GROUNDWATER INFORMATION FOR MANAGEMENT OF THE UPPER CANNING SOUTHERN WUNGONG CATCHMENT

WATER AND RIVERS COMMISSION REPORT
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SALINITY AND LAND USE IMPACTS

Water and Rivers Commission

GROUNDWATER INFORMATION FOR MANAGEMENT OF THE UPPER CANNING SOUTHERN WUNGONG CATCHMENT

by

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Cover photograph:
Wungong Brook by
Rezina Shams

Foreword

The Swan Hydrogeological Resource Base and Catchment Interpretation project was a Natural Heritage Trust (NHT) and Water and Rivers Commission (WRC) funded project (NHT 973705). The study areas were three priority catchments of the Swan-Canning rivers—the Ellen Brook, Brockman River and the combined Upper Canning Southern Wungong catchments.

The following were the main objectives of the study:

- To liaise with the Swan Working Group and catchment groups to determine issues, needs and appropriate products.
- To provide baseline groundwater information essential for the catchment groups to implement management plans.
- To compile maps of hydrogeological information at a scale appropriate to the decision-making processes of catchment managers.
- To transfer expertise into the priority sub-catchments by training, publications and advice in interpretation.

This report comprises a brief overview of the areas and management guidelines from the perspective of the groundwater issues. More detailed information can be found in the following project reports, posters and CD-ROM.

Reports
Groundwater information and management options for the Brockman River Catchment SLUI 2
Hydrogeological information for management planning in the Ellen Brook catchment SLUI 11
Groundwater information for management of the Ellen Brook, Brockman River and Upper Canning Southern Wungong catchments SLUI 12

Posters
Managing Nutrient Movement into Ellen Brook
Geology of Ellen Brook
Hydrogeology of Ellen Brook
Salt affected land? Yes! It's a groundwater problem! Brockman River Catchment

*CD-ROM**
Groundwater information and Management Zones for the Ellen Brook, Brockman River and combined Upper Canning and Southern Rivers and Wungong Brook catchments.

> *The data package on the CD-ROM contains the following themes in GIS format: surface water catchments and their subcatchments; hydrogeological zones; water monitoring sites for groundwater and surface water; management boundaries; regional soil surveys; topographic contours; roads; Local Government boundaries; and general climatic data.

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Summary

The combined Upper Canning Southern Wungong Catchments form a composite catchment undergoing major land use change and development near the Perth metropolitan area. Changes since settlement have already resulted in erosion, waterlogging, water quality degradation, emerging dryland salinisation and contamination of groundwater resources.

The catchment has a diverse geology and this has a major influence on the occurrence and vulnerability of water to European land use practices. The occurrence and quality of groundwater is most highly variable from east to west across the main geologic changes. Furthermore fresh groundwater is localised and limited in the eastern half of the catchment, while large groundwater resources are present in the western third of the area.

Erosion is significant mainly where the surface is clayey and the landscape steep, particularly the valleys and scarps of the Darling Plateau. There is major erosion in cleared areas, especially along streamlines where there is stock access and land development.

Shallow watertables in the clayey areas in the east of the Swan Coastal Plain and in the Darling Plateau can contribute to waterlogging and inundation of low-lying poorly drained land.

Groundwater in sandy surficial sediments varies in quality, may contain high nutrient levels at the watertable or at depth from point source contamination, and transports nutrients in solution from the western part of the catchment into the Southern River.

Nutrients enter the Upper Canning and Southern Rivers bound to eroding soil particles especially where ridges, slopes and drainage lines are poorly vegetated and used by stock and humans.

Land clearing on the Darling Plateau is the cause of localised mobilisation of salt stored in the soil profile, leading to the discharge of saline groundwater and land salinisation.

Investigations of groundwater contamination from land use, particularly landfill and liquid waste disposal, are well documented.

This report describes the current status and processes occurring in the catchment and gives guidelines for management of development and discusses its impact on land and water quality, in particular groundwater.

Keywords: Yilgarn Southwest Province, Perth Basin, hydrogeology, catchment, water quality, denudation, salinity, land use planning, Armadale, Kelmscott, Roleystone, Serpentine, SI5002

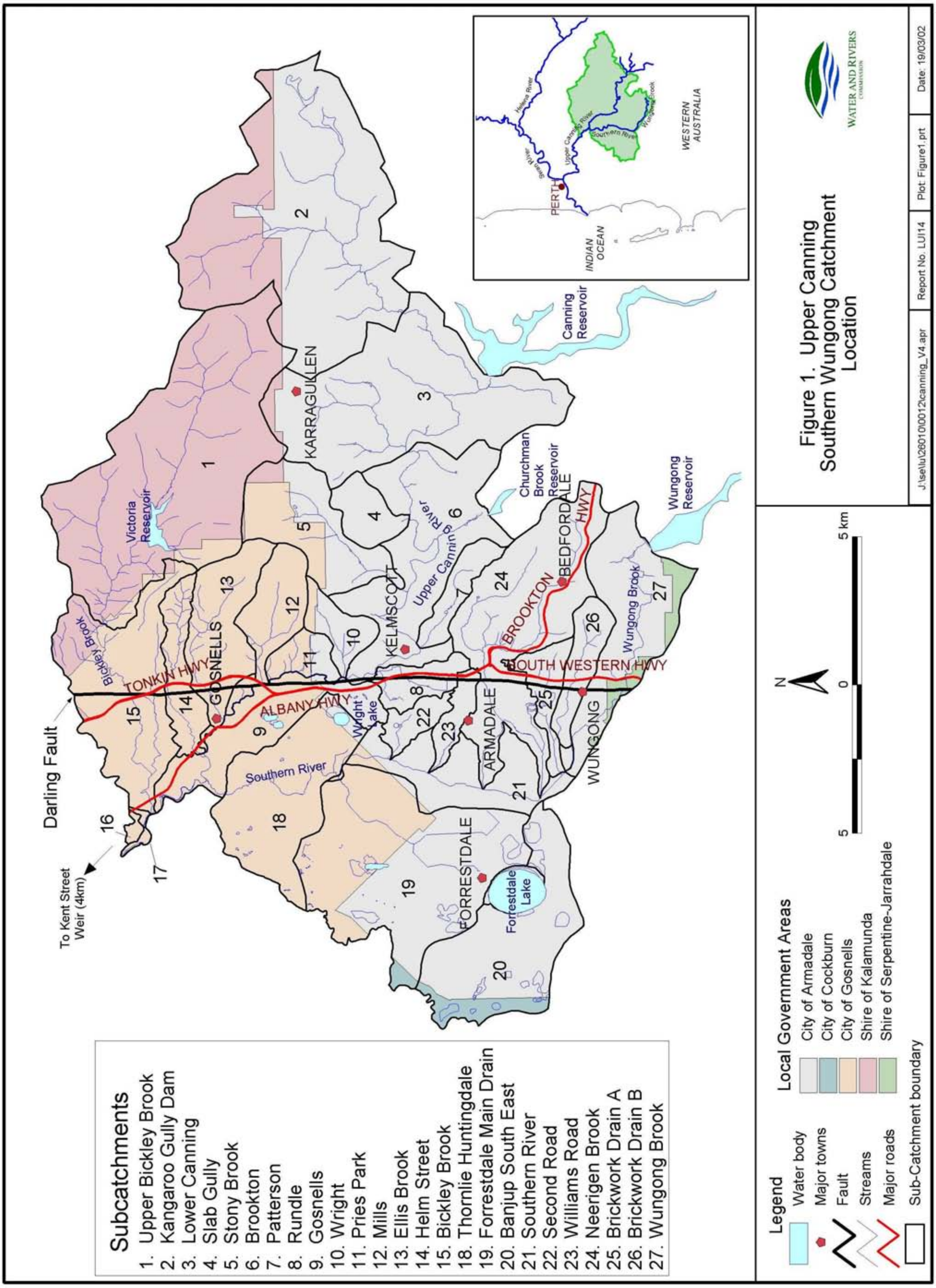

Figure 1. Upper Canning Southern Wungong Catchment Location

1 Introduction to the catchment of the Upper Canning and Southern rivers and Wungong Brook

Management of several subcatchments of the Swan and Canning Rivers is important to the Swan Canning Cleanup Program as the quality of water they discharge adversely impacts the environment downstream in the Swan and Canning Rivers (Swan River Trust and Water and Rivers Commission, 1999). Catchment groups identified that hydrogeological information in forms readily understood and useful to land planners and managers to undertake effective catchment planning was not available.

This report is part of a hydrogeological resource base compiled by the Water and Rivers Commission (Smith and Shams, 2002) that applies what we know about the hydrogeology of the Upper Canning Southern Wungong Catchment to management and planning issues. Other components of the resource base are a CD-ROM called "*Groundwater Information and Management Zones for the Ellen Brook Catchment, Brockman River Catchment and combined Upper Canning and Southern Rivers and Wungong Brook Catchment*" and posters entitled "*Nutrient movement into Ellen Brook" and "Salt affected land? Yes! It's a groundwater problem. Brockman River Catchment*". Erosion of banks and slopes, waterlogging and inundation of flats, nutrient entry to ground and surface water, salinisation on the plateau, and contamination of groundwater resources are important issues for management. The clearing and land use history, together with the differing groundwater behaviour across the geologically diverse catchment, have been instrumental in the emergence of the current issues for management and planning. An appreciation of the differing hydrogeological conditions is important to achieving good management practice and addressing the environmental issues.

The Upper Canning Southern Wungong Catchment of this study is the combined catchments of the Upper Canning River, the Southern River and Wungong Brook and is topographically subdivided into 27 subcatchments (Fig. 1). About one-third of the catchment is west of the Darling Fault scarp on the Swan Coastal Plain and two-thirds on the significantly higher dissected Darling Plateau (Fig. 2). The catchment extends downstream from the Canning and Wungong water supply dams on the Darling Plateau to the confluence of the Canning and Southern Rivers. Added to this area are the catchments of the Ellis and Bickley Brooks and two small unnamed catchments (16 & 17 on Fig. 1) on the eastern side of the Canning River, upstream of Yule Brook and about 4 km upstream of the Kent Street Weir. Below the Kent Street weir tidal movement in the Swan-Canning estuary influences water quality. The composite catchment, between 20 and 40 km south-east of Perth and between 20 and 50 km east of the coastline of Western Australia, covers an area of 405 km^2. It falls partly into five local government administrative areas – the City of Armadale, the City of Gosnells and the Shire of Kalamunda, with minor coverage by the City of Cockburn and the Shire of Serpentine-Jarrahdale.

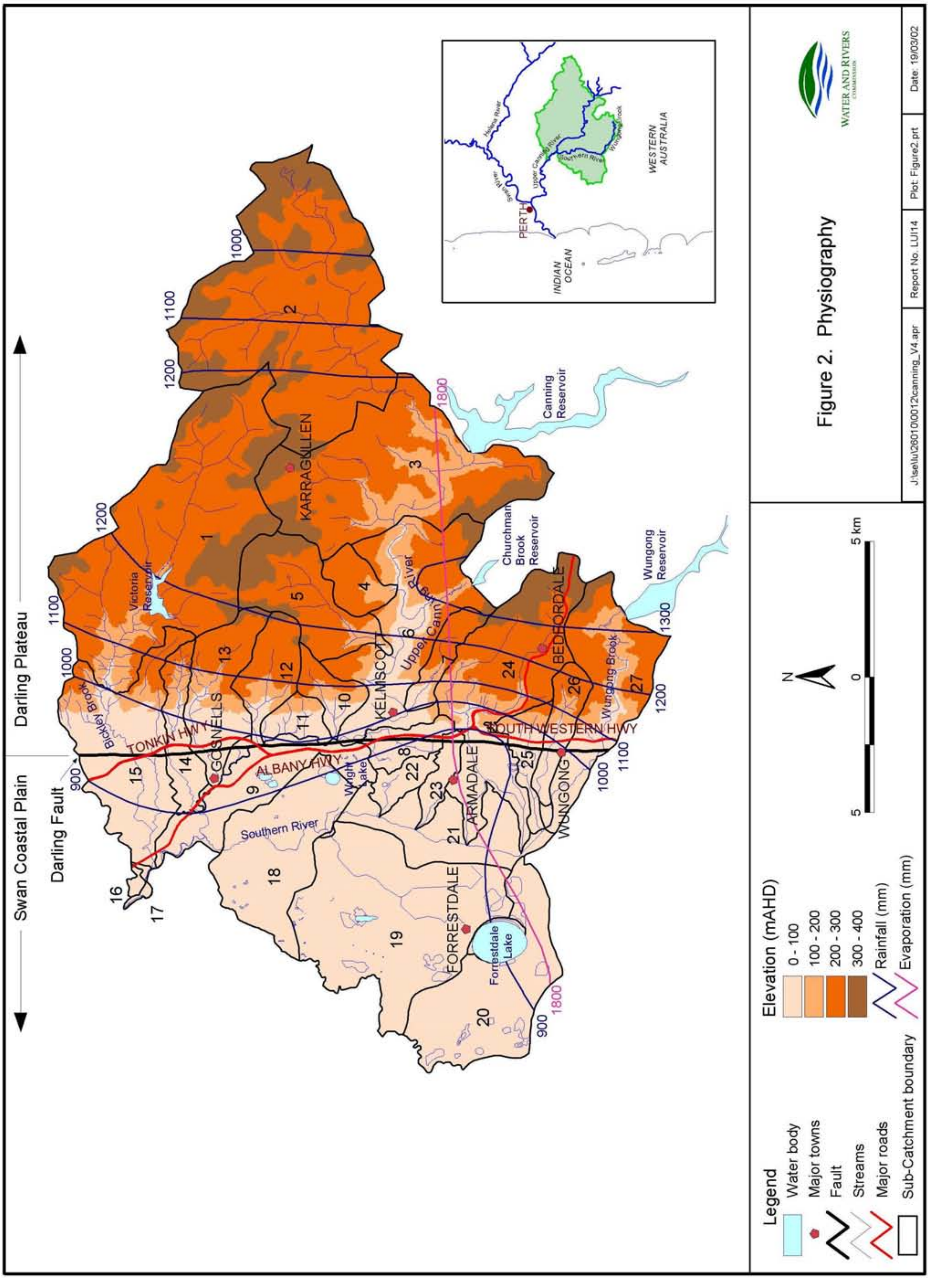

Figure 2. Physiography

2 Issues for catchment management

This report addresses the following 5 groundwater and surface water related issues:

- Erosion
- Waterlogging and flooding
- Nutrient export and water quality
- Salinisation
- Contamination of groundwater resources

As the catchment is eroding, the rivers suffer from sedimentation and weed infestation. They have been severely impacted over the years by decreased water flow with the construction of four public water supply dams (Canning, Wungong, Churchman and Victoria) and the summer damming of a significant perennial creek in Roleystone.

The Southern River and Wungong Brook are together the third highest contributor of nutrients, predominantly in soluble form, to the Swan-Canning Estuary, delivering an average of 5.7 tonnes of total phosphorus (TP) and 37 tonnes of total nitrogen (TN) each year to this river system (Donohue et al., 1994). In contrast the Upper Canning River has low phosphorus and moderate nitrogen loads but carries high sediment loads. Much of the nutrient, particularly phosphorus, is bound to clay particles. The combined nutrient load from the Southern River and Wungong Brook and high sediment loads from the Upper Canning River (Horwood, 1997) result in the excess nutrients in the Swan-Canning estuary and consequently algal blooms and fish deaths.

The change from native forests to agriculture and urban land use in this catchment of such variable landscape, physiography and geology has greatly altered the dynamic systems of groundwater, surface water and vegetation. Watercourses and aquifers receive leachate from fertiliser, landfill, liquid waste disposal, industry, animal wastes, septic tanks and sewage.

