Water Authority
of Western Australia

Next Major Public Water Supply Source for Perth (post 1992)

Environmental Review and Management Programme
Stage 1: Evaluation of Alternatives

Supporting Document

A Fauna Assessment of Four Water Supply Sources in the Darling Ranges

J. N. Dunlop & Associates, and
Ninox Wildlife Consulting
October 1987

Water Authority
of Western Australia

WATER RESOURCES DIRECTORATE
Water Resources Planning Branch

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Published by the

Water Authority of Western Australia
John Tonkin Water Centre
629 Newcastle Street
Leederville WA 6007

Telephone: (09) 420 2420

ISBN for complete set of 7 volumes
0 7309 1724 X
ISBN for this volume 0 7309 1726 6

October 1987

This report is published by the Water Authority of Western Australia as a technical supporting document to the Environmental Review and Management Programme, Stage 1 report titled 'Next Major Public Water Supply Source for Perth (post 1992)'.

The document published within these covers is a copy of the Consultant's report to the Water Authority. As such, the Consultant is responsible for the accuracy of the information and statements contained in the report which constitutes specialist technical advice to the Authority.

The Water Authority acknowledges the work of the Consultants for the efficient manner in which they undertook their investigations and provided their advice to the Authority.

A FAUNA ASSESSMENT OF FOUR WATER SUPPLY SOURCES IN THE DARLING RANGES

RAISED MUNDARING DAM

RAISED CANNING DAM

SOUTH CANNING DAM

NORTH DANDALUP DAM

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of Western Australia by:

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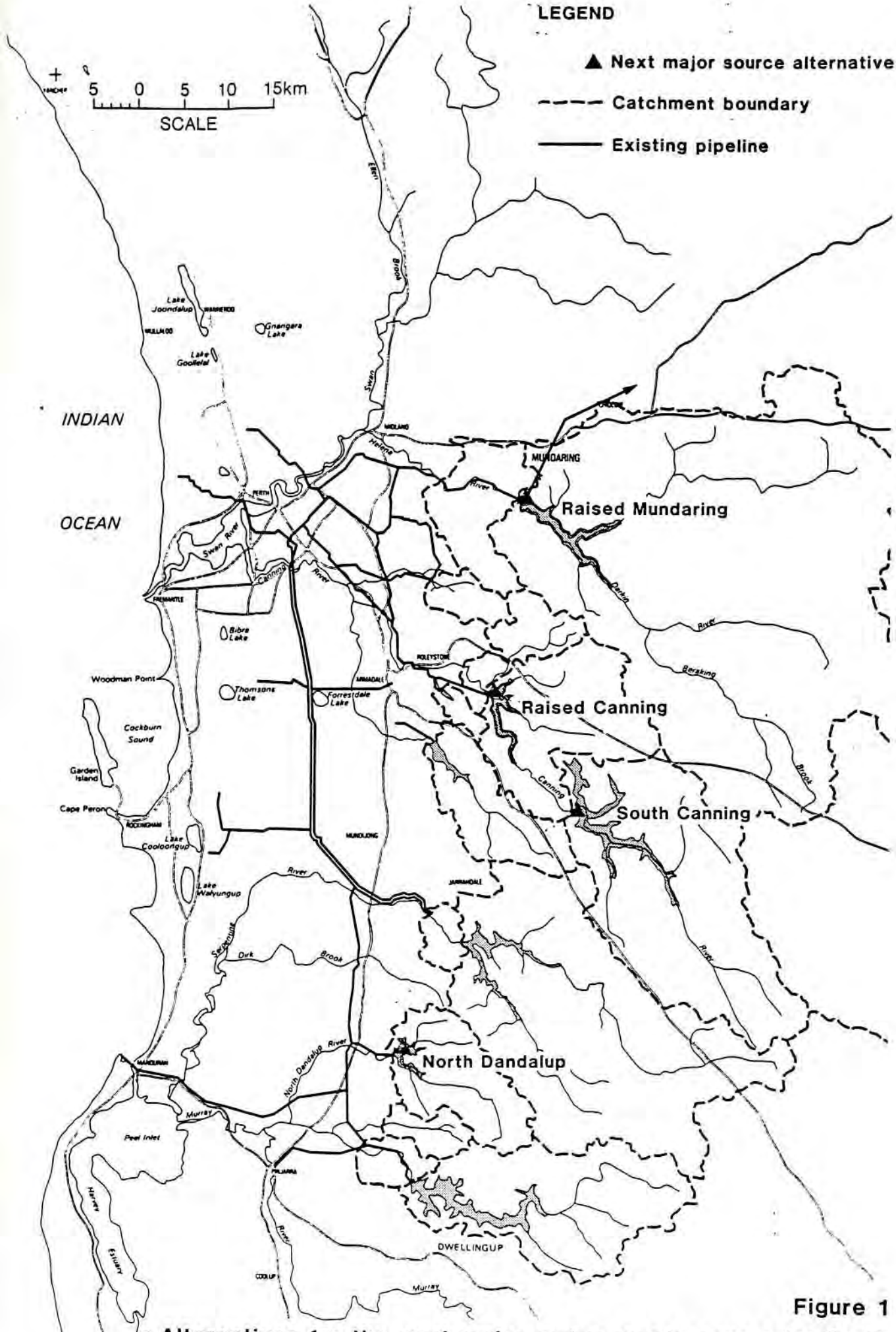


Figure 1

Alternatives for the next major water supply source for Perth

1. INTRODUCTION

The continued expansion of the Perth metropolitan area, and growth in demand for high quality water, is forecast to necessitate the development of another water source in the Darling Ranges by the early 1990's. If the growth in water demand continues unabated into the future then ultimately water supply development will occur on most available streams in the region (Mauger, 1987). The most productive and economic water supply options in the Darling Ranges have already been utilised and successive developments from this time will be more expensive and will compound the environmental cost of public water supply. The Water Authority is now pursuing a policy of demand management which it is hoped will defer well into the future the environmental impact of building some dams. However preparations are now required to plan the next major 'hills' water supply scheme so that it can be constructed and commissioned by the time demand exceeds supply.

