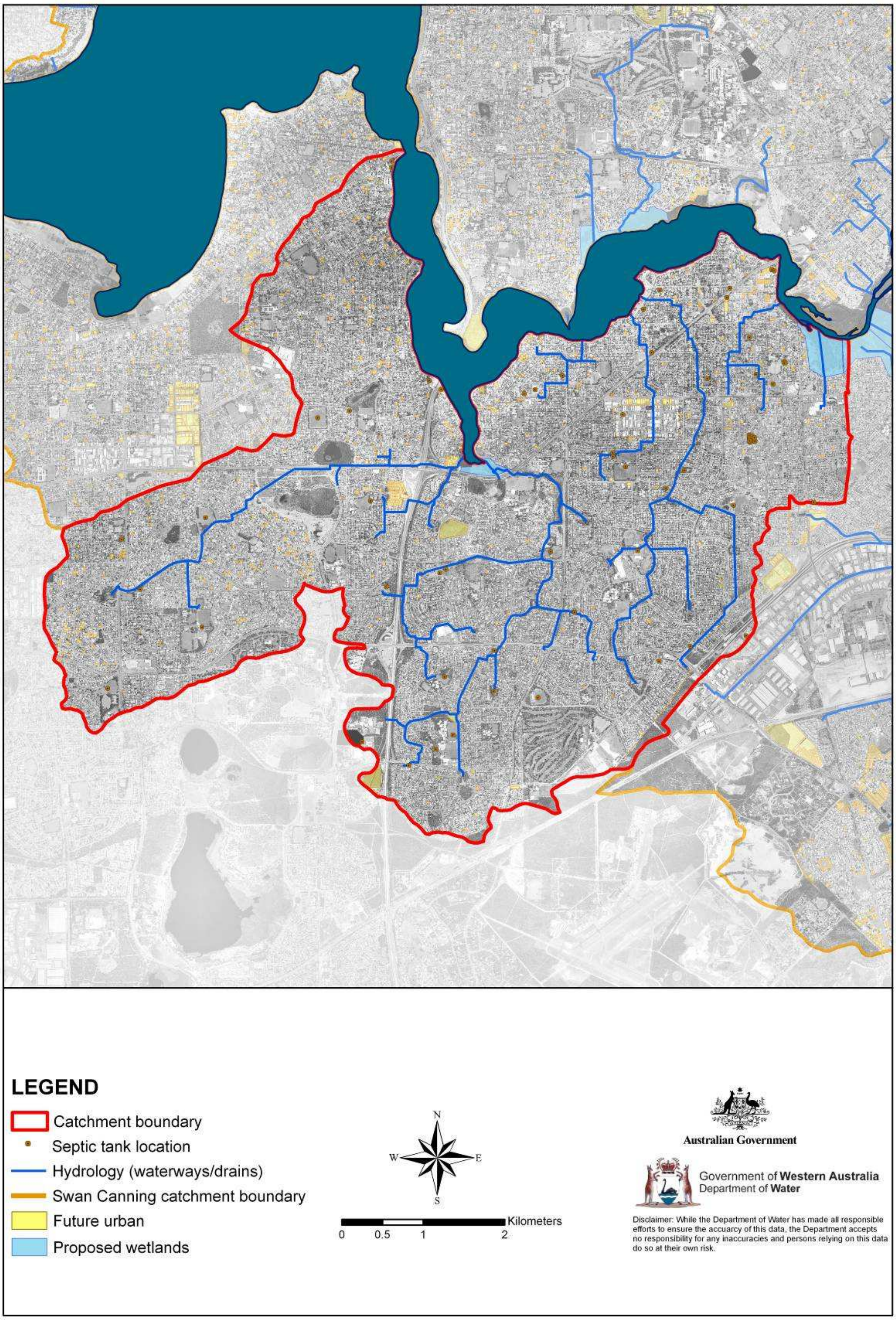


Bullcreek

Land use map



Locations of septic tanks, future urban development and proposed wetlands

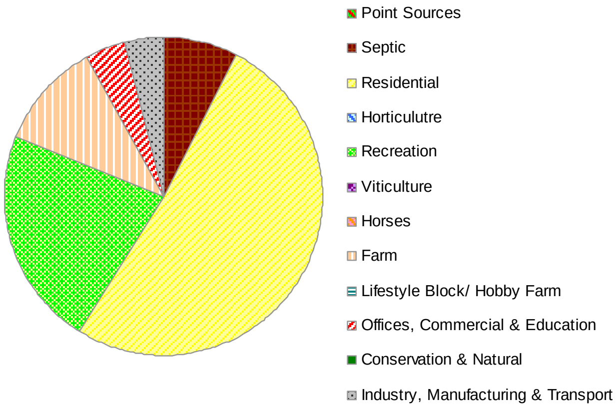


Phosphorus				
	At Outlet to Swan River Estuary		At Sampling Location 6162311	
	Current	15% Input Reduction	Current	15% Input Reduction

Bullcreek – Source separation

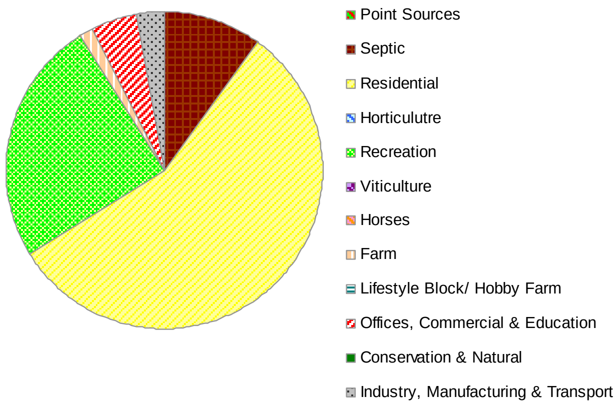
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.99	0.05	0.13	0.50	0.05	0.27	0.05	0.05	0.18	0.05	0.09	0.05	0.09
1998	1.11	0.06	0.15	0.57	0.06	0.30	0.06	0.06	0.19	0.06	0.10	0.06	0.10
1999	1.17	0.06	0.15	0.61	0.06	0.31	0.06	0.06	0.19	0.06	0.10	0.06	0.10
2000	1.18	0.06	0.15	0.62	0.06	0.31	0.06	0.06	0.19	0.06	0.10	0.06	0.10
2001	1.06	0.05	0.13	0.56	0.05	0.28	0.05	0.05	0.16	0.05	0.09	0.05	0.09
2002	1.26	0.06	0.15	0.68	0.06	0.32	0.06	0.06	0.18	0.06	0.11	0.06	0.10
2003	1.39	0.06	0.16	0.76	0.06	0.36	0.06	0.06	0.19	0.06	0.12	0.06	0.11
2004	1.21	0.05	0.13	0.66	0.05	0.31	0.05	0.05	0.16	0.05	0.10	0.05	0.09
2005	1.47	0.06	0.15	0.81	0.06	0.37	0.06	0.06	0.19	0.06	0.12	0.06	0.11
2006	1.13	0.04	0.12	0.63	0.04	0.28	0.04	0.04	0.14	0.04	0.09	0.04	0.08
Load (non adj)	1.20	0.05	0.14	0.64	0.05	0.31	0.05	0.05	0.18	0.05	0.10	0.05	0.10
Load (t/yr)	**1.20**	**0.00**	**0.09**	**0.61**	**0.00**	**0.27**	**0.00**	**0.00**	**0.13**	**0.00**	**0.05**	**0.00**	**0.05**
Load (%)	**100.0%**	**0.0%**	**7.6%**	**51.2%**	**0.0%**	**22.4%**	**0.0%**	**0.0%**	**10.7%**	**0.0%**	**4.3%**	**0.0%**	**3.8%**



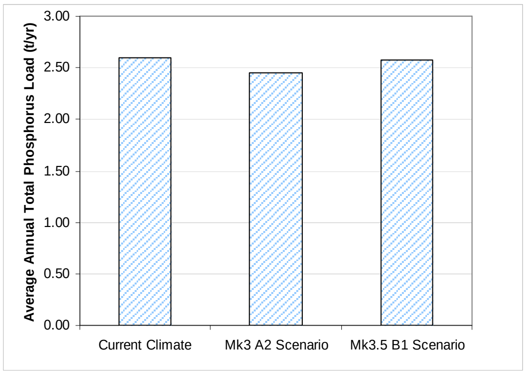
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	10.6	0.8	2.1	5.6	0.8	3.2	0.8	0.8	1.0	0.8	1.2	0.8	1.0
1998	11.5	0.8	2.3	6.3	0.8	3.4	0.8	0.8	1.0	0.8	1.3	0.8	1.1
1999	13.0	0.8	2.4	7.2	0.8	3.7	0.8	0.8	1.0	0.8	1.3	0.8	1.0
2000	12.3	0.7	2.1	7.0	0.7	3.5	0.7	0.7	0.8	0.7	1.2	0.7	1.0
2001	10.4	0.6	1.6	6.2	0.6	3.0	0.6	0.6	0.7	0.6	1.0	0.6	0.8
2002	11.2	0.7	1.7	6.8	0.7	3.4	0.7	0.7	0.8	0.7	1.2	0.7	1.0
2003	12.2	0.7	1.6	7.5	0.7	3.6	0.7	0.7	0.8	0.7	1.3	0.7	1.1
2004	9.8	0.6	1.2	6.2	0.6	3.0	0.6	0.6	0.6	0.6	1.1	0.6	0.9
2005	12.3	0.7	1.3	7.9	0.7	3.7	0.7	0.7	0.7	0.7	1.3	0.7	1.0
2006	8.0	0.5	0.9	5.2	0.5	2.5	0.5	0.5	0.5	0.5	0.9	0.5	0.7
Load (non adj)	11.1	0.7	1.7	6.6	0.7	3.3	0.7	0.7	0.8	0.7	1.2	0.7	1.0
Load (t/yr)	**11.1**	**0.0**	**1.1**	**6.1**	**0.0**	**2.7**	**0.0**	**0.0**	**0.1**	**0.0**	**0.5**	**0.0**	**0.3**
Load (%)	**100.0%**	**0.0%**	**9.7%**	**54.9%**	**0.0%**	**24.3%**	**0.0%**	**0.0%**	**1.3%**	**0.0%**	**4.7%**	**0.0%**	**2.7%**

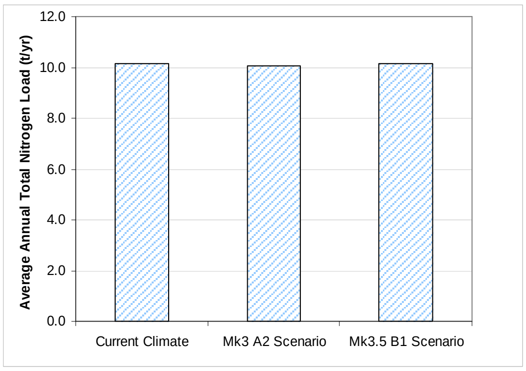


Bullcreek – Climate change

Phosphorus			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	2.38	2.24	2.36
2058	2.62	2.47	2.60
2059	2.69	2.55	2.67
2060	2.66	2.53	2.64
2061	2.33	2.20	2.31
2062	2.69	2.54	2.67
2063	2.93	2.76	2.90
2064	2.49	2.36	2.47
2065	2.96	2.79	2.93
2066	2.23	2.11	2.21
Average Load for RF Sequence (t/yr)	**2.60**	**2.45**	**2.58**

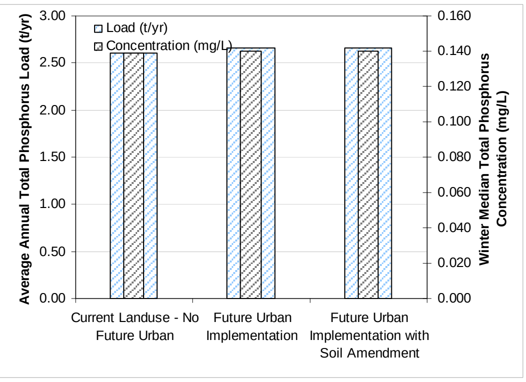


Nitrogen			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	9.6	9.4	9.6
2058	10.4	10.2	10.4
2059	11.7	11.6	11.7
2060	11.0	11.0	10.9
2061	9.4	9.3	9.5
2062	10.1	10.0	10.1
2063	11.2	11.0	11.2
2064	9.1	9.1	9.1
2065	11.5	11.3	11.5
2066	7.5	7.4	7.5
Average Load for RF Sequence (t/yr)	**10.2**	**10.0**	**10.2**

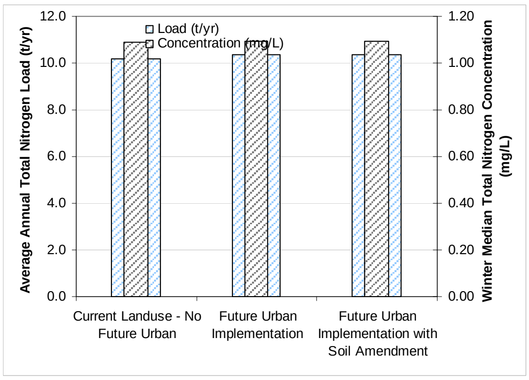


Bullcreek – Future urban

Phosphorus			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	2.38	2.44	2.44
2058	2.62	2.68	2.68
2059	2.69	2.75	2.75
2060	2.66	2.72	2.72
2061	2.33	2.39	2.38
2062	2.69	2.76	2.75
2063	2.93	3.00	2.99
2064	2.49	2.55	2.54
2065	2.96	3.03	3.02
2066	2.23	2.29	2.29
Average Load for RF Sequence (t/yr)	**2.60**	**2.66**	**2.66**
Median Winter Concentration (mg/L)	**0.139**	**0.140**	**0.140**

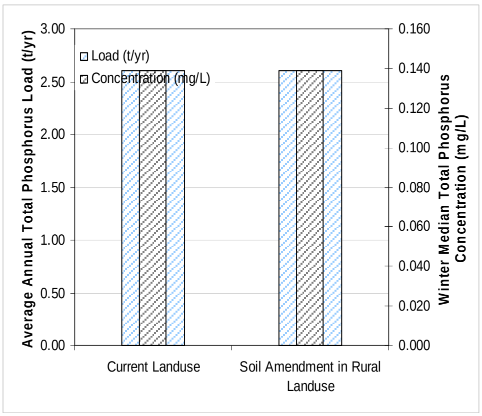


Nitrogen			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	9.6	9.8	9.8
2058	10.4	10.6	10.6
2059	11.7	11.9	11.9
2060	11.0	11.2	11.2
2061	9.4	9.6	9.6
2062	10.1	10.3	10.3
2063	11.2	11.4	11.4
2064	9.1	9.3	9.3
2065	11.5	11.7	11.7
2066	7.5	7.6	7.6
Average Load for RF Sequence (t/yr)	**10.2**	**10.3**	**10.3**
Median Winter Concentration (mg/L)	**1.09**	**1.09**	**1.09**



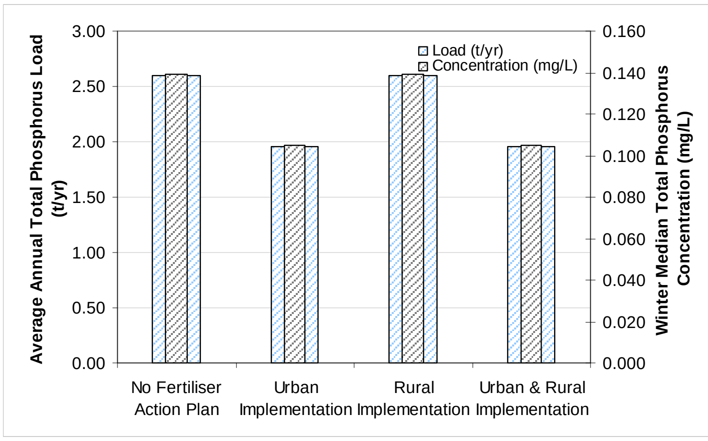
Bullcreek – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	2.38	2.38
2058	2.62	2.62
2059	2.69	2.69
2060	2.66	2.66
2061	2.33	2.33
2062	2.69	2.69
2063	2.93	2.93
2064	2.49	2.48
2065	2.96	2.95
2066	2.23	2.23
Average Load for RF Sequence (t/yr)	**2.60**	**2.60**
Median Winter Concentration (mg/L)	**0.139**	**0.139**



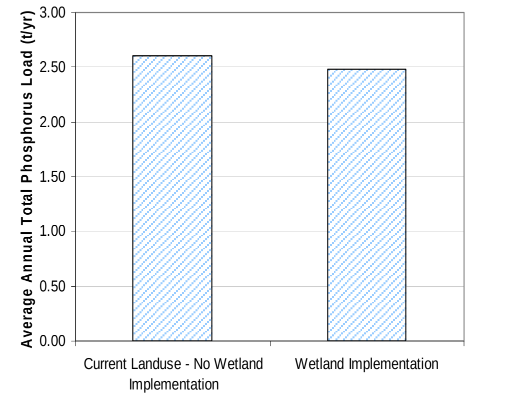
Bullcreek – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	2.38	1.81	2.38	1.81
2058	2.62	1.99	2.62	1.99
2059	2.69	2.04	2.69	2.04
2060	2.66	2.01	2.66	2.01
2061	2.33	1.75	2.33	1.75
2062	2.69	2.02	2.69	2.02
2063	2.93	2.19	2.93	2.19
2064	2.49	1.86	2.49	1.86
2065	2.96	2.21	2.96	2.21
2066	2.23	1.66	2.23	1.66
Average Load for RF Sequence (t/yr)	**2.60**	**1.95**	**2.60**	**1.95**
Median Winter Concentration (mg/L)	**0.139**	**0.105**	**0.139**	**0.105**

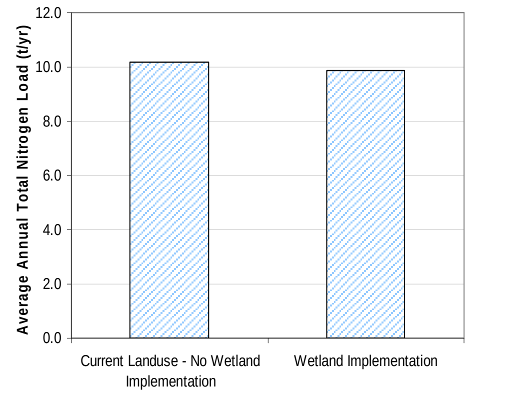


Bullcreek – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	2.38	2.27
2058	2.62	2.50
2059	2.69	2.57
2060	2.66	2.53
2061	2.33	2.23
2062	2.69	2.58
2063	2.93	2.78
2064	2.49	2.38
2065	2.96	2.81
2066	2.23	2.12
Average Load for RF Sequence (t/yr)	**2.60**	**2.48**

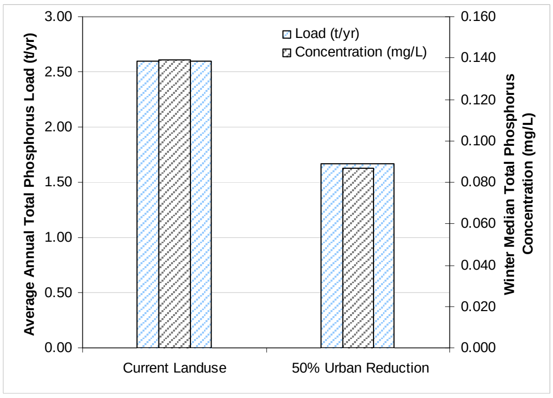


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	9.6	9.4
2058	10.4	10.2
2059	11.7	11.4
2060	11.0	10.7
2061	9.4	9.2
2062	10.1	9.9
2063	11.2	10.9
2064	9.1	8.9
2065	11.5	11.2
2066	7.5	7.3
Average Load for RF Sequence (t/yr)	**10.2**	**9.9**

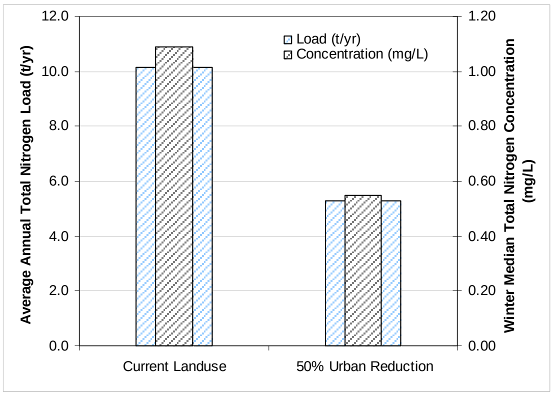


Bullcreek – Urban 50% reduction

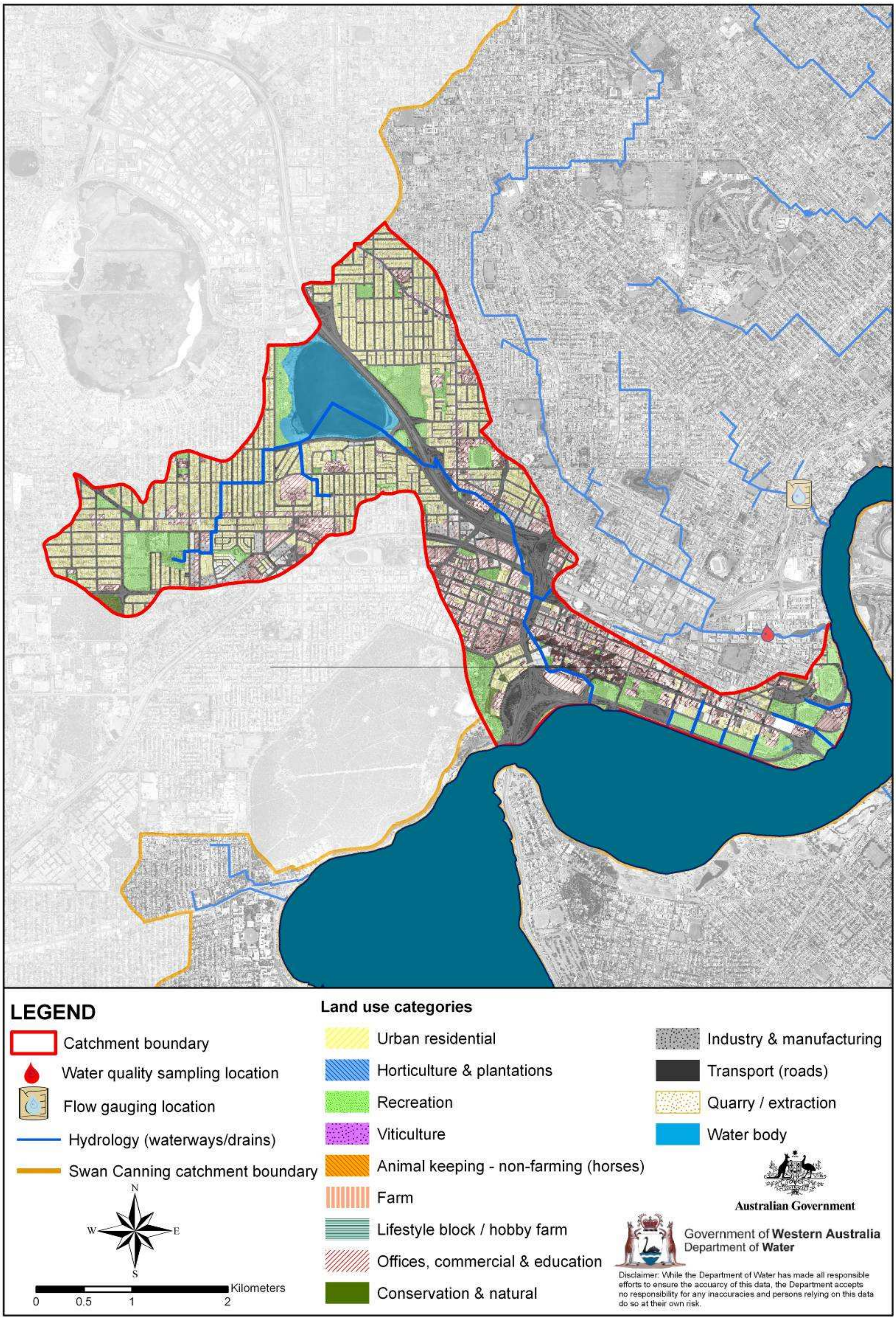
Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	2.38	1.55
2058	2.62	1.70
2059	2.69	1.74
2060	2.66	1.71
2061	2.33	1.49
2062	2.69	1.72
2063	2.93	1.86
2064	2.49	1.58
2065	2.96	1.87
2066	2.23	1.41
Average Load for RF Sequence (t/yr)	**2.60**	**1.66**
Median Winter Concentration (mg/L)	**0.139**	**0.087**



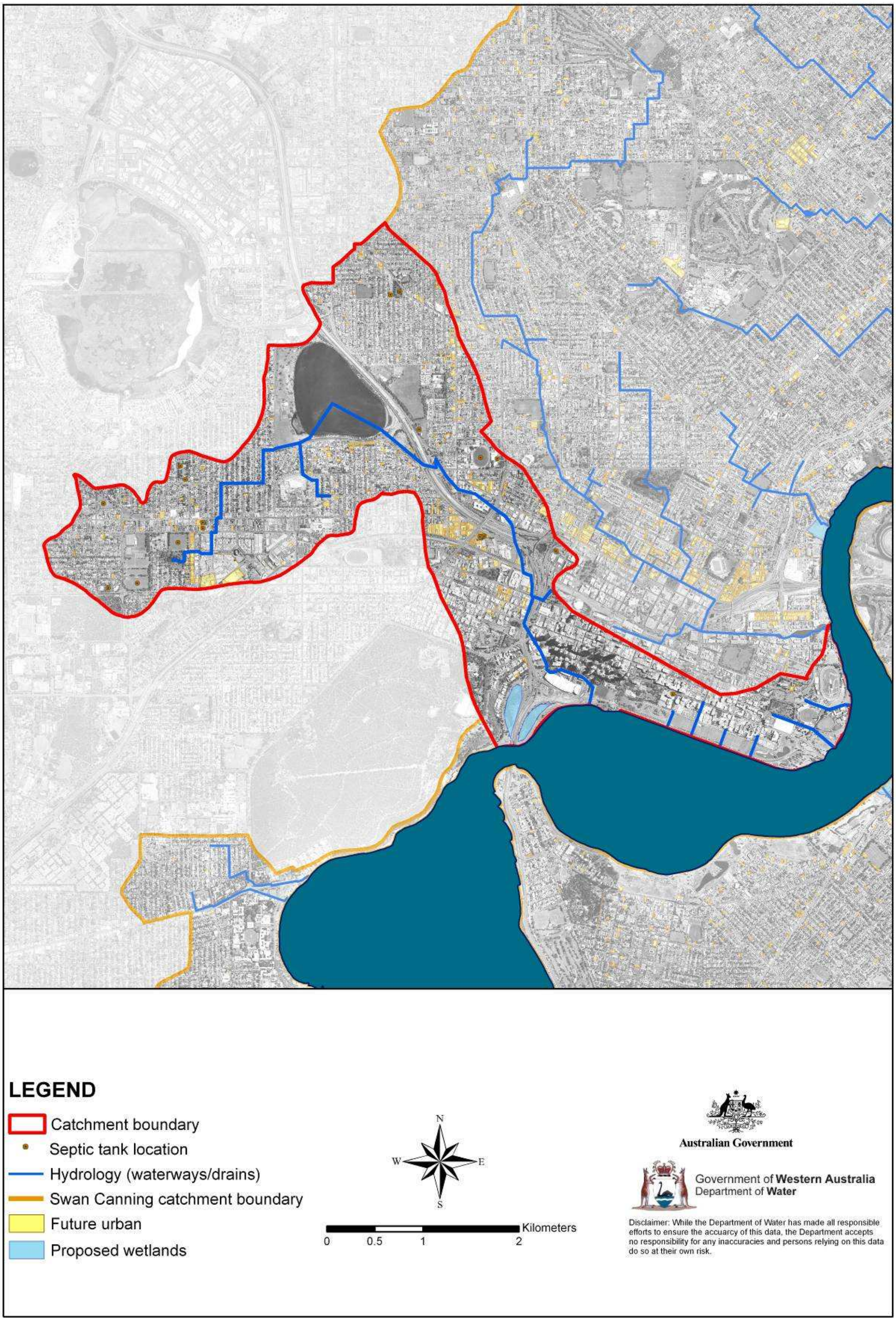
Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	9.6	5.0
2058	10.4	5.5
2059	11.7	6.1
2060	11.0	5.7
2061	9.4	4.9
2062	10.1	5.3
2063	11.2	5.9
2064	9.1	4.8
2065	11.5	6.0
2066	7.5	3.9
Average Load for RF Sequence (t/yr)	**10.2**	**5.3**
Median Winter Concentration (mg/L)	**1.09**	**0.55**



CBD
Land use map



Locations of septic tanks, future urban development and proposed wetlands



CBD - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Subcatchment #6		
	Current	22% Input Reduction		Current	22% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.21	0.20	*1997*	0.12	0.11
1998	0.25	0.23	*1998*	0.14	0.13
1999	0.23	0.21	*1999*	0.13	0.12
2000	0.22	0.20	*2000*	0.13	0.12
2001	0.21	0.19	*2001*	0.12	0.11
2002	0.27	0.24	*2002*	0.15	0.14
2003	0.26	0.23	*2003*	0.15	0.14
2004	0.24	0.20	*2004*	0.14	0.12
2005	0.31	0.25	*2005*	0.18	0.15
2006	0.21	0.17	*2006*	0.13	0.10
Average	**0.24**	**0.21**	**Average**	**0.14**	**0.12**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.056**	**0.050**	**SQUARE:**	**0.056**	**0.050**
Target:	**0.050**		**Predicted:**	**0.056**	
Load Target (t/yr)		**0.21**			
Load Reduction Target (t/yr)		**0.03**			
Required Reduction (%)		**12%**			
Time Required (yr)		**10**			

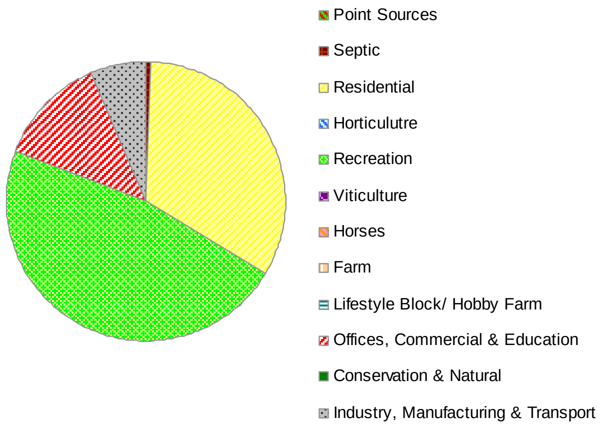
Nitrogen

At Outlet to Swan River Estuary			At Subcatchment #6		
	Current	95% Input Reduction		Current	95% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	5.0	1.6	*1997*	3.8	1.2
1998	6.0	1.9	*1998*	4.5	1.4
1999	5.4	1.7	*1999*	4.1	1.2
2000	5.2	1.7	*2000*	3.9	1.2
2001	4.7	1.6	*2001*	3.6	1.2
2002	5.7	1.9	*2002*	4.2	1.4
2003	5.5	1.9	*2003*	4.1	1.4
2004	4.8	1.7	*2004*	3.5	1.2
2005	5.9	2.0	*2005*	4.3	1.5
2006	3.7	1.5	*2006*	2.7	1.0
Average	**5.2**	**1.7**	**Average**	**3.8**	**1.3**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.60**	**0.50**	**SQUARE:**	**1.60**	**0.50**
Target:	**0.50**		**Predicted:**	**1.60**	
Load Target (t/yr)		**1.7**			
Load Reduction Target (t/yr)		**3.4**			
Required Reduction (%)		**67%**			
Time Required (yr)		**30**			

CBD – Source separation

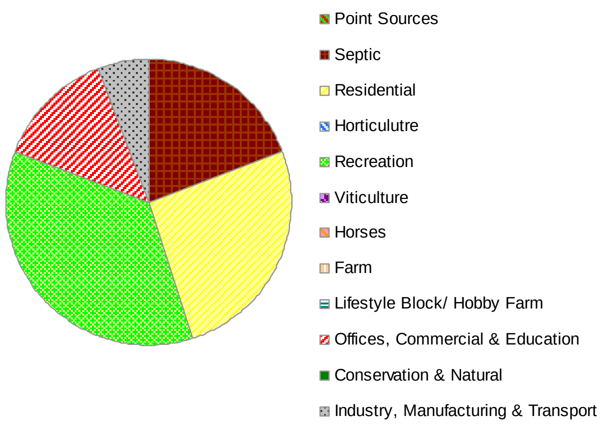
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.21	0.00	0.00	0.07	0.00	0.10	0.00	0.00	0.00	0.00	0.03	0.00	0.01
1998	0.25	0.00	0.00	0.08	0.00	0.12	0.00	0.00	0.00	0.00	0.03	0.00	0.02
1999	0.23	0.00	0.00	0.07	0.00	0.11	0.00	0.00	0.00	0.00	0.03	0.00	0.02
2000	0.22	0.00	0.00	0.07	0.00	0.10	0.00	0.00	0.00	0.00	0.03	0.00	0.01
2001	0.21	0.00	0.00	0.07	0.00	0.10	0.00	0.00	0.00	0.00	0.03	0.00	0.01
2002	0.27	0.00	0.00	0.09	0.00	0.13	0.00	0.00	0.00	0.00	0.03	0.00	0.02
2003	0.26	0.00	0.00	0.09	0.00	0.13	0.00	0.00	0.00	0.00	0.03	0.00	0.02
2004	0.24	0.00	0.00	0.08	0.00	0.11	0.00	0.00	0.00	0.00	0.03	0.00	0.02
2005	0.31	0.00	0.00	0.11	0.00	0.14	0.00	0.00	0.00	0.00	0.04	0.00	0.02
2006	0.21	0.00	0.00	0.07	0.00		0.00	0.00	0.00	0.00	0.03	0.00	0.01
Load (non adj)	0.24	0.00	0.00	0.08	0.00	0.11	0.00	0.00	0.00	0.00	0.03	0.00	0.02
Load (t/yr)	**0.24**	**0.00**	**0.00**	**0.08**	**0.00**	**0.11**	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	**0.00**	**0.02**
Load (%)	**100.0%**	**0.0%**	**0.6%**	**33.0%**	**0.0%**	**47.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**12.6%**	**0.0%**	**6.5%**

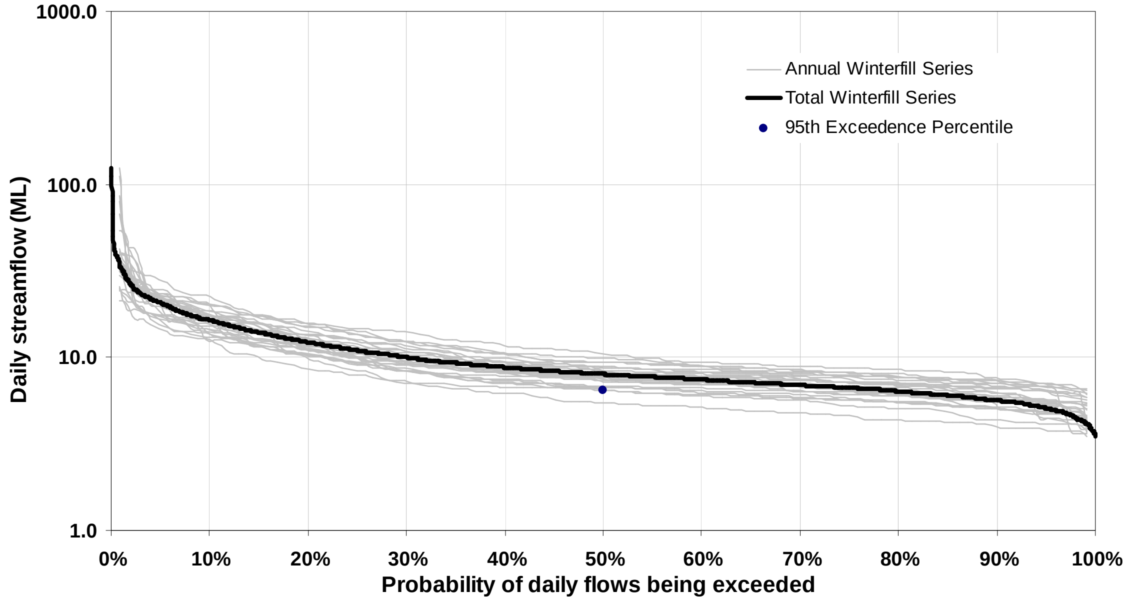


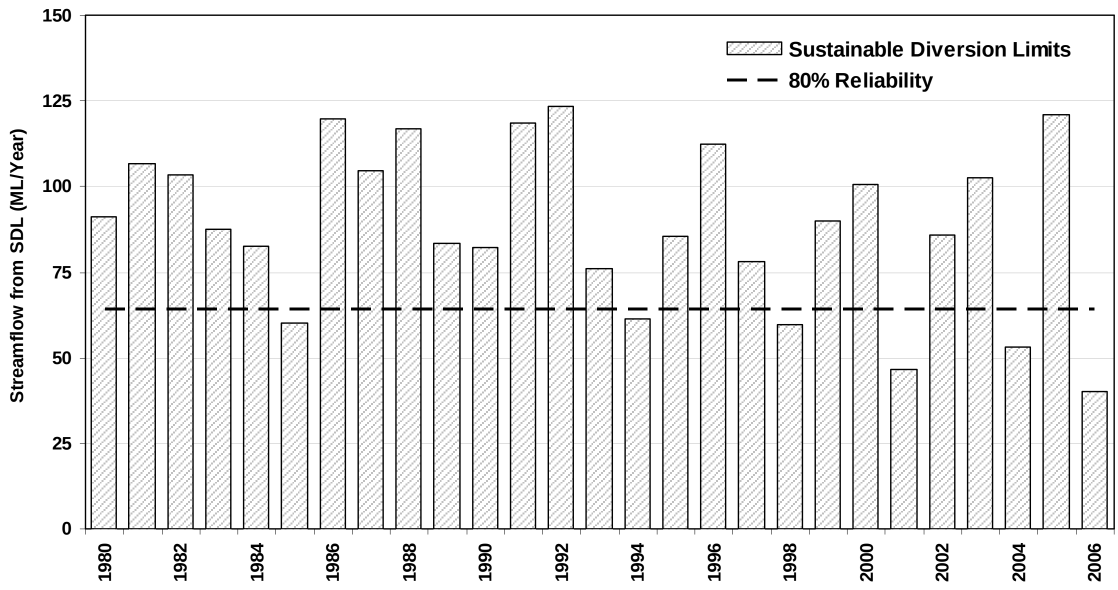
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	5.0	0.0	1.6	2.1	0.0	2.9	0.0	0.0	0.0	0.0	1.1	0.0	0.5
1998	6.0	0.0	2.0	2.5	0.0	3.5	0.0	0.0	0.0	0.0	1.3	0.0	0.6
1999	5.4	0.0	1.6	2.3	0.0	3.0	0.0	0.0	0.0	0.0	1.1	0.0	0.5
2000	5.1	0.0	1.6	2.2	0.0	2.9	0.0	0.0	0.0	0.0	1.1	0.0	0.5
2001	4.8	0.0	1.4	2.0	0.0	2.7	0.0	0.0	0.0	0.0	1.0	0.0	0.5
2002	5.7	0.0	1.8	2.4	0.0	3.4	0.0	0.0	0.0	0.0	1.3	0.0	0.6
2003	5.5	0.0	1.7	2.3	0.0	3.2	0.0	0.0	0.0	0.0	1.2	0.0	0.5
2004	4.8	0.0	1.5	2.0	0.0	2.8	0.0	0.0	0.0	0.0	1.1	0.0	0.5
2005	5.9	0.0	1.8	2.4	0.0	3.4	0.0	0.0	0.0	0.0	1.3	0.0	0.6
2006	3.7	0.0	1.2	1.6	0.0	2.2	0.0	0.0	0.0	0.0	0.9	0.0	0.4
Load (non adj)	5.2	0.0	1.6	2.2	0.0	3.0	0.0	0.0	0.0	0.0	1.1	0.0	0.5
Load (t/yr)	**5.2**	**0.0**	**0.9**	**1.2**	**0.0**	**1.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.6**	**0.0**	**0.3**
Load (%)	**100.0%**	**0.0%**	**16.8%**	**22.7%**	**0.0%**	**31.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**11.7%**	**0.0%**	**5.0%**



CBD – Sustainable diversion limits

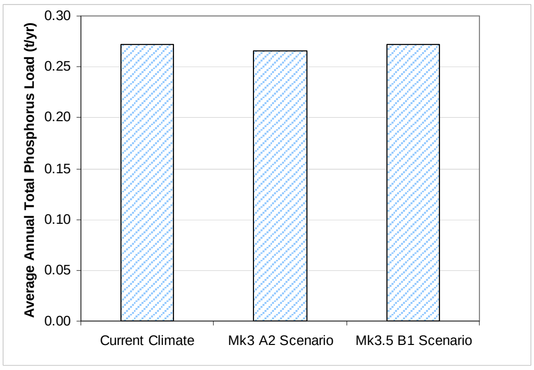




CBD – Climate change

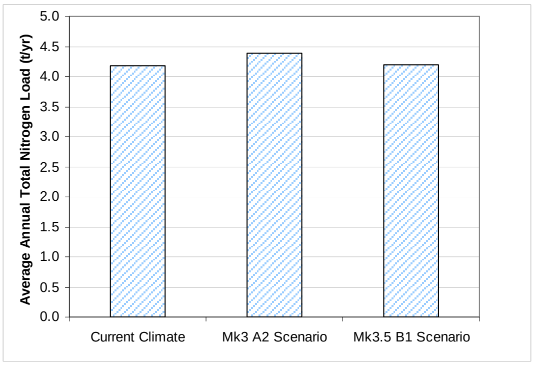
Phosphorus

	At Catchment Outlet		
Year	*Current Climate Load (t/yr)*	*Mk3 A2 Climate Change Scenario Load (t/yr)*	*Mk3.5 B1 Climate Change Scenario Load (t/yr)*
2057	0.25	0.25	0.25
2058	0.30	0.29	0.30
2059	0.27	0.26	0.27
2060	0.26	0.25	0.26
2061	0.24	0.24	0.24
2062	0.30	0.30	0.30
2063	0.30	0.29	0.30
2064	0.26	0.25	0.26
2065	0.32	0.31	0.32
2066	0.22	0.22	0.22
Average Load for RF Sequence (t/yr)	**0.27**	**0.27**	**0.27**



Nitrogen

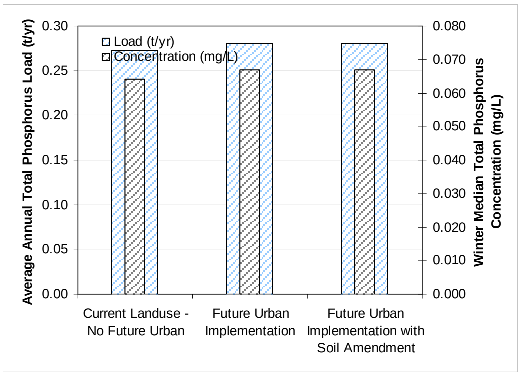
	At Catchment Outlet		
Year	*Current Climate Load (t/yr)*	*Mk3 A2 Climate Change Scenario Load (t/yr)*	*Mk3.5 B1 Climate Change Scenario Load (t/yr)*
2057	4.0	4.2	4.0
2058	4.7	4.9	4.7
2059	4.2	4.6	4.3
2060	4.1	4.4	4.1
2061	3.8	4.0	3.8
2062	4.5	4.7	4.5
2063	4.5	4.7	4.5
2064	3.8	4.0	3.8
2065	4.8	5.1	4.9
2066	3.2	3.4	3.2
Average Load for RF Sequence (t/yr)	**4.2**	**4.4**	**4.2**



CBD – Future urban

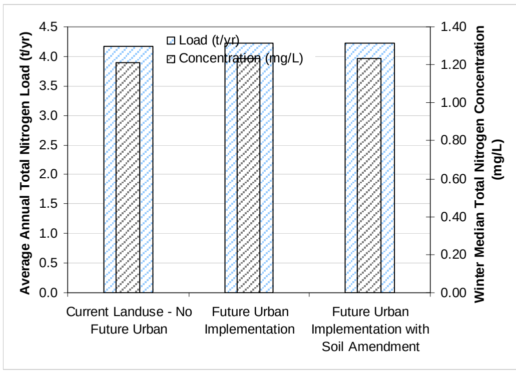
Phosphorus

	At Catchment Outlet		
Year	*Current Landuse - No Future Urban Load (t/yr)*	*Future Urban Implementation Load (t/yr)*	*Future Urban Implementation with Soil Amendment Load (t/yr)*
2057	0.25	0.26	0.26
2058	0.30	0.30	0.30
2059	0.27	0.27	0.27
2060	0.26	0.27	0.27
2061	0.24	0.25	0.25
2062	0.30	0.31	0.31
2063	0.30	0.31	0.31
2064	0.26	0.26	0.26
2065	0.32	0.33	0.33
2066	0.22	0.23	0.23
Average Load for RF Sequence (t/yr)	**0.27**	**0.28**	**0.28**
Median Winter Concentration (mg/L)	**0.064**	**0.067**	**0.067**



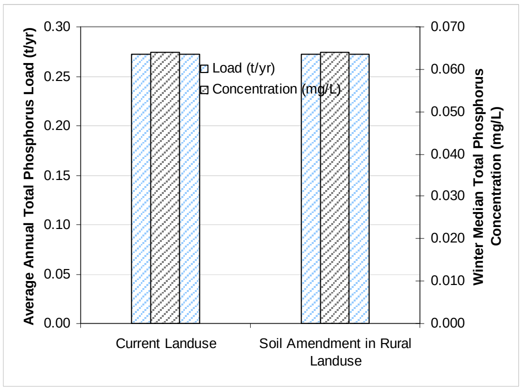
Nitrogen

	At Catchment Outlet		
Year	*Current Landuse - No Future Urban Load (t/yr)*	*Future Urban Implementation Load (t/yr)*	*Future Urban Implementation with Soil Amendment Load (t/yr)*
2057	4.0	4.1	4.1
2058	4.7	4.7	4.7
2059	4.2	4.3	4.3
2060	4.1	4.1	4.1
2061	3.8	3.9	3.9
2062	4.5	4.6	4.6
2063	4.5	4.5	4.5
2064	3.8	3.9	3.9
2065	4.8	4.9	4.9
2066	3.2	3.3	3.3
Average Load for RF Sequence (t/yr)	**4.2**	**4.2**	**4.2**
Median Winter Concentration (mg/L)	**1.21**	**1.24**	**1.24**



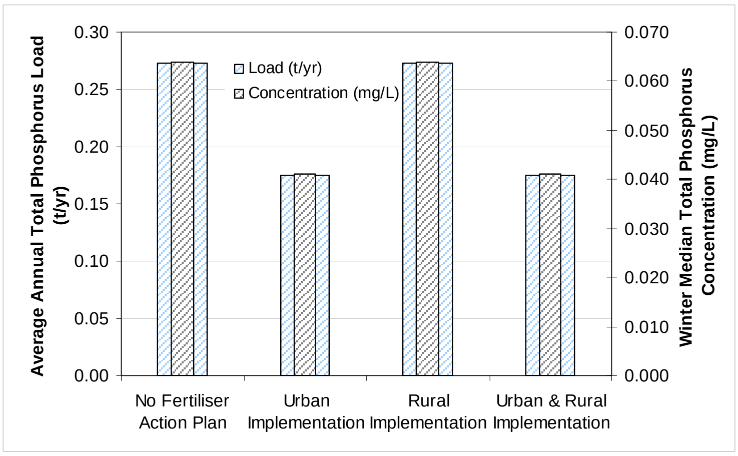
CBD – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.25	0.25
2058	0.30	0.30
2059	0.27	0.27
2060	0.26	0.26
2061	0.24	0.24
2062	0.30	0.30
2063	0.30	0.30
2064	0.26	0.26
2065	0.32	0.32
2066	0.22	0.22
Average Load for RF Sequence (t/yr)	**0.27**	**0.27**
Median Winter Concentration (mg/L)	**0.064**	**0.064**



CBD – *Fertiliser action plan*

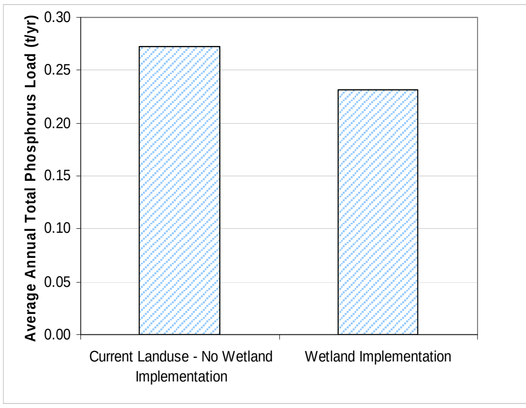
Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.25	0.16	0.25	0.16
2058	0.30	0.19	0.30	0.19
2059	0.27	0.17	0.27	0.17
2060	0.26	0.17	0.26	0.17
2061	0.24	0.16	0.24	0.16
2062	0.30	0.19	0.30	0.19
2063	0.30	0.19	0.30	0.19
2064	0.26	0.16	0.26	0.16
2065	0.32	0.21	0.32	0.21
2066	0.22	0.14	0.22	0.14
Average Load for RF Sequence (t/yr)	**0.27**	**0.17**	**0.27**	**0.17**
Median Winter Concentration (mg/L)	**0.064**	**0.041**	**0.064**	**0.041**



CBD – Wetland implementation

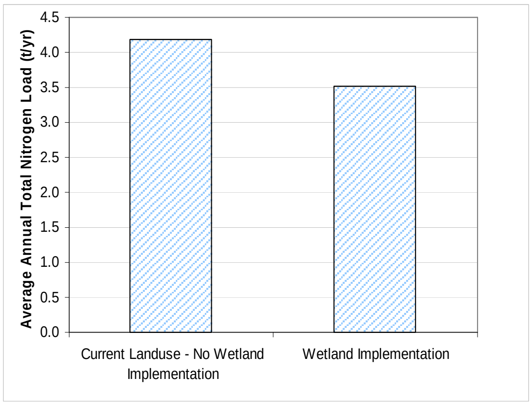
Phosphorus

	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.25	0.22
2058	0.30	0.25
2059	0.27	0.23
2060	0.26	0.22
2061	0.24	0.21
2062	0.30	0.26
2063	0.30	0.25
2064	0.26	0.22
2065	0.32	0.27
2066	0.22	0.19
Average Load for RF Sequence (t/yr)	**0.27**	**0.23**



Nitrogen

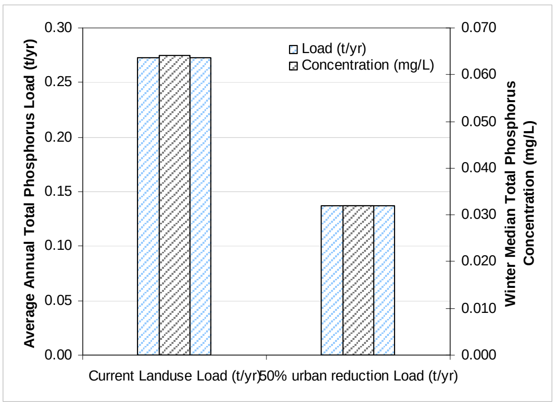
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	4.0	3.4
2058	4.7	4.0
2059	4.2	3.6
2060	4.1	3.4
2061	3.8	3.2
2062	4.5	3.8
2063	4.5	3.7
2064	3.8	3.2
2065	4.8	4.1
2066	3.2	2.7
Average Load for RF Sequence (t/yr)	**4.2**	**3.5**



CBD – Urban 50% reduction

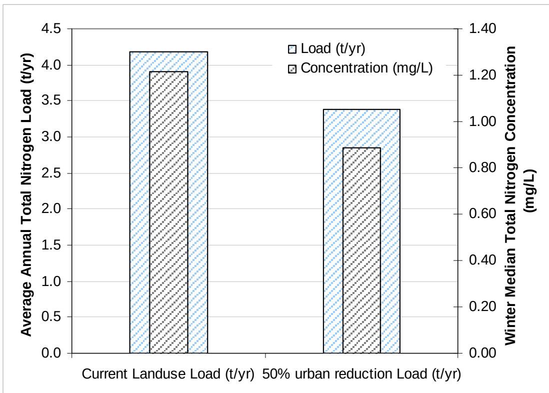
Phosphorus

	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.25	0.13
2058	0.30	0.15
2059	0.27	0.13
2060	0.26	0.13
2061	0.24	0.12
2062	0.30	0.15
2063	0.30	0.15
2064	0.26	0.13
2065	0.32	0.16
2066	0.22	0.11
Average Load for RF Sequence (t/yr)	**0.27**	**0.14**
Median Winter Concentration (mg/L)	**0.064**	**0.032**



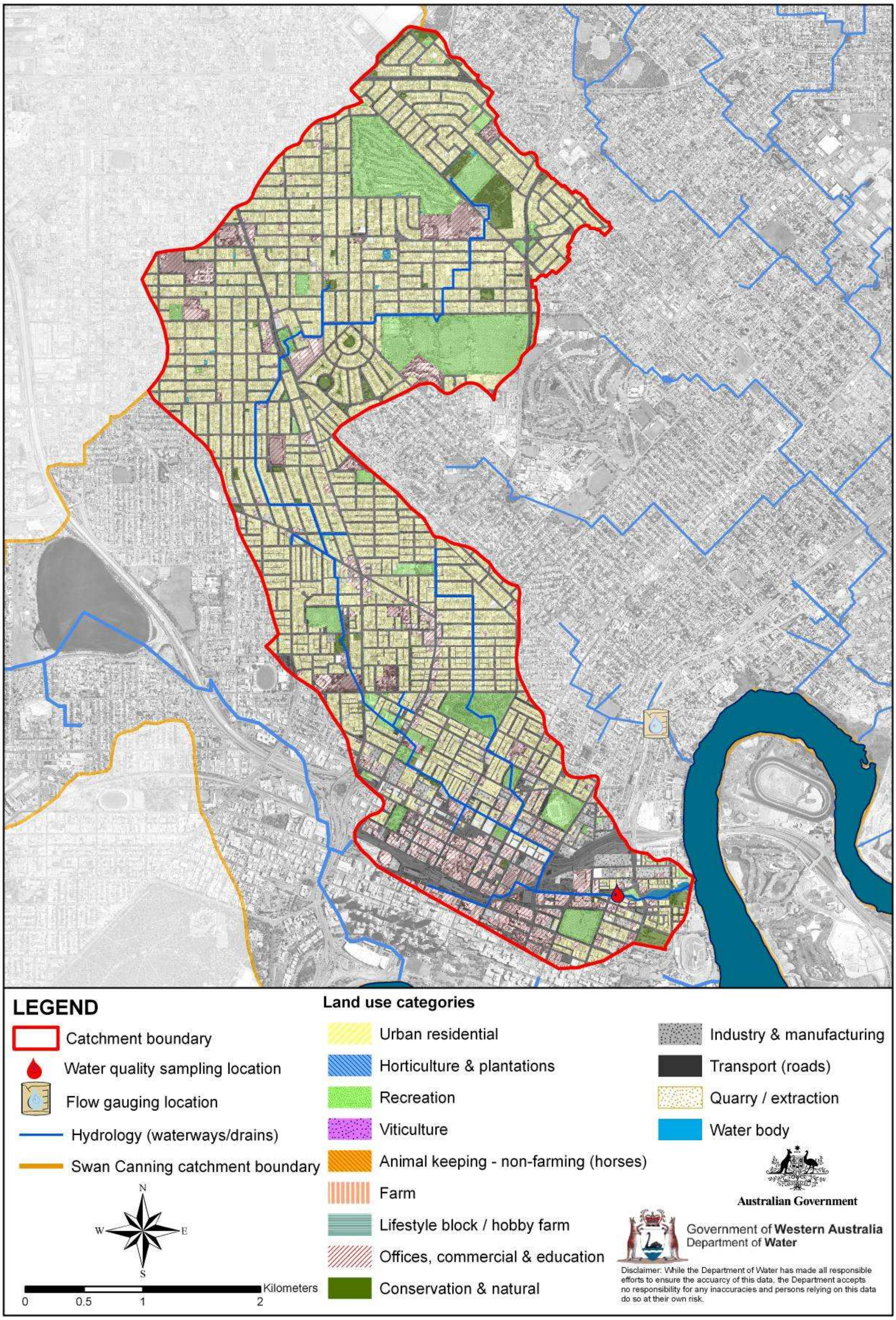
Nitrogen

	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	4.0	3.2
2058	4.7	3.8
2059	4.2	3.3
2060	4.1	3.3
2061	3.8	3.1
2062	4.5	3.7
2063	4.5	3.6
2064	3.8	3.1
2065	4.8	3.9
2066	3.2	2.7
Average Load for RF Sequence (t/yr)	**4.2**	**3.4**
Median Winter Concentration (mg/L)	**1.21**	**0.89**

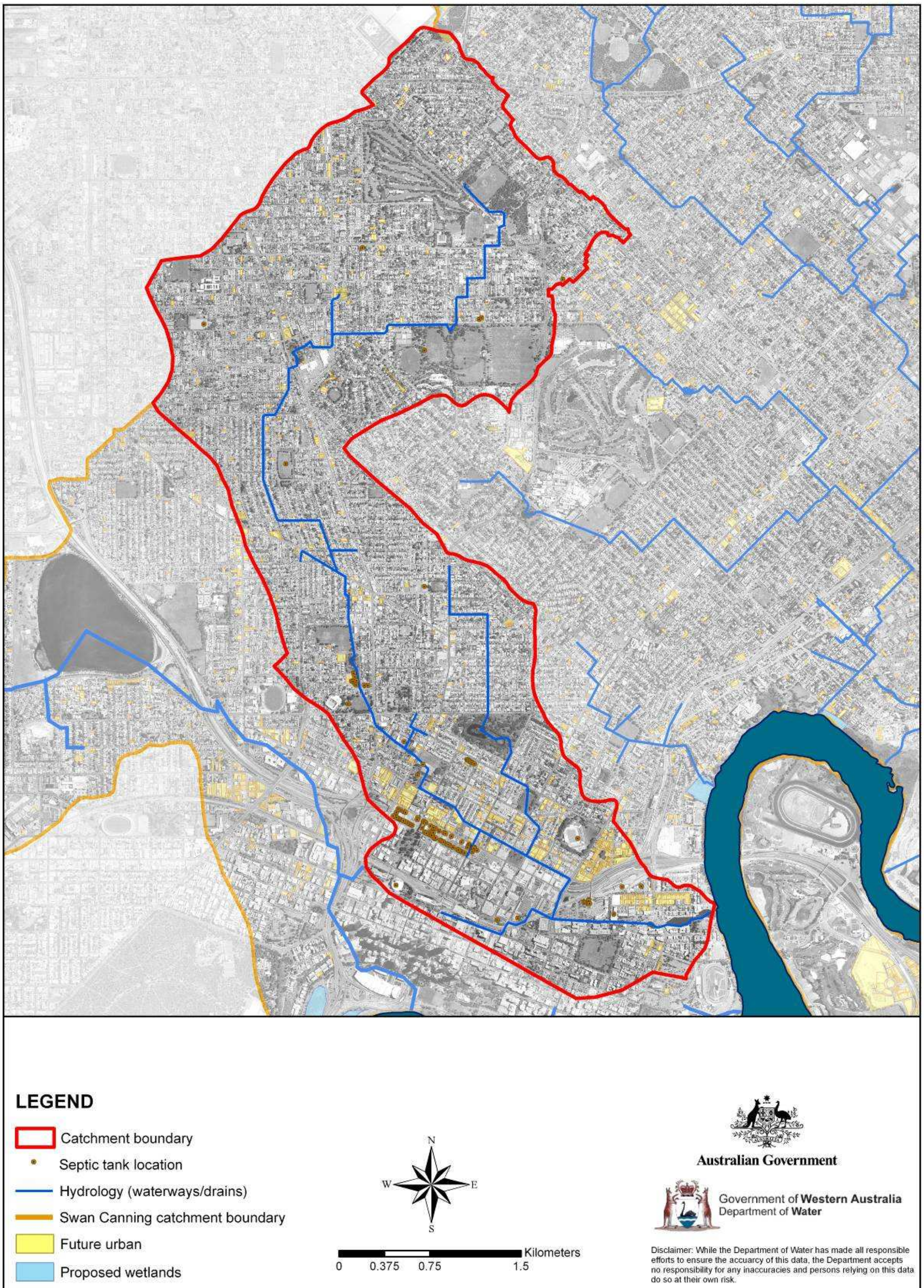


Claisebrook Main Drain

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Claisebrook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary		
	Current	20% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*
1997	0.28	0.22
1998	0.31	0.24
1999	0.35	0.26
2000	0.35	0.27
2001	0.32	0.26
2002	0.31	0.25
2003	0.31	0.26
2004	0.24	0.20
2005	0.35	0.30
2006	0.18	0.16
Average	**0.30**	**0.24**
Median Winter Conc (mg/L):		
SQUARE	**0.056**	**0.046**
Target	**0.050**	
Load Target (t/yr)		**0.24**
Load Reduction Target (t/yr)		**0.06**
Required Reduction (%)		**19%**
Time Required (yr)		**20**

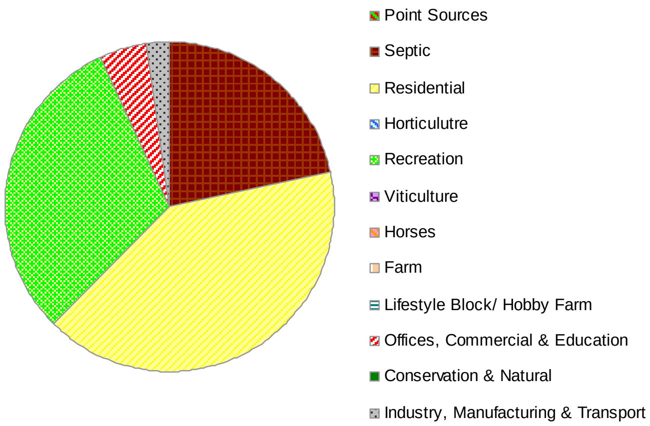
Nitrogen

At Outlet to Swan River Estuary		
	Current	52% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*
1997	5.0	1.3
1998	5.0	1.4
1999	5.8	1.5
2000	5.2	1.4
2001	4.5	1.2
2002	4.5	1.3
2003	4.9	1.5
2004	3.9	1.2
2005	4.8	1.5
2006	2.9	0.9
Average	**4.7**	**1.3**
Median Winter Conc (mg/L):		
SQUARE	**1.70**	**0.49**
Target	**0.50**	
Load Target (t/yr)		**1.3**
Load Reduction Target (t/yr)		**3.3**
Required Reduction (%)		**71%**
Time Required (yr)		**40**

Claisebrook Main Drain – Source separation

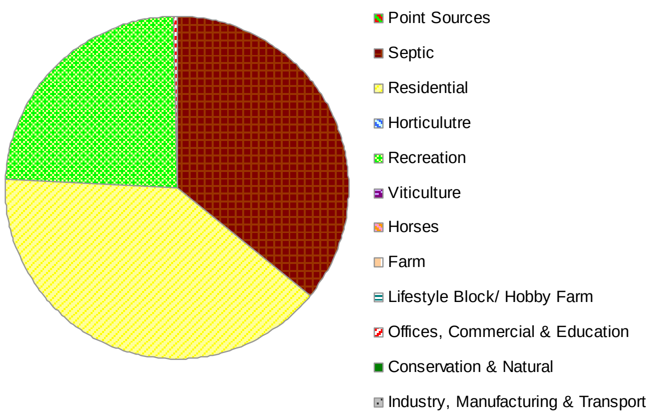
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.28	0.00	0.07	0.11	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.01
1998	0.31	0.00	0.08	0.12	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.00	0.01
1999	0.35	0.00	0.09	0.13	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2000	0.35	0.00	0.09	0.14	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2001	0.32	0.00	0.07	0.13	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2002	0.31	0.00	0.07	0.13	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2003	0.31	0.00	0.06	0.13	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2004	0.24	0.00	0.04	0.10	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2005	0.35	0.00	0.06	0.15	0.00	0.11	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2006	0.18	0.00	0.03	0.08	0.00	0.06	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Load (non adj)	0.30	0.00	0.07	0.12	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Load (t/yr)	**0.30**	**0.00**	**0.06**	**0.12**	**0.00**	**0.09**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**21.7%**	**40.8%**	**0.0%**	**30.5%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**4.9%**	**0.0%**	**2.2%**

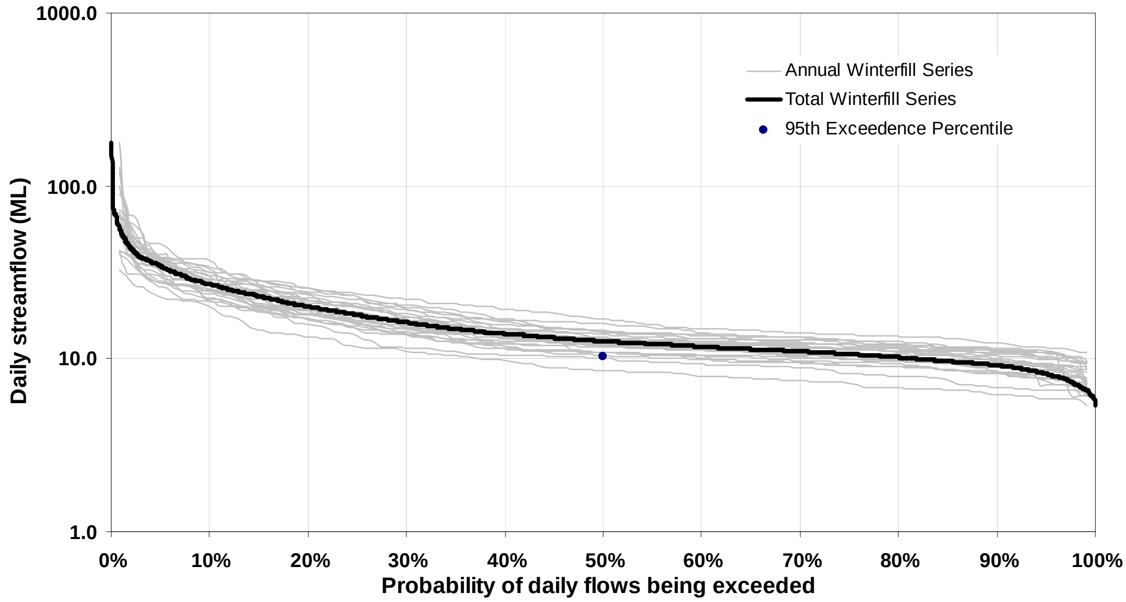


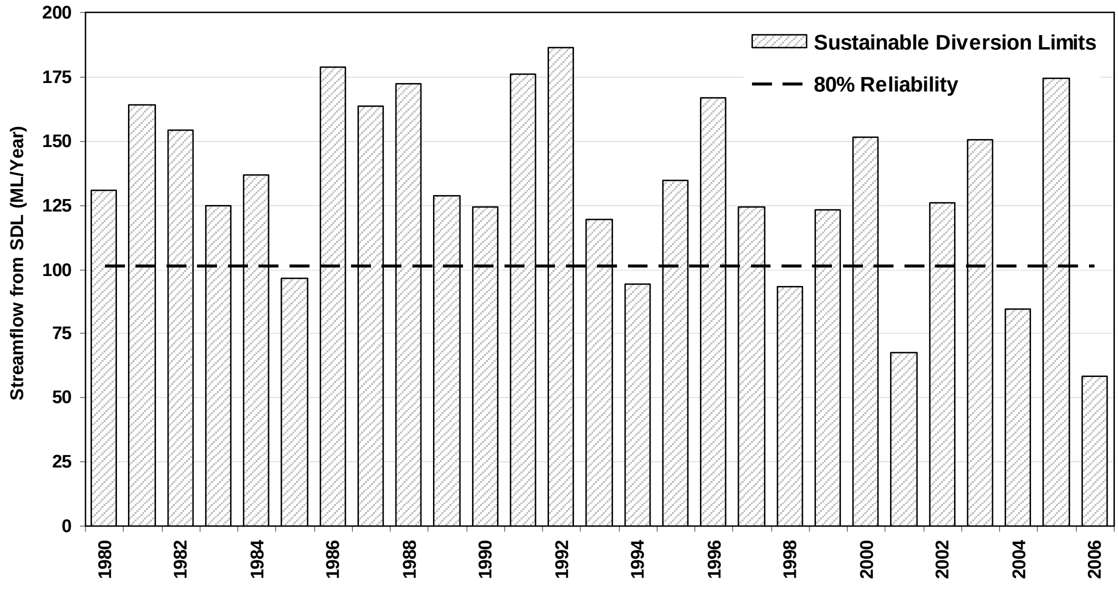
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	5.0	0.0	1.7	1.4	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	5.0	0.0	1.7	1.4	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	5.8	0.0	2.0	1.6	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	5.2	0.0	1.7	1.5	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	4.5	0.0	1.3	1.3	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	4.5	0.0	1.2	1.4	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	4.9	0.0	1.1	1.6	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	3.9	0.0	0.8	1.3	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	4.8	0.0	0.9	1.7	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	2.9	0.0	0.5	1.1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (non adj)	4.7	0.0	1.3	1.4	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (t/yr)	**4.7**	**0.0**	**1.7**	**1.9**	**0.0**	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**35.7%**	**40.1%**	**0.0%**	**23.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.3%**	**0.0%**	**0.0%**



Claisebrook Main Drain – Sustainable diversion limits

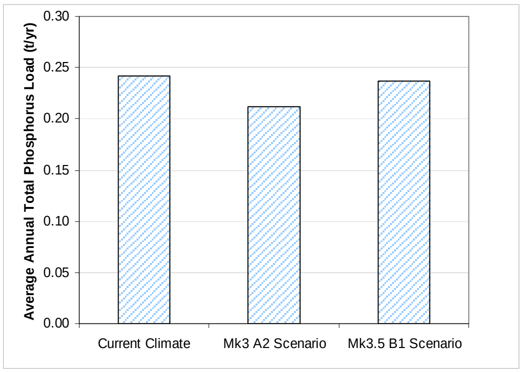




Claisebrook Main Drain – Climate change

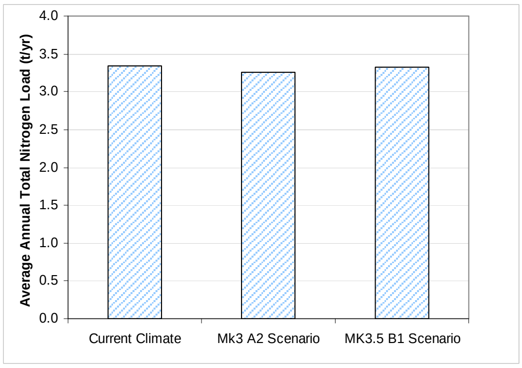
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.22	0.19	0.22
2058	0.24	0.21	0.24
2059	0.26	0.24	0.26
2060	0.27	0.25	0.27
2061	0.26	0.23	0.25
2062	0.25	0.21	0.24
2063	0.26	0.22	0.25
2064	0.20	0.18	0.20
2065	0.30	0.25	0.29
2066	0.16	0.14	0.16
Average Load for RF Sequence (t/yr)	**0.24**	**0.21**	**0.24**



Nitrogen

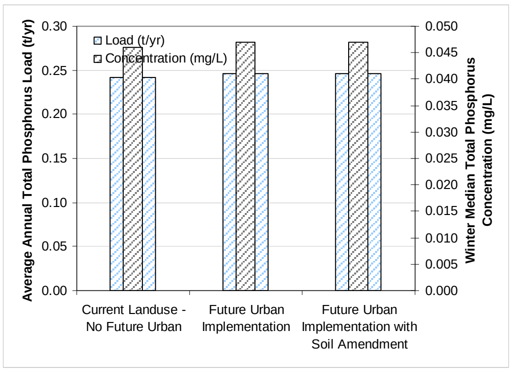
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	3.3	3.2	3.3
2058	3.4	3.3	3.4
2059	3.8	3.8	3.8
2060	3.5	3.5	3.5
2061	3.1	3.0	3.1
2062	3.3	3.2	3.3
2063	3.7	3.6	3.7
2064	3.0	2.9	3.0
2065	3.8	3.8	3.9
2066	2.4	2.2	2.3
Average Load for RF Sequence (t/yr)	**3.3**	**3.3**	**3.3**



Claisebrook Main Drain – Future urban

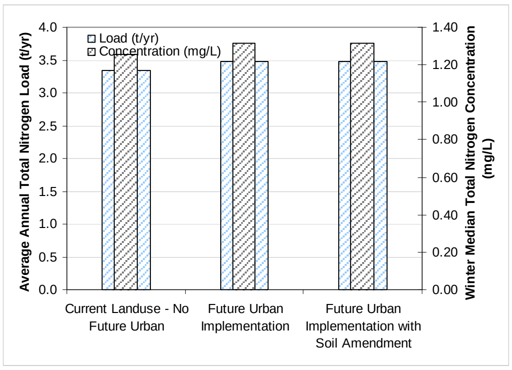
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.22	0.22	0.22
2058	0.24	0.25	0.25
2059	0.26	0.27	0.27
2060	0.27	0.28	0.28
2061	0.26	0.26	0.26
2062	0.25	0.25	0.25
2063	0.26	0.26	0.26
2064	0.20	0.20	0.20
2065	0.30	0.31	0.30
2066	0.16	0.16	0.16
Average Load for RF Sequence (t/yr)	**0.24**	**0.25**	**0.25**
Median Winter Concentration (mg/L)	**0.046**	**0.047**	**0.047**



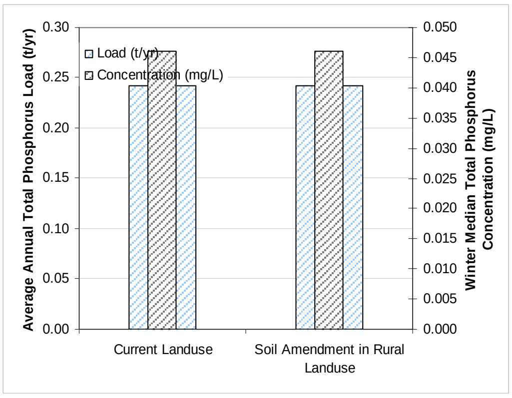
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	3.3	3.4	3.4
2058	3.4	3.5	3.5
2059	3.8	4.0	4.0
2060	3.5	3.6	3.6
2061	3.1	3.3	3.3
2062	3.3	3.4	3.4
2063	3.7	3.9	3.9
2064	3.0	3.2	3.2
2065	3.8	4.0	4.0
2066	2.4	2.5	2.5
Average Load for RF Sequence (t/yr)	**3.3**	**3.5**	**3.5**
Median Winter Concentration (mg/L)	**1.25**	**1.32**	**1.32**



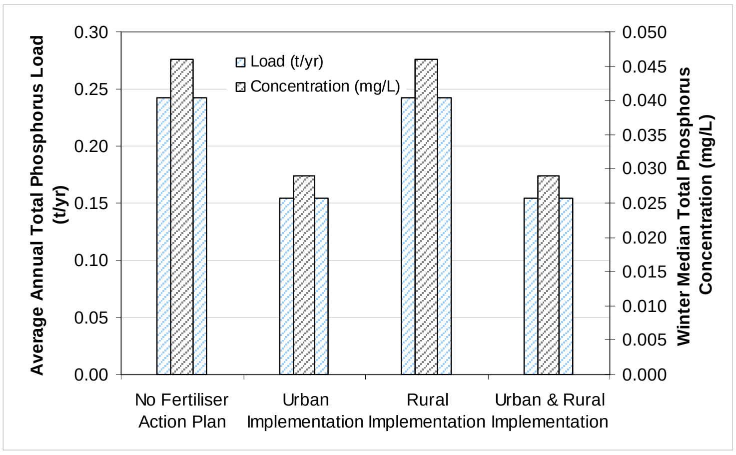
Claisebrook Main Drain – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.22	0.22
2058	0.24	0.24
2059	0.26	0.26
2060	0.27	0.27
2061	0.26	0.26
2062	0.25	0.25
2063	0.26	0.26
2064	0.20	0.20
2065	0.30	0.30
2066	0.16	0.16
Average Load for RF Sequence (t/yr)	**0.24**	**0.24**
Median Winter Concentration (mg/L)	**0.046**	**0.046**



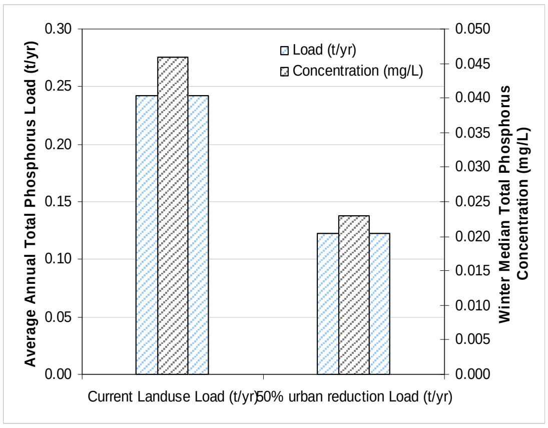
Claisebrook Main Drain – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.22	0.14	0.22	0.14
2058	0.24	0.15	0.24	0.15
2059	0.26	0.17	0.26	0.17
2060	0.27	0.17	0.27	0.17
2061	0.26	0.16	0.26	0.16
2062	0.25	0.16	0.25	0.16
2063	0.26	0.16	0.26	0.16
2064	0.20	0.13	0.20	0.13
2065	0.30	0.19	0.30	0.19
2066	0.16	0.10	0.16	0.10
Average Load for RF Sequence (t/yr)	**0.24**	**0.15**	**0.24**	**0.15**
Median Winter Concentration (mg/L)	**0.046**	**0.029**	**0.046**	**0.029**

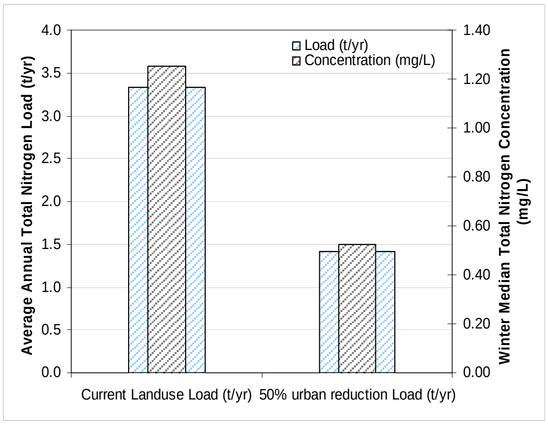


Claisebrook Main Drain – Urban 50% reduction

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.22	0.11
2058	0.24	0.12
2059	0.26	0.13
2060	0.27	0.14
2061	0.26	0.13
2062	0.25	0.13
2063	0.26	0.13
2064	0.20	0.10
2065	0.30	0.15
2066	0.16	0.08
Average Load for RF Sequence (t/yr)	**0.24**	**0.12**
Median Winter Concentration (mg/L)	**0.046**	**0.023**

