AGGREGATED EMISSIONS OF TOTAL NITROGEN AND TOTAL PHOSPHORUS TO THE BLACKWOOD AND SCOTT RIVER CATCHMENTS, WESTERN AUSTRALIA

A SUBMISSION TO THE NATIONAL POLLUTANT INVENTORY

Prepared by

Resource Science Division

Water and Rivers Commission

WATER AND RIVERS COMMISSION

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Summary

The Blackwood and Scott River catchments in Western Australia encompass an area of 2.25 million hectares, which has large variations in physiography, rainfall, soil type and land use. The catchment outlet is at Hardy Inlet at Augusta. Aggregated emissions of total nitrogen (TN) and total phosphorus (TP) to the environment from diffuse and point sources in the catchment are modelled with the Catchment Management Support System (CMSS). These are reported to the National Pollutant Inventory for each land use in specified subcatchments. The total average annual emissions are estimated to be 1,891 tonnes of TN and 156 tonnes of TP. Intensive land uses in the high rainfall areas of the catchment close to Hardy Inlet contribute disproportionately large amounts of nutrient to the environment compared to areas further east. Management actions aimed at reducing the amount of nutrient reaching Hardy Inlet should concentrate on these land uses.

The TN and TP loads in streams at many locations in the catchment are calculated from concentration and flow data. In order to compare these loads with emissions estimated by CMSS, the in-stream assimilation of nutrients is modelled. The TN and TP average annual loads to Hardy Inlet are estimated to be 1,540 tonnes and 43 tonnes respectively. The Blackwood River and its tributaries appear to be assimilating proportionally greater amounts of phosphorus and smaller amounts of nitrogen than the Scott River. Management actions aimed at reducing sediment loads to the rivers and improving the health of riparian vegetation should be encouraged, especially in the Blackwood catchment.

1 Introduction

The National Pollutant Inventory (NPI) is a national database, designed to provide the community, industry and government with information on the types and amounts of certain substances being emitted to the air, land and water. The NPI is managed by Environment Australia (Department of the Environment and Heritage), with environmental agencies from each State and Territory participating in the program.

Since the NPI was introduced in 1998, Australian industrial facilities triggering certain conditions have been required to estimate and report emissions of NPI substances annually. The NPI program also requires that aggregated emissions from priority water catchments will be estimated by the relevant State or Territory environment authority. The NPI database is accessible on the internet and can be viewed at <www.npi.gov.au>**.**

There are two reporting levels for nutrient pollution. Annual aggregated emissions are defined to be total nitrogen (TN) and total phosphorus (TP) emissions to the environment from:

1) point-source facilities which discharge less than 15 tonnes per annum of TN and/or 3 tonnes per annum of TP, and
2) diffuse sources.

Point sources which discharge above these thresholds are known as “reporting facilities” and are required to report directly to the NPI.

This report examines the annual aggregated emissions of TN and TP to the Blackwood and Scott River catchments in Western Australia. The combined catchment drains an area of approximately 2.25 million hectares and has large variations in physiography, climate and soils type. The catchment is approximately 76% cleared and supports many different land uses, from wheat / sheep farming in the east to horticulture and dairy farming in the high rainfall areas in the west. The Blackwood-Scott catchment drains to Hardy Inlet and thus to the Southern Ocean at Augusta.

The aggregated emissions are estimated using the Catchment Management Support System (CMSS) model, as discussed in Letcher et al (1999). In keeping with the NPI guidelines, the aggregated emissions assume little assimilation of nutrient across large catchments and no in-stream assimilation.

Stream nutrient loads of TN and TP are calculated for many locations in the Blackwood-Scott catchment using flow and nutrient concentration data. In order to compare the nutrient emissions estimated by CMSS with the observed stream loads, the assimilation of nutrients in the waterways is also modelled. CMSS does this by applying a simple exponential decay function which depends on the travel time and an attenuation rate coefficient.

The Blackwood-Scott catchment is divided into 21 subcatchments. The aggregated emissions are estimated for each subcatchment, as well as the assimilated stream load at the catchment outlet. The TN and TP loads from each of the rivers to Hardy Inlet are also estimated.

2 Catchment description

2.1 Location

The Blackwood-Scott catchment, displayed in Figure 2.1, is the second largest catchment (after the Avon) in the south west of Western Australia and covers an area of approximately 2.25 million hectares. The catchment is elongated with an axis that tends west south-west. The catchment is bounded by latitudes $32^0\ 35'$ and $34^0\ 25'$ south and longitudes 115^0 and $118^0\ 25'$ east. The Blackwood and Scott rivers drain into the Hardy Inlet and thus the Southern Ocean. The eastern extent of the catchment is east of Kukerin and Nyabing approximately 300 km inland. Major towns within the catchment include Narrogin, Wagin, Katanning and Dumbleyung in the east, Kojonup and Boyup Brook in the central region, and Bridgetown, Nannup and Augusta in the south west.

2.2 Climate

The Blackwood-Scott catchment experiences a Mediterranean climate in the western region; rainfall decreases to the east to a semi-arid climate. Temperatures vary from warm to hot in summer, mild during late autumn and spring, to cold with occasional frosts in winter.

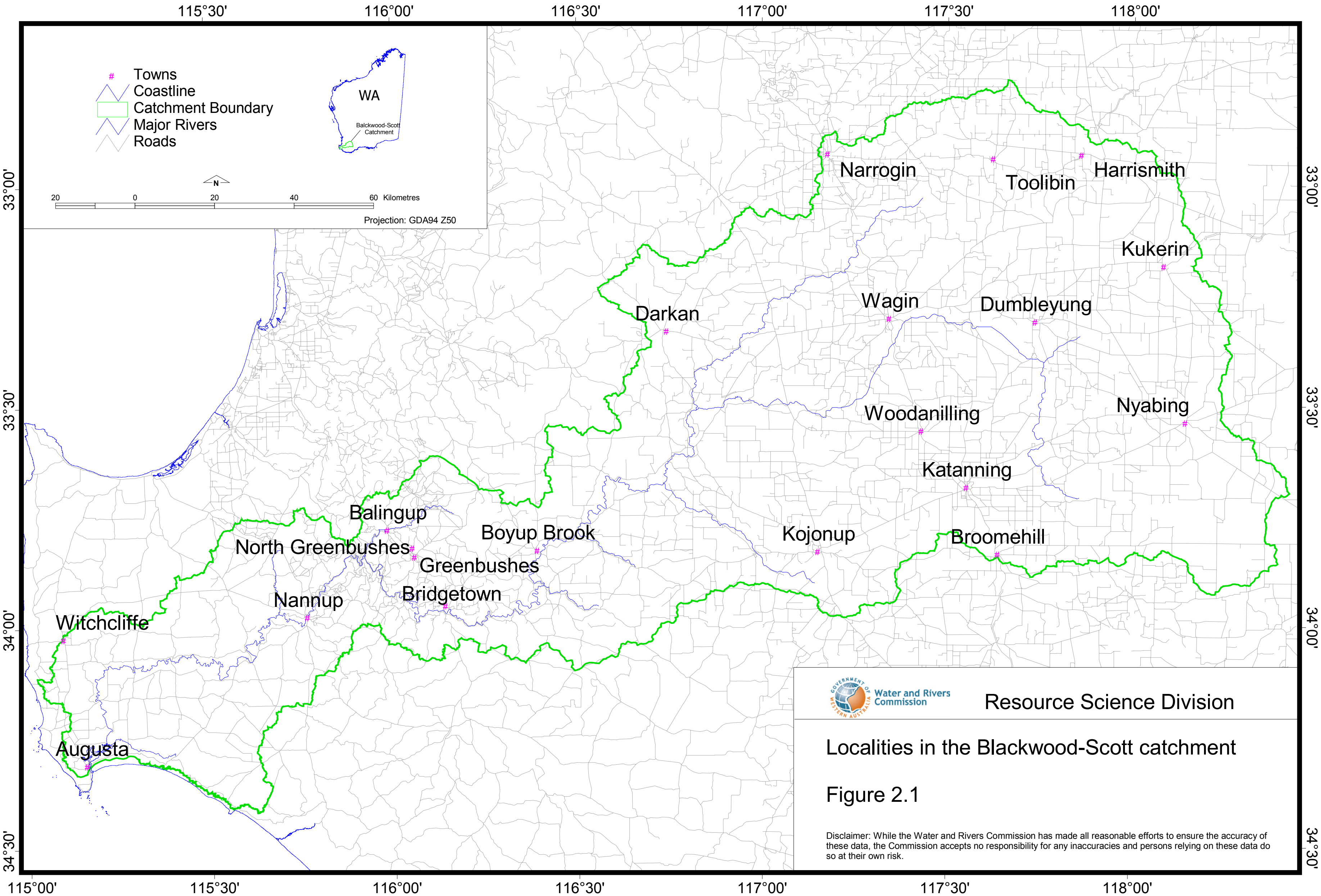
Average annual rainfall decreases from approximately 1200 mm in the proximity of Hardy Inlet to approximately 400 mm at the eastern extreme of the catchment. The isohyets determined from long-term rainfall records are displayed in Figure 2.2. Figure 2.2 also contains the average annual rainfall for the years 1996 to 2000 for each of the subcatchments of the Blackwood-Scott. Regular seasonal rainfall occurs between May and October. Summer rainfall is limited, but occasional thunderstorms and tropical cyclones can produce short periods of heavy rainfall. The cyclonic activity in January 1982 caused a flood in the Blackwood River thought to be the largest since European settlement (Bowman and Ruprecht, 2000).

Except in the very western margin of the catchment, the annual evaporation exceeds annual rainfall. The annual average evaporation ranges from approximately 900 mm in the west to 1900 mm in the east (Figure 2.2).

2.3 Physiography

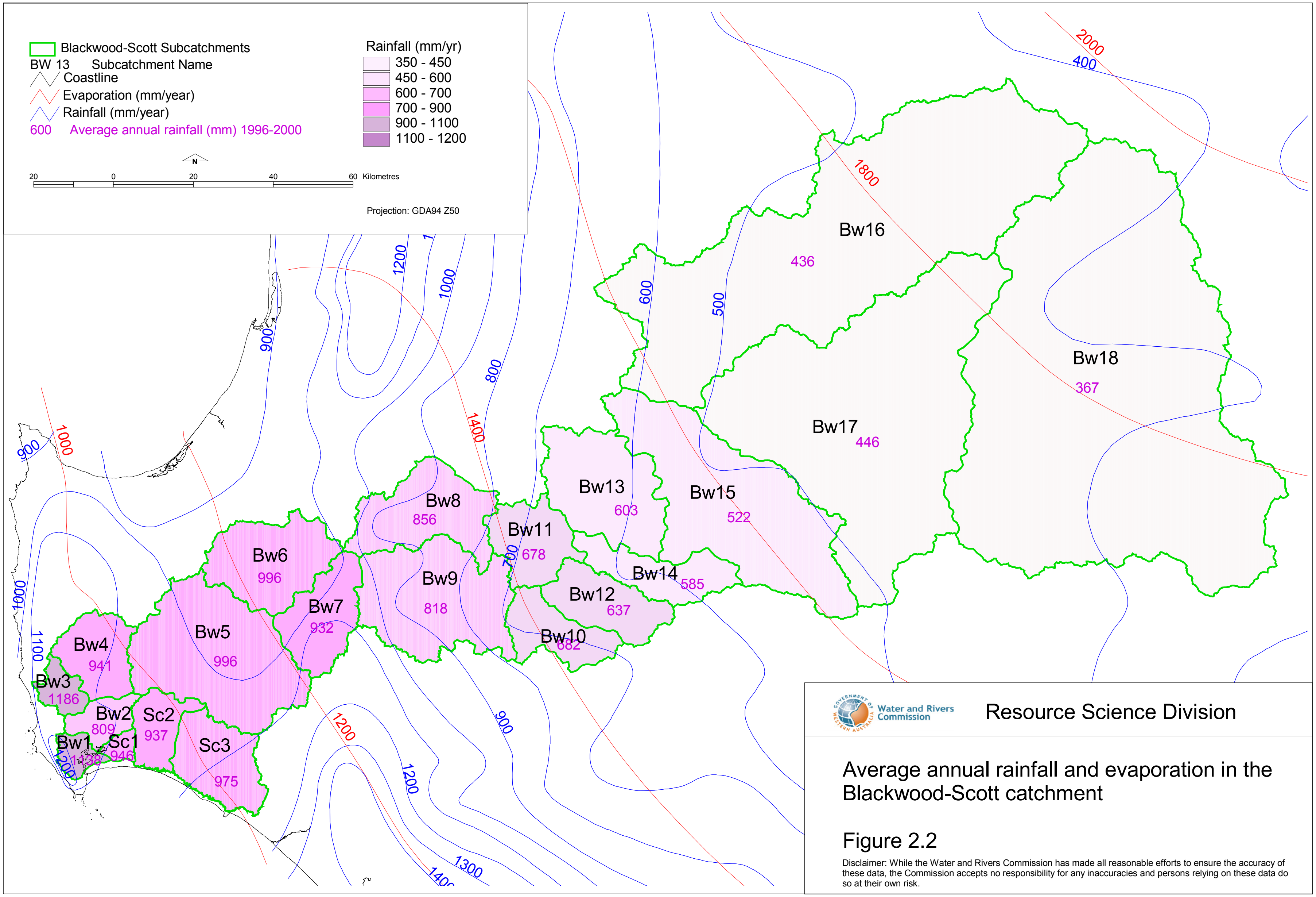
The physiography of the Blackwood-Scott catchment is shown in Figure 2.3. Most of the catchment lies to the east of the Darling Scarp on the Darling Plateau, where it is divided into three main zones according to the landforms and soil types. These are the Zone of Ancient Drainage (Upper Catchment), the Zone of Rejuvenated Drainage (Upper-middle Catchment) and the Darling Range (Lower-middle Catchment). The remainder of the catchment, located west of the Darling Scarp, drains the Blackwood Plateau, Scott Coastal Plain and the Leeuwin-Naturaliste Ridge (Lower Catchment) and is termed the Donnybrook Sunklands.

The Upper Catchment (Zone of Ancient Drainage) is characterised by low topographic gradients. Landforms consist of broad flat-floored valleys containing thick sequences of valley-fill, often inclusive of Tertiary palaeochannel sediments and salt lake systems. Surface waters tend to drain



Localities in the Blackwood-Scott catchment

Figure 2.1



Average annual rainfall and evaporation in the Blackwood-Scott catchment

Figure 2.2

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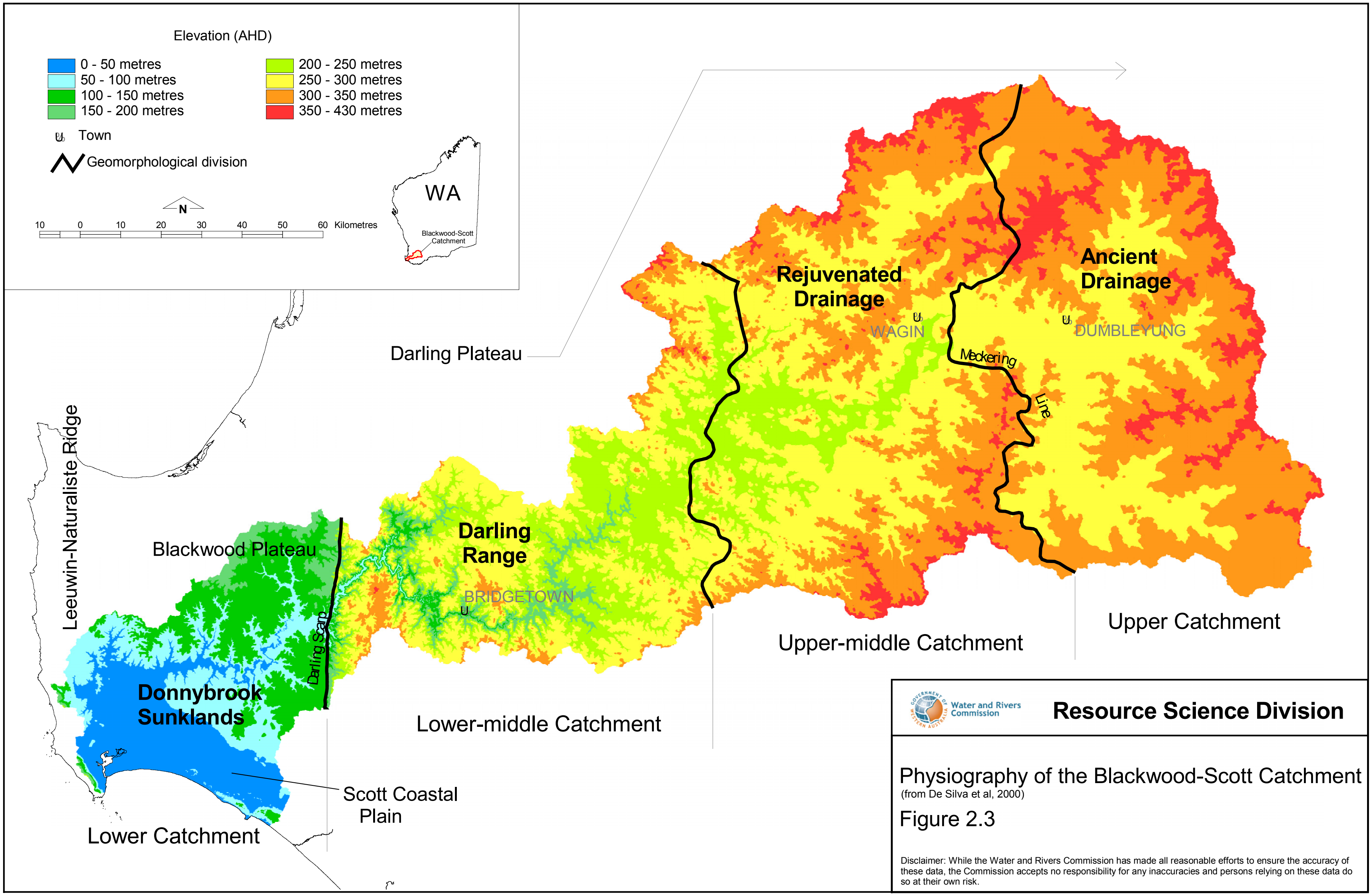

Physiography of the Blackwood-Scott Catchment
(from De Silva et al, 2000)

Figure 2.3

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internally in this zone and unless Lake Dumbleyung overflows (thought to have occurred three times in the last century) the Upper Catchment does not contribute flow to the Blackwood River.

Topographic gradients are greater in the Middle Catchment. The depth of incision of the Blackwood River and its tributaries increases westwards. This corresponds to a decrease in the thickness of valley fill, as the increased topographic gradients are more effective in the removal of weathered and transported material.

The Lower Catchment, primarily the Donnybrook Sunklands, has low surface elevations and the principal drainage channels are less incised than those in the Middle Catchment.

2.4 Geology

Figure 2.4 displays the geology of the Blackwood-Scott catchment. Over 85% of the catchment (Upper and Middle Catchments) drains the Archaean (and minor) Proterozoic basement rocks of the Yilgarn Shield (De Silva et al, 2000). The remaining 15% of the catchment (Lower Catchment) drains the predominantly sedimentary Mesozoic rocks of the southern Perth Basin and the Proterozoic crystalline rocks of the Leeuwin Complex. Within the Yilgarn Shield, Permian sedimentary rocks are preserved in the Boyup Basin. Surficial sediments, primarily Tertiary-Quaternary in age, occur in all three geological provinces.

