EGERTON MOUND SPRING AND ADJACENT BUSHLAND, ELLENBROOK

Boundary Definition: bushland (part taken to cadastre)/conservation wetland (Boundary adjusted after negotiations with land owner(s) in response to a submission to draft *Perth's Bushplan.*)

SECTION 1: LOCATION INFORMATION

Bush Forever Site no. 22 **Area (ha):** bushland 20.3
Map no. 31 **Map sheet series ref. no.** 2034–II NE
Other Names: Submission Area 115, part of Ellenbrook National Estate Area
Local Authorities (Suburb): Shire of Swan (Ellenbrook)

SECTION 2: REGIONAL INFORMATION

LANDFORMS AND SOILS
Pinjarra Plain
Guildford Formation (Qpa: Mgs1)
Bassendean Dunes
Bassendean Sands (Qpb: S8)
Bassendean Dunes/Pinjarra Plain
Bassendean Sands over Guildford Formation (Qpb/Qpa: S10)
Wetlands (within the Bassendean Dunes)
Holocene Swamp Deposits (Qhw: Cps)
VEGETATION AND FLORA
Vegetation Complexes
Bassendean Dunes
Bassendean Complex — North
Combinations of Bassendean Dunes/Pinjarra Plain
Southern River Complex
Floristic Community Types: *not sampled, types inferred
Supergroup 2: Seasonal Wetlands
*S17 *Eucalyptus rudis — Agonis linearifolia* wetlands in Bassendean Dunes
REGIONAL WETLANDS
Wetland Types: sumpland, creek, palusplain
Natural Wetland Groups
Bassendean—Pinjarra transition OR Bassendean with fluvial features
Muchea (B/P.3)
Bassendean Dunes
Jandakot (B.3)
Wetland Management Objectives: Conservation (21.2ha, 12m), Resource Enhancement
Swan Coastal Plain Lakes EPP: none identified
THREATENED ECOLOGICAL COMMUNITIES
Not assessed, Not determined, Critically Endangered (Communities of Tumulus Springs)

SECTION 3: SPECIFIC SITE DETAIL

Landscape Features: vegetated wetland, creek, vegetated uplands
Vegetation and Flora: limited survey (DEP 1999, Jasinska and Knott 1994, GJ Keighery pers. comm.); detailed survey (Tingay, Alan & Associates 1994a)
Structural Units: mapping (Tingay, Alan & Associates 1994a)
Wetlands: *Eucalyptus rudis* Closed Forest to Open Forest, often with *Melaleuca preissiana* and *Banksia littoralis*; *Melaleuca preissiana* Low Woodland to Low Open Woodland, *Melaleuca rhaphiophylla* Low Closed Forest, often with *Eucalyptus rudis*; Closed Heaths to Open Low Heaths of *Agonis linearifolia*, *Astartea* aff. *fascicularis*, *Hypocalymma angustifolium* or *Pericalymma ellipticum*; Sedgelands of *Baumea articulata* or *Cyathochaeta teretifolia*
Vegetation Condition: >90% Excellent to Very Good, <10% Good to Degraded, with small areas of severe localised disturbance
Total Flora: >80 native taxa (Tingay, Alan & Associates 1994a, with additions from Jasinska and Knott 1994 and GJ Keighery pers. comm.) (>75% expected native flora of Site)
Significant Flora: *Cyathochaeta teretifolia* (3), *Aotus cordifolia* (3); *Hibbertia perfoliata*, *Lycopodium serpentinum*; taxa uncommon on the Swan Coastal Plain found in association with permanent freshwater

seepages or springs — *Hibbertia perfoliata*, *Lycopodium serpentinum*, *Goebelobryum unguiculatum*, *Hyalolepidozia longiscypha*

Fauna: structured survey for birds (8 species), native mammals (3 species), reptiles (5 species) and amphibians (5 species) (Tingay, Alan & Associates 1994d). Significant bird species: category 3 (1) and category 4 (1). Significant mammal species: Honey Possum and Quenda (Friend 1996 D). Contains a rich and diverse aquatic invertebrate fauna (Jasinska and Knott 1994)

Linkage: no adjacent bushland; part of Greenway 36 (Tingay, Alan & Associates 1998a)

Other Special Attributes: the only Ellen Brook mound spring studied by Jasinska and Knott (1994) without degraded vegetation and with a new, monotypic genus of amphipod discovered in 1994; only known occurrence of the club moss *Lycopodium serpentinum* and the leafy liverworts *Goebelobryum unguiculatum* and *Hyalolepidozia longiscypha* in the PMR dependent on water regime in spring; National Trust of Australia (WA) Classification; contains part of the area recommended for conservation by Semeniuk, V&C Research Group (1992)

SECTION 4: INTERNATIONAL AND NATIONAL SIGNIFICANCE

Entered in the Register of the National Estate; subject to protection under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

SECTION 5: SELECTION CRITERIA AND RECOMMENDATIONS

Criteria: Representation of ecological communities, Diversity, Rarity, Maintaining ecological processes or natural systems, Scientific or evolutionary importance, General criteria for the protection of wetland, streamline and estuarine fringing vegetation and coastal vegetation

Recommendation: Urban Negotiated Planning Solution (see Table 3, Volume 1).

EGERTON MOUND SPRING AND ADJACENT BUSHLAND, ELLENBROOK

Boundary Definition: bushland taken to cadastre/conservation wetland boundary (part Bushplan Site, wetlands, subject to Ministerial Condition No. 372, 18 November 1994)

SECTION 1: CADASTRAL INFORMATION

(Lots, locations and derived information to be updated in the public submission period)

Bushplan Site no. 22 **Map no.** 41 **Map sheet series ref. no.** 2034–II NE

Other Names
Submission Area 115

Area (ha): total 35.5; bushland 33.9

Local Authorities (Suburb)
Shire of Swan (Ellenbrook)

Zoning
MRS: Urban
TPS: Special Purpose

Ownership Categories
Private (commercial organisation)

Lot/Location/Reserve numbers (Purpose), Street name
148 Millhouse Rd

SECTION 2: REGIONAL INFORMATION

LANDFORMS AND SOILS

Pinjarra Plain
Guildford Formation (Qpa: Mgs1)

Bassendean Dunes
Bassendean Sands (Qpb: S8)

Bassendean Dunes/Pinjarra Plain
Bassendean Sands over Guildford Formation (Qpb/Qpa:S10)

Wetlands (within the Bassendean Dunes)
Holocene Swamp Deposits (Qhw: Cps)

VEGETATION AND FLORA

Vegetation Complexes

Bassendean Dunes
Bassendean Complex — North

Combinations of Bassendean Dunes/Pinjarra Plain
Southern River Complex

Floristic Community Types: *not sampled, types inferred

Supergroup 2: Seasonal Wetlands
*S17 *Eucalyptus rudis/Agonis linearifolia* wetlands in Bassendean Dunes

Supergroup 3: Uplands centred on Bassendean Dunes and Dandaragan Plateau
*21c Low lying *Banksia attenuata* woodlands or shrublands
*23b Northern *Banksia attenuata* — *B. menziesii* woodlands

REGIONAL WETLANDS

Wetland Types: palusplain, sumpland, creek

Natural Wetland Groups

Bassendean—Pinjarra transition OR Bassendean with fluvial features
Muchea (B/P.3)

Bassendean Dunes
Jandakot (B.3)

Wetland Management Objectives: Conservation (21.2ha, 12m), Resource Enhancement

Swan Coastal Plain Lakes EPP: none identified

THREATENED ECOLOGICAL COMMUNITIES

Not assessed, Not determined, Critically Endangered (Communities of Tumulus Springs)

SECTION 3: SPECIFIC SITE DETAIL

Landscape Features: vegetated wetland, creek, vegetated uplands

Vegetation and Flora: detailed survey (Tingay, Alan & Associates 1994a); limited survey (Jasinska and Knott 1994, G.J. Keighery pers. comm.)

Structural Units: mapping (Tingay, Alan & Associates 1994a)

Uplands (Bassendean Sands): *Banksia attenuata* and *B. menziesii* Low Woodland with *Eucalyptus todtiana*; *E. calophylla* and *E. marginata* Woodlands to Open Forests, with *Banksia attenuata, B. ilicifolia* or *B. grandis* or combinations of them

Wetlands: *Eucalyptus rudis* Closed Forest to Open Forest, often with *Melaleuca preissiana* and *Banksia littoralis*; *Melaleuca preissiana* Low Woodland to Low Open Woodland, *Melaleuca rhaphiophylla* Low Closed Forest, often with *Eucalyptus rudis*; Closed Heaths to Open Low Heaths of *Agonis linearifolia, Astartea* aff. *fascicularis, Hypocalymma angustifolium* or *Pericalymma ellipticum*; Sedgelands of *Baumea articulata* or *Cyathochaeta teretifolia*

Vegetation Condition: >90% Excellent to Very Good, <10% Good to Degraded, with small areas of severe localised disturbance

Total Flora: 168 native taxa, approximately 30 species of weeds expected (Tingay, Alan & Associates 1994a, with additions from Jasinska and Knott 1994 and G.J Keighery pers. comm., WA Wildflower Society pers. comm.) (area greater than that of Bushplan Site, estimated <20% not in Bushplan Site, estimated >75% expected native flora of Bushplan Site)

Significant Flora: *Cyathochaeta teretifolia* (3), *Aotus cordifolia* (3), *Conostephium minus* (4); *Verticordia nitens*, taxa uncommon on the Swan Coastal Plain found in association with permanent freshwater seepages or springs - *Hibbertia perfoliata, Lycopodium serpentinum, Goebelobryum unguiculatum, Hyalolepidozia longiscypha*

Fauna: structured survey by Tingay, Alan and Associates (1994d) for birds (38), native mammals (3), reptiles (9) and amphibians (6). Significant bird species: category 3 (3) and category 4 (2). Significant mammal species: Honey Possum and Quenda (Friend 1996 D). Significant reptile species: a legless lizard (*Pletholax gracilis*), Black-headed Snake (*Rhinoplocephalus gouldii*) and Black-striped Snake (*Simoselaps calonotus*). Contains a rich and diverse aquatic invertebrate fauna (Jasinska and Knott 1994)

Linkage: adjacent bushland to north (outside BS); part of proposed Greenway 37 (Tingay, Alan & Associates 1997a)

Other Special Attributes: the only Ellen Brook mound spring studied by Jasinska and Knott (1994) without degraded vegetation and with a new, monotypic genus of amphipod discovered in 1994; only known occurrence of the club moss *Lycopodium serpentinum* and the leafy liverworts *Goebelobryum unguiculatum* and *Hyalolepidozia longiscypha* in the PMR dependent on water regime in spring; National Trust of Australia (WA) Classification; contains part of the area recommended for conservation by Semeniuk, V&C Research Group (1992)

SECTION 4: INTERNATIONAL AND NATIONAL SIGNIFICANCE

Listed on the Register of the National Estate

SECTION 5: SELECTION CRITERIA AND RECOMMENDATIONS

Criteria: Representation of ecological communities, Diversity, Rarity, Maintaining ecological processes or natural systems, Scientific or evolutionary importance, General criteria for the protection of wetland, streamline and estuarine fringing and coastal vegetation

Opportunities and/or Constraints

Opportunities: Bushplan Site/part Bushplan Site subject to Swan and Canning Rivers EPP; location of Declared Rare Flora, conservation category wetlands

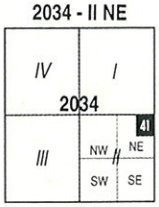
Constraints: private land; under MRS Urban Zoning, Priority and General Mineral Resource Area (sand)

Recommendation: The most appropriate mechanism for the protection of this Bushplan Site be considered through the public comment period in consultation with the land owner(s). (Note: Part Bushplan Site, wetlands, subject to Ministerial Condition No. 372, 18 November 1994.)

LEGEND

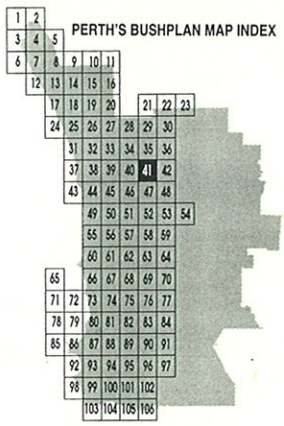
- 472 — Bushplan Sites With Regionally Significant Bushland
- Other Native Vegetation
- Conservation Category Wetlands
- Bushplan Sites With Some Existing Protection
- 696 — Lot Number, Location Number
- Channel Wetlands
- Local Government Boundary

2034 - II NE



1 : 25 000 AMG Reference Grid showing Perth's Bushplan Map Sheet Breakdown

PERTH'S BUSHPLAN MAP INDEX



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SCALE

0 500 1000

Metres

Produced by Project Mapping Section
Land Information Branch, Ministry for Planning, Perth W.A. November 1998

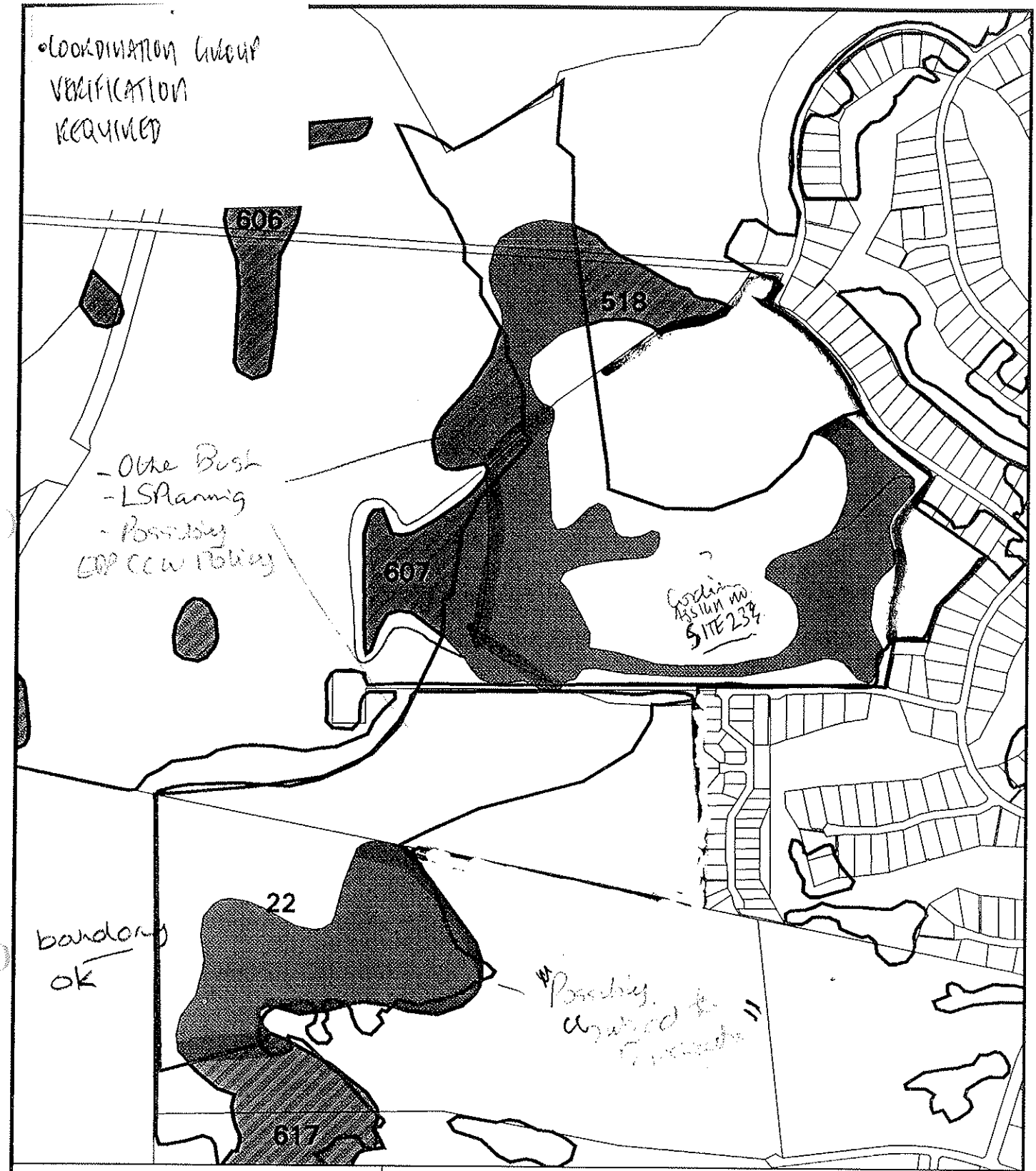
ntw-map11//environ/bushplan//bushv2_41.dgn

Cadastral Data supplied by Department of Land Administration, W.A.

Wetlands Data supplied by Water and Rivers Commission

Native Vegetation Extent for Study Area supplied by Agriculture Western Australia

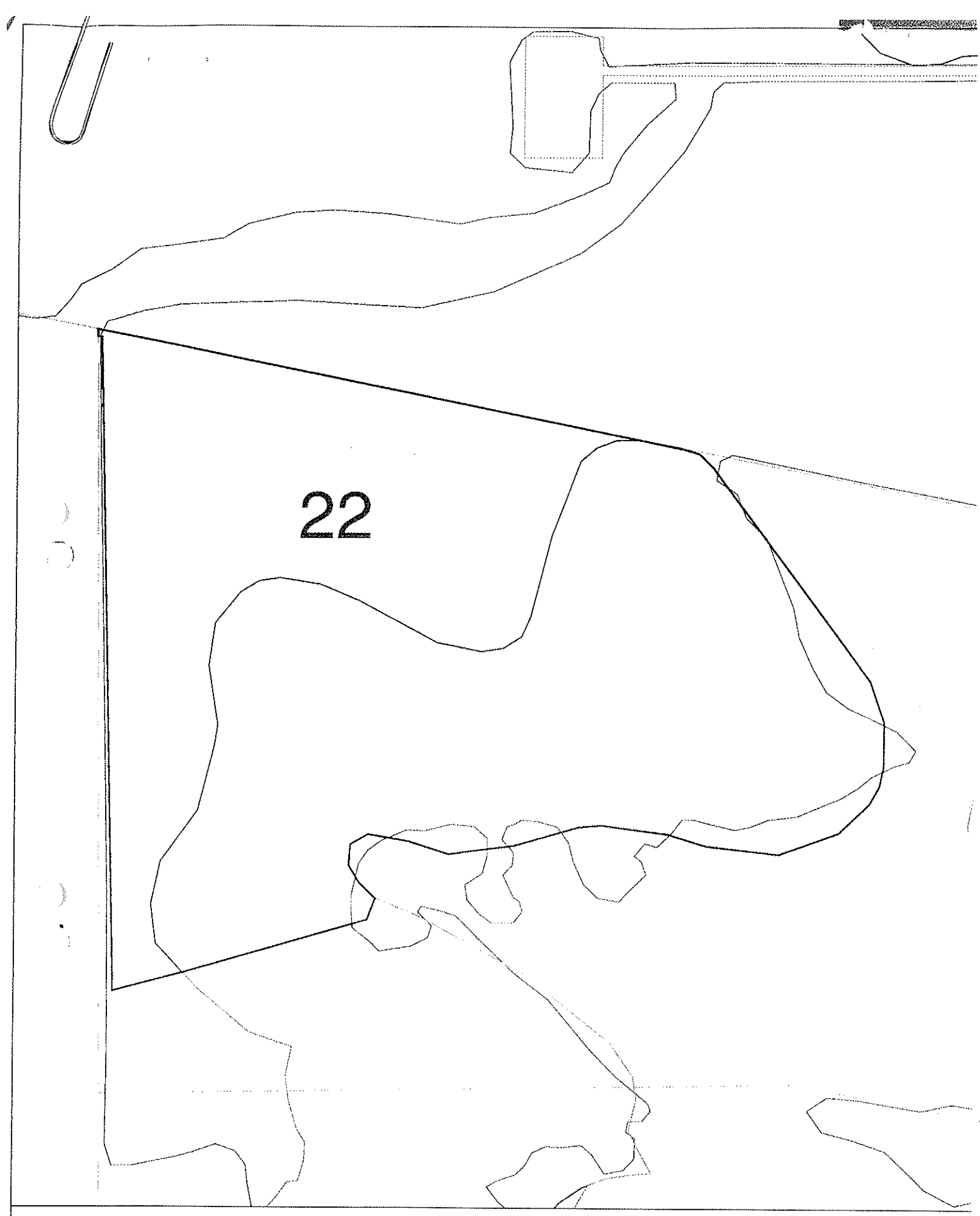
Bushplan Site Map



bp site 22

MFP INTERNAL USE ONLY	
Prepared By: Andrea Zappacosta	
Prepared For:	
Map Ident: plot980522_1	
Date: 22 May 98	
Scale 1:13190	

- AG VEG 1998 BOUNDARY THEME
- Cadastre
- Bushplan sites refno 1-500 SCP BOUNDARY THEME
- cons category wetlands
- Verified CCWs



SEE 23 FOR DETAILS.

BUSHPLAN SITES CORRECTED

B BJ/TC 22/10/98

THE GOVERNMENT OF WESTERN AUSTRALIA

WESTERN AUSTRALIAN PLANNING COMMISSION

CUSTOMER FOCUS WESTERN AUSTRALIA

N

Rezoning of land from Urban Deferred to Urban, Egerton (adjacent to Ellenbrook)

Multiplex Constructions Pty Ltd

Report and recommendations
of the Environmental Protection Authority

Environmental Protection Authority
Perth, Western Australia
Bulletin 743
June 1994

Contents

Figures

Appendices

Bronwen

Do you think the Melaleuca viminea/huegii remnant is important (Mucken complex?)

Kari

These include seasonally inundated sumplands of the Muchea Suite and flat wetlands including seasonally inundated floodplains and seasonally waterlogged palusplains (Refer Figure 13 of the Consultative Environmental Review). The groundwater table is at, or just below, the surface of the ground in the palusplain.

A number of seasonally inundated creeks also traverse the subject land. "The seasonal creeks at Egerton cross the palusplain mainly in the north-east sector of the property and flow to Ellen Brook. In places the creeks have been dammed to provide water for agricultural purposes and at least one of these dams has heritage significance." (Allan Tingay & Associates 1994a).

The wetlands were categorised using the Environmental Protection Authority's wetland evaluation method published in Bulletin 374 *A guide to wetland management in Perth* (recently updated by Bulletin 686), as Resource Enhancement or Multiple Use wetlands. The sumplands were categorised as Resource Enhancement, where the management objective is to maintain and enhance the existing ecological function. The palusplain is categorised as Multiple Use where the management objectives should be considered in the context of catchment and land use planning (especially drainage, nutrient enrichment, surface and groundwater pollution), in terms of the current value of the wetland and the potential value to the community if rehabilitated.

However, investigations by the proponent indicate that "...the sumplands remain in the Resource Enhancement Category in terms of their general attributes but some can also be included in the High Conservation Category as a result of the presence of a rare and endangered species, the Southern Brown Bandicoot (*Isoodon obesulus*)" (Allan Tingay & Associates 1994b).

Following investigation of wetlands on the subject land, the proponent has also advocated that some changes to the wetland classification indicated on the Water Authority maps is required. "This investigation indicated that one area shown as sumpland on the WAWA map is actually a palusplain. This area is in the south-west sector adjacent to the western boundary." (Allan Tingay & Associates 1994b).

The Environmental Protection Authority notes from the Water Authority maps that two small sumplands located in the eastern part of the subject land are not represented in Figure 12 of the proponent's report or represented within the Structure Plan. In addition, the Structure Plan does not indicate the width of separation between proposed development and the wetlands retained within the Open Space.

The Environmental Protection Authority recognises that waterbodies in their natural state are generally surrounded by two 'layers' of vegetation, of varying widths and distinction. Immediately adjacent to the waterbody, fringing or wetland vegetation occurs which is directly dependent on the close proximity of the watertable in these areas. Fringing vegetation may include emergent species, paperbarks, riparian vegetation along watercourses, and other species that can tolerate wet conditions. In turn, the fringing vegetation is surrounded by the 'dryland buffer', comprising dryland vegetation that is less tolerant of wet and waterlogged soil conditions.

With the exception of parts of the Mound Spring area in the north west of the Egerton land the Environmental Protection Authority notes that most other wetlands on the property are surrounded by pine plantation or cleared pasture and do not have an existing 'dryland buffer' consisting of natural vegetation.

However, all waterbodies are affected by nearby land uses: whether they are immediately adjacent to that waterbody, or carried out at some distance from the waterbody but within its catchment. Vegetation buffers for waterbodies provide important functions which include:

- separating water habitats from human activities on surrounding land;
- providing complementary habitats for fauna (e.g. Bandicoots, waterbirds) using the waterbody; and
- trapping nutrients and sediments entering a waterbody.

CONSERVATION AREA

PHASE B
FILL ZONE

6

VILLAGE CENTRE

Approx Location
WC Waste Water
Treatment Plant

Wrong location

PHASE C
FILL ZONE

CORRIDOR

Existing Water
Supply Site

DISTRICT CENTRE

PHASE A
FILL ZONE

Existing
Limestone Track.

VILLAGE CENTRE

3

BS 22

STAGE ONE
CUT AREA

Diagram in Application
gained Ministerial approval 1st
week August 1998

Aquatic fauna in Gnangara Mound discharge areas of the Ellen Brook catchment, Western Australia.

A REPORT SUBMITTED TO THE WATER AUTHORITY OF WESTERN AUSTRALIA

NOVEMBER 1994

by

Edyta J. Jasinska and Brenton Knott

Department of Zoology, The University of Western Australia, Nedlands 6009.

SURVEY OF THE WESTERN SWAMP TORTOISE (*PSEUDEMYDURA UMBRINA*) AT EGERTON

Report to **MULTIPLEX CONSTRUCTIONS Pty Ltd** and

ALAN TINGAY & ASSOCIATES

by

Dr Gerald Kuchling

Principal Investigator, Western Swamp Tortoise Recovery Team
Phone: (09) 381 5187 Fax: (09) 381 5187

February 1996

CHELONIA ENTERPRISES
PO Box 1359, Subiaco
WESTERN AUSTRALIA 6008

Conservation and Development
Opportunities at Ellenbrook

(Responses to Conditional
Environmental Approval)

March 1993

ELLENBROOK FAUNA

1. Report on Fauna Conservation Values of the Northern Section of the Ellenbrook Project Area (Watkins D.G. & Bamford M.J. & A.R)

2. Survey for Western Swamp Tortoises (Burbridge A.A. & Fuller P.J)

ELLENBROOK MANAGEMENT PTY LTD

ELLENBROOK
PUBLIC ENVIRONMENTAL REVIEW REPORT

Volume 1

14th April 1992

Feilman Planning Consultants

Conservation and Development
Opportunities at Ellenbrook

(Responses to Conditional
Environmental Approval)

March 1993

FLORA AND VEGETATION

MULTIPLEX CONSTRUCTIONS PTY LTD

A STRATEGY FOR THE PROTECTION OF THE SOUTHERN BROWN BANDICOOT (*ISOODON OBESULUS*) AT EGERTON

ALAN TINGAY & ASSOCIATES
ENVIRONMENTAL SCIENTISTS

MGA **Mitchell Goff & Associates**
TOWN PLANNING CONSULTANTS

26 Mayfair Street
West Perth 6005
Western Australia

Telephone (08) 9321 3011
Facsimile (08) 9324 1961

Postal Address:
PO Box 104
WEST PERTH 6872

A.C.N. 008 867 230

78

BS 22

Our Ref: 1533

PB005

25 March 1999

Perth Bushplan
Ministry for Planning
Albert Facey House
469 Wellington Street
PERTH WA 6000

RE: SUBMISSION ON PERTH'S BUSHPLAN, MULTIPLEX CONSTRUCTIONS PTY LTD, LOT 148 MILLHOUSE ROAD, ELLENBROOK (EGERTON)

We write on behalf of our clients Multiplex Constructions Pty Ltd to provide the following comments on proposals contained within Perth Bushplan which affect the Company's landholding. In particular, the Bushplan site referred to is site number [redacted]. The grounds of the submission are as follows.

1. The Egerton property comprises some 495 hectares of Urban zoned land. The land is owned by Multiplex Constructions Pty Ltd and Multiplex Energy Pty Ltd.

2. Urban zoning over the Egerton property was achieved following a Consultative Environmental Review (CER) which identified an area of around 15% of the total site as wetland and conservation space. The landowner has generously agreed to concede this area as open space even though the contribution from the property will well exceed the policy standard of 10%.

3. In addition to the land being zoned Urban as a consequence of the CER process, the site is also zoned Special Purpose - Ellenbrook in the Shire of Swan's Town Planning Scheme and there is an approved Structure Plan over the whole site as well as an approved Development Plan and subdivision approval over parts of the site. The Environmental Protection Authority (EPA) has also confirmed that the proposal (urban development) is substantially commenced.

4. Bushplan site number 22 covers 35.5 hectares (page 157; volume 2; part B) of which approximately 18 hectares is shown to be open space on the approved structure plan as a consequence of recommendations flowing from the CER process. Approximately 16 hectares of land affected by site number 22 is earmarked for urban development in accordance with the approved plans. This area is generally referred to as the "dry land buffer" and is the area of primary concern in this submission.

...2/..

SUBMISSION NO 334

MINISTRY FOR PLANNING
26 MAR 1999
805-2-1-32pt12
FILE

5. At page 158 of volume 2, part B it is noted that the site is listed in the Register of the National Estate. The State Government however is known to have resisted this listing on the grounds that the State's environmental approval processes are adequate and cleared the dry land buffer for development and secured the protection of the wetland portion of site number 22.

6. More recently, it is claimed by the Water and Rivers Commission, the Department of Conservation and Land Management and the Department of Environmental Protection that new information attaches greater importance to the wetland (referred to variously as the Egerton seep, tumulus spring or mound spring) and the necessity to maintain a naturally vegetated dry land buffer. The wetland is now classified as a critically endangered community.

7. The recommendation at page 158 of volume 2, part B of Bushplan suggests that the most appropriate mechanism for the protection of this Bushplan site be considered through the public comment period in consultation with the landowner. To this extent, the landowner's representative, Mr Terry Martin, has met with the Hon. Minister for the Environment whereat there was an undertaking to attempt to resolve the issue. Potential resolutions consist of the possibility of land exchanges within the site as well as with land off site. Constraints imposed under the Aboriginal Heritage Act restrict exchanges with other conservation areas on site and no land suitable for exchange has been identified off site.

8. Whilst the regional significance of the wetland (Egerton seep) is universally acknowledged there may be some doubt about the significance of the dry land buffer. This area suffers from weed invasion, fire breaking, fencing and has been grazed in the past. Moreover, specialist hydrological advice (Jim Davies & Associates) suggests that the catchment of the Egerton seep to the west of the wetland covers an area of approximately 500 metres radius shown on the attached figure. It therefore extends well beyond the boundaries of the Egerton property into the neighbouring Ellenbrook joint venture area which has been cleared of native vegetation, approved and readied for development. The altered natural bushland remaining within Egerton comprises only a relatively small part of the catchment area/dry land buffer.

9. It is evident from discussions with officers of Government agencies that there is divided opinion on the quality of the vegetation of the buffer area. The Environmental Protection Agency opinion - which must be regarded as authoritative - is that the bush is not of a standard in itself warranting conservation. That rating is being held up as reason to prevent a recommendation to the Western Australian Planning Commission that the land be reserved for Parks and Recreation. It is of course not the sole purpose of the Metropolitan Region Scheme to reserve land for bush conservation purposes under the classification Parks and Recreation reserves, despite that having become the case increasingly over the last decade. Land may be reserved for other qualities including natural and scientific interest.

...3/..

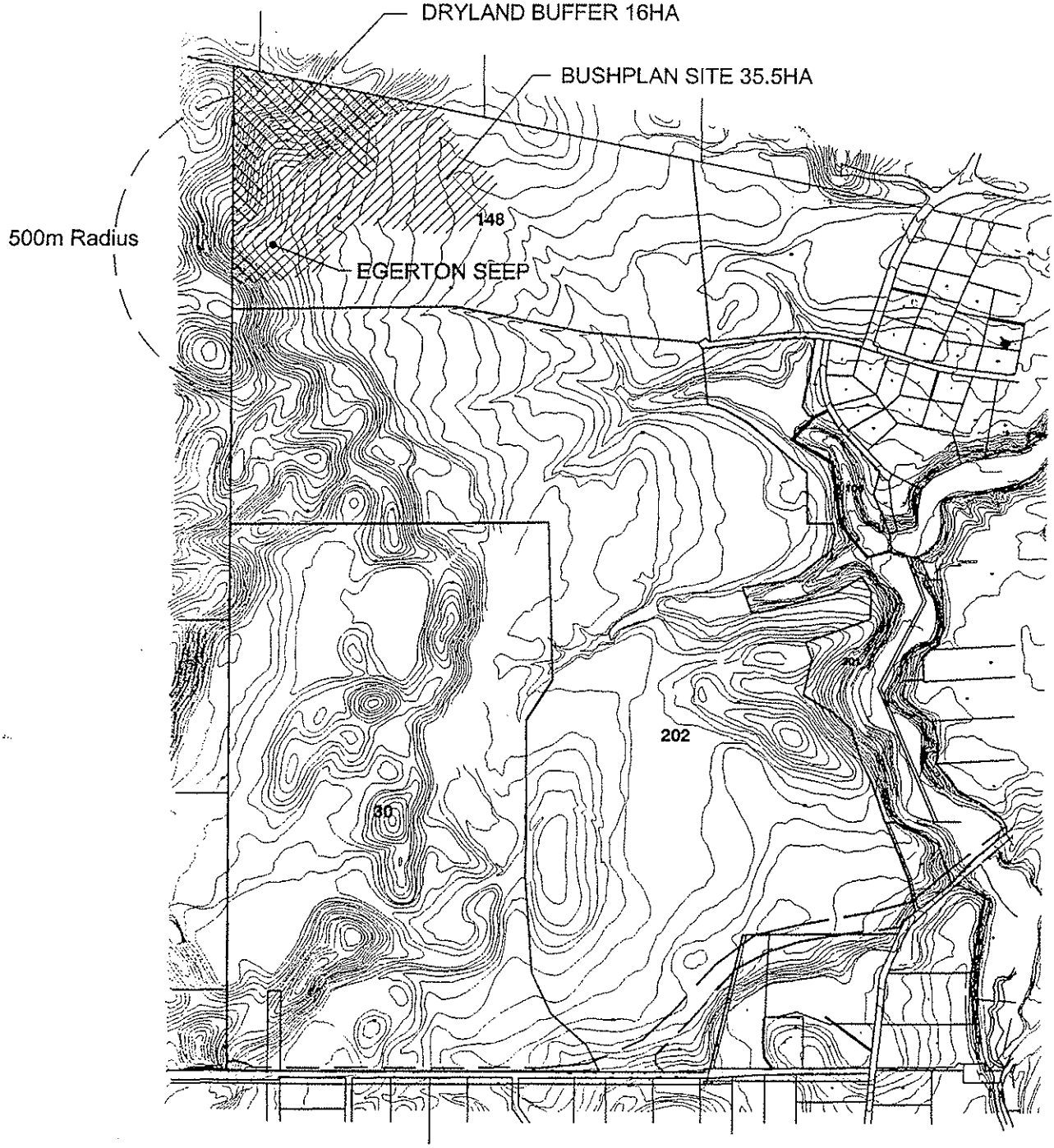
If the land earmarked as Site 22 in Bushplan is not being conserved for the quality of the bush itself but because of the endangered associated ecology, then perhaps Bushplan is not the appropriate vehicle. It may be that the distinction of the place justifies regional reservation of land additional to that set aside as open space as a result of CER and Structure Plan deliberations.

10. In conclusion, the consultation through the public comment period as recommended at page 158 of Bushplan volume 2, part B has failed to produce a satisfactory result, despite the personal involvement of the Hon. Minister for the Environment. If the dry land buffer portion of site number 22 is of local significance only, the current approvals to develop the area should be acknowledged and the Bushplan recommendation removed from the subject land and development allowed to proceed unhindered. Alternatively. If the area is deemed to be of regional significance (or greater) then in the absence of any ability to negotiate suitable arrangements to protect the site via other means, this significance should be recognised by reservation in the Metropolitan Region Scheme leading to the land's acquisition and the owner's compensation.

In accordance with the above grounds of submission, we look forward to either the deletion of the dry land buffer from site number 22 within Bushplan or alternatively the site's reservation in the Metropolitan Region Scheme as Parks and Recreation.

Yours faithfully

P M GOFF



Notes/Revisions

N

0 Metres 500

SCALE 1:20000

Date : 25 March 1999 Ref.

EGERTON SEEP CATCHMENT

Mitchell Goff and Associates Town and Regional Planners Tel. (08) 9321 3011 Fax (08) 9324 1961

BS 22

In L. Botosaneanu (Ed.) "Studies in Crenobiology The biology of springs and springbrooks" Backhuys Publishers, Leiden (1998)

MOUND SPRINGS OF AUSTRALIA

by

B. KNOTT & EDYTA J. JASINSKA

Department of Zoology, The University of Western Australia, Nedlands, Western Australia 6907.

ABSTRACT

The present state of knowledge of mound springs in Australia is reviewed. Points of groundwater discharge, characterised by mounds of peat or calcarenite about the spring boil, they function as mesic refuges for plants and animals in an arid landscape. Studies to date have concentrated predominantly on the physicochemical and biological attributes of the, often spectacular, mound springs of the Great Artesian Basin, particularly of the Lake Eyre and Dalhousie Springs supergroups in South Australia. In terms of the mound spring fauna, results of distributional surveys and physiological tolerance tests of a number of fish and hydrobiid molluscs show that even species endemic to springs with nearly constant physicochemistry tolerate a wide range of temperatures and salinities. The origins and mechanisms of dispersal of the fish and hydrobiid snails from the springs are also addressed. Elsewhere in Australia, mound springs are found in Western Australia: in the Ellenbrook area near Perth and in several locations in the northwest of the State, but only the former have been studied to a limited extent. The Ellenbrook mound springs are raised peat structures and occur only in a restricted area but comprise discrete plant and animal communities which include endemic species and northern outlier populations of mesic species which now occur only in the wetter southwest of Western Australia. The conservation of all Australian mound springs is under threat from three principal causes: groundwater abstraction from their source aquifers; physical destruction either by land-clearing or cattle-grazing; and invasion of exotic plant and animal species.

Introduction

In Australia, the term "mound springs" is used to describe points of groundwater discharge which are elevated above the surrounding landscape (forming mounds) through the build up of calcarenites and/or peat about the spring boil. Mound springs, small mesic refuges within arid landscapes, are known from three areas (fig. 1), the Great Artesian Basin (GAB) in central Australia and from restricted areas in Western Australia: Ellenbrook near Perth (Jasinska *et al.*, in prep.) and at several locations in the northwest of the State (pers. comm. Dr. W.F. Humphreys and also A. Storey). Those from the GAB are the better known (for example, Habermehl, 1980, 1982; Ponder, 1986) and are the more significant in terms of their area of distribution, total number and individual size. The GAB mound springs are aggregated in 11 major 'supergroups' of which the most extensively studied are the Dalhousie Springs (Zeidler & Ponder, 1989) and the Lake Eyre Supergroup (LESG) (Greenslade *et al.*, 1985) in the Lake Eyre drainage basin in northern South Australia. In the past, central Australian aborigines used the GAB mound springs as oases within the Australian desert, following the outcrops of springs along a 'dreaming trail' when trading in various commodities (Bonython, 1988). The mound springs also provided important 'stepping stones' facilitating the opening up of arid central Australia to Europeans (Harris, 1989). Mound springs from the Ellenbrook area have been labelled as such by botanists since the 1940s and although acknowledged as having high conservation value

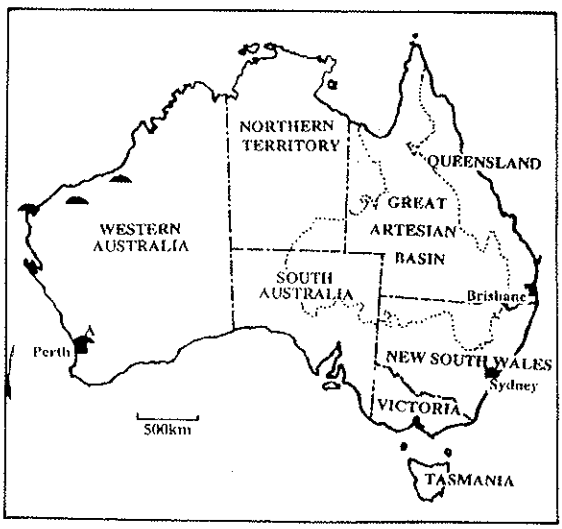


fig. 1. Distribution of mound springs in Australia, with the Great Artesian Basin indicated. Mound symbols show the location of mound springs in Western Australia (distribution of GAB mound springs is shown in fig. 2). A indicates the location of the Ellenbrook mound spring area.

out the GAB, but the potentiometric heads of the uppermost confined (late Cretaceous) aquifers are below ground level. Water velocity through the aquifers averages between 1-5 m per year, giving a travel time of up to 3 x 10^6 years (Habermehl, 1982). Water chemistry of the GAB artesian system is summarised in Habermehl (1980, 1982). Westward-flowing ground water from the eastern recharge zones in the deeper, early Jurassic aquifers is of higher quality (0.5-1.0 g L^{-1} TDS, mainly as $NaHCO_3$) than from the late Cretaceous and younger beds (Habermehl, 1980). Sulphate, chloride and salinity levels are elevated in Dalhousie Springs discharge (of groundwater originating from the western recharge area), with TDS varying between 0.7 to 9.7 g L^{-1} (Smith 1989). Water temperature in artificial wells tapping Jurassic to early Cretaceous aquifers usually range between 30-50 °C, but temperatures to 100 °C have been noted (Habermehl, 1980). Isotopic data confirm that the groundwater is of meteoric origin (Habermehl, 1980), and does not include any connate contribution as Gregory (1906) speculated might be the case. Discharge occurs naturally through vertical leakage, *via* mound springs and through groundwater flow into adjacent sedimentary basins (Habermehl, 1980).

Mound springs

Evaporation of discharged ground water at the surface results in the deposition of $CaCO_3$ as travertine and salts crusts which cement sand, clay and silt particles effluxing from the spring and, together with wind-blown sand, lead to the formation of the mounds. The springs have developed: along fault lines, where groundwater flow is directed towards the surface by the intervention of outcropping bedrock; or where the confining layer is either thin or absent (Habermehl, 1982). The Dalhousie Springs, for example, lie across the Dalhousie Anticline from which the upper confining layers have been eroded away to a level enabling discharge from the aquifer to the land surface *via* vertical faults (Krieg, 1989). Thomson & Barnett (1985) classified the springs as extinct (Pleistocene), active, waning and non-active. Extinct mounds, their vents now filled with aeolian deposits, were formed under conditions of higher than present potentiometric heads and under stable hydraulic conditions. The mounds reach heights of 28-43 m above the surrounding plain (slopes 75-80°) their diameters being between 10-20 times wider than that of the active mound springs. Active springs are distinguished by having one or two overflow channels which carry the water onto adjacent playas or swamps. The active mounds range from several decimetres in width and height (Habermehl, 1982) to 4 m above ground (slopes slightly asymmetrical, 2 to 35°) and range in diameter from 2 to 25.5 m, the largest springs containing vents up to 15.2 m wide, with water either bubbling up or still. Waning springs have mounds 3-4 m high (slopes 10-25° and slightly asymmetrical) and 15-18 m diameter. The vents of waning mound springs are blocked, the seepage occurring mainly within the basal two thirds of the mound. Non-active mound springs, mainly of late Holocene age, totally lack an outflow. They rise to 2-3 m above ground (slopes 20-25°) with diameters ranging from 15 to 18 m.

The age of the active mound springs, till recently, was placed in the late Holocene (Thomson & Barnett, 1985) but thermoluminescence dating of springs in the LESG now show a much greater age. Dating of the Bubbler, an active mound spring, indicates activity > 40 000 years, and dating of an inactive spring in the Elizabeth group yielded an age > 500 000 years (Prof. J. R. Prescott, pers. comm.). Krieg (1989) favoured the estimate of 1-2 x 10^6 years for the age of Dalhousie Springs based on the time required for erosion of the anticlinal dome to enable the aquifer to gain access to the surface. Thomson & Barnett (1985) predict that the more recent mound springs (active, waning and non-active) are temporary structures which will erode away much sooner than the larger, extinct structures.

Mound spring discharge is difficult to measure; Williams & Holmes (1978) correlated discharge with the area of surrounding swamp vegetation. Where the actual rate of discharge was measured it varied generally from seepages (not flowing) to 85 L s^{-1} (Habermehl, 1980), and to 140 L s^{-1} in one of the Dalhousie springs (Smith, 1989). Stronger discharges are sufficient to generate short outflow creeks, some only a few tens of metres long and rarely exceeding 1.5 km in length because of transpiration, infiltration and high levels of evaporation.

Spring water temperatures across the GAB vary between 20-40 °C (Habermehl, 1980) but some within the Dalhousie complex at higher (30-46 °C) temperatures where the upper value approximates the temperatures of bore water in the area (Smith, 1989). At Dalhousie, springs with lower discharge temperatures correlate with lower discharge rates (greater heat loss to surroundings), higher salinity (due to increased evaporation), increased pH (due to loss of H_2S) and higher dissolved oxygen concentration (due to greater time for aeration) (Smith, 1989). Significant water temperature gradients are generated in the spring outflows; Glover (1982) recorded both horizontal gradients (for example a 25 °C difference across a 7 m

transect between open pool and littoral vegetated zones) and vertical gradients (for example a 10 °C temperature difference between the water column and the underlying substrate).

Water chemistry of the springs reflects the chemistry of the source water, although with some increase in salinity (Habermehl, 1980; 1982). Springs of the Lake Eyre Supergroup show two patterns of cationic dominance: Na>Ca>K>Mg or Na>Ca>Mg>K; anionic dominance is $Cl>HCO_3>SO_4$ (Mitchell, 1985; Ponder *et al.*, 1989). The Dalhousie springs are enriched in SO_4 ($Cl>SO_4>HCO_3$) (Smith, 1989). Spring pH ranges between 7.2 to 7.9 in LESG and in Dalhousie Springs between 6.4 to 7.9 (Mitchell, 1985; Smith, 1989). At the point of efflux, spring waters are oxygen depleted (23% saturation in the Bubbler of the LESG, for example), but oxygenation increases to supersaturation, at least on a diurnal cycle near the ends of the spring outflow channels, particularly in association with algal mats. High nitrate levels (3-14 mg L^{-1}) in springs between Marree - Peake (LESG) were thought by Mitchell (1985) to be due to inputs from cattle droppings, but phosphate levels are low throughout the mound springs probably due to the precipitation of phosphate as $Ca_3(PO_4)_2$.