Four feasible water supply alternatives are being evaluated in terms of their economic and technical performance and their physical, biological and social environmental impacts. Two options involve the raising of existing dams (Mundaring and Canning Dams) whilst the remaining alternatives would lead to the construction of new dams in the headwaters of the Canning River (South Canning Dam) and on the North Dandalup River near the existing pipehead dam (Figure 1).

This study documents the fauna resources of the land areas and streams which would be affected in the four project areas. The objectives are twofold. Initially the study is to provide a basis for the evaluation of the fauna resources as a contribution to a wider 'multi-objective' investigation of the four options aimed at selecting the source which will benefit society most with the least associated cost/impact. Secondly the study is to provide adequate documentation of fauna to provide for the stage 1 Environmental Review and Management Programme of the next water supply source, whichever option may be proposed for development. Since little site specific data is available most of the information presented ensues from fauna surveys conducted in the catchment areas in November/December 1986.

Wildlife resources can be evaluated from a number of perspectives. The conservation interest may value attributes such as the representation of underconserved ecosystems, habitat units or populations, uniqueness or rarity, diversity or local abundance. Coupled with these attributes are the less clearly understood parameters which reflect long term environmental quality, sustainability or manageability should the wildlife constitute an alternative resource or land use. Whilst in general the scientific interest would value similar attributes also it has more specific values related to lines of research. An area may

be strategically important because of its biogeographic position, suitability as a reference area or control, significant past history of management or of scientific investment. The maintenance of an area may preseve 'type localities' or allow ecological experiments to be repeated (a basic tenent of the scientific method).

As a basis for an evaluation of fauna resources in four alternative project areas it was of importance that the timing, methodology and sampling efforts were standardised as far as possible. The rapid survey of fauna over one seasonal period, and in a single year, is unlikely to be exhaustive however the results from simultaneous and standardised surveys would allow direct comparisons to be made between alternative project locations. For the evaluation it was necessary to select fauna groups which were diverse and could be sampled relatively completely in the context of a rapid survey providing quantitative data and ecological indices which could be used to rank sites or project areas. These groups would also provide data for classificatory analyses to assist in the assessment of site uniqueness and affinity (representativeness). Birds and ants were selected as these core fauna groups. Mammals (including bats), herptiles and fishes were also surveyed to allow a general description and assessment of the fauna of each project area.

2. STUDY METHODS

2.1 Literature Review

With the exception of North Dandelup (Liehne, 1984) no fauna surveys had been conducted in the immediate study areas. The Liehne survey covered vertebrate and aquatic invertebrate animals over a wider area at North Dandalup than that being considered in the present study.

The main emphasis in the literature review was to develop a perspective of the fauna of the Northern Jarrah Forest, i.e. in the area of the Darling Plateau and Scarp from Mundaring (32°S) to Collie (31.5°S). This in turn would assist in the evaluation of the fauna resources of the project areas.

Two recent bibliographies were available which documented both published and ongoing fauna studies in the Northern Jarrah Forest (Forest Fauna Research Working Group, 1984; Department of Conservation & Environment, 1984). The most current and useful sources were a survey of the vertebrate fauna of the southern forests by the then Forest Department (Christensen et al., 1985), a biogeographic analysis of the south-western herptile fauna (Chapman & Dell, 1985) and the work of the Darling Range mining companies (e.g. Worsley Alumina Pty. Ltd, 1985; Nicholls et al., 1981). A computer search was conducted of the mammal, herptile and fish collections of the Western Australian Museum. All records were sought from a rectangular area within the Latitude - Longitude coordinates 31°55'S, 116°00'E and 31°55'S, 116°20'E in the north and 33°00'S, 116°00'E and 33°00'S, 116°20'E in the south. This region incorporated all four project areas and the encompassing forested plateau and scarp.

2.2 Fauna Survey

Field teams conducted terrestrial fauna surveys of the project areas in November and early December 1986. In all cases these surveys involved standard bird census, ant sampling, bat trapping and day and night fauna searches and vehicle traverses. Small mammal and herptile trapping was conducted at all project areas except Raised Canning where the field time was shortened.

2.2.1 Bird census

The bird communities of forest, stream zone and woodland habitats in each project area (as defined by dam full supply levels) were censused using a standard method, the 'variable circular-plot census procedure', which was utilised to estimate of bird densities (Wardell-Johnson, 1984). This procedure allows bird numbers to be related to area sampled in a measure of density by first estimating the effective census area around the observer. This also

compensates for the effect of the observer on the behaviour of the birds recorded.

In each selected habitat (described in Table 1a) ten (10) observation stations were established. The distance between stations was not less than 120m. Stations were normally arranged on a linear traverse but where the available habitat was limited other arrangements were used. Where habitat patches are small, stations can be 'nested' over a wide area. In this study traverses followed contours in most instances.

All traverses (and stations) were visited on five seperate days during the survey period. At each station on each day five minutes of sightings were recorded by a stationary observer. For each sighting (or 'contact') the observer recorded the bird species, number of individuals (if a group or flock), and the distance at which the sighting was made in 10m classes up to 60m. Both visual and audible contacts were recorded.