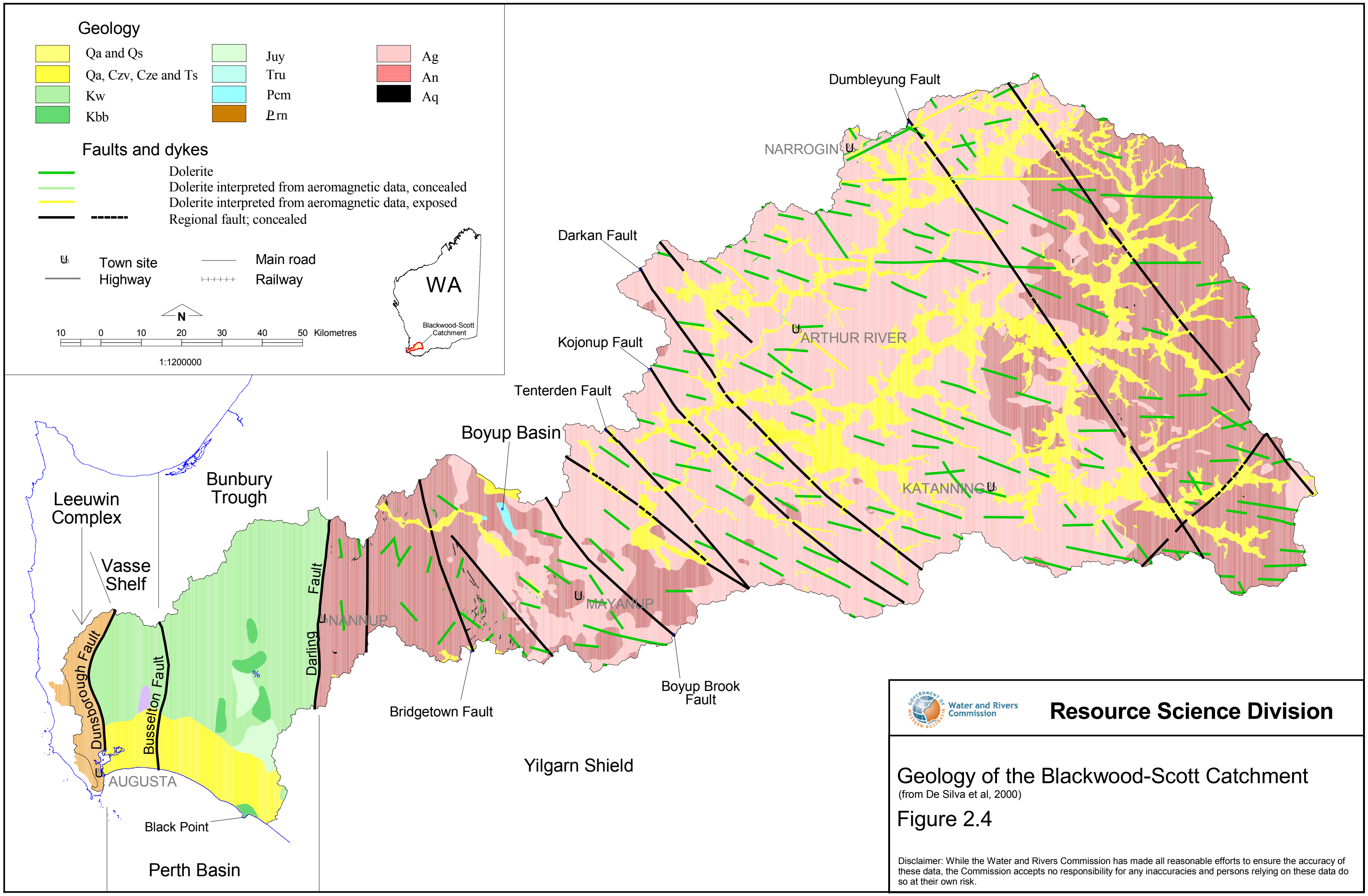
Basement rocks of the Yilgarn Shield comprise mainly heterogeneous Archaean gneiss complexes and younger, less intensely deformed, Archaean granitoid rocks. A number of suites of Proterozoic dykes and veins of predominantly north-west orientation have intruded the basement rocks. Faults dissecting the shield display similar trends (De Silva et al., 2000).

The southern Perth Basin is divided into two major structural units, the Bunbury Trough and the Vasse Shelf. The Bunbury Trough, which lies west of the Darling Scarp, contains Palaeozoic sedimentary rocks which range in age from Permian to Early Cretaceous, down to depths of 8000 metres. The Vasse Shelf which lies to the west of the Bunbury Trough contains up to 3000 metres of sediments. Jurassic and Cretaceous sedimentary rocks commonly subcrop on these structural units and are overlain by Early Tertiary and Quaternary age sediments (De Silva et al., 2000). The Leeuwin Complex bounds the southern Perth Basin to the west.

2.5 Hydrogeology

Hydrogeology of the Blackwood River Catchment, Western Australia (De Silva et al., 2000) provides a comprehensive description of the hydrogeology of the catchment and explains variations in groundwater yield and quality. De Silva’s study focuses particularly on land salinisation from increased aquifer recharge and subsequent watertable rises. Dryland salinity is a serious environmental and ecological problem facing the drier eastern portion of the catchment.

The major hydrogeological provinces of the Blackwood-Scott catchment are the Yilgarn South West Province and the Perth Basin. The Leeuwin province and Boyup Basin form minor provinces. Aquifers exist in the weathered profile and fractures and joints of crystalline rocks (prevalent in the Yilgarn South West Province and the Leeuwin province) and in unconsolidated and lithified sediments. However, faults, fractures and joints are generally localised and have therefore limited groundwater potential. Similarly, the weathered profile of crystalline rocks contains only localised



Geology of the Blackwood-Scott Catchment
(from De Silva et al, 2000)

Figure 2.4

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groundwater as these materials exhibit variable but generally low porosity and hydraulic conductivity (Clarke et al., 2000). Consequently, substantial supplies of groundwater are generally restricted to the sedimentary rocks within the Perth Basin.

The distribution of groundwater within the catchment is apparent from baseflows to streams and rivers. In the Yilgarn South West Province (east of the Darling Fault) baseflow generally ceases during the dry summer months, whereas baseflow is evident all year round in the Blackwood River where it flows through the Perth Basin.

2.6 Soils

As discussed above, the Upper and Middle Catchments lie on the Yilgarn Shield. The basement rocks consist of Archaean gneiss, granite, migmatite and granulite. Deep weathering during the Tertiary Period formed a lateritic profile which once covered this area. This lateritic plateau still covers large areas of the Middle Catchment, but has been partially or completely removed by erosion from most of the Upper Catchment. A variety of sedimentary deposits are also found overlying the Yilgarn Shield.

Gravelly soils and sands are associated with the lateritic profile. In the Upper Catchment where the ironstone capping has been removed, grey sandy and loamy duplex soils prevail.

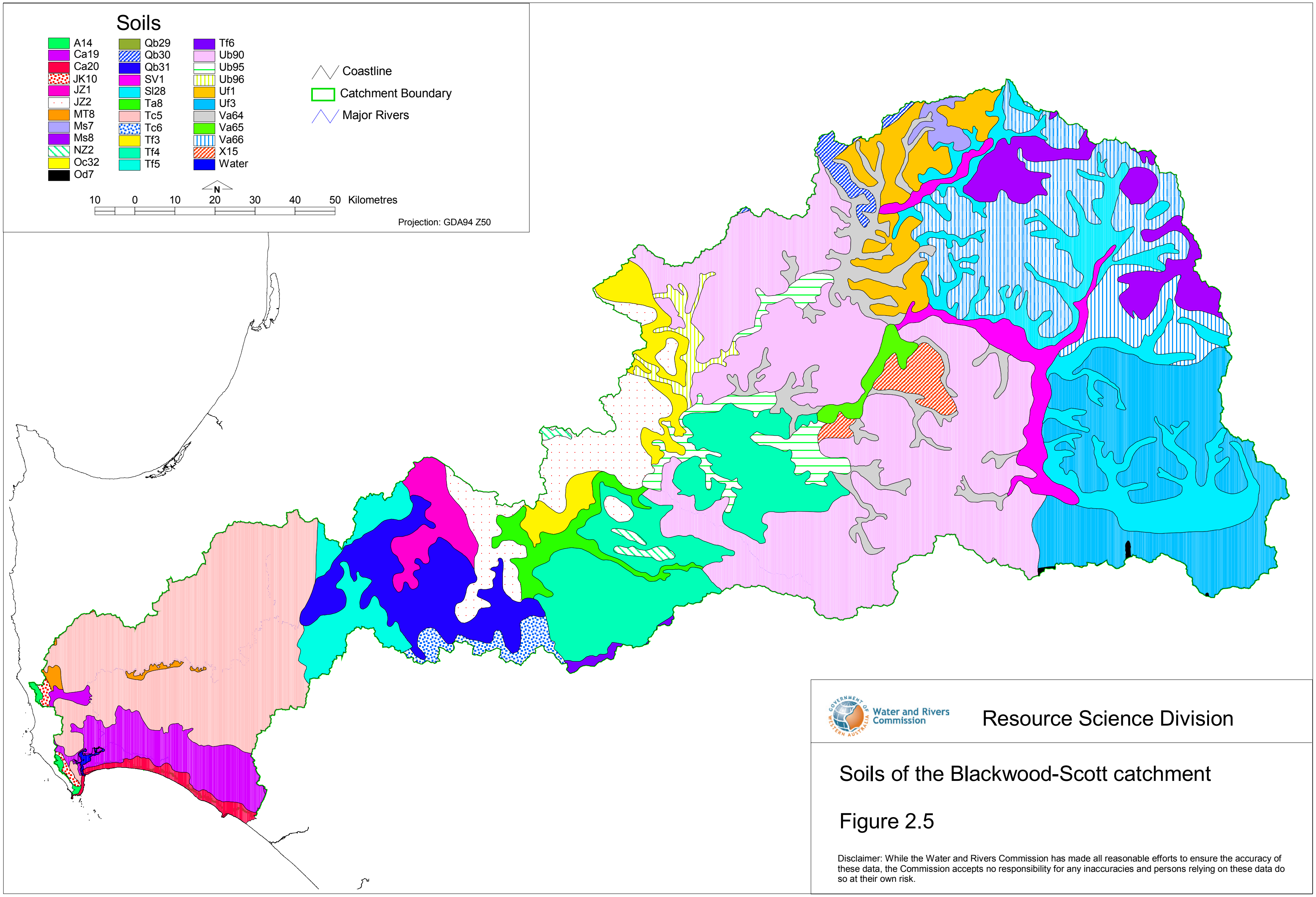
In the Lower Catchment, the Donnybrook Sunklands west of the Darling Scarp, there is a dramatic change in the geology and land forms. The underlying geology is the sedimentary rocks of the Perth Basin. Laterite is widespread, giving rise to yellow-brown and grey sandy gravels and sands. At the bottom of the catchment, the Scott coastal plain consists of poorly drained deep loose sands.

A soil map for the Blackwood-Scott catchment is given in Figure 2.5. This is an extraction from the Atlas of Australian Soils. These data were collected from field soil survey and interpretation of aerial photography, and were digitised from 1:250,000 map sheets. The stated positional accuracy is +/- 500m, which for the purpose of modelling at a subcatchment scale is considered adequate. Appendix A contains descriptions of the soil types shown in Figure 2.5.

2.7 Surface drainage

The streams, lakes and subcatchments of the Blackwood-Scott catchment are displayed in Figure 2.6. For the purposes of this study, the catchment has been divided into 21 subcatchments. Subcatchment Bw1 drains the land immediately surrounding Hardy Inlet. Seventeen subcatchments have been defined for the Blackwood River system and three for the Scott River.

The subcatchment boundaries have been defined to coincide with the confluences of the major tributaries and/or the gauging stations. There are three large subcatchments in the east, Bw16, Bw17 and Bw18, which encompass the regions of Ancient Drainage and Rejuvenated Drainage. Bw18 is the largest and has an area of 627,113 ha. The subcatchments in the Lower-middle and Lower Catchment are smaller and range in size from 4,930 ha for Sc1 to 159,478 ha for Bw15. Table 2.1 lists the subcatchments, their areas and their annual average rainfall for the years 1996 to 2000. A brief description of each subcatchment is also given.



Soils of the Blackwood-Scott catchment

Figure 2.5

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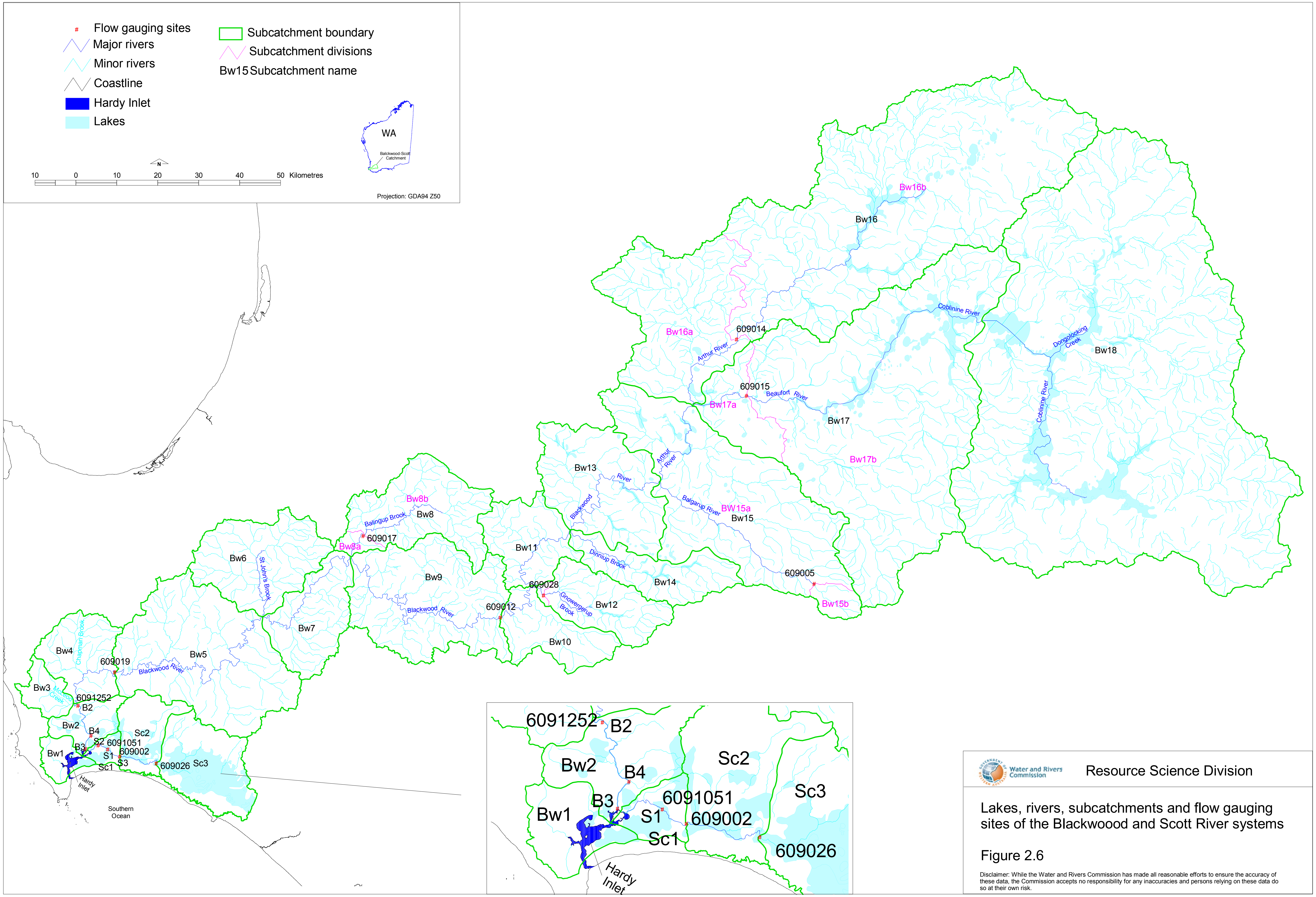


Lakes, rivers, subcatchments and flow gauging sites of the Blackwoood and Scott River systems

Figure 2.6

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

Table 2.1: Subcatchment areas and average annual rainfall for the years 1996 to 2000.

Subcatchment	Area (ha)	Average Annual Rainfall (mm)	Description
Bw1	9260	1138	Hardy Inlet Environs
Bw2	15148	809	Blackwood River downstream of Alexandra Bridge
Bw3	11496	1186	McLeod Creek
Bw4	32438	941	Chapman Brook and Blackwood River between Alexandra Bridge and Hut Pool
Bw5	113266	996	Blackwood River between Hut Pool and St John's Brook confluence.
Bw6	57039	996	St John's Brook
Bw7	41059	932	Blackwood River near Nannup
Bw8	59472	856	Balingup Brook
Bw9	92867	818	Blackwood River near Bridgetown
Bw10	32579	682	Blackwood River
Bw11	36085	678	Blackwood River near Boyup Brook
Bw12	38406	637	Gnowergerup Brook
Bw13	72381	603	Blackwood River
Bw14	37285	585	Dinninup Brook
Bw15	159478	522	Lower Arthur River and Balgarup River
Bw16	409565	436	Arthur River north
Bw17	337805	446	Beaufort River and Coblinine River
Bw18	627113	367	Lake Dumbleyung catchment
Sc1	4930	946	Scott River downstream of Brennan's Ford
Sc2	21969	937	Scott River between Brennan's Ford and Milyeannup
Sc3	41195	975	Scott River upstream of Milyeannup

2.8 Vegetation and land use

Because of the large variations in rainfall, soil and physiography across the Blackwood-Scott catchment the native vegetation is highly variable. Since European settlement, much of this vegetation has been cleared for agriculture, particularly in the wheatbelt of the catchment. Much of the jarrah-marri forest in the higher rainfall area west of Bridgetown remains (relatively) intact, though much of this was selectively logged in the first half of last century. The areas of deep-rooted vegetation, that is remnant vegetation and plantation forestry, have been determined by the Land Monitor project <www.landmonitor.wa.gov.au> and are listed as a percentage area for each subcatchment in Table 2.2. The percentage of deep-rooted vegetation for the whole catchment is 26%. As plantation forestry occupies approximately 2% of the catchment, clearing in the Blackwood-Scott is estimated to have occurred in approximately 76% of the catchment.

The remnant native vegetation on the Scott coastal plain consists of peppermint woodlands near the coast; areas with wetter soils support paperbarks, sedgelands, reed swamps and occasional heath. Some karri forest exists on the Leeuwin-Naturaliste Ridge. The native vegetation of the remainder of the Lower Catchment consists primarily of jarrah-marri forest. The fringes of the Blackwood River support some flooded gum (*Eucalyptus rudis*), blackbutt and bullich.

The native vegetation of the Lower-middle Catchment consists primarily of medium jarrah-marri forest in the west. This changes to marri-wandoo woodland, but includes areas of jarrah, salmon gum and yate as the rainfall drops to the east. Pockets of casuarina and paperbark exist, depending on the local landscape conditions.

