Sydney WATER

WETLANDS OF THE NEPEAN - HAWKESBURY CATCHMENT

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PREFACE

This study of the wetlands of the Hawkesbury–Nepean catchment was undertaken as part of the Water Board's (now Sydney Water Corporation) Strategic Rivers Management Program. The focus of this Program is currently the Hawkesbury–Nepean River. The purpose of the study was to clarify the distribution and characteristics of the Hawkesbury–Nepean catchment wetlands and to provide information for strategic catchment management and in particular, the management of water resources in the river system. The study and this report were funded by the Special Environment Levy.

This report is a descriptive summary of the literature and field investigations completed by the Water Board's Environment Management Unit during 1990/91. Data from the field surveys and air photo interpretation has been recorded in a database and digitised information is being recorded in a Geographic Information System (GIS).

This overview study is a small contribution to the knowledge of Australian wetlands and highlights the need for detailed studies of these important ecosystems.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION TO WETLANDS

After years of neglect and mismanagement, wetlands are now recognised as a valuable natural resource, however in general, wetlands in N.S.W. are poorly known, with little information available to assist resource managers and land owners. A study of urban wetlands in the Sydney Region between Broken Bay and Lake Illawarra, and west to the Nepean River, was completed in 1989 by the Nature Conservation Council on behalf of the Department of Planning (Stricker and Adam, unpubl. report, 1990). Other studies by the National Herbarium of N.S.W., Sydney and the Blue Mountains City Council have added to our knowledge of wetlands in the Blue Mountains. A preliminary study of wetlands throughout the Water Board's area of operation, completed by the Shortland Wetland Centre in 1988, indicated the need for more detailed information.

The study reported here was undertaken by the Water Board in response to that need for more detailed identification and assessment of wetlands within the Water Board's area of operations. The study area is the water catchment of the Hawkesbury–Nepean River system. This regional information base will assist the Board in meeting its statutory responsibilities with respect to the Board's own works, and will also be of benefit to other agencies in the successful application of catchment management and water cycle management strategies throughout the Sydney Region. The study was funded by the Special Environmental Levy as part of the Water Board's Strategic Rivers Management Program.

1.1 Definition of Wetland

Wetlands are ecosystems that occupy the hydrological gradient between fully aquatic and truly terrestrial environments. The diversity of habitats at this interface is generally greater than is found in either dryland or aquatic ecosystems.

> Wetlands occur on ".... any land where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. These wetlands are areas of marsh, fen, peatland or water whether natural or artificial, permanent, seasonal or cyclical, with water that is static or flowing, fresh, brackish, or salt, including mudflats and mangrove areas exposed at low tide."
> *(Adapted from the RAMSAR Convention, 1971)*

The definition above has been adopted for the proposed Australian National Wetland Inventory and provides an umbrella definition that may be modified to suit the purposes of regional or special use inventories. The term wetland is a modern invention and traditional terms such as marshes, swamps, bogs, fen and mires are still used. Traditional terms used in this report are defined in the glossary.

For the purpose of this report, shallow lakes, ponds and farm dams which support emergent vegetation are regarded as wetlands, but the deep (>3m) waters of lakes and reservoirs are not.

This definition of wetlands includes: swamps, billabongs, and other depressions on floodplains adjacent to streams; all impoundments greater than 1 hectare either wholely or, in the case where lands are permanently flooded to a depth of more than 3 metres, the margins; and overflow areas characterised by anastamosing channels. Excluded from this definition, and therefore excluded from consideration in this study, are: lands permanently flooded to a depth of more than 3 metres; constructed water supply and drainage channels and associated borrow pits; impoundments less than one hectare; and freehold land used for agriculture and covered by irrigation water and aquaculture ponds. Although artificially created, some farm dams and water supply storages support areas of wetland vegetation and have at least some of the more obvious functions attributed to wetlands. Where such wetlands met the criterion of being greater than one hectare in area they were included.

1.2 Functions and Values of Wetlands

Historical attitudes towards wetlands have been drawn from fear and ignorance. Wetlands have been regarded as the dwelling places of evil spirits and the less endearing wetland animals – toads, leeches and newts – have figured prominently in the witches brews described by Shakespeare and other imaginative writers. Certainly, waterborne pathogens have claimed the lives of both humans and domestic animals throughout our history, and humans and animals have sunk to their deaths in bogs and marshes. Therefore it is not altogether surprising that wetlands have been regarded as 'unhealthy' wastelands to be filled for human uses as garbage tips, sports fields and agriculture. The decision of the 1883 Royal Commission to declare the extensive wetlands at Botany as the site for the city's noxious trades and industry is not surprising in this context. However this decision was undoubtedly influenced by the availability of water from these wetlands then

found on the sand beds to the north of Botany Bay as the Botany Wetlands had been supplying water for industrial and domestic use since 1828 (Thorpe, 1953).

In recent decades, science has discovered that wetlands perform a range of functions that are beneficial to the human community, and anthropocentric values of wetlands have been described. The terms functions and values are not synonymous: functions describe what wetlands do; values assign relative importance to those functions. Functions are objective and are intrinsic attributes of wetlands, values are a subjective construct. Very rarely are the minutiae of wetland functions known, but the obvious functions can be classified as follows (after Hammer 1992).

1. Habitat or life support for many types of fauna from microbes to mammals.

At the interface between terrestrial and aquatic habitats, wetlands provide a diversity of habitats rarely equalled by other less variable ecosystems. Wetlands of the Hawkesbury–Nepean provide breeding and feeding areas for many fish including economically valuable commercial and recreational species (John Harris, Fisheries Research Institute, pers. comm.) The floodplain wetlands have been widely recognised as being important to several migratory bird species and native waterfowl (Goodrick, 1970; Pressey, 1987) and to other birds such as reed warblers, cisticolas and grass birds that prefer tall dense vegetation. A small number of non–avian vertebrate species use wetlands for foraging and/ or shelter and these are identified in section 1.3 Fauna in Wetlands.

Several species of plants are restricted to upland swamps in the catchment and some plant species that were formerly widespread in other Sydney catchments, are found in the wetlands of the Hawkesbury–Nepean catchment.

2. Hydrologic Regulation

The hydrological role of wetlands may include flood storage and attenuation of flood peaks, groundwater recharge and discharge and base flow augmentation, depending on their position in and relative size to the watershed. Wetlands in the Hawkesbury–Nepean catchment frequently form the headwater feeder systems of streams, absorbing surface and subsurface flows and releasing water to the streams. In particular the wetlands of the Newnes, Boyd

and Woronora Plateaux, the Penrose and Nepean Swamps, the Blue Mountains Sedge Swamps, Wingecarribee Swamp, and Crown Swamp in the Upper Capertee Valley, all provide water harvesting functions and cover large areas of the headwater stream systems. Further down the streams and on the floodplain wetlands buffer both the volume and velocity of floodwaters, affording protection from erosion and reducing flood peaks. Examples of these wetlands are the riverine and floodplain wetlands of the Wingecarribee, Colo, Macdonald, Hawkesbury Rivers and the Mulwaree Ponds on the Wollondilly River.

3. Water Quality Modification

The creation of wetlands for the purification or 'polishing' of wastewater and urban run-off is based on intrinsic properties of wetlands. The submerged stems and leaves of both living and decaying wetland plants provide a large surface area for nitrate-converting microbial life to flourish. By transporting oxygen from the atmosphere to their roots, wetland plants provide an oxgenated zone around their roots that not only allows them to survive in anaerobic conditions but enhances the uptake of phosphorus and the adsorption of heavy metals (as oxides) onto their roots (Bowmer, 1985). The nutrient cycle is then completed by the conversion of nutrients to the plant biomass which may become part of the wetland food chain, or decay to form substrate for the nitrate processing microbes.

Wetlands are nature's sediment basins in which dense vegetation reduces flow velocities allowing sediments to settle out of the water column. Wetlands influence the quality of water in rivers and estuaries by controlling turbidity and altering the chemical composition of waters passing through them. Monitoring of constructed wetlands receiving wastewater indicates that some types of wetlands may also have a disinfectant capability, reducing the numbers of faecal bacteria by several orders of magnitude.

4. Erosion Protection

Wetland vegetation binds sediments, protecting banks and shorelines from erosion and the more robust plants are effective in dissipating wave energy in lakes and water storages. The upland swamps of the Hawkesbury-Nepean catchment are important in reducing erosion and sedimentation into water storages and streams because of their position in the catchment and their structural density.

5. Landscape Quality and Open Space

The varied colour tones and textures of wetland vegetation and open water provide visual relief to developed areas and enhances the variety of natural bush landscapes in many areas of the Blue Mountains. Floodplain and estuarine wetlands are of significant value to the Hawkesbury River landscape and are part of the visual heritage of this historic area.

6. Research and Education

Wetlands offer a wide range of educational and research opportunities for a number of disciplines. The Longneck Lagoon Field Studies Centre uses the Lagoon for experiential and classroom eductaion on a range of themes from the ecology of the food chain to catchment management. For example, the peat and sediment deposits in some wetlands provide a record of past vegetation, climatic and fire and flood regimes spanning thousands of years, at Wingecarribee Swamp for example, to one million years in the case of Lake Bathurst.

7. Geochemical Storage

Wetlands under permanent inundation or waterlogging, and particularly peatlands, are natural sinks for carbon, sulphur, iron, manganese and other sedimentary minerals, because their anaerobic processes are so slow. In contrast, wetlands with fluctuating water levels, and therefore more aerobic conditions, that recycle carbon and other elements at a rate relative to the generation times of the vegetation.

1.3 Classification of Wetlands

The classification of the wetlands facilitates comparison of the conservation status of the wetlands within the Hawkesbury–Nepean catchment and with other wetlands throughout the region. Classification is only a tool for wetland ecology and conservation and should be shaped to suit the application. There are numerous classification schemes for wetlands but none universally accepted, although the Austalian Nature Conservation Agency's *Directory of Important Wetlands in Australia* has based its classification on that used by the Ramsar Convention in describing wetlands of international importance, but with minor modifications to accommodate the range of Australian wetlands. In this report we have adopted a primary division according to the botanical

divisions used in the *Flora of New South Wales* published by the Royal Botanic Gardens, Sydney. These divisions are based on the major ecogeographic areas of the State, reflecting the dominant climatic regimes and physical features that determine vegetation types in those areas. The Hawkesbury–Nepean catchment spans two ecogeographical regions; the Coastal Division and the Tablelands Division that includes the Central Tablelands and the Southern Tablelands (see Figure 3). The Upper Nepean Swamps span the boundary of the Central Coastal Division and the Southern Tablelands and are included in the latter Division due their elevation. Within the Tablelands Division the wetlands remain grouped as they have been by previous authors using either geographical names, for example Lake Bathurst, or descriptive names such as the Blue Mountains Sedge Swamps (Keith and Benson, 1988; Blue Mountains City Council, 1990). Although names such as Blue Mountains Sedge Swamps and Newnes Plateau Shrub Swamps may be misleading in that both groups comprise shrub and sedge communities depending on fire history and aspect, the detailed analysis required to validate finer classification is beyond the scope of this report, although the database will allow more rigorous classification to be undertaken for specific criteria.

Wetland terminology developed in the northern hemisphere and often has precise meanings for which there are no equivalents in Australia, although some terms have been used in a broad sense. For example, most of the upland swamps of the sandstone plateaux surrounding Sydney can be described as "soligenous mires" (Keith & Myerscough, 1993) due to their attributes of peat formation and almost constant seepage of water, although mires of northern latitudes tend to have developed under conditions that favoured more constant, and therefore deeper, peat development. The mires support a number of different types of vegetation types including paperbark (*Melaleuca* species) wetlands, shrubs dominated by teatree (*Leptospermum* species), sedge mires, and in particular, buttongrass (*Gymnoschoenus sphaerocephalus*) mires, restiad and moss communities. Several vegetation communities may occur at the one wetland and thus a classification based only on vegetation is too complex for these wetlands of such high diversity. The term swamp continues to be used generously in the Australian literature, referring to primarily lentic wetlands, many of which are also mires. The majority of wetland names used in this report incorporate the term swamp and although the wetlands may more accurately classed as fens or bogs, for example, Wingecarribee Swamp, it is more convenient to follow the local names as they appear on vegetation and topographical maps and in the literature.

1.4 Survey and Mapping Methods

Wetlands were identified and mapped using aerial photographs and 1:25000 topographic maps, with ground truthing where possible within the time frame of the study. Where available, information from existing maps was used. For example, the Natural Constraints maps for the Blue Mountains Environmental Management Plan (Blue Mountains City Council, 1990) were used in conjunction with vegetation studies by the National Herbarium (Keith and Benson, 1988) to delineate the Blue Mountains Sedge Swamps of the Blue Mountains City Council area. The use of aerial photographs allowed large areas of the catchment to be surveyed quickly and areas requiring ground truthing to be identified. Numbers were assigned to the wetlands as they were identified on the maps, including and following on from the existing numbering system used for the Sydney Urban Wetlands Inventory by Stricker and Adam (unpubl report).

Upland swamps comprise a small number of plant communities distributed along environmental gradients of soil moisture, depth, particle size and nutrient availability. The plant communities are dominated by rushes and sedges and/or by shrubs of the Proteacea and Myrtaceae. Although the communities at the dryer end of the moisture gradient may be termed heath, they intergrade with the wetter communities, whereas the boundary between heath and woodland is abrupt and relatively stable over time. This disjunction and the work of Dr David Keith (Keith, 1991; Keith & Myerscough, 1993) has persuaded us to the view that the mapping of the heaths of the sandstone plateaux and the Blue Mountains as part of the upland swamp complexes is ecologically valid.

As noted above existing names (Keith and Benson, 1988; Blue Mountains City Council, 1990; and Young, 1982) were used for the wetland groups identified previously in the literature. Where no name was found, a name based on the geographical location of that group was applied.

