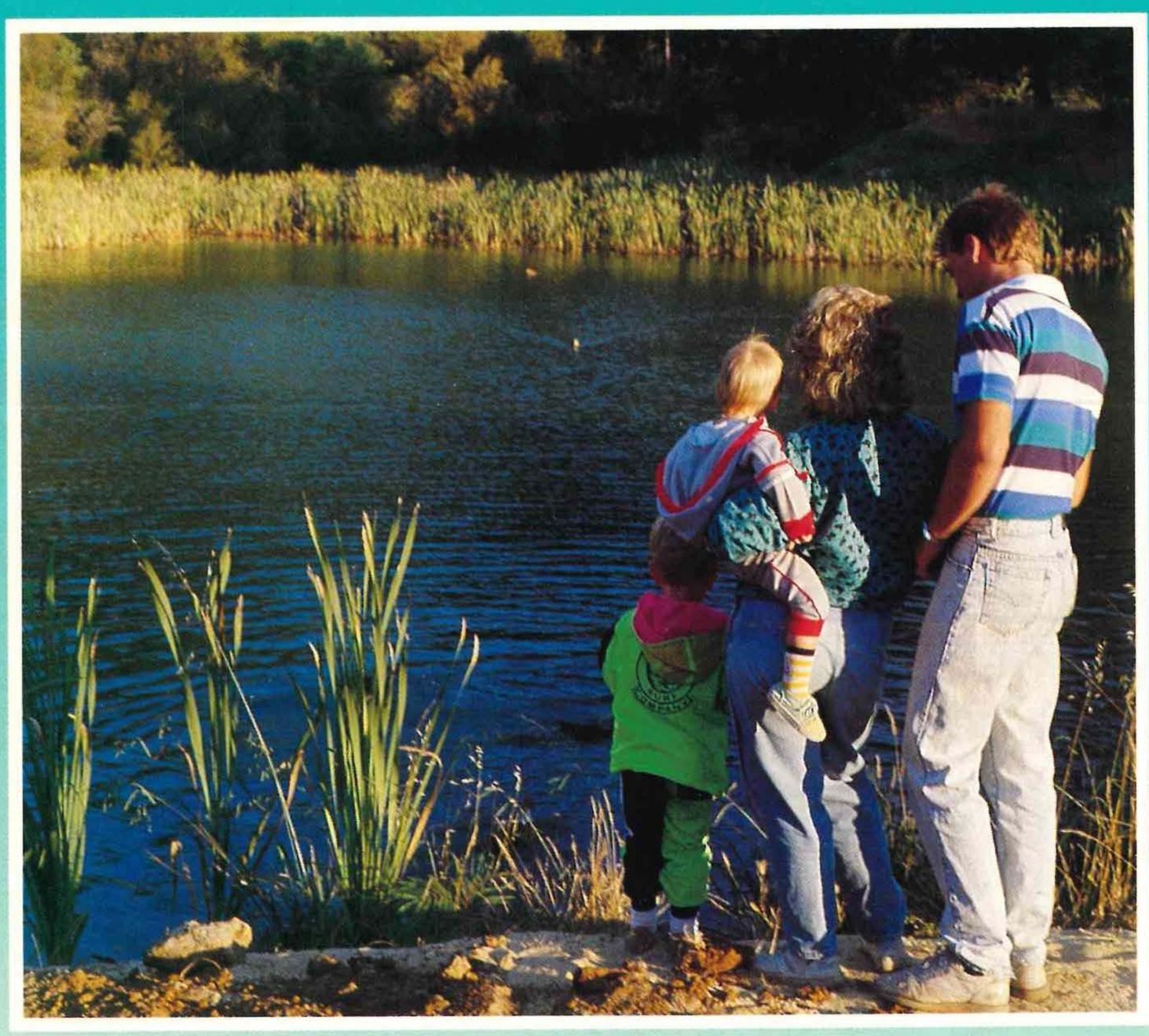
JENNY ARNOLD'S

PERTH WETLANDS RESOURCE BOOK



CHAPTERS 1 - 4

INTRODUCTION

SOURCE OF INFORMATION AND CLASSIFICATION SYSTEM

FEATURES OF WETLANDS IN THE PERTH REGION

APPENDICES

ENVIRONMENTAL PROTECTION AUTHORITY
AND THE WATER AUTHORITY OF WESTERN AUSTRALIA

BULLETIN 266 DECEMBER 1990

Jenny Arnold's Perth Wetlands Resource Book

Chapters 1 - 4: Introduction, Source of Information & Classification System, Features of Wetlands in the Perth Region and Appendices

Environmental Protection Authority and
the Water Authority of Western Australia

Bulletin 266 December 1990

ISSN 1030-0120
ISBN 0 7309 19730

Produced by the Australian Government Publishing Service, Perth, W.A. Tel. (09) 325 9121

Bulletin 266 was prepared by the late Dr Jenny Arnold in her work with the Environmental Protection Authority and the Water Authority of Western Australia as part of the Perth Urban Water Balance Study. It represents over three years of information gathering and writing which Jenny did along with her many other tasks. Unfortunately she died before she could complete the work. Her notes have been edited for publication by Ron Van Delft, John Sutton and June Hutchison.

Jenny was a dedicated worker whose enthusiasm belied her ill-health. Her death was sudden and unexpected to all but her closest friends, relations and colleagues.

Vale Jenny Arnold

ACKNOWLEDGEMENTS

The genesis of this document came from a request from the Water Authority of Western Australia which, recognising the importance of groundwater for the coastal plain wetlands, called for the then Department of Conservation and Environment to provide the Urban Water Balance Study with information about the wetlands of the Perth metropolitan area.

I was given the opportunity to work as part of the Urban Water Balance Study team for almost a year, with the task of providing information about the wetlands. The original intention was to compile a computer data base but this was found to be unrealistic within the time frame for someone not at all versed in computer skills. The approach was then changed to one of developing systematic descriptions of as many of the wetlands as possible. The final outcome could more accurately be regarded as a set of working notes compiled from information gathered from a range of sources and from personal experience.

Special thanks to the Water Resources Directorate of the Water Authority of Western Australia and to the Perth Urban Water Balance Study team, who were unfailingly supportive with resources, information and discussion.

It was planned to include with the descriptions simple maps which showed the major categories of vegetation, along with land uses of the land surrounding the wetlands. The Urban Water Balance Study employed Rod Robinson to undertake the mapping, a task into which he put a great deal of effort and carried out with a considerable commitment.

Rod also painstakingly sketched diagrammatic cross-sections of each of the wetlands, to show the relationship of the vegetation boundaries to the wetland terrain.

Brian Stewart provided great assistance with the preparation of the report. Greg Beeston and his team used the Intergraph system to produce the maps of wetlands south of Wanneroo from tracings. Particular thanks to Greg Mlodowski and Gunther Arndt.

In a number of instances, generalisations and statements have been made about conservation and management issues. These generalisations are my opinions.

Jenny Arnold
Senior Environmental Officer
Environmental Protection Authority
1987

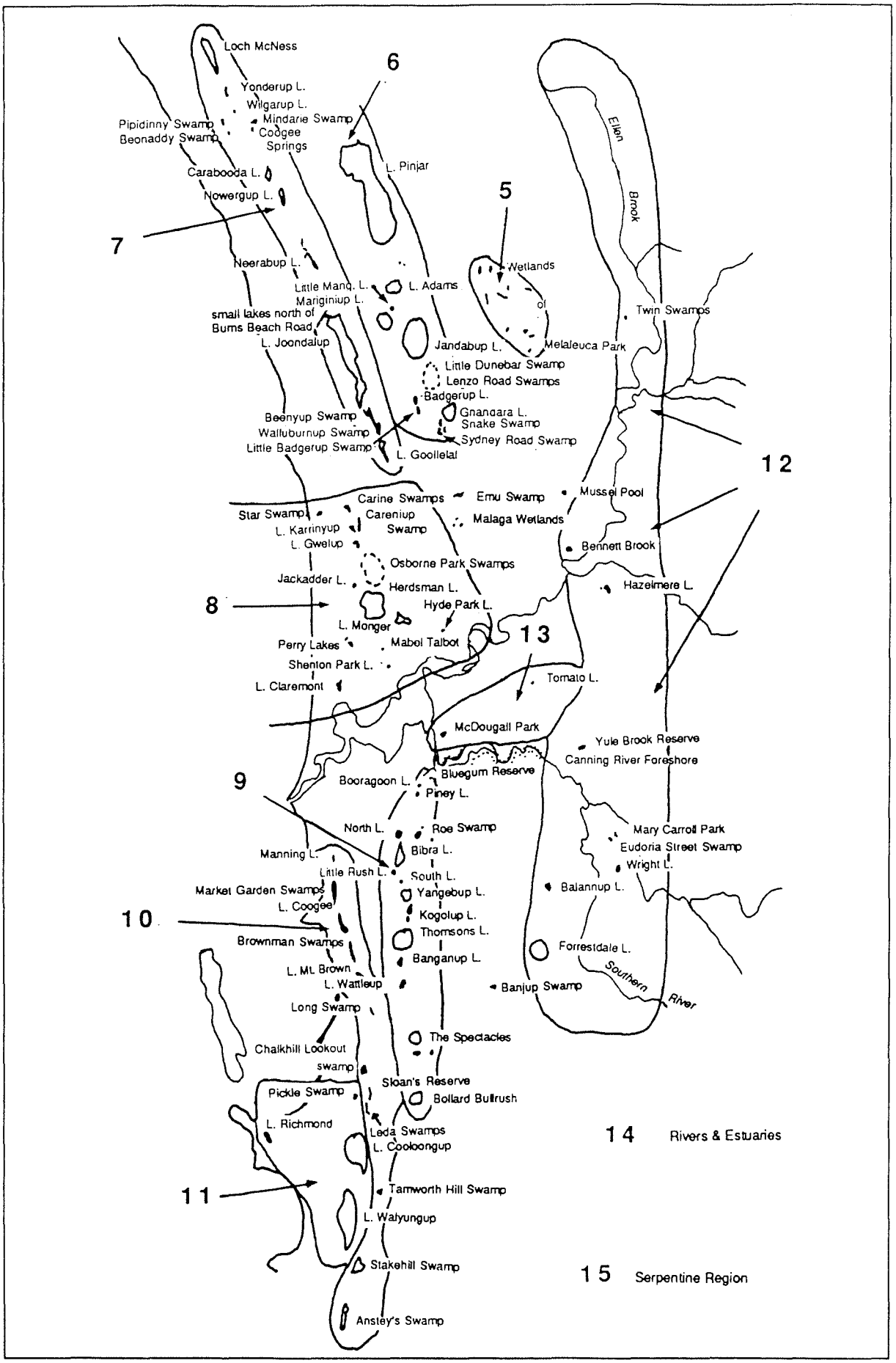
NOTES FOR USERS

Bulletin 266 consists of 15 chapters published in 6 separate volumes.

Chapters 1 - 4 (bound with the appendices) contain information general to wetlands. They form essential background to the subsequent chapters which describe most of the clearly definable seasonal and permanent lakes with open water.

The Bulletin is not an exhaustive inventory of all wetland types. Readers are referred to C. A. Semeniuk (1987), Wetlands of the Darling System - A geomorphic approach to habitat classification. Journal of the Royal Society of Western Australia. Volume 69, Part 3. pp 95-112 for a comprehensive classification of wetland types on the Swan Coastal Plain.

The index map on page (iv) shows how the wetland chains have been grouped into chapters. The position in the text where individual wetlands are discussed is shown in the index on page 418 (Chapters 1 - 4).



Map of Perth's wetlands showing the grouping of wetlands into Chapters in this Bulletin.

TABLE OF CONTENTS

Chapters 1 - 4: Introduction, Source of Information & Classification System, Features of Wetlands in the Perth Region and Appendices

APPENDICES

CONTENTS (Cont'd)

Other chapters in this series

1. INTRODUCTION

Bulletin 266 was prepared to provide information about the wetlands of the Perth Metropolitan Region to the Water Authority of Western Australia for its Perth Urban Water Balance Study. They attempt to draw together fragmentary information about a large number of Perth wetlands. The unattributed views presented are those of the author and not of the Environmental Protection Authority.

The Perth Urban Water Balance Study was undertaken by the Water Authority of Western Australia and the Centre for Water Research to identify technically feasible options for management of the groundwater resources of the Perth Region. The Study recognised that maintenance of environmental quality is an important aspect of water resource management. It also recognised that wetlands are significant features of the local landscape. It therefore sought to take into account the water requirements of wetlands in the development of its management options.

The questions the Perth Urban Water Balance Study asked included:

. which are the important wetlands in the region? and
. how much water do they require, when do they require it? and
. how much damage is caused if a wetland dries out in summer?