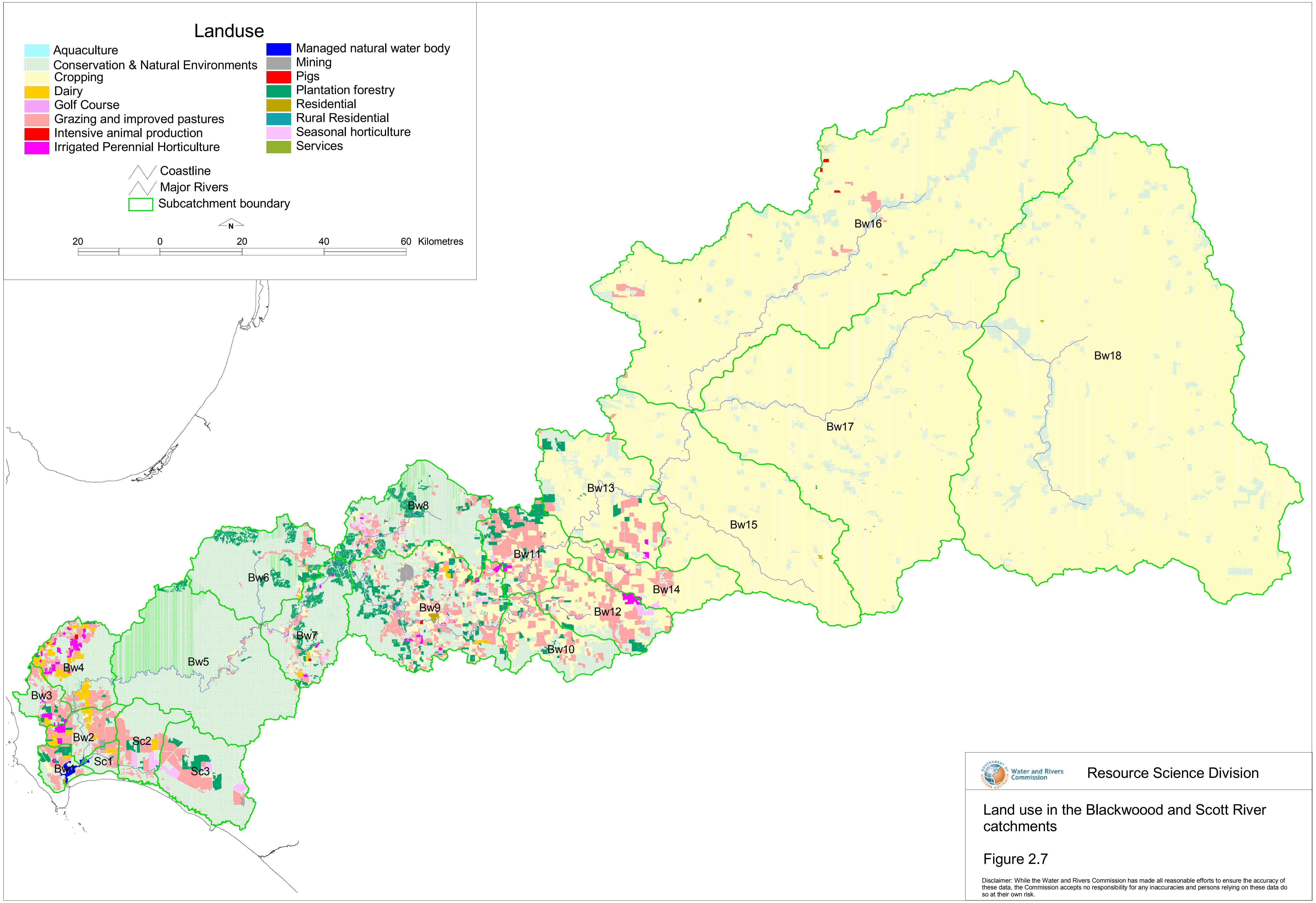
The amount of remnant native vegetation in the Upper-middle and Upper Catchment is low (Table 2.2). This has lead to widespread salinity problems which are still worsening. The remnant vegetation of the western section of the Upper-middle Catchment consists of mixed woodland, primarily of marri and wandoo, but with areas containing jarrah, yate, york gum (to the north), powderbark, mallet and teatree. The drier eastern portion of the Upper-middle catchment consists primarily of medium woodland of york gum, wandoo and salmon gum (*E. salmonophloia*), powderbark and mallet. Some areas of casuarina, melaleuca, teatree and samphire occur particularly around the water courses and salt lakes. The remnant vegetation of the Upper catchment tends to mallee scrub (*E. eremophila*) and black marlock (*E. redunca*) to the east.

The land use of the Blackwood catchment is displayed in Figure 2.7. This land use map was derived from the land use map produced for the National Land and Water Resources Audit (NLWRA) by the Department of Agriculture of Western Australia. Corrections were made to the NLWRA map following comparisons with larger scale land use maps produced by the Lower Blackwood Land Conservation District and the Augusta-Margaret River Shire (Delaney and Gardner, 2000) and aerial photography.

The dominant land use in the eastern half of the catchment is wheat/sheep farming, designated as "cropping" in the land use map. For the medium rainfall areas (between approximately 600 mm and 800 mm per year), the land use is a mix of cropping and grazing with some plantation forestry. The higher rainfall areas of the catchment support a diverse range of agricultural activities including seasonal and perennial horticulture, dairy farming, cropping, grazing and improved pastures, intensive animal production and plantation forestry. Large areas of native forest remain in this part of the catchment. Hobby farming and tourism activities are becoming increasingly prevalent.

Table 2.2: Percentage deep-rooted vegetation in the Blackwood-Scott subcatchments in 2000.

Subcatchment	Subcatchment Area (ha)	% Deep-Rooted Vegetation	Subcatchment	Subcatchment Area (ha)	% Deep-Rooted Vegetation
Bw1	9,260	44	Bw12	38,406	25
Bw2	15,148	42	Bw13	72,381	26
Bw3	11,496	54	Bw14	37,285	15
Bw4	32,438	60	Bw15	159,478	12
Bw5	113,266	93	Bw16	409,565	12
Bw6	57,039	87	Bw17	337,805	10
Bw7	41,059	77	Bw18	627,113	9
Bw8	59,472	77	Sc1	4,930	51
Bw9	92,867	55	Sc2	21,969	61
Bw10	32,579	42	Sc3	41,195	69
Bw11	36,085	21	**TOTAL**	**2,250,836**	**26**


Landuse
Aquaculture
Conservation & Natural Environments
Cropping
Dairy
Golf Course
Grazing and improved pastures
Intensive animal production
Irrigated Perennial Horticulture
Managed natural water body
Mining
Pigs
Plantation forestry
Residential
Rural Residential
Seasonal horticulture
Services
Coastline
Major Rivers
Subcatchment boundary
N
20 0 20 40 60 Kilometres
Bw1
Bw2
Bw3
Bw4
Bw5
Bw6
Bw7
Bw8
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Sc1
Sc2
Sc3
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Land use in the Blackwoood and Scott River catchments
Figure 2.7
Disclaimer: While the Water and Rivers Commission has made all reasonable efforts to ensure the accuracy of these data, the Commission accepts no responsibility for any inaccuracies and persons relying on these data do so at their own risk.

3 Observed nutrient loads in streams and rivers

3.1 Water quality sampling

The Water and Rivers Commission (WRC) carries out routine sampling throughout the Blackwood-Scott catchment and has long time series of water quality data from many sites. Similarly, BHP Billiton has been monitoring the Blackwood and Scott Rivers around its Beenup mineral sands mine near Augusta since 1990. Land care and community groups have taken “snapshots” of water quality in local regions of the catchment to monitor background water quality and to find “hotspots” of nutrient pollution. Other water quality sampling has been done to monitor possible point sources of nutrient pollution such as Waste Water Treatment Plants (WWTP’s), the abattoir at Katanning, mining operations and intensive horticulture or animal production. Such sampling is generally specified as a condition of licence of the facility. Delaney and Gardner (2000) outline historic and ongoing sampling in the catchment.

Data used for this study are taken from the WRC’s Water Information Network (WIN) database, WRC Bunbury office database and BHP Billiton Beenup data. The number of samples for different forms of nitrogen and phosphorus, the sampling site reference (AWRC reference) and the date range of the sampling from each of these databases are given in Appendix B.

3.2 Load estimation methodology

To calculate nutrient loads or evaluate trends in water quality in streams and rivers, flow data are also required. The flow data and nutrient data must both be of high quality. The water quality sampling needs to be done in accordance to strict standards such as those described in King (2002) based on the Australian / New Zealand standard AS/NZS 5667.1 (1998). The laboratory analysis needs to be appropriate to the levels of detection required and also conform to given standards, for example, the National Association of Testing Authorities, Australia (NATA) certified methods which are based on the American Public Health Association (1998) quality assurance procedures. Close examination of the available nutrient data reveals that much are of inferior quality and unsuitable for load calculations. In particular, the results of the TP sampling undertaken by WRC Bunbury in the Blackwood catchment can not be used as their laboratory analysis has a detection limit of 0.1 mg/l and a reporting limit of 0.4 mg/l. Generally, TP concentrations throughout the Blackwood River basin are below these limits. WRC Bunbury data from one site in the Scott River (609026) have sufficiently high TP concentrations to be considered useful. The BHP Billiton pre-1996 nutrient data are also of insufficient quality to be used for load calculations.

To estimate nutrient loads, a concentration-flow relationship is established using a LOWESS (Locally Weighted Scatterplot Smoothing) fit (Helsel and Hirsch, 1992, p288). This fit is then used to estimate daily nutrient concentration values for the days for which there are no water quality data. The daily load is then calculated by multiplying the flow by the concentration and summed to give estimated annual loads.

The errors in loads derived from fixed interval water quality sampling are generally large. To estimate these errors at any particular site, intensive water quality sampling is necessary (Donohue and Nelson, 1999). For site 609002 (Brennan’s Ford) on the Scott River, intensive TN sampling was carried out in 1998 and 1999. Examination of these data indicates that loads calculated from a weekly sampling regime would have very little bias and an error of –33% to +75%. Fortnightly sampling would overestimate the load by about 10% and have a similar error range. These error ranges are obtained from 100 Monte-Carlo simulations of possible loads and are of similar magnitude to those estimated by D.A. Lord & Associates (2001b) in their study of the Peel-Harvey catchment. Error analyses are not available for TN load calculations from other sites and for TP load calculations because of the lack of intensive sampling data, however the errors will be of similar magnitude.

3.3 Results

For TN, discrete water quality sampling was carried out at, or close to, 11 flow gauging sites. Annual TN loads are estimated for sites 609014, 609015, 609005, 609028, 609012, 609017, 609019 and 6091252 in the Blackwood catchment and for sites 609026, 609002 and 6091051 in the Scott River and are displayed in Table 3.1. The locations of the gauging sites are shown in Figure 2.6. For most sites there are sufficient data to estimate loads for the years 1996 to 2000. For 6091252 and 609028 loads are estimated for 1999 and 2000 only. The consequent average annual loads are likely to be grossly underestimated as no high flow (high load) years such as 1996 are included in the analyses.

TP loads are calculated for sites 609026, S1, S2 and S3 in the Scott River and sites B2, B3 and B4 in the Blackwood River and are displayed in Table 3.2. The latter six sites are BHP Billiton sites; their locations are plotted in Figure 2.6. Tidal influence reaches approximately 40 km upstream in the Blackwood and 8 km upstream in the Scott in summer. Flows at sites within these river reaches (B2, B3, B4 and S2) are estimated from flow gauging sites upstream. As nutrient loads are carried predominantly in winter flows, the loads estimated for these tidally-influenced sites are considered reasonable.

The total average annual TN export to Hardy Inlet is more than 1237 tonnes, as the sites closest to the inlet for which TN loads are calculated - 6091051 (Brennan's Bridge) on the Scott River and 609019 (Hut Pool) on the Blackwood River - have estimated average annual loads of 174 and 1163 tonnes respectively. Similarly, the total average annual TP export to Hardy Inlet is estimated to be more than 42 tonnes (19.8 tonnes from the Scott River (S2) and 22.3 tonnes from the Blackwood River (B3)).

There are few published nutrient load estimations for the Blackwood and Scott Rivers. Gerritse (1996) and Rose (1996) estimate loads from 1995 data. As the data analysed here are for the period 1996 to 2000 it is difficult to make comparisons.

For site 609002 (Brenan's Ford) in the Scott River, Gerritse estimates a 1995 TP load of 26 tonnes; Rose's estimate is 21 tonnes. Annual TP load versus annual flow for this site is plotted in Figure 3.1. Assuming a similar flow-concentration relationship for 1995 as for the following five years, a linear interpolation gives an estimated 1995 TP load of 16 tonnes.

Gerritse estimates the TP load at 609019 (Hut Pool) in the Blackwood River for 1995 to be 10 tonnes. Data are unavailable for this site. However, annual TP load versus flow for site B2, 25 km downstream from 609019, is plotted in Figure 3.2. A linear interpolation gives an estimated 1995 TP load at B2 of 10 tonnes. There is much intensive land use in the catchment between sites 609019 and B2; 609019 should have a TP load which is much less than the load at B2.

Gerritse seems to overestimate TP loads compared to those deduced here. Similarly his TN loads are also higher (Gerritse, 1996). Without re-analysing his data it is difficult to draw any conclusions. Rose's estimate of TP load for site 609002 for 1995 agrees reasonable well with the data analysed in this report.

Table 3.1: Annual flows and TN loads for sites in the Blackwood-Scott catchment.

Scott River:

609026 (Milyeannup)

Year	Flow	TN (tonnes)
1996	80416	132
1997	74325	122
1998	54187	92
Average	**69643**	**116**
#pts in LOWESS fit		138

609002 (Brennan's Ford)

Year	Flow	TN (tonnes)
1996	177416	221
1997	123067	180
1998	106646	171
1999	163480	239
2000	116016	161
Average	**137325**	**194**
#pts in LOWESS fit		110

6091051 (Brennan's Bridge)

Year	Flow	TN (tonnes)
1996	183933	215
1997	127588	164
1998	110563	142
1999	169485	205
2000	120278	146
Average	142369	**174**
#pts in LOWESS fit		175

Blackwood River system:

609014

Year	Flow (ML)	TN (tonnes)
1996	83502	148
1997	4582	4.7
1998	45205	72
1999	19332	20
2000	18495	22
Average	**34223**	**53**
#pts in LOWESS fit		51

609015

Year	Flow (ML)	TN (tonnes)
1996	62790	98
1997	13511	15
1998	35763	59
1999	15872	19
2000	11914	14
Average	**27970**	**41**
#pts in LOWESS fit		46

609005

Year	Flow (ML)	TN (tonnes)
1996	5634	6.8
1997	3279	3.3
1998	3789	4.4
1999	3752	3.8
2000	2514	2.5
Average	**3794**	**4.1**
#pts in LOWESS fit		35

609028

Year	Flow (ML)	TN (tonnes)
1999	24559	23.7
2000	17577	16.8
Average	**21068**	**20.3**
#pts in LOWESS fit		56

609012

Year	Flow (ML)	TN (tonnes)
1996	707444	1757
1997	163547	172
1998	304703	553
1999	274266	348
2000	242967	386
Average	338586	**643**
#pts in LOWESS fit		112

609017

Year	Flow (ML)	TN (tonnes)
1996	71991	125
1997	26581	28.5
1998	20789	23.8
1999	49551	67.7
2000	32828	43.5
Average	**40348**	**58**
#pts in LOWESS fit		109

609019

Year	Flow (ML)	TN (tonnes)
1996	1289440	2518
1997	488297	552
1998	569290	795
1999	818972	1164
2000	565849	786
Average	**746370**	**1163**
#pts in LOWESS fit		95

6091252

Year	Flow (ML)	TN (tonnes)
1999	1014134	846
2000	717434	578
Average	**865784**	**712**
#pts in LOWESS fit		35

Table 3.2: Annual flows and TP loads for sites in the Blackwood-Scott catchment.

Scott River:

609026

Year	Flow (ML)	TP (tonnes)
1996	80416	18.8
1997	74325	16.6
1998	54187	9.4
Average	**69643**	**14.9**
#pts in LOWESS fit		238

Data for 609026 from WRC Bunbury

S3 (609002)

Year	Flow (ML)	TP (tonnes)
1996	177416	21.9
1997	123077	15.7
1998	106654	13.7
1999	163490	20.9
2000	116016	14.8
Average	**137331**	**17.4**
#pts in LOWESS fit		57

S1 (6091051)

Year	Flow (ML)	TP (tonnes)
1996	183933	20.9
1997	127598	15.0
1998	110572	12.7
1999	169496	19.9
2000	120278	14.2
Average	**142375**	**16.5**
#pts in LOWESS fit		64

S2

Year	Flow (ML)	TP (tonnes)
1996	188540	27.0
1997	130794	17.2
1998	113341	15.1
1999	173741	23.3
2000	123290	16.3
Average	**145941**	**19.8**
#pts in LOWESS fit		58

Blackwood River system:

B2

Year	Flow (ML)	TP (tonnes)
1996	1547193	15.8
1997	603327	8.9
1998	719661	9.1
1999	1014134	15.1
2000	717434	10.6
Average	**920350**	**11.9**
#pts in LOWESS fit		59

B4

Year	Flow (ML)	TP (tonnes)
1996	1618085	32.7
1997	634965	14.4
1998	761018	15.5
1999	1067811	22.9
2000	759126	16.2
Average	**968201**	**20.3**
#pts in LOWESS fit		56

B3

Year	Flow (ML)	TP (tonnes)
1996	1633111	32.7
1997	641671	16.6
1998	769785	18.4
1999	1079189	26.0
2000	767963	17.6
Average	**978344**	**22.3**
#pts in LOWESS fit		56

Data for sites S1, S2, S3, B2, B3, B4 from BHP Bilitton

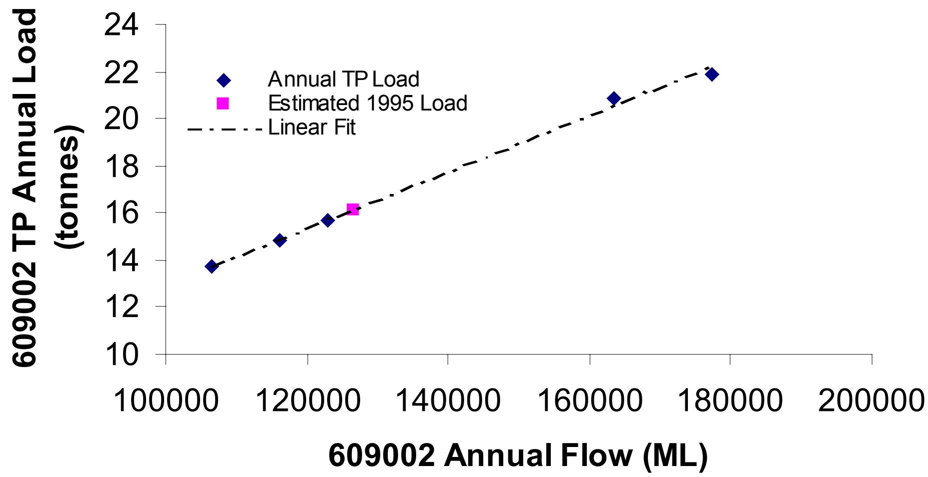


Figure 3.1: Annual TP load as a function of annual flow at site 609002.