Figure 1 Ecogeographical Divisions

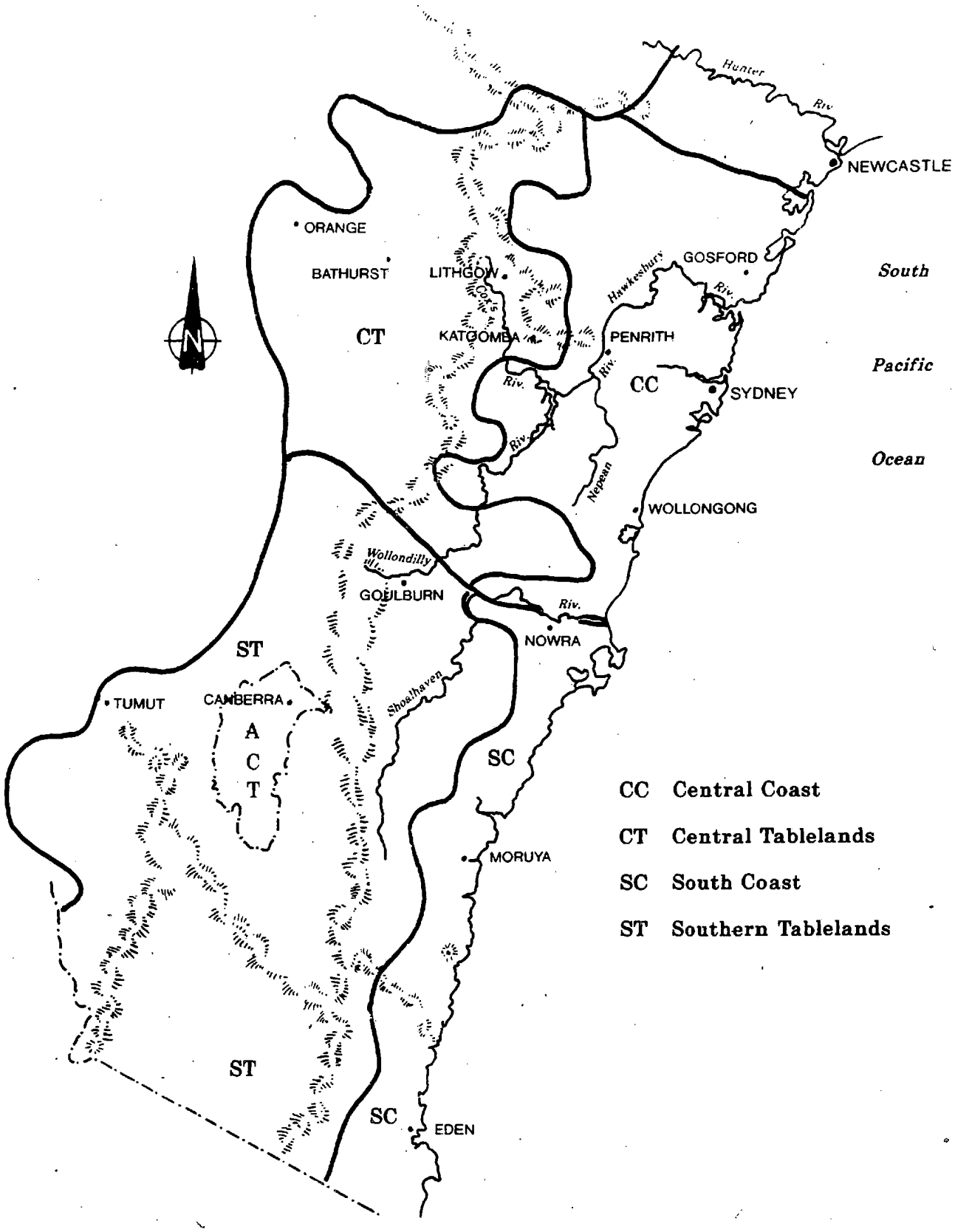
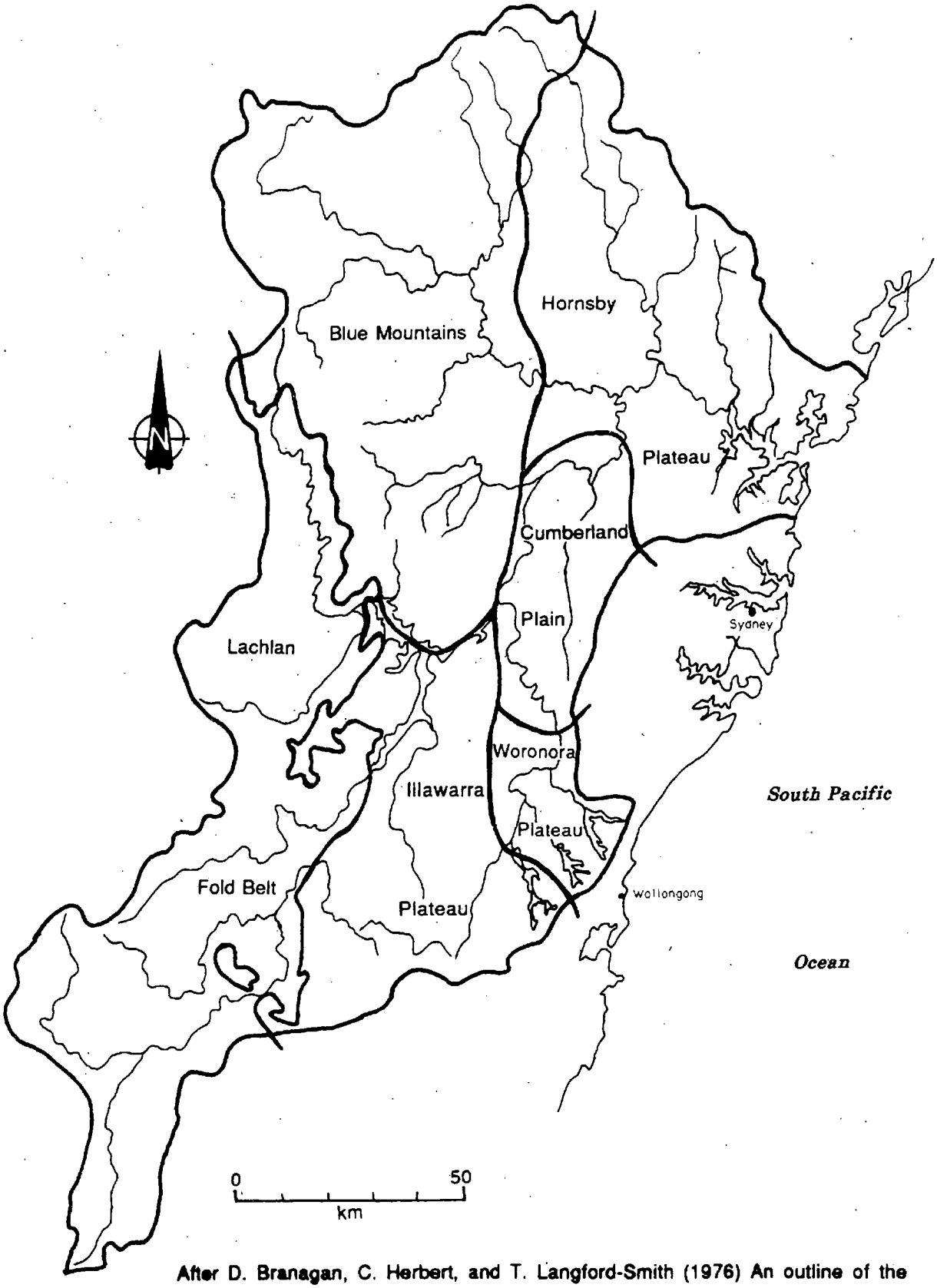


Figure 2: Physiography of the Nepean-Hawkesbury Catchment



After D. Branagan, C. Herbert, and T. Langford-Smith (1976) An outline of the Geology and Geomorphology of the Sydney Basin. Science Press, Sydney.

2.0 PHYSIOGRAPHY OF THE HAWKESBURY-NEPEAN CATCHMENT

The major landforms of the 216,765 square kilometres of the Hawkesbury–Nepean catchment may be viewed as a lowland plain surrounded by elevated plateaux of sedimentary rocks, with a belt of igneous and metamorphic rocks to the south and west (see Figure 1).

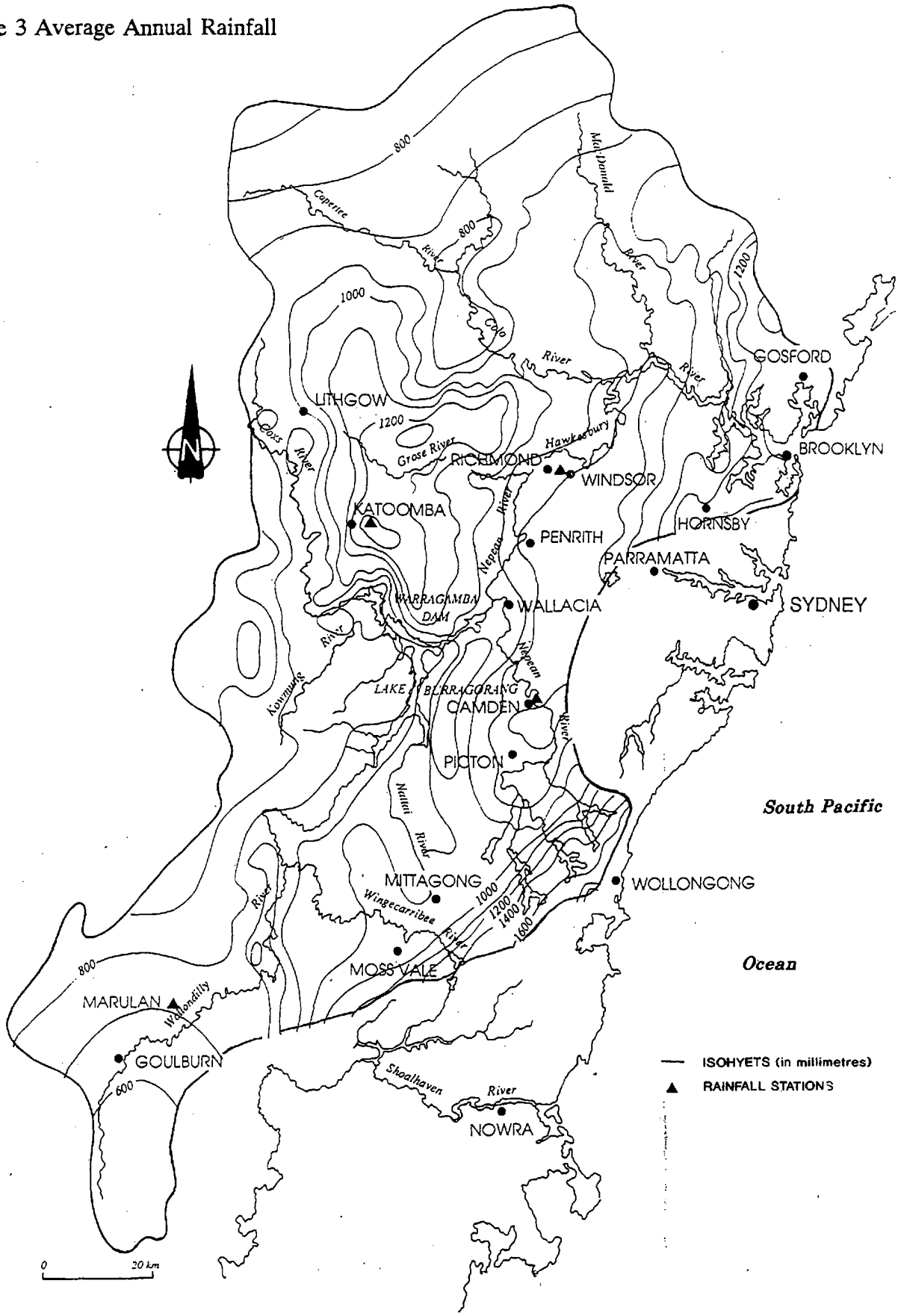
The Cumberland Plain is a relatively flat region that contains most of the metropolitan area of Sydney. The elevation of the Cumberland Plain rarely exceeds 100m ASL (above sea level). Wianamatta Shale that gives rise to silty–clay sediments, is the dominant rock type here. The broad alluvial Hawkesbury floodplain and its wetlands fit wholly within the Cumberland Plain.

A number of elevated plateaux surround the Cumberland Plain; they are the Hornsby Plateau, the Blue Mountains Plateau, the Illawarra Plateau and the Woronora Plateau (see Figure 1). They generally form gently–sloping ramp–like structures adjoining the Plain, but the Lapstone Monocline forms a relatively steep connection between the Cumberland Plain and the Blue Mountains Plateau (Branagan et al., 1976).

The bedrock of the plateaux are dominantly Hawkesbury sandstone and Narrabeen Group rocks. Erosion of these rocks has resulted in the formation of canyons that dissect the undulating to flat surfaces of the plateaux (Branagan et al., 1976). Above these canyons, upland valleys have been cut into the plateau surfaces. These upland valleys often contain the upland swamps that are typical of the Plateaux.

To the south and west of the Blue Mountains and Illawarra Plateaux lies the Lachlan Fold Belt. It consists of a variety of rocks, the result of igneous intrusions and the metamorphosis of the original rocks. The landforms of the Lachlan Fold Belt depend on the local geology and structures such as faults.

Figure 3 Average Annual Rainfall



3.0 WETLANDS OF THE HAWKESBURY-NEPEAN CATCHMENT

Fauna of Wetlands

Wetlands, being the interface between terrestrial and aquatic environments, provide food and water for many land-based animal species. Animal species using wetlands may do so for part or all of their life cycles, or may come to feed on the resident species.

Invertebrates

The most populous and diverse animal group in wetlands are the invertebrates. This group plays a major role in wetland ecosystems, particularly in nutrient cycling. A large proportion of the energy flow through wetlands is through the invertebrate population.

Many invertebrates including crayfish, live in the sediments of wetlands. The smaller species of crayfish are efficient burrowers and survive dry spells by keeping cool and moist in the substrate. They are common in many of the upland swamps.

A variety of insect species have an aquatic larval stage followed by an often short-lived flying adult stage, for example, dragonflies and mayflies. Flying adults are frequently caught in the webs of spiders which suspend their webs from the densely growing sedges and rushes of both saline and freshwater wetlands.

Frogs

Frog calls are often the first indicator to a passer-by of a wetland nearby. Due to the permeable nature of a frog's skin, they only inhabit freshwater wetlands. In saline water, frogs would lose water from their bodies by osmosis. Frogs primarily use the margins of wetlands and many species return to the water only to breed.

There are several species of frogs in the Hawkesbury-Nepean catchment that are particularly associated with wetlands, and one species, the Red-Crowned Toadlet (*Pseudophryne australis*) is totally restricted to Hawkesbury Sandstone habitats.

Adult frogs prey on most terrestrial invertebrates and, at various stages of their life cycles, are themselves a major food source for many animal groups including fish, tortoises, snakes and birds. The endangered Green and Golden Bell Frog, (*Litoria*

aurea) is described by Cogger (1975) as a "voracious, cannibalistic species" and is apparently dependent on permanent water and wetland or riparian vegetation, in areas devoid of the *Gambusia* (Mosquito Fish) which prey on the eggs of frogs.

Snakes, Lizards and Tortoises

There are several species of snakes and lizards that frequent wetlands in the catchment. The Eastern Water Dragon (*Physiognathus lesueurii*) is a semi-aquatic and arboreal lizard which feeds on a variety of insects, including mosquito wrigglers, and frogs. The Water Dragon's preferred habitat is in trees with branches overhanging water. The authors have recorded this species along Cattai Creek, and it is common throughout the region.

Two species of freshwater turtle occur naturally in the catchment. The Eastern Long-Necked Turtle (*Chelodina longicollis*), is still relatively common in suitable habitats. A shorter-necked turtle is found less commonly in the Sydney Region and the Hawkesbury-Nepean catchment belonging to the genus *Emydura,* however the taxonomy of the coastal population of this genus is unclear to date., (Alan Greer, Australian Museum, pers. comm.)

Although many species of snakes are attracted to wetlands to feed on frogs and other wetland inhabitants, only a small number of species typically live in and around wetlands. The most common and widespread of these is the Red-Bellied Black Snake (*Pseudechis porphyriacus*), although both the Copperhead (*Austrelaps superbus*) and the Tiger Snake (*Notechis scutatus*) may be locally common. The Copperhead is usually restricted to the mid to higher Blue Mountains and Southern Highlands. The Black-Bellied Swamp Snake (*Hemiaspis signata*) also occurs in marshy areas.

Fish

The distribution of fish species in the wetlands was not surveyed by the authors due to lack of expertise and resources. This work would be more efficiently done by qualified consultants for specific wetlands as required. The following criteria may provide an indication of the value of individual wetlands as fish nursery and breeding areas:

- water regime, both long-term stability and flooding frequency and duration
- density of macrophyte vegetation

- density of fallen logs and snags
- hydraulic connection between wetland and the main channel
- seasonality; high water levels are more desirable in summer when temperatures and productivity are high.

These criteria are adapted from Pressey (1987) who commented on the scarcity of existing information on the fisheries values of specific wetlands.

Mammals

Macropods

The Eastern Grey Kangaroo (*Macropus giganteus*), the Swamp Wallaby (*Wallabia bicolor*), and Common Walleroo (*Macropus robustus*) are probably frequent visitors to wetlands adjacent to forest habitats. These macropods graze on the sedges and rushes of wetland margins as well as using the water supply. Several Eastern Grey Kangaroos and Swamp Wallabies were seen by the authors grazing around the margins of wetlands on the Newnes and Boyd Plateaux in June 1990. It is likely that larger wetlands may be a refuge to these animals during forest fires.

The Potoroo (*Potorus tridactylus*) may also frequent wetland margins (Jelinek, 1978).

Small Mammals

The dense plant cover of most wetland types is an ideal habitat for many small mammal species. Several of these species make runways through the vegetation enabling them to travel around the area whilst minimising the risk of detection by predators such as owls.

Both the vegetarian native rodents and the insectivorous and carnivorous dasyurids find a plentiful food supply in these wetlands. The Swamp Rat (*Rattus lutreolus*) and the Dusky Antechinus (*Antechinus swainsonii*) prefer the moist habitats of wetland margins and riparian vegetation while the Bush Rat (*Rattus fuscipes*), Common Dunnart (*Sminthopsis murina*) and Brown Antechinus (*Antechinus stuartii*) range through heaths and woodlands.