The answer to the first of these questions is that the wetlands of the Swan Coastal Plain are a very important environmental resource. The reduction in wetland area as a result of rural and urban development has been so substantial that every effort should be made to conserve the area remaining. Nevertheless, there remains a need to establish priorities for management and these priorities will depend upon the criteria used to determine them. These criteria could include:

. condition of the natural vegetation and fauna;
. presence of rare or endangered species;
. scientific and educational value;
. recreational value (including a wide range of passive and active forms of recreation);
. landscape and property value;
. potential to provide for any of the above;
. Aboriginal sites and heritage value, and
. intangible and unquantifiable values.

Any developments which impinge upon wetlands are likely to generate public controversy, because of the wide range of perceptions of their values. Examples of recent controversies include:

. Public concern over waterbirds affected by botulism, eg at Jackadder Lake, City of Stirling; Lake Monger, City of Perth; Bibra, North and Thomson Lakes, City of Cockburn; Lake Forrestdale, Town of Armadale; and Mary Carroll Park, City of Gosnells.

. Community objections to the construction of Farrington Road through Roe Swamp in 1984, Cities of Cockburn and Melville.

. Community objections to the development of Watts Road Lake, City of Canning.

. Debate on the availability of groundwater for 'special rural developments' in the rural areas of the Cities of Wanneroo and Cockburn.

- Concern about the possible effects of groundwater abstraction from the Gnangara mound for public water supply, City of Wanneroo.

- Controversy about drainage works on Shenton Park Lake, Town of Subiaco.

- Concern about summer drying of lakes, eg Perry Lakes, City of Perth.

- Development of the ski-tow facility near Market Garden Swamps, City of Cockburn.

- Developments of industrial and residential areas on the margins of Herdsman Lake, State Planning Commission.

- Proposed road link through Hazelmere, Shire of Swan.

Regular reading of community newspapers or reference to conservation groups could extend this list.

In the urban setting, criteria based on natural features, such as undisturbed vegetation, intact ecological systems and native fauna, cannot be the only basis for assessing the value of wetlands. On such criteria alone, highly modified lakes such as Lake Monger could be ranked as "unimportant" despite the fact that local residents and tourists use the lake environs for a wide range of activities from walking and picnics to active sports. However, although it lacks natural fringing and emergent plants, Lake Monger supports many species of birds - courtship displays and clutches of downy chicks can be seen during winter and spring and very large numbers of native birds use the lake as a drought refuge during dry summers. Highly modified parkland lakes such as Lake Monger and Hyde Park have to be judged differently from, for instance, Lake Joondalup, Yule Brook Reserve, the wetlands of Melaleuca Park or the Loch McNess fenland, all of which retain areas of native vegetation, and offer a range of habitats for wildlife. Many of these less modified wetlands support species with restricted distributions including, for example, the Short-necked Tortoise at Ellen Brook Reserve and Twin Swamps Reserve; invertebrate cave fauna at Yanchep; primitive plant species at Yule Brook Reserve and native species of fish in Ellen Brook.

Water requirements for wetlands will differ depending on whether they are managed to provide amenities in suburban settings or to preserve the natural ecosystem. The community may demand that the water supply of inner urban lakes is supplemented. Management of such demands could involve judicious control of drainage waters, waste water treatment and modifications to patterns of water use for private gardens and parklands. Urbanisation has the potential to affect groundwater chemistry and these effects have implications for the management of the groundwater resource as well as the wetlands. While such changes may not jeopardise some aspects of wetland values for passive recreation and landscape amenity, changes in water chemistry, the timing and rate of water inflows and changes to the seasonal pattern of water level variation, could have significant effects on ecological balances in wetland ecosystems.

Native wetland plants and animals are adapted to seasonal changes in water level which reflect high winter rainfall and summer drought. The ecological diversity of less modified lakes on the outer margins of the metropolitan region is best maintained by a natural water regime of falling water levels in summer and rising water levels in winter. However, the water supply of the less modified wetlands is most vulnerable to water table drawdown if

significant volumes of groundwater are pumped for irrigated agriculture and public water supply. Furthermore, pine plantations may significantly alter the regional water balance. The water demands for any use is, of course, highest during hot, dry summers and in periods of low rainfall - under the same conditions which place the greatest stress on the natural systems. At the same time public opinion is likely to be a less potent force for conservation of these "natural" wetlands because they are less within the public focus.

In attempting to answer the questions posed by the Perth Urban Water Balance Study, this paper set out:

(i) to find a working definition of wetlands;
(ii) to examine the functions and uses of wetlands;
(iii) to provide an inventory of wetlands which includes descriptions of their characteristic features and a summary of available information;
(iv) to take into account a variety of "natural" and "social" factors assessing the importance of wetlands to the community;
(v) to derive recommendations on environmental needs of wetlands.

1.1 DEFINITIONS OF A WETLAND

Wetlands have been variously defined but a detailed analysis of the range of definitions will not be attempted here. Only a few examples will be used to illustrate some approaches.

The Wetlands Advisory Committee of the Environmental Protection Authority (1977) used inundation as the most important characteristic of wetlands. It defined wetlands as: "Areas of seasonally, intermittently or permanently waterlogged soils or inundated land, whether natural or otherwise, fresh or saline, eg waterlogged soils, ponds, billabongs, lakes, swamps, tidal flats, estuaries, rivers and their tributaries". A drawback of this definition is that it takes into account areas which may be inundated for a few months or years as a result of changes in the water balance of an area. Such changes have occurred on the coastal plain as a result of removal of vegetation and urban development.

Mitchell and Roberts (1982), in a discussion on wetland management, chose to consider those areas which regularly contain populations of truly aquatic plants. While such a definition is appropriate for undisturbed wetlands, it does not take into account the residual wildlife value of seasonally flooded areas whose vegetation has been removed. It may also leave out of consideration areas which have been cleared but remain capable of regenerating to some form of wetland vegetation and waterbird habitat.

Paijmans et al. (1985) defined wetlands as "land permanently or temporarily under water or waterlogged. Temporary wetlands must have surface water or waterlogging of sufficient frequency and/or duration to affect the biota. Thus the occurrence at least sometimes of hydrophytic vegetation or use by water birds are necessary attributes."

A definition adopted by Cowardin et al. (1979) (Fish and Wildlife Service of the United States) uses a combination of inundation, hydric soils and aquatic plants. A wetland is identified by the presence of two out of three of these factors.

Howard-Williams (1985) used a terse and useful adaptation of the US definition which emphasises function: "A wetland is an area where the water table is at or near the land surface for long enough each year to promote the formation of hydric soils and to support the growth of emergent plants".

For the purposes of this review, the approaches of Cowardin et al., Paijmans and Howard-Williams have been followed with wetlands identified by a combination of present-day hydrology (inundation), long-term history of inundation as indicated by the presence of hydric soils, and shorter-term history of inundation as reflected by wetland vegetation.

1.2 CLASSIFICATION

Classifications are useful because they provide a way of organising information. Good classifications make use of key features as bases for organisation, and emphasise structural and functional relationships. They provide an important first step in the process of conserving the natural environment. A great deal of effort has been made to devise a classification for wetlands in the United States (for example, see Cowardin et al., 1979).

Until recently, a system of classification had not been proposed for Australian wetlands. However, Paijmans et al.. (1985) proposed a simple hierarchical classification of Australian wetlands. The classification includes groupings for wetlands which are convenient for use in the Perth region as follows:

CATEGORY I. LAKES : areas of open water generally over 1 m deep with little or no persistent vegetation

CLASS 1. Permanent and near-permanent lakes
subclass: (b) Permanent lakes of coastal dunes and beach ridge plains
subclass: (f) Permanent karst lakes

CATEGORY II. SWAMPS : dominantly vegetated; water, when present, generally less than 1 m deep; persistent emergent vegetation

CLASS 1. Permanent swamps: wet most of the time
subclass: (b) Permanent swamps of coastal dunes and beach ridge plains
subclass: (g) Permanent swamps fed by springs

CLASS 2. Seasonal swamps: seasonally wet and dry each year
subclass: *seasonal groundwater discharge swamps (see below)

CLASS 3. Intermittent swamps: alternately, but irregularly, wet and dry
subclass: **intermittent groundwater discharge swamps (see below)

* and ** Class 2, subclass: seasonal groundwater discharge swamps and Class 3, subclass: intermittent groundwater discharge swamps are not recognised in Paijmans' classification but they do occur in the Perth region. The necessary addition of groundwater-related seasonal and intermittent swamps to the classification of Paijmans et al. emphasises the importance of groundwater to the wetlands of the Perth region.

Allen (1981) classified the lakes of the Perth region by reference to strong association with the north-south trending elements of the surface geology and to the unconfined groundwater flow systems within these

superficial deposits. Allen recognised six types of lakes on the coastal plain ranging from his Bambun type, on the eastern side of the coastal plain between the Bassendean dunes and the Pinjarra Plain representing the oldest type, the Cooloongup type, on the western side of the plain within the most recently formed dune system, representing the youngest type; and the remainder being of intermediate ages. A classification based on geomorphic relationships is useful in the local context because it highlights the strong relationship between the wetlands and the groundwater flow systems.

C A Semeniuk uses geomorphic setting together with geometry, bathymetry and water quality as means of classifying coastal plain wetlands (Western Australian Water Resources Council, 1987).

Wetland classifications can be based on biological characteristics, such as vegetation or bird habitat (see Pressey, 1983, for references). However the biological elements of wetland ecosystems are determined by the physical characteristics of the systems and are strongly influenced by human activities. Such classifications may be appropriate in regions where wetlands are in a relatively pristine state but less relevant in the highly modified environment in and around Perth.

Where the emphasis is on management, a classification which makes use of factors which directly relate to processes may be appropriate. The Wetlands Advisory Committee (1977) classified wetlands on the basis of the functional characteristics of:

. still or flowing water (lentic or lotic);

. water chemistry (salinity);

. size;

. permanence, and

. vegetation cover.

This approach summarises a considerable amount of information relevant to management.

Factors which influence ecosystem processes rather than morphological, taxonomic or habitat criteria are used by Howard-Williams (1985) to recognise four subdivisions of lentic (still water) wetlands. Two of his subdivisions occur in the Perth region.

1. Freshwater versus brackish or saline wetlands

2. Permanently inundated versus periodically inundated wetlands.

Classifications provide convenient means of grouping and displaying information. Detailed classification has not been pursued here. However, the major wetlands of the Perth region can be grouped according to the geomorphological classification adopted in the Geological Survey of Western Australia Environmental Geology map series (Gozzard 1982a, 1982b, 1983a, 1983b, 1986; Jordan 1986), as follows:

PHYSIOGRAPHIC CATEGORY QUINDALUP DUNES

Interdunal (or inter-ridge) swale, eg : ephemeral swamps in Warnbro region

Lake, eg : Lakes Richmond, Cooloongup and Walyungup

PHYSIOGRAPHIC CATEGORY SPEARWOOD DUNES

Swamp/lake in low level interbarrier depressions with prominent karstic features, eg : Loch McNess; Yonderup Lake; Wilgarup Swamp; Pipidinny Swamp; Beonaddy Swamp; Lake Mindarie; Coogee Springs; Lake Carabooda; Lake Nowergup; Lake Neerabup; 'North Joondalup'; Lake Joondalup; Beenyup Swamp; Walluburnup Swamp; Lake Goollelal.

Swamp/lake in low level interbarrier depressions, eg : Lake Manning; Market Garden Swamps; Lake Coogee; Brownman Swamps; Lake Mount Brown; Long Swamp; Leda Swamps; Sloans Reserve Swamps; Tamworth Hill Swamp; Anstey's Swamp; other unnamed swamps in Baldivis.

Swamp in interdunal swale, eg : Shenton Park Lake; Mason Gardens lake; Jackadder Lake; Lake Claremont; Perry Lakes; Herdsman Lake; Mongers Lake; Lake Gwelup; Careniup Swamp; Lake Karrinyup; Carine Swamps; Osborne Park swampland; Star Swamp; Bluegum Lake; Booragoon Lake; Piney Lake; MacDougall Park Lake; Marmion Reserve Lake; small swamps in Spearwood Dunes west of the Serpentine River.

PHYSIOGRAPHIC CATEGORY BASSENDEAN DUNES

Swamp/lake in high level interbarrier depression, eg : Lake Bindiar; Lake Pinjar; Lake Adams; Lake Mariginiup; Little Mariginiup; Lake Jandabup; Lake Badgerup; Lake Gnangara; Emu Lake; North Lake; Roe Swamp; Bibra Lake; Little Rush Lake; South Lake; Yangebup Lake; Kogolup Lake; Thomson Lake; Banganup Lake; swamps in Wattleup/Mandogalup localities; Mandogalup Swamp (now entirely utilised for horticulture); Large Eye Spectacle; Small Eye Spectacle; Bollard Bullrush Swamp;extensive areas of peats and lacustrine deposits associated with the Serpentine River, south of Karnup.