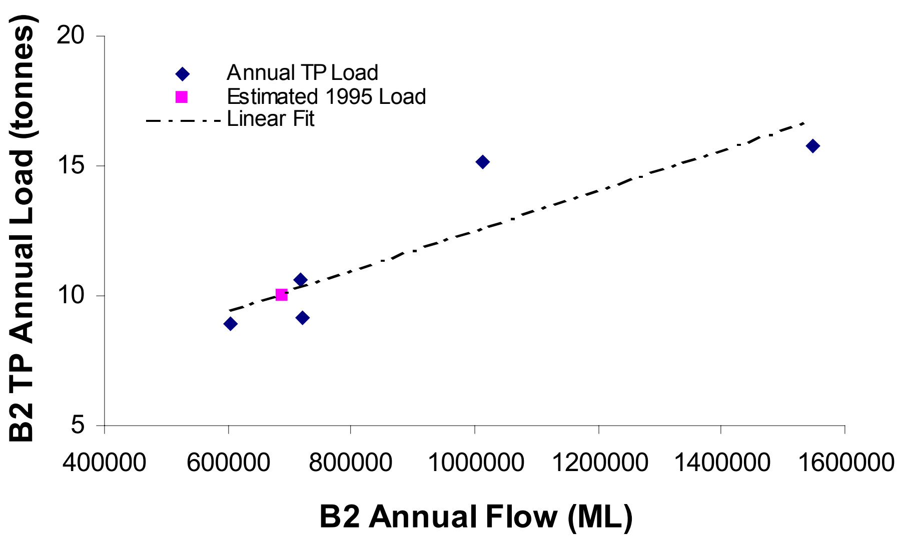


Figure 3.2: Annual TP load as a function of annual flow at site B2.

4 CMSS modelling

4.1 Description of CMSS

CMSS is a simple catchment-scale empirical model which may be used to estimate annual nutrient loads delivered to streams and rivers. Nutrient generation or export rates are specified for each land use. Land use may be designated as either a diffuse source, in which case the export rate is given as the amount of nutrient exported per area of the land use per year (i.e. kg/ha/yr), or as a point source, in which case the nutrient export rate is given as the amount of nutrient exported per facility per year (i.e. kg/source/yr). These export rates often require refinement to reflect the soil type or landscape position of the particular land use. CMSS sums the product of these generation rates and associated land use area along with point source contributions to produce the total nutrient export from the catchment. The export rates represent average annual values, as CMSS does not model processes such as rainfall-runoff.

Large catchments such as the Blackwood-Scott are divided into subcatchments. Average annual TN and TP export are estimated for each of the subcatchments. CMSS then routes the river flows and these nutrient loads through the river system and attenuates the nutrient loads in the process. Including the in-stream assimilation of nutrients in the modelling is necessary for large catchments to allow validation against nutrient loads calculated from observed data.

However, the NPI is concerned with emissions of TN and TP from land to water assuming no loss in transport across large catchments or in waterways. Thus the aggregated emissions data reported to the NPI database are the average annual TN and TP export from each of the individual subcatchments, assuming no in-stream assimilation.

4.2 Point sources in the Blackwood-Scott catchment

Several WWTP's located within the Blackwood-Scott catchment are licensed with the Department of Environmental Protection (DEP). Data from the Water Corporation of W.A. for most of these are displayed in Table 4.1. No data are available for the Nannup WWTP, as a new plant is under construction. Nutrient exports of 600 kg per year for TN and 50 kg per year for TP are estimated for this site. The Augusta WWTP is outside the catchment boundary. No data are available for the Dumbleyung WWTP, which is not included in the modelling as emissions are thought to be low.

The WAMMCO abattoir at Katanning is also licensed with the DEP to emit nutrients to the environment. As part of their licence agreement they monitor the volume and TN and TP concentrations of their effluent. Using these data, the estimated annual TN and TP export from this facility are 11 tonnes and 1.7 tonnes respectively.

Most of the towns in the catchment have a landfill rubbish tip. Data on these are not available and they have not been included in the CMSS modelling.

The Katanning abattoir and the WWTP's listed in Table 4.1 are included in the CMSS modelling. As all these facilities are "subthreshold" point sources their emissions are also included in the aggregated emissions data reported to the NPI.

Table 4.1: TN and TP emissions from point sources in the Blackwood-Scott catchment

Subcatchment	Facility	Average annual TN export (kg/source/yr)	Average annual TP export (kg/source/yr)
Bw7	Nannup WWTP	600*	50*
Bw9	Bridgetown WWTP	1500	290
Bw15a	Kojonup WWTP	900	50
Bw16b	Narrogin WWTP	9000	2100
Bw17b	Wagin WWTP	1200	525
Bw18	Katanning WWTP	5400	1500
Bw18	WAMMCO Abattoir	11000	1700

*Estimated values

4.3 Export rates for diffuse sources

Export rates for diffuse sources may be deduced by monitoring the stream nutrient loads from catchments with a single land use. Alternately, stream nutrient load data from several catchments with multiple land uses may be analysed using a multiple regression technique to deduce the export rates for the various land uses (McFarland and Hauck, 2001). This technique works well for land uses which occupy significant portions of the catchment. Otherwise, the uncertainty in the derived export rate is large. For example, in the NPI study of nutrient export from the Peel-Harvey catchment (D.A. Lord & Associates, 2001b) a TP export rate of 0.009 kg/ha/yr was derived for "primary production from dryland agriculture with >500 mm rainfall" on "wet soils". "Wet soils" make up approximately 0.11% of the Peel-Harvey catchment. In a similar study of the Avon catchment by the same author (D.A. Lord & Associates, 2001a) the corresponding export rate was 1.000 kg/ha/yr, more than a hundred times greater.

Another important consideration when selecting export rates is the size of the catchment.
The longer the travel time of water within the catchment, the greater will be the in-stream assimilation of nutrients by processes such as sedimentation, riparian zone uptake and de-nitrification. Export rates for small catchments will be greater than for larger ones. The NPI is concerned with emissions of TN and TP from land to water assuming no loss in transport across large catchments or in waterways. However, no guidance is given on appropriate catchment size for the CMSS modelling; this varies with the particular application and is dependent on the climate, physiography, the river system, soil type and land use.

The subcatchment size used for the modelling of the Blackwood-Scott varies from 4,930 ha to 627,113 ha with a median value of 41,059 ha. The CMSS export rates are based on those used by Kelsey (2001) in her modelling of the Ellen Brook and Southern River catchments which have areas of 71,500 ha and 14,890 ha respectively.

The export rates for diffuse sources are displayed in Table 4.2. As CMSS does not model rainfall-runoff, cropping and grazing are given different export rates depending on their annual rainfall. The sandy soils of the Scott coastal plain have low nutrient retention capability so export rates are also varied on soil type. The sandy soils are defined by their phosphorus retention index (PRI)

Table 4.2: Export rates for diffuse sources in the Blackwood-Scott catchment

Land use	Soil PRI	TN Export rate (kg/ha/yr)	TN Error (kg/ha/yr) +/-	TP Export rate (kg/ha/yr)	TP Error (kg/ha/yr) +/-
Conservation & Natural Environments	H / L	0.8	0.2	0.001	0.0005
Dairy	H	50	20	1	0.5
Intensive animal production	H	50	20	1	0.5
Pigs	H	50	20	1	0.5
Mining	H / L	1.9	0.5	0.13	0.1
Residential	H / L	4.5	1	0.7	0.3
Rural Residential	H / L	4.5	1	0.7	0.3
Services	H / L	4.5	1	0.7	0.3
Golf Course	H / L	4.5	1	0.7	0.3
Cropping > 500mm rainfall	H	0.58	0.2	0.14	0.05
Cropping < 500mm rainfall	H	0.14	0.05	0.02	0.01
Grazing and improved pastures > 500mm rainfall	H	2	0.5	0.14	0.05
Grazing and improved pastures < 500mm rainfall	H	0.14	0.05	0.02	0.01
Plantation forestry	H	1	0.2	0.01	0.01
Horticulture	H	14	4	1	0.3
Dairy	L	50	20	5	2
Cropping > 500mm rainfall	L	2	0.5	1.2	0.4
Grazing and improved pastures > 500mm rainfall	L	5	1	1.2	0.4
Plantation forestry	L	1	0.2	0.1	0.1
Horticulture	L	50	25	3	1

*H = high PRI, L = low PRI

(McPharlin et al, 1990). Some of the export rates from the previous study (Kelsey, 2001) have been modified to reflect the different conditions of the Blackwood-Scott catchment. The TN export rate for “cropping with annual rainfall >500 mm on high PRI soils” has been derived from comparison with observed loads at site 609005 as this small catchment (8,248 ha) has this single land use. The TN export rates for broad-acre agricultural land with annual rainfall less than 500 mm are taken from the NPI Avon study (D.A. Lord & Associates, 2001a). “Conservation and natural environments” land use is given a TN export rate of 0.8 kg/ha/yr from the NPI Peel-Harvey study (D.A. Lord & Associates, 2001b).

The export rates represent average annual values. The errors in the export rates (Table 4.2) do not take into account the variability in nutrient export due to the variation in rainfall from year to year. The difference in nutrient export between an average rainfall year and a high rainfall year may be more than 100%. The errors in the export rates reflect the uncertainty associated with the nutrient loads in an “average” rainfall year. Assigning errors to CMSS export rates is generally problematic due to the paucity of data from which to derive them. They are included in the calculations of the aggregated nutrient emissions from the individual subcatchments and land uses. The modelled assimilated loads have similar errors, however, these are not displayed as their inclusion would detract from the readability of the associated tables and figures.

4.4 In-stream assimilation of nutrients

For large catchments such as the Blackwood-Scott the assimilation of nutrients in the stream will cause a significant reduction in nutrient load.

The assimilation model used in CMSS is based on the work of Simmons, University of Western Sydney (Davis, Young and Cuddy, 1996). The model predicts the reduction in nutrient loads as a function of time, or downstream travel distance and is of the form:

$$L_t = L_0 e^{-kt} \quad (4.1)$$

where L_0 is the load at $t = 0$,

L_t is the load at time t,

t is the time for decay,

and k is the rate coefficient

The time value t for each subcatchment is the average time of travel for flows in the subcatchment. The travel time depends on the topography, channel dimensions and flow levels. In this study, the travel times are estimated by considering typical winter flow velocities at points for which the Water and Rivers Commission have data. The distance of travel is taken to be either the stream length from the catchment inlet to the catchment outlet, or, for the upland catchments without a main stream channel, the length of the catchment multiplied by 1.5 to allow for the sinuosity of the river. The estimated distance of travel and travel time, t for each of the subcatchments are displayed in Table 4.3.

The assimilation rate coefficient, k which must be supplied for each subcatchment, represents the rate of loss of nutrient for each of the possible loss pathways. In the CMSS Tutorial Book (Davis, Young and Cuddy, 1996) the value of k is related to depth of water using the relationship

$$\ln k = 1.4 - 1.2 * depth \qquad \text{for } depth \leq 4m \quad (4.2)$$

and

$$\ln k = -3.5 \qquad depth > 4m.$$

This relationship was derived using data from the Hawkesbury River as well as other eastern Australian and northern-hemisphere rivers and implies that assimilation is stronger in shallower waters than in deeper waters. Of the two major loss pathways, riparian zone uptake and sedimentation, riparian zone uptake is generally the stronger process and dominates the losses in shallow water. In most rivers, however, the assimilation rate coefficients for nitrogen and phosphorus will be different, and these will also vary in different parts of the landscape.

To compare assimilated loads from CMSS with loads calculated from stream nutrient concentration data, four of the subcatchments (Bw8, Bw15, Bw16, Bw17) have been subdivided so that nutrient export can be estimated for areas upstream of stream gauges. These subcatchment subdivisions are displayed in Figure 2.6.

The average stream depths have been estimated (Richard Pickett, pers. comm.) and are displayed in Table 4.3. As a first estimation, k was calculated using Equation (4.2) and the attenuation factor, e^{-kt} for each subcatchment was derived. The assimilated nutrient loads thus calculated compare poorly to those derived from flow and nutrient data.

Table 4.3: Travel times, average stream depths and attenuation factors for Blackwood-Scott subcatchments.

Subcatchment	Distance of travel (km)	Travel time (days)	Depth (m)	Attenuation factor, e^{-kt}	
				TN	TP
Bw1	10.5	0.61	0.2	0.963	0.061
Bw2	18.5	0.32	4	1	0.985
Bw3	17.6	0.60	1	0.971	0.348
Bw4	24.8	0.43	3	0.998	0.934
Bw5	91.3	1.58	2.5	0.987	0.632
Bw6	33.3	0.86	1	0.959	0.22
Bw7	47.9	0.83	2	0.988	0.644
Bw8a	9.2	0.26	1	0.988	0.644
Bw8b	44.8	1.26	1	0.941	0.109
Bw9	85.7	1.50	2	0.978	0.452
Bw10	27.7	0.49	2	0.996	0.858
Bw11	34.2	0.60	2	0.991	0.728
Bw12	44.4	1.28	1	0.940	0.105
Bw13	34.2	0.60	2	0.991	0.728
Bw14	51.8	1.50	1	0.93	0.071
Bw15a	33.1	0.58	1	0.972	0.361
Bw15b	19.0	0.73	1	0.965	0.277
Bw16a	28.5	1.10	0.5	0.908	0.029
Bw16b	134	5.15	0.5	0.636	7.E-08
Bw17a	17.7	0.30	0.5	0.974	0.382
Bw17b	81.7	2.36	0.5	0.813	0.0005
Bw18	143	15000	0.5	0	0
Sc1	12.9	0.18	1.5	0.892	0.930
Sc2	11.5	0.16	1.5	0.903	0.938
Sc3	34.5	0.67	1.5	0.653	0.764

For TN, nine gauges in the catchment have sufficient data to calculate reasonable observed loads at subcatchment outlets. Of these, five (upland catchments Bw8b, Bw15b, Bw16b, Bw17b and Sc3) are used to refine the TN assimilation rate coefficient, *k*. In this analysis, the datum from the Scott catchment Sc3 is an outlier, suggesting different TN assimilation rates for the Scott and Blackwood rivers. For TP, the assimilation rate coefficients for the Blackwood and Scott rivers are refined by comparison with load calculations for sites B2 and B3, and site S3 respectively.

The assimilation rate coefficients, *k* were modified by multiplication with a constant value. In terms of Equation (4.2) this causes the following adjustments to *k*:

TN assimilation rate coefficient:
Blackwood River $\ln k = -1.83 - 1.2 * depth$
Scott River $\ln k = 1.35 - 1.2 * depth$
TP assimilation rate coefficient:
Blackwood River $\ln k = 1.76 - 1.2 * depth$
Scott River $\ln k = 0.89 - 1.2 * depth$

These assimilation rate coefficients, as well as the theoretical one from Equation (4.2) are displayed in Figure 4.1.

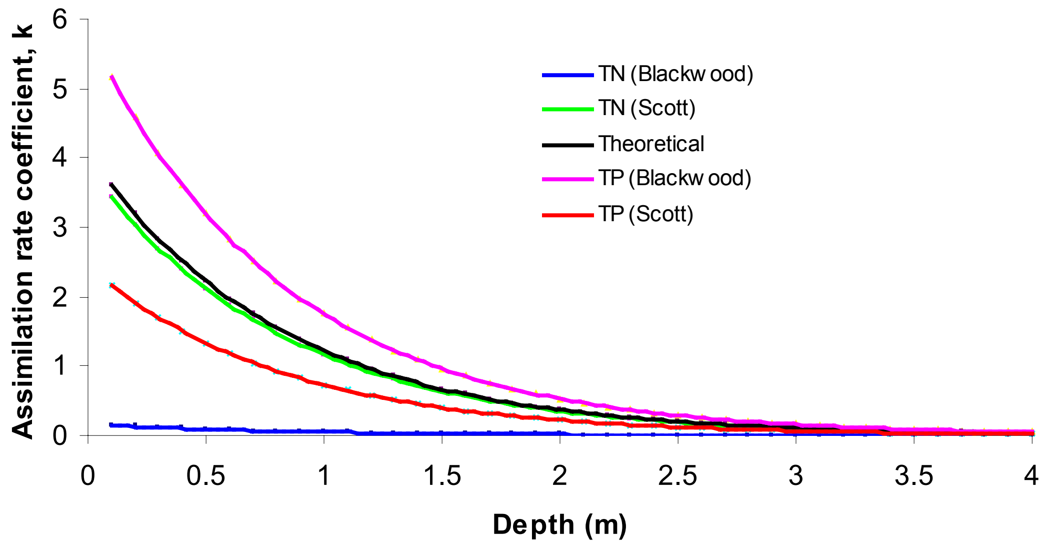


Figure 4.1: Assimilation rate coefficients for the Blackwood and Scott rivers

Using these new assimilation rate coefficients the TN and TP attenuation factors for each of the Blackwood-Scott subcatchments are derived and are displayed in Table 4.3. These data along with the theoretical attenuation factor, e^{-kt} where k is defined by Equation (4.2) are plotted in Figure 4.2.

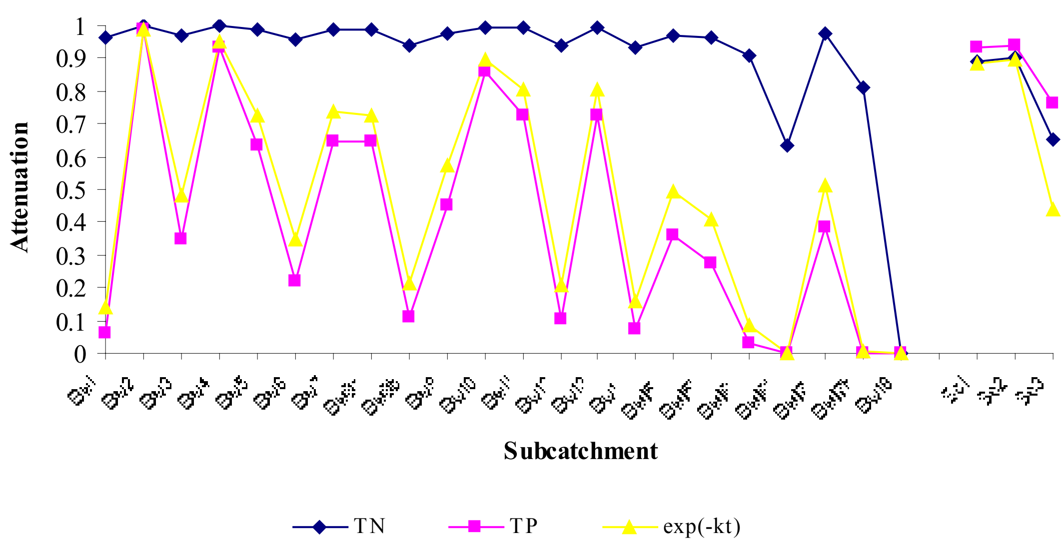


Figure 4.2: Attenuation applied to nutrient loads in the Blackwood-Scott subcatchments.

The TN and TP assimilation rates for the Scott River are not too different to those derived from the relationship in the CMSS Handbook. The Scott River has areas of healthy riparian vegetation. It seems reasonable to conclude that riparian zone uptake and denitrification play a significant role in nutrient loss in this river.