Although no confirmed recordings of small mammals were found by the authors, it is probable that the Brown Antechinus and Bush Rat are common throughout the Warragamba catchment, and the entire Blue Mountains and Macdonald River Valleys and Little Cattai Creek Valley. It is also likely that the Eastern Water Rat (*Hydromys chrysogaster*) and Platypus (*Ornithorhynchus anatinus*) live in many of the larger streams of the catchment. There have been several sightings of Platypus recorded for the Wollondilly River near Goulburn and Canyonleigh, the Kowmung River, and the upper reaches of the Nepean River near Maldon. There are a few records for the Coxs River near Little Hartley and above Wallerawang. Most of the remaining records are from the Colo River system, especially Wheeny Creek; also the Wolgan River on the Newnes Plateau and the Capertee River, (T. Grant, unpubl. data).

The Dusky Antechinus is a species of uncertain conservation status. Due to its limited habitat preference this species has a disjunct distribution and populations are particularly sensitive to fire. Long-term population studies commenced by The Australian Museum, of small mammal species at Nadgee Nature Reserve indicated that a high proportion of the Dusky Antechinus population was killed by fire and that post-fire recovery was slow compared with Brown Antechinus and Bush Rat (Lunney, 1978). The status of the Swamp Rat in the catchment wetlands is similarly uncertain although this species is more robust than the Dusky Antechinus.

Birds

All wetlands are of value to at least a small number of bird species. The bird habitat values of wetlands and methodologies to assess these have been described by various authors, notably Goodrick (1970), Pressey (1987) and Gilligan (1984).

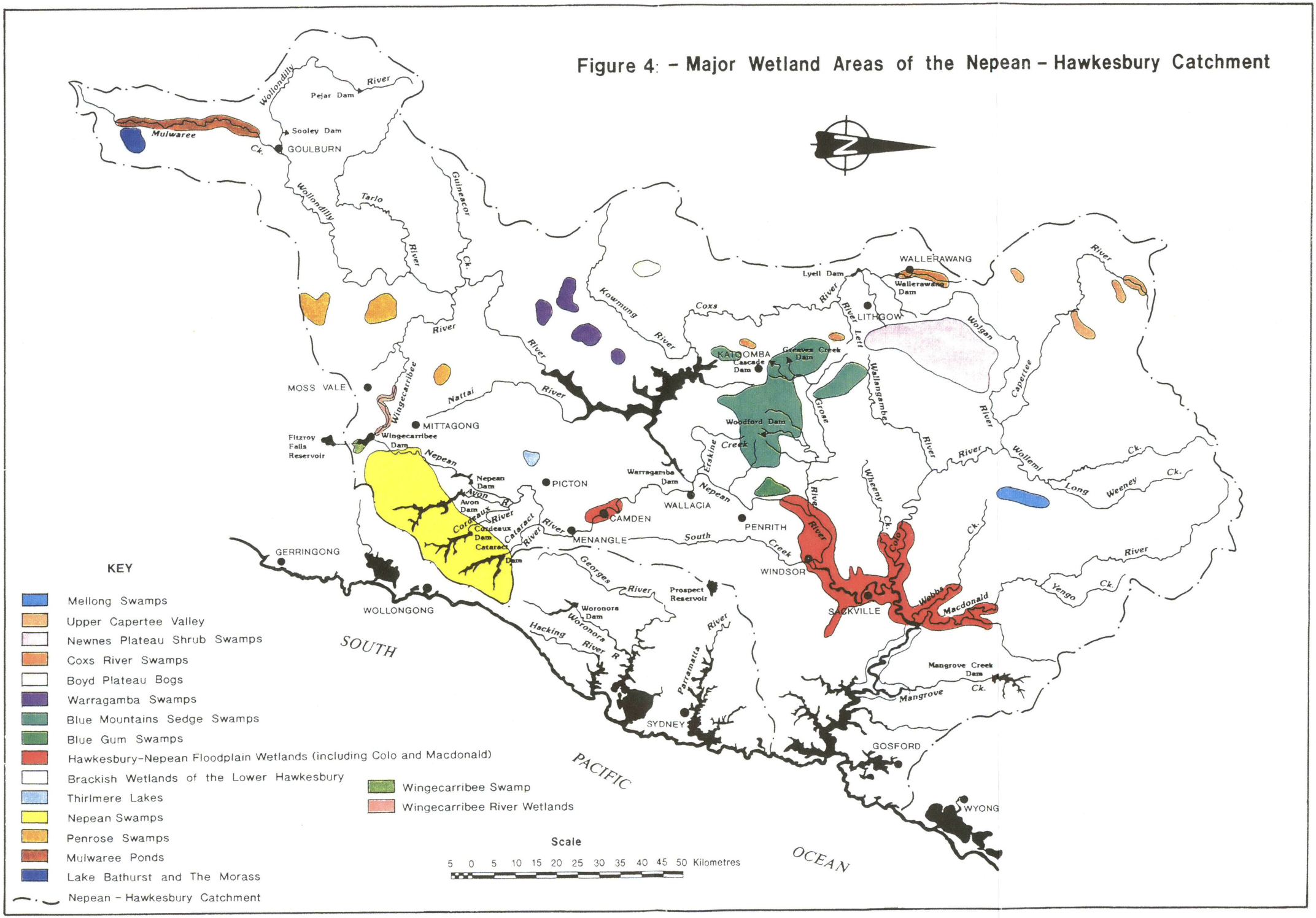
There is often a synergistic relationship between wetlands of different types such that birds may use a treeless open water lagoon for feeding but fly to wetlands with denser plant cover for roosting and nesting.

Although public interest has been largely centred on migratory bird species, there is a large number of native bird species, both nomadic and sedentary, that depend on wetlands in the Hawkesbury-Nepean catchment. Rails, crakes and bitterns are some of the less common groups of birds for which these wetlands provide habitat, but many other species, both common and rare, are provided for in this diverse catchment. Many of the smaller wrens and near-ground nesting birds such as finches make use of the dense wetland vegetation for nesting.

Almost every migratory bird species sighted in N.S.W. has been recorded from the Hawkesbury floodplain wetlands, including many waders more usually associated with estuarine wetlands. There is, therefore, a strong imperative under Australia's international obligations (Japan and Australia Migratory Bird Agreement and China and Australia Migratory Bird Agreement and Ramsar Convention on Wetlands of International Importance) to protect the habitats of these birds by appropriate management strategies.

Honeyeaters and Thornbills are particularly attracted to the flowering proteaceous shrubs (*Banksia*, *Grevillea*, and *Hakea* species) and tea-trees (*Leptospermum* species) which produce copious nectar. They are therefore to be seen in the wetland types that support these woody perennials. Most of these bird species are seasonal visitors, depending on flowering time. This group of birds is thus not wetland-dependent but is opportunistic in its use of wetlands. In contrast the migratory birds, ducks and grebes are dependent on wetlands and use the wetlands of the catchment regularly.

Figure 4: - Major Wetland Areas of the Nepean - Hawkesbury Catchment



TABLELANDS DIVISION

Southern Tablelands Division

3.1 Mulwaree Ponds

The Mulwaree River follows a north–south oriented fault line that divides two provinces of past tectonic activity. The geology of the region is complex. Beginning in the Ordovician period, sedimentary rocks such as sandstone, siltstone, shale, and limestone were deposited. Since then, tectonic activity has produced metamorphic rocks such as slate, chert and quartzite, as well as a variety of mainly granitic igneous rocks. Erosion of these rocks has produced the sediments that form the present floodplain of the Mulwaree River, Crisps Creek and Bungalore Creek, and the lakebeds of The Morass and Lake Bathurst.

The wetlands of the Mulwaree River and its tributaries occur along the channels and on the present floodplain of these rivers at about 640 metres altitude, and are known as the Mulwaree Ponds. Reasonably diverse plant communities occur along the Mulwaree River, considering the heavy disturbance to which they have been subjected. The floating aquatic, *Nymphoides montana* and the submerged aquatic *Vallisneria gigantea* grow in pools of standing water. Stands of *Typha* sp. grow along Crisps Creek. On the boggy river margins, stands of graminoid dominated vegetation grow, including *Juncus* sp. and small species of Spikerush (*Eleocharis* spp.) On the less frequently inundated present floodplain, the tussock sedge *Carex* sp. is common with a grass (*Poa* sp.) in the drier spots.

The whole area of the Mulwaree Ponds appears to have been subjected to clearing and grazing. Only the steeper slopes of the catchment have retained tree cover. The wetlands may be significantly altered from their natural state, but still perform important water quality functions and support indigenous plant communities. The authors found no information on the fauna of the region but during the inspection of the wetlands, several Grebes, Pied Cormorants, Coots and Seagulls were observed.

3.2 Lake Bathurst and The Morass

Lake Bathurst and The Morass are shallow lakes at the southernmost extremity of the Nepean–Hawkesbury catchment. They lie about one kilometre to the east of the Mulwaree River at about 670 metres altitude and are mostly surrounded by flat to gently sloping land.

Lake Bathurst probably developed as a deflation hollow in the deeply weathered Tertiary surface. The initial damming of the lake probably occurred as a result of faulting to the west. Indeed, seismic surveys indicate that a bedrock structure running parallel to the Mulwaree exists beneath the slight rise in the ground surface between the lake and the river (D. Gillison, Australian Defence Force Academy, pers. comm.). Analysis of sediment cores taken from the lakebed indicate that the lake is over 1 million years old, and the sediment is over 80 m deep.

The waterbodies of the Lake Bathurst area may be divided into three parts, separated from each other by north–south oriented lunettes. A shallow lake to the east known as The Morass is separated from Lake Bathurst proper which is in turn divided into an eastern and western part. The lunettes, represented by low ridges, are approximately 10–15 000 years old (D. Gillison, pers. comm.). The whole lake system is a "watertable window" and the groundwater body associated with the lakes is probably a very large and important one. This is supported by the fact that the water levels in Lake Bathurst respond very slowly to large rainfall events and that water levels vary only slightly in comparison to the wide range of levels observed at Lake George to the west, just outside the Nepean–Hawkesbury catchment. The low rise between the lake and the river has been breached by water on the surface only once or perhaps twice since the turn of the century (D. Gillison, pers. comm.)

At the time of our observations, there was little native wetland vegetation on the shores of these lakes. *Juncus* sp. was growing in the boggiest parts, but pasture grasses and weeds dominated the majority of the lake margins. It appears that as the lake levels fall, bare soil is exposed. However, the presence of washed–up debris of the submerged aquatic plant *Vallisneria gigantea* (Ribbonweed) revealed its occurrence in the deeper sections of the lake and illustrated the power of wave action which can build up over fetches of up to 5 km in the lakes. However the lake at various times has submerged aquatic vegetation of *Ruppia megacarpa* or *Potamogeton* spp. as well as the Ribbonweed (S. Jacobs, pers. comm.). When dry conditions prevailed for

several years and the waterbody almost disappeared, extensive growths of two plants were been reported (Anon, 1977). The herb *Selliera radicans* covered much of the bed of the lake. The other plant was a species of *Cassytha,* " whose stems made large, bright orange mats, and were very conspicuous on the lake bed."

Conservation and Management

The entire margin of Lake Bathurst and The Morass is grazed and cleared. Scattered snowgums grow on the rises but the pre–European extent of tree cover in this basin is uncertain. The impacts of clearing and grazing, such as soil erosion, sedimentation, trampling by stock, and invasion by pasture grasses are exacting heavy stresses on the fringing vegetation and dryland salinity and gully erosion are significant land management problems in the upper catchment of Lake Bathurst (Kodela and Foster, 1990). The lakes are listed in the Australian Nature Conservation Agency's *Directory of Important Wetlands* as an important refuge habitat during inland droughts, being one of only two large semipermanent lake systems on the Southern Tablelands.

Central Tablelands

3.3 Penrose Swamps

Along drainage lines to the west of Moss Vale, a number of upland swamps have developed on the Permian sandstones of the lower Berry Formation at elevations of 600–700 metres above sea level. Floristic differences between the wetlands in this group are the result of local differences in soils and/or hydrology. The sandy peat substrate and the occurrence of Button Grass (*Gymnoschoenus sphaerocephalus*) in the majority of these swamps indicates that these swamps have affinities with the 'dells' of the Woronora Plateau, the Upper Nepean Swamps and the Blue Mountains Sedge Swamps.

The similarities between the Penrose swamps and the Woronora 'dells' in terms of vegetation structure and soils suggests that the Penrose swamps may have developed under similar influences to those of the Ilawarra and Woronora Plateaux. The vegetation of the Penrose swamps consists of a herb layer dominated by sedges and a shrub layer and appears similar to the communities described by Keith and Myerscough (1993). Shrub species include *Callistemon sieberi, Leptospermum grandifolium, L. myrtifolia and L. lanigerum, Hakea teretifolia,* with *Persoonia linearis, Platysace linarifolia* and

Dillwynia ramosissima on the upper margins of the swamps. Sedges include *Restio complanatus*, *Lepidosperma* sp., *Chorizandra sphaerocephala*, *Ptilanthelium deustum*, *Gymnoschoenus sphaerocephalus*. *Centrolepis strigosa*, *Xyris* sp., *Hibbertia acicularis*, *Pimelea linifolia*, and *Centella asiatica* are found in the herb layer. *Sphagnum* moss and the aquatic *Villarsia exaltata* are present in some wetlands, and the fern *Gleichenia dicarpa* is common in the wetter areas of many swamps where dense ti–tree thickets grow. Many of the swamps, such as Stingray and Long Swamp are headwater swamps of Paddy's River and its tributaries.

Conservation and Management

A large area of these swamps is now used for pine plantations by the Forestry Commission (Belanglo and Penrose State Forests). Here the swamps are usually left uncleared, but the important fringing heath and woodland vegetation is removed and replaced with pine forest. The swamps then become islands of habitat for both plants and animals, and their habitat value and ability to respond to, and survive environmental change is considerably reduced. Road–building, and possibly burning practices, have impacted on some swamps in the State Forests.

Stingray Swamp retains its fringing native woodland vegetation including the rare *Eucalyptus aquatica*. This picturesque wetland is conserved within the 30 HaStingray Swamp Flora Reserve (No. 91) on the eastern edge of Penrose State Forest. The southern section of it is affected by nutrient discharge from the sewerage treatment works on Paddys River near Bundanoon. Invasion by exotic species such as Blackberry and Radiata Pine may also threaten its natural integrity (pers. comm., Forestry Commission, 1991).

Elsewhere the swamps are threatened by clearing and catchment disturbance. The upper catchment of Long Swamp Creek is at present relatively undisturbed, but is currently being subdivided for 'hobby farms.' The lower section of Long Swamp has been disturbed by extraction of the peaty bed of the wetland.

3.4 Wingecarribee Swamp

This large peat swamp between Robertson and Moss Vale is about 690 hectares in area and blankets the floor of a broad, westward–draining valley at an altitude of 680 m. The swamp may be fed by permanent nutrient–rich

spring lines along the contact between the Robertson Basalt and the Wianamatta Group shales and sandstones in the catchment (Hope and Southern, 1983). The Swamp is the largest montane mire (peat-forming wetland) on the Australian mainland (Hope and Southern, 1983).

Wingecarribee Swamp is a valuable site for palaeoenvironmental research with a potential record of the last 20,000 years of palaeoecological history. Radiocarbon dates of the peat at 10m depth indicate that the peat deposit is at least 15 000 years old (Hope and Southern, 1983). At the western end of the swamp, "degraded swamp clays are overlain by sand, indicating a former swamp phase in the valley" which occurred about 37 000 years ago (Hope and Southern, 1983). Fossil wood more than 35,000 years old has been found on the north western edge of the swamp and it is thought that the swamp deposits may yield rare information on the glacial period between 23,000 and 14,000 years BP. This period is largely missing from organic deposits elsewhere in Australia. This deposit therefore contains some of the best scientific records of past vegetation, hydrology and climatic history, and an ongoing research program into the flood history of the Nepean catchment is centred on findings from this locale.

The present vegetation of the swamp consists of a ground layer of sedge-like plants and herbs, with low shrubs that may be remnant *Leptospermum* thickets. Shrub species present today include *Leptospermum obovatum, L. juniperinum, Pultenaea* divaricata, *Olearia glandulosa* and *Comesperma retusum*. The lower strata plants include *Carex* spp., *Eleocharis* spp., *Lepyrodia anarthria, Restio australis, Juncus* spp., *Galium* sp., *Leptorhynchos squamatus*, *Lythrum salicaria*, *Sparganium antipodum*, *Vernonia cinerea*, *Viola caleyana*, *Craspedia* sp., *Persicaria* spp., *Hydrocotyle peduncularis*, the insectivorous sundew *Drosera binata* and *Deyeuxia quadriseta*. The aquatic plants *Typha orientalis*, *Phragmites australis* and *Villarsia exaltata* grow where there is free water at the surface. Some *Sphagnum* moss is also present, and may have been more extensive in the past (Hope and Southern, 1983; Phillip Kodela, pers. comm., 1988).