Swamp in interdunal swales in deep Bassendean Sands (ie with no underlying alluvial deposits), eg : swamps of Melaleuca Park (swamps 1 - 45, Muir, 1983); Yeal Swamp; swamps elsewhere in State Forest 65, eg east of Lake Pinjar, Lake Jandabup and Lake Gnangara; unnamed swamps north of Lake Jandabup; Little Dundarbar Swamp; Lenzo Road Swamps; Tomato Lake; wetlands of Willetton/Canning Vale area (now mostly urbanised); wetlands of Jandakot, Banjup, Wandi, Anketell, and Wellard localities; wetlands west of Serpentine and Keysbrook and east of Serpentine River.

Swamp/lake/channel in interdunal swale in shallow sands over alluvial deposits (Southern River and Yanga formations of Churchward and McArthur), eg : Lakes Muckenburra, Bambun, Nambung and Mungala; Lake in Reserve 31241; Quins Brook; Lake Catambro; seasonal tributaries to Gingin Brook; seasonal tributaries on western side of Ellen Brook; Twin Swamps Reserve; headwater streams of Henley Brook; headwater streams and upper reaches of Bennett Brook (Whiteman Park); Malaga wetlands; Hazelmere Lakes and related wetlands; wetlands of South Guildford, Newburn, Kewdale, Welshpool, Queens Park localities; wetlands of the Southern River, Huntingdale, Gosnells, Forrestdale localities, eg Lake Ballanup, Mary Carroll Park; Lake Forrestdale; wetlands of Lowlands - Hymus Swamp and others, Punrak Drain, Yangedi Swamp areas.

PHYSIOGRAPHIC CATEGORY ALLUVIAL PLAINS

Swamp on alluvial plains, eg : Lake Chandala; Ellen Brook Reserve; Bennett Brook - Pyrton; wetlands of the Kenwick locality, eg Yule Brook reserve; wetlands associated with Wungong Brook in Wungong locality; wetlands associated with the coastal plain sections of Manjedal Brook, Cardup Brook, etc.

Freshwater swamp on river floodplain and river terrace, eg : swamps on Canning River upstream from Kent Street Weir; swamps above tidal influence on the estuarine reaches of the Swan and Canning Rivers, eg at Wilson, Riverton and Ferndale, Clontarf, Bull Creek, Ashfield Flats.

Swamp on river floodplain and river terrace under tidal influence, eg : Canning River wetlands at Riverton, Ferndale and Wilson, Clontarf, Salter Point, Swan River at Alfred Cove, Maylands, Bayswater, Redcliffe, Ashfield Flats, South Guildford.

River terrace subject to winter inundation, eg : lower reaches of Ellen Brook; lower reaches of Jane Brook; lower reaches of Helena River.

River pool, cut-off meander, ox-bow etc, eg : features in the Swan Valley, Folly Pool, Maramanup Pool, Yalbanberup Pool

1.3 EMPAHSIS OF DOCUMENTATION AND DESCRIPTION OF WETLANDS IN THIS SERIES

A variety of methods have been used to describe and evaluate wetlands. Pressey (1983) provided a brief review of methodologies. The ways in which the methods were used to indicate value reflect major differences in aims, scope and constraints of the approach to wetland evaluation. Pressey devised a method for surveying New South Wales coastal floodplain wetlands which emphasised vegetation and habitat. Other studies have sought to evaluate wetlands as bird habitat, notably Riggert (1966) in the Western Australian context.

The approach taken here is to document, as far as possible, existing information about as many wetlands in the Perth region as time permitted. Most emphasis has been placed on the large, relatively well-known lakes and swamps. There are many locally important small wetlands which have not been included. These are located particularly on the top and eastern flanks of the groundwater mounds, and on the eastern coastal plain.

In the Perth metropolitan region wetlands represent a complex of resources for which competition is intense. Competition for resources results in stress to the wetland systems and in actual or potential conflict. Therefore it is appropriate to attempt to describe the metropolitan wetlands with reference to most of the resources which are subject to competition.

These include:

(i) Water: the wetlands are groundwater-dependent and face competition for water from demands for agricultural, public, private and industrial uses.

(ii) Land: wetlands have been drained for agriculture (Riggert, 1966), filled for development of various kinds, and used for service easements (cheap land), eg roadworks (Le Provost, Semeniuk and Chalmer, 1985).

(iii) Materials (mining and extractive industries): wetlands may contain economic resources of sand, peat, diatomite, and clay.

(iv) Service functions: because they are low on the landscape wetlands are readily adapted to function as drainage and infiltration basins; as wetlands used for drainage receive surface runoff as opposed to groundwater inflow, changed patterns of assimilation of dissolved and suspended materials are imposed upon them.

(v) Recreation opportunities: pressures exist to use water bodies for various kinds of recreation, with consequences for physical and biological elements of the wetlands.

1.4 REFERENCES

Allen, A D (1981), Groundwater resources of the Swan Coastal Plain, near Perth, Western Australia. pp 29 - 74 in Groundwater resources of the Swan Coastal Plain (1981). Edited by B R Whelan. CSIRO Division of Land Resources Management.

Cowardin, L M, Carter, V, Golet, F C and LaRoe, E T (1979), Classification of wetlands and deepwater habitats of the United States. United States Fish and Wildlife Service FWS/OBS - 79/31. Washington.

Gozzard, J R (1982a), Muchea Sheet 2034 I and Part 2134 IV, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1982b), Yanchep Sheet 2034 IV, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1983a), Fremantle Part Sheets 2033 I & IV, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1983b), Rockingham Part Sheets 2033 III and 2033 II. Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1986), Perth, Sheet 2034 II and Part 2034 III and 2134 III. Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Howard-Williams, C (1985), Cycling and retention of nitrogen and phosphorus in wetlands: a theoretical and applied perspective. Freshw. Biol. 15, 391 - 431.

Jordan, J E (1986), Serpentine Part Sheets 2033 II and 2133 III, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Le Provost, Semeniuk and Chalmer (1985), The impact of roadworks on metropolitan wetlands - citing work of C A Semeniuk. Report prepared for the Department of Conservation and Environment, Western Australia.

Mitchell, D, and Roberts, J (1982). Wetland management: philosophies and principles. pp 62 - 67 in Wetlands in New South Wales. New South Wales National Parks and Wildlife Service, Sydney.

Paijmans, Galloway, R W, Faith, D P, Fleming, P M, Haantgens, H A, Heyligers, P C Kalma, J D, and Loffler, E (1985), Aspects of Australian westlands. Division of Water and Land Resources. Technical Paper No 44, CSIRO, Australia.

Pressey, R L (1983), A method for description and evaluation of coastal floodplain wetlands. In Survey methods for nature conservation. Edit: K Myers, C R Margule and I Musto. Sponsored by the South Australian Department of Environment and Planning under the auspices of the Council of Nature Conservation Ministers in association with CSIRO, Division of Land and Water Resources, the Bureau of Flora and Fauna and the Ecological Society of Australia.

Riggert, T L (1966), A study of the wetlands of the Swan Coastal Plain. Department of Fisheries and Fauna, Perth, Western Australia.

Wetlands Advisory Committee to the Environmental Protection Authority (1977), The status of wetland reserves in System 6. Department of Conservation and Environment, Western Australia.

Western Australian Water Resources Council (1987), Classification of wetlands (Appendix One). In "Environmental significance of wetlands in the Perth to Bunbury Region", Water Authority of Western Australia.

Page

2. SOURCES OF INFORMATION AND CLASSIFICATION SYSTEMS USED TO PREPARE THIS SERIES

2.1 SOURCES OF INFORMATION

There is a considerable volume of information available about the metropolitan wetlands but it is lacking in coherence. Sources of information for this study are summarised in Table 2.1.

Table 2.1. Sources of Information on Wetland Sites.

INFORMATION RESOURCE	NUMBER OF WETLAND SITES	SOURCE OF
Air photographs	all wetlands	Department of Lands & Surveys
Geology	all wetlands	Published maps
Water table & surface contours	all wetlands	Water Authority of Western Australia plans
Hydrographs	30 wetlands	Water Authority of Western Australia
Water quality		Water Authority of
. spot values	23 wetlands	Western Australia
. detailed	5 wetlands	research papers
Drains		
. main drains	41 wetlands	Water Authority of WA
. local	? most urban wetlands	local authorities
Vegetation		
. published	23 wetlands	research papers
. this study	all wetlands	air photographs
Bird fauna	40 wetlands	Royal Australasian Ornithologists' Union
Invertebrate fauna		
. detailed	5 wetlands	Davis & Rolls (1987)
. other	11 wetlands	research papers
Land status	all wetlands	EPA (1983); Metropolitan Region Scheme maps
Land use	all wetlands	air photographs

2.2 CATEGORISATION OF WETLANDS

Each wetland has been categorised using the method devised by the Wetlands Advisory Committee (1977). The relevant extract from the Committee's report is included as Appendix 4 and a summary key is presented in Section 2.5.

2.3 VEGETATION AND LAND USE MAPPING

Vegetation of the wetlands was mapped using air photographs. Limited ground checking was carried out, so the resulting maps should be regarded as preliminary. Boundaries between wetland plant communities were traced from air photographs onto acetate sheets. Wetland plant communities were mapped according to dominant genera and, where possible, species. The method of Beard and Webb (1974) of using lower case letters with subscripts on the left to indicate dominant plant genus and species; upper case letter to indicate physiognomy of the dominant stratum; and lower case letters on the right to provide an estimate of vegetation cover was used.

A key to the vegetation maps is presented in Section 2.5.

Where cadastral information was available in digitised form, the vegetation and land use boundaries mapped by photo-interpretation were digitised and merged with data files containing property boundaries and road reserves. For northern wetlands, where digitised cadastral details were not accessible, vegetation and land use boundaries and limited cadastral information were hand-sketched.

(i) Surrounding land use

Boundaries of upland vegetation and various forms of land use were traced onto acetate sheets from air photographs to indicate influences on the wetland surroundings. The following land use categories were recognised:

- uncleared native vegetation (not wetland species);
- non-irrigated rural uses;
- residential and related uses, and
- industrial uses.

(ii) Other features

Key streets and roads, major drains, boundaries of water supply areas, sumps and infiltration basins and service easements are included on the maps where appropriate.

General features:

- Reserve boundary;
- Metropolitan Region Scheme, Parks and Recreation Reserve boundary;
- PWSA/UWPCA boundary;
- Cul-de-sac
- Main drain
- Local drain
- Wetland edge
- Track/easement
- Fence
- Road
- 'Informal' drain, and
- Sump/infiltration basin

2.4 CROSS-SECTIONS

Cross-sections of wetlands were sketched using Water Authority maps which show surface contours at 2 m or 5 m intervals and cadastral information Bathymetric contours were available for 10 wetlands. Vegetation and land use boundaries were shown for the sections, as was additional relevant information where available.

The planes of the cross-sections are shown on the vegetation maps by bold lines.

2.5 KEY TO MAPS AND CATEGORISATION OF WETLANDS

Due to the length of the map key it has not been reproduced for every map, but has been summarised on these reference pages. All maps have been reproduced in this Bulletin at one of the following scales: 1:5000, 1:10000, 1:15000, 1:20000, 1:30000 or 1:40000. The map key has been divided into three sections; General legend; Vegetation; and Land use.

GENERAL LEGEND

Wetland Boundary
Metropolitan Region Scheme Boundary
MD Drain - Main (M)
Local (L)
Informal (I)
Fence
Sump
GW Groundwater Flow

VEGETATION MAP: MAPPING NOTATION AND FORMULAE.

Consists of three letters, viz:

(a) dominant genus and species - lower case letter on left;
(b) physiognomy of dominant stratum - upper case letter in centre; and
(c) projective vegetation cover - lower case letter on right.