Lloyd (1997, 1998) compiled a snapshot overview of land degradation in each of the subcatchments (Fig. 3, Table 1). The detailed issues at subcatchment level discussed in the Upper Canning Southern Wungong Catchment Management Plan (Everall Consulting Biologist, 1999) are summarised in Table 1. The community has identified some of the major issues in the catchment to be:

- Erosion of soil
- The entry of nutrients to the rivers
- Rapid urban growth and development
- Inappropriate development and land use
- Degradation due to incomplete management
- Spread of weeds
- Public perception and ownership of catchment issues

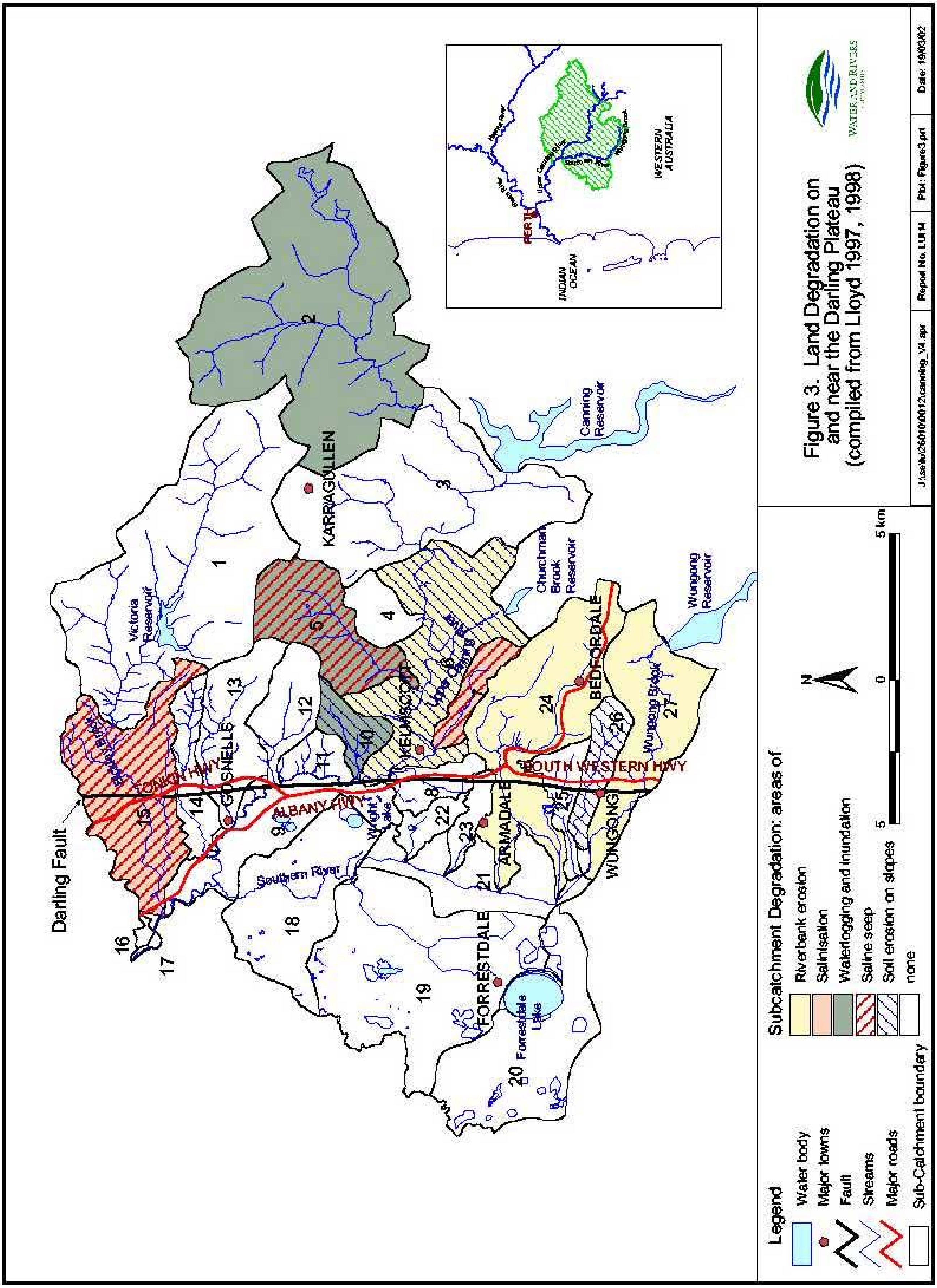

Figure 3. Land Degradation on and near the Darling Plateau (compiled from Lloyd 1997, 1998)

Table 1. Description of the subcatchments

This table has been adapted from Swan River Trust and Water and Rives Commission, 1999.

Subcatchment	*Area ha (km^2)*	*Surface water*	*Drainage lines*	*Land use includes remnant vegetation and condition*	*Issues*	*Shires/ Managers*
1. Upper Bickley Brook	5140 (51.4)	Shedding	13.2 km foreshore, Munday & Bickley Brooks	85% Water Corporation (native vegetation), 10% orchard, 5% recreation & quarry	Minor erosion of road side, firebreaks, undeveloped subdivision	Kalamunda, Gosnells, Water Corporation
2. Kangaroo Gully Dam	5450 (54.5)	Shedding, some ponding on the east	11.8 km foreshore	95% native vegetation, 5% developed for orchards & quarry	Minor erosion on roadside, embankments	Armadale, Kalamunda, Water Corporation, CALM
3. Lower Canning	3660 (36.6)	Receiving from sub-catchment 2 and shedding	9.1 km Kangaroo Gully	80% Water Corporation catchment area (remnant vegetation), 10% orchard, 10% small holdings, Araluen Park	Erosion of embankments & roadside, no sediment trapping from developed land, silt entering river	Armadale, Water Corporation, CALM
4. Slab Gully	420 (4.2)	Shedding	2.6 km channel, eroding, grassed, exotic species revegetated	85% urban development, 5% horticulture, 5% small holding, 5% remnant native vegetation	Minor erosion roadside	Armadale, Private
5. Stony Brook	1320 (13.2)	Shedding	5.9 km long	50% natural vegetation, 25% horticulture (orchard), 20% small holdings, 5% urban	Erosion in new subdivision	Armadale, Gosnells
6. Brookton	2370 (23.7)	Receiving from sub-catchments 2 & 3 and shedding,	14.2 km channel, erosion & weeds	50 % small holdings, 35% natural vegetation, 15% urban	Erosion along steep embankment, drainage line, subdivision, inappropriate access, poor vegetation practice	Armadale
7. Patterson	380 (3.8)	Shedding	4.2 km channel, grassed, weeds, eroding	25% urban, 25% natural vegetation, 50% small holdings (horses, park, horticulture)	Erosion due to rocks in drainage	Armadale, Private
8. Rundle	390 (3.9)	Shedding, ponding on flat areas	3.2 km is a excavated drain	Little natural vegetation	Erosion on roadside, drainage, embankment	Armadale
9. Gosnells	1240 (12.4)	Ponding, ill defined drainage	Poor condition, weeds	75% urban, 15% smallholdings (orchard & undeveloped paddock), 10% light industrial. Very little remnant vegetation	Erosion of roadside, gully, drainage line, wind erosion, poor storm water management led to wetland siltation & outlet erosion	Gosnells
10. Wright	390 (3.9)	Shedding	2.8km channel, silted from erosion	55% remnant vegetation, 30% horticulture & small holdings (in the hills), 15% suburban	Siltation due to sheet erosion from subdivision, erosion of roadside, embankment, firebreak, drainage line	Armadale

11. Pries Park	310 (3.1)	Shedding	5 parallel drains west to Canning River	50% remnant vegetation, 30% small holdings & playing fields, 20% suburban	Erosion of roadside, embankment, firebreaks and not drainage lines	Armadale, Gosnells
12. Mills	680 (6.8)	Shedding. Some waterlogging	6.8 km channel in good condition,	70% native vegetation, 15% orchard, 15% small holdings	Erosion of roadside, firebreaks, embankment	Gosnells
13. Ellis Brook	1200 (12.0)	Shedding, receiving, ponding	6.2 km channel, erosion, siltation	50% remaining vegetation (good condition), 35% small holdings, 5% each of (quarry & orchard and horticulture & suburban)	Erosion to roadside, embankment, inappropriate firebreak construction, wind erosion	Gosnells
14. Helm Street	600 (6.0)	Shedding in hills, receiving lower down, ponding on flat	7.1 km channel, empties into underground storm water drain	40% bushland, 15% small holding, 5% light industry/horticulture, 40% urban (Maddington golf course)	Erosion of drainage line, embankment, roadside, firebreaks	Gosnells
15. Bickley Brook	2130 (21.3)	Receiving, shedding, some ponding	9.6 km channel, lower part of channel is a ditch, defined by excavation, erosion	30% remaining bush (in good condition but degrading due to development), 40% small holding, 15% each of light industrial and urban	Erosion of firebreaks, roadside, embankment, drainage, wind erosion on bare paddocks	Gosnells
16 and 17 too small – no descriptions supplied						
18. Thornlie Huntingdale	1910 (19.1)	Receiving, ponding on Swan Coastal Plain	6.8 km channel is defined and natural, wetlands, on either side, downstream are unstable and eroding	55% urban (increasing), 15% small holdings, 5% poultry, 10% parks, 15% remaining bush (along drainage, degraded due to development)	Erosion of firebreaks, roadside, embankment, drainage, siltation from actively eroding areas	Armadale, Gosnells
19. Forrestdale Main Drain	3600 (36.0)	Ponding	8.1 km of constructed (Forrestdale Main) Drain, several wetlands on flat catchment	45% small holdings, 40% remnant bush (good condition in undeveloped areas, but degrading due to access tracks), 5% urban, 5% horticulture, 5% park/golf course, Prison complex, kennels, Water Corporation Septage Treatment Plant	Erosion of drainage line, roadside wind erosion of firebreaks on unstable sandy rise, clearing of new subdivision without stabilising	Armadale, Gosnells, CALM
20. Banjup South East	2050 (20.5)	Ponding, flat	No defined drainage, several wetland	50% small holdings (horses), 40% undeveloped bush (degraded due to access and stock), 5% intensive farming, 5% parks/quarry	Erosion of firebreaks, roadside, embankment, wind erosion due to poor pasture cover and access track	Armadale
21. Southern River	1210 (12.1)	Receiving, ponding	7.2 km channel, eroding	80% small holdings (horses & orchards), 15% urban housing, 5% remaining vegetation fringing channel, sparse and in poor condition)	Wind erosion from poorly pastured blocks, erosion to non-kerbed roadside	Armadale

22. Second Road	270 (2.7)	Receiving, ponding	No defined drainage, excavated stormwater drain	55% urban, 20% light industrial, 15% small holdings, 5% parks, 5% remaining native vegetation (in good condition)	Drain erosion and wind erosion	Armadale, Water Corporation
23. Williams Road	270 (2.7)	Receiving, ponding	Water Corporation stormwater drain, no main drainage	70% suburban, 20% smallholdings, 5% parks, 5% (horticulture & poultry). No remaining natural vegetation	Drain and roadside erosion	Armadale, Water Corporation
24. Neerigen Brook	2670 (26.7)	Shedding in hills, receiving on lower part	12.6 km channel, erosion in some areas, riparian vegetation varies	40% natural vegetation (in Bungendore Park and Armadale Settlers Common, in good condition), 25% small holdings, 25% urban (commercial centre of Armadale), 5% light industry, 5% orchards	Drainage line, roadside, embankment, sheet, wind, gully & firebreak erosion. Multiple use of brooks running through different smallholdings led to conflicting management strategy	Armadale, Bungendore Park Management Committee
25. Brickwork Drain A	400 (4.0)	Shedding, receiving, ponding on west	Defined as stormwater drain terminating in a wetland	30% small holding, 25% urban, 20% light industrial, 20% natural bush (encroached by development, grazing)	Drainage line, roadside, embankment, firebreak, rill, wind and gully erosion. Inappropriate steep subdivision construction is hazardous	Armadale, Bungendore Park Management Committee, Water Corporation
26. Brickwork Drain B	520 (5.2)	Shedding, receiving, ponding in west	4.3 km of main channel, become ill defined, ends in wetland	50% natural bush (good condition), 45% small holding , 5% light industrial	Erosion to drainage line due to inappropriate drop structure where storm water enter main drainage, roadside and embankment erosion	Armadale, Bungendore Park Management Committee, Water Corporation
27. Wungong Brook	1710 (17.1)	Shedding, receiving, ponding on west	9.9 km main channel in good condition, some weed invasion	65% bush (in good condition), 30% small holding (horse), 5% intensive horticulture	Drainage line, roadside, embankment, firebreak, rill & gully erosion due to multiple tracks and understorey removal by bushfire	Armadale, Bungendore Park Management Committee, Water Corporation

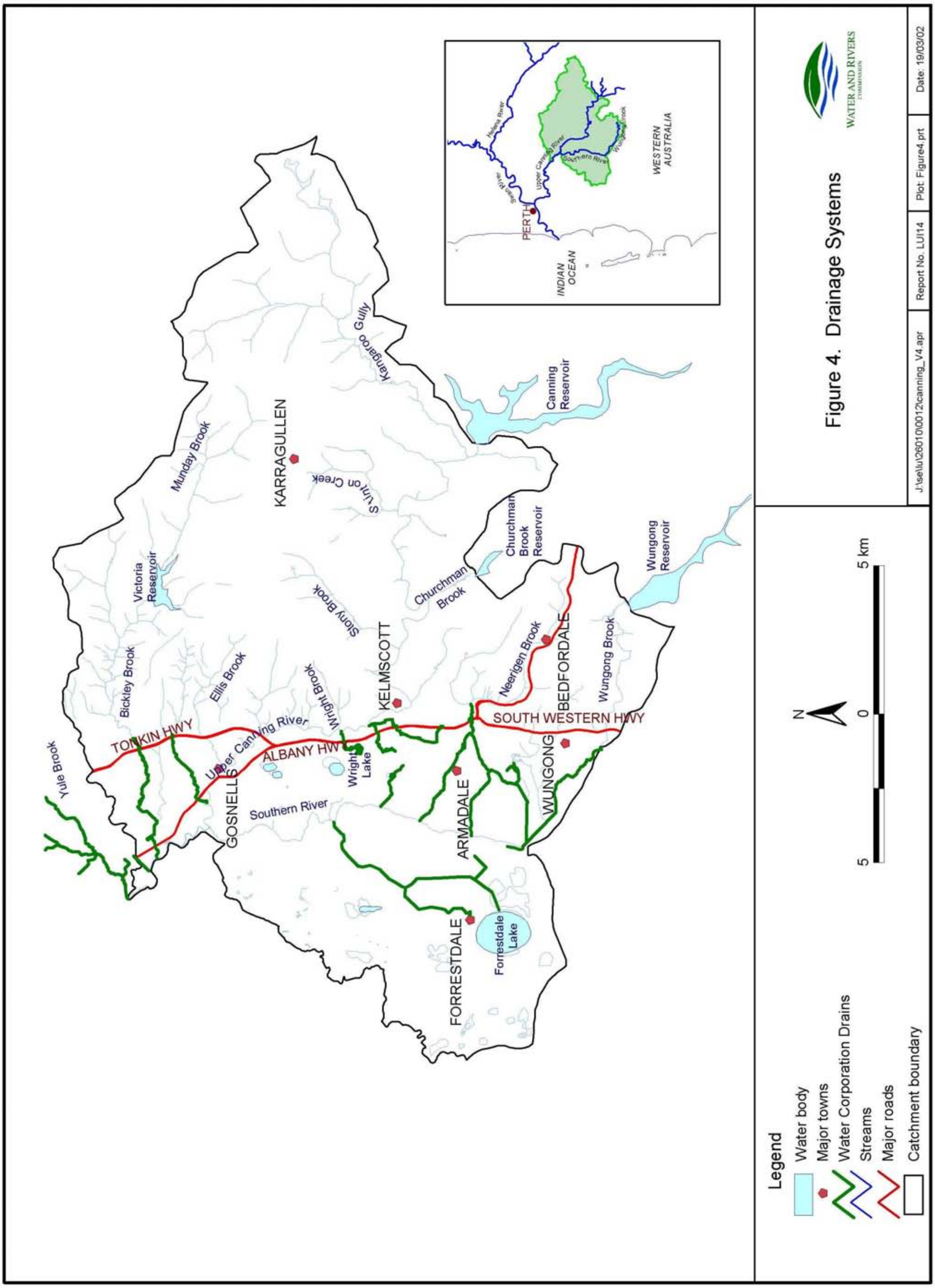

Figure 4. Drainage Systems

3 Catchment description

3.1 Geomorphology, rainfall and drainage

The Upper Canning Southern Wungong Catchment comprises two major physiographic units, the Swan Coastal Plain and the Darling Plateau, separated by the Darling Scarp, a surface expression of the Darling Fault (Fig. 2). The Darling Plateau is an ancient erosion surface extending east of the scarp with a maximum elevation of about 300 mAHD. The elevation of the Darling Scarp foothills ranges between 50 and 70 m AHD and the Swan Coastal Plain, extending westward from the foot of scarp, ranges in elevation between 10 and 30 mAHD. The Swan Coastal Plain comprises in the east a low-lying alluvial corridor (up to 10 km wide and known as the Pinjarra Plain) and in the west comprises undulating hills of the Bassendean Dune System.