The western half of the swamp is now beneath a water supply reservoir built in 1974 by the Sydney Water Board. The eastern part is proclaimed catchment area and public access is restricted. However the prior uses of peat mining and agriculture continue there. Drains associated with peat mining and agriculture may have changed the hydrology of the swamp (Fiander, 1993), as has the ponding of water in the reservoir. Grazing and cropping have resulted in the

clearance of much of the original swamp vegetation and has contributed to the spread of introduced weeds. Burning activities also affect the vegetation and the peat substrate (Hope and Southern, 1983; Kodela and Hope, 1992).

Rare Plants

Two species of plants that are thought to be endemic to peaty swamps of the southern highlands, grow on the margins of the Swamp. *Gentiana wingecarribiensis* is a small short-lived herb growing in the littoral herbland, sometimes with emergent shrubs. The conservation status of this endangered species is classified **2E** by Briggs and Leigh (1988). The **2** signifies that the species has a geographic range less than 100km, **E** signifies that the species is considered to be endangered with a serious risk of extinction over then next few decades. There are currently only two known populations of *G. wingecarribiensis* totalling about 110 individuals at the time of the 1992 survey (Cohn, 1993). A ground orchid, *Prasophyllum uroglossum* that grows near the gentian populations is thought to be similarly rare and endangered. Both species grow on private land and their habitat is currently under threat from grazing and trampling by stock, burning pactices and fluctuations in the water table. The National Parks and Wildlife Service of New South Wales has prepared a conservation research statement and recovery plan for *G. wingecarribiensis* (Cohn,1993). Two species of rare eucalyptus trees, *Eucalyptus macarthurii* (Camden Woollybutt or Paddy's River Box), and *Eucalyptus ovata* (Swamp Gum), grow near the edges of Wingecarribee Swamp, along with a number of uncommon plant species.

Fauna

The Swamp is historically an important site for studying herpetofauna and has been well-known for its populations of Tiger Snakes(*Notechis scutatus)*, Copperheads (*Austrelaps superba*) and Black Snakes (*Pseudechis porphyriacus*), and provides habitat for a number of frog species. The Green and Golden Bell Frog, *Litoria aurea* has been recorded from Burrawang and is likely to occur at Wingecarribee Swamp (Australian Museum records, NPWS, per comm.). The Australian Bittern, a cryptic bird that is endangered in NSW, was observed in the Swamp in 1992.

Conservation and Management

Currently this wetland is subject to active peat mining, frequent but patchy burning, grazing and slashing. The western half of the swamp is now beneath the stored water of a small reservoir built by the Water Board in 1974 to supply the local townships and to store water that is transferred from Tallowa Dam to Warragamba Dam during extended drought. An environmental management plan for this important wetland is urgently required, and it is recommended that research into the relationships of the physical, chemical and biological components of this unique ecosystem be undertaken.

As a cultural resource, the landscape and historic items of the Wingecarribee Swamp and its environs have potentially high significance. The Wingecarribee Swamp was a focus for human settlement from Aboriginal prehistory through early European settlement of the 19th century to the present day.

Wingecarribee Swamp is one of the best examples of upland peatlands on mainland Australia and is "unique as a large montane peatland at a relatively low altitude" (Kodela & Hope, 1992). The scientific resource of the peat bed is irreplaceable, being an archive of almost every aspect of regional environmental history. The Swamp provides a major fen and bog habitat for many highly specialised plant and animal species including the rare and threatened endemic plant species *Gentiana wingecarribiensis* and *Prasophyllum uroglossum*. The National Trust of Australia (Sydney) has listed the Wingecarribee Swamp as a Landscape Conservation Area (Figure 6) and the Australian Heritage Commission listed the Swamp on the Register of the National Estate on 15/5/90. The Wingecarribee Swamp is therfore recognised as an ecosystem and environmental resource of local, state, national and international significance.

3.5 Wingecarribee River Wetlands

Prior to European occupation it is likely that the character of the Wingecarribee River was a chain of ponds – a series of discontinuous pools along a grassy meandering channel through a broad shallow valley. The River has been modified by European land management practices: clearing of the natural brush and forest vegetation has increased the runoff and the Wingecarribee River has become a continuous channel (Robin Warner, pers. comm., 1991). Following construction of the Wingecarribee Dam in the early

1970's the reduced flow has narrowed the channel. The installation of three weirs along the River has formed pondages, each with upstream sedimentation and downstream scour.

The wetlands of the Wingecarribee River have been heavily influenced by modifcation of the River environment, however they have developed in response to the more or less stable environmental regime, including periodic flooding that exists today. The nature and distribution of wetlands along the Wingecarribee River are influenced by the reservoir which regulates the natural headwater flow, the weirs and the climate. The climate of the Wingecarribee valley is relatively cool and humid due to its high elevation (approx. 700m). Average rainfall decreases markedly from the upper catchment of the River; 1166mm at East Kangaloon to 950mm at Mittagong. Rainfall is fairly evenly distributed throughout the year. The following description of the major contemporary wetland communities is taken from the results of a survey during 1991/2 by C. Wall for the Water Board's Wingecarribee River Management Project.

Kellys Swamp

Where Kellys Creek joins the Wingecarribee River, the floodplain is especially wide and criss-crossed with secondary channels. This area, known as Kellys Swamp, provides a large area of shallow water wetland habitat when the River floods. Kellys Swamp contains a range of wetland habitats grading to pasture, between the Reservoir and Berrima Weir, including the faster flowing aquatic habitats of the present active River channel. It probably supports the the full complement of aquatic plant species that occur in shallow water and boggy ground.

The true aquatic plants (which generally require standing water) of Kellys Swamp include the Water Snowflake (*Nymphoides geminata*) Floating Pondweed (*Potamogeton tricarinata*), Blunt Pondweed (*Potamogeton ochreatus*), at least three species of Water Milfoil (*Myriophyllum* spp.), Water Plantain (*Alisma plantago-aquatica*) a small Spikerush (*Eleocharis acuta*), Ribbonweed (*Vallisneria gigantea*), Watercress (*Rorippa nasturtium-aquaticum*) and the River Buttercup (*Ranunculus inundatus*).

On the damp margins and marshy areas occupying the largest area of the Kellys Swamp wetland grows a mix of pasture grasses, Knotweeds (*Persicaria* spp.), Rushes (*Juncus* spp), Creeping Buttercup (*Ranunculus repens*), Swamp Starwort (*Stellaria angustifolia*), and Bedstraw (*Galium* spp.).

Along the River channel, scattered stands of Common Reed (*Phragmites australis*), Tall Spikerush (*Eleocharis sphacelata*) and Reed Sweetgrass (*Glyceria maxima*) occur. In slow-flowing areas of the channel are well developed beds of Water Snowflake (*Nymphoides geminata*).

Tyrees Dam

Tyrees Dam is a privately owned and managed structure immediately downstream of Kellys Swamp. The water body of the main dam provides an area of wetland habitat that is relatively deep – over 1m. A supplementary structure on the northeastern edge of the main water body provides another area of habitat that contained standing water during the Water Board surveys. Plants observed include Tall Spikerush (*Eleocharis sphacelata*) Water Plantain (*Alisma plantago-aquatica*), Knotweed (*Persicaria decipiens*), at least three species of *Juncus* and Starwort (*Callitriche*).

Cecil Hoskins Nature Reserve – Bong Bong Weir

Water has been ponded at Bong Bong since the early 1920's when the weir was built. The area was declared a Wildlife Sanctuary in 1932 as there was abundant birdlife. Cecil Hoskins Nature Reserve was gazetted in 1975, and is currently managed by the NSW National Parks and Wildlife Service.

The relatively still and permanently ponded water of the wetland upstream of Bong Bong extends beyond the boundaries of the Nature Reserve, a total length of 2 km. The wetland vegetation includes deepwater aquatic communities, floating mats and marsh communities near the islands and the picnic area. Parts of the Bong Bong impoundment are deeper than 2metres and support aquatic plant species that generally occur in deeper water. These include the submergent plants Ribbonweed (*Vallisneria* sp.) Yellow Bladderwort (*Utricularia australis*), and the emergent Tall Spikerush (*Eleocharis sphacelata*), and species of Water Milfoil (*Myriophyllum* spp).

In small embayments around the margins of the water body the floating leaves and yellow flowers of the attractive Water Snowflake (*Nymphoides geminata)* grow. Free floating plants of Starwort (*Callitriche* sp.) and the fern *Azolla* sp. may be found amongst the waterlily leaves. In the large embayment on the southern side of the pondage, there are small islands and large mats of floating vegetation. Plant species associated with the islands include the Water Primrose (*Ludwigia peploides* ssp *montevidensis*), River Buttercup (*Ranunculus inundatus*) Swamp Starwort (*Stellaria angustifolia*). The floating mats consist chiefly of Parrots Feather (*Myriophyllum aquaticum*), with some Nardoo (*Marsilea mutica*). There are also some relatively small areas of marsh habitat at Bong Bong that are dominated by the native sedge *Carex gaudichaudiana* (Lembit 1988) and the introduced Creeping Buttercup (*Ranunculus repens*).

Fauna

The following information on the avifauna of the Wingecarribee River wetlands has been extracted from a report prepared by Mr Phil Straw for the Water Board in 1992. During dry periods the major river channel is the only wet area in the valley apart from Bong Bong Weir pondage and Tryees Dam and only small populations of Pacific Black Duck, the occasional White–faced Heron and Little Pied Cormorant are found away from the pondage and dam. Clamorous Reed Warblers live in the reed (*Phragmites australis*) beds below the Wingecarribee reservoir. Kellys Swamp regularly attracts small numbers of Pacific Black Duck, Black Swan, White–faced Heron, and Large Egret. Other species periodically associated with this wetland are Black–winged Stilt, Ibis, Little Pied Cormorant and Marsh Harriers. During times of flood or bulk water transfers down the River, the Swamp is used by large numbers of all the foregoing species.

Tyrees Dam and the adjacent small perched dam attract moderate to high numbers of wildfowl although at the time of the survey emergent aquatic plants were sparse. However a good growth of submergent plants was evident. High numbers of Hoary–headed Grebe and Grey Teal were observed and a flock of Eurasion Coot, disproportionately large for such a small area, were observed.

An island near the poplar plantation immediately upstream of the Cecil Hoskins Nature Reserve appears to be an important habitat for large numbers of duck and Eurasion Coot. The trees of the island and southern shore are a preferred habitat for night herons which may breed in the area. An area around

the island to the north and west forms a shallow wetland dominated by low emergent vegetation. This area is favoured by swamphen and as a nesting site for Black Swans.

Within the Reserve, egrets, spoonbills and herons are nearly always present in small numbers feeding along the shallows and margins of the main water body while most duck species congregate in large numbers upstream where there are larger expanses of open water. The large areas of emergent plants, floating and submerged vegetation of the Reserve provide ideal conditions for waterbirds to feed and nest, in particular Purple Swamphen and Eurasian Coot. Other waterbirds found nesting in this vegetated area include Musk Duck, Great Crested Grebe and Black Swan. Black Duck were observed nesting in the reserve in the dense vegetation bordering areas of the northern shore. A number of other bird species have been observed in the Nature Reserve periodically and these are noted in Appendix A of Straw's report.

3.6 Nepean Swamps

The Nepean and Avon Rivers are derived from many small streams and headwater swamps on the Illawarra Plateau, to the south-east of the Woronora Plateau. Throughout the upper Nepean and Avon Rivers catchments swamps have developed on low gradient slopes, drainage lines, and seepage zones on steeper slopes, and are similar in their genesis, floristics and ecology to the Woronora dells.

The upland swamps or "dells" of the Illawarra and Woronora Plateaux, so-called by Young (1982) in reference to their similarity to those phenomena termed "dellen" by German geomorphologists, are a prominent feature of the Plateaux but are less common on both plateaux west of the 1200mm isohyet. The Illawarra and Woronora Plateaux slope gently upward in a southeasterly direction, from 100 metres elevation at the Nepean River to 300 metres at the crest of the Illawarra Escarpment near Coalcliff to 550 metres near Robertson in the south. The major rivers flow in the direction of maximum dip of the Hawkesbury Sandstone, which generally corresponds to the Plateau surface (Young, 1982). The average slope is less than 1° over a distance of 15-25 kilometres (Young and Johnson, 1977). The portion of the Woronora Plateau that is north of the Cataract Dam catchment, forms the catchment of the Georges and Woronora Rivers and is outside of the Nepean-Hawkesbury catchment. Thus the swamps of the Darkes Forest area and O'Hares Creek catchment are not included in this study.

The swamps occur only on the Hawkesbury Sandstone, which provides a surface of low permeability, and water, from groundwater seepage through the joints in the sandstone and from precipitation, contributes to the development and maintenance of the swamps. A bed of peat is formed under many of these swamps and thus they may termed 'mires'. Radiocarbon dates for Martins Swamp, Drillhole Swamp, Loddon River and Dahlia Swamp on the Woronora Plateau, suggest basal ages of up to about 17 000 years, which correlates well with Hollands (1974) results for the Blue Mountains sedge swamps.

The vegetation of the Upper Nepean Catchment swamps is similar to that described by Keith and Myerscough (1993) in the swamps near Darkes Forest area to the north and the communities described below correspond to the five communities identified in that area, i.e. Ti–tree Thicket, Cyperoid Heath, Restioid Heath, Sedgeland and Banksia Thicket. The spatial distribution of the communities within the swamps is clearly related to the hydrological, and thus sedimentological processes. Ti–tree thicket of *Leptospermum juniperinum* and *L. grandifolium* with *Melaleuca squarrosa*, *Banksia robur*, flourishes on the deeper waterlogged sediments of the main drainage lines with areas of the large sedges (Cyperiod Heath), *Lepidosperma limicola* and *Gymnoschoenus sphaerocephalus* bordering the drainage lines. Button Grass (*Gymnoschoenus sphaerocephalus*) is a major constituent of the vegetation of most of the upland swamps on sandstone, particularly those of the Woronora Plateau, Blue Mountains, Boyd Plateau and Penrose swamps, the Budderoo Plateau south of Roberston and the Hornsby Plateau to the north of Sydney (Buchanan, 1980).

As the slope increases smaller cyperaceous and restionaceous sedges, characterised by *Empodisma minus* and *Lepyrodia scariosa* form an open sedgeland. *Sprengelia incarnata*, species of *Boronia* and *Blandfordia nobilis* (Christmas Bells) are found in the sedgeland. A wet heath community (equivalent to Keith's Restiod Heath) of *Banksia oblongifolia, Hakea teretifolia,* with *Petrophile pulchella* and *P. sessilis*, with smaller shrubs forms an open and patchy stratum on areas that are periodically dry. *Banksia paludosa* grows here also, close to the northern limit of its coastal distribution. The common sedges in this community are *Empodisma minus, Leptocarpus tenax, Lepyrodia scariosa, Schoenus brevifolius* and *Ptilantheum deusteum*. Banksia Thicket of *Banksia ericifolia* and the single–stemmed form of *Hakea teretifolia* forms a tall and dense community on damp soils around the larger swamps. The occurrence of any these communities is modified by their fire history.

Fire is an important influence on the swamp vegetation on the dells: Consett Davis (1941) described the quick regrowth of the swamp plants after fire. However, frequent fire may affect the distribution of communities within the swamp boundaries and weaken eucalypts causing retreat of the woodland boundary. Burning may encourage or impede the development of a shrub stratum depending on regime.

Two of the larger swamps in the Upper Nepean catchment are part of the complex of headwater swamps for the Avon and Nepean Rivers. These swamps known as North Pole and Stockyard form horseshoe shaped `amphitheatres,' harvesting and storing groundwater and atmospheric moisture, from the highland mists as well as from rain, over a wide area which then narrows towards the outlet, channelling the water to form streams.