Biota

Two surveys of mound springs within the past two decades have provided considerable information concerning their biota: of springs of the LESG (Greenslade *et al.*, 1985) and of the Dalhousie complex (Zeidler & Ponder, 1989). Mound springs in both supergroups are isolated from river systems and show greater endemicity of forms than mound springs of the northeastern GAB which are closer to permanent river systems and between which there is a continuity of fauna (Ponder, 1995). The greatest diversity and endemism is shown by animals with restricted powers of dispersal, for example hydrobiid snails, amphipods and fish.

Flora

The microalgae of Dalhousie Springs are restricted predominantly to benthic diatoms (31 spp.) and cyanophytes (21 spp.) (Ling *et al.*, 1989). Thirteen species of filamentous algae also are known from mound springs, including Chlorophyta (Oedogoniales, 3 spp.; Zygnemales, 9 spp.) and Chrysophyta (Vaucheriales, 1 sp.) (Skinner, 1989). The physiologically harsh conditions (warm to hot water, sulphurous water with low O_2) and great distances from the nearest sources favours the presence of highly vagile euryhaline forms which typically are widespread. Enigmatic forms include *Hyalodiscus* sp., an endemic species of a predominantly marine genus of diatom and *Gomphosphaeria aponina* Kutz., var. *multiplex* Nygaard, a form of colonial cyanophyte known elsewhere only from coral islands (Ling *et al.*, 1989).

A noteworthy feature of Dalhousie Springs is the ~20 km^2 of wetland vegetation from which 95 species of vascular plants, 5 bryophytes (3 liverworts, 2 of moss) and two fungi have been recorded. The most conspicuous species is *Melaleuca glomerata* F. Muell., a 10-12 m high tea tree which elsewhere grows only as a shrub up to 3 m tall (Mollemans, 1989). There is marked zonation of vascular plants around the springs. The dominant species within the springs is the reed, *Phragmites australis* (Cav.) Trin. ex Steud. (comprising approximately 75% of the total vegetation), often in association with the rush, *Juncus* sp., and sedges. This inner zone is surrounded by the reed *Typha domingensis* Pers., either as a dominant or co-dominant with *P. australis*. The outermost zone comprises sedges (*Cyperus gymnocaulos* Steud.) and *Juncus* sp. In springs of the LESG, there are 20 species of wetland vascular plants with sedges, *Cyperus laevigatus* L. and *C. gymnocaulos* and *P. australis* occurring at the majority of sites sampled. Many of the species are widely distributed, but the presence of *Eriocaulon carsoni* F. Muell. (button grass), *Gahnia trifida* Labill. (sedge) and *Machaerina juncea* (R. Br.) Koyama (bare twigrush) within springs of the LESG is of considerable significance (Symon, 1985). *E. carsoni* has been recorded from three sites only, all spring sites within the GAB, and probably no longer survives at the first two recorded localities (Symon, 1985). *G. trifida* and *M. juncea* are known from several, widely disjunct localities across southern South Australia and their presence at the springs represent significant northern outliers. In the more saline habitats on flats adjacent to the spring mounds from both supergroups, Chenopodiaceae (21 species, including 7 of the genus *Halosarcia*) and *Nitraria billardieri* F. Muell. (Zygophyllaceae) dominate the vegetation.

Fauna

Aquatic invertebrates from the LESG and Dalhousie springs comprise two categories: (1) species of high vagility which also occur in temporary waters and are widespread throughout arid Australia; (2) and a "unique mound spring faunal assemblage" (Mitchell, 1985) of species lacking resistant stages, with some endemicity in mound springs and unable to exploit temporary waters (Tables 1 & 2). Greenslade (1985) identified a third category, of Heteroptera (3 spp.) and Coleoptera (3 spp.) from waterside micro-habitats. Despite limitations in the LESG data set pre-

Table 1: Aquatic fauna from springs of the Lake Eyre Supergroup, data from Mitchell (1985) and Greenslade (1985), excluding fish and hydrobiid snails.

high vagility forms widely distributed in Australia and also found in temporary waters of the study area; **low vagility** forms typically without drought-resistant stages.

TAXA **high vagility**	**TAXA** **high vagility** (continued)	**TAXA** **low vagility**
ODONATA	**COLEOPTERA** (continued)	**CRUSTACEA**
Zygoptera	*Trogophloeus* sp.	**Ostracoda**
Amphipterygidae	*Megacephala australia* Chaudoir	
Coenagrionidae	*Cicindala semicinata* Brulle	*Ngarawa dirga* De Dekker
Calopterygidae	*C. blackburni* Sloane	*Heterocypris* sp.
Lestidae	*C. parasemicinata* Freitag	*Potamocypris* sp.
Lestoidae		
	DIPTERA	**Isopoda**
Anisoptera		
Aeschniidae	Chironomidae	**(Amphisopidae)**
Corduliidae	Ceratopogonidae	*Phreatomerus latipes* (Chilton)
Gomphidae	Culicidae	
Libellulidae	Stratiomyidae	**Amphipoda**
Synthemidae		
	CRUSTACEA	**(Hyalellidae)**
HETEROPTERA		*Austrochiltonia* sp.
	Copepoda	
Agraptocorixa eurynome Kirkaldy	Calanoida (1 sp.)	**Decapoda**
Micronecta robusta Hale		
Micronecta sp.	(Cyclopoida)	**(Atyidae)**
Anisops thienemanni Lundblad	*Microcyclops denzizicus* Lepeschkin	*Caridina* sp.
Anisops sp.	*Mesocyclops leuckarti* (Claus)	
Microvelia sp.		
	(Harpacticoida)	
COLEOPTERA	*Nitocra lacustris* (Schmankewitsch)	
Antiporus gilbertii Clark	**Cladocera**	
Laccophilus sp.		
Coelostoma cowleyi Blackburn	*Daphnia carinata*	
Berosus 2 spp.	var. *cephalata* King	
Pheropsophus sp.	1 unidentified species	
	ROTIFERA	
	Brachionus sp.	

cluding quantitative analysis of microhabitat control on species diversity, significance of the mound springs nevertheless is apparent. No named aquatic or waterside species in Greenslade (1985) were common to both springs and bores. The species number per spring varied between 1 (Beresford) and 24 (including both "highly vagile" and "mound spring" categories from Blanche Cup) with a mean number of 8.8 (n=11) (Mitchell, 1985) but this is an underestimate since most springs have 4 species of hydrobiid (Ponder *et al.*, 1989) not 3 as listed in Mitchell (1985). The species numbers from the non-mound spring sites varied from 0 to 11 (mean 5.8, n=11), with the numbers per site from artesian bores and associated swamps and dams, particularly if close to mound springs, being at the higher end of this range (11 species from Coward Spring bore and Beresford Spring dam, 10 species from a temporary pool near Hamilton Hill Homestead Spring, for example).

De Deckker (1979) described *Ngarawa dirga* De Deckker, a new species and genus of small (~1 mm), coloured benthic ostracod common in springs near Strangways. The ostracod has been observed crawling in very shallow water on algal-covered rock to sandy substrates and at temperatures varying between 14 - 31 °C. The first member of the Macrostomidae (Platyhelminthes) from Australia, *Promacrostomum palum* Sluys, was described from springs in the

Table 2. Aquatic crustaceans from Dalhousie Springs, data from Zeidler (1989) and Greenslade (1985), excluding fish and hydrobiid snails.

high vagility forms widely distributed in Australia and also found in temporary waters of the study area; **low vagility** forms, typically without drought-resistant stages.

TAXA **high vagility**	**TAXA** **high vagility** (continued)	**TAXA** low vagility
CRUSTACEA	**Copepoda**	**Amphipoda**
Cladocera	**(Calanoida)** *Boeckella symmetrica* Sars *Calamoecia ampulla* (Searle)	**(Hyalellidae)** *Phreatochiltonia anophthalma* Zeidler *Austrochiltonia dalhousiensis* Zeidler
Bosmina meridionalis Sars *Ceriodaphnia cornuta* Sars *Daphnia carinata* King	**(Cyclopoida)** *Eucyclops medius** *Halicyclops* sp. *Mesocyclops albicans* (Smith) *Microcyclops varicans* (Sars) *Paracyclops chiltoni* (Thompson)	**Decapoda**
Ostracoda	**(Harpacticoida)** *Nitocra lacustris* (Schmankewitsch) *Cletocamptus* sp. *Onychocamptus bengalensis* (Sewell) Darcythompsoniidae Entocytheridae	**(Parastacidae)** *Cherax destructor* Clark
Candonopsis sp. *Cypretta*, 2 spp. *Cyprideis* sp. *Darwinula* sp. *Heterocypris tatei* (Brady) *Ilyocypris(?) australiensis* Sars *Limnocythere* sp. *Limnocythere mowbrayensis* Chapman *Sarscypridopsis aculeata* (Costa) Entocytheridae		

*Called *Eucyclops medius* in Zeidler (1989), but if the species is *medius*, then it is correctly called *Ectocyclops rubescens* Brady, a senior synonym of *Ectocyclops medius* Kiefer (Morton, 1990).

LESG (Sluys, 1986). Ponder (1995) cites the presence in springs of the LESG of an undescribed genus of oligochaete.

Isopoda. A zoologically important member of the LESG crustacean fauna is the phreatoicid isopod *Phreatomerus latipes* (Chilton, 1922; Mitchell, 1985). Phreatoicids are a Gondwanan element restricted predominantly to cool, permanent waters (Knott, 1975). *P. latipes* is not a subterranean form, being eyed with dark, pigmented body to 20 mm in length; levels of genetic differentiation between phreatoicids from separate spring groups have not been measured. The species is widespread in the springs of the LESG (Chilton, 1922; Mitchell, 1985), where it occurs at densities to 800 m^{-2} in water temperatures to 30 °C (Mitchell, 1985) and it is not unusual to find specimens moving on moist substrates some distance from the springs. Knott (1975) grouped *P. latipes* with *Amphisopus* and *Paramphisopus*, two genera restricted to southwestern Australia, and observed that all members had the capacity to tolerate both higher salinities compared with most phreatoicids and also drying conditions in summer by burying into moist sediments. A genetic study of *P. latipes* is required to reveal whether there has been a radiation within the separate spring groups.

Amphipoda. Two species of freshwater amphipod have been described from Dalhousie mound springs: *Phreatochiltonia anophthalma* (Zeidler, 1991) and *Austrochiltonia dalhousiensis* (Zeidler, in press). The genus *Chiltonia* in Australia for long was treated as belonging to the family Ceinidae (Barnard & Williams, 1991), but Zeidler (1991) reinstated the original family designation, Hyalellidae. Athalassic members of this group are widespread across southern Australia but have not colonised montane regions or very pure waters (TDS <0.001 g L^{-1}): they have exploited and speciated in areas of the hinterland of Western Australia which have become saline over recent decades (pers. unpub. data). In addition, *Austrochiltonia subtenuis*, widespread in fresh and brackish waters in Western Australia has also invaded groundwater cave streams at Yanchep north of Perth (Burt, 1982; Stuckey, 1991; Jasinska & Knott, in press). *P. anophthalmia* is eyeless and nonpigmented with males to 3 mm and females to 4 mm in length. It occurs in moderate abundance within 5 small, shallow seeps, typically within the temperature range 17-23 °C, never >30 °C. A morphologically similar, but genetically distinct, form occurs in springs of the

Table 3: Distribution of Hydrobiidae in mound springs of the South Australian Lake Eyre Supergroup (LESG) and in the Queensland mound spring supergroups of the Great Artesian Basin, from Ponder *et al.* (1995) and Ponder & Clark (1990) respectively.

B Bubbler; BC Blanche Cup; BK Billa Kalina; BS Beresford; CS Coward; DS Davenport; E Emerald; ES Elizabeth; FR Freeling; FS Francis Swamp; HH Hermit Hill complex; HHH Hamilton Hill Homestead; JE Jersey; JS Julie; KH Kewson Hill; MSC Mt Margaret Complex; OS Outside; SS Strangways; TM Twelve Mile; WA Warburton; WS Welcome.

South Australia			Queensland
TAXA	MAX. SIZE (mm)	DISTRIBUTION	TAXA
LESG	LENGTH		BARCALDINE SUPERGROUP
Fonscochlea accepta Ponder, Hershler & Jenkins	3.8	DS E HHC WS	*Jardinella acuminata* Ponder & Clark
F. aquatica Ponder, Hershler & Jenkins	4.8	B BC BS BK CS ES FR FS HHH JE JS KH OS TM WA	*J. colmani* Ponder & Clark *J. coreena* Ponder & Clark *J. corrugata* Ponder & Clark
F. variabilis Ponder, Hershler & Jenkins	2.8	BC BS CS DS ES JE JS KH WA WS	*J. edgbastonensis* Ponder & Clark
F. billakalina Ponder, Hershler & Jenkins	2.4	BK FS SS	*J. jesswiseae* Ponder & Clark
F. expandolabra Ponder, Hershler & Jenkins	3.5	FR OS TM	*J. pallida* Ponder & Clark *J. zeidlorum* Ponder & Clark
F. zeidleri Ponder, Hershler & Jenkins	5.3	BC BK BS CS ES FR FS HH JE JS KH OS SS TM WA	SPRINGSURE SUPERGROUP *J. carnarvonensis* Ponder & Clark *J. exigua* Ponder & Clark
	WIDTH		
Trochidrobia punicea Ponder, Hershler & Jenkins	2.2	BC CS DS ES HH JE JS KH SS WS	SPRINGVALE SUPERGROUP
T. smithi Ponder, Hershler & Jenkins	2.1	BC BK BS FS MSC OS SS TM	*J. isolata* Ponder & Clark
T. minuta Ponder, Hershler & Jenkins	1.2	FS OS TM	EULO SUPERGROUP
T. inflata Ponder, Hershler & Jenkins	1.7	FS	*J. eulo* Ponder & Clark

Flinders Range. *A. dalhousiensis*, black-eyed and pale green in colour, occurs in shallow margins of spring overflow swamps amongst the sedges and of 3 active springs (2 with bore temperatures > 40 °C but there the amphipods were near the spring margins where the water temperature was near ambient; water temperature at the other site was 35 °C). Most specimens are about 4 mm long, but males range to 5.2 mm and females to 6.5 mm. Undescribed amphipods of the genus *Austrochiltonia* also occur in mound springs of the LESG (Zeidler, 1989) and of the Barcaldine Supergroup in Queensland (Ponder, 1995).

Decapoda. Freshwater crayfish, known locally as yabbies, occur in the flowing water of the spring outflows of all but one spring groups at Dalhousie (Zeidler, 1989). A morphological study involving 50 metric and multistate characters showed the yabbies to be distinctive with respect to the broadness of the areola and shortness of the thorax and rostrum but otherwise to be part of the *Cherax destructor*-complex with berried females noteworthy for their short abdomens (Sokal, 1987). Zeidler (1989) suggested that yabbies might breed all year round at Dalhousie under the influence of the constant environment, instead of once or twice per year as is the case elsewhere, throughout the range of the species. Yabbies of the *C. destructor*-complex are widely distributed throughout central Australia (Riek, 1969) and occur in bore drains and dams near Lake Eyre but not in mound springs of the LESG (Zeidler, 1989). In a morphological and genetic taxonomic study of

Table 4: Distribution of fishes from mound springs of the Great Artesian Basin. Based on Glover (1982,1989).

LESG Lake Eyre Supergroup, DS Dalhousie Springs, **max. size** refers to standard length of fish, **temp. min.max.** maxima and minima of spring temperatures where the fish occur, **max. salinity** the maximum salinities observed in the springs with fish.

taxon	occurrence	# of springs / # of DS groups where the fish occur	max. size in springs / max. size elsewhere in GAB (mm)	temp. min.-max. (°C)	max. salinity (‰)
Plotosidae					
Neosilurus sp. nov.	DS (endemic)	5 /2	120 / -	17-44	10
Neosilurus 3 spp.	LESG				
Poeciliidae					
Gambusia agnis Baird & Girard	LESG, widespread			3-40	25
Atherinidae					
Craterocephalus tercusmuscarum Gunther	widespread: DS	4/2	50 / 110		
C. eyressi Steindachner	LESG				
C. dalhousiensis (Ivantsoff& Glover)	LESG			9-37	110
	DS	7/2	78 / -	15-44	10
Teraponidae					
Leiopotherapon unicolor Günther	DS	6/3	172 / 310	5.3-44	35.5
	LESG				
Eleotridae					
Mogurnda mogurnda Richardson	DS	11/5	135 / 175	5-31	10
Gobiidae	LESG				
Chlamydogobius eremius Zietz	LESG,		-/ 63	5-41	60
Chlamydogobius sp. nov.	Widespread DS	30/7	36 / -	13-44.7	

populations from the eastern and southern margins of this distribution Austin (1996) concluded that the 4 species of Riek comprising the '*C. destructor*-complex' form one phenotypically plastic species, *C. destructor* Clark. Genetic structure of populations from the hinterland of South Australia, especially of the Lake Eyre drainage basin has not been undertaken yet but will be integral to unravelling the relationships and evolutionary history of the Dalhousie populations. Yabbies had been introduced, with the spread of Europeans, into dams as far north as Oodnadatta but Sokal (1987) questioned whether there had been sufficient time for generation of the morphological distinctiveness of the Dalhousie specimens through this source of colonisation. Consequently, he thought it unlikely that they had been introduced into these springs within historical times, even though yabbies were first collected there in 1984 and not during field studies in 1968 and 1974 (Sokal, 1987). Although Sokal quoted an opinion that Dalhousie springs may have been flooded numerous times in the past 1 000 years, this idea does not receive strong support (Kotwicki, 1989). Horwitz & Knott (1995) suggested that early aboriginal communities may have cultured yabbies and have been responsible for translocating them throughout central Australia; this hypothesis remains to be tested and it could provide an explanation for the occurrence of yabbies at Dalhousie but it does not explain their absence from the LESG springs.

Undescribed atyid shrimps of the genus *Caridina* are widespread through New South Wales and Queensland including Coward and Elizabeth springs of the LESG and sites near, but not from, Dalhousie springs. *Caridina thermophila* Riek occurs in springs of the Barcaldine Supergroup (Ponder, 1995). The freshwater crab *Holthuisana (Austrotelphusa) transversa* (von Martens), also widespread throughout central Australia and known from sites near Dalhousie and within the Finke River system, does not occur in mound springs of either the Dalhousie or LESG (Zeidler, 1989).

Mollusca. Of the molluscs recorded from springs of the GAB the most diverse group is the family Hydrobiidae (a cosmopolitan family of predominantly marine operculate prosobranch gastropods) which has undergone a number of adaptive radiations in athalassic waters. Based on shell and anatomical characters, GAB hydrobiids have undergone 3 adaptive radiations (Table 3), (i) of 12 species within the genus *Jardinella* (Ponder & Clark, 1990) in 8 springs within 4 spring supergroups of southwestern Queensland, (ii) of 6 species within the genus *Fonscochlea* (subdividing 4 species into a total of 10 sub-forms cited as 'A', 'B' and 'C') and 5 species within the genus *Trochidrobia* Ponder *et al.* (1989), most confirmed in an allozyme study (Ponder *et al.*, 1995), both genera endemic to springs of the LESG, and (iii) at least 6 species of hydrobiids within an endemic undescribed genus related to *Jardinella* and *Fonscochlea* (Ponder & Clark, 1990), within the Dalhousie complex (Ponder, 1989). Furthermore, Ponder *et al.* (1989) identified, in springs of the LESG, three distributional patterns: (i) endemic to a single spring: *F. zeidleri* form 'B' in Big Cadnaowie Spring and *F. accepta* form 'C' from Emerald Spring; (ii) restricted to a single spring group (*T. inflata*, *F. aquatica* 'B' and *F. variabilis* 'C'); and (iii) distributed across several spring groups (the most common pattern). The lack of hydrobiids and endemic crustaceans in several LESG springs (Ponder *et al.*, 1989) possibly is due to poor water quality (especially in springs with increased sulphate levels) and/or to restricted opportunity for colonisation.

Allozyme data were used to evaluate the bases of genetic differentiation of the LESG hydrobiids (Ponder *et al.*, 1995). Genetic differences were correlated with: (i) geographic distance and (ii) mound spring type. The springs of this supergroup lie essentially in a line and plotting Rogers' modified genetic distance values against log- transformed geographic distances yielded significant ($P < 0.05$) correlations in *F. accepta, F. aquatica, F. variabilis, F. zeidleri, T. punicea* and *T. smithi*, with insufficient samples preventing correlations to be calculated for the remaining species; but a major genetic discontinuity occurred, for example, between populations of the species *F. aquatica* inhabiting Beresford and Strangways spring groups, separated by only 8.5 km. Because the Strangways spring boils are still in their original position (on top of a large mound) whereas the Beresford Spring outflows have shifted to the base of the mound, Ponder *et al.* (1995) postulated that the Strangways population has evolved *in situ* while those of Beresford appear to be derived from large springs to the southeast.

In terms of the relationship between genetic differentiation of hydrobiids and mound spring type the over-riding trend, within spring groups, was related to the size of the spring. Populations from individual small springs were more genetically distinct than populations from large springs. Colgan & Ponder (1994) and Ponder *et al.* (1995) considered that these genetic patterns indicate comparatively high levels of genetic flow between snail populations of large springs through avian dispersal, with reduced likelihood of birds visiting smaller springs and thereby there being much lower levels of gene flow affecting hydrobiids of small springs. Avian dispersal of snails has generally been thought to involve young stages attached to the feet, legs or feathers of a bird (Boag, 1986). However, regurgitation of large numbers of live snails would also enable translocation over short distances. Regurgitation of live snails by silver gulls was observed on the Houtman Abrolhos Islands (Prof. M. S. Johnson pers. comm.). The two most likely causes of regurgitation are over-feeding on the snails, and ingestion of the snails by birds that find the hydrobiids unpalatable but swallowed them accidentally by drinking [as described by Fisher *et al.* (1972)] the spring water.

The LESG spring hydrobiids are markedly reduced in body size compared with stream-dwelling forms but, with the exception of stunted forms of *F. zeidleri* from several of the middle spring groups, the gastropods do not respond to differences in environmental parameters between springs (of size, extent of vegetation, substrate, salinity, TDS, pH, flow rate, for example) through generation of phenotypically distinctive morphs (Ponder *et al.*, 1989). Snails living in shaded habitats have no pigment and those in more exposed habitats accumulate black pigments about their visceral masses (Ponder *et al.*, 1989).

Hydrobiids can reach densities in excess of 1×10^6 m^{-2} (Ponder, 1989; Ponder *et al.*, 1989; Ponder & Clark, 1990). Usually only one species of *Jardinella* was found per spring but in two of the Edgbaston springs of the Barcaldine Supergroup, 5 species occurred with some zonation evident (Ponder & Clark, 1990). Up to 5 species of *Jardinella* occur in individual springs of the LESG, with zonation also evident and with changes in relative abundance of species in the different zones. Given the high densities attained by hydrobiids in many of the springs and limited resources available, Ponder *et al.* (1989) considered diversity in these mound springs to be controlled according to the species packing model, with considerable competition and limited niche overlap between species. Up to 3 species possibly inhabit each spring of the Dalhousie Supergroup, one spe-

cies inhabiting the sides and depths of the spring head and outflow, another the margin of the air/water interface of the spring head and the third an amphibious species near the rim of the spring head (Ponder, 1989).

Since the boils of individual mound springs are virtually constant in terms of temperature and salinity one might expect that the fauna inhabiting these habitats would exhibit a narrowing in physiological tolerance limits to fluctuations in these parameters. Ponder *et al.* (1989) addressed this hypothesis and found that the physicochemical range within which the snails remained active far exceeded the natural range found in the springs where they occur. The larger hydrobiid species were particularly tolerant to salinity extremes, *e.g. F. zeidleri, F. aquatica* and *F. accepta* remaining fully active at 12 ‰ while the springs known to contain hydrobiids have maximal salinities of only 5.2 ‰. The hydrobiid snails respond to deoxygenated waters with reduced activity but in general tolerate anoxic conditions quite well. In regard to temperature also, all species showed activity over a much wider range than found in their original spring habitats. For example, a large hydrobiid species from Dalhausie spring Ca 1 tolerates temperatures of 13-46 °C while the temperature of the spring is practically constant at 37-38 °C (Ponder, 1989). This tolerance to ranges in temperature and salinity far wider than the snails experience naturally is reminiscent of thermal tolerances of desert pupfish (*Cyprinodon* spp.) in Death Valley, North America (Brown & Feldmeth, 1971), indicating that there is no advantage in narrowing the range of physiological tolerance of both parameters under constant environments. However, in light of the implications for snail dispersal by birds, maintaining of tolerance to a wide range of physicochemical conditions is clearly of advantage to the snails.

Fish. The Australian fish fauna (< 200 spp.) is depauperate due, in part, to the "long isolation, historical climatic regimes and generally low featureless topography" (Allen, 1989). Is it paradoxical, then, that ~30 species (Glover, 1982) occur in the Lake Eyre drainage basin, an area which exemplifies *par excellence* extremes of isolation and low featureless topography? The greatest fish diversity in the GAB is achieved by: eel-tailed catfishes (Plotosidae, approximately 6 spp.); hardyheads, also known as silversides (Atherinidae, 4 spp.); and grunters (Teraponidae, 5 spp.). In addition, the gudgeons (Eleotridae) and gobies (Gobidae) are a prominent component of the mound spring faunas. Progress in central Australian ichthyology has been thoroughly reviewed by Ivantsoff & Glover (1974), Glover & Sim (1978), Glover (1982, 1989), and Crowley & Ivantsoff (1989). At least 9 valid species have been recorded from mound springs (Table 4).

The goby is the most widespread fish in the LESG while the hardyheads are the most abundant (Mitchell, 1985). The goby is physiologically labile, tolerating salinities from 0.2-110 g L^{-1}, temperatures over the range 9-40 °C, and oxygen concentrations down to 0.8 mg L^{-1}; specimens have been observed partially out of water possibly indulging in aerial respiration (Mitchell, 1985). They avoid high temperatures by exploiting the strong lateral temperature gradients and sheltering under vegetation (Glover, 1982). Australian hardyheads are normally sexually dimorphic only during the breeding season but adult specimens (> 40 mm) of *C. dalhousiensis* remain sexually dimorphic, a feature normal for the closely related rainbow fish (Melanotaeniidae) and blue eyes (Pseudomugilinae) (Ivantsoff & Glover, 1974) but, it also indicates that the near constant spring environments promote continuous breeding. Kodric-Brown & Brown (1993) analysed the structure of fish communities from 38 isolated springs at Dalhousie (including 4 with multiple spring outflow points). Species richness of the 28 fish communities showed positive correlation with a number of environmental parameters reflecting spring size (for example area of source pool, discharge rate, length of outflow, area of riparian vegetation). Each species occurred in all springs above a threshold size, with the order of increasing threshold size being goby<gudgeon<catfish<hardyheads (treated as 1 species) <perch. Neither temperature nor isolation appeared to affect species diversity. Kodric-Brown & Brown (1993) concluded that fish community structure at Dalhousie Springs is controlled deterministically by spring size, with historical and uncontrolled environmental factors not contributing substantially to the fish community structure.

It is pertinent to question how the fish have colonised the isolated springs, particularly given that 2 species widespread throughout the drainage basin, namely bony bream (*Nematalosa erebi*) and rainbow fish (*Melanotaenia splendida*), both occurring in 6 river systems, artesian bores, dams (Glover, 1982), are not present in the mound springs. Birds are unlikely to have been important agents of dispersal (Glover, 1982, 1989) leaving flooding as the most likely route. Perch have been observed swimming across flooded paddocks and wheel ruts but do not aestivate as was suggested in early reports (Llewellyn, 1973). Because the springs of the LESG lie along a line perpendicular to the drainage lines, floods are

likely to form connections within but not between spring groups. Fish dispersal into Dalhousie Springs (between the Fink and The Stevenson rivers) raises the question of whether the nearest wadi, the Finke could have flooded the springs. The Finke River, despite its isolation, harbours 18 species of fish, the greatest number of all 8 such systems listed in Glover (1982) and compares favourably with the 9 species from the Diamantina River which flows a little more regularly. Although the Dalhousie Springs are likely to have been flooded in the past, they are unlikely to have been inundated during the past 10 000 years (Kotwicki quoted in Glover 1989). Chance dispersal through floodwaters would filter out those species unable to cope physiologically with the lower temperatures and variable salinities. *Neosilurus* sp. nov., for example, is unable to survive in temperatures < 20 °C. Hardyheads die rapidly when transferred to temperatures only a little different from those normally experienced. Species migrating through Lake Eyre must tolerate the higher salinities of that lake. The distribution of fish within the Eyre drainage basin (Glover, 1982) and the deterministic controls of the species associations at Dalhousie (Kodric-Brown & Brown, 1993) together suggest that dispersal of fishes generally through the area was established under the wetter climates operating until about 2.5 x 10^6 years ago (Bowler, 1982). Further dispersal into springs presumably has been a lottery event, predominantly restricted to wetter Pleistocene interglacials, the last of which ended about 40 000 yrs ago (Frakes *et al.*, 1987) and would have depended upon the ability of fish to cope with a variety of substrates over which the floodwaters would flow.

Terrestrial fauna. Terrestrial animals make limited use of springs: terrestrial arthropod diversity from springs and other microhabitats of the area of the LESG ranked as follows: creekbeds>springs>other habitats>bores; importantly, a distinctive riparian fauna was associated with mound springs (Greenslade, 1985). No frogs have been recorded from the LESG springs (Thompson, 1985) but *Limnodynastes tasmaniensis* Günther, possibly a new morph, occurs at Dalhousie (Harris, 1989). Even terrestrial vertebrates make limited use of mound springs, although reptiles find refuges in the travertine (Thompson, 1985). Birds were far more prevalent at artesian bores (particularly at the large vegetated swamps and lagoons) than at mound springs (Badman, 1985). Very few small native mammals use mound springs perhaps due to the presence of dingoes and exotic feral animals (camels, cattle, donkeys, pigs) but larger forms (dingo, red kangaroo, euro) use them as watering holes.

Origins of the mound spring fauna

The mound spring fauna is seemingly derived from two sources, one northern (the fishes), one southern or Gondwanan (the crustaceans). The fish belong to Indo-Pacific families with the greatest diversity of the Australian representatives occurring in the northern and eastern coastal streams. The very low and flat northern divide between the GAB and the Gulf of Carpentaria may well be crossed when extensive monsoonal flooding renders contiguous adjacent river catchments. During wet interglacial periods, including the last (about 40 000 years ago), when sea levels where up to 8 m higher than at present, this invasion route would have provided to northern invaders even greater access to central Australia. Significantly, earlier invasions are also possible. During the early Cretaceous, the GAB was covered by an epicontinental sea transgressing through the Gulf of Carpentaria (Wilford & Brown, 1994), itself an offshoot of the Tethys Sea. Throughout the first half of the Cretaceous, the waters overlying the GAB fluctuated greatly between marine, estuarine and lacustrine. By late Cretaceous times, the epicontinental sea had regressed, and had been replaced in the Tertiary by extensive freshwater lakes which fluctuated in extent, at times opening to the Southern Ocean until about 20 Ma, after which it progressively dried (Wilford & Brown, 1994). If some of the mound spring animals constitute relicts of the Cretaceous marine transgression they also can be regarded as Tethyan relicts. Other species with exclusively pre-Cretaceous freshwater origins, *e. g.* the phreatoicid isopods, must have colonised the springs in post-Cretaceous times possibly during episodes when the GAB was inundated by a great freshwater lake. Determination of the sequence of fish and crustacean invasion events within spring supergroups and across the whole GAB, using genetic techniques, would provide important insights into the past patterns of flooding in the area.

Mound springs of Ellenbrook

The rheocrene, limnocrene and helocrene springs (*sensu* Williams, 1983), at elevations between 40-60 m above sea level in the Ellenbrook area near Perth, Western Australia (fig. 3), are discharge points from the eastern Gnangara Mound, a shallow unconfined aquifer within Quaternary dune deposits between the Swan and Moore rivers of the Swan Coastal Plain (Allen, 1976; Davidson, 1995). Also present and common until two decades ago were peat mound springs for which Jasinska *et al.* (in prep.) have proposed the term *tumulus* to distinguish them from mound springs of the GAB. The Ellenbrook

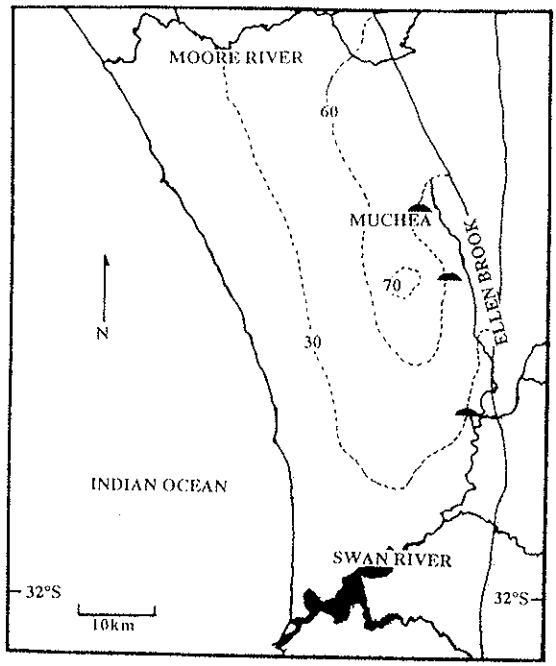


fig. 3. Locations of tumulus springs and Gnangara Mound, Ellenbrook area, Western Australia. Contours describe the watertable of the Gnangara Mound in m Australian Height Datum; light stippling shows the extent of the Perth metropolitan area; mound symbols represent mound spring outcrops, hatched line indicates scarps, major landform features in the area.

Fig. 4. A Dalhousie spring northwest of Lake Eyre. From: L. Meier, P. Figgis & J.G. Mosley, Australia's Wilderness Heritage, vol. 1 (Weldon Publishing, 1988).

tumulus springs can be distinguished from raised bog mires (Gore, 1983) by their smaller size and strictly groundwater (non-artesian) origin. Unfortunately, all but 3 tumulus springs have been destroyed to create farm dams or pastures (Jasinska *et al.*, in prep.).

Jasinska *et al.* (in prep.) provide a description based predominantly on the 3 remaining tumulus outcrops but also using accounts from local residents and botanists who have sampled the springs in the past. The springs occur at the boundary between the impermeable fluviatile Guildford Clays (which direct the aquifer to the surface) and the overlying aeolian siliceous Bassendean Sands (which carry the aquifer). The tumulus springs are raised about 2 m above the surrounding land surface by localised peat build-up and are about 3 m in diameter at the base but aggregates were also common. In active springs, discharge occurred through a central vertical channel with an apical vent of about 10 cm diameter. Less active springs discharge from the overall surface of the mound rather than from a discrete channel. The spring water is fresh dominated by Na and Cl (order of cationic dominance Na>Mg>K>Ca) of salinity ~0.2 g L^{-1}, temperature ~19 °C and pH ~4.5. The fauna of one spring at Muchea harboured 12 species of microinvertebrates, 10 of which, so far as our limited definition of relevant taxa enables us to comment, occurred in at least one other spring but none from surface water habitats from the area. The southern-most tumulus spring harbours a new genus of crangonyctoid amphipod. The permanently moist conditions provided by tumulus springs at Ellenbrook, enabled the persistance of mesic species such as a liverwort (*Gleobelobryum ungriculatum* Steph.), bog clubmoss (*Lycopodium serpentinum* L.) and sundew (*Drosera pulchella* Lehm.) in an area of hot dry summers and an annual rainfall of 780 mm (data from Bureau of Meteorology, Perth). These plants occur in permanently wet swamps of the lower southwest of Western Australia but north of Perth they were known only from tumulus springs. Recharge to the Gnangara Mound is seasonal, given the Mediterranean climate, with 90% of the rainfall occurring between May and October.

Recharge occurs through the sand ridges to the west of the spring line of Ellenbrook; these ridges are covered with a *Banksia*-dominated woodland with some *Eucalyptus* spp. and *Melaleuca* spp. where the land surface dips closer to the water table. The Gnangara Mound in this area reaches its maximum elevation of 70 m above sea level. Formation of tumulus springs may well have been initiated with the formation of the Gnangara Mound, early in the Pleistocene.

Conservation

It is important that both sets of mound springs be conserved both as natural formations and for the biota for which they provide a habitat and a refuge in a dry landscape. Their importance as refuges applies not only to endemic species but also in those cases where the spring populations are significantly isolated outliers to species with widely disjunct distributions (2 examples in plants). This applies not only to the aquatic forms but also to terrestrial forms which are unable to persist in the arid landscapes where the springs are located. Furthermore, a variety of animals living in the surrounding arid landscapes use the mound springs as reliable sources of drinking water and food. Last but not least, the peat formations associated with both sets of springs [there are peat remnants between springs in spring groups of the GAB (Symon, 1985)] are likely to be a very valuable repository of information enabling the Pleistocene/Holocene climatic history and dating of vegetational changes to be unravelled.

Spring conservation depends on 2 issues: reliability of water supply, and minimisation/absence of damage to the springs themselves and their associated microhabitats. In the GAB, 4 700 bores have been drilled to 2 000 m (mean 500 m); discharge from the 3 100 active bores in 1970s was 1.5×10^6 m^3 per day compared with 2×10^6 m^3 per day from 1 500 bores in 1918 (Habermehl, 1980). In the early years much water was wasted, an issue causing great concern, even then, to Gregory (1906) amongst others who thought that part of the water resource was irreplaceable being connate. Discharge throughout the GAB has now stabilized at a new steady state level and, given the awareness of the need to conserve this valuable resource, increasing discharge is unlikely to be allowed. However, recharge areas of the GAB also need to be managed very carefully, and this point requires emphasis in the literature.

There has been considerable habitat destruction of springs in the GAB mostly caused by agricultural and pastoral pursuits. Terrestrial vegetation on a number of the LESG springs has been reduced to 2-3 dominant species by cattle grazing with concomitant reduction in habitat complexity. Reduced habitat complexity possibly explains the occurrence there of, amongst spiders, only hunting forms (Greenslade, 1985) and undoubtedly has had a flow-on effect in reducing the numbers of terrestrial invertebrates generally. What impact high nitrate levels from cattle excrement might have on the biota within the LESG springs has yet to be determined (Mitchell, 1985). The response to impacts of these kinds has been to fence off springs, although we are unaware of any studies evaluating what size the fenced-off areas should be to mitigate edge effects. Artesian bores and their outflow swamps do not serve as alternative habitats to the unique mound spring fauna (Greenslade, 1985; Mitchell, 1985). However, whether this reflects real, inherent differences between the 2 microhabitats or is simply a function of the mound spring fauna having been unable to colonise bores and their swamps in the short time which has been available has still to be evaluated.

With respect to the Ellenbrook tumulus springs, nearly all were completely destroyed, especially over the past two decades mainly through pastoral activities. Only three tumulus outcrops appear to have remained: one of them has already been purchased for protection of the springs, while the conservation value of the remaining two outcrops is also presently being recognised by the relevant Government planning authorities. Their recharge areas are located within a few kilometres of the discharge points, and the Gnangara Mound is seen as a major water resource for urban Perth. It will be interesting to see whether the water extraction programmes can be fine-tuned sufficiently to prevent the drying of the springs during particularly dry years.

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BS 22

Melaleuca Swamp and Edgecombe Spring, Ellenbrook, Western Australia.

Brenton Knott & Edyta Jasinska, Department of Zoology, The University of Western Australia, Nedlands, Western Australia. 6907.

Introduction

The Gnangara Mound is a major subterranean water resource to the north of Perth with the north-south boundaries at the Moore and Swan rivers, respectively, and the east - west boundaries the Darling Scarp and Indian Ocean, respectively. The water reserves of the Mound are important as a source from which to supplement the supply for use within Perth. Concomitant with this use, the northward expansion of Perth is encroaching onto the landscape overlying the Mound.

The Mound reaches a topographical high point of 70 m AHD (Australian Height Datum) (Allen, 1981). From the high surfaces of the Mound, water flows westwards to the Indian Ocean and eastwards into Ellen Brook. The westwards flow is evident at the land surface particularly about the chains of lakes from Loch McNess to Monger: the limnological significance of these lakes has been studied over a number of years and documented in numerous publications.(Balla and Davis, 1993; Davis *et al.*, 1993). More recently, awareness of the presence of a diverse and significant groundwater fauna associated with root mats in the shallow epiphreatic streams in several caves at Yanchep National Park, also on the western slopes of the Mound, has developed predominantly through the efforts of Jasinska (1990). In contrast, investigation of the eastwards outflow of the Mound did not begin until 1992 through the instigation of Mr Jeff Kite, Water Authority of Western Australia. The outflow eastwards occurs predominantly through a series of springs between the 40 - 60 m AHD contours between Ellenbrook and Muchea. Ahmat, and predominantly Jasinska (papers in preparation), have drawn attention to the biological significance of these springs, and particularly to the resource lost with the widespread destruction of the *tumulus* springs of the Ellenbrook to Muchea area.

The subject of this Report is Melaleuca Swamp, a permanent swamp on the south eastern flanks of the Mound. Edgecomb Spring is another outflow point some distance south of Melaleuca Swamp. Both sites are to be assessed as being suitable points for monitoring the eastern outflow of the Mound to detect ecologically undesirable consequences of groundwater extraction. Two other sites are to be included in this assessment, but only recently has permission been granted to have access to them for study.

Study Sites

Melaleuca Swamp

There are four swamps in close proximity to each other (Fig. 1) which collectively may be referred to as the Melaleuca wetlands. These swamps appear to be the remnants of one, large, wetland - as revealed by aerial photography of the area (Fig. 2). The main swamp and the largest of the four, hereafter called Melaleuca Swamp and initially identified as the sole swamp for this study, is drained to the eastwards by a temporary creek called, in this Report, Melaleuca Creek. Otherwise, there is no other surface drainage throughout the area. Two additional sites, MSa (the western-most swamp) and MSb (the northern extension of Melaleuca Swamp) were also sampled as part of the present study (Fig. 1).

The surroundimg area of the remnant swamps is dominated by an open *Banksia menziesii* woodland with low, scattered *Eucalyptus* spp. *Eucalyptus calophylla* (marri) and *Eucalyptus marginatus* (jarrah) grade into a fringing zone of *Melaleuca preissiana* (ti tree) immediately around Melaleuca Swamp.

Melaleuca Swamp, 115° 57' 48" E., 31° 42' 22" S, approximately 170 x 110 m, covers an area of nearly 1.5 ha. Vegetational zonation, markedly shore-parallel, is most obviously developed along the eastern side of the swamp where the margin to the swamp is also clearly defined. *Leptocarpus* sp. 1 (Restionaceae) grows at the shoreline, *Leptocarpus* sp. 2, overlain by *Astartea fascicularis* with scattered *Calothamnus lateralis*, grows further into the swamp. The zone of *Leptocarpus* sp. 2 grades into a zone of *Lepidosperma longitudinalis*, which in turn is replaced throughout much of the central area of the swamp by *Baumea articulata*. The area of *B. articulata*, covers a 0.7 ha or 47% of the total swamp area. When the swamp is filled with water, there is very little open water habitat; the little there is occurs between the *L. longitudinalis* and the *B. articulata* on the eastern side. The growth of *L. longitudinalis* on fire columns to a height of >21 cm indicates that part of the swamp, at least, has been burnt, and fire edges are clearly evident in the aerial photographs crossing the area of *B. articulata*.

The base of Melaleuca Swamp is 50.41 m AHD and the top of the casing of the nearby bore GNM 14 is 51.805 m AHD (S. Bates, pers comm., 14 May 1996). On 15 November 1995, the maximum water depth in Melaleuca Swamp was 0.65 m so that the water surface of the swamp was 51.06 m AHD. At the same time, the distance from the top of the casing of bore GNM 14 to the water table was 1.077 m, i. e. groundwater level at that point was 50.728 m AHD. This

indicates some perching of swamp water at least during late winter: this slight evidence indicates that a year-long study of the swamp - groundwater relationships could be important in understanding the limnology of this swamp.

The general geology controlling the distribution of spring outflows of the eastern Gnangara Mound in the Ellen Brook area is described in detail in Jasinska and Knott (1994). Briefly, the springs occur where the Bassendean sands interdigitate with the Guildford Formation where groundwater is forced to the surface because of the low permeability of the Guildford clays.

The Edgecombe Spring site is described in detail in Jasinska and Knott (1994). This is a permanent rheocrene spring with groundwater flow along an epiphreatic conduit in quartz sand.

Melaleuca Swamp and its outflow creek, and Edgecombe Spring were sampled for temperature and water chemistry on 4 November 1995. The methods and results are as follows.

Temperatures.

Temperatures were measured using a fully immersing Hg thermometer with 0.1°C divisions.

Creek. Temperatures measured at 14 .00 hours.

Air temperature (°C)	Water temperature[1] (°C)	Water temperature[2] (°C)
26.9	27.7	25.4

Water temperature[1]: 4 cm depth, in shade.
Water temperature[2]: in deepest channel.

Swamp. Temperature measurement commenced 16.20 hours, concluded 17.20 hours. Air temperature 28.8°C.

Water depth (cm)	Water temperature (°C)		
	Site 1	Site 2	Site 3
Surface	24.9	25	24.9
10	18.8	22.2	18.8
17			16.7

This temperature gradient could not be fully measured on 4 November 1995 because it was impossible to read the thermometer at depths >17 cm. Consequently, temperature measurements were repeated on 15 November 1995, using a LF 95 WTW Conductivity Meter, with results as follows.

	Site				
	MSa	MSb	MS 1	MS 2	MS 3
Time of day (hours)	11.00	12.00	14.30	13.30	14.00
Air temperature (°C)	25.3	27.5	25.5	24.6	25
Depth (cm)	**Water temperatures (°C)**				
2			29.5	26.8	26.7
5	21.6	21.7	25.5		23.0
10	21.0	21.0	21.6	19.9	20.0
20	16.9	19.0	17.8	16.8	16.9
30	16.6	17.7	17.0	15.9	16.2
40			15.8	15.4	15.5
50			15.3		15.3
60			14.9		14.9
65	16.1		14.8		14.9

Comment.

These data show clearly a gradient in water temperature between the surface and bottom temperatures at all sites. This gradient undoubtedly is due to an interaction between: the influx of cooler groundwater, limited penetration of sunlight into the water column, and very limited mixing - indicating very little impact from the light breezes.

Ryder & Horwitz (in press) observed the same phenomenon in their study on Lake Jandabup, suggesting that it could be a feature of all dark water lakes on the Swan Coastal Plain. The

temperature gradients must have a substantial impact on the rate of processing nutrients and organic matter in such lakes and consequently on the whole-system ecology of such lakes, an effect which would be desirable to evaluate.

Total Dissolved Solids & Salinity.

Salinity

Total dissolved solids (TDS) and salinity were measured using a I F 95 WTW Conductivity Meter.

The results of measurements of samples collected on 4 November 1995 are as follows.

Site	Temperature (°C)	µS/cm
Edgecombe Spring	12.7	195
	13.8 - 15	198
Melaleuca Swamp	13.5	347
	9.5	331
Melaleuca, creek	11.5	338

The results of measurements on 15 November 1995 are as follows.