Average annual rainfall for some 12 stations in the catchment, ranges widely from 850 to 1250 mm. Long term rainfall records (1901 to 2000) exist for two of the stations on both the Swan Coastal Plain (Armadale and Canning River Weir) and on the Darling Plateau (Churchman Brook and Wungong Dam). Although average annual rainfall exceeds 1000 mm at Araluen, Churchman Brook, Wungong Dam, Canning River Weir, Roleystone, Karragullen and Kelmscott, potential evaporation is about 1800 mm/a, increasing northeastward with temperature.

The drainage courses are labelled in Figure 3. The Upper Canning River is the section of the Canning River between the Canning Dam and Yule Brook, about 4 km upstream of the Kent Street Weir. Wungong Brook extends below Wungong Dam, but changes course northward and assumes the name Southern River near Wungong, before joining the Canning River at Thornlie. These main rivers have numerous tributaries dissecting the Darling Plateau. The courses of many of the brooks, for example Ellis Brook, have been influenced by bedrock fractures (Davis, 1942). Many of these streams are fed by springs, some of which flow all year round issuing from just below the laterite, so there are perennial brooks such as Wright Brook and Wungong Brook (downstream of the Wungong Reservoir).

In addition to the natural drainage channels on the Swan Coastal Plain, there is an extensive network of rural drains constructed for agricultural and urban land uses. This network comprises main drains and a more extensive network of smaller drains, particularly on road reserves, and private drains on freehold land. The smaller drains that are maintained by local authorities and landholders feed the main drains and branch drains, controlled by the Water Corporation (Fig. 3). To avoid flooding, the Water Corporation limits the flow from development sites when land use changes are proposed.

3.2 Significant areas, especially wetlands

There are many sites of special environmental value and cultural significance in the catchment including lakes, wetlands and sites significant to Aboriginal communities for artefacts, man-made structures, burial, ceremony or mythology, (Aboriginal Sites Register System of the Aboriginal Affairs Department, WA).

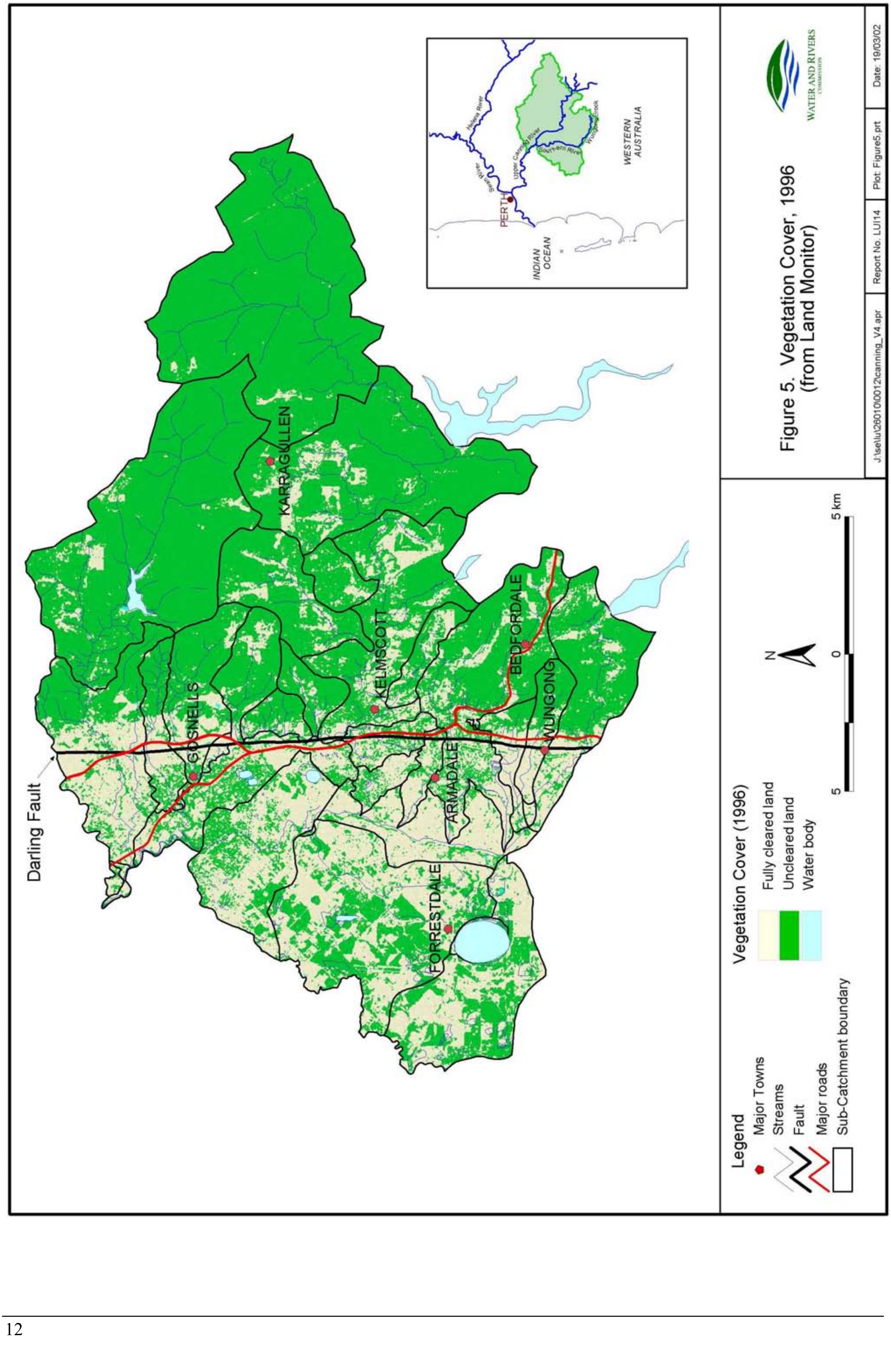

Figure 5. Vegetation Cover, 1996 (from Land Monitor)

Wetlands occur extensively in the Southern River Catchment, with palusplain type wetlands in the upstream catchment and dampland type wetlands in the downstream catchment area (Hill et al., 1996). Forrestdale Lake and Wright Lake are the two most important lakes, with sumpland and damplands also scattered around Forrestdale Lake (Fig. 2).

Forrestdale Lake in the Southern River catchment is a breeding ground and a stopover for migratory birds. It is listed in the Directory of Important Wetlands (Australian Nature Conservation Agency, 1993), is included under the Ramsar Convention (Department of Foreign Affairs, 1975), and is on the register of the National Estate.

Forrestdale Lake, a brackish seasonal lake with fringing sedgeland, is located at the margin between the Bassendean Sand on the west and Guildford Clay on the east. The lake is an ovoid sumpland rimmed with 5 m high sand ridge. The lake bed sediments consist of sandy organic mud overlying soft marly limestone and clayey sand. The lake is recharged by rain, groundwater discharge and several surface water drains, and is usually dry during three months of late summer and autumn. The mean water depth is 0.7 m, the mean salinity is 1480 mg/L and the pH ranges from 6 to 10.8. Although the lake has a 50 m wide buffer of native vegetation, it is threatened with eutrophication due to the increased nutrient input from the surrounding urban and rural land, groundwater extraction, and the spread of exotic plants (Australian Nature Conservation Agency, 1993).

Wright Lake is an oval shaped seasonal sumpland lake with a flat, shallow basin, limited fringing vegetation and urban development close on two sides. The lake is dry for at least 4 months of the year when summer groundwater levels fall to around 1.5–2 m below the lakebed. Maximum water depths of about 0.5 m occur during winter when groundwater levels rise. Artificial drains cut to the lake through a low ridge of surrounding dunes supply limited surface water input. The 1990–1992 study found it to be alkaline, turbid and with nitrogen and phosphorus concentrations high enough that to cause eutrophication.

A large proportion of low permeability clay in the soil profiles at the lake margins restricts groundwater movement into and out of the lake and groundwater beneath the lake is commonly saline. Wright Lake is one of the eastern-most lakes on the Swan Coastal Plain and is usually saline (Water Authority of Western Australia, 1993).

3.3 Vegetation, clearing history and land use

Large areas on the Darling Plateau are fully forested (Department of Conservation and Environment, 1978). Figure 5 shows the 1996 vegetation map prepared using Landsat Thematic Mapper imagery by the Land Monitor project 1988–1998 (http://www.landmonitor.wa.gov.au/index.html). Churchward and McArthur (1980) discuss the vegetation complexes on the Darling Plateau and the Swan Coastal Plain and Pen (1993) documents the present day vegetation. The dominant vegetation community along Canning and Southern Rivers is flooded gum and small paperbark but introduced weeds including watsonia, arum lily, and paspalum have replaced the native understorey. Bullrush is associated with recent disturbance of land and stormwater runoff. Small citrus orchards are scattered along the Canning River. A huge range of vegetation, a community referred to as a winter wet depression complex, remains undisturbed on the coastal plain in the south along the low-lying waterlogged land of Southern River and

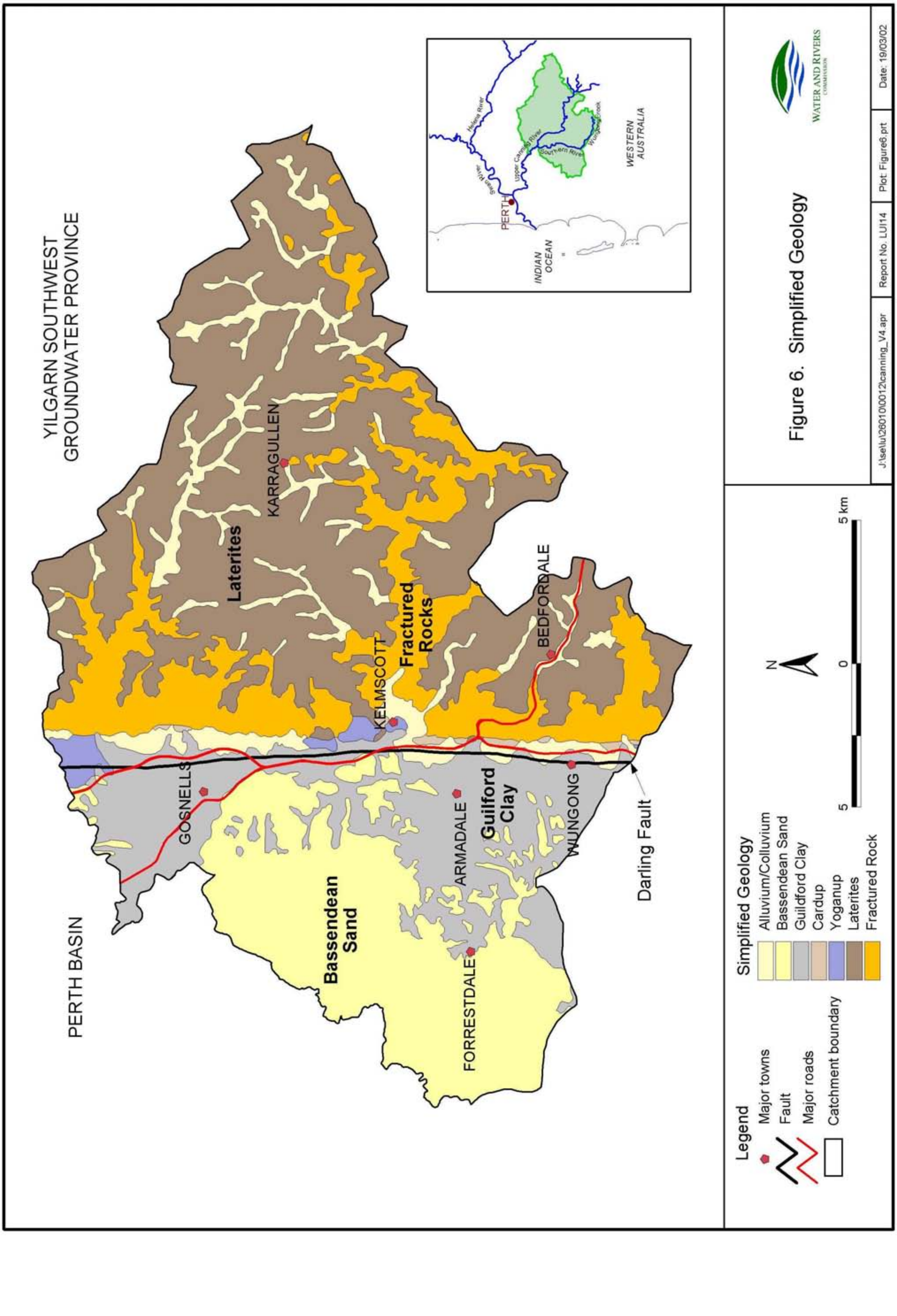

Figure 6. Simplified Geology

Wungong Brook. This vegetation community comprises *Eucalyptus rudis, Eucalyptus calophylla* etc. on pastured land; *Banksia attenuata, Banksia menzeissi* etc. on sandy rises; and *Melaleuca raphiophylla, Juncus* sedgeland*, Typha orientalis* etc. on the wetlands. Below the plateau, the introduced weed community in the understorey is considered a threat to native vegetation in the long run. On the slopes and ridge tops of the Darling Plateau, *Eucalyptus calophylla* and *Eucalyptus wandoo* are present above the native understorey and pastures.