EXAMPLE: m_1Ld = Melaleuca rhaphiophylla; low trees < 10 m tall; dense cover> 70%

(a) Dominant genera and species

a	Acacia	k	Halophytes eg samphire
b_2	Banksia littoralis	l	Leptocarpus
c	Casuarina	m	Melaleuca sp
cl_1	Baumea articulata	m_1	Melaleuca rhaphiophylla
cl_2	Baumea juncea	m_2	M. preissiana
d	Dryandra	m_3	M. lateritia
e_1	Eucalyptus rudis	m_4	M. teretifolia
e_2	Eucalyptus gomphocephala	m_5	M. cuticularis
e_3	E. marginata	p	Callitris
e_4	E. calophylla	s	Scirpus
e_5	E. todtiana	t	Typha
g	Gahnia trifida	w	Weeds or introduced grasses eg Kikuyu
h	Coastal heath	x	Mixed or other
j	Juncus		

(b) Physiognomy of Dominant Stratum

T	Tall trees > 30 m tall	V	Rushes and sedges < 1 m tall
M	Medium trees 10 - 30 m tall	G	Bunch grasses
L	Low trees < 10 m tall	H	Hummock grasses e.g. Spinifex
S	Shrubs > 1 m tall	F	Forbs
Z	Dwarf shrubs < 1 m tall	L	Lichens and mosses
R	Rushes and sedges > 1 m tall	C	Succulents

(c) Canopy Cover

d Dense Cover > 70% foliage cover
c Mid Dense 30 - 70% foliage cover
i Incomplete Canopy - open, not touching

r Rare but conspicuous foliage cover < 10%
b Vegetation largely absent
p Scattered groups - no definite foliage cover

LAND USE

Uncleared bushland

Partly or fully cleared land; uses can include pasture cropping, pine plantations, easements and no current use, ie unimproved.

Fully cleared and irrigated or used for recreation

Intensive animal production, quarries, landfill, liquid waste disposal sites and industrial areas

Urban areas or sealed areas (eg car parks)

WETLAND CATEGORISATION

The characteristics summarised are as follows:

LE: non-flowing - all of the individual wetlands considered are non-flowing.

f/b/s: Total Dissolved Solids (TDS) f= <1000 mg/L: b = 1000-3000 mg/L; S = > 3000 mg/L.

s/m/l: s = small <25 ha; m = medium 26-50 ha; l = large > 50 ha.

p/s: p = permanent; s = seasonal.

o/so/sc/c: vegetated area(ha)/total wetland area x 100

o = <25%, so = 26-60%, sc = 61-90%, c = >90% L.E.f.l.p.sc

Example: Lake Jandabup (Eastern Wanneroo wetlands) LE.f/l/5.sc

2.6 REFERENCES

Beard, J S and Webb, M J (1974), The vegetation survey of Western Australia, its aims, objects and methods. Part I of Great Sandy Desert, University of Western Australia Press, Nedlands.

Davis, J A & Rolls, S W (1987), A baseline biological monitoring programme for the urban wetlands of the Swan Coastal Plain, Bulletin 265, Environmental Protection Authority, Western Australia.

Environmental Protection Authority (1983), Conservation reserves for Western Australia as recommended by the EPA. The Darling System. Report 13, Department of Conservation and Environment, Western Australia.

Wetlands Advisory Committee (1977), The status of wetland reserves in System six, Department of Conservation and Environment, Western Australia.

3. LAYOUT AND USE OF THIS SERIES

3.1. GROUPING OF WETLANDS

The chapters below group wetlands according to their geographical location, physical characteristics and shared influences. A brief general discussion of each group is followed by descriptions of the individual wetlands.

3.2 INFORMATION PROVIDED FOR INDIVIDUAL WETLANDS

The amount of information gathered for each individual wetland varies significantly, but the information is presented using a standard set of subject headings which suit the needs of this document. For some of the smaller or little known wetlands fewer headings and a different system of notation is used.

The standard set of subject headings is incorporated into this report using a decimal notation system. The first number refers to the group of wetlands in which the wetland occurs (which in this report is the chapter number), the second refers to the individual wetland(s) and the third refers to the subject heading. The decimal notations for the subject headings appears below:

. 1. General Information;
. 2. Physiography and Geological Setting;
. 3. Areas and Bathymetry;
. 4. Hydrology;
. 5. Water Quality;
. 6. Land Use (Type and effects of);
. 7. Vegetation;
. 8. Fauna;
. 8.1 Microbial Fauna;
. 8.2 Invertebrate Fauna;
. 8.3 Vertebrate Fauna;
. 8.4 Birds;
. 9. Management Issues (Includes Stresses, Potential and Human Impact; Comments on Conservation Values and Ecological Notes);
. 10. References.

For smaller wetlands with fewer headings, letters rather than numbers are used in the decimal notation.

Under the "general information" heading the following information is usually provided.

AMG REF: This is the Australian Mapping Grid Reference, which can be determined from 1:100 000 topographic maps produced by the Department of National Resources and available from the Central Map Agency. This information only appears in some chapters.

LOCAL AUTHORITY:

MRS ZONE: The zoning of the wetland by the Metropolitan Region Scheme. Please note that the Metropolitan Region Scheme presents a broad brush approach and many small parks zoned for "recreation" or "parks" by the local authority town planning scheme appear as "urban" under the Metropolitan Region Scheme.

RESERVE NO:

PURPOSE:

MANAGEMENT:

SYSTEM 6 RECOMMENDATION: (if applicable)

WAC CLASSIFICATION: The Wetlands Advisory Committee Categorisation. Refer to Section 2.5 and Appendix 4 for more information.

WATER RESERVE: Groundwater control area; if relevant.

DRAINAGE:

3.3 ADDING NEW INFORMATION TO THIS SERIES

Users are encouraged to establish a filing system using the Chapter numbers in this Bulletin. This file can be used until information collected exceeds its capacity! Each wetland vegetation and land use map is on its own page to facilitate the use of the map in the field and corrections or additions to the map by users as required.

Page

4. FEATURES OF WETLANDS IN THE PERTH REGION

4.1 GENERAL INFORMATION

The South-West of Australia has a relatively arid climate but, nevertheless, it contains many types of wetlands. The importance of fresh water in the dry summers characteristic of the mediterranean climate of the region cannot be too heavily emphasised. However, much of the wetland which existed at the time of European settlement has been irreversibly altered by development of the land for rural and urban uses. Inland freshwater wetlands and rivers have become saline as a result of land clearing and, as a consequence, the importance of the remaining freshwater coastal plain wetlands as wildlife breeding areas and refuges has increased and will remain extremely high. It is important, therefore, that efforts should be made to prevent any further losses of inland aquatic systems.

The Swan Coastal Plain of south-western Australia (Allen, 1981), including that portion occupied by the growing Perth metropolitan region, has many shallow freshwater and saline wetlands and large shallow estuaries. The wetlands are shallow permanent lakes and seasonal and intermittent swamps. If the presence of peats and other soils formed in wet conditions is used as an indicator, it can be seen that wetlands occupy a significant area of the coastal plain. (See Geological Survey of Western Australia Environmental Geology map series)(Gozzard 1982a,1982b,1983a, 1983b,1986; Jordan 1986).

The coastal wetlands have been greatly altered; Riggert (1966) documented the impact of settlement on them. More recently, the focus of conflict between wetland conservation and other land uses is increasingly coming to be competition for the good quality water of the unconfined groundwater flow systems of the coastal plain (Bestow, 1976).

According to classification systems designed for large regional or continental inventories of aquatic systems, the range of types occurring in the Perth metropolitan region is limited. Nevertheless there are many subtle differences between the lakes and swamps which reflect differences in origin and history.

For example:

- The Wanneroo linear lakes and Rottnest Island lakes are associated with karstic limestone.
- Many of the lakes are associated with barrier dunes on old shorelines, Lake to Bollard Bullrush Swamp; Lake Pinjar to Lake Gnangara. The processes which shaped these lakes are in action at present in the lakes of Yalgorup National Park and Harvey Estuary.
- Cooloongup and Walyungup Lakes show their close relationship to the beach ridges of the Rockingham plain (Woods and Searle, 1983).
- Lake Richmond is a marine relic related to the formation of Point Peron (Fairbridge, 1948).
- Lake Forrestdale and Lake Thomson are surrounded by lunettes and probably represent deflation basins.

. Seasonal wetlands high on the Bassendean Dunes are shallow expressions of the groundwater while on the eastern and western flanks they are discharge zones forming the headwaters of seasonal tributaries to coastal plain streams such as Gingin, Ellen, Bennett and Henley Brooks north of the Swan River, and Wungong and Southern Rivers (now largely altered by drains) in the south-east of the metropolitan region. Small mound springs occur at some of these discharge zones.

4.2 PHYSIOGRAPHY AND GEOLOGICAL SETTING

The physiography and geological setting have been used to provide a basis for classifying Perth's wetlands. Refer to Section 1.2 for further details.

4.3 AREAS - Refer to Riggert (1966)

4.4 HYDROLOGY

Most of the wetlands have a close relationship to the groundwater rather than being perched water bodies. They receive their water supply from rain falling directly onto the surface and from seepage from the shallow unconfined aquifers. The sandy soils of much of the coastal plain are very porous so that there is little surface runoff into wetlands except, possibly, in very wet periods when the unconfined flow systems are fully charged. Wetlands associated with stream channels are sites where groundwater seeps from the ground, rather than areas receiving onflow from the related stream, except for some tidal areas on the lower reaches of estuaries. The strong connection between the wetlands and the groundwater makes them different from many wetlands studied elsewhere in the world. Standard texts on limnology give scant attention to 'seepage lakes', described by Hutchinson (1975) as those in which groundwater enters and from which water leaves by seeping through the walls of the lake basin, as opposed to those lakes which receive the bulk of their water supply from inflowing streams.

In order to show some aspects of the relationship between the wetlands of the Bassendean Dunes, in particular, to the unconfined groundwater systems which sustain them, four diagrammatic cross-sections orientated approximately west-east across the Bassendean Dunes were constructed. Emphasis is placed on this group of seasonal wetlands in the Bassendean Dunes because they are most directly affected by pumping of groundwater from unconfined aquifers. The pressures on wetlands situated more peripherally on the mounds are more varied and complex.

These diagrammatic sections (Figures 5.2, 5.4, 10.2, 10.3) illustrate the positions of the wetlands in the landscape.

Evaporation from water surfaces in lakes and swamps and transpiration from wetland vegetation account for considerable fluxes of water from the unconfined groundwater flow systems to the atmosphere. These losses are at their highest in the hot dry summers characteristic of the mediterranean climate of the region. As the wetlands are windows on the fresh groundwater resources of the unconfined flow systems, evapotranspirative losses represent losses of potentially usable water resources.

The close relationship between the wetlands and the groundwater has been weakened in farmed and residential areas. The wetland soils have large stores of organic material and, therefore, are fertile in comparison with other coastal plain soils. Because of this fertility, many wetlands in rural areas have been drained and used for agriculture. In urban areas, drainage to lower the water table, and filling to raise the ground surface above the water table, have reduced the amount of wetland. Drainage waters and runoff are channelled into remaining wetlands which function as compensating and infiltration basins. As a result their water regimes have been changed from principal dependence on groundwater to greater dependence on surface flow.

4.5 WATER QUALITY

Most of the shallow wetlands are naturally eutrophic systems, having been sinks for carbon and nutrients for relatively long periods. Bestow, (1981), and Megirian (1982) reported deep peat deposits in Hertha Road Swamp and Bibra and North Lakes respectively. Nutrients will be exchanged between the sediments and the wetland waters according to the prevailing conditions (Carbon et al., personal communication). Thus, dilution of lake waters by rain or addition of water from another source may result in release of nutrients from the sediment store; while concentration of nutrients dissolved in wetland waters by evaporation may result in some transfer of nutrients from the water to the sediments.

Wetlands such as Jandabup, Mariginiup and other lakes high on the Gnangara Mound have relatively thin lake deposits, primarily of diatomite. The differences in the nature of the lake deposits may reflect the lower nutrient status of the latter lakes, or discontinuous functioning - ie they may have dried out more frequently and for significant periods. Differences in the nature of lake deposits reflecting different water regimes in the past may provide insights into the water needs of the different types of wetlands.

The ecologically significant parts of the aquatic systems are the interfaces between the wetland water and the sediments and between the wetland sediments and the groundwater flow system. Increasing levels of nitrogen and phosphorus in groundwaters (Appleyard and Bawden, 1987) will result in increasing loads of nutrients entering wetlands via the groundwater, in addition to the loads entering in surface runoff from urban catchments. The physical and microbiological processes taking place at the water - sediment interfaces require study. As it is, some urban wetlands are expected to function as tertiary water treatment systems as well as provide landscape features and wildlife habitats.

The abundance of phytoplankton in wetland waters provides a means of measuring cultural eutrophication. Many urban lakes have massive blooms of phytoplankton and blue-green algae. Other symptoms of stressed aquatic ecosystems include:

- changes to wetland vegetation, including loss of fringing trees;
- high bacterial counts, including Salmonella (Iveson, 1979);
- bird deaths from botulism and algal poisoning (Grubb, 1964);
- increased midge and mosquito populations (Davis et al., 1987).

4.6 LAND USE

4.7 VEGETATION

Wetland vegetation is central to wetland processes. It utilises and fixes nutrients, provides the primary production for wetland ecosystems and a range of habitats for aquatic and terrestrial fauna.