	Sites									
	MSa		MSb		MS 1		MS 2		MS 3	
Depth (cm)	mg/L	µS/cm	mg/L	µS/cm	mg/L	µS/cm	mg/L	µS/cm	mg/L	µS/cm
2	263	355					270	358		365
5			252	335	270	351			275	365
10	272	358	255	343	274	355	279	370	278	365
20			257	343	275	369	284	378	282	375
30	275	366	259	343	277	368	285	381	283	379
40					275	369	285	381	284	380
50					275	366			284	380
60	278	370			275	366			284	380
65					276	370			284	380

pH.

pH was measured on 4 November 1995, using a LC80A pH meter calibrated using standard buffer solutions pH 4.0 and 7.0, with results as follows.

Site	pH
Edgecombe Spring	5.71
Melaleuca Swamp	3.80
Melaleuca, creek	3.70

Nutrients.

Samples for chemical analysis were collected on 4 November 1995 as follows. Samples for orthophosphate, ammonia and nitrate - nitrite/ were filtered in the field using 0.2m Millipore filter papers and collected in acid-washed plastic bottles. Samples for total phosphorus and total nitrogen analyses were collected unfiltered. Samples for ion and colour analysis were filtered through Whatman (Ltd). GF/C papers. 1 L samples for chlorophyll analysis were filtered in the field on Whatman (Ltd). GF/C papers and delivered to the Chemistry Centre in Whirlpaks. All samples were kept cool on ice until delivery to the Chemistry Centre.

Appendix 1. Microinvetebrate species list.

species	Edgecombe spring	iron deposit	MSa	MSb	MS Baumea	MS ti-tree	MS reeds	Mel. creek	MS whole
CRUSTACEA									
Cladocera									
Macrothricidae									
Ilyocryptus sp.							+		+
Daphniidae									
Scapholeberis kingi (Sars 1903)			+	+	+		+	+	+
Daphnia ?thomsoni (variab. morph.) bloom			+						
Chydoridae									
Alonella clathratula			+		+		+		+
Biapertura setigera (Brehm 1931)			+		+	+	+		+
Biaperura rigidicaudis(Smirnov 1971)				+	+	+	+	+	+
Graptoleberis testudinaria (Fischer 1848)					+				+
Monope reticulata (Henry 1922)					+	+	+		+
Rak obtusus (Smirnov and Timms 1983)						+	+		+
? gen. nov. (closest to *Rhynchochydorus*)						+			+
Copepoda									
Calanoida									
Calamoecia tasmanica				+	+	+	+		+
Cyclopoida									
Mesocyclops sp1			+	+		+	+	+	+
Paracyclops sp1			+	+	+	+	+	+	+
Paracyclops sp2	+	+							
Harpacticoida spp	+		+						
Ostracoda									
Candona sp1	+								
Candona sp2		+							
Darwinula sp	+								
Ilyodromus sp						+	+		+
Syncarida: Bathenyllacaea sp	+								
Decapoda									
Cherax quinquecarinatus			+	+		+	+	+	+
INSECTA: **Diptera**									
Chironomidae									
Alotanypus ?dalyupensis								+	+
Chironomus sp.2	+								
Chironomus sp1			+						
*Dicrolendipes*sp			+	+					
Harrisius sp								+	+
Limnophyes pallulus			+		+		+	+	+

Paramerina parva								+	+
Tanytarsus sp								+	+
Tipulididae (larvae) sp	+								
ACARINA									
Hydracarina: Pionidae sp1			+			+		+	+
sp2								+	+
Limnohalacarida: *Lobohalacarus* sp.	+	+							
Oribatida spp	+	+	+					+	+
ROTIFERA spp	+	+							
OLIGOCHAETA: Naididae									
*Pristina*sp (new record for Australia)	+	+							
Pristinella jenkinae (Stephenson 1931)			+	+		+	+		+
TURBELLARIA									
Macrostomium sp		+							
Rhabdocoelomate turbellarians sp	+								
NEMATODA spp	+	+	+	+	+	+	+		+

The analyses were performed by the Chemistry Centre (WA), and their methods are summarized as follows.

Analyte	Description	Method
Chloro_a	Chlorophyll "a"	iCHLA1WACO
Chloro_b	Chlorophyll "b"	iCHLA1WACO
Chloror_c	Chlorophyll "c"	iCHLA1WACO
Phaeoph_a	Phaeophytin "a"	iCHLA1WACO
Colour	Colour, Gilvin (g 440m^{-1})	iCOL1WAGI
N_NH_3	Nitrogen, ammonia fraction	iAMMN1WAAA
N_NO_3	Nitrogen, nitrate fraction	iNTAN1WAAA
N_total	Nitrogen, persulphate total	iNP1WTAA
P_SR	Posphorus, soluble reactive	iP1WTCO
P_total	Posphorus, persulphate total	iPP1WTCO

The results are as follows.

Analyte	Unit	Sites		
		Edgecombe Spring	Melaleuca Swamp	Melaleuca creek
Chloro_a	mg/L	<0.001	<0.001	<0.001
Chloro_b	mg/L	0.001	0.003	0.001
Chloro_c	mg/L	0.001	0.004	0.001
Phaeoph_a	mg/L	0.001	0.012	0.005
Colour	TCU	8	1200	1200
N_NH_3	mg/L	<0.02	0.09	0.10
N_NO_3	mg/L	2.5	0.06	0.06
N_total	mg/L	3.2	2.4	2.1
P_SR	mg/L	0.02	0.02	0.01
P_total	mg/L	0.02	0.01	0.01

Discussion

The salinity levels are all considerably less than 2475 µS cm-1: the swamps form fresh water wetlands. Given the obvious input through springs along the western margin of the swamp - there were pools of water 10 cm deep about these springs late (4 April, 1996) in summer - perhaps there is need to find an explanation for the high water colour levels of the swamp.

The shallow Secchi disc depth on 4.XI.1995 of 13 cm when water depth was 65 cm is readily understandable given the high values for colour. Davis & Rosich (1993) suggest that the minimum water colour of Swan Coastal Plain swamps should be set at 52 $_{g440}$ m^{-1} or 300 HU. The maximum HU values for Swan Coastal wetlands is < 600 HU (Schmidt and Rosich 1993). Conversion of the Gilvin values for Melaleuca swamp gives an HU value of >6900! Clearly Melaleuca Swamp is correctly identified as a coloured wetland although the source of the discrepancy has to be detected.

Of greater importance, phosphorus concentrations of 0.01 mgL^{-1} (=10 μgL^{-1}), combined with very low chlorophyll values, indicates a swamp of very low primary productivity. Indeed, there was little evidence on both sampling days of water-column based primary productivity, beyond limited epiphytic growth on *L. longitudinalis* and *B. articulata* stems. There is a well defined reservoir of detrital material (leaves and twigs of terrestrial plants, fragmenting stems of the emergent macrophytes) which presumably serves as the major primary carbon source for the animals present.

Fauna

Although only the main Melaleuca swamp was initially targeted for study, all three swamps were sampled on 15 November, 1995, for fauna in view of the importance of the specimens collected on the first sampling occasion. Furthermore, although the original sampling plan was to collect up to 10 replicate samples from each of the microhabitats identified, this protocol was dropped in light of the experience on the first sampling occasion. Numbers of animals were so small, that efforts were made instead simply to collect specimens to compile an inventory of the fauna of the lake - albeit from discrete microhabitats. It may be that November was too late to sample, and we will resample all sites in September this year.

Faunal list

Fish

Galaxiella nigrostriata (Shipway, 1953). *G. nigrostriata* and *Galaxiella munda* can be difficult to separate (Berra & Allen, 1989) and identification was confirmed by Dr Gerald Allen, Western Australian Museum. Reasonably abundant in Melaleuca Swamp and MS B but not present in MSa.

This is a quite significant record for the occurrence of this species considerable north of its hitherto known distribution, namely "confined to the only a few sites in the lower Southwest" [Drake 1995: 22 (sic)]

Amphibia

Tadpoles were collected from Melaleuca Swamp and Melaleuca Creek but they belonged to a taxonomically difficult group and it was not possible to classify them even to genus. It will be necessary to collect adults.

	Melaleuca Swamp					
Taxon	*Baumea*	*Astartea*	*Lepido.*	Creek	MSa	MSb
Odonata						
Austolestes io			+			+
Argiolestes pusillus					+	
Argiolestes coeruleum		+	+			
Family Anisoptera					+	
Austogomphus?			+			
Austrolestes analis			+			
Hemiptera						
Sigara mullaka			+			
Vellidae		+			+	+
Hebriidae		+				
Gerridae		+				
Diptera						
Chaoborinae				+	+	
Coleoptera						
Antiporus sp.(larvae)		+	+		+	
Antiporus (adult) sp.1		+	+	+	+	+
Antiporus (adult) sp.2					+	
Hyphydrus elegans	+?	+?	+?	+?	+	+
Dystiscidae				+		
Dryopidae		+			+	
Hydrophilidae		+		+	+	
Hydrochus sp.				+	+	
Hydrovatus sp.						+
Limbodessus sp.	+				+	
Trichoptera						
Leptoceridae sp.1	+	+	+	+	+	
Leptoceridae sp. 2		+	+			+
Crustacea : Decapoda						
Cherax quinquecarinatus		+	+	+	+	+

Comments.

In terms of species number, Melaleuca Swamp, with a total of 42, ranks favourably with the species component of the seven dark-water swamps unambiguously identifiable from Growns et al. (1993), namely from 34 -61 species on a single sampling occasion. However, there is little concordance of species between this study and the lists from the 40 wetlands of the Davis *et al.* study (Growns *et al.*, 1993). The fish *G. nigrostriata* and several of the cladoceran crustaceans constitute northern outlier populations of species which previously had been recorded in Western Australia only from highly coloured, acid water temporary swamps of well to the south between Walpole and Windy Harbour. This relationship is being studied this year. The other record of note is the discovery of a syncarid crustacean from Edgecombe Spring different to the syncarid from the Yanchep caves. This finding is in accord with the comments of Jasinska and Knott (1994) that the groundwater faunas from the eastern and western sides of Gaaanangara Mound are quite dissimilar in terms of species composition. Otherwise, the aquatic fauna from the Melaleuca sites shows little obvious separation into microhabitats - but this feature will be assessed again in 1996 in September when it may be possible to detect more clearly any patterns of distribution which might develop.

One final difficulty which has been experienced in the present study concerns the very early development shown by much of the fauna, making it impossible to classify the forms to families in some cases let alone genera or species. This problem should be rectified in a sampling programme in September.

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MULTIPLEX CONSTRUCTIONS PTY LTD

EGERTON

FAUNA SURVEY

TECHNICAL REPORT:
SUPPLEMENT TO
CONSULTATIVE ENVIRONMENTAL REVIEW

ALAN TINGAY & ASSOCIATES

FEBRUARY 1994

REPORT NO: 93/74

APPENDIX B

FROGS, REPTILES AND MAMMALS OBSERVED AT EGERTON

Key for habitat types at survey sites.

1. *Pericalymma ellipticum* Heath
2. *Eucalyptus/Pinus pinaster* Woodland
3. *Melaleuca* Woodland
4. *Banksia* Woodland
5. *Juncus pallidus* Sedgeland with Bracken

(o) Observed during survey.
(i) Introduced species.

HABITAT SURVEYED

	1	2	3	4	5
FROG SPECIES					
LEPTODACTYLIDAE					
Crinea georgiana	*	*		*	*
Heleioporus eyrei			*	*	
Heleioporus sp (inornatus)?			*		
Limnodynastes dorsalis	*				
Ranidella glauerti	*		*		*
Ranidella insignifera			*		
LIZARD SPECIES					
GEKKONIDAE					
Diplodactylus spinigerus				*	
AGAMIDAE					
Pogona minor		*	*		
SCINCIDAE					
Cryptoblepharus plagiocephalus				*	
Hemiergis quadrilineata				*	
Egernia napoleonis			*		
Lerista praepedita				*	
Lerista elegans		*			
Menetia greyii		*		*	
SNAKE SPECIES					
ELAPIDAE					
Notechis scutatus			*		
Tiger Snake					

MAMMAL SPECIES	1	2	3	4	5
MACROPODIDAE					
Macropus fuliginosus (o)	*	*	*	*	*
Western Grey Kangaroo					
TARSIPEDIDAE					
Tarsipes rostratus			*		
Honey Possum					
PERAMELIDAE					
Isoodon obesulus	*		*	*	*
Southern Brown Bandicoot					
MURIDAE (i)					
Mus musculus	*			*	*
House Mouse					
Rattus rattus			*		
Black Rat					
CANIDAE (i) (o)					
Vulpes vulpes		*			
Fox					
LEPORIDAE (i) (o)					
Oryctolagus cuniculus		*		*	
Rabbit					

APPENDIX C

BIRD SPECIES RECORDED AT EGERTON

Key for bird habitat types at survey sites:

1. *Pericalymma ellipticum* Heath (Wetland)
2. *Pinus pinaster* Plantation with some native vegetation
3. *Melaleuca* Low Woodland to Low Closed Forest (Wetland)
4. *Banksia* Woodland
5. Farmland
6. Ornamental Lake
7. Mill Pond

(o) Observed during survey
(i) Introduced species.

BIRD SPECIES	1	2	3	4	5	6	7
DROMAIIDAE							
Dromaius novaehollandiae					*		
Emu							
PODICIPEDIDAE							
Tachybaptus novaehollandiae						*	
Australasian Grebe							
PHALACROCORACIDAE							
Phalacrocorax melanoleucos						*	
Little Pied Cormorant							
PLATALEIDAE							
Threskiornis aethiopica					*		
Sacred Ibis							
ANATIDAE							
Tadorna tadornoides						*	
Australian Shelduck							
Anas superciliosa						*	
Pacific Black Duck							
PANDIONIDAE							
Aquila audax		*					
Wedge-tailed Eagle							
ACCIPITRIDAE							
Elanus notatus	*						
Black-shouldered Kite							
RALLIDAE							
Fulica atra						*	
Eurasian Coot							
Porphyrio porphyrio						*	
Swamp Hen							
COLUMBIDAE							
Streptopelia senegalensis					*		
Laughing Turtle-Dove (i)							

BIRD SPECIES	1	2	3	4	5	6	7
CACATUIDAE							
Cacatua roseicapilla					*		
Pink & Grey Galah							
Cacatua pastinator							*
Little Corella							
POLYTELITIDAE							
Platycercus zonarius			*	*	*		
Ring-necked Parrot (28)							
CUCULIDAE							
Cuculus pyrrhophanus				*	*		
Fan-tailed Cuckoo							
Chrysococcyx lucidus			*		*		
Shining (Golden) Bronze Cuckoo							
ALCEDINIDAE							
Dacelo novaeguineae			*		*		*
Laughing Kookaburra							
Halycon sancta		*			*		
Sacred Kingfisher							
CORACIIDAE							
Merops ornatus					*		
Rainbow Bee-eater							
CAMPEPHAGIDAE							
Coracina novaehollandiae		*					*
Black-faced Cuckoo Shrike							
PACHYCEPHALIDAE							
Pachycephala rufiventris	*		*	*	*	*	
Rufous Whistler							
Collurcincla harmonica					*		
Grey Shrike Thrush							
MONARCHIDAE							
Rhipidura fuliginosa				*	*	*	
Grey fantail							

BIRD SPECIES	1	2	3	4	5	6	7
Rhipidura leucophrys		*			*		
Willy Wagtail							
SYLVIIDAE							
Acrocephalus australis							
Australian Reed-warbler							
MALURIDAE							
Malurus splendens		*		*			
Splendid Wren							
ACANTHIZIDAE							
Gerygone fusca		*		*	*		
Western Warbler							
Acanthiza apicalis			*				
Inland Thornbill							
MELIPHAGIDAE							
Anthocheara carcunculata						*	
Red Wattle Bird							
Anthochaera chrysoptera				*			
Little Wattle Bird							
Acanthorhynchus superciliosus		*					
Western Spinebill							
Phylidonyris nigra				*			
White-cheeked Honeyeater							
Lichmera indistincta	*	*		*	*		
Brown Honeyeater							
ZOSTEROPIDAE							
Zosterops lateralis	*	*	*		*		
Silvereye							
GRALLINIDAE							
Grallina cyanoleuca				*	*		
Magpie-lark							

BIRD SPECIES	1	2	3	4	5	6	7
CRACTICIDAE							
Cracticus torquatus				*			*
Grey Butcher Bird							
Gymnorhina tibicen					*		
Magpie							
CORVIDAE							
Corvus coronoides				*	*		*
Australian Raven							

MULTIPLEX CONSTRUCTIONS PTY LTD

EGERTON

STRUCTURE PLAN

CONSULTATIVE ENVIRONMENTAL REVIEW

BS 22
EGERTON
BASIN

ALAN TINGAY & ASSOCIATES

FEBRUARY 1994

REPORT NO: 93/61

AN INVITATION TO COMMENT ON THIS CER

The Environmental Protection Authority (EPA) invites people to make a submission on this Consultative Environmental Review (CER).

The CER has been prepared by Multiplex Constructions Pty Ltd in accordance with the Environmental Protection Act, 1986 and describes an urban Structure Plan for the Egerton property in the Shire of Swan. At present the land involved is zoned Urban Deferred. The CER is available for public review for four weeks from 15 February 1994 to 15 March 1994.

Comments from Government agencies and from the public will assist the EPA to prepare an Assessment Report on the Structure Plan in which it will make recommendations to Government.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated confidentially unless it is stated that they can be used publicly, then they may be quoted either in full or in part in each report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to ten people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the CER or with specific aspects. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific items in the CER:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable; and
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- Attempt to list points so that the issues raised are clear. A summary of your submission is helpful.

- Refer each point to the appropriate section, chapter or recommendation in the CER.

- If you discuss different sections of the CER, keep them distinct and separate, so there is no confusion as to which section you are considering.

- Attach any factual information you wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name,
- your address, and
- the date.

The closing date for submissions is:

15 March 1994.

Submissions should be addressed to:

The Chairman
Environmental Protection Authority
8th Floor, Westralia Square
141 St George's Tce
PERTH WA 6000

Attention: Mr Ian Harvey

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SUMMARY

1. INTRODUCTION

This Consultative Environmental Review (CER) describes a Structure Plan for an urban estate on the Egerton property in the Shire of Swan. The land affected by the Structure Plan is adjacent to, and to the east of, the Ellenbrook Estate. Both the Egerton and Ellenbrook land are currently zoned Urban Deferred.

In 1993, the owners of the Ellenbrook land applied for the Deferred status to be lifted, i.e for the land to be zoned Urban, so that it would be available for development.

As Ellenbrook and Egerton are adjacent to each other and have a common zoning, it was considered appropriate that this application should include both parcels of land. In order for this to happen it was necessary for the owners of Egerton, Multiplex Constructions Pty Ltd, to prepare a Structure Plan to illustrate the main features of a future urban estate. This Structure Plan is an essential component of the application for changes to the zoning.

The Structure Plan also provides a basis for the Environmental Protection Authority (EPA) to assess the environmental implications of urbanisation at Egerton. These environmental implications are the subject of the present CER.

2. DESCRIPTION OF PROPOSAL

The Egerton Structure Plan has been developed on the basis of an analysis of the environmental features of the land involved and incorporates an urban structure which is designed to protect and preserve the most important natural environmental features. In particular, the Structure Plan provides for the retention of a chain of wetlands within Open Space. With sympathetic development these wetlands will become major community assets to future residents while still retaining their natural physical and biological values.

The major road system within the estate has also been determined by the dominant environmental features of the site. In particular, the road alignments have been selected so as to minimise the need for earthworks and to avoid the important wetlands.

Access within the development to the different neighbourhoods, wetland corridors and a zoological garden, which is based on an existing private zoo, is provided by dual use path networks.

Surface drainage will be via a conventional system of road gullies and underground pipes draining to detention basins within Open Space and ultimately to Ellen Brook. The detention basins will enable control of the quantity and quality of runoff prior to final discharge. Subsoil drainage will also be necessary in areas of high groundwater.

Water supply to the development will be derived from the Lexia borefield on the Gnangara Mound to the east, and the development will be deep sewered. Electricity will be supplied from the existing high voltage system on Gnangara Road, telephone connections can be provided by the extension of optic-fibre cables from the existing OTC facility and natural

gas can be made available via a connection to SECWA's existing Dampier to Bunbury pipeline.

3. EXISTING ENVIRONMENT

Groundwater

The Egerton property is located on the easternmost fringe of the Gnangara Mound. Groundwater flow within the Gnangara Mound is from west to east, so there is no possibility that the proposed development will have any effect on any Public Water Supply Area.

Wetlands

Two separate groups of wetlands have been identified on the Egerton property:

- the Ellen Brook Suite, and
- the Muchea Suite.

The Ellen Brook Suite comprises a creek system that provides the natural surface drainage to Ellen Brook whilst the Muchea Suite are small to medium scale sumplands and floodplains in depressions at the base of the Bassendean Dunes.

None of the wetlands on the property are within areas identified in the System 6 Study Report of the Environmental Protection Authority (EPA) or in the Environmental Protection (Swan Coastal Plain Lakes) Policy, 1991.

Surface Flows

Egerton is a discrete surface subcatchment of Ellen Brook as all surface flows originate entirely on the property. The Egerton property covers 0.8% of the total Ellen Brook catchment, and discharge from the property is estimated to be approximately 275,220m^3/yr.

Surface Water Quality

Based on a number of studies of the Ellen Brook catchment, it is estimate that nutrient loads discharged from Egerton are in the order of:

- Total Nitrogen 574.2kg/yr
- Soluble Reactive Phosphorus 143.55kg/yr
- Total Phosphorus 193.05kg/yr.

Land Capability

The eastern part of the Egerton property is dominated by the Yanga soil unit. The soils on the western side of the property belong to the Jandakot, Gavin and Joel units, which are all Bassendean Sands. Seasonal Swamps occur in the south-western half of the property

and a Drainage Line unit dissects the Jandakot unit at the base of the property. Karrakatta and Muchea sands occur along the south-eastern edge of the property.

The Yanga, Joel, Drainage Line and Seasonal Swamp units require fill and drainage prior to development. The Jandakot, Karrakatta and Muchea units are susceptible to wind erosion but this does not present a problem for urbanisation. The Gavin unit has a high capability for urban development.

Flora and Vegetation

Most of the native vegetation on the Egerton property has been cleared for pine plantations and agricultural use. A total of 158 native species were recorded on the Egerton property. No declared rare flora species were recorded, although a large population of the Priority 3 species *Aotus cordifolia* was located.

Twenty-four vegetation associations occur on the property. The vegetation types are similar in floristic composition to those on the adjacent Ellenbrook Estate, and all the associations at Egerton are represented within the proposed conservation areas on Ellenbrook Estate.

Vertebrate Fauna

Fifty species of indigenous (native) vertebrates have been recorded at Egerton together with four introduced mammal species and 2 introduced bird species.

The vertebrate fauna is typical of the region, and comprises a sub-set of that found in surveys of Whiteman Park and Ellenbrook.

The Southern-Brown Bandicoot is present and appears to be mainly associated with wetland habitats. This species is classified as rare and endangered.

Aboriginal Sites

There are 3 areas of significance to Aboriginal people on the Egerton property. Two of these being camp sites and the other an archaeological site located near the camp sites.

A Waugal or Rainbow Serpent Dreaming Track was also identified. However, it was noted that the Waugal is associated with all areas of open water.

4. ENVIRONMENTAL IMPLICATIONS AND MANAGEMENT

Wetlands

The sumplands are considered to be the primary environmental asset of the Egerton property, and have been substantially included within Public Open Space. A series of open ponds will also be created, which are intended to increase the variety of habitats available to waterbirds and other aquatic fauna, and to provide landscape diversity and aesthetic appeal in the POS system.

Hydrological issues

Surface drainage will be by conventional road gullies and underground pipes connected to disposal basins in Open Space areas. Retention basins will also be placed in the system to enable control of runoff quantity and quality.

Runoff following urbanisation is expected to increase by approximately 3% on current rates. If untreated, this runoff could increase phosphorus output. To counter this, detention basins will be lined with neutralised red mud to absorb phosphorus.

Data is presented in the CER which indicate that there will be a substantial reduction in phosphorus outflows from Egerton to Ellen Brook following urban development.

Flora and Vegetation

The proposal will have no significant implications in terms of the conservation of regional flora, as most of the flora on Egerton is typical of the northern and eastern uplands and wetlands of the Bassendean Dune Sands.

Most of the remnant vegetation on the property is associated with wetlands that are to be substantially included within POS. The Priority 3 species, *Aotus cordifolius* will also be protected within Open Space.

Vertebrate Fauna

The vertebrate fauna at Egerton is typical of the bushland and farmland areas of the local area and the Perth Metropolitan Region. The fauna at Egerton is not significant in terms of regional conservation, however the fauna has local intrinsic significance.

The retention of a large proportion of the remaining natural vegetation within POS at Egerton will continue to provide a variety of habitats for vertebrate fauna.

The Southern Brown Bandicoot requires special consideration due to its status of rare and endangered. The favoured habitat of this species is the dense vegetation associated with the principal wetlands, much of which will be substantially retained within the POS areas. One option for management of this species is to develop a specific management plan to protect the species from predation by domestic animals or foxes and their habitat from damage. The other option is to capture, remove and relocate the local bandicoot population to secure conservation reserves.

Aboriginal Sites

There is no potential for the disturbance of the majority of Aboriginal Sites under the current Structure Plan for Egerton. This includes the stream associated with the Waugal. However, part of one archaelogical site could be affected by the present proposal. It may become necessary to make an application to disturb this site.

5. CONCLUSIONS

The information presented in this CER suggests that the proposed urban development of the Egerton property will have no significant adverse environmental impacts. This is mainly because the Structure Plan for the estate takes into account the most important environmental features of the property. In particular, the Plan includes the Muchea Suite sumplands, and their associated high quality vegetation and important fauna habitats, within Open Space.

1. INTRODUCTION

1.1 Background

The Egerton property is located in the Swan Valley in the Shire of Swan. It is to the south-west of The Vines Resort and is immediately adjacent to, and east of, the proposed Ellenbrook Residential Estate.

In 1992, the owners of the Ellenbrook Estate (Sanwa Vines Pty Ltd, Homeswest, and Mount Lawley Pty Ltd) proposed that the area of land which they owned should be rezoned from Rural to Urban Deferred. This proposal was referred to, and was formally assessed by, the Environmental Protection Authority (EPA). Subsequently, the proposal received environmental approval from the Minister for Environment subject to certain conditions.

In its Assessment Report on the Ellenbrook proposal, the EPA also referred to Egerton. It indicated that in its view the two properties could be rezoned at the same time but that environmental issues associated with urban development of the Egerton property would require specific assessment. In effect, this meant that for the Urban Deferred zoning at Egerton to be lifted a Structure Plan would have to be prepared for consideration by the EPA and by the planning authorities.

In 1993, both Ellenbrook and Egerton were zoned Urban Deferred.

The owners of the Ellenbrook property, in accordance with normal planning procedures, then applied for the Deferred zoning to be lifted so that their property would be available for urban development. It was considered appropriate that an application should also be made at the same time for the lifting of the Urban Deferment at Egerton.

The owners of the Egerton property, Multiplex Constructions Pty Ltd, therefore prepared a Structure Plan to support the application for the removal of the Deferred status over their land. The environmental implications of this Structure Plan are the subject of this Consultative Environmental Review (CER). The CER has been prepared in accordance with guidelines provided by the EPA which are included in Appendix 1.

1.2 General Scope of the CER

The CER provides a description of the Structure Plan for Egerton, a description of the present environmental features of the property affected by the Structure Plan, an analysis of the environmental issues relevant to that Plan, and a description of strategies for environmental management that have been incorporated into the Plan.

1.3 The Proponent

The proponent for the lifting of the Urban Deferred zoning at Egerton is:

Multiplex Constructions Pty Ltd
15th Floor
214 St Georges Tce
PERTH WA 6000

1.4 The EPA Assessment Process

The Western Australian environmental impact assessment process is outlined in the Guide to the Environmental Protection Act (Environmental Protection Authority, 1987) and is illustrated in Figure 1. Essentially, the proponent (in this case Multiplex Constructions Pty Ltd) is required to notify the EPA of any proposal which may have significant environmental implications. The EPA then determines whether the proposal should be formally assessed. If a decision is made for a formal assessment, the EPA requires the proponent to prepare a detailed account of the environmental implications in a report such as the present Consultative Environmental Review (CER).

After the CER has been prepared, it is reviewed by the EPA to ensure that it provides sufficient detail and a comprehensive coverage of issues. When this has been established, the CER is released for a public review period. At the end of the public review period, a summary of submissions is supplied to the proponent and a response is sought. The EPA then undertakes to assess the development proposal.

The results of the EPA assessment are published in the form of an Assessment Report which includes recommendations made to the Minister for Environment. Interested parties can appeal against the level of assessment set by the EPA, and against the content of the EPA Assessment Report, or any of its recommendations. Ultimately the Minister for the Environment decides whether the proposal is acceptable and what conditions will be imposed upon it.

The environmental assessment process is designed to enable State authorities to consider in detail the environmental and social implications of development proposals. These considerations are based on technical assessments of the nature and extent of changes to the existing natural and social environments, on proposed management strategies designed to control or limit adverse changes, and on monitoring programs designed to document and analyse the effectiveness of such strategies.

The environmental assessment process also enables members of the public to obtain details of the proposal and to formally comment on any matters of interest to them. These inputs are required within a specified public review period and are considered together with the technical assessments. The public is encouraged to provide written comments to the EPA as part of the environmental review process. Details of the public review period for the Egerton proposal and advice on how to make a submission are provided at the beginning of this CER.

1.5 Public Consultation

During the preparation of the CER, a meeting was held on 12 October 1993 between the Chairman of the Ellenbrook Conservation Group (Mr Kingsley Dunstan), a Councillor from the Shire of Swan (Ms Jan Zeck), and the environmental consultants (Alan Tingay & Associates) in order to identify the issues which are of concern to the local community.

At this meeting the following environmental issues were raised.

"Mound Spring" - the Ellenbrook Conservation Group (ECG) were concerned about protection of a "Mound Spring" in the north-west corner of the property and associated vegetation.

The spring is in fact a groundwater seepage area and is described in Sections 3.7 and 3.8 of the CER. This area will be protected within Open Space.

The ECG stated their knowledge of the presence of two rare flora species in the area of "spring".

A specific flora survey for the CER identified two Priority Flora species (Section 3.12.3) but no Declared Rare Flora on the property. The Department of Conservation and Land Management (CALM) does not have any records of rare flora on the property nor does it expect any to occur there.

The potential to create a bushland corridor from Egerton to the Lexia Wetlands and Whiteman Park also was raised.

The Egerton Structure Plan has a system of POS linked internally and to Ellen Brook to the east. However it is not possible to link these areas to other bush areas outside the Egerton boundary given current planning for the Ellenbrook Estate and the lack of bush linkages to Whiteman Park.

The ECG indicated the possible presence of the Honey Possum (*Tarsipes spencerae*) in the area.

The presence of this species has been confirmed by the fauna survey (Section 3.13) but as only one individual was caught, the status of the population is not known.

The potential pollution of Ellen Brook and Henley Brook was a primary concern.

The effect of the urbanisation at Egerton on water quality is discussed generally in Sections 3.10 and 4.4 and will be modelled in detail in the Drainage Management Plan which the proponents have committed to prepare. It is expected that there will be a reduction in nutrient levels in runoff following urbanisation.

2. DESCRIPTION OF THE PROPOSAL

2.1 Location, Titles and Zoning

The Egerton property is located approximately 20km north of the City of Perth in the Shire of Swan (Figure 2). The land currently zone Urban Deferred comprises three titles as follows:

•	Lot 148	98.1077ha
•	Lot 30	174.9051ha
•	Lot 2	222.3412ha
Total Area		495.3540ha

The land is part of a larger property owned by Multiplex Construction Pty Ltd which also is known as Egerton. The Urban Deferred zone at Egerton is part of a larger area to the west and north which is the Ellenbrook Urban Deferred zone.

2.2 Planning Framework

The State Planning Commission (SPC) through the Department of Planning & Urban Development (DPUD) is responsible for planning urban development within the Perth Metropolitan Region. The broad strategy for development of the region is described in Metroplan (DPUD, 1990a) while specific areas for urban development are identified in the Urban Expansion Policy Statement (DPUD, 1990b) and the Metropolitan Development Program 1991-92/1995-96 (DPUD, 1991). The Policy Statement identified Ellenbrook as one of the areas most likely to be developed in the short to medium term while the Development Program described it as the most significant opportunity for development in the north-east sector of the Perth Metropolitan Region in the period up to 1996. The location identified included all of the land now currently zoned Urban Deferred including both Ellenbrook and parts of Egerton.

The implementation of urban development requires appropriate zoning under the Metropolitan Region Scheme (MRS) administered by the SPC and the Town Planning Scheme (TPS) of the Shire of Swan which are the main statutory bases for planning in the region. Until recently, Egerton and Ellenbrook were zoned "Rural" under both the MRS and the Shire of Swan TPS No. 9 District Zoning Scheme. Both locations however, were rezoned to Urban Deferred after an application by the owners of Ellenbrook and environmental approval from the Minister for Environment. That approval was based on recommendations of the EPA following assessment of a Public Environmental Review (PER) for the Ellenbrook proposal (EPA, 1992).

The next step in the planning process involves rezoning the land from Urban Deferred to Urban under the MRS and to Residential Development or a similar zoning under the Shire of Swan TPS. These steps have been initiated. The EPA however, decided to formally assess the proposal for rezoning Egerton to Urban as specific details of this location were not included in the Ellenbrook PER. In particular, the EPA wishes to determine that the

rezoning from Urban Deferred to Urban is appropriate given a specific Structure Plan for future residential development of the land.
Assuming that the Minister for Environment gives environmental approval for the Structure Plan for Egerton, following assessment by the EPA, the necessary amendments to the MRS will occur in accordance with the provisions of the Metropolitan Region Town Planning Scheme Act, 1993. The equivalent amendment to TPS No. 9 of the Shire of Swan also will be processed in accordance with the normal procedures of the Town Planning and Development Act, 1928-1965 and Town Planning Regulations, 1967.

2.3 The Egerton Structure Plan

2.3.1 General Description

The Egerton Structure Plan is described in detail in a specific publication (Multiplex Constructions Pty Ltd, 1993). The Plan, which is illustrated in Figure 4, presents a framework for an urban estate which responds to the specific opportunities and constraints to the site. In particular, the environmental "constraints" on the site, which are the main wetlands and the creek lines, are converted into planning assets through their inclusion in a network of Open Space linked by walking and cycling trails. This Open Space network is the dominant feature of the Structure Plan and has been the primary determinant of the other components of the Plan.

The topography and remaining natural vegetation on the site have been used to produce distinctive character zones in the Structure Plan. The Plan uses these features to define individual linked neighbourhoods each of which will have special qualities created by the retention and enhancement of existing vegetation, retention of wetland areas, creation of new wetland habitats, views to major landscape features, and access to Open Space.

The road and dual purpose path network has also been substantially determined by the dominant environmental features of the site. These corridors focus on the "town centre" where shopping, commercial, and community facilities are concentrated.

The dual use paths network, as well as linking the neighbourhoods, also provides access to particular areas of interest such as the wetland corridors and the zoological gardens. The paths will allow a diverse choice of walks of varying distance and ready access to major Open Space and schools.

The zoological gardens are based on an existing private zoo which houses a small but diverse collection of birds and some other vertebrate fauna. The zoo is constructed to the highest standards and includes a completely enclosed wetland containing mature *Melaleuca preissiana*. This feature is considered to be a major potential educational, public and tourist asset for the area as well as a unique local attraction for future residents.

The road system will play a major part of defining the quality of the area. The roads will be flanked by tree plantings designed to suggest and reinforce a hierarchy. The primary distributor road running north from Gnangara Road will be a parkway with substantial roadside planting. This road has been located to the east of the primary wetland chain and elevated areas in the western sector of the site so that it can be constructed with minimum environmental disturbance. Land uses such as drainage detention basins, Open Space and

the high school have been located along the route to present users with an open aspect wherever possible.

In the elevated western sector the slopes are often steep and the roads have been aligned to take account of the existing contours and to reduce the need for earthworks in their construction.

The major road link to the Ellenbrook Estate in particular, has been specifically located in a "valley" like depression within the ridge system and crosses the wetland Public Open Space network at a location which has been significantly disturbed, in order to minimise environmental impacts.

2.3.2 Land Use Allocation

The Structure Plan makes provision for some 3,650 residential lots at an average density of approximately 7.4/ha. The projected maximum population at Egerton is in the order of 11,800 people. The proposed housing mix has been based on present market trends and a developable area of 358.9ha. The mix of lot sizes is given in Table 1.

TABLE 1

PROPOSED RANGE OF LOT SIZES

Average Land Per Unit (m^2)	Number of Units	Proportion %
570	730	20
700	1460	40
770	1095	30
450	182	5
250	182	5

The Structure Plan allows for a retail centre with floor space of approximately 15,000m^2 on a 6ha site. Provision is also made for future commercial units in an area of 3.4ha. There are two primary schools each comprising 4ha and 1 high school site of 10ha. A community use site, which may include a central community hall, church, daycare, and or other uses, comprising 2.05ha is located adjacent to the primary retail/commercial centre.

As mentioned above, the extent of Public Open Space is a feature of the Structure Plan. The total area of Open Space is 84ha which comprises approximately 17% of the development area compared to the statutory requirement of 10%. The Open Space will fall into a number of categories as described in Table 2.

TABLE 2

CATEGORIES OF OPEN SPACE

Open Space	Total Area (ha)
Major conservstion reserve: with managed public access.	34.5
Parkland corridors and water bodies.	27.8
Pocket parks, local play and incidental space.	3.0
Zoological Gardens	10.7
Sportsgrounds	8.0
TOTAL OPEN SPACE	**84.0**

It is possible that the zoological gardens may be privately owned and therefore may not constitute part of the Open Space.

2.3.3 Pedestrian and Vehicle Movements

The Structure Plan includes a comprehensive path system designed to encourage walking and cycling from residential areas to schools, Open Space and the town centre. The primary path system is located substantially within Open Space corridors or adjacent roadways. Secondary footpaths will link the primary paths to form circular routes to provide recreational opportunities as well as ease of access.

Motor vehicle traffic will be catered for by the primary distributor roads which cross the site and provide access from Gnangara Road and connections west to the Ellenbrook urban estate. The compatibility of the primary road network with the environmental features of the site has been described in Section 2.3.1 above.

The residential neighbourhoods will be served by a loop road system which also corresponds to the physical features of the site.

Traffic modelling for the Ellenbrook proposal has included the potential development of Egerton and indicates that traffic originating in Egerton with a destination outside the area will total approximately 11,100 trips per day. It is anticipated that the traffic flows on the regional and distributor roads will be of the order indicated in Table 3.

TABLE 3

PREDICTED TRAFFLIC FLOWS

Road	Volumes (VPD)
Lord Street extension south	3890
Lord Street extension north	1110
Rookwood Street south	2220
Great Northern Highway south	550
Great Northern Highway north	1000
Internal Roads north	660
Gnangara Road west	1670

2.3.4 Services

As a result of the presence of wetlands of particular significance and other areas of high groundwater within the Egerton property, particular attention will be given to the treatment of stormwater drainage. The drainage system will based on the broad principles established under the North-East Corridor Drainage Strategy of the Water Authority of Western Australia (WAWA). In general, it is expected that surface drainage will be via a conventional system of road gullies and underground pipes draining to disposal basins within the Open Space areas. The pipe system will be designed to cater for runoff from storms with a frequency of up to 1 in 5 years with flows from less frequent events provided for in overland floodways comprising road reserves and/or linear Open Space systems. In both cases a water sensitive approach will be adopted for design and construction of the drainage system to maximise the potential for groundwater recharge and minimise the risk of pollution of downstream receiving waters including wetlands within the site and Ellen Brook to the east.

Other elements of the drainage strategy will include the incorporation of retention basins within the system to control both runoff quantities and qualities prior to final discharge. These will combine dry basins which are landscaped as part of the Open Space areas and artificial or groundwater lakes developed within or adjacent to the existing wetlands or high groundwater level areas.

In the areas with high groundwater which are allocated for residential purposes it may be necessary to incorporate subsoil drainage as well as fill to provide adequate clearances between the groundwater and finished building levels. This drainage will be designed to ensure that the extent of groundwater export from the area is adequately controlled.

A model of both the surface drainage and groundwater flows associated with the Structure Plan is currently being developed and will form a component of a comprehensive Drainage Management Plan.

The water supply to Egerton will be derived from the Lexia borefield operated by WAWA on the Gnangara Mound to the east. Supply to both Ellenbrook and Egerton will be via trunk and distribution water mains linking to a main reservoir and treatment plant located

on higher ground along the State Forest boundaries west of Ellenbrook. Separate high level reservoirs may be required to service the higher sectors of Egerton.

The water supply facilities will be implemented in stages and it is expected that initial supply will be via permanent bores within the Lexia system on the Gnangara Mound to the west and a permanent high level reservoir or temporary on ground reservoir within the estate itself. Temporary treatment facilities will also be constructed either as a central plant or as separate plants at each bore site.

The Egerton urban estate will be deep sewered. WAWA's current planning for sewerage of urban areas in the north-eastern corridor of the Perth Metropolitan Region is to collect sewage and pump it to existing and future treatment plants to the west. This would involve an initial link to the existing Beenyup Treatment Plan but with ultimate connection to the proposed Alkimos Treatment Plant. The capital costs of these projected works will be very high and, as a result, a number of alternative schemes are being considered as part of the planning for Ellenbrook and Egerton.

These alternative schemes include systems for the on-site treatment and disposal of sewage incorporating both permanent and temporary facilities staged to suit the pattern and rate of urbanisation. Such treatment would be in package plants incorporating secondary and tertiary process systems as necessary to meet any environmental requirements for effluent disposal. A range of disposal options exist including on-site irrigation, dual water supply, seepage, etc. These will need to be investigated as part of more detailed planning, however, initial assessments suggest that the concepts involved are feasible. It is possible that on-site facilities may become the long term permanent scheme for sewerage of the area.

The proponent recognises that the use of on-site effluent treatment and disposal will need to be investigated as part of more detailed development planning and that specific proposals may require further assessment by the Environmental Protection Authority.

Electricity supply to Egerton will be from the existing high voltage system on Gnangara Road. This system has sufficient capacity to service the intial development. Telephone connections can be provided by the extension of optic-fibre cables from the existing OTC facility off Gnangara Road, west of the Egerton property. Natural gas can also be made available to the area via a connection from SECWAs existing Dampier to Bunbury pipeline which runs through the south-east corner of the State Forest, west of Egerton.

3. EXISTING ENVIRONMENT

3.1 Introduction

The main existing features of the Egerton property are:

- An elevated sandy ridge in the western sector which slopes down to the east.
- A series of wetlands mostly located at the base of the ridge which are manifestations of a shallow groundwater level.
- A plain which extends from the wetlands beyond the eastern boundary of the present Urban Deferred zone to the valley of Ellen Brook.
- some intermittent and perennial streams which run from the wetlands across the plain to Ellen Brook.
- The general absence of indigenous vegetation and fauna habitat over much of the land, except the wetland areas, as a result of clearing for agriculture and the development of an extensive pine plantation.

The Structure Plan for Egerton has been developed in accordance with the opportunities and constraints presented by the existing features of the site as explained in Section 4 of this CER. The present section provides a basis for that explanation and includes a detailed description of the existing environment.

3.2 Climate

A description of the climate at Egerton is important for an understanding of site conditions and particularly the dynamics of wetlands and the proposed groundwater and drainage management plans. These plans are an integral part of the development proposal.

The Perth Metropolitan Area, of which Egerton is a part, is described as having a 'warm mediterranean' climate regime and experiences seasonal changes with warm to hot dry summers and mild wet winters. The actual definition of a 'warm mediterranean' climate regime is related to the annual distribution of rainfall. This relationship is illustrated in Figure 5 as an ombrothermic diagram in which monthly mean rainfall is plotted against temperature on double the scale (Beard, 1979). Months in which rainfall plots above the temperature line are considered 'wet' while months in which rainfall plots below the temperature line are considered dry.

At Egerton, the dry period extends from approximately mid October to the end of March. Rainfall in the summer months (December to March) is less than 20mm per month. Rainfall at Egerton occurs mostly during the winter months (June to August) with mean monthly totals during this period in excess of 100mm and up to nearly 160mm in July. Seasonal rainfall results from westerly frontal systems bringing moist air from the Indian Ocean to coastal and inland areas.

Local rainfall information is available from the Upper Swan Research Station which is located approximately 3km north-east of Egerton. The exact location of the Research Station is 31°45' South and 116°01' East and the data covers a 35 year period from 1957 to 1992 (Figure 6a and 6b).

The average yearly rainfall at the Research Station is 737mm.

As the dry period at Egerton is in summer, and the wet in winter the climate fits the pattern of 'mediterranean'. This description is used in a global context where mediterranean climates are unusual and occur only in California (USA), Chile, South Africa, Southern Australia and adjacent to the Mediterranean Sea.

The length of the dry season determines the type of mediterranean climate attributable to an area. For example, a regime with only 3 to 4 dry months is classified as 'moderate mediterranean', whilst a regime with 5 to 6 dry months is a 'warm mediterranean' climate (Beard, 1979). Egerton experiences 6 dry months and may be described as a temperate mediterranean climate.

Based on records from the Upper Swan Research Station, winds from the south-west are most common in spring and summer afternoons (30 to 40% occurrence at 1500hrs). During summer, winds are common from the east (55%) at 0900 hours, but not at 1500 hours (25%) (Figure 7).

Prevailing winds tend to be easterly in the morning and south-westerly in the afternoons.

3.3 Geology

The Egerton locality comprises four distinct geological formations which are associated with various origins (Gozzard, 1986) (Figure 8). The north and mid-western section of the property has areas of peaty clays which are dark grey and black with variable sand content. These two areas are of lacustrine (wetland) origin and were formed in the Holocene (less than 10,000 years before present).

To the north and south of the peaty clays on the western half of the property is Bassendean Sand which is very light grey at the surface and yellow at depth. The sand is fine to medium grained, with subrounded, moderately well sorted quartz. This formation is of aeolian origin.

Associated with these sands is another formation which consists of a thin veneer of Bassendean Sands over the Guildford Formation. In this case, the Guildford Formation consists of pebbly, strong brown silt. Also present are fine to occasional coarse-grained, subrounded laterite quartz with heavily weathered granite pebbles. Quartz sand is present and is fine to medium grained and of alluvial origin.

The north-eastern sector of the locality consists of the Guildford Formation (as described above) without the Bassendean Sand veneer. The Guildford Formation derives from river (alluvial) sediment deposits which are associated with Ellen Brook and the nearby Swan River.

3.4 Geomorphology

Egerton is situated approximately 5km west of the Darling Scarp on the Swan Coastal Plain. This plain is an undulating lowland bounded to the east by the dissected uplands of the Darling and Dandaragan plateaus and to the west by the Indian Ocean.