There has been major clearing on the lateritic upland (Fig. 6) and the area bounded by the Upper Canning River in the south and Munday-Bickley Brook in the north (Fig. 4)**.** On the Pinjarra Plain native vegetation was cleared extensively from both sides of the Southern River, and only a sporadic distribution of remnant vegetation can now be found on the Bassendean Sand to the west. Land clearing took place along the Canning and Southern Rivers in the late 1830s and 1840s and there was widespread clearing in the 1890s for the development for market gardens, orchards, dairies, vineyards and grazing. Extensive jarrah logging on the Darling Plateau continued until the early 1900s. Urbanisation along the Canning River began in the early 1940s and peaked in the 1970s with orchards and paddocks coexisting with the residential development. Semi-rural land still straddles the banks of the Southern River and Wungong Brook, however, there is increasing pressure for urbanization in these catchments (Pen, 1993).

On the Darling Plateau, major land uses are rural, urban and forested. Horticultural activities, mainly orchards, predominate along the valleys of the Upper Canning River, Stony Brook, Slab Gully, Stinton Creek, Kangaroo Gully, and Neerigen Brook. Pasture and turf growing are other small-scale agricultural activities on the plateau. Pockets of urban development occur on slopes and hill tops in the Roleystone and Kelmscott area. Large areas classified as forest are remnant vegetation or State Forest pine plantations managed by CALM and some of these are on top of catchment areas for Public Water Supply reservoirs. There are also several quarries, a waste disposal and several illegal landfill sites on the Darling Plateau.

On the Swan Coastal Plain, both urban and rural activities are important. Urban residential and industrial developments are mainly along the Upper Canning River and lower reaches of the Southern River (City of Armadale zoning map and City of Gosnells town planning scheme no.1). Rural residential, poultry, pasture and nursery activities are the land uses in the upper reaches of the Southern River. In addition there are several waste management sites still operating. In Gosnells there are two out of seven landfill sites possibly still active (Water and Rivers Commission, Site Legaci database). In Armadale there are two known former waste disposal sites at John Dunn Reserve and Springdale Road, Roleystone, and one active landfill site at Hopkinson Road (City of Armadale, 2000). Local industries include brickworks, beef farming, orchards, and tourism. The non-sewered areas of the City are in the Forrestdale town site, Roleystone urban area, Churchman Brook, Champion Road industrial strip at Kelmscott, south Armadale industrial area and the hills urban area to the east. The Shire of Gosnells is about 75% sewered leaving an area on Wannaping Road to be infilled by the Water Corporation, future subdivisions to be connected by developers, public open space north of Bickley Road and the coastal plain south of Holmes Street.

Regeneration of native species is occurring along the rivers on the Swan Coastal Plain and near the Darling Scarp with the change in land practice from agriculture to urban. Previously agricultural practices destroyed seedlings and saplings, and prevented regrowth. However the human activity and vehicle access associated with urbanization is favouring infestation by *Acacia saligna,* a species known to exploit disturbed sites. On the plateau, regeneration of native species along the rivers is under threat due to weed infestation and bank erosion.

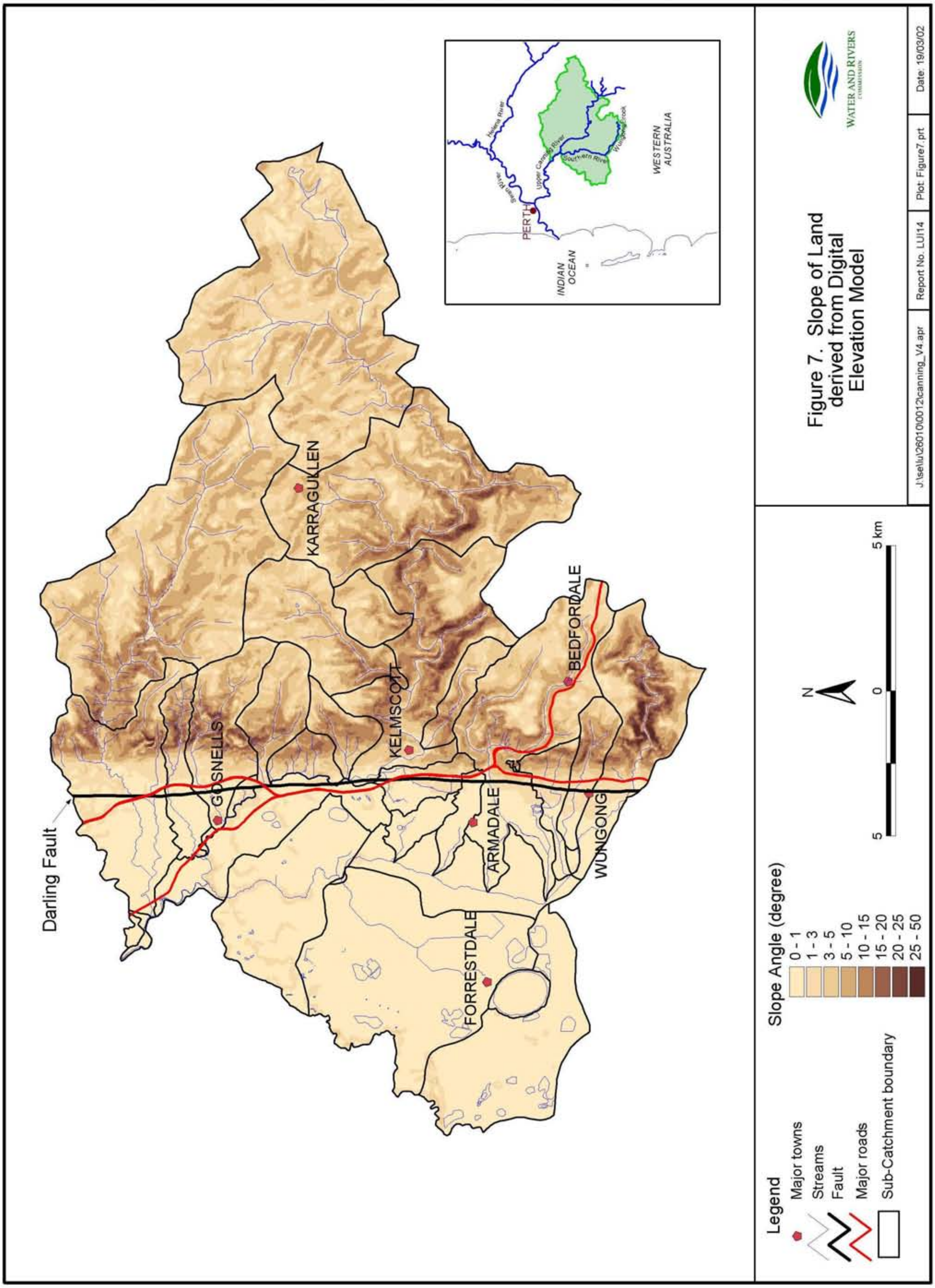

Figure 7. Slope of Land derived from Digital Elevation Model

4 Why geology and groundwater are important in catchment management

The geology (Fig. 6) influences the occurrence of groundwater, its movement, and its varied response to land practices and thus strongly influences the nature and extent of land and water degradation. The properties of individual geological units play a significant role in the interaction of surface water and groundwater, and determine susceptibility to salinisation. The slope of the land where these geological units occur, their proximity to geological structures (such as a fault zone) and their ground cover determines the potential for degradation by erosion.

The Upper Canning Southern Wungong Catchment is bisected by the Darling Fault, which separates crystalline rocks of the Yilgarn Southwest Groundwater Province in the east from sedimentary aquifers of the Perth Basin. To the west of the Darling Fault the basement rock was gradually down thrown some 12 km as sediments, comprising sand, silt, clay and limestone, were deposited. To the east of the Darling Fault, the Precambrian crystalline basement rock has been weathered and eroded to form the Darling Plateau. Sedimentary rocks of the Cardup Group, Ridge Hill Sandstone and Yoganup Formation occur sporadically as a narrow band along the scarp between the granitic rocks on the east and the younger horizontal sediments of the Perth Basin on the west (Wilde and Low, 1980). The following sections describe the variation in geology (Fig. 6), quality and movement of groundwater and discuss the implications for degradation in each of the two major physiographic units (the Swan Coastal Plain and Darling Plateau) and the scarp area between them.

4.1 Darling Plateau geology and groundwater

The crystalline rocks on the Darling Plateau comprise granites, migmatites, gneisses and dolerites of Pre-Cambrian age (Prider, 1943). Thomson (1943) and Davis (1942) discussed the crystalline rocks of the Wungong, Armadale and Gosnells areas. Hybridised gneiss is the predominant rock in Armadale and Wungong. Massive granitic rocks with gneissic structure are common in Gosnells. The rocks are intruded (vertically) by thin quartz veins and basic dykes, although the quartz veins are limited within the granitic rocks. The trends of the veins are north-northwest at Wungong, west-northwest at Armadale, northeast at Gosnells. Basic dykes, younger than the quartz veins, are common and show marked variation in trends. At Armadale they trend east with few north trends and at Gosnells they trend north.

The parent crystalline granitic and gneissic rocks on the Darling Plateau have undergone weathering and erosion, and the plateau (partially dissected by present drainage) has a laterite-capped regolith on the upland. The weathering process leading to the development of regolith from these rocks, the physical properties of laterite developed from granite, the chemical and mineralogical variations through the laterite and bauxite profiles, and the hydraulic property variations of the different zones within the regolith are discussed by many authors (Anand, 1995; McCrea and Stratico, 1989; Davy, 1979, Clarke et al., 2000). Most laterite developed *in situ* by the weathering of bedrock and grades downward through a pallid zone of variable thickness into weathered bedrock. Differences in colour, texture and composition can be observed between laterite developed over felsic and mafic rocks. The main period of laterization on the Darling Plateau is considered Tertiary.

Tertiary age sediments are also present in the catchment. A conglomerate occurs near the foot of Darling Scarp at Kelmscott, Armadale and on the flank of valleys incised into the scarp at Roleystone. Thin ribbons of alluvium with minor colluvium locally overlie the laterite of the Darling Range at the heads of present valleys. They are flat deposits upgradient of colluvium or rock outcrop (Wilde and Low, 1980).

The slope of the land is important factor in the vulnerability to erosion. The slope of the land is determined from the digital elevation model (Fig. 7). Along the face of Darling Scarp, the slope increases from 6^o to 16^o within 300 m. The valley sides of major rivers and tributaries have steeper slopes of about 20^o (33%). Steeper valley sides are also observed in the lower reaches of Neerigen Brook. These areas are proximal to a major fault line (the Darling Fault), sheared zone and sheared rocks (Wilde and Low, 1980) where the rocks may be highly fractured. Occurrence of fractured and faulted rocks on steep slopes suggests a landscape that is vulnerable to erosion. The removal of vegetation reduces the stability of these land surfaces and further increases the potential for erosion. High levels of nutrients bound to clay are readily transported into waterways due to the erosion of clay (from the weathered profile beneath the laterite) especially on steeper slopes such as in Kelmscott (Tan, 1991).

On the Darling Plateau, limited groundwater resources are found within the aquifers developed in the regolith. There are sparse unevenly distributed data. Information on the geological strata in about 85 bores on the Darling Plateau is recorded in the WIN database. These bores are mainly located close to the scarp, with some on the lateritic ridges and along the valleys. They were drilled within the weathered overburden above the granite basement rock ranging in depth between 1.5 and 40 m.

Dryland salinisation is evident in cleared sections of the plateau but will remain limited while the catchment is substantially forested. The WIN database has about 100 groundwater salinity records, ranging between 77 and 7 000 mg/L TDS. About 80% indicate fresh, 10% marginal, and 10% brackish to saline groundwater, with fresh and saline groundwater found both near the scarp and on the plateau. Saline bore water was found associated with salt affected land near the head of tributaries to Stinton Creek, Kangaroo Gully and Munday Brook (Figs 5 & 4). The link between the clearing of native vegetation and subsequent land salinisation is well documented (Wood, 1924; Henschke, 1983; Williamson et al., 1987; George, et al, 1997 and many others), and the areas mapped as salt affected land in 1987 and 1996 were cleared prior to 1988 (http://www.landmonitor.wa.gov.au/index.html). Clearing of further vegetation will result in rising groundwater levels, as the catchment has between 1000 and 1300 mm average annual rainfall. Tsykin and Slessar (1985) state there is little accumulation of salt in the soil profile near Darling Scarp because of significant groundwater contribution to stream flow attributed to high rainfall in the area and development of an incised landscape. Flushing rather than accumulation of windborne salt predominates due to the high rainfall and generally steep, well-draining landscape.

4.2 Darling Scarp geology and groundwater

Sediments of different types are present as narrow bands of isolated outcrops along the scarp face. The rocks are present as isolated patches trending parallel to the scarp on the west of the granitic rocks of the Darling Plateau (Fig. 6).

The Cardup Group is a series of slaty sediments comprising weakly metamorphosed shale, siltstone, sandstone and minor conglomerate (Wilde and Low, 1980). The sediments dip steeply west and strike

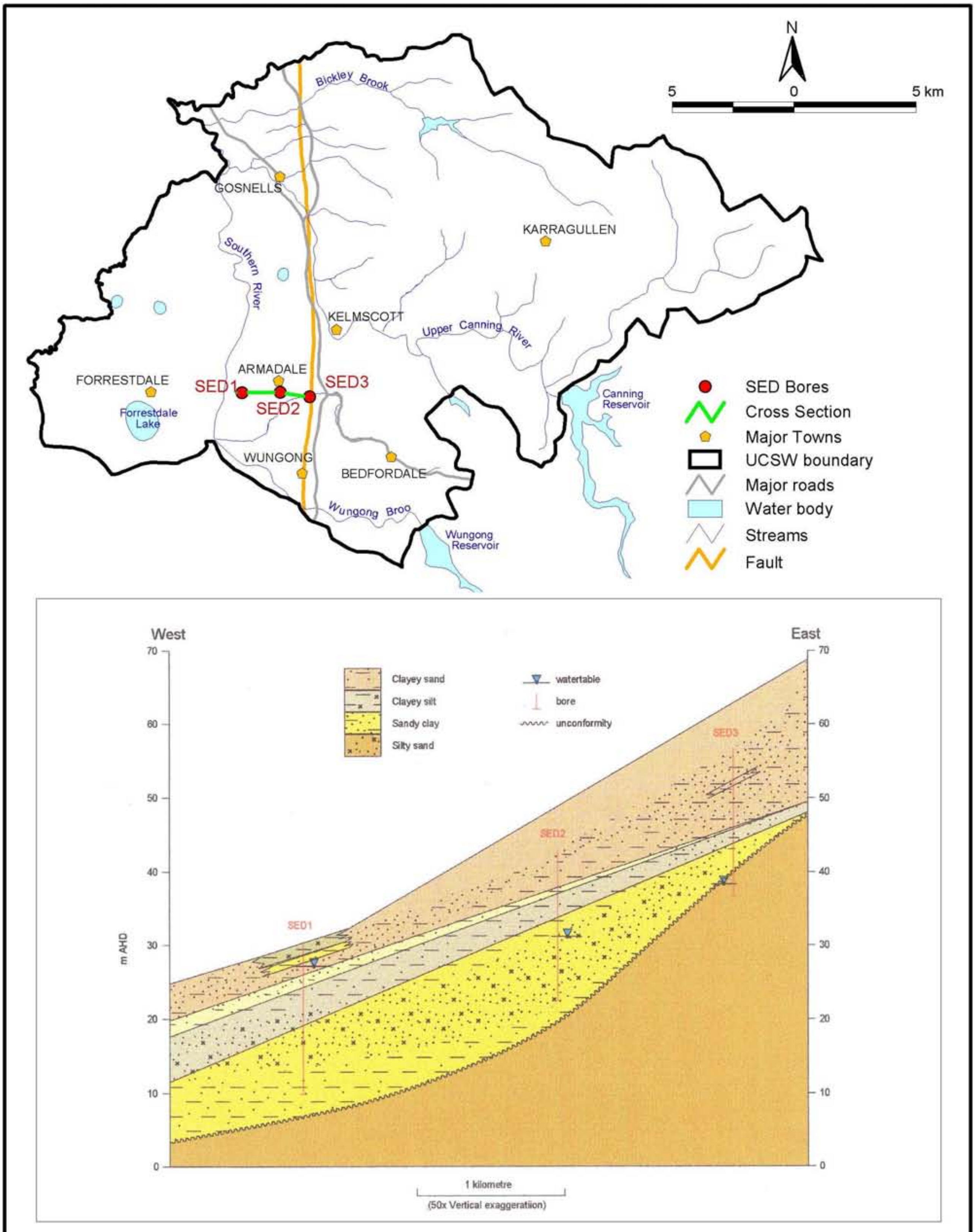

Figure 8. Geological section of the foothills

J:\se\lu\26010\0012\canning_extra_V3.apr | Report No. LUI14 | Plot: Figure8.prt | Date: 18/02/02 almost due north. They are found near Wungong, Armadale and Gosnells and outcrop west of the granite near Ellis Brook (Davis, 1942) and Wungong Brook (Thomson, 1943). The contact between the Cardup Group and the granite gneiss is nowhere exposed however quartz dolerite dykes have intruded along the contact. Larger dykes trend east and narrower dykes strike north to north-northwest (Thomson, 1943). The slaty rocks are susceptible to erosion. Bores drilled in these rocks have obtained groundwater but the quality is not known.