Most of the definitions of wetlands discussed in Section 1.1 use the presence of wetland plants or hydrophytes as one of the defining features. The structures, physiological processes and methods of reproduction of wetland plants are adapted for life in water-saturated conditions for at least part of the annual cycle. Gradients of saturation, aeration and substrate chemistry within the wetland environment directly affect the distribution of the plant species. Thus, the presence of plants with such adaptations is a key indicator of wetland conditions.

In the Perth region, vegetation on the groundwater mounds is so strongly related to the depth to the water table that a close approximation of groundwater contours can be mapped by observing the boundary between banksia woodland and the paperbark - wetland heath and sedgelands of the seasonal wetlands. Salinity has also been shown to be a factor with a strong influence on vegetation (Pen, 1981; Cresswell and Bridgewater, 1985). The limits and extent of wetlands can be mapped from air photographs using vegetation boundaries.

Briggs (1981), in a discussion of the vegetation of Australian freshwater wetlands, described the generalised zonation in wetlands near Perth. This description was based largely on the work of McComb and McComb (1967) who made a detailed study of the vegetation of Loch McNess. They identified sedge communities, the Melaleuca /Eucalyptus rudis community, the Banksia littoralis community and other fringing communities. These authors also made comparisons between the Loch McNess vegetation and similar formations in other temperate regions. They observed that Loch McNess vegetation is similar structurally and floristically to that in wetlands in other temperate areas of Australia and abroad. They also noted the low proportion of endemic plant species in wetlands compared with dry land communities. Other studies of wetland vegetation include those of Congdon and McComb (1973) who described the vegetation of wetlands of the Wanneroo region; Heddle (1980) who studied the vegetation of the northern Swan Coastal Plain and identified species tolerant to wet soils on the Gnangara mound; and Speck and Baird (1984) who described the extremely rich flora of Yule Brook Reserve as an example of the alluvial plain wetlands of the eastern coastal plain. Bell and Stephens (1984) showed that the patterns of flowering and fruiting of Yule Brook plants are strongly determined by climatic conditions, especially water availability. Pen (1981, 1983) described and mapped the vegetation of estuarine and riverine wetlands.

Cresswell and Bridgewater (1985) identified 49 vegetation units on the aeolian deposits of the Swan Coastal Plain. Of these, 26 vegetation units occurred on wetlands. Vegetation of coastal wetlands was found to vary from west to east. This change was attributed to changing salinity of the groundwater. Highly saline wetlands of estuarine origin are species-poor, while low salinity wetlands of freshwater origin are species-rich by comparison. Wetlands in the Bassendean/Southern River dune systems have the greatest species richness.

Semeniuk et al. (in preparation) are proposing a classification of wetland vegetation in the region.

The wetland plant communities of wetlands on the Swan Coastal Plain have been significantly altered by clearing, grazing and fire. There have been notable expansions in the distribution of invasive species such as Typha orientalis. Factors combining to favour Typha may include:

. disturbance of wetland margins which allows seeds to germinate and young plants to establish;

. falling water levels providing suitable water depths for rhizome growth;

. nutrient enrichment from fertilisers and grazing stock.

Wetlands species are said to be less tolerant to fire than upland species; weed invasion may follow fire or marginal disturbance from other causes. Plant species adapted to grow in saturated saline conditions are important elements of estuarine wetlands and of the saline wetlands of the western coastal plain, eg Lake Coogee, Lakes Cooloongup and Walyungup.

The roles of wetland plants in the wetland ecosystems are many: Chambers (1984) has recently reviewed the literature on the functions of wetland vegetation. Their functions include primary production which supports directly or indirectly all other elements of the food-webs; aeration of wetland soils and provision of shelter and support for other organisms.

4.8 FAUNA

Wetlands represent sinks which have accumulated stores of biologically useful molecules. Whereas the primary producers tend to maximise the retention of nutrients within the ecosystem, the animals are involved with the redistribution of nutrients (Main,1981). The presence of fresh water and the accumulation of nutrients make wetlands very important habitats for animals. Significant wetland animals include many invertebrate groups, particularly molluscs, annelids, crustacea, and insects. Wetlands are also important for vertebrates including fish, frogs, turtles, lizards and snakes. In the past, wetland margins have been very important habitats for mammals, eg Bandicoots, wallabies and small carnivorous forms. The water-birds and wading birds represent the groups most frequently associated with wetlands. However, as representatives for the most part of higher-order consumers, their well-being is dependent upon the other elements of wetland ecosystems.

4.8.1 MICROBIAL FAUNA

Microorganisms are important but poorly known elements of wetland ecosystems. They include the organisms of the sediments, the periphyton and metaphyton (see Davis and Rolls, 1987 - Lake Joondalup), the phytoplankton and zooplankton, and the fungi and bacteria involved in breakdown of detritus and with the cycling and storage of nutrients. The roles and functions of the microorganisms are virtually unknown in local systems but they are likely to be of immense importance.

4.8.2 INVERTEBRATE FAUNA

Apart from a few groups such as the Chironomid midges aquatic invertebrate animals of local still waters have received relatively little systematic study until recently. There is now growing interest in the invertebrate fauna and studies are providing insights into the health of aquatic systems. Systematic sampling of the invertebrate fauna of five

metropolitan lakes has been carried out as part of the Urban Water Balance Study (see Davis and Rolls, 1987) and this work has been extended to other Perth wetlands (Davis and Rolls, in preparation). The invertebrate fauna is rich and diverse. It contains elements of both ancient Gondwanaland fauna and more recently arrived species. Included among the interesting organisms is a representative of the Onychophora, a group which is restricted to humid environments in the southern hemisphere.

4.8.3 VERTEBRATE FAUNA

The vertebrate fauna of wetlands is also incompletely known. Vertebrate groups of importance include:

- freshwater fish - depleted because of water quality changes and introductions of exotic fish (How, 1978);
- frogs - biology reasonably well known as a result of a number of studies;
- tortoises - both the Short-necked Tortoise and the Long-necked Tortoise;
- snakes and lizards, particularly skinks (How, 1978);
- mammals - it is likely that the freshwater wetlands were of great importance for small mammals - eg wallabies, dasyurids, bandicoots;
- rodents - How (1978) showed that there are very few mammals now to be found in wetland habitats. The Department of Conservation and Environment has prepared a research inventory of vertebrate fauna in Western Australia (Daze, 1984).

4.8.4 BIRDS

Birds are very conspicuous users of wetland habitats. The waterbirds are, of course, a major focus of interest because of their strong dependence upon wetlands for food, breeding and other aspects of their life cycles. However, the importance of wetlands for many species of passerine and raptorial birds should not be ignored. There are many species of water- birds, each with rather specific ecological requirements. Some species occur in large flocks, others are solitary and cryptic.

Wetlands vary in the sources of food, nesting sites, loafing sites, and shelter they provide.

The distribution, biology and ecology of birds is relatively well known, largely through the efforts of amateur observers.

The Royal Australasian Ornithologists Union (RAOU) has a large amount of information on the species and numbers of birds using metropolitan wetlands.

The RAOU acted as consultant to the Environmental Protection Authority to provide a brief summary of the habitat requirements of the species of waterbirds and wading birds to be found in the Perth region. A summary is included here.

The basic habitat needs of waterbirds were identified as feeding sites, loafing sites and nesting sites. Different birds have different requirements for each of these needs; for example, a Pink-eared Duck requires shallow water to feed, whilst a Blue-billed Duck needs deep water.

Fourteen wetland units were identified by the report, each differing in the type of food, nesting sites and shelter it provides. The units are defined mainly by water depth and vegetation structure.

Appendix 1 lists the wetland units identified.

Appendix 2 lists the waterbird species that are able to use each of the 14 wetland units and how they use them. If a species is not listed for a particular wetland unit it does not always mean that it will never occur there. Exceptions will always be found for some species while for others there is much to learn about their needs and preferences. In the absence of information obtained from surveys of a wetland, this list can be used to indicate the species that could be expected to occur in particular units. The list of species able to use each wetland unit gives the maximum potential use of that unit.

Factors such as size of wetland unit, nutrient levels, disturbance, aquatic plants and animals present and time of year will influence the use of wetland units by waterbirds.

The information provided here can never replace regular surveys as a means of determining waterbird usage of any wetland.

The richness of a wetland as an environment for birds is determined by its complexity, in other words by the number of types of habitat available within its limits.

Appendix 3 is a summary of the kinds of wetland units to be found in a range of Perth wetlands. This table was compiled by Jenny Arnold.

4.9 MANAGEMENT ISSUES

Stresses

Every wetland in the metropolitan region has, to a greater or lesser degree, been subject to human influence. This review makes no attempt to consider pre-European human influences although it is now clear that the Aborigines took an active role in manipulating the environment. As wetlands would have been important sources of food and water, as well as having strong cultural significance, they were undoubtedly manipulated by Aboriginal communities.

European man has had an immense impact on the aquatic systems of south-western Australia (see, for example: Riggert, 1966; Hodgkin et al., 1980; Humphries, Robertson & Robertson, 1982). Within the Perth metropolitan region wetland form and function have been greatly altered by direct and indirect effects of human activities.

Wetlands are dynamic systems. The changes that occur will be influenced by geological and climatic factors, while human-induced changes will be superimposed, or may even override these other influences. Keddy (1983) pointed out that while direct effects of human influence, such as agriculture, urbanisation and construction, can readily be recognised,

indirect effects such as lowering of the water table or changes in the amplitude of water table fluctuation, increased sedimentation and nutrient enrichment, and alteration of fire regimes, may alter the direction or rate of change in plant successions and hence habitats.

In the Perth region, direct and indirect human-induced effects and effects of variations in rainfall on the regional water balance combine to influence the wetlands very strongly. Thus, clearing of the native vegetation and increase in run-off as a result of urban development cause water tables to rise, resulting in increased lake levels and increased areas of ephemeral wetlands. A sequence of years of above-average rainfall can have the same effect as can replacement of deep-rooted perennial species with shallow-rooted annual plants. The lakes in North Perth in the nineteenth century, Shenton Park Lake and Butler's Swamp in the 1920's, and North Lake and Frederick Baldwin Park at present are all examples of this pattern of events.

On the other hand, replacement of arid-adapted woodland with pines, or increased use of groundwater for agriculture, public water supply, irrigation of recreation areas and private gardens, or removal of water by drains, can mimic the effect of low rainfall, causing lower water tables and reduced water levels in wetlands. Indirect human influences accentuate and speed up oscillations in the regional water balance and this will be reflected in the behaviour of the wetlands. The consequences are changes in vegetation patterns and changes in the fauna. These changes are further driven by direct modifications of wetlands.

Enrichment of wetlands by nutrient-rich drainage waters and groundwater seepage is an important cause of indirect change to Perth wetlands. Many of the most well-known wetlands are showing serious signs of such changes, eg Mongers Lake, Lake Joondalup, Herdsman Lake, North Lake, and Bibra Lake. Very large populations of chironomid midge larvae in enriched anoxic lake sediments which manifest in nuisance swarms of adults, is another symptom of indirect changes to the wetland ecosystems. In the case of the midges, the use of pesticides to control the problem may have reduced the numbers of natural predators.

Management Issues

Differences in the nature of lake deposits reflecting different water regimes in the past may provide insights into the water needs of the different types of wetlands. There appears to be growing interest in investigating the lake sediments of the region. Such studies will contribute to an understanding of the way the systems have functioned in the past.

There is a growing body of information about the invertebrate aquatic animals of the wetlands. These organisms are integral parts of the wetland ecosystems as secondary producers and elements of the food webs. Sampling to determine the range and diversity of organisms present can be used to monitor the health of wetlands, once the baseline information is available.

To build up a good understanding of wetland ecosystems then, it would be useful to know something about:

- water quality and quantity;
- lake sediments - capacity to assimilate nutrients (includes both physical and biological components);

- lake macrophytes - patterns of growth and reproduction and responses to seasonal changes, water needs and capacity to assimilate nutrients;

- lake aquatic flora - phytoplankton and blue-green algae - response to water regime and nutrient cycling;

- aquatic animals - ecological requirements for water quality, quantity and seasonality.

Artificial Wetlands

There is increasing use of artificial lakes as landscape features in residential areas. The emphasis on most of these developments is on amenity - providing attractive landscapes for housing developments, public buildings and recreation areas. Most of the artificial wetlands have little environmental complexity so that they provide wildlife habitats for relatively few species with rather generalised ecological requirements.

There has been some effort to study the management requirements for artificial wetlands (Ballajura - Newman pers comm).

Proponents of the construction of artificial lakes or the modification of existing wetlands should be required to provide evidence that the new or modified lake is not competing for water with existing users, and that the resulting waterbody will not be subject to system dysfunctions resulting from unsatisfactory water quality.