At Mundaring, South Canning and North Dandalup five traverses including 50 stations were established. At Raised Canning this was reduced to three traverses of 30 stations. Up to two traverses were undertaken by a given observer on a single day. Four of the five visits to each traverse were made in the first four hours of daylight. A fifth was conducted at dusk. The habitats sampled by the bird census traverses are described in Table 1a and the traverse locations are shown on Figures 2, 3, 4 and 5.

2.2.2 Mammals and herptiles

Small mammals and herptiles were captured in pitfall traps, using drift lines. A trapline consisted of ten (10) lined pits (0.18m diameter x 0.43m deep), placed approximately 3m apart, along and on alternate sides of, a 0.25m high, 35 - 45m long flywire fence. Voucher specimens were taken of most species captured thereafter all animals were recorded and released. Pitfall and drift fence traplines operated from nine to eleven (11) days.

Pitfall and drift traplines were only established in forest habitats sufficiently above the water table to prevent flooding of the holes. These habitats are described in Table 1b. At each trapping locality (Figures 2, 3, 4 & 5) lines of Elliott box traps and cage traps were run across the contours from the pitfall and drift lines into the stream zone. These lines consisted of twenty (20) "Elliott" traps (sizes B & D) and one wire cage trap (always placed in the stream zone). Traps were baited with the 'universal' mixture.

Intensive fauna searches were conducted in the viscinity of the traplines and in habitats which could not be pitfall trapped (i.e. granite outcrops).

Mist nets were set for bats in forest flyways, in small clearings; and over water Bat-traps ("harp" traps) were also used in selected localities.

All birds, herptiles and mammals observed on daylight

and night traverses of the project areas were noted with a record of the habitat(s) utilised.

2.2.3 Ants

Ants were pitfall trapped in plastic specimen jars (43mm I.D.) containing about 50ml of preservative (70% alcohol & glycerol mix, 70/30 v/v). Twenty jars were set at each sampling site. These were arranged as five sets of four jars, with sets being 20m apart and with each jar in a set being on the corner of a one metre square quadrat. The 100m long ant traplines were located near the traverses censused for birds (habitats described in Table 1c). Each ant sampling location (Figure 2, 3, 4 and 5) was searched for 30 minutes in both daylight and at night, and foraging species were collected by hand.

2.2.4 Fishes

"Electro-fishing" was utilised to sample fishes and decapod crustaceans in a variety of stream types on the Helena, Darkin, Canning and North Dandalup Rivers (Figures 2, 3, 4 & 5). A 24 volt electric current was passed through the water stunning and disorienting the fish and allowing them to be scoop netted for identification. Fishes not required as specimens usually recovered and were released.

2.3 Data Analyses

2.3.1 Bird census

The "point centred" or "variable circular plot" technique of bird census is designed to estimate the density of birds in the 'effective area' of observation. This area varies from bird species to species, due to factors such as size and behaviour, and from habitat to habitat due mainly to the influence of vegetation structure on intervisibility. The average numbers of birds sighted from five counts within circular areas of observation with radii of 10, 20, 30, 40, 50, and 60 metres were used to calculate densities. The circular area in which the highest density occurs was the effective census range and the density at that range was taken as the value for that species. Densities were calculated for each species on each traverse, pooling the results from the ten stations and five periods of observation (i.e. data from 250 station /minutes of observation per traverse). Total bird densities for each traverse were calculated by summing the densities for individual species.

The species lists for each traverse and the associated density values were utilised in a Similarity Analysis. Broadly these analyses group and distance sites according to the similarity or dissimilarity of species composition. Using some indices species occurrence can be weighted

Table 1a

Habitat descriptions of the bird census traverses. Land-system and vegetation classifications follow Havel Land Consultants (1987). Mundaring sites are coded ME, South Canning SC, Raised Canning CE and North Dandalup ND.

Bird census traverse	Land-system unit	Habitat description
ME-1	Murray, valley floor	Flooded Gum *Eucalyptus rudis* fringing woodland. Site/vegetation type AQ.
ME-2	Murray, valley floor	Stream zone, closed *Melaleuca rhaphiophylla* thicket. Site/vegetation type AQ.
ME-3	Murray, low elevation and rock	Open Wandoo *Eucalyptus wandoo* woodland on granite. Site/vegetation types LG, YM, M & Q.
ME-4	Murray, low elevation & valley floor	Wandoo *Eucalyptus wandoo* woodland on clay soil. Site/vegetation types MY to CY.
ME-5	Murray, low elevation	Jarrah *Eucalyptus marginata* forest on sandy soil. Site/vegetation types WQ & WP.
SC-1	Valley floor, Murray land system	Densely vegetated stream zone. Site/vegetation type CQ.
SC-2	Valley floor, Murray land system	Densely vegetated stream zone. Site/vegetation type CQ.
SC-3	Valley floor, Murray land system	Wandoo *Eucalyptus wandoo* on clay soil, with narrow band of stream zone vegetation. Site/vegetation type Y with ecotonal CY, WY & AY on drainage line.
SC-4	Low elevation, Dwellingup land-system	Jarrah forest on laterite. Site/vegetation type WZ.
SC-5	Slopes, Murray land system	Jarrah forest on laterite and reddish sandy loam. Site/vegetation types TQ & T.

Table 1a cont...