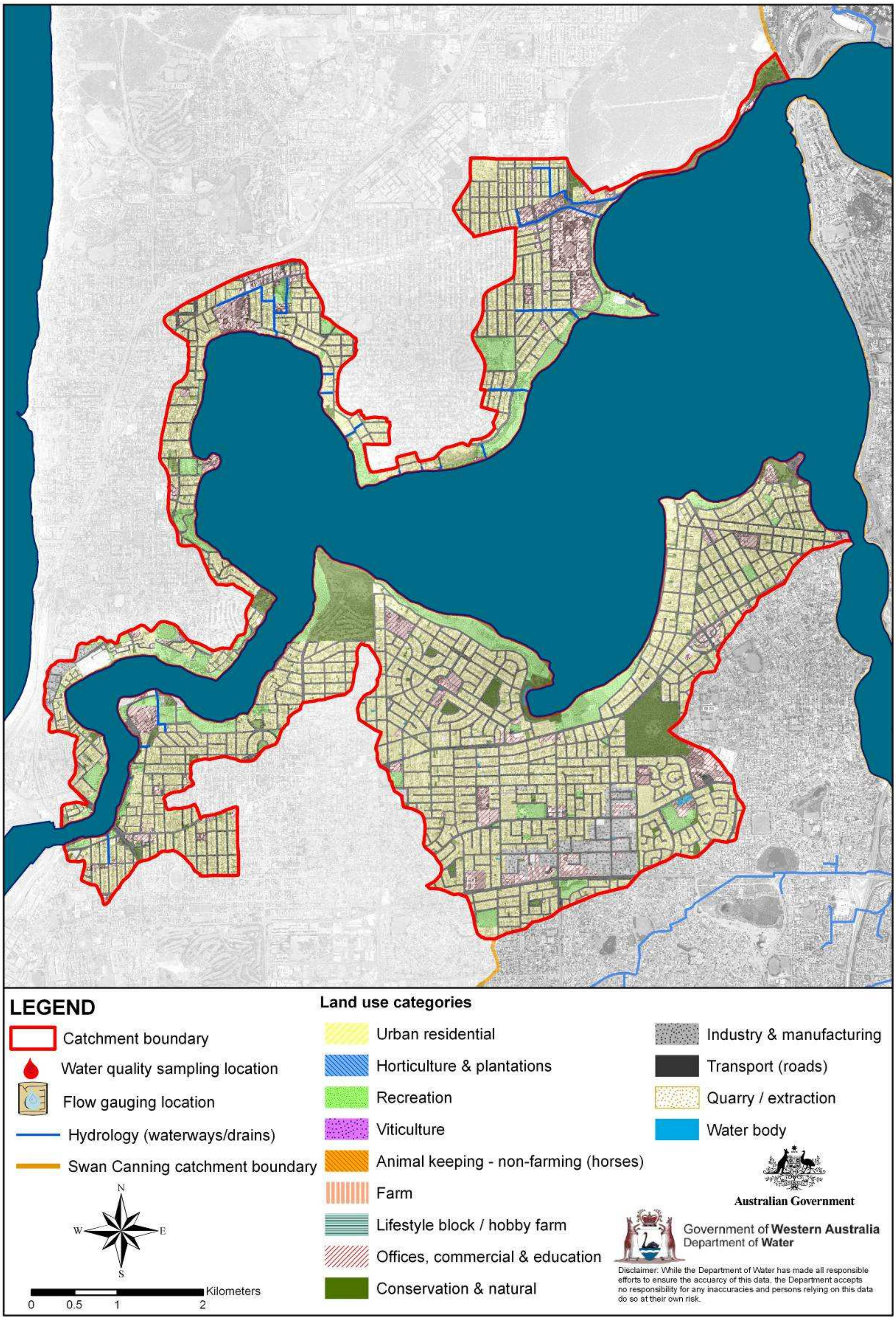


Nitrogen		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	3.3	1.4
2058	3.4	1.4
2059	3.8	1.6
2060	3.5	1.5
2061	3.1	1.3
2062	3.3	1.4
2063	3.7	1.6
2064	3.0	1.3
2065	3.8	1.6
2066	2.4	1.0
Average Load for RF Sequence (t/yr)	**3.3**	**1.4**
Median Winter Concentration (mg/L)	**1.25**	**0.52**

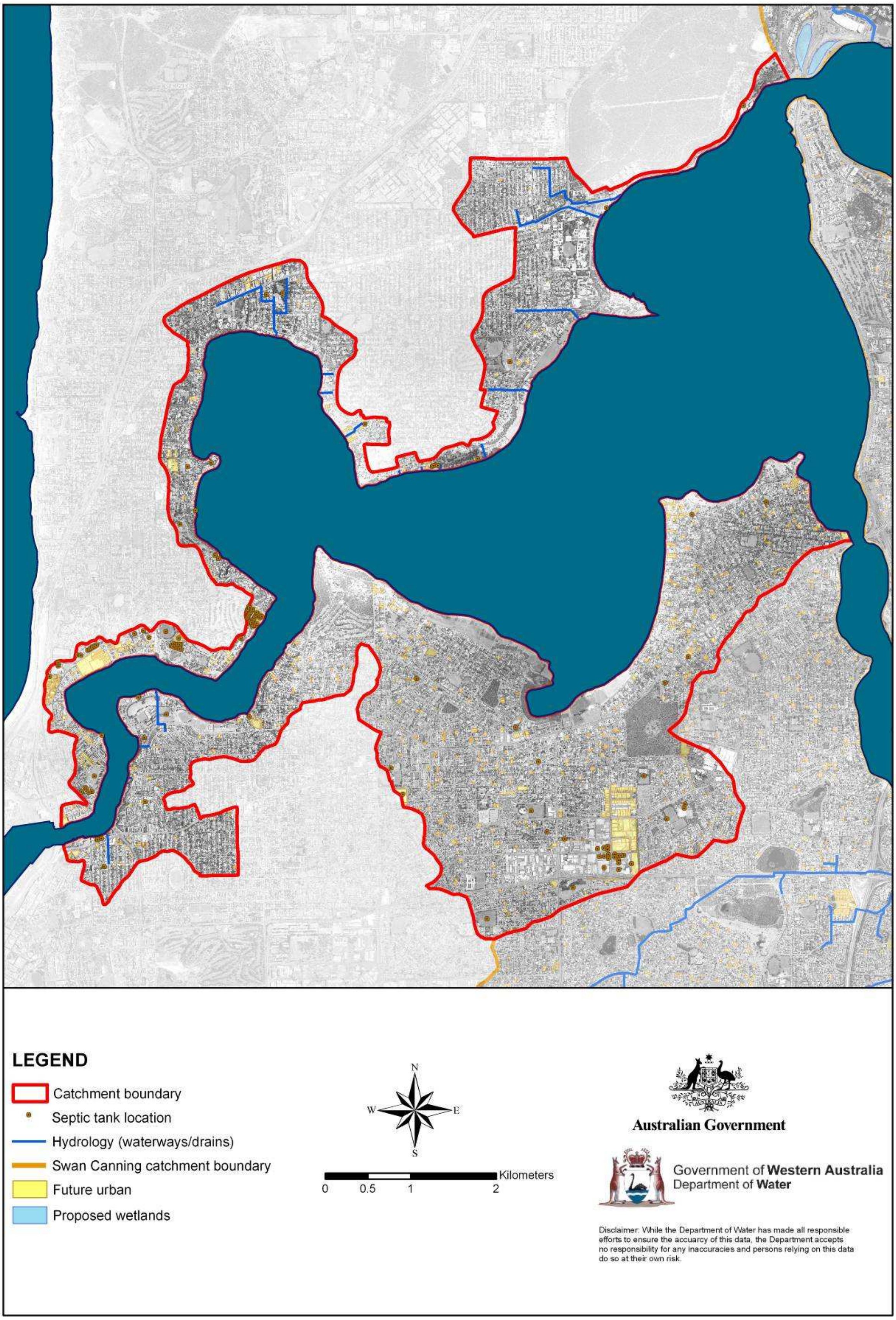


Downstream

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Downstream - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary		
	Current	No Reduction Required
Year	*Load (t/yr)*	*Load (t/yr)*
1997	0.29	-
1998	0.32	-
1999	0.29	-
2000	0.29	-
2001	0.28	-
2002	0.30	-
2003	0.33	-
2004	0.27	-
2005	0.34	-
2006	0.28	-
Average	**0.30**	**-**
Median Winter Concentration (mg/L):		
SQUARE:	**0.050**	
Target:	**0.050**	
Load Target (t/yr)		**0.30**
Load Reduction Target (t/yr)		**0.00**
Required Reduction (%)		**0%**
Time Required (yr)		**0**

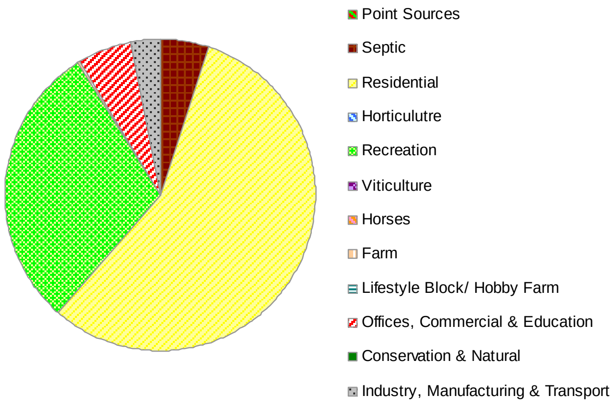
Nitrogen

At Outlet to Swan River Estuary		
	Current	60% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*
1997	6.3	3.4
1998	7.3	3.8
1999	8.0	3.6
2000	7.1	3.3
2001	6.2	3.1
2002	6.8	3.5
2003	8.0	4.0
2004	6.3	3.1
2005	7.8	4.0
2006	5.5	3.0
Average	**6.9**	**3.5**
Median Winter Concentration (mg/L):		
SQUARE:	**1.20**	**0.49**
Target:	**0.50**	
Load Target (t/yr)		**3.5**
Load Reduction Target (t/yr)		**3.5**
Required Reduction (%)		**50%**
Time Required (yr)		**30**

Downstream – Source separation

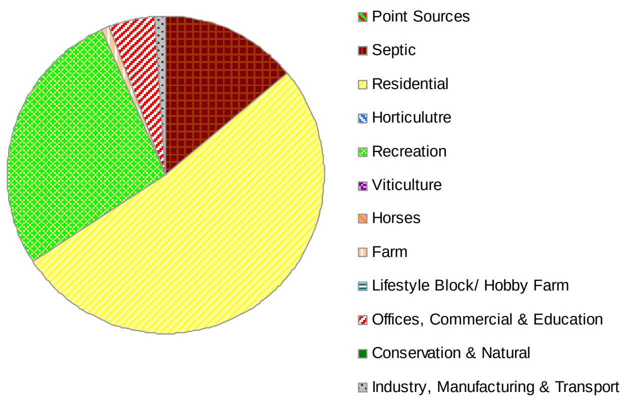
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.30	0.00	0.02	0.17	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.00	0.01
1998	0.33	0.00	0.02	0.19	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.01
1999	0.30	0.00	0.02	0.17	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2000	0.30	0.00	0.02	0.17	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2001	0.28	0.00	0.02	0.16	0.00	0.08	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2002	0.31	0.00	0.02	0.18	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2003	0.33	0.00	0.01	0.19	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2004	0.27	0.00	0.01	0.15	0.00	0.08	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2005	0.34	0.00	0.01	0.20	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2006	0.27	0.00	0.01	0.16	0.00	0.08	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Load (non adj)	0.30	0.00	0.02	0.17	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Load (t/yr)	**0.30**	**0.00**	**0.02**	**0.17**	**0.00**	**0.09**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**5.0%**	**56.5%**	**0.0%**	**29.6%**	**0.0%**	**0.0%**	**0.2%**	**0.0%**	**5.7%**	**0.0%**	**2.9%**



Nitrogen (t/yr)

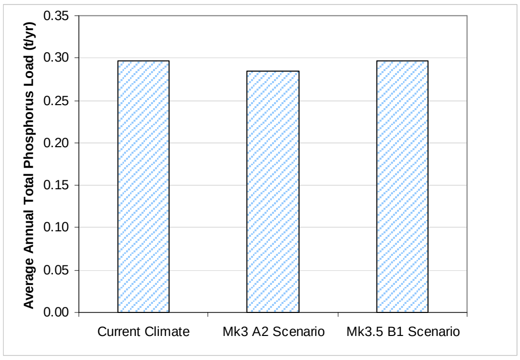
Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	5.4	0.4	1.4	3.0	0.4	1.8	0.4	0.4	0.4	0.4	0.6	0.4	0.5
1998	6.2	0.5	1.7	3.6	0.5	2.1	0.5	0.5	0.5	0.5	0.7	0.5	0.5
1999	6.8	0.4	1.6	3.7	0.4	2.1	0.4	0.4	0.4	0.4	0.7	0.4	0.4
2000	6.2	0.4	1.4	3.5	0.4	2.0	0.4	0.4	0.4	0.4	0.6	0.4	0.4
2001	5.6	0.4	1.1	3.2	0.4	1.9	0.4	0.4	0.4	0.4	0.6	0.4	0.4
2002	6.3	0.4	1.1	3.6	0.4	2.1	0.4	0.4	0.5	0.4	0.7	0.4	0.5
2003	7.5	0.4	1.1	4.2	0.4	2.4	0.4	0.4	0.5	0.4	0.8	0.4	0.5
2004	6.0	0.3	0.9	3.4	0.3	1.9	0.3	0.3	0.4	0.3	0.6	0.3	0.4
2005	7.4	0.4	1.2	4.3	0.4	2.5	0.4	0.4	0.5	0.4	0.8	0.4	0.5
2006	5.3	0.4	1.0	3.1	0.4	1.8	0.4	0.4	0.4	0.4	0.6	0.4	0.4
Load (non adj)	6.3	0.4	1.2	3.6	0.4	2.1	0.4	0.4	0.4	0.4	0.7	0.4	0.5
Load (t/yr)	**6.3**	**0.0**	**0.8**	**3.1**	**0.0**	**1.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.3**	**0.0**	**0.1**
Load (%)	**100.0%**	**0.0%**	**13.2%**	**49.6%**	**0.0%**	**26.5%**	**0.0%**	**0.0%**	**0.8%**	**0.0%**	**4.4%**	**0.0%**	**1.1%**



Downstream – Climate change

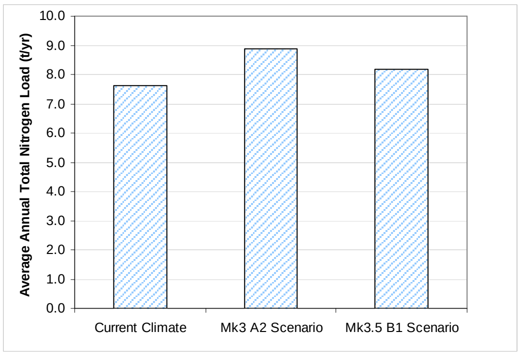
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.29	0.27	0.28
2058	0.32	0.31	0.32
2059	0.29	0.28	0.29
2060	0.29	0.27	0.29
2061	0.27	0.26	0.27
2062	0.30	0.29	0.30
2063	0.33	0.31	0.33
2064	0.27	0.25	0.27
2065	0.34	0.33	0.34
2066	0.27	0.26	0.27
Average Load for RF Sequence (t/yr)	**0.30**	**0.28**	**0.30**



Nitrogen

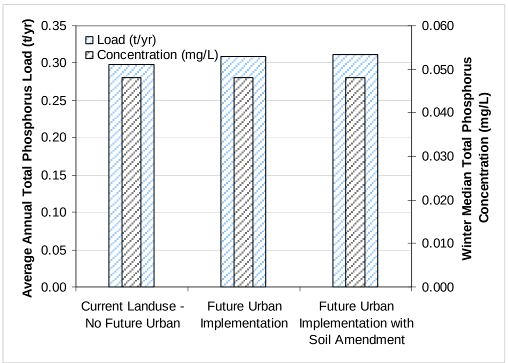
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	7.7	8.9	8.3
2058	8.3	9.9	9.0
2059	8.4	10.2	9.0
2060	7.4	8.9	8.0
2061	6.7	7.6	7.2
2062	7.4	8.5	8.0
2063	8.7	9.8	9.3
2064	6.8	7.9	7.3
2065	8.5	10.1	9.2
2066	6.1	7.0	6.6
Average Load for RF Sequence (t/yr)	**7.6**	**8.9**	**8.2**



Downstream – Future urban

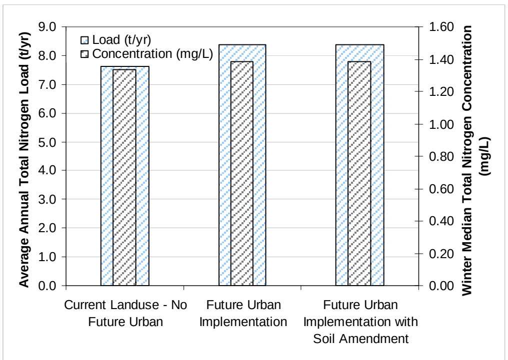
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.29	0.30	0.30
2058	0.32	0.34	0.34
2059	0.29	0.30	0.30
2060	0.29	0.30	0.30
2061	0.27	0.29	0.29
2062	0.30	0.31	0.32
2063	0.33	0.34	0.34
2064	0.27	0.28	0.28
2065	0.34	0.35	0.36
2066	0.27	0.29	0.29
Average Load for RF Sequence (t/yr)	**0.30**	**0.31**	**0.31**
Median Winter Concentration (mg/L)	**0.048**	**0.048**	**0.048**



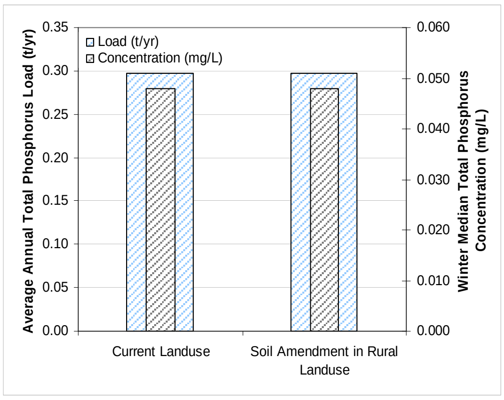
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	7.7	8.4	8.4
2058	8.3	9.2	9.2
2059	8.4	9.2	9.2
2060	7.4	8.2	8.2
2061	6.7	7.4	7.4
2062	7.4	8.2	8.2
2063	8.7	9.6	9.6
2064	6.8	7.5	7.5
2065	8.5	9.5	9.5
2066	6.1	6.8	6.8
Average Load for RF Sequence (t/yr)	**7.6**	**8.4**	**8.4**
Median Winter Concentration (mg/L)	**1.33**	**1.38**	**1.38**



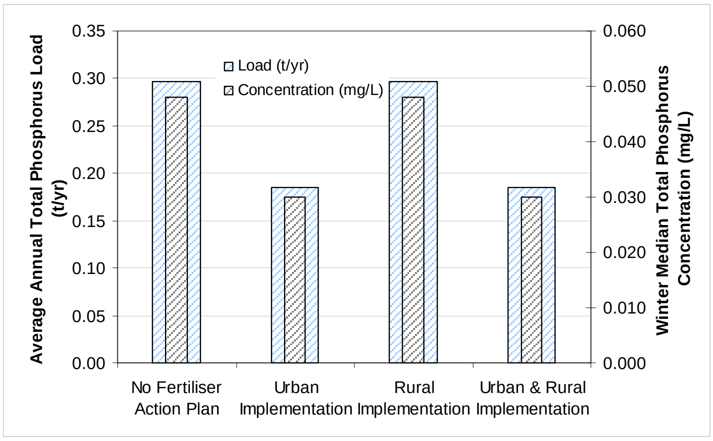
Downstream – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.29	0.29
2058	0.32	0.32
2059	0.29	0.29
2060	0.29	0.29
2061	0.27	0.27
2062	0.30	0.30
2063	0.33	0.33
2064	0.27	0.27
2065	0.34	0.34
2066	0.27	0.27
Average Load for RF Sequence (t/yr)	**0.30**	**0.30**
Median Winter Concentration (mg/L)	**0.048**	**0.048**



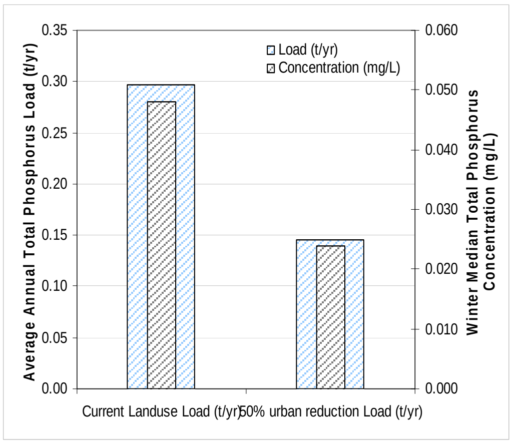
Downstream – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.29	0.18	0.29	0.18
2058	0.32	0.20	0.32	0.20
2059	0.29	0.18	0.29	0.18
2060	0.29	0.18	0.29	0.18
2061	0.27	0.17	0.27	0.17
2062	0.30	0.19	0.30	0.19
2063	0.33	0.20	0.33	0.20
2064	0.27	0.17	0.27	0.17
2065	0.34	0.21	0.34	0.21
2066	0.27	0.17	0.27	0.17
Average Load for RF Sequence (t/yr)	**0.30**	**0.19**	**0.30**	**0.19**
Median Winter Concentration (mg/L)	**0.048**	**0.030**	**0.048**	**0.030**

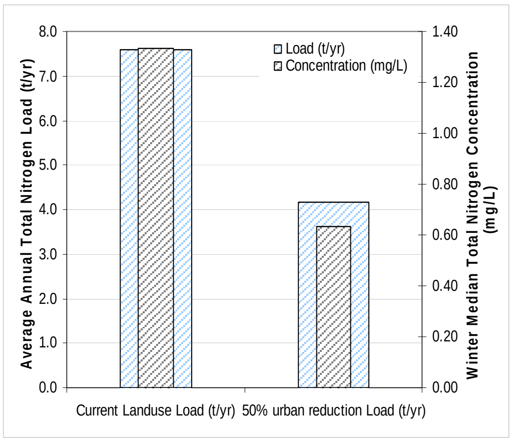


Downstream – Urban 50% reduction

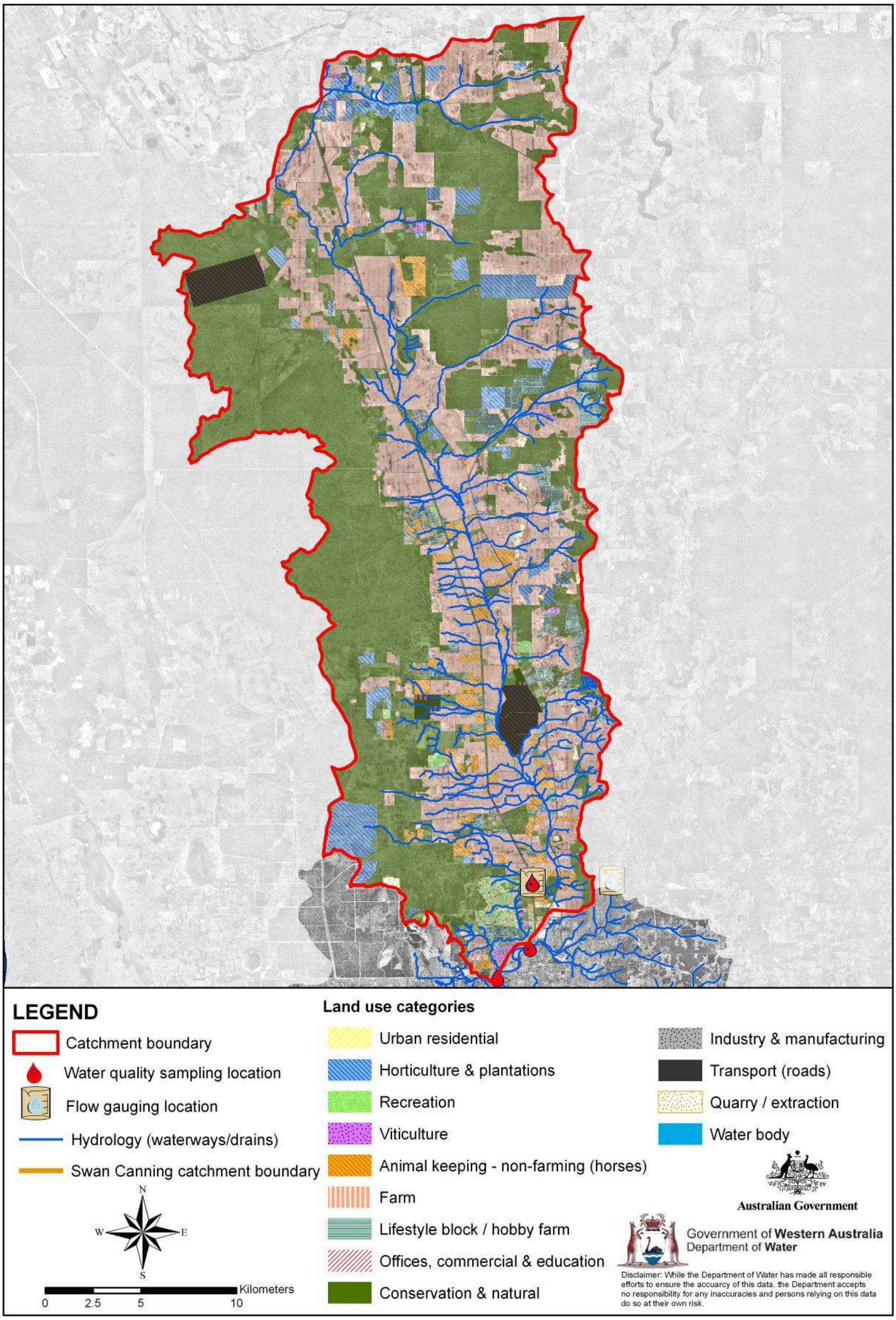
Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.29	0.14
2058	0.32	0.16
2059	0.29	0.14
2060	0.29	0.14
2061	0.27	0.13
2062	0.30	0.15
2063	0.33	0.16
2064	0.27	0.13
2065	0.34	0.17
2066	0.27	0.13
Average Load for RF Sequence (t/yr)	**0.30**	**0.15**
Median Winter Concentration (mg/L)	**0.048**	**0.024**



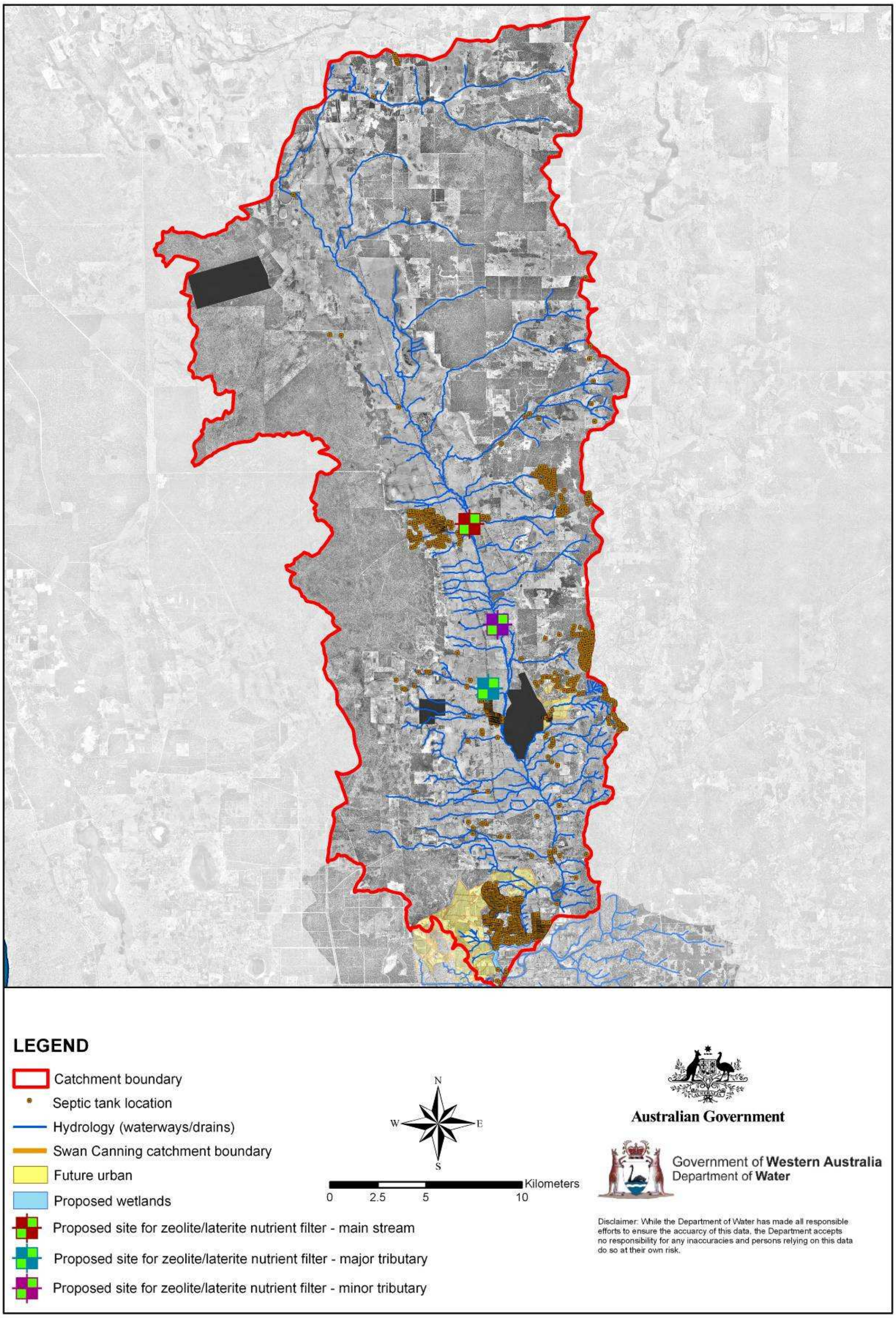
Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	7.7	4.1
2058	8.3	4.6
2059	8.4	4.4
2060	7.4	4.0
2061	6.7	3.7
2062	7.4	4.2
2063	8.7	4.8
2064	6.8	3.7
2065	8.5	4.8
2066	6.1	3.5
Average Load for RF Sequence (t/yr)	**7.6**	**4.2**
Median Winter Concentration (mg/L)	**1.33**	**0.64**



Ellen Brook
Land use map



Locations of septic tanks, future urban development, proposed wetlands and zeolite/laterite filters



Ellen Brook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616189		
	Current	83% Input Reduction		Current	83% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	7.73	1.18	*1997*	7.25	1.06
1998	9.58	2.10	*1998*	8.99	1.93
1999	16.08	3.43	*1999*	15.48	3.26
2000	13.43	2.92	*2000*	12.47	2.62
2001	5.41	1.18	*2001*	4.86	1.03
2002	6.50	1.37	*2002*	6.05	1.24
2003	13.90	3.15	*2003*	13.03	2.85
2004	6.59	1.42	*2004*	6.11	1.28
2005	16.40	3.53	*2005*	15.45	3.21
2006	4.77	0.98	*2006*	4.42	0.89
Average	**10.04**	**2.13**	**Average**	**9.41**	**1.94**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.455**	**0.100**	**SQUARE:**	**0.448**	**0.095**
Target:	**0.100**		**Observed:**	**0.450**	
Load Target (t/yr)		**2.13**			
Load Reduction Target (t/yr)		**7.91**			
Required Reduction (%)		**79%**			
Time Required (yr)		**40**			

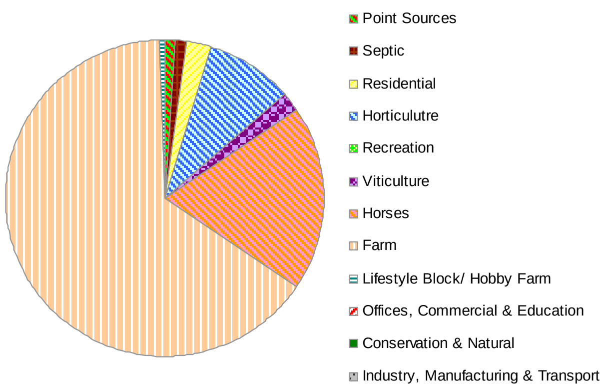
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616189		
	Current	51% Input Reduction		Current	51% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	38.2	12.7	*1997*	33.3	10.6
1998	76.0	27.5	*1998*	66.6	24.1
1999	115.4	40.1	*1999*	104.9	36.5
2000	79.5	26.5	*2000*	68.4	23.4
2001	41.6	13.2	*2001*	34.3	10.7
2002	41.7	13.6	*2002*	36.9	12.0
2003	134.0	33.9	*2003*	114.9	29.3
2004	39.1	13.2	*2004*	33.5	11.4
2005	123.1	31.3	*2005*	105.1	27.2
2006	25.8	9.5	*2006*	23.2	8.5
Average	**71.4**	**22.1**	**Average**	**62.1**	**19.4**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**2.73**	**1.00**	**SQUARE:**	**2.55**	**0.92**
Target:	**1.00**		**Observed**	**2.55**	
Load Target (t/yr)		**22.1**			
Load Reduction Target (t/yr)		**49.3**			
Required Reduction (%)		**69%**			
Time Required (yr)		**30**			

Ellen Brook – Source separation[1]

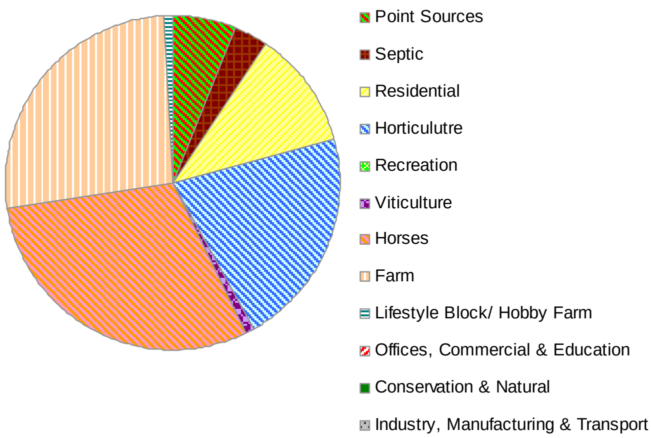
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	7.73	0.15	0.15	0.23	0.48	0.08	0.23	1.58	4.83	0.12	0.08	0.08	0.08
1998	9.58	0.31	0.31	0.41	0.94	0.23	0.37	2.01	5.85	0.27	0.23	0.23	0.23
1999	16.08	0.42	0.42	0.60	1.70	0.28	0.50	2.83	9.78	0.36	0.28	0.28	0.28
2000	13.43	0.42	0.42	0.61	1.61	0.29	0.52	2.51	8.33	0.35	0.29	0.29	0.29
2001	5.41	0.11	0.11	0.21	0.42	0.06	0.17	1.11	3.30	0.08	0.06	0.06	0.06
2002	6.50	0.11	0.11	0.23	0.35	0.04	0.15	1.26	3.99	0.07	0.04	0.04	0.04
2003	13.90	0.45	0.45	0.66	1.63	0.31	0.54	2.40	8.44	0.37	0.31	0.31	0.31
2004	6.59	0.11	0.11	0.23	0.33	0.04	0.17	1.40	4.01	0.07	0.04	0.04	0.04
2005	16.40	0.47	0.47	0.77	2.07	0.28	0.52	2.86	9.67	0.36	0.28	0.28	0.28
2006	4.77	0.05	0.05	0.14	0.16	0.01	0.11	1.16	2.80	0.03	0.01	0.01	0.01
Load (non adj)	10.04	0.26	0.26	0.41	0.97	0.16	0.33	1.91	6.10	0.21	0.16	0.16	0.16
Load (t/yr)	**10.04**	**0.11**	**0.11**	**0.27**	**0.89**	**0.00**	**0.18**	**1.92**	**6.52**	**0.05**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**1.1%**	**1.1%**	**2.7%**	**8.8%**	**0.0%**	**1.8%**	**19.1%**	**64.9%**	**0.5%**	**0.0%**	**0.0%**	**0.0%**



Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	38.2	0.9	0.7	1.5	2.3	0.2	0.3	7.5	4.6	0.2	0.2	0.2	0.2
1998	76.0	1.2	1.0	3.1	5.3	0.3	0.5	7.5	6.1	0.4	0.3	0.3	0.3
1999	115.4	2.2	1.7	3.9	8.8	0.8	0.9	9.5	8.3	1.0	0.8	0.8	0.8
2000	79.5	1.8	1.3	2.7	5.5	0.5	0.7	7.5	8.0	0.7	0.5	0.5	0.5
2001	41.6	0.9	1.1	2.9	3.3	0.2	0.4	5.4	5.9	0.5	0.2	0.2	0.2
2002	41.7	1.3	1.0	2.1	3.0	0.3	0.4	4.7	6.3	0.5	0.3	0.3	0.3
2003	134.0	2.3	1.8	5.6	10.4	0.6	0.8	8.9	7.8	0.9	0.6	0.6	0.6
2004	39.1	2.1	1.0	2.2	2.8	0.3	0.4	5.8	5.8	0.5	0.3	0.3	0.3
2005	123.1	3.6	1.9	5.6	9.9	0.7	0.9	8.7	8.6	1.0	0.7	0.7	0.7
2006	25.8	1.6	0.3	1.0	1.0	0.1	0.2	6.7	4.3	0.2	0.1	0.1	0.1
Load (non adj)	71.4	1.8	1.2	3.1	5.2	0.4	0.6	7.2	6.6	0.6	0.4	0.4	0.4
Load (t/yr)	**71.4**	**2.8**	**1.6**	**5.5**	**9.9**	**0.0**	**0.3**	**14.0**	**12.7**	**0.4**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**4.0%**	**2.2%**	**7.6%**	**13.9%**	**0.0%**	**0.4%**	**19.6%**	**17.7%**	**0.5%**	**0.0%**	**0.0%**	**0.0%**

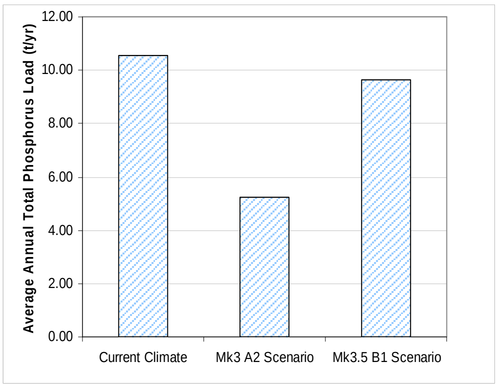


[1] Nitrogen fixation (on average 24.2 tonnes/year) is not included in source separation. It should be attributed to 'Farm' (90%) and 'Horses' (10%) land uses

Ellen Brook – Climate change

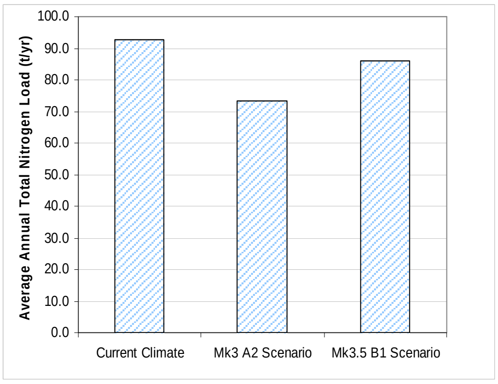
Phosphorus

	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	5.76	2.72	5.20
2058	10.33	5.05	9.61
2059	17.31	9.13	15.83
2060	14.34	7.75	13.13
2061	5.76	2.89	5.27
2062	6.95	3.35	6.31
2063	15.37	7.50	14.10
2064	7.17	3.33	6.50
2065	17.52	8.09	15.81
2066	4.97	2.41	4.40
Average Load for RF Sequence (t/yr)	**10.55**	**5.22**	**9.62**



Nitrogen

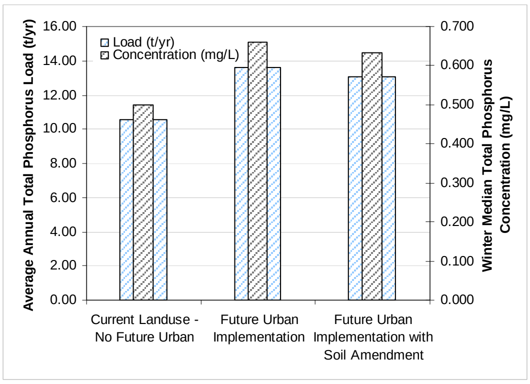
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	46.7	27.9	42.2
2058	127.7	94.0	122.2
2059	185.5	183.3	175.1
2060	111.4	96.5	105.2
2061	42.4	24.2	38.0
2062	43.9	25.7	39.3
2063	166.4	140.6	155.9
2064	40.0	24.4	36.3
2065	138.1	99.1	124.1
2066	25.7	16.4	22.6
Average Load for RF Sequence (t/yr)	**92.8**	**73.2**	**86.1**



Ellen Brook – Future urban

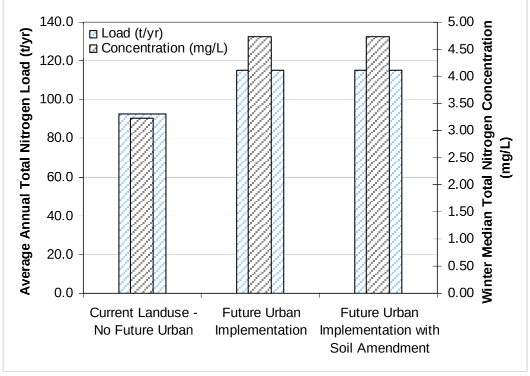
Phosphorus

	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	5.76	8.03	7.69
2058	10.33	13.00	12.51
2059	17.31	21.26	20.37
2060	14.34	18.09	17.38
2061	5.76	8.13	7.81
2062	6.95	9.63	9.12
2063	15.37	19.36	18.45
2064	7.17	9.96	9.48
2065	17.52	22.02	20.93
2066	4.97	6.90	6.64
Average Load for RF Sequence (t/yr)	**10.55**	**13.64**	**13.04**
Median Winter Concentration (mg/L)	**0.500**	**0.659**	**0.633**



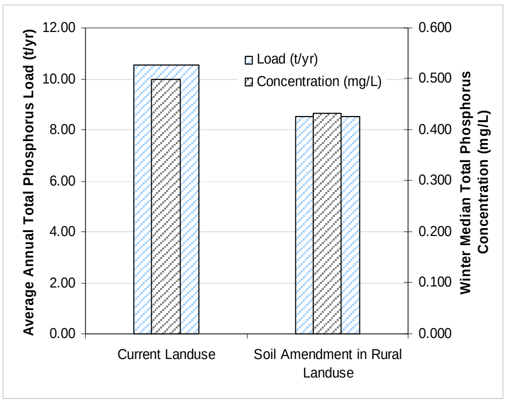
Nitrogen

	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	46.7	69.6	69.6
2058	127.7	156.1	156.1
2059	185.5	206.6	206.6
2060	111.4	126.8	126.8
2061	42.4	70.9	70.9
2062	43.9	63.4	63.4
2063	166.4	194.7	194.7
2064	40.0	60.2	60.2
2065	138.1	166.5	166.5
2066	25.7	39.6	39.6
Average Load for RF Sequence (t/yr)	**92.8**	**115.4**	**115.4**
Median Winter Concentration (mg/L)	**3.23**	**4.72**	**4.72**



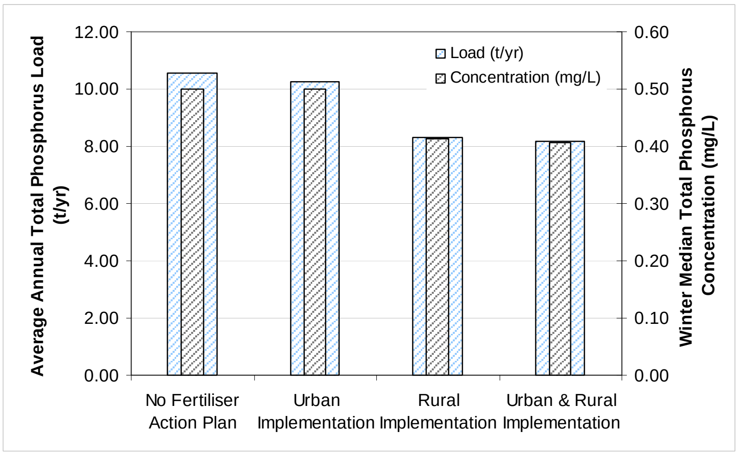
Ellen Brook – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	5.76	4.73
2058	10.33	8.38
2059	17.31	13.92
2060	14.34	11.63
2061	5.76	4.81
2062	6.95	5.55
2063	15.37	12.44
2064	7.17	5.79
2065	17.52	13.97
2066	4.97	4.13
Average Load for RF Sequence (t/yr)	**10.55**	**8.53**
Median Winter Concentration (mg/L)	**0.500**	**0.432**



Ellen Brook – *Fertiliser action plan*

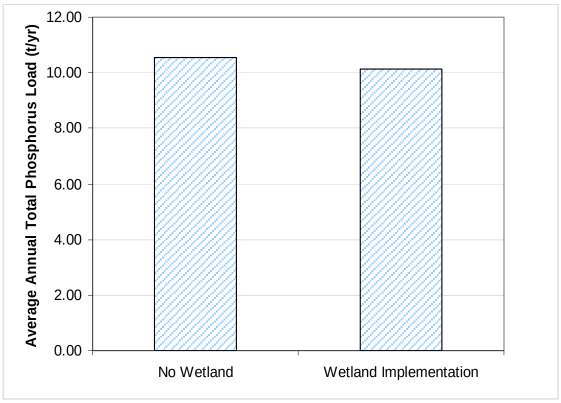
Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	5.76	5.60	4.42	4.35
2058	10.33	10.08	8.16	8.06
2059	17.31	16.89	13.80	13.64
2060	14.34	13.96	11.28	11.12
2061	5.76	5.61	4.42	4.35
2062	6.95	6.76	5.32	5.24
2063	15.37	15.00	12.37	12.20
2064	7.17	6.99	5.48	5.39
2065	17.52	17.06	13.94	13.72
2066	4.97	4.86	3.75	3.70
Average Load for RF Sequence (t/yr)	**10.55**	**10.28**	**8.29**	**8.18**
Median Winter Concentration (mg/L)	**0.50**	**0.50**	**0.412**	**0.407**



Ellen Brook – Wetland implementation

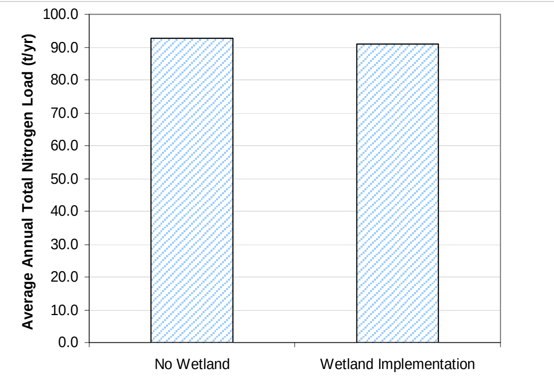
Phosphorus

	At Catchment Outlet	
Year	*No Wetland Load (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	5.76	5.54
2058	10.33	9.94
2059	17.31	16.65
2060	14.34	13.79
2061	5.76	5.54
2062	6.95	6.69
2063	15.37	14.78
2064	7.17	6.90
2065	17.52	16.86
2066	4.97	4.79
Average Load for RF Sequence (t/yr)	**10.55**	**10.15**



Nitrogen

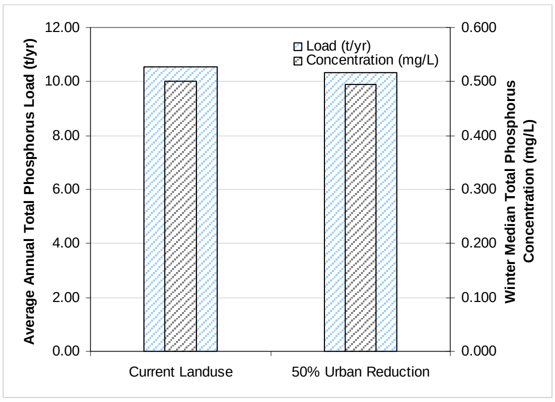
	At Catchment Outlet	
Year	*No Wetland Load (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	46.7	45.8
2058	127.7	125.2
2059	185.5	181.8
2060	111.4	109.2
2061	42.4	41.6
2062	43.9	43.0
2063	166.4	163.0
2064	40.0	39.2
2065	138.1	135.4
2066	25.7	25.1
Average Load for RF Sequence (t/yr)	**92.8**	**90.9**



Ellen Brook – Urban 50% reduction

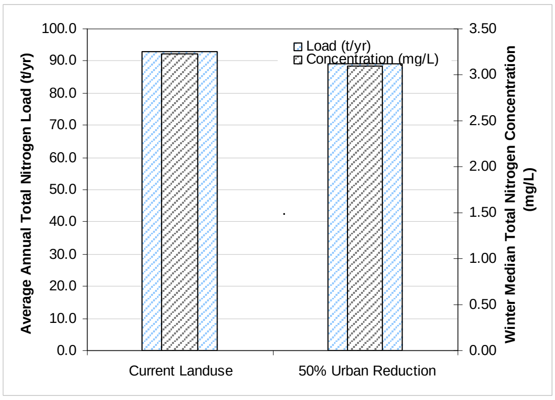
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	5.76	5.63
2058	10.33	10.15
2059	17.31	17.01
2060	14.34	14.03
2061	5.76	5.63
2062	6.95	6.80
2063	15.37	15.05
2064	7.17	7.02
2065	17.52	17.13
2066	4.97	4.88
Average Load for RF Sequence (t/yr)	**10.55**	**10.33**
Median Winter Concentration (mg/L)	**0.500**	**0.495**



Nitrogen

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	46.7	44.1
2058	127.7	122.6
2059	185.5	180.0
2060	111.4	106.8
2061	42.4	39.7
2062	43.9	41.9
2063	166.4	159.4
2064	40.0	38.0
2065	138.1	132.2
2066	25.7	24.8
Average Load for RF Sequence (t/yr)	**92.8**	**89.0**
Median Winter Concentration (mg/L)	**3.23**	**3.10**

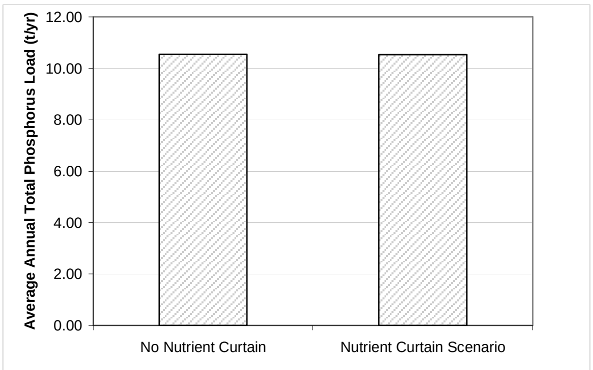


Ellen Brook – Zeolite/laterite nutrient filter

Ellen Brook - Zeolite/Laterite Nutrient Curtain Scenario

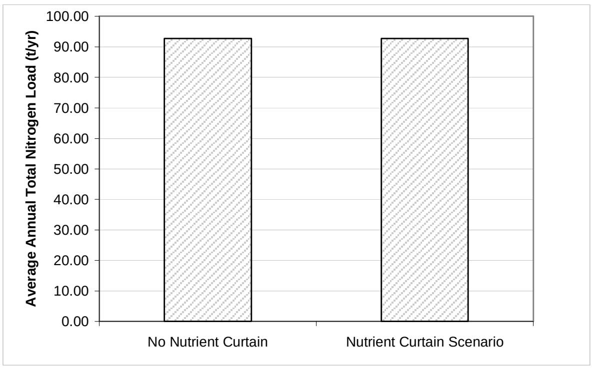
Phosphorus

	At Catchment Outlet				
Year	*No Nutrient Curtain Load (t/yr)*	*Phosphorus Removed - Main Stream (t/yr)*	*Phosphorus Removed - Major Trib. (t/yr)*	*Phosphorus Removed - Minor Trib (t/yr)*	*Nutrient Curtain Implementation (t/yr)*
2057	5.76	0.02	0.00	0.00	5.74
2058	10.33	0.02	0.00	0.00	10.31
2059	17.31	0.02	0.00	0.00	17.28
2060	14.34	0.02	0.00	0.00	14.31
2061	5.76	0.01	0.00	0.00	5.75
2062	6.95	0.02	0.00	0.00	6.93
2063	15.37	0.02	0.00	0.00	15.35
2064	7.17	0.02	0.00	0.00	7.15
2065	17.52	0.02	0.00	0.00	17.49
2066	4.97	0.02	0.00	0.00	4.96
Average Load for RF Sequence (t/yr)	**10.55**	**0.02**	**0.00**	**0.00**	**10.53**

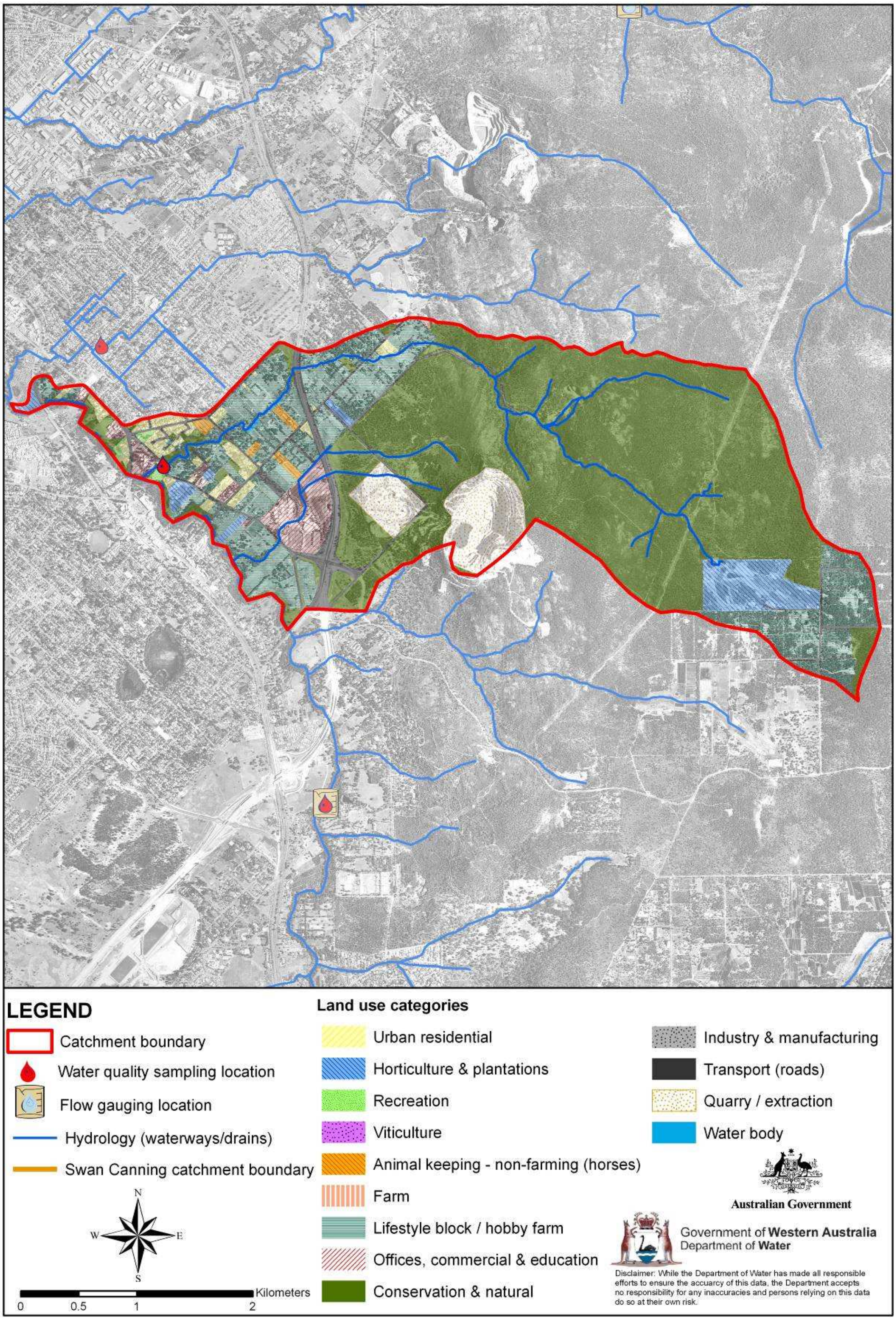


Nitrogen

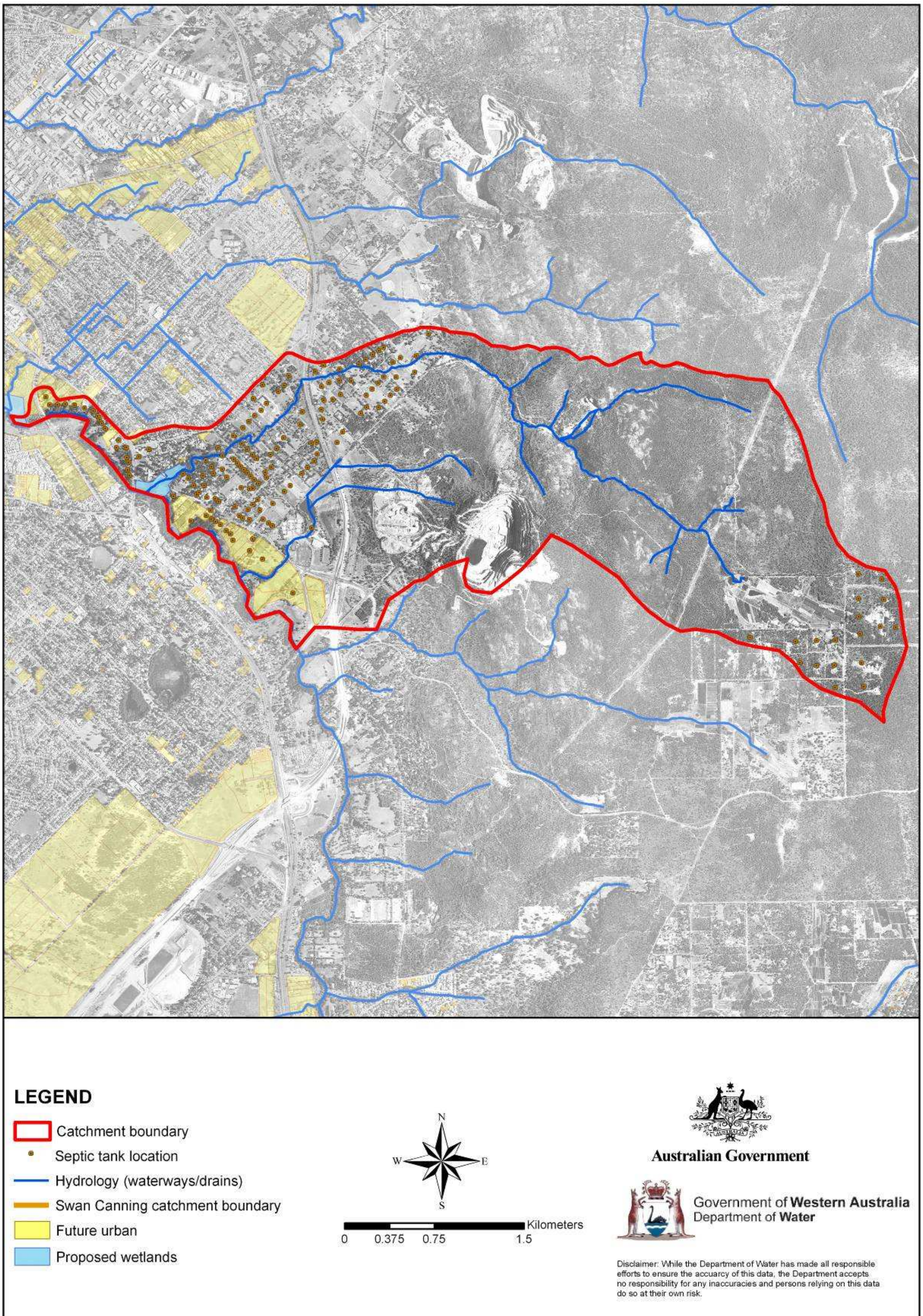
	At Catchment Outlet				
Year	*No Nutrient Curtain Load (t/yr)*	*Nitrogen Removed - Main Stream (t/yr)*	*Nitrogen Removed - Major Trib (t/yr)*	*Nitrogen Removed - Minor Trib (t/yr)*	*Nutrient Curtain Implementation (t/yr)*
2057	46.69	0.00	0.00	0.00	46.69
2058	127.72	0.00	0.00	0.00	127.71
2059	185.51	0.01	0.00	0.00	185.50
2060	111.39	0.01	0.00	0.00	111.38
2061	42.42	0.00	0.00	0.00	42.42
2062	43.87	0.00	0.00	0.00	43.86
2063	166.36	0.00	0.00	0.00	166.35
2064	40.02	0.00	0.00	0.00	40.01
2065	138.14	0.01	0.00	0.00	138.13
2066	25.66	0.00	0.00	0.00	25.65
Average Load for RF Sequence (t/yr)	**92.78**	**0.00**	**0.00**	**0.00**	**92.77**



Ellis Brook
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Ellis Brook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Sampling Location 6160690		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.02	-	*1997*	0.01	-
1998	0.01	-	*1998*	0.01	-
1999	0.02	-	*1999*	0.01	-
2000	0.02	-	*2000*	0.01	-
2001	0.01	-	*2001*	0.00	-
2002	0.01	-	*2002*	0.01	-
2003	0.02	-	*2003*	0.01	-
2004	0.01	-	*2004*	0.00	-
2005	0.02	-	*2005*	0.01	-
2006	0.01	-	*2006*	0.00	-
Average	**0.02**	**-**	**Average**	**0.01**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.017**	**-**	**SQUARE:**	**0.016**	**-**
Target:	**0.100**		**Observed:**	**0.015**	
Load Target (t/yr)		**0.02**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**-**			

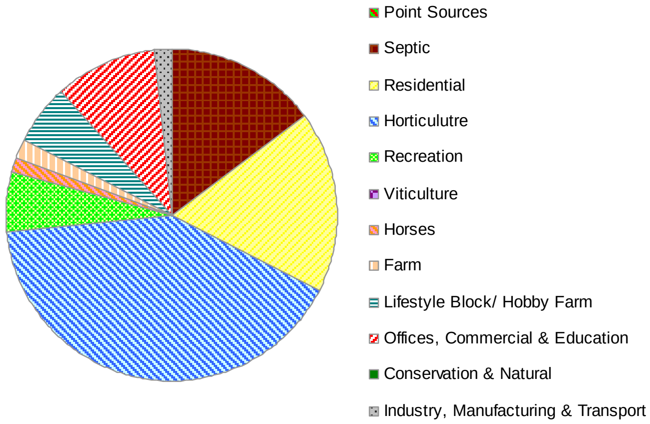
Nitrogen

At Outlet to Swan River Estuary			At Sampling Location 6160690		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.7	-	*1997*	0.2	-
1998	0.7	-	*1998*	0.2	-
1999	0.9	-	*1999*	0.2	-
2000	1.0	-	*2000*	0.2	-
2001	0.6	-	*2001*	0.1	-
2002	0.6	-	*2002*	0.1	-
2003	0.8	-	*2003*	0.2	-
2004	0.6	-	*2004*	0.1	-
2005	0.9	-	*2005*	0.2	-
2006	0.4	-	*2006*	0.1	-
Average	**0.7**	**-**	**Average**	**0.2**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.46**	**-**	**SQUARE:**	**0.39**	**-**
Target:	**1.00**		**Observed:**	**0.39**	
Load Target (t/yr)		**0.7**			
Load Reduction Target (t/yr)		**0.0**			
Required Reduction (%)		**0%**			
Time Required (yr)		**-**			

Ellis Brook – Source separation

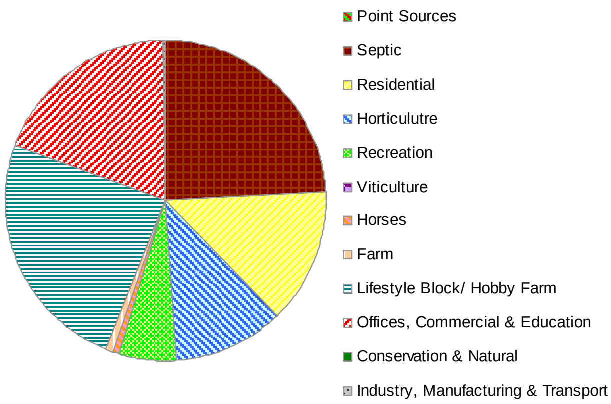
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1998	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01
1999	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2000	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2001	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
2003	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2004	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2006	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Load (non adj)	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Load (t/yr)	**0.02**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**0.0%**	**14.7%**	**17.8%**	**40.8%**	**5.8%**	**0.0%**	**1.5%**	**1.9%**	**5.9%**	**10.0%**	**0.0%**	**1.7%**



Nitrogen (t/yr)

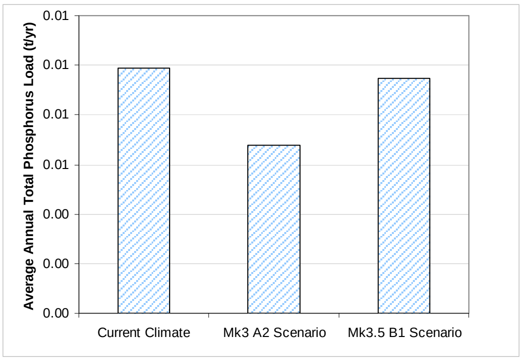
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.7	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.7	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	1.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
2001	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
2004	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
2006	0.4	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0
Load (non adj)	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (t/yr)	**0.7**	**0.0**	**0.1**	**0.1**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.2**	**0.1**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**21.3%**	**12.0%**	**10.0%**	**5.2%**	**0.0%**	**0.4%**	**0.8%**	**21.7%**	**16.9%**	**0.0%**	**0.1%**



Ellis Brook – Climate change

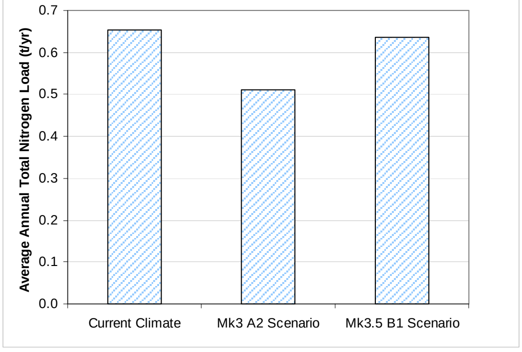
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.01	0.01	0.01
2058	0.01	0.01	0.01
2059	0.01	0.01	0.01
2060	0.01	0.01	0.01
2061	0.01	0.01	0.01
2062	0.01	0.01	0.01
2063	0.01	0.01	0.01
2064	0.01	0.01	0.01
2065	0.01	0.01	0.01
2066	0.01	0.00	0.01
Average Load for RF Sequence (t/yr)	**0.01**	**0.01**	**0.01**



Nitrogen

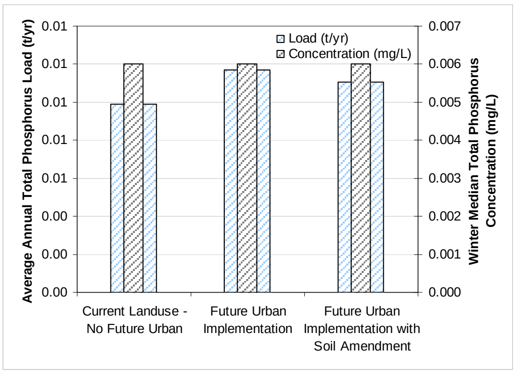
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.5	0.4	0.5
2058	0.6	0.5	0.6
2059	0.8	0.7	0.8
2060	0.9	0.7	0.9
2061	0.5	0.4	0.5
2062	0.6	0.4	0.6
2063	0.8	0.6	0.8
2064	0.6	0.4	0.6
2065	0.8	0.7	0.8
2066	0.4	0.2	0.3
Average Load for RF Sequence (t/yr)	**0.7**	**0.5**	**0.6**



Ellis Brook – Future urban

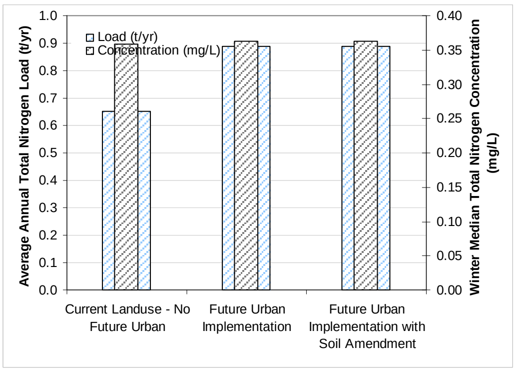
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.01	0.01	0.01
2058	0.01	0.01	0.01
2059	0.01	0.01	0.01
2060	0.01	0.02	0.01
2061	0.01	0.01	0.01
2062	0.01	0.01	0.01
2063	0.01	0.01	0.01
2064	0.01	0.01	0.01
2065	0.01	0.01	0.01
2066	0.01	0.01	0.01
Average Load for RF Sequence (t/yr)	**0.01**	**0.01**	**0.01**
Median Winter Concentration (mg/L)	**0.006**	**0.006**	**0.006**



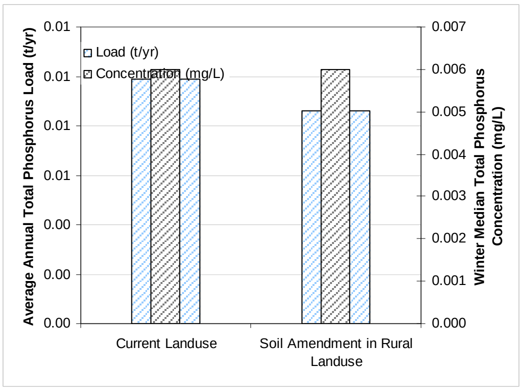
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.5	0.7	0.7
2058	0.6	0.8	0.8
2059	0.8	1.1	1.1
2060	0.9	1.2	1.2
2061	0.5	0.7	0.7
2062	0.6	0.8	0.8
2063	0.8	1.1	1.1
2064	0.6	0.8	0.8
2065	0.8	1.1	1.1
2066	0.4	0.6	0.6
Average Load for RF Sequence (t/yr)	**0.7**	**0.9**	**0.9**
Median Winter Concentration (mg/L)	**0.36**	**0.36**	**0.36**



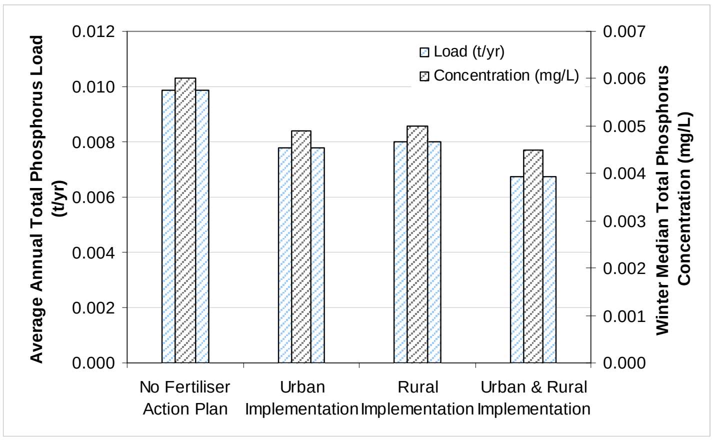
Ellis Brook – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.01	0.01
2058	0.01	0.01
2059	0.01	0.01
2060	0.01	0.01
2061	0.01	0.01
2062	0.01	0.01
2063	0.01	0.01
2064	0.01	0.01
2065	0.01	0.01
2066	0.01	0.01
Average Load for RF Sequence (t/yr)	**0.01**	**0.01**
Median Winter Concentration (mg/L)	**0.006**	**0.006**



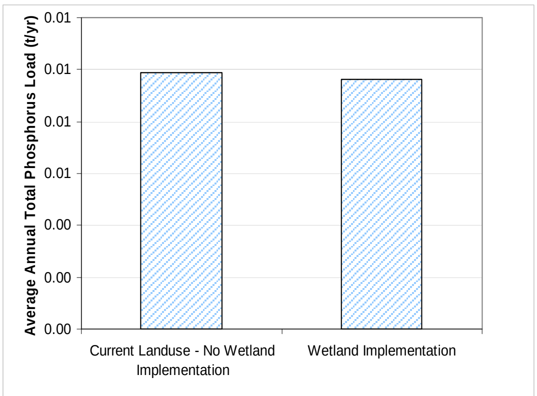
Ellis Brook – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.01	0.01	0.01	0.01
2058	0.01	0.01	0.01	0.01
2059	0.01	0.01	0.01	0.01
2060	0.01	0.01	0.01	0.01
2061	0.01	0.01	0.01	0.01
2062	0.01	0.01	0.01	0.01
2063	0.01	0.01	0.01	0.01
2064	0.01	0.01	0.01	0.01
2065	0.01	0.01	0.01	0.01
2066	0.01	0.00	0.01	0.00
Average Load for RF Sequence (t/yr)	**0.01**	**0.01**	**0.01**	**0.01**
Median Winter Concentration (mg/L)	**0.006**	**0.005**	**0.005**	**0.005**

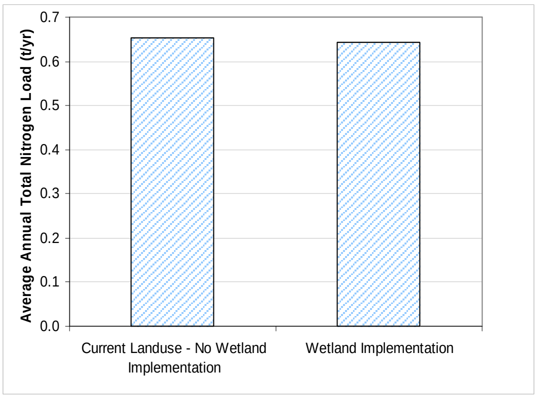


Ellis Brook – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.01	0.01
2058	0.01	0.01
2059	0.01	0.01
2060	0.01	0.01
2061	0.01	0.01
2062	0.01	0.01
2063	0.01	0.01
2064	0.01	0.01
2065	0.01	0.01
2066	0.01	0.01
Average Load for RF Sequence (t/yr)	0.01	0.01

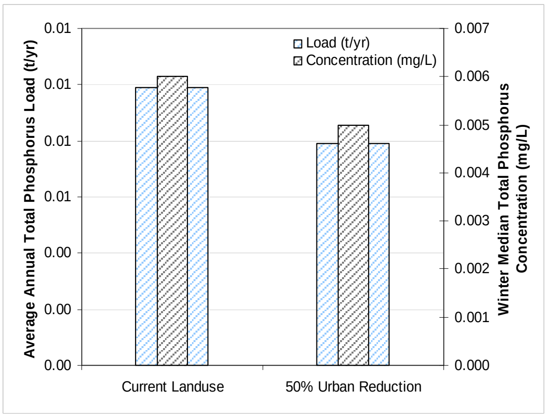


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.5	0.5
2058	0.6	0.6
2059	0.8	0.8
2060	0.9	0.9
2061	0.5	0.5
2062	0.6	0.6
2063	0.8	0.8
2064	0.6	0.6
2065	0.8	0.8
2066	0.4	0.4
Average Load for RF Sequence (t/yr)	0.7	0.6

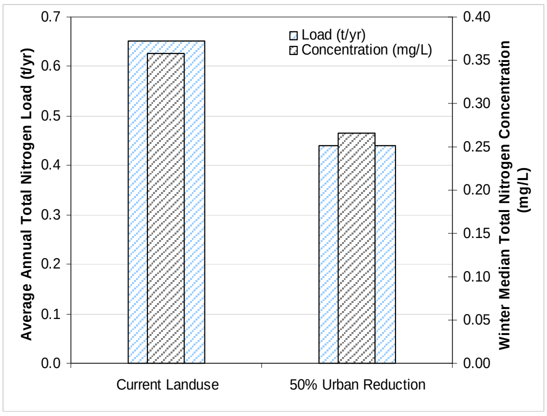


Ellis Brook – Urban 50% reduction

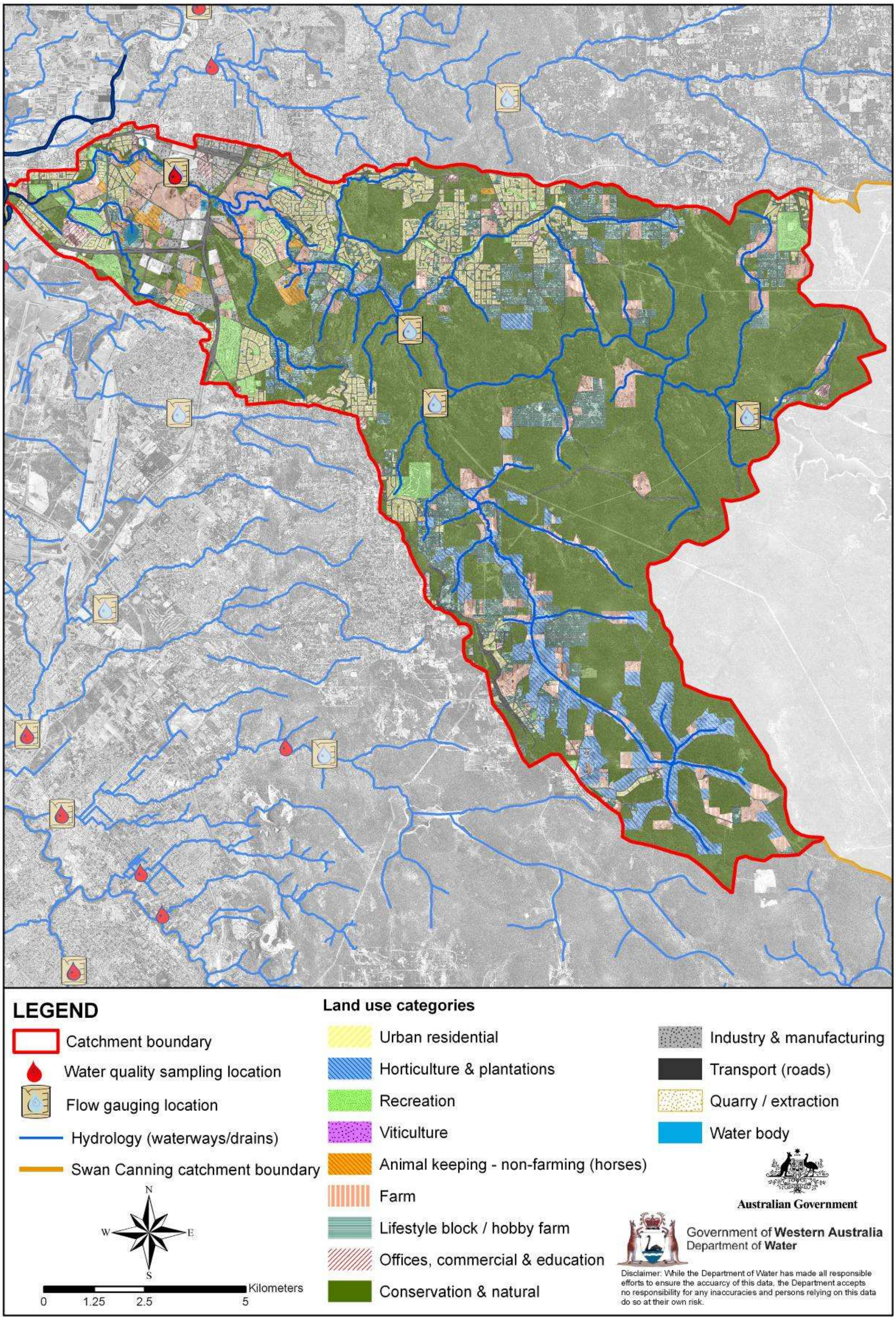
Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.01	0.01
2058	0.01	0.01
2059	0.01	0.01
2060	0.01	0.01
2061	0.01	0.01
2062	0.01	0.01
2063	0.01	0.01
2064	0.01	0.01
2065	0.01	0.01
2066	0.01	0.00
Average Load for RF Sequence (t/yr)	0.01	0.01
Median Winter Concentration (mg/L)	0.006	0.005