An urgent consideration in the development of artificial wetlands is the balance between the water needs of the region and the water requirements for the development. There should a rational consideration of water availability and long-term management costs in the planning of lake features.

Comments on Conservation Issues and Ecological Notes

There are many perceptions of the functions and values of wetlands in the metropolitan region. At present they are valued because they support wildlife and provide landscape features; they are resented because they are sites of high evaporative water loss from the groundwater, because they are breeding sites for mosquitoes and midges and because, when ecological processes are disturbed, they generate unsightly and malodorous water-blooms. They have economic value to developers who modify them to help sell land but give little attention to the long-term consequences of the modification. Wetlands have economic value to drainage authorities as they are used as sinks for stormwater and function as compensating basins. Part of this use involves the wetlands accepting and assimilating loads of pollutants and nutrients.

So far, little attention has been given to understanding the ecological processes of the local wetlands. It will be seen from following sections that the information available is fragmentary and is descriptive rather than process-orientated. There is urgent need to change emphasis towards understanding the processes and the conditions, most importantly water quality and quantity, in which they take place most effectively.

4.10 REFERENCES

Allen, A D (1981), Groundwater resources of the Swan Coastal Plain, near Perth, Western Australia. pp 29 - 74 in Groundwater resources of the Swan Coastal Plain. Edit. B R Whelan. CSIRO Division of Land Resources Management.

Appleyard, S & Bawden, J (1987), The effects of urbanisation on nutrient levels in the unconfined aquifer underlying Perth, Western Australia. pp 587 - 594 in Proceedings of the international conference on groundwater systems under stress. Conference Series No.13, Australian Water Resources Council. Australian Government Publishing Service, Canberra.

Bell, D T & Stephens, L J (1984), Seasonality and phenology of kwongan species. pp 205 - 226 in Kwongan: plant life of the sandplain. Edit. J S Pate and J S Beard. University of Western Australia Press, Perth.

Bestow, T T (1976), Water balance of the Coastal Plain. In Groundwater resources of the Swan Coastal Plain. Edit. B A Carbon. CSIRO Division of Land Resources Management, 1976. pp 77 - 88.

Briggs, S V (1981), Freshwater wetlands. pp335 - 360 in Australian vegetation. Edit. R H Groves. Cambridge University Press, Cambridge, 1981.

Chambers, J M (1984), The potential of natural and artificial wetlands for phosphorus removal in the Harvey catchment, Bulletin 202, Environmental Protection Authority, Western Australia.

Congdon, R A & McComb, A J (1976), The nutrients and plants of Lake Joondalup, a mildly eutrophic lake experiencing large seasonal changes in volume. Journ. Roy. Soc. Western Australia. 59, 14 - 23.

Creswell, I P & Bridgewater, P B (1985), Dune vegetation of the Swan Coastal Plain, Western Australia. Journ. Roy. Soc Western Australia 67 (3-4) 137-148.

Davis, J A, Christidis, F, Wienecke, B C, Balla, S A & Rolls, S W (1987), Forrestdale Lake Chironomid Study: A study of the larval chironomids in Forrestdale Lake WA and the effects of the pesticide Abate. School of Environmental and Life Sciences, Murdoch University, prepared for the Department of Conservation and Land Management, Western Australia.

Davis, J A & Rolls, S W (1987), A baseline biological monitoring programme for the urban wetlands of the Swan Coastal Plain, Western Australia. Bulletin 265, Environmental Protection Authority, Western Australia.

Daze, D (1984), A bibliography and research inventory of vertebrate fauna in Western Australia. Bulletin 177, Department of Conservation and Environment, Western Australia.

Fairbridge, R W (1947), The geology and geomorphology of Point Peron, Western Australia. Journ. Roy. Soc. Western Australia 34, 35 - 72.

Gozzard, J R (1982a), Muchea Sheet 2034 I and Part 2134 IV, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1982b), Yanchep Sheet 2034 IV, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1983a), Fremantle Part Sheets 2033 I & IV, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1983b), Rockingham Part Sheets 2033 III and 2033 II.Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Gozzard, J R (1986), Perth, Sheet 2034 II and Part 2034 III and 2134 III. Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Grubb,W B (1964), Avian Botulism in Western Australia. Austral. Journ. Exp. Biol. 44, pp17 - 26.

Heddle, E M (1980), Effects of changes in soil moisture on the native vegetation of the northern Swan Coastal Plain. Forests Department of Western Australia. Bulletin 92.

Hodgkin, E P, Birch, P B, Black, R E & Humphries, R B (1980), The Peel-Harvey estuarine system study (1976-1980), Report No 9, Department of Conservation and Environment, Western Australia.

How, R (editor) (1978), The fauna of the northern Swan Coastal Plain. Report prepared by the Western Australian Museum for the Department of Conservation and Environment, Western Australia.

Humphries, R, Robertson, J G M & Robertson, F E (1982), A resource inventory and management information system for Wilson Inlet, Western Australia. Bulletin 132, Department of Conservation and Environment, Western Australia.

Hutchinson, G E (1975), A treatise on limnology. Vol 1, Part 1: Geography and physics of lakes. John Wiley & Sons 1957, 1975.

Iveson, J B (1979), Salmonella infections in Silver Gulls in Western Australia. West Australian Health Surveyor Quarterly 1(1), 5 - 14.

Jordan, J E (1986), Serpentine Part Sheets 2033 II and 2133 III, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Keddy, P A (1983), Freshwater wetlands human-induced changes: indirect effects must also be considered. Environ. Manag. 7(4), 299 - 302.

Le Provost, Semeniuk & Chalmer (1985), The impact of roadworks on metropolitan wetlands - citing work of C A Semeniuk. Report prepared for the Department of Conservation and Environment, Western Australia.

McComb, J A & McComb, A J, (1967), A preliminary account of the vegetation of Loch McNess, a swamp and fen formation in Western Australia. Journ. Roy. Soc. Western Australia. 50 (4), 105 -112.

Main, A R (1981), Ecosystem theory and management. Journ. Roy. Soc. Western Australia. 64(1), 1 - 4.

Megerian, D (1982), The hydrogeology of North and Bibra Lakes, Western Australia. Unpublished BSc. Hons thesis, Department of Geology, University of Western Australia.

Newman P. pers comm: School of Environmental and Life Sciences, Murdoch University, Murdoch WA 6150

Pen, L J (1981), The peripheral vegetation of the Swan and Canning Rivers: past, present and future. Unpublished BSc. Honours thesis, Murdoch University.

Pen, L J (1983), Peripheral vegetation of the Swan and Canning estuaries, 1981. Bulletin 113, Department of Conservation and Environment, Western Australia.

Riggert, T L (1966), A study of the wetlands of the Swan Coastal Plain. Department of Fisheries and Fauna, Perth, Western Australia.

Speck, N H & Baird, A M (1984), Vegetation of Yule Brook Reserve near Perth, Western Australia. J Roy. Soc of Western Australia 66(4) 147-162.

Wetlands Advisory Committee to the Environmental Protection Authority (1977), The status of wetland reserves in System 6. Department of Conservation and Environment, Western Australia.

Woods, P J & Searle, D J (1983), Radiocarbon dating and Holocene history of the Becher/Rockingham Beach Ridge Plain, West Coast, Western Australia. Search 14 (1-2), 44 - 46.

APPENDICES FOR THE FIFTEEN CHAPTERS
IN BULLETIN 374

WETLAND HABITAT UNITS

PREPARED BY SHAPELLE McNEE, RAOU

The 14 wetland units are defined mainly on water depth and vegetation structure. The first nine wetland units listed occur in swamps and lakes, the waters of which may range from fresh to brackish and permanent to temporary. The wetland units 10, 11 and 12 occur in estuaries and are influenced by tides. They are more saline than most of the lakes and swamps. Wetland unit 13 refers to roosting sites which can occur on swamps, lakes or estuaries. Wetland unit 14 refers to waterbird nesting sites which are usually outside wetlands.

Saline lakes such as Lake Coogee are not included within the wetland units defined here. The same salt-tolerant and salt-liking bird species which occur on estuary wetland units can be expected to occur on the saline lakes. Some salt lakes, such as Lake Cooloongup, have fresh water seepage into the lake which enables waterbird species preferring fresh water to use them.

1. DEEP FRESH WATER

Open water > 50 cm deep, usually 1 - 2 m deep at the highest water level each year. Permanent wetlands will tend to have deep fresh water throughout the year while seasonal wetlands will have deep fresh water in late winter, becoming shallow open water in the summer months.

2. SHALLOW OPEN WATER

Open water < 5 cm deep. Water may be fresh to brackish to slightly saline; water not covered by terrestrial vegetation.

3. MUDFLATS

Mudflats on lakes and swamps (not estuaries). Water may be fresh to brackish to slightly saline. Mudflats exist as a result of falling water levels as the lake dries out. This unit includes exposed moist mudflats to mudflats covered with water up to 15 cm deep.

4. BARE EDGES OF LAKES

The substrate may be sand or mud (clay and peat). Bare edges result from a small drop in water level in wetlands with steep banks. This unit is most significant in the permanent wetlands where bare edges occur throughout the summer without the lake drying out. The bare areas provide an interface between wet and dry areas.

5. GRASSLANDS: PADDOCKS

Paddocks without any surface water adjacent to wetlands or, in some cases, some distance away. This unit would most often be used by insect-eating and grazing waterbirds when the grass is green. Dry paddocks with dry grass may be used.

6. GRASSLANDS: PARKLAND LAWNS

Parkland lawns are maintained green and short by watering and mowing. Used by waterbirds for grazing and roosting.

WETLAND HABITAT UNITS (Cont'd)
PREPARED BY SHAPELLE McNEE, RAOU

7. REEDBEDS (SEDGE BEDS)

Reedbeds may be restricted to edges of swamps and lakes or extend further into the wetland. The size of the stand, length of time water stands in the reedbed and the species of reeds will influence waterbird usage of this unit.

8. FLOODED MELALEUCA (PAPERBARK) WOODLAND

May be restricted to the edges of the swamp or lake or throughout most of the wetland. The stand will often be made up of several species of Melaleuca, depending on water levels and amount of clearing on the wetland edge. Wetland Melaleuca species require flooding for at least part of the year. Melaleuca woodland almost permanently flooded is most likely to be used by colonial nesting birds such as the cormorants, ibis and egrets.

9. FLOODED GRASSLANDS

Fresh temporary water, usually < 50 cm deep. Most of the waterbody cleared of shrubs and trees; with green grass at the margins. Wetland becomes green grassland as the water dries out.

10. ESTUARY: OPEN WATER

Includes all open water other than that on mudflats, thus includes water > 15 cm deep. The water may be fairly saline in the summer months.

11. ESTUARY: MUDFLATS

Includes from the shore edge to the mudflats covered with water up to 15 cm deep at low tide.

12. ESTUARY: SAMPHIRE AND REEDS

Areas of samphire can be extensive on the margins of estuaries which are inundated by tides. The samphire plant species are salt-tolerant. Reeds (sedges) occur at the high tide level and behind the samphire areas. Both samphire and reeds provide refuge, feeding and nesting areas for a number of waterbird species.

13. ROOSTING ROCKS AND POSTS

Rocks and posts situated in swamps, lakes and estuaries (most often at the edges) which waterbirds use for roosts. They are particularly important for cormorants and the darter which need roosting sites to dry their wings after dives.

14. TREE STUMPS AND HOLLOWS

Used as nest sites by some waterbird species. Tree stumps and hollows suitable for nesting may be on dry land alongside wetlands or some distance away.