Bird Census traverse	Land-system unit	Habitat Description
CE-1	Murray, valley floor	Dense stream zone vegetation with Blackbutt *Eucalyptus patens*. Site vegetation types Q & CQ.
CE-2	Murray, valley floor	Stream zone with exposed granite. Site/vegetation types C, W & R.
CE-3	Murray, low elevation & slopes	Jarrah *Eucalyptus marginata* forest with dense understorey on a steep slope. Site/vegetation types T & S.
ND-1	Murray, valley floor	Stream zone & swamp. Site/vegetation type CG.
ND-2	Helena, valley floor & rock	*Eucalyptus laeliae* woodland with dense heath near granite & drainage lines. Site/vegetation types CQ on stream CR & WG on slopes.
ND-3	Myara, valley floor & slope	Blackbutt *Eucalyptus patens* woodland & narrow densely vegetated stream zone. Site/vegetation types C & S.
ND-4	Dwellingup land-system, Myara, slope & valley floor.	Jarrah forest on slope. Site/vegetation types CQ & RS.
ND-5	Yarragil, Murray slope & valley floor	Jarrah *Eucalyptus marginata* forest. Site vegetation types S & P, C in gullies.

Table 1b

Habitat descriptions of the vertebrate trapping localities. Land-system and vegetation classifications follow Havel Land Consultants (1987).

Trapping locality	Land-system unit	Habitat description
MT-1	Murray, valley floor	Flooded gum *Eucalyptus rudis* fringing woodland. Site/ vegetation type AQ.
MT-2	Murray, low elevation	Jarrah *Eucalyptus marginata* forest on sandy soil. Site/ vegetation types WQ & WP.
MT-3	Murray, low elevation & rock	Open Wandoo *Eucalyptus wandoo* woodland on granite. Site/ vegetation type YM.
MT-4	Murray, low elevation	Wandoo *Eucalyptus wandoo* wood-land on clay soil. Site/ vegetation type MY.
MT-5	Murray, valley floor	Stream zone, closed *Melaleuca* thicket. Site/vegetation type AQ.
ST-1	Murray, valley floor	Wandoo *Eucalyptus wandoo* woodland on clay soil. Site/ vegetation type Y.
ST-2	Dwellingup low elevation & Murray valley floor	Jarrah *Eucalyptus marginata* forest on deep reddish loam abutting stream zone. Site/ vegetation types Q & CQ.
ST-3	Murray, valley floor	Jarrah *Eucalyptus marginata* and Blackbutt *Eucalyptus patens* open forest on sand. Site/vegetation types B & C.
ST-4	Murray, slopes & valley floor	Jarrah *Eucalyptus marginata* forest abutting dense stream zone. Site/vegetation types TQ & CQ.
ST-5	Yarragil, land system	Jarrah *Eucalyptus marginata* forest on shallow sand over laterite. Site/vegetation type WS.

Table 1b cont...

Trapping locality	Land-system unit	Habitat description
NT-1	Murray, valley floor	Closed stream zone vegetation. Site/vegetation type CG.
NT-2	Yarragil, land system	Jarrah Eucalyptus marginata forest. Site/vegetation type S.
MT-3	Myara, slopes	Jarrah Eucalyptus marginata forest on a sleep lateritic slope abutting narrow stream zone. Site/vegetation types S & C.
NT-4	Myara, slopes & valley floor	Open stream zone abutting Jarrah forest. Site/ vegetation type CQ.
MT-5	Dwellingup land-system	Jarrah Eucalyptus marginata forest with understorey of Banksia grandis on laterite. Site/vegetation type 5.

Table 1c

Habitat descriptions of the ant sampling sites. Land-system and vegetation classifications follow Havel Land Consultants (1987).

Ant sampling site	Land-system unit	Habitat description
ME-1A	Murray, valley floor	Flooded Gum *Eucalyptus rudis* fringing woodland. Site/ vegetation type AQ.
ME-2A	Murray, valley floor	Stream zone, closed *Melaleuca* thicket. Site/vegetation type AQ.
ME-3A	Murray, low elevation & rock	Open Wandoo *Eucalyptus wandoo* woodland on granite. Site/ vegetation type YM.
ME-4A	Murray, low elevation	Wandoo *Eucalyptus wandoo* woodland on clay soil. Site/ vegetation type MY.
ME-5A	Murray, low elevation	Jarrah *Eucalyptus marginata* forest on sandy soil. Site/ vegetation type WQ.
SC-1A	Valley floor, Murray land-system	Wandoo *Eucalyptus wandoo* woodland on clay soil. Site/ vegetation type Y.
SC-2A	Low elevation, Dwellingup	Jarrah forest on laterite. Site/vegetation type WZ.
SC-3A	Valley floor, Murray land-	Densely vegetated stream zone. Site/vegetation type CQ.
SC-4A	'as above'	'as above'
SC-5A	Slopes, Murray land-system	Jarrah forest on laterite and reddish sandy loam. Site/ vegetation type T.
CE-1A	Valley floor, Murray land-system	Dense stream zone with Black-butt *Eucalyptus patens*. Site/vegetation type CQ.
CE-2A	Murray, low elevation & slopes	Jarrah *Eucalyptus marginata* forest with dense understorey on a steep slope. Site/ vegetation type T.

Table 1c cont...