The main geomorphic features that make up the Swan Coastal Plain are aligned sub-parallel to the present coastline. The most easterly of these is the Ridge Hill Shelf, which is a series of laterite covered spurs forming the foothills of the Darling Scarp (McArthur, 1976). There is then a series of dune systems which extend westward to the coast. The easternmost is the Bassendean Dune System, then the Spearwood Dune System, and closest to the coast the Quindalup Dune System.

The Egerton property is located on the eastern margin of the Bassendean Dune System.

There are three distinct geomorphic units present at Egerton. These units are illustrated in Figure 9 and include:

- Bassendean Dunes: a geomorphically degraded surface of aeolian origin.
- Alluvial Flood Plains at the north-east of the property. These are associated with drainage lines which run from damplands in the north-western portion of the property to Ellen Brook.
- Lacustrine marshes in interdunal swales which are situated in the north to mid-western part of the property. These areas are associated with damplands.

3.5 Topography

The most elevated area of the property is along the north-western boundary at 61m AHD (Figure 10). The western third of the property is dominated by prominent ridges with slopes generally between 3° and 10° but steeper in some places. The ridge lines generally run north to south with undulations forming swales between the dunes. To the east, the topography is less steep with slope of 0° to 3°. The elevation drops gradually to between 25 and 16m AHD at the eastern boundary.

3.6 Groundwater

The Bassendean Sand Formation, which is the dominant surface geological unit at Egerton, contains groundwater. This groundwater is referred to as a shallow or superficial aquifer and it has formed, and is replenished by, infiltration of rainwater.

The superficial aquifer under Egerton is a component of a much larger groundwater system which underlies the Bassendean Sand Formation on the Swan Coastal Plain between the Swan River northwards to near Gingin Brook. This very large aquifer is known as the Gnangara Mound, a large part of which is a major source of public water supply for the Perth Metropolitan Region. Active and potential water supply areas are

defined on the Gnangara Mound by the Water Authority of Western Australia (WAWA) and specific requirements are imposed on land use within these areas.

The Egerton property is located within the defined Swan Groundwater Area and is to the east of the Mirrabooka Public Water Supply Area. While the Swan Groundwater Area is not a designated Public Water Supply Area, WAWA nevertheless requires groundwater and surface water management strategies within this area to be evaluated on the basis of their potential regional impact on the groundwater system and the environment.

As the Mirrabooka Public Water Supply Area is to the west of Egerton and the groundwater flow in the Gnangara Mound is from west to east (see Figure 11), there is no possibility that urbanisation will have any effect on the Public Water Supply Area.

In 1992, a draft policy, referred to as the Environmental Protection (Gnangara Mound Private Land Groundwater) Policy 1993, was established by the EPA to protect groundwater supplies of the private land portion of the Gnangara Mound from pollution. The Egerton property is located outside of this policy area.

The surface of the groundwater (i.e. the water table) under Egerton is at a variable depth below the ground surface depending on the surface topography. For example, in the north-west corner of the Egerton property, ground surface elevations may be in the order of 50m AHD while the water table is at about 40m AHD. In the south-east corner of the property the ground level is 25m AHD while the watertable is at about 20m AHD. As the groundwater results from rainfall, the water table fluctuates by about 1 to 1.5m according to the season, with peak levels from September to October and minimum levels from April to May.

The thickness of the aquifer (i.e. the saturated zone within the sand) is about 10m.

As the water table levels become progressively lower across the property from west to east the groundwater flows "downhill" towards the eastern side of the property and Ellen Brook (Figure 11). Some groundwater "leaks" to a lower geological formation (the Marine Sands) and some groundwater also leaks upwards from this lower deposit into the superficial aquifer.

3.7 The "Mound Springs"

Some public submissions to the Ellenbrook Public Environmental Review (PER) drew attention to the presence of a "mound spring" on the Egerton property as did the Ellenbrook Conservation Group in discussions associated with this CER. The EPA also specifically referred to the spring in its Assessment Report on the Ellenbrook PER.

Mound springs derive from deep aquifers and deposit materials over time on the surface which forms a characteristic prominent mound above the surrounding land.

The location of the spring was said to be in the north-west sector of the Egerton property. In the course of studies associated with the present CER however, the entire property was closely inspected and no evidence of a mound spring was found.

A notable seepage area is located near the sumpland in the north-west sector of the property. It may be that the term mound spring has been used to refer to this seepage of water associated with the Gnangara Mound rather than with a true mound spring. It is assumed therefore that the water seepage in the north-west sector is the spring which has been referred to previously.

The results of an assessment of the seepage area by the Geological Survey of Western Australia indicates that the water is relatively recent (aged 90 years) and that it has a chemical signature which reflects this age (i.e. a low pH, salinity, alkalinity, temperature, and high dissolved carbon dioxide content) (see Appendix 2). In contrast, groundwater sampled from the Leederville Formation aquifer at a depth of about 200m below ground level, had an age of 12,700 years and a mature chemical signature shown by moderate salinity, alkalinity and temperature, and low dissolved carbon dioxide content. The assessment concluded that the groundwater flowing from the seepage area originates from relatively young shallow groundwater within the Bassendean Sand aquifer to the west known as the Gnangara Groundwater Mound. Groundwater discharge from this aquifer results in seepage where the contact between the Bassendean Sand and underlying clayey Guildford Formation is exposed. This type of seepage is common in the Swan Valley area in areas of low elevation.

3.8 Wetlands

The wetlands of the Swan Coastal Plain have been classified into related or consanguineous suites by Semeniuk (1988) on the basis of their geomorphic setting. Two separate groups of wetlands on the Egerton property have been identified:

- The Ellen Brook Suite, and
- The Muchea Suite.

The Ellen Brook Suite comprises very small creeks meandering across a floodplain, which formed as a result of fluvial incision and surface runoff. This creek system is the natural surface drainage to Ellen Brook and is of particular importance in the proposed urban drainage scheme.

The Muchea Suite are small to medium scale sumplands and floodplains which occur along depressions at the base of the Bassendean Dunes, and at the headwaters of the tributaries of creeks.

The wetlands at Egerton also have been mapped by the Western Australian Water Authority for the compilation of the Wetland Management and Conservation Estate Map Series (1993) (Figure 12). While there are a series of distinct 'swamps' on the site and the remainder has the appearance of farmland, two-thirds of property is shown as wetlands of various types and significance on this map. In particular, the map indicates that a chain of sumplands (seasonally inundated basins) occurs in the western section of the property, and a palusplain (seasonally waterlogged flat) covers the majority of the property to the east of the sumplands. These wetlands are the Muchea Suite identified above.

As part of the present assessment each of these wetland areas were investigated. This investigation indicated that one area shown as a sumpland on the WAWA map is actually

a palusplain. This area is in the south-west sector adjacent to the western boundary. The wetland map shown in Figure 12 therefore has been modified accordingly. There are also indications that peat has been extracted in the past from one of the sumplands located in the western central sector of the property.

The wetlands are typical of the eastern margin of the Bassendean Dunes in this region and of the associated Gnangara Groundwater Mound and are a subset of a wetland system which extends a considerable distance north of Egerton. This is illustrated in Figure 13.

None of the wetlands on the property are within areas identified in the System 6 Study Report of the EPA (Department of Conservation and Environment, 1983) or in the Environmental Protection (Swan Coastal Plain Lakes) Policy, 1991.
The sumplands on the property can be classified in the Resource Enhancement category in terms of the management strategies referred to in EPA Bulletin 374 - A Guide to Wetland Management in Perth (1990). This category includes wetlands that have been modified to some degree and have no clearly recognised human uses. The management objectives for resource enhancement are to maintain and enhance the existing ecological functions of the wetlands. Opportunities may exist, however, for commercial development to enhance the conservation values of wetlands (ie. the wetland resource) in this category and development may be recommended for approval by the EPA provided that:

- The wetland function is retained within the development, or

- An equivalent area of wetland of a similar type is constructed or rehabilitated to fulfil equivalent functions.

The EPA Bulletin 374 has recently been updated (Environmental Protection Authority, 1993). In terms of the revised classification system, the sumplands remain in the Resource Enhancement Category in terms of their general attributes but some also can be included in the High Conservation Category as a result of the presence of a rare and endangered species, the Southern Brown Bandicoot (*Isoodon obesulus*). Further information on this species is provided in Section 3.13

The palusplains on the Egerton property are categorised as Multiple Use in terms of Bulletin 374 and its update, indicating that they have been significantly degraded, and possesses few natural attributes. They are therefore considered to be of limited human interest. Despite this, management objectives need to be considered in the context of catchment and land use planning (especially drainage, nutrient enrichment, surface and groundwater pollution).

3.9 Surface Water Flows

Surface water and shallow groundwater flows into Ellen Brook from the Egerton property. While the groundwater flow is a component of a larger regional system as described in Section 3.6, the surface flows all originate entirely on the property. The Egerton property therefore is a discrete surface subcatchment of Ellen Brook.

The entire catchment area of Ellen Brook covers approximately 640km^2 and is located from just west of the Darling Scarp between Gingin and Upper Swan, to just south-east of

Egerton where the brook joins the Swan River (Waugh & Ng, 1987). About 65% of the catchment area has been cleared, mainly for sheep and cattle grazing but also for vines and orchards. The townships of Bullsbrook and Muchea (including the TiWest Mineral Sands processing plant) are within the catchment area.

The Egerton property essentially is a micro-cosm of the total Ellen Brook catchment. It covers an area of 495ha (or 0.8% of the total catchment area), and mostly comprises pasture used for cattle and sheep grazing and pine plantations, but with some remnant vegetation.

Although the volume of water in Ellen Brook and flowing from Egerton varies from year to year depending on rainfall and other factors, estimates of annual flows are available in, or can be derived from, the report of Deeley et al (1993). These authors estimated the total discharge from the entire catchment of Ellen Brook during the period 1987 to 1992 to be in the order of 37 million m^3/yr or 556m^3/ha/yr.

As the area of Egerton is 495ha, the discharge from the property in the same period therefore can be estimated at approximately 275,220m^3/yr.

3.10 Surface Water Quality

Information on water quality can be derived from Deeley et al (1993). These authors document the average total load of nutrients in Ellen Brook and the export rate from each hectare in the catchment as listed in Table 4.

TABLE 4

AVERAGE NUTRIENT LOADS IN ELLEN BROOK AND EXPORT RATES FROM THE ELLEN BROOK CATCHMENT AREA (1987-1992)

	LOAD (tonnes/yr)	EXPORT (kg/ha/yr)
Total Nitrogen	77	1.16
Soluble Reactive Phosphorus	19	0.29
Total Phosphorus	26	0.39

Using the above export rates, the load of nutrients discharged each year from Egerton in the period 1987-1992 can be estimated at:

- Total Nitrogen 495ha x 1.16kg/ha = 574.2kg
- Soluble Reactive Phosphorus 495ha x 0.29kg/ha = 143.55kg
- Total Phosphorus 495ha x 0.39kg/ha = 193.05kg

However, the data collected by Deeley et al. (1993) suggests that the export rates of nutrients from Egerton actually were lower in 1992 compared to the Ellen Brook catchment north of Egerton.

GB Hill & Partners (1992) in the drainage and groundwater management study for the Ellenbrook Public Environmental Review, assume that the phosphorus export from active rural areas is 0.019kg/person/yr plus 4kg/ha/yr. For present purposes the rate of 4kg/ha/yr may be used to calculate a possible load from Egerton. As approximately 50% (or 247.5ha) of the Egerton property can be classified as active rural, the load would be 247.5ha x 4kg/ha = 990kg. This load is considerably larger than that estimated in the empirical study of Deeley et al (1993) and it would appear therefore that the assumptions made by GB Hill & Partners (1992) are very conservative.

The actual application rates of fertilisers on the Egerton property are listed in Table 5. The study by Deeley et al (1993) indicates that the majority of the fertiliser applied at Egerton is effectively taken up by vegetation and that relatively little is exported.

TABLE 5

FERTILISER APPLICATION AT EGERTON FARM

Fertiliser	Location	Application	%P	%N	Annual P Load (tonnes)	Annual N Load (tonnes)
Superphosphate	Whole property (except pines)	80t per year	21	-	16.8	-
Superphosphate + trace elements	Whole property (except pines)	80t per 3 years	21	-	5.6	-
Superphosphate	Irrigated pastures & lawns	40t per year	21	-	8.4	-
Agras	Irrigated pastures & lawns	12t every 6 weeks in summer	7.6	17.5	2.7	6.3
Urea	Irrigated pastures & lawns	12t every 6 weeks in summer	-	46	-	16.6
Complete	Lawns	5t every 12 weeks	1.8	12.3	0.4	2.5
Poultry litter	Lawns	10t per year	1	1	0.1	0.1
					34.0	25.5

3.11 Land Capability

Land capability assessments have been developed by soil and agricultural scientists to provide an indication of the ability of sites to sustain different land uses given the physical features of those sites. For example, a site which is prone to waterlogging in its natural condition will be classified as having low capability for house construction.

It is emphasised however, that this does not mean that houses should not be built on such sites. Rather, the land capability assessment indicates the natural features of the site that need to be managed or modified to make that site suitable for the proposed land use. Thus, in the above example, a site which is subject to waterlogging may be made suitable for house construction by appropriate filling, drainage and other measures.

A land capability assessment for the Shire of Swan has been prepared by McArthur (1985). This assessment includes the Egerton property. In addition, the Department of Agriculture is currently undertaking the Metropolitan Regional Soils Project which will include soils information on the rural areas on the outskirts of Perth. These two sources have been combined to produce the land capability map for Egerton shown in Figure 14.

The soils on the western side of the property belong to the Jandakot, Gavin and Joel Units, which are all Bassendean Sands. The Jandakot unit (Ja) predominates, and the soil is an iron podzol with a grey surface, an almost white subsurface and a yellow sandy subsoil at 1 to 2m.

Seasonal swamps (Ws), which are depressions that contain free water in winter, occur in the south western half of the property within the Jandakot unit. These seasonal swamps are characterised by humus podzols and peats.

The Joel unit (J), which often has a peaty surface and a black indurated hardpan, covers a small area in the south-west corner of the property. The Gavin (1) unit is an iron-humus podzol with a dark grey subsurface, and a dark brown, sometimes indurated, subsoil. There may also be iron concretions in the subsoil. This unit forms a small pocket at the southern end of the property.

A Drainage Line (DL) unit dissects the Jandakot unit at the base of the property and partially encloses the Gavin unit. Drainage Lines are characterised by broad shallow canals and peaty soils.

The remainder of the Egerton property is dominated by the Yanga unit (Ya), interspersed with pockets of the Jandakot unit (Ja), along the north to north-eastern edge of the property. The Yanga unit is characterised by variable soil types, and includes shallow sand over heavy clay, shallow sand over limestone, and deep sand.

Karrakatta sands (Ks) which are of aeolian origin, are deep sands with grey sand and organic matter to a depth of 30cm over yellow sand. These sands are found in the south-eastern corner of the property.

A small area of Muchea sand (Mus) occurs along the south eastern boundary of the property. Muchea sands are deep, light grey sands and are also of aeolian origin.

3.12 Flora and Vegetation

3.12.1 Introduction

The native vegetation on Egerton has largely been cleared with most of the sand ridges occupied by a pine plantation and much of the plain used for agricultural purposes. The

remaining native vegetation belongs to the Southern River Vegetation Complex as mapped by Heddle et al, (1980). This unit typically consists of open woodlands of Marri-Jarrah and *Banksia* species with fringing woodlands of Flooded Gum - Paperbark along creek beds. The *Banksia* Woodland in the north-west corner of the site is more closely aligned to vegetation of the Bassendean Complex North which abuts the property to the west.

A survey of the remnant native vegetation was undertaken in spring and early summer of 1993 with the aim of compiling a flora list and a vegetation map for this CER.

3.12.2 Methods

No previous flora or vegetation surveys have been undertaken at Egerton. Therefore a thorough field survey was initiated in September 1993.
Records of rare and priority species known to occur or likely to occur in the area were provided by CALM. In addition, advice was sought from CALM botanists familiar with the flora of the region.

The Flora and Vegetation report prepared by Weston et al, (1993) for the Ellenbrook Estate was used extensively in assessing the significance of the Egerton results.

Plant nomenclature follows that of Green (1985) in the Census of the Vascular Plants of Western Australia. The Priority flora were assessed using the most up to date list published by CALM (28 October 1992). Vegetation descriptions use the system of Beard as adapted by Aplin (1979).

3.12.3 Flora

(a) Flora Recorded

A total of 159 native species have been recorded in the Egerton property (Appendix 3). This total is comprised of 1 fern species, 1 Gymnosperm, 43 Monocotyledons and 114 Dicotyledons. The families represented by the most species include the Pea family (Papilionaceae - 21 species), Myrtle family (Myrtaceae - 19), Proteaceae (11), Orchid family (Orchidaceae - 9) and Heath family (Epacridaceae - 9).

The total number of 159 species is low compared to nearby Ellenbrook Estate (427 species), Melaleuca Park (at least 300 species) and Whiteman Park (at least 250 species) (Weston et al, 1993). The low number of species is considered to be related to the small area (approximately 106ha) of native vegetation remaining.

The distribution of the species according to habitat types (i.e. dryland, transitional, wetland), shows that the dry upland areas support more species (98 species) than the areas influenced by high water tables (53 species) and the fringing areas in between (24 species). Only one species, *Eucalyptus marginata,* was found in all three categories, although it does not occur where water is above ground level.

53
24
77

(b) Significant Species

No Declared Rare Flora species have been recorded at Egerton. Two species currently listed on the CALM Priority List occur on the property. *Aotus cordifolia* and *Conostephium minus* are Priority 3 species which means that they have several poorly known populations with some on conservation lands.

Aotus cordifolia is a straggling shrub that occurs in swamps on the Coastal Plain and Darling Range in the Perth Region from Ellenbrook Estate south to Dwellingup. At Egerton, the species occurs abundantly in the swampy areas. The largest population of hundreds, if not thousands, of individuals is located in the northern wetland under an *Agonis linearifolia* Scrub.

Conostephium minus is a much branched shrub up to 50cm high that occurs in sandy soils on the Coastal Plain from near Perth to Gingin. It extends outside this area north to Badgingarra. At Egerton, *Conostephium minus* has been located in two small populations in *Banksia attenuata* Low Woodland on dry sandy soil.

3.12.4 Vegetation

(a) Vegetation Recorded

A vegetation map for Egerton and a map of vegetation quality are provided in Figures 15 and 16 respectively. A total of 24 vegetation associations was recorded from the property (see Appendix 4).

The diversity of vegetation types is influenced predominantly by the relationship to groundwater levels.

The dry upland areas in the north-west corner of the property contain *Banksia attenuata/B. menziesii* Low Woodlands. *Eucalyptus todtiana* (Prickly Bark) is also present but not in such large numbers as to be co-dominant with the Banksias. The understorey of the dry *Banksia* Low Woodland consists of a Low Open Heath dominated by *Scholtzia involucrata, Eremaea pauciflora* and *Hibbertia hypericoides.*

Towards the bottom of the sand dunes the Banksia Low Woodlands give way to *Eucalyptus calophylla* (Marri) Woodlands and *E. marginata* (Jarrah) Woodlands with a sub-canopy including *Banksia grandis* (Bull Banksia), *B. ilicifolium*, and *Adenanthos cygnorum* (Woolly Bush). The shrub layer under the *Eucalypt* Woodlands is generally quite sparse with *Hibbertia hypericoides* common and a larger number of hardy liliaceous species such as *Xanthorrhoea preissii, Dasypogon bromeliifolius, Patersonia occidentalis* and *Phlebocarya ciliata.*

Downslope from the *Eucalyptus* Woodland and *Banksia* Low Woodlands, the vegetation changes usually fairly abruptly to *Melaleuca preissiana* (Moonah Paperbark) Low Open to Low Woodlands and a variety of Closed Heath and Scrub vegetation types. Areas that were dry at the time of survey but which had the water table close to the surface are dominated by *Pericalymma ellipticum* and *Astartea fascicularis* Closed Heath, often in association with *Hypocalymma angustifolium*. Some Heath areas also have scattered *Melaleuca preissiana* trees in a Low Open Woodland formation over the Closed Heath.

Pteridium esculentum (Bracken fern) is also common around the fringes of the *M. preissiana* Low Woodlands.

In one area only, *Eucalyptus rudis* (Flooded Gum) forms an Open Forest over a dry *M. preissiana* Low Woodland.

In areas where the water table was at or just above ground level during the survey the understorey of the *Melaleuca preissiana* Low Woodlands is dominated by *Agonis linearifolia* and *Juncus pallidus*. Towards the northern part of the property *Banksia littoralis* and *Eucalyptus rudis* are also dominant with *M. preissiana* in a Closed Forest type formation which is so dense in part as to preclude the development of much understorey.

Several areas of permanently wet drainage lines or seepage areas exist along the eastern part of the wetlands on the plain. These areas support *Melaleuca rhaphiophylla* (Swamp Paperbark) instead of the *M. preissiana* that occurs on drier swamp soils. The *M. rhaphiophylla* is present as a Low Closed Forest, often with *Eucalyptus rudis*. The understorey of these areas is limited due to the dense tree canopy, but occasionally includes stands of *Baumea articulata* and *Juncus pallidus*.

One large stand of *Baumea articulata* (Jointed Twig Rush) Sedgeland occurs in the central wetland within the Bassendean dunes. This area was reportedly excavated for peat more than 20 years ago. The surface level of the wetlands is now lower than normal and therefore is inundated to deeper levels and for longer periods than would have existed prior to removal of the peat. The *Baumea articulata* Sedgeland may not have been there previously and may have colonised the area following the altered hydrological regime.

Significant areas of palusplain have been severely impacted upon by grazing. These areas consist of *Melaleuca preissiana* Low Woodlands over an understorey almost entirely of *Juncus pallidus* and introduced pasture species. Further degradation of these areas has resulted in large areas of *Juncus pallidus* Sedgelands with the tree canopy completely removed.

One small area of *Acacia saligna* Low Woodland over *Agonis linearifolia* Open Heath occurs towards the southern part of the site. While other small stands of *Acacia saligna* occur between wetland areas and pine plantations, it is not clear whether these are natural associations or a part of the buffer rows of native trees planted around the pine plantation.

(b) Vegetation Condition

Most of the native vegetation at Egerton has been cleared or is in a severely degraded condition (Figure 16). The main areas considered to be in a near natural condition or to have a low degree of disturbance include the Banksia and Eucalypt Woodlands in the north-west corner and three wetland areas in the north-west, west and central west parts of the property. A narrow zone of Paperbark and Marri woodland in poor condition links the two wetland areas at the base of the dunes.

Other areas containing native vegetation have been disturbed by partial clearing of either the understorey (e.g. remnant Paperbark stands and drainage lines) or tree canopies (e.g.

Juncus Sedgelands) to assist grazing by cattle and sheep. As a result, these areas have an abundance of introduced pasture species.

The areas of good quality remnant vegetation are protected from stock grazing by a network of fences.

One small area was identified which has signs consistent with the presence of dieback caused by *Phytophthora cinnamomi*. The small pocket of Jarrah and *Banksia* woodland on the southern edge of the north-west wetland contains stag-horned Jarrah trees, dead *Banksia* trees and dying *Xanthorrhoea preissii* shrubs. A few other areas exist which have dead *Banksia* trees, however there are no additional signs which would indicate infection by dieback.

(c) Regional Significance

An assessment of the significance of the remnant vegetation at Egerton needs to consider the following points:

- Presence of rare, priority or unusual species,
- Diversity of native flora,
- Presence of unusual vegetation types,
- Representation of flora and vegetation in conservation reserves,
- Value of the area as a fauna habitat and/or wildlife corridor, and
- Condition of the vegetation.

While the area does not contain any known populations of Declared Rare Flora, the wetland heaths and Paperbark Woodlands and Forests contain possibly the largest known population of the Priority 3 species *Aotus cordifolius*.

The site does not have a high number of native species compared to the Ellenbrook Estate, Melaleuca Park, or Whiteman Park. This is due to the small area of native vegetation remaining and the low percentage of this which is species rich *Banksia* woodland. Only 6 of the 158 native species at Egerton have not been found at Ellenbrook, with 3 of these 6 possibly just differences in plant identification. Therefore only 3 species at Egerton, *Verrauxia reinwardtii*, *Burtonia conferta* and *Daviesia divaricata* do not occur at Ellenbrook. None of these species are considered rare or endangered, and all are represented in conservation reserves.

While a rigorous comparison of the vegetation at Egerton with other nearby areas has not been made it can be concluded that the vegetation types at Egerton are similar with regards to floristic composition to those at Ellenbrook.

Moreover, all of the associations are represented on the Ellenbrook Estate within the proposed conservation area (Weston et al, 1993). Conversely, particular associations considered to be important at Ellenbrook also occur at Egerton, namely:

- *Melaleuca preissiana* Low Woodland over *Agonis linearifolia* Closed Heath
- *Eucalyptus calpohylla* (Marri)/*M. preissiana* Woodland, and
- *Acacia saligna* Low Woodland.

Areas of *Melaleuca preissiana/Agonis linearifolia* occur in all three main wetland areas in good condition. They generally indicate the wettest phase of tolerance for *M. preissiana* compared to drier areas where *Pericalymma ellipticum* is dominant in the understorey.

The Marri - *M. preissiana* woodlands occur on the eastern margin of the wetland springs. They therefore tend to be in a disturbed condition due to partial clearing or from grazing pressures.

The *Acacia saligna* Low Woodland is a small, isolated stand which occurs towards the south-west of the property in a wetland palusplain largely cleared for grazing by sheep.

The diversity of vegetation types at Egerton is most noticeable in the north-west wetland or spring area where Closed Heaths and Low Closed Forests interchange within short distances. The variety of different formation types i.e., heath, woodland, forest, provides for a variety of fauna habitats as evidenced by the results of the fauna survey.

3.13 Vertebrate Fauna

A vertebrate fauna survey of the Egerton property was carried out by Alan Tingay & Associates in October 1993. The survey was designed to encompass the major habitat types on the property, and included pine plantation with an admixture of *Eucalyptus* spp., Heath, *Banksia* Woodlands, *Melaleuca* Woodland, and *Melaleuca* Forest.

Fifty species of indigenous (native) vertebrates were recorded during the survey including 5 species of frogs, 6 reptiles, 36 birds and 3 species of mammals. In addition, 4 introduced mammal species and 2 introduced bird species were encountered. A complete list of vertebrate species is provided in Appendix 5.

The largest number of vertebrate species was recorded on the farmland areas and included 20 species of birds and 1 mammal, the Western Grey Kangaroo (*Macropus fuliginosus*). The relatively high number of bird species reflects the diversity of habitats provided by open areas and remnant trees, and other vegetation.

The next largest number of native species was recorded in *Banksia* Woodland with 12 species of birds, 2 frogs, 2 reptiles and 2 mammals. Species number was relatively high also in the *Melaleuca* Forests associated with the sumplands (15 species), and in remnant native vegetation within the pine plantation (14 species). The distribution of fauna species according to the major habitat units is listed in Table 5.

TABLE 5

NUMBER OF FAUNA SPECIES RECORDED IN FIVE MAJOR HABITAT UNITS ON THE EGERTON PROPERTY

Habitat	Number of Native Species Recorded					
	# Traps	Frogs	Reptiles	Birds	Mammals	Total
Pericalymma Heath	18	3	0	4	2	9
Pinus Woodland with some native vegetation	16	1	3	9	1	14
Melaleuca Forest	35	3	3	6	3	15
Banksia/Eucalyptus Woodland	38	2	2	12	2	18
Juncus Sedgeland	10	2	0	-	2	4
Farmland	-	-	-	20	1	21
Ornamental Lake	-	-	-	9	-	9
Mill Pond	-	-	-	6	-	6

The vertebrate fauna is typical of the region and comprises a sub-set of that found in surveys of Whiteman Park and at Ellenbrook. A smaller number of species has been recorded at Egerton to date compared to these other localities, probably as a result of the smaller area and less diverse habitats at Egerton and differences in survey time.

Nevertheless, 3 species recorded at Egerton are of interest for various reasons. The Burrowing Frog (*Heleioporus inornatus*) generally occurs in the Darling Range from Chidlow, south of the vicinity of Nannup, and east to Walpole and Mt Barker. Its occurrence at a site on the Swan Coastal Plain is unusual, however Egerton is relatively close to the escarpment of the Darling Range.

The Honey Possum (*Tarsipes rostratus*) was recorded in *Melaleuca* Woodland at Egerton. This species is seldom recorded in the Perth Metropolitan Region but does occur at the nearby Whiteman Park. It is not classified as rare or endangered.

The Southern Brown Bandicoot (*Isoodon obesulus*) was recorded at Egerton in all major habitats surveyed except for the pine plantations. However, they appeared to be restricted to areas within and surrounding wetlands possibly as a result of the denser cover in these areas. A total of 9 individual Bandicoots were captured during the survey.

The Southern Brown Bandicoot is a ground dwelling marsupial about the size of a small cat. The species has a relatively extensive distribution across southern Australia but is most abundant in the south-west of Western Australia, and in Victoria and Tasmania. In Western Australia there is concern that the species may be declining as a result of continuing loss and predation pressures primarily due to the introduced European Fox

(*Vulpes vulpes*). This concern has led to the species being gazetted as rare and endangered under the provisions of the Western Australian Wildlife Conservation Act, 1950-1979.

3.14 Cultural Significance

3.14.1 Aboriginal Sites

A specific archaeological and ethnographic survey of the Egerton property has been made in accordance with the provisions of the Aboriginal Heritage Act, 1972-1980 and to provide information for this CER and for the development of the Structure Plan (McDonald Hale & Associates, 1993).

The ethnographic survey included consultation with 11 Aboriginal informants. These informants identified 3 areas of significance to Aboriginal people. Two of these were camp sites used until the 1950's on a seasonal basis. Both of these camp sites are associated with one of the sumplands.

A Waugal or Rainbow Serpent Dreaming Track was also identified by one informant. This track runs westward along one of the small tributaries of Ellen Brook which crosses the Egerton property. All of the informants however, indicated that the Waugal is associated with all areas of freshwater.

The archaeological survey located a single site which comprises a sparse scatter of stone artefacts. This was located adjacent to one of the sumplands and close to the camp sites identified.

3.14.2 European Sites

There are two recognised sites of European cultural significance on the Egerton property but both are outside of the urban deferred zone. One of these is the house and associated buildings generally known as Henry Bulls Cottage. This is located on the eastern bank of Ellenbrook. The other site is a pond which is located on one of the streamlines which cross the Egerton property a short distance from Ellen Brook. This pond was constructed at about the same time as the farm complex on the opposite side of the river. Both of these sites date from the early period of occupation of the Swan River colony.

4. ENVIRONMENTAL IMPLICATIONS AND MANAGEMENT

4.1 Introduction

The environmental description of Egerton presented in Section 3 of this CER indicates a number of features which are relevant to the urban development proposal. The most important of these features are hydrological in nature and are:

- the defined wetlands or swamps are their associated natural vegetation and fauna habitats.
- the drainage lines and dams leading to Ellen Brook, and
- the damplands in various parts of the property which are currently developed for pasture but which will require drainage and/or fill to make them suitable for development.

The implications of urban development in terms of possible effects on the underlying groundwater (and the surface wetlands which are expressions of the groundwater), and on the quantity and quality of surface water flowing into Ellen Brook and on to the Swan River also need to be considered.

Essentially, these principal issues have been addressed through the preparation of an environmentally sensitive urban development proposal which will be combined with a drainage management plan specifically designed to ensure preservation of the major wetlands and their habitats, and acceptable drainage outflows to Ellen Brook.

These and other issues are discussed in detail below.

4.2 Topography

The development of properties for urban purposes can involve significant modification of existing topography due to earthmoving required for roads, housing lots, etc. In the present case however, the structure plan has been designed specifically to take account of the main existing topographical features and to minimise earthworks.

In particular, the western ridge on the property is considered to be an asset as it will provide future residents with views to the east across the Swan Valley to the escarpment of the Darling Range. The elevation and general slope of the ridge therefore will be maintained.

Major roads in the Egerton proposal also have been located specifically to minimise disturbance to the western ridge and to the wetlands at the base of that ridge. The main south to north road is located well to the east of the ridgeline on a relatively level section of the plain. The main east to west road is aligned in a depression or valley in the western ridge both to reduce the need for earthworks and to reduce the prominence of the road in the landscape. This alignment also enables the road to cross the south to north linear wetland chain at a narrow and significantly disturbed location. Most of this wetland chain will be preserved within Public Open Space (POS) (see Section 2.3).

These road alignments are considerably different from earlier proposals. In earlier plans the roads traversed the western ridge and wetland chain and their construction would have involved considerable environmental modification and damage.

Significant earthworks will be required, however, for certain parts of Egerton. In particular, some low lying areas will need to be filled to provide a suitable surface and depth of soil for the development of houses and the installation of services. The areas requiring fill correspond to parts of the Yanga, Seasonal Swamp, Drainage Line, and Joel land use capability units described in Section 3.11.

The areas involved include seasonally inundated sumplands and seasonally waterlogged palusplain areas in the south and south-west sectors of the property and much of the extensive palusplain in the central east and north-east sectors. Virtually all of these are currently used for agricultural purposes and consist of pasture with remnant trees. The filling therefore has minor implications for the existing environment.

4.3 The Wetlands

In strictly scientific terms, considerable areas of the Egerton property are classified as wetlands (see Section 3.8 and Figure 12). Much of these wetlands however, comprise land which is waterlogged in winter (ie. the palusplain areas) and which is currently used to provide grazing pasture. There is very little natural vegetation on these seasonally waterlogged areas and they provide no significant fauna habitat. The filling of most of these areas therefore is not considered to have important environmental implications.

The second group of wetlands on the Egerton property comprises seasonally inundated sumplands and seasonal creeks.

The sumplands are located within, and at the eastern base of, the western ridge area and mostly support *Melaleuca* forest and other wetland vegetation of good quality and high aesthetic appeal.

The sumplands are considered to be the primary environmental asset of the Egerton property and therefore they substantially have been included within POS. The Structure Plan also includes a series of open ponds within the POS system which are intended to increase the variety of niches or habitats available to waterbirds and other aquatic fauna and to provide more landscape diversity and aesthetic appeal in the POS system. The ponds will be located so that there is no need for disturbance of the best swamp paperbark areas.

This system of ponds also will serve a drainage management function.

The seasonal creeks at Egerton cross the palusplain mainly in the north-east sector of the property and flow to Ellen Brook. In places the creeks have been dammed to provide water for agricultural purposes and at least one of these dams has heritage significance (see Section 3.14.2).

This creek and dam system will form the basis of the surface drainage network for the urban estate. The creeks will be modified as necessary for drainage purposes but

substantially will remain in their present state and alignment. The remaining natural vegetation along the creek lines and around the dam will substantially be left intact and will be supplemented by appropriate landscaping and further tree planting. The entire surface drainage network will form the basis of a linear system of POS that will eventually link to Ellen Brook. This network will also be integrated with the POS containing the high quality sumplands and will incorporate walking and bicycle trails and elevated boardwalks through some of the best quality paperbark areas.

4.4 Hydrological Issues

The management of groundwater levels and surface water runoff will be emphasised in the detailed design for the Egerton urban estate and a specific Drainage Management Plan is being prepared for this purpose. This plan will be based on a model of both the groundwater and surface water flows and will seek to minimise:

- adverse changes to water levels and water quality,
- changes to the water regime of the wetlands within the Open Space areas,
- changes to storm runoff peak flows entering Ellen Brook and the Swan River, and
- nutrient loads transported from the urban area by the drainage system.

The drainage scheme will be based on the broad principles established under the WAWA North-East Corridor Drainage Strategy as noted in Section 2.3.4 of this CER. In general, the surface drainage will be by conventional road gullies and underground pipes connecting to disposal basins located in Open Space areas. These will include the existing basins or dams in the creek lines. There also will be retention basins within the system to enable the control of runoff quantity and quality.

For the purposes of this CER, an estimate can be provided of the impact of urbanisation at Egerton on the quantity and quality of runoff compared to the existing land uses.

GB Hill & Partners Pty Ltd (1992) in an assessment of the Ellenbrook development, assumed that in flood events in urban areas 25% of total rainfall falls on impervious surfaces while 75% falls on pervious surfaces. Similarly, it is assumed that 90% of the rainfall falling on the impervious surfaces becomes run-off, i.e. 22.5% of the total rainfall. Runoff from pervious areas is assumed to be 12%, i.e. 9% of total rainfall.

Therefore, in total about 31.5% of the total rainfall during flood events in urban areas is assumed to be converted into run-off. By comparison, the run-off during equivalent events in existing non-urban conditions is considered to about 12% of the total rainfall.

In areas with no subsoil drainage, the remaining rainfall is lost due to evaporation, infiltration into the soil and transpiration (i.e. take up by plants). In areas with fill and subsoil drainage (which will be the case at Egerton) about 52.5% of the rainfall which is not converted directly to run-off is collected by the drains and the remainder is lost due to evaporation etc. Studies in progress for the preparation of a Drainage Management Plan for Egerton, suggest that this percentage is likely to be an overestimate.

In terms of water quality, phosphorus is of primary concern (Section 3.10). GB Hill & Partners Pty Ltd (1992) assumed that the population of urban areas at Egerton will be about 36 people/ha and the phosphorus load will be about 0.019kg/person/yr. In fact, the Structure Plan for Egerton provides for a maximum of about 25 people per hectare. The estimated phosphorus load at Egerton with these assumption therefore is 25 people x 495ha x 0.019kg/yr or 235kg/yr. This is likely to be an over estimate as it assumes total urban development of the Egerton property.

In comparison, the estimated present phosphorus loads to Ellen Brook from the Egerton property based on Deeley et. al. (1993) is about 193.05kg/yr. Therefore, the urban runoff if untreated may involve an increase in phosphorus output.

If this conclusion is supported by the more detailed studies that will form a component of the drainage management plan, the detention basins in the drainage system at Egerton will be lined with neutralised red mud which has a significant capacity to absorb phosphorus. It is estimated that this will achieve a 78% reduction in phosphorus output which, on the basis of the above figures, would mean 52kg of phosphorus export each year.

While it is not possible at this stage to present a more detailed account of nutrient export from Egerton, it is apparent from the information presented in this CER that there will be a substantial reduction in phosphorus export to Ellen Brook as a result of urbanisation and the associated more effective management of drainage.

However, while this will be a positive environmental benefit, the improvement of water quality flowing from Egerton and from the Ellenbrook Estate further east, is not likely in itself to cause a substantial improvement in water quality in Ellen Brook. This is because the present water quality in the brook does not appear to be substantially affected by nutrient exports from the lower catchment area as export rates from the remainder of the catchment are so high.

The total nitrogen levels in Ellen Brook in the period 1987-1992 were the second highest of 15 tributaries and drains of the Swan River System monitored by Deeley et al (1993). The total phosphorus levels were the highest of any recorded by a substantial margin. The average annual flow weighted concentration of total nitrogen was 1.97mg/L and the concentration of total phosphorus was 0.71mg/L. A high proportion of the phosphorus is in the soluble reactive form as noted above.

Furthermore, the nitrogen to phosphorus ratio is considered to be very low and this, together with the high loads, favour the growth of nitrogen fixing blue-green algae. While blue-green algae are considered to be a relatively unimportant component of the phytoplankton community in the upper Swan River at present, the nutrient ratio and loads in Ellen Brook are considered to pose a risk of encouraging increases in the blue-green algae populations.

The authors comment that there are several possible point sources for nutrients from Ellen Brook including sewage treatment plants and piggeries in the catchment.

4.5 The Seepage Area

The water seepage in the north-west sector of the property which has been referred to as a "mound springs" will be retained within Open Space and the proposed Drainage Management Plan will seek to ensure that the seepage continues.

4.6 Land Use Capability

As noted in Section 3.11, the land capability assessments for Egerton indicate that the certain areas of the property have low natural suitability for house and road construction and that fill and drainage measures will therefore be required in these areas. These requirements apply to the Yanga, Joel, Seasonal Swamp and Drainage Line land capability units.

The remaining land capability units (the Jandakot, Gavin, Muchea, and Karrakatta units) are considered to be suitable for house and road construction with the only potential problem being wind erosion of sand. Blown sand, however, is usually no more than a transient nuisance in the early stages of urban development on Bassendean Dune areas.

According to the Geological Survey 1:50,000 Environmental Geology Map Series (Gozzard, 1982), there appear to be few problems associated with road construction and excavation on the property, except in the peaty wetland areas. Possible problems may also occur with urban development in the southern area of the property, due to the potential for waterlogging and inundation. These areas will be filled prior to development as described above. There are few constraints to urban development in the northern section of the property, providing that the peaty swamp areas are avoided as is proposed.

4.8 Flora and Vegetation

4.8.1 Flora

The flora at Egerton is typical of the uplands and wetlands of the northern and eastern sectors of the Bassendean Dune Sands of the Swan Coastal Plain. The Structure Plan therefore has no significant implications in terms of conservation of the regional flora.

Within the property itself, most of the remnant vegetation is associated with the wetlands which will be substantially protected within open space. The flora of the *Banksia* and *Eucalypt* Woodlands in the north-west sector, however, will largely be removed. This flora is typical of these vegetation associations which are common in the region.

No declared rare flora occurs on the Egerton property but 2 Priority Three species, *Aotus cordifolius* and *Conostephium minus* are present. The *Aotus cordifolius* populations occur exclusively in the swampy habitats. As mentioned above, the wetlands where this species occurs at Egerton, are protected within Open Space in the Structure Plan. The small *Conostephium minus* populations will not be retained. However, local populations of *C. minus* will be protected in the Ellenbrook Estate conservation reserve.

4.8.2 Vegetation

Most of the areas affected by the residential components of the Egerton Structure Plan are currently substantially cleared of native vegetation or support pine plantations. Urban development of these areas therefore is considered to have no significance in terms of vegetation removal.

Of the remaining areas of natural vegetation, the sumplands and associated high quality vegetation are protected within public open space, which has been designed specifically for the conservation of vegetation and fauna habitat. Much of *Banksia* and *Eucalypt* Woodland in the north-west sector, however, would be removed. These woodlands are extensive in state forest and conservation reserves in the region, as well as in parts of the Ellenbrook Estate allocated for conservation purposes. They are not considered to be as important at Egerton as the protection of the wetlands and their associated vegetation.

It is recognised that the majority of vegetation associations which will be retained at Egerton are influenced by their relationship to the water table. Subtle differences in the degree of inundation or depth to watertable can mean the difference between a fringing eucalypt woodland, a Closed Heath or a Paperbark Forest. The relationship between the different associations and the water table fluctuations has not been quantified. However, it is evident that any shift in the hydrological balance which caused the wetlands to become drier or wetter in the long term would result in a change in vegetation and a decrease in the variety of vegetation types. A fundamental objective of the Drainage Management Plan therefore will be to minimise changes to the water regime of the wetlands in the Open Space areas (see Section 4.4).

4.9 Vertebrate Fauna

The vertebrate fauna at Egerton is typical of bushland and farmland areas of the Perth Metropolitan Region and more particularly of the local area. This is illustrated by the fact that virtually all of the species recorded by the vertebrate fauna survey have been recorded at Ellenbrook and Whiteman Park.

Given the extent of land allocated for conservation purposes at Ellenbrook, and the provisions for the protection of vegetation and fauna habitat at Whiteman Park, it can be concluded that the vertebrate fauna at Egerton is not significant in terms of regional conservation. Nevertheless, the fauna has local intrinsic significance and certain features of the Structure Plan have been specifically designed to promote the possibility that the majority of the vertebrate fauna species will continue to occur at Egerton following urban development.

In particular, the extent of natural vegetation that is proposed within Open Space in the Structure Plan represents a large proportion of the natural vegetation remaining on the property, as most of the area has been converted to farmland and pine plantations. This vegetation, and the wetlands it is associated with will continue to provide a variety of habitats for vertebrate fauna including frogs, reptiles, birds and mammals. The present diverse habitat for birds in the farmland areas also should continue to be provided through the relatively extensive areas of parklands and playing fields as well as on adjacent properties which are not likely to be developed for urban purposes.

The primary natural habitat that will be removed by the development will be the Banksia Woodland. At Egerton the extent of these woodlands is relatively limited but extensive areas will be protected at Ellenbrook, and in other parts of the northern Bassendean Dunes within State Forests and Conservations Reserves. The loss of this habitat at Egerton may cause a reduction in populations of bird species such as honeyeaters but all of the species currently present should continue to occur within the urban context.

The particular species of fauna at Egerton which requires special consideration is the Southern Brown Bandicoot as it is gazetted as a rare and endangered species. The vertebrate fauna survey indicated that the favoured habitat of bandicoots at Egerton is the relatively dense vegetation associated with the principal wetlands. This finding is consistent with other surveys of this species in the Perth Metropolitan Region which indicate that in localities where there are no active control measure for foxes, it prefers dense vegetation.

These wetland habitats at Egerton will be substantially retained within Open Space. There is the basis therefore, for the bandicoots to continue to exist on the property. There remains however, the question as to whether the bandicoot population can survive in the urban context given possible predation from cats and dogs, interference from human activities, and the possibility of habitat destruction due to an increased potential of fires.

There are two possible management strategies in this case. These are:

- To develop a specific management plan for the Southern Brown Bandicoot at Egerton with the objectives of protecting the species from predation and their habitat from damage. Such a plan would include specific fire control measures, signage and general education of the urban population, and possibly protective fencing of certain vegetation.

- Capture, removal and relocation of the local bandicoot population to secure conservation reserves.

Both of these strategies are currently being applied by land owners in association with the Department of Conservation and Land Management (CALM) at a number of localities within the Perth Metropolitan Region where urban development is occurring. The first alternative however, is experimental in the sense that the factors which may be relevant to the survival of bandicoot population in urban contexts are not known. Nevertheless, the species does occur in a number of urban areas where there are no specific management provisions designed to promote its survival (for example, in the foothills region). As the possibility of cat or dog predation is presumably high in these areas, it does not appear that predation pressures from domestic pets is necessarily a significant factor in the local survival of bandicoots. This suggests that the principal factor controlling survival may be the presence of absence of foxes together with the continued presence of suitable habitat.

It is considered reasonable therefore, to assume that there is a significant probability that bandicoots would survive at Egerton given specific management measures.

The second strategy above has proved to be successful to date and CALM has relocated bandicoots to recolonise conservation reserves where the species was formerly extinct. In these cases, the extinctions were considered to be the result primarily of predation by

foxes, and active fox control measures are in place to protect the new bandicoot populations.

Multiplex Constructions Pty Ltd will seek the advice of the Minister for the Environment in determining which of the above strategies will be applied. The Minister has the ability under the provisions of the Wildlife Conservation Act, 1950-1978 to determine measures for the protection of rare and endangered species.

4.10 Cultural Significance

4.10.1 Aboriginal Sites

The Aboriginal Heritage Act, 1972-1980 requires specific approval from the Minister for Aboriginal Affairs for the disturbance of any archaeological or ethnographic site. Any decision of the Minister in such cases is taken after advice is received from the Aboriginal Cultural Materials Committee. If approval is granted this may include a requirement to salvage the archaeological materials.