Conservation and Management

The swamps of the upper Nepean catchment are of great value for their role in harvesting, storing and channelling both groundwater and precipitation to the Nepean, Avon, Cordeaux and Cataract Rivers. The species–richness of the upland swamps of the northern Woronora Plateau were found by Keith and Myerscough (1993) to be among the highest values in the world for shrub/sedge dominated vegetation, with upto 70 vascular plant species in 15 square metres and it is likely that the upper Nepean swamps are similarly high in species richness. This richness is inversely related to the resource gradient (Keith and Myerscough, 1992) and may be enhanced by fire which, for a short time reduces competition for resources, in particular light, (Keith 1991), promoting the establishment of species that may be competitively excluded in an older communtity. In these swamps, and their surrounding woodland, directional changes in the vegetation are primarily propelled by fire regime and conversely the maintenance of high species richness is dependent on the disturbance caused by fire. However knowledge of the fire responses of individual species is poor, particularly in the wetter habitats. Keith (1991) proposed a model to provide a framework for fire management as a conservation tool for upland swamps and he points out that the scale of fire mosaics is crucial in the survival of particular species, but that mosaic patterns are difficult to maintain due to the problems of controlling wildfires. Keith's model predicts that in the short–term, species diversity may be maintained by fires at "intermediate intervals (*ca.* 12–25 year intervals)". The model also predicts that occasional and short fire intervals are necessary to maintain full diversity in wet and dry habitats respectively and that the replacement of

eucalypt woodland by swamp vegetation may be hastened by frequent fires across their boundary.

3.7 Warragamba Swamps

Three areas of upland wetlands occur in the western portion of the Warragamba Catchment Area. These swamps, known locally as the Bindook Swamps, Tomat Swamps, and Mootik Swamps, are at altitudes of 800–900 metres. These swamps are formed on drainage lines and depressions on generally infertile soils derived from Triassic and Permian sandstones. The The Shoalhaven Group sandstones are a residual capping on the Bindook Highlands, giving rise to relatively infertile and "hardsetting sandy loam yellow texture soils" (Fisher & Ryan, 1993). Residual cappings of the Permian Illawarra Coal Measures occur on the Mootik Plateau above the Shoalhaven Group sandstones.

The vegetation of the swamps consists of a discontinuous shrub layer over a herb layer dominated by species of the families Restionaceae and Cyperaceae. Shrub species include *Grevillea acanthifolia, Leptospermum polygalifolium, Lepyrodia searioc, L. Multrflora, L. grandifolium, Callistemon pallidus, Hakea dactyloides, Epacris microphylla* and *Bauera rubioides*. Species of the herb layer include *Lepyrodia scariosa, Empodisma minus, Lepidosperma limicola, Geranium solanderi* and *Themeda australis*. Scattered clumps of *Gahnia sieberana* also occur in some swamps. Fisher and Ryan, 1993 have mapped one of the Tomat Heights swamps as the Random Swamp Scrub vegetation unit and this appears to be similar to other swamps in the area with the exception of the stunted Eucalyptus mannifera that is an occasional emergent at Random Swamp.

Conservation and Management

The Warragamba Swamps are wholely contained in the Warragamba Water Catchment Area, and management and protection of the Area is the joint responsibility of the Water Board and the National Parks and Wildlife Service. Disturbance in the water catchment is minimised in order to optimise water quality. There is minor disturbance to the Warragamba Swamps from access tracks and grazing in some of the swamps. Wild pigs cause substantial, but generally localised, loss of vegetation although the resulting erosion may affect water quality in in Lake Burragorang.

3.8 Boyd Plateau Bogs

These wetlands occupy shallow headwater valleys in the undulating surface of the Boyd Plateau, above 1100m altitude. The substrate of the swamps is a dark brown peaty layer of only partly decomposed plant material including *Sphagnum* moss, overlying granitic rocks. The Boyd Plateau Bogs are related to the alpine and subalpine bogs of the Southern Tablelands, as evidenced by the presence of species such as *Sphagnum* sp., *Wahlenbergia ceracea*, *Celmisia* sp. aff. *longifolia* (Keith and Benson, 1988), and *Callistemon sieberi* (Alpine bottlebrush) (Harris, 1970).

The swamps support closed sedgelands and tea–tree thickets. Species found in the sedgeland are; *Carex appressa*, *C. gaudichaudiana*, *Juncus holoschoenus* subsp. *fockei*, *Restio australis*, *Xyris ustulata*, *Agrostis hiemalis*, and *Deyeuxia gunniana*. Herbs growing in these areas include *Patersonia fragilis*, *Asperula gunii* and *Geranium neglectum*, and emergent shrubs include *Epacris paludosa*, *Hakea microcarpa* and *Baeckea utilis*. The tea–tree thickets are generally composed of *Leptospermum myrtifolium*, *L. lanigerum*, *L. obovatum* and *Callistemon sieberi* flourish. Around the drier swamp margins, relatively open areas support *Empodisma minus*, *Lepidosperma filiforme*, *Amphipogon strictus*, *Wahlenbergia ceracea* and *Helichrysum bracteatum* (Keith and Benson, 1988; this study).

Rare Plants

Two plant species of the Boyd Plateau Bogs are recognised as vulnerable: *Boronia deanei* (local endemic), and *Wahlenbergia ceracea* (local disjunct population).

Conservation and Management

The Boyd Plateau Bogs are wholely preserved within Kanangra–Boyd National Park but many have been affected by past grazing practices. Rehabilitation, including rare plant protection, is the main management concern (Gellie, unpubl.).

3.9 Cox's River Swamps

Where creeks that drain the Triassic sandstone plateaux of the western Blue Mountains deposit their sediment load at the base of the escarpment, a number of swamps have developed along the watercourses. The swamps occur above 600 metres elevation in valleys and headwaters of creeks, and are filled with rather clayey, organic sediments derived from the Permian Illawarra Coal Measures (Keith and Benson, 1988). The distribution of the Cox's River Swamps is naturally restricted: they occur chiefly in the cliff-lined upper valleys of the upper arms of the Cox's River system, at Kerosene Creek (Hartley Vale) and in the Megalong Valley below Nellies Glen (Keith and Benson, 1988; Gellie (unpubl.).

The vegetation consists of a shrub layer of variable density with a dense groundcover. Characteristic shrub species include *Leptospermum obovatum*, *L. continentale*, *L. polygalifolium* and *Grevillea acanthifolia*; the ground layer species include *Carex* spp. and *Juncus* spp. (Keith and Benson, 1988; Benson and Keith, 1990). Benson and Keith (1990) describe a sedgeland of *Carex gaudichaudiana* and *C. fascicularis* with herbs including *Viola caleyana*, *Stellaria angustifolia*, *Hydrocotyle triparitita*, *Mitrasacme serpyllifolia*, *Epilobium billardieranum* subsp. *hydrophylla*, *Utricularia dichotoma* and grasses such as *Poa labillardieri* and *Deyeuxia quadriseta*. *Sphagnum* moss was found by the authors in some wetlands on the upper Coxs River and Nellies Glen.

The swamps near Nellies Glen are filled with sediments rather richer in sand and the vegetation is more diverse, with *Leptospermum polygalifolium*, *L. obovatum*, *L. juniperinum*, *Epacris pulchella*, *Callistemon paludosus*, and *Hakea salicifolia* forming the shrub component. The ground layer here includes several species of the Cyperaceae/Juncaceae families, including *Juncus articulatus*, *Schoenus melanostachys*, and *Schoenus nitens*. In addition to those species listed above, Gellie (unpubl.) records *Epacris paludosa*, *Acacia dorothea*, *Gahnia clarkei*, *Baumea* sp. and *Empodisma minus* for these swamps on Permian Valley sediments.

Fauna

Birds occurring in the Coxs River Swamps include New Holland Honeyeater (*Phylidonyris pyrrhoptera*), Yellow-faced Honeyeater (*Lichenostromus chrysops*), Eastern Spinebill (*Acanthorhynchus tenuirostris*), Brown Thornbill (*Acanthiza pusilla*), Striated Thornbill (*Acanthiza lineata*), Variegated Wren (*Malurus lamberti*), and Southern Emu Wren (*Stipiturus malachurus*). Mammals include Swamp Rat (*Rattus lutreolus*), Bush Rat (*Rattus fuscipes*), Brown Antechinus (*Antechinus stuartii*) and Dusky Antechinus (*Antechinus swainsonii*) (Blue Mountains City Council, 1989).

Conservation and Management

The restricted occurrence of the Coxs River swamps is evident in Gellie's (unpubl.) estimate of only 175 Ha for the total area of this wetland type. These swamps remain largely unprotected; they are not represented in any local reserves (Benson and Keith, 1990). Grazing, leading to invasion of exotic species and trampling by stock is the most significant impact observed by the authors. Management problems listed by Gellie (unpubl.) are clearing of catchments, grazing, too-frequent burning, and feral animals, especially pigs. The Cox's River swamps are also "frequently affected by hydrological changes due to underground mining operations" (Gellie, unpubl.). The Dusky Antechinus is particularly dependent on the type of habitat provided by these wetlands, as its habitat tolerances are narrow resulting in disjunct populations on "islands" of suitable habitat. Active conservation, including where possibly, rehabilitation, is needed to ensure the survival of this group of wetlands and their dependent fauna.

3.10 Blue Mountains Sedge Swamps

These swamps, are also known as 'hanging swamps' because they are frequently found on steep slopes. They occur in the plateau valleys of the Blue Mountains below 1000 metres altitude, on the Triassic rocks (mainly sandstones) of the Narrabeen Group. Claystones within the sandstone beds act as aquicludes, controlling the movement of groundwater and therefore the development of the swamps. The swamps `hang' down the valley sides below the claystones where groundwater is forced to the surface of the slope. This process and the development of valley segmentation is described in Holland et al (1992a & b). The swamps occupy various positions within each valley, some on the broad basal depressions where sediment is deposited due to the

reduced gradient. These valley–floor sediments contain a black to grey sandy–peaty fill, sometimes with small quartz pebbles. The depth of this fill ranges up to 2.7 m, with basal dates of about 4,110–17,000 years B.P.(before present), suggesting that deposition began in the Holocene and late Pleistocene (Holland, 1974). Sedimentation rates of 0.1–0.3mm/year over the ensuing period have been recorded by Holland and Stockton (1974) for 5 swamps in the Blue Mountains.

The soils of valley–sides are shallow (rarely exceeding 30 cm, although ranging to 150cm where localised depressions or `alluvial bulges' (Holland et al 1992, and Glossary) occur. Soils are a sandy matrix with varying proportions of organic material, giving a black to grey appearance (Holland, 1974) and pebbles. On both valley–side and valley–floors, water is retained by the peaty soil and the relatively impermeable sandstone beneath it for longer periods determined by slope gradient and aspect.

The ecotone between the woodland of the ridgetops and upper slopes, and the swamps, is abrupt, and generally follows the upper edge of the claystone beds. Slope aspect, gradient and fire regime influence the development ofthe vegetation communities. Generally the permanently waterlogged areas are occupied by a closed sedgeland of large sedge species characterised by *Gymnoschoenus sphaerocephalus*, *Lepidosperma limicola*, *Empodisma minus*, *Xyris ustulata* (Keith and Benson, 1988), *Goodenia bellidifolia* and *Drosera spathulata* (Gellie, unpubl.) with occasional shrubs of *Baeckea linifolia*, *Leptospermum lanigerum*, *Acacia ptychoclada* and *Pultenaea divaricata* (Keith and Benson, 1988). Tea–tree thickets are also common in the permamnent swamps of the Blue Mountains, with a closed canopy of *Leptospermum* species and *Callistemon citrinus*. The parts of the valleys that dry out periodically support a community of smaller sedges including *Ptilanthelium deustum*, *Leptocarpus tenax*, *Empodisma minus* and *Lepyrodia scariosa*. Shrubs of *Hakea teretifolia*, *Leptospermum squarrosum*, *Epacris obtusifolia*, *E. microphylla*, *Sprengelia incarnata*, *Hibbertia cistiflora*, *Dampiera stricta*, *Pultenaea incurvata* and the endemic *Grevillea acanthifolia*.

Two species of Christmas Bells are often found in the sedge swamps or in areas of seepage on rock ledges. The coastal species *Blandfordia grandiflora* is found in the lower and middle Blue Mountains but is replaced by *B. cunninghamii* in the upper Blue Mountains.

Rare Plants

According to Keith and Benson (1988), plant species of particular conservation significance in the Blue Mountains sedge swamps are *Pultenaea glabra,* the local endemic species *Pultenaea incurvata*, *Acacia ptychoclada* and a local disjunct population of *Xanthosia dissecta* at Wentworth Falls). The shrub *Grevillea acanthifolia*, is endemic to the upper Blue Mountains and grows in the periodically dry soils of headwater swamps.

Fauna

The dense plant cover of the sedge swamps provides particularly good nesting sites, food and shelter for a variety of fauna. Birds include the Tawny Grassbird (*Megalurus gramineus*), the Beautiful Firetail (*Emblema bella*) (Mosley, 1989), New Holland Honeyeater (*Phylidonyris pyrrhoptera*), Yellow-faced Honeyeater (*Lichenostromus chrysops*), Eastern Spinebill (*Acanthorhynchus tenuirostris*), Brown Thornbill (*Acanthiza pusilla*), Striated Thornbill (*Acanthiza lineata*), Variegated Wren (*Malurus lamberti*), and Southern Emu-Wren (*Stipiturus malachurus*) (Blue Mountains City Council, 1989). Mammals probably include Dusky Antechinus (*Antechinus swainsonii*), Swamp Rat (*Rattus lutreolus*), Bush Rat (*Rattus fuscipes*), Brown Antechinus (*Antechinus stuartii*), Common Dunnart (*Sminthopsis murina*), and Potoroo (*Potorous tridactylus*) (Jelinek, 1978). Mt King Ecological Surveys (1990) report the Brown and Dusky Antechinus, the Bush and Swamp Rat and a bandicoot from wetland habitats. Snakes likely to be found in or near the swamps are the Copperhead (*Austrelaps superbus*) and Black Snake (*Pseudechis porphryiacus*) frogs include the Brown Toadlet (*Pseudophryne bibronii*), the Bleating Tree Frog (*Litoria dentata*), and the Leaf Green Tree Frog (*Litoria phyllochroa*) (Jelinek, 1978). Freshwater crayfish (yabbies) are a common inhabitant of most Blue Mountains wetlands.

Conservation and Management

A large proportion (78%) of the total 1675 Hectares of the Blue Mountains sedge swamps is conserved in the Blue Mountains National Park (Gellie, unpubl.). However, swamps are vulnerable to water-borne sediments and pollutants from development in their catchments. Development outside the National Park can cause severe impacts on the swamps inside the Park boundary, such as siltation and pollution. Impervious sandstone layers can carry effluent from septic absorption trenches to a swamp before the wastes are

purified. The effluent carries microorganisms and contaminants that downgrade water quality, and nutrients that increase the fertility of the soil and thereby encourage weed invasion. Blackberry and Broome are particularly troublesome weeds in this area, (Blue Mountains City Council, 1989).

Drainage works that concentrate water flow into a swamp may cause it to slide off the slope under its own weight of absorbed water. Diversion of water supply away from a swamp may lead to the desiccation of the swamp and the death of the wetland. Both types of interference with the hydrology lead to a reduction in the swamp's capacity to fulfil its flow dispersion and purification functions. The ultimate consequence is erosion, increased turbidity, and siltation of the river environment downstream, as well as disturbance to the vegetation communities downstream from the swamp (Blue Mountains City Council, 1989), and loss of local biodiversity.

Regular burning poses another threat by favouring the graminoid species that regenerate quickly by vegetative means after fire. Many shrub species are killed by fire, and can regenerate only from seed. If burning is too frequent, these young plants are unable to mature and set seed before the next fire and the species is lost from the area. As a result of too-frequent burning, shrub species may become locally extinct. Burning may also destroy part or all of the underlying peat that supports the vegetation. Populations of the Dusky Antechinus are susceptible to fire, and their habitat highly disturbed. Recolonisation by the Dusky Antechinus is slow and poor if regular burning is continued (Blue Mountains City Council, 1989).

3.11 Newnes Plateau Shrub Swamps

North of Lithgow, the Blue Mountains Plateau is rather less dissected than in the east. This landform unit, known as the Newnes Plateau, is formed of the shales, sandstones, and tuff of the Triassic Narrabeen Group rocks. In the shallow headwater valleys of the Newnes Plateau above 1000 m elevation, wetland communities have developed on poorly drained, acid, sandy peat soils (Keith and Benson, 1988).