Ant Sampling site	Land-system unit	Habitat description
CE-3A	Murray, valley floor	Stream zone with exposed granite. Site/vegetation type C.
ND-1A	Murray, valley floor	Stream zone & swamp. Site/ vegetation type CG.
ND-2A	Yarragil, land-system	Jarrah Eucalyptus marginata forest. Site/vegetation type S.
ND-3A	Myara, valley floor	Blackbutt Eucalyptus patens woodland & narrow densely vegetated stream zone. Site/ vegetation type C.
ND-4A	Myara slope	Jarrah forest on slope. Site/ vegetation type RS.
ND-5A	Helena, valley floor & rock	Eucalyptus laeliae woodland with dense heath near exposed granite & drainage lines. Site/vegetation types CQ & WG.

according to the 'importance' values of individual taxa (measured of relative abundance, numbers, biomass etc.). This will for example reduce biases caused by exceptionally rare 'uncharacteristic' species. The result is an ecological classification of sites or samples based on the affinities of their faunal assemblages. The bird traverses from the four project areas were analysed using the Cosine Theta Coefficient (Imbrie & Purdy, 1962). This method of Similarity Analysis allowed the application of the bird density estimates as 'importance' values. The results are presented in the form of a dendrogram, the level and grouping of its branches indicating the degree of affinity between sites.

2.3.2 Mammals and herptiles

The survey of the herptiles and mammal faunas of the project areas, including the trapping activities, were only expected to provide inventry information in the time available. These results were summarised with reference to the habitat(s) in which species were recorded or collected in each project area.

2.3.3 Ants

Ants collected in the pitfall traps were sorted by species and counted. The number of species in the sets of four jars from the one metre square sub-samples were recorded as a measure of species density (Majer, 1983). The number of species trapped in a transect was used to determine 'pitfall' species richness. This was supplemented by the species collected by hand in day and night searches to give 'total' species richness. The dominance index was calculated for the ant communities, derived from pitfall trapping, on each transect.

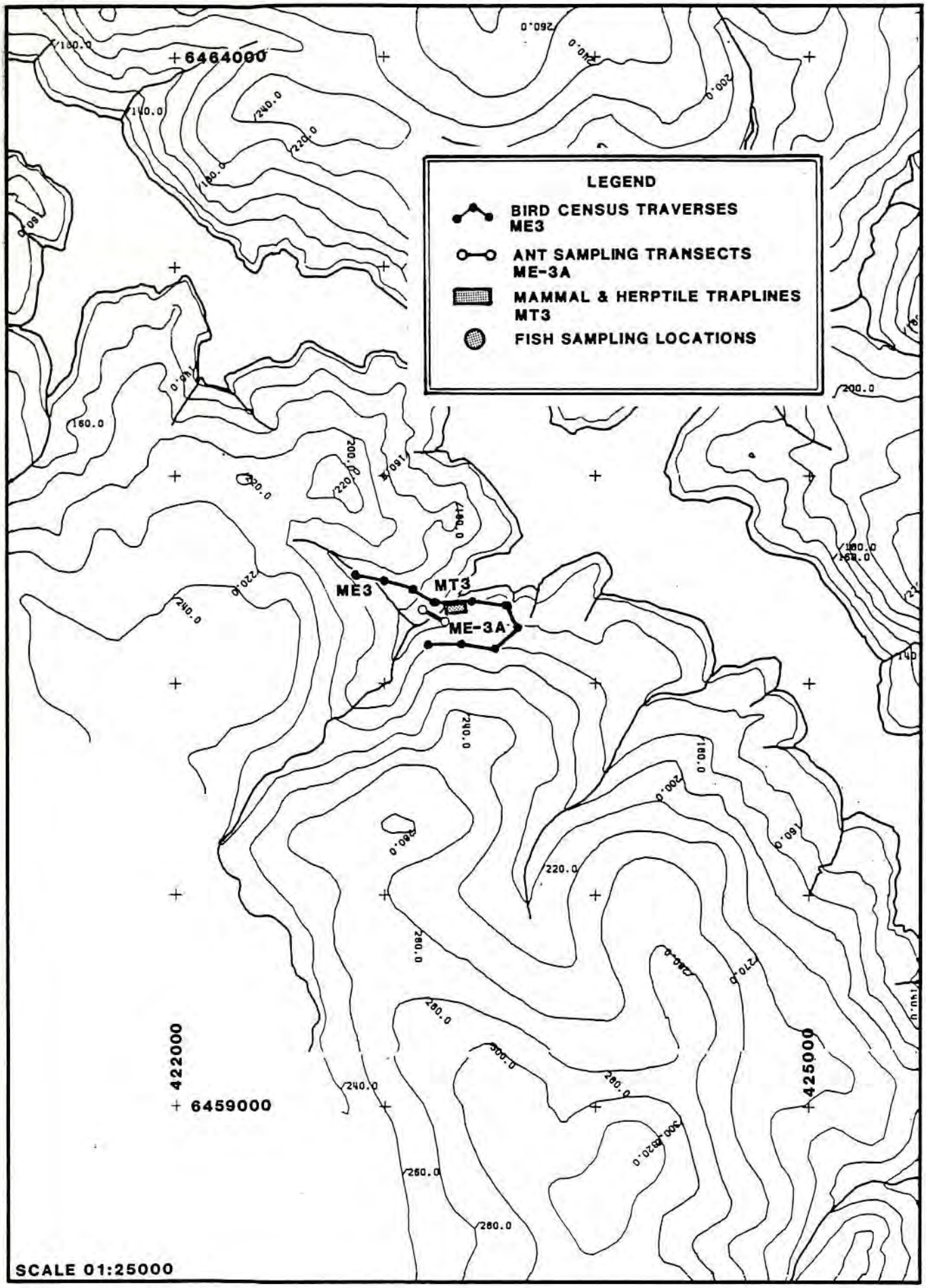
$$\text{Dominance Index} = \sum \left(\frac{ni}{N}\right)^2$$

where ni = individuals of the ith species
N = the total number of ants captured.