The Structure Plan for Egerton does not involve the potential for disturbance of the majority of the sites identified by the archaeological and ethnographic surveys including the stream associated with the Waugal. At least part of an archaeological site, however, would be affected. The proponent has considered the possibility of adjusting the Structure Plan at the detailed subdivision design stage to incorporate the whole site within open space. However, it is not likely that this measure would prevent incidental and continued disturbance of the site by users of the open space. Therefore, it is likely that an application will have to be made to disturb the site and to salvage the archaeological material if required.

4.10.2 European Sites

The features of the Egerton property that have European significance are outside of the area directly affected by the Structure Plan and will not be disturbed.

5. COMMITMENTS

Multiplex Constructions Pty Ltd, will:

5.1 Prepare management plans for the Open Space areas at Egerton which will have the objective to provide for the retention of the majority of the natural vegetation and associations of the Muchea Suite sumplands. The management plans will be prepared prior to final subdivision approval to the satisfaction of DPUD and the Shire of Swan.

5.2 Prior to the commencement of any major works, prepare a Drainage Management Plan for Egerton to the satisfaction of the EPA.

5.3 Seek advice from the Minister for the Environment on the preferred method for management of the Southern Brown Bandicoot population and prepare and implement a strategy based on that advice to the satisfaction of the Minister prior to development.

5.4 Comply with all requirements of the Aboriginal Heritage Act, 1972-1980.

6. CONCLUSIONS

The information presented in this CER suggests that the Structure Plan for the Egerton property in the Shire of Swan has no significant adverse environmental implications. This is primarily because the Plan takes into account the most important environmental features of the property and proposes that they become key community assets. In particular, the Structure Plan provides for the inclusion of the Muchea Suite sumplands, and their associated high quality vegetation and important fauna habitats, within Open Space. This major wetland Open Space system will eventually be linked to Ellen Brook along the natural drainage lines which cross the property and will incorporate a network of footpaths and cycleways.

In addition, in the preparation of the Structure Plan, careful attention has been paid to road alignments and the topography of the site in order to reduce the amount of earthworks required during the development phase.

Finally, the proponents recognise the importance of managing surface and groundwater in the urban context to ensure that the hydrological regime of the wetlands is maintained and that the quantity and quality of water discharged to Ellen Brook is environmentally acceptable. These issues will be addressed in a specific Drainage Management Plan which will be submitted to the EPA for its approval.

The proponents, Multiplex Constructions Pty Ltd, submit that the Egerton Structure Plan provides an example of the way in which a sensitive approach to environmental features in urban planning can provide an attractive and unique living environment for future residents.

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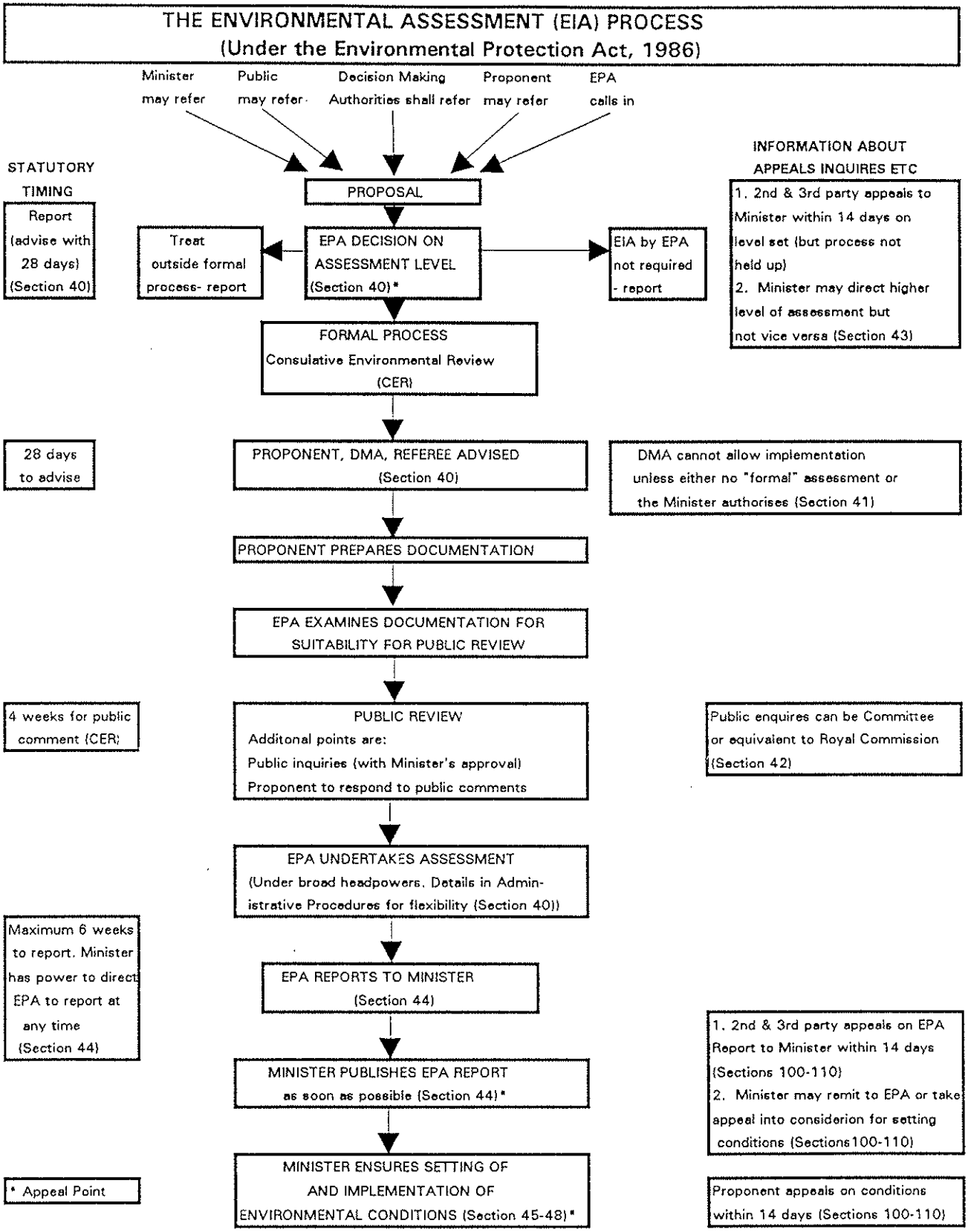
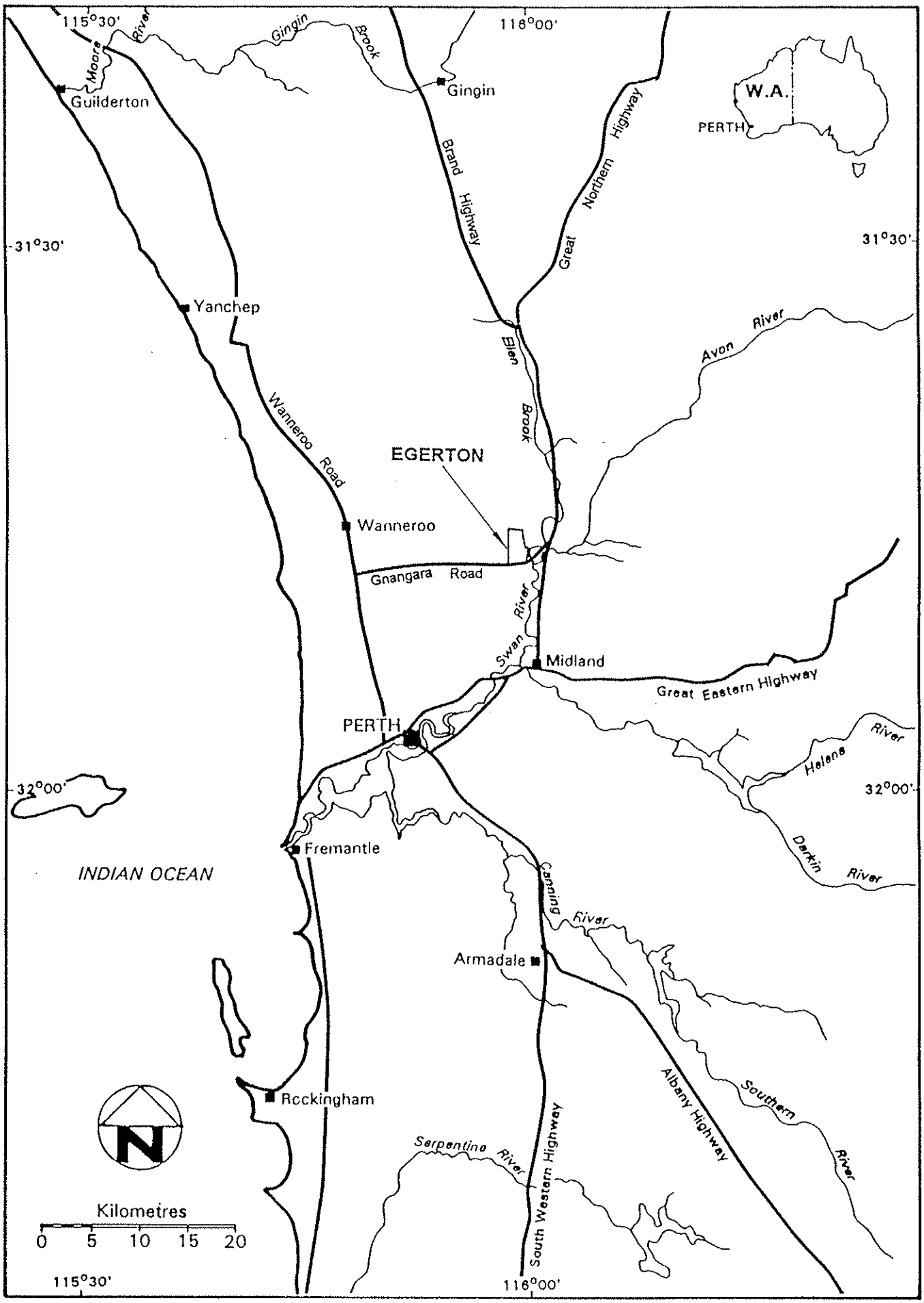
FIGURES



ALAN TINGAY & ASSOCIATES

THE CONSULTATIVE ENVIRONMENTAL REVIEW (CER) PROCESS

FIGURE 1



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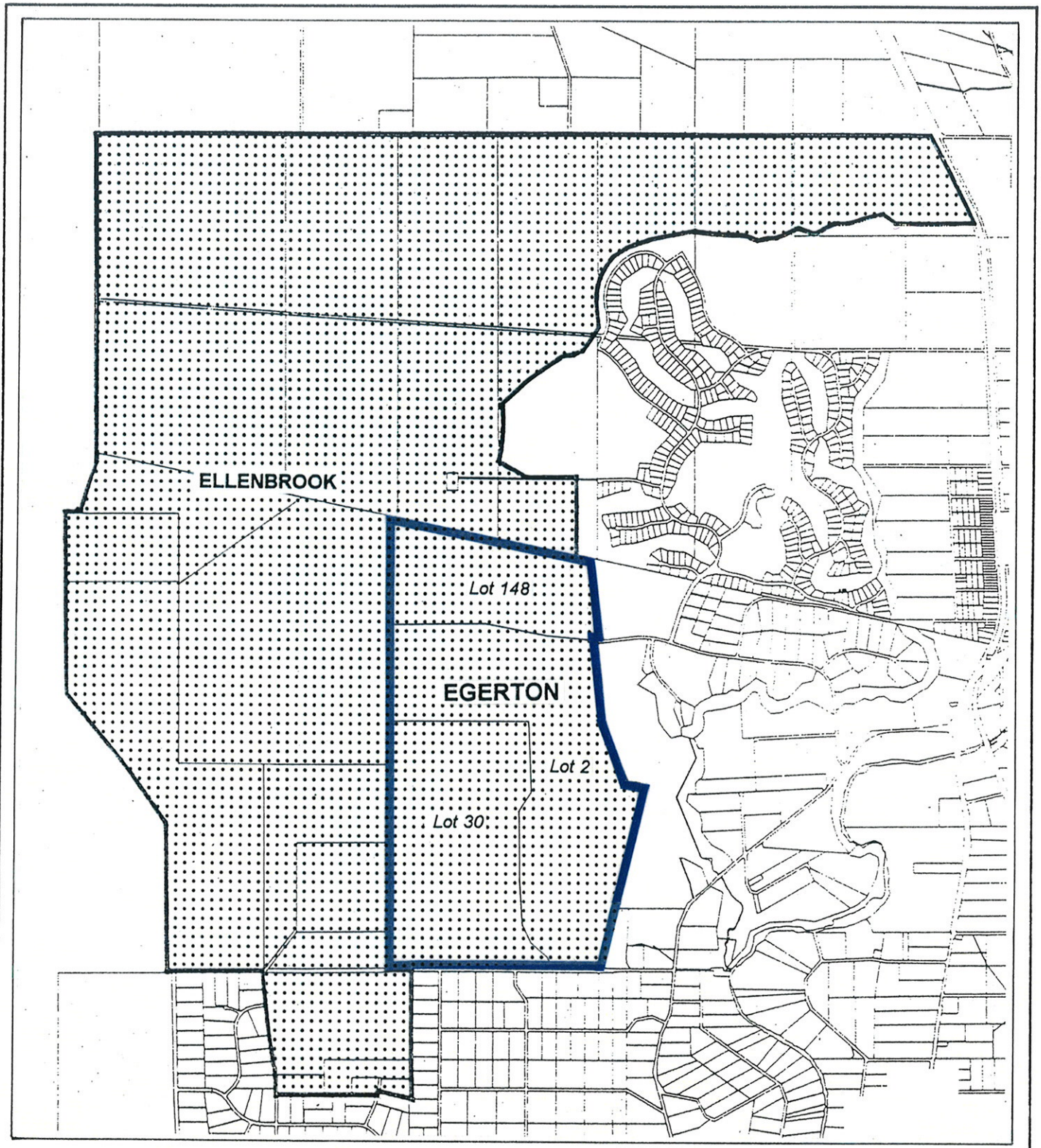
EGERTON REGIONAL LOCATION

FIGURE 2



SOURCE: FEILMAN PLANNING CONSULTANTS, 1993

LEGEND

Property Owned by Multiplex Constructions Pty Ltd

Land Zoned Urban Deferred

N

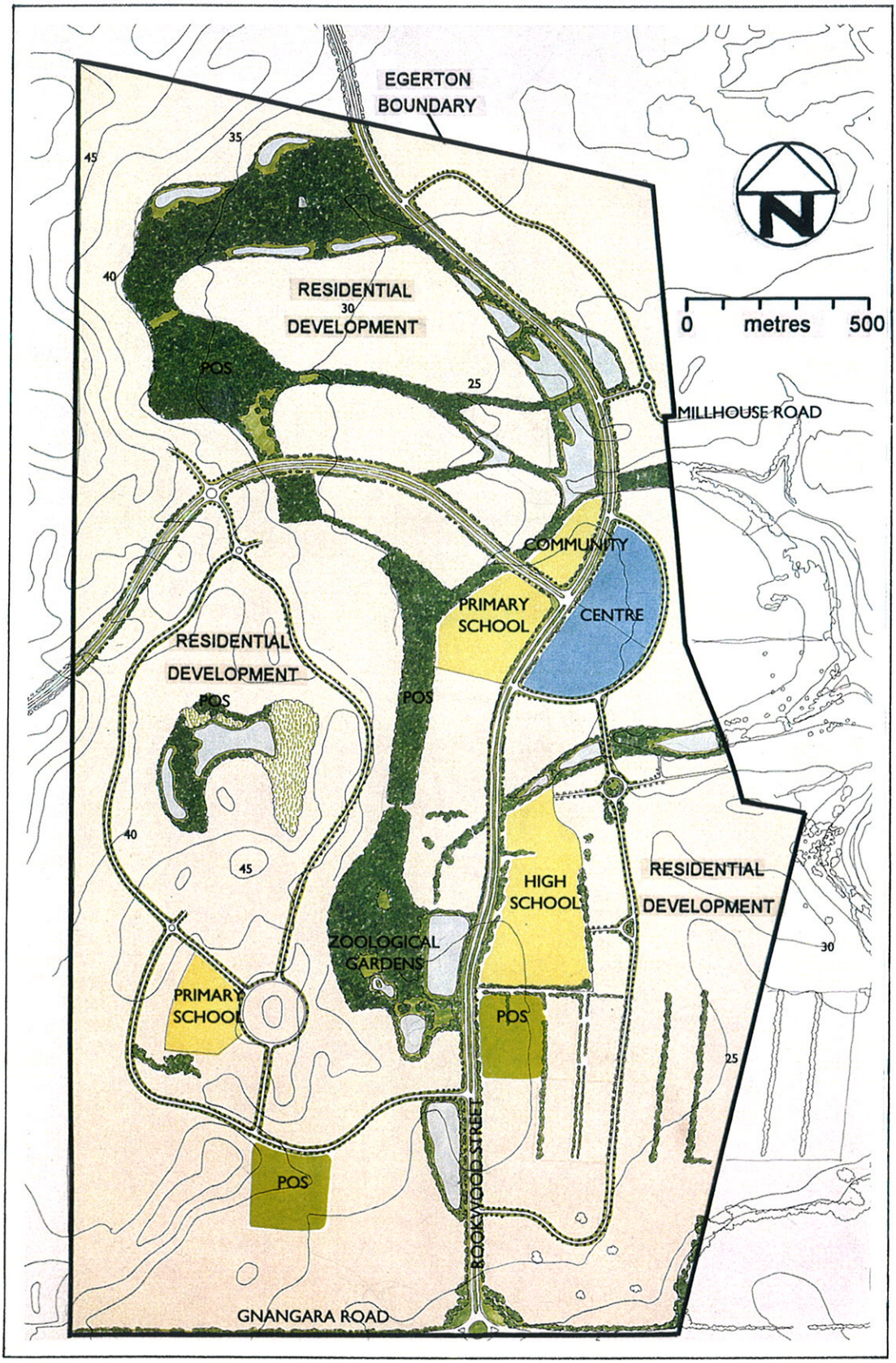
SCALE 1:40,000

0 Kilometres 1

ALAN TINGAY & ASSOCIATES

EGERTON CADASTRAL BOUNDARIES & ZONING

FIGURE 3

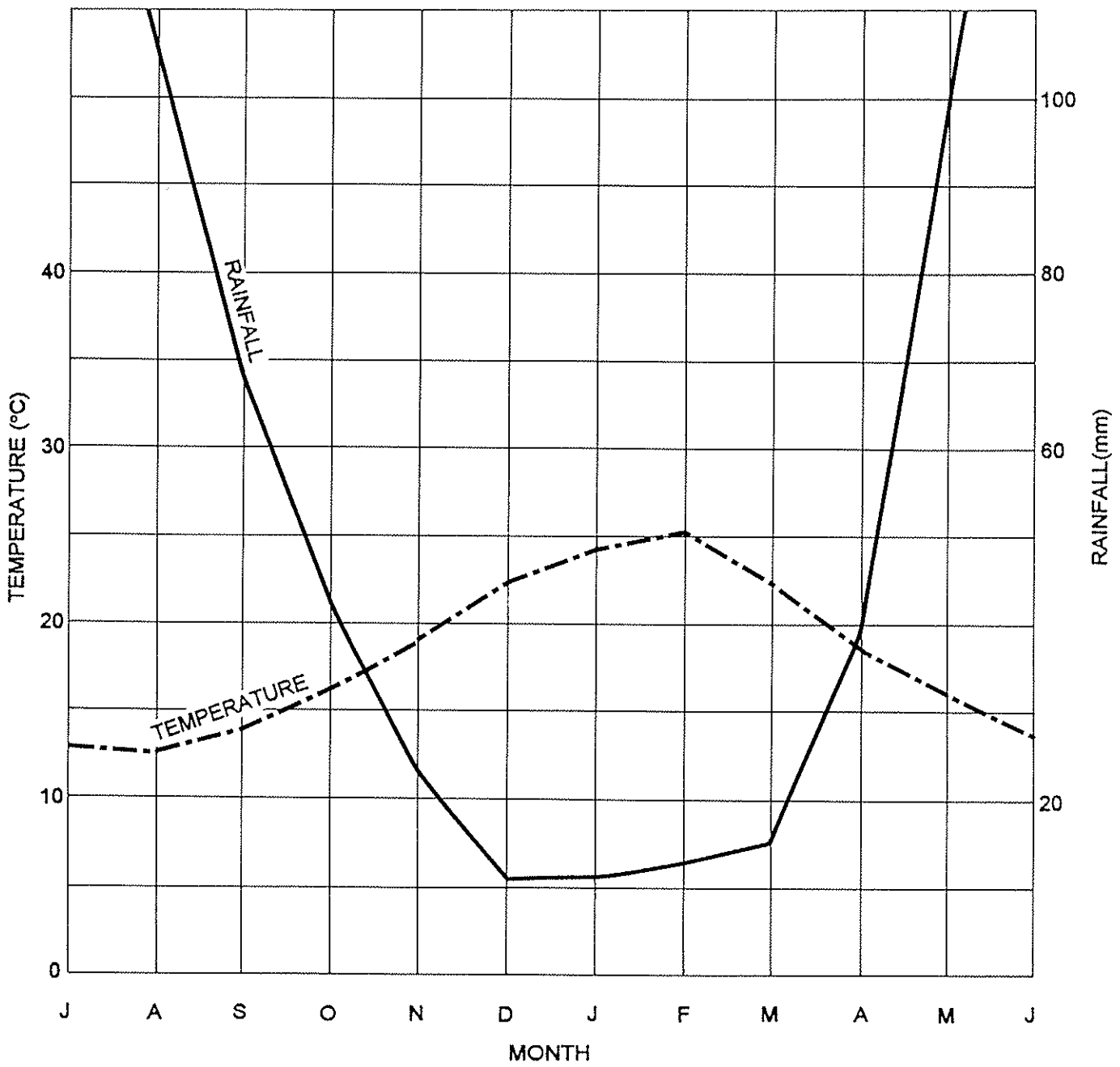


SOURCE: MULTIPLEX CONSTRUCTIONS PTY LTD, 1993

ALAN TINGAY & ASSOCIATES

EGERTON STRUCTURE PLAN

FIGURE 4



Temperature Data - 20 Years of Record

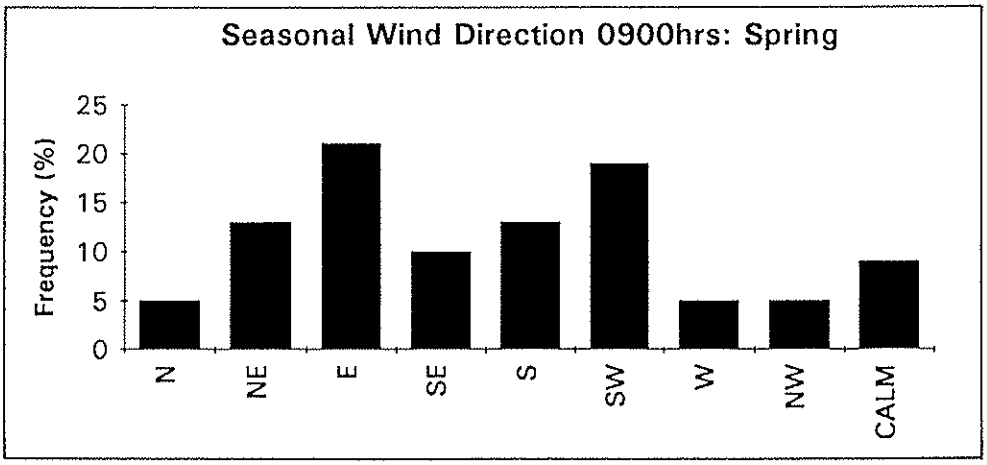
Rainfall Data - 32 Years of Record

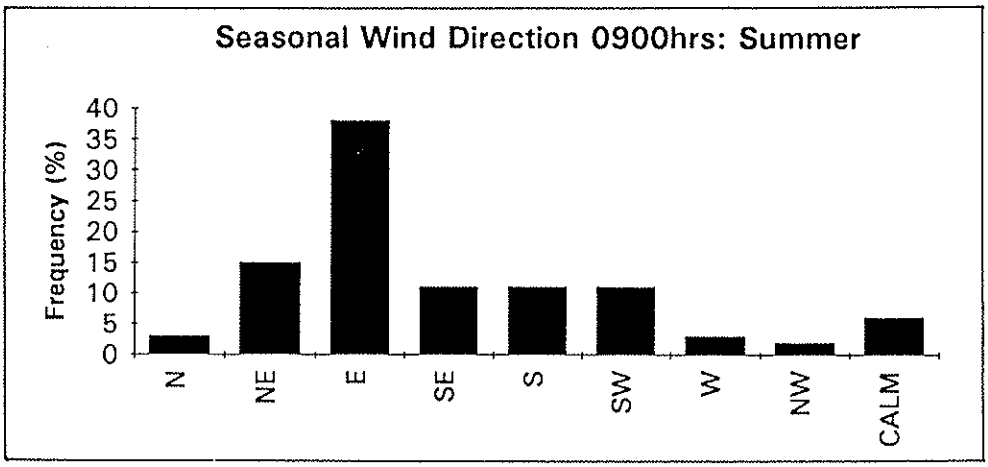
SOURCE: BUREAU OF METEOROLOGY, UPPER SWAN RESEARCH STATION

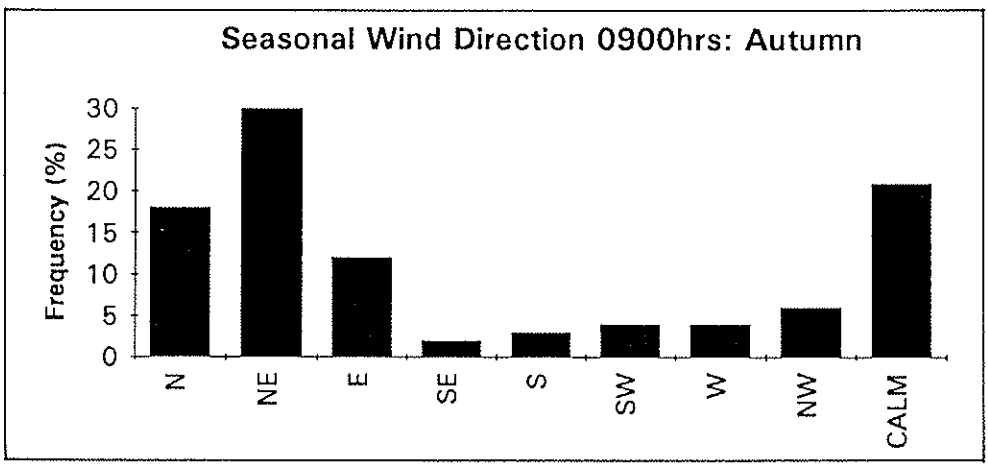
ALAN TINGAY & ASSOCIATES

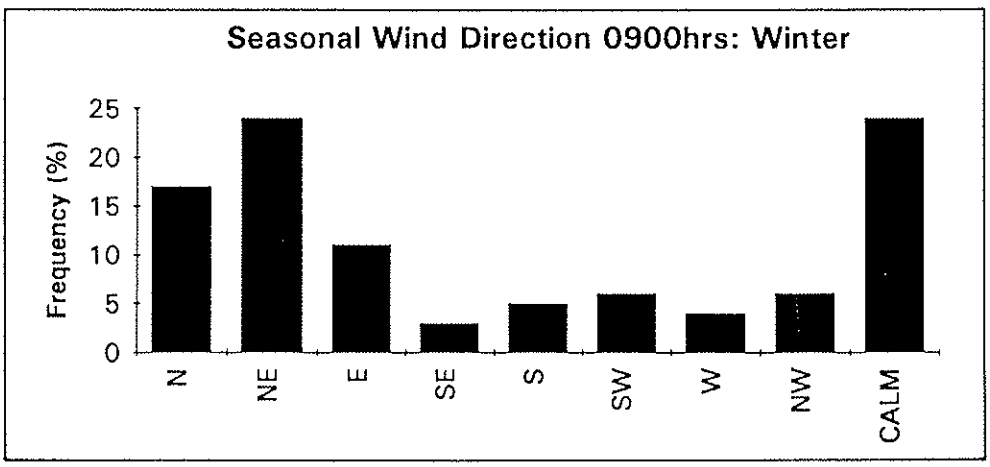
OMBROTHERMIC DIAGRAM FOR EGERTON

FIGURE 5





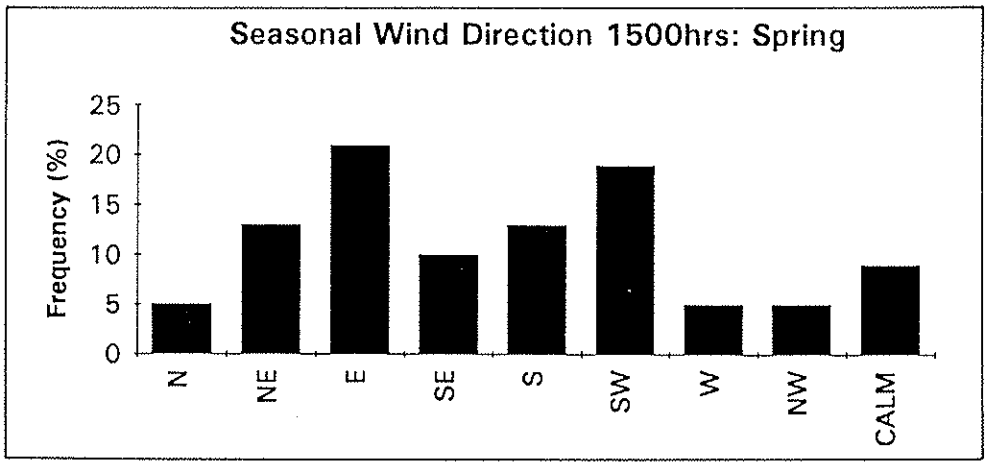


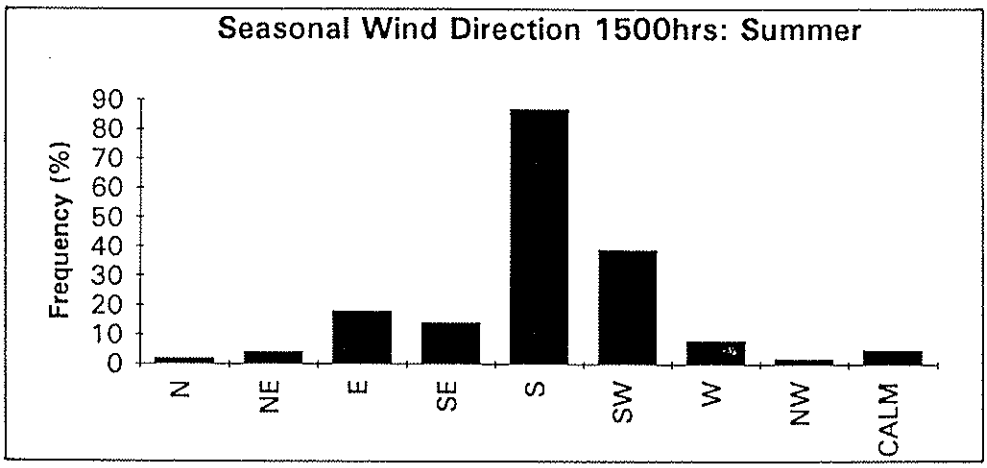


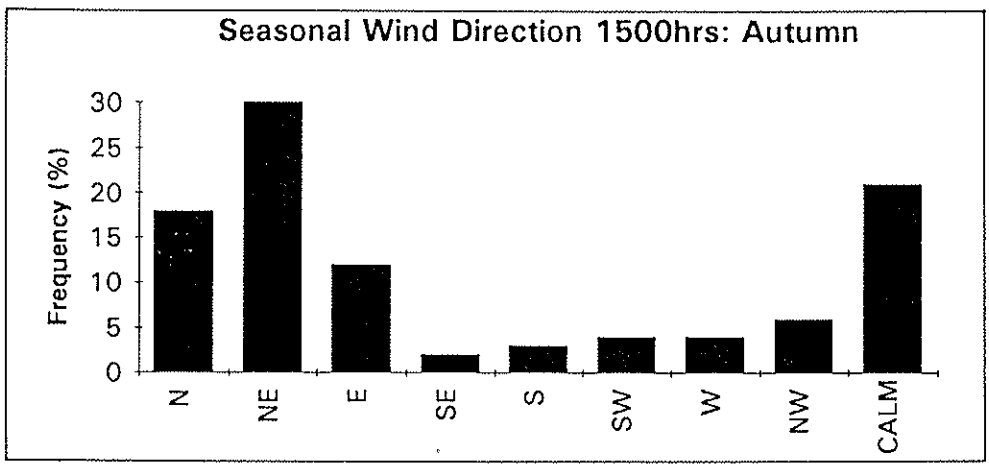
ALAN TINGAY & ASSOCIATES

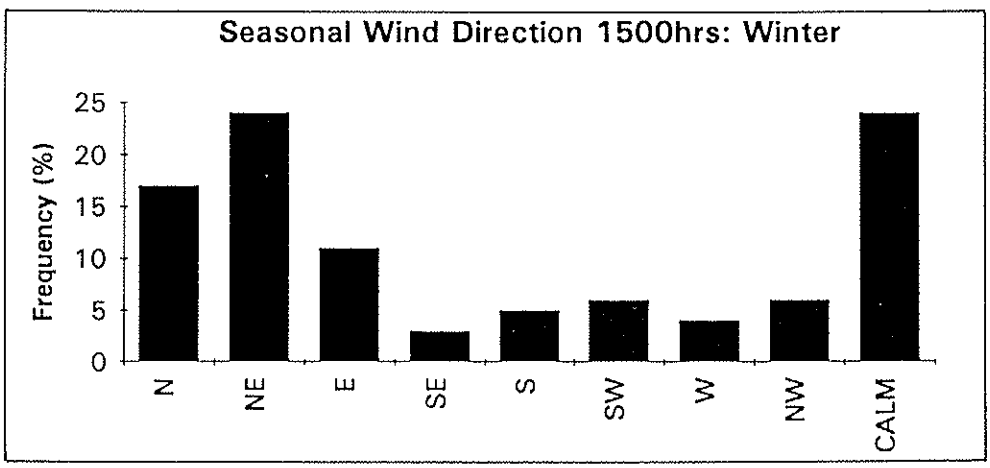
EGERTON SEASONAL WIND DIRECTIONS 0900HRS

FIGURE 6A





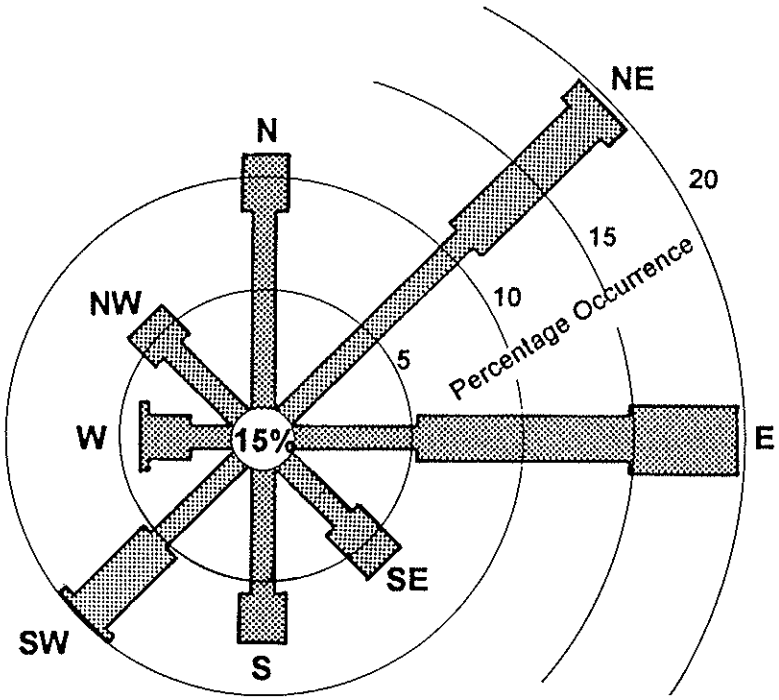




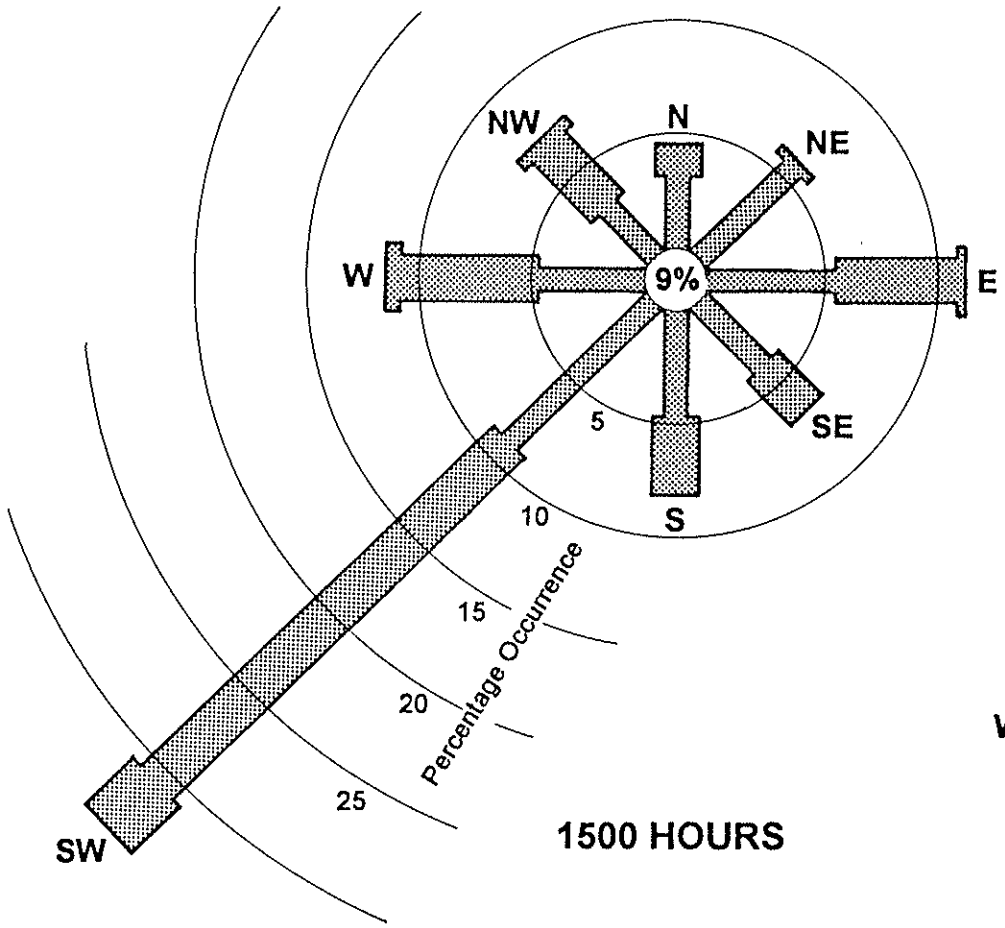
ALAN TINGAY & ASSOCIATES

EGERTON SEASONAL WIND DIRECTIONS 1500HRS

FIGURE 6 B



0900 HOURS



1500 HOURS

WIND SPEED(km/hr)

30+ Fresh/Strong

10-30 Gentle/Moderate

1-10 Light Winds

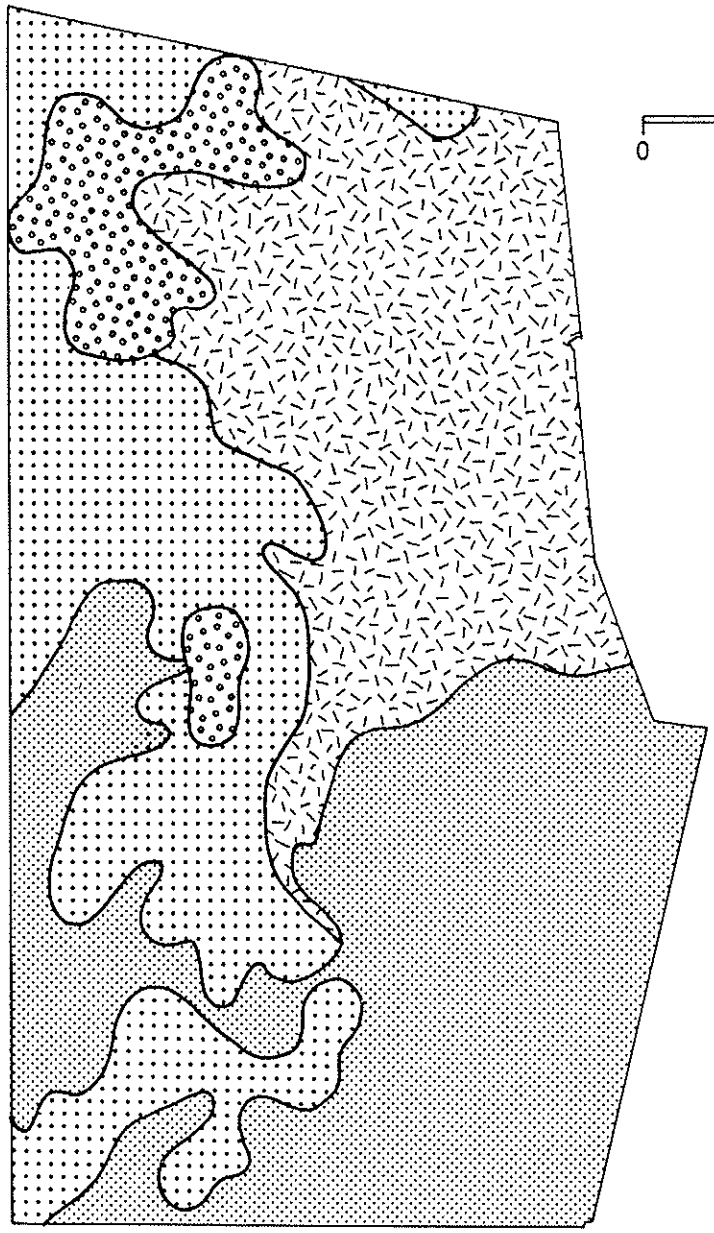
12 % Calm

SOURCE: BUREAU OF METEOROLOGY, UPPER SWAN RESEACH STATION

ALAN TINGAY & ASSOCIATES

ANNUAL WIND ROSES - EGERTON

FIGURE 7



N

0 Kilometre 1

SCALE 1:20 000

LEGEND

	S_8	Bassendean Sand. Sand - very light grey at surface, yellow at depth. Fine to medium grain, sub-rounded quartz. Moderately well sorted. Aeolian origin.
	S_{10}	Thin Bassendean Sand over Guildford Formation Sand - as for S_8, forming a thin veneer over Guildford Formation(Mgs_1)
	Mgs_1	Guildford Formation Pebbly Silt - Strong brown silt with common, fine to occasionally coarse-grained, sub-rounded laterite quartz, heavily weathered granite pebble. Some fine to medium grained quartz sand. Alluvial origin.
	Cps	Swamp Deposits Peaty Clay - dark grey & black with variable sand content. Lacustrine origin.