The Yoganup Formation is a shoreline deposit consisting of a basal conglomerate and foredune with local concentrations of heavy minerals above the conglomerate. These rocks occur in isolated patches along the face of the Darling Scarp and their base lies from 35 to 45 m above sea level. In the north of the catchment, it occurs in an area bounded by Bickley Brook, Yule Brook and Tonkin Highway. The unit also occurs in several isolated patches in the area bounded by Upper Canning River, Wright Brook and Albany Highway near Kelmscott. Another occurrence is south of the intersection between the South Western Highway and Wungong Brook. The Yoganup Formation is usually unsaturated and rarely targeted for water drilling. Groundwater is likely to be fresh but vulnerable to contamination. It infiltrates through this surficial formation to recharge deeper aquifers.

Colluvial deposits consist of interbedded and lensoid clay (mainly grey to orange stiff and hard clay) and sandy clay with minor sand and gravel beds (Fig. 8). Their stratigraphy and groundwater potential were revealed in the construction of five of a series of monitoring bores in the foothills of the Darling Scarp between Armadale and Keysbrook (Rockwater Pty Ltd, 1995). Drilling indicated the depth to basement rock is about 20 m. Saturated thickness of these superficial deposits decreases from 25 m near Armadale in the north to 10–15 m in the south near Serpentine. Groundwater is generally fresh to brackish but saline groundwater is also found in some areas. Small groundwater resources are available from the sand and gravel beds. Water resources along the foothill region are limited and localised due to the sediment variability and spatial discontinuity of the sand lenses.

These minor aquifers are recharged by rainfall and seepage from streams draining the Darling Scarp. The flow of groundwater from the foothill region is at a steep hydraulic gradient (average about 0.01) toward the Southern and Canning Rivers. Locally groundwater also discharges into the Wungong Brook.

Depth to water is more than 4 m northeast of the Southern River and Wungong Brook, 0.5 m adjacent to the Southern River, and 1–3 m near the Wungong Brook. In some areas, with clay layers and cemented ferruginous sand (coffee-rock) near the watertable, groundwater is perched above the regional watertable. Where colluvial sediments overlie a deeper aquifer (Leederville or Yarragadee Formation), some groundwater moves downward to recharge them. During winter, with recharge from more elevated areas in the east, some of the bores in the interlayered sand and gravel beds develop artesian heads.

Due to the clayey soils, the surface drainage is generally poor and numerous drains have been constructed to alleviate flooding. Although the susceptibility to flooding has been mitigated by lower rainfall, improved drainage and damming of rivers, additional clearing in the uphill area has caused groundwater levels to rise and exacerbated inundation of the land surface.

4.3 Swan Coastal Plain geology and groundwater

The Swan Coastal Plain on the west of the Darling Scarp is part of the Perth Basin (Playford et al., 1976). Sediments in the Perth Basin are about 12 000 m thick but only the uppermost 50 m are significant for understanding catchment degradation. These superficial sediments of Late Tertiary (Pliocene) to Quaternary age (from 2 million years ago to Recent), collectively known as the superficial formation (Davidson, 1995), comprise the Ascot Formation, Guildford Clay, Gnangara Sand and Bassendean Sand (Table 2). They consist of sand, silt and limestone deposited in marine, shallow marine, fluvial, lacustrine, and colluvial environments. Guildford Clay in the east and Bassendean Sand in the west form the surface geology. The Ascot Formation and Gnangara Sand occur in the subsurface (Fig. 9).

Table 2. Stratigraphic sequence on the Swan Coastal Plain

Age		*Stratigraphic unit*		*Symbol*	*Occurrence*	*Lithology*	*Groundwater*
Cainozoic	Late Tertiary–Quaternary	Superficial formations	Bassendean Sand	Qd	Surface	Sand with silt and clay	Superficial aquifer
			Gnangara Sand	Qn	Subsurface	Sand and gravel with silt and clay	
			Guildford Clay	Qg	Surface	Clay with sand and gravel	Local confining bed
			~~ Unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~				
			Ascot Formation	Ta	Subsurface	Limestone, sand, shells and clay	Superficial aquifer
			~~ Unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~				

The Bassendean Sand occurs widely west of the Southern River, overlies the Gnangara Sand and interfingers with the Guildford Clay to the east. It consists of pale grey to white, fine to coarse-grained, but predominantly medium grained, moderately sorted, subrounded to rounded quartz sand fining upward. Dark heavy minerals occur scattered throughout the formation. A layer of friable, limonite-cemented sand (coffee rock) occurs at about the watertable throughout most of the area.

Areas of Bassendean Sand are not susceptible to water erosion because of the sandy character and the very flat ground (slope is generally less than 1º). Rainfall readily infiltrates to recharge groundwater and thus generates little runoff. Depth to groundwater is generally between 1 and 5 m and in some areas is more than 10 m. However where the watertable is shallow and rises above ground in winter, groundwater inundates the land surface and generates overland flow. Contaminants in such groundwater move readily with overland flow into the drains and eventually into the Southern and Upper Canning Rivers.

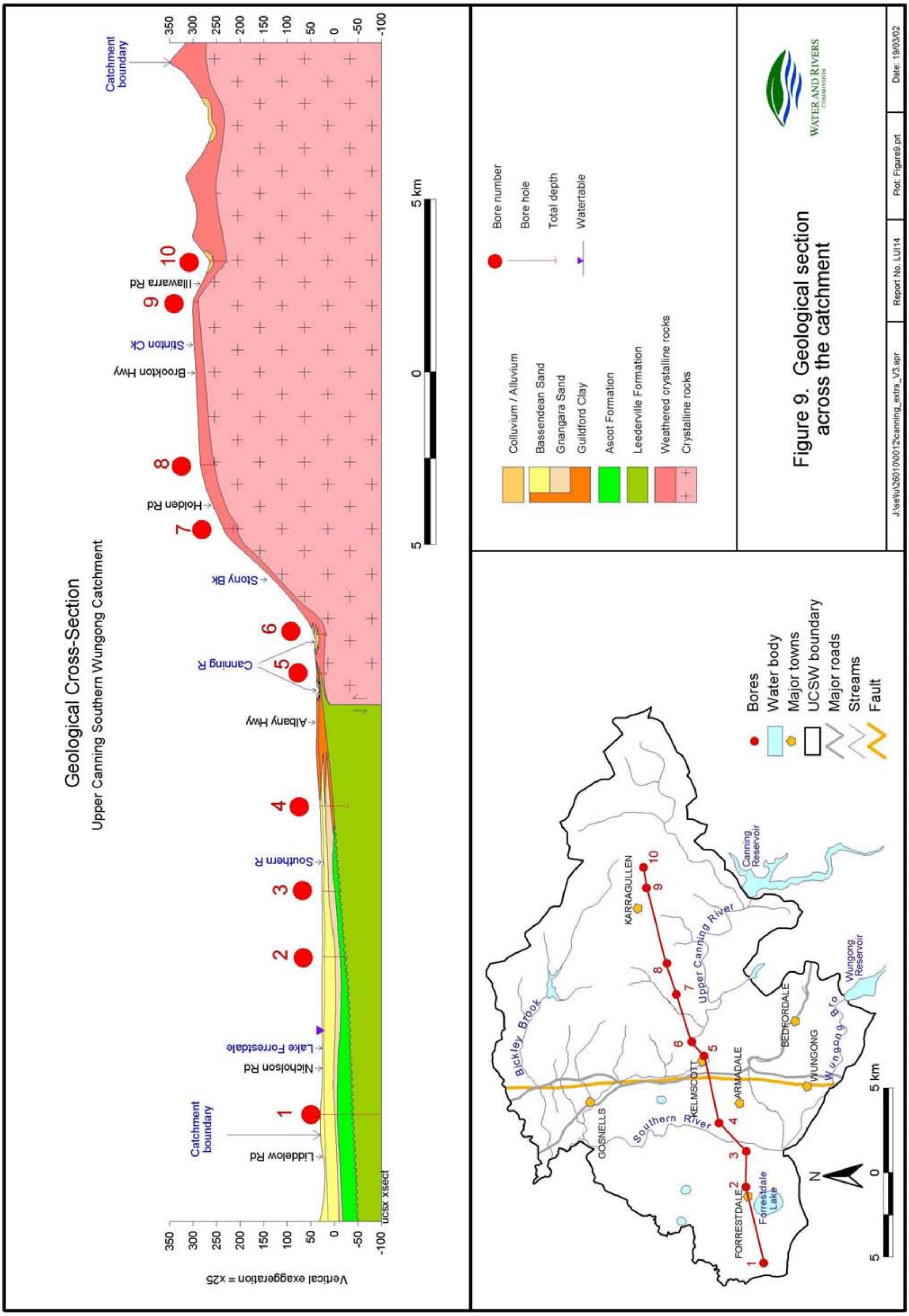

Figure 9. Geological section across the catchment

The Gnangara Sand is basal sand interfingering with the Guildford Clay in the east and resting unconformably on the Ascot formation. It is overlain by Bassendean Sand in the west. It consists of pale-grey, fine-to very coarse-grained, very poorly sorted, subrounded to rounded quartz sand and abundant feldspar.

The Guildford Clay consists of pale-grey, blue, but predominantly brown silty and slightly sandy clay, and interfingers to the west with the Gnangara Sand and Bassendean Sand. The unit occurs widely east of the Southern River. A chalky calcrete deposit known as the 'Muchea Limestone' occurs in small isolated patches on the Guildford Clay around the Southern River in the south of the catchment. Although the surface of the Guildford Clay is very flat it is clayey so rainfall runoff is significantly greater than infiltration.

The Ascot Formation lies unconformably on Cretaceous sediments. It comprises hard to friable, grey to fawn calcarenite with thinly interbedded sand commonly containing shell fragments, glauconite and phosphatic nodules at the base. The fine to coarse sand is very poorly sorted, angular to rounded, and contains a rich assemblages of bivalves and gastropods. Thick beds of shelly, silty clay are found locally with thinly bedded glauconitic clay near the base of the formation. A thin band of well-cemented calcareous sandstone occurs at the top of the formation.

The groundwater occurrence and flow in the superficial aquifer of the Swan Coastal Plain is discussed in detail by Davidson (1995). Groundwater in the superficial aquifer is unconfined. Thickness of the superficial aquifer is about 40 m to the west of the Southern River and about 20 m to the east. Groundwater moves in both lateral and vertical directions, with lateral movement being dominant. The lateral flow in the west of the catchment is east and northeast from the Jandakot Mound (a recharge area) to discharge into the Southern and Upper Canning Rivers. However, locally groundwater flow is influenced by local land uses (that increase the recharge) and radial groundwater flow from the Southern River liquid disposal site (Hirschberg, 1982; Sinclair Knight Merz, 2000).

West of Southern River large groundwater resources are present in extensive aquifers consisting of Bassendean Sand, Gnangara Sand and Ascot Formation. These geological units are in hydraulic connection with each other allowing transference of groundwater between two adjacent units. The hydraulic conductivity of about 20 m/d evaluated for the superficial aquifer comprising Bassendean Sand, Gnangara Sand and Ascot formation by many workers (Smith, 1982; Martin and Baddock, 1989; Deeney, 1985a,b; Wharton, 1981a, b) suggest rapid movement of groundwater. Regional groundwater flow through these units is in the same direction.

East of the Southern River, small groundwater resources are present in the Guildford Clay and the watertable is very shallow (between 1 and 5 m below ground). Evaporation from the shallow watertable concentrates salt that, due to the low drainage properties of the clay, cannot be flushed out. Thus brackish to saline groundwater occurs at the watertable in these areas. In winter these areas are inundated by overland flow due to rising groundwater. Hill et al. (1996) maps these areas as palusplain, sumpland and dampland. In the south of the catchment, Guildford Clay flanks the Southern River both on the east and west. On the east of the Southern River, the Guildford Clay is recharged from rainfall and from the surface runoff from the scarp. Groundwater then moves west, discharging into the Southern River. On the west of the Southern River the groundwater in the Guildford Clay is recharged by rainfall and throughflow of groundwater from the west, discharging into the Southern River.

The physical and geological setting of the Southern River is similar to the Ellen Brook. Both channels are incised into the Guildford Clay containing isolated patches of Muchea Limestone, on the Swan Coastal Plain. A drilling investigation in the Ellen Brook catchment (Shams, 2000) revealed Guildford Clay (upper clay horizon) at the surface overlay Bassendean Sand and Gnangara Sand (lower sand horizon). Water quality varied between the upper clay and the lower sand horizons. Groundwater in the upper clay horizon recharged locally and was brackish to saline as salt concentrated due to evaporation. Groundwater in the lower sand horizon is recharged by throughflow from the Bassendean Sand and is fresh. Nutrient concentration variations between the two horizons correspondingly reflect a local source of nutrients in the clay horizon and a distant source for the lower sand horizon. Similar variation of groundwater quality is, therefore, expected on the immediate west of the Southern River. Compared to the Ellen Brook, the groundwater component of the flows in the Southern River is more significant than the surface runoff because the Southern River is a perennial river whereas the Ellen Brook is generally dry in summer.

Groundwater contamination is reported from several waste disposal facilities located on the Bassendean Sand. Unless these are reduced along the flow path there is the potential for them to be carried via groundwater into the Southern and Upper Canning Rivers. Site specific geological information is documented as part of many investigations associated with contaminated sites (Section 5). There is potential for acid sulphate soils associated with dewatering of buried wetlands on the coastal plain. Recent findings in Stirling and Bassendean areas indicate that acidic groundwater has leached out heavy metals and nutrients.

5 Investigations of land use impacts on water quality

Many surveys, monitoring and investigation programs have been undertaken to define the degradation status of this catchment, and to establish the impact of land use on groundwater and runoff water quality both on the Swan Coastal Plain and on the Darling Plateau.

5.1 Land use impact investigations and groundwater quality on the Swan Coastal Plain

The impact on groundwater quality due to various land use activities within the Swan Coastal Plain area of the catchment is well documented. The groundwater quality (mainly nutrient concentrations) of the superficial aquifer was measured in several point source contamination investigations, including waste disposal sites and kennel zones (Hirschberg, 1982; Golder Associates Pty Ltd, 1992 and 1996; Manning, 1998; Thorpe and Manning, 1995; Sinclair Knight Merz, 2000).