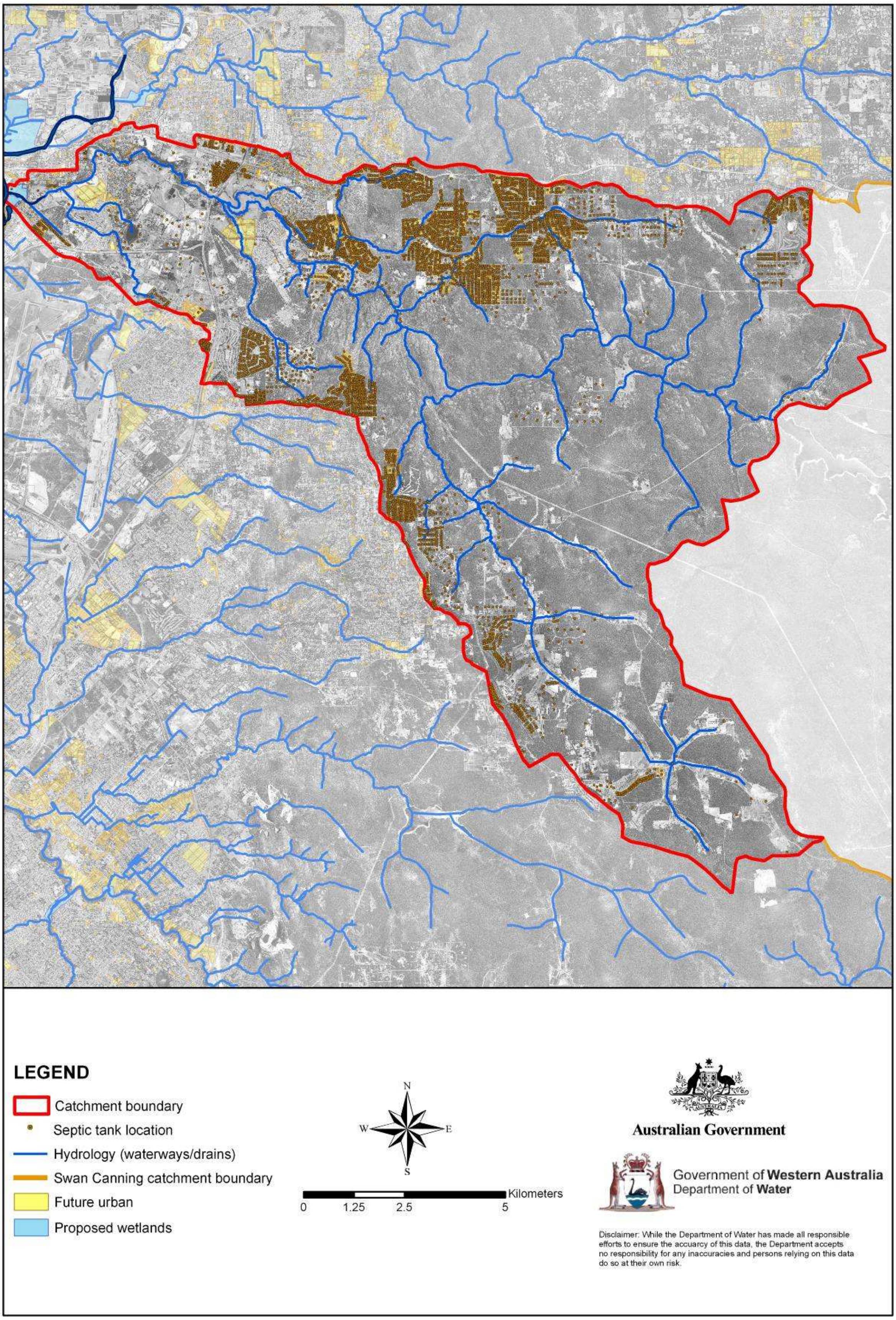
Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.5	0.3
2058	0.6	0.4
2059	0.8	0.5
2060	0.9	0.6
2061	0.5	0.4
2062	0.6	0.4
2063	0.8	0.5
2064	0.6	0.4
2065	0.8	0.6
2066	0.4	0.2
Average Load for RF Sequence (t/yr)	0.7	0.4
Median Winter Concentration (mg/L)	0.36	0.27



Helena River
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Helena River - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616086		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.26	-	*1997*	0.14	-
1998	0.24	-	*1998*	0.13	-
1999	0.26	-	*1999*	0.16	-
2000	0.25	-	*2000*	0.18	-
2001	0.18	-	*2001*	0.12	-
2002	0.18	-	*2002*	0.12	-
2003	0.24	-	*2003*	0.16	-
2004	0.22	-	*2004*	0.12	-
2005	0.32	-	*2005*	0.19	-
2006	0.14	-	*2006*	0.08	-
Average	**0.23**	**-**	**Average**	**0.14**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.024**		**SQUARE:**	**0.022**	
Target:	**0.100**		**Observed:**	**0.020**	
Load Target (t/yr)		**0.23**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

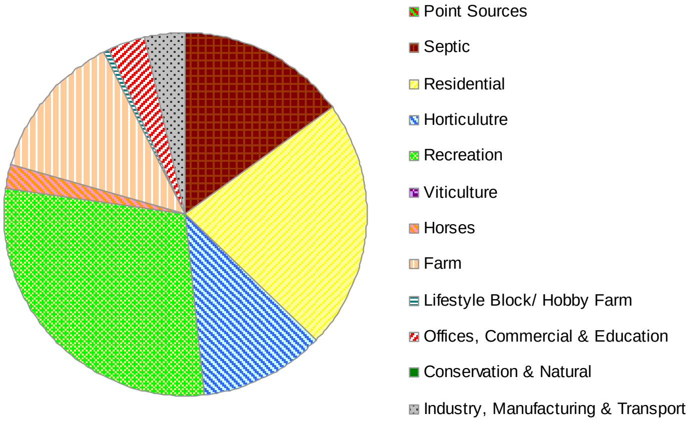
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616086		
	Current	42% Input Reduction		Current	42% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	6.2	3.2	*1997*	3.2	1.6
1998	6.6	3.6	*1998*	3.3	1.6
1999	7.6	4.3	*1999*	3.8	2.2
2000	6.5	3.9	*2000*	4.0	2.1
2001	4.9	3.2	*2001*	3.9	1.5
2002	4.0	2.5	*2002*	2.7	1.1
2003	5.0	3.5	*2003*	3.8	1.6
2004	5.0	3.4	*2004*	2.8	1.7
2005	8.1	5.2	*2005*	5.0	2.8
2006	3.8	2.8	*2006*	2.0	1.3
Average	**5.8**	**3.6**	**Average**	**3.5**	**1.7**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.20**	**1.00**	**SQUARE:**	**0.88**	**0.77**
Target:	**1.00**		**Observed:**	**0.83**	
Load Target (t/yr)		**3.6**			
Load Reduction Target (t/yr)		**2.2**			
Required Reduction (%)		**38%**			
Time Required (yr)		**20**			

Helena River – Source separation

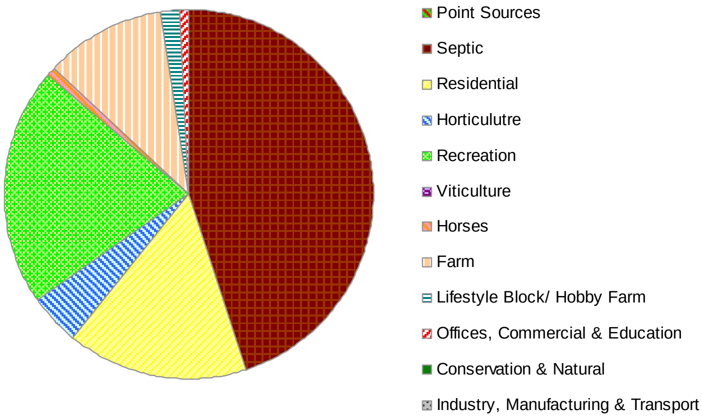
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.26	0.01	0.05	0.05	0.03	0.08	0.01	0.01	0.05	0.01	0.01	0.01	0.02
1998	0.24	0.00	0.04	0.05	0.03	0.07	0.00	0.01	0.04	0.00	0.01	0.00	0.01
1999	0.26	0.01	0.05	0.06	0.03	0.08	0.01	0.01	0.05	0.01	0.01	0.01	0.01
2000	0.25	0.00	0.04	0.06	0.03	0.08	0.00	0.01	0.04	0.01	0.01	0.00	0.01
2001	0.18	0.00	0.03	0.04	0.02	0.05	0.00	0.01	0.02	0.00	0.01	0.00	0.01
2002	0.18	0.00	0.03	0.04	0.02	0.05	0.00	0.01	0.02	0.00	0.01	0.00	0.01
2003	0.24	0.00	0.03	0.06	0.03	0.07	0.00	0.01	0.03	0.00	0.01	0.00	0.01
2004	0.22	0.00	0.03	0.05	0.03	0.06	0.00	0.01	0.03	0.00	0.01	0.00	0.01
2005	0.32	0.00	0.04	0.08	0.04	0.10	0.00	0.01	0.04	0.01	0.01	0.00	0.01
2006	0.14	0.00	0.02	0.04	0.02	0.04	0.00	0.00	0.02	0.00	0.01	0.00	0.01
Load (non adj)	0.23	0.00	0.04	0.05	0.03	0.07	0.00	0.01	0.03	0.00	0.01	0.00	0.01
Load (t/yr)	**0.23**	**0.00**	**0.03**	**0.05**	**0.03**	**0.07**	**0.00**	**0.00**	**0.03**	**0.00**	**0.01**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**14.9%**	**22.4%**	**11.1%**	**28.8%**	**0.0%**	**2.2%**	**13.1%**	**0.7%**	**3.2%**	**0.0%**	**3.6%**



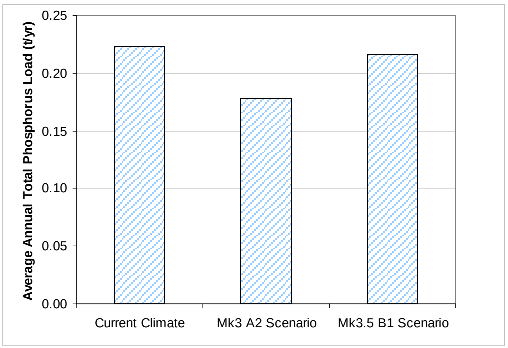
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	6.2	0.2	2.8	0.7	0.5	1.0	0.2	0.3	0.9	0.3	0.3	0.2	0.2
1998	6.6	0.3	2.9	1.0	0.4	1.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3
1999	7.6	0.3	2.9	1.1	0.6	1.6	0.3	0.3	1.1	0.3	0.3	0.3	0.3
2000	6.5	0.2	2.5	1.1	0.6	1.3	0.2	0.3	0.8	0.3	0.3	0.2	0.3
2001	4.9	0.3	2.2	0.9	0.4	1.0	0.3	0.3	0.6	0.3	0.3	0.3	0.3
2002	4.0	0.2	1.7	0.8	0.3	0.8	0.2	0.3	0.5	0.3	0.3	0.2	0.2
2003	5.0	0.3	1.9	1.0	0.4	1.2	0.3	0.3	0.6	0.3	0.3	0.3	0.3
2004	5.0	0.3	2.0	0.9	0.4	1.1	0.3	0.3	0.6	0.3	0.3	0.3	0.3
2005	8.1	0.3	2.7	1.6	0.7	2.0	0.3	0.4	0.9	0.4	0.4	0.3	0.3
2006	3.8	0.1	1.6	0.6	0.2	0.7	0.1	0.2	0.5	0.2	0.1	0.1	0.1
Load (non adj)	5.8	0.2	2.3	1.0	0.5	1.2	0.2	0.3	0.7	0.3	0.3	0.2	0.3
Load (t/yr)	**5.8**	**0.0**	**2.6**	**0.9**	**0.3**	**1.2**	**0.0**	**0.0**	**0.6**	**0.1**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**44.7%**	**15.7%**	**4.5%**	**20.8%**	**0.0%**	**0.8%**	**10.6%**	**1.6%**	**0.7%**	**0.0%**	**0.1%**

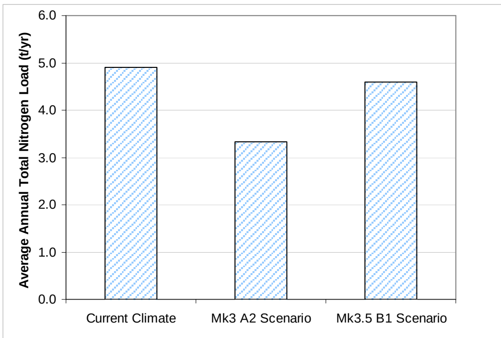


Helena River – Climate change

Phosphorus			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.23	0.18	0.22
2058	0.22	0.18	0.22
2059	0.25	0.20	0.25
2060	0.25	0.20	0.24
2061	0.18	0.14	0.17
2062	0.18	0.15	0.17
2063	0.24	0.19	0.24
2064	0.22	0.18	0.21
2065	0.31	0.24	0.30
2066	0.14	0.12	0.14
Average Load for RF Sequence (t/yr)	**0.22**	**0.18**	**0.22**

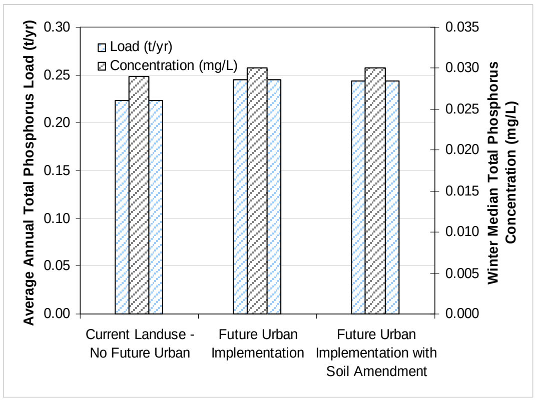


Nitrogen			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	4.5	3.1	4.0
2058	5.0	3.3	4.6
2059	6.0	4.2	5.7
2060	5.4	3.9	5.3
2061	4.4	2.9	4.1
2062	3.3	2.3	2.9
2063	4.9	3.3	4.3
2064	4.7	3.1	4.3
2065	7.3	4.6	6.8
2066	3.8	2.5	3.6
Average Load for RF Sequence (t/yr)	**4.9**	**3.3**	**4.6**

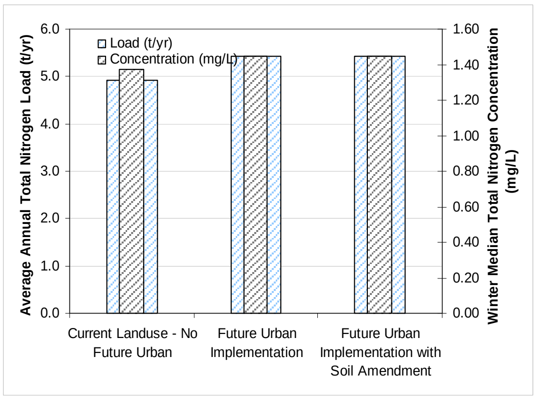


Helena River – Future urban

Phosphorus			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.23	0.25	0.25
2058	0.22	0.25	0.25
2059	0.25	0.28	0.28
2060	0.25	0.27	0.27
2061	0.18	0.20	0.20
2062	0.18	0.20	0.20
2063	0.24	0.27	0.27
2064	0.22	0.24	0.24
2065	0.31	0.34	0.34
2066	0.14	0.16	0.16
Average Load for RF Sequence (t/yr)	**0.22**	**0.25**	**0.24**
Median Winter Concentration (mg/L)	**0.029**	**0.030**	**0.030**

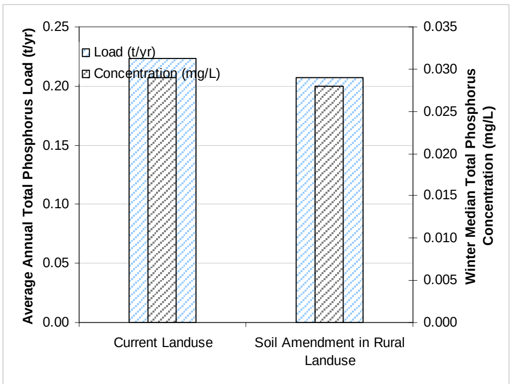


Nitrogen			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	4.5	4.9	4.9
2058	5.0	5.5	5.5
2059	6.0	6.6	6.6
2060	5.4	5.9	5.9
2061	4.4	4.8	4.8
2062	3.3	3.7	3.7
2063	4.9	5.4	5.4
2064	4.7	5.2	5.2
2065	7.3	8.0	8.0
2066	3.8	4.2	4.2
Average Load for RF Sequence (t/yr)	**4.9**	**5.4**	**5.4**
Median Winter Concentration (mg/L)	**1.37**	**1.44**	**1.44**



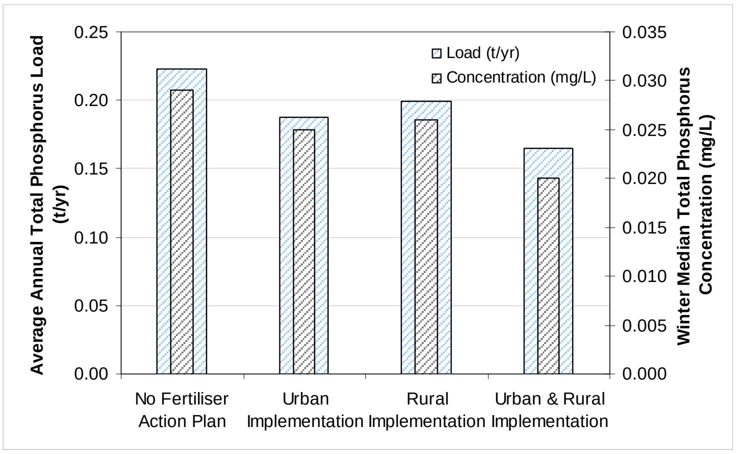
Helena River – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.23	0.21
2058	0.22	0.21
2059	0.25	0.24
2060	0.25	0.23
2061	0.18	0.16
2062	0.18	0.16
2063	0.24	0.23
2064	0.22	0.20
2065	0.31	0.29
2066	0.14	0.13
Average Load for RF Sequence (t/yr)	**0.22**	**0.21**
Median Winter Concentration (mg/L)	**0.029**	**0.028**



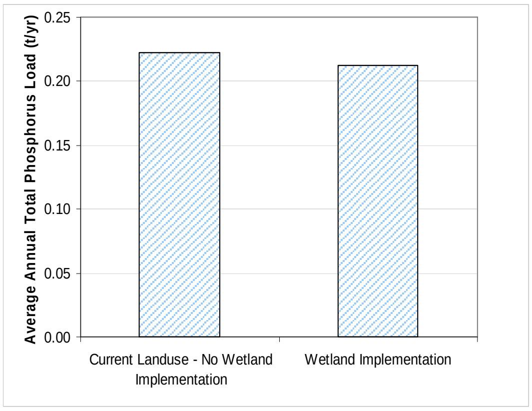
Helena River – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.23	0.19	0.20	0.17
2058	0.22	0.19	0.20	0.17
2059	0.25	0.21	0.23	0.19
2060	0.25	0.21	0.22	0.18
2061	0.18	0.15	0.16	0.13
2062	0.18	0.15	0.16	0.13
2063	0.24	0.21	0.22	0.18
2064	0.22	0.18	0.20	0.16
2065	0.31	0.26	0.28	0.23
2066	0.14	0.12	0.13	0.11
Average Load for RF Sequence (t/yr)	**0.22**	**0.19**	**0.20**	**0.17**
Median Winter Concentration (mg/L)	**0.029**	**0.025**	**0.026**	**0.020**

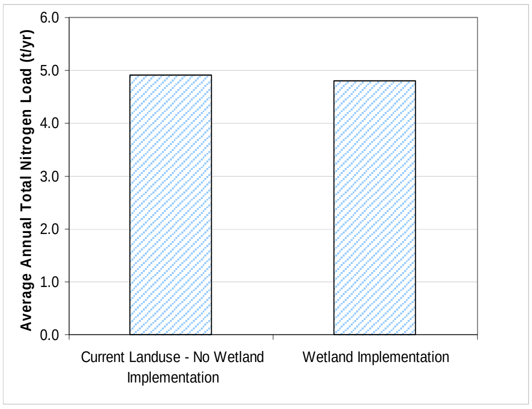


Helena River – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.23	0.21
2058	0.22	0.21
2059	0.25	0.24
2060	0.25	0.24
2061	0.18	0.17
2062	0.18	0.17
2063	0.24	0.23
2064	0.22	0.21
2065	0.31	0.30
2066	0.14	0.14
Average Load for RF Sequence (t/yr)	**0.22**	**0.21**

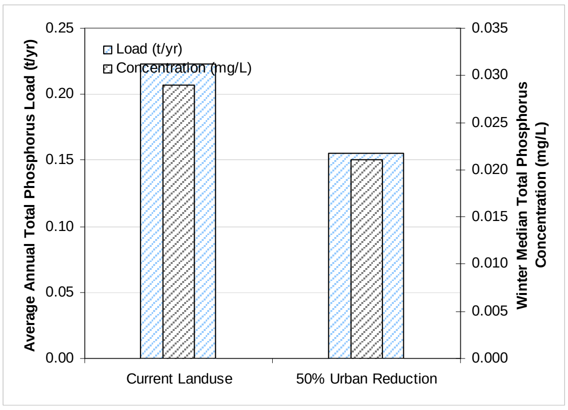


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	4.5	4.4
2058	5.0	4.9
2059	6.0	5.9
2060	5.4	5.3
2061	4.4	4.3
2062	3.3	3.3
2063	4.9	4.8
2064	4.7	4.6
2065	7.3	7.1
2066	3.8	3.7
Average Load for RF Sequence (t/yr)	**4.9**	**4.8**

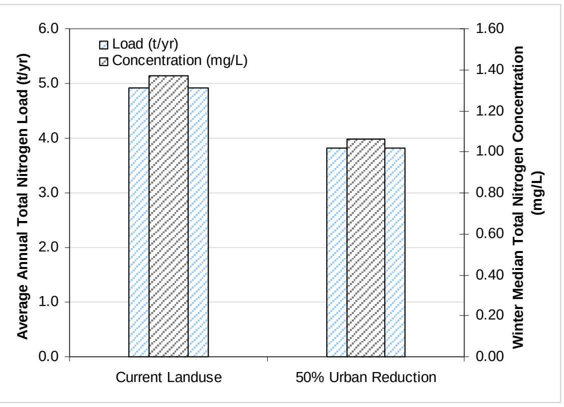


Helena River – Urban 50% reduction

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.23	0.16
2058	0.22	0.16
2059	0.25	0.18
2060	0.25	0.17
2061	0.18	0.12
2062	0.18	0.13
2063	0.24	0.17
2064	0.22	0.15
2065	0.31	0.22
2066	0.14	0.10
Average Load for RF Sequence (t/yr)	**0.22**	**0.16**
Median Winter Concentration (mg/L)	**0.029**	**0.021**

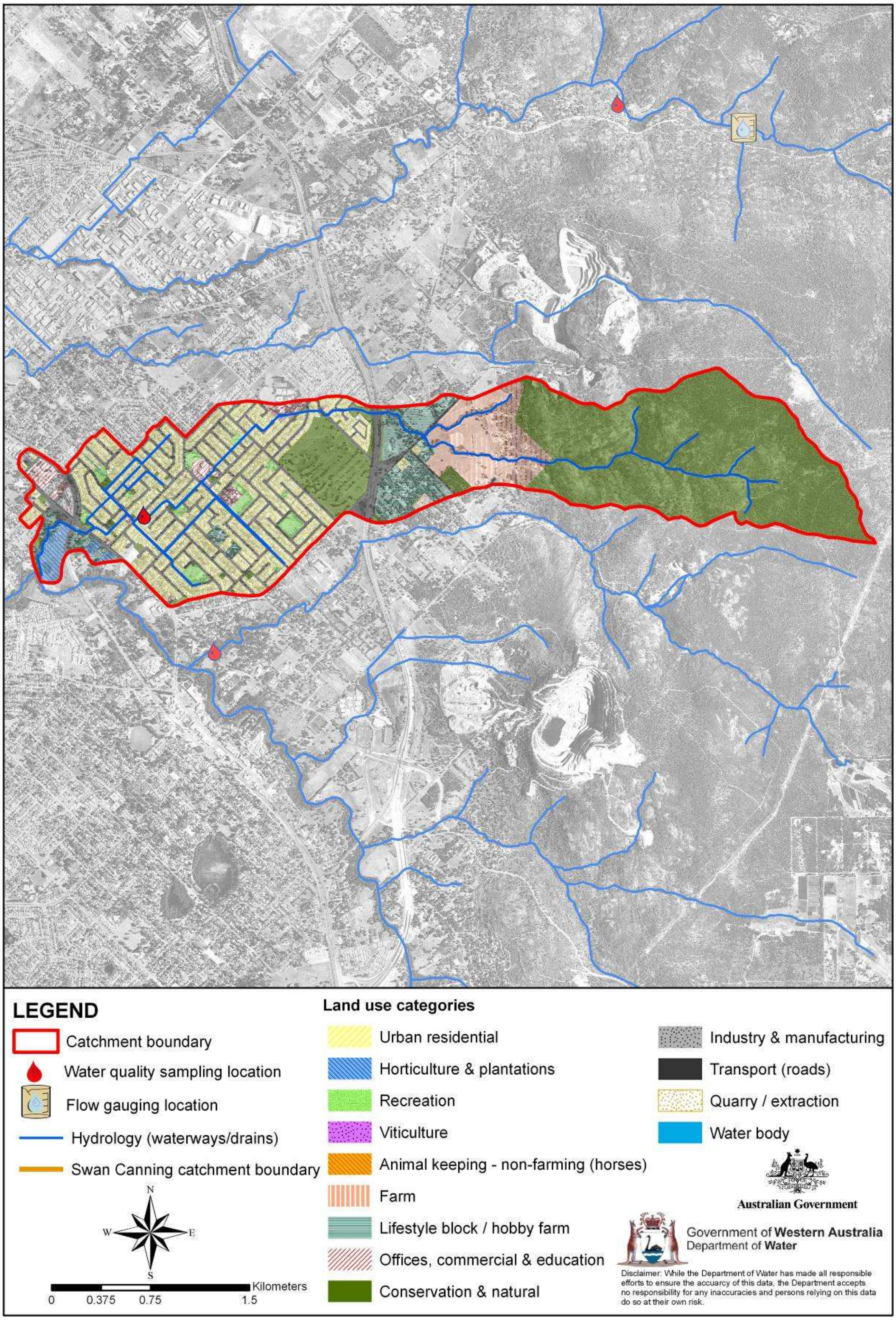


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	4.5	3.5
2058	5.0	3.8
2059	6.0	4.6
2060	5.4	4.3
2061	4.4	3.4
2062	3.3	2.7
2063	4.9	3.7
2064	4.7	3.7
2065	7.3	5.6
2066	3.8	3.0
Average Load for RF Sequence (t/yr)	**4.9**	**3.8**
Median Winter Concentration (mg/L)	**1.37**	**1.06**

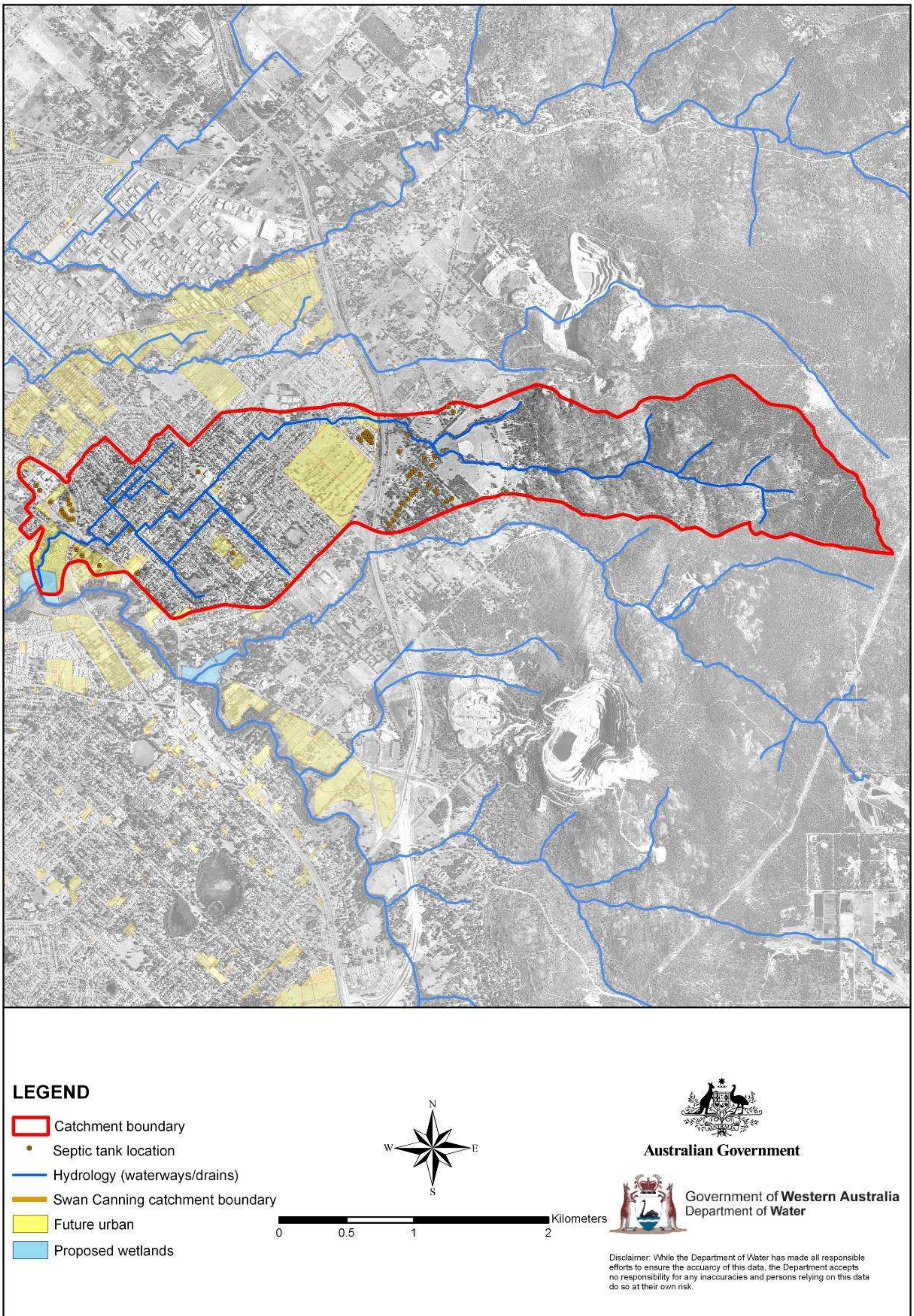


Helm Street

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Helm Street - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Sampling Location 6162313		
	Current	26% Input Reduction		Current	26% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.07	0.03	*1997*	0.02	0.01
1998	0.06	0.04	*1998*	0.01	0.01
1999	0.08	0.05	*1999*	0.02	0.01
2000	0.10	0.06	*2000*	0.02	0.01
2001	0.05	0.03	*2001*	0.01	0.01
2002	0.06	0.04	*2002*	0.01	0.01
2003	0.07	0.05	*2003*	0.02	0.01
2004	0.05	0.04	*2004*	0.01	0.01
2005	0.08	0.06	*2005*	0.02	0.01
2006	0.04	0.03	*2006*	0.01	0.01
Average	**0.07**	**0.04**	**Average**	**0.02**	**0.01**
Median Winter Conc (mg/L):			**Median Winter Conc (mg/L):**		
SQUARE	**0.110**	**0.075**	**SQUARE**	**0.041**	**0.026**
Target	**0.075**		**Observed**	**0.041**	
Load Target (t/yr)		**0.04**			
Load Reduction Target (t/yr)		**0.02**			
Required Reduction (%)		**35%**			
Time Required (yr)		**30**			

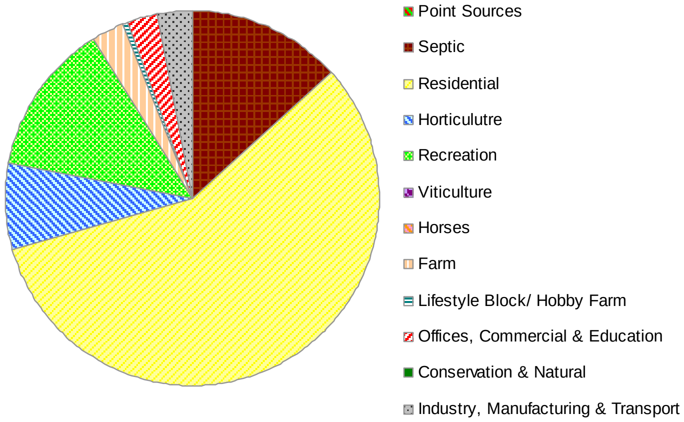
Nitrogen

At Outlet to Swan River Estuary			At Sampling Location 6162313		
	Current	60% Input Reduction		Current	60% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	1.5	0.4	*1997*	0.6	0.2
1998	1.6	0.5	*1998*	0.6	0.2
1999	2.1	0.6	*1999*	0.8	0.2
2000	2.3	0.7	*2000*	0.9	0.3
2001	1.3	0.4	*2001*	0.5	0.1
2002	1.5	0.5	*2002*	0.6	0.2
2003	2.0	0.6	*2003*	0.8	0.2
2004	1.4	0.4	*2004*	0.5	0.2
2005	2.2	0.7	*2005*	0.9	0.3
2006	0.9	0.3	*2006*	0.3	0.1
Average	**1.7**	**0.5**	**Average**	**0.7**	**0.2**
Median Winter Conc (mg/L):			**Median Winter Conc (mg/L):**		
SQUARE	**2.34**	**0.75**	**SQUARE**	**1.60**	**0.51**
Target	**0.75**		**Observed**	**1.60**	
Load Target (t/yr)		**0.5**			
Load Reduction Target (t/yr)		**1.2**			
Required Reduction (%)		**69%**			
Time Required (yr)		**40**			

Helm Street – Source separation

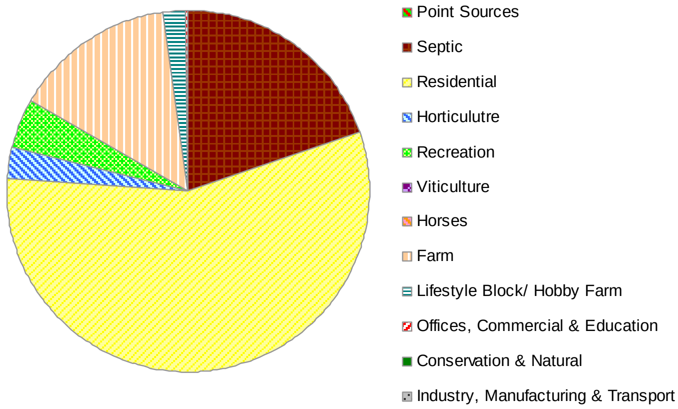
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.07	0.00	0.02	0.04	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01
1998	0.06	0.00	0.01	0.03	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
1999	0.08	0.00	0.02	0.04	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01
2000	0.10	0.00	0.02	0.05	0.01	0.02	0.00	0.00	0.01	0.01	0.01	0.00	0.01
2001	0.05	0.00	0.01	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.06	0.00	0.01	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.07	0.00	0.01	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2004	0.05	0.00	0.01	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.08	0.00	0.01	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2006	0.04	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Load (non adj)	0.07	0.00	0.01	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Load (t/yr)	**0.07**	**0.00**	**0.01**	**0.04**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**0.0%**	**13.2%**	**57.3%**	**7.5%**	**13.0%**	**0.0%**	**0.0%**	**2.9%**	**0.5%**	**2.6%**	**0.0%**	**3.0%**



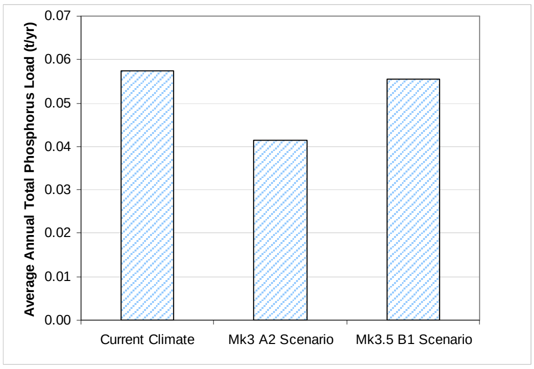
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	1.5	0.0	0.3	0.5	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0
1998	1.6	0.0	0.3	0.6	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0
1999	2.1	0.0	0.4	0.7	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0
2000	2.3	0.0	0.4	0.8	0.1	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0
2001	1.3	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
2002	1.5	0.0	0.2	0.6	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
2003	2.0	0.0	0.2	0.9	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0
2004	1.4	0.0	0.1	0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
2005	2.2	0.0	0.2	1.0	0.1	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0
2006	0.9	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Load (non adj)	1.7	0.0	0.2	0.7	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Load (t/yr)	**1.7**	**0.0**	**0.3**	**0.9**	**0.0**	**0.1**	**0.0**	**0.0**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**19.3%**	**54.6%**	**2.8%**	**4.4%**	**0.0%**	**0.0%**	**14.1%**	**1.8%**	**0.2%**	**0.0%**	**0.0%**

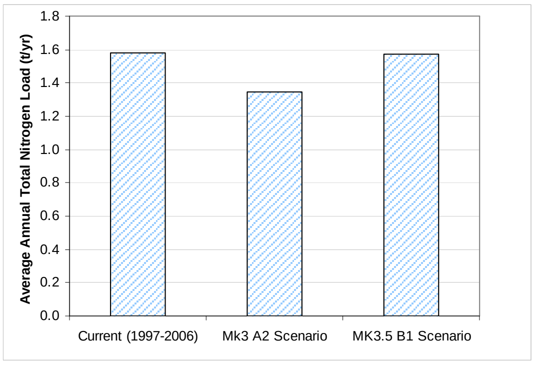


Helm Street – Climate change

Phosphorus			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.04	0.03	0.04
2058	0.05	0.03	0.05
2059	0.07	0.05	0.07
2060	0.08	0.07	0.08
2061	0.05	0.04	0.04
2062	0.05	0.04	0.05
2063	0.07	0.05	0.07
2064	0.05	0.04	0.05
2065	0.08	0.05	0.07
2066	0.04	0.03	0.03
Average Load for RF Sequence (t/yr)	**0.06**	**0.04**	**0.06**

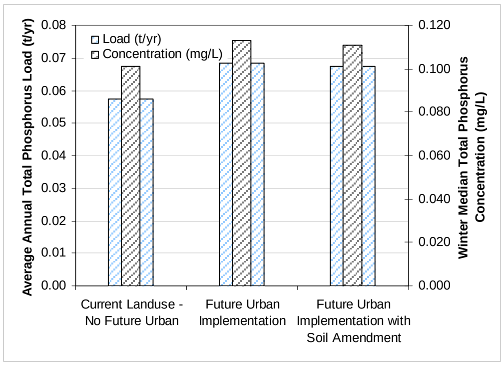


Nitrogen			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	1.3	1.0	1.3
2058	1.5	1.2	1.5
2059	1.9	1.6	1.9
2060	2.2	2.0	2.1
2061	1.3	1.1	1.3
2062	1.4	1.2	1.4
2063	1.9	1.6	1.9
2064	1.3	1.2	1.3
2065	2.1	1.7	2.1
2066	0.9	0.8	0.9
Average Load for RF Sequence (t/yr)	**1.6**	**1.3**	**1.6**

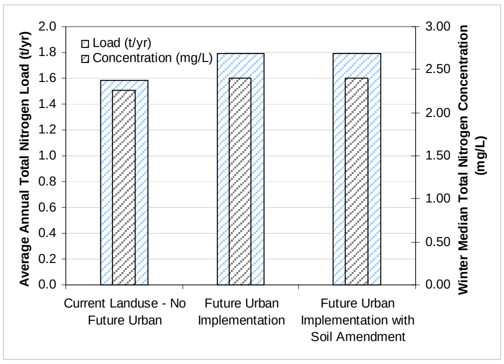


Helm Street – Future urban

Phosphorus			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.04	0.05	0.05
2058	0.05	0.06	0.06
2059	0.07	0.08	0.08
2060	0.08	0.10	0.10
2061	0.05	0.05	0.05
2062	0.05	0.06	0.06
2063	0.07	0.08	0.08
2064	0.05	0.06	0.06
2065	0.08	0.09	0.09
2066	0.04	0.04	0.04
Average Load for RF Sequence (t/yr)	**0.06**	**0.07**	**0.07**
Median Winter Concentration (mg/L)	**0.101**	**0.113**	**0.111**

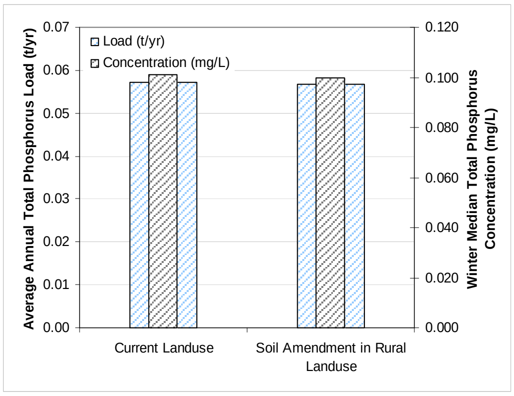


Nitrogen			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	1.3	1.5	1.5
2058	1.5	1.7	1.7
2059	1.9	2.3	2.3
2060	2.2	2.5	2.5
2061	1.3	1.3	1.3
2062	1.4	1.5	1.5
2063	1.9	2.1	2.1
2064	1.3	1.5	1.5
2065	2.1	2.3	2.3
2066	0.9	1.1	1.1
Average Load for RF Sequence (t/yr)	**1.6**	**1.8**	**1.8**
Median Winter Concentration (mg/L)	**2.26**	**2.40**	**2.40**



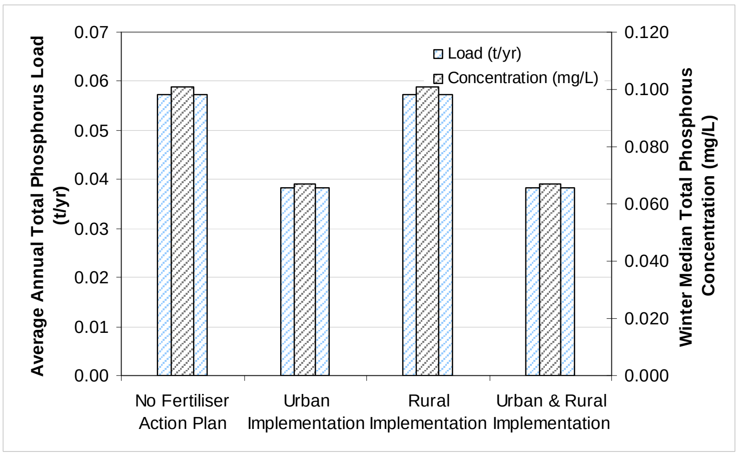
Helm Street – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.04	0.04
2058	0.05	0.05
2059	0.07	0.07
2060	0.08	0.08
2061	0.05	0.04
2062	0.05	0.05
2063	0.07	0.07
2064	0.05	0.05
2065	0.08	0.08
2066	0.04	0.03
Average Load for RF Sequence (t/yr)	**0.06**	**0.06**
Median Winter Concentration (mg/L)	**0.101**	**0.100**



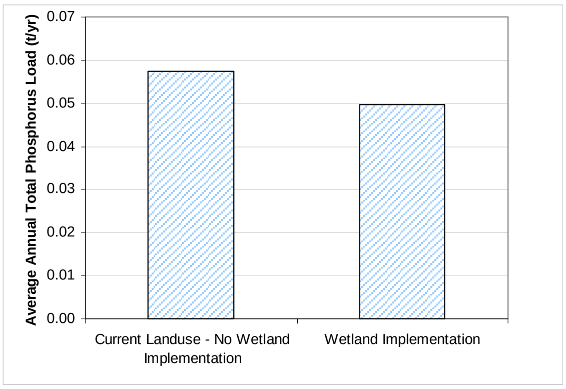
Helm Street – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)*	Urban and Rural Implementation (t/yr)
2057	0.04	0.03	0.04	0.03
2058	0.05	0.03	0.05	0.03
2059	0.07	0.05	0.07	0.05
2060	0.08	0.06	0.08	0.06
2061	0.05	0.03	0.05	0.03
2062	0.05	0.04	0.05	0.04
2063	0.07	0.05	0.07	0.05
2064	0.05	0.03	0.05	0.03
2065	0.08	0.05	0.08	0.05
2066	0.04	0.02	0.04	0.02
Average Load for RF Sequence (t/yr)	**0.06**	**0.04**	**0.06**	**0.04**
Median Winter Concentration (mg/L)	**0.101**	**0.067**	**0.101**	**0.067**

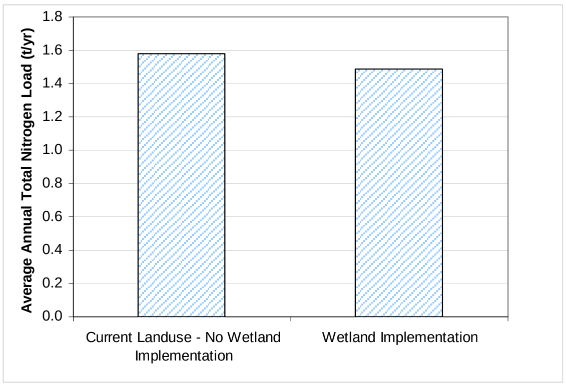


Helm Street – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	***Current Landuse - No Wetland Implementation (t/yr)***	***Wetland Implementation Load (t/yr)***
2057	0.04	0.04
2058	0.05	0.04
2059	0.07	0.06
2060	0.08	0.07
2061	0.05	0.04
2062	0.05	0.05
2063	0.07	0.06
2064	0.05	0.04
2065	0.08	0.07
2066	0.04	0.03
Average Load for RF Sequence (t/yr)	**0.06**	**0.05**

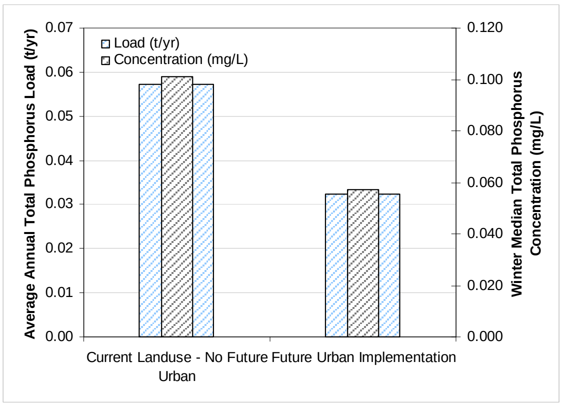


Nitrogen		
	At Catchment Outlet	
Year	***Current Landuse - No Wetland Implementation (t/yr)***	***Wetland Implementation Load (t/yr)***
2057	1.3	1.2
2058	1.5	1.4
2059	1.9	1.8
2060	2.2	2.0
2061	1.3	1.2
2062	1.4	1.3
2063	1.9	1.8
2064	1.3	1.3
2065	2.1	2.0
2066	0.9	0.8
Average Load for RF Sequence (t/yr)	**1.6**	**1.5**

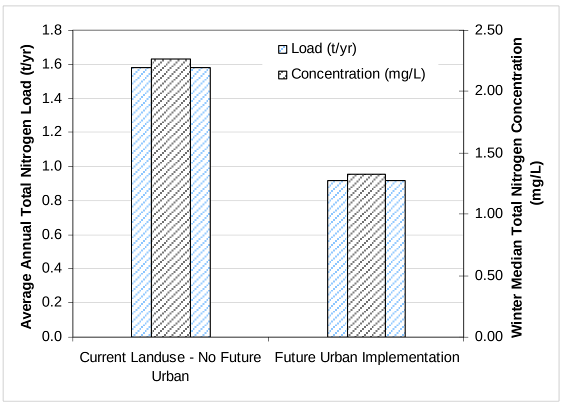


Helm Street – Urban 50% reduction

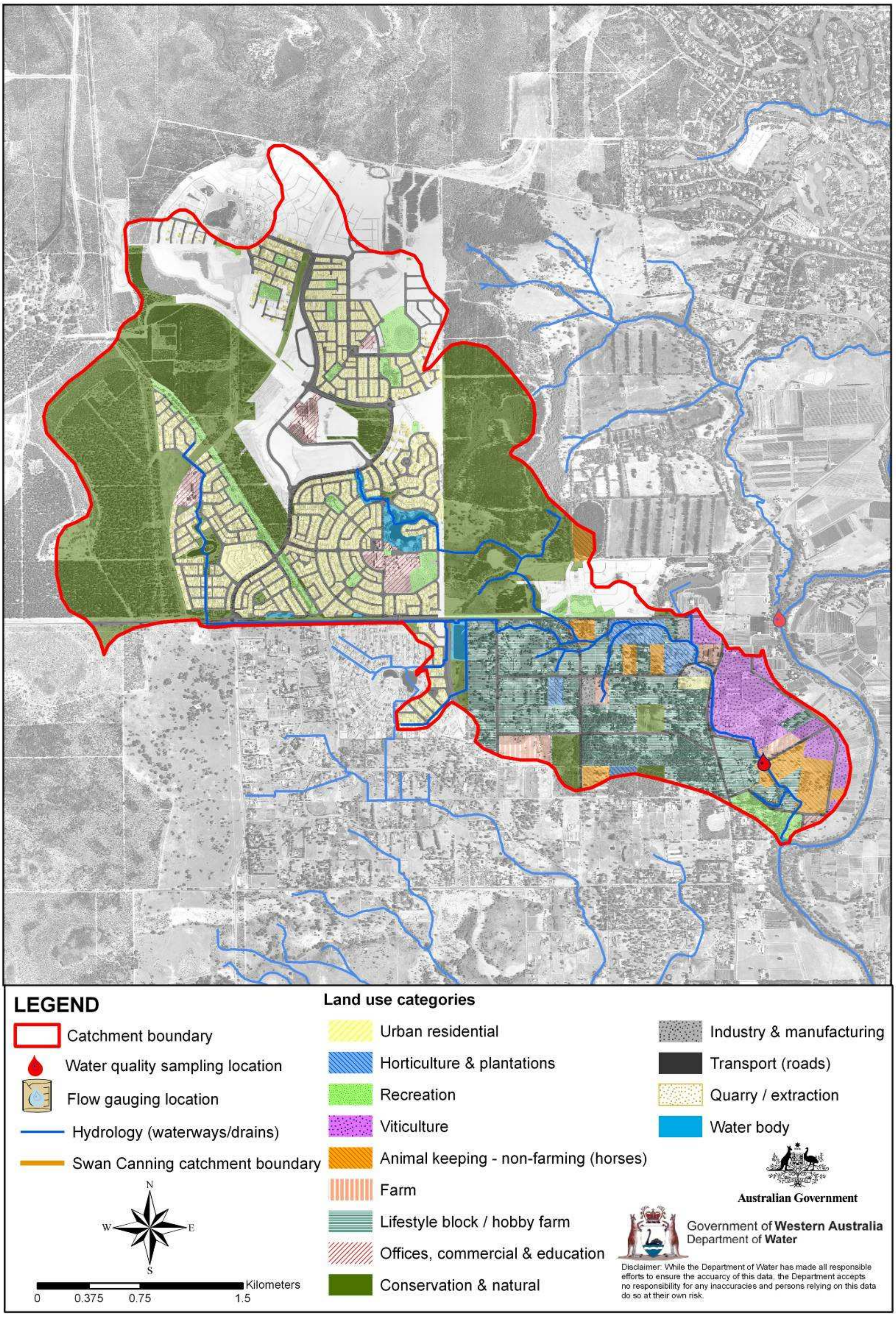
Phosphorus		
	At Catchment Outlet	
Year	***Current Landuse Load (t/yr)***	***50% urban reduction Load (t/yr)***
2057	0.04	0.02
2058	0.05	0.03
2059	0.07	0.04
2060	0.08	0.05
2061	0.05	0.03
2062	0.05	0.03
2063	0.07	0.04
2064	0.05	0.03
2065	0.08	0.04
2066	0.04	0.02
Average Load for RF Sequence (t/yr)	**0.06**	**0.03**
Median Winter Concentration (mg/L)	**0.101**	**0.057**



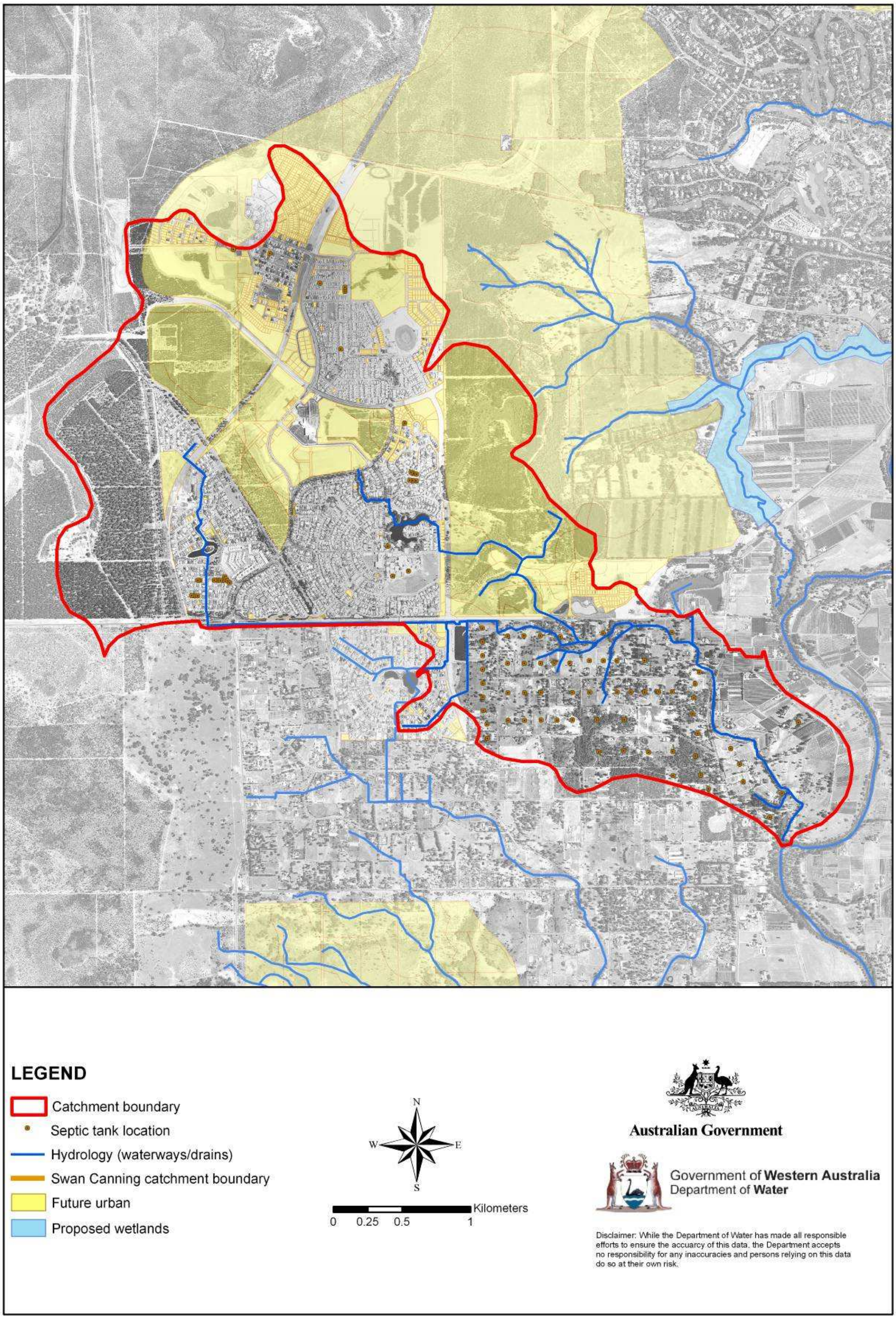
Nitrogen		
	At Catchment Outlet	
Year	***Current Landuse Load (t/yr)***	***50% urban reduction Load (t/yr)***
2057	1.3	0.7
2058	1.5	0.8
2059	1.9	1.1
2060	2.2	1.3
2061	1.3	0.7
2062	1.4	0.8
2063	1.9	1.1
2064	1.3	0.8
2065	2.1	1.2
2066	0.9	0.5
Average Load for RF Sequence (t/yr)	**1.6**	**0.9**
Median Winter Concentration (mg/L)	**2.26**	**1.33**



Henley Brook
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Henley Brook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Sampling Location 6161692		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.04	-	1997	0.04	-
1998	0.03	-	1998	0.03	-
1999	0.05	-	1999	0.04	-
2000	0.06	-	2000	0.05	-
2001	0.03	-	2001	0.02	-
2002	0.04	-	2002	0.03	-
2003	0.06	-	2003	0.05	-
2004	0.06	-	2004	0.05	-
2005	0.10	-	2005	0.09	-
2006	0.04	-	2006	0.03	-
Average	**0.05**	**-**	**Average**	**0.04**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.116**		**SQUARE:**	**0.096**	
Target:	**0.100**		**Observed:**	**0.093**	
Load Target (t/yr)		**0.05**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

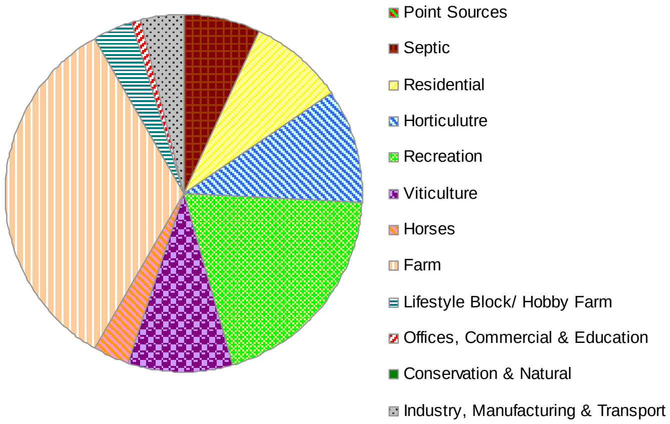
Nitrogen

At Outlet to Swan River Estuary			At Sampling Location 6161692		
	Current	20% Input Reduction		Current	20% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.6	0.7	1997	0.5	0.6
1998	0.5	0.5	1998	0.4	0.5
1999	0.7	0.8	1999	0.6	0.7
2000	0.9	0.9	2000	0.7	0.8
2001	0.5	0.3	2001	0.4	0.3
2002	0.6	0.4	2002	0.5	0.4
2003	0.9	0.7	2003	0.8	0.6
2004	0.9	0.6	2004	0.8	0.6
2005	1.4	1.0	2005	1.2	0.9
2006	0.6	0.3	2006	0.6	0.2
Average	**0.8**	**0.6**	**Average**	**0.7**	**0.5**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.63**	**0.99**	**SQUARE:**	**1.41**	**0.91**
Target:	**1.00**		**Observed:**	**1.40**	
Load Target (t/yr)		**0.6**			
Load Reduction Target (t/yr)		**0.1**			
Required Reduction (%)		**18%**			
Time Required (yr)		**40**			

Henley Brook – Source separation

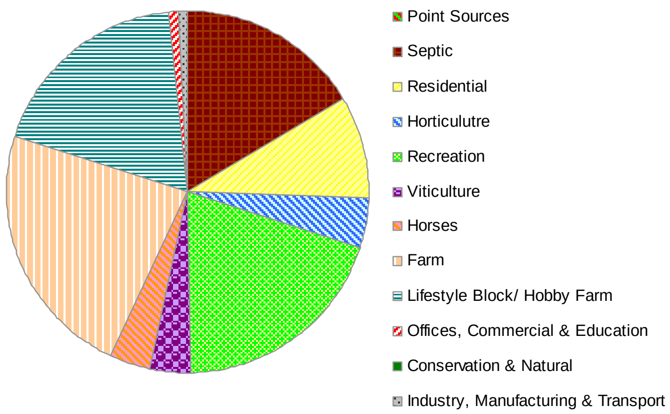
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01
1998	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
1999	0.05	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.03	0.01	0.01	0.01	0.01
2000	0.06	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
2001	0.03	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00
2002	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
2003	0.06	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.03	0.01	0.01	0.01	0.01
2004	0.06	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.03	0.01	0.01	0.01	0.01
2005	0.10	0.03	0.03	0.04	0.03	0.04	0.03	0.03	0.05	0.03	0.03	0.03	0.03
2006	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Load (non adj)	0.05	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Load (t/yr)	**0.05**	**0.00**	**0.00**	**0.00**	**0.01**	**0.01**	**0.00**	**0.00**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**0.0%**	**7.0%**	**8.5%**	**10.3%**	**19.7%**	**9.5%**	**3.5%**	**33.1%**	**3.8%**	**0.7%**	**0.0%**	**3.9%**



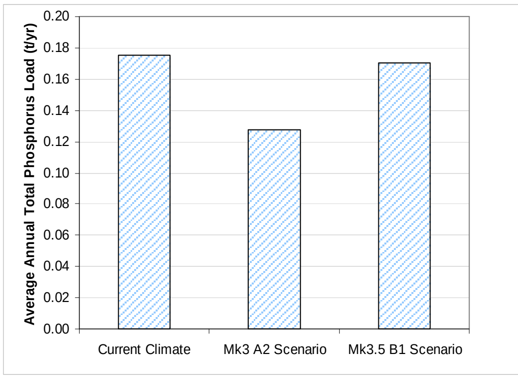
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.6	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.2
1998	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.2
1999	0.7	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.3	0.3
2000	0.9	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.3	0.3
2001	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
2002	0.6	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.4
2003	0.9	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4
2004	0.9	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4
2005	1.4	0.7	0.8	0.8	0.7	0.8	0.7	0.7	0.7	0.8	0.7	0.7	0.7
2006	0.6	0.4	0.4	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Load (non adj)	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Load (t/yr)	**0.8**	**0.0**	**0.1**	**0.1**	**0.0**	**0.2**	**0.0**	**0.0**	**0.2**	**0.1**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**16.5%**	**9.1%**	**4.4%**	**19.6%**	**3.5%**	**3.8%**	**22.9%**	**18.4%**	**0.7%**	**0.0%**	**0.9%**

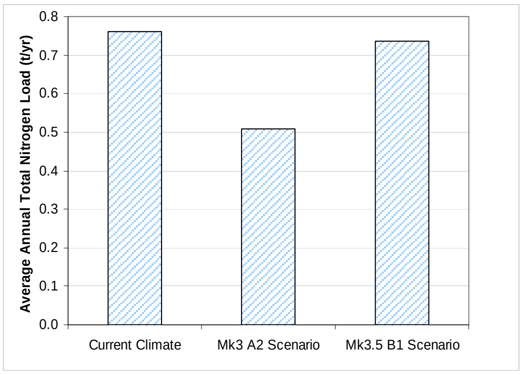


Henley Brook – Climate change

Phosphorus			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.20	0.14	0.19
2058	0.16	0.12	0.16
2059	0.21	0.15	0.21
2060	0.22	0.17	0.22
2061	0.10	0.07	0.10
2062	0.13	0.09	0.12
2063	0.20	0.14	0.19
2064	0.18	0.13	0.18
2065	0.26	0.19	0.25
2066	0.09	0.06	0.08
Average Load for RF Sequence (t/yr)	**0.18**	**0.13**	**0.17**

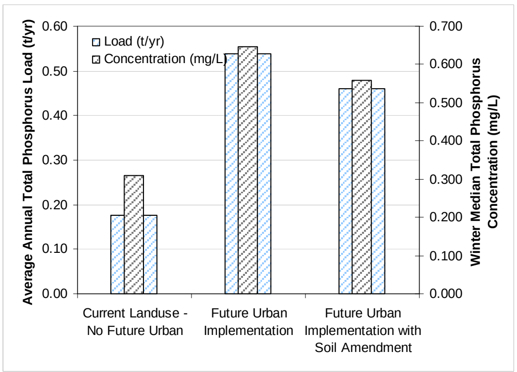


Nitrogen			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.9	0.6	0.8
2058	0.6	0.5	0.6
2059	1.0	0.6	0.9
2060	1.1	0.7	1.0
2061	0.4	0.3	0.4
2062	0.5	0.3	0.5
2063	0.9	0.5	0.8
2064	0.8	0.5	0.8
2065	1.2	0.8	1.1
2066	0.3	0.2	0.3
Average Load for RF Sequence (t/yr)	**0.8**	**0.5**	**0.7**

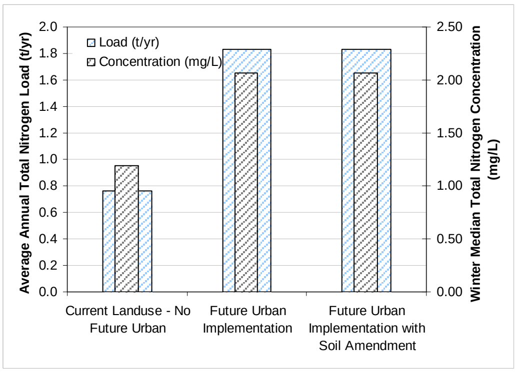


Henley Brook – Future urban

Phosphorus			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.20	0.59	0.50
2058	0.16	0.50	0.44
2059	0.21	0.64	0.54
2060	0.22	0.67	0.56
2061	0.10	0.32	0.29
2062	0.13	0.39	0.35
2063	0.20	0.63	0.54
2064	0.18	0.54	0.46
2065	0.26	0.81	0.68
2066	0.09	0.27	0.26
Average Load for RF Sequence (t/yr)	**0.18**	**0.54**	**0.46**
Median Winter Concentration (mg/L)	**0.309**	**0.647**	**0.559**

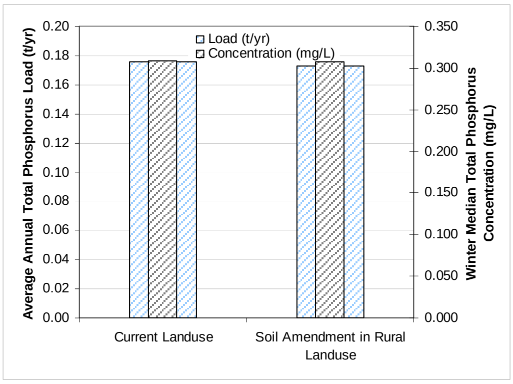


Nitrogen			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.9	2.1	2.1
2058	0.6	1.7	1.7
2059	1.0	2.3	2.3
2060	1.1	2.4	2.4
2061	0.4	1.0	1.0
2062	0.5	1.2	1.2
2063	0.9	2.1	2.1
2064	0.8	1.8	1.8
2065	1.2	2.9	2.9
2066	0.3	0.8	0.8
Average Load for RF Sequence (t/yr)	**0.8**	**1.8**	**1.8**
Median Winter Concentration (mg/L)	**1.20**	**2.07**	**2.07**



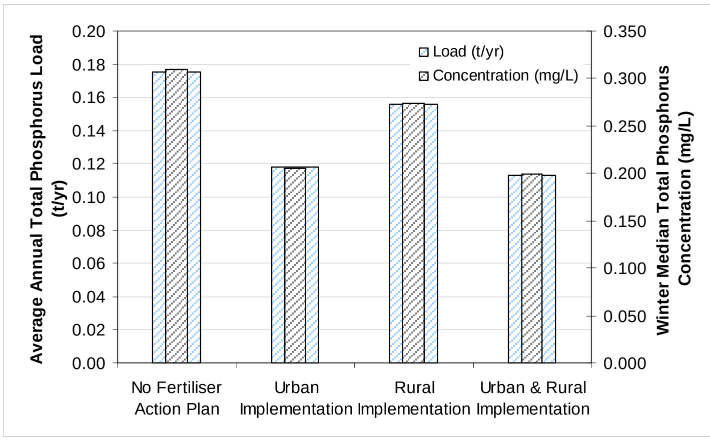
Henley Brook – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.20	0.19
2058	0.16	0.16
2059	0.21	0.21
2060	0.22	0.22
2061	0.10	0.10
2062	0.13	0.13
2063	0.20	0.20
2064	0.18	0.18
2065	0.26	0.26
2066	0.09	0.09
Average Load for RF Sequence (t/yr)	**0.18**	**0.17**
Median Winter Concentration (mg/L)	**0.309**	**0.307**



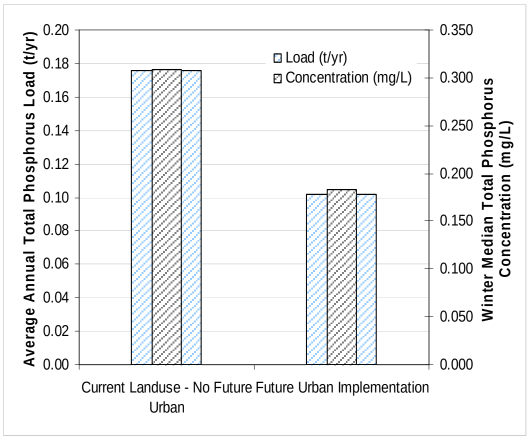
Henley Brook – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.20	0.13	0.17	0.13
2058	0.16	0.11	0.14	0.10
2059	0.21	0.14	0.19	0.14
2060	0.22	0.15	0.20	0.14
2061	0.10	0.07	0.09	0.07
2062	0.13	0.09	0.11	0.08
2063	0.20	0.14	0.18	0.13
2064	0.18	0.12	0.16	0.12
2065	0.26	0.18	0.23	0.17
2066	0.09	0.06	0.08	0.06
Average Load for RF Sequence (t/yr)	**0.18**	**0.12**	**0.16**	**0.11**
Median Winter Concentration (mg/L)	**0.309**	**0.206**	**0.274**	**0.199**

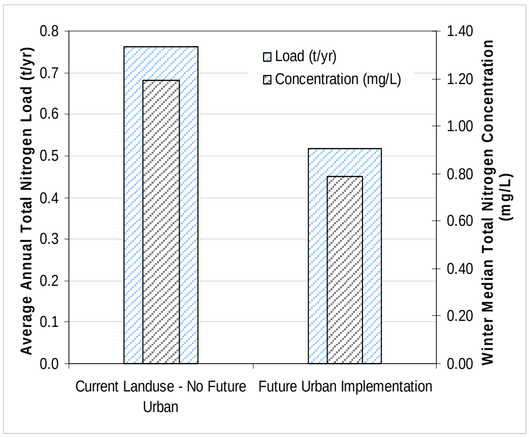


Henley Brook – Urban 50% reduction

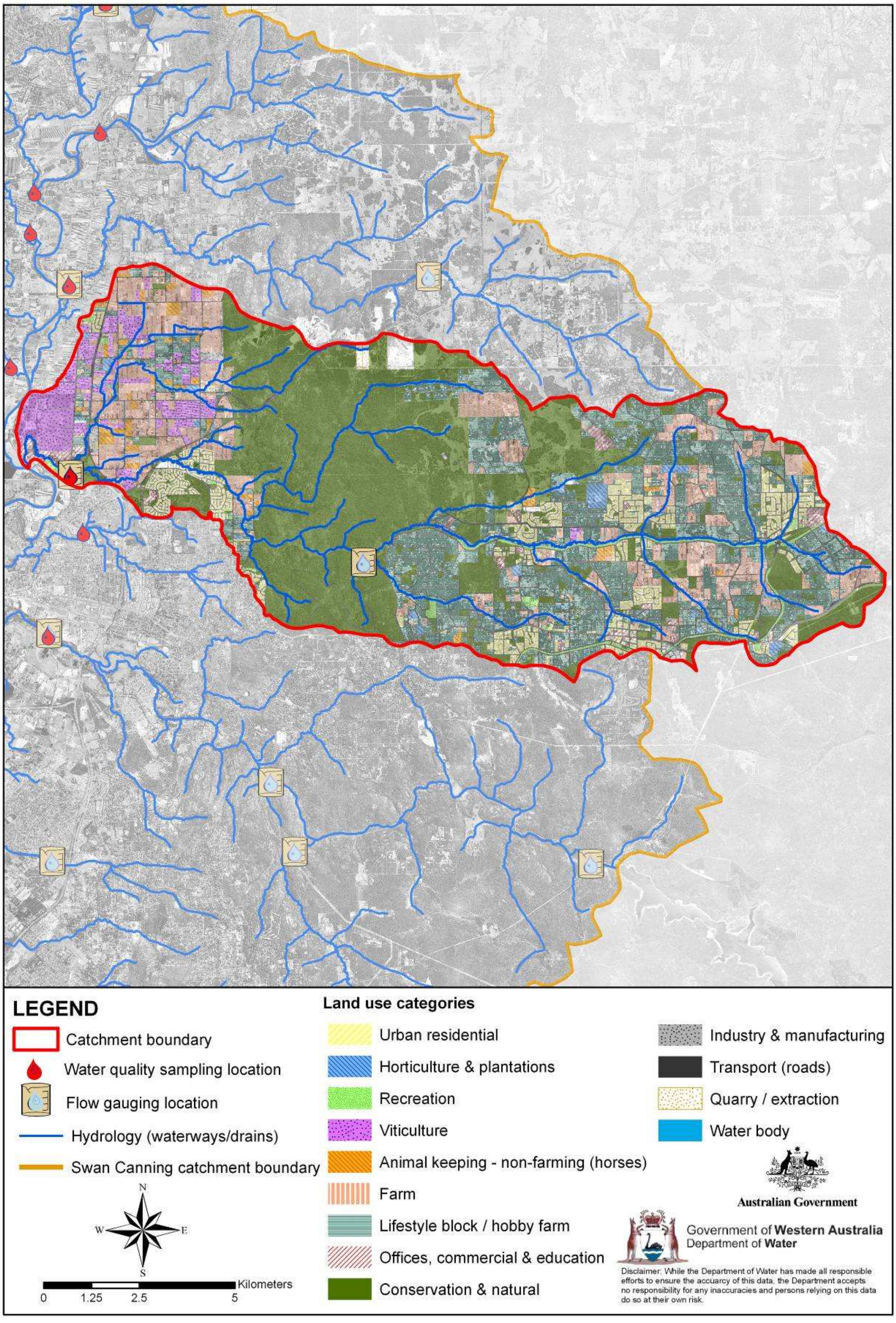
Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.20	0.11
2058	0.16	0.09
2059	0.21	0.12
2060	0.22	0.13
2061	0.10	0.06
2062	0.13	0.07
2063	0.20	0.12
2064	0.18	0.10
2065	0.26	0.15
2066	0.09	0.05
Average Load for RF Sequence (t/yr)	**0.18**	**0.10**
Median Winter Concentration (mg/L)	**0.309**	**0.183**



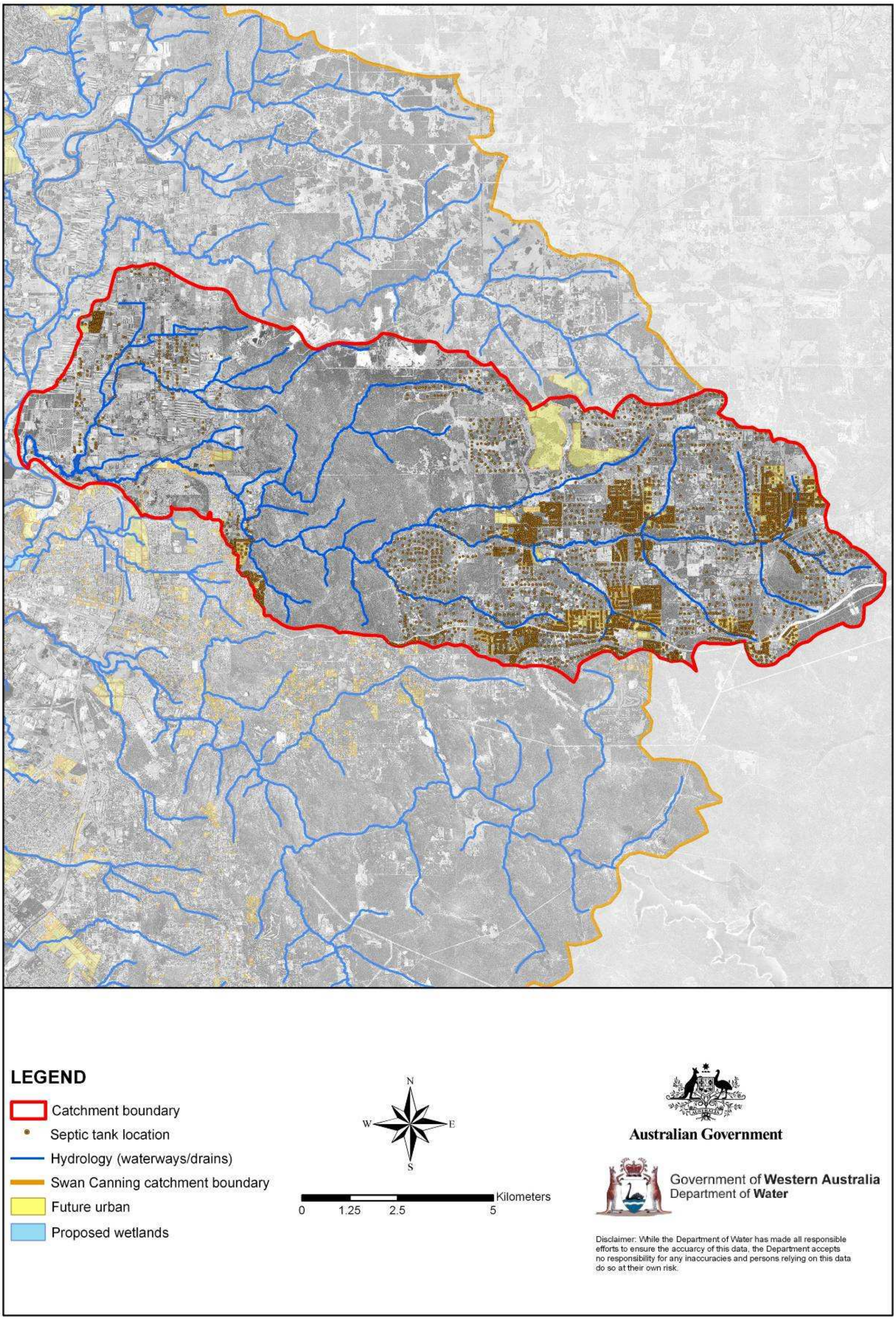
Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.9	0.6
2058	0.6	0.4
2059	1.0	0.6
2060	1.1	0.7
2061	0.4	0.3
2062	0.5	0.3
2063	0.9	0.6
2064	0.8	0.5
2065	1.2	0.8
2066	0.3	0.2
Average Load for RF Sequence (t/yr)	**0.8**	**0.5**
Median Winter Concentration (mg/L)	**1.20**	**0.79**