SOURCE: GOZZARD, 1986

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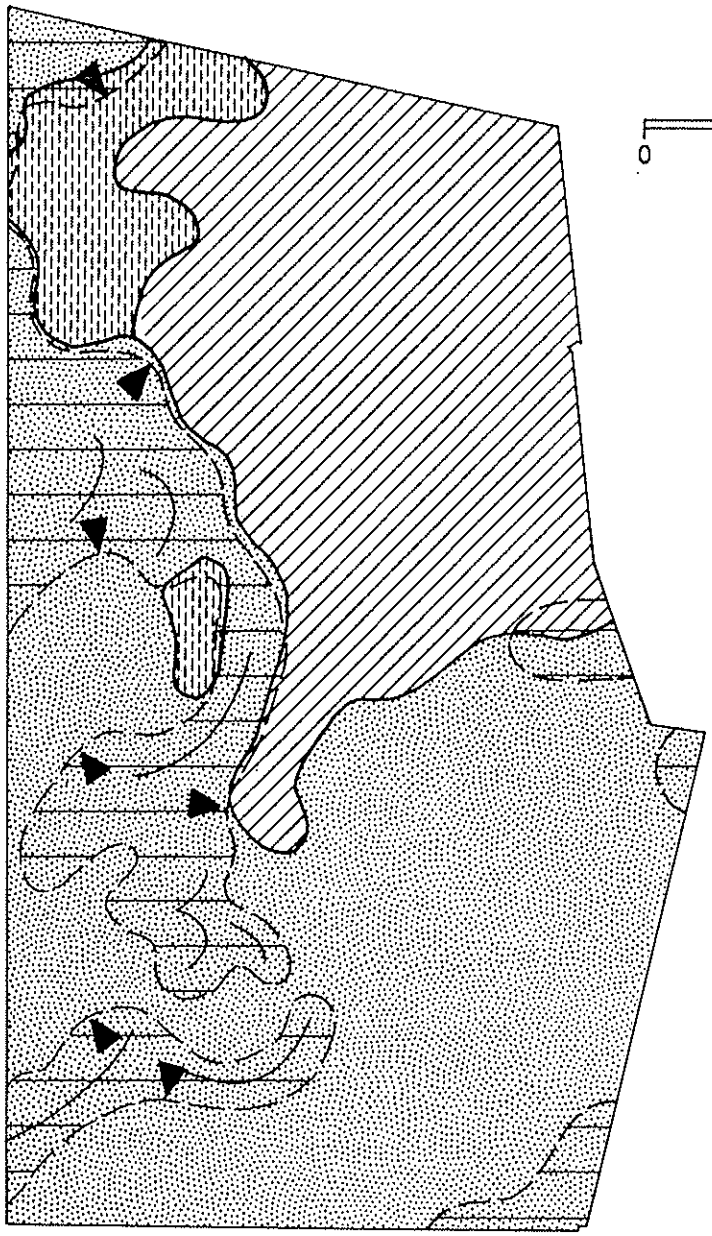
EGERTON GEOLOGY

FIGURE 8



N

0 Kilometre 1

SCALE 1:20 000

LEGEND

Degraded surface of aeolian origin - Bassendean Dunes

Marsh in interdunal swales

Alluvial plain

Slopes

0°-3°

3°-10°

Prominent ridge

Sharp concave break of slope

SOURCE: GOZZARD, 1986

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EGERTON GEOMORPHOLOGY

FIGURE 9

LEGEND

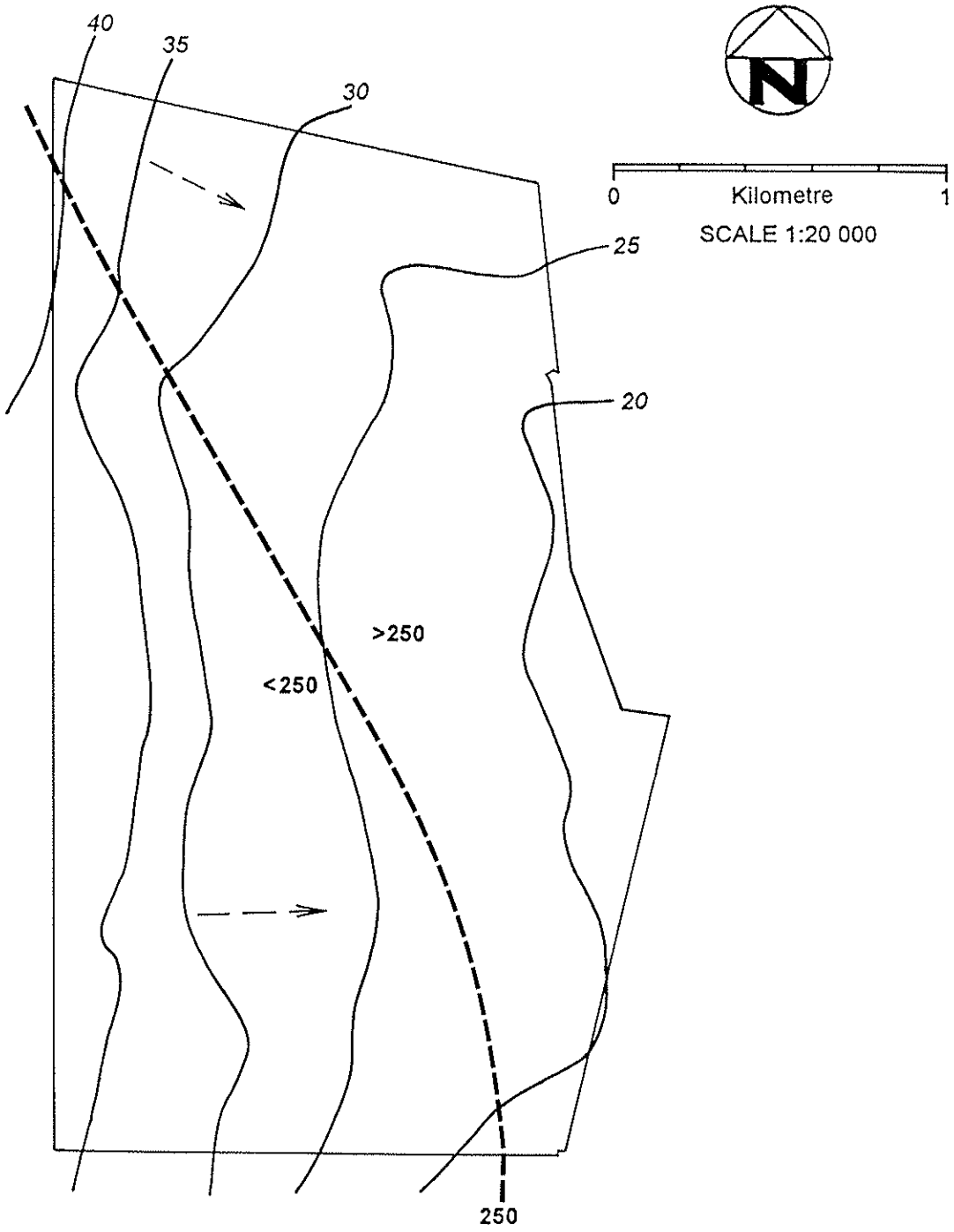
20 Topographic Contours (1m AHD intervals)

Drainage Lines

ALAN TINGAY & ASSOCIATES

EGERTON TOPOGRAPHY

FIGURE 10



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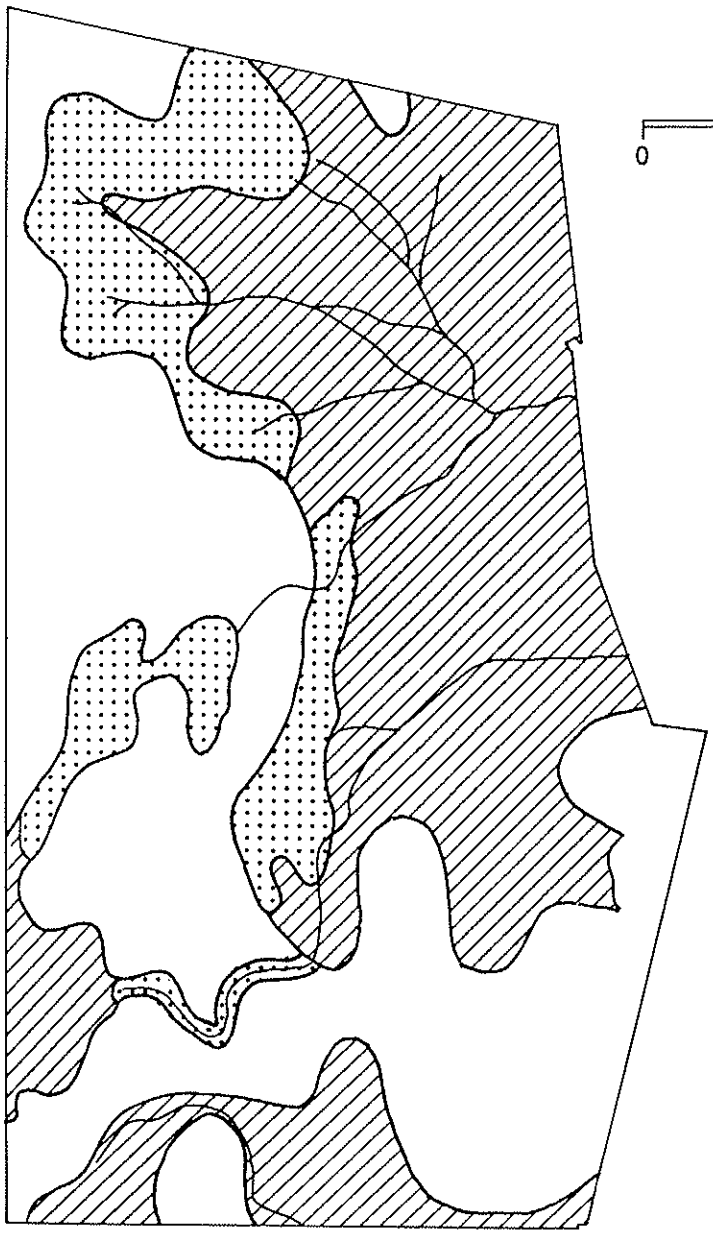
EGERTON GROUNDWATER & ISOHALINE CONTOURS

FIGURE 11



0 Kilometre 1

SCALE 1:20 000

LEGEND

Creek (seasonally inundated drainage channel)

Dampland & Sumpland (seasonally waterlogged/inundated basin)

Palusplain (seasonally waterlogged flat)

SOURCE: MODIFIED AFTER WATER AUTHORITY OF WESTERN AUSTRALIA, 1993

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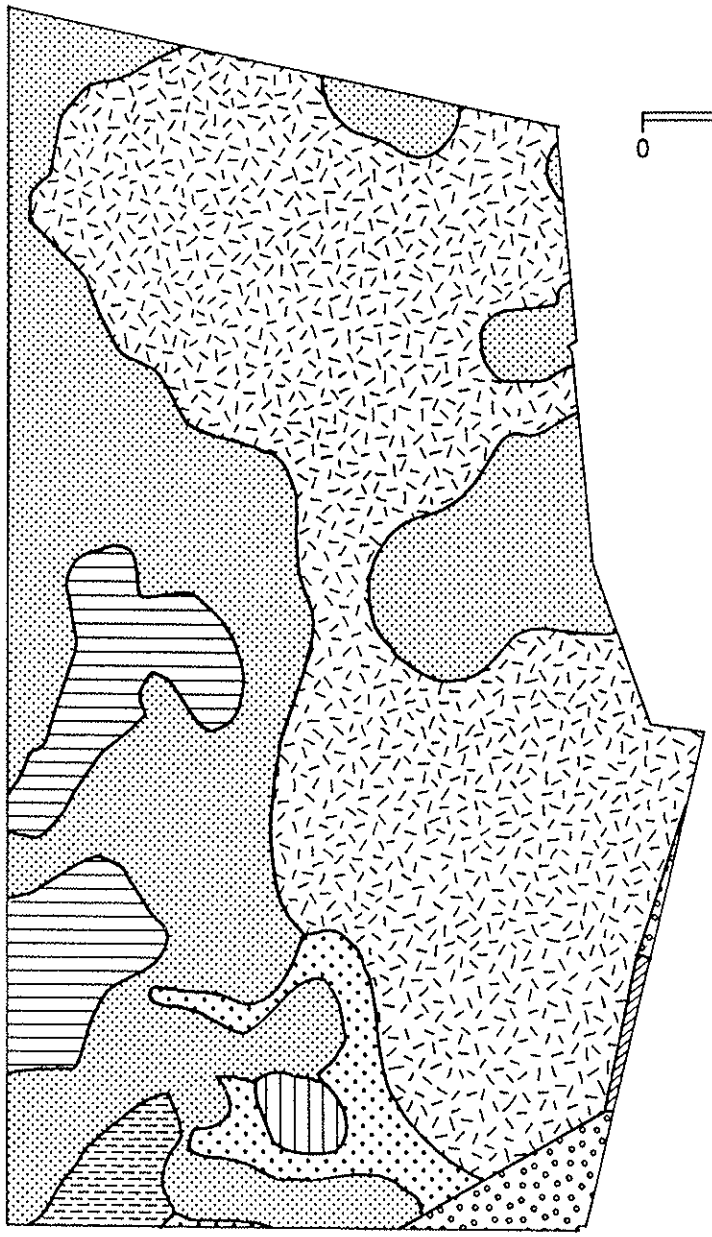
EGERTON WETLANDS

FIGURE 12



N

0 Kilometre 1

SCALE 1:20 000

LEGEND

Land Capability Unit

- Ya — Yanga
- Ja — Jandakot
- Ws — Seasonal Swamps
- DL — Drainage Lines

Land Capability Unit

- J — Joel
- 1 — Gavin
- Ks — Karrakatta Sand
- Mus — Muchea Sand

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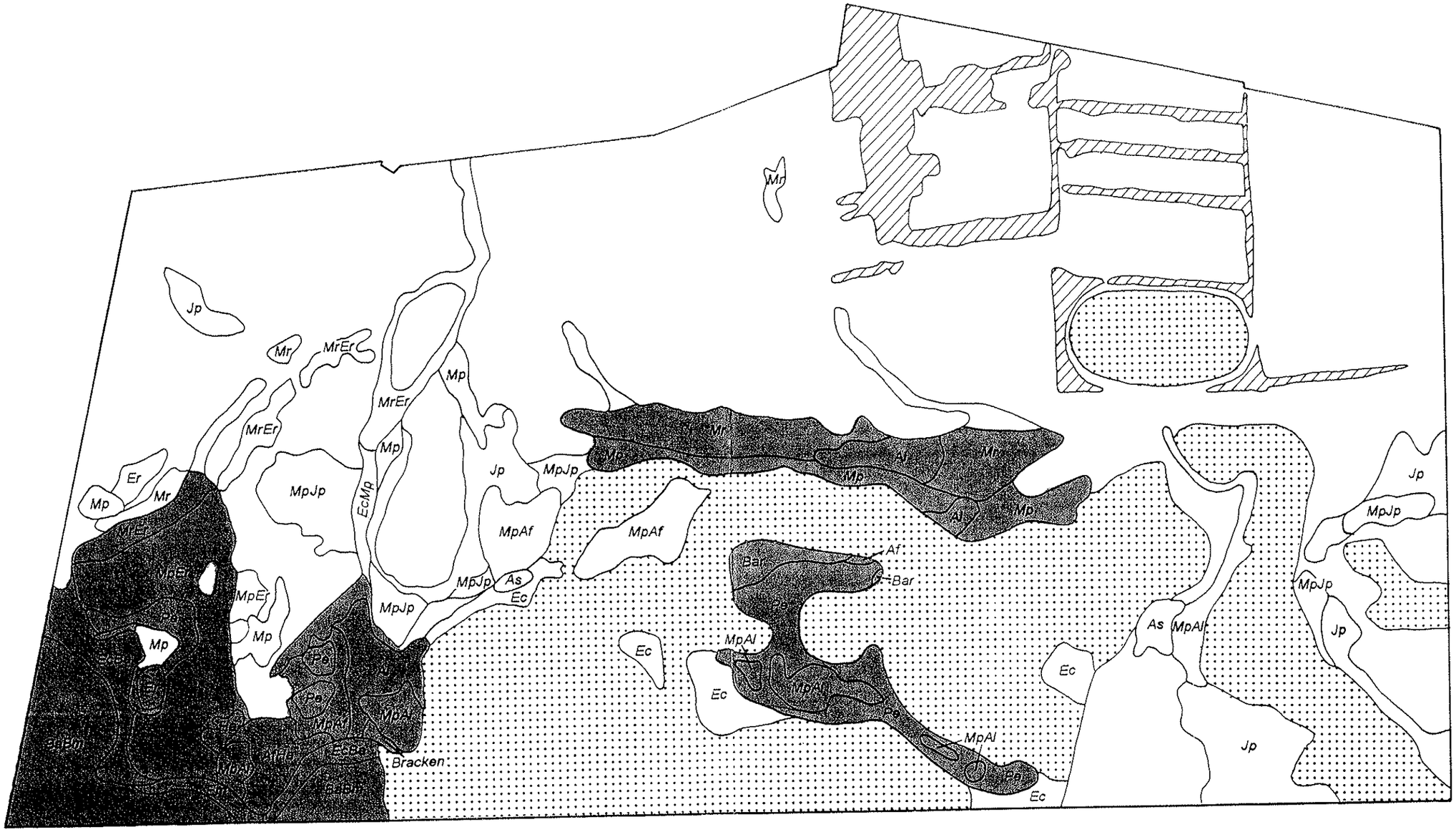
EGERTON LAND CAPABILITY MAP

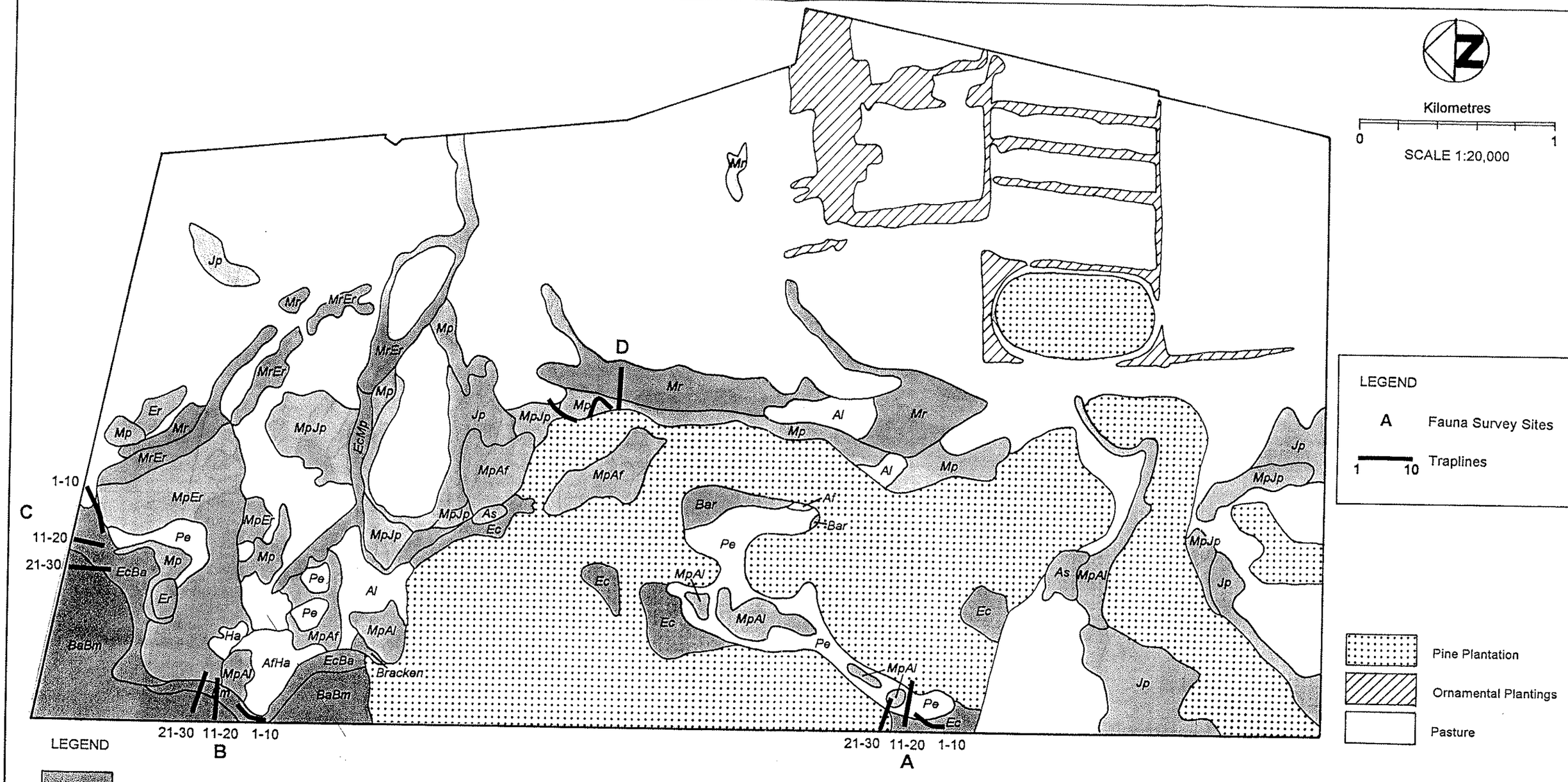
FIGURE 14



LEGEND

- Slightly Disturbed
- Obvious Disturbance
- Severely Disturbed
- Degraded

EGERTON
NATIVE VEGETATION QUALITY MAP
FIGURE 16



LEGEND

Dry/Woodlands

BaBm - *Banksia attenuata/B. menziesii* Low Woodland

Transitional/Woodlands

Ec - *Eucalyptus calophylla* Woodland

EcBa - *Eucalyptus calophylla/Banksia attenuata* Woodland

Em - *Eucalyptus marginata* Woodland

Dampland/Heaths & Sedgelands

Pe - *Pericalymma ellipticum* Closed Heath

Al - *Agonis linearifolia* Open Heath over *Juncus pallidus* Sedgeland

Af *Astartea fascicularis* Closed Heath

AfHa - *Astartea fascicularis/Hypocalymma angustifolium* Closed Heath

Ha - *Hypocalymma angustifolium* Closed Heath

Dampland/ Forests, Woodlands & Heaths

Er - *Eucalyptus rudis* Open Forest

MpEr - *Melaleuca preissiana/Eucalyptus rudis* Closed Forest with *Banksia littoralis*

Mp - *Melaleuca preissiana* Low Woodland

MpJp - *Melaleuca preissiana* Low Woodland over *Juncus pallidus* Sedgeland

MpAl - *Melaleuca preissiana* Low Open to Low Woodland over *Agonis linearifolia* Closed Heath

MpPe - *Melaleuca preissiana* Low Open Woodland over *Pericalymma ellipticum* Closed Heath

MpAf - *Melaleuca preissiana* Low Open Woodland over *Astartea fascicularis* Closed Heath

As - *Acacia saligna* Low Woodland over *Agonis linearifolia* Open Heath

Jp - *Juncus pallidus* Sedgeland

Sumpland & Creeks/Forests, Woodlands & Sedgelands

Mr - *Melaleuca rhaphiophylla* Low Closed Forest

MrEr - *Melaleuca rhaphiophylla/Eucalyptus rudis* Low Closed Forest

EcMp - *Eucalyptus calophylla* Woodland over *Melaleuca preissiana* Low Woodland

Bar - *Baumea articulata* Closed Sedgeland

ALAN TINGAY & ASSOCIATES

EGERTON VEGETATION TYPES FIGURE 15

APPENDIX 1

EPA GUIDELINES FOR THE EGERTON CER

PROPOSED REZONING OF LAND FROM URBAN DEFERRED TO URBAN AT EGERTON (ADJACENT TO ELLEN BROOK)

CONSULTATIVE ENVIRONMENTAL REVIEW GUIDELINES

Overview

In Western Australia all environmental reviews are about protecting the environment. The fundamental requirement is for the proponent to describe what they propose to do, to discuss the potential environmental impacts of the proposal, and then to describe how those environmental impacts are going to be managed so that the environment is protected.

If the proponent can demonstrate that the environment will be protected then the proposal will be found environmentally acceptable; if the proponent cannot show that the environment would be protected then the Environmental Protection Authority (EPA) would recommend against the proposal.

Throughout the process it is the aim of the EPA to advise and assist the proponent to improve or modify the proposal in such a way that the environment is protected. Nonetheless, the environmental review in Western Australia is proponent driven, and it is up to the proponent to identify the potential environmental impacts and design and implement proposals which protect the environment.

For this proposal, protecting the environment means that the natural and social values associated with Ellen Brook and its associated tributaries, wetlands, including palusplain, on the site are protected. Where they cannot be protected, proposals to mitigate the impacts are required.

Purpose of a CER

The primary function of a CER is to provide the basis for the EPA to provide advice to Government on protecting the environment. An additional function is to communicate clearly with the public so that EPA can obtain informed public comment. As such, environmental impact assessment is quite deliberately a public process. The CER should set out the series of decisions taken to develop this proposal at this place and time and why.

Objectives of the review

The Consultative Environmental Review should have the following objectives:

- to place this project in the context of the progressive environmental management for the region;
- to explain the issues and decisions which led to the choice of this project at this place at this time;
- to set out the environmental impacts that the project may have; and
- for each impact, to describe any environmental management steps the proponent believes would avoid, mitigate or ameliorate that impact.

The CER should focus on the major issues for the area and anticipate the questions that members of the public will raise. Data describing the environment should be directly related to the discussion of the potential impacts of the proposal. Both should then relate directly to the actions proposed to manage those impacts.

Key issues

The critical issue for the proposal is likely to be the management of water quality and quantity for the site. An integrated study of groundwater, surface water run off and environmental issues is required to address the surface and subsurface water quality and quantity aspects for key elements of the proposal. The CER needs to show a detailed understanding of the conservation, landscape, and social values in the area, and whether they are represented elsewhere. The conservation values of areas to be disturbed should he examined in detail.

The key issues for this project should be clearly identified and the content of succeeding sections determined by their relevance to these issues.

In this case the key issues should include:

- the reasons for the proposal and the alternatives considered;
- management of water quality and quantity with particular reference to Ellen Brook and the Swan River, wetlands on the site, including palusplain, the possible presence of a mound spring and the impacts to local water balance (downstream);
- management of wetlands and the mound spring which are not protected by legislation;
- initiatives such as water sensitive urban design should be considered and discussed, it may be necessary to include nutrient stripping basins to ensure satisfactory quality of recharge to the groundwater and run off to Ellen Brook and the Swan River;
- the status and implementation, of the foreshore reserve for Ellen Brook should be discussed;
- flora, fauna and ecosystems:
    - land units and their secure representation elsewhere;
    - rare and poorly known flora, fauna and communities, shown on distribution maps;
    - inter-relationships of the biota and environment, including consideration of wildlife corridors;
- landscape and recreation values, including protection of Ellen Brook and the Swan Valley Policy Area;
- the relationship and compatibility between this proposal and those of adjoining landholders with particular reference to water quality and quantity management of surface and subsurface water. It is important to show that this proposal will not adversely affect wetland water level criteria and groundwater criteria established through the Ellenbrook proposal;
- local environmental issues associated with transit access to the site;
- cultural impact on Aboriginal people with traditional affiliation to the land;

plus any other key issues raised during the preparation of the report.

Public partition and consultation

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the CER. It should describe the activities undertaken, the dates, the groups and individuals involved and the objectives of the activities. Cross reference should be made with the description of environmental management for the proposal which should clearly indicate how community concerns have been addressed. Where these concerns are dealt with via other departments or procedures, outside the EPA process, these can

be noted and referenced here.

Detailed list of environmental commitments

The commitments being made by the proponent to protect the environment should be clearly defined and separately listed. Where an environmental problem has the potential to occur, there should be a commitment to rectify it. They should be numbered and take the form of:

a who will do the work;

b what the work is;

c when the work will be carried out; and

d to whose satisfaction the work will be carried out.

- All actionable and auditable commitments made in the body of the document should be numbered and summarised in this list.

APPENDIX 2

GROUNDWATER ISOTOPE STUDIES OF SPRINGS AT EGERTON, WEST SWAN ROAD, ELLENBROOK

GROUNDWATER ISOTOPE STUDIES OF SPRINGS AT EGERTON, WEST SWAN ROAD, ELLENBROOK

by Dr P M Thorpe

Client: Paul van der Mezel, Tingay Allen and Associates, 35 Labouchere Rd, South Perth. Telephone/Fax: 474 1300/ 474 3394.

AIM: To determine the age and source of water issuing from springs on the north eastern part of the Egerton property using isotope groundwater age dating techniques.

The spring water may originate from two possible sources:

- Discharge of young, shallow groundwater (<2000 years) from the unconfined Quaternary Bassendean Sand aquifer on the eastern edge of the property may occur at the contact of the Bassendean Sand and the underlying clays of the Guildford Formation.

- Discharge of old groundwater (20 000 to 30 000 years) derived by upward leakage from the underlying deep confined artesian Cretaceous Leederville Formation aquifer.

Existing information from an extensive groundwater age dating study of the confined aquifers in the Perth metropolitan area conducted by the Geological Survey (Thorpe and Davidson, 1991) shows that groundwater in the Leederville Formation in the area is likely to be from 20 000 to 30 000 years in age as shown in the Figure.

METHOD

Samples for isotope dating were taken from the following sources on November 18 and 19 1993 by officers of the Geological Survey to asertain the origin of the groundwater at the springs :

1. The springs. Samples were collected from a shallow creek supplied by the springs at about 20m from their source. Dense vegetation and marshy ground conditions prevented direct access to the spring source.

2. The Leederville Formation aquifer. A representative sample was collected from the artesian monitoring bore AM31A located near the Egerton property, about 4.5 km south east of the springs on Swan Street. This bore is screened in the middle part of the Leederville Formation at 200 to 203 m depth.

3. The shallow aquifer. A sample was collected from the only available equipped shallow depth production bore on the property located near the Old Mill adjacent to Ellen Brook. The depth of this bore is estimated to be about 40 m, however construction details including depth of screen were not available Groundwater from this source is not representative of groundwater in the Bassendean Sand on the eastern edge of the property. The bore probably intersects groundwater produced from thin sand beds within the Cretaceous Osborne Formation beneath the Quaternary deposits.

RESULTS

The isotope and field chemical data from the three water sources are given in the Table and show the following:

1. Water collected from the springs has a relatively young Carbon-14 age of 90 years. It also exhibits an immature chemical signature, that is, a low pH, salinity, alkalinity, temperature and high dissolved carbon dioxide content.

2. Groundwater from the Leederville Formation aquifer (AM31A) is relatively old at 12 700 years and has a mature chemical signature shown by a moderate salinity, alkalinity and temperature; and low dissolved carbon dioxide content.

3. Groundwater from the shallow production bore on the property is relatively old at >28 800 years and shows a mature chemical signature.

CONCLUSIONS

The age dating studies show the following:

1. The groundwater issuing at the springs on the north eastern part of the Egerton property does not originate from discharge by upward leakage from the artesian Leederville Formation aquifer. The groundwater discharging from the springs is substantially younger in age than that found in the Leederville Formation aquifer in the area.

2. Groundwater flowing from the springs originates from relatively young shallow groundwater within the Bassendean Sand aquifer to the west known as the Gnangara Groundwater Mound. Groundwater discharge from this aquifer results in springs where the contact between the Bassendean Sand and underlying clayey Guildford Formation is exposed. This type of spring development is probably common in the Swan Valley area in areas of low elevation.

3. Groundwater from the shallow production bore sampled on the Egerton property is not representative of groundwater in the Bassendean Sand on the eastern edge of the property. The bore probably intersects old groundwater from thin sand beds within the Cretaceous Osborne Formation beneath the Quaternary deposits.

REFERENCES

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Thorpe, P. M. and Davidson, W. A., 1991, Groundwater age and hydrodynamics of the confined aquifers, Perth, Western Australia, in Proceedings of the International Conference on Groundwater in Large Sedimentary Basins, Perth, Western Austraia, 1990: Australian Water Resources Council, Conference Series no. 20, p. 420-436.

P. M. Thorpe 29/12/93

Dr P M Thorpe (Isotope Hydrogeologist, Geological Survey Of Western Australia).

TABLE. ISOTOPE AND FIELD CHEMICAL DATA

Bore/ source	AMG	Sample interval (m depth)	Formation sampled	C-14 age (years BP)	Error (years BP)	C-14 activity (pmC)	Error (pmC)	T (oC)	EC (mS/cm)	Salinity TDS *	pH	DO *	Alkalinity (as CaCO3*)	CO2 dissolved*
Springs	N 6484350 E 403400	surface	-	90	90	98.9	1	15.6	0.29	160	5.07	13.1	12	620
AM31A	N 6480550 E 406030	200-203	Kl	12 700	110	21.6	0.3	23.3	1.05	570	6.13	1.9	113	137
Property bore	N 6483300 E 405250	? 40	? Ko	>28 800	-	1.5	0.8	21.6	0.62	330	6.51	1.5	107	54

Where:

BP	= before present (1950 AD)
pmC	= percent modern carbon
T	= temperature
EC	= electrical conductivity
TDS	= total dissolved solids estimated from EC
DO	= dissolved oxygen
*	= mg/L
Ko	= Osborne Formation
Kl	= Leederville Formation

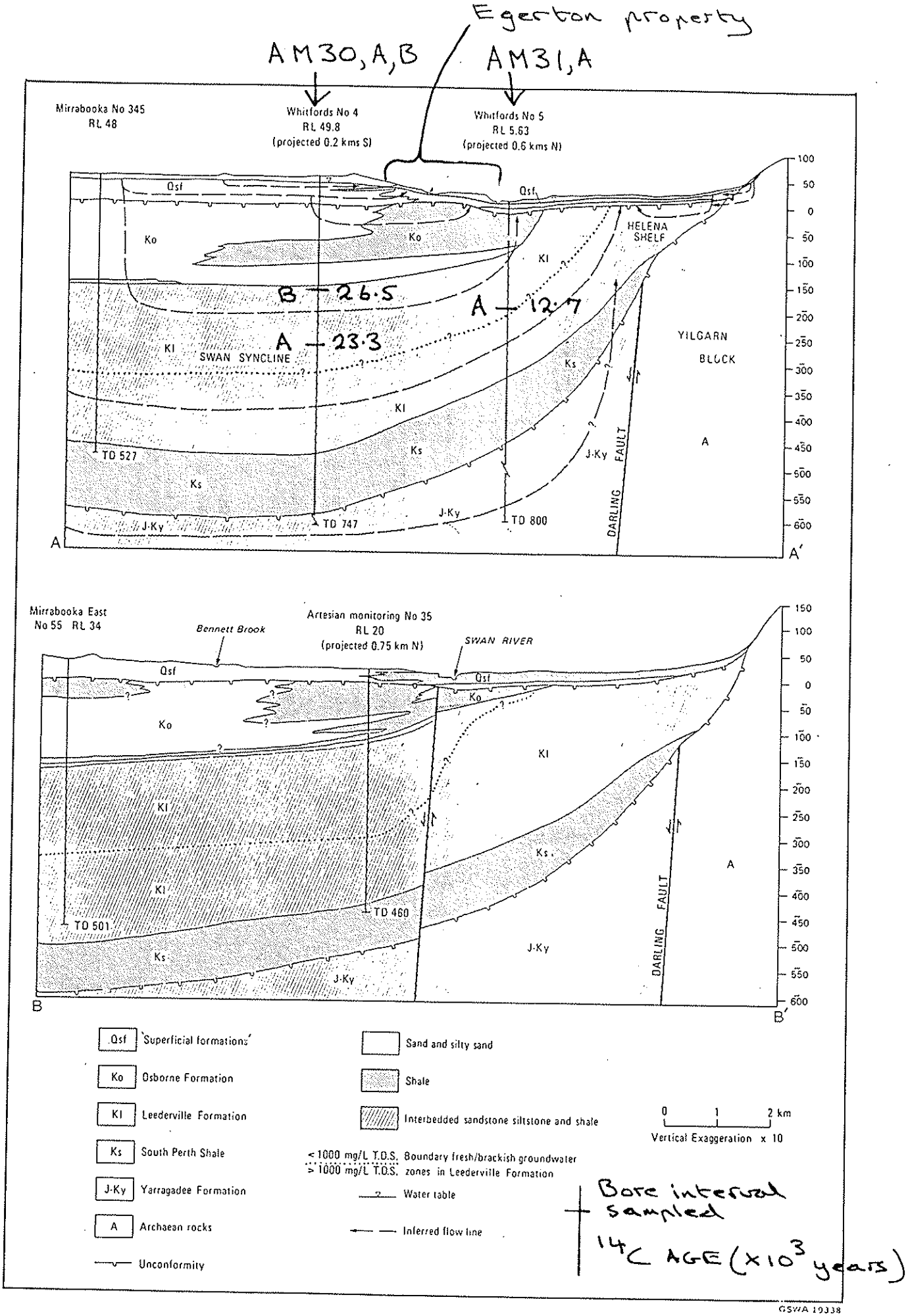

Figure : Hydrogeological cross-sections of the Swan Valley.

(After Allen, 1981)

APPENDIX 3

LIST OF NATIVE FLORA RECORDED AT EGERTON

Species	Dry	Transitional	Wet
FERNS			
Dennstaedtiaceae		x	x
Pteridium esculentum			
CYCADS			
Zamiaceae			
Macrozamia riedlei	x		x
MONOCOTYLEDONS			
Anthericaceae			
Laxmannia squarrosa	x		
Thysanotus manglesianus	x		
Colchicaceae			
Burchardia umbellata	x		
Wurmbea dioica			x
Cyperaceae			
Baumea articulata			x
Isolepis marginata	x		
Lepidosperma angustatum		x	
Lepidosperma leptostachyum	x		
Mesomelaena pseudostygia	x		
Schoenus curvifolius	x		
Tetraria octandra			x
Haemodoraceae			
Anigozanthos humilis	x		
Anigozanthos manglesii	x		
Conostylis aculeata	x		
Conostylis aurea	x		
Conostylis juncea		x	
Haemodorum laxum	x		
Haemodorum paniculatum	x		
Phlebocarya ciliata		x	
Iridaceae			
Patersonia occidentalis	x		
Potamogetonaceae			
Potamogeton sp.			x
Juncaceae			
Juncus pallidus			x
Juncus planifolius			x
Juncaginaceae			
Triglochin procera			x
Dasypogonaceae			
Calectasia cyanea	x		
Dasypogon bromeliifolius		x	
Lomandra odera			x

Species	Dry	Transitional	Wet
Orchidaceae			
Caladenia flava	x		
Caladenia aff heugelii			x
Caladenia sp.	x		
Elythranthera brunonsis	x		x
Elythranthera emarginata		x	
Lyperanthus nigricans			x
Microtis unifolia			x
Pterostylis vittata			x
Pterostylis nana			x
Restionaceae			
Alexgeorgea nitens	x		
Hypolaena exsulca			x
Loxocarya flexuosa	x		
Loxocarya pubescens	x		
Lyginia barbata	x		
Restio sp.	x		
Xanthorrhoeaceae			
Xanthorrhoea preissii		x	x
DICOTYLEDONAE			
Apiaceae			
Trachymene pilosa	x		
Asteraceae			
Podotheca chrysantha	x		
Cotula coronopifolia			x
Lagenifera huegelii	x	x	
Millotia myosotidifolia	x		
Podotheca gnaphalioides	x		
Quinetia urvillei	x		
Casuarinaceae			
Allocasuarina fraseriana	x		
Allocasuarina humilis	x		
Crassulaceae			
Crassula colorata	x		
Dilleniaceae			
Hibbertia aurea	x		
Hibbertia huegelii	x		
Hibbertia hypericoides	x		
Hibbertia subvaginata	x		x
Hibbertia vaginata	x		
Hibbertia perfoliata			x

Species	Dry	Transitional	Wet
Droseraceae			
Drosera erythrorhiza	x		x
Drosera gigantea			x
Drosera macrantha			x
Drosera menziesii	x		
Drosera pulchella			x
Drosera sp			x
Epacridaceae			
Astroloma xerophyllum			
Brachyloma preissii	x		
Conostephium minus	x		
Conostephium pendulum	x		
Leucopogon australis		x	x
Leucopogon conostephioides	x		
Leucopogon gibbosus	x		
Leucopogon racemulosus	x		
Leucopogan sprengelioides	x		
Goodeniaceae			
Dampiera linearis	x		x
Lechenaultia floribunda	x		
Scaevola paludosa	x		
Verrauxia reinwardtii	x		
Lamiaceae			
Hemiandra pungens	x		
Lauraceae			
Cassytha racemosa			x
Cassytha glabella	x		
Lentibulariaceae			
Polypompholyx multifida			x
Lobeliaceae			
Lobelia tenuior		x	
Loranthaceae			
Nuytsia floribunda	x		x
Menyanthaceae			
Villarsia albiflora			x
Mimosaceae			
Acacia saligna		x	
Acacia sessilis	x		
Acacia huegelii	x		
Acacia pulchella	x		
Molluginaceae			
Macarthuria australis	x		

Species	Dry	Transitional	Wet
Myrtaceae			
Agonis linearifolia			x
Astartea fascicularis	x		x
Beaufortia elegans	x		
Calothamnus lateralis			x
Calythrix angulata	x		
Calythrix fraseri	x		
Eremaea pauciflora	x		
Eucalyptus calophylla		x	
Eucalyptus marginata	x	x	x
Eucalyptus rudis			x
Eucalyptus todtiana	x		
Hypocalymma angustifolium		x	x
Melaleuca preissiana		x	x
Melaleuca rhaphiophylla			x
Pericalymma ellipticum			x
Regelia inops	x		
Scholtzia involucrata			x
Verticordia nitens	x		
Papilionaceae			
Aotus cordifolius			x
Bossiaea eriocarpa	x		
Burtonia conferta	x		
Daviesia preissii	x		
Daviesia divaricata	x		
Daviesia triphylla	x		
Euchilopsis linearis			x
Eutaxia virgata			x
Gompholobium aristatum	x		
Gompholobium tomentosum	x		
Hovea pungens	x		
Hovea trisperma	x		
Jacksonia densiflora	x		
Jacksonia furcellata	x		
Jacksonia sternbergiana		x	
Kennedia prostrata		x	
Nemcia reticulata		x	
Oxylobium lineare			x
Pultenaea reticulara	x	x	
Sphaerolobium medium			x
Viminaria juncea			x
Polygalaceae			
Comesperma virgatum			x
Proteaceae			
Adenanthos cygnorum	x	x	
Banksia attenuata	x		
Banksia grandis		x	
Banksia ilicifolium		x	
Banksia littoralis			x
Banksia menziesii	x		
Conospermum stoechadis	x		
Persoonia saccata	x		

Species	Dry	Transitional	Wet
Petrophile linearis	x		
Stirlingia latifolia	x		
Synaphaea spinulosa	x		
Rubiaceae			
Opercularia hispidula			x
Rutaceae			
Eriostemon spicatus	x		
Boronia ramosa			x
Stylidiaceae			
Stylidium aff. piliferum	x		
Stylidium brunonianum	x		
Stylidium calcaratum	x		
Stylidium diuroides	x		
Stylidium junceum			x
Stylidium macrocarpum	x		
Stylidium repens	x		
Stylidium schoenoides	x		
Thymeleaceae			
Pimelea leucantha	x		
Violaceae			
Hybanthus calycinus	x		
Stackhousiaceae			
Stackhousia huegelii			x

APPENDIX 4

LIST OF VEGETATION ASSOCIATIONS RECORDED AT EGERTON

EGERTON VEGETATION TYPES

BaBm	*Banksia attenuata/B. menziesii* Low Woodland
EcBa	*Eucalyptus calophylla/Banksia attenuata* Woodland
BmBaBi	*Banksia menziesii/B. attenuata/B. ilicifolium* Low Woodland
Ac	*Adenanthos cygnorum* Open Scrub
EcMp	*Eucalyptus calophylla* Woodland over *Melaleuca preissiana* Low Woodland
MpJp	*Melaleuca preissiana* Low Woodland over *Juncus pallidus* Sedgeland
Jp	*Juncus pallidus* Sedgeland
Pe	*Pericalymma ellipticum* Closed Heath
Al	*Agonis linearifolia* Open Heath over *Juncus pallidus* Sedgeland
MpAl	*Melaleuca preissiana* Low Open to Low Woodland over *Agonis linearifolia* Closed Heath
AfHa	*Astartea fascicularis/Hypocalymma ellipticum* Closed Heath
MpErBl	*Melaleuca preissiana/Eucalyptus rudis* Closed Forest with *Banksia littoralis*
ErMp	*Eucalyptus rudis* Open Forest over *Melaleuca preissiana* Low Woodland
MrEr	*Melaleuca rhaphiophylla/Eucalyptus rudis* Low Closed Forest
MpPe	*Melaleuca preissiana* Low Open Woodland over *Pericalymma angustifolium* Closed Heath
Er	*Eucalyptus rudis* Open Forest
Bar	*Baumea articulata* Closed Sedgeland
Mr	*Melaleuca rhaphiophylla* Low Closed Forest
As	*Acacia saligna* Low Woodland over *Agonis linearifolia* Open Heath
Em	*Eucalyptus marginata* Woodland
Mp	*Melaleuca preissiana* Low Woodland
Ha	*Hypocalymma angustifolium* Closed Heath
MpAf	*Melaleuca preissiana* Low Open Woodland over *Astartea fascicularis* Closed Heath
Ec	*Eucalyptus calophylla* Woodland

APPENDIX 5

LIST OF VERTEBRATE FAUNA RECORDED AT EGERTON, ELLENBROOK & WHITEMAN PARK

Amphibian and reptile species recorded on the coastal plain between the Swan and Moore Rivers, indicating those species known (+) at Ellenbrook, Whiteman and Melaleuca Parks and Egerton.

Species present on the northern Swan Coastal Plain	Species present at: Ellenbrook Park	Whiteman Park	Melaleuca Park	Egerton
FROGS				
Leptodactylidae (Ground Frogs)				
Crinia georgiana	+	+	+	+
Heleioporus albopunctatus				
Heleioporus barycragus				
Heleioporus eyrei	+	+	+	+
Heleioporus inornatus				+
Heleiporus psammophilus				
Limnodynastes dorsalis	+	+		+
Myobatrachus gouldii	+	+		
Neobatrachus pelobatoides				
Pseudophryne guentheri	+	+	+	
Ranidella glauerti	+		+	+
Ranidella insignifera	+	+	+	+
Hylidae (Tree Frogs)				
Litoria adelaidensis	+		+	
Litoria moorei	+			
TORTOISES				
Chelidae (Side-neck Tortoises)				
Chelodina oblonga	+	+	+	
Pseudemydura umbrina				
LIZARDS				
Gekkonidae (Geckoes)				
Crenadactulus ocellatus				
Diplodactylus alboguttatus		+		
Diplodactylus polyopthalmus				
Diplodactylus spinigerus	+		+	+
Gehyra variegata				
Heteronotia binoei				
Phyllodactylus marmoratus		+		
Underwoodisaurus milii				

Species present on the northern Swan Coastal Plain	Species present at: Ellenbrook Park	Whiteman Park	Melaleuca Park	Egerton
Pygopodidae (Legless Lizards)				
Aclys concinna				
Aprasia pulchella				
Aprasia repens	+	+	+	
Delma fraseri	+		+	
Delma grayii				
Lialis burtonis	+	+	+	
Pletholax gracilis	+	+		
Pygopus lepidopodus		+	+	
Agamidae (Dragons)				
Ctenophorus ornatus				
Pogona minor	+	+	+	+
Tympanocryptis adelaidensis	+	+	+	
Varanidae (Monitors or Goannas)				
Varanus gouldii	+	+		
Varanus rosenbergi		+		
Varanus tristis				
Scincidae (Skinks)				
Bassiana trilineata	+	+	+	
Cryptoblepharus plagiocephalus	+	+	+	+
Ctenotus delli				
Ctenotus fallens	+	+	+	
Ctenotus gemmula	+	+	+	
Ctenotus impar		+		
Ctenotus labillardieri				
Ctenotus lesueurii	+	+	+	
Cyclodomorphus branchialis				
Egernia kingii				
Egernia luctuosa				
Hemiergis initialis				
Egernia napoleonis	+	+	+	+
Hemiergis quadrilineata	+			+
Lerista christinae	+			
Lerista distinguenda				
Lerista elegans	+	+	+	+
Lerista lineata				
Lerista lineopunctulata				
Lerista praepedita	+		+	+
Menetia greyii	+	+	+	+
Morethia lineoocellata	+	+	+	
Morethia obscura	+	+	+	
Tiliqua occipitalis	+	+		

Tiliqua rugosa	+	+	+	
SNAKES				
Typhlopidae (Blind Snakes)				
Ramphotyphlops australias	+	+		
Ramphotyphlops bituberculata				
Ramphotyphlops pinguis				
Ramphotyphlops waitii				
Boidae (Pythons)				
Morelia spilota				
Morelia stimsoni				
Elapidae (Front-fanged Snakes)				
Acanthophis antarcticus				
Demansia psammophis				
Demansia reticulata				
Notechis coronatus				
Notechis curtus				
Notechis scutatus	+	+		+
Pseudechis australis				
Pseudonaja affinis	+	+	+	
Pseudonaja modesta				
Pseudonaja nuchalis				
Rhinoplocephalus gouldii	+	+	+	
Rhinoplocephalus nigriceps				
Vermicella bertholdi	+		+	
Vermicella bimaculata			+	
Vermicella calonotus	+	+	+	
Vermicella fasciolata		+		
Vermicella semifasciata	+			

Totals	North Swan Coastal Plain (WA Museum, 1978)	Species positively identified at: Ellenbrook	Whiteman Park	Melaleuca Park	Egerton
Frogs	14	9	6	7	6
Tortoises	2	1	1	1	
Geckoes	8	1	2	1	1
Pygopods	8	4	4	3	
Dragons	3	2	2	2	1
Varanids	3	1	2		
Skinks	25	15	13	12	6
Snakes	23	7	6	5	1
TOTAL	86	40	36	31	15

Species of birds present at Ellenbrook (RAOU) and Whiteman Park (Arnold et al, 1991) Compared to those confirmed at Egerton.