The Dominance Index is a measure of the apportionment of individuals amongst the taxa (i.e. species) with values between 1 and 0. Communities with most individuals concentrated in one or a few taxa will have values approaching 1 whilst those with an even spread of individuals amongst the taxa have indices nearer 0.

Similarity analysis using the Cosine Theta Coefficient was also undertaken for ants. Pitfall and hand collected species were utilised to produce the dendrograms. The numbers of individuals pit-trapped were adopted as 'importance' values whilst species which were only hand collected were assigned the value 1. For the purposes of this study it was not considered necessary to identify ants with named species or numbered reference specimens in State and National Insect collections. This could however be

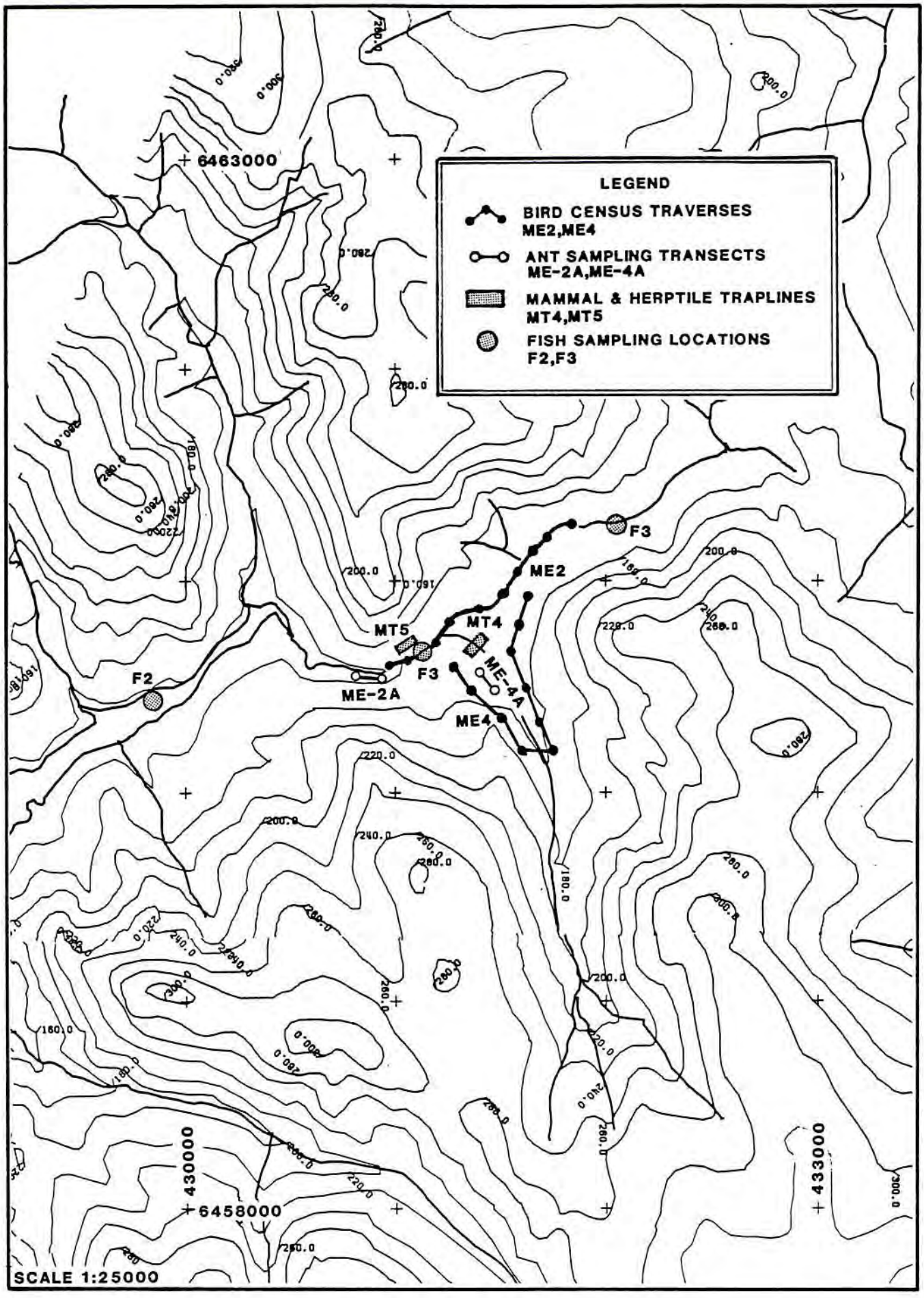
undertaken for the E.R.M.P. presentation. Each species is identified to genus and assigned a project field number.