Jane Brook
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Jane Brook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Sampling Location 6161692		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.35	-	*1997*	0.24	-
1998	0.44	-	*1998*	0.30	-
1999	0.48	-	*1999*	0.37	-
2000	0.78	-	*2000*	0.52	-
2001	0.35	-	*2001*	0.24	-
2002	0.31	-	*2002*	0.28	-
2003	0.95	-	*2003*	0.71	-
2004	0.40	-	*2004*	0.33	-
2005	1.48	-	*2005*	0.84	-
2006	0.25	-	*2006*	0.21	-
Average	**0.58**	**-**	**Average**	**0.41**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.022**		**SQUARE:**	**0.023**	
Target:	**0.075**		**Observed:**	**0.023**	
Load Target (t/yr)		**0.58**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

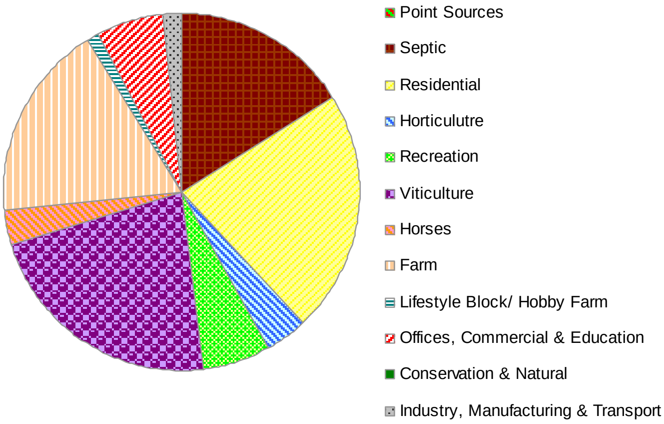
Nitrogen

At Outlet to Swan River Estuary			At Sampling Location 6161692		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	10.3	-	*1997*	8.0	-
1998	10.2	-	*1998*	8.0	-
1999	13.7	-	*1999*	10.9	-
2000	12.4	-	*2000*	9.9	-
2001	8.9	-	*2001*	7.0	-
2002	8.9	-	*2002*	7.1	-
2003	13.7	-	*2003*	11.0	-
2004	10.2	-	*2004*	8.2	-
2005	15.8	-	*2005*	12.8	-
2006	6.3	-	*2006*	5.0	-
Average	**11.0**	**-**	**Average**	**8.8**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.71**		**SQUARE:**	**0.70**	
Target:	**0.75**		**Observed:**	**0.70**	
Load Target (t/yr)		**-**			
Load Reduction Target (t/yr)		**0.0**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

Jane Brook – Source separation

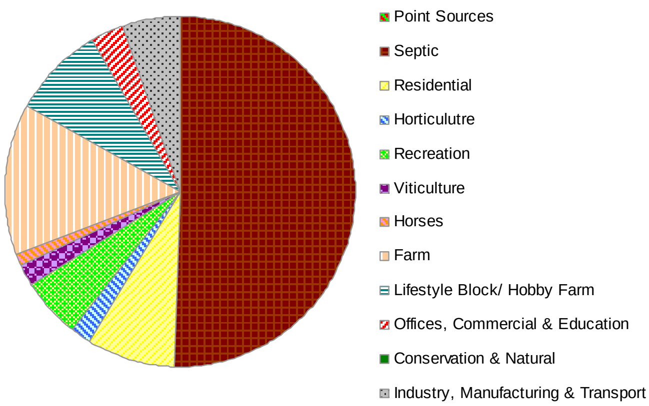
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.35	0.01	0.07	0.08	0.03	0.04	0.08	0.01	0.06	0.01	0.02	0.01	0.01
1998	0.44	0.01	0.08	0.09	0.03	0.04	0.11	0.02	0.08	0.01	0.03	0.01	0.01
1999	0.48	0.01	0.11	0.12	0.03	0.04	0.08	0.02	0.07	0.01	0.04	0.01	0.02
2000	0.78	0.01	0.14	0.18	0.04	0.08	0.19	0.03	0.11	0.02	0.05	0.01	0.02
2001	0.35	0.00	0.06	0.09	0.02	0.03	0.08	0.01	0.04	0.01	0.02	0.00	0.01
2002	0.31	0.00	0.07	0.10	0.02	0.02	0.02	0.01	0.03	0.01	0.03	0.00	0.01
2003	0.95	0.01	0.12	0.18	0.03	0.06	0.21	0.04	0.25	0.01	0.06	0.01	0.02
2004	0.40	0.00	0.09	0.13	0.02	0.03	0.04	0.01	0.04	0.01	0.03	0.00	0.01
2005	1.48	0.01	0.15	0.22	0.04	0.06	0.45	0.08	0.35	0.01	0.11	0.01	0.03
2006	0.25	0.00	0.06	0.09	0.01	0.02	0.02	0.01	0.02	0.00	0.02	0.00	0.00
Load (non adj)	0.58	0.01	0.10	0.13	0.03	0.04	0.13	0.02	0.11	0.01	0.04	0.01	0.01
Load (t/yr)	**0.58**	**0.00**	**0.09**	**0.13**	**0.02**	**0.04**	**0.13**	**0.02**	**0.10**	**0.01**	**0.04**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**16.2%**	**21.8%**	**3.9%**	**6.2%**	**22.2%**	**3.0%**	**17.9%**	**1.0%**	**6.2%**	**0.0%**	**1.6%**



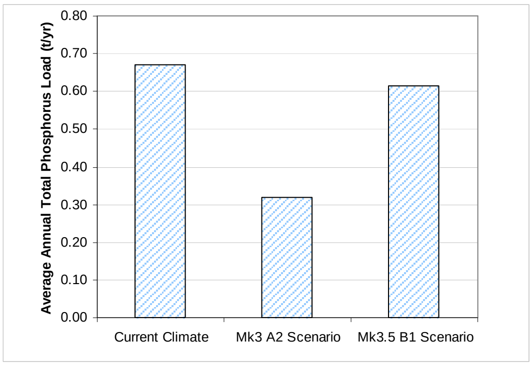
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	10.3	1.1	7.4	2.1	1.3	1.8	1.3	1.2	3.0	2.2	1.2	1.1	1.8
1998	10.2	1.0	7.4	2.1	1.4	1.8	1.3	1.3	3.0	2.3	1.2	1.0	1.8
1999	13.7	1.4	9.8	2.6	1.7	2.3	1.6	1.5	3.8	2.8	1.6	1.4	2.2
2000	12.4	1.1	8.8	2.3	1.6	1.8	1.4	1.4	3.4	2.5	1.5	1.1	2.0
2001	8.9	0.9	6.6	1.9	1.1	1.6	1.1	1.0	2.4	1.9	1.3	0.9	1.6
2002	8.9	0.7	6.4	1.7	1.0	1.4	0.9	0.9	2.4	1.8	1.3	0.7	1.4
2003	13.7	1.4	9.8	2.8	1.7	2.3	1.6	1.5	3.5	2.8	2.0	1.4	2.3
2004	10.2	1.0	7.5	2.0	1.2	1.7	1.2	1.1	2.6	2.0	1.5	1.0	1.6
2005	15.8	1.8	11.5	3.0	2.0	2.6	2.0	1.8	3.9	3.0	2.4	1.8	2.4
2006	6.3	0.5	4.6	1.2	0.7	1.0	0.6	0.7	1.7	1.2	0.9	0.5	1.0
Load (non adj)	11.0	1.1	8.0	2.2	1.4	1.8	1.3	1.2	3.0	2.3	1.5	1.1	1.8
Load (t/yr)	**11.0**	**0.0**	**5.2**	**0.8**	**0.2**	**0.6**	**0.2**	**0.1**	**1.4**	**0.9**	**0.3**	**0.0**	**0.5**
Load (%)	**100.0%**	**0.0%**	**47.0%**	**7.5%**	**1.9%**	**5.2%**	**1.6%**	**1.2%**	**12.9%**	**8.0%**	**2.8%**	**0.0%**	**4.9%**

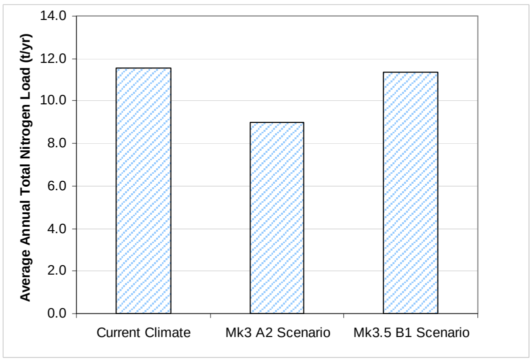


Jane Brook – Climate change

Phosphorus			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.37	0.23	0.35
2058	0.55	0.28	0.50
2059	0.60	0.38	0.56
2060	1.24	0.48	1.12
2061	0.38	0.21	0.36
2062	0.34	0.23	0.33
2063	1.02	0.40	0.90
2064	0.43	0.26	0.41
2065	1.50	0.57	1.36
2066	0.27	0.16	0.25
Average Load for RF Sequence (t/yr)	**0.67**	**0.32**	**0.61**

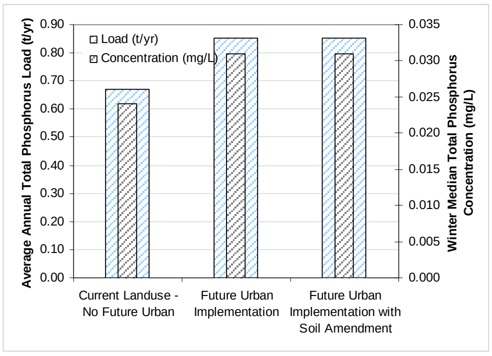


Nitrogen			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	9.8	7.3	9.7
2058	11.2	8.2	11.0
2059	14.9	13.1	14.8
2060	14.1	12.5	13.9
2061	9.4	6.6	9.3
2062	9.4	6.1	9.1
2063	14.6	12.4	14.5
2064	10.3	7.2	10.0
2065	15.3	12.5	15.0
2066	6.5	4.2	6.3
Average Load for RF Sequence (t/yr)	**11.6**	**9.0**	**11.4**

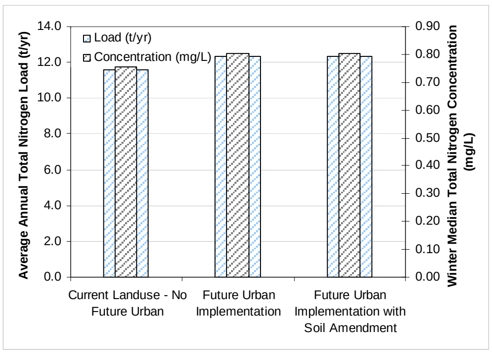


Jane Brook – Future urban

Phosphorus			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.37	0.49	0.49
2058	0.55	0.70	0.70
2059	0.60	0.76	0.76
2060	1.24	1.59	1.59
2061	0.38	0.54	0.54
2062	0.34	0.49	0.49
2063	1.02	1.24	1.24
2064	0.43	0.58	0.58
2065	1.50	1.69	1.69
2066	0.27	0.45	0.45
Average Load for RF Sequence (t/yr)	**0.67**	**0.85**	**0.85**
Median Winter Concentration (mg/L)	**0.024**	**0.031**	**0.031**

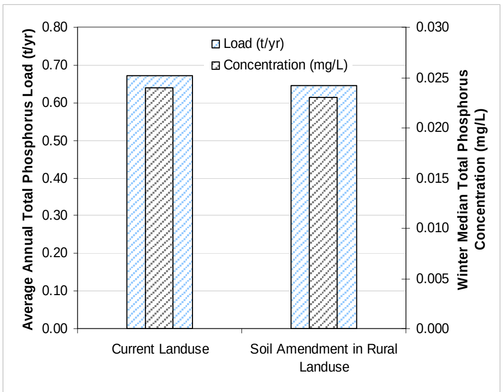


Nitrogen			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	9.8	10.2	10.2
2058	11.2	11.9	11.9
2059	14.9	16.0	16.0
2060	14.1	15.1	15.1
2061	9.4	10.1	10.1
2062	9.4	9.9	9.9
2063	14.6	15.4	15.4
2064	10.3	11.0	11.0
2065	15.3	16.2	16.2
2066	6.5	7.2	7.2
Average Load for RF Sequence (t/yr)	**11.6**	**12.3**	**12.3**
Median Winter Concentration (mg/L)	**0.75**	**0.80**	**0.80**



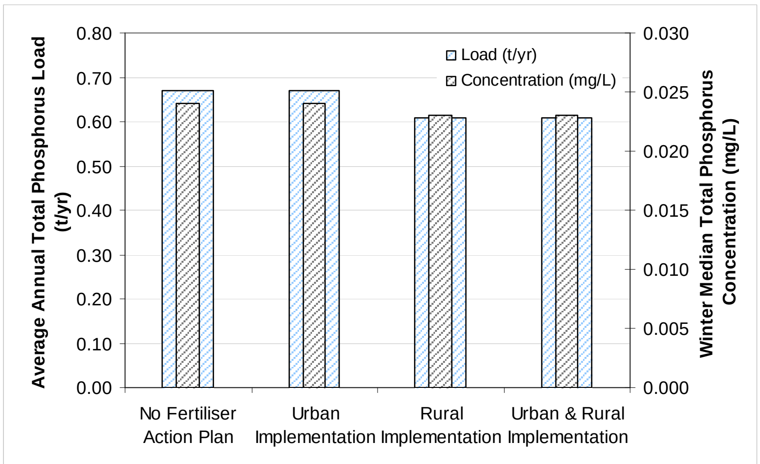
Jane Brook – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.37	0.36
2058	0.55	0.54
2059	0.60	0.58
2060	1.24	1.19
2061	0.38	0.37
2062	0.34	0.34
2063	1.02	0.98
2064	0.43	0.43
2065	1.50	1.41
2066	0.27	0.26
Average Load for RF Sequence (t/yr)	**0.67**	**0.64**
Median Winter Concentration (mg/L)	**0.024**	**0.023**



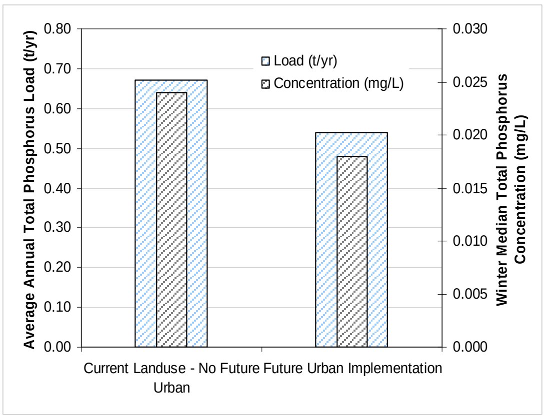
Jane Brook – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.37	0.37	0.35	0.35
2058	0.55	0.55	0.50	0.50
2059	0.60	0.60	0.55	0.55
2060	1.24	1.24	1.11	1.11
2061	0.38	0.38	0.34	0.34
2062	0.34	0.34	0.33	0.33
2063	1.02	1.02	0.93	0.93
2064	0.43	0.43	0.41	0.41
2065	1.50	1.50	1.30	1.30
2066	0.27	0.27	0.26	0.26
Average Load for RF Sequence (t/yr)	**0.67**	**0.67**	**0.61**	**0.61**
Median Winter Concentration (mg/L)	**0.024**	**0.024**	**0.023**	**0.023**

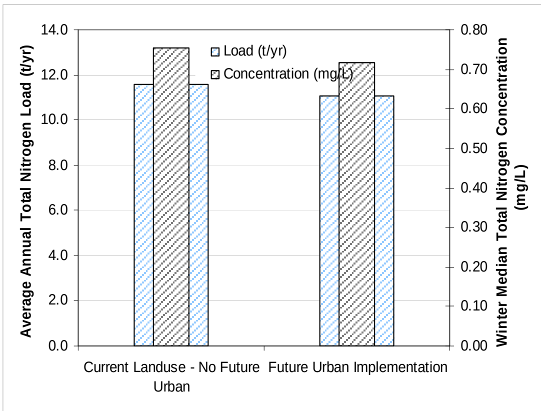


Jane Brook – Urban 50% reduction

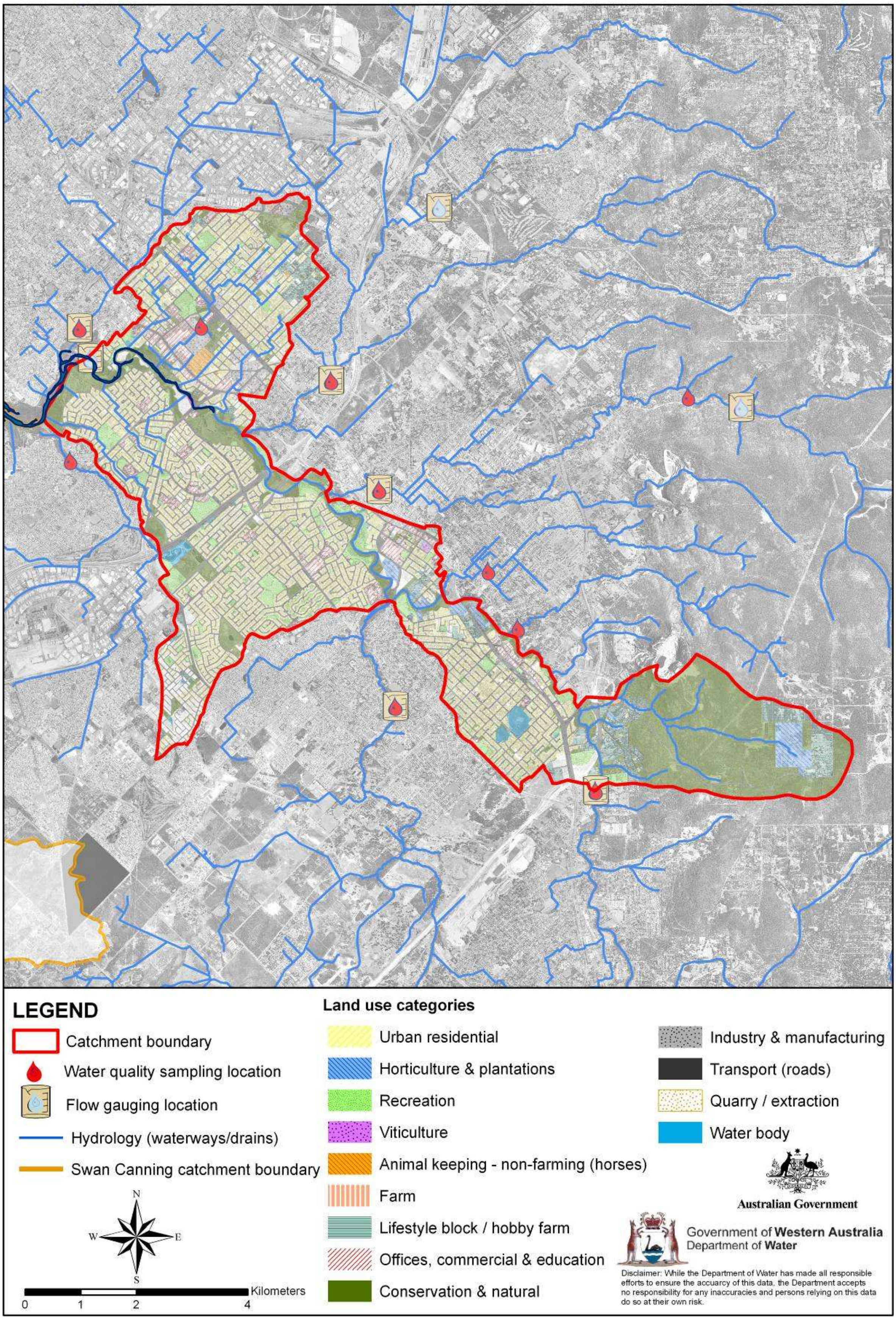
Phosphorus	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.37	0.28
2058	0.55	0.43
2059	0.60	0.45
2060	1.24	1.03
2061	0.38	0.29
2062	0.34	0.25
2063	1.02	0.84
2064	0.43	0.32
2065	1.50	1.28
2066	0.27	0.20
Average Load for RF Sequence (t/yr)	**0.67**	**0.54**
Median Winter Concentration (mg/L)	**0.024**	**0.018**



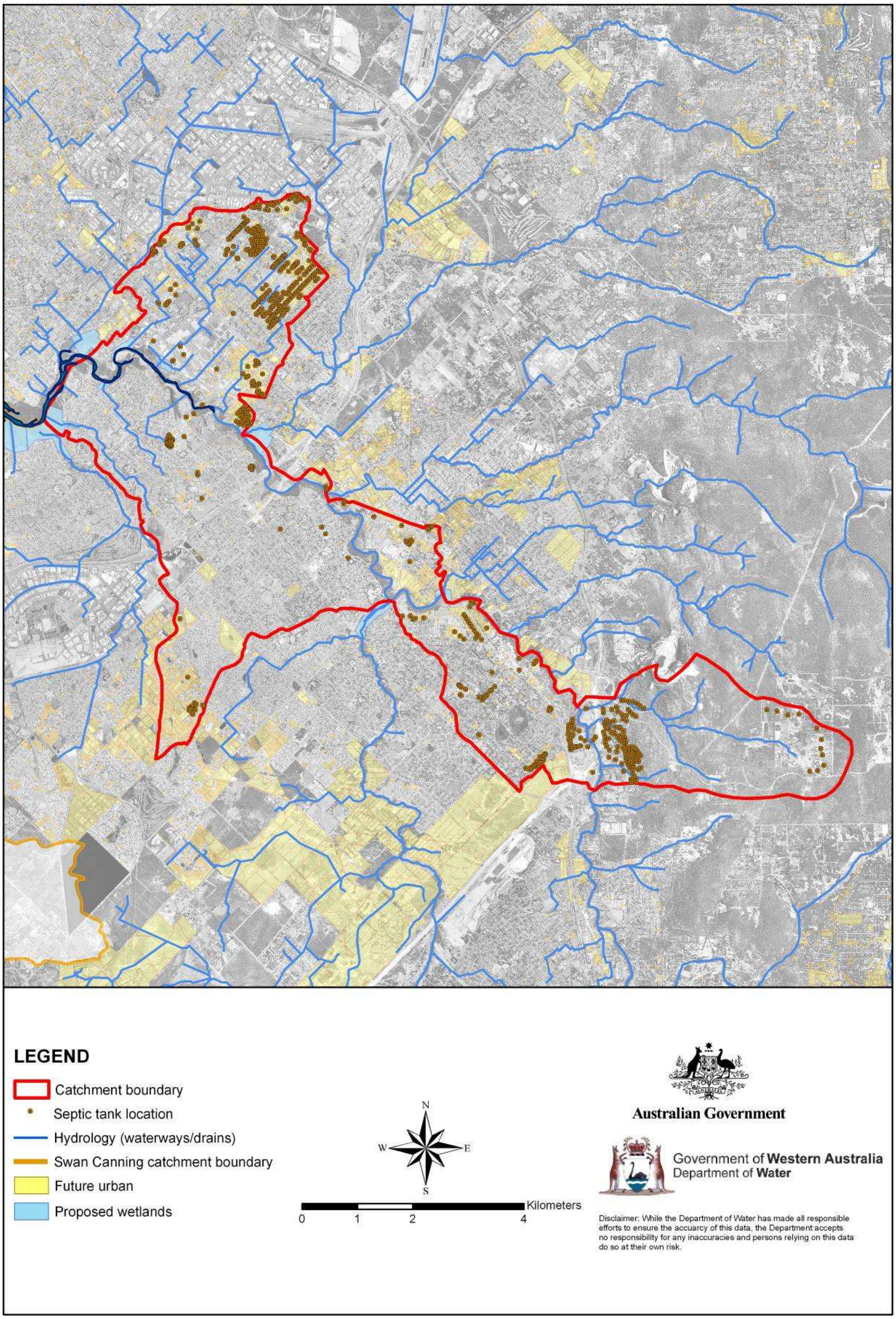
Nitrogen	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	9.8	9.5
2058	11.2	10.8
2059	14.9	14.3
2060	14.1	13.5
2061	9.4	9.1
2062	9.4	9.0
2063	14.6	14.0
2064	10.3	9.9
2065	15.3	14.7
2066	6.5	6.3
Average Load for RF Sequence (t/yr)	**11.6**	**11.1**
Median Winter Concentration (mg/L)	**0.75**	**0.72**



Lower Canning River
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Lower Canning - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary		
	Current	50% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*
1997	1.21	0.51
1998	1.04	0.49
1999	1.18	0.56
2000	1.09	0.55
2001	0.68	0.37
2002	0.75	0.41
2003	0.99	0.55
2004	0.84	0.48
2005	1.26	0.69
2006	0.62	0.34
Average	**0.97**	**0.50**
Median Winter Concentration (mg/L):		
SQUARE:	**0.190**	**0.075**
Target:	**0.075**	
Load Target (t/yr)		**0.50**
Load Reduction Target (t/yr)		**0.47**
Required Reduction (%)		**48%**
Time Required (yr)		**40**

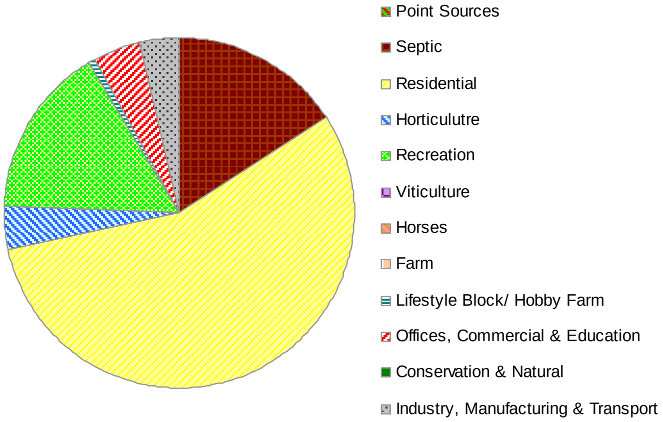
Nitrogen

At Outlet to Swan River Estuary		
	Current	51% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*
1997	9.2	3.23
1998	8.3	3.18
1999	9.9	3.71
2000	9.5	3.60
2001	5.5	2.21
2002	5.9	2.43
2003	8.1	3.41
2004	7.1	3.08
2005	10.7	4.90
2006	4.5	2.01
Average	**7.9**	**3.2**
Median Winter Concentration (mg/L):		
SQUARE:	**2.30**	**0.75**
Target:	**0.75**	
Load Target (t/yr)		**3.2**
Load Reduction Target (t/yr)		**4.7**
Required Reduction (%)		**59%**
Time Required (yr)		**30**

Lower Canning – Source separation

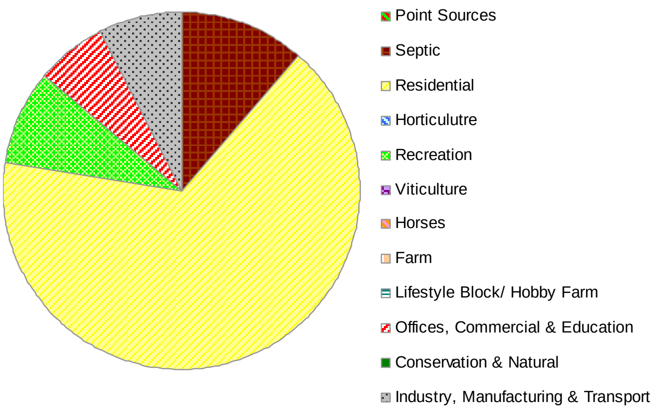
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	1.21	0.00	0.30	0.56	0.05	0.17	0.00	0.00	0.00	0.01	0.05	0.00	0.04
1998	1.04	0.00	0.26	0.48	0.04	0.14	0.00	0.00	0.00	0.01	0.04	0.00	0.03
1999	1.18	0.00	0.29	0.55	0.04	0.16	0.00	0.00	0.00	0.01	0.05	0.00	0.04
2000	1.09	0.00	0.22	0.55	0.04	0.16	0.00	0.00	0.00	0.01	0.04	0.00	0.03
2001	0.68	0.00	0.09	0.38	0.03	0.10	0.00	0.00	0.00	0.00	0.03	0.00	0.02
2002	0.75	0.00	0.08	0.44	0.03	0.12	0.00	0.00	0.00	0.00	0.03	0.00	0.03
2003	0.99	0.00	0.08	0.60	0.04	0.17	0.00	0.00	0.00	0.01	0.05	0.00	0.04
2004	0.84	0.00	0.06	0.52	0.03	0.14	0.00	0.00	0.00	0.00	0.04	0.00	0.03
2005	1.26	0.00	0.07	0.78	0.05	0.23	0.00	0.00	0.00	0.01	0.06	0.00	0.05
2006	0.62	0.00	0.03	0.40	0.02	0.10	0.00	0.00	0.00	0.00	0.03	0.00	0.03
Load (non adj)	0.97	0.00	0.15	0.53	0.04	0.15	0.00	0.00	0.00	0.01	0.04	0.00	0.03
Load (t/yr)	**0.97**	**0.00**	**0.15**	**0.54**	**0.04**	**0.15**	**0.00**	**0.00**	**0.00**	**0.01**	**0.04**	**0.00**	**0.03**
Load (%)	**100.0%**	**0.0%**	**15.7%**	**55.8%**	**4.0%**	**15.9%**	**0.0%**	**0.0%**	**0.0%**	**0.6%**	**4.4%**	**0.0%**	**3.6%**



Nitrogen (t/yr)

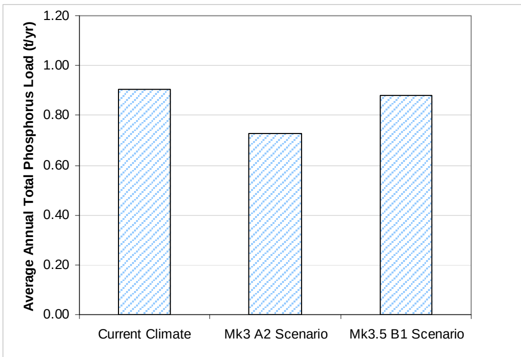
Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	9.2	0.8	2.2	4.0	0.8	1.3	0.8	0.8	0.8	0.8	1.2	0.8	1.2
1998	8.3	0.7	2.0	3.7	0.7	1.1	0.7	0.7	0.7	0.7	1.0	0.7	1.1
1999	9.9	0.8	2.3	4.4	0.8	1.3	0.8	0.8	0.8	0.8	1.1	0.8	1.1
2000	9.5	0.8	2.0	4.4	0.8	1.3	0.8	0.8	0.8	0.8	1.1	0.8	1.2
2001	5.5	0.6	0.9	2.9	0.6	0.9	0.6	0.6	0.6	0.6	0.9	0.6	0.9
2002	5.9	0.6	0.9	3.3	0.6	0.9	0.6	0.6	0.6	0.6	0.9	0.6	1.0
2003	8.1	0.7	0.9	4.6	0.7	1.3	0.7	0.7	0.7	0.7	1.1	0.7	1.2
2004	7.1	0.7	0.7	4.2	0.7	1.2	0.7	0.7	0.7	0.7	1.0	0.7	1.1
2005	10.7	0.9	0.8	6.5	0.9	1.8	0.9	0.9	0.9	0.9	1.3	0.9	1.4
2006	4.5	0.7	0.4	2.9	0.7	0.8	0.7	0.7	0.7	0.7	0.9	0.7	1.0
Load (non adj)	7.9	0.7	1.3	4.1	0.7	1.2	0.7	0.7	0.7	0.7	1.0	0.7	1.1
Load (t/yr)	**7.9**	**0.0**	**0.9**	**5.2**	**0.0**	**0.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.5**	**0.0**	**0.6**
Load (%)	**100.0%**	**0.0%**	**11.3%**	**66.1%**	**0.0%**	**8.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**6.2%**	**0.0%**	**7.6%**



Lower Canning – Climate change

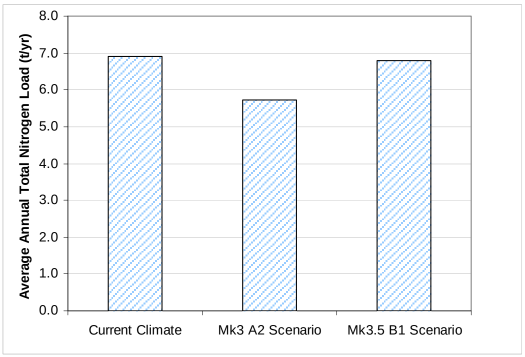
Phosphorus

	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.93	0.73	0.90
2058	0.89	0.72	0.87
2059	1.02	0.83	1.00
2060	1.00	0.82	0.97
2061	0.68	0.56	0.66
2062	0.76	0.61	0.74
2063	1.02	0.80	0.98
2064	0.87	0.70	0.85
2065	1.27	0.99	1.23
2066	0.62	0.52	0.61
Average Load for RF Sequence (t/yr)	**0.91**	**0.73**	**0.88**



Nitrogen

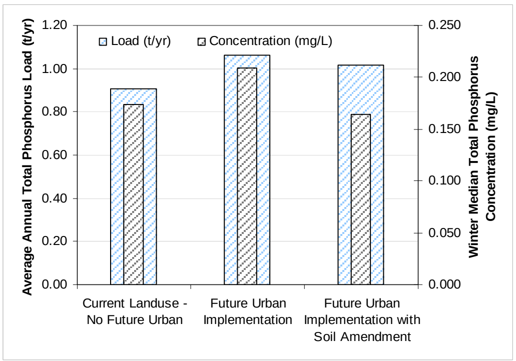
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	7.1	5.7	6.9
2058	7.0	5.8	6.9
2059	8.1	6.9	8.0
2060	7.9	7.0	7.8
2061	4.8	4.1	4.8
2062	5.3	4.3	5.2
2063	7.4	5.9	7.2
2064	6.7	5.6	6.7
2065	10.3	8.5	10.1
2066	4.4	3.8	4.3
Average Load for RF Sequence (t/yr)	**6.9**	**5.7**	**6.8**



Lower Canning – Future urban

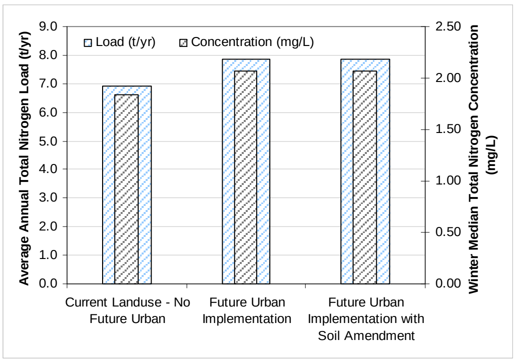
Phosphorus

	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.93	1.09	1.04
2058	0.89	1.05	1.01
2059	1.02	1.21	1.14
2060	1.00	1.18	1.11
2061	0.68	0.79	0.77
2062	0.76	0.89	0.86
2063	1.02	1.19	1.15
2064	0.87	1.02	0.98
2065	1.27	1.49	1.40
2066	0.62	0.74	0.71
Average Load for RF Sequence (t/yr)	**0.91**	**1.06**	**1.02**
Median Winter Concentration (mg/L)	**0.174**	**0.209**	**0.164**



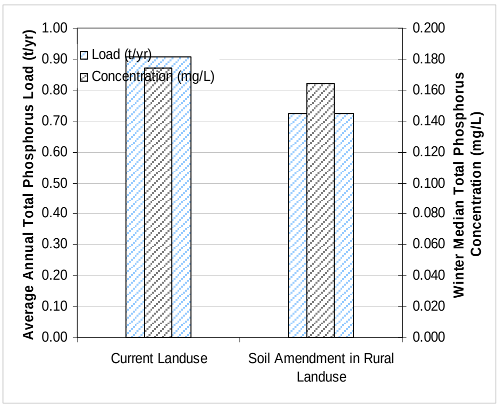
Nitrogen

	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	7.08	8.0	8.0
2058	6.98	8.0	8.0
2059	8.13	9.2	9.2
2060	7.90	8.9	8.9
2061	4.84	5.5	5.5
2062	5.30	6.0	6.0
2063	7.44	8.5	8.5
2064	6.75	7.7	7.7
2065	10.25	11.6	11.6
2066	4.41	5.1	5.1
Average Load for RF Sequence (t/yr)	**6.9**	**7.9**	**7.9**
Median Winter Concentration (mg/L)	**1.84**	**2.07**	**2.07**



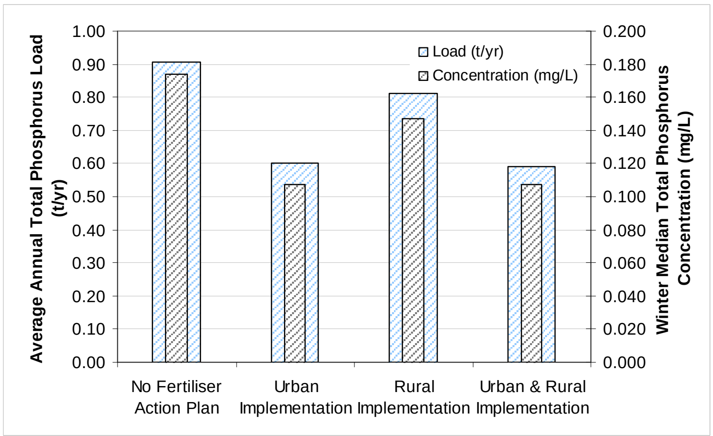
Lower Canning – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.93	0.73
2058	0.89	0.71
2059	1.02	0.82
2060	1.00	0.82
2061	0.68	0.55
2062	0.76	0.61
2063	1.02	0.80
2064	0.87	0.70
2065	1.27	0.98
2066	0.62	0.51
Average Load for RF Sequence (t/yr)	**0.91**	**0.72**
Median Winter Concentration (mg/L)	**0.174**	**0.164**



Lower Canning – *Fertiliser action plan*

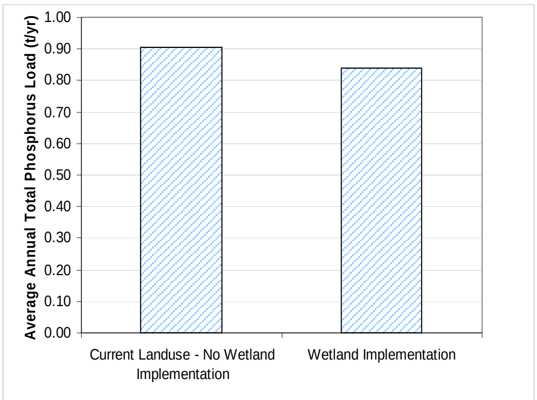
Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.93	0.62	0.83	0.60
2058	0.89	0.59	0.80	0.58
2059	1.02	0.68	0.92	0.67
2060	1.00	0.66	0.89	0.65
2061	0.68	0.45	0.60	0.44
2062	0.76	0.51	0.68	0.50
2063	1.02	0.68	0.92	0.66
2064	0.87	0.58	0.78	0.57
2065	1.27	0.85	1.14	0.83
2066	0.62	0.41	0.55	0.40
Average Load for RF Sequence (t/yr)	**0.91**	**0.60**	**0.81**	**0.59**
Median Winter Concentration (mg/L)	**0.174**	**0.107**	**0.147**	**0.107**



Lower Canning – Wetland implementation

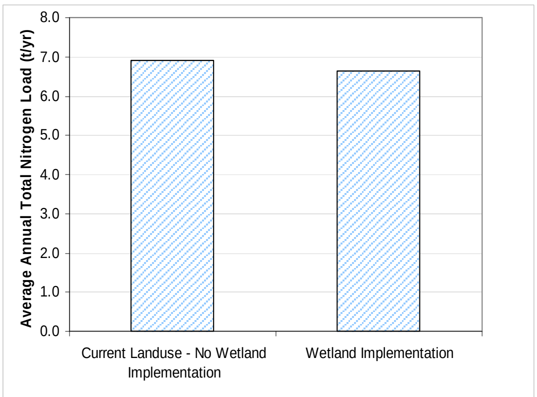
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	0.93	0.85
2058	0.89	0.83
2059	1.02	0.95
2060	1.00	0.93
2061	0.68	0.63
2062	0.76	0.71
2063	1.02	0.93
2064	0.87	0.81
2065	1.27	1.18
2066	0.62	0.56
Average Load for RF Sequence (t/yr)	**0.91**	**0.84**



Nitrogen

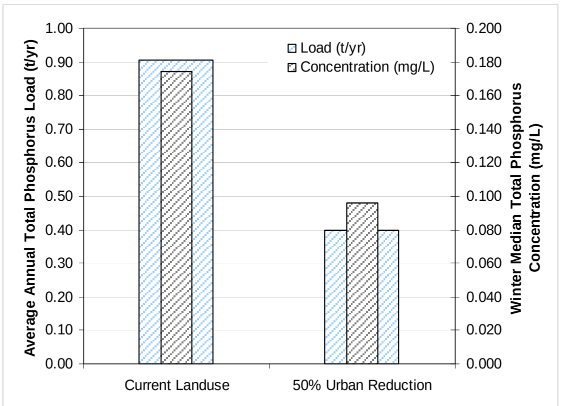
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	7.08	6.8
2058	6.98	6.7
2059	8.13	7.8
2060	7.90	7.6
2061	4.84	4.7
2062	5.30	5.1
2063	7.44	7.1
2064	6.75	6.5
2065	10.25	9.9
2066	4.41	4.2
Average Load for RF Sequence (t/yr)	**6.9**	**6.6**



Lower Canning – Urban 50% reduction

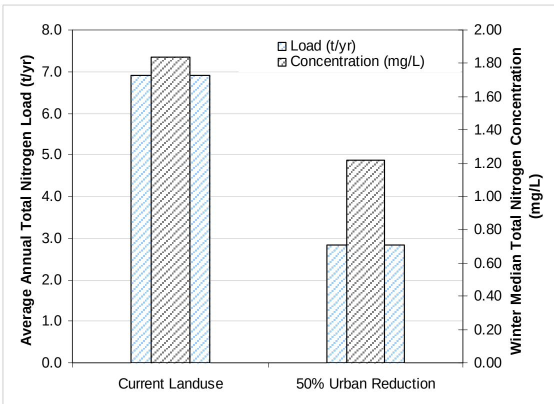
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.93	0.40
2058	0.89	0.39
2059	1.02	0.45
2060	1.00	0.45
2061	0.68	0.30
2062	0.76	0.33
2063	1.02	0.44
2064	0.87	0.38
2065	1.27	0.54
2066	0.62	0.28
Average Load for RF Sequence (t/yr)	**0.91**	**0.40**
Median Winter Concentration (mg/L)	**0.174**	**0.096**

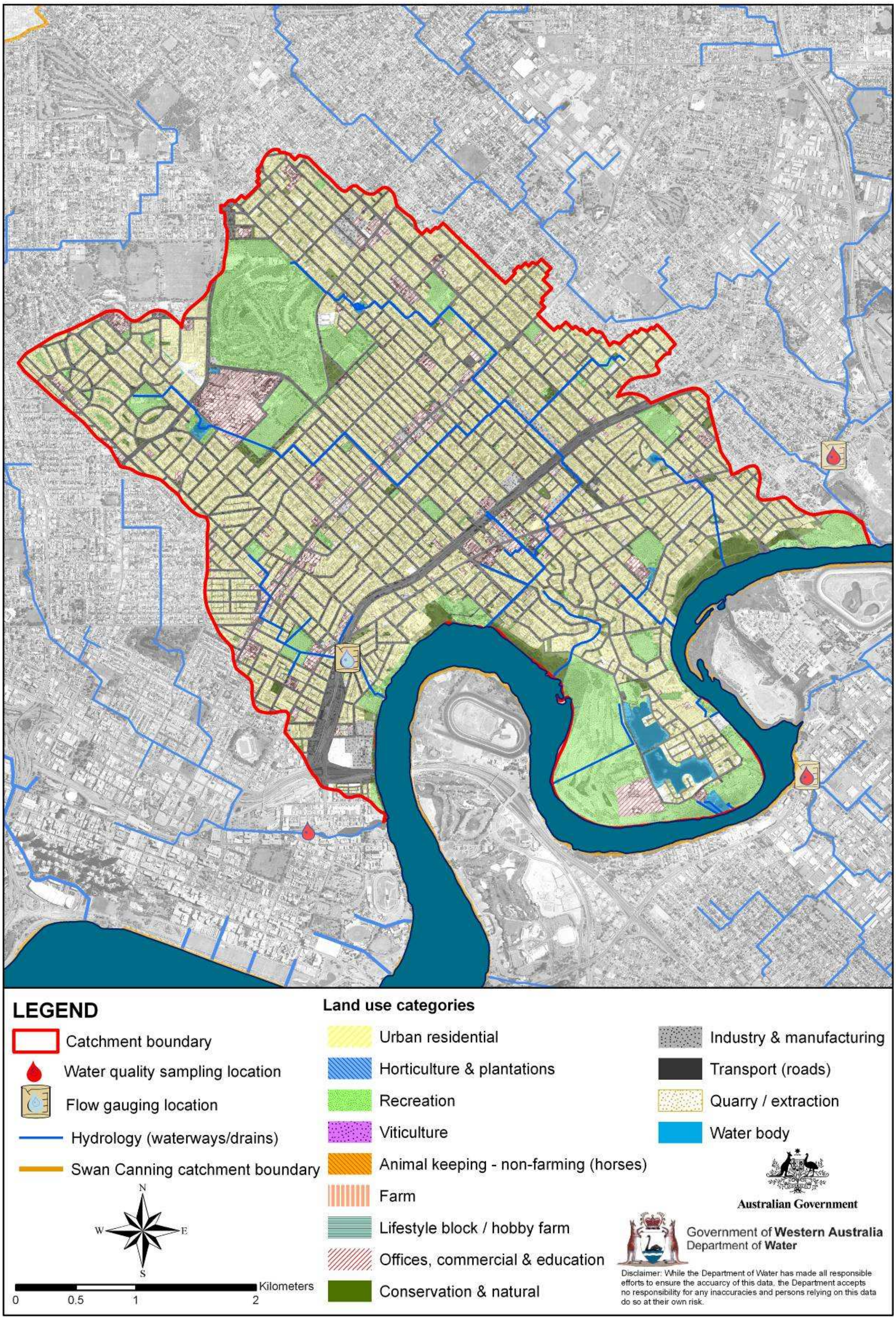


Nitrogen

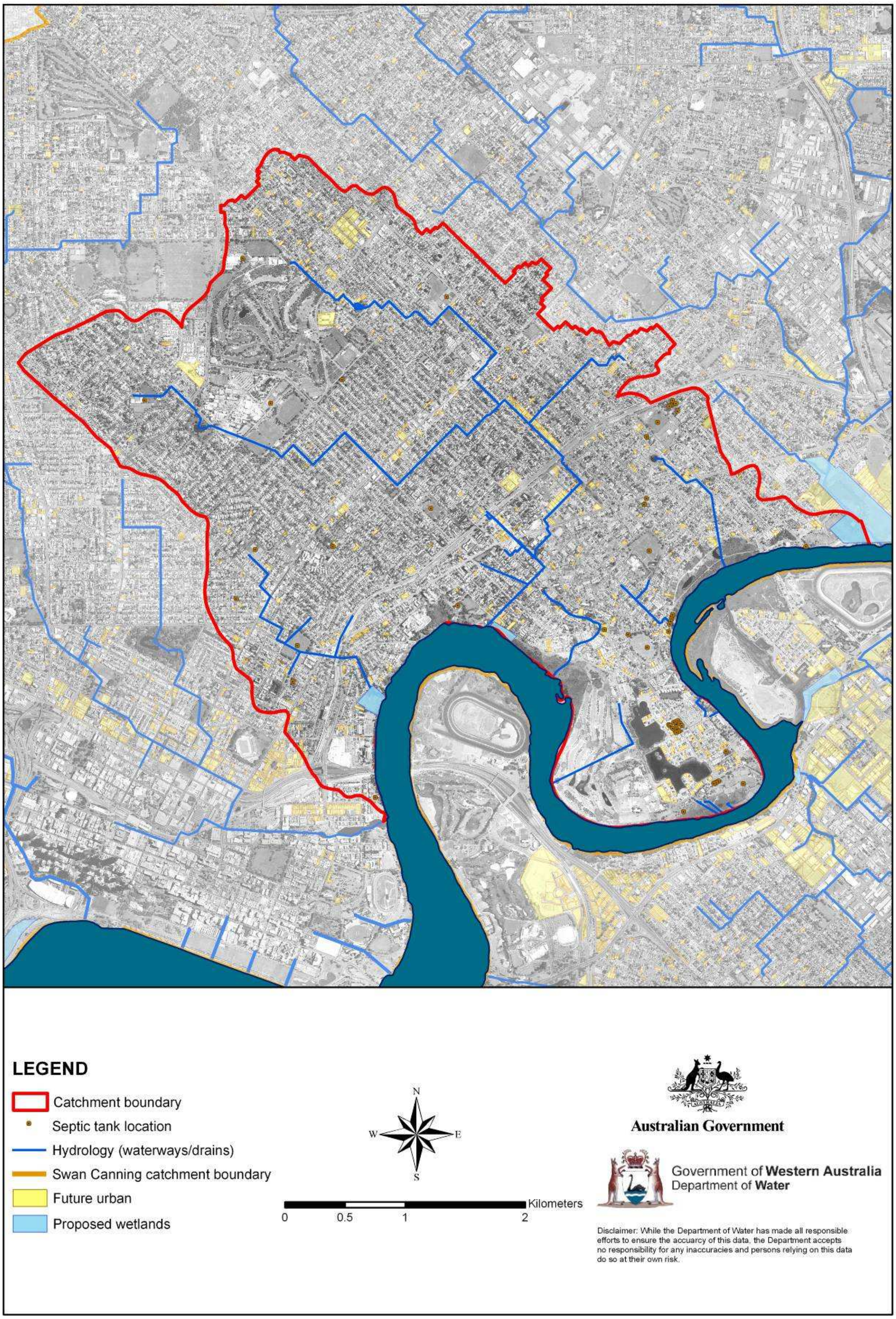
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	7.08	2.81
2058	6.98	2.83
2059	8.13	3.39
2060	7.90	3.44
2061	4.84	2.03
2062	5.30	2.11
2063	7.44	2.89
2064	6.75	2.74
2065	10.25	4.18
2066	4.41	1.86
Average Load for RF Sequence (t/yr)	**6.9**	**2.8**
Median Winter Concentration (mg/L)	**1.84**	**1.22**



Maylands
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Maylands - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616045		
	Current	No Reduction Required		Current	No Reduction Required
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	0.27	-	*1997*	0.02	-
1998	0.30	-	*1998*	0.03	-
1999	0.28	-	*1999*	0.02	-
2000	0.27	-	*2000*	0.02	-
2001	0.23	-	*2001*	0.02	-
2002	0.30	-	*2002*	0.02	-
2003	0.29	-	*2003*	0.03	-
2004	0.25	-	*2004*	0.02	-
2005	0.31	-	*2005*	0.03	-
2006	0.21	-	*2006*	0.02	-
Average	**0.27**	**-**	**Average**	**0.02**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.040**		**SQUARE:**	**0.054**	
Target:	**0.050**		**Observed:**	**-**	
Load Target (t/yr)		**0.27**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

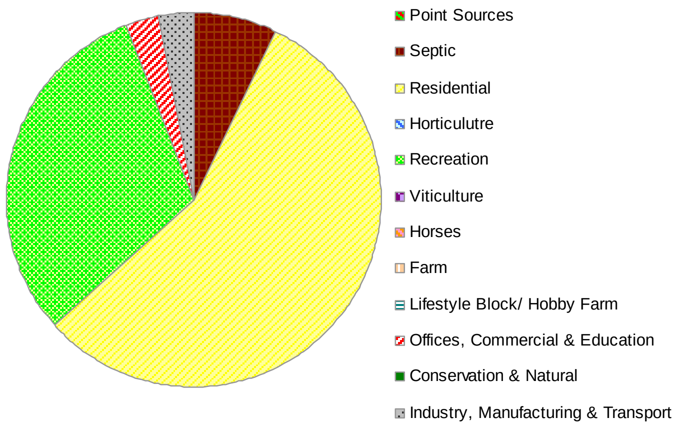
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616045		
	Current	77% Input Reduction		Current	77% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	10.2	5.0	*1997*	0.4	0.2
1998	11.5	5.8	*1998*	0.4	0.2
1999	12.0	5.1	*1999*	0.4	0.2
2000	11.0	4.8	*2000*	0.4	0.2
2001	10.0	4.5	*2001*	0.4	0.1
2002	12.2	5.8	*2002*	0.4	0.2
2003	12.6	5.6	*2003*	0.5	0.2
2004	10.3	4.7	*2004*	0.4	0.1
2005	13.2	6.0	*2005*	0.5	0.2
2006	8.3	4.0	*2006*	0.3	0.1
Average	**11.1**	**5.1**	**Average**	**0.4**	**0.2**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.89**	**0.49**	**SQUARE:**	**1.20**	**0.41**
Target:	**0.50**		**Observed:**	**-**	
Load Target (t/yr)		**5.1**			
Load Reduction Target (t/yr)		**6.0**			
Required Reduction (%)		**54%**			
Time Required (yr)		**30**			

Maylands – Source separation[2]

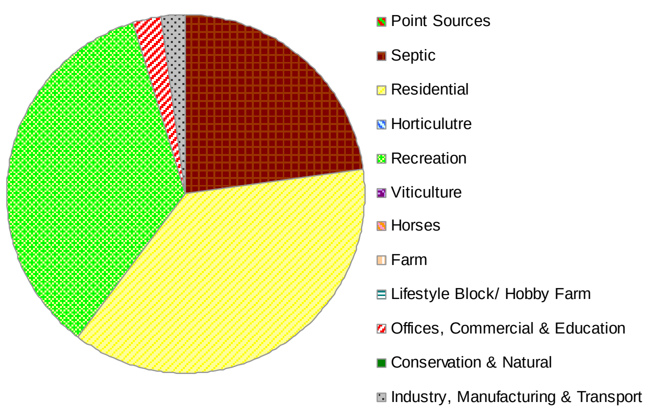
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.28	0.00	0.03	0.15	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.01
1998	0.33	0.00	0.03	0.17	0.00	0.09	0.00	0.00	0.00	0.00	0.01	0.00	0.01
1999	0.29	0.00	0.03	0.15	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2000	0.28	0.00	0.02	0.15	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2001	0.28	0.00	0.02	0.13	0.00	0.07	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2002	0.31	0.00	0.02	0.17	0.00	0.09	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2003	0.32	0.00	0.02	0.16	0.00	0.09	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2004	0.27	0.00	0.01	0.14	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2005	0.33	0.00	0.01	0.18	0.00	0.10	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2006	0.27	0.00	0.01	0.12	0.00	0.07	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Load (non adj)	0.30	0.00	0.02	0.15	0.00	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Load (t/yr)	**0.30**	**0.00**	**0.02**	**0.17**	**0.00**	**0.09**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**7.3%**	**56.0%**	**0.0%**	**30.9%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**2.7%**	**0.0%**	**3.0%**



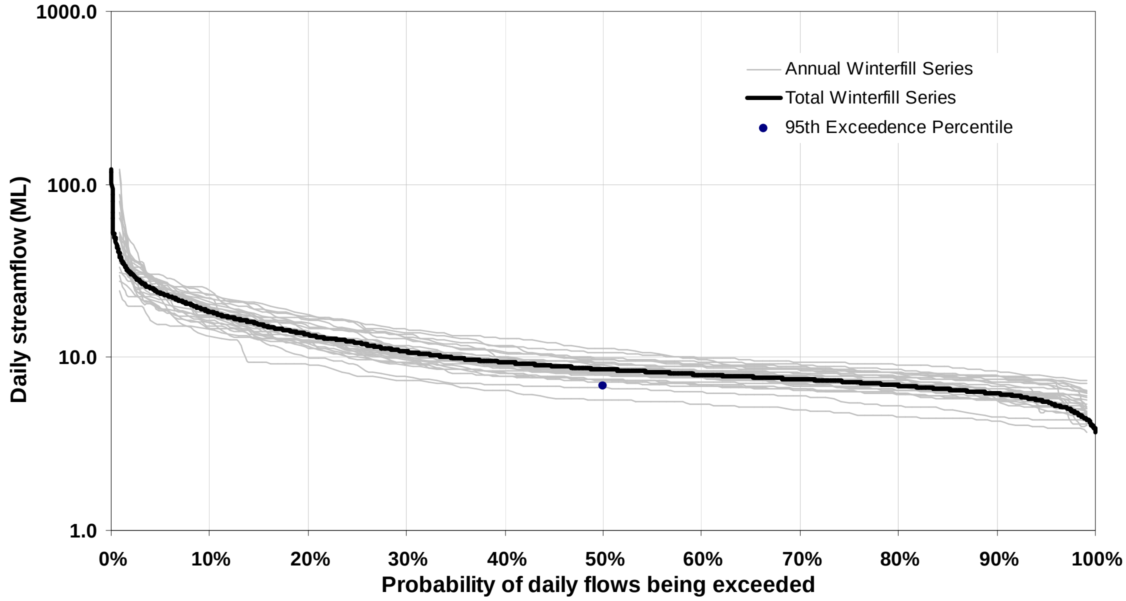
Nitrogen (t/yr)

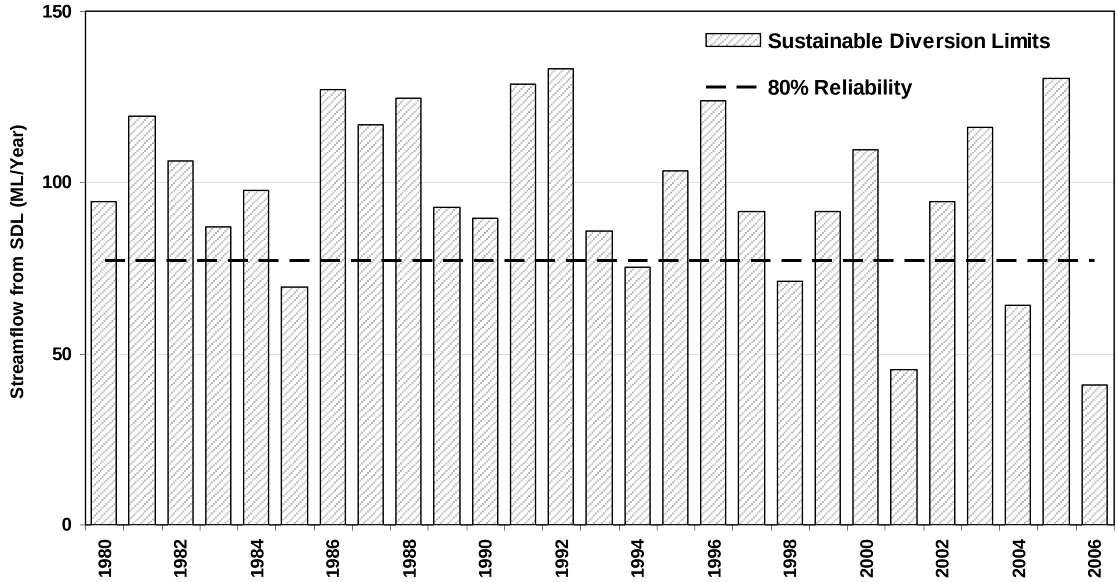
Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	9.8	0.7	3.8	5.2	0.7	4.9	0.7	0.7	0.7	0.7	1.0	0.7	0.9
1998	11.7	0.8	4.6	6.1	0.8	5.6	0.8	0.8	0.8	0.8	1.1	0.8	1.1
1999	11.8	0.7	4.0	5.8	0.7	5.7	0.7	0.7	0.7	0.7	1.0	0.7	0.9
2000	10.8	0.5	3.7	5.4	0.5	5.3	0.5	0.5	0.5	0.5	0.9	0.5	0.8
2001	9.9	0.6	3.4	5.1	0.6	4.8	0.6	0.6	0.6	0.6	0.9	0.6	0.8
2002	11.4	0.9	4.6	6.6	0.9	6.0	0.9	0.9	0.9	0.9	1.3	0.9	1.2
2003	12.6	0.8	4.0	6.5	0.8	6.2	0.8	0.8	0.8	0.8	1.2	0.8	1.1
2004	9.9	0.6	3.2	5.5	0.6	5.1	0.6	0.6	0.6	0.6	1.0	0.6	0.9
2005	12.6	0.8	3.9	7.1	0.8	6.7	0.8	0.8	0.8	0.8	1.3	0.8	1.2
2006	8.7	0.5	2.6	4.7	0.5	4.2	0.5	0.5	0.5	0.5	0.8	0.5	0.8
Load (non adj)	10.9	0.7	3.8	5.8	0.7	5.4	0.7	0.7	0.7	0.7	1.0	0.7	1.0
Load (t/yr)	**10.9**	**0.0**	**2.3**	**3.9**	**0.0**	**3.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.3**	**0.0**	**0.2**
Load (%)	**100.0%**	**0.0%**	**21.4%**	**35.3%**	**0.0%**	**32.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**2.4%**	**0.0%**	**2.1%**



[2] Source separation loads slightly different to current loads on previous page. The parameters were adjusted slightly, but the source separation was not re-calculated

Maylands – Sustainable diversion limits

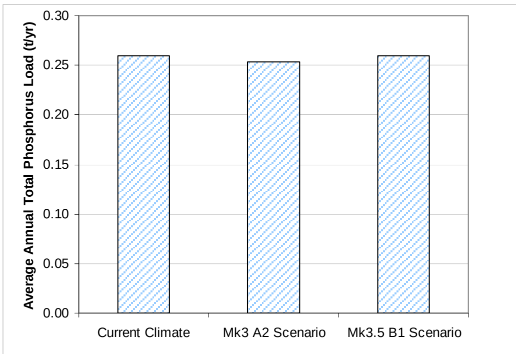




Maylands – Climate change

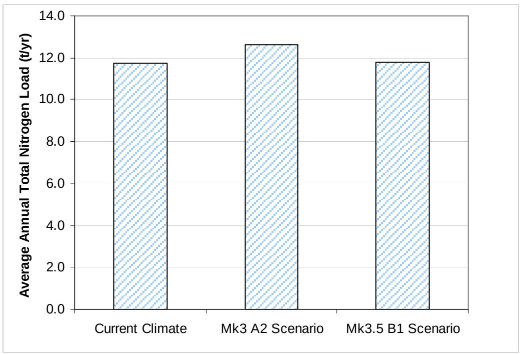
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.25	0.24	0.25
2058	0.29	0.28	0.29
2059	0.26	0.25	0.26
2060	0.25	0.25	0.25
2061	0.22	0.21	0.22
2062	0.29	0.28	0.29
2063	0.28	0.27	0.28
2064	0.25	0.24	0.24
2065	0.31	0.30	0.31
2066	0.21	0.21	0.21
Average Load for RF Sequence (t/yr)	**0.26**	**0.25**	**0.26**



Nitrogen

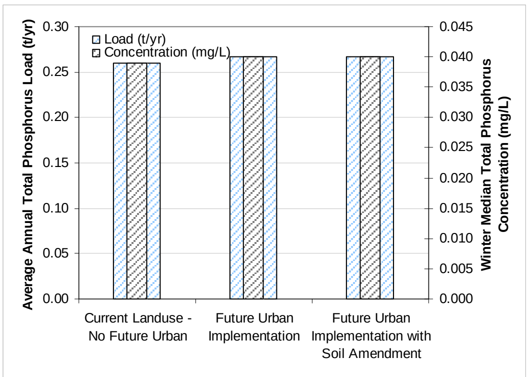
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	11.9	12.3	12.0
2058	13.0	13.9	13.1
2059	12.8	14.3	12.9
2060	11.5	12.9	11.6
2061	10.4	11.0	10.5
2062	12.4	13.3	12.5
2063	12.9	14.0	13.0
2064	10.5	11.2	10.6
2065	13.4	14.6	13.6
2066	8.4	8.8	8.4
Average Load for RF Sequence (t/yr)	**11.7**	**12.6**	**11.8**



Maylands – Future urban

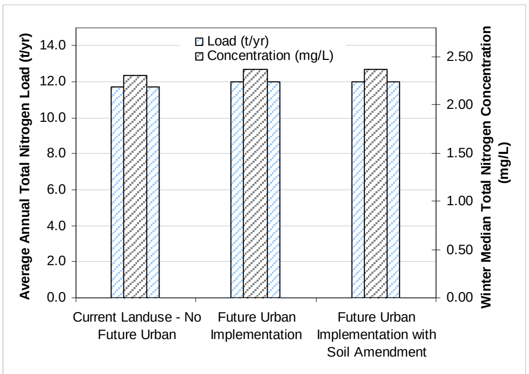
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.25	0.25	0.25
2058	0.29	0.29	0.29
2059	0.26	0.26	0.27
2060	0.25	0.26	0.26
2061	0.22	0.23	0.23
2062	0.29	0.30	0.30
2063	0.28	0.29	0.29
2064	0.25	0.25	0.25
2065	0.31	0.31	0.31
2066	0.21	0.21	0.21
Average Load for RF Sequence (t/yr)	**0.26**	**0.27**	**0.27**
Median Winter Concentration (mg/L)	**0.039**	**0.040**	**0.040**



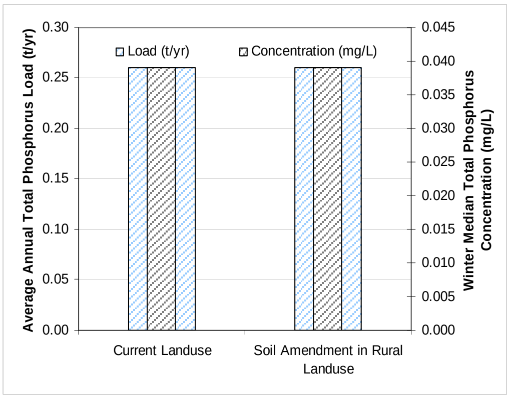
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	11.9	12.2	12.2
2058	13.0	13.3	13.3
2059	12.8	13.1	13.1
2060	11.5	11.7	11.7
2061	10.4	10.6	10.6
2062	12.4	12.7	12.7
2063	12.9	13.2	13.2
2064	10.5	10.7	10.7
2065	13.4	13.8	13.8
2066	8.4	8.6	8.6
Average Load for RF Sequence (t/yr)	**11.7**	**12.0**	**12.0**
Median Winter Concentration (mg/L)	**2.30**	**2.37**	**2.37**



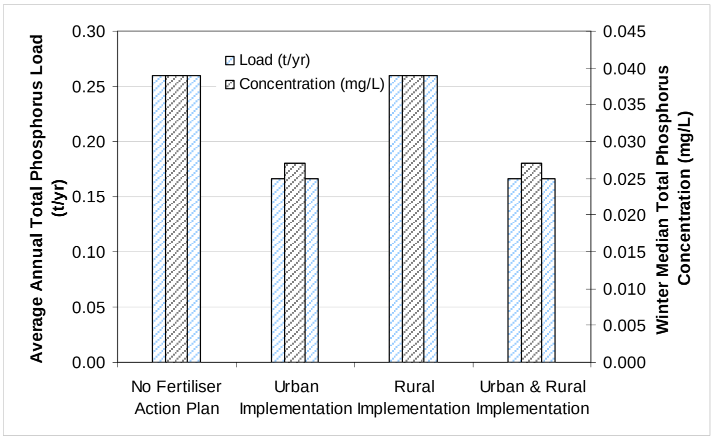
Maylands – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.25	0.25
2058	0.29	0.29
2059	0.26	0.26
2060	0.25	0.25
2061	0.22	0.22
2062	0.29	0.29
2063	0.28	0.28
2064	0.25	0.25
2065	0.31	0.31
2066	0.21	0.21
Average Load for RF Sequence (t/yr)	**0.26**	**0.26**
Median Winter Concentration (mg/L)	**0.039**	**0.039**



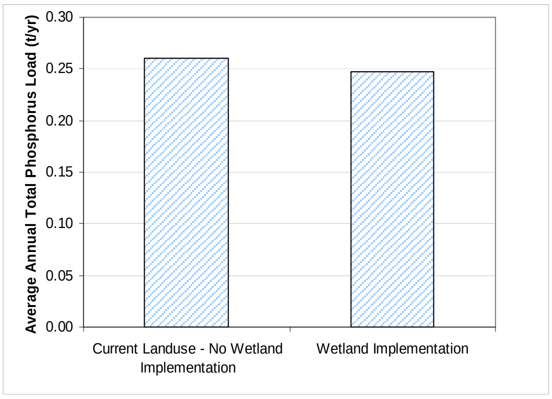
Maylands – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.25	0.16	0.25	0.16
2058	0.29	0.18	0.29	0.18
2059	0.26	0.17	0.26	0.17
2060	0.25	0.16	0.25	0.16
2061	0.22	0.14	0.22	0.14
2062	0.29	0.19	0.29	0.19
2063	0.28	0.18	0.28	0.18
2064	0.25	0.16	0.25	0.16
2065	0.31	0.20	0.31	0.20
2066	0.21	0.13	0.21	0.13
Average Load for RF Sequence (t/yr)	**0.26**	**0.17**	**0.26**	**0.17**
Median Winter Concentration (mg/L)	**0.039**	**0.027**	**0.039**	**0.027**

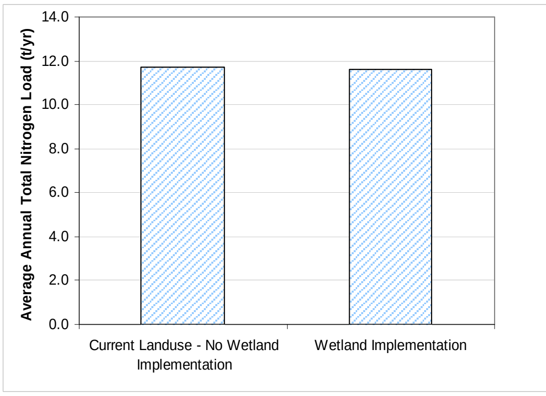


Maylands – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	0.25	0.24
2058	0.29	0.27
2059	0.26	0.25
2060	0.25	0.24
2061	0.22	0.21
2062	0.29	0.28
2063	0.28	0.26
2064	0.25	0.23
2065	0.31	0.29
2066	0.21	0.20
Average Load for RF Sequence (t/yr)	**0.26**	**0.25**

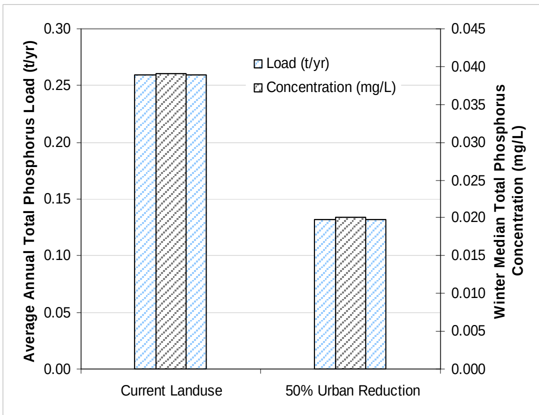


Nitrogen		
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	11.9	11.8
2058	13.0	12.9
2059	12.8	12.7
2060	11.5	11.3
2061	10.4	10.3
2062	12.4	12.3
2063	12.9	12.8
2064	10.5	10.4
2065	13.4	13.3
2066	8.4	8.3
Average Load for RF Sequence (t/yr)	**11.7**	**11.6**

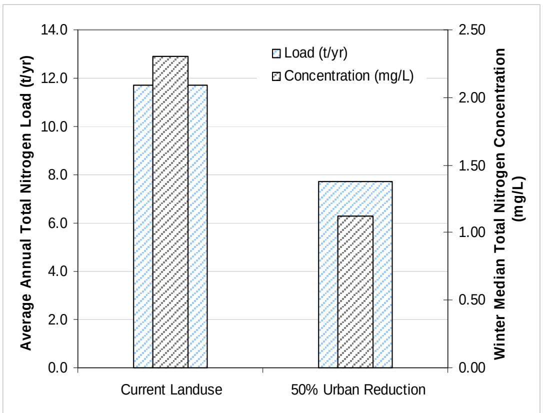


Maylands – Urban 50% reduction

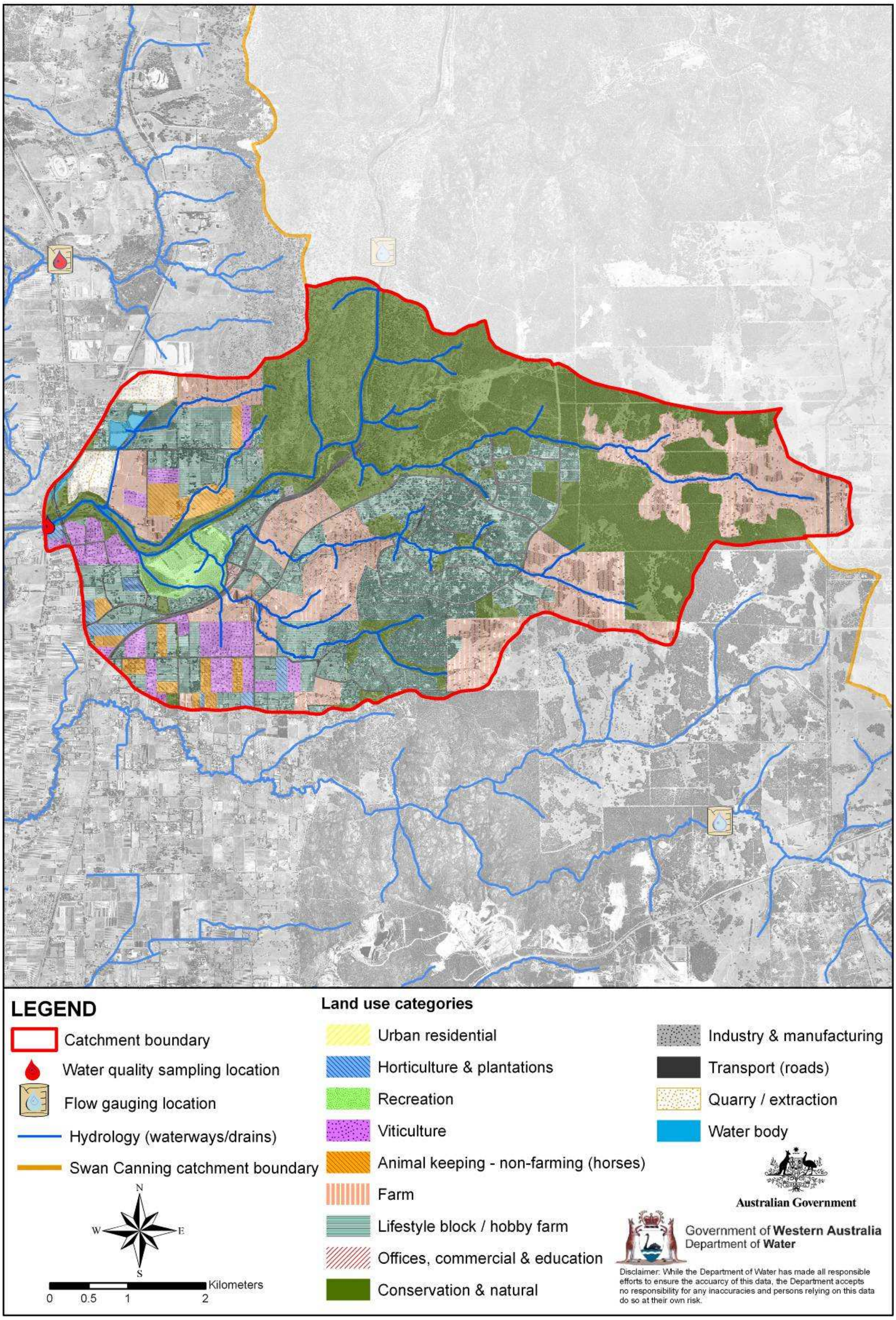
Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.25	0.13
2058	0.29	0.14
2059	0.26	0.13
2060	0.25	0.13
2061	0.22	0.11
2062	0.29	0.15
2063	0.28	0.14
2064	0.25	0.12
2065	0.31	0.15
2066	0.21	0.11
Average Load for RF Sequence (t/yr)	**0.26**	**0.13**
Median Winter Concentration (mg/L)	**0.039**	**0.020**