Species	Ellenbrook and/or Whiteman Park	Confirmed at Egerton
Emu/*Dromaius novaehollandiae*	+	+
Australasian Grebe/*Tachybaptus novaehollandiae*		+
Pacific Heron/*Ardea pacifica*	+	
Little Pied Cormorant/*Phalacrocorax melanoleucos*		+
Sacred Ibis/*Threskiornis aethiopica*		+
Australian Shelduck/*Tadorna tadornoides*		+
Pacific Black Duck/*Anas superciliosa*		+
Black-shouldered Kite/*Elanus notatus*	+	+
Brown Goshawk/*Accipiter fasciatus*	+	
Collared Sparrowhawk/*Accipiter cirrhocephalus*	+	
Wedge-tailed Eagle/*Aquila audax*	+	+
Australian Hobby/*Falco longipennis*	+	
Brown Falcon/*Falco berigora*	+	
Australian Kestrel/*Falco cenchroides*	+	
Unidentified Quail/*Coturnix sp.*	+	
Eurasian Coot/*Fulica atra*		+
Swamp Hen/*Porphyrio porphyrio*		+
Laughing Turtle-Dove/*Streptopelia senegalensis* (i)		+
Common Bronzewing/*Phaps chalcoptera*	+	
Little Corella *Cacatua pastinator*		+
Pink & Grey Galah/*Cacatua roseicapilla*		+
Red-capped Parrot/*Purpureicephalus spurius*	+	
Ringnecked Parrot '28'/*Barnardius zonarius*	+	+
Elegant Parrot/*Neophema elegans*	+	
Fan-tailed Cuckoo/*Cuculus pyrrhophanus*	+	+
Shining Bronze-Cuckoo/*Chrysococcyx lucidus*		+
Southern Boobook Owl/*Ninox novaeseelandiae*	+	
Barn Owl/*Tyto alba*	+	
Tawny Frogmouth/*Podargus strigoides*	+	
Australian Owlet-nightjar/*Aegotheles cristatus*	+	
Fork-tailed Swift/*Apus pacificus*	+	
Laughing Kookaburra/*Dacelo novaeguineae*		+
Sacred Kingfisher/*Halcyon sancta*	+	+

Rainbow Bee-eater/*Merops ornatus*	+	+
Welcome Swallow/*Hirundo noexena*	+	
Tree Martin/*Cecropis nigricans*	+	
Black-faced Cuckoo-shrike/*Coracina novaehollandiae*	+	+
Scarlet Robin/*Petroica multicolor*	+	
Hooded Robin/*Melandryas cucullata*	+	
Rufous Whistler/*Pachycephala rufiventris*	+	+
Golden Whistler/*Pachycephala pectoralis*	+	
Grey Shrike-thrush/*Collurcincla harmonica*	+	+
Grey Fantail/*Rhipidura fuliginosa*	+	+
Willie Wagtail/*Rhipidura leucophrys*	+	+
Australian Reed Warbler/*Acrocephalus australis*	+	+
Splendid Wren/*Malurus splendens*		+
Weebill/*Smicrornis brevirostris*	+	
Western Warbler/*Gerygone fusca*	+	+
Brown Thornbill/*Acanthiza apicalis*	+	+
Western Thornbill/*Acanthiza inornata*	+	
Yellow-rumped Thornbill/*Acanthiza chrysorrhoa*	+	
Varied Sittella/*Daphoenositta chrysoptera*	+	
Red Wattlebird/*Anthochaera carunculata*	+	+
Little Wattlebird/*Anthochaera chrysoptera*	+	+
Yellow-throated Miner/*Manorina flavigula*	+	
Singing Honeyeater/*Lichenostomus virescens*	+	
Brown-headed Honeyeater/*Melithreptus brevirostris*	+	
Brown Honeyeater/*Lichmera indistincta*		+
New Holland Honeyeater/*Phylidonyris*	+	
novaehollandiae	+	+
White-cheeked Honeyeater/*Phylidonyris nigra*	+	
Tawny-crowned Honeyeater/*Phylodonyris melanops*	+	+
Western Spinebill/*Acanthorhynchus superciliosus*	+	
Mistletoebird/*Dicaeum hirundinaceum*	+	
Spotted Pardalote/*Pardalotus punctatus*	+	
Striated Pardalote/*Pardalotus striatus*	+	+
Red-eared Firetail/*Emblema oculata*	+	+
Australian Magpie-lark/*Grallina cyanoleuca*	+	
Masked Woodswallow/*Artamus personatus*	+	
Grey Butcherbird/*Cracticus torquatus*	+	
Magpie *Gymnorhina tibicen*	+	+
Australian Raven *Corvus coronoides*		
Total present	57	36

KEY: (+) Present (i) Introduced Species

Mammal Species Confirmed at Ellenbrook, Whiteman Park (Arnold et al, 1991) and Egerton.

Species Found on the Swan Coastal Plain	Species confirmed at: Ellenbrook	Whiteman Park	Egerton
Tachyglossidae (Echidnas)			
Tachyglossus aculeatus/Echidna		+	
Dasyuridae			
Sminthopsis griseoventer/Dunnart			
Dasyurus geoffroii/Chuditch			
Peramelidae (Bandicoots)			
Isoodon obesulus/Southern Brown Bandicoot	+	+	+
Phalangeridae (Possums)			
Trichosurus vulpecula/Brush-tailed Possum			
Burramyidae (Pygmy Possums)			
Cercartetus concinnus/Western Pygmy Possum			
Tarsipedidae (Honey Possums)			
Tarsipes rostratus/Honey Possum		+	+
Macropodidae (Kangaroos and Wallabies)			
Macropus fuliginosus/Western Grey Kangaroo	+	+	+
Macropus irma/Western Brush Wallaby	+	+	
Mollosidae (Mastiff Bats)			
Tadarida australis/White-striped Bat			
Mormopterus planiceps			
Vespertilionidae (Vesper Bats)			
Chalinolobus gouldii/Gould's Wattled Bat			
Chalinolobus morio/Chocolate Wattled Bat			
Eptesicus regulus			
Nyctophilus geoffroyi/Lesser Long-eared Bat			
Nyctophilus major/Greater Long-eared Bat			
Muridae (Rats and Mice)			
Hydromys chrysogaster/Water Rat		+	
Mus musculus/House Mouse (i)		+	+
Pseudomys albocinereus/Ash-grey Mouse		+	
Rattus fuscipes/Southern Bush-Rat			
Rattus rattus/Black Rat (i)		+	+

Leporidae (Rabbits and Hares)			
Oryctolagus cuniculus/Rabbit (i)	+	+	+
Canidae (Foxes and Dogs)			
xVulpes vulpes/European Red Fox (i)	+	+	+
Felidae (Cats)			
Felis catus/Feral Cat (i)			
Number of species confirmed:			
Native	3	7	3
Introduced	2	4	4

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MULTIPLEX CONSTRUCTIONS PTY LTD

EGERTON
WETLAND MANAGEMENT STRATEGY

ALAN TINGAY & ASSOCIATES

FEBRUARY 1995

REPORT NO: 94/39

MULTIPLEX CONSTRUCTIONS PTY LTD

EGERTON
WETLAND MANAGEMENT STRATEGY

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SUMMARY

This Wetland Management Strategy for Egerton has been prepared in accordance with Ministerial Condition 4-1 of the Minister for the Environment which relates to approval of the Egerton Rezoning proposal.

The Strategy identifies four main wetland areas which will be retained as Open Space in the Egerton development:

- The north-west wetland,
- The north-south linear wetland
- The mid-west wetland, and
- The creeklines.

These areas have been selected from the best wetland areas at Egerton and total 74ha or 15% of the development area. The total allocation of Open Space in the development including sportsgrounds and landscaped parks is 84ha or 17%.

The wetlands will serve a range of functions within the urban environment. To assist in management of the wetlands, Management Priority Areas (MPA) have been designated which relate to these anticipated functions. The MPA categories are Special Conservation, Conservation, Passive Recreation, Drainage and Access.

Due to the degraded state of most of the surrounding non-wetlands areas and to the nature of the wetlands with seasonally wet, seasonally damp and seasonally dry areas, the boundary of the Open Space area has been set as the boundary of the wetland vegetation. No additional non-wetland buffer is proposed. A buffer of native vegetation will be retained around the seepage area in the north-west wetland.

The Strategy recommends that more detailed, prescriptive Wetland Management Plans be prepared at the subdivison level. Responsibilities for implementation, monitoring and management are also presented in the Strategy.

1. INTRODUCTION

1.1 Background

The Egerton property is located about 20km from Perth in the North-East Corridor, adjacent to the Swan Valley (Figure 1).

In 1993, the owners of Egerton, Multiplex Constructions Pty Ltd, proposed that the Urban Deferred part of the property should be rezoned Urban in the Metropolitan Region Scheme. This proposal was referred to the Environmental Protection Authority (EPA) and was subsequently assessed at the Consultative Environmental Review (CER) level (Alan Tingay & Associates, 1994). The CER received environmental approval by the Minister for the Environment subject to certain conditions.

The CER contained a commitment by the proponent to prepare management plans prior to subdivision approval for wetland areas that are to be retained as Public Open Space in the urban development.

In its report and recommendations on the Egerton rezoning proposal (EPA Bulletin, 743), the EPA endorsed this commitment but considered that an overall wetland management strategy should be prepared at the structure plan level of planning prior to the detailed management plans.

Ministerial Condition 4-1 reflects the EPA's recommendations in this regard. Condition 4-1 states as follows:

> *"Prior to adoption of the structure plan required by the Shire of Swan Town Planning Scheme, the proponent shall prepare a strategy for management of wetlands on the site, to the requirements of the Minister for the Environment on advice of the Department of Environmental Protection.*
>
> *This strategy shall be provided in detail at least consistent with that provided in the Structure Plan and shall include, but not necessarily be limited to, the following:*
>
> *1) definition of the boundary of the Public Open Space conservation areas having regard for wetland conservation, including dry land fauna habitat;*
>
> *2) definition of wetland functions; and*
>
> *3) management requirements for protection of wetland functions, and identification of the agency responsible for management and monitoring.*

This Wetland Management Strategy has been prepared in accordance with Ministerial Condition 4-1. The Strategy identifies the boundaries of the wetland areas to be retained in the development and describes the broad principles for management of the wetland areas within an urban environment.

The Strategy first describes the wetland areas at Egerton, their hydrology, vegetation, flora and fauna. This description identifies management issues which need to be

considered. In recognition of existing wetland functions and future wetland functions in an urban environment, wetland management is discussed in terms of Management Priority Areas. Finally, the Strategy identifies the necessary monitoring requirements and implementation responsibilities for the ongoing development in and around the Egerton wetlands.

The following objectives were addressed in the preparation of this strategy:

1. To identify, with justification, the wetland areas to be retained within the development.

2. To define the boundary of the wetland areas to be retained as Public Open Space (Open Space), at a scale of 1:5000.

3. To determine the function of wetlands to be retained in the development.

4. To provide adequate protection around areas of high conservation value.

5. To identify management requirements for the maintenance of wetland function.

6. To determine a strategy aimed at achieving the desired overall management objectives.

1.2 Egerton Structure Plan

1.2.1 General Description

The Egerton Structure Plan is described in detail in a specific publication (Multiplex Constructions Pty Ltd, 1993). The Plan, which is illustrated in Figure 2, presents a framework for an urban estate which responds to the specific opportunities and constraints of the site. In particular, the environmental "constraints" on the site, which are the main wetlands and the creek lines, are converted into planning assets through their inclusion in a network of Open Space linked by walking and cycling trails. This Open Space network is the dominant feature of the Structure Plan and has been the primary determinant of the other components of the Plan.

The topography and remaining natural vegetation on the site have been used to produce distinctive character zones in the Structure Plan. The Plan uses these features to define individual linked neighbourhoods each of which will have special qualities created by the retention and enhancement of existing vegetation, retention of wetland areas, creation of new wetland habitats, views to major landscape features, and access to Open Space.

The road and dual purpose path network has also been substantially determined by the dominant environmental features of the site. These corridors focus on the "town centre" where shopping, commercial, and community facilities are concentrated.

The dual use paths network, as well as linking the neighbourhoods, also provides access to particular areas of interest such as the wetland corridors and the zoological gardens. The

paths will allow a diverse choice of walks of varying distance and ready access to major Open Space and schools.

The zoological gardens are based on an existing private zoo which houses a small but diverse collection of birds and some other vertebrate fauna. The zoo is constructed to the highest standards and includes a completely enclosed wetland containing mature *Melaleuca preissiana*. This feature is considered to be a major potential educational, public and tourist asset for the area as well as a unique local attraction for future residents.

The road system will play a major part of defining the quality of the area. The roads will be flanked by tree plantings designed to suggest and reinforce a hierarchy. The primary distributor road running north from Gnangara Road will be a parkway with substantial roadside planting. This road has been located to the east of the primary wetland chain and elevated areas in the western sector of the site so that it can be constructed with minimum environmental disturbance. Land uses such as drainage detention basins, Open Space and the high school have been located along the route to present users with an open aspect wherever possible.

In the elevated western sector the slopes are often steep and the roads have been aligned to take account of the existing contours and to reduce the need for earthworks in their construction.

The major road link to the Ellenbrook Estate in particular, has been specifically located in a "valley"-like depression within the ridge system and crosses the wetland Open Space network at a location which has been significantly disturbed, in order to minimise environmental impacts.

1.2.2 Land Use Allocation

The Structure Plan makes provision for some 3,650 residential lots at an average density of approximately 7.4/ha. The projected maximum population at Egerton is in the order of 11,800 people. The proposed housing mix has been based on present market trends and a developable area of 358.9ha.

The Structure Plan allows for a retail centre with floor space of approximately 15,000m^2 on a 6ha site. Provision is also made for future commercial units in an area of 3.4ha. There are two primary schools each comprising 4ha and 1 high school site of 10ha. A community use site, which may include a central community hall, church, daycare, and or other uses, comprising 2.05ha is located adjacent to the primary retail/commercial centre.

As mentioned above, the extent of Open Space is a feature of the Structure Plan. The total area of Open Space is 84ha which comprises approximately 17% of the development area compared to the statutory requirement of 10%. The Open Space will fall into a number of categories as described in Table 1.

TABLE 1

CATEGORIES OF OPEN SPACE

Open Space	Total Area (ha)
Major conservation reserve: with managed public access.	34.5
Parkland corridors and water bodies.	27.8
Zoological Gardens	10.7
Sportsgrounds	8.0
Pocket parks, local playgrounds and incidental space.	3.0
TOTAL OPEN SPACE	**84.0**

It is possible that the zoological gardens may be privately owned and therefore may not constitute part of the Open Space.

Within the framework of the Structure Plan, the wetlands form a long linear green belt which will be retained as Open Space from the north-western corner of Egerton to the centre of the proposed development. The wetlands will serve several functions within the urban development. These functions include:

- Flora and fauna conservation,
- Passive recreation,
- Drainage, and
- Strategically placed access.

2. WETLANDS ON THE SWAN COASTAL PLAIN

2.1 Classification

The Swan Coastal Plain contains a wide range of wetland types which vary in size, shape, water characteristics, stratigraphy and vegetation. Wetland attributes are determined by regional features such as geology, geomorphology, soils, climate and hydrology. Processes which can form and assist wetlands include fluvial processes, physical and chemical processes, aeolian processes, groundwater flow and karstification.

Semeniuk (1988) has classified wetlands of the Swan Coastal Plain into consanguineous suites based on their geomorphic setting. Collectively, the Egerton wetlands belong to two separate groups, the Muchea and Ellen Brook Suites.

Individual wetlands within suites can be classified according to the following characteristics:

- water permanence,
- water salinity,
- consistency of water salinity,
- cross sectional shape,
- size,
- plan shape.

According to this classification, wetlands at Egerton fall into the category of creeks, sumplands, damplands and palusplains which have the following characteristics.

- Creek - seasonally inundated channel
- Sumpland - seasonally inundated basin
- Dampland - seasonally waterlogged basin
- Palusplain - seasonally waterlogged flat.

2.2 Wetland Functions

The EPA (1993) has determined that wetlands are valuable assets because they carry out a number of important processes, either ecological (biological and chemical), hydrological or social. These processes are described as wetland "functions", and are described below.

Ecological functions of wetlands are described as:

- Food (resource) webs that include plants, animals and micro-organisms,
- Drought refuge for waterbirds,
- Provision of summer feeding areas for trans-equatorial migratory wading birds which are the subject of international agreement (to achieve this, a range of wetland types need to be protected and controls placed on surrounding land uses),

- Habitats for plants, animals or communities considered to be rare of restricted occurrence or distribution,

- Limited capacity to assimilate loads of nutrients, other pollutants, sediment and litter, and

- Index of environmental quality. Indexes of environmental quality include changes in water levels, nutrient enrichment, and changes in wetland vegetation.

Hydrological functions of wetlands include:

- Wetland areas act as compensating or retention basins during storms and therefore have a flood control function.

- The vegetation fringing lakes and wetlands act, to a certain extent, as filters which assimilate nutrients, sediments and pollutants in surface runoff from adjoining land.

Social functions of wetlands may include:

- Cultural and heritage significance,
- Recreation,
- Nature study,
- Research and education,
- Access to wildlife, and
- Aesthetic considerations.

The range of functions which the Egerton wetlands provide is discussed in Section 3.5.

2.3 Wetland Management

The EPA has outlined guidelines for management of Perth's lakes and wetlands (Bulletin 374 and 686). These guidelines are based on an evaluation method which considers the natural and human use attributes of individual wetlands. A questionnaire is used to obtain a score which determines the management category of a wetland. Five management categories exist which have different management priorities and objectives. These management categories are:

High Conservation (Category H)

These wetlands possess a high degree of naturalness and there is a high level of interest in using the wetlands for various human purposes. This category is recognised as having the highest priority for establishment and implementation as regional park wetlands.

Management Objectives

Active management to maintain and enhance the wetland attributes, particularly natural attributes. Where there is no active management present it should be put in place as a matter of highest priority.

Active management requires that a detailed management plan is prepared and implemented, with sufficient resources to maintain or improve the wetland's current condition.

Conservation (Category C)

These wetlands possess a high degree of naturalness.

Management Objectives

To maintain and enhance natural attributes and functions.

Conservation and Recreation (Category O - Open Space)

These wetlands have been modified but are considered to play important roles in their urban and/or rural settings.

Management Objectives

To provide for human uses whilst maintaining and enhancing the existing natural attributes.

Resource Enhancement (Category R)

These wetlands have been modified and do not have clearly recognised human uses in their urban or rural settings. Some of the wetlands in this category will be the focus for controversy if uncontrolled developments begin to impinge upon them.

Management Objectives

To maintain and enhance the existing ecological functions.

Development of resource enhancement wetlands may be recommended for approval provided:

a) The wetland function is retained within the development, or

b) An equivalent area of wetland of a similar type is constructed or rehabilitated to fulfil equivalent functions.

The term 'resource enhancement' has been used to indicate that opportunities may exist for commercial developments to enhance the conservation values of wetlands (i.e. the wetland resource in this management category.

Multiple Use (Category M)

Wetlands in this category are significantly degraded, possessing few natural attributes and limited human use interest. Despite this, wetlands in this category can be a focus for controversy if developments impinge upon them. Despite having few natural attributes, some of these wetlands may provide valuable waterbird habitat.

Management Objectives:

Should be considered in the context of catchment and land use planning (especially drainage, nutrient enrichment, surface and groundwater pollution), in terms of the current value of the wetland and the potential value to the community if rehabilitated.

Therefore, uses may be proposed that involve significant alterations to the wetland, provided the considerations noted above are addressed. The EPA may be satisfied with a well prepared environmental report for developments affecting these wetlands, but a higher level of environmental assessment may be determined if the situation requires it.

2.4 Wetland Management Policies

The EPA has developed a strategy for wetland management on the Swan Coastal Plain (EPA Bulletin 374, 1990; Bulletin 685, 1993; Bulletin 686, 1993).

The EPA discourages proposals which would affect significantly affect the functional attributes of lakes and wetlands, i.e.:

- Lakes nominated for protection in the Environmental Protection (Swan Coastal Plain Lakes) Policy Approval Order 1992,
- Representative wetlands recommended for protection in the EPA's System 6 Report, and
- Wetland recognised by international agreement because of their importance primarily for waterbirds and their habitats.

Wetlands at Egerton are not directly affected by these categories, but may be included in:

- Wetlands with rare vegetation communities not adequately represented in reserves, or rare flora and fauna (and their habitats).

Proposals affecting wetlands which do not fall into the above categories are expected to be managed by the proponent within the management objectives for the relevant category of wetland identified in the EPA's Bulletin 686 "A Guide to Wetland Management in the Perth and Near Swan Coastal Plain Area" (1993).

3. WETLANDS AT EGERTON

3.1 Classification

The Egerton wetlands have been classified by Semeniuk (1988) into two groups namely:

- The Ellen Brook Suite, and
- The Muchea Suite.

The Ellen Brook Suite comprises very small creeks meandering across a floodplain, which formed as a result of fluvial incision and surface runoff. This creek system is the natural surface drainage to Ellen Brook and is of particular importance in the proposed urban drainage scheme.

The Muchea Suite are small to medium scale sumplands and floodplains which occur along depressions at the base of the Bassendean Dunes, and at the headwaters of the tributaries of the Ellen Brook creeks. The stratigraphy of areas containing the Muchea Suite comprises variable patterns of quartz sands, clay laterite and calcrete. Water in these wetlands are expressions of discharge of groundwater. Ponding of water occurs due to impermeable sediments in the wetlands.

The wetlands at Egerton also have been mapped by the Western Australian Water Authority for the compilation of the Wetland Management and Conservation Estate Map Series (1993) (Figure 3). While there are a series of distinct 'swamps' on the site and the remainder has the appearance of farmland, two-thirds of property is shown as wetlands of various types and significance on this map. In particular, the map indicates that a chain of sumplands (seasonally inundated basins) occurs in the western section of the property, and a palusplain (seasonally waterlogged flat) covers the majority of the property to the east of the sumplands. The map also shows creeklines which emerge from the sumpland areas.

Detailed investigation of the wetlands on the property show that, in fact, four types of wetlands exist. The sumplands mapped by WAWA include both dampland (seasonally waterlogged basin) and sumpland (seasonally inundated basin) areas, with a predominance of damplands. Dampland areas do not contain above-ground water at any stage of the year but have a shallow groundwater level which influences the type of vegetation present.

In addition, one area of sumpland mapped by WAWA was determined to be a palusplain in the CER process.

None of the wetlands on the property are within areas identified in the System 6 Study Report of the EPA (Department of Conservation and Environment, 1983) or in the Environmental Protection (Swan Coastal Plain Lakes) Policy, 1992.

The sumplands on the property can be classified in the Resource Enhancement category in terms of the management strategies referred to in EPA Bulletin 374 - A Guide to Wetland Management in Perth (1990). This category includes wetlands that have been modified to some degree and have no clearly recognised human uses. The management objectives for resource enhancement are to maintain and enhance the existing ecological functions of the wetlands. Opportunities may exist, however, for commercial development to enhance the

conservation values of wetlands (i.e. the wetland resource) in this category and development may be recommended for approval by the EPA provided that:

- The wetland function is retained within the development, or
- An equivalent area of wetland of a similar type is constructed or rehabilitated to fulfil equivalent functions.

The EPA Bulletin 374 has recently been updated (Environmental Protection Authority, Bulletin 686, 1993). In terms of the revised classification system, the sumplands remain in the Resource Enhancement Category with respect to their general attributes but some also can be included in the High Conservation Category as a result of the presence of a rare and endangered species, the Southern Brown Bandicoot (*Isoodon obesulus*). Further information on this species is provided in Section 3.6.

The palusplains on the Egerton property are categorised as Multiple Use in terms of Bulletin 374 and its update, indicating that they have been significantly degraded, and possesses few natural attributes. They are therefore considered to be of limited human interest. Despite this, management objectives need to be considered in the context of catchment and land use planning (especially drainage, nutrient enrichment, surface and groundwater pollution).

3.2 Groundwater

Groundwater is present at Egerton as a shallow or superficial aquifer and it has formed, and is replenished by infiltration of rainwater. Groundwater at Egerton is discharged to ground surface in certain areas, and forms streams which flow to Ellen Brook (Figure 4).

The superficial aquifer under Egerton is a component of a much larger groundwater system which underlies the Bassendean Sand Formation on the Swan Coastal Plain between the Swan River northwards to near Gingin Brook. This large aquifer is known as the Gnangara Mound, a large part of which is a major source of public water supply for the Perth Metropolitan Region.

The surface of the groundwater (i.e. the water table) under Egerton is at a variable depth below the ground surface depending on the surface topography. For example, in the north-west corner of the Egerton property, ground surface elevations may be in the order of 50m AHD while the water table is at about 40m AHD. In the south-east corner of the property the ground level is 25m AHD while the watertable is at about 20m AHD. As the groundwater results from rainfall, the water table fluctuates by about 1 to 1.5m according to the season, with peak levels from September to October and minimum levels from April to May.

The thickness of the aquifer (i.e. the saturated zone within the sand) is about 10m, and increases in width from east to west.

3.3 The Seepage or "Mound Spring"

Some public submissions to the Ellenbrook Public Environmental Review (PER) drew attention to the presence of a "mound spring" on the Egerton property, as did the Ellenbrook Conservation Group in discussions associated with the CER (Alan Tingay & Associates, 1994a). The EPA also specifically referred to the "mound spring" in its Assessment Report on the Ellenbrook PER (EPA, 1992) and Egerton CER (EPA, 1994).

Mound springs derive from deep artesian aquifers and deposit materials over time on the surface which forms a characteristic prominent mound above the surrounding land. A notable seepage area is located near the sumpland in the north-west sector of the property. It may be that the term "mound spring" has been used to refer to this seepage of water associated with the Gnangara Mound rather than with a true mound spring. It is assumed therefore that the water seepage in the north-west sector is the spring which has been referred to previously.

The results of an assessment of the seepage area by the Geological Survey of Western Australia indicates that the water associated with the seepage is relatively recent (aged 90 years) and that it has a chemical signature which reflects this age (i.e. a low pH, salinity, alkalinity, temperature, and high dissolved carbon dioxide content). In contrast, groundwater sampled from the Leederville Formation aquifer at a depth of about 200m below ground level, had an age of 12,700 years and a mature chemical signature shown by moderate salinity, alkalinity and temperature, and low dissolved carbon dioxide content. The assessment concluded that the groundwater flowing from the seepage area originates from relatively young shallow groundwater within the Bassendean Sand aquifer to the west known as the Gnangara Groundwater Mound. Groundwater discharge from this aquifer results in seepage where the contact between the Bassendean Sand and underlying clayey Guildford Formation is exposed. This type of seepage is common in the Swan Valley in areas of low elevation.

However, due to unusual vegetation found in association with the seepage or "mound spring" the area will be incorporated within Open Space, with public access restricted to allow for its conservation.

3.4 Wetland Vegetation

The native vegetation types at Egerton (Figure 5) are predominantly influenced by soil type and proximity of groundwater to the land surface. In areas where the water table is present, close to or just above ground level, *Melaleuca preissiana* Low Woodlands is dominated by *Agonis linearifolia* and *Cyathochaeta avenacea*. The northern wetlands have *Banksia littoralis* and *Eucalyptus rudis* which are dominant with *Melaleuca preissiana* in a Closed Forest formation. The Closed Forest is so dense, in places that the development of a substantial understorey has been precluded.

Areas that are dry but which have the water table close to the surface are dominated by *Pericalymma ellipticum* and *Astartea fascicularis* Closed Heath, often in association with *Hypocalymma angustifolium*. Some Heath areas also have scattered *Melaleuca preissiana* trees in a Low Open Woodland formation over the Closed Heath. *Pteridium*

esculentum (Bracken fern) is also common around the fringes of the *M. preissiana* Low Woodlands.

In one area only, *Eucalyptus rudis* (Flooded Gum) forms an Open Forest over a dry *M. preissiana* Low Woodland.

Permanently wet drainage lines or seepage areas exist along the eastern margin of the wetlands on the plain. These areas support *Melaleuca rhaphiophylla* (Swamp Paperbark) instead of *M. preissiana* which occurs on drier swamp soils. The *M. rhaphiophylla* is present as a Low Closed Forest, often with *Eucalyptus rudis*. The understorey of these areas is limited due to the dense tree canopy, but occasionally includes stands of *Baumea articulata* and *Cyathochaeta avenacea*.

A large stand of *Baumea articulata* (Jointed Twig Rush) Sedgeland occurs in the central wetland within the Bassendean dunes. This area was reportedly excavated for peat more than 20 years ago. The surface level of the wetlands is now lower than normal and therefore is inundated to deeper levels and for longer periods than would have existed prior to removal of the peat. The *Baumea articulata* Sedgeland may not have been there previously and may have colonised the area following the altered hydrological regime.

The wetland areas in the north-west, west and central west parts of Egerton have native vegetation in near natural condition or with a low degree of disturbance (Figure 6). The fringes of these wetland areas have been disturbed through partial clearing of the understorey or tree canopies and establishment of introduced pasture species. This is the case for most of the drainage lines and other areas that have been used for pastoral activities (including remnant Paperbark stands and *Juncus* Sedgelands).

A small area on the southern edge of the north-west wetland has signs consistent with the presence of dieback caused by the fungal disease *Phythophthora cinnamomi*. The small pocket of Jarrah and *Banksia* Woodland contains stag-horned jarrah trees, dead *Banksia* trees and dying *Xanthorrhoea preissii* shrubs. Although a few other areas exist which have dead Banksia trees, these sites have no additional signs which would indicate infection by dieback.

3.5 Wetland Flora

A total of 159 native species of flora have been recorded at Egerton. Most of these species have been recorded in dry upland habitat (98 species) with 53 species in areas influenced by high water tables and 24 species in the transition zone between the two (Alan Tingay & Associates, 1994a).

The species *Aotus cordifolia* is currently listed on the Department of Conservation and Land Management (CALM) Priority List and occurs in the wetlands at Egerton. This plant is listed as a Priority 3 species which means it has several poorly known populations, with some on conservation reserves.

Aotus cordifolia is a straggling shrub which occurs abundantly in the swampy areas at Egerton. The largest population of perhaps a few thousand individual plants is located in the northern wetland under *Agonis linearifolia* Scrub.

Unusual flora is found in association with the seepage or "mound spring" including two species of liverwort (*Goebelebyrum unguiculatum* and *Hyalolepidozia longiscypha*) and a fern ally (*Lycopodium serpentinum*)

3.6 Wetland Fauna

A vertebrate fauna survey of the Egerton property was carried out by Alan Tingay & Associates in October 1993 (Alan Tingay & Associates, 1994b). The survey included sampling of the major habitat types on the property and included pine plantation, *Eucalyptus* Woodlands, Heath, *Banksia* Woodlands, *Melaleuca* Woodlands, and *Melaleuca* Forest.

Fifty species of native vertebrates were recorded during the survey, including five frog species, six reptile species, 36 bird species and three species of mammal. In addition, four introduced mammal species and two introduced bird species were encountered. The relatively high number of bird species reflects the diversity of habitat provided by open areas, remnant trees, and other vegetation.

The largest number of vertebrate species was recorded on the farmland areas and included 20 species of birds and 1 mammal, the Western Grey Kangaroo (*Macropus fuliginosus*).

The next largest number of native species was recorded in *Banksia* Woodland with 12 species of birds, 2 frogs, 2 reptiles and 2 mammals. Species number was relatively high in the *Melaleuca* Forests associated with sumplands (15 species), and in remnant native vegetation within the pine plantation (14 species).

Three species recorded at Egerton are of special interest for various reasons. The burrowing frog (*Heleioporus inornatus*) generally occurs on the Darling Range from Chidlow, south of the vicinity of Nannup, and east to Walpole and Mt Barker. Its occurrence at a site on the Swan Coastal Plain is unusual, however Egerton is relatively close to the escarpment of the Darling Range. The Honey Possum (*Tarsipes rostratus*) was recorded in *Melaleuca* Woodland at Egerton. This species is seldom recorded in the Perth Metropolitan Region but does occur at the nearby Whiteman Park. It is not classified as rare or endangered.

The Southern Brown Bandicoot (*Isoodon obesulus*) was recorded at Egerton in all major habitats surveyed except for the pine plantation. However, they appeared to be restricted to areas within and immediately surrounding wetlands, possibly as a result of the denser cover and food resources in these areas. A total of 9 individual bandicoots were captured during the survey. It is estimated that between 20 to 60 bandicoots inhabit the Egerton wetlands and environs.

The Southern Brown Bandicoot is a ground dwelling marsupial about the size of a small cat. The species has a relatively extensive distribution across southern Australia but is most abundant in the south-west of Western Australia, and in Victoria and Tasmania. In Western Australia there is concern that the species may be declining as a result of continuing loss of habitat and predation pressures primarily due to the introduced European Fox (*Vulpes vulpes*). This concern has lead to the species being gazetted as rare

and endangered under the provisions of the Western Australian Wildlife Conservation Act, 1950-79.

In accordance with the Environmental Conditions set by the Minister for the Environment, a strategy for bandicoot management and protection at Egerton is in preparation.

3.7 Present Wetland Functions

As outlined in Section 2.2, the main functions of wetlands can be categorised as ecological, hydrological and social. Ecological functions are those which are related to the support of biological communities through the maintenance of specific habitats. Hydrological functions are the processes of wetlands which contribute to the storage or discharge of water which reflects on the local and regional water balance. Additional hydrological functions include filtering and stripping nutrients from surface and subsurface water. Social functions are values which the human community perceives to be of use including use of the wetland area for passive recreation, visual amenity, relief from the urban landscape and scientific values.

3.7.1 Ecological Functions

The number and type of ecological functions can generally be correlated with the diversity and degree of naturalness of habitats found in any particular wetland. Factors such as seasonality and depth of surface water, salinity and range of vegetated habitats (sedgelands, heathlands, shrublands, woodlands and forests) combine to create habitats with varying niches for flora and fauna communities.

There are a wide range of habitats and niches within the wetlands at Egerton including:

- Damplands (Heaths and Sedgelands)

  Pericalymma ellipticum Closed Heath
  Agonis linearifolia Open Heath over *Cyathochaeta avenacea* Sedgeland
  Astartea fascicularis Closed Heath
  Astartea fascicularis/Hypocalymma angustifolium Closed Heath
  Hypocalymma angustifolium Closed Heath

- Damplands (Forests, Woodlands and Heaths)

  Eucalyptus rudis Open Forest
  Melaleuca preissiana/Eucalyptus rudis Closed Forest with *Banksia littoralis*
  Melaleuca preissiana Low Woodland over *Juncus pallidus* Sedgeland
  Melaleuca preissiana Low Woodland to Low Woodland over *Agonis linearifolia* Closed Heath
  Melaleuca preissiana Low Open Woodland over *Pericalymma ellipticum* Closed Heath
  Melaleuca preissiana Low Open Woodland over *Astartea fascicularis* Closed Heath
  Acacia saligna Low Woodland over *Agoni linearifolia* Open Heath
  Juncus pallidus Sedgeland

- Sumplands and Creeks (Forests, Woodlands and Sedgelands)

  Melaleuca rhaphiophylla Low Closed Forest
  Melaleuca rhaphiophylla/Eucalyptus rudis Low Closed Forest
  Eucalyptus calophylla Woodland over *Melaleuca preissiana* Low Woodland
  Baumea articulata Closed Sedgeland

These vegetation types provide seasonal refuge, food resources and shelter of a wide range of vertebrate and invertebrate fauna.

The wetlands at Egerton have limited areas of open water in winter and no above-ground water in summer. However, the 'dry' wetland areas provide habitat for invertebrate fauna, which in turn supports frogs, lizards, snakes, birds and mammals, including the rare and endangered Southern Brown Bandicoot (*Isoodon obesulus*). The wetlands do not provide drought refuge for waterbirds or summer feeding areas for wading birds except for the artificial dams already constructed along some creeklines.

The wetland flora, although not rich compared to Banksia woodland nearby, contain one Priority species, *Aotus cordifolia* and other interesting (though not endangered) flora including two liverworts and a *Lycopodium*.

3.7.2 Hydrological Functions

Wetlands at Egerton function as compensating and discharge basins for subsurface and surface rainwater runoff. The basin-type wetlands which are more or less flat within the Bassendean Dunes are also expressions of the water table at the ground surface as the water moves laterally from the middle section of the Gnangara Water Mound to Ellen Brook. The wetlands at the base of the Bassendean Dunes may be more influenced by local runoff rather than groundwater levels.

The creeks promote aeration of water as it flows from the wetlands into dams or Ellen Brook.

The seepage area in the north-west wetland, commonly referred to as the "Mound Spring" appears to flow continuously and supports some flora and possibly fauna which do not exist elsewhere at Egerton.

3.7.3 Social Functions

Social functions pertaining to wetlands are related to recreation and appreciation. Recreation includes active recreation (water sports) or passive types such as picnicking, bird watching, walking and nature studies.

At the present time, only the wetland area around the site of the aviary near the proposed zoo has any perceived social functions under this definition.

Cultural functions are closely related to social function but incorporate the idea of posterity and heritage. Wetlands which have cultural value may have rare features or have a limited distribution. Equally, they may be recognised as having significance to

Aboriginal or European people as a resource or place of beauty. These aspects may be seen as being important to preserving endemic cultural, identity and landscape values.

Aboriginal heritage sites have been identified adjacent to the wetlands at Egerton but not within the wetland boundaries. In addition, a Waugal (Serpent Dreaming Track) was also identified within the creeklines.

4. WETLAND STRATEGY CONSIDERATIONS

4.1 Introduction

The preceding chapters have described the wetlands at Egerton as they currently exist. This chapter outlines the factors which will be considered in planning the incorporation of wetlands into an urban environment. These issues are discussed under the sub-headings of Ecological, Hydrological, Social and Planning Considerations. In Chapter 5 these issues are used to justify which wetland areas are to be retained in the development, the boundary of these areas and the future uses for which the wetlands will be managed.

4.2 Ecological Considerations

4.2.1 Vegetation

The Egerton wetlands include a wide variety of wetland vegetation types including Sedgelands, Heath, Woodland and Forest. While none of the vegetation types is unique, the variety of different types provides for a diverse array of fauna habitats and also has scientific value for research on the interaction of wetland vegetation with hydrology.

The quality of the wetland vegetation ranges from degraded to low disturbance. The vegetation on palusplain areas is the most disturbed.

POINT 1 The Egerton wetlands present a wide variety of vegetation types.

POINT 2 The quality of the Egerton wetland vegetation ranges from degraded to one of low disturbance.

4.2.2 Priority Flora

The wetlands contain large populations of the Priority 3 species *Aotus cordifolia*, particularly in the north-west wetland.

The seepage area in the north-west contains several species which are not rare or endangered but nevertheless are not found elsewhere at Egerton and are not common in general.

POINT 3 Priority species and unusual flora occur in some wetland areas at Egerton, particularly the north-west wetland.

4.2.3 Fauna

A fauna survey by Alan Tingay & Associates (1994b) showed that the Rare and Endangered Southern Brown Bandicoot was present at Egerton and centred around the wetlands and associated vegetation. It was calculated that between 20 to 60 individuals may be present at Egerton. A Bandicoot Protection Strategy is currently being prepared in consultation with CALM which will advocate retention of bandicoots in the north-west wetland and the north-west linear wetland and relocation of bandicoots from other wetland areas to conservation reserves.

This Wetland Management Strategy includes measures designed to promote the continuation of bandicoot populations in post development wetland Open Space areas. Special considerations for bandicoot protection include fire control and management, control of cats, dogs and foxes and preservation of the integrity of the existing wetland vegetation.

Of particular importance for the retention of bandicoots within wetland areas is the amount of dryland habitat that will be available within the wetland Open Space boundary. Dryland areas will be essential within the Open Space to provide winter refuge areas for bandicoots, and other terrestrial fauna during times when the water table in high and other wetland areas are inundated. However, large areas of dryland fauna habitats occur within the wetlands (Figure 6) and there is no requirement for additional buffer areas outside the wetland vegetation to provide for fauna refuge. Furthermore, most of the existing non-wetland areas surrounding the wetlands which contain bandicoots are degraded, and consist of irrigated pasture or pine plantations. Such areas do not provide safe habitat for bandicoots.

POINT 4 Bandicoots will be retained within two main wetland areas at Egerton.

POINT 5 Dryland fauna habitat exists within the wetland areas without the need to add a non-wetland buffer strip.

POINT 6 The non-wetland fringes are mostly degraded.

4.3 Hydrological Considerations

A Nutrient and Drainage Management Plan has been prepared for the Egerton development to address the management of groundwater and stormwater following urban development.

A drainage system has been designed which incorporates a series of wet detention basins and artificial wetlands (Figure 8). The majority of these basins will be constructed along existing drainage lines. Two basins and will be located within the wetland areas in the mid-western portion of the property.

All basins will be designed as artificial wetlands that will attenuate stormwater flow and maximise nutrient retention. These wet detention basins will have permanent, open water and will add to the variety of wetland habitats on the property.

POINT 7 Drainage management will be effected by creating wet detention basins along some existing creeklines, existing dams and within the mid west wetland.

The seepage area, or 'mound spring' in the north-west wetland is a good example of a natural seepage area on the eastern edge of the Gnangara Mound. The seepage area remains covered in native vegetation and is an area of scientific interest for the hydrological nature of the perennial seep, the associated stream fauna and the wetland flora on the boggy seepage area.

Because of the curiosity and scientific value of the seep, management of the area will need to ensure that the area does not become degraded.

POINT 8 The seepage area in the north-west wetland is an interesting feature which warrants protection.

4.4 Social Considerations

The Egerton wetlands will have a particular social function in an urban environment in the provision of passive recreation facilities and for education and scientific purposes. Demand will be placed on the wetlands for nature walks, picnic areas, bird watching activities and limited play areas. The provision of such activities should be designed so as not to conflict with other objectives for the wetlands, eg. conservation.

However, conservation areas should be viewed as an opportunity for education and scientific purposes. Total exclusion of people from areas of high conservation is perhaps not practical for small areas of Open Space surrounded by urban development.

The wetland Open Space areas will not be used for active recreation purposes. Sportsgrounds have been designed to be associated with the school sites. The position of these sites in relation to the wetland Open Space areas is shown in Figure 10.

POINT 9 The Egerton wetlands will need to provide for passive recreation with facilities such as paths and picnic areas.

POINT 10 The demand for passive recreation should complement rather than conflict with other objectives for the wetlands, eg. conservation, drainage.

POINT 11 The areas of conservation significance have value for educational and scientific purposes.

The introduction of pressures such as fire, weeds, pests and rubbish will be associated with human use of Open Space and of urbanisation around the wetlands.

POINT 12 Detailed management plans will be required for the wetland areas to protect against human pressures.

4.5 Planning Considerations

The total area at Egerton which is the subject of future development proposals is 495.4ha. Current State Planning Commission policy requires that 10% of the area (49.5ha) be given over as Open Space. This Open Space includes areas for active recreation, pocket parks and playgrounds, as well as areas for passive recreation and conservation.

The total area of wetlands on the property, as mapped by WAWA, is 270ha which includes about 205ha of palusplain and 65ha of damplands and sumplands. The area of creeklines is included in these figures. A large proportion of this area, predominantly all the palusplain area, is degraded. Even so, the area of good quality damplands and

sumplands (about 60ha) is in excess of the total requirement for Open Space, including active recreation sports grounds. As a result, the wetland areas which should be considered for retention as Open Space should be selected from the highest quality areas.

POINT 13 The amount of good quality wetland areas at Egerton is in excess of the normal 10% requirement for Open Space.

5. WETLAND MANAGEMENT STRATEGY

5.1 Introduction

The points relating to development in and around the Egerton wetlands, as described in the previous chapter, provide the basis for a strategy for incorporating the wetlands into the urban Structure Plan.

In this chapter the rationale for determining which wetlands are to be retained is described. Having established the areas to be retained, the actual boundaries are then determined. Finally, the strategy for developing and managing the wetlands is outlined.

5.2 Wetland Areas to be Retained

The primary issues which determine the wetland areas to be retained in the development are:

1. The amount of good quality wetlands is in excess of normal Open Space requirements.

2. By retaining good quality wetlands, the important ecological values contained within the wetlands will also be retained.

Compared to these issues, the social and hydrological functions of the wetlands are considered to have secondary importance.

The wetland areas selected for retention as Open Space are shown in Figure 9. Essentially there are four main wetland areas:

- The north-west wetland,
- The north-south linear wetland,
- The dumbell-shaped wetland near the mid-western portion of the property, and
- The creeklines.

The rationale for selecting these four areas is that they include all the wetland vegetation types, most of the bandicoot habitat, the seepage area and important flora populations.

The total area of wetland Open Space is 74ha.

The north-west wetland and north-south linear wetland will be retained intact, without any modifications to existing wetland boundaries. The mid-western wetland has been modified to a more uniform shape to accommodate planning requirements for that precinct. This has resulted in the "tail" section of this wetland being omitted from the Open Space. This section contains good quality Closed Heath vegetation with emergent Paperbark (*Melaleuca preissiana*) trees. Large areas of similar vegetation type will be retained within other parts of this wetland.

The creek lines will be modified in places for the construction of wet detention basins as required by the drainage management plan.

5.3 Management Priority Areas

The wetland Open Space areas determined above will perform a variety of functions in the Egerton development. To facilitate future management requirements for the wetland Open Space, Management Priority Areas (MPA) have been designated based on the priority function of each area. These are illustrated in Figure 10.

Five types of MPA have been determined on the basis of their existing functional values and proposed functions within the urban development as follows:

- Special Conservation MPA
- Conservation MPA
- Passive Recreation MPA
- Drainage MPA
- Access MPA

5.3.1 Special Conservation Areas

The seepage area commonly known as the 'mound spring' has been identified as the area of most significance in the Egerton wetlands. This area will be included in a Special Conservation MPA.

Extra control will be applied to this area in the form of fencing type and location of paths so that the impact of uncontrolled access is reduced.

The seep area has high educational and research value.

5.3.2 Conservation Areas

Wetland areas at Egerton which have a conservation priority are those that contain only slightly disturbed vegetation as illustrated in Figure 9. These areas support the Southern Brown Bandicoot and a wide range of other fauna and contain important flora in certain areas.

Controlled public access to these areas will be necessary to prevent deterioration of the conservation values.

Access paths and boardwalks through the Open Space will avoid areas likely to become inundated during winter and where practicable follow fencelines and tracks already present in the area.

Passive recreational pursuits including walking, bird watching and nature studies will be suitable activities in most areas.

5.3.3 Areas for Passive Recreation

The wetland system has the potential to be a valuable and unique opportunity for passive recreational pursuits. Such activities could include nature walks, bird watching and picnic areas.

Some of these activities are suitable within conservation areas on a limited basis. However, the main focus for passive recreation should be centred around grassed picnic areas created near areas of permanent water and in degraded sections of the wetland.

The wet detention basins in the mid-western wetland will be of sufficient size and aesthetic appeal to attract people. More informal-type picnic facilities could be developed within dry clearings in the north-west wetland. A path system could link these areas and provide through access as well as a nature walk.

5.3.4 Areas for Drainage

The post development drainage system at Egerton is required to accommodate surface drainage from urban areas and subsoil drains, while at the same time preventing deterioration of wetlands, eutrophication of Ellen Brook and the Swan River, and control of peak flows into downstream water bodies.