In the Blackwood River and its tributaries, TP assimilation is occurring at greater rates than expected. The Blackwood has a high sediment load and much of the phosphorus transported is bound to soil particles. It appears that this particulate phosphorus is being deposited in the watercourse sediments. The TN assimilation rates for the Blackwood River and its tributaries are very low and little nitrogen is being assimilated except in the subcatchments which have long resident times.

This low assimilation of nitrogen in the Blackwood River indicates an unhealthy river system. This is most likely due to the high salt load in the streams as a consequence of the extensive clearing in the east of the catchment and the degraded riparian vegetation through much of the catchment. Further study of the riparian and sedimentation processes in the watercourses of the Blackwood River catchment is warranted.

4.5 Results of CMSS modelling

4.5.1 Aggregated emissions of TN and TP to the Blackwood-Scott catchment

CMSS models the emissions of TN and TP to the environment from specified land uses in each of the subcatchments of the Blackwood-Scott. The results of this modelling are displayed in Appendix C. These data are aggregated over the subcatchments and displayed in Table 4.4. The average annual emissions to the Blackwood catchment are 1,578 tonnes of TN and 126 tonnes of TP. For the Scott catchment the average annual emissions are 313 tonnes of TN and 30 tonnes of TP.

In order to compare the emissions from different subcatchments the average annual TN and TP aggregated emission rates (kg/ha/yr) are calculated and are shown in Table 4.5 and Figures 4.3 and 4.4 respectively. The subcatchments with the highest average annual aggregated emission rates are the Scott River catchments and the subcatchments Bw1, Bw2, Bw3 and Bw4 of the Blackwood River. This reflects the intensive land use, such as horticulture, dairying and intensive animal production of these catchments. The average annual emission rates for the whole catchment are 0.84 kg/ha/yr for TN and 0.069 kg/ha/yr for TP.

The annual emissions of TN and TP are also aggregated by land use and displayed in Table 4.6. The intensive land uses - “dairy”, “pigs”, “intensive animal production”, “seasonal horticulture” and “irrigated perennial horticulture” - contribute disproportionately to the nutrient emissions. These land uses occupy 1% of the area of the catchment, but contribute 40% of the TN emissions and 21% of the TP emissions. In contrast, farming in the wheatbelt, designated “cropping < 500mm rainfall on high PRI soils”, occupies 53% of the catchment but contributes only 9% and 15% of the TN and TP emissions respectively.

Table 4.4: Annual aggregated emissions of TN and TP to the subcatchments of the Blackwood and Scott rivers.

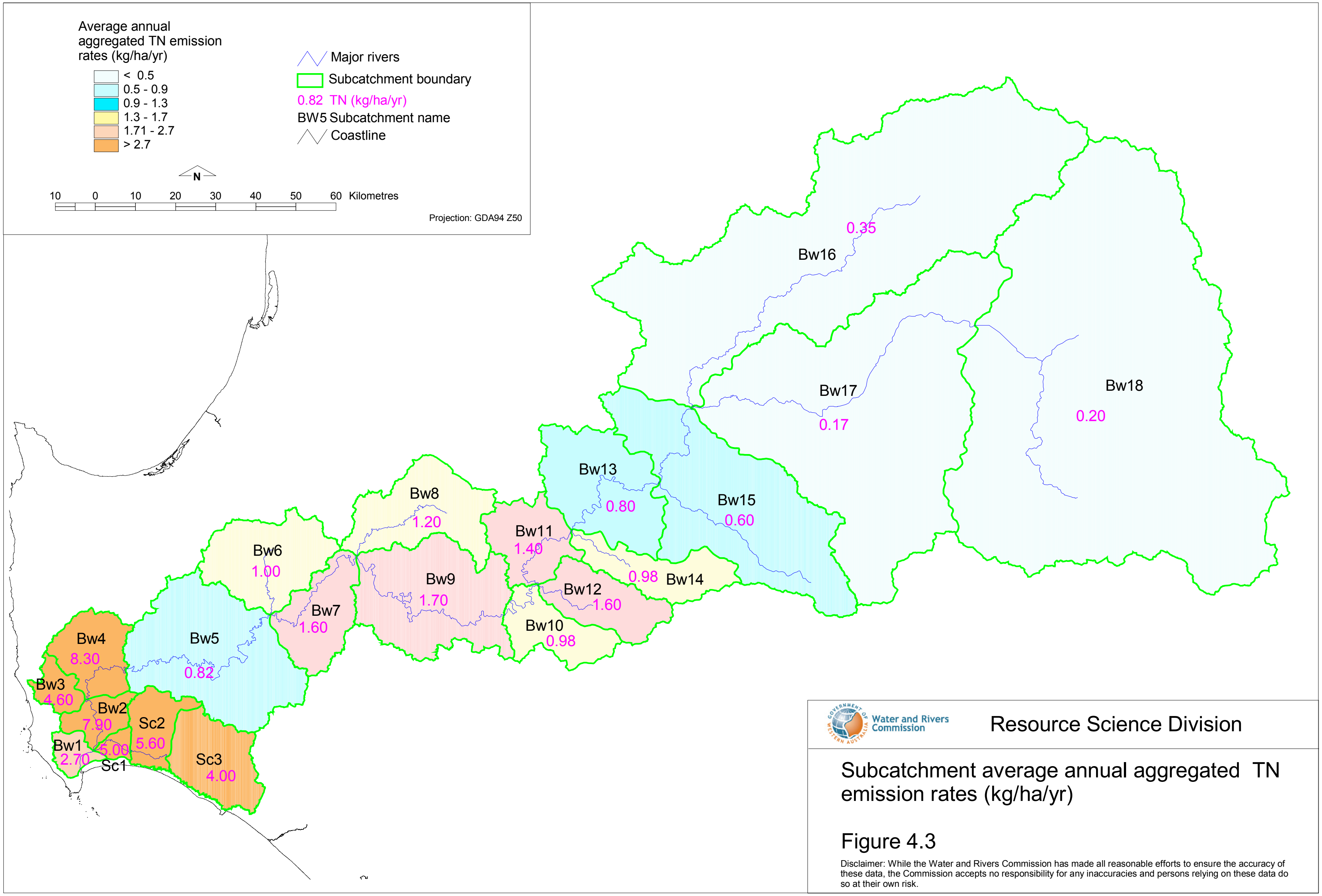
Subcatchment	Area (ha)	TN		TP	
		Emission (tonne)	Error (tonne) +/-	Emission (tonne)	Error (tonne) +/-
Blackwood					
Bw1	9,260	25	7	2.5	0.9
Bw2	15,148	119	43	7.6	2.9
Bw3	11,496	53	18	2.9	1.1
Bw4	32,438	270	100	7.6	3.2
Bw5	113,266	92	23	0.33	0.1
Bw6	57,039	58	15	0.77	0.3
Bw7	41,059	67	20	2.1	0.8
Bw8	59,472	73	19	2.7	1.0
Bw9	92,867	159	48	8.2	3.3
Bw10	32,579	32	9	2.6	0.9
Bw11	36,085	50	13	4.4	1.6
Bw12	38,406	60	17	5.7	1.9
Bw13	72,381	58	17	8.3	3.0
Bw14	37,285	36	11	5.3	1.9
Bw15	159,478	96	33	21	7.7
Bw16	409,565	142	53	21	9.8
Bw17	337,805	59	20	7.0	3.8
Bw18	627,113	128	53	15	9.2
Subtotal	**2,182,742**	**1,578**	520.8	**126**	53.4
Scott					
Sc1	4,930	25	7.9	3.4	1.2
Sc2	21,969	123	48.3	12	4.1
Sc3	41,195	166	66.5	15	5.0
Subtotal	**68,094**	**313**	122.7	**30**	10.4
TOTAL	**2,250,836**	**1,891**	644	**156**	64

Table 4.5: Average annual aggregated emission rates of TN and TP for the subcatchments of the Blackwood and Scott rivers.

Subcatchment	Area (ha)	TN Average annual aggregated emission rate (kg/ha/yr)	TP Average annual aggregated emission rate (kg/ha/yr)
Blackwood			
Bw1	9,260	2.7	0.27
Bw2	15,148	7.9	0.50
Bw3	11,496	4.6	0.26
Bw4	32,438	8.3	0.23
Bw5	113,266	0.82	0.003
Bw6	57,039	1.0	0.014
Bw7	41,059	1.6	0.050
Bw8	59,472	1.2	0.046
Bw9	92,867	1.7	0.089
Bw10	32,579	0.98	0.081
Bw11	36,085	1.4	0.12
Bw12	38,406	1.6	0.15
Bw13	72,381	0.80	0.12
Bw14	37,285	0.98	0.14
Bw15	159,478	0.60	0.13
Bw16	409,565	0.35	0.052
Bw17	337,805	0.17	0.021
Bw18	627,113	0.20	0.024
Subtotal	2,182,742	**0.72**	**0.058**
Scott			
Sc1	4,930	5.0	0.69
Sc2	21,969	5.6	0.53
Sc3	41,195	4.0	0.35
Subtotal	68,094	**4.6**	**0.44**
Total	2,250,836	**0.84**	**0.069**

Table 4.6: Average annual aggregated TN and TP emissions for land uses in the Blackwood-Scott catchment

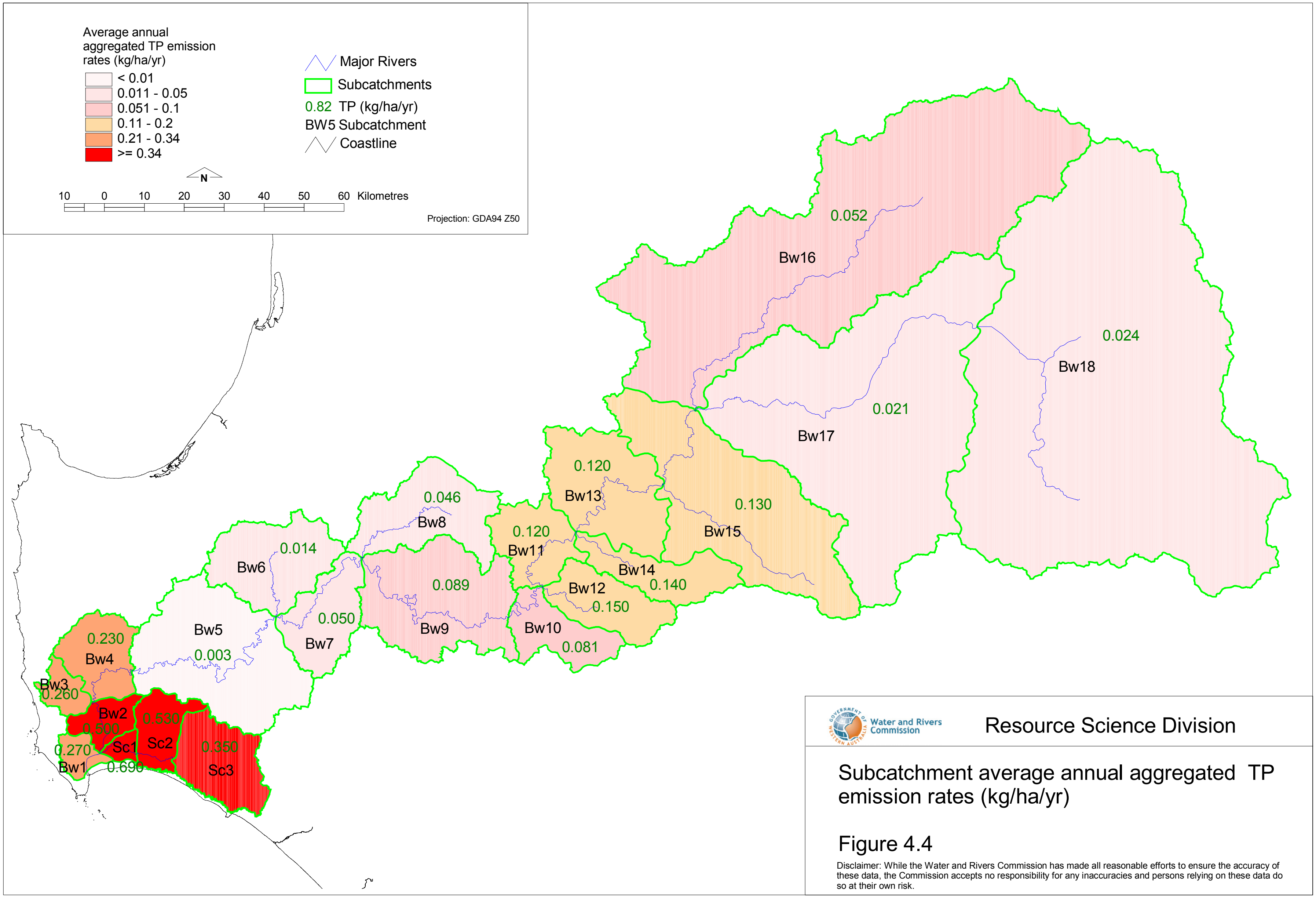
Land Use	Soil PRI	Area (ha)	TN Emission (tonne)	TN Error (tonne) +/-	TP Emission (tonne)	TP Error (tonne) +/-
DIFFUSE SOURCES						
Conservation & natural environments	H	441,286	353	88	0.44	0.22
Dairy	H	7,312	366	146	7.3	3.7
Intensive animal production	H	291	15	6	0.29	0.15
Pigs	H	272	14	5	0.27	0.14
Mining	H / L	1,809	3.4	0.9	0.24	0.18
Residential	H / L	815	3.7	0.8	0.57	0.24
Rural residential	H / L	259	1.2	0.3	0.18	0.08
Services	H / L	322	1.4	0.3	0.23	0.10
Golf course	H / L	79	0.4	0.1	0.06	0.02
Cropping > 500mm rainfall	H	391,826	227	78	55	20
Cropping < 500mm rainfall	H	1,199,486	168	60	24	12
Grazing and improved pastures > 500mm rainfall	H	87,628	175	44	12	4.4
Grazing and improved pastures < 500mm rainfall	H	2,627	0.4	0.1	0.05	0.03
Plantation forestry	H	42,274	42	8	0.42	0.42
Seasonal horticulture	H	4,752	67	19	4.8	1.4
Irrigated perennial horticulture	H	5,380	75	22	5.4	1.6
Conservation & natural environments	L	36,150	29	7	0.04	0.02
Dairy	L	922	46	18	4.6	1.8
Cropping > 500mm rainfall	L	710	1.4	0.4	0.85	0.28
Grazing and improved pastures > 500mm rainfall	L	18,009	90	18	21.6	7.2
Plantation forestry	L	3,901	3.9	0.8	0.39	0.39
Seasonal horticulture	L	3,386	169	85	10.2	3.4
Irrigated perennial horticulture	L	205	10	5	0.61	0.20
Water		1,136				
POINT SOURCES						
WWTP's			19	5	4.52	0.80
Katanning abattoir			11	3	1.70	0.40
TOTAL		**2,250,836**	**1,891**	**622**	**156**	**59**



Subcatchment average annual aggregated TN emission rates (kg/ha/yr)

Figure 4.3

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



Subcatchment average annual aggregated TP emission rates (kg/ha/yr)

Figure 4.4

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

4.5.2 Cumulative loads of TN and TP in the Blackwood and Scott rivers

CMSS models cumulative nutrient load at subcatchment outlets by summing the nutrient load coming into the subcatchment with the contribution from within, and allowing assimilation to occur as the nutrient is transported through the subcatchment, as discussed in Section 4.4. The modelled subcatchment average annual aggregated emissions and the average annual cumulative assimilated loads at subcatchment outlets for TN and TP are shown in Table 4.7 and in Figures 4.5 and 4.6 respectively. The annual cumulative loads from the Blackwood River to Hardy Inlet are estimated to be 1,332 tonnes for TN and 20 tonnes for TP. From the Scott River, the cumulative loads are estimated to be 208 tonnes for TN and 23 tonnes for TP.

Table 4.7: Subcatchment average annual aggregated emissions and average annual cumulative loads

		TN		TP	
Subcatchment	**Area (ha)**	**Subcatchment aggregated emission (tonne)**	**Cumulative assimilated load at outlet (tonne)**	**Subcatchment aggregated emission (tonne)**	**Cumulative assimilated load at outlet (tonne)**
Blackwood					
Bw1	9,260	25	23	2.5	0.15
Bw2	15,148	119	1,309	7.6	20
Bw3	11,496	53	51	2.9	1.0
Bw4	32,438	270	1,139	7.6	12
Bw5	113,266	92	871	0.33	5.2
Bw6	57,039	58	56	0.77	0.17
Bw7	41,059	67	734	2.1	7.7
Bw8	59,472	73	68	2.7	0.29
Bw9	92,867	159	607	8.2	9.6
Bw10	32,579	32	461	2.6	13
Bw11	36,085	50	375	4.4	12
Bw12	38,406	60	56	5.7	0.60
Bw13	72,381	58	295	8.3	12
Bw14	37,285	36	34	5.3	0.38
Bw15	159,478	96	239	21	7.6
Bw16	409,565	142	102	21	0.39
Bw17	337,805	59	48	7.0	0.21
Bw18	627,113	128	0	15	0
Total aggregated emissions		**1,578**		**126**	
Load			**1,332**		**20**
Scott					
Sc1	4,930	25	208	3.4	23
Sc2	21,969	123	209	12	21
Sc3	41,195	166	108	15	11
Total aggregated emissions		**313**		**30**	
Load			**208**		**23**
Total aggregated emissions		**1,891**		**156**	
Total load			**1,540**		**43**

Considering the relative size of the two catchments, (the Blackwood catchment is 32 times the area of the Scott catchment (Table 4.4)), the Scott contributes a disproportionate nutrient load, particularly of TP, to Hardy Inlet. This is a result of the intensive land use and high rainfall of the catchment coupled with the low nutrient retention capacity of its soils. It should be noted, however, that the Blackwood subcatchments located close to Hardy Inlet, in the high rainfall zone, also contribute greatly to the nutrient pollution of the inlet, as indicated by their high average annual aggregated emission rates (Table 4.5 and Figures 4.3 and 4.4).