This list of habitats shows that birds make use of a range of water conditions and wetland plant communities. Birds also utilise strongly altered environments such as paddocks, lawns and flooded grassland, habitats which have formed as a result of human intervention.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLAND HABITATS IN SOUTH-WEST WESTERN AUSTRALIA

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITAT 1: Deep fresh water - open water of lakes and swamps, >0.5 m deep.	
Great Crested Grebe	feeding/nesting/loafing
Hoary-headed Grebe	feeding/nesting/loafing
Australasian Grebe	feeding/nesting/loafing
Australian Pelican	feeding/loafing
Great Cormorant	feeding
Little Black Cormorant	feeding
Little Pied Cormorant	feeding
Black Swan	feeding/loafing
Freckled Duck (X)	feeding/loafing
Australian Shelduck	feeding/loafing
Pacific Black Duck	feeding/loafing
Mallard (introduced species)	feeding/loafing
Muscovy (introduced species)	feeding/loafing
Grey Teal	feeding/loafing
Chestnut Teal (X)	feeding/loafing
Australasian Shoveler	feeding/loafing
Pink-eared Duck	feeding/loafing
Hardhead	feeding/loafing
Maned Duck	loafing
Blue-billed Duck	feeding/loafing
Musk Duck	feeding/loafing
Dusky Moorhen	feeding/loafing
Eurasian Coot	feeding/loafing
Silver Gull	feeding/loafing
Whiskered Tern	feeding
White-winged Tern	feeding
WETLAND HABITAT 2: Shallow open water - fresh, brackish to saline water <0.5 m deep.	
Hoary-headed Grebe	feeding/nesting/loafing
Australasian Grebe	feeding/nesting/loafing
Little Black Cormorant	feeding
Little Pied Cormorant	feeding
Pacific Heron	feeding
White-faced Heron	feeding
Great Egret	feeding
Cattle Egret (X)	feeding
Little Egret (X)	feeding

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLAND HABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITAT 2: Shallow open water - fresh, brackish to saline water <0.5 m deep (Cont'd).	
Rufous Night Heron	feeding
Glossy Ibis (X)	feeding
Sacred Ibis	feeding
Straw-necked Ibis	feeding
Royal Spoonbill (X)	feeding
Yellow-billed Spoonbill	feeding
Black Swan	feeding/loafing
Freckled Duck (X)	feeding/loafing
Australian Shelduck	feeding/loafing
Pacific Black Duck	feeding/loafing
Mallard (introduced species)	feeding/loafing
Muscovy (introduced species)	feeding/loafing
Grey Teal	feeding/loafing
Chestnut Teal (X)	feeding/loafing
Australasian Shoveler	feeding/loafing
Pink-eared Duck	feeding/loafing
Hardhead	feeding/loafing
Maned Duck	loafing
Marsh Harrier	feeding
Dusky Moorhen	feeding/loafing
Eurasian Coot	feeding/loafing
Black-winged Stilt	feeding/loafing
Banded Stilt	feeding/loafing
Red-necked Avocet	feeding/loafing
Black-tailed Godwit	feeding/loafing
Bar-tailed Godwit	feeding/loafing
Silver Gull	feeding/loafing
Whiskered Tern	feeding
White-winged Tern	feeding
WETLAND HABITAT 3: Mudflats (non-tidal) - on lakes and swamps, includes exposed mud and mud with up to 0.15 m over it.	
Pacific Heron	feeding
White-faced Heron	feeding
Great Egret	feeding
Little Egret (X)	feeding
Rufous Night Heron	feeding
Glossy Ibis (X)	feeding

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLAND HABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITAT 3: Mudflats (non-tidal) - on lakes and swamps, includes exposed mud and mud with up to 0.15 m over it (Cont'd).	
Sacred Ibis	feeding
Straw-necked Ibis	feeding
Australian Shelduck	loafing
Pacific Black Duck	loafing
Chestnut Teal (X)	loafing
Australasian Shoveler	loafing
Pink-eared Duck	loafing
Hardhead	loafing
Marsh Harrier	feeding
Dusky Moorhen	feeding
Purple Swamphen	feeding
Masked Lapwing (X)	feeding/loafing
Banded Lapwig	feeding/loafing
Lesser Golden Plover (X)	feeding/loafing
Red-kneed dotterel	feeding/nesting/loafing
Black-fronted Plover	feeding/loafing
Black-winged Stilt	feeding/loafing
Banded Stilt	feeding/loafing
Red-necked Avocet	feeding/loafing
Wood Sandpiper	feeding/loafing
Common Sandpiper	feeding/loafing
Greenshank	feeding/loafing
Marsh Sandpiper (X)	feeding/loafing
Black-tailed Godwit (X)	feeding/loafing
Bar-tailed Godwit	feeding/loafing
Sharp-tailed Sandpiper	feeding/loafing
Pectoral Sandpiper (X)	feeding/loafing
Red-necked Stint	feeding/loafing
Long-toed Stint (X)	feeding/loafing
Curlew Sandpiper	feeding/loafing
Broad-billed Sandpiper (X)	feeding/loafing
Ruff (X)	feeding/loafing
Silver Gull	feeding/loafing
Whiskered Tern	loafing
White-winged Tern	loafing

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLAND HABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITAT 4: Bare edges of lakes - a sandy or mud substrate, usually occurring in permanent wetlands with only a small seasonal change in water level.	
Australian Pelican	loafing
Pacific Heron	feeding
White-faced Heron	feeding
Great Egret	feeding
Little Egret (X)	feeding
Rufous Night Heron	feeding
Royal Spoonbill (X)	loafing
Yellow-billed Spoonbill	loafing
Black Swan	loafing
Freckled Duck	loafing
Australian Shelduck	loafing
Pacific Black Duck	loafing
Mallard (introduced species)	loafing
Muscovy (introduced species)	loafing
Grey Teal	loafing
Chestnut Teal (X)	loafing
Australasian Shoveler	loafing
Pink-eared Duck	loafing
Hardhead	loafing
Maned Duck	loafing
Marsh Harrier	feeding
Black-tailed Native-hen	feeding
Dusky Moorhen	feeding/loafing
Purple Swamphen	feeding/loafing
Eurasian Coot	loafing
Masked Lapwing (X)	feeding/loafing
Banded Lapwing	feeding/loafing
Red-kneed Dotterel	feeding/nesting/loafing
Red-capped Plover	feeding/nesting/loafing
Black-fronted Plover	feeding/nesting/loafing
Black-winged Stilt	feeding/loafing
Wood Sandpiper	loafing
Common Sandpiper	feeding/loafing
Greenshank	feeding/loafing
Marsh Sandpiper (X)	loafing
Black-tailed Godwit (X)	loafing
Bar-tailed Godwit	loafing
Sharp-tailed Sandpiper	loafing

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLAND HABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND HABITAT IS USED
WETLAND HABITAT 4: Bare edges of lakes - a sandy or mud substrate, usually occurring in permanent wetlands with only a small seasonal change in water level (Cont'd).	
Pectoral Sandpiper (X)	loafing
Red-necked Stint	loafing
Long-toed Stint (X)	loafing
Curlew Sandpiper	loafing
Ruff (X)	loafing
Oriental Pratincole (X)	loafing
Silver Gull	feeding/loafing
Whiskered Tern	loafing
White-winged Tern	loafing
WETLAND HABITAT 5: Grasslands - paddocks - dry or green paddocks adjacent to wetlands.	
White-faced Heron	feeding
Cattle Egret (X)	feeding
Sacred Ibis	feeding
Straw-necked Ibis	feeding
Australian Shelduck	feeding
Pacific Black Duck	feeding
Grey Teal	feeding
Australasian Shoveler	nesting
Hardhead	nesting
Maned Duck	feeding/nesting/loafing
Marsh Harrier	feeding
Buff-banded Rail	feeding/nesting
Black-tailed Native-hen	feeding
Dusky Moorhen	feeding
Purple Swamphen	feeding
Masked Lapwing (X)	feeding/nesting/loafing
Banded Lapwing	feeding/nesting/loafing
Black-fronted Plover	feeding/nesting
Oriental Pratincole (X)	feeding/loafing
Silver Gull	loafing
Whiskered Tern	loafing
White-winged Tern	loafing

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLANDHABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITAT 6: Grasslands - lawns - adjacent to wetland, grass watered and mown.	
Black Swan	feeding/loafing
Australian Shelduck	feeding/loafing
Pacific Black Duck	feeding/loafing
Mallard (X)*	feeding/loafing
Muscovy (X)*	feeding/loafing
Grey Teal	feeding/loafing
Maned Duck	feeding/loafing
Black-tailed Native-hen	feeding
Dusky Moorhen	feeding
Purple Swamphen	feeding
Eurasian Coot	feeding/loafing
Masked Lapwing (X)	feeding/loafing
Black-fronted Plover	feeding/loafing
Silver Gull	feeding/loafing
WETLAND HABITAT 7: Rushbeds - usually temporarily flooded with fresh water, on edges or throughout wetlands.	
Great Crested Grebe	nesting
Rufous Night Heron	loafing
Little Bittern	feeding/nesting/loafing
Australasian Bittern (X)	feeding/nesting/loafing
Glossy Ibis	nesting
Sacred Ibis	nesting
Straw-necked Ibis	nesting
Black Swan	feeding/nesting
Freckled Duck ! (X)	nesting/loafing
Pacific Black Duck	feeding/loafing
Grey Teal	feeding/loafing
Australasian Shoveler	feeding/loafing
Pink-eared Duck	loafing
Hardhead	nesting/loafing
Blue-billed Duck	nesting/loafing
Musk Duck	nesting/loafing
Marsh Harrier	feeding/nesting/loafing
Buff-banded Rail	feeding/nesting/loafing
Baillon's Crake	feeding/nesting/loafing

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLANDHABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITAT 7: Rushbeds - usually temporarily flooded with fresh water, on edges or throughout wetlands (Cont'd).	
Australian Crake	feeding/nesting/loafing
Spotless Crake	feeding/nesting/loafing
Black-tailed Native-hen	feeding/nesting/loafing
Dusky Moorhen	feeding/nesting/loafing
Purple Swamphen	feeding/nesting/loafing
Eurasian Coot	feeding/nesting/loafing
Clamorous Reed-Warbler	feeding/nesting/loafing
Little Grassbird	feeding/nesting/loafing
WETLAND HABITAT 8: Inundated trees and shrubs - temporary to permanent with fresh water, on edge of wetland or throughout.	
Hoary-headed Grebe	nesting
Darter	feeding/loafing
Great Cormorant	feeding/loafing
Little Black Cormorant	feeding/loafing
Little Pied Cormorant	feeding/loafing
Pacific Heron	feeding/loafing
White-faced Heron	feeding/loafing
Great Egret!	feeding/loafing
Little Egret ! (X)	feeding/loafing
Rufous Night Heron	feeding/loafing
Little Bittern	feeding/loafing
Glossy Ibis ! (X)	feeding/loafing
Sacred Ibis	feeding/loafing
Straw-necked Ibis !	feeding/loafing
Royal Spoonbill! (X)	feeding/loafing
Yellow-billed Spoonbill!	feeding/loafing
Freckled Duck ! (X)	feeding/loafing
Pacific Black Duck	feeding/loafing
Grey Teal	feeding/loafing
Chestnut Teal (X)	feeding/loafing
Australasian Shoveler	loafing
Pink-eared Duck	nesting/loafing
Hardhead	nesting/loafing
Blue-billed Duck	nesting
Musk Duck	nesting
Osprey	loafing
White-bellied Sea-eagle	loafing

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLAND HABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITAT 8: Inundated trees and shrubs - temporary to permanent with fresh water, on edge of wetland or throughout (Cont'd).	
Marsh Harrier	loafing
Buff-banded Rail	feeding/nesting/loafing
Baillon's Crake	feeding/nesting/loafing
Australian Crake	feeding/nesting/loafing
Spotless Crake	feeding/nesting/loafing
Black-tailed Native-hen	feeding/nesting/loafing
Dusky Moorhen	feeding/nesting/loafing
Purple Swamphen	feeding/loafing
Eurasian Coot	feeding/nesting/loafing
Clamorous Reed-Warbler	feeding/nesting/loafing
WETLAND HABITAT 9: Flooded grasslands - adjacent to wetlands, or some distance away, fresh water, temporary, shallow water <0.5 m deep.	
Hoary-headed Grebe	feeding/nesting/loafing
Australasian Grebe	feeding/nesting/loafing
Pacific Heron	feeding
White-faced Heron	feeding
Great Egret	feeding
Cattle Egret (X)	feeding
Little Egret (X)	feeding
Rufous Night Heron	feeding
Glossy Ibis (X)	feeding
Sacred Ibis	feeding
Straw-necked Ibis	feeding
Royal Spoonbill (X)	feeding
Yellow-billed Spoonbill	feeding
Black Swan	feeding/loafing
Pacific Black Duck	feeding/loafing
Grey Teal	feeding/loafing
Australasian Shoveler	feeding/nesting/loafing
Pink-eared Duck	feeding/loafing
Maned Duck	feeding/loafing
Marsh Harrier	feeding
Buff-banded Rail	feeding
Baillon's Crake	feeding
Black-tailed Native-hen	feeding
Dusky Moorhen	feeding