A number of variants on the basic Newnes Plateau Shrub Swamp vegetation type exist, developed in response to local soil and other conditions such as the degree of waterlogging and fire history. According to Keith and Benson (1988), the characteristic members of the closed heath community are *Leptospermum grandifolium, Baeckea linifolia, Grevillea acanthifolia* and

Epacris paludosa. The ground layer is composed mainly of graminoid plants including *Xyris ustulata, Restio australis, Empodisma minus, Lepyrodia scariosa, Lepyrodia anarthria, Lepidosperma limicola* and *Patersonia fragilis*. Dense growths of *Gymnoschoenus sphaerocephalus* and *Gleichenia dicarpa* develop in the most waterlogged areas near drainage lines. In more open areas, herbs such as *Hydrocotyle acicularis, Viola hederacea, Gonocarpus tetragynus* and *Xanthosia dissecta* grow (Keith and Benson, 1988).

During the survey conducted for this study, more species were identified in addition to those listed above, and including *Leptospermum juniperinum, Leptospermum myrtifolium, Baeckea utilis, Baeckea diosmifolia, Epacris microphylla, Epacris pulchella, Callistemon sieberi* and *Bossiaea lenticularis*; the herbs *Helichrysum scorpiodes, Geranium neglectum, Gonocarpus micranthus, Stylidium* sp., *Myriophyllum propinquum, Hydrocotyle* sp., *Xyris gracilis* ssp. *gracilis, Patersonia sericea*; the sedges *Lepidosperma linifolia, Lepidosperma longitudinale, Gahnia subaequiglumis,* and the clubmoss *Lycopodium* sp.

Inspection of the above species list indicates that the plants growing in the Newnes Plateau shrub swamps vary considerably in their environmental requirements, and that a variety of vegetation subtypes may exist in response to local conditions. One case, described by Keith and Benson (1988) and surveyed by the authors, is a community growing on soils with a relatively high clay content. The species growing here also grow on the granite–derived soils of the Boyd Plateau and include *Leptospermum myrtifolium, L. polygalifolium, Callistemon sieberi* and *Juncus continuus* (Keith and Benson, 1988).

Rare Plants

Two rare plant species, *Olearia quercifolia* and *Isopogon prostratus* are listed by N. Gellie (unpubl. report) for the Newnes Plateau Shrub Swamps. *Boronia deanei,* occurs near Newnes in addition to its main occurrence on the Boyd Plateau (Keith and Benson, 1988); *Dillwynia stipulifera, Celmisia* sp. nov. aff. *longifolia* and *Eucalyptus gregsoniana* are locally restricted to swamps on the Newnes Plateau, but occur also in the Budawangs (Benson and Keith, 1990).

Fauna

The fauna of the Newnes Plateau appears to be poorly known. Eastern Grey Kangaroos and Wallaroos frequented the area during this survey. Other species likely to inhabit the Newnes Plateau shrub swamps are those listed in the description of the `Blue Mountains Sedge Swamps'.

Conservation and Management

A small proportion of the 823 hectares of the Newnes Plateau Shrub Swamps is conserved in Wollemi National Park (12%) and in Blue Mountains National Park (3%) (Gellie, unpubl.). However, the conserved examples are small and none of the larger swamps on the Newnes Plateau to the north are protected (Keith and Benson, 1988). The Plateau is also used by State Forests of NSW for a major pine plantation, although no new planting has taken place over the last few decades (Mosley, 1989). However, swamps near the Newnes State Forest are prone to invasion by *Pinus radiata* seedlings from the plantation (Gellie, unpubl.), and some swamps have been disturbed by siltation and runoff (Benson and Keith, 1990). Sand mining on the Plateau is also carried out at a number of quarries close to the boundary of the Blue Mountains National Park (Mosley, 1989). Expansion of the sand mining industry poses a significant threat to the swamps of the Newnes Plateau (Benson and Keith, 1990).

3.12 Upper Capertee Valley

The upper reaches of the Capertee River and its tributaries flow through a broad, undulating valley before entering the gorges of the Blue Mountains Plateau to the southeast. Erosion of the Narrabeen Group rocks of the Plateau has left a spectacular line of cliffs and more or less isolated mesas that enclose the eastern side of the upper Capertee Valley. Sedimentary rocks of the Illawarra Coal measures form steep, often forested, slopes at the base of the cliffline. The hills to the west are of much older Devonian sedimentary and volcanic rocks. The Permian sedimentary rocks of the Shoalhaven Group, and Quaternary alluvial deposits form the valley floor. The Capertee Valley wetlands have developed on these riverine deposits.

Little wetland vegetation remains as almost the whole valley floor has been cleared for agriculture. Watercourse margins that are protected from grazing support stands of *Eleocharis* and *Typha* species. Where the watertable occurs close to the surface, species of *Juncus* and *Ranunculus* grow on brown to black silty clay sediments. These communities are grazed and heavily invaded by pasture grasses. They almost certainly supported many more native species prior to clearing for agriculture. Indeed, no fringing vegetation survives around some of the more heavily grazed wetlands.

Conservation and Management

The heavy use of fertiliser and the severe rill and gully erosion throughout the valley is likely to be causing increases in nutrient concentrations and sedimentation in wetland waters. The consequences of these processes can be seen in the heavily disturbed wetlands, although the extent of effects downstream may be more subtle and far–reaching. Crown Swamp in the south of the valley, although intermittently grazed, is probably best protected from these impacts because its catchment is still largely forested. No conservation reserves exist in the Capertee Valley, although Crown Swamp is contained within a wildlife refuge.

3.13 Mellong Swamps

The plateau surface of Hawkesbury Sandstone and Narrabeen group rocks forms part of the larger Hornsby plateau. The streams of the Mellong Plateau flow westwards, against the regional dip. The Lapstone Monocline may be the cause of this as yet unexplained phenomenon (Mosley, 1989). Where water collects along drainage lines in broad shallow valleys, grey sandy sediments have been deposited with varying amounts of clay. A loose, dark reddish–brown organic layer has accumulated on top of these Quaternary deposits, that are up to 10 m deep (Mosley, 1989).

The swamp vegetation occurs in a convoluted pattern, interfingering with woodland, and consists of a 2–3 m tall layer of often widely scattered shrubs, over a diverse herb layer dominated by grass–like plants. Shrub species include *Banksia spinulosa, Leptospermum continentale, L. juniperinum, Melaleuca thymifolia,* and *Isopogon anemonifolius*. In some areas, the shrubs form a very minor component, being often replaced by *Xanthorrhoea* sp. Common species of the herb layer include *Ptilanthelium deustum, Leptocarpus tenax, Lepyrodia scariosa, Xyris complanata* and *Gonocarpus tetragynus*. Other species to be

found in the ground layer include *Utricularia lateriflora, Patersonia glabrata, Drosera spathulata, Eriocaulon scariosum, Haemodorum planifolium, Dianella* sp., *Dampiera stricta, Goodenia bellidifolia, Schoenus apogon, Themeda australis, Axonopus affinis, Eragrostis leptocarpa, Imperata cylindrica, Paspalum distichum, Panicum simile, Lomandra sp.,* and *Philydrum lanuginosum*. Where there are deeper pools of water (usually along creek lines), communities of the emergents *Eleocharis sphacelata,* (Tall Spike–rush) and *Typha orientalis* (Cumbungi), grow fringed by the rushes *Juncus planifolius, J. prismatocarpus*. Occasionally thickets of Tea Tree (*Leptospermum* sp.) and Native Broom (*Viminaria juncea*) occur on swamp margins or along watercourses.

Conservation and Management

Approximately 2400 Ha. of the Mellong Swamps remain. They are affected by frequent burning that has led to a reduction in the dominance of the shrubs in favour of the herb layer (Gellie, unpubl. report). Other impacts include weed invasion, roadworks, reclamation, grazing, and past logging.

FRESHWATER LAGOONS

3.15 Glenbrook Lagoon

Around the turn of the century a dam was formed across a drainage depression at Glenbrook to form a lagoon as a water storage for steam trains (Mike Eades, Blue Mountains City Council, pers comm.). Unfortunately there does not appear to be any description of the vegetation of this area prior to the construction of the low dam. Today this depression in the sandstone plateau is an open water lagoon supporting a variety of submergent and emergent wetland plants. The catchment of the Lagoon has been developed primarily as a residential area but retains a bushland buffer on its northern side. Although the catchment is sewered and the roads sealed, there are stormwater drains entering the Lagoon and the urban run-off carried by these drains has undoubtedly brought nutrients and silt from the catchment to the Lagoon.

The most obvious botanical feature of the Lagoon is the sage-green fringe of the giant sedge *Lepironia articulata* that encircles the open water. Growing amongst the three metre high *Lepironia* are other emergent sedges to about two metres in height:the Tall Spike-rush, *Eleocharis sphacelata,* the Bulrush, *Schoenoplectus validus,* and the Jointed Twigrush *Baumea articulata.* The open water area supports a variety of submergent plants and floating-leaved plants including water lilies, the Giant Ribbonweed *Vallisneria gigantea* and a number of troublesome aquatic weeds. The aquatic fern *Salvinia molesta* and parrotfeather *Myriophyllum aquaticum* are two of the weed species that are indicative of high levels of nutrients in the Lagoon.

Blue gums and spotted gums provide a backdrop to this attractive Lagoon and the Crimson Bottlebrush, *Callistemon citrinus* and the Paperbark known as Snow in Summer, *Melaleuca linariifolia,* are found in the swampy area to the north of the Lagoon.

Conservation and Management

Although artificially enhanced by construction of the dam and roadway on its eastern side, the Lagoon vegetation is of considerable botanical interest and is of value to the local community for passive recreation and environmental

education. It is used by several local schools for art and science lessons. The Lagoon provides one of the few open water habitats for waterfowl in the Blue Mountains. The problem of aquatic weeds already encountered underlines the urgency of reducing nutrient inputs to this Lagoon before eutrophication causes further changes to the flora and fauna of this unique wetland.

3.16 Mountain Lagoon

On the headwaters of Gospers Creek, about 10 km east of Bilpin is a geomorphically interesting wetland known as Mountain Lagoon. Earth movements associated with the formation of the Lapstone Monocline and Kurrajong Fault may have formed the Lagoon at an altitude of 540 metres by creating a small basin shaped valley. The construction of a road around the perimeter of the Lagoon is likely to have caused further impedance to the drainage. Although the geology of the area is predominantly Hawkesbury Sandstone, the catchment of Mountain Lagoon consists of shales and sandstones of the lower Wianamatta Group. Water levels in the wetland fluctuate widely, apparently depending on rainfall.

The wetland is visually dominated by tall, thick-girthed paperbark trees, *Melaleuca linariifolia,* commonly known as "Snow in Summer". This species will withstand shallow inundation for several weeks although the limit of their tolerance is not well known and is likely to be dependent on the whether the trees are inundated in the growing season or not. The senior author has visited this wetland twice, in October 1989 and again in August 1992 and on both occasions about 40cm of water surrounded many of the paperbarks, although it may have dried out more than once between visits. Some trees had died prior to the first visit in 1989 and the death of parts of the canopies of others was evident on both visits. The healthier trees were those that were positioned on the slight rise above the area of inundation. Under the canopy of the paperbark trees and extending into the standing water are a number of sedges and aquatic herbs. Most abundant of the sedges is *Lepidosperma longitudinale,* with lesser areas of *Baumea rubiginosa* and one of the smaller species of *Eleocharis* (Spikerush). The attractive floating-leaved aquatic Water Snowflake, *Nymphoides geminata* is common here as is Creeping Buttercup, *Ranunculus repens*. The presence of permanently water-logged soils with a relatively high rainfall is indicated by the growth of *Sphagnum* sp. moss and *Selaginella uliginosa*, under the shady canopy of tea-tree (*Leptospermum polygalifolium* and *L.juniperinum*). The rushes *Juncus usitatus* and *J. planifolius* grow on the margins of the standing water.

Conservation and Management

The catchment of the Lagoon is largely cleared for agriculture, although Blue Gum (*Eucalyptus deanei*) woodland remains on the steeper slopes. Grazing and orcharding are the main activities. Within the Lagoon and its immediate catchment there has been disturbance in the past, by fire, clearing and grazing, and these activities have reduced the area of wetland vegetation. Thickets of tea-trees are now regenerating on the land rising to the north and east of the depression, indicating that the paddocks now enclosing the Lagoon may once have supported teatree brush. The unusually large *Melaleuca* trees suggest that at least part of the Lagoon has not been burnt for many years. It appears that grazing in the area is now more limited than in the past and this will allow the regeneration of the wetland vegetation to continue and its floristic relationships to be established.

3.17 Thirlmere Lakes

The Thirlmere Lakes are a series of 5 elongated, shallow bodies of water lying in a horse-shoe shaped bend in an ancient river valley of Hawkesbury Sandstone, at an elevation of 300 metres. Earth movements have left this section of the watercourse perched above normal levels of erosion, isolating it from the main river system. Infilling by mud and sedges have led to the development of a small chain of lakes. It has been suggested that the Thirlmere Lakes have changed very little since the Pleistocene. The limited catchment of the lakes and the nature of the Hawkesbury Sandstone have probably been important factors in this slow rate of siltation (NSW National Parks and Wildlife Service, 1979). The maximum depth of the deepest lake is 6 metres. Three of the lakes are interconnected by artificial canals, and when water levels are high, water flows through the whole system (Timms et al., 1983).

The lakes have extensive growths of aquatic plants, mainly the tall sedge *Lepironia articulata* (here at the southern limit of its range) and the floating-leaved aquatic *Brasenia schreberi*. The sedges *Eleocharis sphacelata* and *E. atricha* also occur here. Two unusual free-floating submerged species grow here, *Lemna trisulca* (Pondweed) and a species of *Utricularia* (Bladderwort). The vegetation of the lake margins includes the rush *Restio gracilis*; the sedges *Schoenus brevifolius*, *S. melanostachys*, *S. villosus*, *Isolepis inundata*, *I. fluitans*, *Lepidosperma longitudinale* and *L. laterale*. The small tree *Melaleuca linariifolia* also grows on the dry fringes of the lakes.

The rare freshwater sponge *Radiospongilla sceptroides* is present in Thirlmere Lakes and only a few other locations within the adjacent proclaimed catchment area (NSW National Parks and Wildlife Service, 1979). It once grew abundantly from the shores to the bottom of the lakes, but had declined by the late 1970's. This sponge species is unusual in that it produces its own green pigment. Another feature of particular ecological interest is the absence of gemmules, structures that allow the species to survive unfavourable conditions in a dormant state. This absence of gemmules reflects the perennial status of the Thirlmere Lakes (NSW National Parks and Wildlife Service, 1979).

Fauna

The invertebrate community of Thirlmere Lakes has many similarities with coastal dune lakes, in particular species composition and community structure. These similarities can be attributed to the similar water chemistry arising from the superficially similar soils of the two types of lakes (Timms *et al.*, 1983). Some typically dune lake water flea species (Cladocerans) live in Thirlmere Lakes. Another feature in common with dune lakes is the low density of molluscs and certain types of crustacean (Ostracods) (Timms *et al.*, 1983).

The introduced Mosquito Fish *Gambusia affinis* is present in Thirlmere Lakes. This pest species may have been responsible for the decline or absence of certain groups of aquatic insects, crustaceans and two fish species (Stanisic, 1972; Timms, 1983). In the past, a Cat Fish (*Tandanus tandanus*) and at least three other native fish species have been recorded from the lakes, but recent surveys have found only Mosquito Fish (NSW National Parks and Wildlife Service, 1979).

Conservation and Management

The Thirlmere Lakes are of particular conservation importance because of their unusual origin and unique biology. They cover an area of about 50 hectares, and are wholely conserved within Thirlmere Lakes National Park. This 627 hectare Park also includes a large portion of the catchment of the lakes.

There are parking and picnic areas on the edges of Lakes 2 and 3. Powerboating and water skiing are the main recreational activities on Lake 2, while swimming and canoeing are the main activities on Lake 3 (NSW National Parks and Wildlife Service, 1979). Petroleum slicks, most probably from motorised boats, have been observed around the margins of Lake 2

(Steve Smith, NPWS, pers. comm. 1991). The effects of these on the ecology and water quality of the lakes are little known, although some lead has accumulated in the sediments of Lake 2, but not at hazardous levels. It has therefore been recommended that unleaded fuel be used for powerboating in Thirlmere Lakes (Horsfall *et al.*, 1988).