Snapshot 2000

As part of Swan Hydrogeological Resource Base and Catchment Interpretation project, a snapshot sampling program was conducted in February 2000 to capture the ambient concentrations of nitrogen and phosphorus in the superficial groundwater (Shams, in prep). Groundwater, collected from sixteen bores on the Swan Coastal Plain and the foothills, ranged from fresh to brackish, with pH neutral to acidic. Although the groundwater samples were mixed rather than from discrete depth intervals, some elevated levels of nitrogen and phosphorus were determined. Elevated nitrate (6.2 mg/L) and ammonia (2.7 mg/L) concentrations were observed in the vicinity of the golf course and the kennel zone respectively. Elevated ortho-phosphate concentrations (between 0.6 and 2.4 mg/L) were found in groundwater on the west, southwest and northeast of Lake Forrestdale (Fig. 10).

An extensively investigated liquid waste disposal site

Hirschberg (1982) assessed the pollution potential of all previous and existing (up to 1982) liquid waste disposal sites in Perth. One of these sites in the Southern River Catchment (Fig. 3) operated between 1955 and 1981. The Southern River Liquid Waste Disposal Site received animal carcases from the local pound, liquid wastes from breweries, septic effluent, oils and poultry washings. Earlier investigation (Hirschberg, 1982) indicated development of a watertable mound underneath the site with high levels of nutrients in groundwater (12 mg/L of P and 82 mg/L of ammonia). Later investigations in 1985 and 1990 using multiport bores indicated elevated nutrients and heavy metals contamination (Appleyard, 1990). Soil samples from the site also indicated heavy metals and total petroleum hydrocarbon exceeding the guideline levels (Golder Associates Pty Ltd, 1992). Groundwater in shallow bores had oil residues and organic compounds. The soils and shallow groundwater both on-site and off-site from this liquid disposal site were contaminated with contaminant plumes about 170 and 270 m east and southeast of the site. The City of Gosnells assumed management of this site after its closure.

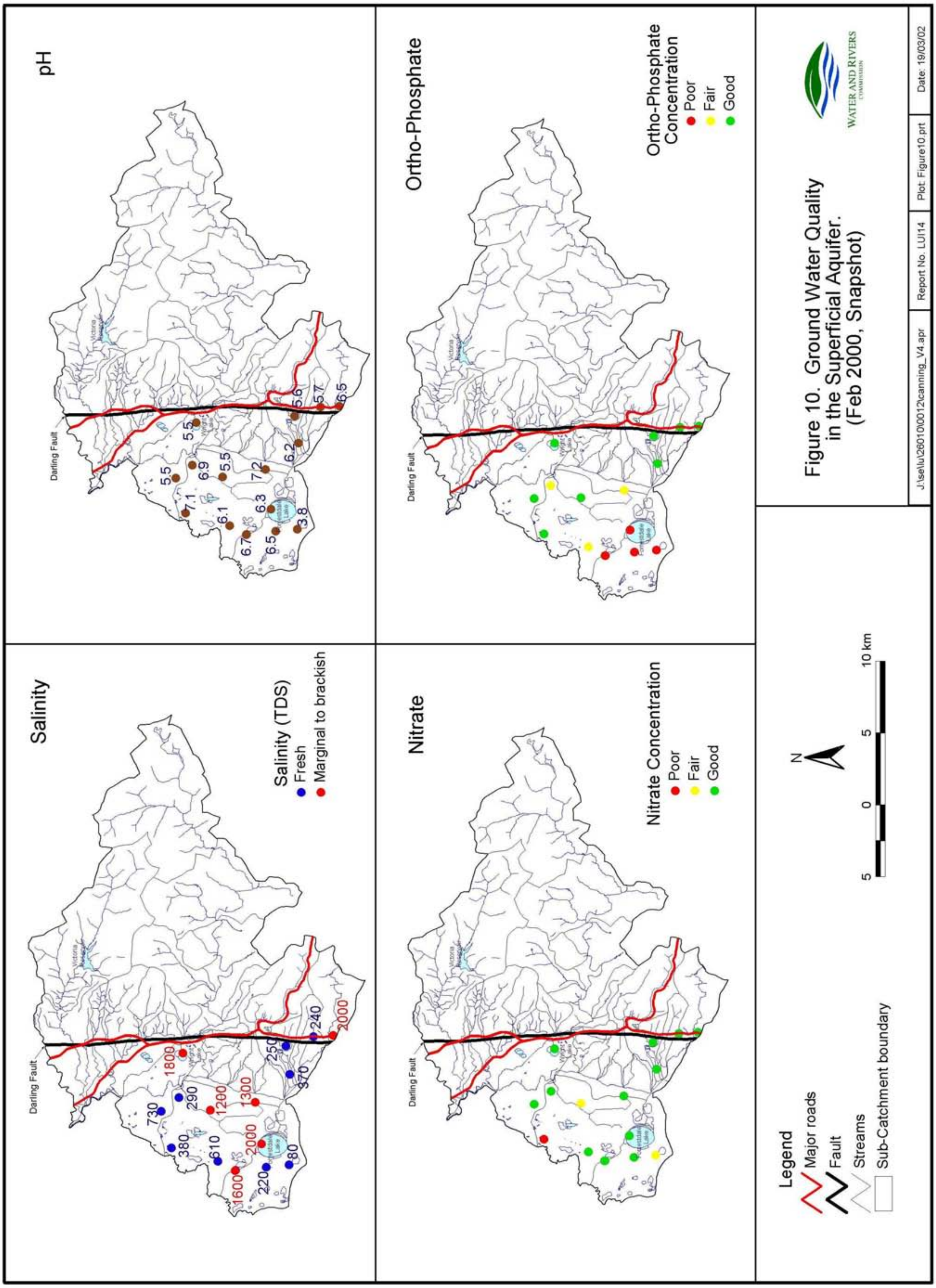

Figure 10. Ground Water Quality in the Superficial Aquifer. (Feb 2000, Snapshot)

An alternative investigation tool was used to identify groundwater contamination plumes from this site. UTS Geophysics (1997) conducted ground based electromagnetic survey within and around the site to measure changes in electrical and magnetic properties in the near surface region. The result indicated a regional trend of increasing conductivity to the north in the direction of regional groundwater flow. Increased conductivity was also identified to the south east, to the south and in the area of the disposal lagoon. These measured conductivity differences are attributed to varying concentrations of conductive materials such as heavy metals, hydrocarbons, and other organic compounds.

Further groundwater investigation was carried out pre-requisite to the Final Groundwater Management Plan for this site (Sinclair Knight Merz, 2000). The two-phase program, involving drilling and groundwater sampling of multilevel bores, describes the geology as sandy material and the watertable depth between 1.2 and 5.78 m below ground. Results show a vertical hydraulic gradient between the shallow and deep parts of the superficial aquifer, radial groundwater flow conditions within the shallow sections of superficial aquifer, and dominant flow in a northeast direction within the deeper part of superficial aquifer. The impact from this site extends laterally to the north, east and south. Contaminants arsenic, nickel, benzene, total phenols, and sulphate that originated from this site were identified throughout the entire saturated profile of the aquifer with concentrations above the Australian Drinking Water Guidelines (National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, 1996). The contaminated plume was identified within 100 and 150 m from the site. Low and irregular concentrations of organic contaminants were reported within the surrounding groundwater.

Treated sewage sludge

Thorpe and Manning (1995) studied the impact on groundwater in Jandakot, beneath a stockpile of treated sewage sludge above unsealed base on quartz sand. The sands are of low adsorptive capacity and the watertable is 1 m below ground. The investigation concluded minimal impact on groundwater after 3 months of storage; however, a leaching test indicated potential for groundwater contamination by metals, sulphur and nutrients.

Kennel wastes

Groundwater quality investigations (Golder Associates, 1996) within the kennel subdivisions of Canning Vale and Banjup showed nitrate and bacterial concentration in excess of drinking water guidelines. The site is located on sandy sediments within the groundwater protection area. Water quality measurement from private and investigation bores around the area exhibited contamination of shallow groundwater from the on-site disposal of kennel wastes and burial of animal faeces.

Kelvin Road waste disposal site

AGC Woodward-Clyde Pty Ltd (1997) monitored groundwater from several monitoring bores around the Kelvin Road Waste Disposal site for the City of Gosnells. Since December 1999 the site has been used for storage of inert and low hazard wastes. Groundwater was analysed 6-monthly for a suite of inorganic determinants (pH, EC, TDS, Cd, Cr, Cu, Pb, Mn, Ni, Zn, K, Cl, N-NH3, N-NO3 and P-total), and biennially for a suite of organic determinants (poly-aromatic hydrocarbons, organo-chlorine and organo-phosphorus pesticides, polychlorinated biphenyls, total aliphatic and aromatic hydrocarbons). The high levels of metal and nutrients in the analyses indicate that the groundwater quality is being impacted by landfill leachate (City of Gosnells, Shire File no. Kel.S. 236).

Wastewater soakage basins

Wastewater from the Water Corporation sewage treatment plant, south of Armadale Road, was disposed in soakage basins to the north of Armadale Road. The substantive use of these basins ceased in late 1983 but minor usage continued until 1986. The disposal site is located on sandy surficial material, with water logging on the west, and the watertable varying between 0 and 2.0 m below the base of the soakage ponds. A series of drains, constructed around the perimeter of disposal ponds to collect excess water, eventually discharges into the Southern River. The drains are up to 2.5 m deep. High concentrations (1.27 and 2.7 mg/L) of phosphate were found in the drainage water in 1996. Bacterial material is unlikely to survive 12 years after the cessation of disposal and any eggs and cysts will be washed through sands to the watertable. Soil sampling results from the disposal site showed that the leachable phosphorus was between 0.2 and 21 mg/kg and leachable nitrogen was between 1.0 and 10 mg/kg (Stephens, 1998).

Warton Road liquid waste disposal site

A comprehensive groundwater and soil testing program by the Water and Rivers Commission in the vicinity of a closed liquid waste disposal site in Warton Road, Banjup between November 1997 and April 1998 suggests that the groundwater is not being contaminated from the disposal site (Manning, 1998). The site is located within Jandakot Underground Water Pollution Control Area (UWPCA), and operated during 1978–1981. Previous investigation (Hirschberg, 1982) suggested of the upper part of the aquifer, and northwesterly groundwater flow rather than the easterly flow predicted from its location on the Jandakot groundwater mound. Investigation indicated an isolated occurrence of hydrocarbon in a domestic bore but not detected on resampling) and detected biological contaminants (faecal coliform) in number of bores.

5.2 Land use and quality of surface runoff

The quality of surface runoff water is determined by the properties of surficial sediments, the land surface cover and the slope of the land which affect the extent of erosion and the movement of nutrients bound to the soil particles. An investigation by Tan (1991) in two urban areas, one located on the Swan Coastal Plain (Westfield) and another on the Darling Plateau (Kelmscott) confirmed that the soil type, waste disposal facility (septic tanks) and slope of the land are decisive factors in the export of nutrient loads. Tan (1991) concluded that:

- Nutrient levels in the runoff from clay catchments are elevated because nutrients bind to the surface of clay particles eroded by wind and rain. Nutrients do not bind to sandy sediments and so are not generally removed via runoff water from sandy catchments, but are exported in solution through leaching to groundwater.

- In similar catchments, much higher annual loads of nutrients are exported from an industrial area than from a residential area. The high percentage of impermeable hard surface area such as roads and pavement within industrial land contribute to high runoff and higher nutrient concentrations.

- Steeper catchments export more nutrients, for example a high annual nutrient load is exported from the Kelmscott area even though it has small percentage of road surface area.

A community-based surface water monitoring project to locate hot spots responsible for a disproportionate share of nutrient input, erosion and other problems was trialled in early 1996 by Horwood (1997). The results indicate some subcatchments contribute more and different pollutants than others. Concentrations of ortho-phosphate were moderate in the Upper Canning River and high in the Southern River, fresh water occurred in all the rivers, and high levels of turbidity were present in the hill catchment area of the Canning River.

Jakowyna and Donohue (2000) provided a qualitative and quantitative assessment of the nutrient concentration in major rivers and urban drains of the catchment, based on a water quality sampling program 1987–98 (Table 3).

Wong and Morrison (1994) reported elevated bacteriological counts, high nutrient and trace metal concentrations in four urban drains (River Road, Cockram, Council Depot and Wharf Street), based on monitoring storm events in 1992 and 1993. Water quality in the drains was affected by activities such as failing septic systems, industrial waste discharges, deliberate dumping of wastes and inappropriate animal waste discharge practices. The results indicated a higher incidence of phosphorus loss from the non-sewered catchments, and no significant variation in nitrogen loss between sewered and non-sewered areas.

Investigation of five urban stormwater drains discharging directly into the Canning River upstream of the Kent Street weir, between February and May in 1999 indicated elevated nutrient levels but generally much lower than those reported from winter The quality of surface runoff water is determined by the properties of surficial sediments, the land surface cover and the slope of the land which affect the extent of erosion and the movement of nutrients bound to the soil particles. An investigation by Tan (1991) in two urban areas, one located on the Swan Coastal Plain (Westfield) and another on the Darling Plateau (Kelmscott) confirmed that the soil type, waste disposal facility (septic tanks) and slope of the land are decisive factors in the export of nutrient loads. His survey concluded that:

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Table 3a. Nutrient assessment of surface water

Drainage	*Status*	*Total Nitrogen (mg/L)*	*Total Phosphorus (mg/L)*
Mills Street	Median	2.7	0.23
Main Drain	Annual median	1.65–3.4	0.18–0.29
	Extreme	0.63–12	0.013–1.2
	Trend	Increasing 1987–90 Decreasing 1994–98	Emerging decrease
Yule Brook	Median	1.1	0.07
	Annual median	0.915–1.6	0.04–0.091
	Extreme	0.38–4.3	0.01–3.04
	Trend	None	None
Bannister	Median	1.9	0.13
Creek	Annual median	1.65–2.0	0.08–0.18
	Extreme	0.72–7.4	0.03–0.97
	Trend	None	Emerging decrease
Bickley	Median	1.2	0.06
Brook	Annual median		
	Extreme	0.43–22	0.006–0.56
	Trend	N/A	N/A
Southern	Median	1.6	0.2
River	Annual median	1.0–2.0	0.14–0.35
	Extreme	0.36–3.6	0.042–0.53
	Trend	Decreasing 1994–98	Decreasing 1987–90
Canning	Median	0.98	0.016
River	Annual median	0.54–1.4	0.01–0.03
	Extreme	0.13–3.9	0.005–0.67
	Trend	None	None

Table 3b. Classification used to assess the status of nitrogen and phosphorus concentrations (Swan River Trust, 2000)

TN (mg/L)	*Description*	*TP (mg/L)*	*Status*
>4.0	Extreme	>0.5	Extremely enriched
3.0 – 4.0	Very high	0.3 – 0.5	Highly enriched
2.0 – 3.0	High	0.2 – 0.3	Enriched
1.0 – 2.0	Moderate	0.1 – 0.2	Mildly enriched
<1.0	Low	<0.1	Close to natural

Wong and Morrison (1994) reported elevated bacteriological counts, high nutrient and trace metal concentrations in four urban drains (River Road, Cockram, Council Depot and Wharf Street), based on monitoring storm events in 1992 and 1993. Water quality in the drains was affected by activities such as failing septic systems, industrial waste discharges, deliberate dumping of wastes and inappropriate animal waste discharge practices. The results indicated a higher incidence of phosphorus loss from the non-sewered catchments, and no significant variation in nitrogen loss between sewered and non-sewered areas.