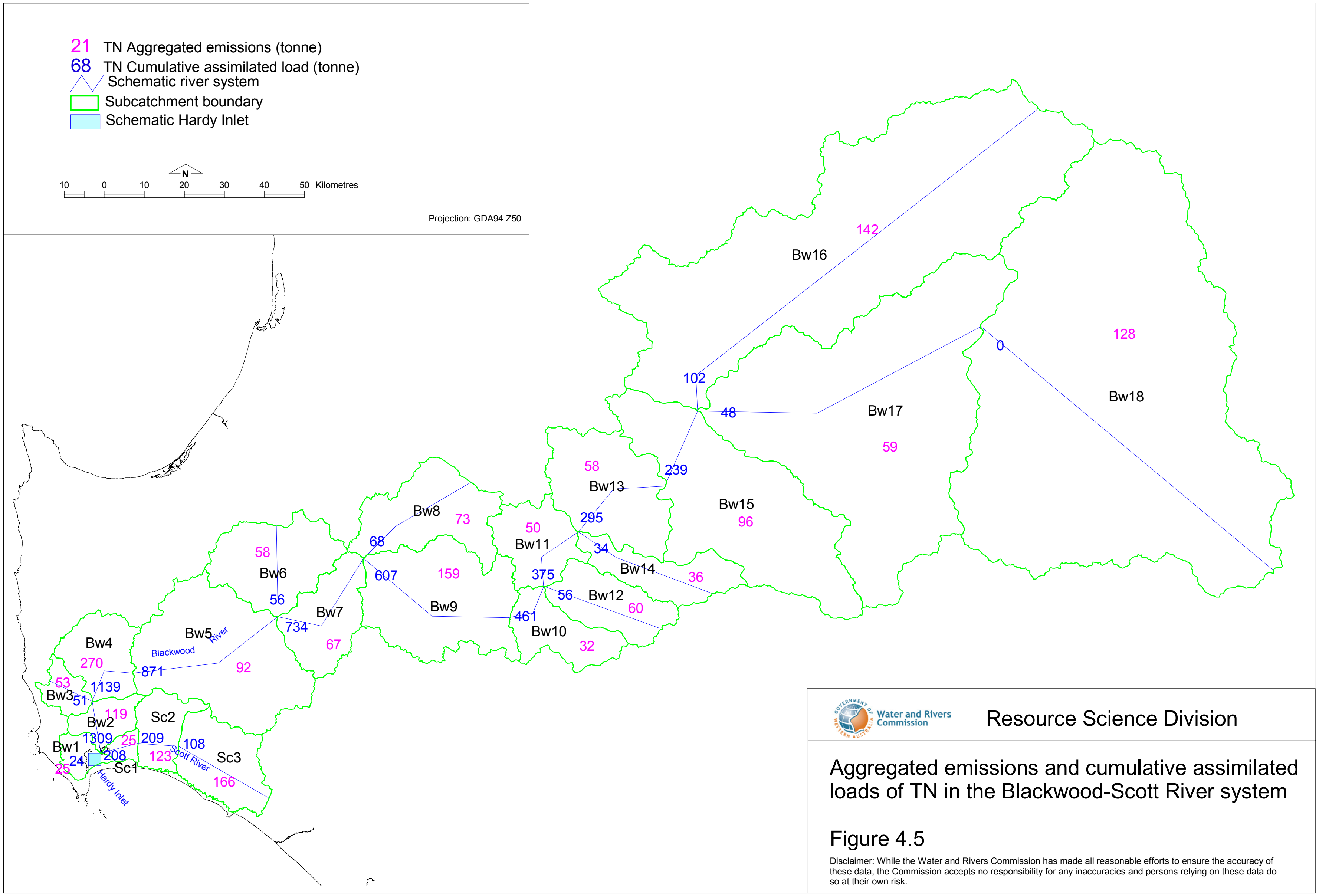
The loads calculated from nutrient concentration and flow data, discussed in Section 3, may be considered to be observed nutrient loads. The cumulative and assimilated loads modelled by CMSS may be compared with these observed loads. Table 4.8 displays the average annual observed loads, and the corresponding CMSS loads, for several sites in the catchment. The difference between the observed and modelled loads is less than 25% at all sites.

Table 4.8: Average annual observed and CMSS TN and TP loads at sample sites in the Blackwood-Scott catchment

		TN			TP		
Subcatchment	**Gauge**	**Observed load (tonnes)**	**CMSS load (tonnes)**	%error	**Observed load (tonnes)**	**CMSS load (tonnes)**	%error
Bw2	B3				22.3	20.3	-9
Bw3 & Bw4	B2				11.9	13.0	9
Bw5	609019	1,163	871	-25			
Bw8b	609017	58	64	10			
Bw15b	609005	4.1	4.6	12			
Bw16b	609014	53	51	-4			
Bw17b	609015	41	43	5			
Sc2	609002 / S3	194	209	7	17.4	21.5	23
Sc3	609026	116	108	-6	14.9	11.1	-25

The average annual river loads from the subcatchments of the Upper and Upper-middle Catchments are small due to the non-intensive land use and the long residence times of these subcatchments. The river loads increase in the eastern portion of the Lower-middle catchment, but then decrease as nutrients are assimilated as the Blackwood flows through the forested catchments around Nannup. The Blackwood River nutrient loads then increase markedly as the river traverses the high rainfall / intensive land use areas in subcatchments Bw2, Bw3 and Bw4. The nutrient loads in the Scott River increase as the river progresses to Hardy Inlet reflecting the high-intensity land use on low nutrient-retaining soils and high rainfall of these subcatchments.

For TN, the average annual aggregated emissions to the catchment are approximately 1,891 tonnes, while the estimated load to Hardy Inlet is 1,540 tonnes. For TP, the average annual aggregated emissions to the catchment are approximately 156 tonnes and the estimated load to Hardy Inlet is 43 tonnes. An estimated 72% of the TP emissions is being assimilated in the waterways. This may be due to TP being deposited in the sediments of the Blackwood River and its tributaries. The apparent small assimilation of TN, approximately 19%, reflects the low assimilation rates of nitrogen in the Blackwood River system.



Water and Rivers Commission

Resource Science Division

Aggregated emissions and cumulative assimilated loads of TN in the Blackwood-Scott River system

Figure 4.5

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

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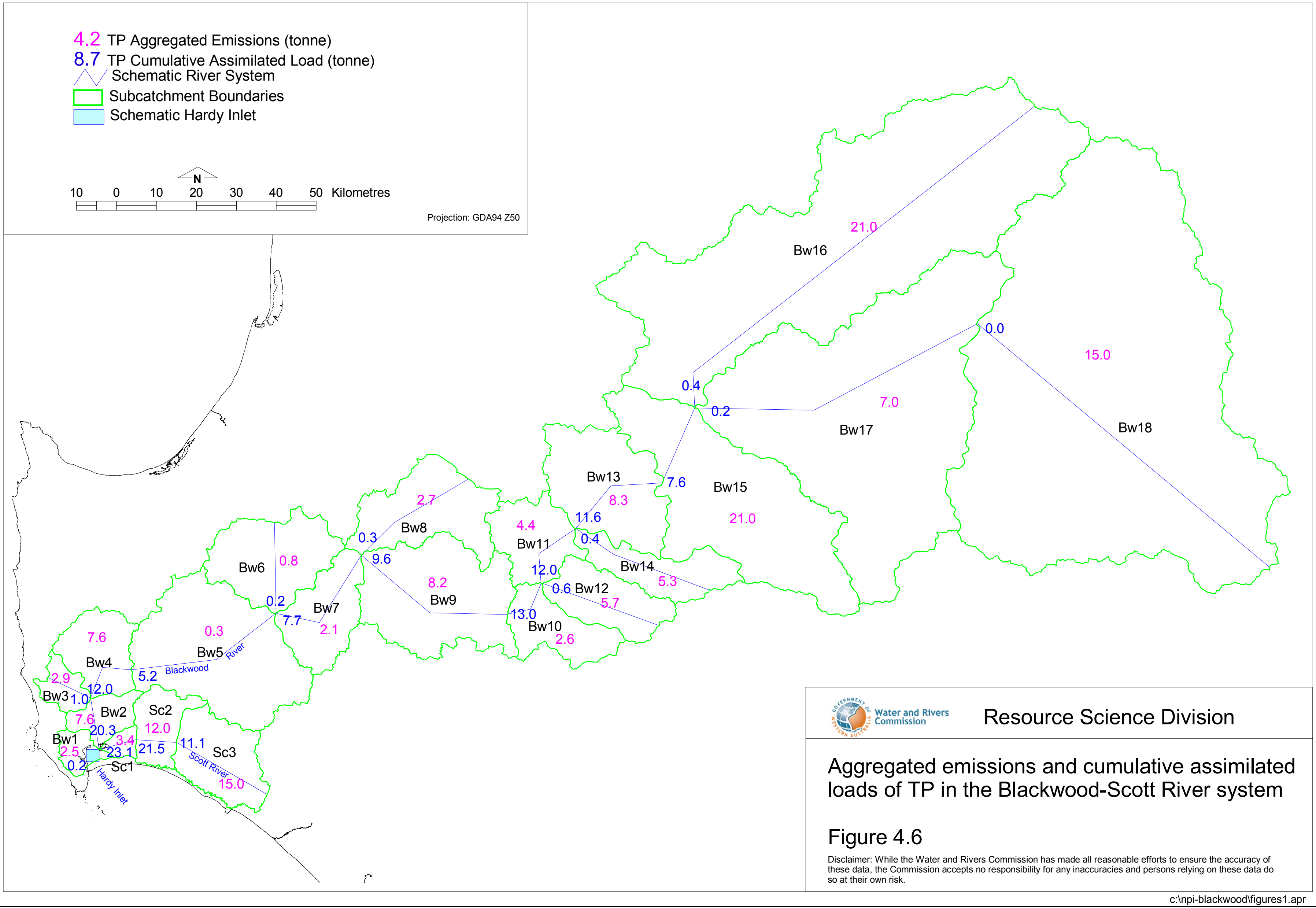

Aggregated emissions and cumulative assimilated loads of TP in the Blackwood-Scott River system

Figure 4.6

5 Conclusion

5.1 Summary of results

CMSS is used to examine the emissions of TN and TP to the Blackwood-Scott catchment and the subsequent loads of TN and TP in the river system and Hardy Inlet. CMSS estimates the TN and TP emissions by aggregating the product of land use areas and land use export rates. A simple assimilation model is used to attenuate the loads of TN and TP during transport in the waterways.

The aggregated nutrient emissions to the Blackwood and Scott catchments and estimated loads to Hardy Inlet are:

		TN (tonnes)	TP (tonnes)
Catchment aggregated emissions:			
	Blackwood	1,578	126
	Scott	313	30
	TOTAL	**1,891**	**156**
Nutrient load to Hardy Inlet:			
	Blackwood	1,332	20
	Scott	208	23
	TOTAL	**1,540**	**43**

The intensive land uses - “dairy”, “pigs”, “intensive animal production”, “seasonal horticulture”, “irrigated perennial horticulture” and “grazing and improved pastures” - in high rainfall catchments close to Hardy Inlet contribute large amounts of nutrient to the environment. Management actions aimed at reducing nutrient concentrations in the inlet should target these land uses. Nutrient emissions from the wheatbelt in the east of the catchment appear to have little impact at Hardy Inlet. However, high nutrient emissions will impact on local waterways, and the over-clearing in this portion of the catchment does have downstream impacts. The elevated salinity levels in the streams, the poor-quality riparian vegetation and high sediment loads all adversely affect the health of the local and downstream waterways.

The Blackwood River and tributaries appear to be assimilating proportionally greater amounts of phosphorus and smaller amounts of nitrogen than the Scott River. Management actions aimed at reducing sediment loads to the rivers and improving the health of riparian vegetation should be encouraged in both catchments. It is difficult to assess the effects of such actions at a local scale. However, modelling such as this provides an overview of catchment health and reinforces the need for remedial actions in all regions of the catchment.

5.2 Major assumptions

Export Rates

There have been few Western Australian studies in which nutrient export rates are derived from direct observation. The export rates used here are ones that have been used to model other Western

Australian catchments (Ellen Brook, Southern River, Peel-Harvey and the Avon catchments). The appropriateness of the selected export rates is judged by comparison between modelled and observed in-stream nutrient loads. An error in the export rate for a particular land use may be masked by a compensating error in export rate for a land use that occurs in similar locations.

Point source nutrient loads
The only point sources included in the modelling are WWTP's and the WAMMCO abattoir at Katanning. Data are not available for other point sources such as local rubbish tips. However, nutrient export from some point sources may be embedded in diffuse export rates such as residential and mining.

In-stream assimilation of nutrients
There are no data available on nutrient assimilation in the Blackwood and Scott rivers. The theoretical assimilation rates discussed in Section 4.4 attenuate river loads derived primarily from the diffuse source export rates. It is possible that incorrect diffuse source export rates may be offset by incorrect assimilation rates.

Year-to-year variation in nutrient emissions
CMSS models annual aggregated nutrient emissions and in-stream nutrient loads for an "average" year. It does not predict nutrient emissions for very dry or very wet years. However, the Scott River TP data displayed in Section 3.3 shows a strong linear relationship between nutrient load and annual rainfall.

5.3 Areas for future study

The requirement for high quality stream data (flow and nutrient concentration) to model nutrient emissions and assimilation in waterways can not be stressed enough. On-going monitoring in large catchments such as the Blackwood-Scott is essential to the development of greater understanding of the processing of nutrients during transport across the catchments, in the streams and in the receiving water body.

The ability of the Scott River to assimilate nutrients is similar to the model derived for eastern states rivers. However, the Blackwood River appears to assimilate a proportionally greater amount of phosphorus and a lesser amount of nitrogen than the Scott River. Studies of the sediment nutrient stores and the processing of nutrients in the riparian zone in the Blackwood River system would help with a better understanding of nutrient processes and the system's health.

CMSS does not model the variability in nutrient emissions due to the variation in rainfall from year to year. It is recommended that future NPI studies of nutrient emissions use the Environmental Management Support System (Vertessy et al, 2001) which models rainfall-runoff in the catchment and relates nutrient emission to the quantity and type of runoff. Use of this model in future NPI studies would allow nutrient emissions to be estimated for dry, average and wet years.

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Appendix A Soil legend

Excerpt from Atlas of Australian Soils legend

Label	Description
A14	Coastal dunes: chief soils are calcareous sands (Uc1.11) on the strongly undulating slopes of the dunes. Associated are small areas of other soils including (Uc6.12) on limestone and (Dr2.61) on gneissic outcrops. Occurs on sheet(s): 5
Ca19	Low-lying poorly drained plains: chief soils are leached sands (Uc2.2 and Uc2.3) the latter more common in the flatter, wetter sites and the former in the better-drained marginal areas. Associated are a variety of soils in shallow depressions and swampy drainage-ways, including acid peats (O); (Dy5.41) and (Uc2.12) soils overlying block laterite. Occurs on sheet(s): 5
Ca20	Coastal dunes and plains: chief soils are leached sands (Uc2.21) of the inland dunes where there are swampy interdune flats of leached sands (Uc2.34). Associated are unconsolidated dunes of calcareous sands (Uc1.11) and a plain also of calcareous sands (Uc1.11) with small freshwater swamps fronting the coast. The dunes of leached sands are underlain by calcareous sandy materials at depths of 3-7 ft. Occurs on sheet(s): 5
JK10	Undulating low slopes of coastal dunes with aeolianite outcrops, caves, and sink holes: chief soils are brown sands (Uc4.2). Associated are small areas of other soils, probably including (Uc1.22) and (Uc2.21). Occurs on sheet(s): 5
JZ1	Dissected plateau having a strongly undulating relief, and with some moderately incised valleys. The unit comprises much of the western part of the Darling Range south of the Swan River. It is characterized by lateritic gravels and block laterite. The chief soils are ironstone gravels with sandy and earthy matrices; the (KS-Uc4.2), (KS-Uc4.11), (KS-Uc2.12), and (KS-Gn2.24) soils blanket the slopes and ridges extending down into the upper ends of the minor valleys. They overlie duricrusts comprising recemented ironstone gravels, and/or vesicular laterite, and/or mottled-zone and/or pallid-zone material. Some (Dy3.81 and Dy3.82) soils containing ironstone gravels in the surface horizons may occur on some of the steeper slopes. Yellow loams (Um5.5), (Dy2.51) soils, and (Uc5.22) soils, all overlying pallid-zone clays and/or ironstone gravels at shallow depths (12-18 in.), occupy the swampy valley floors. Gravelly yellow earths (Gn2.2) are found downslope from granite bosses which occur occasionally in t. Occurs on sheet(s): 5
JZ2	Dissected plateau having a gentle to moderately undulating relief, and with broad swampy drainage-ways and basins. It is characterized by lateritic gravels and block laterite: the chief soils are ironstone gravels with sandy and earthy matrices (KS-Uc4.2), (KS-Uc4.11), (KS-Gn2.24), and (KS-Uc2.12). They overlie duricrusts of recemented ironstone gravels and/or vesicular laterite, and/or mottled-zone and/or pallid-zone material. These soils cover ridges and slopes where some (Dy3.81 and Dy3 .82) soils containing ironstone gravels also occur. Leached sands (Uc2.2 and Uc2.3) are a feature of the drainage-ways and basins. Areas of (Dy5.41) and (Dy5.82) soils occur on pediments in some areas of this unit where it merges with unit Tf3. Occurs on sheet(s): 5
MT8	Gently undulating terrain of broad shallow valleys and low ridges with moderate amounts of laterite and lateritic (ironstone) gravel: chief soils of the broad shallow valleys are acid grey earths (Gn2.94) sometimes containing ironstone gravels and possibly with some (Dy5.81) and/or (Dy5.41) soils also. Associated are leached sands (Uc2.2 and Uc2.3) in valley deposits and outwash areas; (Dy3.61) and (Dr2.61) soils containing ironstone gravels on ridges and their slopes and areas of block laterite; and minor areas of various soils such as (Um4.2), (Dr2.21), and (Dy3.21) on river terraces. As mapped, areas of unit Tc5 may be included. Occurs on sheet(s): 5