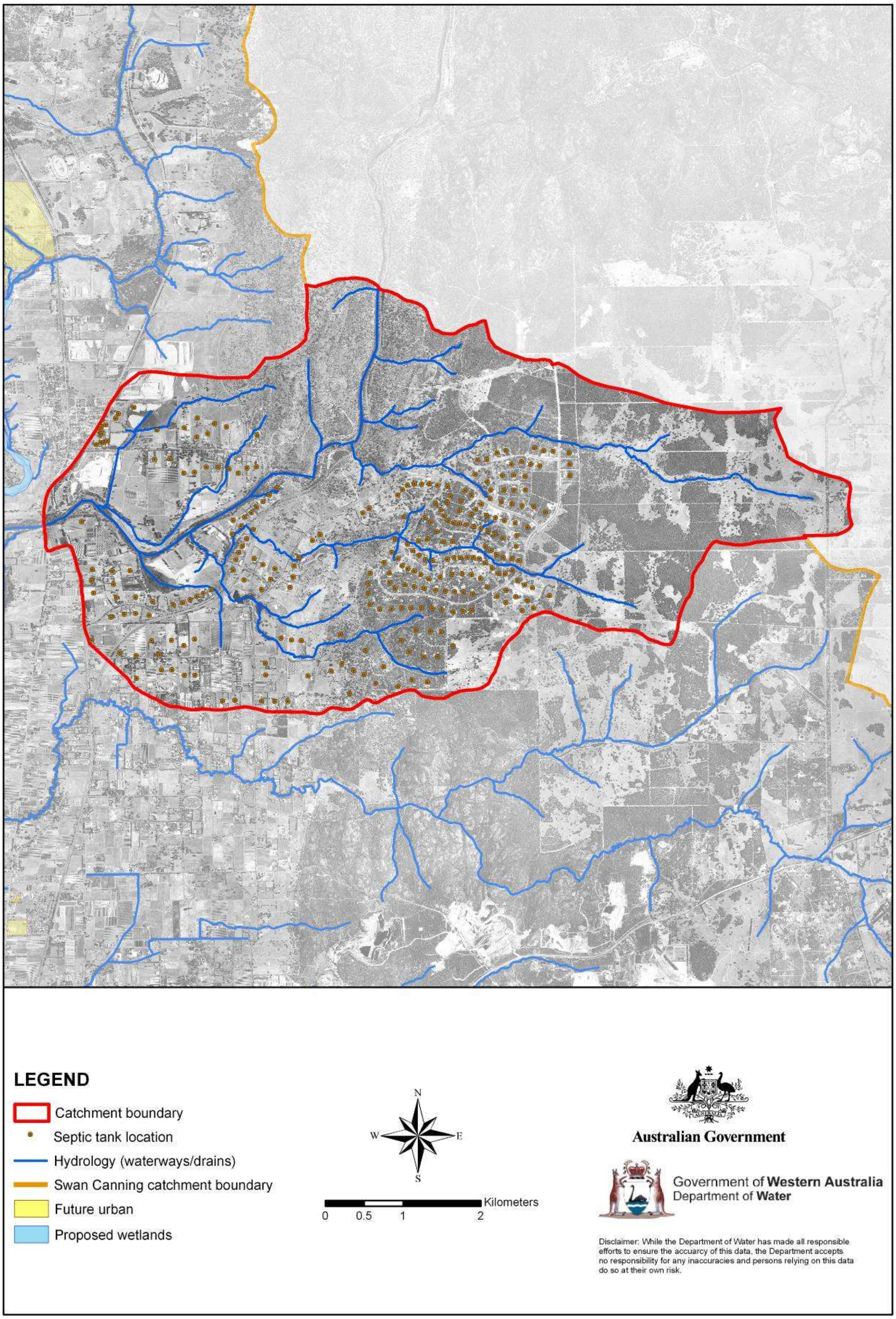
Nitrogen		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	11.9	7.7
2058	13.0	8.6
2059	12.8	8.1
2060	11.5	7.4
2061	10.4	6.8
2062	12.4	8.5
2063	12.9	8.5
2064	10.5	7.0
2065	13.4	8.9
2066	8.4	5.8
Average Load for RF Sequence (t/yr)	**11.7**	**7.7**
Median Winter Concentration (mg/L)	**2.30**	**1.12**



Millendon
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Millendon - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616076		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.13	-	*1997*	0.13	-
1998	0.14	-	*1998*	0.14	-
1999	0.18	-	*1999*	0.18	-
2000	0.18	-	*2000*	0.18	-
2001	0.13	-	*2001*	0.13	-
2002	0.12	-	*2002*	0.12	-
2003	0.18	-	*2003*	0.18	-
2004	0.14	-	*2004*	0.14	-
2005	0.21	-	*2005*	0.21	-
2006	0.09	-	*2006*	0.09	-
Average	**0.15**	**-**	**Average**	**0.15**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.024**		**SQUARE:**	**0.024**	
Target:	**0.100**		**Observed:**	**0.021**	
Load Target (t/yr)		**0.15**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

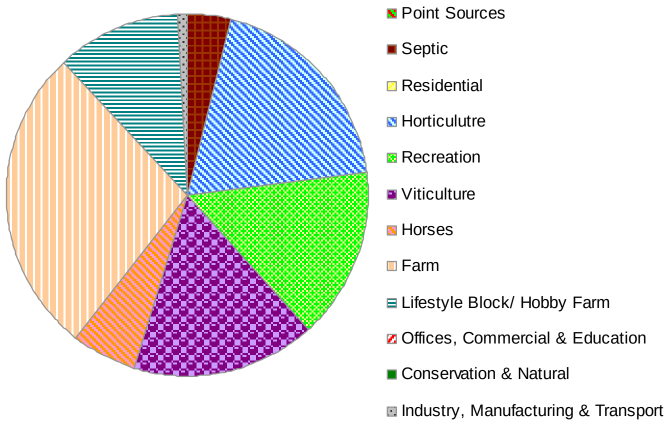
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616076		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	1.6	-	*1997*	1.6	-
1998	2.3	-	*1998*	2.3	-
1999	3.9	-	*1999*	3.9	-
2000	3.4	-	*2000*	3.4	-
2001	2.0	-	*2001*	2.0	-
2002	1.1	-	*2002*	1.1	-
2003	3.4	-	*2003*	3.4	-
2004	2.2	-	*2004*	2.2	-
2005	5.0	-	*2005*	5.0	-
2006	0.8	-	*2006*	0.8	-
Average	**2.6**	**-**	**Average**	**2.6**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.85**		**SQUARE:**	**0.85**	
Target:	**1.00**		**Observed:**	**0.83**	
Load Target (t/yr)		**2.6**			
Load Reduction Target (t/yr)		**0.0**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

Millendon – Source separation

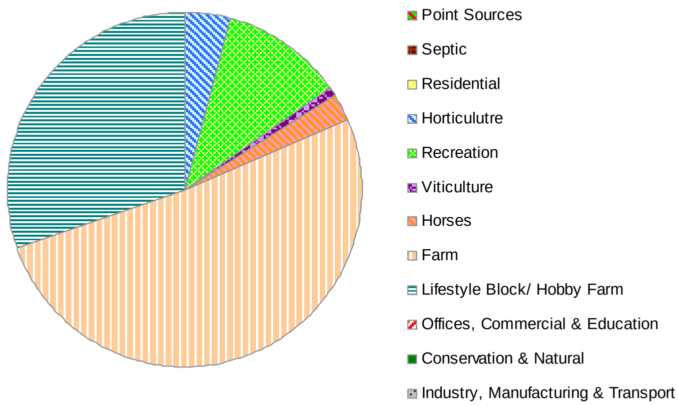
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.13	0.00	0.01	0.00	0.02	0.02	0.02	0.01	0.04	0.01	0.00	0.00	0.00
1998	0.14	0.00	0.01	0.00	0.03	0.02	0.02	0.01	0.04	0.02	0.00	0.00	0.00
1999	0.18	0.00	0.01	0.00	0.04	0.02	0.03	0.01	0.04	0.02	0.00	0.00	0.00
2000	0.18	0.00	0.01	0.00	0.04	0.02	0.03	0.01	0.04	0.02	0.00	0.00	0.00
2001	0.13	0.00	0.01	0.00	0.02	0.02	0.02	0.01	0.04	0.02	0.00	0.00	0.00
2002	0.12	0.00	0.01	0.00	0.01	0.02	0.02	0.01	0.04	0.01	0.00	0.00	0.00
2003	0.18	0.00	0.01	0.00	0.04	0.03	0.03	0.01	0.05	0.02	0.00	0.00	0.00
2004	0.14	0.00	0.01	0.00	0.02	0.02	0.02	0.01	0.04	0.02	0.00	0.00	0.00
2005	0.21	0.00	0.01	0.00	0.05	0.03	0.04	0.01	0.05	0.02	0.00	0.00	0.00
2006	0.09	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.03	0.01	0.00	0.00	0.00
Load (non adj)	0.15	0.00	0.01	0.00	0.03	0.02	0.02	0.01	0.04	0.02	0.00	0.00	0.00
Load (t/yr)	**0.15**	**0.00**	**0.01**	**0.00**	**0.03**	**0.02**	**0.02**	**0.01**	**0.04**	**0.02**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**0.0%**	**3.9%**	**0.0%**	**19.2%**	**15.2%**	**16.3%**	**5.9%**	**27.4%**	**11.2%**	**0.0%**	**0.0%**	**0.7%**



Nitrogen (t/yr)

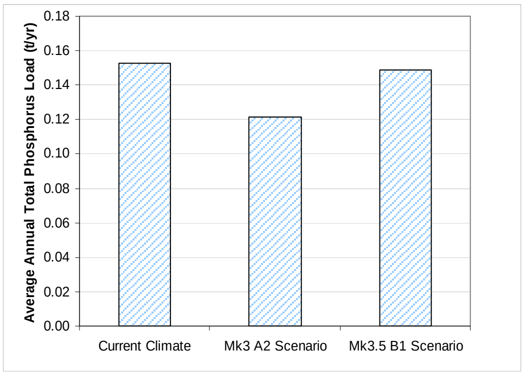
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	1.6	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.5	0.4	0.1	0.1	0.1
1998	2.3	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.7	0.5	0.2	0.2	0.2
1999	3.9	0.2	0.2	0.2	0.3	0.4	0.2	0.3	1.2	0.7	0.2	0.2	0.2
2000	3.4	0.2	0.2	0.2	0.2	0.3	0.2	0.2	1.0	0.6	0.2	0.2	0.2
2001	2.0	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.5	0.5	0.1	0.1	0.1
2002	1.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.4	0.3	0.1	0.1	0.1
2003	3.4	0.2	0.2	0.2	0.2	0.4	0.2	0.2	0.9	0.6	0.2	0.2	0.2
2004	2.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.7	0.5	0.2	0.2	0.2
2005	5.0	0.4	0.4	0.4	0.5	0.6	0.4	0.5	1.6	1.1	0.4	0.4	0.4
2006	0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1
Load (non adj)	2.6	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.8	0.5	0.2	0.2	0.2
Load (t/yr)	**2.6**	**0.0**	**0.0**	**0.0**	**0.1**	**0.3**	**0.0**	**0.1**	**1.3**	**0.8**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**0.0%**	**0.0%**	**4.2%**	**11.0%**	**1.0%**	**2.3%**	**51.1%**	**30.4%**	**0.0%**	**0.0%**	**0.0%**



Millendon – Climate change

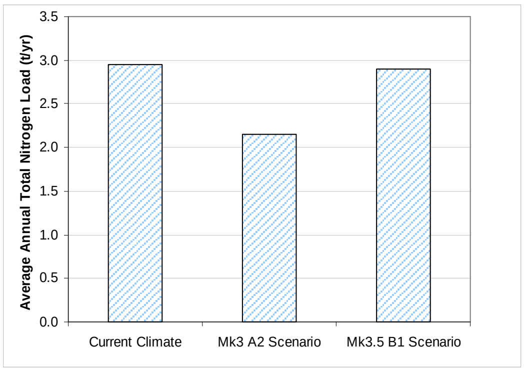
Phosphorus

Year	At Catchment Outlet: Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.13	0.10	0.13
2058	0.14	0.11	0.14
2059	0.18	0.14	0.18
2060	0.19	0.16	0.19
2061	0.14	0.10	0.13
2062	0.12	0.10	0.12
2063	0.19	0.15	0.18
2064	0.14	0.11	0.14
2065	0.21	0.15	0.20
2066	0.09	0.08	0.09
Average Load for RF Sequence (t/yr)	**0.15**	**0.12**	**0.15**



Nitrogen

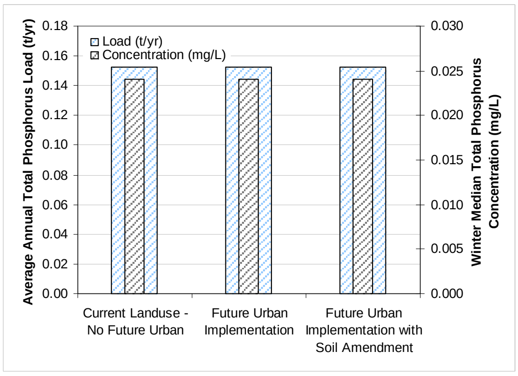
Year	At Catchment Outlet: Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	1.9	1.2	1.9
2058	2.8	1.9	2.8
2059	4.7	3.6	4.7
2060	4.0	3.6	4.0
2061	2.3	1.7	2.3
2062	1.2	0.9	1.2
2063	3.8	3.2	3.8
2064	2.4	1.5	2.3
2065	5.3	3.2	5.0
2066	1.0	0.7	1.0
Average Load for RF Sequence (t/yr)	**2.9**	**2.2**	**2.9**



Millendon – Future urban

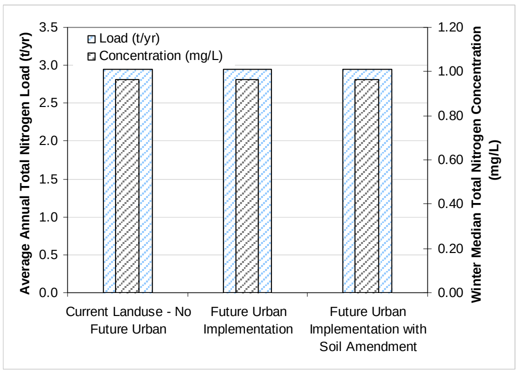
Phosphorus

Year	At Catchment Outlet: Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.13	0.13	0.13
2058	0.14	0.14	0.14
2059	0.18	0.18	0.18
2060	0.19	0.19	0.19
2061	0.14	0.14	0.14
2062	0.12	0.12	0.12
2063	0.19	0.19	0.19
2064	0.14	0.14	0.14
2065	0.21	0.21	0.21
2066	0.09	0.09	0.09
Average Load for RF Sequence (t/yr)	**0.15**	**0.15**	**0.15**
Median Winter Concentration (mg/L)	**0.024**	**0.024**	**0.024**



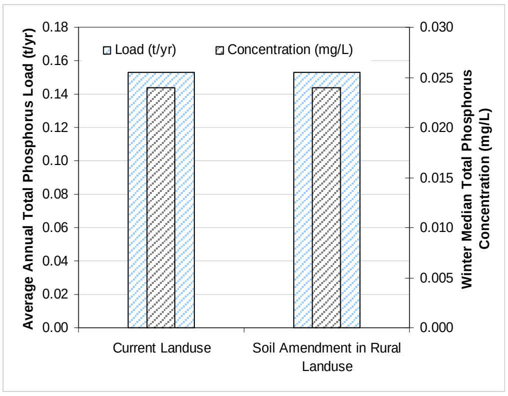
Nitrogen

Year	At Catchment Outlet: Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	1.9	1.9	1.9
2058	2.8	2.8	2.8
2059	4.7	4.7	4.7
2060	4.0	4.0	4.0
2061	2.3	2.3	2.3
2062	1.2	1.2	1.2
2063	3.8	3.8	3.8
2064	2.4	2.4	2.4
2065	5.3	5.3	5.3
2066	1.0	1.0	1.0
Average Load for RF Sequence (t/yr)	**2.9**	**2.9**	**2.9**
Median Winter Concentration (mg/L)	**0.97**	**0.97**	**0.97**



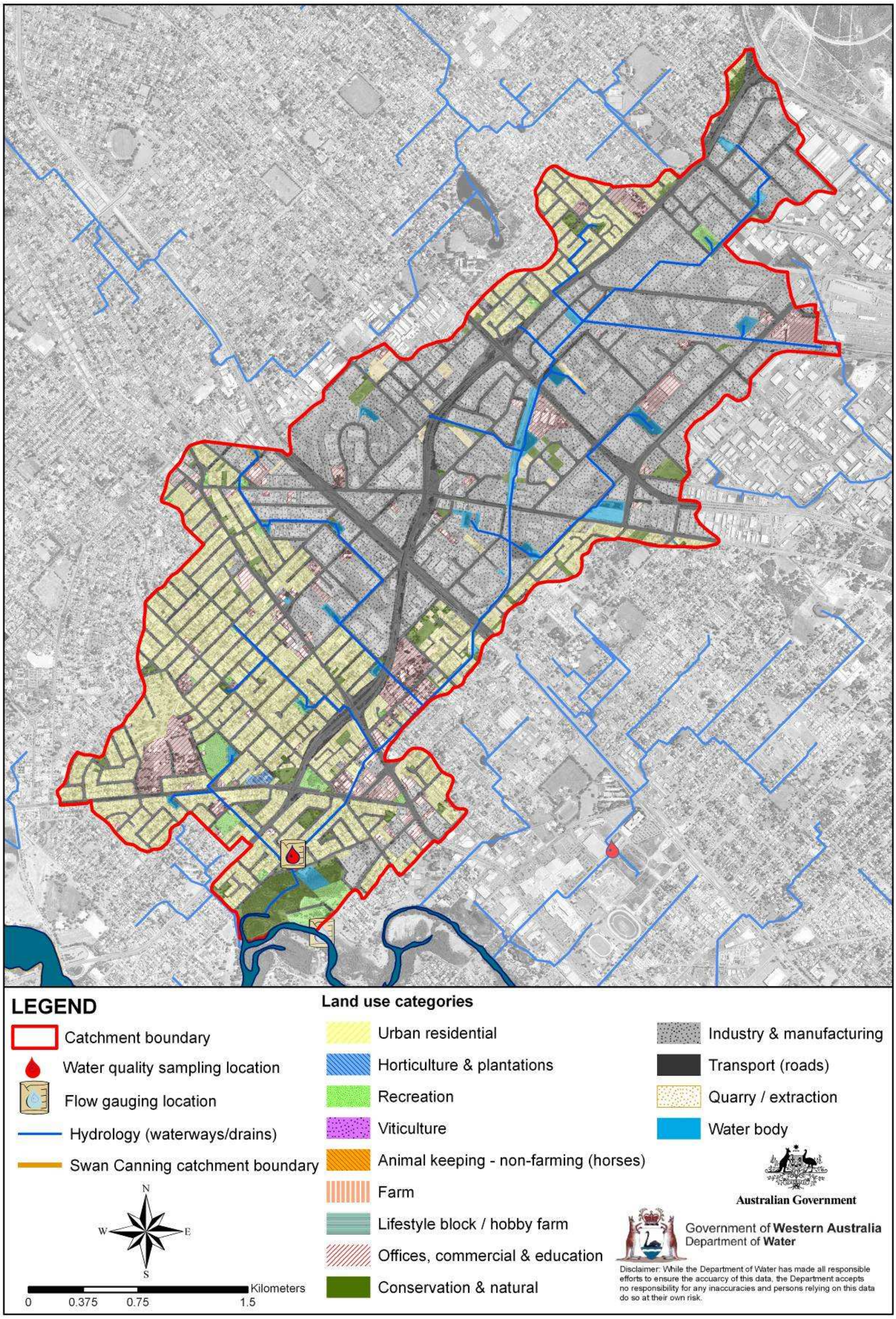
Millendon – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.13	0.13
2058	0.14	0.14
2059	0.18	0.18
2060	0.19	0.19
2061	0.14	0.14
2062	0.12	0.12
2063	0.19	0.19
2064	0.14	0.14
2065	0.21	0.21
2066	0.09	0.09
Average Load for RF Sequence (t/yr)	**0.15**	**0.15**
Median Winter Concentration (mg/L)	**0.024**	**0.024**

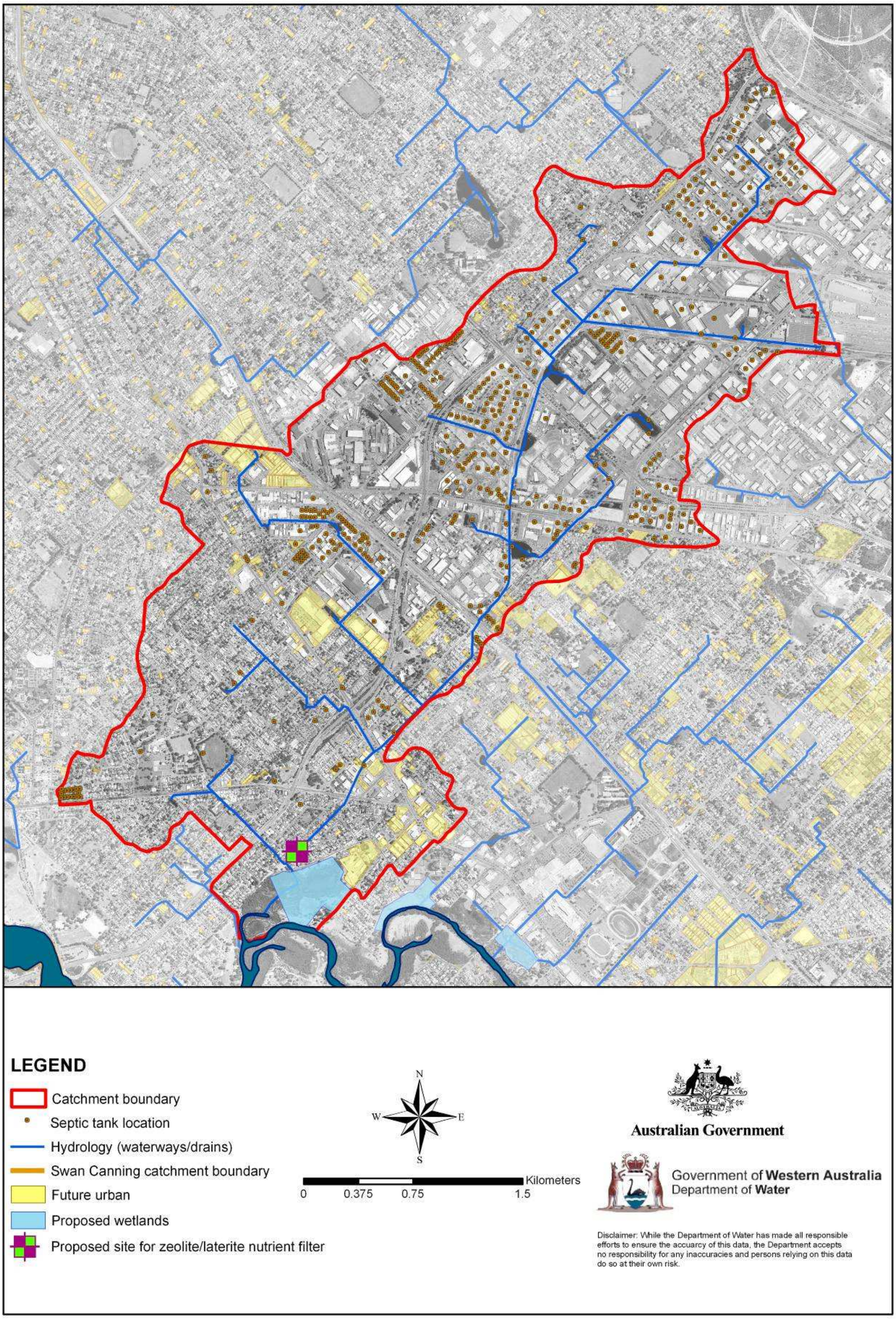


Mills Street Main Drain

Land use map



Locations of septic tanks, future urban development, proposed wetlands and zeolite/laterite filter



Mills Street Main Drain - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616043		
	Current	10% Input Reduction*		Current	10% Input Reduction*
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	0.79	0.26	*1997*	0.74	0.22
1998	0.77	0.27	*1998*	0.72	0.23
1999	0.89	0.30	*1999*	0.83	0.26
2000	0.89	0.31	*2000*	0.84	0.26
2001	0.73	0.26	*2001*	0.69	0.22
2002	0.79	0.28	*2002*	0.74	0.24
2003	0.84	0.31	*2003*	0.78	0.26
2004	0.70	0.25	*2004*	0.65	0.22
2005	0.87	0.32	*2005*	0.82	0.27
2006	0.58	0.21	*2006*	0.55	0.18
Average	**0.78**	**0.28**	**Average**	**0.74**	**0.24**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.135**	**0.048**	**SQUARE:**	**0.149**	**0.047**
Target:	**0.050**		**Observed:**	**0.150**	
Load Target (t/yr)		**0.28**			
Load Reduction Target (t/yr)		**0.51**			
Required Reduction (%)		**65%**			
Time Required (yr)		**20**			

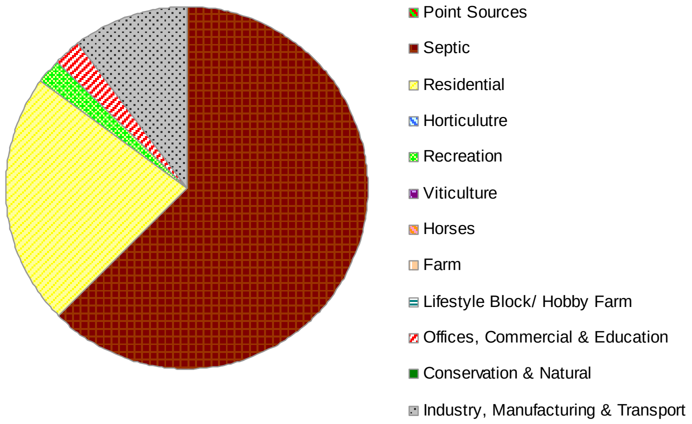
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616043		
	Current	35% Input Reduction		Current	35% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	7.1	2.5	*1997*	5.7	1.4
1998	7.3	2.7	*1998*	5.7	1.5
1999	8.0	2.7	*1999*	6.4	1.6
2000	7.7	2.6	*2000*	6.2	1.5
2001	6.5	2.2	*2001*	5.1	1.3
2002	7.4	2.7	*2002*	5.7	1.5
2003	7.7	2.9	*2003*	5.9	1.6
2004	6.3	2.3	*2004*	4.9	1.3
2005	7.8	2.9	*2005*	5.9	1.6
2006	5.3	2.0	*2006*	4.0	1.1
Average	**7.1**	**2.6**	**Average**	**5.5**	**1.4**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.56**	**0.49**	**SQUARE:**	**1.40**	**0.36**
Target:	**0.50**		**Observed:**	**1.40**	
Load Target (t/yr)		**2.6**			
Load Reduction Target (t/yr)		**4.6**			
Required Reduction (%)		**64%**			
Time Required (yr)		**30**			

Mill Street Main Drain – Source separation

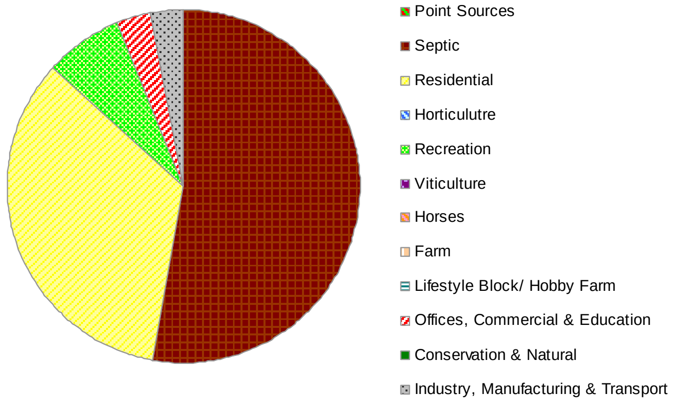
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.79	0.00	0.51	0.17	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.08
1998	0.77	0.00	0.50	0.17	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.07
1999	0.89	0.00	0.57	0.19	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.09
2000	0.89	0.00	0.57	0.20	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.09
2001	0.73	0.00	0.46	0.16	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.08
2002	0.79	0.00	0.49	0.18	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.08
2003	0.84	0.00	0.51	0.20	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.09
2004	0.69	0.00	0.42	0.16	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.08
2005	0.87	0.00	0.53	0.21	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.10
2006	0.58	0.00	0.35	0.14	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.06
Load (non adj)	0.78	0.00	0.49	0.18	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.08
Load (t/yr)	**0.78**	**0.00**	**0.49**	**0.18**	**0.00**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.00**	**0.08**
Load (%)	**100.0%**	**0.0%**	**62.5%**	**22.5%**	**0.0%**	**2.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**2.5%**	**0.0%**	**10.3%**

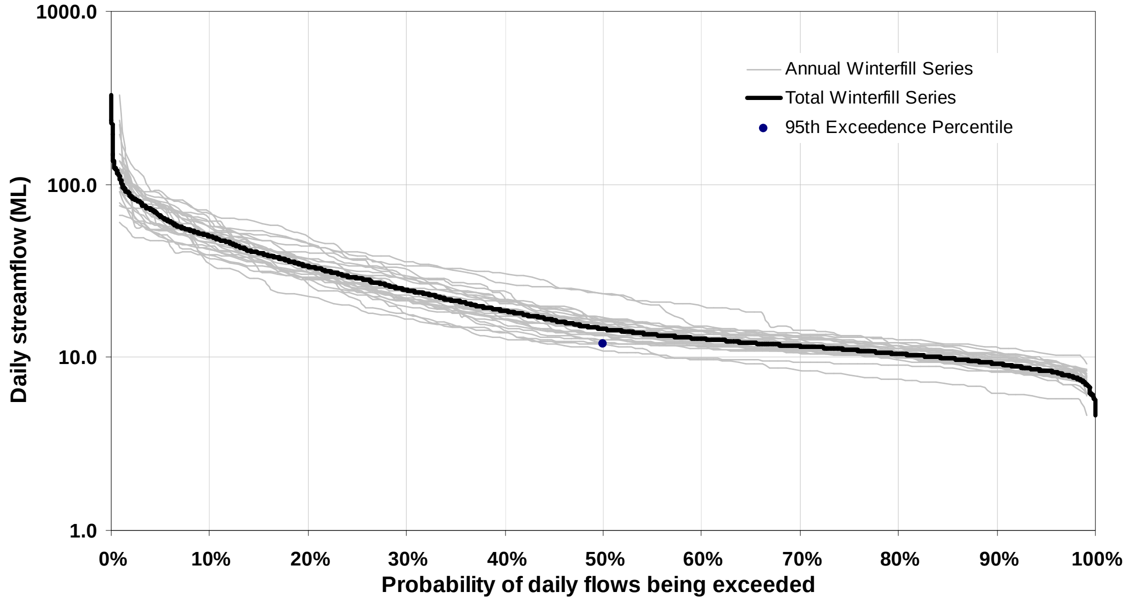


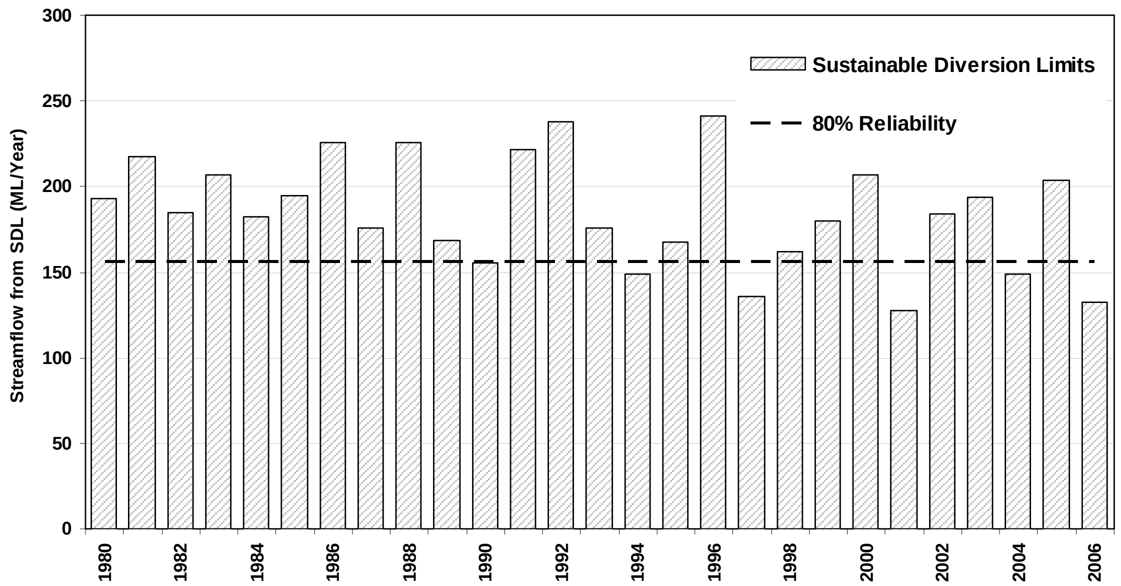
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	7.1	0.6	4.5	2.9	0.6	1.0	0.6	0.6	0.6	0.6	0.8	0.6	0.8
1998	7.3	0.7	4.6	3.1	0.7	1.2	0.7	0.7	0.7	0.7	0.9	0.7	0.9
1999	8.0	0.6	5.0	3.1	0.6	1.0	0.6	0.6	0.6	0.6	0.8	0.6	0.8
2000	7.7	0.5	4.7	2.9	0.5	0.9	0.5	0.5	0.5	0.5	0.7	0.5	0.7
2001	6.5	0.4	3.9	2.6	0.4	0.9	0.4	0.4	0.4	0.4	0.6	0.4	0.6
2002	7.5	0.5	4.4	3.1	0.5	1.1	0.5	0.5	0.5	0.5	0.8	0.5	0.8
2003	7.7	0.5	4.5	3.2	0.5	1.1	0.5	0.5	0.5	0.5	0.7	0.5	0.7
2004	6.3	0.4	3.6	2.6	0.4	0.9	0.4	0.4	0.4	0.4	0.6	0.4	0.6
2005	7.8	0.5	4.4	3.3	0.5	1.1	0.5	0.5	0.5	0.5	0.7	0.5	0.7
2006	5.3	0.3	2.9	2.3	0.3	0.8	0.3	0.3	0.3	0.3	0.5	0.3	0.5
Load (non adj)	7.1	0.5	4.2	2.9	0.5	1.0	0.5	0.5	0.5	0.5	0.7	0.5	0.7
Load (t/yr)	**7.1**	**0.0**	**3.6**	**2.3**	**0.0**	**0.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.2**	**0.0**	**0.2**
Load (%)	**100.0%**	**0.0%**	**50.1%**	**32.3%**	**0.0%**	**6.9%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**2.8%**	**0.0%**	**3.0%**



Mill Street Main Drain – Sustainable diversion limits

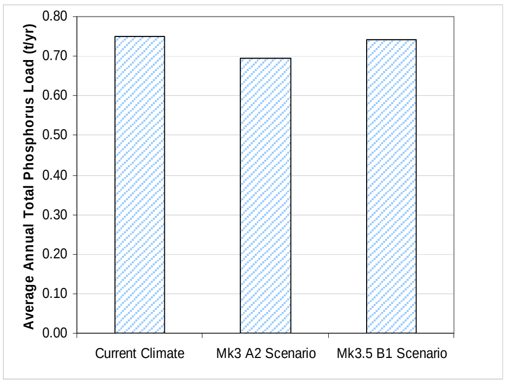




Mill Street Main Drain – Climate change

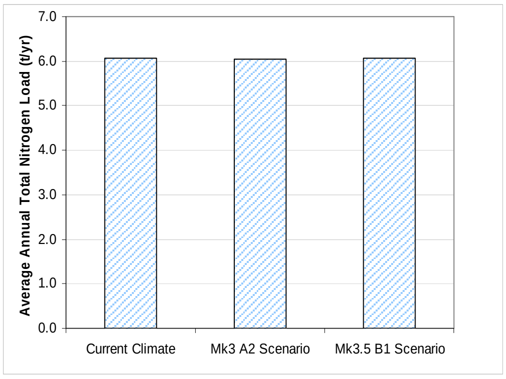
Phosphorus

	At Catchment Outlet		
Year	*Current Climate Load (t/yr)*	*Mk3 A2 Climate Change Scenario Load (t/yr)*	*Mk3.5 B1 Climate Change Scenario Load (t/yr)*
2057	0.71	0.66	0.71
2058	0.72	0.67	0.72
2059	0.82	0.77	0.81
2060	0.83	0.78	0.81
2061	0.70	0.65	0.70
2062	0.77	0.70	0.76
2063	0.82	0.76	0.81
2064	0.68	0.64	0.68
2065	0.86	0.79	0.85
2066	0.58	0.54	0.57
Average Load for RF Sequence (t/yr)	**0.75**	**0.69**	**0.74**



Nitrogen

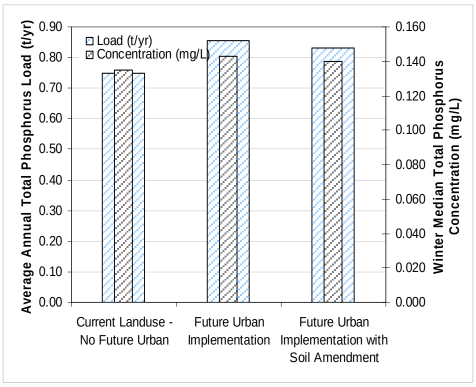
	At Catchment Outlet		
Year	*Current Climate Load (t/yr)*	*Mk3 A2 Climate Change Scenario Load (t/yr)*	*Mk3.5 B1 Climate Change Scenario Load (t/yr)*
2057	5.9	5.8	5.9
2058	6.2	6.1	6.2
2059	6.7	6.7	6.7
2060	6.4	6.5	6.4
2061	5.4	5.4	5.5
2062	6.3	6.2	6.3
2063	6.7	6.7	6.7
2064	5.5	5.6	5.5
2065	6.9	6.8	6.9
2066	4.7	4.7	4.7
Average Load for RF Sequence (t/yr)	**6.1**	**6.0**	**6.1**



Mill Street Main Drain – Future urban

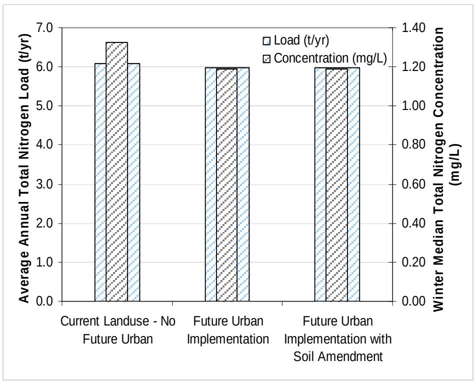
Phosphorus

	At Catchment Outlet		
Year	*Current Landuse - No Future Urban Load (t/yr)*	*Future Urban Implementation Load (t/yr)*	*Future Urban Implementation with Soil Amendment Load (t/yr)*
2057	0.71	0.83	0.80
2058	0.72	0.83	0.81
2059	0.82	0.94	0.92
2060	0.83	0.93	0.90
2061	0.70	0.79	0.76
2062	0.77	0.87	0.85
2063	0.82	0.95	0.93
2064	0.68	0.78	0.75
2065	0.86	1.00	0.97
2066	0.58	0.63	0.61
Average Load for RF Sequence (t/yr)	**0.75**	**0.85**	**0.83**
Median Winter Concentration (mg/L)	**0.135**	**0.143**	**0.140**



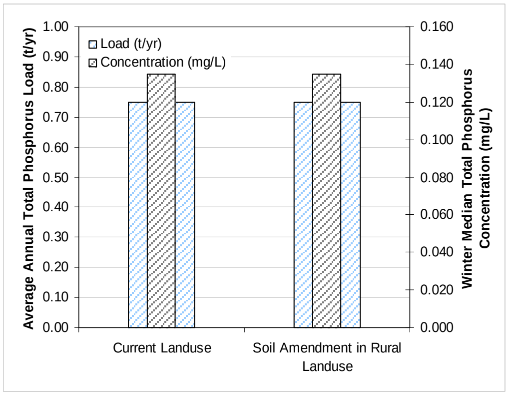
Nitrogen

	At Catchment Outlet		
Year	*Current Landuse - No Future Urban Load (t/yr)*	*Future Urban Implementation Load (t/yr)*	*Future Urban Implementation with Soil Amendment Load (t/yr)*
2057	5.9	5.8	5.8
2058	6.2	6.1	6.1
2059	6.7	6.6	6.6
2060	6.4	6.3	6.3
2061	5.4	5.4	5.4
2062	6.3	6.2	6.2
2063	6.7	6.7	6.7
2064	5.5	5.4	5.4
2065	6.9	6.8	6.8
2066	4.7	4.5	4.5
Average Load for RF Sequence (t/yr)	**6.1**	**6.0**	**6.0**
Median Winter Concentration (mg/L)	**1.33**	**1.19**	**1.19**



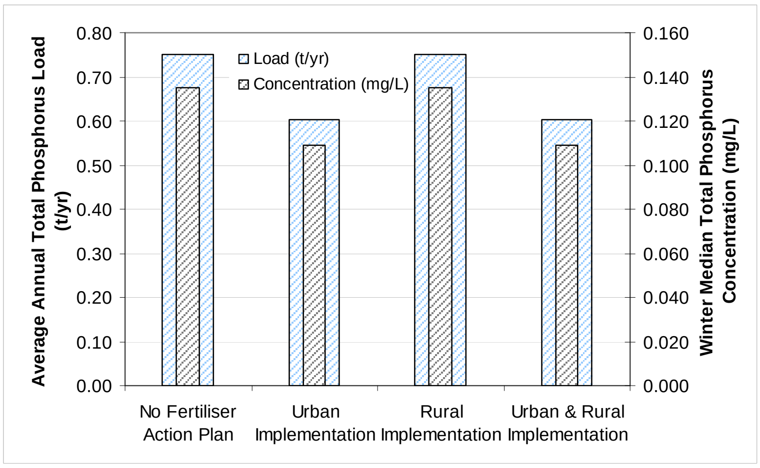
Mill Street Main Drain – Soil amendment in rural land use

Phosphorus		
At Catchment Outlet		
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.71	0.71
2058	0.72	0.72
2059	0.82	0.82
2060	0.83	0.83
2061	0.70	0.70
2062	0.77	0.77
2063	0.82	0.82
2064	0.68	0.68
2065	0.86	0.86
2066	0.58	0.58
Average Load for RF Sequence (t/yr)	**0.75**	**0.75**
Median Winter Concentration (mg/L)	**0.135**	**0.135**



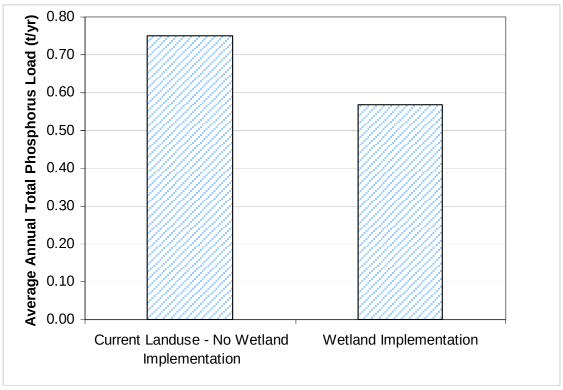
Mill Street Main Drain – *Fertiliser action plan*

Phosphorus				
At Catchment Outlet				
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.71	0.58	0.71	0.58
2058	0.72	0.58	0.72	0.58
2059	0.82	0.66	0.82	0.66
2060	0.83	0.67	0.83	0.67
2061	0.70	0.57	0.70	0.57
2062	0.77	0.62	0.77	0.62
2063	0.82	0.66	0.82	0.66
2064	0.68	0.55	0.68	0.55
2065	0.86	0.69	0.86	0.69
2066	0.58	0.46	0.58	0.46
Average Load for RF Sequence (t/yr)	**0.75**	**0.60**	**0.75**	**0.60**
Median Winter Concentration (mg/L)	**0.135**	**0.109**	**0.135**	**0.109**

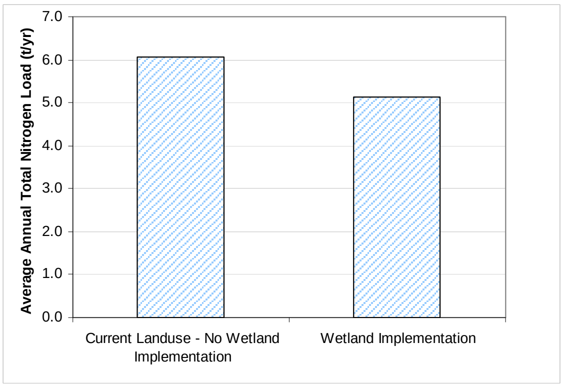


Mill Street Main Drain – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.71	0.54
2058	0.72	0.57
2059	0.82	0.63
2060	0.83	0.61
2061	0.70	0.56
2062	0.77	0.58
2063	0.82	0.61
2064	0.68	0.53
2065	0.86	0.63
2066	0.58	0.43
Average Load for RF Sequence (t/yr)	**0.75**	**0.57**

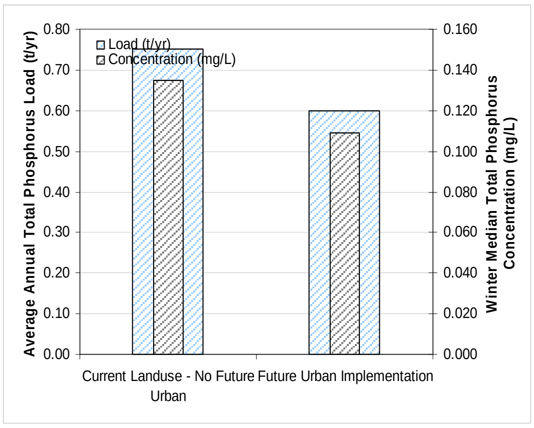


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	5.9	5.0
2058	6.2	5.3
2059	6.7	5.7
2060	6.4	5.4
2061	5.4	4.7
2062	6.3	5.3
2063	6.7	5.6
2064	5.5	4.7
2065	6.9	5.8
2066	4.7	3.9
Average Load for RF Sequence (t/yr)	**6.1**	**5.1**

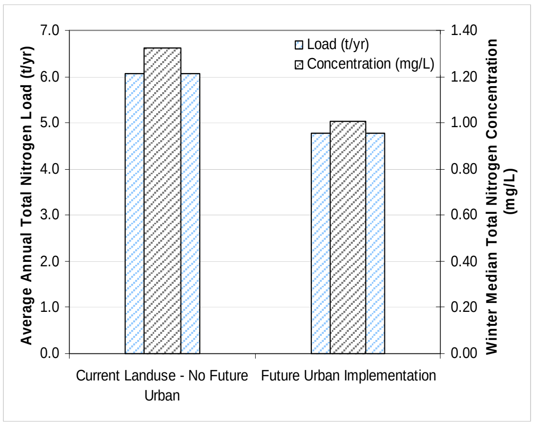


Mill Street Main Drain – Urban 50% reduction

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.71	0.57
2058	0.72	0.58
2059	0.82	0.65
2060	0.83	0.67
2061	0.70	0.56
2062	0.77	0.61
2063	0.82	0.65
2064	0.68	0.54
2065	0.86	0.69
2066	0.58	0.46
Average Load for RF Sequence (t/yr)	**0.75**	**0.60**
Median Winter Concentration (mg/L)	**0.135**	**0.109**



Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	5.9	4.7
2058	6.2	4.9
2059	6.7	5.2
2060	6.4	5.0
2061	5.4	4.3
2062	6.3	5.0
2063	6.7	5.3
2064	5.5	4.3
2065	6.9	5.4
2066	4.7	3.7
Average Load for RF Sequence (t/yr)	**6.1**	**4.8**
Median Winter Concentration (mg/L)	**1.33**	**1.00**

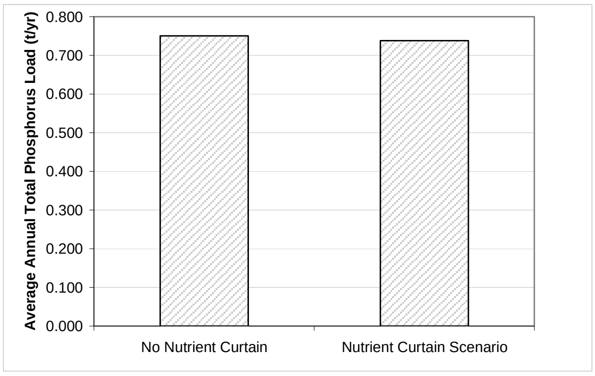


Mill Street Main Drain – Zeolite/laterite nutrient filter

Mills Street Main Drain - Zeolite/Laterite Nutrient Curtain Scenario

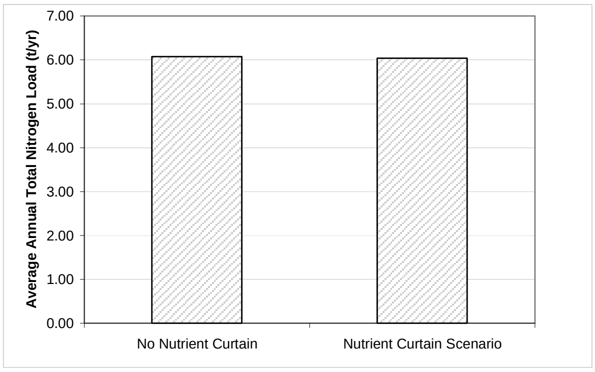
Phosphorus

Year	No Nutrient Curtain Load (t/yr)	Phosphorus Removed - Main Stream (t/yr)	Nutrient Curtain Implementation (t/yr)
2057	0.714	0.012	0.702
2058	0.723	0.012	0.711
2059	0.819	0.012	0.807
2060	0.833	0.012	0.822
2061	0.704	0.011	0.693
2062	0.768	0.012	0.756
2063	0.820	0.011	0.809
2064	0.683	0.012	0.671
2065	0.860	0.011	0.849
2066	0.578	0.012	0.566
Average Load for RF Sequence (t/yr)	**0.750**	**0.012**	**0.739**



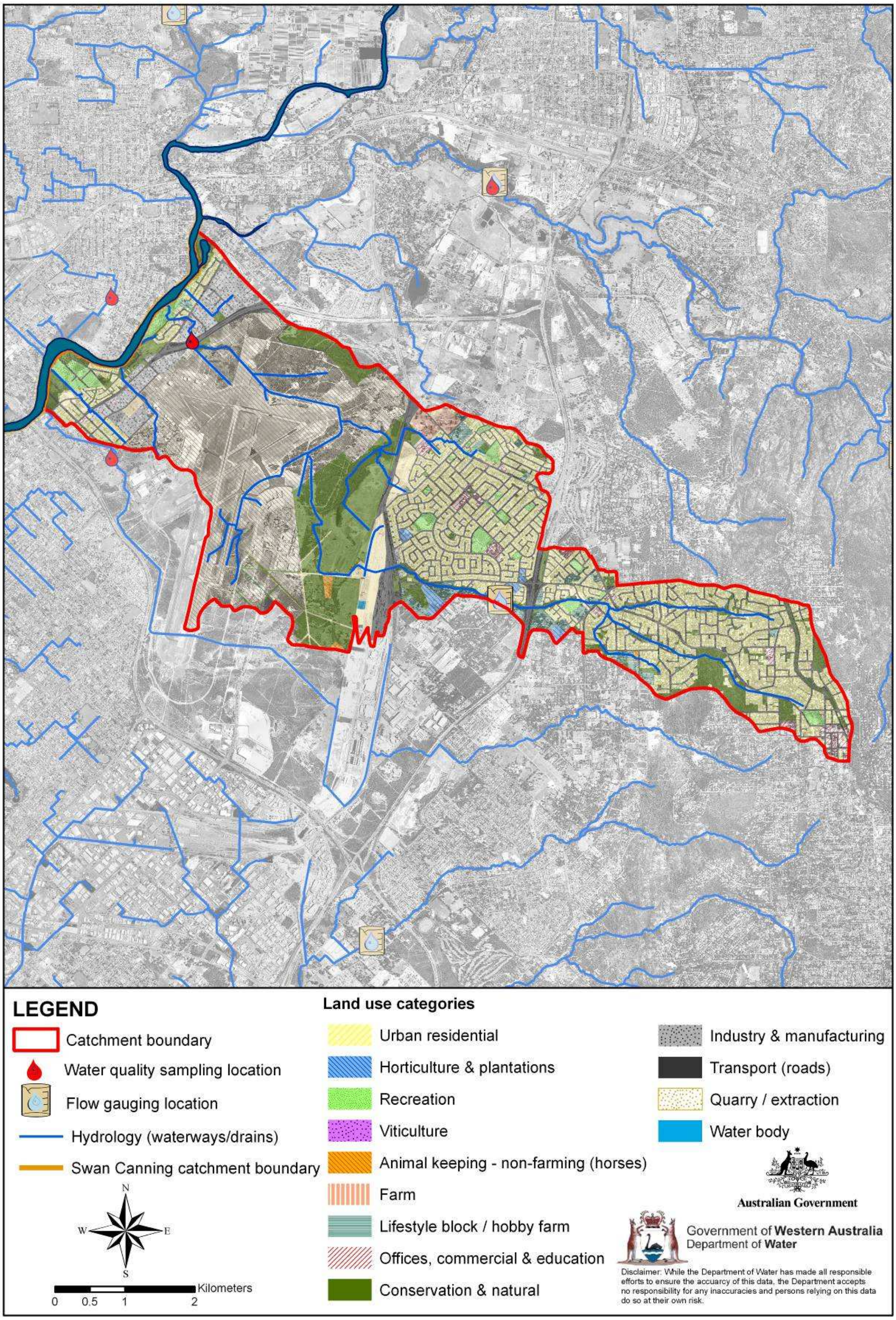
Nitrogen

Year	No Nutrient Curtain Load (t/yr)	Nitrogen Removed - Main Stream (t/yr)	Nutrient Curtain Implementation (t/yr)
2057	5.92	0.04	5.88
2058	6.17	0.04	6.13
2059	6.67	0.04	6.64
2060	6.43	0.04	6.40
2061	5.45	0.03	5.42
2062	6.30	0.04	6.26
2063	6.69	0.03	6.66
2064	5.53	0.03	5.49
2065	6.89	0.03	6.86
2066	4.68	0.04	4.65
Average Load for RF Sequence (t/yr)	**6.07**	**0.04**	**6.04**

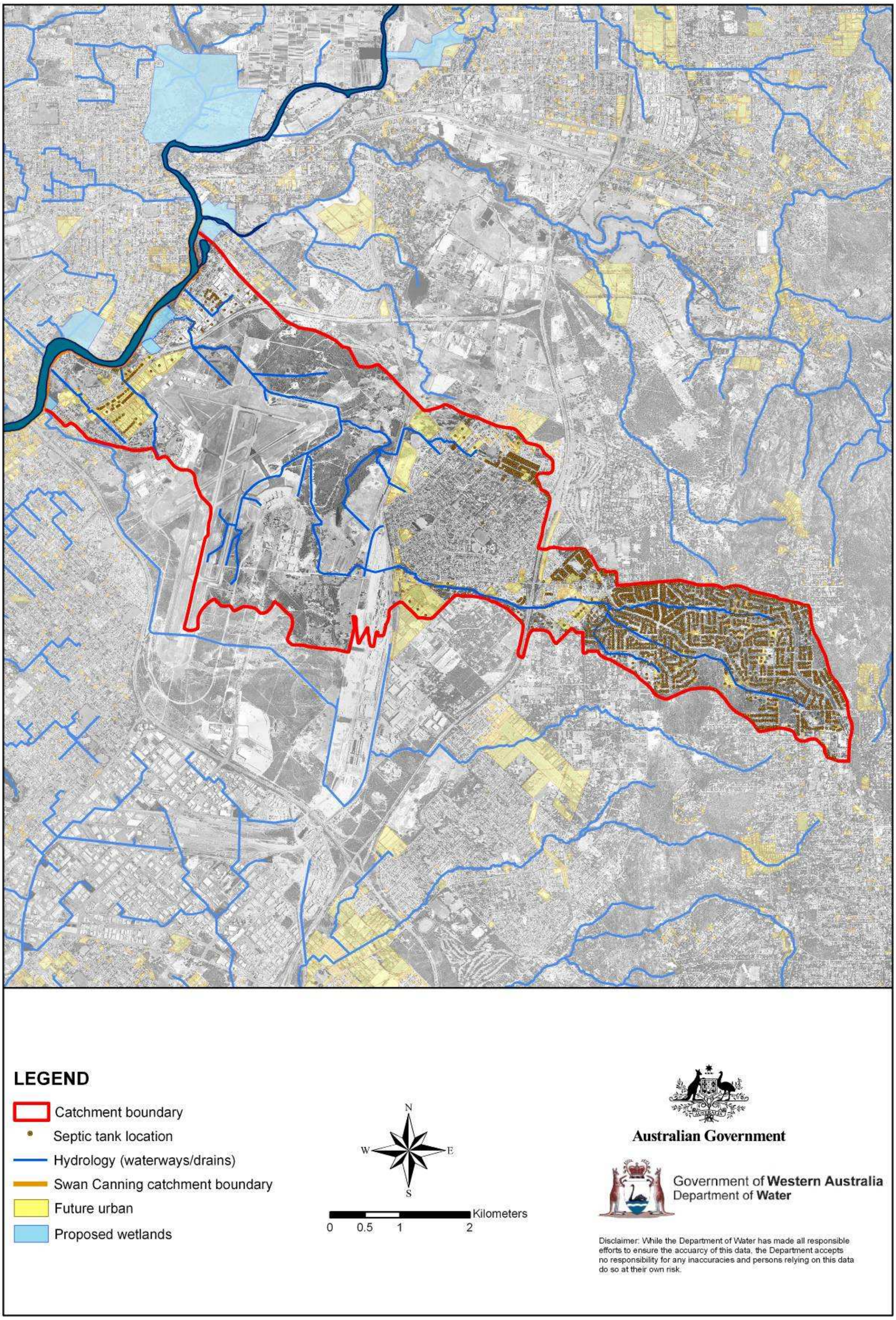


* Nutrient Curtain assumed to contain 500 cubic metres of Laterite and 8 cubic metres of zeolite

Perth Airport North
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Perth Airport North - Current loads and load reduction targets

Phosphorus

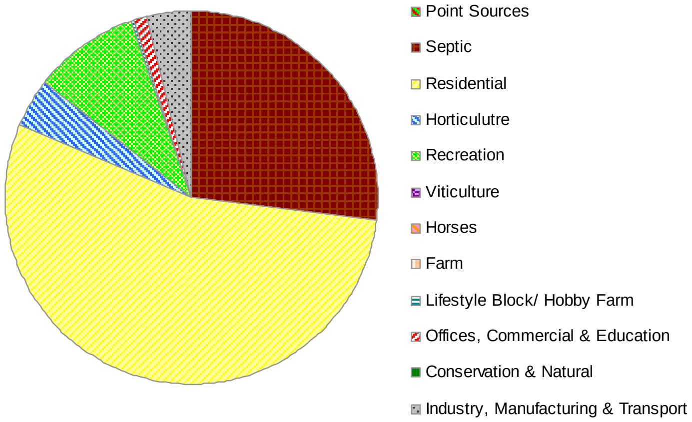
At Outlet to Swan River Estuary			At Sampling Location 6162318		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.22	-	1997	0.15	-
1998	0.23	-	1998	0.16	-
1999	0.22	-	1999	0.15	-
2000	0.20	-	2000	0.14	-
2001	0.17	-	2001	0.13	-
2002	0.19	-	2002	0.15	-
2003	0.24	-	2003	0.18	-
2004	0.19	-	2004	0.14	-
2005	0.25	-	2005	0.18	-
2006	0.17	-	2006	0.14	-
Average	**0.21**	**-**	**Average**	**0.15**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.042**		**SQUARE:**	**0.040**	
Target:	**0.075**		**Observed:**	**0.040**	
Load Target (t/yr)		**0.21**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

Nitrogen

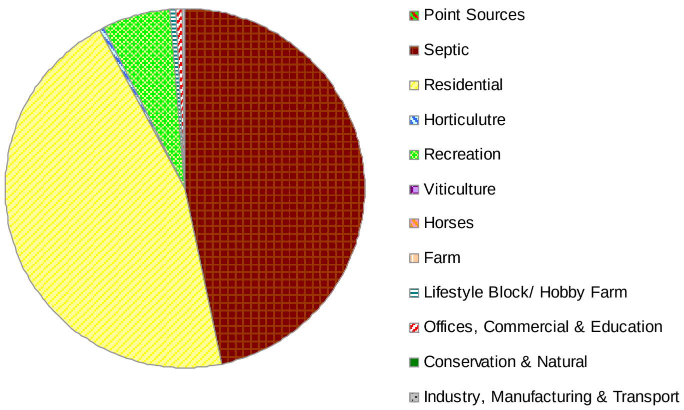
At Outlet to Swan River Estuary			At Sampling Location 6162318		
	Current	30% Input Reduction		Current	30% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	1.9	1.5	1997	1.7	1.4
1998	2.3	1.5	1998	2.0	1.4
1999	2.6	1.6	1999	2.3	1.5
2000	2.0	1.2	2000	1.8	1.1
2001	1.7	1.1	2001	1.6	1.0
2002	1.8	1.1	2002	1.6	1.0
2003	2.3	1.5	2003	2.1	1.4
2004	2.1	1.4	2004	1.9	1.3
2005	2.6	1.7	2005	2.4	1.6
2006	1.0	0.7	2006	0.9	0.6
Average	**2.0**	**1.3**	**Average**	**1.8**	**1.2**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.11**	**0.75**	**SQUARE:**	**1.06**	**0.75**
Target:	**0.75**		**Observed:**	**1.00**	
Load Target (t/yr)		**1.3**			
Load Reduction Target (t/yr)		**0.7**			
Required Reduction (%)		**34%**			
Time Required (yr)		**30**			

Perth Airport North – Source separation

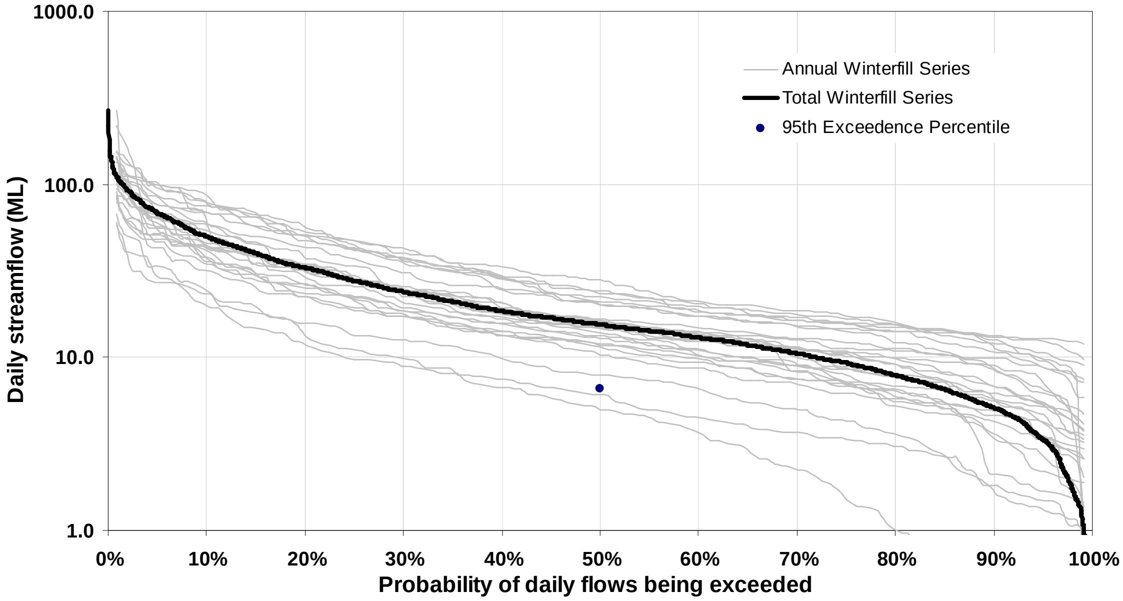
Phosphorus (t/yr)													
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.22	0.00	0.07	0.11	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1998	0.23	0.00	0.07	0.11	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1999	0.22	0.00	0.07	0.11	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2000	0.19	0.00	0.06	0.10	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2001	0.17	0.00	0.05	0.09	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2002	0.19	0.00	0.05	0.11	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2003	0.23	0.00	0.06	0.13	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2004	0.19	0.00	0.04	0.11	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2005	0.24	0.00	0.05	0.14	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2006	0.17	0.00	0.03	0.10	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Load (non adj)	0.21	0.00	0.05	0.11	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Load (t/yr)	**0.21**	**0.00**	**0.06**	**0.11**	**0.01**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**26.9%**	**54.5%**	**4.1%**	**9.2%**	**0.0%**	**0.0%**	**0.0%**	**0.4%**	**1.2%**	**0.0%**	**3.9%**

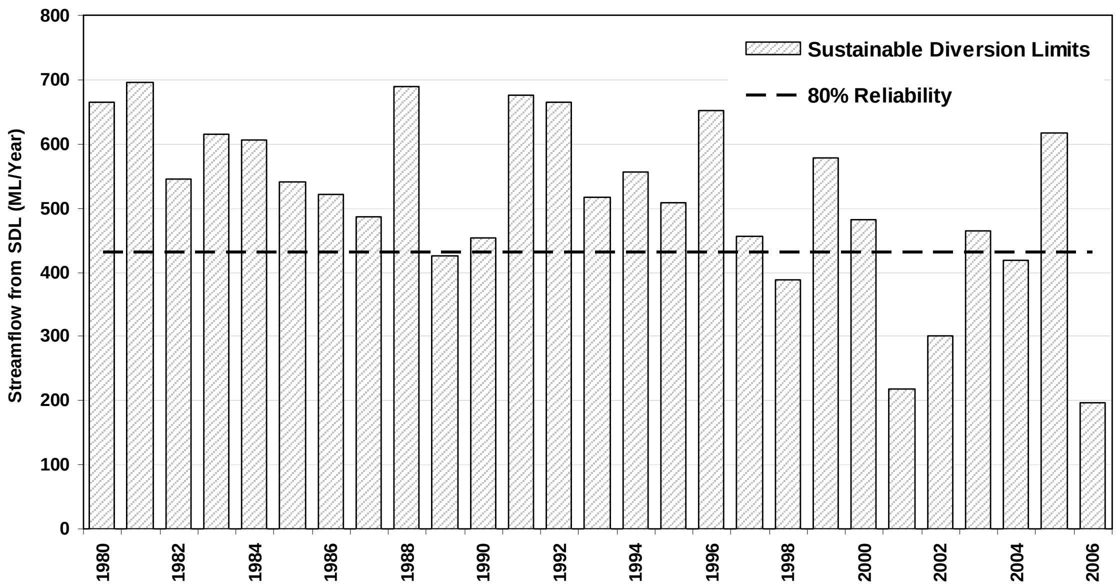


Nitrogen (t/yr)													
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	1.9	0.0	1.7	1.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	2.2	0.0	2.0	1.7	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	2.5	0.0	2.2	2.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	1.9	0.0	1.7	1.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	1.7	0.0	1.5	1.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	1.8	0.0	1.6	1.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	2.3	0.0	1.9	1.9	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	2.0	0.0	1.6	1.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	2.6	0.0	1.9	2.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.9	0.0	0.7	0.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (non adj)	2.0	0.0	1.7	1.6	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (t/yr)	**2.0**	**0.0**	**0.9**	**0.9**	**0.0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**46.8%**	**45.4%**	**0.4%**	**6.0%**	**0.0%**	**0.0%**	**0.0%**	**0.7%**	**0.5%**	**0.0%**	**0.2%**



Perth Airport North – Sustainable diversion limits

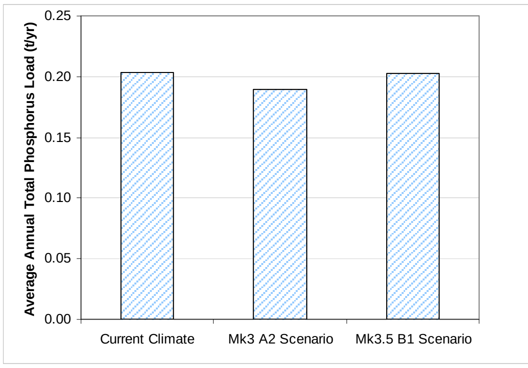




Perth Airport North – Climate change

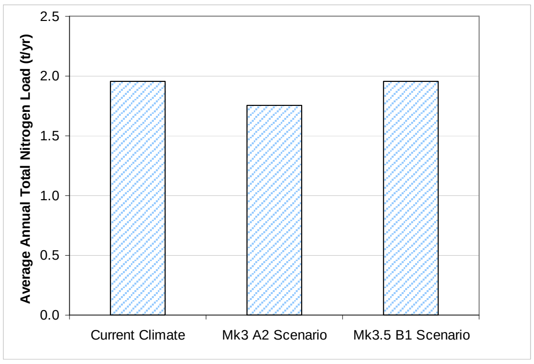
Phosphorus

	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.22	0.22	0.22
2058	0.21	0.20	0.21
2059	0.21	0.20	0.21
2060	0.19	0.17	0.19
2061	0.16	0.15	0.16
2062	0.19	0.17	0.19
2063	0.23	0.22	0.23
2064	0.19	0.18	0.19
2065	0.25	0.23	0.25
2066	0.17	0.15	0.17
Average Load for RF Sequence (t/yr)	**0.20**	**0.19**	**0.20**



Nitrogen

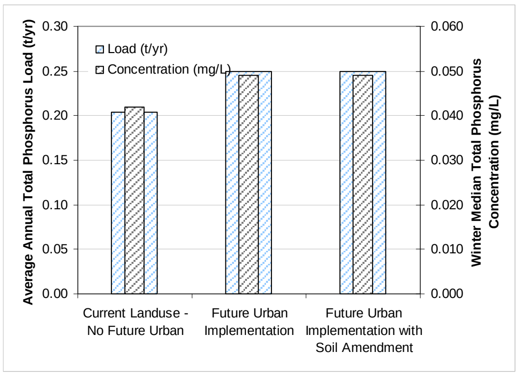
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	2.2	2.0	2.2
2058	2.2	1.8	2.2
2059	2.4	2.3	2.4
2060	1.8	1.8	1.8
2061	1.6	1.2	1.5
2062	1.6	1.2	1.6
2063	2.2	1.9	2.2
2064	2.0	1.9	2.1
2065	2.6	2.6	2.6
2066	1.0	0.8	1.0
Average Load for RF Sequence (t/yr)	**2.0**	**1.8**	**2.0**



Perth Airport North – Future urban

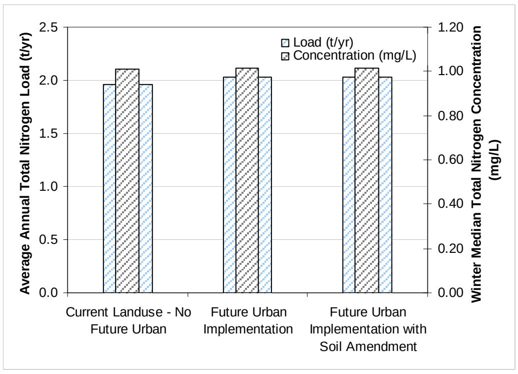
Phosphorus

	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.22	0.27	0.27
2058	0.21	0.27	0.27
2059	0.21	0.25	0.25
2060	0.19	0.23	0.23
2061	0.16	0.20	0.20
2062	0.19	0.23	0.23
2063	0.23	0.29	0.29
2064	0.19	0.24	0.24
2065	0.25	0.31	0.31
2066	0.17	0.21	0.21
Average Load for RF Sequence (t/yr)	**0.20**	**0.25**	**0.25**
Median Winter Concentration (mg/L)	**0.042**	**0.049**	**0.049**



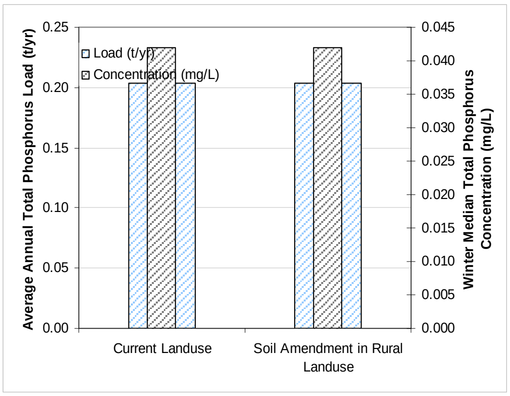
Nitrogen

	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	2.2	2.3	2.3
2058	2.2	2.3	2.3
2059	2.4	2.5	2.5
2060	1.8	1.8	1.8
2061	1.6	1.7	1.7
2062	1.6	1.7	1.7
2063	2.2	2.3	2.3
2064	2.0	2.1	2.1
2065	2.6	2.7	2.7
2066	1.0	1.0	1.0
Average Load for RF Sequence (t/yr)	**2.0**	**2.0**	**2.0**
Median Winter Concentration (mg/L)	**1.01**	**1.02**	**1.02**



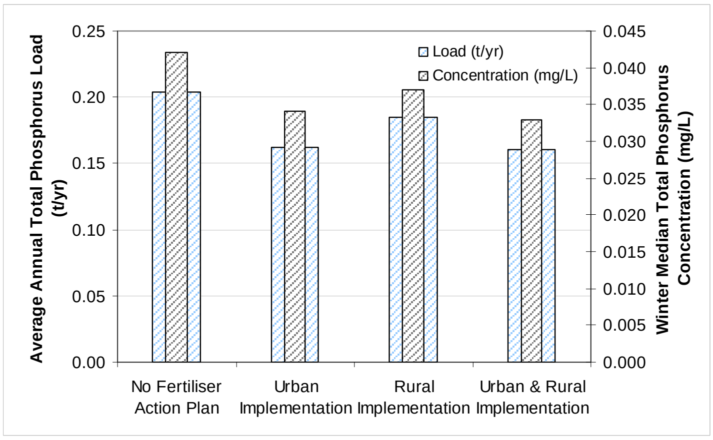
Perth Airport North – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.22	0.22
2058	0.21	0.21
2059	0.21	0.21
2060	0.19	0.19
2061	0.16	0.16
2062	0.19	0.19
2063	0.23	0.23
2064	0.19	0.19
2065	0.25	0.25
2066	0.17	0.17
Average Load for RF Sequence (t/yr)	**0.20**	**0.20**
Median Winter Concentration (mg/L)	**0.042**	**0.042**



Perth Airport North – *Fertiliser action plan*

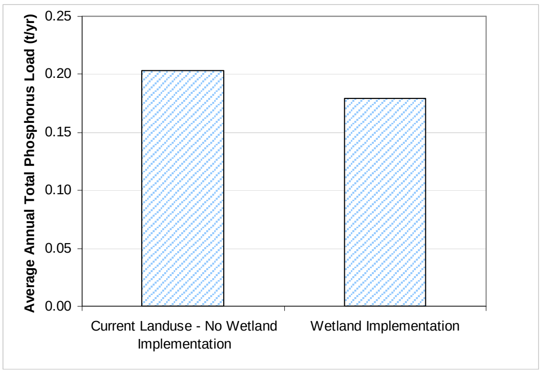
Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.22	0.18	0.20	0.17
2058	0.21	0.17	0.19	0.17
2059	0.21	0.17	0.19	0.16
2060	0.19	0.15	0.17	0.15
2061	0.16	0.13	0.15	0.13
2062	0.19	0.15	0.17	0.15
2063	0.23	0.19	0.21	0.18
2064	0.19	0.15	0.17	0.15
2065	0.25	0.20	0.23	0.20
2066	0.17	0.14	0.16	0.13
Average Load for RF Sequence (t/yr)	**0.20**	**0.16**	**0.18**	**0.16**
Median Winter Concentration (mg/L)	**0.042**	**0.034**	**0.037**	**0.033**



Perth Airport North – Wetland implementation

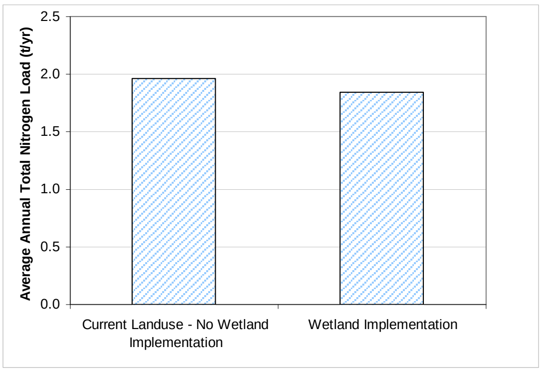
Phosphorus

Year	At Catchment Outlet: Current Landuse - No Wetland Implementation (t/yr)	At Catchment Outlet: Wetland Implementation Load (t/yr)
2057	0.22	0.19
2058	0.21	0.19
2059	0.21	0.18
2060	0.19	0.17
2061	0.16	0.14
2062	0.19	0.17
2063	0.23	0.21
2064	0.19	0.17
2065	0.25	0.22
2066	0.17	0.15
Average Load for RF Sequence (t/yr)	**0.20**	**0.18**



Nitrogen

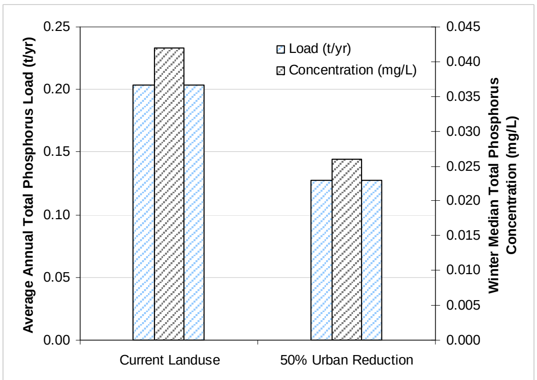
Year	At Catchment Outlet: Current Landuse - No Wetland Implementation (t/yr)	At Catchment Outlet: Wetland Implementation Load (t/yr)
2057	2.2	2.1
2058	2.2	2.1
2059	2.4	2.3
2060	1.8	1.7
2061	1.6	1.5
2062	1.6	1.5
2063	2.2	2.1
2064	2.0	1.9
2065	2.6	2.4
2066	1.0	0.9
Average Load for RF Sequence (t/yr)	**2.0**	**1.8**



Perth Airport North – Urban 50% reduction

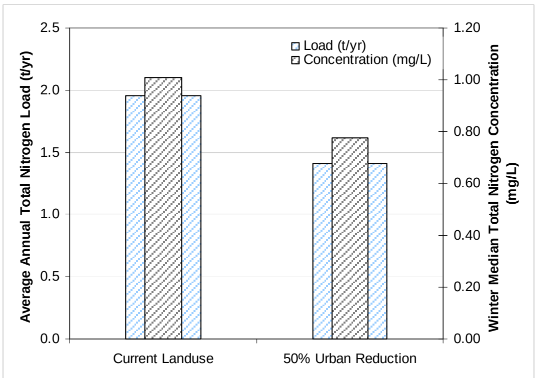
Phosphorus

Year	At Catchment Outlet: Current Landuse Load (t/yr)	At Catchment Outlet: 50% urban reduction Load (t/yr)
2057	0.22	0.14
2058	0.21	0.13
2059	0.21	0.13
2060	0.19	0.12
2061	0.16	0.10
2062	0.19	0.12
2063	0.23	0.15
2064	0.19	0.12
2065	0.25	0.16
2066	0.17	0.11
Average Load for RF Sequence (t/yr)	**0.20**	**0.13**
Median Winter Concentration (mg/L)	**0.042**	**0.026**