A study of benthic invertebrates (Timms *et al.*, 1983) showed higher standing crops in Lakes 2 and 3, probably associated with higher nutrient levels in these lakes resulting from human disturbance. Higher nutrient levels may explain the elevated phytoplankton biomass in Lake 2 that has probably contributed to the higher benthic standing crop there (Horsfall *et al.*, 1988). It was recommended that "further effort should be made to prevent unnatural entry of nutrients into these lakes" (Timms et al., 1983). In recent years, measures to reduce sediment runoff from the picnic/parking areas, including the laying of turf and restricting vehicle access have been taken (Brian Leahy, pers. comm. 1991).

FLOODPLAIN WETLANDS

3.18 Blue Gum Swamps

In the lower Blue Mountains at about 200 metres elevation, swamps have developed on alluvium in deep sandstone gullies associated with the Kurrajong Fault. The alluvium, that commonly exceeds 2 metres in depth, consists of single-grained sands derived from the Hawkesbury Sandstone, and displays little true soil development (Blue Mountains City Council, 1989). Where the alluvial deposits are poorly drained, swamps have developed on the valley floor. These swamps, known locally as the 'Blue Gum Swamps' occur amongst *Eucalyptus deanei* forest in patches along Long Angle Creek, Fitzgeralds Creek and Frasers Creek.

The high water table has created anaerobic conditions that inhibit decomposition of dead plant material so that peaty layers have developed in the soil, under sandy, humus-rich upper horizons (Gellie, unpubl.).

The stream channel is lined with *Juncus* sp. (gregiflorus group) with some *J. planifolius*, which give way to the fern *Gleichenia dicarpa*, and the sedges *Ptilanthelium deustum*, *Schoenus melanostachys* and *Gahnia* sp. where the ground is less frequently inundated. Shrubs such as *Acacia rubida*, *Banksia oblongifolia*, *Callistemon citrinus*, *Leptospermum continentale*, and *Melaleuca linariifolia* dominate the margins, forming an almost continuous layer.

Fauna

Little is known about the fauna of the Blue Gum Swamps but a study by the Blue Mountains City Council (1989) suggests that the dense vegetation of these Swamps, like that of the other upland sedge and shrub swamps, is likely to provide "particularly rich habitats for small native mammals". The Dusky and Brown Antechinus and some of the native rodents, in particular the Swamp Rat and the Water Rat are likely inhabitants of these wetlands. Snakes, frogs and yabbies undoubtedly find suitable living quarters in and around these wetlands.

Conservation and Management

The restricted distribution of the Blue Gum Swamps, combined with their poor representation in the Blue Mountains National Park makes them particularly vulnerable to disturbance. Most examples of this wetland type are subject to the impacts of urbanisation, hazard reduction burning and off-road driving in their catchments. Some face major siltation as a result of soil disturbance in the catchment and the invasion of weeds promoted by urban run-off from residential areas.

3.19 Colo River Valley

The wetlands of this valley occur on the floodplains of tributaries of the Colo River. In most cases they occupy the greater part of the floor of these side valleys. Wheeny Creek is an extensive wetland system of some 188 ha providing diverse plant and wildlife habitats. Turnbull's Swamp is similar though less extensive.

Several lagoons, including Gees, Gospers, and Greens Swamp, support stands of the 3m high sedge *Lepironia articulata*, that is relatively common in freshwater coastal lagoons of the East Coast, but reaches the southern limit of its distribution in the Sydney Region. Some of the Colo River wetlands have stands of the floating-leaved aquatic plant *Brasenia schreberi*, (Cabombaceae) which provides food for wetland birds. The Lagoons are often structurally diverse in having a tall littoral canopy of paperbarks, *Melaleuca linariifolia* and shrub layer of bottlebrush, *Callistemon* species, including *C. paludosus*, and tea-trees, *Leptospermum* species with a number of sedges and rushes of different sizes in the various depths of water.

Fauna

The Colo Lagoons provide habitat for a wide variety of wetland dependent fauna although some groups, particularly fish and invertebrates are not well known. The dense vegetation around some of the Lagoons and their tributaries is ideal for many ground dwelling birds such as the crakes and rails and Lewin's Water Rail (*Rallus pectoralis*), has been reported in the area of Turnbull's Swamp by the National Parks and Wildlife Service.

Conservation and Management

Each of the Lagoons has its own management issues but generally the prime concern is to protect the water quality of the Lagoons and their tributaries and to protect the integrity of their vegetation. Many of these wetlands retain a high degree of physical integrity with complete vegetation structure and zonation not commonly seen in floodplain wetlands in the Sydney Region.

3.20 Macdonald River Valley Wetlands

The Macdonald River has meandered across the floor of this valley forming a variety of wetlands in old channels and bends. St Albans Common is the largest wetland in this river system and has been used for the grazing of horses and cattle for at least one hundred years. It has been altered substantially by this use and more recently by application of superphosphate for pasture improvement.

There are smaller wetlands along the river floodplain and in most of the side valleys. These wetlands vary in physical integrity with the major impacts being from agricultural uses of the land. Nonetheless they retain important hydrological functions and many provide feeding and breeding areas for birds such as the Black Swan and the Great Egret. The Long-necked Tortoise (*Chelodina longicollis*) is a common animal in the valley.

Conservation and Management

There are several wetlands of high conservation value along the valley floor, including several paperbark (*Melaleuca* species) and sedge swamps that are among the best representatives of this wetland type remaining in the Sydney Region. The uncommon sedge *Cladium procerum* occurs in a small number of brackish wetlands along the lower reaches of the River, and along Webbs

Creek. This tall sedge was found by the authors in only one other wetland in the catchment, and other stands in the Region are small and may not be viable in the long–term. In general the wetlands of the Macdonald River Valley need sympathetic management to ensure that the (primarily) agricultural land uses in these valley are compatible with the viability of the wetlands.

3.21 Hawkesbury Floodplain wetlands

A variety of fluvial processes have led to the formation of the floodplain wetlands. Depositional processes have formed backswamps and ponded tributaries behind stream levees on the aggrading floodplain surface (Pressey and Harris, 1988). The soils of these wetlands, based on the layered alluvial sands, loams and clay sediments of the Hawkesbury floodplain have undergone varying degrees of pedogenesis (soil development). On the active depositional zones of the floodplain, little or no pedogenesis has occurred. The loams and clay soils may be structured or unstructured (Hazelton *et al.*, 1989), and gleyed if permanently or frequently inundated. Where sedgeland grows on very flat areas, a peaty topsoil often develops. At Longneck Lagoon where highly saline groundwater rises to the surface, salt scalds have developed resulting in breakdown of the soil structure and with salt encrusting the surface of the scald.

The wetlands of the Hawkesbury floodplain have been classified into three types by Stricker and Adam (unpubl. report 1990) on the basis of water regime: permanent, semi–permanent, and seasonal wetlands. A single wetland of varying water depths may include all three wetland types. The dependency of the individual wetlands on flood frequency is not well known. Some wetlands receive run–off from their own watersheds and are infrequently inundated by backflooding from the river, while others are apparently entirely dependent on overbank flooding and/or groundwater to maintain their water budget.

The permanent wetlands, as the name suggests, have permanent free surface water and often include areas of open water; the semi–permanent wetlands are inundated for most of the year. Both permanent and semi–permanent wetlands commonly support Tall Spike–Rush (*Eleocharis sphacelata*) as the dominant emergent, and for convenience will be discussed together below.

Many of the floodplain wetlands are low in species diversity as a direct result of clearing of trees and shrubs from wetland margins, to grazing and cropping of wetlands, and in the short-term, partially due to the frequent floods that occured in the in the late 1980's. A discussion of the importance to plant distribution at Bushell's Lagoon of some of these factors is given in Yen and Myerscough (1989). A small number of permanent and semi-permanent wetlands are conserved at Longneck Lagoon, and at Cattai State Park. The vegetation of these wetlands is not as diverse as it was before grazing and the clearing of their catchments, however they retain elements of their previous vegetation structure and provide habitat for fauna.

The vegetation of these wetlands is influenced by soils derived from the underlying shales and gravels and support paperbarks, *Melaleuca linariifolia* and *M. decora*, with emergents *Eleocharis sphacelata*, *Schoenoplectus* (syn. *Scirpus) validus* and the cosmopolitan *Phragmites australis.* A number of the effects of catchment mismanagement are evident at Longneck Lagoon resulting in the decrease of emergent, floating-leaved and submergent vegetation and the increasing occurrence of blue-green algae, (Adam & Murray, 1979 unpubl. species list). Some of the species that have not been seen at Longneck Lagoon in recent years are however still evident at other wetlands such as Pugh's Lagoon near Richmond, for example the nardoo, *Marsiliea mutica* and the water primrose *Ludwigia peploides ssp montevidensis*.

Wetlands supporting paperbark woodland, (primarily *Melaleuca decora* and to a lesser extent *M. linariifolia*), remain at a small number of locations on both sides of the River.

Two uncommon plant species, the sedge *Carex neurochlamys* and the grass *Pseudoraphis paradoxa* have been recorded on the margins of Little Cattai Creek. *Brasenia schreberi*, (Watershield), an aquatic species that is less common here than in the Colo Lagoons, has been recorded in Broadwater Swamp (National Herbarium, Sydney, records).

On the Tertiary sand deposits south of Windsor, are freshwater wetlands displaying the higher diversity typical of oligotrophic wetlands. These wetlands range from paperbark swamps with stands of cumbungi (*Typha* sp.) to open herbfields and have been listed on the register of the National Estate.

Seasonal wetlands are found on floodways and backchannels of the River and are often dry at the surface for most of the year, depending on the pattern and amount of rainfall. *Juncus usitatus* dominates these wetlands, and *Persicaria* spp., *Carex* spp., *Gahnia* spp. and *Bolboschoenus caldwellii* and *Ludwigia peploides* are characteristic of these wetlands. The aquatic fern *Azolla filiculoides* is an opportunistic component of the flora of these wetlands and therefore erratic in its occurence. Blooms of *Azolla* are probably related to high nutrient run-on (Dr S. Jacobs, National Herbarium, Sydney, pers. comm.). Seasonal wetlands are generally the most disturbed, as they are often cropped when dry. However, the seasonal wetlands are resilient and the plant communities will rapidly regenerate with a change in management practice. The highest degree of seasonal wetland integrity is found on the Richmond Lowlands near Richmond and on parts of Cranebrook Creek. However a large area of seasonal wetlands on Cranebrook Channel south of Cranebrook Creek are being excavated for gravel and are being "remodelled" to form the "Penrith Lakes" development.

Fauna

The permanent and semi-permanent wetlands of the Hawkesbury floodplain are of high value as drought refuge for birds (Stricker and Adam, unpubl. report 1990). Pressey (1979) recognises 13 wetlands of the Hawkesbury floodplain as significant waterbird habitat, but only 5 of these have substantial areas of emergent plants or surrounding trees required by the birds for roosting and/or breeding. The bird community using the wetlands varies seasonally as well as according to antecedent weather conditions (e.g.drought). Birds observed on the floodplain include the Great Egret, Little Egret, Plumed Egret, White-necked Heron, Australasian Grebes, Pink-ear Duck, Black Duck and Wood Duck and Grey Teal, Blue-winged Shoveller, Straw-Necked Ibis and a number of migratory wading species including Latham's Snipe. Other fauna groups that may be using the wetlands are less well known and it is recommended that surveys of other faunal groups be carried out to determine their status and relationships with the floodplain wetlands.

Conservation and Management

The high fertility of the alluvial soils and the flat land of the Hawkesbury Floodplain make it one of the most suitable areas for agriculture in the region. Almost all the native vegetation has been cleared, and the majority of the wetlands have been cleared, converted to pasture, grazed and cropped. Where

the exclusion of grazing and other agricultural practices is possible the wetlands are likely to regenerate if nutrients inputs are controlled and in some cases, supplementary planting is undertaken.

Brackish Wetlands

3.22 Brackish Wetlands of the Lower Hawkesbury

Both the River Mangrove, *Aegicerus corniculatum* and the Grey Mangrove, *Avicennia marina* extend along the banks of the Hawkesbury and its larger tributaries as far up river as Bathurst Reach. Where topography is suitable, saltmarshes are found usually landward of mangroves, along the river east of Gunderman. Where freshwater creeks enter the river, Swamp Oak (*Casuarina glauca*) and Paperbark (*Melaleuca* species) forests grow behind the saltmarshes. At some sites a swamp forest of Swamp Mahogany (*Eucalyptus robusta*) and the wattle *Acacia parramattensis* has developed. *Melaleuca ericifolia* is the most common paperbark in this area, with *Melaleuca linariifolia* less common and *Melaleuca styphelioides* grows at a small number of sites.

The lower Hawkesbury wetlands contribute 53.7% of the mangroves of the Sydney Region, 47.5% of the saltmarsh, and 81.9% of the Swamp Oak forest in the Region. Extensive wetlands complexes enhance the habitat, recreational and aesthetic values of the lower River. Wetlands of 40hectares to 160hectares are found near Spencer, Couranga Point and other sites east of Gunderman.

4.0 CONCLUSIONS

Wetlands are one of the more significant features of the Hawkesbury–Nepean catchment and the majority of wetlands, both in number and in area, are found in the headwaters of the many streams that contribute to the Nepean–Hawkesbury River system. These upland swamps are a major determinant of catchment hydrology because they absorb, retain and release groundwater and precipitation in the higher rainfall areas, above 1000 mm average annual rainfall. Quantification of the base flow from key upland swamps would refine our understanding of catchment hydrology, on both a sub–catchment and total catchment basis.

Upland swamps of the Woronora Plateau (Keith & Myerscough, 1993) are among the most species–rich ecosystems in the world at the 1–15 square metre scales, and other upland swamps on the sandstone plateaux that encircle Sydney appear to similarly diverse although not necessarily having species–richness values as high as those of the Woronora Plateau swamps. The upland swamps therefore greatly enhance the biodiversity of the Southern and Central Tablelands. High species–richness is inversely proportional to the resource gradient, with fire, as a disturbance that temporarily reduces competition for resources, such as solar radiation, as a contributing factor. The maintenance of biodiversity should be an objective of any conservation or management plan for these areas. In particular the development of a fire management plan for the swamps and surrounding woodland is essential to the successful maintenance of species–richness in these ecosystems.

The majority of the individual wetlands of the Nepean and Warragamba groups are contained within water supply catchments. The Boyd Plateau Bogs are wholly reserved within the Kanangra–Boyd National Park and the Blue Mountains Sedge Swamps – the `hanging swamps'– are afforded some degree of protection by the Blue Mountains Local Environment Plan and some are contained within the Blue Mountains National Park. The majority of wetlands outside reserves are in private ownership, including floodplain wetlands of the Hawkesbury, Colo and Macdonald Rivers and at least two of the best examples of Blue Mountains Sedge Swamps, near Bullaburra.

Of the catchment wetlands, only Wingecarribee and Lake Bathurst have been included in the Australian Nature Conservation Agency's *Directory of Important Wetlands in Australia*. A small number of wetlands have been registered on the National Estate including the Wingecarribee Swamp and Cecil Hoskings Nature Reserve one the Wingecarribee River, Thirlmere Lakes, and Pitt Town Nature Reserve on the Nepean Hawkesbury Floodplain. This report has identified other wetlands that satisfy the criteria for inlusion in the *Directory* and these are: Boyd Plateau Bogs, Blue Mountains Sedge Swamps, Thirlmere Lakes, Nepean Swamps, Penrose Swamps and the Hawkesbury Floodplain Wetlands. Table 1 provides the criteria for inclusion.

Major wetlands of the Nepean-Hawkesbury catchment.
(Central Tablelands Division).