Ms7	Gently sloping to gently undulating plateau areas with long and very gentle slopes and, in places, abrupt erosional scarps: chief soils are (i) on gently convex slopes of the plateau, sandy yellow earths (Gn2.21) containing ironstone gravels and with clay D horizons; (ii) on depositional slopes flanking erosional sites, yellow earthy sands (Uc5.22) sometimes with ironstone gravels at depth; (iii) on erosional ridges and slopes, leached sands (Uc2.12) containing ironstone gravels and overlying mottledor pallid-zone clays; and (iv) sandy depressions of leached sands (Uc2.22) with some (Dy) soils. Soil dominance tends to vary locally between (i) and (iii). As mapped, areas of unit Uf1 are included. Occurs on sheet(s): 5
Ms8	Gently sloping to gently undulating plateau areas or uplands with long and very gentle slopes and, in places, abrupt erosional scarps: chief soils are (i) on depositional slopes, sandy yellow earths (Gn2.21 and Gn2.22) containing some ironstone gravels, and yellow earthy sands (Uc5.22) often with ironstone gravels at depths below 6-7ft; and (ii) on erosional ridges and slopes, ironstone gravels (KS-Uc4.11) together with (Uc4.11) and (Uc2.12) (both containing ironstone gravels), all underlain by hardened mottled-zone material by depths of 12-24 in. Soil dominance tends to vary locally between (i) and (ii) but overall the soils of (i) seem to have a slight dominance over the soils of (ii). Associated are smaller areas of other soils, such as (Dy3.82) containing ironstone gravels in its surface horizons. As mapped, small areas of units JJ16, Va66, DD9, X17, and possibly Sl28 are included. Occurs on sheet(s): 5
NZ2	Shallow swampy flat valley floors at moderately high elevation: chief soils are sandy acidic gley soils (Dg3.81) and hard acidic gley soils (Dg2.81) and (Dg1.81). Associated are possibly some (Dy5.8) soils. As mapped, there are included areas of unit JZ2, particularly ironstone gravels (KS-Uc4) and leached sands (Uc2.2 and Uc2.3). Occurs on sheet(s): 5
Oc32	A generally rolling terrain with some low gilgais: chief soils are hard alkaline red, yellow, and dark soils (Dr2.33), (Dy2.43), and (Dd1.33) in intimate association with Fey and brown cracking clays (Ug5.2 and Ug5.3), including (Ug5.38). Data are very limited. Occurs on sheet(s): 5
Od7	Undulating terrain traversed by numerous streams, many of which exhibit features of salinity; some gneissic rock outcrops: chief soils seem to be hard alkaline red soils and neutral red soils (Dr2.43 and Dr2.42), (Dr3.43 and Dr3.42), and (Dr2.33) with hard alkaline yellow soils (Dy3.43 and Dy3.42) and (Dy2.43). Associated are (Dr2.32) soils on ridge slopes; some areas of (Dr5.42) and (Dy5.42) soils; and (Uc1.2) soils on sandy deposits in some of the larger stream valleys. As mapped, areas of unit Oc32 are included; and small ridges of the dominant soils of unit Uf3 may be included. Data are very limited. Occurs on sheet(s): 5
Qb29	Rolling to hilly with some steep slopes; gneissic rock outcrops common: chief soils are hard neutral red soils (Dr2.22) with others such as (Dr2.62) and (Dr3.42). Associated are (Dy3.42) soils on slopes; patches of (Ug5.37) and (Ug5.2) soils with some gilgai also on slopes; colluvial slopes of (Gn2) soils such as (Gn2.12) and (Gn2.45); and variable areas of other soils seem likely. As mapped, areas of unit Uf1 and small areas of unit Oc30 may be included. Occurs on sheet(s): 5
Qb30	Rolling to hilly with some steep slopes; gneissic rock outcrops common; some lateritic mesas and buttes on drainage divides: chief soils are hard neutral red soils and acidic red soils (Dr2.22), (Dr3.42 and Dr3.41), and possibly similar related soils. Associated are (Dy3.42 and Dy3.41) soils; (Dy3.82 and Dy3.81) soils containing ironstone gravels; and smaller areas of other soils including those of the lateritic mesas and buttes. As mapped, areas of adjoining units may be included. This unit has similarities with both units Qb29 and Ub90. Occurs on sheet(s): 5
Qb31	Hilly to steep hilly terrain of rather broken relief: chief soils are hard neutral red soils and acidic red soils (Dr2.22 and Dr2.21) with hard neutral, and also acidic, yellow mottled soils (Dy3.22 and Dy3.21). Associated are colluvial slump areas of (Gn2.45) and other soils on the slopes; narrow terrace and mass movement deposits of (Gn2.15 and Gn2.14) soils, and possibly other soils similar to those of unit Mu12, along some valleys; some siliceous sands (Uc1.21) on dunes in the main valleys; and remnants of the main soils of units Tf5 and JZ1 on some interfluve ridges. As mapped, areas of adjoining units are included. Occurs on sheet(s): 5

SV1	Saline valleys and salt lakes--salt-lake channels, mostly devoid of true soils, and their fringing areas; few freshwater lakes: common soils are gypseous and saline loams (Um1.1 and Um1.2) on riverine wash and usually underlain by clayey or sandy strata by about 12 in. Associated are various resalinized (Dy) soils such as (Dy4.83) on fringe areas, and dunes and lunettes of various sandy (Uc), silty (Um), and clayey (Uf) soils of slight profile development. Deposits of common salt, gypsum, lime, and alunite occur as do remnants of the old lateritic profile and occasionally outcrops of country rock. Occurs on sheet(s): 5
Sl28	Broad flat valleys with small clay pans and salt-lake remnants in some localities: chief soils are hard alkaline yellow soils (Dy2.43 and Dy2.33) underlain by acid lateritic clays below depths of from 2 to 4 ft. Associated are small areas of (Dy5.43) soils in sandy localities; (Ug5.22) soils in areas where some low gilgai microrelief is present; some (Dy3.43) soils, especially in western valleys; and other soils on lunettes and dunes some of which are gypseous. As mapped, small areas of units Oc31, Vb2, DD9, and Va66 are included. Occurs on sheet(s): 5
Ta8	Incised valley side slopes of moderate to very steep relief: chief soils are hard acidic, and also neutral, yellow mottled soils (Dy3.21 and Dy3.22) with hard neutral yellow mottled soils (Dy3.62) containing ironstone gravels. Associated are (Dr2.22 and Dr2.21) soils on slopes; some dunes of siliceous sands (Uc1.21) along valleys; some flats of (Dy3.42) soils in the valleys together with swampy areas of undescribed soils; and some ridges of soils of the adjoining units. Occurs on sheet(s): 5
Tc5	Dissected plateau at low elevation of gently undulating to low hilly relief and characterized by extensive block laterite and lateritic (ironstone) gravels; some swamps: chief soils on slopes and undulating areas generally are hard acidic yellow mottled soils (Dy3.61) containing small to very large amounts of ironstone gravels. Associated are: (KS-Uc2.12), (KS-Uc2.2), and (Uc2.12) soils underlain by block laterite on the less dissected areas devoid of stream channels; acid grey earths (Gn2.94) sometimes containing ironstone gravels in shallow flat-bottomed valleys; (Uc2.32 and Uc2.33) soils on slopes below laterite-capped ridges and on flat areas at various levels (some areas have a clay substrate at depth); areas of unit MT8; small areas of (Dr2.61) soils containing ironstone gravels and often intimately associated with the (Dy3.61) soils; some (Gn2.22) soils containing ironstone gravels in colluvial sites; some (Dy) and (Uc2) soils in swamps; and minor areas of other soils. Occurs on sheet(s): 5
Tc6	Dissected lateritic plateau of hilly relief at moderate elevation: chief soils of the dissected hilly areas are hard acidic yellow mottled soils (Dy3.61), (Dy3.71), and (Dy3.81) with some hard acidic red mottled soils (Dr3.21) and brown earths (Gn2.45), all containing ironstone gravels; some (Um5.2) soils on major stream terraces. Associated are (Dy3.42), some (Dy3.43) and (Ug5) soils often with massive ironstone pavements, in the broad flat drainage-ways; and block laterite, gravelly and bouldery (Dy5.81) and (KS-Uc4.2) soils on the tops of rises and their colluvial slopes, together with some areas of leached sands (Uc2.3). Occurs on sheet(s): 5
Tf3	Low hilly to hilly terrain that occupies a zone flanking unit JZ2. It comprises valleys that are frequently narrow and have short fairly steep pediments, along with breakaways, mesas, and occasional granite tors. Included also are undulating areas representing elements of unit JZ2: chief soils are hard acidic yellow mottled soils (Dy3.81) along with sandy acidic yellow mottled soils (Dy5.41) and (Dy5.81), all of which contain moderate to large amounts of ironstone gravels in their surface horizons. Ironstone gravels (KS-Uc4.2) occur on the ridge crests and on the fine gravel deposits of the gently undulating parts of the unit, along with leached sands (Uc2.21). Occurs on sheet(s): 5
Tf4	Low hilly to hilly portions of dissected lateritic plateau with gently undulating ridge crests and narrow incised valleys: chief soils are hard acidic yellow mottled soils (Dy3.81) and (Dy3.61) containing moderate to large amounts of ironstone gravel. Associated are (KS-Uc4.2) ironstone gravels and (Dy5.8) soils containing ironstone gravels on ridge crests; valley side slopes of the soils of unit Ub90; and (Uc2.21), sometimes with ironstone gravels and boulders in colluvial situations. As mapped, inclusions of adjoining units are likely. Occurs on sheet(s): 5

Tf5	Dissected lateritic plateau of a generally hilly relief: chief soils on the slopes are hard acidic, and also neutral, yellow mottled soils (Dy3.81 and Dy3.82), (Dy3.61 and Dy3.62) containing moderate to large amounts of ironstone gravels. Associated are block laterite, gravelly and bouldery (Dy5.81) and (KS-Uc4.2) soils on ridge tops; leached sands (Uc2.3), some on deposits containing water-worn stones; and small areas of soils of adjoining units. Occurs on sheet(s): 5
Tf6	Undulating to hilly portions of dissected lateritic plateau at moderate elevation: chief soils are hard acidic and neutral yellow mottled soils (Dy3.81 and Dy3.82), (Dy3.61 and Dy3.62) containing small to large amounts of ironstone gravels; possibly the (Dy3 .8) soils are more common in the eastern and the (Dy3.6) soils in the western portions. Associated are leached sands (Uc2.33) and sometimes (Dy5.42) soils in the flatter valleys; (Dy5.81) soils containing ironstone gravels adjacent to areas of unit Cd22, small areas of which are included also; small swampy areas of unit Cb43 soils; and valley side slopes of unit Ta9 soils where dissection is incised below the laterite. This unit merges with unit Cd22. Occurs on sheet(s): 5
Ub90	Generally rolling to hilly country with tors; lateritic mesas and buttes on some interfluve areas: chief soils are hard neutral and acidic yellow mottled soils (Dy3.42 and Dy3.41) sometimes containing ironstone gravels. Associated are variable areas of hard acidic and neutral red soils (Dr2.31), (Dr2.21), (Dr2.32), and (Dr2.22) on slopes; (Dy3.82 and Dy3.81) soils containing moderate to large amounts of ironstone gravels on ridges, crests of hills, and upper slopes; and many small areas of other soils. As mapped, areas of adjoining units may be included. Occurs on sheet(s): 5
Ub95	Valley plains with some sandhills, dunes, lateritic gravel areas, and swamps: chief soils are hard neutral and sandy neutral yellow mottled soils (Dy3.42) and (Dy5.42). Associated are leached sands (Uc2.21) and siliceous sands (Uc1.21) of the sandhills and dunes; some (KS-Uc) gravels on residual knolls and ridges; areas of the soils of units Ub96 and Va64; and undescribed swamp soils. As mapped, areas of adjoining units may be included. There are similarities with unit Ca22. Occurs on sheet(s): 5
Ub96	Valley plains in which some salinity is usually present: chief soils are hard neutral, and also alkaline, yellow mottled soils (Dy3.42 and Dy3.43). Associated are small areas of many other soils including minor areas of sands as for unit Ub95. As mapped, areas of adjoining units may be included. Occurs on sheet(s): 5
Uf1	Undulating terrain with ridges, spurs, and lateritic mesas and buttes: chief soils on the broad undulating ridges and spurs are hard, and also sandy, neutral, and also acidic, yellow mottled soils (Dy3.82 and Dy3.81), (Dy5.82 and Dy5.81), all containing ironstone gravels. Associated are a variety of soils on the shorter pediment slopes, including (Dr2.32), (Dr3.41), (Dy2.33), and others of similar form; and dissection products of the lateritic mesas and buttes. As mapped, small areas of unit Ms7 may occupy some drainage divides, unit Va63 traverse some drainage-ways, and unit Qb29 occur in localities of deeper dissection. Occurs on sheet(s): 5
Uf3	Dissected plateau at low elevation having an undulating to rolling ridge and slope relief with some steep bluffs adjacent to drainage-ways; some swamps: chief soils are hard neutral yellow mottled soils (Dy3.82) containing ironstone gravels in their surface horizons on the flat to gently undulating ridge crests. Associated are leached sands (Uc2.2) sometimes underlain by boulder laterite and (Dy5.8) soils on the ridge crests; (Dy3.42), (Dy2.42), (Dr2.32), (Dr3.42), and possibly other similar (Dy) and (Dr) soils on the valley side slopes; and small areas of (Uc4.11) soils adjacent to tors on valley side slopes. As mapped, small areas of unit Od8 occurring in areas of major dissection are included. Occurs on sheet(s): 5
Va64	Plains--shallow flat-bottomed valley plains in which some salinity is usually evident: chief soils are hard alkaline and neutral yellow mottled soils (Dy3.43 and Dy3.42). Associated are small areas of many soils including occasional terraces of (Dr2.4) soils. As mapped, areas of adjoining units are included. Occurs on sheet(s): 5

Va65	Plains characterized by lakes with lunettes (often multiple lunettes) and other aeolian deposits covering ironstone gravel ridges: chief soils in a very variable soil situation are probably hard alkaline and neutral yellow mottled soils (Dy3.43 and Dy3.42). Associated are hard alkaline and neutral red soils such as (Dr2.43) and (Dr2.72) on older lunettes; (Dy2.33) soils in swales between lunettes; (Uc1.21) sands on younger lunettes; (Dr2.23 and Dr2.33) soils, often only 9-12 in. thick, on aeolian deposits covering ironstone gravel ridges; and probably other soils. Occurs on sheet(s): 5
Va66	Gently undulating to rolling terrain with some ridges and uneven slopes; and with the variable presence of lateritic mesas and buttes and granitic tors and bosses: chief soils are hard alkaline yellow mottled soils (Dy3.43) and hard alkaline red soils (Dr2.33), (Dr3.33), and (Dr2.43), either of which may be dominant locally. Associated are a variety of soils, notably (Dy) soils such as (Dy3.82 and Dy3.83) and (Dr) soils such as (Dr3.32). Acid lateritic strata are common below 4-5 ft. As mapped, lateritic mesas and buttes of unit Ms8 soils are a constant feature, as are small granitic bosses and tors of unit JJ16 and minor valleys of units Sl28, Oc31, and Vb2. Western occurrences of this unit have some features transitional to unit Uf1, especially the larger areas of (Dy3.82) soils. Occurs on sheet(s): 5
X15	Gently undulating sandy plains with low sand ridges: chief soils are sandy neutral and alkaline yellow mottled soils (Dy5.42 and Dy5.43). Associated are leached sands (Uc2.2) on sand ridges and deeper sandy areas generally; and some (Dy5.8) soils containing ironstone gravels with (KS-Uc2.12) gravels on spurs, buttes, and their slopes. The area seems to have an acid substrate of kaolinitic clays below 3-5 ft in depth. Occurs on sheet(s): 5

Appendix B Nutrient sampling undertaken in the Blackwood-Scott catchment by WRC and BHP Billiton

WRC WIN nutrient data for the Blackwood and Scott rivers – number of samples

Site	N (ox sol)	N (tot kjeldahl)	N (tot ox)	N (tot pers) pTN	N (tot)	NH3-N/NH4-N (sol)	NH4+ (insitu)	NO2-N (sol)	NO3 (sol)	NO3-N (sol)	P (reactive sol) (FRP)	P (tot pers) (pTP)	P (tot)	PO4-p (sol)	First reading	Last reading
609009		6	6		6	6		5	4				6	6	27/08/1991	08/12/1994
6091007									15		4				11/05/1983	15/10/1985
6091009									16		8				18/05/1983	01/10/1985
6091012									12		4				23/06/1983	03/10/1985
6091021		10	3			10			15	7	11		10		29/07/1981	12/09/1985
6091022		8	2			8			13	6	10		8		03/07/1981	12/09/1985
6091023		7	1			7			9	6	8		7		31/08/1981	12/09/1985
6091024		4	4		4	4		2	2				4	4	23/11/1992	10/08/1994
6091025		4	4		4	4		2	3				4	4	12/11/1993	10/08/1994
6091026		6	6		6	6		4	5				6	6	27/08/1991	10/08/1994
6091027		4	4		4	4		2	3				4	4	23/11/1992	10/08/1994
6091028		3	3		3	3		2	1				3	3	23/11/1992	10/08/1994
6091029									16		5				03/06/1983	22/08/1986
6091030									13		3				01/07/1983	22/08/1986
6091042					1					1			1		25/10/1999	25/10/1999
6091043					1					1			1		25/10/1999	25/10/1999
6091044					1					1			1		25/10/1999	25/10/1999
6091048		13	6			13			17	7	16		13		16/10/1981	12/09/1985
6091049		9	3			9			12	6	10		9		16/10/1981	12/09/1985
6091050		9	9			9			9		9		9		23/02/1982	03/06/1983
6091051		10	10		10	10	1		5		10		10		18/05/2000	20/11/2001
6091052									12		5				03/06/1983	03/10/1985
6091053									14		6				09/05/1983	03/10/1985
6091054									12		6				18/05/1983	01/10/1985
6091056									14		6				07/06/1983	01/10/1985
6091057									13		4				23/06/1983	03/10/1985
6091058									14		5				02/06/1983	03/10/1985
6091059									14		5				02/06/1983	03/10/1985
6091060									14		5				02/06/1983	03/10/1985
6091061									13		5				30/06/1983	15/10/1985
6091062									14		7				11/05/1983	15/10/1985
6091063									14		7				18/05/1983	01/10/1985
6091064									13		4				23/06/1983	03/10/1985
6091065									15		6				02/05/1983	03/10/1985
6091066									15		5				15/06/1983	16/10/1985

WRC WIN nutrient data for the Blackwood and Scott rivers – number of samples (cont.)