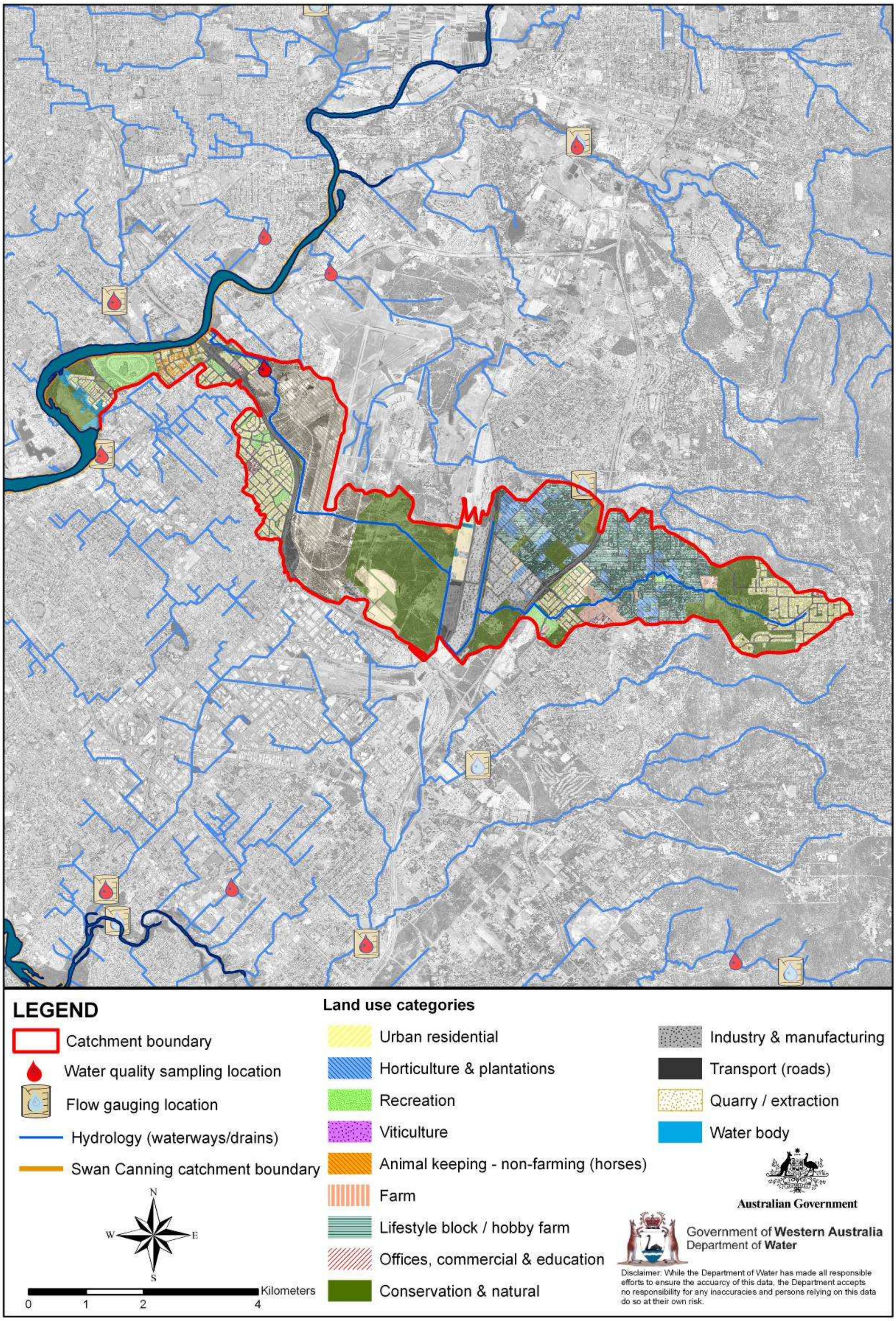


Nitrogen

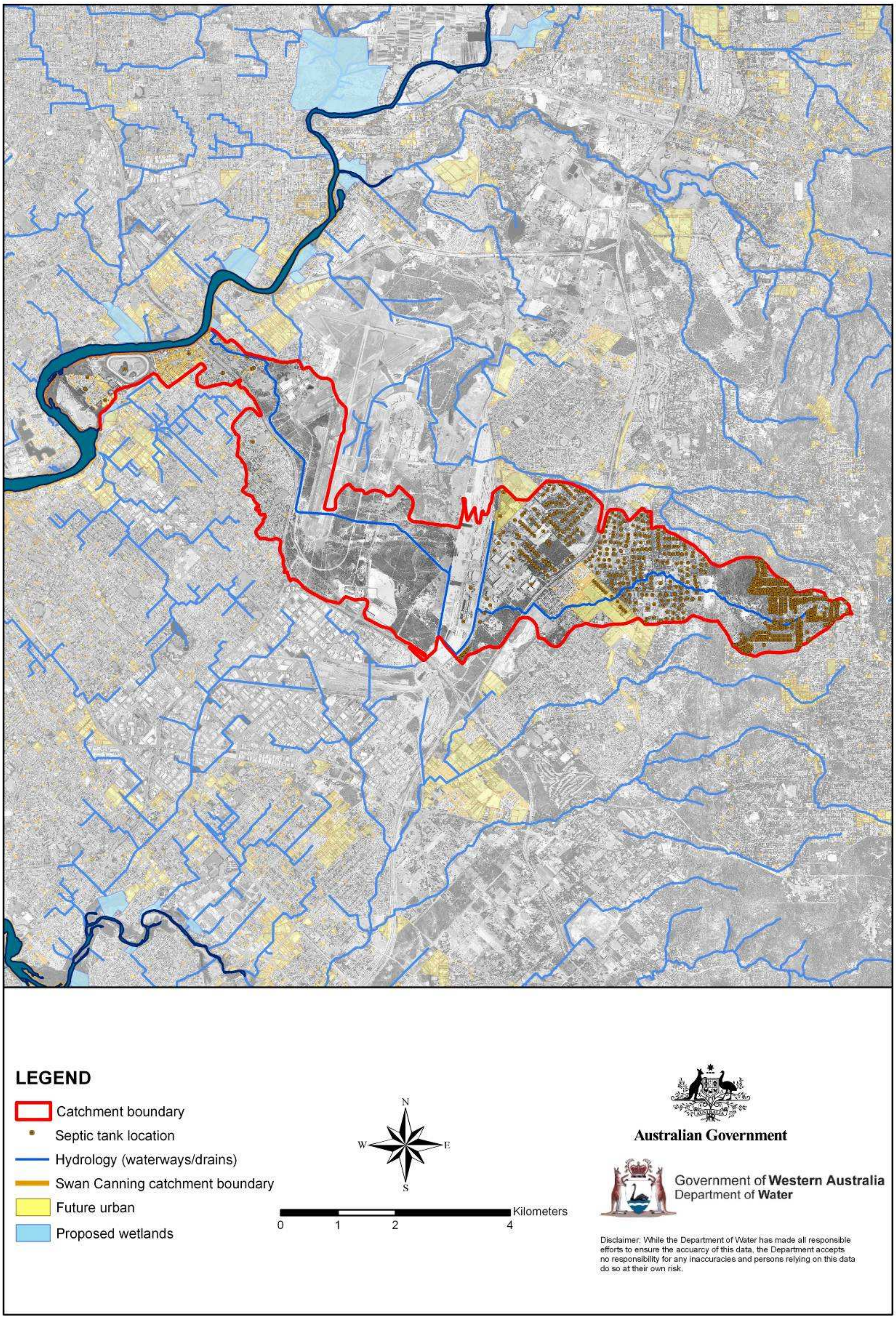
Year	At Catchment Outlet: Current Landuse Load (t/yr)	At Catchment Outlet: 50% urban reduction Load (t/yr)
2057	2.2	1.6
2058	2.2	1.6
2059	2.4	1.7
2060	1.8	1.3
2061	1.6	1.1
2062	1.6	1.2
2063	2.2	1.6
2064	2.0	1.5
2065	2.6	1.9
2066	1.0	0.7
Average Load for RF Sequence (t/yr)	**2.0**	**1.4**
Median Winter Concentration (mg/L)	**1.01**	**0.77**



Perth Airport South
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Perth Airport South - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Sampling Location 6162317		
	Current	No Reduction Required		Current	No Reduction Required
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	0.23	-	*1997*	0.13	-
1998	0.21	-	*1998*	0.12	-
1999	0.24	-	*1999*	0.14	-
2000	0.16	-	*2000*	0.09	-
2001	0.11	-	*2001*	0.07	-
2002	0.10	-	*2002*	0.07	-
2003	0.21	-	*2003*	0.11	-
2004	0.15	-	*2004*	0.09	-
2005	0.24	-	*2005*	0.15	-
2006	0.06	-	*2006*	0.04	-
Average	**0.17**	**-**	**Average**	**0.10**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.026**		**SQUARE:**	**0.018**	
Target:	**0.100**		**Observed:**	**0.018**	
Load Target (t/yr)		**0.17**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**-**			

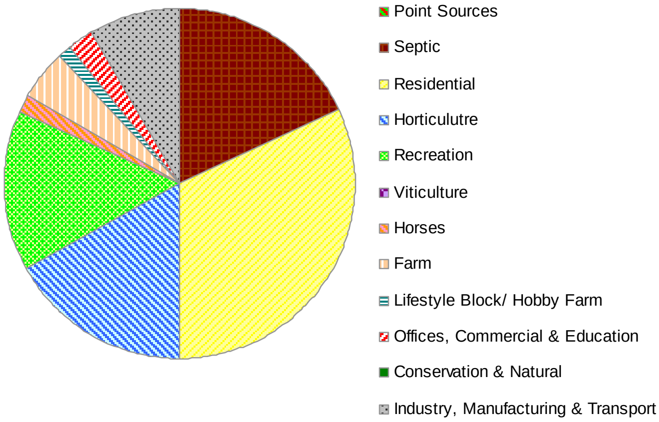
Nitrogen

At Outlet to Swan River Estuary			At Sampling Location 6162317		
	Current	No Reduction Required		Current	No Reduction Required
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	1.2	-	*1997*	1.1	-
1998	1.3	-	*1998*	1.1	-
1999	1.5	-	*1999*	1.4	-
2000	1.2	-	*2000*	1.1	-
2001	0.8	-	*2001*	0.7	-
2002	0.8	-	*2002*	0.7	-
2003	1.1	-	*2003*	1.0	-
2004	1.0	-	*2004*	0.9	-
2005	1.2	-	*2005*	1.1	-
2006	0.4	-	*2006*	0.3	-
Average	**1.1**	**-**	**Average**	**0.9**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.65**		**SQUARE:**	**0.64**	
Target:	**1.00**		**Observed:**	**0.64**	
Load Target (t/yr)		**1.1**			
Load Reduction Target (t/yr)		**0.0**			
Required Reduction (%)		**0%**			
Time Required (yr)		**-**			

Perth Airport South – Source separation

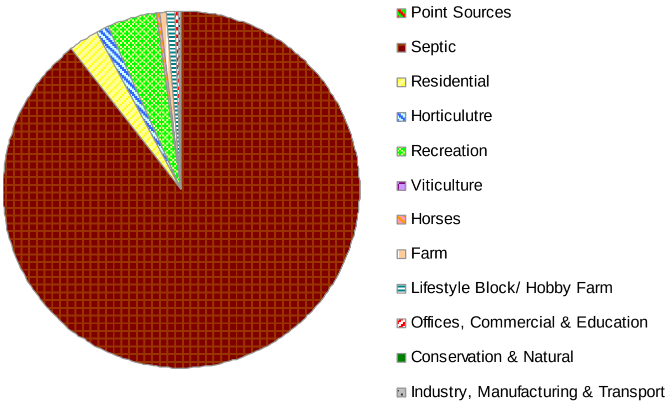
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.23	0.00	0.06	0.06	0.03	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.01
1998	0.21	0.00	0.06	0.05	0.03	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.01
1999	0.24	0.00	0.06	0.06	0.04	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.02
2000	0.16	0.00	0.03	0.04	0.03	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.01
2001	0.11	0.00	0.02	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2002	0.10	0.00	0.02	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2003	0.21	0.00	0.02	0.09	0.03	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.02
2004	0.15	0.00	0.01	0.05	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2005	0.24	0.00	0.02	0.08	0.06	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.02
2006	0.06	0.00	0.00	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Load (non adj)	0.17	0.00	0.03	0.05	0.03	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Load (t/yr)	**0.17**	**0.00**	**0.03**	**0.05**	**0.03**	**0.03**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**18.2%**	**31.8%**	**16.9%**	**14.8%**	**0.0%**	**1.7%**	**4.7%**	**1.3%**	**2.4%**	**0.0%**	**8.3%**

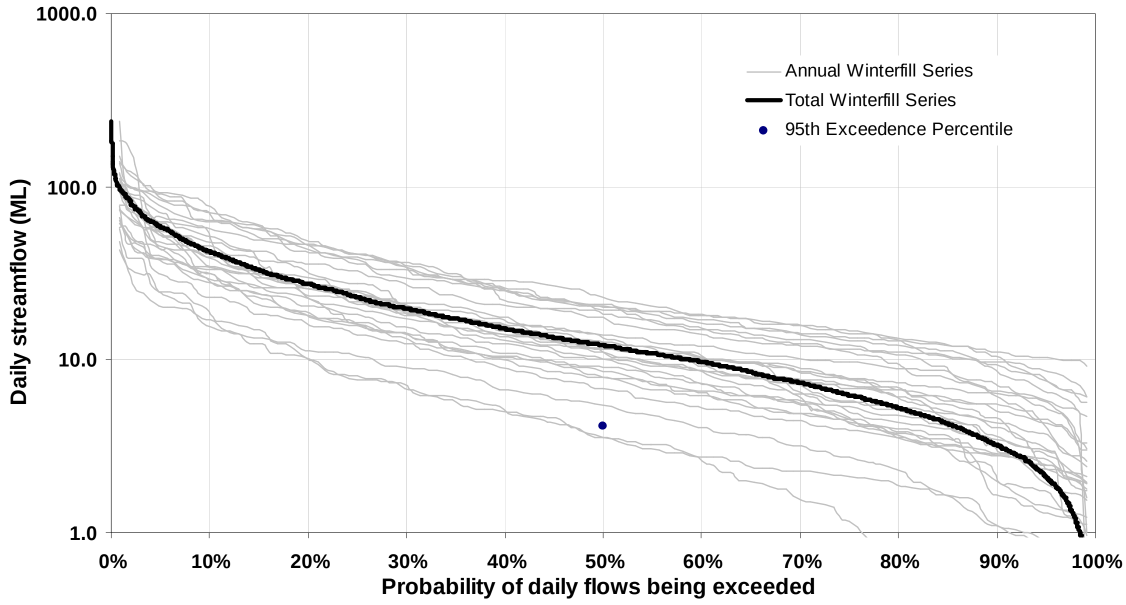


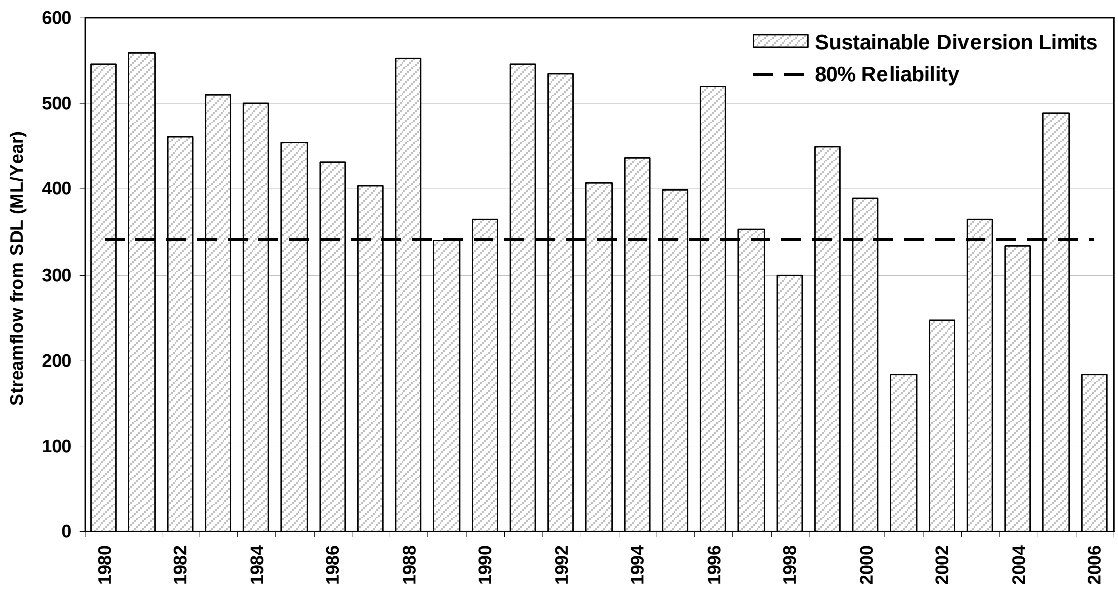
Nitrogen (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	1.2	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	1.3	0.0	1.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	1.5	0.0	1.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	1.2	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.8	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.8	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	1.1	0.0	0.9	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	1.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	1.2	0.0	1.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (non adj)	1.1	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Load (t/yr)	**1.1**	**0.0**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**89.5%**	**2.6%**	**1.3%**	**4.4%**	**0.0%**	**0.1%**	**0.6%**	**0.9%**	**0.3%**	**0.0%**	**0.3%**



Perth Airport South – Sustainable diversion limits

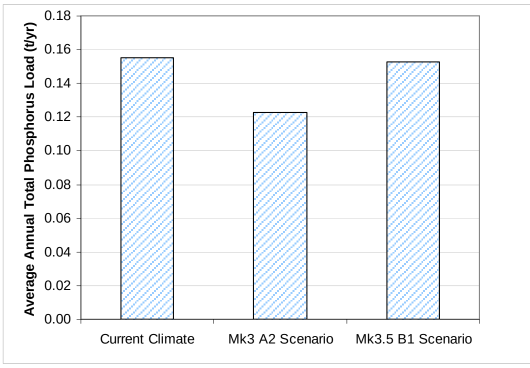




Perth Airport South – Climate change

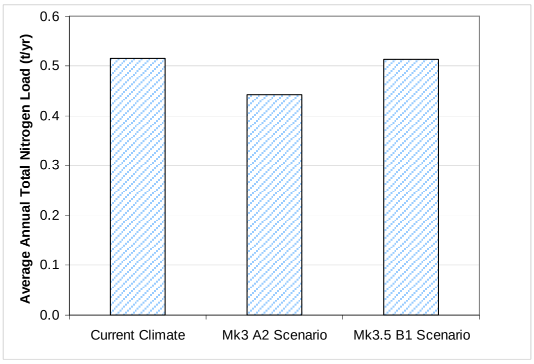
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.23	0.12	0.22
2058	0.15	0.10	0.15
2059	0.18	0.16	0.18
2060	0.15	0.25	0.15
2061	0.11	0.05	0.10
2062	0.09	0.04	0.08
2063	0.20	0.09	0.20
2064	0.15	0.10	0.15
2065	0.24	0.28	0.24
2066	0.06	0.03	0.06
Average Load for RF Sequence (t/yr)	**0.16**	**0.12**	**0.15**



Nitrogen

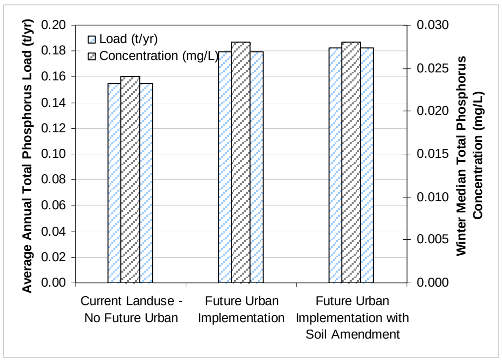
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.5	0.5	0.5
2058	0.5	0.4	0.5
2059	0.7	0.6	0.7
2060	0.5	0.5	0.5
2061	0.4	0.3	0.4
2062	0.4	0.3	0.3
2063	0.6	0.5	0.6
2064	0.6	0.5	0.6
2065	0.8	0.7	0.8
2066	0.3	0.2	0.3
Average Load for RF Sequence (t/yr)	**0.5**	**0.4**	**0.5**



Perth Airport South – Future urban

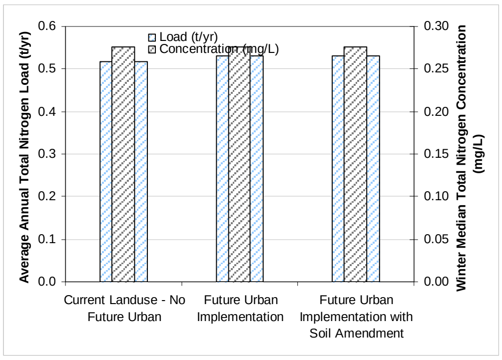
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.23	0.26	0.27
2058	0.15	0.17	0.18
2059	0.18	0.21	0.21
2060	0.15	0.17	0.17
2061	0.11	0.12	0.12
2062	0.09	0.11	0.11
2063	0.20	0.22	0.23
2064	0.15	0.17	0.18
2065	0.24	0.28	0.28
2066	0.06	0.07	0.07
Average Load for RF Sequence (t/yr)	**0.16**	**0.18**	**0.18**
Median Winter Concentration (mg/L)	**0.024**	**0.028**	**0.028**



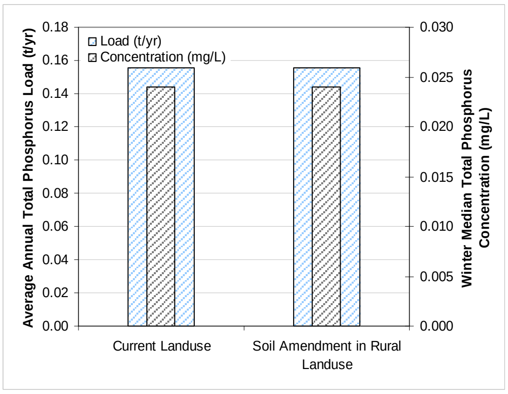
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.5	0.6	0.6
2058	0.5	0.6	0.6
2059	0.7	0.7	0.7
2060	0.5	0.5	0.5
2061	0.4	0.4	0.4
2062	0.4	0.4	0.4
2063	0.6	0.6	0.6
2064	0.6	0.6	0.6
2065	0.8	0.8	0.8
2066	0.3	0.3	0.3
Average Load for RF Sequence (t/yr)	**0.5**	**0.5**	**0.5**
Median Winter Concentration (mg/L)	**0.28**	**0.28**	**0.28**



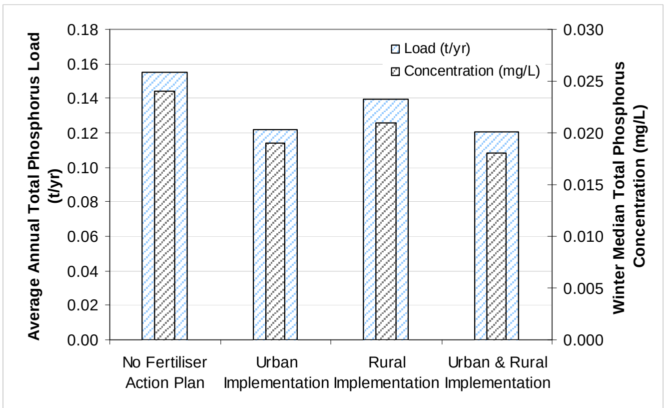
Perth Airport South – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.23	0.23
2058	0.15	0.15
2059	0.18	0.18
2060	0.15	0.15
2061	0.11	0.11
2062	0.09	0.09
2063	0.20	0.20
2064	0.15	0.15
2065	0.24	0.24
2066	0.06	0.06
Average Load for RF Sequence (t/yr)	**0.16**	**0.16**
Median Winter Concentration (mg/L)	**0.024**	**0.024**



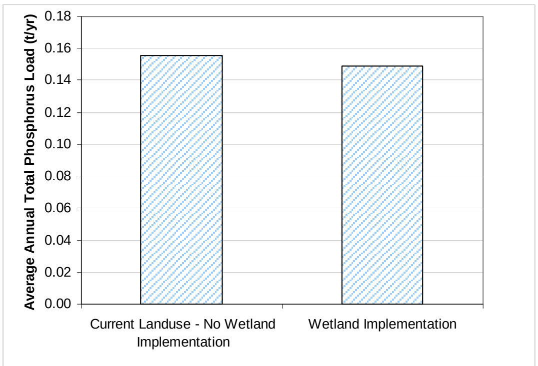
Perth Airport South – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.23	0.18	0.21	0.17
2058	0.15	0.12	0.13	0.11
2059	0.18	0.14	0.16	0.14
2060	0.15	0.12	0.13	0.12
2061	0.11	0.08	0.10	0.08
2062	0.09	0.07	0.08	0.07
2063	0.20	0.15	0.18	0.15
2064	0.15	0.12	0.13	0.12
2065	0.24	0.20	0.22	0.20
2066	0.06	0.04	0.05	0.04
Average Load for RF Sequence (t/yr)	**0.16**	**0.12**	**0.14**	**0.12**
Median Winter Concentration (mg/L)	**0.024**	**0.019**	**0.021**	**0.018**

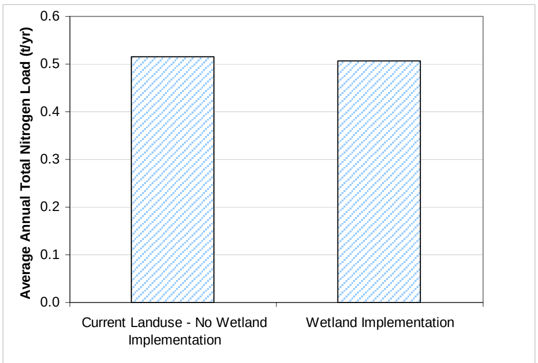


Perth Airport South – Wetland implementation

Phosphorus	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.23	0.22
2058	0.15	0.14
2059	0.18	0.17
2060	0.15	0.15
2061	0.11	0.10
2062	0.09	0.09
2063	0.20	0.19
2064	0.15	0.14
2065	0.24	0.23
2066	0.06	0.06
Average Load for RF Sequence (t/yr)	0.16	0.15

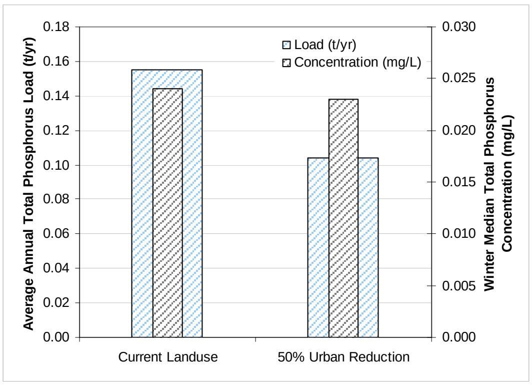


Nitrogen	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.5	0.5
2058	0.5	0.5
2059	0.7	0.7
2060	0.5	0.5
2061	0.4	0.4
2062	0.4	0.3
2063	0.6	0.6
2064	0.6	0.5
2065	0.8	0.8
2066	0.3	0.2
Average Load for RF Sequence (t/yr)	0.5	0.5

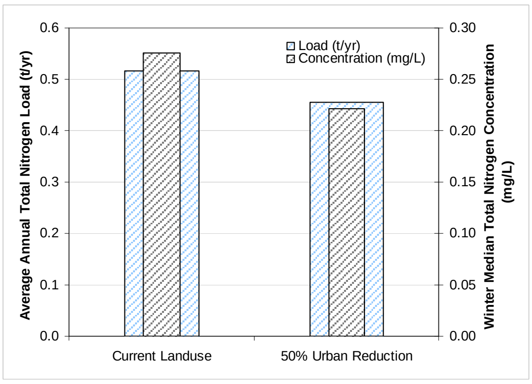


Perth Airport South – Urban 50% reduction

Phosphorus	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.23	0.15
2058	0.15	0.10
2059	0.18	0.12
2060	0.15	0.11
2061	0.11	0.07
2062	0.09	0.06
2063	0.20	0.13
2064	0.15	0.10
2065	0.24	0.17
2066	0.06	0.04
Average Load for RF Sequence (t/yr)	0.16	0.10
Median Winter Concentration (mg/L)	0.024	0.023

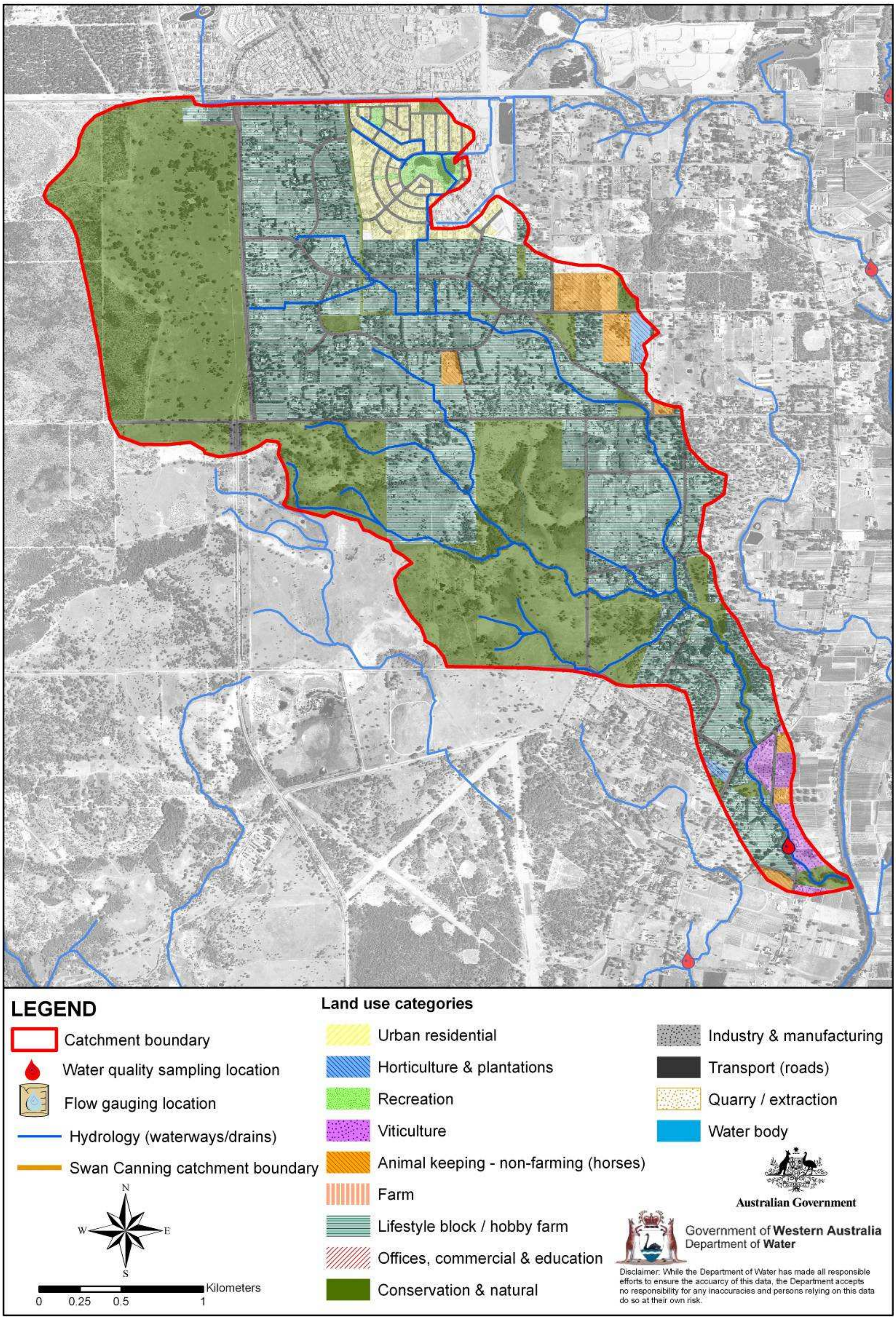


Nitrogen	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.5	0.5
2058	0.5	0.5
2059	0.7	0.6
2060	0.5	0.5
2061	0.4	0.3
2062	0.4	0.3
2063	0.6	0.5
2064	0.6	0.5
2065	0.8	0.7
2066	0.3	0.2
Average Load for RF Sequence (t/yr)	0.5	0.5
Median Winter Concentration (mg/L)	0.28	0.22

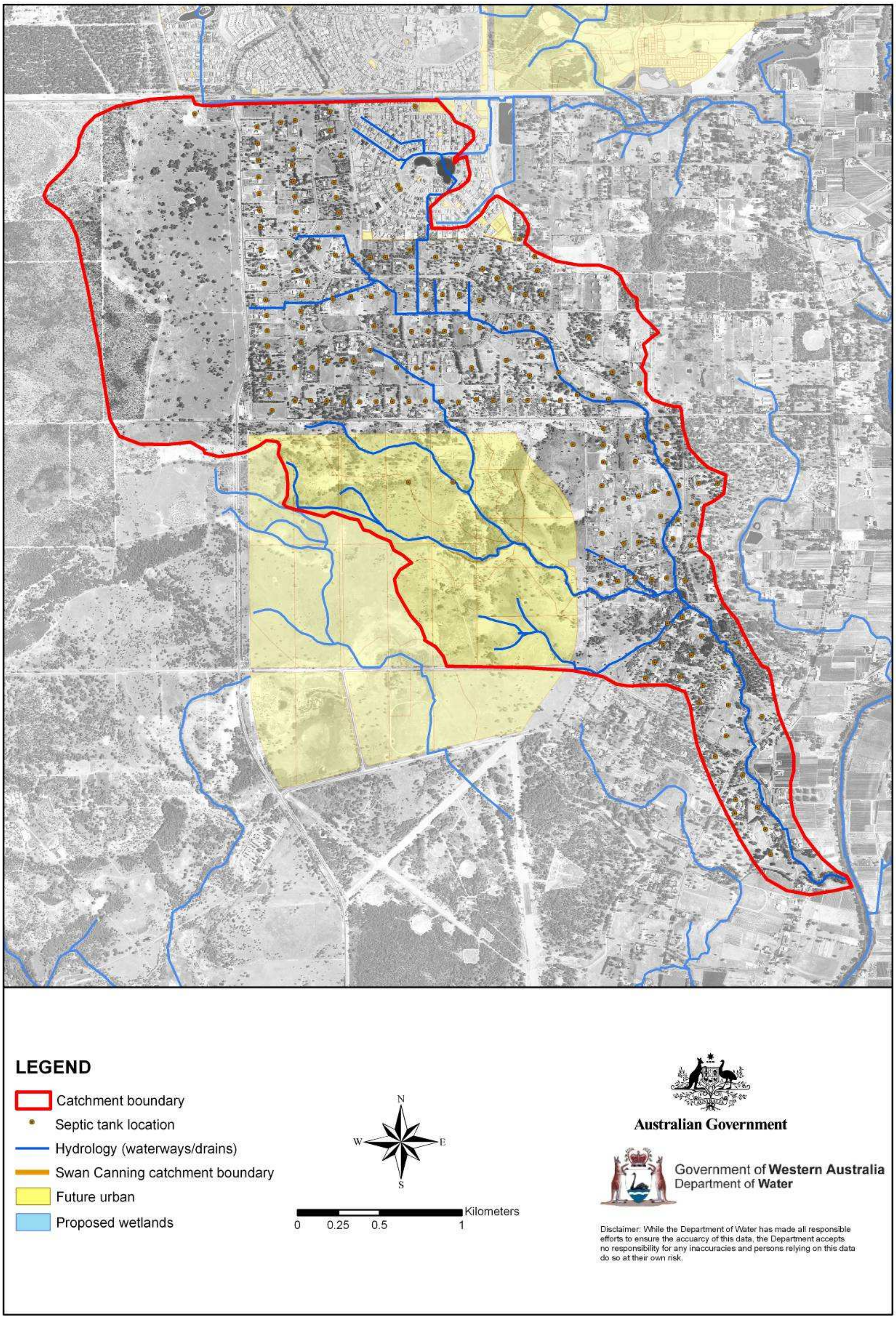


Saint Leonards Creek

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Saint Leonards Creek - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Sampling Location 6162319		
	Current	33% Input Reduction		Current	33% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.20	0.06	*1997*	0.19	0.06
1998	0.18	0.08	*1998*	0.18	0.08
1999	0.24	0.11	*1999*	0.24	0.11
2000	0.13	0.12	*2000*	0.13	0.12
2001	0.03	0.07	*2001*	0.03	0.07
2002	0.05	0.10	*2002*	0.05	0.10
2003	0.13	0.12	*2003*	0.12	0.11
2004	0.10	0.09	*2004*	0.10	0.09
2005	0.27	0.20	*2005*	0.27	0.20
2006	0.07	0.05	*2006*	0.07	0.05
Average	**0.14**	**0.10**	**Average**	**0.14**	**0.10**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.114**	**0.104**	**SQUARE:**	**0.115**	**0.106**
Target:	**0.100**		**Observed:**	**0.115**	
Load Target (t/yr)		**0.10**			
Load Reduction Target (t/yr)		**0.04**			
Required Reduction (%)		**30%**			
Time Required (yr)		**20**			

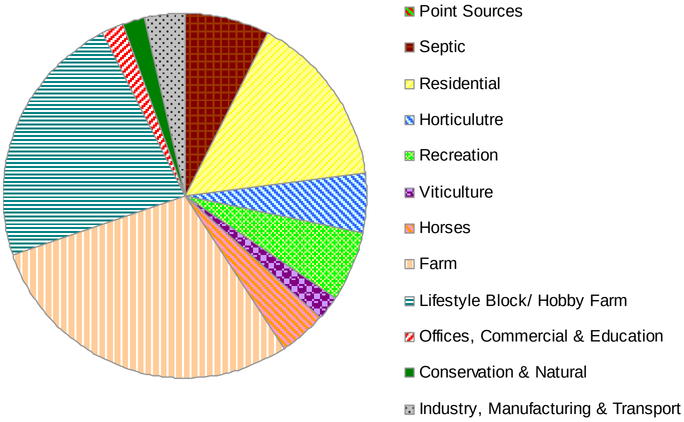
Nitrogen

At Outlet to Swan River Estuary			At Sampling Location 6162319		
	Current	27% Input Reduction		Current	27% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	1.7	0.3	*1997*	1.7	0.3
1998	1.7	0.4	*1998*	1.7	0.4
1999	2.2	0.5	*1999*	2.2	0.5
2000	2.0	0.6	*2000*	2.0	0.6
2001	1.3	0.4	*2001*	1.3	0.4
2002	1.1	0.4	*2002*	1.1	0.4
2003	1.4	0.6	*2003*	1.4	0.6
2004	0.9	0.4	*2004*	0.9	0.4
2005	1.5	0.7	*2005*	1.5	0.7
2006	0.6	0.3	*2006*	0.6	0.3
Average	**1.4**	**0.5**	**Average**	**1.4**	**0.5**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**2.70**	**0.99**	**SQUARE:**	**2.70**	**0.99**
Target:	**1.00**		**Observed:**	**2.70**	
Load Target (t/yr)		**0.5**			
Load Reduction Target (t/yr)		**1.0**			
Required Reduction (%)		**68%**			
Time Required (yr)		**30**			

Saint Leonards Creek – Source separation

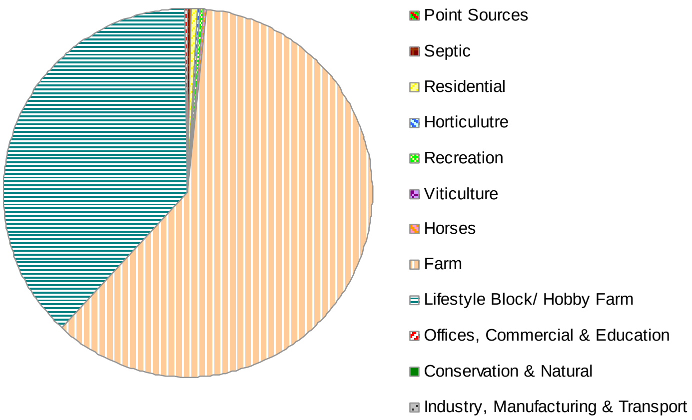
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.20	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.14	0.04	0.01	0.01	0.01
1998	0.18	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.13	0.04	0.01	0.01	0.01
1999	0.24	0.00	0.01	0.01	0.02	0.01	0.01	0.02	0.17	0.05	0.01	0.01	0.01
2000	0.13	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.05	0.05	0.00	0.00	0.00
2001	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
2002	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
2003	0.13	0.00	0.01	0.05	0.01	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.01
2004	0.10	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.00	0.00
2005	0.27	0.00	0.03	0.10	0.02	0.03	0.00	0.01	0.00	0.08	0.00	0.00	0.01
2006	0.07	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Load (non adj)	0.14	0.00	0.01	0.03	0.01	0.01	0.00	0.01	0.05	0.04	0.00	0.00	0.01
Load (t/yr)	**0.14**	**0.00**	**0.01**	**0.02**	**0.01**	**0.01**	**0.00**	**0.01**	**0.04**	**0.03**	**0.00**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**7.4%**	**15.7%**	**5.3%**	**5.9%**	**2.3%**	**4.1%**	**29.0%**	**22.8%**	**1.9%**	**1.9%**	**3.6%**



Nitrogen (t/yr)

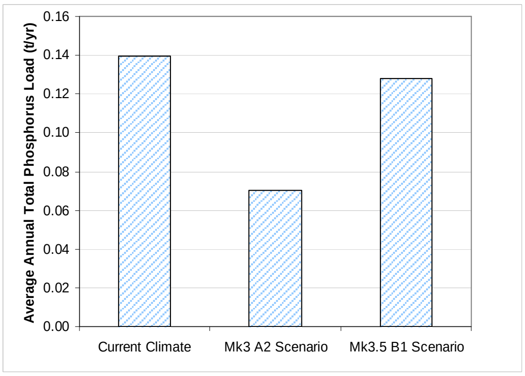
Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.4	0.0	0.0	0.0
1998	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.0	0.0	0.0
1999	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.5	0.0	0.0	0.0
2000	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0	0.0
2001	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.0	0.0
2002	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.3	0.0	0.0	0.0
2003	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0
2004	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.0
2005	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0	0.0
2006	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0
Load (non adj)	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.4	0.0	0.0	0.0
Load (t/yr)	**1.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**0.5**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**0.3%**	**0.6%**	**0.2%**	**0.2%**	**0.1%**	**0.2%**	**60.5%**	**37.9%**	**0.1%**	**0.1%**	**0.0%**



Saint Leonards Creek – Climate change

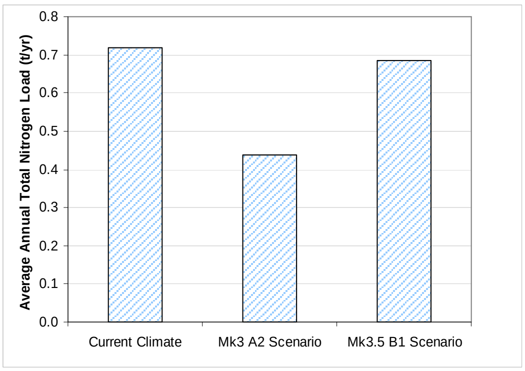
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.09	0.04	0.08
2058	0.11	0.05	0.10
2059	0.15	0.08	0.14
2060	0.17	0.09	0.16
2061	0.09	0.05	0.09
2062	0.14	0.07	0.13
2063	0.16	0.08	0.15
2064	0.12	0.06	0.12
2065	0.28	0.16	0.26
2066	0.07	0.03	0.06
Average Load for RF Sequence (t/yr)	**0.14**	**0.07**	**0.13**



Nitrogen

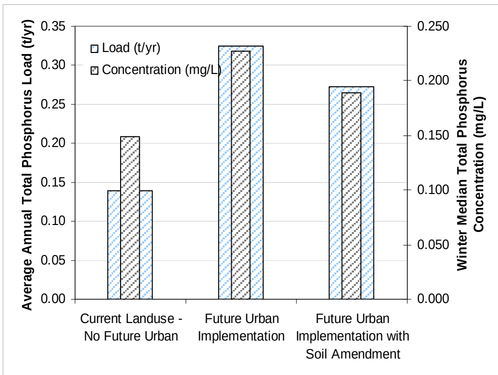
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.5	0.3	0.5
2058	0.6	0.3	0.6
2059	0.8	0.5	0.8
2060	0.9	0.6	0.9
2061	0.7	0.5	0.7
2062	0.6	0.3	0.6
2063	0.9	0.6	0.9
2064	0.6	0.3	0.6
2065	1.1	0.7	1.0
2066	0.5	0.2	0.4
Average Load for RF Sequence (t/yr)	**0.7**	**0.4**	**0.7**



Saint Leonards Creek – Future urban

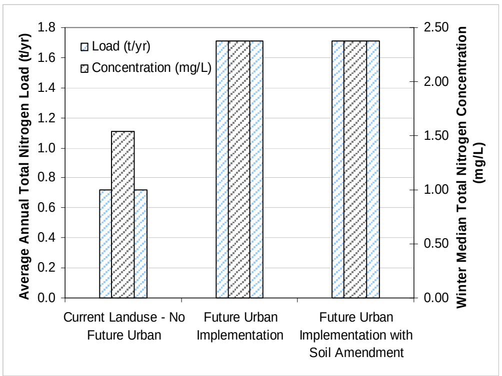
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.09	0.22	0.18
2058	0.11	0.27	0.23
2059	0.15	0.37	0.31
2060	0.17	0.41	0.35
2061	0.09	0.22	0.19
2062	0.14	0.32	0.27
2063	0.16	0.39	0.33
2064	0.12	0.28	0.23
2065	0.28	0.57	0.49
2066	0.07	0.18	0.15
Average Load for RF Sequence (t/yr)	**0.14**	**0.32**	**0.27**
Median Winter Concentration (mg/L)	**0.149**	**0.227**	**0.189**



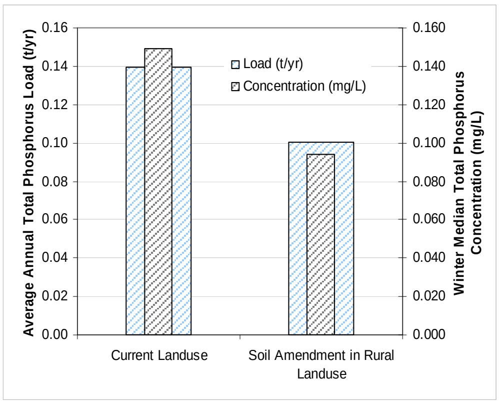
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.5	1.5	1.5
2058	0.6	1.7	1.7
2059	0.8	1.9	1.9
2060	0.9	1.9	1.9
2061	0.7	1.6	1.6
2062	0.6	1.6	1.6
2063	0.9	2.0	2.0
2064	0.6	1.6	1.6
2065	1.1	2.2	2.2
2066	0.5	1.2	1.2
Average Load for RF Sequence (t/yr)	**0.7**	**1.7**	**1.7**
Median Winter Concentration (mg/L)	**1.54**	**2.37**	**2.37**



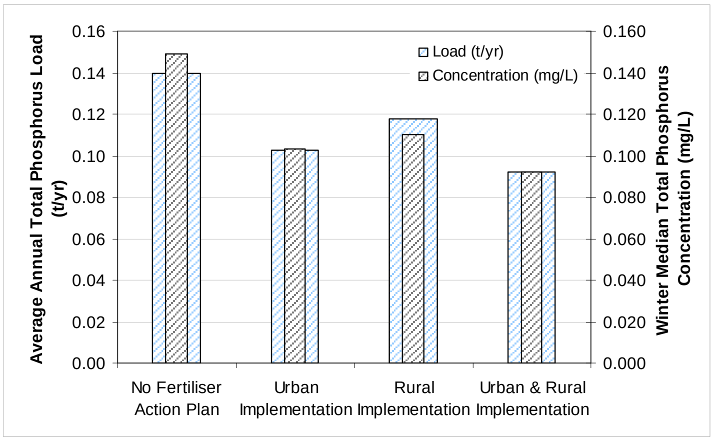
Saint Leonards Creek – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.09	0.07
2058	0.11	0.08
2059	0.15	0.11
2060	0.17	0.12
2061	0.09	0.07
2062	0.14	0.10
2063	0.16	0.12
2064	0.12	0.09
2065	0.28	0.19
2066	0.07	0.06
Average Load for RF Sequence (t/yr)	**0.14**	**0.10**
Median Winter Concentration (mg/L)	**0.149**	**0.094**



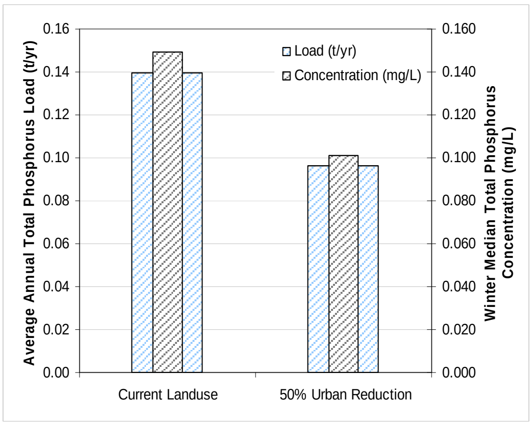
Saint Leonards Creek – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.09	0.06	0.07	0.06
2058	0.11	0.08	0.10	0.07
2059	0.15	0.11	0.13	0.10
2060	0.17	0.13	0.14	0.11
2061	0.09	0.07	0.08	0.06
2062	0.14	0.10	0.11	0.09
2063	0.16	0.12	0.14	0.11
2064	0.12	0.09	0.10	0.08
2065	0.28	0.22	0.24	0.19
2066	0.07	0.05	0.06	0.05
Average Load for RF Sequence (t/yr)	**0.14**	**0.10**	**0.12**	**0.09**
Median Winter Concentration (mg/L)	**0.149**	**0.103**	**0.110**	**0.092**

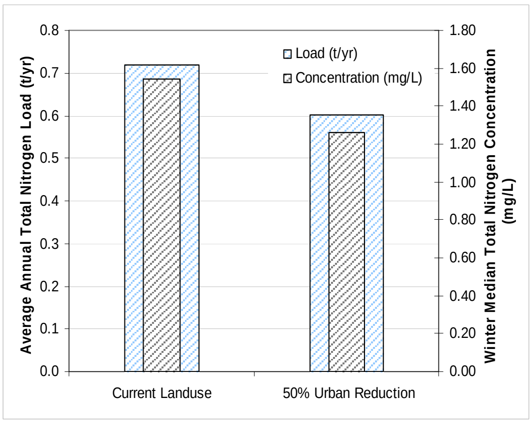


Saint Leonards Creek – Urban 50% reduction

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.09	0.06
2058	0.11	0.08
2059	0.15	0.10
2060	0.17	0.12
2061	0.09	0.06
2062	0.14	0.09
2063	0.16	0.11
2064	0.12	0.08
2065	0.28	0.21
2066	0.07	0.05
Average Load for RF Sequence (t/yr)	**0.14**	**0.10**
Median Winter Concentration (mg/L)	**0.149**	**0.101**

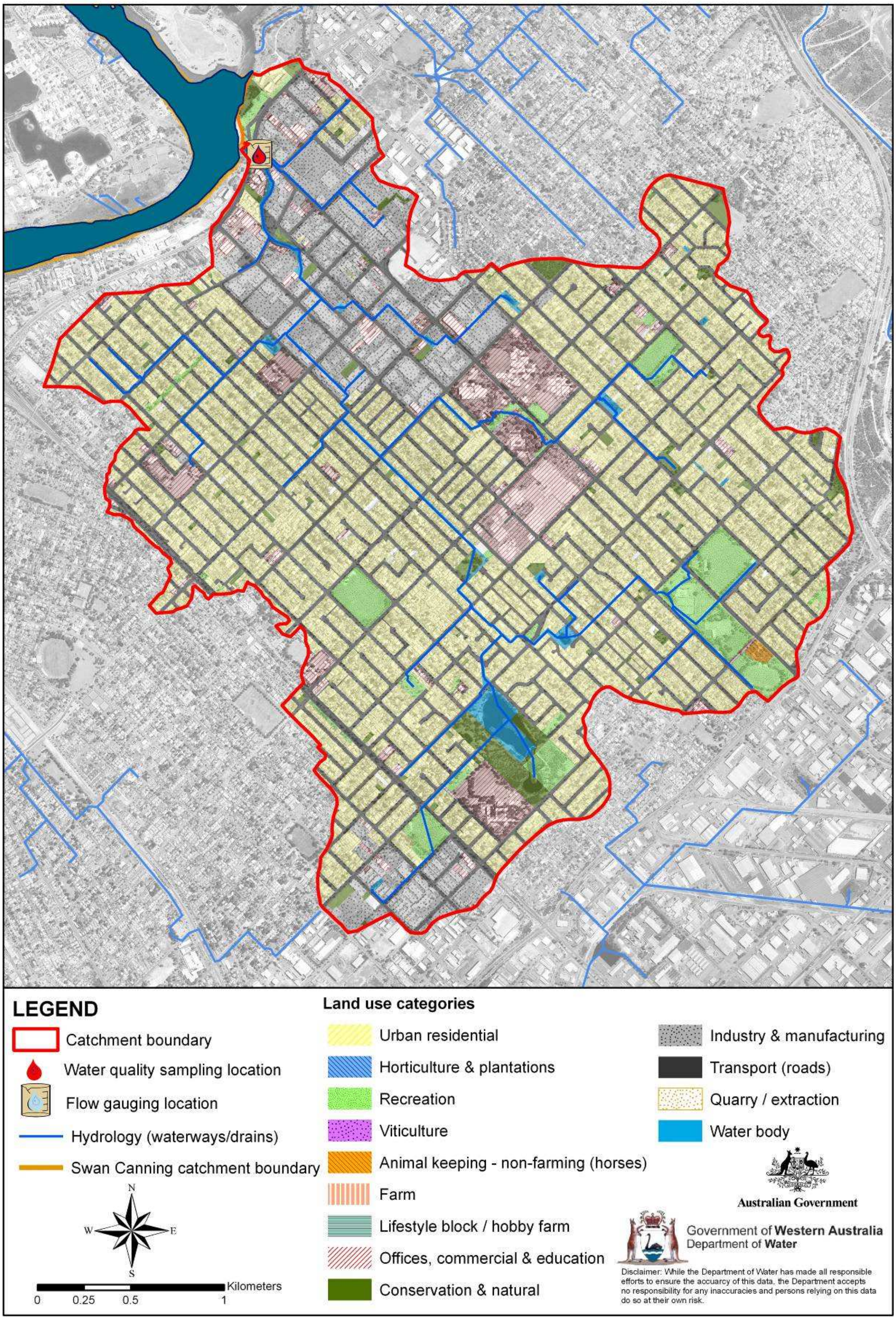


Nitrogen		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.5	0.4
2058	0.6	0.5
2059	0.8	0.7
2060	0.9	0.8
2061	0.7	0.6
2062	0.6	0.5
2063	0.9	0.8
2064	0.6	0.5
2065	1.1	0.9
2066	0.5	0.4
Average Load for RF Sequence (t/yr)	**0.7**	**0.6**
Median Winter Concentration (mg/L)	**1.54**	**1.26**

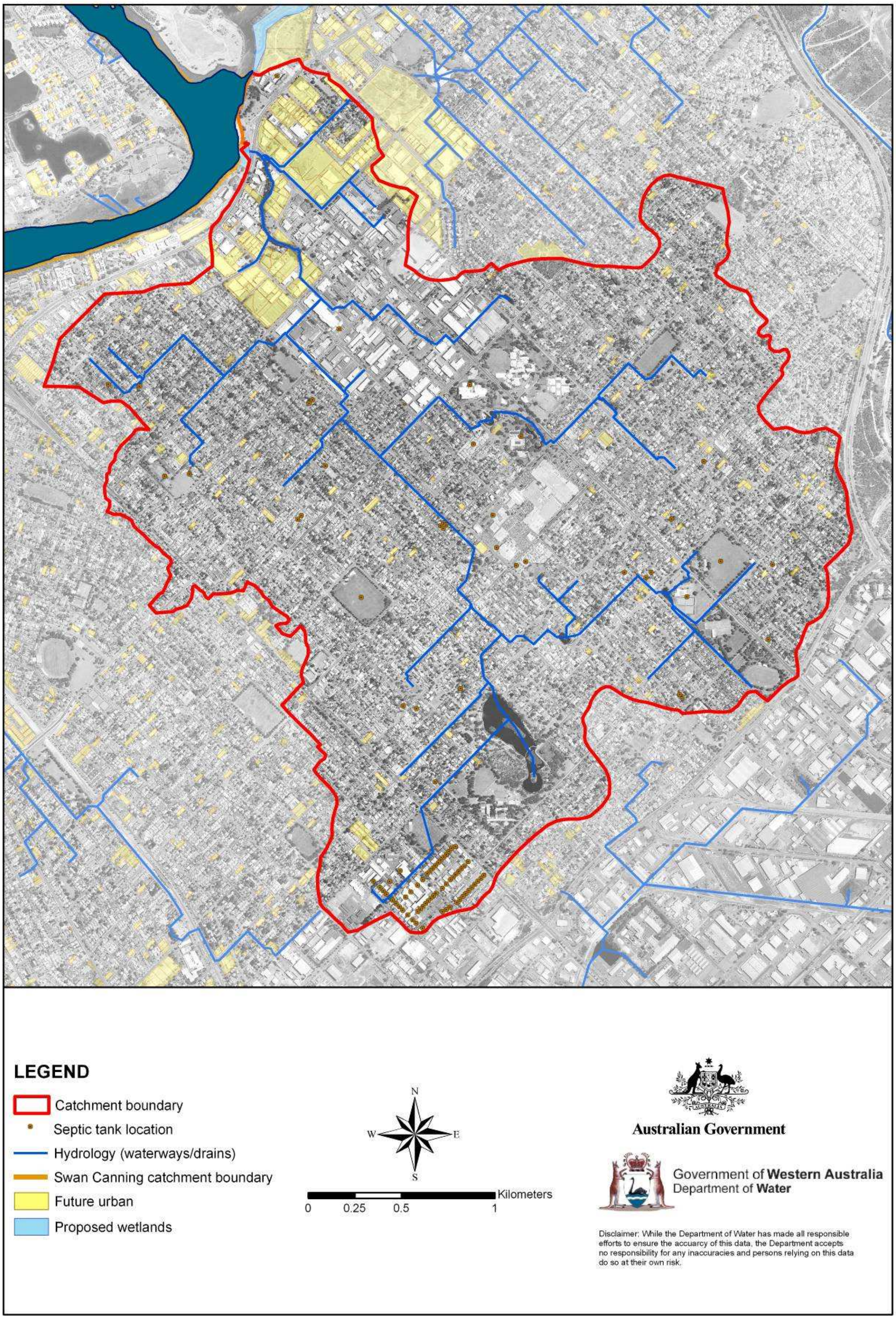


South Belmont

Land use map



Locations of septic tanks, future urban development and proposed wetlands



South Belmont - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616087		
	Current	40% Input Reduction		Current	40% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	0.26	0.13	*1997*	0.25	0.13
1998	0.25	0.13	*1998*	0.24	0.13
1999	0.27	0.15	*1999*	0.27	0.14
2000	0.26	0.14	*2000*	0.26	0.14
2001	0.21	0.12	*2001*	0.21	0.12
2002	0.25	0.14	*2002*	0.25	0.14
2003	0.27	0.15	*2003*	0.26	0.15
2004	0.22	0.13	*2004*	0.22	0.13
2005	0.26	0.15	*2005*	0.26	0.15
2006	0.19	0.11	*2006*	0.18	0.11
Average	**0.24**	**0.13**	**Average**	**0.24**	**0.13**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.097**	**0.053**	**SQUARE:**	**0.096**	**0.053**
Target:	**0.050**		**Observed:**	**0.092**	
Load Target (t/yr)		**0.13**			
Load Reduction Target (t/yr)		**0.11**			
Required Reduction (%)		**45%**			
Time Required (yr)		**40**			

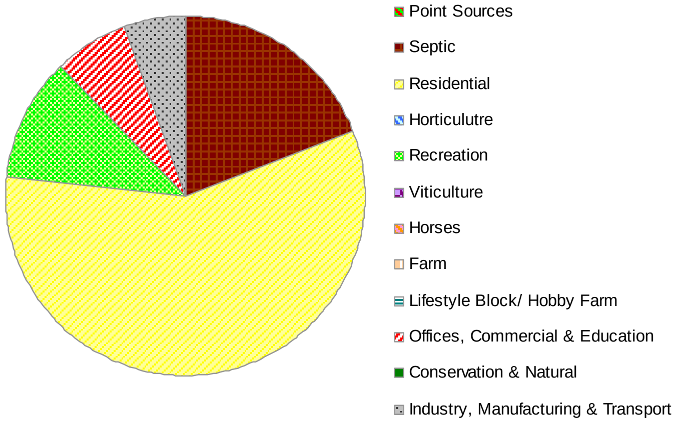
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616087		
	Current	30% Input Reduction		Current	30% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	1.8	1.0	*1997*	1.7	1.0
1998	1.9	1.0	*1998*	1.8	1.0
1999	2.1	1.1	*1999*	2.1	1.1
2000	1.9	1.0	*2000*	1.9	1.0
2001	1.6	0.9	*2001*	1.6	0.9
2002	1.7	1.0	*2002*	1.7	1.0
2003	1.9	1.1	*2003*	1.8	1.1
2004	1.5	0.9	*2004*	1.4	0.9
2005	1.8	1.1	*2005*	1.8	1.1
2006	1.1	0.7	*2006*	1.1	0.7
Average	**1.7**	**1.0**	**Average**	**1.7**	**1.0**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.83**	**0.50**	**SQUARE:**	**0.84**	**0.50**
Target:	**0.50**		**Observed:**	**0.82**	
Load Target (t/yr)		**1.0**			
Load Reduction Target (t/yr)		**0.7**			
Required Reduction (%)		**44%**			
Time Required (yr)		**30**			

South Belmont – Source separation

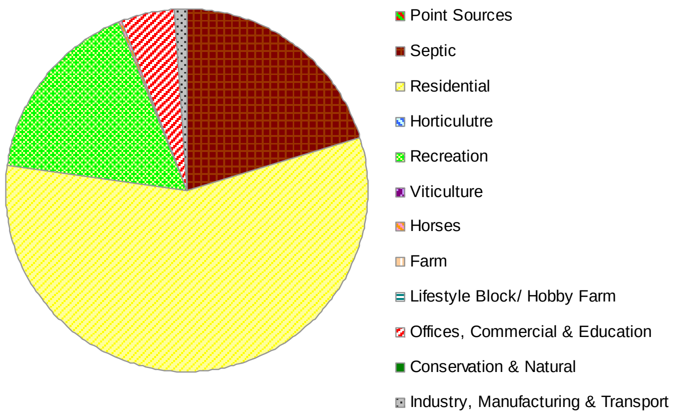
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	0.26	0.00	0.06	0.14	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
1998	0.25	0.00	0.06	0.14	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
1999	0.27	0.00	0.07	0.15	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
2000	0.26	0.00	0.06	0.15	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
2001	0.21	0.00	0.05	0.12	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.01
2002	0.25	0.00	0.05	0.15	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
2003	0.27	0.00	0.05	0.16	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
2004	0.22	0.00	0.04	0.13	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
2005	0.26	0.00	0.04	0.16	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
2006	0.19	0.00	0.03	0.12	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Load (non adj)	0.24	0.00	0.05	0.14	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02
Load (t/yr)	**0.24**	**0.00**	**0.05**	**0.14**	**0.00**	**0.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**19.0%**	**57.7%**	**0.0%**	**11.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**6.8%**	**0.0%**	**5.5%**

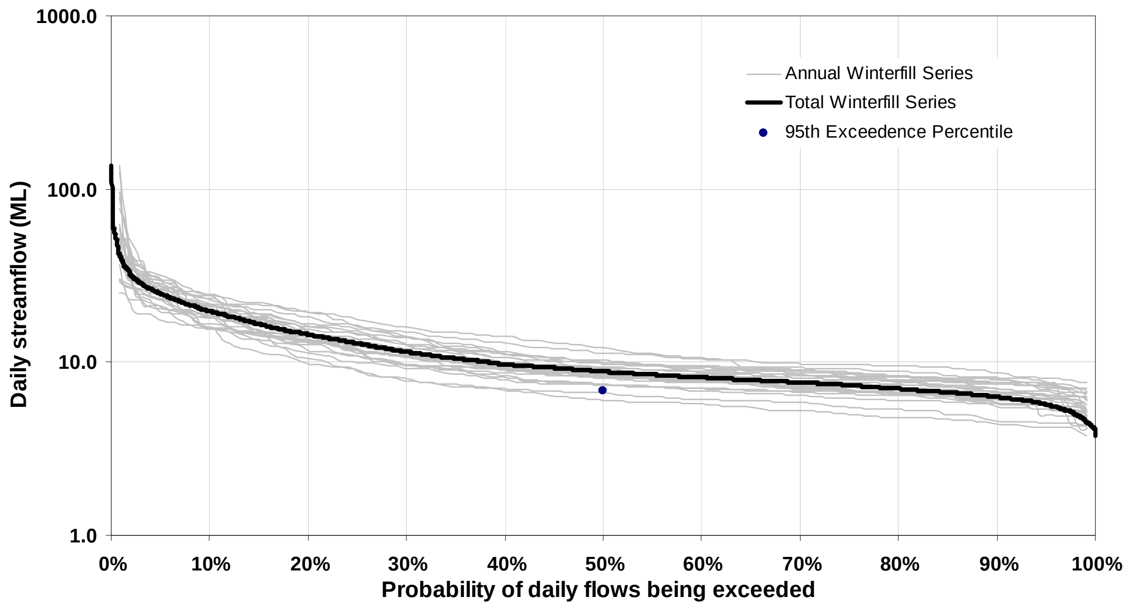


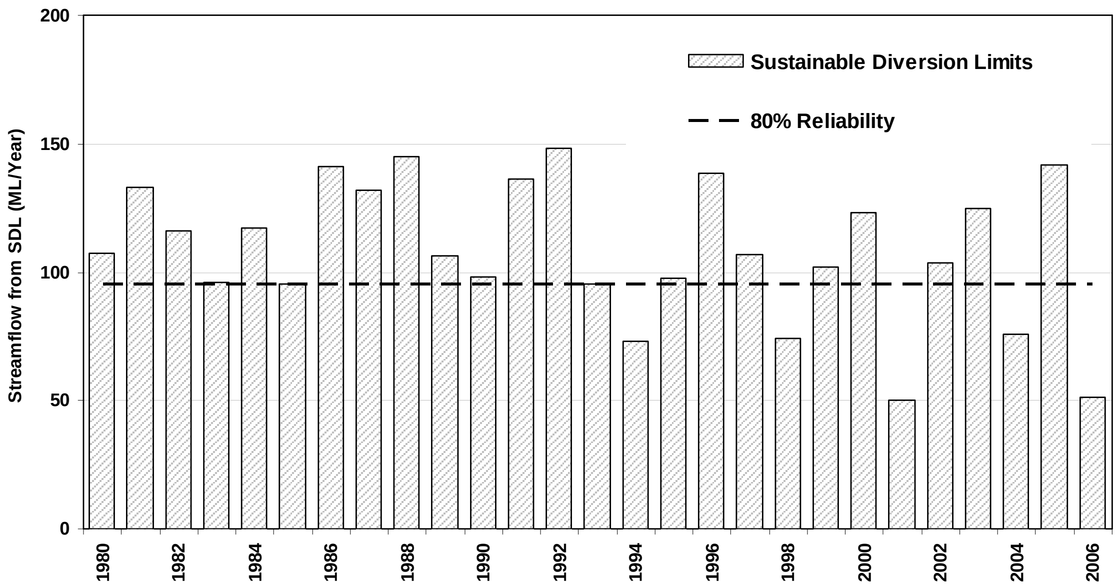
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	1.8	0.3	0.7	1.0	0.3	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1998	1.9	0.3	0.7	1.1	0.3	0.5	0.3	0.3	0.3	0.3	0.4	0.3	0.3
1999	2.1	0.3	0.8	1.2	0.3	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
2000	1.9	0.2	0.6	1.1	0.2	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.2
2001	1.6	0.2	0.5	1.0	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2002	1.7	0.2	0.5	1.1	0.2	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.2
2003	1.9	0.2	0.5	1.2	0.2	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.2
2004	1.5	0.2	0.3	0.9	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2005	1.8	0.2	0.4	1.2	0.2	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.2
2006	1.1	0.1	0.2	0.7	0.1	0.3	0.1	0.1	0.1	0.1	0.2	0.1	0.1
Load (non adj)	1.7	0.2	0.5	1.1	0.2	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.2
Load (t/yr)	**1.7**	**0.0**	**0.3**	**1.0**	**0.0**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**20.1%**	**56.7%**	**0.0%**	**16.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**4.7%**	**0.0%**	**1.2%**



South Belmont – Sustainable diversion limits

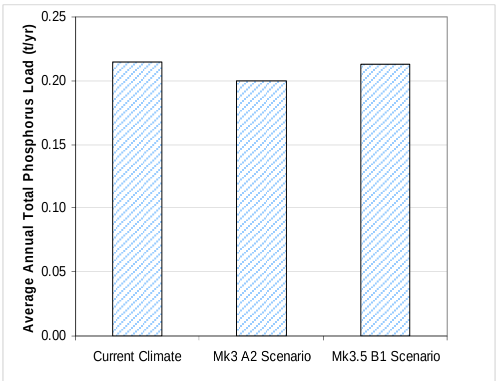




South Belmont – Climate change

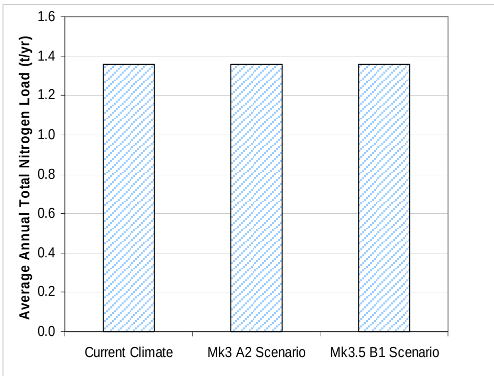
Phosphorus

Year	At Catchment Outlet: Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.20	0.19	0.20
2058	0.21	0.19	0.21
2059	0.23	0.22	0.23
2060	0.22	0.21	0.22
2061	0.19	0.17	0.19
2062	0.22	0.20	0.22
2063	0.24	0.22	0.24
2064	0.20	0.19	0.20
2065	0.24	0.23	0.24
2066	0.17	0.16	0.17
Average Load for RF Sequence (t/yr)	**0.21**	**0.20**	**0.21**



Nitrogen

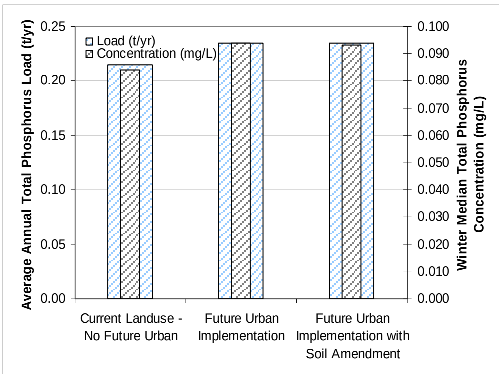
Year	At Catchment Outlet: Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	1.4	1.4	1.4
2058	1.4	1.4	1.4
2059	1.5	1.6	1.6
2060	1.4	1.4	1.4
2061	1.2	1.2	1.2
2062	1.4	1.3	1.4
2063	1.5	1.5	1.5
2064	1.2	1.2	1.2
2065	1.5	1.6	1.5
2066	0.9	0.9	0.9
Average Load for RF Sequence (t/yr)	**1.4**	**1.4**	**1.4**



South Belmont – Future urban

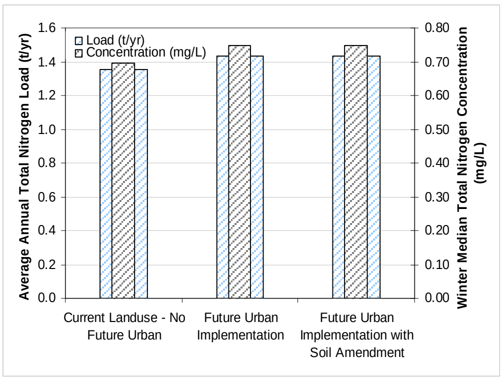
Phosphorus

Year	At Catchment Outlet: Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.20	0.22	0.22
2058	0.21	0.23	0.23
2059	0.23	0.26	0.25
2060	0.22	0.25	0.24
2061	0.19	0.21	0.21
2062	0.22	0.24	0.24
2063	0.24	0.26	0.26
2064	0.20	0.22	0.22
2065	0.24	0.27	0.27
2066	0.17	0.19	0.19
Average Load for RF Sequence (t/yr)	**0.21**	**0.23**	**0.23**
Median Winter Concentration (mg/L)	**0.084**	**0.094**	**0.093**



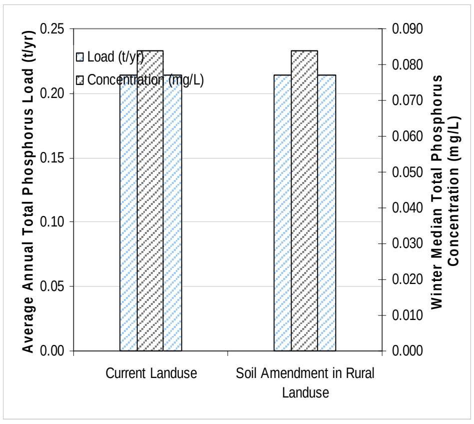
Nitrogen

Year	At Catchment Outlet: Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	1.4	1.5	1.5
2058	1.4	1.5	1.5
2059	1.5	1.6	1.6
2060	1.4	1.5	1.5
2061	1.2	1.3	1.3
2062	1.4	1.4	1.4
2063	1.5	1.6	1.6
2064	1.2	1.3	1.3
2065	1.5	1.6	1.6
2066	0.9	1.0	1.0
Average Load for RF Sequence (t/yr)	**1.4**	**1.4**	**1.4**
Median Winter Concentration (mg/L)	**0.70**	**0.75**	**0.75**



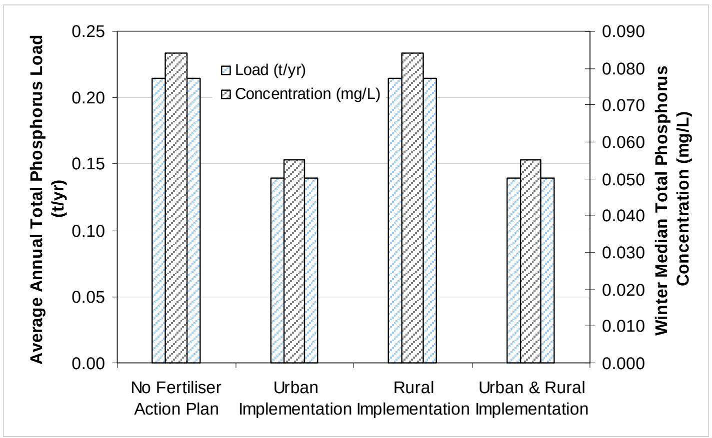
South Belmont – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.20	0.20
2058	0.21	0.21
2059	0.23	0.23
2060	0.22	0.22
2061	0.19	0.19
2062	0.22	0.22
2063	0.24	0.24
2064	0.20	0.20
2065	0.24	0.24
2066	0.17	0.17
Average Load for RF Sequence (t/yr)	**0.21**	**0.21**
Median Winter Concentration (mg/L)	**0.084**	**0.084**



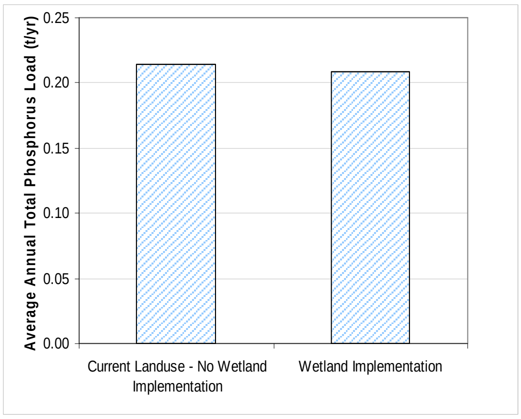
South Belmont – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	No Fertiliser Action Plan (t/yr)	Urban Implementation (t/yr)	Rural Implementation (t/yr)	Urban and Rural Implementation (t/yr)
2057	0.20	0.13	0.20	0.13
2058	0.21	0.14	0.21	0.14
2059	0.23	0.15	0.23	0.15
2060	0.22	0.15	0.22	0.15
2061	0.19	0.12	0.19	0.12
2062	0.22	0.14	0.22	0.14
2063	0.24	0.16	0.24	0.16
2064	0.20	0.13	0.20	0.13
2065	0.24	0.16	0.24	0.16
2066	0.17	0.11	0.17	0.11
Average Load for RF Sequence (t/yr)	**0.21**	**0.14**	**0.21**	**0.14**
Median Winter Concentration (mg/L)	**0.084**	**0.055**	**0.084**	**0.055**

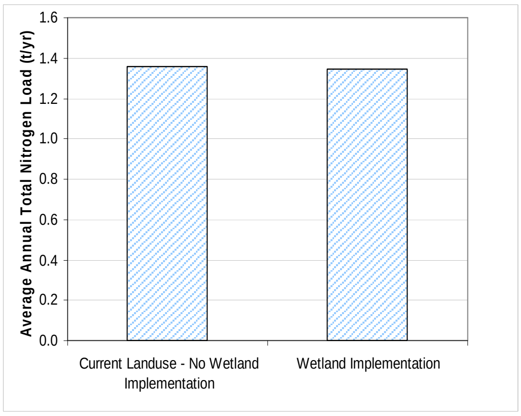


South Belmont – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.20	0.20
2058	0.21	0.21
2059	0.23	0.23
2060	0.22	0.22
2061	0.19	0.18
2062	0.22	0.21
2063	0.24	0.23
2064	0.20	0.20
2065	0.24	0.24
2066	0.17	0.17
Average Load for RF Sequence (t/yr)	**0.21**	**0.21**

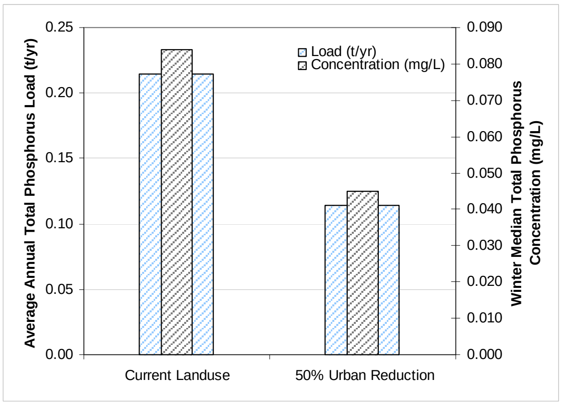


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	1.4	1.4
2058	1.4	1.4
2059	1.5	1.5
2060	1.4	1.4
2061	1.2	1.2
2062	1.4	1.3
2063	1.5	1.5
2064	1.2	1.2
2065	1.5	1.5
2066	0.9	0.9
Average Load for RF Sequence (t/yr)	**1.4**	**1.3**