Investigation of five urban stormwater drains discharging directly into the Canning River upstream of the Kent Street weir, between February and May in 1999 indicated elevated nutrient levels but generally much lower than those reported from winter storm event sampling (Paice, 1999). These drains flow throughout the dry period and are not routinely sampled. Summer sampling results are summarised in Table 4.

Table 4. Summer water quality in urban stormwater drains, February to May, 1999

Total Nitrogen	*Main Drain*	*Total Phosphorus*	*Volatile organics, hydrocarbon, heavy metal*	*Coliform*
Low to moderate	Wharf Street	Low to moderate	Low	High
Low to moderate	Cockram Street	Low to moderate	Low	High
Low to moderate	Liege Street	High	Low	High
High	Lacey Street	High	High	High
Low to moderate	Menzies Road	Low to moderate	Low	High

Most of the water quality measurements for nutrients in surface water were carried out in the Swan Coastal Plain part of the catchment. Very limited data on nutrient concentrations are available from waterways on the Darling Plateau. A community water qual0ity monitoring program by Canning River Residents Environmental Protection Association (CRREPA) measures water quality four times a year. CRREPA has collected data since April 1994 as a result of community concern about the health of the Canning River. The CRREPA data are managed by the National Waterwatch database, Ribbons of Blue Program, for the Swan Region of the Water and Rivers Commission. Results from the sites on the Darling Plateau (Table 5) show elevated nitrate and ortho-phosphate concentrations in the area associated with golf, residential, orchard and vineyard land uses.

Table 5. Snapshot of nutrient concentrations in the Upper Canning River on the Darling Plateau (2000)

Site	*Site Code*	*Easting mE*	*Northing mN*	*Mean nitrate (mg/L)*	*Mean ortho-phosphate (mg/L)*
Lady McNess Bridge	CAN001	414 900	6 444 900	1.32	18
Slab Gully at Croyden Road Bridge	CAN002	412 400	6 445 300	3.08	0.38
Thompson Road Bridge	CAN003	412 500	6 444 950	0.792	0.26
Soldiers Road Bridge	CAN004	411 660	6 444 900	1.452	0.16

6 Management plans

This section reviews plans to manage land and water degradation issues relating to current land use and future developments.

6.1 Integrated catchment management

The Upper Canning Southern Wungong Catchment Management Team (Everall Consulting Biologist, 1999) has developed an integrated catchment management plan to manage and minimise degradation of land and water. The plan reviews the current biophysical and administrative structure of the catchment, and documents major issues identified by the community. The management plan emphasises that sound and reliable data on the physical aspects of land and water are important to understanding the various degradation processes.

6.2 Water quality improvement plans

City of Gosnells plan

The management of stormwater runoff and nutrient export from a proposed residential development area is addressed in a drainage and nutrient management plan (DNMP), prepared for the City of Gosnells (JDA Consultant Hydrologists, 1999). The plan proposes total water quality management through a series of wet detention basins, multiple use corridors and swales within the development area. The basins are designed to attenuate post-development peak runoff rates to pre-development levels, and improve water quality by provision of sufficient detention storage time to facilitate nutrient removal. The DNMP is based on the principles of Water Sensitive Urban Design and includes an ongoing monitoring program.

The City of Armadale plan

The City of Armadale (2000) prepared a State of the Environment Report, outlining the responsibility of its Planning and Health Department and mapping the potentially contaminated sites in the City. The report arose out of concerns raised in the Swan Canning Industry Survey Draft report (Swan River Trust and Water and Rivers Commission, 1999) which noted discrepancies between the amount of waste generated and the amount recorded, raised concerns for the storage of waste on open sealed or unsealed surfaces, the storage of chemicals on premises without bunding, the disposal of industrial effluent in unacceptable ways; and the improper on-site storm water treatment facilities of many industries. The City proposes an industrial survey and education program to industrial premises to enable it to consider the potential nutrient exports from all developments and monitor the use of septic tanks and alternative treatment units. The City endorses strategies identified in the South East Corridor Urban Water Management project, for the protection of wetland, reduction of nutrient export, improvement of water quality, and proposes to adopt urban stormwater quality management guidelines.

Caring for the Canning

"Caring for the Canning: A plan to revitalise the Canning, Southern and Wungong Rivers" is an initiative from the Swan Canning Cleanup Program Action Plan to address the surface water problems of the rivers. Management programs include: Manage the flow regimes; Manage the Kent Street Weir; Implementation and Training in Best Management Practices; Environmental Evaluation and Monitoring; Legislation and Policy Development; Restoring the riparian zone and functions; and Increasing Awareness and Participation in catchment and river management. (Swan River Trust, 2001)

6.3 Land use plans

South-east corridor

To progress the south-east corridor, a strategic plan (Ministry for Planning, 1999) was prepared for areas of the Southern River, Forrestdale and Brookdale using technical and community data derived from previous studies, land capability assessment, groundwater level monitoring and extensive community consultation. An optional structure plan is proposed based on reviewing all planning initiatives for potential development from rural to urban since 1973. The plan identifies that future development in the area is constrained by high watertables, low lying land, regionally significant conservation areas, contaminated sites, community expectations and limited infrastructure. There is potential land and water contamination at many sites (poultry farm, kennel, animal feedlot, animal processing plant, septage disposal area, former noxious liquid waste dump, and landfill rubbish dump). This document proposes the required buffer around each of these sites.

Pressure for rezoning and urban development in the Perth South East Corridor as part of the amended Metropolitan Regional Scheme prepared by the Department of Planning and Urban Development led to the preparation of a Water Resource Management Plan for Middle Canning Catchment in two stages (Evangelisti and Associates, 1995). The Stage 1 report defines water body interactions in the hydrological cycle, identifies environmental values, and proposes levels of water resource and environmental protection. The Stage 2 report prepares a Stormwater Management Plan for the Forrestdale/Southern River area, application of water sensitive design principles on a sub-catchment, precinct and sub-precinct basis, identifies suitable areas for urbanization, no go development areas, and land requiring drainage (Evangelisti and Associates, 1996). Some of the issues considered in relation to the development are protection of public water supply and natural wetlands, management of storm water, protection of existing and new developments from flooding. Water resource management strategies to combat these problems are developed on the basis of Water Sensitive Urban Design Guidelines (Water and Rivers Commission, 1998).

City of Armadale rural environment

Maintenance of the rural environment also received attention and the City of Armadale (1996) developed a management strategy for the current and future economic and social benefit of the rural community at present and in the future. It provides a vision of potential land use and development within areas zoned rural and general rural. It identifies the potential point sources of nutrient contamination from land uses including piggeries, poultry farms, intensive horticulture, holiday accommodation, rubbish disposal, and sewered and non-sewered areas. Land units with potential for leaching of phosphorus were mapped. Land capability and suitability for various land uses (mainly rural residential, grazing, annual and perennial horticulture) are also assessed and mapped, and land capability for various land uses for each of nine Planning Precincts (Forrestdale, West Armadale, Wungong, Bedfordale, Canns, Kelmscott, Canning Valley, Roleystone and Karragullen).

Environmental review reports are prepared to address management measures with regard to changing land use or rezoning from rural to urban in the Canning Vale area of the Southern River Catchment (BSD Consultants, 1997).

6.4 Community education program

Through the “P Project”, the Natural Heritage Trust funded a community awareness campaign to reduce the phosphorus loads in the Canning River catchment. The project aims to educate the public on the appropriate use of fertilisers, the use of phosphorus-free household products, and to raise awareness of the connection between backyards, stormwater drains and the Canning River. eg spraying of road drains in catchment with “water to river” and Ribbons of Blue.

6.5 Groundwater resource management plan

Water resources in the catchment are managed through policies and management plans adopted by the Water and Rivers Commission. Water is sourced from bores, surface water and the Water Corporation supply scheme. Groundwater abstraction from the Leederville aquifer is licensed. Groundwater withdrawal from the superficial aquifer above 1 500 kL per annum and surface water use for commercial ventures or for public water supply are also licensed.

Groundwater is managed through defining groundwater areas and determining the resources of each area. Then groundwater management areas are proclaimed under the Rights in Water & Irrigation Act (RIWI) to control the extraction through licensing of groundwater. The type of licensing active within these boundaries specifies what can and cannot be done. Conditions are put upon the extraction and use of groundwater resources in order to conserve the condition of the water and the environment. This is to prevent over-extraction and the consequent production of saline water. The coastal plain part of the catchment falls mainly within the Perth and Jandakot groundwater areas.

The Jandakot Groundwater Scheme supplies water to households and industries in suburbs of the South West Corridor from a shallow unconfined aquifer in the western part of the catchment that contains part of a regional mound of shallow groundwater known as the Jandakot Mound. McCrea and Stratico (1998) summarise the operation and environmental management of the Jandakot Groundwater Scheme (GWS) and private use of water in the Jandakot Groundwater Area. The impacts of both private and public groundwater abstraction are reported by the Water and Rivers Commission and the reporting on the water treatment plant is entrusted to the Water Corporation. Water and Rivers Commission believes that there have been no unacceptable environmental effects from the operation of the Jandakot GWS during 1997–98.

6.6 Surface water management

Public water supplies are also drawn from the Canning, Victoria, Wungong and Churchman Brook Reservoirs (Fig. 1). Dams constructed on the Darling Plateau (on the Canning River in 1940 and Wungong Brook in 1979) greatly altered the natural condition of the rivers (Everall, 1999). One of the major effects was the reduction of summer flow in these rivers. Summer flows are maintained for riparian and licensed users down stream of the dams, through release of water from the scheme water pipeline and through implementing a water restriction policy on the users. The policies are adopted jointly by the Canning, Wungong, Southern Rivers Advisory Committee and the Water and Rivers Commission (1996). The Water Corporation releases water at five locations on the Canning River and at one location on the Wungong Brook. On the Swan Coastal Plain the Kent Street Weir, constructed in 1927, protects water in the Upper Canning River by preventing saltwater intrusion from the Swan-Canning estuary.

Riparian rights to water from Canning River are available upstream of the Kent Street Weir. Water use is not metered, however use by riparian dwellers for irrigation of more than 2 ha of land or for commercial ventures, and use by non-riparian dwellers is licensed. There are no riparian users in the area of foreshore reserves managed by CALM.

The Wungong Brook has both riparian and non-riparian users. On the upper reaches, lands with riparian entitlements are mainly vested with government agencies but on the lower reach the riparian users are mainly private. The entitlements are for stock water (with direct access to the brook), irrigation of domestic gardens and commercial orchards (Greenbase EIC, 1997). The interim policy for Wungong Brook is similar to that for the Upper Canning River but as no users are licensed this is under review. The riparian and/or non-riparian users of the Southern River are not licensed and information on usage is not available.

A management plan for the Canning and Southern Rivers and Wungong Brook is being prepared by the Water and Rivers Commission to provide a strategy and recommendations for improvement of water quality, the management of surface water allocation and the Water Corporation releases into the rivers (Swan River Trust, 2001).

6.7 Water resource protection plans

The water resources require protection against the effects of pollution from the diversified land uses in the catchment. The Public Drinking Water Source Areas (PDWSAs) are protected and managed under the *Country Areas Water Supply Act 1947* (CAWS) and the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* (MWSS&D). The Acts are administered under the *Water and Rivers Commission Act 1995*. The Act's by-laws enable the Water and Rivers Commission to control potentially polluting activities, to regulate land use, inspect premises and to take steps to prevent or clean up pollution. The *Environmental Protection Act 1986* also provides a very important legislative framework for protecting water resources from contamination.

Existing and future drinking water sources are protected after declaration under the appropriate act - as Underground Water Pollution Control Areas (UWPCA) to protect shallow groundwater resources, as Catchment Areas to protect surface water resources, and as Water Reserves to protect potential surface water and groundwater catchments or existing groundwater public drinking water source areas. Additionally, identification as Priority Protection Areas provides three levels of water quality protection across PDWSAs.

The Water and Rivers Commission (WRC) works with planning and local government agencies to incorporate water protection with the land planning process, and also provides guidance in water quality management issues through various documents. These are:

- policy documents stating WRC statutory, philosophical and operational approaches to industrial, commercial and urban activities;
- guideline documents addressing issues relating to industrial, commercial and urban activities which interact with the WRC role in water resources conservation and management; and
- water quality protection notes providing a basis for developing formal best management practice guidelines in consultation with key stakeholders.

The boundaries of declared UWPCAs and Priority Protection Areas were reviewed (Dames & Moore, 1996).

7 Key messages

1. An understanding of the influence of the surficial geology is important for managing current environmental issues in the catchment, in particular excess nutrient export into Upper Canning and Southern Rivers, erosion on slopes and the emergence of dryland salinity on the Darling Plateau. The geological composition and properties of the catchment surface are highly variable so a variety of management practices will be required to alleviate the problems.

2. Erosion is significant mainly where the surface is clayey and the landscape has steep sided valleys and scarps. The latter is found on the Darling Plateau where surface water flow has deeply incised drainage lines, and groundwater plays a minor role. Steep slopes and fractured rocks developed near the Darling Fault render this area vulnerable to erosion. There is major erosion in cleared areas, especially along streamlines where there is stock access and land development.

3. The occurrence and quality of groundwater is directly related to the geology and is highly variable, especially from east to west, but also locally. The similarity in physical and geological setting of the Swan Coastal Plain area of the catchment to the Ellen Brook catchment prompts the suggestion that groundwater quality will vary with depth and that isolated very high nutrient levels may occur at the watertable or at depth. Shallow watertables in the clayey areas in the east of the Swan Coastal Plain and in the Darling Plateau can contribute to waterlogging and inundation of lowlying poorly drained land.

4. Groundwater that discharges into waterways and drains from areas of shallow watertable where the surficial sediments are sandy transports nutrients in solution. This occurs in the western part of the catchment where groundwater is an important contributor to flow and nutrients in the Southern River.

5. Nutrients enter the Upper Canning and Southern Rivers bound to eroding soil particles. Such movement is exacerbated where ridges, slopes and drainage lines are poorly vegetated and trafficable by stock and humans. Nutrient movement and erosion are associated with land and stream degradation and siltation of rivers.

6. Land clearing is the cause of an emerging (localised) problem of land salinisation on the plateau where mobilisation of salt stored in the soil profile leads to the discharge of saline groundwater at the surface. Unlike better-known salt affected areas in WA the surface water in this catchment is still fresh so the problem is not severe.

7. Investigations of groundwater contamination from land use, particularly landfill and liquid waste disposal, are well documented. The water resources of the catchment are protected under existing plans, and rely on vigilance to control contamination.

8 Recommendations

The following are broad recommendations that managers consider the complexity and variability of the catchment geology and groundwater, set in place adequate monitoring and evaluation and build community awareness and support. In the section following these recommended actions are management guidelines for planners.

1. The state and local government agencies involved in land planning and management should consider in their current and future urban and rural development schemes, the differences in potential for degradation in the various parts of the catchment.

2. Monitoring and evaluation are important to help determine the impact of both existing and new developments, to ensure that the catchment is not degrading further, and that the management actions are effective.

    - Monitor the quality of groundwater discharging into rivers by measuring groundwater quality from different depths of the superficial aquifer in the vicinity of Southern River and Upper Canning River on the Swan Coastal Plain. Investigate in detail to establish the recharge and discharge of groundwater along each river.

    - Reduce nutrient export into waterways on the Swan Coastal Plain firstly by reducing entry of overland flow from inundated areas into drainages through maintenance of riparian zones and secondly control erosion and waterlogging of potential new areas of inundation.

    - On the Darling Plateau, measure groundwater quality down-gradient from potential source areas to ascertain if groundwater is exporting nutrients from these activities.