Site	N (ox sol)	N (tot kjeldahl)	N (tot ox)	N (tot pers) pTN	N (tot)	NH3-N/NH4-N (sol)	NH4+ (insitu)	NO2-N (sol)	NO3 (sol)	NO3-N (sol)	P (tot reactive sol)	P (tot pers) (pTP)	P (tot)	PO4-p (sol)	First reading	Last reading
6091067									16		7				21/04/1983	16/09/1985
6091068									13		4				31/05/1983	16/09/1985
6091069									15		5				02/06/1983	16/09/1985
6091070									13		4				22/06/1983	16/09/1985
6091071									13		4				14/06/1983	16/09/1985
6091072									16		6				21/04/1983	16/09/1985
6091073									12		5				30/06/1983	15/10/1985
6091074									15		7				21/07/1983	15/10/1985
6091075									13		6				21/07/1983	15/10/1985
6091152		20	21		8	14		2					21		12/08/1992	11/08/1998
6091153		20	21		8	14		2					21		12/08/1992	11/08/1998
6091154		10	11			11							11		12/08/1992	31/10/1995
6091200		7	7			7							7		27/05/1994	02/07/1996
6091201		4	4			4							4		07/09/1994	02/07/1996
6091205													1		07/08/1996	07/08/1996
6091207		1	1		1								2		13/09/1995	07/08/1996
6091209													1		13/09/1995	13/09/1995
6091210		1	1		1	1		1					2	1	13/09/1995	07/08/1996
6091215													1		13/09/1995	13/09/1995
6091218		1	1		1								1		07/08/1996	07/08/1996
6091219													1		13/09/1995	13/09/1995
6091222		8	8		8	8					8		8		31/05/2000	08/09/2000
6091223		10	10		10	10					10		10		18/05/2000	08/09/2000
6091224		7	7		7	7					7		7		15/06/2000	08/09/2000
6091225		7	7		7	7					7		7		15/06/2000	08/09/2000
6091226		8	8		8	8	2				8		8		18/05/2000	24/08/2000
6091227													1		07/08/1996	07/08/1996
6091228													1		07/08/1996	07/08/1996
6091229													1		07/08/1996	07/08/1996
6091252	2	18	67	53	16	69	1				69	40	29		14/01/1999	19/01/2001
6091292				1						1		1			25/10/1999	25/10/1999
6091293				1						1		1			25/10/1999	25/10/1999
6091294				1						1		1			25/10/1999	25/10/1999
6091299		7	7	7		7					7	7			18/05/2000	24/08/2000
6091300		7	7	7		7					7	7			18/05/2000	24/08/2000
6091301		1	1	1		1					1	1			28/06/2000	28/06/2000
Total	2	230	250	71	115	268	4	22	487	38	346	58	241	28		

WRC Bunbury nutrient data for the Blackwood and Scott Rivers – number of samples

Site	Conductivity (mS/cm)	Salinity (ppt)	FRP (mg/l)	TP (mg/l)	NH4+ (mg/l)	NH3-N (mg/l)	TON (mg/l)	TKN (mg/l)	NO2-N (mg/l)	NO3-N (mg/l)	NOX (mg/l)	TN (mg/l)	TSS (mg/l)	Date range	
609002	16	11	15	167		27		13	14	14	13	167	90	07/06/1996	02/11/2000
609026	78	72	91	240		88	7	13	68	63	13	238	22	13/06/1996	02/11/2000
6091051	75	72	87	218		87	6	13	64	60	15	215	21	19/06/1996	02/11/2000
6091222	67	61	84	96		82	6	12	61	57	12	94	20	13/06/1996	02/11/2000
6091223	59	55	75	84		75	6	12	55	51	12	84	21	13/06/1996	20/10/2000
6091224	59	56	69	77		69	5	11	51	49	11	75	20	27/06/1996	02/11/2000
6091225	16	14	25	25		25		9	16	16	9	25	17	11/06/1998	05/10/2000
6091226	53	51	66	74		66	3	12	47	44	12	72	20	07/07/1996	20/10/2000
6091223B			6	6		6			6	6		6		11/06/1998	20/08/1998
6091299			9	9		9		9			9	9	8	18/05/2000	20/10/2000
6091300			9	9		9		9			9	9	8	18/05/2000	20/10/2000
6091301			1	1		1		1			1	1	1	28/06/2000	28/06/2000
609005	46	45	36	45		35			36	37		44		04/06/1996	24/12/2001
609007	61	61	3	54	3	2			2	2		54		09/03/1999	24/01/2002
609010	9	9	9	9		8			9	9		8		21/06/1996	29/10/1996
609012	119	119	60	113	3	56			60	59		112		11/06/1996	23/01/2002
609014	65	64	38	63		37			39	40		61		19/07/1996	24/12/2001
609015	60	59	39	57		39			41	41		57		21/06/1996	24/12/2001
609017	119	117	70	109	3	68			70	69		109		07/06/1996	24/01/2002
609018	24	23	22	22		23			24	24		22		07/06/1996	29/07/1997
609019	115	114	42	99	3	41			46	46		96		07/06/1996	22/01/2002
609020	21	20	21	22		20			21	21		21		06/06/1996	22/07/1998
609021	11	11	11	11		11			11	11		11		23/06/1998	08/12/1998
609022	8	8	8	8		8			8	8		8		24/04/1997	29/07/1997
609028	62	62	22	56	3	20			20	19		56		13/05/1998	09/01/2002
609039	11	11		11								11		21/08/2001	09/01/2002
609040	20	20	2	20								20		01/05/2001	24/01/2002
6091059	54	54	24	49	3	18			18	17		49		13/05/1998	24/12/2001
6091071	54	54	21	50	3	16			16	15		50		09/06/1998	27/11/2001
6091232	8	8	7	8		7			7	7		8		24/04/1997	29/07/1997
6091258	70	70	31	64	3	26			27	25		64		21/07/1998	23/01/2002
6091271	24	24	12	20		12			12	11		20		21/07/1998	07/08/2001
6091276	60	60	3	54	3	1			1	1		54		09/03/1999	24/01/2002
6091277	59	59	5	51	3	4			4	4		51		09/03/1999	24/01/2002
6091312	10	10	10	10		10			10	10		10		06/09/2001	11/01/2002
6091313	8	8	8	9		8			8	8		9		06/09/2001	27/12/2001

BHP Billiton nutrient data for the Blackwood and Scott rivers – number of samples

Site	Total Dissolved Solids - gravimetric (mg/L)	Total Suspended Solids (mg/L)	Nitrate as Nitrogen (mg/L)	Nitrogen - Ammoniacial (mg/L)	Nitrogen - Total Kjeldahl (mg/L)	Phosphorous - Ortho (mg/L)	Phosphorous - Total (mg/L)	First reading	Last reading
B2	84	143	143	84	84	92	142	28/06/1990	03/12/2001
B3	89	148	142	84	89	92	146	28/06/1990	03/12/2001
B4		57	57			6	56	15/10/1996	03/12/2001
S1	89	148	142	84	89	92	146	28/06/1990	30/11/2001
S2	90	148	147	90	90	98	147	28/06/1990	05/12/2001
S3	87	144	139	82	87	90	143	26/07/1990	30/11/2001

B2	Alexander Bridge
B3	Malloy Island
B4	Twinem Bend
S1	6.4 km upstream of Malloy Island (catchment area = 654.8 km2)
S2	2.9 km upstream of Malloy Island (catchment area = 671.2 km2)
S3	Brennan's Ford (catchment area = 631.6 km2)

Appendix C Results of CMSS modelling of the Blackwood-Scott catchment

TN modelling

Land use	PRI	Bw1 base export (kg)	Bw2 base export (kg)	Bw3 base export (kg)	Bw4 base export (kg)	Bw5 base export (kg)	Bw6 base export (kg)	Bw7 base export (kg)	Bw8a base export (kg)	Bw8b base export (kg)	Bw9 base export (kg)	Bw10 base export (kg)	Bw11 base export (kg)	Bw12 base export (kg)	Bw13 base export (kg)	Bw14 base export (kg)
DIFFUSE SOURCES																
Conservation & natural environments	H	428	1719	2062	14969	89094	38278	23563	1425	32393	34828	10332	3168	5121	9663	1487
Dairy	H	7354	66555	25079	206140	0	7952	16313	0	0	31191	0	0	0	0	0
Intensive animal production	H	0	0	0	5736	0	0	2458	0	0	6352	0	0	0	0	0
Pigs	H	0	0	0	0	0	0	0	0	904	450	0	0	0	0	0
Mining	H/L	0	439	0	0	0	0	0	0	0	2344	0	0	0	0	0
Residential	H/L	384	56	0	6	0	0	109	0	39	1657	0	249	0	0	0
Rural residential	H/L	24	150	0	0	0	0	0	0	41	0	0	579	0	0	0
Services	H/L	195	0	0	253	0	0	0	0	626	90	0	0	0	0	0
Golf course	H/L	0	0	0	0	0	0	0	0	0	355	0	0	0	0	0
Cropping > 500mm rainfall	H	96	172	88	398	210	418	1190	36	1855	9428	6893	8105	11197	29696	16564
Cropping < 500mm rainfall	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grazing and improved pastures > 500mm rainfall	H	3858	7009	5270	11791	1408	5185	5152	1369	9428	36166	13563	24611	19212	12483	12821
Grazing and improved pastures < 500mm rainfall	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantation forestry	H	825	160	527	274	771	5651	5690	1795	5275	10679	999	5081	1481	2592	62
Seasonal horticulture	H	0	0	1152	2638	858	619	9307	690	16449	13726	0	5104	11174	0	3808
Irrigated perennial horticulture	H	890	6900	6736	26415	0	0	2956	0	993	10533	0	3011	11402	3750	1737
Conservation & natural environments	L	2286	2688	2576	183	0	0	0	0	0	0	0	0	0	0	0
Dairy	L	2652	11948	0	0	0	0	0	0	0	0	0	0	0	0	0
Cropping > 500mm rainfall	L	643	117	56	5	0	0	0	0	0	0	0	0	0	0	0
Grazing and improved pastures > 500mm rainfall	L	5157	14674	4966	1346	0	0	0	0	0	0	0	0	0	0	0
Plantation forestry	L	368	150	221	0	0	0	0	0	0	0	0	0	0	0	0
Seasonal horticulture	L	0	0	71	0	0	0	0	0	0	0	0	0	0	0	0
Irrigated perennial horticulture	L	0	6381	3859	0	0	0	0	0	0	0	0	0	0	0	0
POINT SOURCES																
WWTP's								600			1500					
Katanning abattoir																
Aggregated emission (kg)		**25159**	**119117**	**52663**	**270154**	**92341**	**58103**	**67337**	**5315**	**68003**	**159299**	**31786**	**49907**	**59587**	**58184**	**36478**
Cummulative load (kg)		25159	1309308	52663	1141177	882067	58103	742891	69307	68003	620488	463136	378618	59587	297360	36478
Attenuation factor		0.926	1.000	0.971	0.998	0.987	0.959	0.988	0.988	0.941	0.978	0.996	0.991	0.940	0.991	0.930
Attenuated load (kg)		**23298**	**1308756**	**51160**	**1139031**	**871023**	**55742**	**733984**	**68443**	**63992**	**607110**	**461189**	**375331**	**56019**	**294779**	**33932**
Hardy Inlet TN from Bw (kg)		**1332053**														
Hardy Inlet TN from Scott (kg)		**208026**														
Total (kg)		**1540079**														

TN modelling (cont.)

Land use	PRI	Bw15a base export (kg)	Bw15b base export (kg)	Bw 16a base export (kg)	Bw16b base export (kg)	Bw17a base export (kg)	Bw17b base export (kg)	Bw18 base export (kg)	BW - total base export (kg)	Sc1 base export (kg)	Sc2 base export (kg)	Sc3 base export (kg)	SC - total base export (kg)	TOTAL BASE EXPORT (kg)
DIFFUSE SOURCES														
Conservation & natural environments	H	5931	2	4319	18184	1563	10903	28119	337,549	0	7602	7878	15,479	353,029
Dairy	H	0	0	0	0	0	0	0	360,584	0	5000	0	5,000	365,584
Intensive animal production	H	0	0	0	0	0	0	0	14,547	0	0	0	0	14,547
Pigs	H	0	0	0	12225	0	0	0	13,580	0	0	0	0	13,580
Mining	H/L	0	0	0	40	0	0	0	2,823	272	0	342	614	3,437
Residential	H/L	396	0	141	272	0	62	246	3,615	54	0	0	54	3,669
Rural residential	H/L	0	0	0	0	0	0	0	793	374	0	0	374	1,166
Services	H/L	0	0	286	0	0	0	0	1,450	0	0	0	0	1,450
Golf course	H/L	0	0	0	0	0	0	0	355	0	0	0	0	355
Cropping > 500mm rainfall	H	82945	4783	53098	0	0	0	0	227,172	0	85	1	86	227,259
Cropping < 500mm rainfall	H	0	0	0	39951	3857	41252	82867	167,928	0	0	0	0	167,928
Grazing and improved pastures > 500mm rainfall	H	1440	0	2804	0	0	0	0	173,567	0	992	696	1,688	175,255
Grazing and improved pastures < 500mm rainfall	H	0	0	0	368	0	0	0	368	0	0	0	0	368
Plantation forestry	H	0	0	0	0	0	0	0	41,861	0	10	403	413	42,274
Seasonal horticulture	H	0	0	1005	0	0	0	0	66,531	0	0	0	0	66,531
Irrigated perennial horticulture	H	0	0	0	0	0	0	0	75,322	0	0	0	0	75,322
Conservation & natural environments	L	0	0	0	0	0	0	0	7,732	2158	3465	15566	21,188	28,920
Dairy	L	0	0	0	0	0	0	0	14,600	14000	17500	0	31,500	46,100
Cropping > 500mm rainfall	L	0	0	0	0	0	0	0	821	0	130	468	598	1,419
Grazing and improved pastures > 500mm rainfall	L	0	0	0	0	0	0	0	26,143	7870	24530	31500	63,900	90,043
Plantation forestry	L	0	0	0	0	0	0	0	739	62	813	2287	3,162	3,901
Seasonal horticulture	L	0	0	0	0	0	0	0	71	0	62400	106850	169,250	169,321
Irrigated perennial horticulture	L	0	0	0	0	0	0	0	10,240	0	0	0	0	10,240
POINT SOURCES									0				0	
WWTP's		900			9000		1200	5400	18,600				0	18,600
Katanning abattoir								11000	11,000				0	11,000
Aggregated emission (kg)		**91612**	**4784**	**61652**	**80041**	**5420**	**53417**	**127632**	**1,577,992**	**24789**	**122527**	**165990**	**313,306**	**1,891,298**
Cummulative load (kg)		245964	4784	112549	80041	48829	53417	127632		233291	230866	165990		
Attenuation factor		0.972	0.965	0.908	0.636	0.974	0.813	0.000		0.892	0.903	0.653		
Attenuated load (kg)		**239176**	**4619**	**102175**	**50897**	**47558**	**43409**	**0**		**208026**	**208502**	**108340**		

Hardy Inlet TN from Bw (kg)

Hardy Inlet TN from Scott (kg) — **Total (unrouted/unassim) (kg)** **1,891,298**

Total (kg)

TP modelling

Land use	Soil PRI	Bw1 base export (kg)	Bw2 base export (kg)	Bw3 base export (kg)	Bw4 base export (kg)	Bw5 base export (kg)	Bw6 base export (kg)	Bw7 base export (kg)	Bw8a base export (kg)	Bw8b base export (kg)	Bw9 base export (kg)	Bw10 base export (kg)	Bw11 base export (kg)	Bw12 base export (kg)	Bw13 base export (kg)	Bw14 base export (kg)
DIFFUSE SOURCES																
Conservation & natural environments	H	1	2	3	19	111	48	29	2	40	44	13	4	6	12	2
Dairy	H	147	1331	502	4123	0	159	326	0	0	624	0	0	0	0	0
Intensive animal production	H	0	0	0	115	0	0	49	0	0	127	0	0	0	0	0
Pigs	H	0	0	0	0	0	0	0	0	18	9	0	0	0	0	0
Mining		0	30	0	0	0	0	0	0	0	160	0	0	0	0	0
Residential		60	9	0	1	0	0	17	0	6	258	0	39	0	0	0
Rural residential		4	23	0	0	0	0	0	0	6	0	0	90	0	0	0
Services		30	0	0	39	0	0	0	0	97	14	0	0	0	0	0
Golf course		0	0	0	0	0	0	0	0	0	55	0	0	0	0	0
Cropping > 500mm rainfall	H	23	41	21	96	51	101	287	9	448	2276	1664	1956	2703	7168	3998
Cropping < 500mm rainfall	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grazing and improved pastures > 500mm rainfall	H	270	491	369	825	99	363	361	96	660	2532	949	1723	1345	874	897
Grazing and improved pastures < 500mm rainfall	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantation forestry	H	8	2	5	3	8	57	57	18	53	107	10	51	15	26	1
Seasonal horticulture	H	0	0	82	188	61	44	665	49	1175	980	0	365	798	0	272
Irrigated perennial horticulture	H	64	493	481	1887	0	0	211	0	71	752	0	215	814	268	124
Conservation & natural environments	L	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0
Dairy	L	265	1195	0	0	0	0	0	0	0	0	0	0	0	0	0
Cropping > 500mm rainfall	L	386	70	34	3	0	0	0	0	0	0	0	0	0	0	0
Grazing and improved pastures > 500mm rainfall	L	1238	3522	1192	323	0	0	0	0	0	0	0	0	0	0	0
Plantation forestry	L	37	15	22	0	0	0	0	0	0	0	0	0	0	0	0
Seasonal horticulture	L	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Irrigated perennial horticulture	L	0	383	232	0	0	0	0	0	0	0	0	0	0	0	0
POINT SOURCES																
WWTP's								50			290					
Katanning abattoir																
Aggregated Emissions (kg)		**2535**	**7610**	**2950**	**7622**	**330**	**771**	**2053**	**174**	**2575**	**8228**	**2636**	**4442**	**5681**	**8348**	**5294**
Cumulative load (kg)		2535	20589	2950	12802	8200	771	11952	454	2575	21266	15203	16448	5681	15977	5294
attenuarion factor		0.061	0.985	0.348	0.934	0.632	0.220	0.644	0.644	0.109	0.452	0.858	0.728	0.105	0.728	0.071
Attenuated load (kg)		**154**	**20275**	**1027**	**11953**	**5180**	**170**	**7700**	**293**	**281**	**9607**	**13038**	**11969**	**598**	**11627**	**378**
Hardy Inlet TP from Bw (kg)		**20429**														
Hardy Inlet TP from Scott (kg)		**23107**														
Total (kg)		**43536**														

TP modelling (cont.)

Land use	Soil PRI	Bw15a base export (kg)	Bw15b base export (kg)	Bw 16a base export (kg)	Bw16b base export (kg)	Bw17a base export (kg)	Bw17b base export (kg)	Bw18 base export (kg)	BW - total base export (kg)	Sc1 base export (kg)	Sc2 base export (kg)	Sc3 base export (kg)	SC - total base export (kg)	**TOTAL BASE EXPORT (kg)**
Conservation & natural environments	H	7	0	5	23	2	14	35	422	0	10	10	19	441
Dairy	H	0	0	0	0	0	0	0	7,212	0	100	0	100	7,312
Intensive animal production	H	0	0	0	0	0	0	0	291	0	0	0	0	291
Pigs	H	0	0	0	245	0	0	0	272	0	0	0	0	272
Mining		0	0	0	3	0	0	0	193	19	0	23	42	235
Residential		62	0	22	42	0	10	38	562	8	0	0	8	571
Rural residential		0	0	0	0	0	0	0	123	58	0	0	58	181
Services		0	0	44	0	0	0	0	226	0	0	0	0	226
Golf course		0	0	0	0	0	0	0	55	0	0	0	0	55
Cropping > 500mm rainfall	H	20021	1154	12817	0	0	0	0	54,835	0	21	0	21	54,856
Cropping < 500mm rainfall	H	0	0	0	5707	551	5893	11838	23,990	0	0	0	0	23,990
Grazing and improved pastures > 500mm rainfall	H	101	0	196	0	0	0	0	12,150	0	69	49	118	12,268
Grazing and improved pastures < 500mm rainfall	H	0	0	0	53	0	0	0	53	0	0	0	0	53
Plantation forestry	H	0	0	0	0	0	0	0	419	0	0	4	4	423
Seasonal horticulture	H	0	0	72	0	0	0	0	4,752	0	0	0	0	4,752
Irrigated perennial horticulture	H	0	0	0	0	0	0	0	5,380	0	0	0	0	5,380
Conservation & natural environments	L	0	0	0	0	0	0	0	10	3	4	19	26	36
Dairy	L	0	0	0	0	0	0	0	1,460	1400	1750	0	3,150	4,610
Cropping > 500mm rainfall	L	0	0	0	0	0	0	0	493	0	78	281	359	852
Grazing and improved pastures > 500mm rainfall	L	0	0	0	0	0	0	0	6,274	1889	5887	7560	15,336	21,610
Plantation forestry	L	0	0	0	0	0	0	0	74	6	81	229	316	390
Seasonal horticulture	L	0	0	0	0	0	0	0	4	0	3744	6411	10,155	10,159
Irrigated perennial horticulture	L	0	0	0	0	0	0	0	614	0	0	0	0	614
POINT SOURCES														
WWTP's		50			2100		525	1500	4,515				0	4,515
Katanning abattoir								1700	1,700				0	1,700
Aggregated Emissions (kg)		**20241**	**1154**	**13156**	**8172**	**553**	**6441**	**15112**	**126,078**	**3383**	**11744**	**14586**	**29,713**	**155,791**
Cumulative load (kg)		21161	1154	13156	8172	556	6441	15112	1	24842	22885	14586		
attenuarion factor		0.361	0.277	0.029	0.000	0.382	0.001	0.000	0.845	0.93016	0.93768	0.76379		
Attenuated load (kg)		**7630**	**320**	**387**	**0**	**213**	**3**	**0**		**23107**	**21459**	**11141**		

Total (unrouted/unassim) (kg) **155791**

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