Name	Location description.	Elevation AMSL	Eastings & Northings #	1:25,000 map	Geology	National Importance criteria	Classification
Nepean Swamps	A large number of small wetlands in the Nepean, Cordeaux, Cataract and Avon River headwaters)	= 100 & < 300 m	Too dispersed for AMG coordinates	Bulli, & Wollongong mainly. Some on adjoining maps to S & SW too	Rh	**3** = Hydrological role as headwater swamps	B1, 2, 15, 13, 10
Wingecarribee Swamp	Above Wingecarribee dam reservoir	700 m	274000E, 6171000N	Robertson	Rw, bb	**3** = Hydrological role **1,5** *Gentiana wingecarribeensis* total known population endemic to Swamp **7** cultural significance **8** = z	B15
Wingecarribee River wetlands	On the Wingecarribee R. downstream of Wingecarribee Dam wall to just above Berrima	> 640 & < 680 m	265000E, 6178000N	Moss Vale, Mittagong.	Rw, Ra		B1, 4, 10
Penrose Swamps	Three areas of wetlands; Mainly on Borehole and Joadja Cks, in Belangalo State Forest and in Penrose State Forest	> 600 & < 700 m 700 to 740m, 680 to 710m, & 630 to 670m	254000E, 6190000N 247000E, 6170000N 244000E, 6162000N	Mittagong, Canyonleigh, Wingello.	Ps	**3** = Hydrological role **6** = *Eucalyptus aquatica*	B9
Warragamba Swamps	Wetlands found on the western side of the Warragamba dam catchment. Lacys Tableland, & Tomat Swamps, in Bindook Highlands.	> 800 & < 900 m	250000E, 6229000N 235000E, 6212000N	Burragorang, Bindook	Ps, Pi	*Grevillea acanthifolia* (endemic)	B9, 15

NB: Easting and Northings are only to indicate an approximate point to use for locating the general area in which the wetlands are found. As often as possible a reference point in one of the wetlands has been used, though this is sometimes limited due to the dispersed distribution of a large number of small wetlands.

Major wetlands of the Nepean-Hawkesbury catchment.
(Coastal wetlands).

Name	Location description.	Elevation AMSL	Eastings & Northings #	1:25,000 map	Geology	National Importance criteria	Classification
Blue Gum Swamps	Swamps of the lower Blue Mountains near Springwood	200 m > 300 & < 330 m	279500E, 6273000N 277000E, 6285000N	Springwood, Kurrajong	Rh		A11
Lower Colo River Valley	On the lower reaches of the Colo near its confluence with the Hawkesbury.	to < 60 m	288000E to 303000E on the Colo R.	Mountain Lagoon & Lower Portland	Qa		A11
Macdonald River Valley wetlands	On the lower reaches of the MacDonald River near its confluence with the Hawkesbury. inc. Webbs Ck.	to < 60 m	6325000N to 6303000N on the MacDonald R.	Auburn, St Albans, & Lower Portland	Qa		A11
Hawkesbury Floodplain wetlands	On the Nepean-Hawkesbury between Penrith and Wisemans Ferry.	to < 60 m	between 312000E, 6304000N and 285000E, 6864000N on the Hawkesbury	Springwood, Wilberforce, & Lower Portland	Qa, Rh, Rn	4 Wintering ground for migratory waders, plus drought refuge.	A11, C2
Brackish Wetlands of the Lower Hawkesbury	On the Hawkesbury downstream of Wisemans Ferry. Also on Mangrove Ck.	< 20 m	From 315000E, 6302000N to its mouth	Gunderman, & Cowan	Qa, Rh, Rn	54% of Sydney's mangroves, 82% of the swamp oak wetlands and 45% of Sydney's other saline wetlands	A6, 7, 8, 9, 11
Glenbrook Lagoon	In the town of Glenbrook in the lower Blue Mountains	200 m	279000E, 6262000N	Penrith	Ts, Rh		C1
Mountain Lagoon	In the head waters of Gospers Ck.	500 m	280000E, 6296500N	Mountain Lagoon	Qa, (Rw)		A11
Thirlmere Lakes	Near Thirlmere & Tahmoor townships.	300 m	273000E, 6210000N	Picton	Rh	6 rare freshwater sponge *Radiospongilla spectroides*, and *Brasenia schreiberi* (3V)	A11

Major wetlands of the Nepean-Hawkesbury catchment.
Southern Tablelands

Name	Location description	Elevation	Eastings & Northings	1:25,000 map	Geology	National Importance Criteria	Classification
Mulwaree Ponds *	On the Mulwaree River between Crisps Ck. and Goulburn	> 640 & < 700 m	On the Mulwaree between 6146000N and 6114000N	Goulburn, Inveralochy, Lake Bathurst	Cza, Qa		B4, 9
Lake Bathurst & The Morass *	Large semipermanent lakes near Tarago approximately 35 km south of Goulburn	670 m	745000E, 6118000N 749000E, 6120000N	Lake Bathurst	Ra, Dl	1, 4 One of only two large semipermanent freshwater lakes in southern tablelands. Important refuge habitat during inland droughts	B6

* These sites are in AMG Zone 55 for Eastings and Northings.

National Importance Criteria			
1	It is a good example of a wetland occurring in Australia.	5	The wetland is of special value for maintaining national biodiversity. For example, because it supports 1% or more of the national populations of any native plant or animal taxa.
2	It is a type of wetland which is rare in Australia	6	The wetland supports native plant or animal taxa or communities which are considered rare, vulnerable, or endangered at the national level
3	It is a type of wetland which plays an integral ecological or hydrological role in the natural functioning of a major wetland system/complex	7	The wetland is of outstanding historical or cultural significance, especially to indigenous people
4	It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought, prevail.	8	The wetland is particularly important for education, research, recreation or has outstanding aesthetic value.

TABLE 1

Major wetlands of the Nepean-Hawkesbury catchment.
(Central Tablelands Division).

Name	Location description.	Elevation AMSL	Eastings & Northings #	1:25,000 map	Geology	National Importance criteria	Classification
Mellong Swamps	Swamps along Mellong Ck. including Wallaby, Howes and Gibba Swamps.	> 300 & < 340 m	285500E, 6329500N	Six Brothers, Wirraba	Rh, Rnn, Qa		B15
Upper Capertee Valley	Four areas of wetland in the upper Capertee Valley. Including Crown Swamp, Umbiella Ck., Emu Swamp and Capertree Ck.	< 420 m	Crown Swamp 325000E, 6328000N	Ben Bullen, Glen Alice, Gospers Mountain, Bogee.	Rnn, Pi		B9, 10. Crown Swamp 17
Newnes Plateau Shrub Swamps	On the Newnes Plateau in the Blue Mountains.	> 1,000 m	247000E, 6289000N	Mount Wilson, Cullen Bullen, Wollongambe.	Rnn		B15
Boyd Plateau Bogs	A group of wetlands on the Boyd Plateau.	> 1,200 m	225000E, 6239500N	Kanangra	Clg	**2** subalpine, **6** *Boronia deanei* (3VC)	B15
Cox's River Swamps	Three areas; In the upper valleys of the Coxs River system down to Wallerawang Dam. Includes Long Swamp. To the west of Bell, on the River Lett & Kerosene Ck. In Megalong Valley below Nellies Glen.	> 600 & < 1,000 m	Too dispersed for AMG coordinates.	Cullen Bullen, Hartley, and Hampton	Pi		B13, 10
Blue Mountains Sedge Swamps	A large number of small hanging swamps found in a large area of the Blue Mountains.	> 200 & < 1,000m	Too dispersed for AMG coordinates.	Mt. Wilson, Katoomba, Springwood	Rh	**1,2** = "hanging swamps" **3** = hydrological role **6** = *Pultenaea glabra* (3V) *P. incurvata* (2RC) *Acacia ptychoclada* (local endemic) *Grevillea acanthifolia* (endemic)	B15, 9

Legend to geology and classification codes.
Classifications (from "A Directory of Important Wetlands in Australia")

Coastal wetlands		Inland wetlands and permanent freshwater ponds etc.			
6	Estuarine waters; permanent waters of estuaries and estuarine systems of deltas.	1	Permanent rivers and streams; includes waterfalls.	10	Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes; seasonally flooded meadows, sedge marshes.
7	Intertidal mud, sand, or salt flats	2	Seasonal and irregular rivers and streams.	13	Shrub swamps; shrub-dominated freshwater marsh on inorganic soils.
8	Intertidal marshes; including salt-marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes.	4	Riverine floodplains; includes river flats, flooded river basins, seasonally flooded grassland, savanna, and palm savanna.	15	Peatlands; forest, shrub or open bogs.
9	Intertidal forested wetlands; includes mangrove swamps, nipa swamps, and tidal freshwater swamp forests.	5	Permanent freshwater lakes (> 8 ha), includes large oxbow lakes.	17	Freshwater springs, oases.
11	Freshwater lagoons and marshes in the coastal zone; includes delta lagoons and marsh systems.	6	Seasonal/intermittent freshwater lakes(> 8 ha), floodplain lakes.	C1	(man made) Water storage areas; reservoirs, barrages, hydro electric dams, impoundments (generally < 8 ha)
C2	(Man made) Ponds, including farm ponds, stock ponds, small tanks (generally < 8 ha).	9	Permanent freshwater ponds (< 8 ha), marshes and swamps on inorganic soils, with emergent vegetation waterlogged for at least most of the growing season.		

Geology and Soils			
Clg	Lower Carboniferous Adamellite, granite & granodirite	Qa	Quaternary alluvium; stream alluvium/estuarine sediments.
C2a	Gravel, sand, clay, claystone, sandstone (T, lafe, Perm)	Ts	Tertiary sand, silt, clay, & gravel; floodplain.
bb	Tertiary olivine basalts (Robertson basalts)	Rn	Narrabeen group sandstone; alluvial/deltaic.
D1	Lake Bathurst thin bedded limestone	Rh	Triassic Hawkesbury sandstone; alluvial abandoned channel fill & overbank.
Pi	Permian Illawarra Coal Measures;	Rw	Wianamatta group shales & sandstone; alluvial & estuarine.
Ps	Permian sandstone, Shoalhaven Group		

5.0 GLOSSARY

aerobic – living or active in the presence of free oxygen; a state in which oxygen dissolved in the water acts as an oxidising agent.

alluvial – relating to or resulting from, the action of rivers. This term may refer to features or processes occurring in river channels, floodplains, estuaries, lakes, and fans at the foot of mountain slopes.

alluvial bulges – a term used by Holland *et al*, 1992a, to describe the ridge and swale pattern, normal to the longitudinal gradient of the slope, that is found in some Blue Mountains Sedge Swamps. The bulges occur where abundant subsurface flows emerge from claystone bed outcrops, increasing the pasticity of the soil downslope. Over long periods suspeneded sediment supplements that transported from further upslope, resulting in a bulge in the profile and slumping downstream, forming the ridge and swale pattern. The ridges are usually enhanced by tussocks of Button Grass *Gymnoschoenus sphaerocephalus*. These features trap sediment, and by dispersing water flows over a wide area, protect the slope from erosion. Similar ridge and swale patterns are found in some of the buttongrass mires of Maddens Plains in O'Hares Creek and Woronora River catchments. (See also flarks).

anaerobic – living or active in the absence of dissolved oxygen. The remaining oxygen may be combined in the form of some organic or inorganic compound e.g. nitrate or sulphate. If sulphate acts as an oxidising agent, hydrogen sulphide is formed giving rise to objectionable odour. Anaerobic conditions assist the formation of peat as they impede organic decay.

anastamosing – a term relating to stream patterns in which the channels bifurcate, branch and rejoin irregularly to create a net–like formation.

bog – permanently waterlogged and peat–covered area that forms on acidic organic soils and typically support Sphagnum moss. In this report this term is used in the name of the `Boyd Plateau Bogs' described by Keith and Benson (1988) and we have continued this usage.

CAMBA – China and Australia Migratory Bird Agreement.

deflation hollow – a large–scale basin of depression formed by the action of the wind in arid or semi–arid lands. The removal of the fine superficial material may lower the ground surface sufficiently to cause the water table to be reached.

estuarine – areas that are influenced by both tidal marine water and freshwater runoff to varying degrees. Includes estuary wetlands (associated with rivers and bays) and brackish lagoons formed behind barrier dunes.

fen – permanently waterlogged and peat–covered areas that form on mineral soils but do not support Sphagnum moss.

flark (Swedish; rimpi, Finnish) – mud–bottom (plant) communities: area of exposed peat with an algal film, sometimes having a sparse cover of sedge. Flarks may be locally frequent and form the hollow part of a hummock and hollow pattern (see alluvial bulge), for example on the Woronora Plateau there are series of parallel flarks and ridges, perpendicular to the slope, upto 77m long and 22 cm deep (McElroy, 1951; Young, 1982; Huggett,1987). Similar features occur in some of the Blue Mountains Sedge ('hanging') Swamps.

floc – an organic precipitate which forms in acidic waters and chemically binds certain elements such as iron.

floodplain swamp/lagoon – wetland, including shallow lagoon and billabong, for which flood water is the dominant water source.

gleyed soils – soils that have undergone anaerobic processes when they are waterlogged, characterised by the reduction of iron thereby producing a blue–grey colouration. If the waterlogging is seasonal rather than permanent, mottling of the soil profile will result.

graminoid – grass–like plants, including (in this report) those of the families Poaceae (grasses), Cyperaceae (sedges). Restionaceae, Juncaceae (rushes), Xanthorrhoeaceae, and Xyridaceae.

hydrophyte – a plant that lives submerged, or almost so, in water.

JAMBA – Japan and Australia Migratory Bird Agreement.

lacustrine – wetlands comprising of or associated with bodies of open water that are situated in topographic depressions or dammed (naturally or artificially) river channels, and that have little or no emergent vegetation. Includes shallow intermittent lakes terminal lakes and lagoons of far–western rivers and marginal wetlands of deep lakes. The water may be fresh to saline (in the inland division). The dominant water source may be either a major drainage system or substantial local runoff, but not flooding.

limnology – the scientific study of physical, biological and chemical conditions in ponds, lakes and streams.

lentic – pertaining to lakes and tarns (slow–moving water).

loam – an easily worked, permeable soil, much valued by farmers. It comprises an almost equal mix of sand, silt but with less than 30% clay.

lotic – pertaining to streams or rivers (fast–moving waters).

lunette – an asymmetrical crescent–shaped ridge on the leeward (downwind) edge of a lake or swamp, thought to be formed by the wind–blown dust gathered from the shores of the seasonally exposed lake–floor.

marsh – vegetated wetland on waterlogged inorganic soils, but not necessarily with standing water.

minerotrophic – a water supply originally derived from mineral soils or rocks; it may eutrophic, mesotrophic or oligotrophic (cf **ombrotrophic**).

mire – an internationally accepted general term embracing all peatlands (q.v.).

ombrotrophic – nutrient and water that are supplied only be precipitation e.g. in some highland bogs.

palustrine – wetlands usually with little or no open water (although some lagoons may be included here, especially those occurring in coastal sand dunes, and on the Tablelands). The dominant water source is run–off from a small local catchment (possibly including small ephemeral creeks) and/or groundwater.

peat – unconsolidated black or dark–brown soil material consisting largely of slightly decomposed or undecomposed fibrous vegetable matter that has accumulated in a waterlogged, often anaerobic environment. It is usually formed under humid climatic conditions.

peatland – wetlands in which peat has, or is forming. In Australia peat formation is variable due to generally wider climatic fluctuations, giving rise to sedimentary layers interleaved with peat layers in some wetlands.

pedogenesis – the natural process of soil formation.

Ramsar Convention – Convention on Wetlands of International Importance.

riparian swamp – wetland associated with the bank of a river receiving water from groundwater as well as from occasional flooding (analagous to floodplain in lowland).

riverine wetlands – wetlands contained within the channel of a river, or associated with a river with flood water from the river being the dominant water source.

soligenous – peat or vegetation communities formed under a regime of slow–moving water. The majority of upland mires in the Sydney Region and Nepean–Hawkesbury catchment are soligenous due to the constant seepage of groundwater from the underlying sandstone and claystone beds.

synergism– the phenomenon whereby the effect of two substances acting together is greater than the sum of their individual effects.

swamp – a general term that encompasses several types of wetlands including both mires, marshe, and the term is used in this sense throughout this report, however some authors have used the term in the more restricted sense of "non–accumulative situations" and mires are "accumulative to varying extent" (Campbell, 1983; p166), in describing Australian wetlands.

upland swamp/lagoon – tableland or plateau wetland, including shallow lagoons, occuring in a depression or on a gentle slope with its dominant water source being ground water (seepage) and/or runoff from a small local catchment. Generally, wetlands above the 100metre contour line.

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