    - In areas on the Darling Plateau identified as salt affected investigate the salt stored in the soil profile and then determine the extent and vulnerability (upon mobilisation) to a dryland salinisation problem.

3. Undertake education programs to raise awareness in the community, local government and industry of the impact of nutrients on the waterways and their responsibility under the Swan Canning EPP.

9 Management guidelines for the Upper Canning Southern Wungong Catchment

Sections 9.1 to 9.5, Table 6(a–e), Figure 11 and poster "*Managing Nutrient movement into Ellen Brook"* set out a range of actions to manage the groundwater-related issues addressed in this report, namely:

- Control of erosion by water
- Control of inundation and waterlogging
- Reduction of nutrient export from the catchment
- Countering dryland salinisation
- Limiting point source contamination of groundwater

Most of the management actions are already widely in use in WA. The subcatchments identified by number in Table 6 are named in Figure 1.

While the reduction of nutrient export from the catchment is probably the most important issue addressed in this resource base, control of erosion, inundation and waterlogging are essentially accompanying issues and so are listed ahead of the management of nutrient export.

9.1 Control of erosion by water

Erosion aided by water can occur under two situations in this catchment. Some management aims and actions to minimise erosion problems are provided (Table 6a, Fig. 11).

Steep slopes – Erosion can occur on steep slopes that are unstable due to lack of vegetation cover. This is a problem on valley sides in the Darling Plateau. The steep slopes are prone to erosion and landslide by rainwater and/or groundwater seepage. Management must aim to stabilise the slopes by restricting grazing, farming appropriately, replanting suitable trees, and engineering in extreme cases.

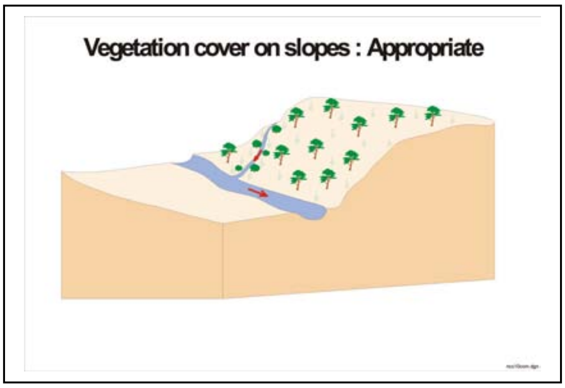
Stream banks – Water erosion can also occur along stream banks where the riparian vegetation is sparse, banks are accessible without fences and the edge of the banks are damaged by animals or human activity. Erosion of stream banks can occur in almost all parts of the catchment where surface drainage is present. Bank stabilisation is the management aim for this degradation, by actions to increase and improve riparian vegetation cover and fence off stream banks to control stock access.

9.2 Control of inundation and waterlogging

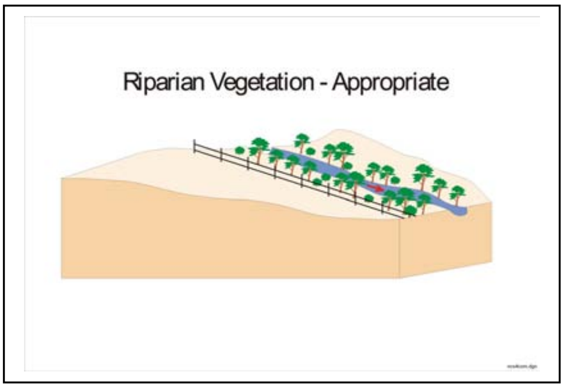
In this catchment, inundation of the land surface is caused by two mechanisms ((Table 6b, Fig. 11). For each mechanism the management objective and some management options are given below.

Watertable rising – Inundation associated with a shallow watertable (~ 2 to 3 m deep) is prevalent where the surface is predominantly clayey and has a low slope. In winter, as the rainfall recharge continues the watertable rises above ground and water ponds on very flat, poorly draining clayey ground. Inundation of land by this mechanism is occurring in the area east of Southern River. Management should aim to maintain the watertable below ground by planting high water use trees and providing urban drainage.

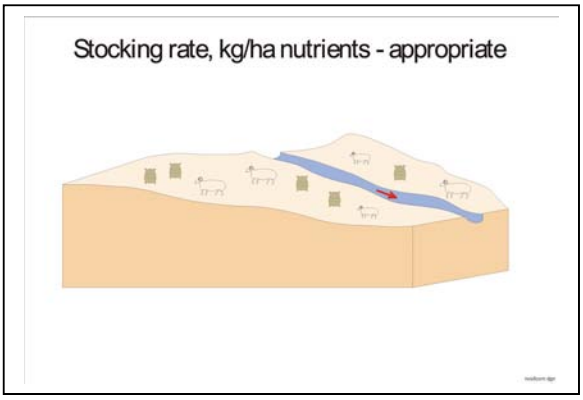
Figure 11. Good management practices



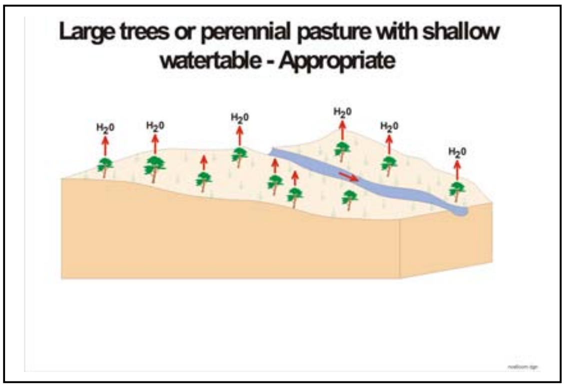
11a. Control erosion on slopes



11b. Control erosion on foreshores



11c. Reduction of nutrient export



11d. Lower watertable with high water use plants

Perching – Land inundation can occur where the regional watertable is at depth but there is some impermeable material (known as an aquitard) much nearer the ground surface. Infiltrating rainfall collects to form a very limited resource perched above the aquitard and causes inundation of the land surface if the perched watertable rises to the ground surface. The land surfaces of the Darling Plateau are susceptible to waterlogging and land inundation due to the presence of lateritic weathering profiles. This type of inundation can be minimised by inducing uptake of water from the perched aquifer and/or planting species tolerant to waterlogging.

9.3 Reduction of nutrient export from the catchment

Nutrients can be transported in four ways:

- near-surface groundwater flow

- throughflow of deeper groundwater
- overland flow and
- bound with eroding sediment

The management objective and some possible management for each mechanism is shown in Table 6c and discussed below.

Near-surface groundwater flow – Nutrients can move in groundwater when the watertable is very shallow especially where a clay layer is near the ground surface with a thin overlying sand layer. The sand layer above the clay has high hydraulic conductivity and can transmit groundwater rapidly. Experience from the Ellen Brook catchment reveals that this condition is prevalent where Guildford Clay is present and the clay is compact with low drainage property. In winter, the watertable rises due to rainfall recharge and the sand layer is saturated. Nutrients held and mobilised at the watertable are then transported by shallow groundwater flow into the waterways. This process is short-lived and most likely to occur over four to five months of late winter and spring. Nutrients can be exported this way on the Swan Coastal Plain, mainly from the area east of Southern River and north-east of the Upper Canning River (Fig. 2 and 6). Management should aim to keep the watertable out of the sandy top layer. Where this is not possible, the shallow movement of groundwater can be intercepted by planting vegetation or creating shallow wetlands or swales.

Throughflow of deeper groundwater – This is nutrient movement via groundwater. Nutrients move with deeper groundwater where the surface is sandy (Bassendean Sand), allowing leaching of nutrients to the watertable, above a sandy aquifer that continues (beneath the Guildford Clay) or has hydraulic continuity with another sandy aquifer extending up to a river. The groundwater (carrying nutrients) discharges into the waterway. This process is present in the western part of the catchment and on the west of Southern River. Nutrient transport by this mechanism can occur throughout the year. Management needs to minimise nutrients leaching into the watertable.

Overland flow – Nutrients move in overland flow when the surface is inundated during the wet seasons. Inundation resulting in overland flow can occur by two processes. One is when the watertable rises and groundwater discharges at the surface, contributing nutrients to the overland flow. Secondly, rainwater can pond on clayey surfaces and this surface water can carry any applied nutrients into drains and waterways. This mechanism is present where surface is Guildford Clay, as the clay has low drainage properties, such as the area east of Southern River and north-east of the Upper Canning River on the Swan Coastal Plain (Figs 6 and 11). Management should concentrate on methods to reduce surface runoff.

Sediment transport – Erosion on steep slopes or along banks of the waterway is the main cause for nutrients to move as particulate bound to soil. It is pronounced when the surface is clay and can occur on the Darling Plateau where crystalline rocks are weathered into clay. Banks (of drains, creeks, and brooks) erode when they become unstable due to reduced riparian vegetation and/or trampling by animals. This process is important on the steep slopes of valleys on Darling Plateau, slopes of the Darling Scarp, and along the river valleys of the both Darling Plateau and Swan Coastal Plain (Fig. 7 and 11). Management should aim to control surface runoff by stabilising slopes and stream banks.

9.4 Countering dryland salinisation

There are two mechanisms for land salinisation.s. The risk areas, mechanisms, management aim and actions for reducing the risk are summarised in Table 6d.

Mobilisation of stored salt – Salts are accumulated in the soil profile or the regolith of a forested catchment over many years. As the rainfall infiltrates the ground, the evapotranspiration by trees take up the water, leaving the rain-borne salt in the regolith. When deep-rooted trees are cleared, recharge increases, the watertable rises and both the recharge and the groundwater mobilise the salt stored in the regolith. Deeper groundwater is already saline in many cases, so where increased recharge causes the saline groundwater to discharge at the surface the result is salinisation of the land. This mechanism is more pronounced where the surface is poorly draining such as in clay. The composition of the regolith above the crystalline rocks make the Darling Plateau a risk area for land salinisation. The risk from salinisation can be limited by controlling clearing and managed by planting deep-rooted salt tolerant species (Fig. 11).

Slow drainage and evaporative concentration - Where the watertable resides in near-surface clay, evaporation from the shallow watertable concentrates salt in shallow clay aquifer. The low drainage characteristics inhibit flushing of the saline groundwater, leading to the occurrence of shallow saline groundwater and local salinisation problems. Such shallow saline groundwater is found in the area east of Southern River (Figs 6 and 11). Since the deeper groundwater is fresh, management needs to be aimed at maintaining the watertable below the clay rich layer with controlled clearing and planting of deep-rooted high water-use trees.

9.5 Limiting point-source contamination of groundwater

Limiting point source-contamination of groundwater – Where the groundwater is shallow, particularly where the surface is also sandy, contaminants from industrial, landfill and waste disposal sites can leach to the watertable. The risk areas, mechanisms, management aim and action for reducing the risk are summarised in Table 6e.

To protect groundwater, land use should be licensed and appropriately located according to land capability. These sites should be monitored as part of their management program, with ongoing education as to industrial Best Management Practice and periodic review of the appropriateness of the licensed land use.

Table 6(a –e) outline management guidelines discussed in 9.1 to 9.5. The subcatchments identified by number in the following tables are named in Figure 1.

Table 6a. Management options to control erosion by water

Groundwater management objective	*Priority areas by subcatchments*	*Recommended actions*	*Examples/actions*
Limit shallow watertables	Areas with steep slopes in parts of 3, 4, 5, 6 10, 11, 12, 13, 14, 15, 24, 25, 26, 27	Adequate drainage	Restrict grazing Plant high water using trees Use appropriate land/farming practice Engineering practices: surface-water management via shallow interceptor banks or grade banks
Limit groundwater discharge on steep slopes	Areas with steep slopes in parts of 3, 4, 5, ,6 10, 11, 12, 13, 14, 15, 24, 25, 26, 27	Stabilise slopes	Restrict grazing Plant high water using trees Use appropriate land/farming practice Engineering practices: surface-water management via shallow interceptor banks or grade banks
Limit groundwater discharge onto unprotected stream banks	Along unprotected stream banks, scarps and major rivers throughout catchment	Stabilise banks	Increase or improve riparian vegetation Fence stream lines Reduce stock access to stream line

Table 6b. Management options to control inundation and waterlogging

Groundwater management objective	*Priority areas by subcatchments*	*Recommended actions*	*Examples/actions*
Limit rising shallow watertable Limit waterlogging	Flat poorly drained clayey ground east of Southern River in parts of 6, 8, 9, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25	Control watertable rise to keep watertable below surface	Plant high water-use trees Adequate urban drainage Commercial farm forestry, Maritime pine, Eucalyptus, Oil mallees, Acacias, and other tree species Management of native vegetation and revegetation Engineering practices: surface-water management via shallow interceptor banks or grade banks
Limit shallow "perched" watertable	Areas of laterite weathering profiles in parts of 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 24, 25, 26, 27	Use or drain shallow "perched" groundwater	Maintain or restore healthy high water use vegetation, eg forestry preferable to pasture Planting species tolerant to waterlogging

Table 6c. Management options to reduce nutrient export

Groundwater management objective	*Priority areas by subcatchments*	*Recommended actions*	*Examples/actions*
Limit near surface groundwater flow (in winter)	Areas with thin sands over shallow clays, in 8, 9,10, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 26	Reduce saturation in winter. Keep watertable out of sandy layer Intercept shallow flow	Drainage High water use vegetation Commercial farm forestry - Maritime pine, Eucalyptus, Oil mallees, Acacias, and other tree species Management of native vegetation and revegetation Perennial pasture Vegetation belts and wetlands and swales
Manage throughflow of groundwater	Where there is a sandy layer and where there is hydraulic connection with river, in 8, 9, 10,11, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26.	Minimise leaching to watertable	Fertiliser & irrigation management Improve land practice Application of soil amendment to low phosphorus-retaining soils
Manage overland flow, (in the wet season)	Where surface is Guildford clay, in 8, 9, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25.	Surface water control	Stream lining to trap and uptake nutrients Planting, graded bank to reduce overland flow
Limit sediment entry to drainage	Areas of groundwater discharge, shallow clay and flat areas. Steep slopes of valleys on Darling Plateau, slopes of Darling Scarp. Along river valleys and banks of Darling Plateau, Swan Coastal Plain, in 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 18, 21, 24, 25, 26, 27.	Control surface runoff	Streamlining Stabilise slopes and stream banks Planting to filter sediments Planting, fencing, stock control to reduce erosion Perennial pastures

Table 6d. Management options to counter dryland salinisation

Groundwater management objective	*Priority areas by subcatchments*	*Recommended actions*	*Examples/actions*
Limit mobilisation of stored salt	Where deep rooted trees have been cleared and there is deep saline groundwater, especially poorly drained clays, for example on Darling Plateau, in 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 24, 25, 26, 27	Manage groundwater recharge	Control clearing Plant deep rooted salt-tolerant vegetation Commercial farm forestry, Maritime pine, Eucalyptus, Oil mallees, Acacias, and other tree species Management of native vegetation and revegetation Engineering practices: surface-water management via shallow interceptor banks or grade banks
Slow drainage and evaporative concentration	Near surface clay, in 6, 8, 9, 14, 15, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25	Maintain or lower watertable, eg below 2m	Control clearing Plant deep rooted high water use trees

Table 6e. Management options to limit point source contamination of groundwater

Groundwater management objective	*Priority areas by subcatchments*	*Recommended actions*	*Examples/actions*
Limit point source contamination of groundwater	Industrial sites Waste disposal sites Landfill sites especially on Bassendean Sand	Protect groundwater	License land use Monitoring Educate on industrial Best Management Practice Review the appropriateness of land use

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