RAISED MUNDARING DAM

Fauna Sampling Sites

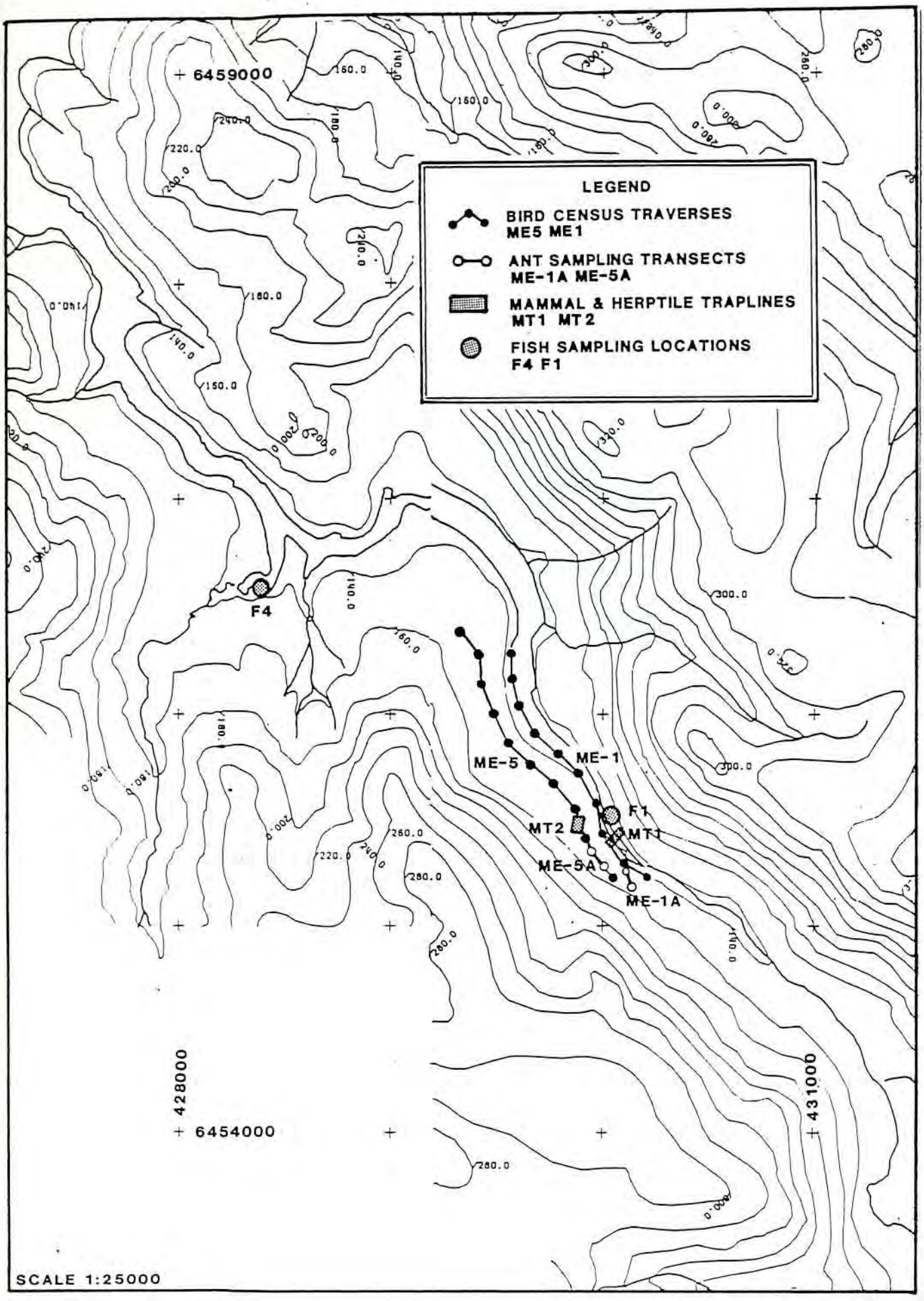
FIGURE 2A



RAISED MUNDARING DAM

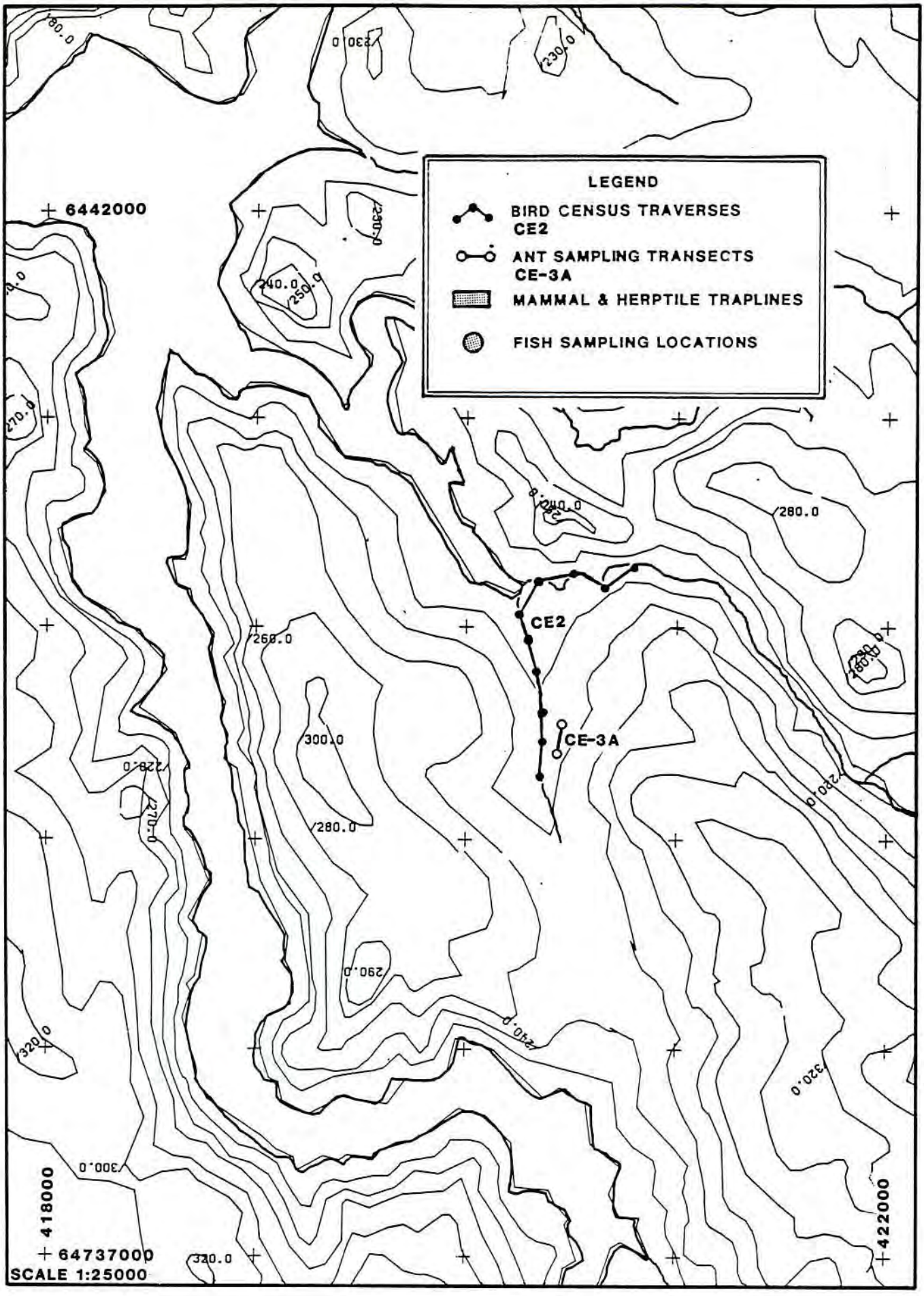