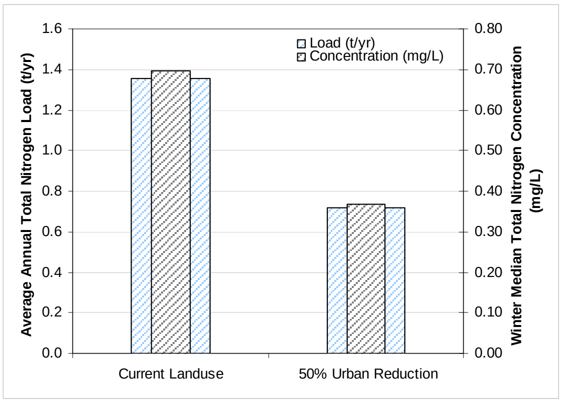


South Belmont – Urban 50% reduction

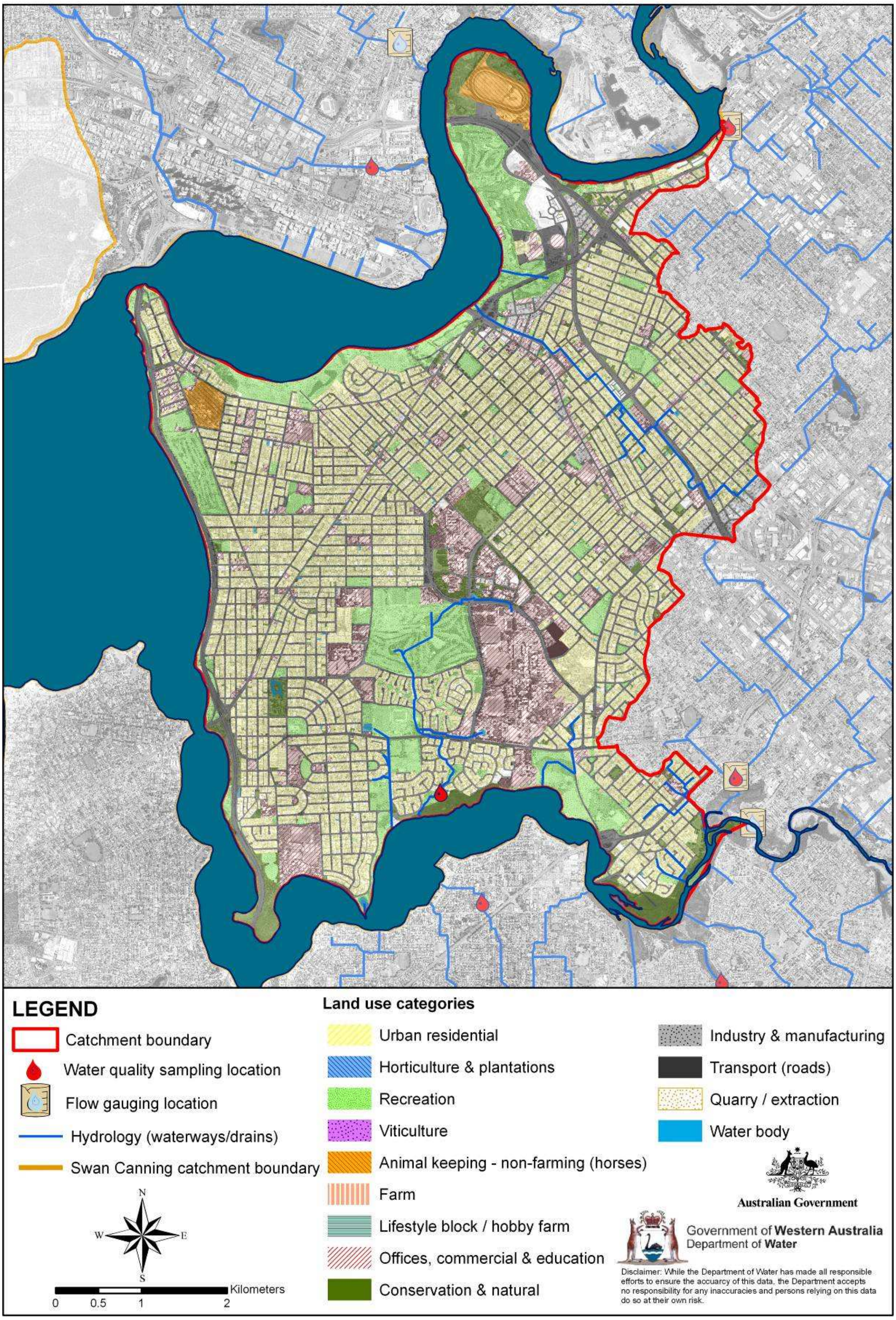
Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.20	0.11
2058	0.21	0.11
2059	0.23	0.12
2060	0.22	0.12
2061	0.19	0.10
2062	0.22	0.12
2063	0.24	0.13
2064	0.20	0.11
2065	0.24	0.13
2066	0.17	0.09
Average Load for RF Sequence (t/yr)	**0.21**	**0.11**
Median Winter Concentration (mg/L)	**0.084**	**0.045**



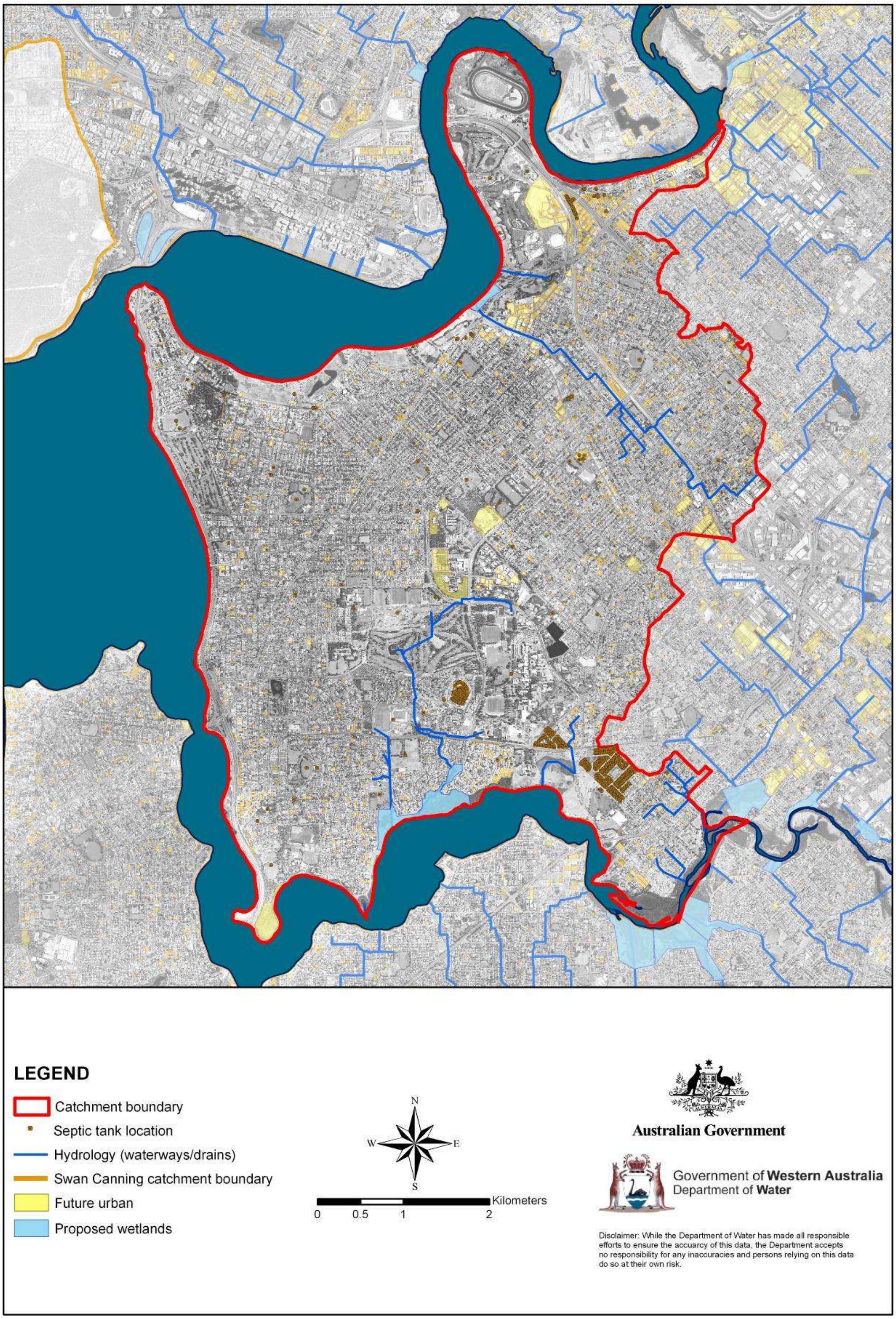
Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	1.4	0.8
2058	1.4	0.7
2059	1.5	0.8
2060	1.4	0.7
2061	1.2	0.7
2062	1.4	0.7
2063	1.5	0.8
2064	1.2	0.6
2065	1.5	0.8
2066	0.9	0.5
Average Load for RF Sequence (t/yr)	**1.4**	**0.7**
Median Winter Concentration (mg/L)	**0.70**	**0.37**



South Perth
Land use map



Locations of septic tanks, future urban development and proposed wetlands



South Perth - Current loads and load reduction targets

Phosphorus

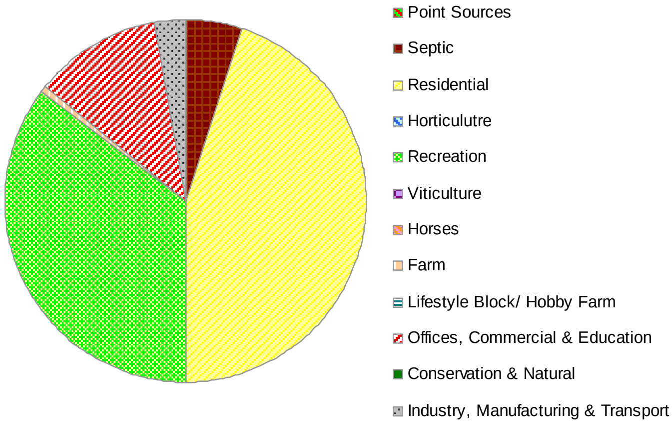
At Outlet to Swan River Estuary		
	Current	9% Input Reduction
Year	Load (t/yr)	Load (t/yr)
1997	1.96	1.67
1998	1.95	1.75
1999	2.23	1.96
2000	2.25	1.97
2001	1.49	1.39
2002	1.92	1.77
2003	2.31	2.16
2004	1.61	1.51
2005	2.36	2.17
2006	1.35	1.24
Average	**1.94**	**1.76**
Median Winter Concentration (mg/L):		
SQUARE:	**0.056**	**0.050**
Target:	**0.050**	
Load Target (t/yr)		**1.76**
Load Reduction Target (t/yr)		**0.19**
Required Reduction (%)		**10%**
Time Required (yr)		**20**

Nitrogen

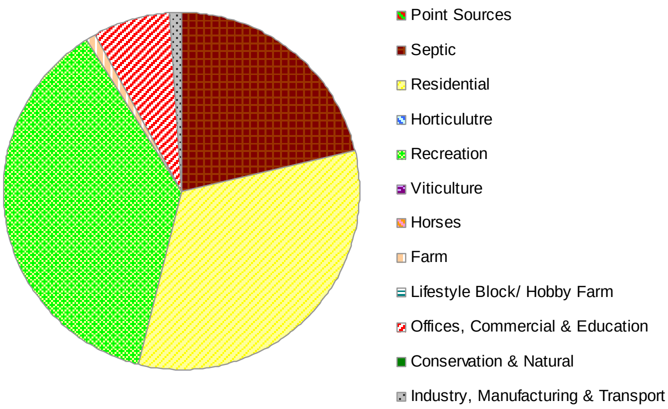
At Outlet to Swan River Estuary		
	Current	21% Input Reduction
Year	Load (t/yr)	Load (t/yr)
1997	12.2	8.6
1998	13.9	9.6
1999	14.9	10.1
2000	13.9	9.3
2001	11.3	7.7
2002	12.3	8.5
2003	14.1	9.9
2004	11.1	7.9
2005	13.8	9.9
2006	9.5	6.9
Average	**12.7**	**8.8**
Median Winter Concentration (mg/L):		
SQUARE:	**0.82**	**0.50**
Target:	**0.50**	
Load Target (t/yr)		**8.8**
Load Reduction Target (t/yr)		**3.9**
Required Reduction (%)		**30%**
Time Required (yr)		**30**

South Perth – Source separation

Phosphorus (t/yr)													
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	1.96	0.00	0.17	0.83	0.00	0.67	0.00	0.00	0.02	0.00	0.21	0.00	0.05
1998	1.95	0.00	0.17	0.82	0.00	0.66	0.00	0.00	0.02	0.00	0.20	0.00	0.05
1999	2.23	0.00	0.19	0.94	0.00	0.76	0.00	0.00	0.02	0.00	0.24	0.00	0.06
2000	2.25	0.00	0.14	0.98	0.00	0.79	0.00	0.00	0.01	0.00	0.25	0.00	0.06
2001	1.49	0.00	0.05	0.68	0.00	0.53	0.00	0.00	0.00	0.00	0.18	0.00	0.04
2002	1.92	0.00	0.05	0.88	0.00	0.69	0.00	0.00	0.00	0.00	0.23	0.00	0.05
2003	2.31	0.00	0.06	1.06	0.00	0.83	0.00	0.00	0.00	0.00	0.27	0.00	0.07
2004	1.61	0.00	0.05	0.75	0.00	0.57	0.00	0.00	0.00	0.00	0.19	0.00	0.05
2005	2.36	0.00	0.06	1.09	0.00	0.85	0.00	0.00	0.00	0.00	0.28	0.00	0.07
2006	1.35	0.00	0.04	0.62	0.00	0.48	0.00	0.00	0.00	0.00	0.17	0.00	0.04
Load (non adj)	1.94	0.00	0.10	0.86	0.00	0.68	0.00	0.00	0.01	0.00	0.22	0.00	0.05
Load (t/yr)	**1.94**	**0.00**	**0.10**	**0.87**	**0.00**	**0.69**	**0.00**	**0.00**	**0.01**	**0.00**	**0.22**	**0.00**	**0.05**
Load (%)	**100.0%**	**0.0%**	**5.1%**	**44.8%**	**0.0%**	**35.4%**	**0.0%**	**0.0%**	**0.4%**	**0.0%**	**11.5%**	**0.0%**	**2.8%**



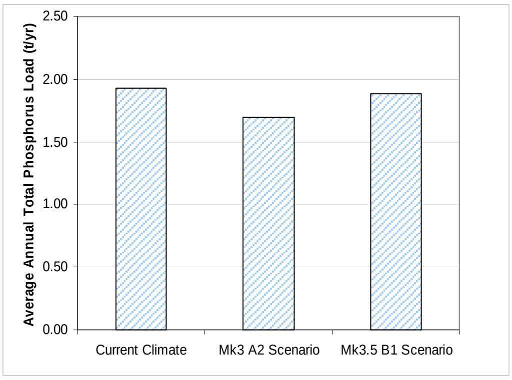
Nitrogen (t/yr)													
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	12.2	0.5	3.3	4.0	0.5	4.7	0.5	0.5	0.7	0.5	1.2	0.5	0.6
1998	13.9	0.5	3.7	4.6	0.5	5.3	0.5	0.5	0.8	0.5	1.4	0.5	0.7
1999	14.9	0.4	3.9	4.9	0.4	5.6	0.4	0.4	0.7	0.4	1.4	0.4	0.6
2000	13.9	0.4	3.6	4.6	0.4	5.2	0.4	0.4	0.6	0.4	1.3	0.4	0.5
2001	11.3	0.4	2.8	3.9	0.4	4.4	0.4	0.4	0.5	0.4	1.1	0.4	0.5
2002	12.3	0.4	2.8	4.3	0.4	4.8	0.4	0.4	0.5	0.4	1.2	0.4	0.5
2003	14.1	0.4	3.0	5.0	0.4	5.6	0.4	0.4	0.4	0.4	1.4	0.4	0.5
2004	11.1	0.3	2.3	4.0	0.3	4.4	0.3	0.3	0.3	0.3	1.1	0.3	0.4
2005	13.8	0.4	2.7	5.0	0.4	5.5	0.4	0.4	0.4	0.4	1.4	0.4	0.5
2006	9.5	0.3	1.8	3.5	0.3	3.8	0.3	0.3	0.3	0.3	1.0	0.3	0.4
Load (non adj)	12.7	0.4	3.0	4.4	0.4	4.9	0.4	0.4	0.5	0.4	1.2	0.4	0.5
Load (t/yr)	**12.7**	**0.0**	**2.7**	**4.1**	**0.0**	**4.7**	**0.0**	**0.0**	**0.1**	**0.0**	**0.9**	**0.0**	**0.1**
Load (%)	**100.0%**	**0.0%**	**21.3%**	**32.7%**	**0.0%**	**37.0%**	**0.0%**	**0.0%**	**1.0%**	**0.0%**	**7.0%**	**0.0%**	**1.0%**



South Perth – Climate change

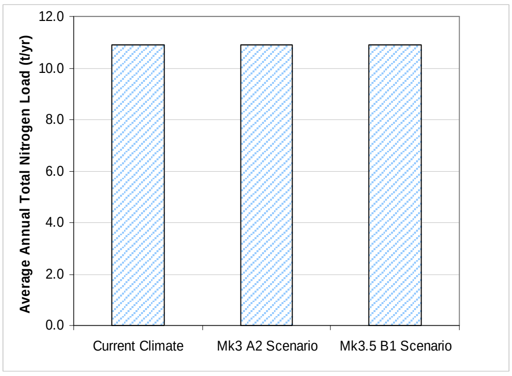
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	1.83	1.58	1.79
2058	1.91	1.67	1.88
2059	2.15	1.93	2.11
2060	2.16	1.94	2.10
2061	1.52	1.34	1.50
2062	1.94	1.70	1.90
2063	2.36	2.05	2.30
2064	1.65	1.47	1.63
2065	2.38	2.07	2.33
2066	1.36	1.21	1.32
Average Load for RF Sequence (t/yr)	**1.93**	**1.70**	**1.89**



Nitrogen

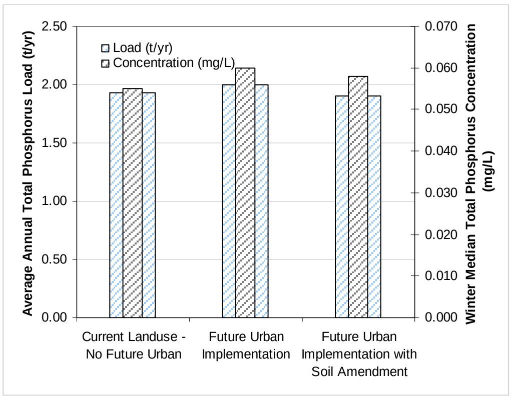
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	10.7	10.5	10.7
2058	11.8	11.7	11.9
2059	12.4	12.6	12.5
2060	11.5	11.6	11.4
2061	9.5	9.5	9.6
2062	10.4	10.4	10.5
2063	12.3	12.2	12.3
2064	9.8	9.8	9.8
2065	12.2	12.1	12.2
2066	8.5	8.5	8.5
Average Load for RF Sequence (t/yr)	**10.9**	**10.9**	**10.9**



South Perth – Future urban

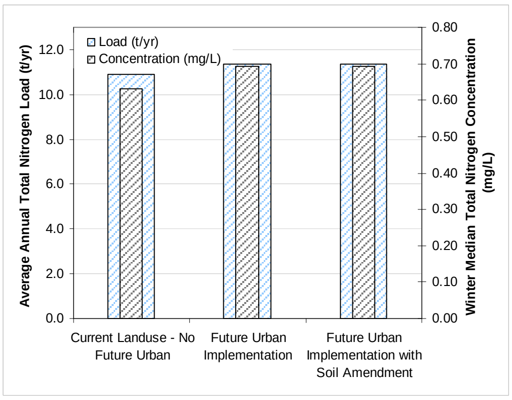
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	1.83	1.90	1.81
2058	1.91	1.99	1.89
2059	2.15	2.23	2.12
2060	2.16	2.25	2.14
2061	1.52	1.58	1.50
2062	1.94	2.01	1.92
2063	2.36	2.46	2.33
2064	1.65	1.72	1.63
2065	2.38	2.47	2.35
2066	1.36	1.41	1.34
Average Load for RF Sequence (t/yr)	**1.93**	**2.00**	**1.90**
Median Winter Concentration (mg/L)	**0.055**	**0.060**	**0.058**



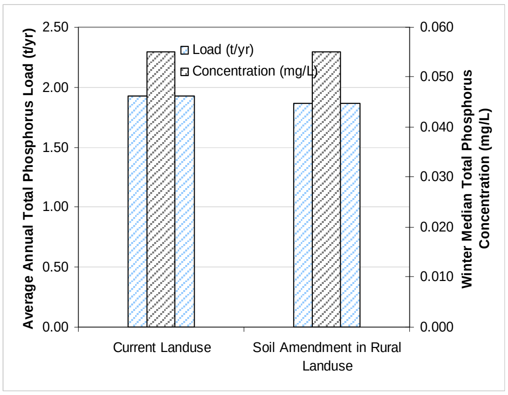
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	10.7	11.1	11.1
2058	11.8	12.3	12.3
2059	12.4	13.0	13.0
2060	11.5	11.9	11.9
2061	9.5	9.9	9.9
2062	10.4	10.9	10.9
2063	12.3	12.8	12.8
2064	9.8	10.2	10.2
2065	12.2	12.7	12.7
2066	8.5	8.8	8.8
Average Load for RF Sequence (t/yr)	**10.9**	**11.4**	**11.4**
Median Winter Concentration (mg/L)	**0.63**	**0.69**	**0.69**



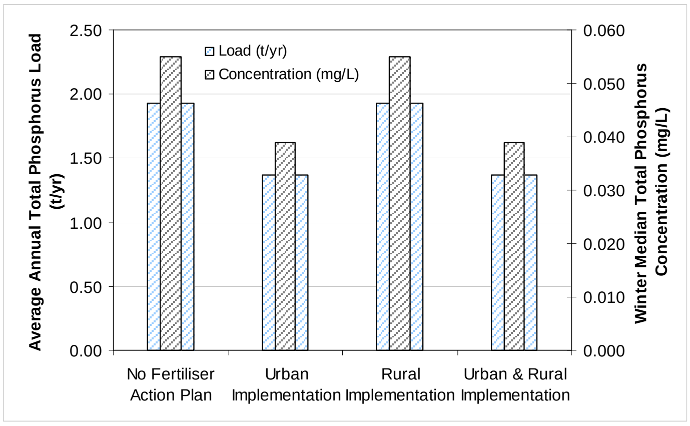
South Perth – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	1.83	1.77
2058	1.91	1.85
2059	2.15	2.08
2060	2.16	2.09
2061	1.52	1.47
2062	1.94	1.87
2063	2.36	2.28
2064	1.65	1.60
2065	2.38	2.30
2066	1.36	1.31
Average Load for RF Sequence (t/yr)	**1.93**	**1.86**
Median Winter Concentration (mg/L)	**0.055**	**0.055**



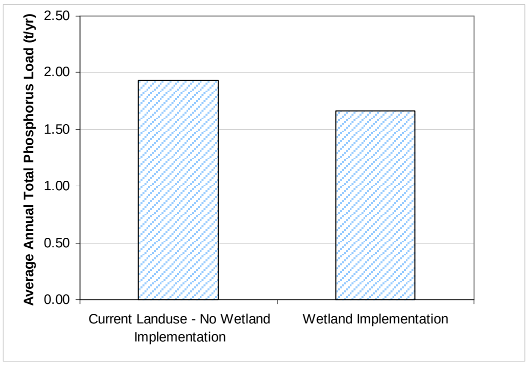
South Perth – *Fertiliser action plan*

Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	1.83	1.30	1.83	1.30
2058	1.91	1.36	1.91	1.36
2059	2.15	1.52	2.15	1.52
2060	2.16	1.53	2.16	1.53
2061	1.52	1.08	1.52	1.08
2062	1.94	1.37	1.94	1.37
2063	2.36	1.67	2.36	1.67
2064	1.65	1.17	1.65	1.17
2065	2.38	1.69	2.38	1.69
2066	1.36	0.96	1.36	0.96
Average Load for RF Sequence (t/yr)	**1.93**	**1.37**	**1.93**	**1.37**
Median Winter Concentration (mg/L)	**0.055**	**0.039**	**0.055**	**0.039**

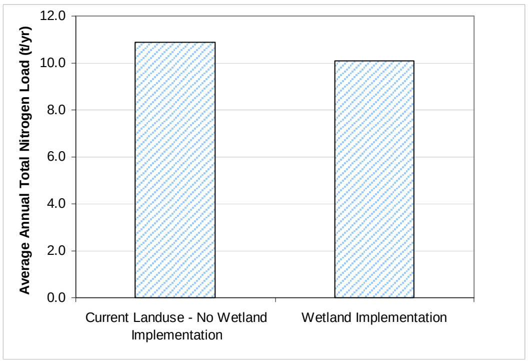


South Perth – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	1.83	1.57
2058	1.91	1.67
2059	2.15	1.87
2060	2.16	1.85
2061	1.52	1.33
2062	1.94	1.69
2063	2.36	2.01
2064	1.65	1.45
2065	2.38	2.05
2066	1.36	1.14
Average Load for RF Sequence (t/yr)	**1.93**	**1.66**

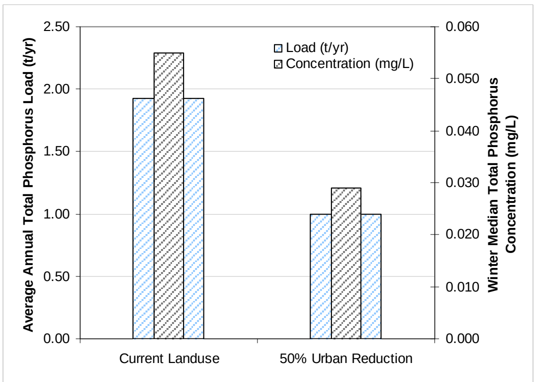


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	10.7	9.9
2058	11.8	11.0
2059	12.4	11.6
2060	11.5	10.5
2061	9.5	8.9
2062	10.4	9.7
2063	12.3	11.3
2064	9.8	9.2
2065	12.2	11.2
2066	8.5	7.8
Average Load for RF Sequence (t/yr)	**10.9**	**10.1**

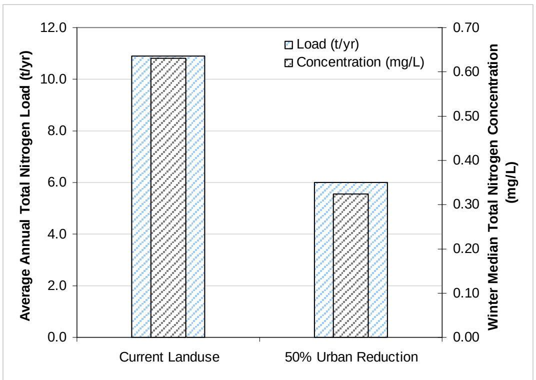


South Perth – Urban 50% reduction

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	1.83	0.95
2058	1.91	0.99
2059	2.15	1.11
2060	2.16	1.12
2061	1.52	0.79
2062	1.94	1.00
2063	2.36	1.22
2064	1.65	0.85
2065	2.38	1.23
2066	1.36	0.70
Average Load for RF Sequence (t/yr)	**1.93**	**1.00**
Median Winter Concentration (mg/L)	**0.055**	**0.029**

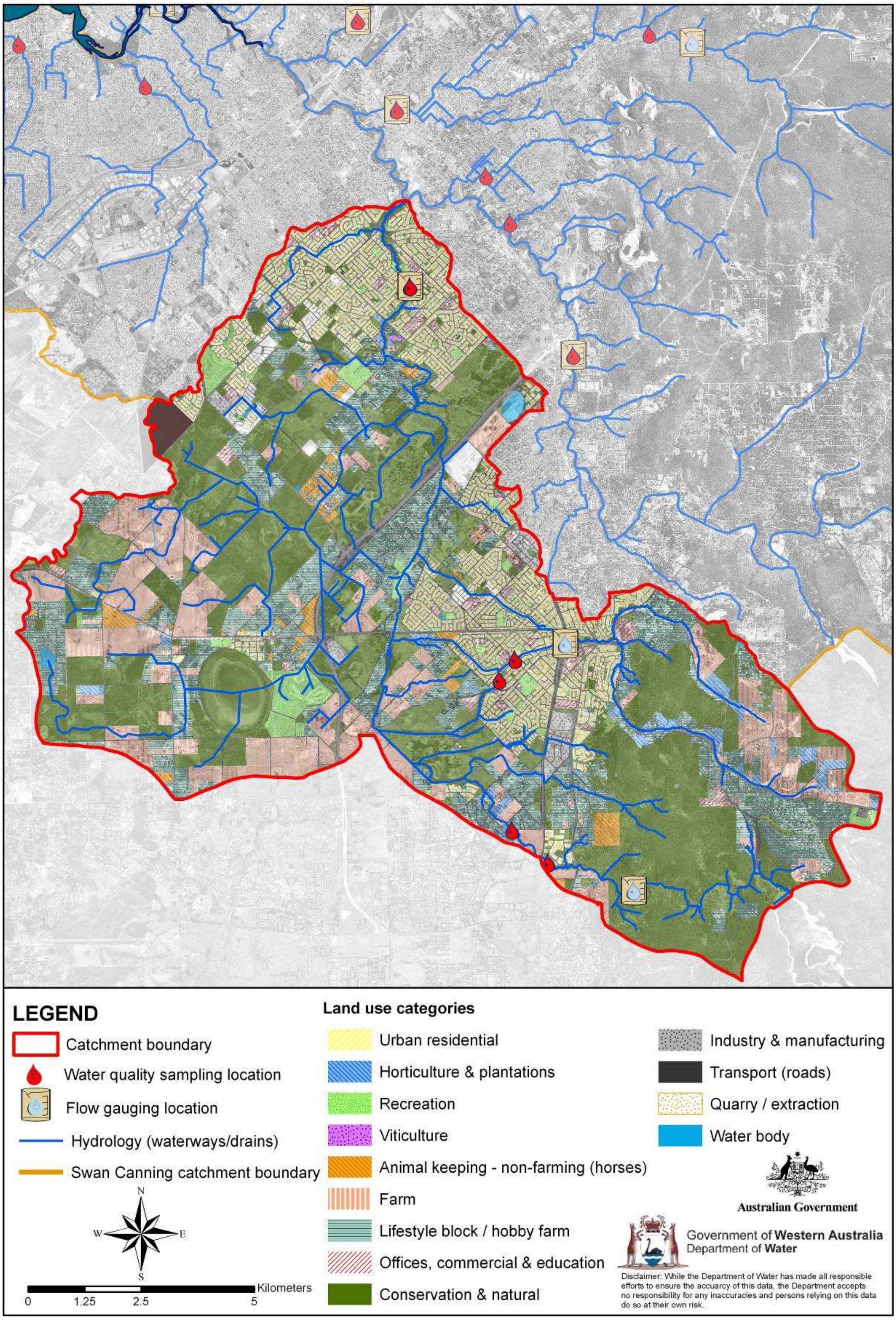


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	10.7	5.9
2058	11.8	6.5
2059	12.4	6.9
2060	11.5	6.3
2061	9.5	5.3
2062	10.4	5.8
2063	12.3	6.8
2064	9.8	5.4
2065	12.2	6.7
2066	8.5	4.7
Average Load for RF Sequence (t/yr)	**10.9**	**6.0**
Median Winter Concentration (mg/L)	**0.63**	**0.33**

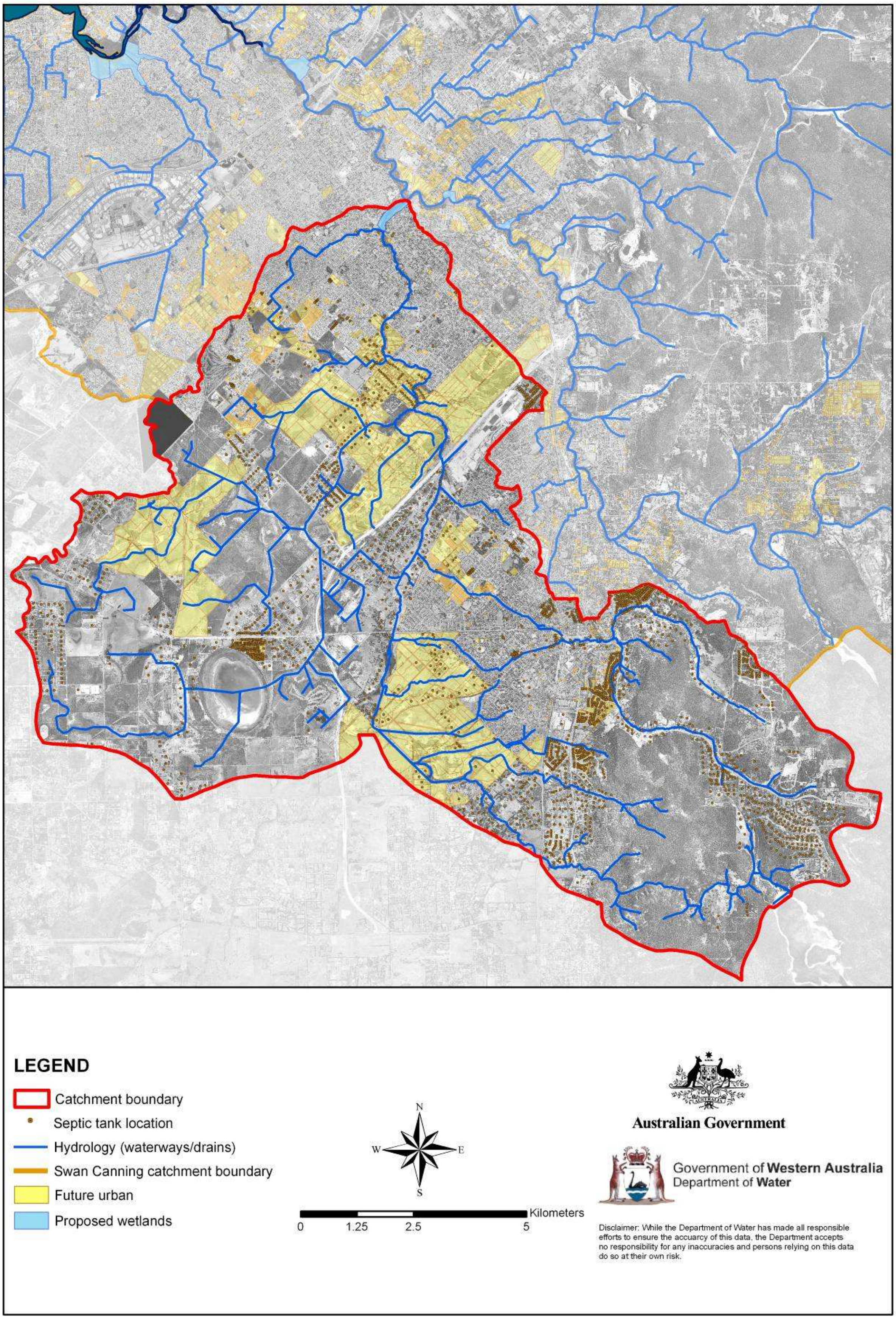


Southern River

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Southern River - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616092		
	Current	44% Input Reduction		Current	44% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	1.97	0.80	*1997*	1.82	0.71
1998	1.80	0.93	*1998*	1.67	0.83
1999	2.50	1.30	*1999*	2.31	1.16
2000	3.41	1.77	*2000*	3.16	1.58
2001	1.56	0.83	*2001*	1.42	0.73
2002	2.18	1.18	*2002*	2.00	1.05
2003	2.83	1.51	*2003*	2.61	1.36
2004	1.79	0.99	*2004*	1.63	0.87
2005	3.17	1.71	*2005*	2.90	1.53
2006	0.87	0.49	*2006*	0.76	0.42
Average	**2.21**	**1.15**	**Average**	**2.03**	**1.02**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.141**	**0.075**	**SQUARE:**	**0.136**	**0.069**
Target:	**0.075**		**Observed:**	**0.135**	
Load Target (t/yr)		**1.15**			
Load Reduction Target (t/yr)		**1.06**			
Required Reduction (%)		**48%**			
Time Required (yr)		**40**			

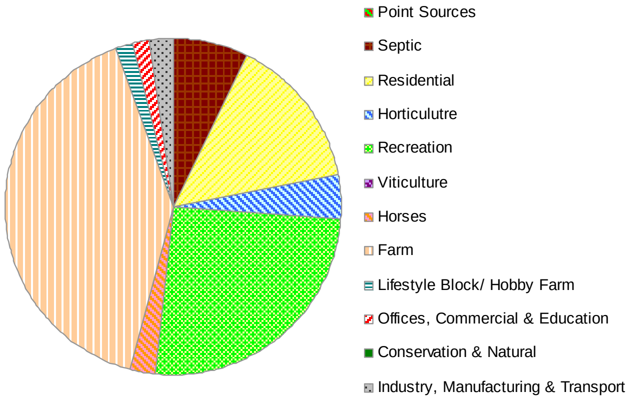
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616092		
	Current	36% Input Reduction		Current	36% Input Reduction
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	18.8	9.9	*1997*	17.0	8.8
1998	20.6	11.2	*1998*	18.5	9.9
1999	27.3	13.1	*1999*	24.8	11.8
2000	31.0	14.9	*2000*	28.7	13.6
2001	14.3	7.8	*2001*	12.6	6.8
2002	22.2	12.4	*2002*	20.1	11.1
2003	26.6	14.9	*2003*	24.1	13.4
2004	16.1	9.2	*2004*	14.3	8.2
2005	29.1	16.4	*2005*	26.1	14.6
2006	7.1	4.2	*2006*	6.1	3.5
Average	**21.3**	**11.4**	**Average**	**19.2**	**10.2**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**1.32**	**0.74**	**SQUARE:**	**1.25**	**0.69**
Target:	**0.75**		**Observed:**	**1.25**	
Load Target (t/yr)		**11.4**			
Load Reduction Target (t/yr)		**9.9**			
Required Reduction (%)		**46%**			
Time Required (yr)		**30**			

Southern River – Source separation

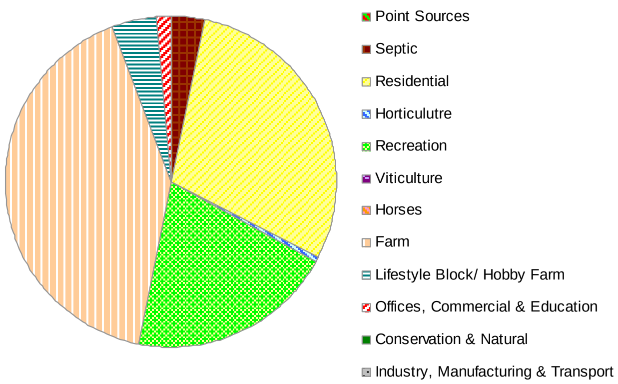
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transp
1997	1.97	0.10	0.21	0.26	0.16	0.48	0.10	0.13	0.77	0.13	0.11	0.10	0.13
1998	1.80	0.08	0.18	0.24	0.14	0.43	0.08	0.11	0.68	0.10	0.09	0.08	0.11
1999	2.50	0.09	0.22	0.31	0.16	0.59	0.09	0.14	0.90	0.12	0.11	0.09	0.13
2000	3.41	0.14	0.32	0.45	0.23	0.80	0.14	0.21	1.34	0.19	0.16	0.14	0.20
2001	1.56	0.05	0.15	0.25	0.11	0.36	0.05	0.08	0.57	0.08	0.07	0.05	0.08
2002	2.18	0.06	0.18	0.32	0.13	0.50	0.06	0.10	0.69	0.09	0.09	0.06	0.10
2003	2.83	0.08	0.24	0.42	0.17	0.66	0.08	0.14	0.93	0.12	0.12	0.08	0.13
2004	1.79	0.05	0.16	0.33	0.12	0.41	0.05	0.09	0.56	0.08	0.08	0.05	0.09
2005	3.17	0.08	0.26	0.52	0.18	0.73	0.08	0.15	1.02	0.13	0.13	0.08	0.14
2006	0.87	0.02	0.08	0.22	0.06	0.20	0.02	0.04	0.26	0.04	0.04	0.02	0.04
Load (non adj)	2.21	0.08	0.20	0.33	0.15	0.52	0.08	0.12	0.77	0.11	0.10	0.08	0.12
Load (t/yr)	**2.21**	**0.00**	**0.16**	**0.33**	**0.09**	**0.56**	**0.00**	**0.06**	**0.89**	**0.04**	**0.03**	**0.00**	**0.05**
Load (%)	**100.0%**	**0.0%**	**7.2%**	**14.9%**	**4.0%**	**25.5%**	**0.0%**	**2.5%**	**40.2%**	**1.9%**	**1.4%**	**0.0%**	**2.3%**



Nitrogen (t/yr)

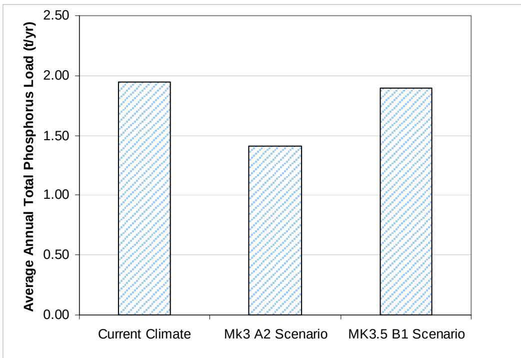
Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transp
1997	18.8	0.4	0.8	2.1	0.5	1.9	0.4	0.4	4.8	0.7	0.5	0.4	0.4
1998	20.6	0.4	0.8	2.6	0.5	2.1	0.4	0.4	5.3	0.8	0.4	0.4	0.4
1999	27.3	0.4	0.9	3.0	0.5	2.7	0.4	0.4	7.3	0.9	0.5	0.4	0.4
2000	31.0	0.5	1.0	3.3	0.7	3.0	0.5	0.5	7.3	1.2	0.6	0.5	0.5
2001	14.3	0.4	0.5	2.6	0.4	1.7	0.4	0.4	2.2	0.6	0.5	0.4	0.4
2002	22.2	0.4	0.8	3.8	0.5	2.8	0.4	0.4	3.5	0.9	0.6	0.4	0.4
2003	26.6	0.5	0.8	4.3	0.6	3.1	0.5	0.5	4.2	1.0	0.7	0.5	0.5
2004	16.1	0.4	0.6	3.0	0.5	1.7	0.4	0.4	2.3	0.7	0.5	0.4	0.4
2005	29.1	0.5	0.9	5.1	0.6	3.1	0.5	0.6	4.8	1.2	0.8	0.5	0.5
2006	7.1	0.3	0.3	1.6	0.3	0.8	0.3	0.3	0.9	0.3	0.3	0.3	0.3
Load (non adj)	21.3	0.4	0.8	3.1	0.5	2.3	0.4	0.4	4.3	0.8	0.6	0.4	0.4
Load (t/yr)	**21.3**	**0.0**	**0.7**	**6.2**	**0.1**	**4.3**	**0.0**	**0.0**	**8.8**	**0.9**	**0.3**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**3.4%**	**29.1%**	**0.6%**	**20.0%**	**0.0%**	**0.0%**	**41.2%**	**4.4%**	**1.3%**	**0.0%**	**0.0%**



Southern River – Climate change

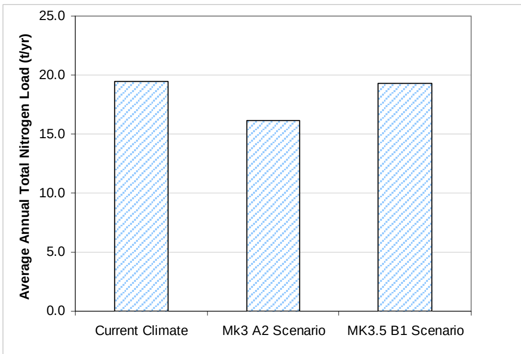
Phosphorus

Year	At Catchment Outlet: Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	1.35	0.91	1.30
2058	1.57	1.07	1.53
2059	2.21	1.56	2.14
2060	2.98	2.34	2.91
2061	1.41	1.15	1.39
2062	1.99	1.37	1.92
2063	2.55	1.77	2.48
2064	1.66	1.24	1.63
2065	2.88	2.01	2.81
2066	0.82	0.63	0.81
Average Load for RF Sequence (t/yr)	**1.94**	**1.41**	**1.89**



Nitrogen

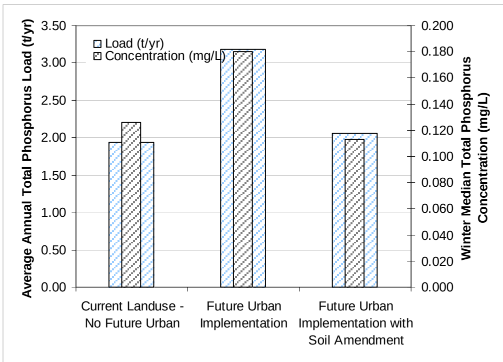
Year	At Catchment Outlet: Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	16.8	12.2	16.4
2058	19.3	15.4	19.1
2059	22.6	19.4	22.5
2060	25.3	23.5	25.2
2061	13.4	11.4	13.4
2062	21.2	16.6	20.7
2063	25.5	21.0	25.3
2064	15.8	13.3	15.7
2065	27.9	22.4	27.6
2066	7.1	6.2	7.1
Average Load for RF Sequence (t/yr)	**19.5**	**16.1**	**19.3**



Southern River – Future urban

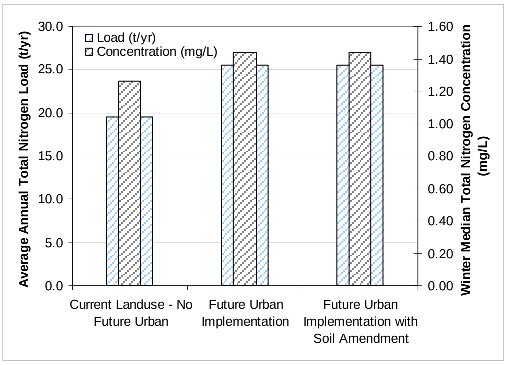
Phosphorus

Year	At Catchment Outlet: Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/
2057	1.35	2.09	1.40
2058	1.57	2.40	1.58
2059	2.21	3.60	2.28
2060	2.98	4.99	3.13
2061	1.41	2.39	1.62
2062	1.99	3.18	2.06
2063	2.55	4.11	2.63
2064	1.66	2.83	1.86
2065	2.88	4.58	2.91
2066	0.82	1.57	1.09
Average Load for RF Sequence (t/yr)	**1.94**	**3.17**	**2.06**
Median Winter Concentration (mg/L)	**0.126**	**0.180**	**0.113**



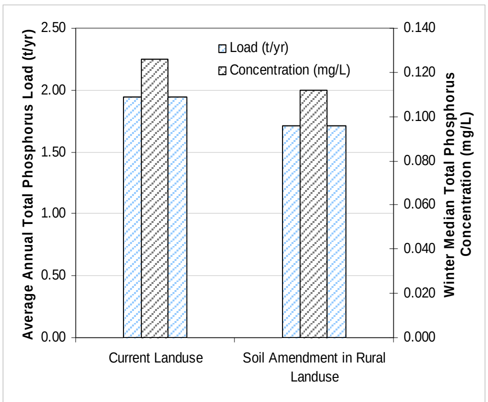
Nitrogen

Year	At Catchment Outlet: Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/...
2057	16.8	21.9	21.9
2058	19.3	25.4	25.4
2059	22.6	29.8	29.8
2060	25.3	32.0	32.0
2061	13.4	18.1	18.1
2062	21.2	27.6	27.6
2063	25.5	32.8	32.8
2064	15.8	20.9	20.9
2065	27.9	35.9	35.9
2066	7.1	10.2	10.2
Average Load for RF Sequence (t/yr)	**19.5**	**25.5**	**25.5**
Median Winter Concentration (mg/L)	**1.26**	**1.44**	**1.44**



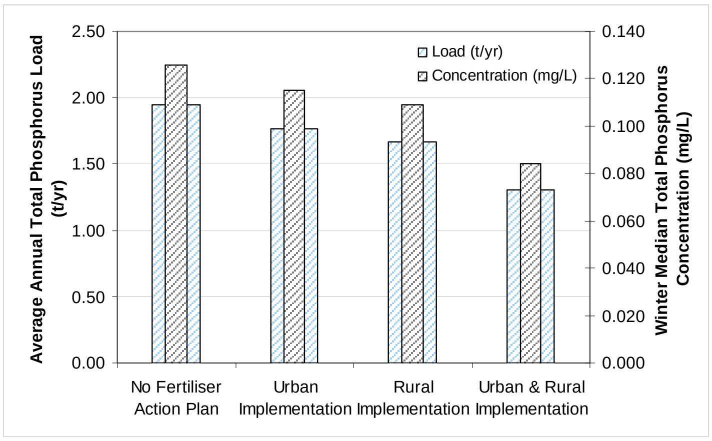
Southern River – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	1.35	1.21
2058	1.57	1.40
2059	2.21	1.96
2060	2.98	2.59
2061	1.41	1.24
2062	1.99	1.76
2063	2.55	2.23
2064	1.66	1.47
2065	2.88	2.51
2066	0.82	0.73
Average Load for RF Sequence (t/yr)	**1.94**	**1.71**
Median Winter Concentration (mg/L)	**0.126**	**0.112**



Southern River – *Fertiliser action plan*

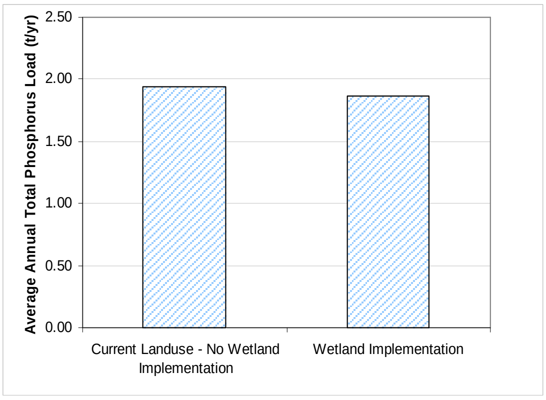
Phosphorus				
		At Catchment Outlet		
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	1.35	1.23	1.16	0.91
2058	1.57	1.43	1.35	1.05
2059	2.21	2.01	1.90	1.47
2060	2.98	2.72	2.56	1.99
2061	1.41	1.28	1.20	0.94
2062	1.99	1.82	1.71	1.33
2063	2.55	2.33	2.19	1.71
2064	1.66	1.52	1.43	1.12
2065	2.88	2.63	2.48	1.93
2066	0.82	0.75	0.70	0.55
Average Load for RF Sequence (t/yr)	**1.94**	**1.77**	**1.67**	**1.30**
Median Winter Concentration (mg/L)	**0.126**	**0.115**	**0.109**	**0.084**



Southern River – Wetland implementation

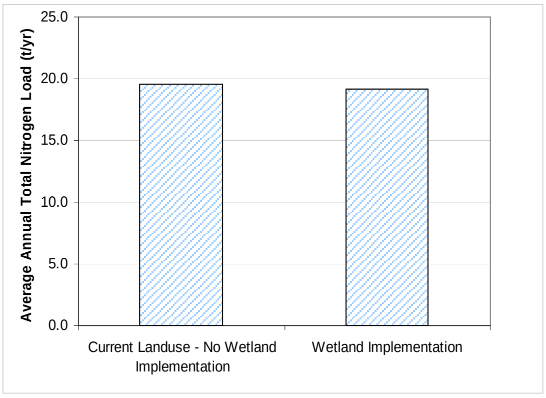
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	1.35	1.30
2058	1.57	1.51
2059	2.21	2.12
2060	2.98	2.86
2061	1.41	1.35
2062	1.99	1.91
2063	2.55	2.45
2064	1.66	1.60
2065	2.88	2.77
2066	0.82	0.79
Average Load for RF Sequence (t/yr)	**1.94**	**1.87**



Nitrogen

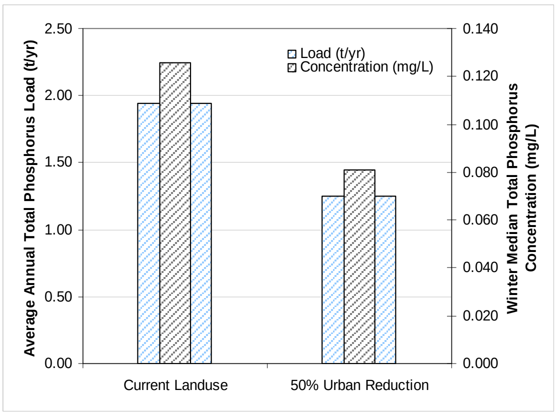
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	16.8	16.5
2058	19.3	18.9
2059	22.6	22.2
2060	25.3	24.9
2061	13.4	13.2
2062	21.2	20.8
2063	25.5	25.0
2064	15.8	15.5
2065	27.9	27.4
2066	7.1	7.0
Average Load for RF Sequence (t/yr)	**19.5**	**19.1**



Southern River – Urban 50% reduction

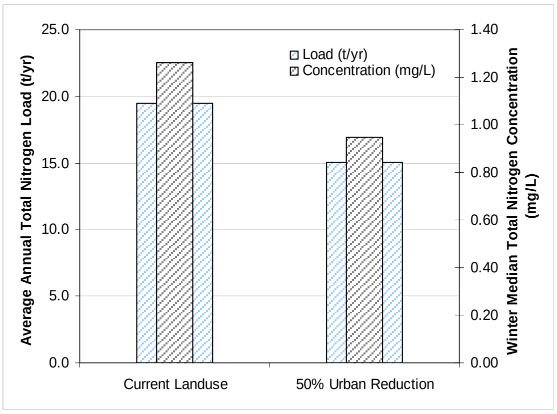
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	1.35	0.87
2058	1.57	1.01
2059	2.21	1.40
2060	2.98	1.91
2061	1.41	0.91
2062	1.99	1.27
2063	2.55	1.64
2064	1.66	1.08
2065	2.88	1.85
2066	0.82	0.54
Average Load for RF Sequence (t/yr)	**1.94**	**1.25**
Median Winter Concentration (mg/L)	**0.126**	**0.081**



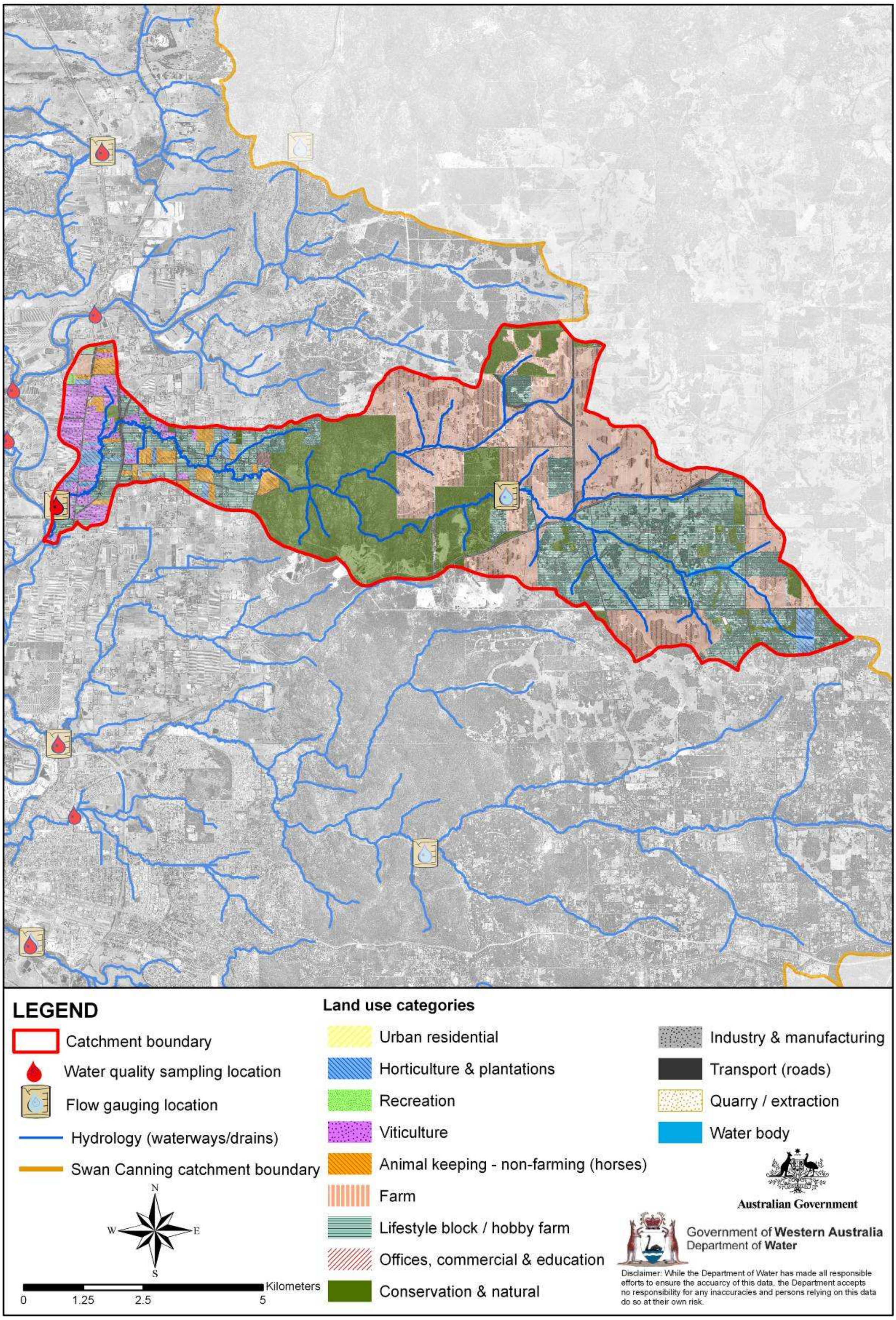
Nitrogen

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	16.8	12.8
2058	19.3	14.6
2059	22.6	17.6
2060	25.3	20.3
2061	13.4	10.1
2062	21.2	16.3
2063	25.5	19.8
2064	15.8	12.2
2065	27.9	21.5
2066	7.1	5.3
Average Load for RF Sequence (t/yr)	**19.5**	**15.0**
Median Winter Concentration (mg/L)	**1.26**	**0.95**

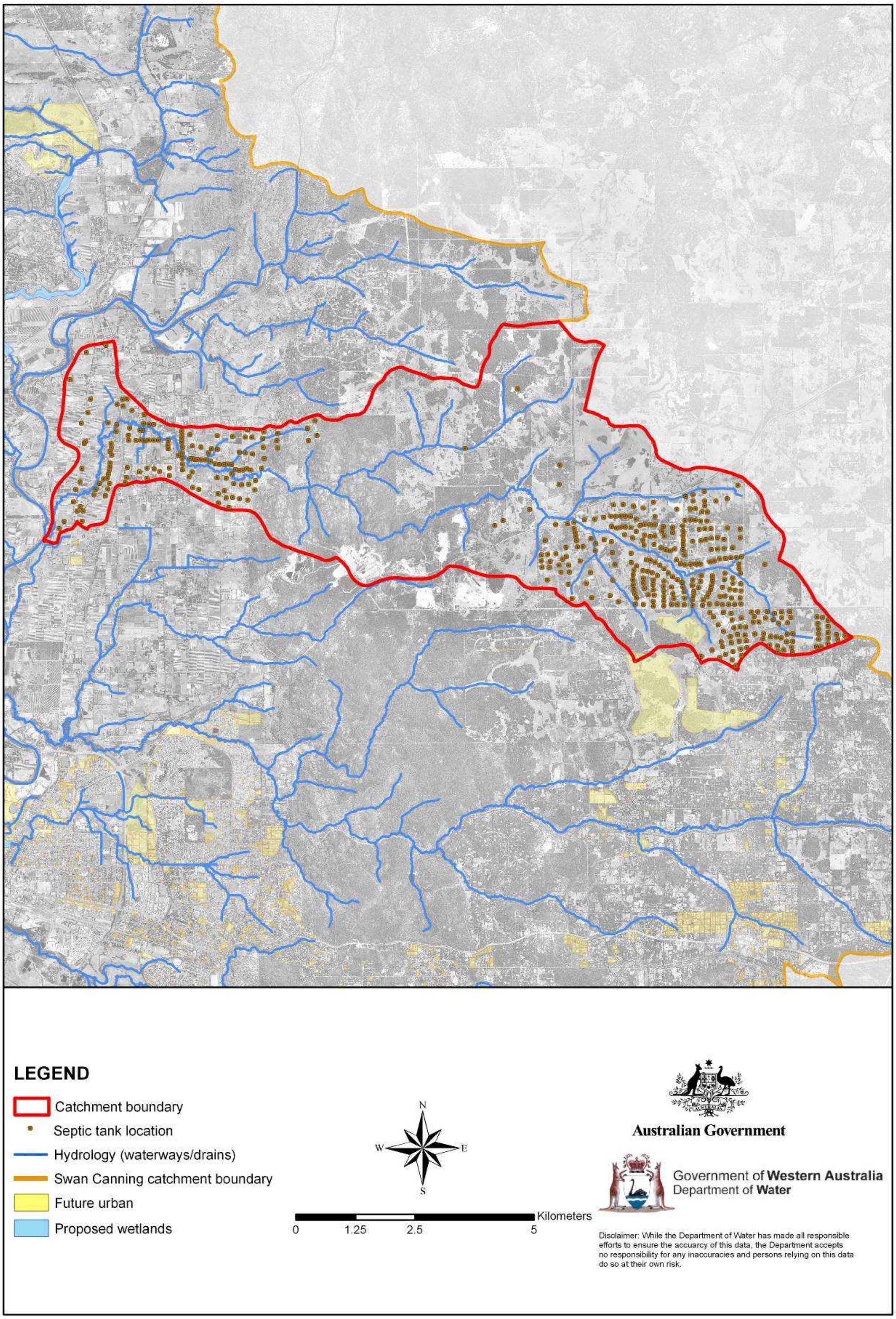


Susannah Brook

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Susannah Brook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616099		
	Current	No Reduction Required		Current	No Reduction Required
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	0.25	-	*1997*	0.25	-
1998	0.54	-	*1998*	0.54	-
1999	0.65	-	*1999*	0.65	-
2000	0.58	-	*2000*	0.58	-
2001	1.79	-	*2001*	1.79	-
2002	0.44	-	*2002*	0.44	-
2003	0.56	-	*2003*	0.56	-
2004	0.43	-	*2004*	0.43	-
2005	0.98	-	*2005*	0.98	-
2006	0.28	-	*2006*	0.28	-
Average	**0.65**	**-**	**Average**	**0.65**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.018**		**SQUARE:**	**0.018**	
Target:	**0.075**		**Observed:**	**0.014**	
Load Target (t/yr)		**0.65**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

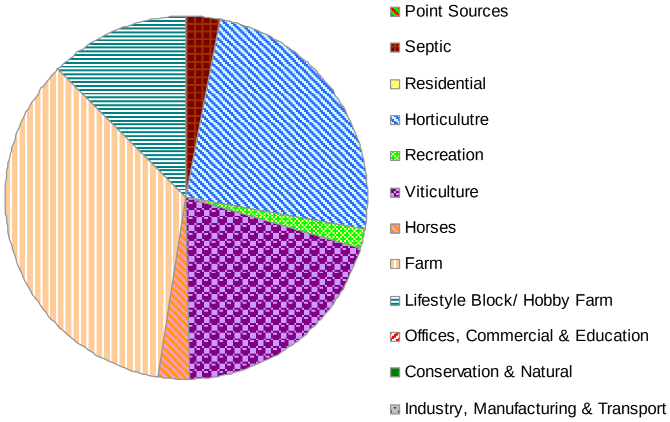
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616099		
	Current	No Reduction Required		Current	No Reduction Required
Year	*Load (t/yr)*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Load (t/yr)*
1997	2.7	-	*1997*	2.7	-
1998	4.8	-	*1998*	4.8	-
1999	5.6	-	*1999*	5.6	-
2000	4.9	-	*2000*	4.9	-
2001	5.3	-	*2001*	5.3	-
2002	4.1	-	*2002*	4.0	-
2003	5.9	-	*2003*	5.9	-
2004	4.2	-	*2004*	4.2	-
2005	8.4	-	*2005*	8.4	-
2006	2.3	-	*2006*	2.3	-
Average	**4.8**	**-**	**Average**	**4.8**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.74**		**SQUARE:**	**0.74**	
Target:	**0.75**		**Observed:**	**0.73**	
Load Target (t/yr)		**4.8**			
Load Reduction Target (t/yr)		**0.0**			
Required Reduction (%)		**0%**			
Time Required (yr)		**-**			

Susannah Brook – Source separation

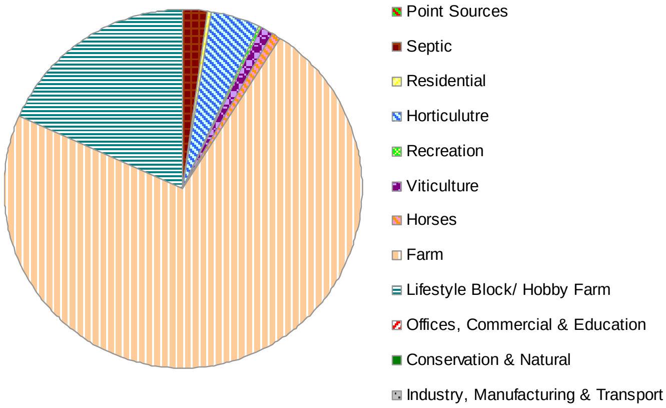
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.25	0.01	0.02	0.01	0.08	0.01	0.05	0.01	0.09	0.03	0.01	0.01	0.01
1998	0.54	0.01	0.03	0.01	0.14	0.02	0.11	0.03	0.21	0.08	0.01	0.01	0.01
1999	0.65	0.01	0.03	0.01	0.17	0.02	0.12	0.03	0.25	0.09	0.01	0.01	0.01
2000	0.58	0.01	0.03	0.01	0.14	0.02	0.10	0.02	0.23	0.08	0.01	0.01	0.01
2001	1.79	0.02	0.06	0.02	0.45	0.06	0.50	0.08	0.51	0.19	0.02	0.02	0.02
2002	0.44	0.01	0.02	0.01	0.12	0.02	0.09	0.02	0.15	0.06	0.01	0.01	0.01
2003	0.56	0.01	0.03	0.01	0.14	0.02	0.10	0.02	0.21	0.09	0.01	0.01	0.01
2004	0.43	0.01	0.02	0.01	0.11	0.01	0.08	0.02	0.16	0.07	0.01	0.01	0.01
2005	0.98	0.02	0.05	0.02	0.23	0.03	0.19	0.04	0.36	0.16	0.02	0.02	0.02
2006	0.28	0.00	0.01	0.00	0.06	0.01	0.04	0.01	0.11	0.05	0.00	0.00	0.00
Load (non adj)	0.65	0.01	0.03	0.01	0.17	0.02	0.14	0.03	0.23	0.09	0.01	0.01	0.01
Load (t/yr)	**0.65**	**0.00**	**0.02**	**0.00**	**0.16**	**0.01**	**0.13**	**0.02**	**0.23**	**0.08**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**0.0%**	**3.1%**	**0.0%**	**24.7%**	**1.6%**	**20.4%**	**2.8%**	**34.9%**	**12.5%**	**0.0%**	**0.0%**	**0.0%**



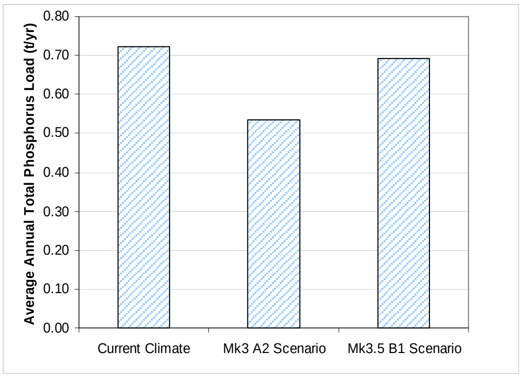
Nitrogen (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	2.7	0.2	0.3	0.2	0.2	0.2	0.2	0.2	2.5	0.5	0.2	0.2	0.2
1998	4.8	1.0	0.9	1.0	1.2	1.0	1.0	1.0	4.4	1.6	1.0	1.0	1.0
1999	5.6	0.8	0.9	0.8	1.0	0.8	0.8	0.8	5.1	1.6	0.8	0.8	0.8
2000	4.9	0.5	0.7	0.5	0.7	0.5	0.5	0.5	4.4	1.3	0.5	0.5	0.5
2001	5.3	0.5	1.5	0.5	0.8	0.5	0.6	0.5	4.4	2.0	0.5	0.5	0.5
2002	4.1	0.4	0.6	0.4	0.6	0.4	0.5	0.5	3.5	1.0	0.4	0.4	0.4
2003	5.9	1.8	1.3	1.8	2.0	1.8	1.8	1.8	5.2	2.5	1.8	1.8	1.8
2004	4.2	0.6	0.7	0.6	0.7	0.6	0.6	0.6	3.5	1.3	0.6	0.6	0.6
2005	8.4	3.3	3.0	3.3	3.7	3.3	3.4	3.3	7.3	5.0	3.3	3.3	3.3
2006	2.3	0.1	0.4	0.1	0.2	0.1	0.1	0.1	1.9	0.5	0.1	0.1	0.1
Load (non adj)	4.8	0.9	1.0	0.9	1.1	0.9	1.0	0.9	4.2	1.7	0.9	0.9	0.9
Load (t/yr)	**4.8**	**0.0**	**0.1**	**0.0**	**0.2**	**0.0**	**0.1**	**0.0**	**3.5**	**0.9**	**0.0**	**0.0**	**0.0**
Load (%)	**100.0%**	**0.0%**	**2.4%**	**0.0%**	**4.5%**	**0.4%**	**1.1%**	**0.7%**	**72.8%**	**18.2%**	**0.0%**	**0.0%**	**0.0%**

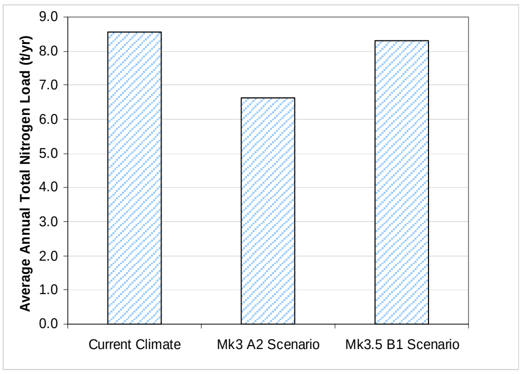


Susannah Brook – Climate change

Phosphorus			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.32	0.25	0.31
2058	0.66	0.50	0.64
2059	0.76	0.59	0.71
2060	0.73	0.59	0.68
2061	1.95	1.45	1.95
2062	0.46	0.32	0.43
2063	0.60	0.42	0.56
2064	0.46	0.35	0.44
2065	1.01	0.65	0.92
2066	0.29	0.23	0.27
Average Load for RF Sequence (t/yr)	**0.72**	**0.53**	**0.69**

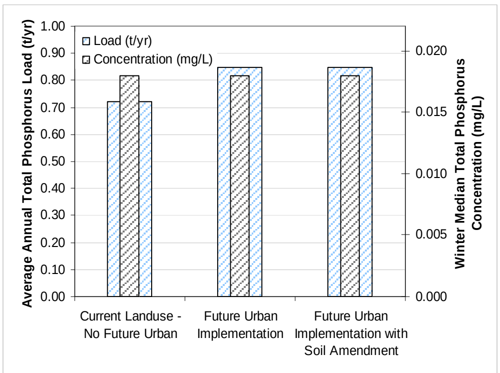


Nitrogen			
	At Catchment Outlet		
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	5.4	4.1	5.4
2058	9.2	7.0	9.0
2059	10.1	8.0	9.7
2060	9.6	8.3	9.4
2061	10.9	9.1	11.0
2062	6.6	4.8	6.4
2063	9.7	7.4	9.3
2064	6.8	5.1	6.6
2065	13.6	9.8	12.9
2066	3.6	2.9	3.5
Average Load for RF Sequence (t/yr)	**8.6**	**6.6**	**8.3**

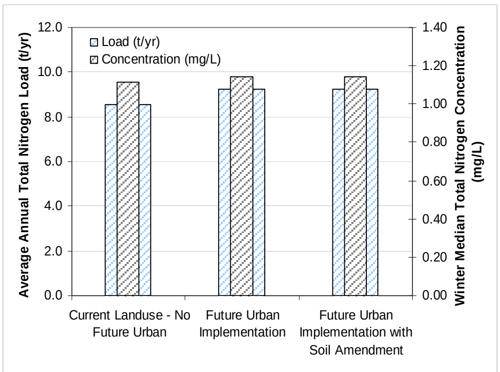


Susannah Brook – Future urban

Phosphorus			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.32	0.38	0.38
2058	0.66	0.78	0.78
2059	0.76	0.90	0.90
2060	0.73	0.86	0.86
2061	1.95	2.24	2.24
2062	0.46	0.53	0.53
2063	0.60	0.71	0.71
2064	0.46	0.53	0.53
2065	1.01	1.20	1.20
2066	0.29	0.34	0.34
Average Load for RF Sequence (t/yr)	**0.72**	**0.85**	**0.85**
Median Winter Concentration (mg/L)	**0.018**	**0.018**	**0.018**

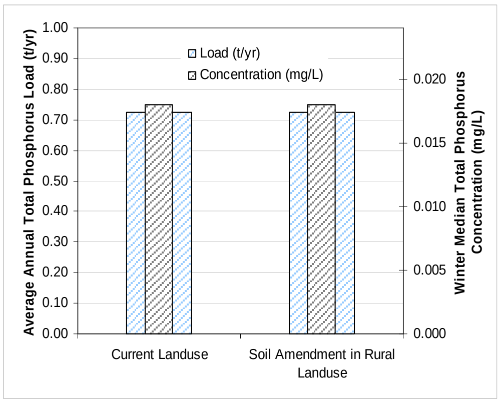


Nitrogen			
	At Catchment Outlet		
Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	5.4	5.8	5.8
2058	9.2	9.8	9.8
2059	10.1	10.9	10.9
2060	9.6	10.3	10.3
2061	10.9	12.5	12.5
2062	6.6	7.0	7.0
2063	9.7	10.3	10.3
2064	6.8	7.2	7.2
2065	13.6	14.5	14.5
2066	3.6	3.9	3.9
Average Load for RF Sequence (t/yr)	**8.6**	**9.2**	**9.2**
Median Winter Concentration (mg/L)	**1.12**	**1.14**	**1.14**