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLAND HABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITAT 9: Flooded grasslands - adjacent to wetlands, or some distance away, fresh water, temporary, shallow water <0.5 m deep (Cont'd).	
Purple Swamphen	feeding
Eurasian Coot	feeding/loafing
Masked Lapwing (X)	feeding
Black-winged Stilt	feeding/nesting
Red-necked Avocet	feeding/loafing
Wood Sandpiper	feeding/loafing
Greenshank	feeding/loafing
Marsh Sandpiper (X)	feeding/loafing
Black-tailed Godwit (X)	feeding/loafing
Sharp-tailed Sandpiper	feeding/loafing
Pectoral Sandpiper (X)	feeding/loafing
Long-toed Stint (X)	feeding/loafing
Ruff (X)	feeding/loafing
Silver Gull	feeding/loafing
WETLAND HABITATS 10, 11, and 12 are all estuarine habitats; lists of bird species using these habitats are not listed here.	
WETLAND HABITATS 13: Non-living roosts - such as rocks, posts, dead trees and man-made objects in swamps, lakes and estuaries.	
Australian Pelican	loafing
Darter	loafing
Great Cormorant	loafing
Pied Cormorant	loafing
Little Black Cormorant	loafing
Little Pied Cormorant	loafing
Pacific Heron	loafing
White-faced Heron	loafing
Great Egret	loafing
Cattle Egret (X)	loafing
Little Egret (X)	loafing
Glossy Ibis (X)	loafing
Sacred Ibis	loafing
Straw-necked Ibis	loafing
Royal Spoonbill (X)	loafing
Yellow-billed Spoonbill	loafing
Freckled Duck (X)	loafing

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

BIRD USE OF WETLAND HABITATS IN SOUTH-WEST WESTERN AUSTRALIA (Cont'd)

BIRD SPECIES	HOW WETLAND UNIT IS USED
WETLAND HABITATS 13: Non-living roosts - such as rocks, posts, dead trees and man-made objects in swamps, lakes and estuaries (Cont'd).	
Pacific Black Duck	loafing
Grey Teal	loafing
Chestnut Teal (X)	loafing
Australasian Shoveler	loafing
Pink-eared Duck	loafing
Hardhead	loafing
Maned Duck	loafing
Osprey	loafing
White-bellied Sea-Eagle	loafing
Marsh Harrier	loafing
Whimbrel	loafing
Common Sandpiper	loafing
Silver Gull	loafing
Whiskered Tern	loafing
White-winged Tern	loafing
Caspian Tern	loafing
Fairy Tern	loafing
Crested Tern	loafing
WETLAND HABITAT 14: Non-living nest sites - tree-stumps, hollows, nest boxes.	
Australian Shelduck	nesting
Pacific Black Duck	nesting
Grey Teal	nesting
Chestnut Teal (X)	nesting
Australasian Shoveler	nesting
Pink-eared Duck	nesting
Hardhead	nesting
Maned Duck	nesting

(X) Indicated species rare or uncommon in South-West WA.
* Although rare or uncommon in the South-West of Western Australian, species are not rare or uncommon in the Perth Metropolitan Area.
! Waterbird species not yet recorded breeding in the Perth Metropolitan Area.

PREPARED BY SHAPELLE McNEE
ROYAL AUSTRALASIAN ORNITHOLOGISTS' UNION

SUMMARY TABLE: NUMBER OF BIRD SPECIES USING WETLAND HABITATS FOR FEEDING, LOAFING AND NESTING

WETLAND HABITAT	TYPE OF USE		
	FEEDING	LOAFING	NESTING
1. Deep fresh water	25	20	4
2. Shallow open water	38	21	2
3. Mudflats (non-tidal)	34	32	2
4. Bare lake edges	19	40	2
5. Grasslands: paddocks	17	5	7
6. Grasslands: lawns	14	11	0
7. Rushbeds (sedgeland)	14	22	25
8. Inundated shrubs and trees	9	34	32
9. Flooded grassland	39	20	4
10. Estuary: open water	29	15	0
11. Estuary: mudflats	40	47	1
12. Estuary: samphire and rushes	20	39	9
13. Non-living roost sites	0	35	0
14. Hollow trees-nest sites	0	0	9

END OF APPENDIX TWO

WATERBIRD HABITATS TO BE FOUND IN 90 PERTH WETLANDS

LAKE NAME	HABITAT TYPE*													
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Banganup	+	+					+	+	+				+	+
Bibra	+	+	+	+	+	+	+	+	+				+	+
Bluegum	+	+	+	+		+	+						+	+
Bollard Bullrush	+	+		+	+		+	+	+				+	+
Booragoon	+	+				+		+					+	+
Kogolup	+	+	+		+		+	+	+				+	+
Little Rush Lake	?	+					+	+					+	+
North Lake	+	+	+	+	+		+		+				+	+
Piney Lakes		+					+	+					+	+
South Lake	?	+					+	+					+	+
Spectacles	+	+			+		+	+	+				+	+
Thomson	+	+	+	+			+	+	+				+	+
Wattleup (north)	+	+			+		+	+	+				+	+
Wattleup (south)	+	+	+		+		+	+	+				+	
Yangebup	+	+	+	+	+		+		+				+	
Bambum	+	+		+	+		+	+	+				+	+
Bindiar		+					+	+					+	+
Yeal		+					+	+					+	+
31241	+	+					+	+					+	+
Ballajura	+	+		+		+								
Ellen Brook	+	+			+			+					+	+
Melaleuca Park	+	+					+	+					+	+
Mussel Pool	+	+	+		+	+	+	+					+	+
Twin Swamps		+						+					+	+

WATERBIRD HABITATS TO BE FOUND IN 90 PERTH WETLANDS (Cont'd)

LAKE NAME	HABITAT TYPE*													
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Balannup	+	+			+		+	+	+				+	+
Bennett Brook	+	+	+	+	+		+	+	+			+	+	+
Forrestdale	+	+	+	+	+		+	+	+				+	+
Hazelmere	+	+		+	+			+	+				+	+
Mary Carroll Park	+	+				+	+						+	+
Wright Lake		+	+	+										
Yule Bk Res		+						+					+	
Cooloongup	+	+	+	+	+		+	+	+			+	+	+
Richmond	+	+	+	+		+	+							
Walyungup	+	+	+	+	+		+	+	+				+	+
Anstey's	+	+	+				+	+					+	+
Leda Swamps	?	+					+	+					+	+
Long Swamp	+	+	+	+	+		+	+				+	+	+
Pickle Swamp Series	?	+	+				+	+					+	+
Sloans Reserve		+				+		+					+	+
Brownman Swamps		+						+					+	+
Coogee	+	+	+	+	+		+					+	+	+
Lake Mt Brown	+	+	+	+				+	+			+	+	+
Manning	+	+	+	+		+	+	+					+	+
Market Garden Swamps	+	+	+	+	+		+	+	+				+	+
Yangedi	+	+			+			+	+				+	
Airport Swamps	+	+			+		+	+					+	
McDougall Park	+	-		-		-							-	-

WATERBIRD HABITATS TO BE FOUND IN 90 PERTH WETLANDS (Cont'd)

LAKE NAME	HABITAT TYPE*													
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Tomato Swamp	+	+	+	+		+		+					+	
Adams	+	+					+							
Badgerup & Little Badgerup	+	+		+	+		+	+	+				+	+
Gnangara	+	+	+	+										
Jandabup	+	+	+	+	+		+		+				+	+
Lenzo Rd	?	+			+		+	+					+	
Mariginiup	+	+	+	+	+		+		+					
Pinjar	+	+			+		+	+	+				+	+
Wetland N Jandabup		+		+	+		+		+					
Beonaddy		+	+	+	+		+	+	+				+	+
Carabooda	+	+			+		+	+	+				+	+
Coogee Springs	+	+			+		+	+	?				+	+
Goollelal	+	+			+		+		+				+	+
Joondalup	+	+	+	+	+	+	+	+	+				+	+
McNess	+	+				+	+	+					+	+
Mindarie		+	+	+	+		+						+	
Neerabup	+	+			+		+	+	+				+	+
North Joondalup	+	+			+		+	+					+	+
Nowergup	+	+	+	+	+		+	+					+	+
Pipidinny		+	+	+	+		+	+	+				+	+
Yonderup	+	+					+	+					+	+
Careniup	+	+			+	+	+	+					+	+
Carine	+	+	+	+	+	+	+	+	+				+	+
Claremont	+	+	+	+		+	+	+					+	+

WATERBIRD HABITATS TO BE FOUND IN 90 PERTH WETLANDS (Cont'd)

LAKE NAME	HABITAT TYPE*													
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Gwelup	+	+	+	+	+		+	+	+				+	+
Herdsman	+	+	+	+	+	+	+		+					
Hyde Park	+	+		+		+							+	+
Jackadder	+	+				+								
Mabel Talbot	+	+		+		+							+	+
Monger	+	+		+		+	+		+				+	
Perry	+	+	+	+		+	+		+				+	+
Star Swamp	+	+	+	+		+	+		+				+	+
TOTALS	63	79	36	40	43	23	63	57	36	0	0	5	49	60

*KEY TO WETLAND HABITAT TYPES:

1. Deep freshwater >50 cm.
2. Shallow open water.
3. Mudflats (non-tidal).
4. Bare lake edges.
5. Grasslands: paddocks.
6. Grasslands: lawns.
7. Rushbeds (sedgebeds).
8. Flooded shrubs and trees.
9. Flooded grassland.
10. Estuary: open water.
11. Estuary: mudflats.
12. Samphire.
13. Roosting sites.
14. Hollow trees - nest sites.

CLASSIFICATION SYSTEM DEVELOPED BY THE WETLANDS ADVISORY COMMITTEE 1977

Background

Several wetland classification systems have been proposed in other countries based on limnological, geological, hydrological, and botanical characteristics, but they do not readily accommodate the types of wetlands found in Western Australia, and hence have little practical applicability for present purposes.

To be useful as an input to management, a classification system was required which would be capable of separating wetlands into groups which allow assessment of their differing potential values or uses.

The Committee developed a classification system based on the following major divisions or categories:

Lentic	(non-flowing)
Lotic	(flowing)
Estuarine	
Artificial	(man-made, excluding reservoirs)

LENTIC wetlands were further divided according to the primary criteria of size, salinity and permanence, and secondly on the degree of vegetative cover. These factors are considered to be crucial in determining the value or potential of a wetland for particular uses e.g. as a waterfowl drought refuge or an area for aquatic recreation.

These criteria are defined as follows:

Primary Criteria (Lentic Wetlands)

(i) Size — regarded as the total area of the wetland system which is delimited by vegetation dependent on a water table very close to the surface. This includes the Paperbark (*Melaleuca spp*) or Flooded Gum (*Eucalyptus rudis*) zone as well as any surrounding sedgelands or winter- wet heathlands.

Categories		
	Small	25 ha.
	Medium	25-50 ha.
	Large	50 ha.

Medium and Large are subdivided into

Seasonal - regularly dries in late summer. (February-March).
Permanent - either never dries or does so only rarely.

(Small wetlands may be either seasonal or permanent, but for the present purpose it is considered that further subdivision is unnecessary).

(ii) Salinity — based on Total Dissolved Solids (TDS) expressed as milligrams per litre. Samples collected in mid-summer (December).

Categories		
	Saline	3,000 mg/l
	Brackish	1,000 - 3,000 mg/l
	Fresh	1,000 mg/l

Two primary criteria (size and salinity) are a basis for a 15 square matrix of lentic wetland types (Fig 3). This matrix deals only with lentic wetland. The addition of lotic, estuarine, and artificial categories, produces a total of 18 "types" of wetland. These 18 types form a basis for management considerations and are referred to as "wetland types" through out the remainder of this report.

Secondary Criteria (Lentic Wetlands)

(i) Plant Cover — regarded as the percentage of the wetland covered by emergent and marginal vegetation, calculated as

$$\frac{\text{vegetated area (ha)}}{\text{total wetland area}} \times 100$$

Categories		
	Open	25%
	Semi Open	26-60%
	Semi Closed	61-90%
	Closed	91%

Examples		
	Open	Lakes Monger, Gnangara, Jandakot.
	Semi Open	Nowergup, Joondalup.
	Semi Closed	Badgerup, Jandabup.
	Closed	Reedswamp, Paperbark Swamp, Sedgeswamp, Fen or Winter-wet Heath.

(Two tertiary criteria were proposed - pH and type of plant cover, but no attempt was made to develop this part of the classification scheme in the present study.

The primary and secondary criteria were allocated symbols for ease of notation (Fig 4).

Thus a fresh, large permanent lake with very little vegetation cover would be designated 'LE.f.l.p.o.'

Similarly the following wetlands would be allocated symbols as indicated:

Swan River (upper reaches)	LO
Swan River (Fremantle)	E
Ornamental lakes in Kings Park	A
Lake Jandabup (Wanneroo)	LE.f.l.p.sc

It is acknowledged that grouping wetlands into such a small number of types could lead to over-simplification in that some wetlands which are biologically dissimilar may be grouped together. However it is felt that the classification proposed has value in identifying wetland groups, their potential uses, and management requirements.

In order to refine the classification and its biological validity further work is required, particularly on the vegetation types and hydrology. This was beyond the scope of the present study.

INDEX OF WETLANDS

INDEX OF WETLANDS (Cont'd)

END OF SECTION