The principal feature of the drainage system is the incorporation of wet detention basins and artificial wetlands along existing creek lines. Three main creek lines will be used to receive water from the main catchments on Egerton. These creeks have been termed North West Creek, Aviary Creek and Gnangara Creek. The basins within each catchment will operate in series with each basin attenuating peak flows and retaining nutrients. The last basin in each system has been termed a water pollution control pond and will be used for maintenance and monitoring responsibilities.

The basins will be constructed with a base level below the average annual low watertable and will therefore contain water above-ground throughout the year. In addition, the basins have been designed to store an adequate volume of stormwater to promote nutrient retention and to attenuate the flow. The basins will compensate storm flows by storing stormwater. The consequent rise in water levels will be controlled by an outflow consisting of pipes at low levels and weirs at high levels.

The detention basins and water pollution control ponds will both be designed as artificial wetlands containing emergent macrophytes, eg. sedges, and a fringing band of trees. The basin/creek system will promote biological nutrient uptake and will also provide a variety of habitats for aquatic fauna and will also function as a biological corridor and recreation corridor with links between the Egerton wetlands and Ellen Brook.

No basins will be constructed within the north-west wetland area or the linear north-south wetland associated with the proposed zoo. The south-west wetland Open Space will have two wet detention basins created for drainage purposes. The approximate size of these basins will be 0.4 and 1.2ha. The actual location and dimensions of these basins has not been determined. However, the objective is to design the basins for drainage control, creation of wetland habitat and for passive recreation purposes.

5.3.5 Areas to Provide Access

The wetland Open Space areas at Egerton meander throughout the future development site and in places create a barrier for human movement through the proposed estate. To facilitate through access, it is recommended that features such as existing tracks and

fencelines be used for walkways and dual use paths where appropriate. Use of existing tracks will minimise disturbance of native vegetation.

Where it is not possible to avoid wetland areas prone to inundation, raised boardwalks will be installed instead of the standard paths.

5.4 Establishing the Wetland Open Space Boundaries

The EPA (1994) has produced guidelines for the establishment of wetland boundaries. A combination of extent of wetland vegetation and extent of inundation are primarily used to define the functional edge of wetlands.

For wetlands with most vegetation intact, the extent of *Melaleuca preissiana* or *M. rhaphiophylla* is used to define the boundary.

The determination of the wetland boundaries at Egerton is mostly straightforward since the areas surrounding the wetlands have largely been cleared for pasture or pine plantation.

The northern boundary of the north-west wetland is the only area which currently has native upland vegetation fringing the wetland. In this case, the wetland boundary was defined as the outer extent of *Melaleuca preissiana* or, where *M. preissiana* was not present, the extent of *Eucalyptus rudis* or Closed Heath vegetation.

The wetland vegetation which links the north-west wetland and north-south linear wetland is quite disturbed. Therefore a narrow strip about 20m wide is proposed for this area. The boundary of the Open Space link has been drawn to incorporate existing wetland vegetation. However, it is anticipated that this area will be fenced off to aid natural regeneration and will also be rehabilitated to dense wetland vegetation.

In the EPA's Report and Recommendations on the Egerton CER (EPA Bulletin 743) reference was made to the importance of vegetation buffers around the wetlands. In particular the function of vegetation buffers was stated as follows:

- To separate water bodies from human activities on surrounding land;
- To provide complementary habitats for fauna (eg bandicoots, waterbirds) using the waterbody; and
- To trap nutrients and sediments entering a waterbody.

These functions need to be considered for the Egerton wetlands in light of the following points:

- The waterbodies (inundated sumplands) at Egerton cover only a small proportion of the wetland vegetation at Egerton.
- There are no open waterbodies in the Egerton wetlands except for man-made dams.

6. MANAGEMENT CONSIDERATIONS FOR THE EGERTON POS WETLANDS

6.1 Introduction

Open Space usually exists in the form of National or Regional Parks, sports fields, conservation reserves, play parks, strips of land with dual use paths and open areas for visual relief from the urban landscape. The value of Open Space has been recognised as important to the social health of the population as it helps provide a structure for community life, places for leisure time activities and the opportunity for relief from the stresses of modern lifestyles (Scott & Furphy *et al.*, 1987).

The recreation of Perth residents generally has changed significantly in the past 35 years (Richard Pawluck & Associates *et al.*, 1992). The traditional reliance on day time active and passive use of parks has moved its focus to a multiplicity of sophisticated private and public indoor and outdoor facilities available day and night. Home based recreation now predominates with the active use of Public Open Space (Open Space) being a minority interest. However, children are the greatest users of parks for play and socialising.

Recent uses for Open Space have been for the conservation of native bush and wetlands which are subsequently managed for conservation and passive recreation.

In the case of the Egerton wetlands, the human use of the wetlands is envisaged to be a combination of passive recreation and limited access to conservation areas. Paths through parts of the wetland areas will provide access across the Open Space from residential to commercial and educational nodes as well as to sportsgrounds and schools.

Urbanisation in the vicinity of conservation areas introduces many pressures associated with human activities. For example, the incidence of wild fires in areas used by people are likely to increase in frequency due to arson and carelessness. Therefore, management and facilities to combat fires are necessary.

Environmental issues that will need to be addressed in the development and management of the Egerton Open Space wetlands are:

- Protection of populations of the rare and endangered Southern Brown Bandicoot (*Isoodon obesulus*).
- Conservation of Priority and unusual flora.
- Prevention of loss of vegetation diversity through weed invasion.
- Fire control and access for fire fighting personnel and vehicles.
- Access paths and boardwalks through dryland and wetland areas. Access controls at Open Space perimeter.
- Refuse and litter disposal.
- Control of pests including introduced feral animals and dieback.

- Facilities to be provided for human users.
- Post-development rehabilitation and maintenance.
- Research and education.
- Drainage.

A brief introduction to each of these management needs is given below. However, these will need to be addressed in more detail in the detailed Management Plans that are proposed for each wetland area. (See Section 8).

6.2 Southern Brown Bandicoots

Southern Brown Bandicoots (*Isoodon obesulus*) are vulnerable to predation by cats, dogs and foxes, especially when dense vegetation in their habitat is thinned. Frequent fires and uncontrolled human access can reduce vegetation cover which makes bandicoots more vulnerable.

6.3 The Seepage, or "Mound Spring"

The seepage, or "mound spring" contains plant species which are unusual and highly susceptible to damage by trampling. It is therefore proposed that the area be adequately fenced to keep unauthorised people out. The unusual nature of the seepage means that it would make an excellent nature study area for local schools and tertiary institutions.

6.4 Weed Invasion

Although a number of weed species ar present in many areas of the Egerton wetlands, urbanisation has the potential to introduce a wide variety of invasive weeds. Uncontrolled fires which clear native vegetation can also favour the invasion of weed species.

A program of total weed eradication is unrealistic but at Egerton many areas could be treated to reduce weeds and replace them with local native species.

The main objective with weed management is to minimise the incidence of weeds and enhance the native vegetation (including ground and canopy cover).

The introduction of lawned areas and residential gardens around the wetland Open Space will increase the likelihood of weed species infesting the native vegetation. This is especially the case in areas where weed incidence is low, compared to areas which are adjacent to pasture and already contain weeds. Strategies will need to be implemented to minimise the introduction and spread of weeds in the wetland Open Space areas.

6.5 Fire Control and Management

Fire can be a useful tool for the long term management of Western Australian bushland. This is because occasional fires can destroy pests and diseases, rejuvenate moribund vegetation and recycle nutrients. However, fires that are too frequent and/or hot may kill animals which are unable to escape, destroy vegetation, understorey and canopy as well as animal food and shelter resources. Severe fires leave the soil bare and vulnerable to erosion by wind or water and susceptible to invasion by weed species.

There are several main objectives for fire management of native bushland in urban areas. These are:

- Conservation and enhancement of the native vegetation.
- The protection of neighbouring properties.
- To ensure the maintenance of the area, e.g. rubbish removal.
- The implementation of a fire control and management plan.

By creating strategic firebreaks, minimising the risk of fire occurrence and suppressing wildfires as they occur can minimise damage from fires. Provisions for fire management will be included in the detailed Wetland Management Plans proposed.

6.6 Access Control

Certain areas within the Open Space are particularly vulnerable to human intrusion and subsequent trampling. The seepage, or "mound spring" is particularly delicate and therefore will be fenced around its perimeter to discourage unauthorised access.

Controlled access through the Egerton wetland Open Space involving fencing, paths and bollards will be detailed in the Wetland Management Plans.

6.7 Pest Control

Dogs and domestic cats that may prey on fauna in the wetland Open Space are likely to live in surrounding residential areas. Foxes and feral cats may also be present or may visit the area. Although some rabbits may live in the wetland Open Space in most areas the water table is too close to the surface to allow the construction of warrens.

Specific measures to control pets and other pest species will be documented in the Wetland Management Plans. The possible effect of such measures on flora and fauna will be taken into account in selecting the most appropriate method for pest control.

6.8 Facilities

The use of the wetland Open Space for passive recreation will require installation of facilities including seats, lights, barbecues, grassed areas, rubbish bins, toilets, and educational signs. Specifications regarding location and design and materials etc., will be contained in the Wetland Management Plans.

6.9 Post-Construction Rehabilitation

Any areas disturbed during the construction of paths, boardwalks or other activities will be rehabilitated with local native plant species. It is expected that the need for rehabilitation will be kept to a minimum through specifications to contractors not to disturb native vegetation.

6.10 Drainage

Most post development stormwater generated at Egerton will be directed to existing natural drainage lines incorporating wet detention basins and water pollution control basins. The drainage lines will be revegetated to allow for biological assimilation of nutrients.

The mid-west wetland will have two areas excavated and revegetated as wet detention basins.

7. MONITORING

7.1 Introduction

A monitoring program for groundwater levels and water quality will be carried out at Egerton as part of the Nutrient and Drainage Management Plan. This program also includes monitoring within the wetland Open Space.

The objectives of the monitoring program are as follows:

- To provide baseline information and to monitor post development water levels and water quality within the Egerton wetlands.
- To ascertain the possible effects of altered water regimes (if any) on wetland vegetation.
- To assess the accuracy of Groundwater Modelling for pre- and post-development groundwater levels.

7.2 Wetland Monitoring

Monitoring of groundwater levels and water quality in the wetland areas to be retained in the development will be used in conjunction with assessments of vegetation quality to determine any impacts of the urban development on the wetlands. Water quality samples will be measured for nutrients and other pollutants.

Vegetation quality will be assessed by establishing ten permanent monitoring transects through the wetland areas. The transects will be located so that as much of the different vegetation types as possible are sampled. The transects will be from 50m to 100m long and 10m wide. Plant cover and abundance and tree vigour will be assessed along the transects at annual intervals. Photographic records will also be kept as a means of assessing vegetation quality. Groundwater levels at nominated quadrats will be measured on a regular (quarterly) basis.

The results of the vegetation quality assessments will be compared with the water level and water quality monitoring data to determine whether any observed changes in vegetation are related to changes in the hydrological regime.

7.3 Groundwater Monitoring

Groundwater monitoring will be undertaken at 25 observation bores installed on the Egerton property and at additional bores to be installed after development. The data obtained from the groundwater monitoring will be used to assess the accuracy of the groundwater model with respect to changes in groundwater levels after development. Any deviations from predicted changes as the staged development proceeds will be used to recalibrate and refine the model.

Monthly monitoring of water levels and 3 monthly water quality samples will be taken from each bore for the duration of the Egerton development and for 2 years after full urbanisation.

Water quality samples will be analysed for conductivity, pH, total phosphorus, orthophosphate, total nitrogen, nitrate, nitrite and ammonia.

7.4 Responsibility for Monitoring

During the development phase at Egerton, the monitoring and maintenance requirements for the groundwater bores, wetland bores and wetland vegetation will be funded by the developer and WAWA (subject to negotiation) (Table 2). The development phase includes the period during which all works occur, until the final subdivision of the land subject to the Egerton Structure Plan is completed.

Following completion of development at Egerton, the maintenance and monitoring requirements for wetland bore monitoring and wetland vegetation monitoring will be the responsibility of the Shire of Swan. Groundwater bores will be monitored and maintained by WAWA after completion of development.

TABLE 2

RESPONSIBILITY FOR CONSTRUCTION, MONITORING AND MAINTENANCE OF BORES AND VEGETATION

Component	Construction Responsibility	Monitoring and Maintenance	
		During Development Responsibility	Post Development Responsibility
Groundwater Monitoring Bores	Developer/WAWA*	Developer/WAWA*	WAWA
Wetland Monitoring Bores	Developer	Developer	Shire of Swan
Wetland Vegetation Monitoring	Not Applicable	Developer	Shire of Swan

* - Subject to negotiation

8. IMPLEMENTATION

8.1 Introduction

The Wetland Management Strategy identifies the wetland areas to be retained as Open Space, delineates the boundaries, and discusses functions and management issues relating to the future incorporation of these areas into the urban development.

To ensure that this Strategy is implemented comprhensively, a management system needs to be established, in which responsibilities and scheduling are outlined.

8.2 Management System

This Strategy has been prepared as part of the Structure Plan process. The discussion of issues therefore is at a level consistent with the detail required at this broad planning stage. At the subdivision level of planning more detail will be required on development and management specifications for each area of wetland Open Space. It is recommended, therefore, that prior to subdivision approval, detailed Wetland Open Space Management Plans be prepared by the developer to the satisfaction of the Shire of Swan. It is envisaged that this will entail the preparation of four separate plans i.e., the north-west wetland, the north-south linear wetland, the mid-west wetland and the creeklines. The subdivision approvals to which this recommendation applies only relate to those which, during construction, will have a direct impact on any of the wetland Open Space areas.

The cost of preparing the Management Plans is to be borne by the developer.

Construction of facilities within the wetland Open Space areas will be the responsibility of the developer, and at the developer's cost, but under the supervision of the Shire of Swan. Management of facilities installed will be the responsibility of the developer for the life of the development, but on completion of development it will become the responsibility of the Shire of Swan.

Table 3 summarises the management system proposed.

TABLE 3

MANAGEMENT SYSTEM FOR THE IMPLEMENTATION OF THE WETLAND MANAGEMENT STRATEGY

Component	Timing	Responsibility & Funding
Wetland Management Plans	Prior to Subdivision Approval	Developer
Implementation of Management Plans	During Construction of Subdivision	Developer
Management of Wetlands	During Development Post Development	Developer Shire of Swan
Wetland Monitoring	During Development Post Development	Developer Shire of Swan

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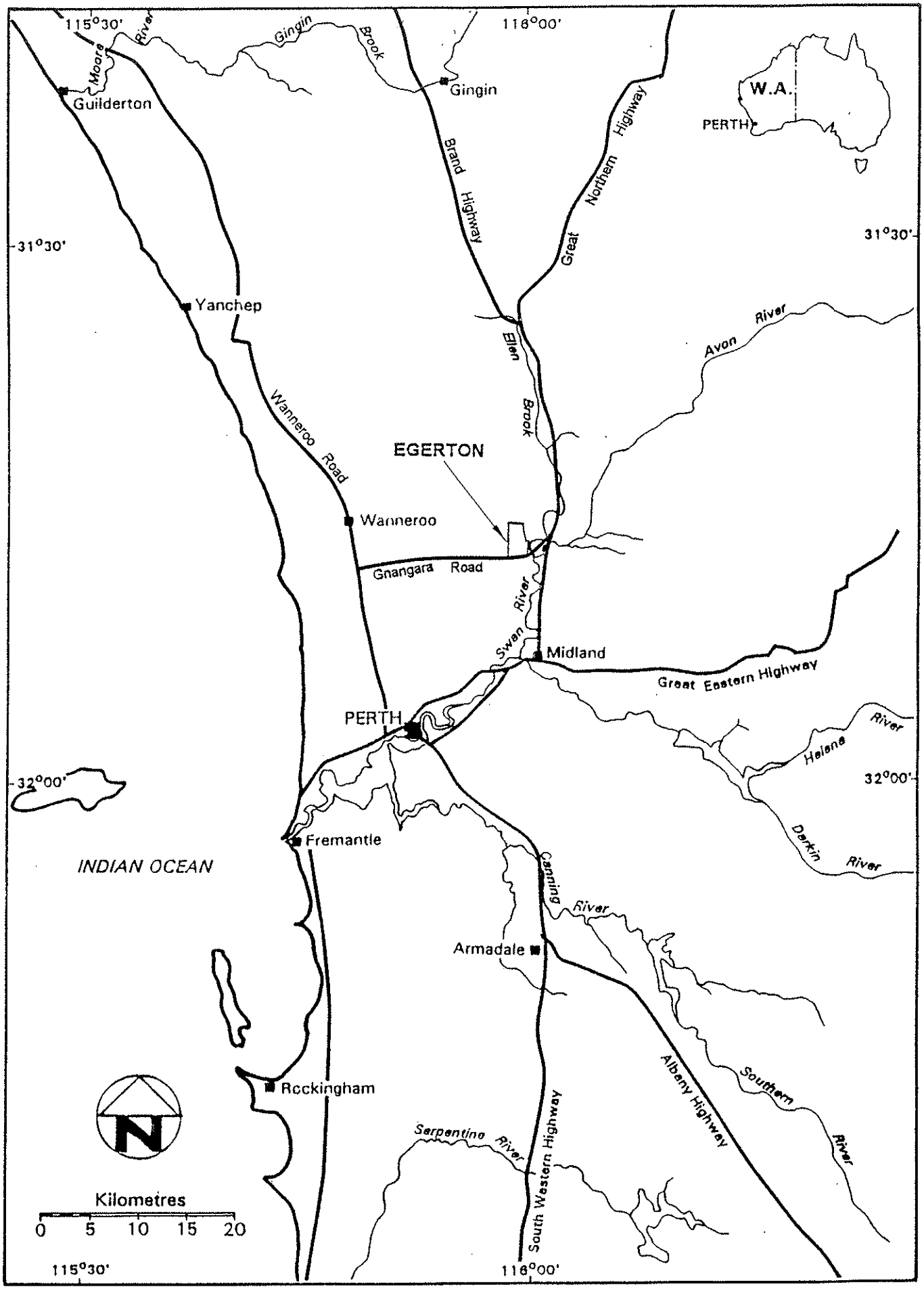
FIGURES



ALAN TINGAY & ASSOCIATES

EGERTON REGIONAL LOCATION
FIGURE 1

• Can we re-negotiate POS? • Table grapes

metres
0
500

MILLHOUSE ROAD

RESIDENTIAL DEVELOPMENT

POS

COMMUNITY CENTRE

PRIMARY SCHOOL & Oval

HIGH SCHOOL & Oval

RESIDENTIAL DEVELOPMENT

PRIMARY SCHOOL & Oval

POS

EGERTON DRIVE

ELVENBROOK DRIVE

POS

RESIDENTIAL DEVELOPMENT

POS

POS

RESIDENTIAL DEVELOPMENT

POS

PRIMARY SCHOOL & Oval

RESIDENTIAL DEVELOPMENT

GNANGARA ROAD

HENLEY BROOK AVENUE

LEGEND

- Residential Development
- Schools & Ovals
- Community Services
- Public Open Space
- Roads
- Topographic Contours in metres AHD

EGERTON STRUCTURE PLAN
FIGURE 2

SOURCE: MULTIPLEX CONSTRUCTIONS PTY LTD, 1994

ALAN TINGAY & ASSOCIATES

Kilometres

0 10

SCALE 1:200,000

LEGEND

BASIN WETLANDS

- Lake (permanently inundated)
- Sumpland (seasonally inundated)
- Dampland (seasonally waterlogged)

FLAT WETLANDS

- Floodplain (seasonally inundated)
- Palusplain (seasonally waterlogged)

CHANNEL WETLANDS

- River (permanently inundated)
- Creek (seasonally inundated)

Yanchep

Two Rocks

Egerton

Alkimos

Clarkson

R.A.A.F. Pearce Air Weapons Range

Quinns Rocks

Mindarie

Pinjar

Wanneroo

Wanneroo

Marangaroo

Ballajura

Balcatta

Midland

EGERTON

PERTH

Warbrook

Jumperkine L

Herne Hill

INDIAN OCEAN

B.1

B.2

B.3

B.4

B.5

B.7

S.1

S.2

Dp.1

D.2

D

SOURCE: WATER AUTHORITY OF WESTERN AUSTRALIA, 1993

WETLAND CLASSIFICATION MAP
PERTH TO TWO ROCKS
FIGURE 3

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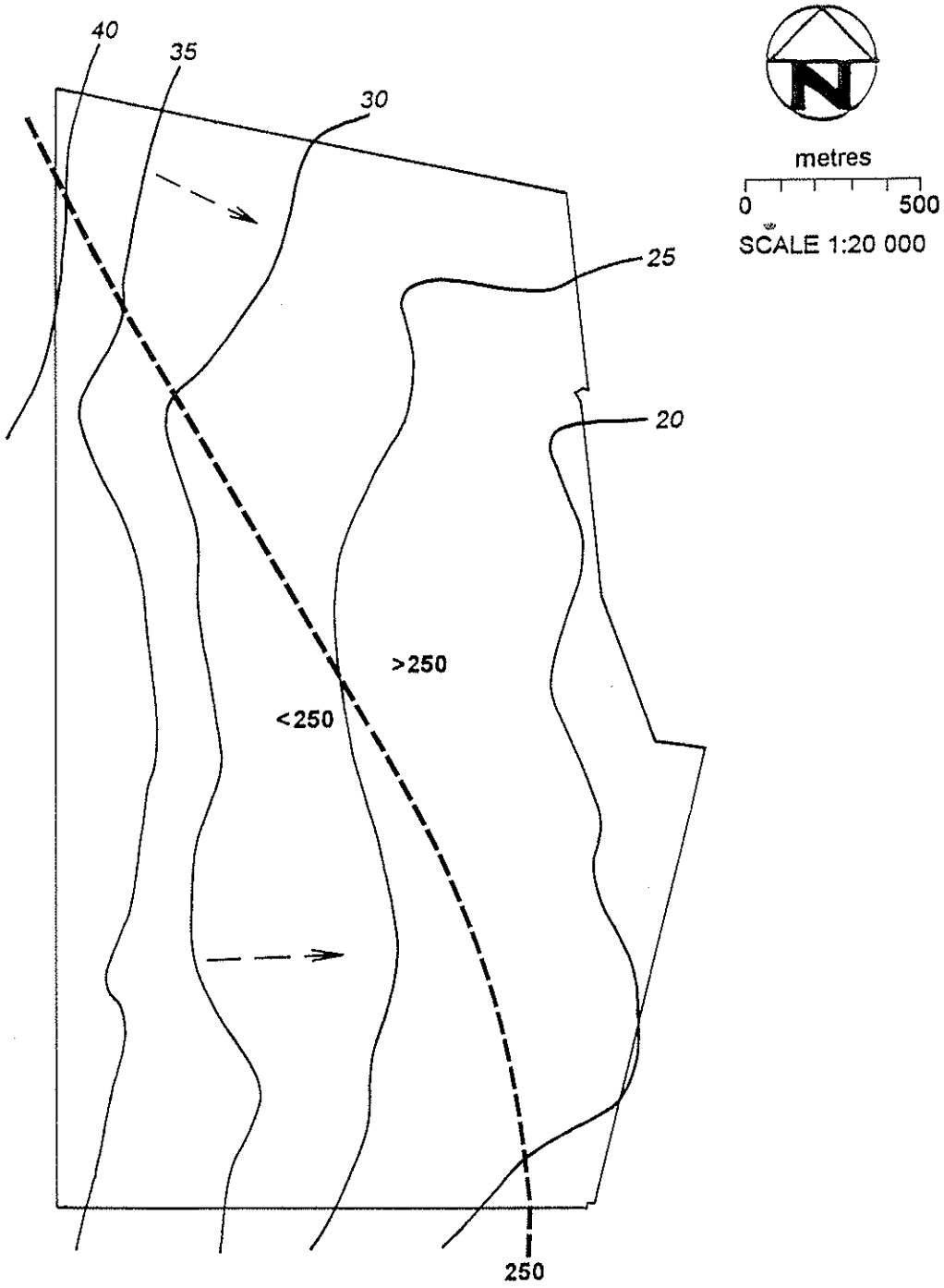

LEGEND

Groundwater Contours (m AHD)

Direction of Groundwater Flow

Isohaline Contour (mg/L TDS)

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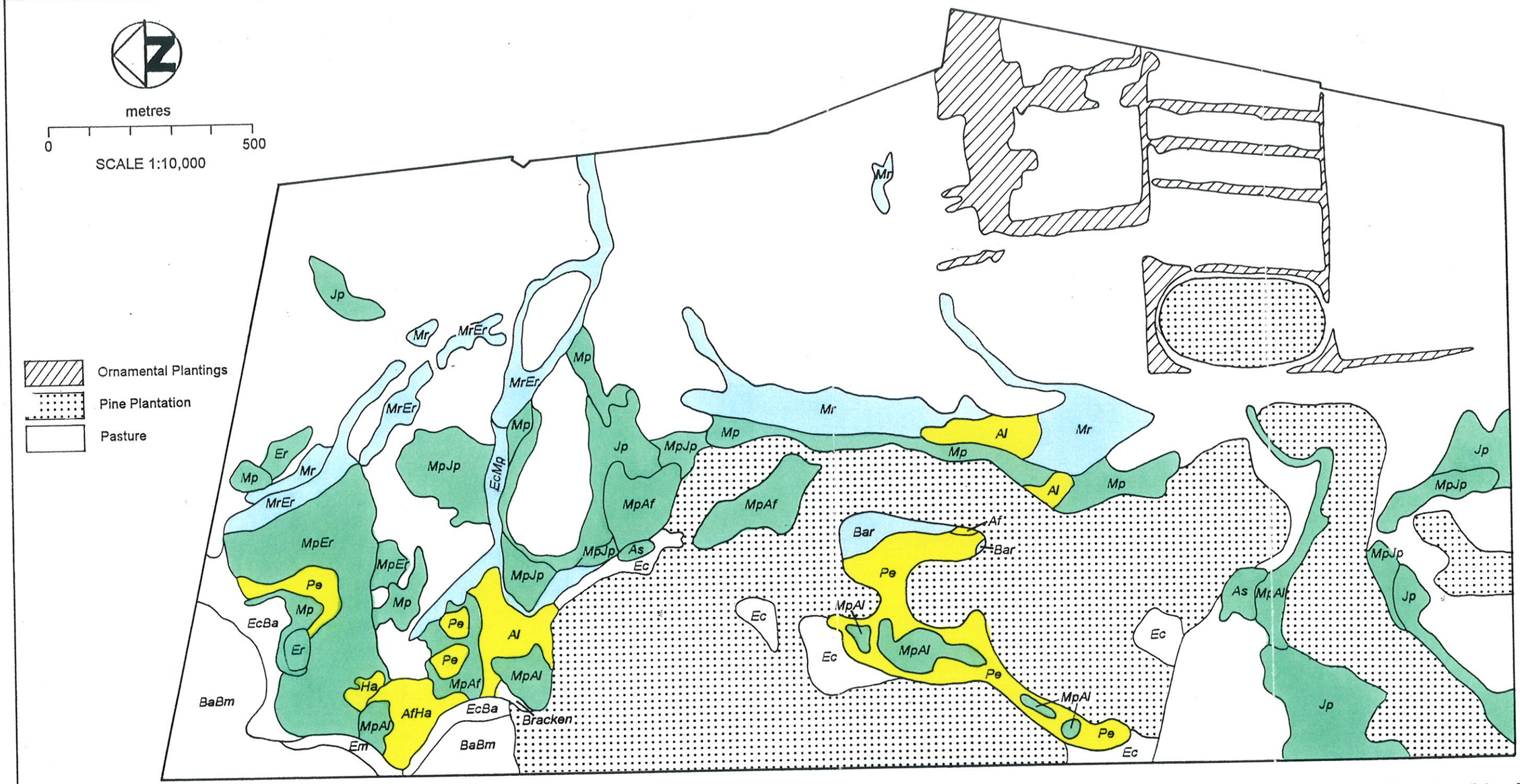
EGERTON GROUNDWATER CONTOURS
FIGURE 4



WETLAND VEGETATION TYPES

Dampland/Heaths

Pe - *Pericalymma ellipticum* Closed Heath

Al - *Agonis linearifolia* Open Heath over *Juncus pallidus* Sedgeland

Af - *Astartea fascicularis Closed Heath*

AfHa - *Astartea fascicularis/Hypocalymma angustifolium* Closed Heath

Ha - *Hypocalymma angustifolium* Closed Heath

Dampland/Forests, Woodlands & Heaths

Er - *Eucalyptus rudis* Open Forest

MpEr - *Melaleuca preissiana/Eucalyptus rudis* Closed Forest with *Banksia littoralis*

Mp - *Melaleuca preissiana* Low Woodland

MpJp - *Melaleuca preissiana* Low Woodland over *Juncus pallidus* Sedgeland

MpAl - *Melaleuca preissiana* Low Open to Low Woodland over *Agonis linearifolia* Closed Heath

MpPe - *Melaleuca preissiana* Low Open Woodland over *Pericalymma ellipticum* Closed Heath

MpAf - *Melaleuca preissiana* Low Open Woodland over *Astertea fascicularis* Closed Heath

As - *Acacia saligna* Low Woodland over *Agonis linearifolia* Open Heath

Jp - *Juncus pallidus* Sedgeland

Sumpland & Creeks/Forests, Woodlands & Sedgelands

Mr - *Melaleuca rhaphiophylla* Low Closed Forest

MrEr - *Melaleuca rhaphiophylla/Eucalyptus rudis* Low Closed Forest

EcMp - *Eucalyptus calophylla* Woodland over *Melaleuca preissiana* Low Woodland

Bar - *Baumea articulata* Closed Sedgeland

OTHER VEGETATION TYPES

Dry/Woodlands

BaBm - *Banksia attenuata/B. menziesii* Low Woodland

Transitional/Woodlands & Sedgelands

Ec - *Eucalyptus calophylla* Woodland

EcBa - *Eucalyptus calophylla/Banksia attenuata* Woodland

Em - *Eucalyptus marginata* Woodland

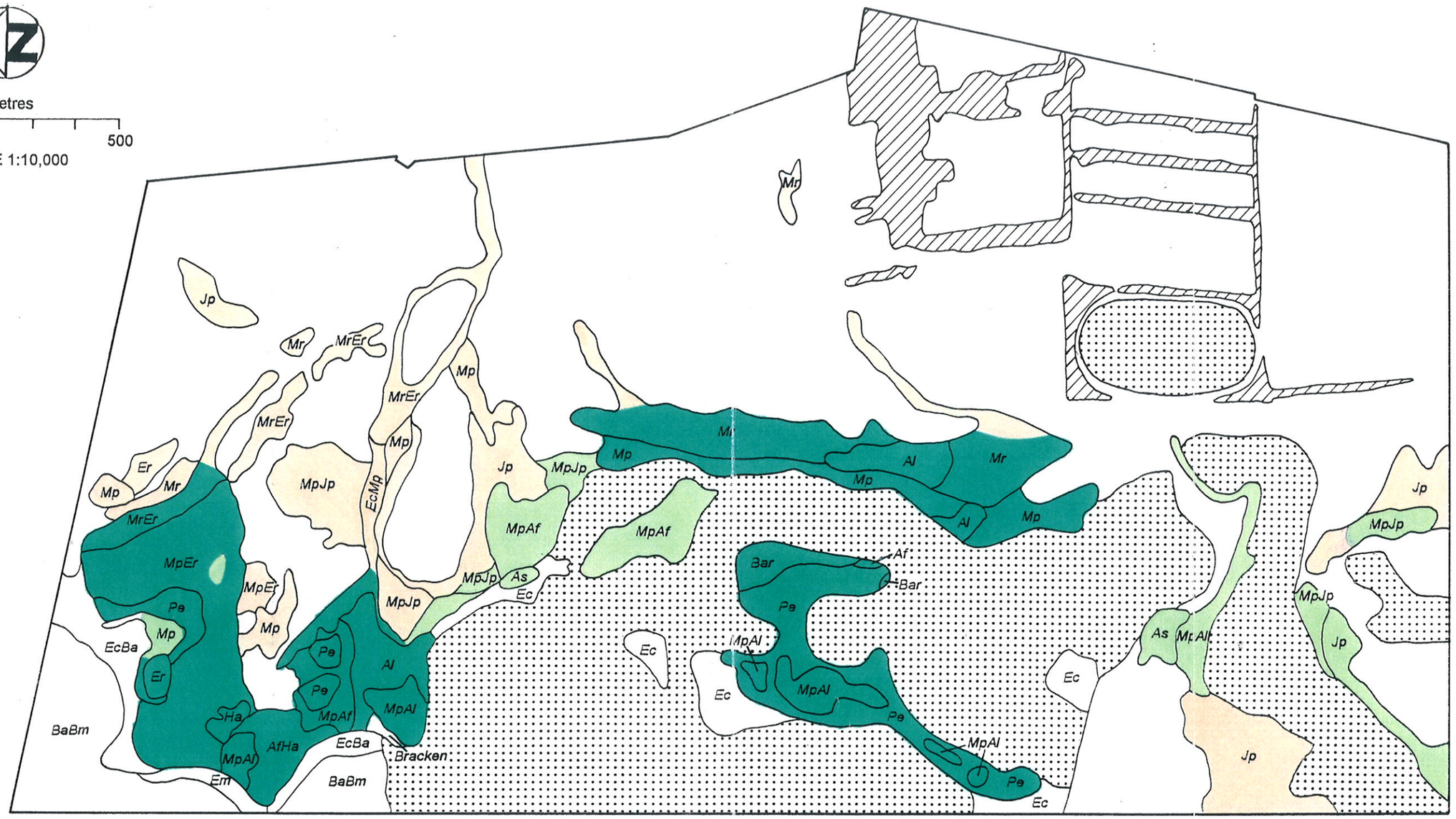
EGERTON WETLAND VEGETATION TYPES FIGURE 5

ALAN TINGAY & ASSOCIATES

metres

0 500

SCALE 1:10,000



LEGEND

MpEr Refer to Figure 5 for details of vegetation associations

- Slightly Disturbed
- Obvious Disturbance
- Severely Disturbed
- Other Vegetation Types (non-wetland)

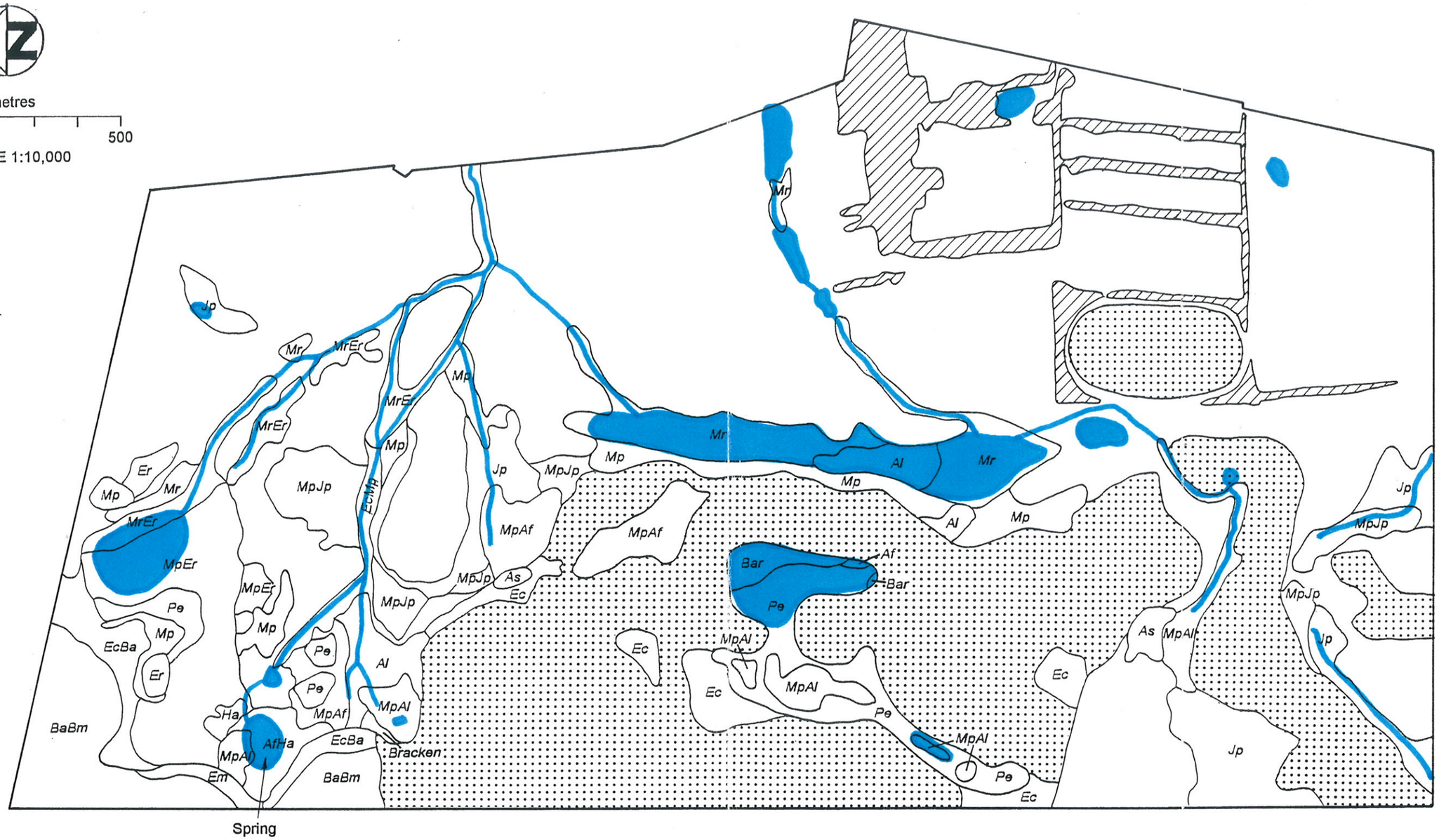
EGERTON WETLAND VEGETATION QUALITY
FIGURE 6

ALAN TINGAY & ASSOCIATES

metres

0 500

SCALE 1:10,000

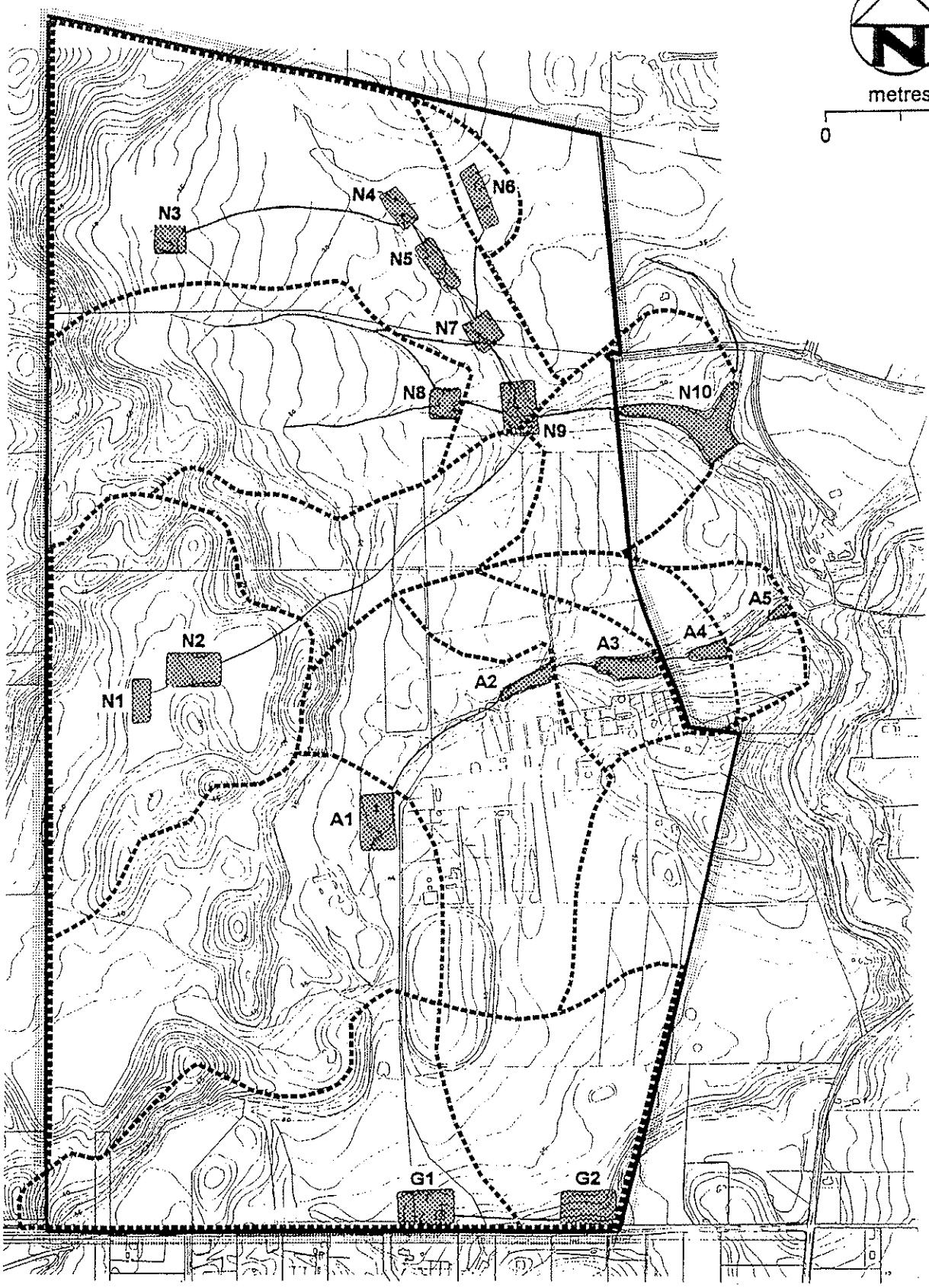


LEGEND

Seasonally Inundated Areas

MpEr Refer to Figure 5 for details of vegetation associations

EGERTON
SEASONALLY INUNDATED AREAS
FIGURE 7



SOURCE: COSSILL & WEBLEY, 1994

ALAN TINGAY & ASSOCIATES

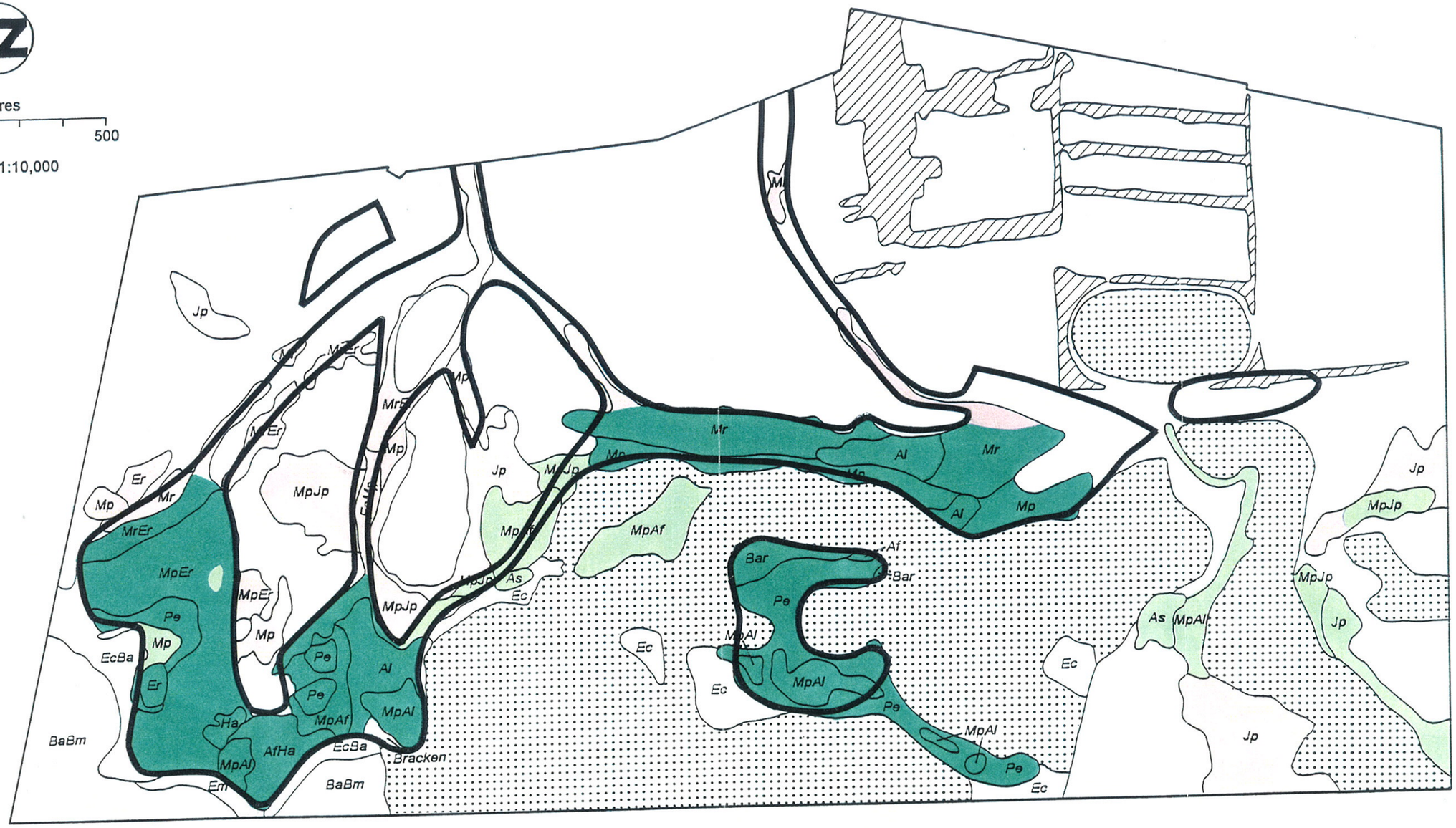
EGERTON CATCHMENT BOUNDARIES AND DRAINAGE BASINS

FIGURE 8

metres

0 500

SCALE 1:10,000



LEGEND

Public Open Space Boundary

MrEr Refer to Figure 5 for details of vegetation associations

WETLAND VEGETATION QUALITY

- Slightly Disturbed
- Obvious Disturbance
- Severely Disturbed
- Other Vegetation Types (non-wetland)

EGERTON
PUBLIC OPEN SPACE BOUNDARY
IN RELATION TO QUALITY OF
WETLAND VEGETATION
FIGURE 9

N

metres

0 500

MILLHOUSE ROAD

EGERTON DRIVE

ELLENBROOK DRIVE

GNANGARA ROAD

HENLEY BROOK AVENUE

MANAGEMENT PRIORITY AREAS

- Public Open Space Boundary
- Conservation
- Special Conservation
- Drainage
- Passive Recreation
- School Ovals
- Public Access Routes

EGERTON MANAGEMENT PRIORITIES FOR PUBLIC OPEN SPACE AREAS FIGURE 10

ALAN TINGAY & ASSOCIATES