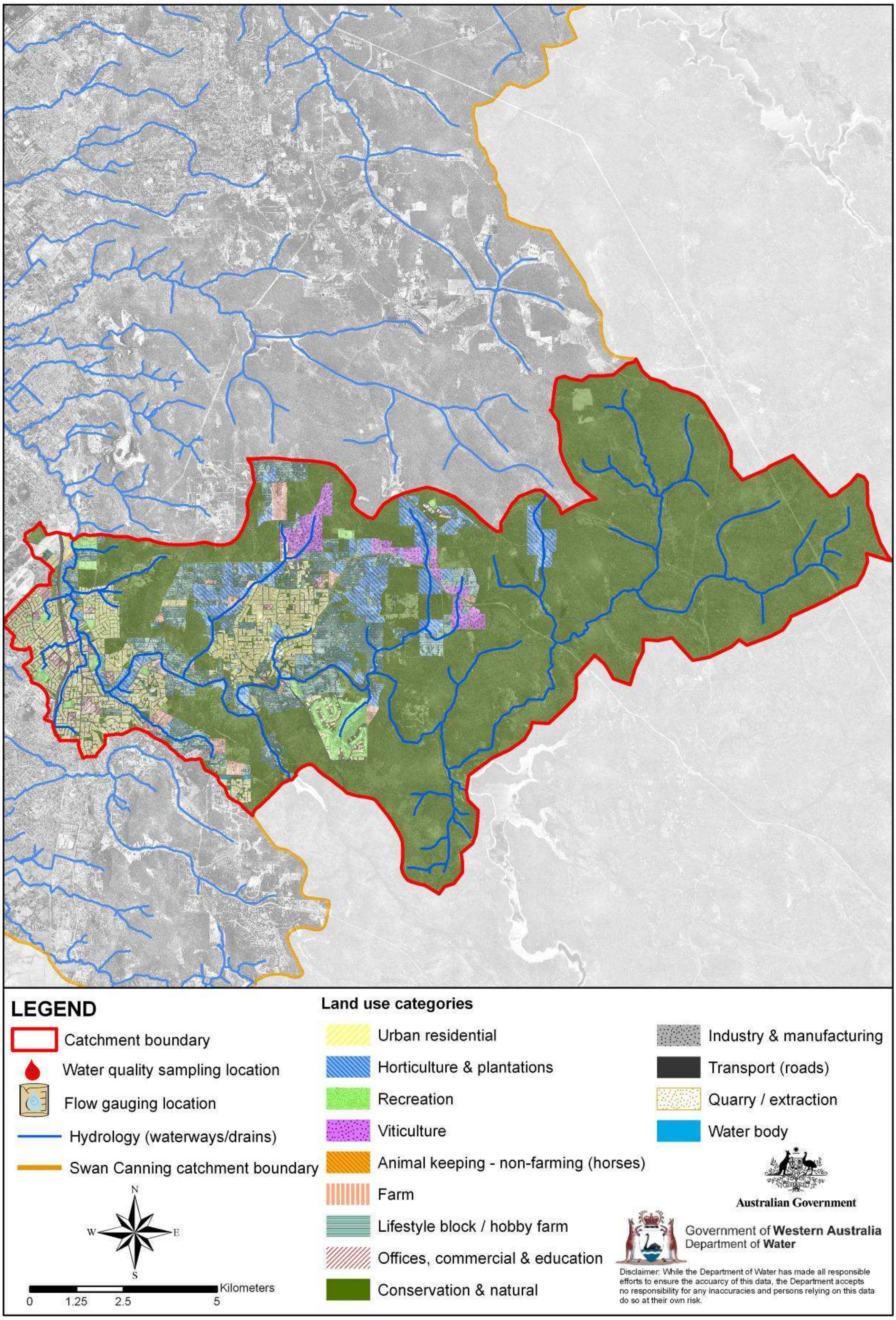


Susannah Brook – Soil amendment in rural land use

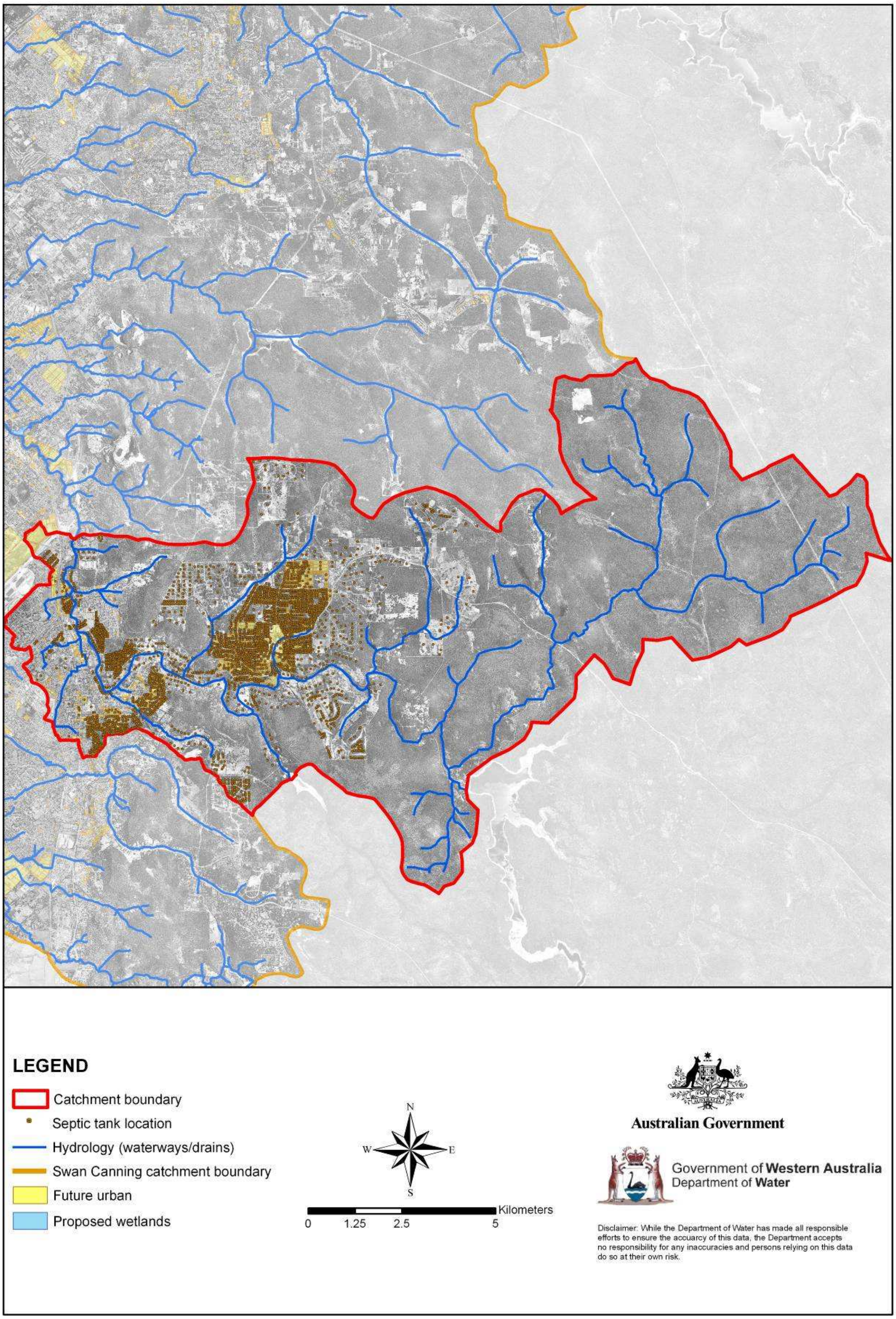
Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	Soil Amendment in Rural Landuse Load (t/yr)
2057	0.32	0.32
2058	0.66	0.66
2059	0.76	0.76
2060	0.73	0.73
2061	1.95	1.95
2062	0.46	0.46
2063	0.60	0.60
2064	0.46	0.46
2065	1.01	1.01
2066	0.29	0.29
Average Load for RF Sequence (t/yr)	**0.72**	**0.72**
Median Winter Concentration (mg/L)	**0.018**	**0.018**



Upper Canning River
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Upper Canning - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616027		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.47	-	*1997*	0.47	-
1998	0.41	-	*1998*	0.41	-
1999	0.43	-	*1999*	0.43	-
2000	0.53	-	*2000*	0.53	-
2001	0.37	-	*2001*	0.37	-
2002	0.39	-	*2002*	0.39	-
2003	0.45	-	*2003*	0.45	-
2004	0.38	-	*2004*	0.38	-
2005	0.51	-	*2005*	0.51	-
2006	0.25	-	*2006*	0.25	-
Average	**0.42**	**-**	**Average**	**0.42**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.029**		**SQUARE:**	**0.028**	
Target:	**0.100**		**Observed:**	**0.028**	
Load Target (t/yr)		**0.42**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

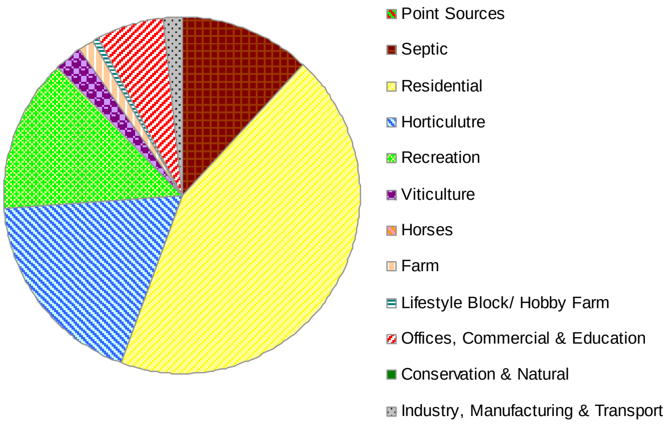
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616027		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	8.4	-	*1997*	8.4	-
1998	7.9	-	*1998*	7.9	-
1999	9.9	-	*1999*	9.9	-
2000	8.6	-	*2000*	8.6	-
2001	6.0	-	*2001*	6.0	-
2002	7.3	-	*2002*	7.3	-
2003	8.0	-	*2003*	8.0	-
2004	6.9	-	*2004*	6.9	-
2005	9.5	-	*2005*	9.5	-
2006	2.9	-	*2006*	2.9	-
Average	**7.5**	**-**	**Average**	**7.5**	**-**
Median Winter Concentration (mg/L):			**Median Winter Concentration (mg/L):**		
SQUARE:	**0.72**		**SQUARE:**	**0.71**	
Target:	**1.00**		**Observed:**	**0.70**	
Load Target (t/yr)		**7.5**			
Load Reduction Target (t/yr)		**0.0**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

Upper Canning River – Source separation

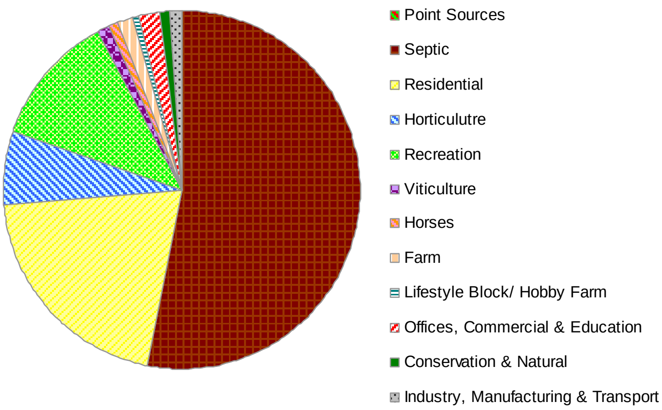
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.47	0.00	0.07	0.17	0.11	0.07	0.02	0.00	0.01	0.01	0.03	0.00	0.01
1998	0.41	0.00	0.06	0.17	0.08	0.06	0.01	0.00	0.01	0.00	0.03	0.00	0.01
1999	0.43	0.00	0.06	0.19	0.07	0.06	0.01	0.00	0.01	0.00	0.03	0.00	0.01
2000	0.53	0.00	0.08	0.23	0.10	0.07	0.01	0.00	0.01	0.00	0.03	0.00	0.01
2001	0.37	0.00	0.04	0.15	0.09	0.05	0.01	0.00	0.01	0.00	0.02	0.00	0.01
2002	0.39	0.00	0.04	0.19	0.06	0.06	0.01	0.00	0.00	0.00	0.03	0.00	0.01
2003	0.45	0.00	0.05	0.22	0.07	0.07	0.01	0.00	0.01	0.00	0.03	0.00	0.01
2004	0.38	0.00	0.04	0.18	0.07	0.05	0.01	0.00	0.00	0.00	0.02	0.00	0.01
2005	0.51	0.00	0.05	0.25	0.08	0.08	0.01	0.00	0.01	0.00	0.03	0.00	0.01
2006	0.25	0.00	0.02	0.11	0.06	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Load (non adj)	0.42	0.00	0.05	0.19	0.08	0.06	0.01	0.00	0.01	0.00	0.03	0.00	0.01
Load (t/yr)	**0.42**	**0.00**	**0.05**	**0.18**	**0.08**	**0.06**	**0.01**	**0.00**	**0.01**	**0.00**	**0.02**	**0.00**	**0.01**
Load (%)	**100.0%**	**0.0%**	**11.9%**	**43.7%**	**18.3%**	**14.1%**	**2.4%**	**0.0%**	**1.3%**	**0.8%**	**6.0%**	**0.0%**	**1.7%**



Nitrogen (t/yr)

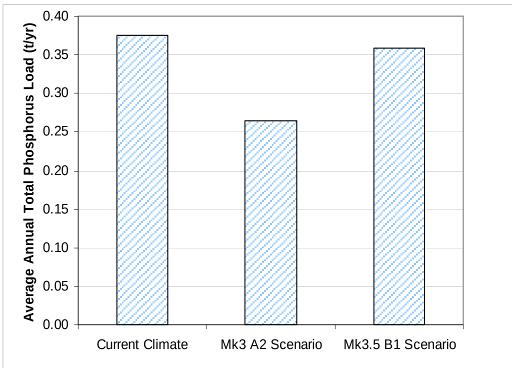
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	8.4	0.4	4.1	1.5	0.8	1.2	0.5	0.5	0.6	0.5	0.5	0.5	0.5
1998	7.9	0.4	3.9	1.6	0.7	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
1999	9.9	0.4	4.7	1.8	0.9	1.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2000	8.6	0.5	4.1	1.7	1.0	1.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6
2001	6.0	0.4	2.8	1.4	0.7	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2002	7.3	0.5	3.4	1.7	0.8	1.1	0.5	0.5	0.5	0.5	0.6	0.5	0.5
2003	8.0	0.5	3.5	1.8	0.9	1.2	0.5	0.5	0.5	0.5	0.6	0.5	0.5
2004	6.9	0.4	2.9	1.6	0.8	1.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2005	9.5	0.6	3.8	2.2	1.1	1.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6
2006	2.9	0.3	1.2	0.9	0.4	0.6	0.4	0.3	0.3	0.3	0.4	0.3	0.4
Load (non adj)	7.5	0.4	3.4	1.6	0.8	1.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Load (t/yr)	**7.5**	**0.0**	**4.0**	**1.6**	**0.5**	**0.9**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Load (%)	**100.0%**	**0.0%**	**52.9%**	**20.8%**	**6.4%**	**12.1%**	**1.0%**	**0.8%**	**1.4%**	**0.8%**	**1.8%**	**0.8%**	**1.1%**



Upper Canning River – Climate change

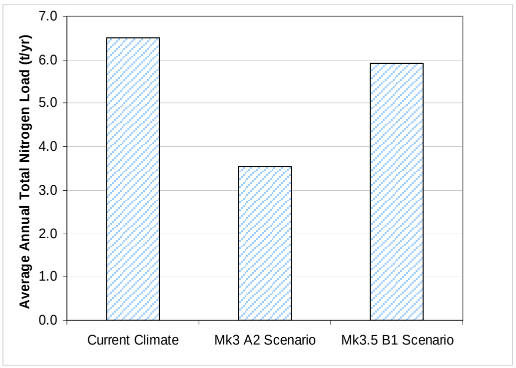
Phosphorus

Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	0.31	0.21	0.29
2058	0.34	0.22	0.32
2059	0.39	0.28	0.37
2060	0.48	0.37	0.46
2061	0.33	0.22	0.31
2062	0.37	0.26	0.35
2063	0.44	0.34	0.43
2064	0.37	0.26	0.35
2065	0.50	0.35	0.48
2066	0.24	0.14	0.21
Average Load for RF Sequence (t/yr)	**0.38**	**0.26**	**0.36**



Nitrogen

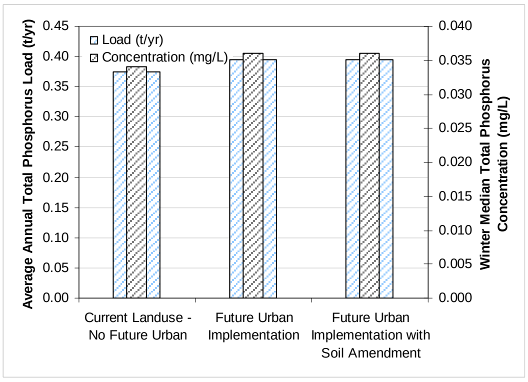
Year	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
	At Catchment Outlet		
2057	5.9	2.7	5.0
2058	5.8	2.5	4.9
2059	7.5	4.5	7.3
2060	7.5	5.9	8.7
2061	5.2	2.3	4.2
2062	6.6	2.9	5.7
2063	7.6	4.9	7.3
2064	6.7	3.5	6.0
2065	9.4	4.8	8.1
2066	2.9	1.4	2.2
Average Load for RF Sequence (t/yr)	**6.5**	**3.5**	**5.9**



Upper Canning River – Future urban

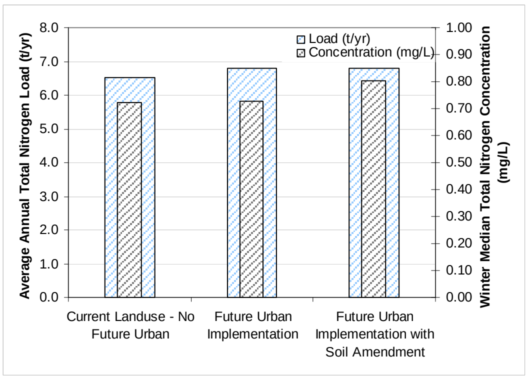
Phosphorus

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	0.31	0.33	0.33
2058	0.34	0.35	0.35
2059	0.39	0.41	0.41
2060	0.48	0.51	0.51
2061	0.33	0.35	0.35
2062	0.37	0.39	0.39
2063	0.44	0.46	0.46
2064	0.37	0.39	0.39
2065	0.50	0.52	0.52
2066	0.24	0.25	0.25
Average Load for RF Sequence (t/yr)	**0.38**	**0.40**	**0.40**
Median Winter Concentration (mg/L)	**0.034**	**0.036**	**0.036**



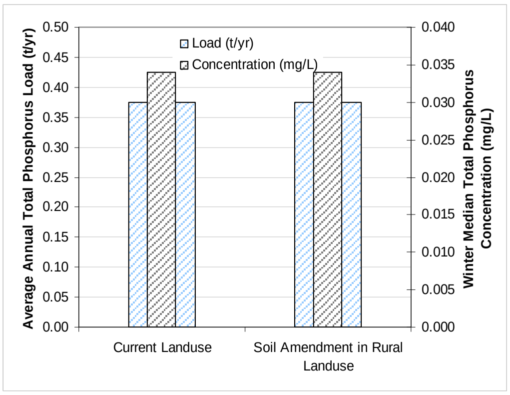
Nitrogen

Year	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
	At Catchment Outlet		
2057	5.9	6.2	6.2
2058	5.8	6.1	6.1
2059	7.5	7.9	7.9
2060	7.5	7.9	7.9
2061	5.2	5.5	5.5
2062	6.6	6.9	6.9
2063	7.6	8.0	8.0
2064	6.7	7.0	7.0
2065	9.4	9.8	9.8
2066	2.9	3.0	3.0
Average Load for RF Sequence (t/yr)	**6.5**	**6.8**	**6.8**
Median Winter Concentration (mg/L)	**0.72**	**0.73**	**0.80**



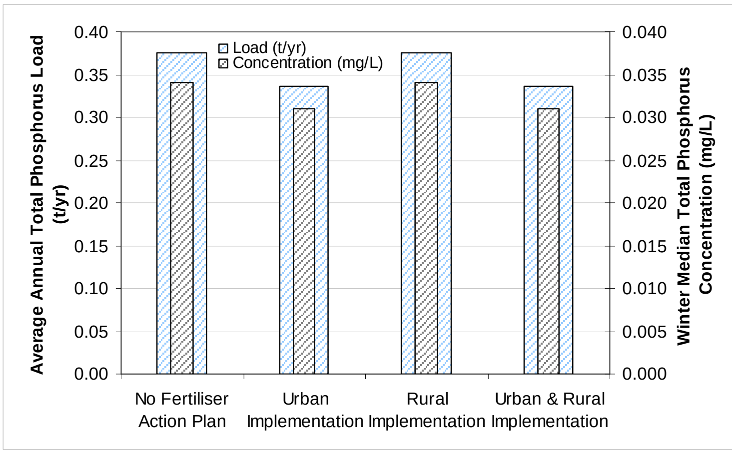
Upper Canning River – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	0.31	0.31
2058	0.34	0.33
2059	0.39	0.39
2060	0.48	0.48
2061	0.33	0.33
2062	0.37	0.37
2063	0.44	0.44
2064	0.37	0.37
2065	0.50	0.50
2066	0.24	0.24
Average Load for RF Sequence (t/yr)	**0.38**	**0.37**
Median Winter Concentration (mg/L)	**0.034**	**0.034**



Upper Canning River – *Fertiliser action plan*

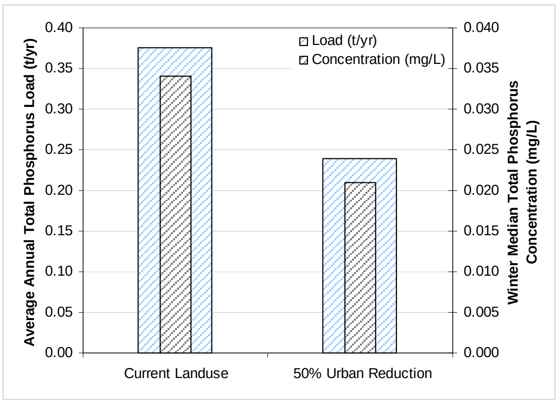
Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)***	*Urban and Rural Implementation (t/yr)*
2057	0.31	0.28	0.31	0.28
2058	0.34	0.30	0.34	0.30
2059	0.39	0.35	0.39	0.35
2060	0.48	0.43	0.48	0.43
2061	0.33	0.30	0.33	0.30
2062	0.37	0.33	0.37	0.33
2063	0.44	0.39	0.44	0.39
2064	0.37	0.33	0.37	0.33
2065	0.50	0.45	0.50	0.45
2066	0.24	0.21	0.24	0.21
Average Load for RF Sequence (t/yr)	**0.38**	**0.34**	**0.38**	**0.34**
Median Winter Concentration (mg/L)	**0.034**	**0.031**	**0.034**	**0.031**



Upper Canning River – Urban 50% reduction

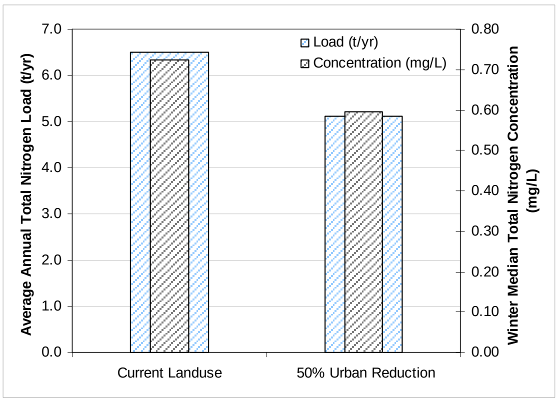
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	0.31	0.19
2058	0.34	0.21
2059	0.39	0.24
2060	0.48	0.31
2061	0.33	0.21
2062	0.37	0.23
2063	0.44	0.28
2064	0.37	0.24
2065	0.50	0.32
2066	0.24	0.16
Average Load for RF Sequence (t/yr)	**0.38**	**0.24**
Median Winter Concentration (mg/L)	**0.034**	**0.021**



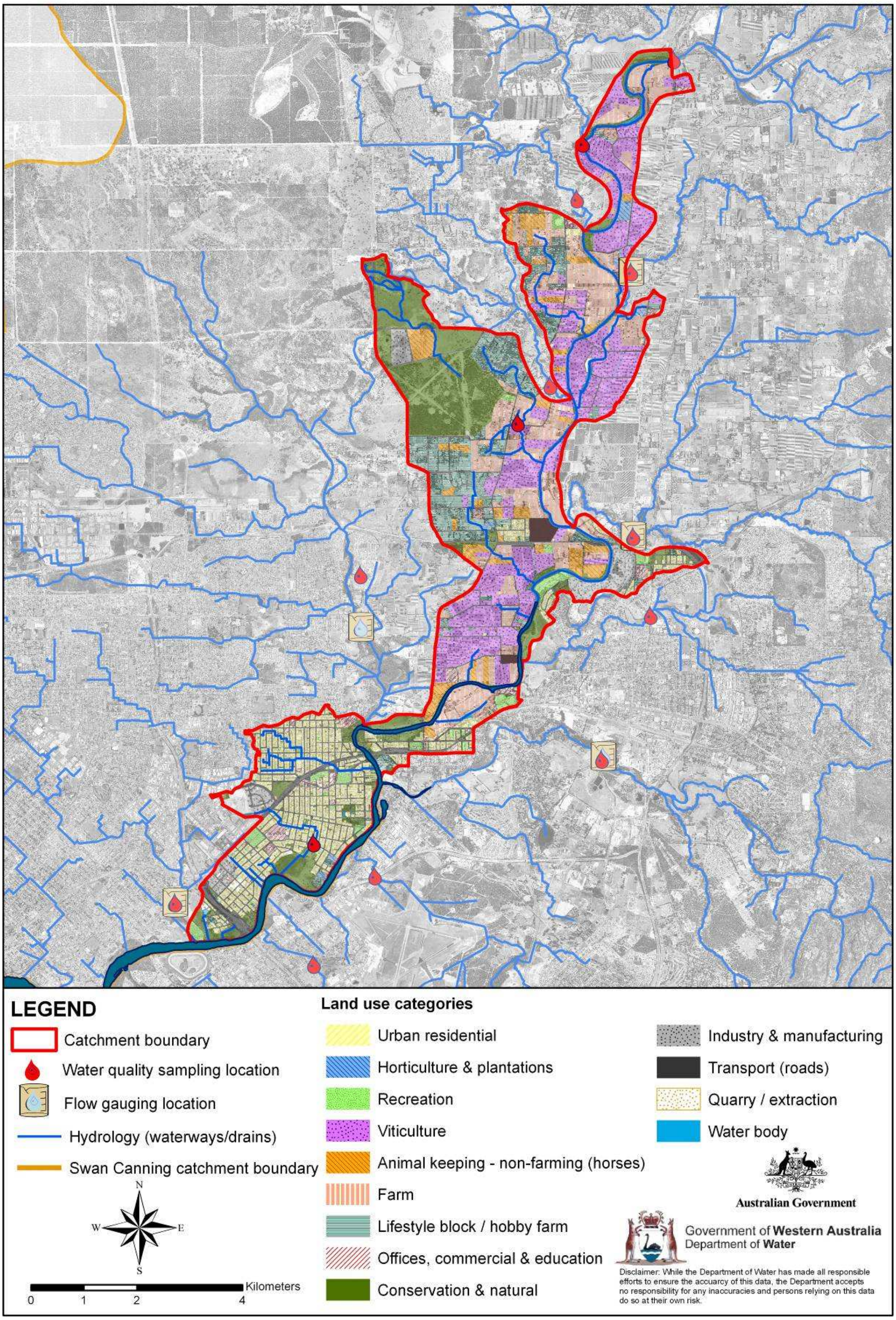
Nitrogen

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	5.9	4.7
2058	5.8	4.6
2059	7.5	5.9
2060	7.5	6.0
2061	5.2	4.0
2062	6.6	5.2
2063	7.6	6.0
2064	6.7	5.3
2065	9.4	7.4
2066	2.9	2.2
Average Load for RF Sequence (t/yr)	**6.5**	**5.1**
Median Winter Concentration (mg/L)	**0.72**	**0.60**

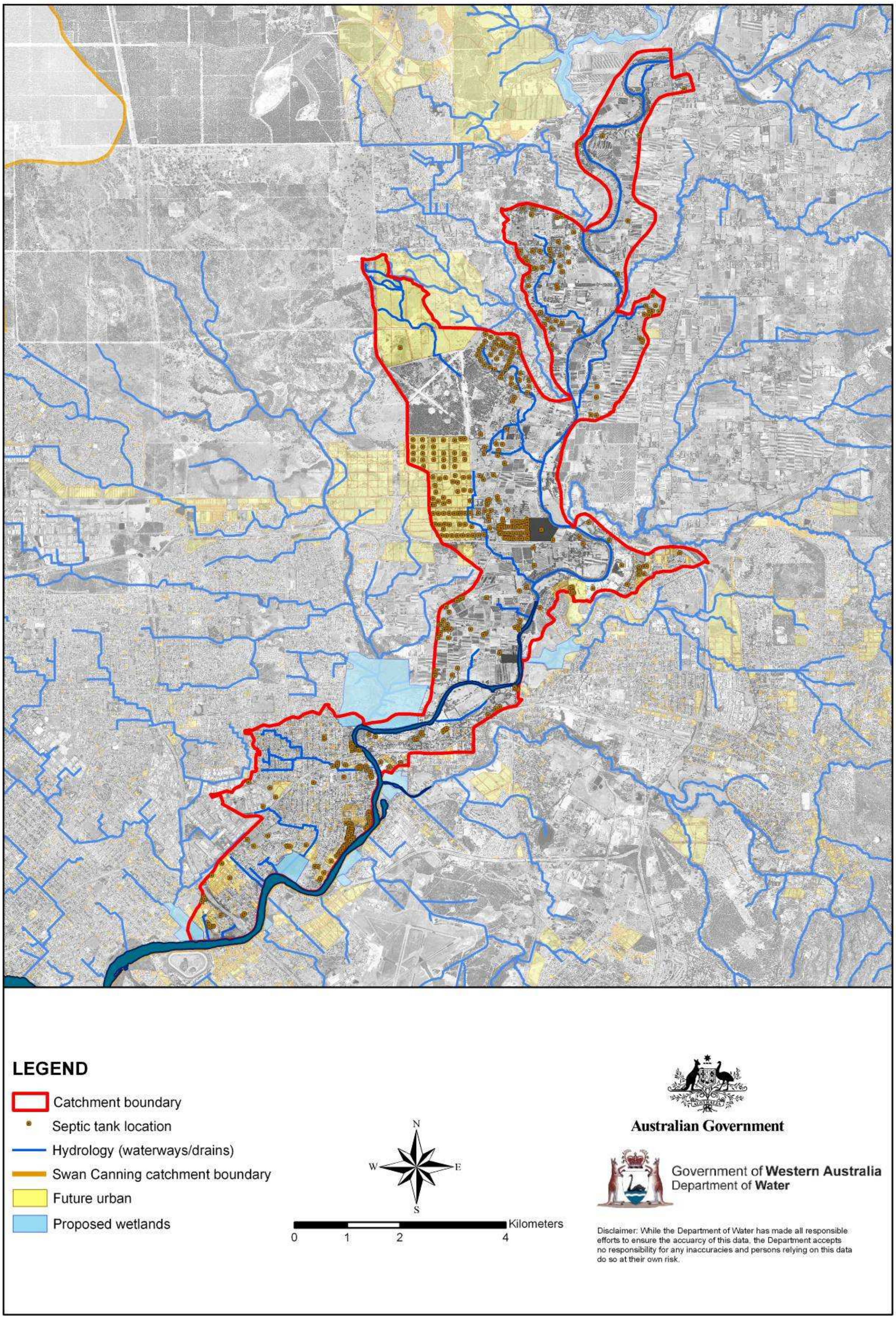


Upper Swan River

Land use map



Locations of septic tanks, future urban development and proposed wetlands



Upper Swan - Current loads and load reduction targets [3]

Phosphorus		
At Outlet to Swan River Estuary		
	Current	30% Input Reduction
Year	Load (t/yr)	Load (t/yr)
1997	2.28	1.07
1998	1.92	1.09
1999	2.19	1.34
2000	2.38	1.52
2001	1.98	1.32
2002	1.82	1.24
2003	1.93	1.34
2004	1.74	1.22
2005	2.19	1.55
2006	1.68	1.19
Average	**2.01**	**1.29**
Median Winter Concentration (mg/L):		
SQUARE:	**0.068**	**0.050**
Target:	**0.050**	
Load Target (t/yr)		**1.29**
Load Reduction Target (t/yr)		**0.72**
Required Reduction (%)		**36%**
Time Required (yr)		**40**

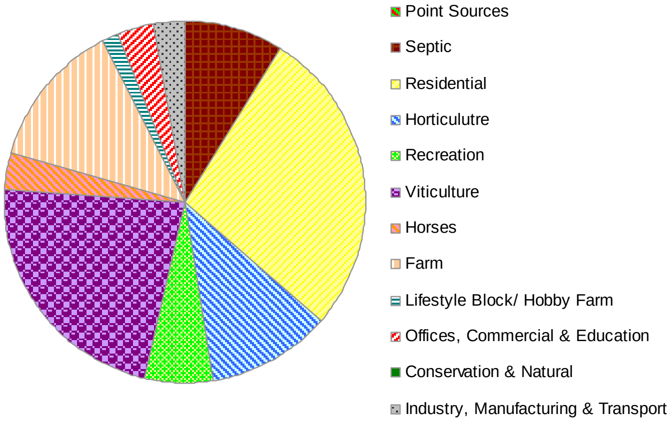
Nitrogen		
At Outlet to Swan River Estuary		
	Current	55% Input Reduction
Year	Load (t/yr)	Load (t/yr)
1997	8.3	5.0
1998	8.2	5.2
1999	10.0	6.3
2000	10.0	7.0
2001	8.1	5.9
2002	7.7	5.8
2003	9.6	6.6
2004	7.5	5.8
2005	10.5	7.3
2006	5.9	5.6
Average	**8.6**	**6.1**
Median Winter Concentration (mg/L):		
SQUARE:	**1.68**	**0.49**
Target:	**0.50**	
Load Target (t/yr)		**6.1**
Load Reduction Target (t/yr)		**2.5**
Required Reduction (%)		**29%**
Time Required (yr)		**30**

[3] Targets for Upper Swan are 0.5 mg/L TN and 0.05 mg/L TP (Table 4.4 lists targets as 0.75 mg/L TN and 0.075 mg/L TP). Upper Swan has 27% impervious which is similar to catchments with targets 0.5 mg/L TN and 0.05 mg/L TP.

Upper Swan – Source separation

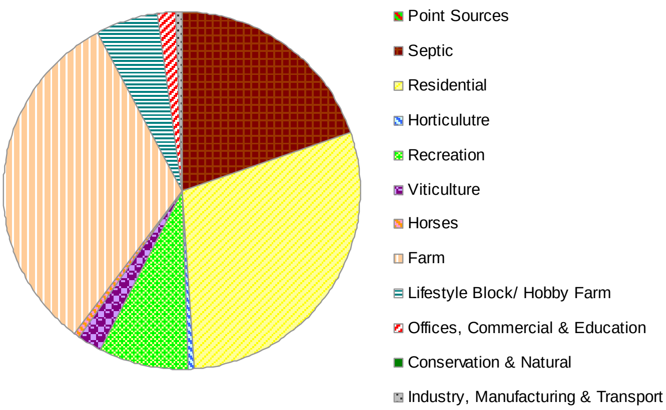
Phosphorus (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	2.28	0.01	0.25	0.52	0.26	0.13	0.57	0.08	0.35	0.04	0.06	0.01	0.06
1998	1.92	0.01	0.22	0.53	0.20	0.13	0.40	0.06	0.26	0.03	0.06	0.01	0.06
1999	2.19	0.01	0.25	0.57	0.25	0.13	0.48	0.07	0.31	0.03	0.07	0.01	0.06
2000	2.38	0.00	0.25	0.61	0.26	0.14	0.55	0.08	0.34	0.04	0.07	0.00	0.07
2001	1.98	0.00	0.18	0.59	0.19	0.15	0.41	0.07	0.24	0.02	0.07	0.00	0.07
2002	1.82	0.00	0.15	0.54	0.20	0.12	0.38	0.06	0.22	0.03	0.07	0.00	0.06
2003	1.93	0.00	0.15	0.55	0.23	0.12	0.42	0.06	0.24	0.03	0.07	0.00	0.06
2004	1.74	0.00	0.13	0.49	0.20	0.11	0.39	0.06	0.22	0.02	0.07	0.00	0.05
2005	2.19	0.00	0.14	0.65	0.25	0.14	0.48	0.07	0.27	0.03	0.09	0.00	0.07
2006	1.68	0.00	0.11	0.44	0.18	0.11	0.41	0.06	0.22	0.02	0.06	0.00	0.05
Load (non adj)	2.01	0.00	0.18	0.55	0.22	0.13	0.45	0.07	0.27	0.03	0.07	0.00	0.06
Load (t/yr)	**2.01**	**0.00**	**0.18**	**0.55**	**0.22**	**0.13**	**0.45**	**0.06**	**0.27**	**0.03**	**0.07**	**0.00**	**0.06**
Load (%)	**100.0%**	**0.0%**	**9.0%**	**27.4%**	**11.1%**	**6.3%**	**22.4%**	**3.1%**	**13.2%**	**1.3%**	**3.3%**	**0.0%**	**2.9%**



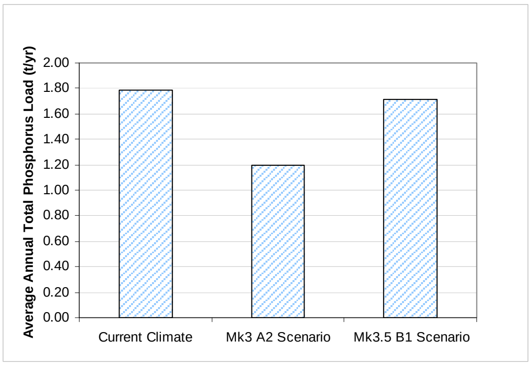
Nitrogen (t/yr)

Year	Current	Point Sources	Septic	Residential	Horticulutre	Recreation	Viticulture	Horses	Farm	Lifestyle Block/ Hobby Farm	Offices, Commercial & Education	Conservation & Natural	Industry, Manufacturing & Transport
1997	8.3	0.3	1.3	1.5	0.3	0.6	0.4	0.3	1.9	0.5	0.3	0.3	0.3
1998	8.2	0.3	1.4	1.6	0.3	0.7	0.4	0.3	1.9	0.5	0.4	0.3	0.3
1999	10.0	0.3	1.6	1.8	0.4	0.7	0.5	0.4	2.3	0.6	0.4	0.3	0.4
2000	10.0	0.4	1.5	1.8	0.4	0.8	0.5	0.4	2.3	0.7	0.5	0.4	0.4
2001	8.1	0.5	1.6	1.9	0.5	1.0	0.6	0.6	1.9	0.8	0.6	0.5	0.5
2002	7.7	0.3	1.2	1.7	0.3	0.7	0.4	0.3	1.5	0.5	0.4	0.3	0.3
2003	9.6	0.3	1.3	1.9	0.4	0.7	0.5	0.4	1.9	0.6	0.4	0.3	0.4
2004	7.5	0.3	0.9	1.6	0.3	0.6	0.3	0.3	1.4	0.5	0.3	0.3	0.3
2005	10.5	0.5	1.3	2.1	0.5	0.9	0.6	0.5	2.2	0.8	0.6	0.5	0.5
2006	5.9	0.2	0.6	1.3	0.2	0.5	0.3	0.2	1.1	0.4	0.3	0.2	0.2
Load (non adj)	8.6	0.3	1.3	1.7	0.4	0.7	0.4	0.4	1.9	0.6	0.4	0.3	0.4
Load (t/yr)	**8.6**	**0.0**	**1.7**	**2.5**	**0.1**	**0.7**	**0.2**	**0.1**	**2.7**	**0.5**	**0.1**	**0.0**	**0.1**
Load (%)	**100.0%**	**0.0%**	**19.8%**	**29.1%**	**0.6%**	**7.9%**	**2.4%**	**0.6%**	**31.9%**	**5.6%**	**1.4%**	**0.0%**	**0.7%**

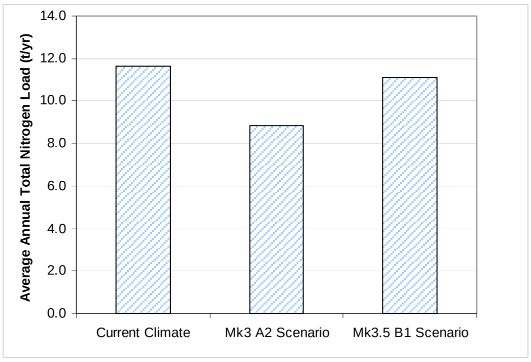


Upper Swan – Climate change

Phosphorus			
	At Catchment Outlet		
Year	*Current Climate Load (t/yr)*	*Mk3 A2 Climate Change Scenario Load (t/yr)*	*Mk3.5 B1 Climate Change Scenario Load (t/yr)*
2057	1.48	0.92	1.41
2058	1.51	0.93	1.44
2059	1.86	1.22	1.78
2060	2.12	1.56	2.03
2061	1.84	1.26	1.78
2062	1.72	1.10	1.64
2063	1.87	1.31	1.81
2064	1.70	1.12	1.63
2065	2.16	1.54	2.09
2066	1.65	1.03	1.56
Average Load for RF Sequence (t/yr)	**1.79**	**1.20**	**1.72**

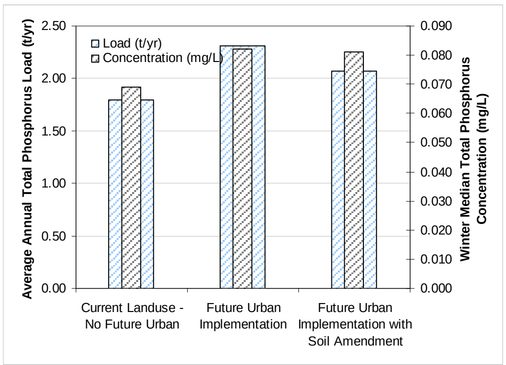


Nitrogen			
	At Catchment Outlet		
Year	*Current Climate Load (t/yr)*	*Mk3 A2 Climate Change Scenario Load (t/yr)*	*Mk3.5 B1 Climate Change Scenario Load (t/yr)*
2057	9.7	7.0	9.2
2058	10.0	7.2	9.5
2059	12.5	9.4	11.9
2060	13.5	10.9	12.9
2061	11.0	8.7	10.6
2062	10.9	7.9	10.3
2063	13.1	10.3	12.6
2064	11.1	8.3	10.6
2065	14.6	11.4	14.0
2066	10.1	7.4	9.5
Average Load for RF Sequence (t/yr)	**11.6**	**8.9**	**11.1**

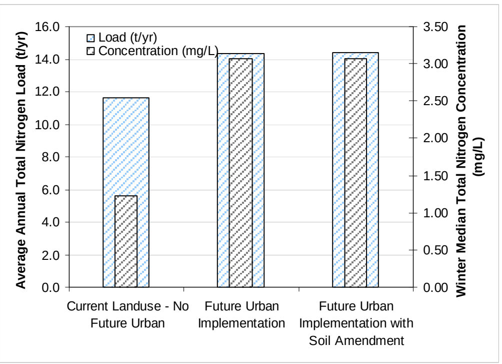


Upper Swan – Future urban

Phosphorus			
	At Catchment Outlet		
Year	*Current Landuse - No Future Urban Load (t/yr)*	*Future Urban Implementation Load (t/yr)*	*Future Urban Implementation with Soil Amendment Load (t/yr)*
2057	1.48	1.92	1.72
2058	1.51	2.00	1.80
2059	1.86	2.40	2.15
2060	2.12	2.69	2.41
2061	1.84	2.43	2.25
2062	1.72	2.21	1.98
2063	1.87	2.39	2.15
2064	1.70	2.16	1.94
2065	2.16	2.76	2.51
2066	1.65	2.08	1.84
Average Load for RF Sequence (t/yr)	**1.79**	**2.31**	**2.07**
Median Winter Concentration (mg/L)	**0.069**	**0.082**	**0.081**

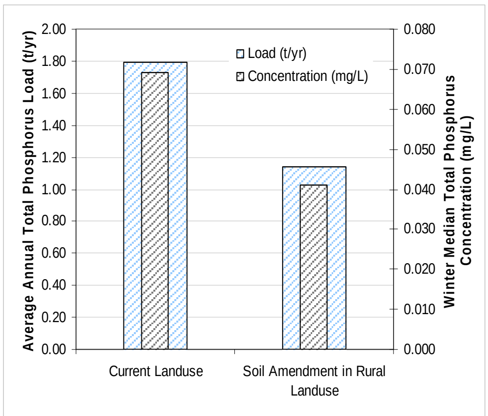


Nitrogen			
	At Catchment Outlet		
Year	*Current Landuse - No Future Urban Load (t/yr)*	*Future Urban Implementation Load (t/yr)*	*Future Urban Implementation with Soil Amendment Load (t/yr)*
2057	9.7	12.1	12.1
2058	10.0	12.7	12.7
2059	12.5	15.4	15.4
2060	13.5	16.3	16.3
2061	11.0	13.8	13.8
2062	10.9	13.6	13.6
2063	13.1	15.9	16.0
2064	11.1	13.7	13.7
2065	14.6	17.6	17.6
2066	10.1	12.5	12.6
Average Load for RF Sequence (t/yr)	**11.6**	**14.4**	**14.4**
Median Winter Concentration (mg/L)	**1.23**	**3.07**	**3.08**



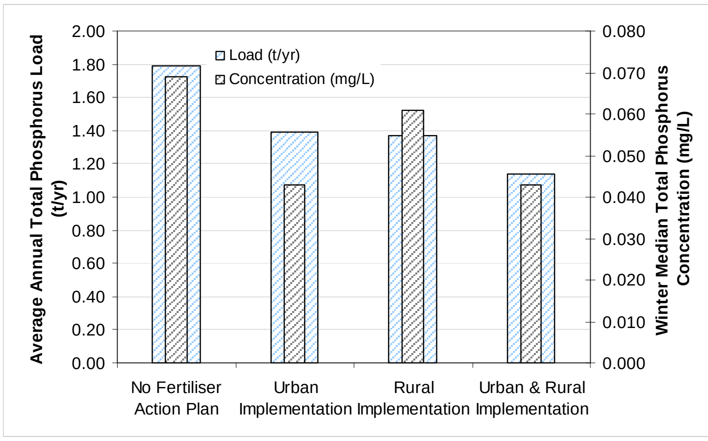
Upper Swan – Soil amendment in rural land use

Phosphorus		
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*Soil Amendment in Rural Landuse Load (t/yr)*
2057	1.48	0.94
2058	1.51	0.97
2059	1.86	1.18
2060	2.12	1.33
2061	1.84	1.19
2062	1.72	1.09
2063	1.87	1.18
2064	1.70	1.07
2065	2.16	1.37
2066	1.65	1.03
Average Load for RF Sequence (t/yr)	**1.79**	**1.14**
Median Winter Concentration (mg/L)	**0.069**	**0.041**



Upper Swan – *Fertiliser action plan*

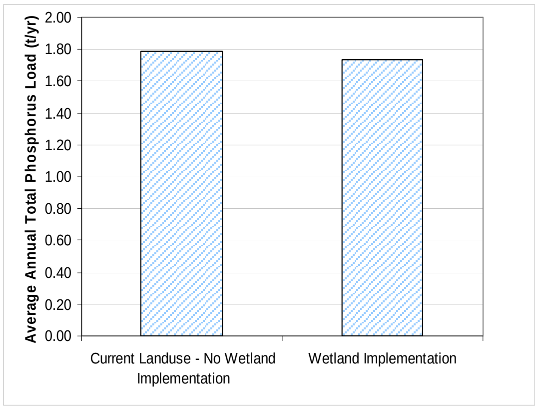
Phosphorus				
	At Catchment Outlet			
Year	*No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	1.48	1.14	1.14	0.94
2058	1.51	1.15	1.17	0.96
2059	1.86	1.44	1.42	1.18
2060	2.12	1.66	1.61	1.35
2061	1.84	1.41	1.42	1.17
2062	1.72	1.33	1.32	1.09
2063	1.87	1.46	1.43	1.19
2064	1.70	1.33	1.29	1.08
2065	2.16	1.69	1.66	1.38
2066	1.65	1.30	1.24	1.05
Average Load for RF Sequence (t/yr)	**1.79**	**1.39**	**1.37**	**1.14**
Median Winter Concentration (mg/L)	**0.069**	**0.043**	**0.061**	**0.043**



Upper Swan – Wetland implementation

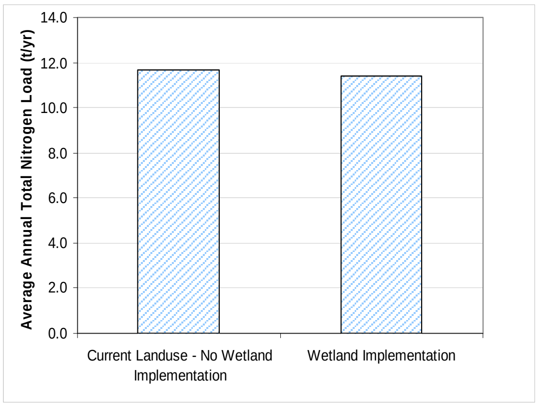
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	1.48	1.44
2058	1.51	1.46
2059	1.86	1.80
2060	2.12	2.05
2061	1.84	1.77
2062	1.72	1.67
2063	1.87	1.81
2064	1.70	1.65
2065	2.16	2.09
2066	1.65	1.62
Average Load for RF Sequence (t/yr)	**1.79**	**1.74**



Nitrogen

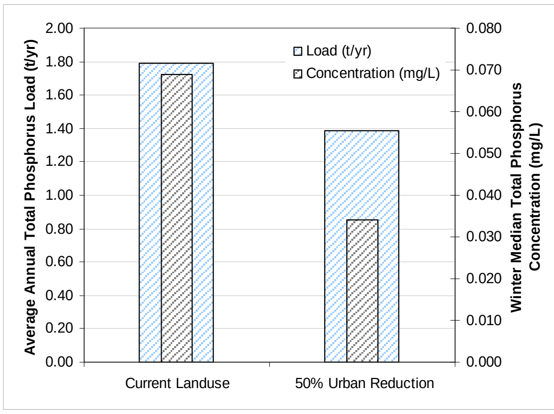
	At Catchment Outlet	
Year	*Current Landuse - No Wetland Implementation (t/yr)*	*Wetland Implementation Load (t/yr)*
2057	9.7	9.4
2058	10.0	9.8
2059	12.5	12.3
2060	13.5	13.3
2061	11.0	10.8
2062	10.9	10.7
2063	13.1	12.9
2064	11.1	10.8
2065	14.6	14.3
2066	10.1	9.9
Average Load for RF Sequence (t/yr)	**11.6**	**11.4**



Upper Swan – Urban 50% reduction

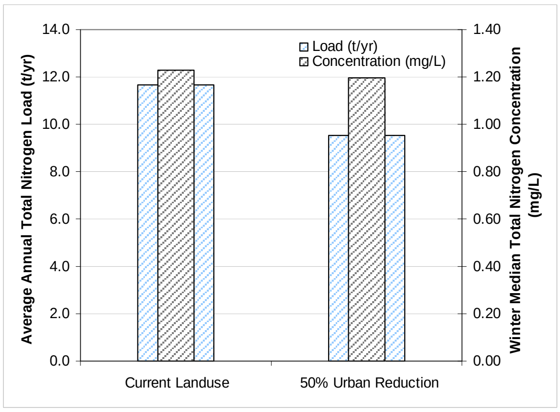
Phosphorus

	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	1.48	1.13
2058	1.51	1.14
2059	1.86	1.44
2060	2.12	1.66
2061	1.84	1.39
2062	1.72	1.32
2063	1.87	1.46
2064	1.70	1.33
2065	2.16	1.68
2066	1.65	1.31
Average Load for RF Sequence (t/yr)	**1.79**	**1.39**
Median Winter Concentration (mg/L)	**0.069**	**0.034**

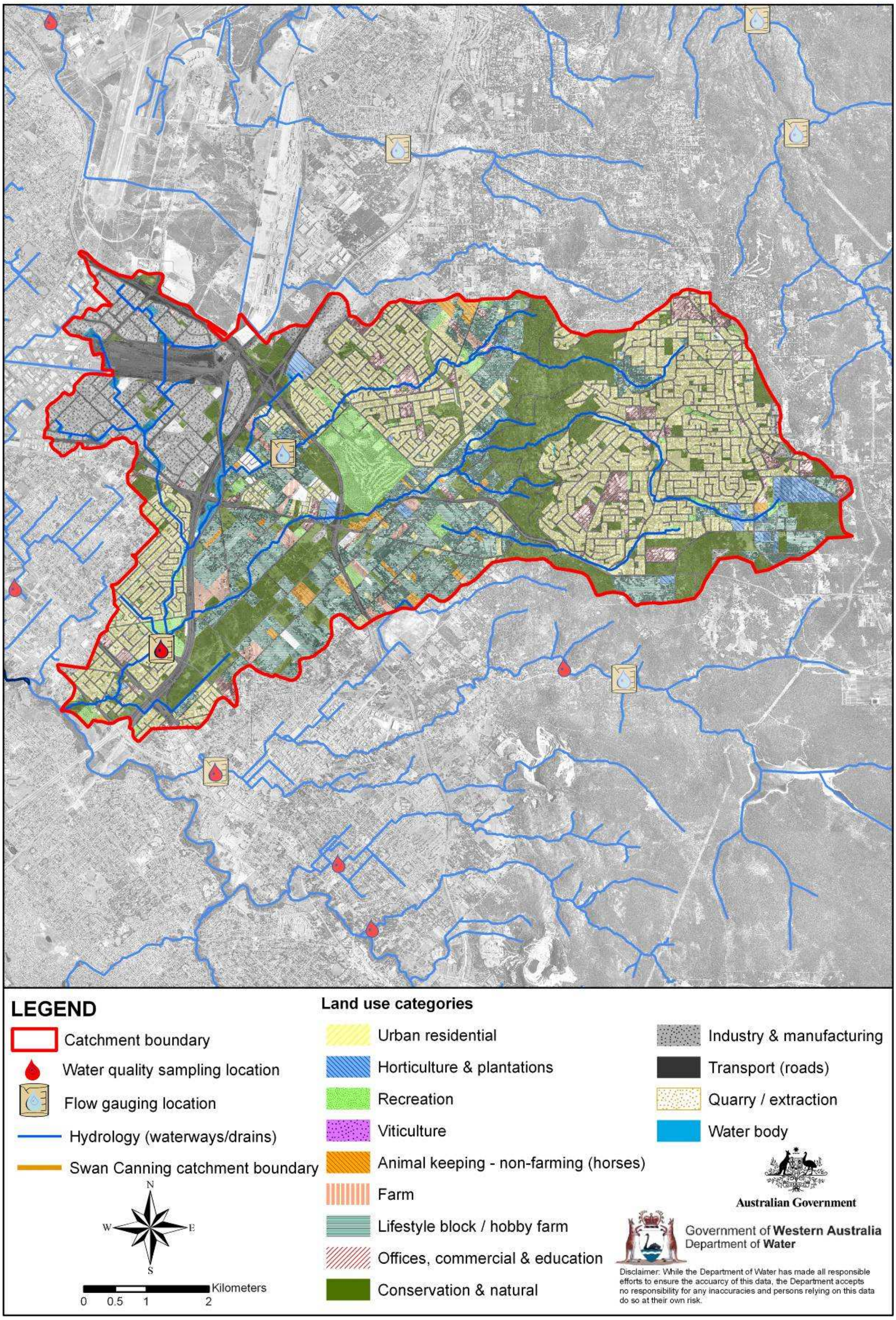


Nitrogen

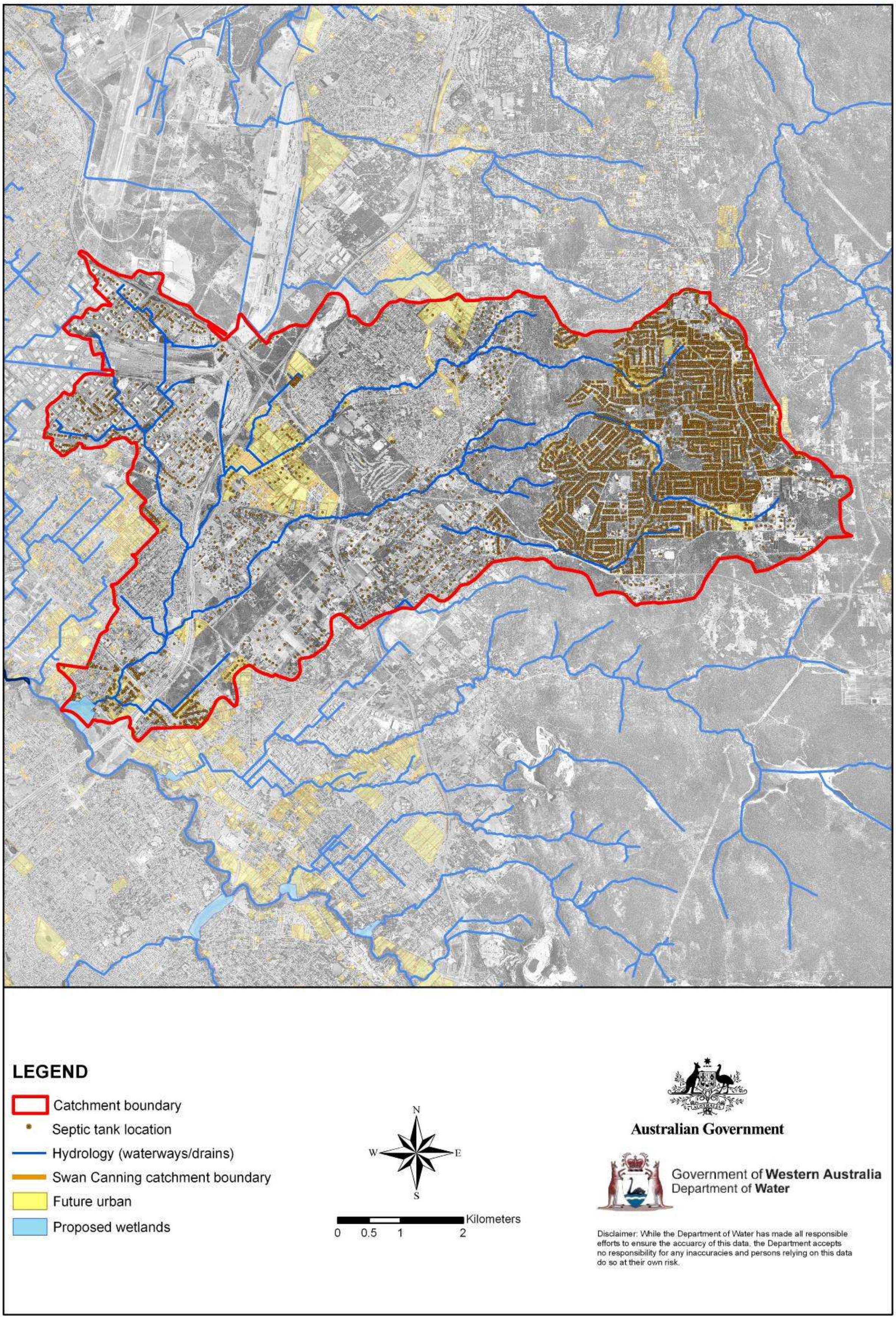
	At Catchment Outlet	
Year	*Current Landuse Load (t/yr)*	*50% urban reduction Load (t/yr)*
2057	9.7	7.8
2058	10.0	8.1
2059	12.5	10.2
2060	13.5	11.2
2061	11.0	9.1
2062	10.9	8.8
2063	13.1	10.8
2064	11.1	9.1
2065	14.6	12.0
2066	10.1	8.3
Average Load for RF Sequence (t/yr)	**11.6**	**9.5**
Median Winter Concentration (mg/L)	**1.23**	**1.20**



Yule Brook
Land use map



Locations of septic tanks, future urban development and proposed wetlands



Yule Brook - Current loads and load reduction targets

Phosphorus

At Outlet to Swan River Estuary			At Gauging Station 616042		
	Current	No Reduction Required		Current	No Reduction Required
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	0.33	-	*1997*	0.28	-
1998	0.28	-	*1998*	0.25	-
1999	0.34	-	*1999*	0.29	-
2000	0.49	-	*2000*	0.43	-
2001	0.31	-	*2001*	0.29	-
2002	0.49	-	*2002*	0.45	-
2003	0.65	-	*2003*	0.60	-
2004	0.42	-	*2004*	0.39	-
2005	0.78	-	*2005*	0.72	-
2006	0.18	-	*2006*	0.17	-
Average	**0.43**	**-**	**Average**	**0.39**	**-**
Median Winter Concentration (mg/L):			**Median Winter Conc (mg/L):**		
SQUARE:	**0.067**		**SQUARE**	**0.064**	
Target:	**0.075**		**Observed**	**0.057**	
Load Target (t/yr)		**0.43**			
Load Reduction Target (t/yr)		**0.00**			
Required Reduction (%)		**0%**			
Time Required (yr)		**0**			

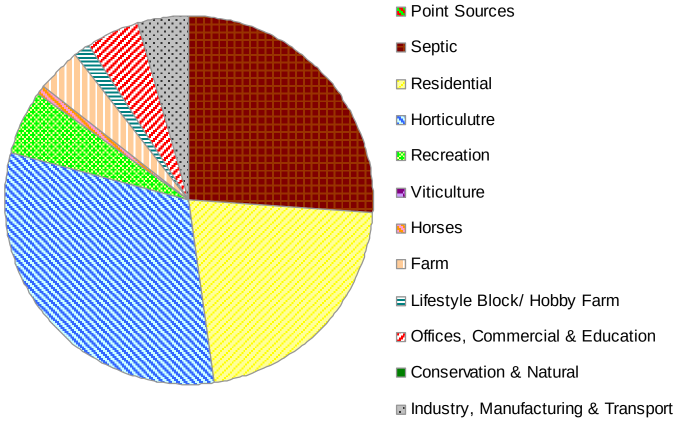
Nitrogen

At Outlet to Swan River Estuary			At Gauging Station 616042		
	Current	33% Input Reduction		Current	33% Input Reduction
Year	Load (t/yr)	Load (t/yr)	Year	Load (t/yr)	Load (t/yr)
1997	7.0	5.3	*1997*	6.5	5.0
1998	6.7	5.2	*1998*	6.2	4.9
1999	9.5	7.0	*1999*	8.8	6.6
2000	9.6	7.0	*2000*	8.9	6.6
2001	5.7	4.2	*2001*	5.2	3.9
2002	7.5	5.5	*2002*	7.0	5.1
2003	10.1	7.4	*2003*	9.5	6.9
2004	6.1	4.6	*2004*	5.7	4.3
2005	10.9	8.0	*2005*	10.2	7.5
2006	2.1	1.7	*2006*	2.0	1.6
Average	**7.5**	**5.6**	**Average**	**7.0**	**5.2**
Median Winter Conc (mg/L):			**Median Winter Conc (mg/L):**		
SQUARE	**1.06**	**0.75**	**SQUARE**	**1.07**	**0.75**
Target	**0.75**		**Observed**	**1.00**	
Load Target (t/yr)		**5.6**			
Load Reduction Target (t/yr)		**1.9**			
Required Reduction (%)		**26%**			
Time Required (yr)		**30**			

Yule Brook – Source separation

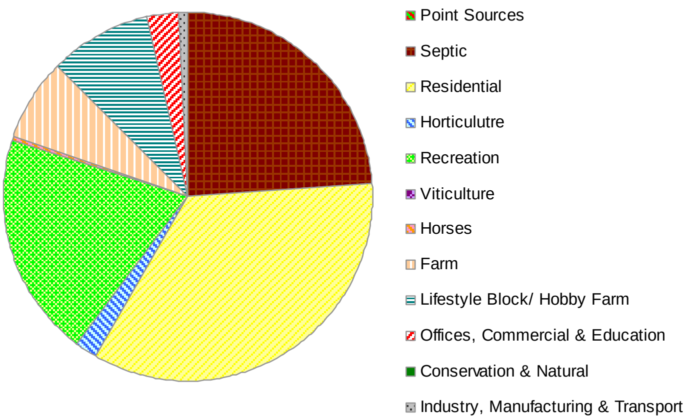
Phosphorus (t/yr)

Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	0.33	0.00	0.12	0.08	0.02	0.02	0.00	0.00	0.04	0.00	0.02	0.00	0.02
1998	0.28	0.00	0.10	0.07	0.02	0.02	0.00	0.00	0.03	0.00	0.02	0.00	0.02
1999	0.34	0.00	0.12	0.09	0.02	0.03	0.00	0.00	0.04	0.00	0.02	0.00	0.02
2000	0.49	0.00	0.13	0.10	0.15	0.03	0.00	0.00	0.02	0.01	0.02	0.00	0.02
2001	0.31	0.00	0.08	0.06	0.12	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.01
2002	0.49	0.05	0.15	0.14	0.22	0.07	0.05	0.05	0.05	0.06	0.07	0.05	0.07
2003	0.65	0.09	0.21	0.21	0.32	0.12	0.09	0.09	0.09	0.10	0.12	0.09	0.11
2004	0.42	0.05	0.14	0.12	0.20	0.07	0.05	0.05	0.05	0.05	0.06	0.05	0.06
2005	0.78	0.05	0.20	0.21	0.37	0.09	0.05	0.06	0.05	0.07	0.09	0.05	0.08
2006	0.18	0.00	0.05	0.04	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Load (non adj)	0.43	0.02	0.13	0.11	0.15	0.05	0.02	0.03	0.04	0.03	0.04	0.02	0.04
Load (t/yr)	**0.43**	**0.00**	**0.11**	**0.09**	**0.13**	**0.02**	**0.00**	**0.00**	**0.02**	**0.01**	**0.02**	**0.00**	**0.02**
Load (%)	**100.0%**	**0.0%**	**26.1%**	**21.8%**	**31.4%**	**5.6%**	**0.0%**	**0.8%**	**3.7%**	**1.6%**	**4.6%**	**0.0%**	**4.5%**



Nitrogen (t/yr)

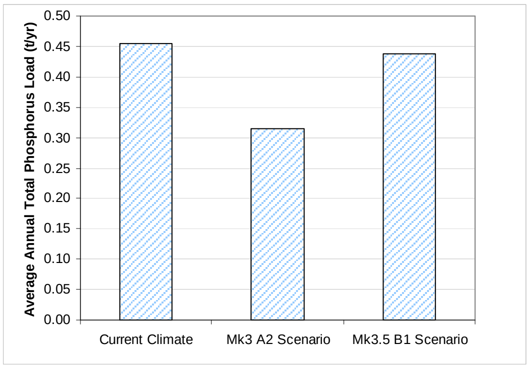
Year	*Current*	*Point Sources*	*Septic*	*Residential*	*Horticulutre*	*Recreation*	*Viticulture*	*Horses*	*Farm*	*Lifestyle Block/ Hobby Farm*	*Offices, Commercial & Education*	*Conservation & Natural*	*Industry, Manufacturing & Transport*
1997	7.0	0.2	1.9	2.2	0.3	1.5	0.2	0.2	0.9	0.7	0.4	0.2	0.3
1998	6.7	0.2	1.8	2.2	0.3	1.4	0.2	0.2	0.8	0.7	0.3	0.2	0.2
1999	9.5	0.2	2.4	3.0	0.3	2.1	0.2	0.3	1.1	0.9	0.4	0.2	0.3
2000	9.6	0.3	2.4	3.2	0.4	2.1	0.3	0.3	1.0	1.0	0.5	0.3	0.3
2001	5.7	0.2	1.5	2.0	0.3	1.1	0.2	0.2	0.5	0.6	0.3	0.2	0.2
2002	7.5	0.2	1.8	2.6	0.3	1.6	0.2	0.2	0.6	0.8	0.4	0.2	0.2
2003	10.1	0.2	2.4	3.7	0.4	2.3	0.2	0.3	0.7	1.1	0.5	0.2	0.3
2004	6.1	0.1	1.5	2.3	0.3	1.2	0.1	0.2	0.5	0.7	0.3	0.1	0.2
2005	10.9	0.2	2.5	4.2	0.5	2.3	0.2	0.3	0.7	1.2	0.6	0.2	0.3
2006	2.1	0.1	0.7	0.9	0.2	0.3	0.1	0.1	0.2	0.3	0.2	0.1	0.1
Load (non adj)	7.5	0.2	1.9	2.6	0.3	1.6	0.2	0.2	0.7	0.8	0.4	0.2	0.3
Load (t/yr)	**7.5**	**0.0**	**1.8**	**2.6**	**0.1**	**1.5**	**0.0**	**0.0**	**0.6**	**0.7**	**0.2**	**0.0**	**0.1**
Load (%)	**100.0%**	**0.0%**	**23.9%**	**34.4%**	**1.9%**	**19.7%**	**0.0%**	**0.3%**	**7.3%**	**8.8%**	**2.7%**	**0.0%**	**0.9%**



Yule Brook – Climate change

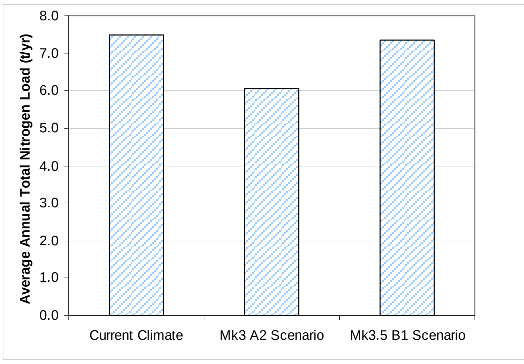
Phosphorus

Year	At Catchment Outlet		
	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	0.41	0.25	0.39
2058	0.41	0.27	0.39
2059	0.49	0.34	0.47
2060	0.56	0.42	0.54
2061	0.33	0.24	0.32
2062	0.46	0.30	0.44
2063	0.58	0.42	0.56
2064	0.39	0.27	0.38
2065	0.75	0.52	0.71
2066	0.19	0.13	0.18
Average Load for RF Sequence (t/yr)	**0.46**	**0.32**	**0.44**



Nitrogen

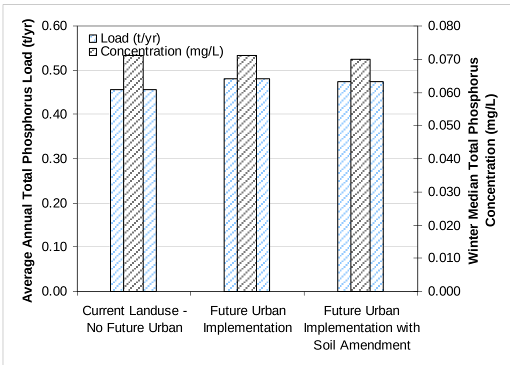
Year	At Catchment Outlet		
	Current Climate Load (t/yr)	Mk3 A2 Climate Change Scenario Load (t/yr)	Mk3.5 B1 Climate Change Scenario Load (t/yr)
2057	7.1	4.5	6.9
2058	7.0	5.1	6.9
2059	9.5	8.3	9.4
2060	9.4	8.6	9.2
2061	5.6	4.2	5.5
2062	7.3	5.4	7.2
2063	9.9	8.8	9.8
2064	6.1	4.5	6.0
2065	10.8	9.2	10.6
2066	2.2	1.8	2.2
Average Load for RF Sequence (t/yr)	**7.5**	**6.1**	**7.4**



Yule Brook – Future urban

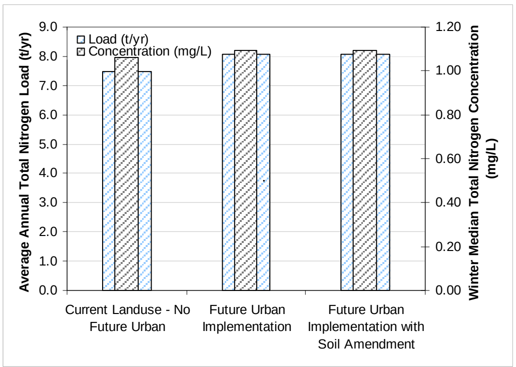
Phosphorus

Year	At Catchment Outlet		
	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	0.41	0.43	0.42
2058	0.41	0.43	0.42
2059	0.49	0.52	0.51
2060	0.56	0.60	0.59
2061	0.33	0.35	0.34
2062	0.46	0.48	0.48
2063	0.58	0.62	0.61
2064	0.39	0.42	0.41
2065	0.75	0.78	0.77
2066	0.19	0.20	0.20
Average Load for RF Sequence (t/yr)	**0.46**	**0.48**	**0.47**
Median Winter Concentration (mg/L)	**0.071**	**0.071**	**0.070**



Nitrogen

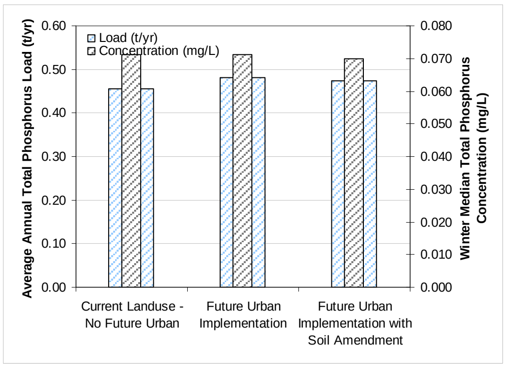
Year	At Catchment Outlet		
	Current Landuse - No Future Urban Load (t/yr)	Future Urban Implementation Load (t/yr)	Future Urban Implementation with Soil Amendment Load (t/yr)
2057	7.1	7.7	7.7
2058	7.0	7.6	7.6
2059	9.5	10.1	10.1
2060	9.4	10.0	10.0
2061	5.6	6.1	6.1
2062	7.3	8.0	8.0
2063	9.9	10.5	10.5
2064	6.1	6.7	6.7
2065	10.8	11.5	11.5
2066	2.2	2.5	2.5
Average Load for RF Sequence (t/yr)	**7.5**	**8.1**	**8.1**
Median Winter Concentration (mg/L)	**1.06**	**1.09**	**1.09**



Yule Brook – Soil amendment in rural land use

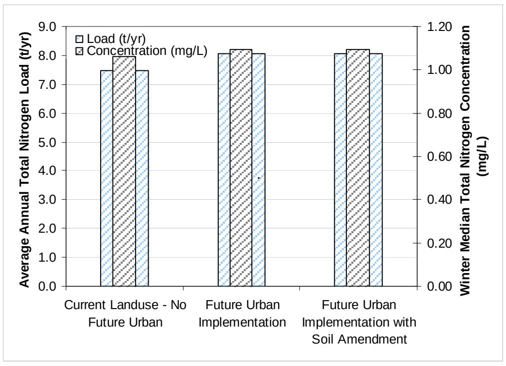
Phosphorus

Year	At Catchment Outlet *Current Landuse - No Future Urban Load (t/yr)*	*Future Urban Implementation Load (t/yr)*	*Future Urban Implementation with Soil Amendment Load (t/yr)*
2057	0.41	0.43	0.42
2058	0.41	0.43	0.42
2059	0.49	0.52	0.51
2060	0.56	0.60	0.59
2061	0.33	0.35	0.34
2062	0.46	0.48	0.48
2063	0.58	0.62	0.61
2064	0.39	0.42	0.41
2065	0.75	0.78	0.77
2066	0.19	0.20	0.20
Average Load for RF Sequence (t/yr)	**0.46**	**0.48**	**0.47**
Median Winter Concentration (mg/L)	**0.071**	**0.071**	**0.070**



Nitrogen

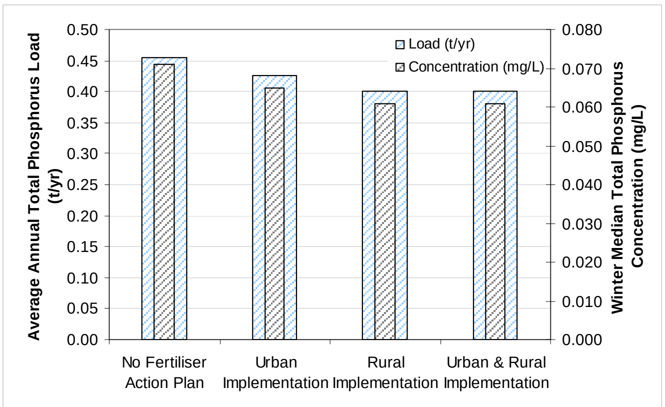
Year	At Catchment Outlet *Current Landuse - No Future Urban Load (t/yr)*	*Future Urban Implementation Load (t/yr)*	*Future Urban Implementation with Soil Amendment Load (t/yr)*
2057	7.1	7.7	7.7
2058	7.0	7.6	7.6
2059	9.5	10.1	10.1
2060	9.4	10.0	10.0
2061	5.6	6.1	6.1
2062	7.3	8.0	8.0
2063	9.9	10.5	10.5
2064	6.1	6.7	6.7
2065	10.8	11.5	11.5
2066	2.2	2.5	2.5
Average Load for RF Sequence (t/yr)	**7.5**	**8.1**	**8.1**
Median Winter Concentration (mg/L)	**1.06**	**1.09**	**1.09**



Yule Brook – *Fertiliser action plan*

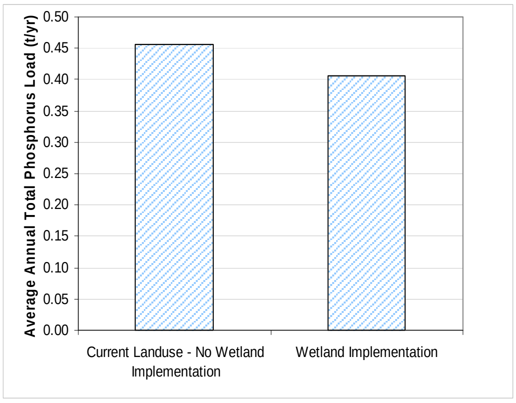
Phosphorus

Year	At Catchment Outlet *No Fertiliser Action Plan (t/yr)*	*Urban Implementation (t/yr)*	*Rural Implementation (t/yr)*	*Urban and Rural Implementation (t/yr)*
2057	0.41	0.38	0.36	0.36
2058	0.41	0.38	0.35	0.35
2059	0.49	0.45	0.43	0.43
2060	0.56	0.52	0.49	0.49
2061	0.33	0.30	0.28	0.28
2062	0.46	0.42	0.40	0.40
2063	0.58	0.55	0.51	0.51
2064	0.39	0.37	0.35	0.35
2065	0.75	0.70	0.67	0.67
2066	0.19	0.17	0.16	0.16
Average Load for RF Sequence (t/yr)	**0.46**	**0.43**	**0.40**	**0.40**
Median Winter Concentration (mg/L)	**0.071**	**0.065**	**0.061**	**0.061**

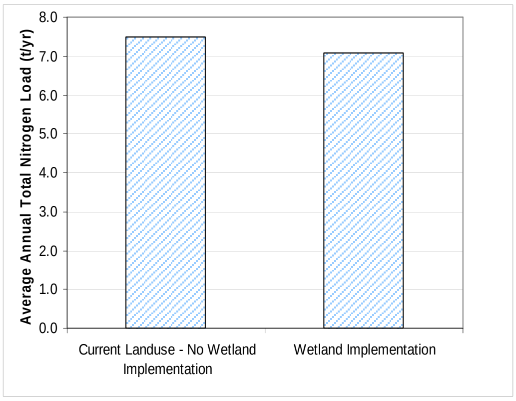


Yule Brook – Wetland implementation

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	0.41	0.36
2058	0.41	0.36
2059	0.49	0.43
2060	0.56	0.50
2061	0.33	0.29
2062	0.46	0.41
2063	0.58	0.52
2064	0.39	0.35
2065	0.75	0.66
2066	0.19	0.17
Average Load for RF Sequence (t/yr)	**0.46**	**0.41**

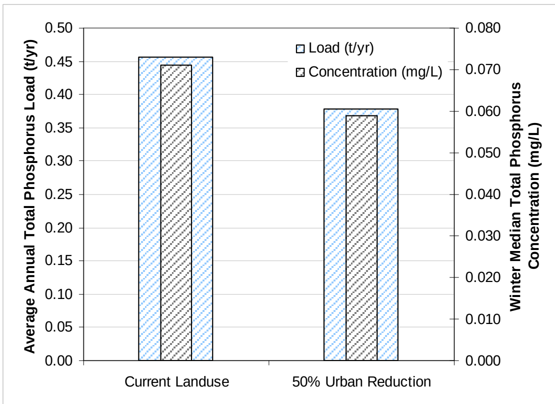


Nitrogen		
	At Catchment Outlet	
Year	Current Landuse - No Wetland Implementation (t/yr)	Wetland Implementation Load (t/yr)
2057	7.1	6.7
2058	7.0	6.6
2059	9.5	9.0
2060	9.4	8.9
2061	5.6	5.3
2062	7.3	6.9
2063	9.9	9.4
2064	6.1	5.8
2065	10.8	10.2
2066	2.2	2.1
Average Load for RF Sequence (t/yr)	**7.5**	**7.1**



Yule Brook – Urban 50% reduction

Phosphorus		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	0.41	0.34
2058	0.41	0.34
2059	0.49	0.40
2060	0.56	0.47
2061	0.33	0.27
2062	0.46	0.38
2063	0.58	0.48
2064	0.39	0.33
2065	0.75	0.62
2066	0.19	0.15
Average Load for RF Sequence (t/yr)	**0.46**	**0.38**
Median Winter Concentration (mg/L)	**0.071**	**0.059**



Nitrogen		
	At Catchment Outlet	
Year	Current Landuse Load (t/yr)	50% urban reduction Load (t/yr)
2057	7.1	4.9
2058	7.0	4.9
2059	9.5	6.5
2060	9.4	6.5
2061	5.6	3.9
2062	7.3	5.1
2063	9.9	6.8
2064	6.1	4.3
2065	10.8	7.4
2066	2.2	1.6
Average Load for RF Sequence (t/yr)	**7.5**	**5.2**
Median Winter Concentration (mg/L)	**1.06**	**0.72**