Fauna Sampling Sites

FIGURE 2B



RAISED MUNDARING DAM **Fauna Sampling Sites**

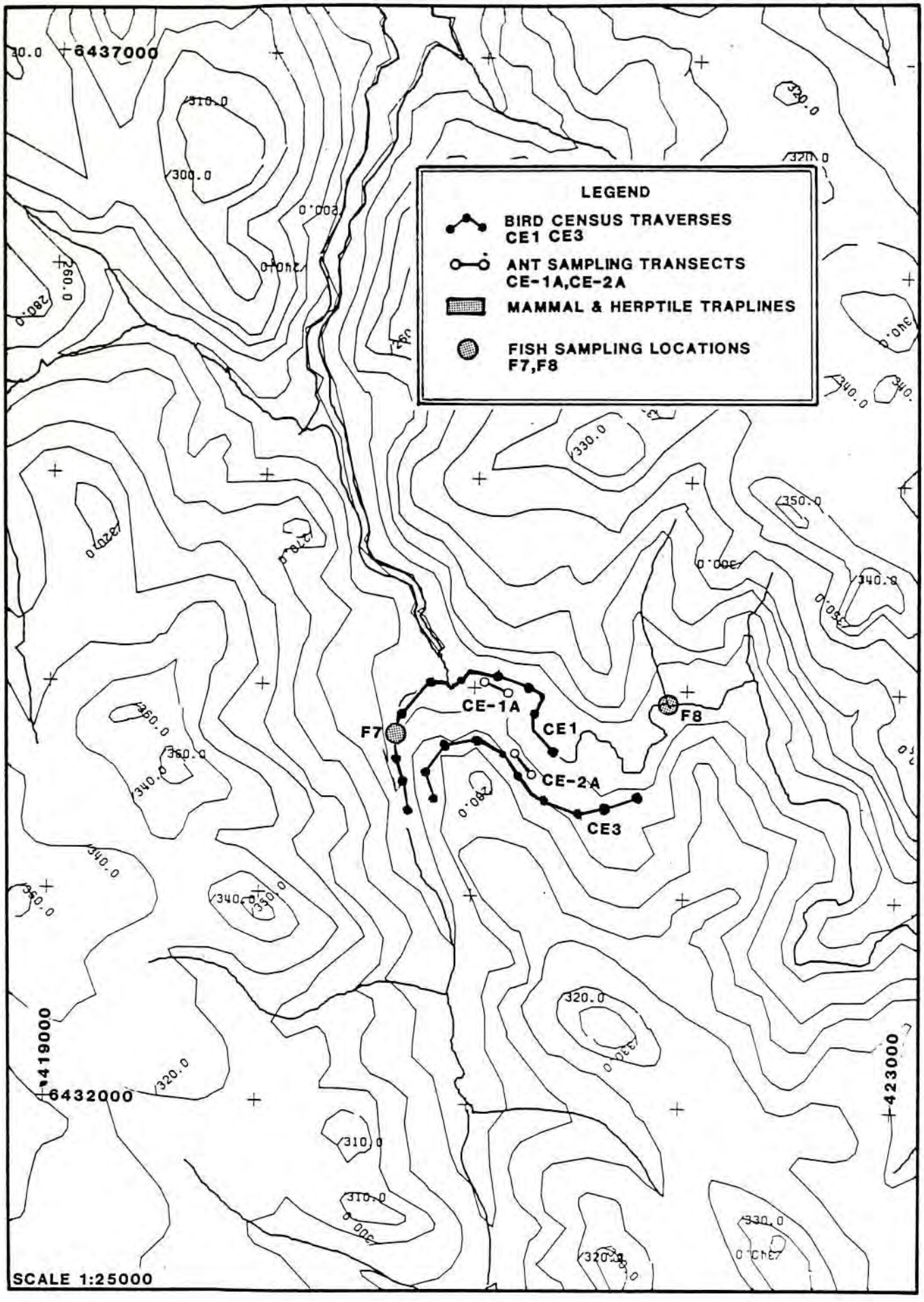
FIGURE 2C



RAISED CANNING DAM

Fauna Sampling Sites

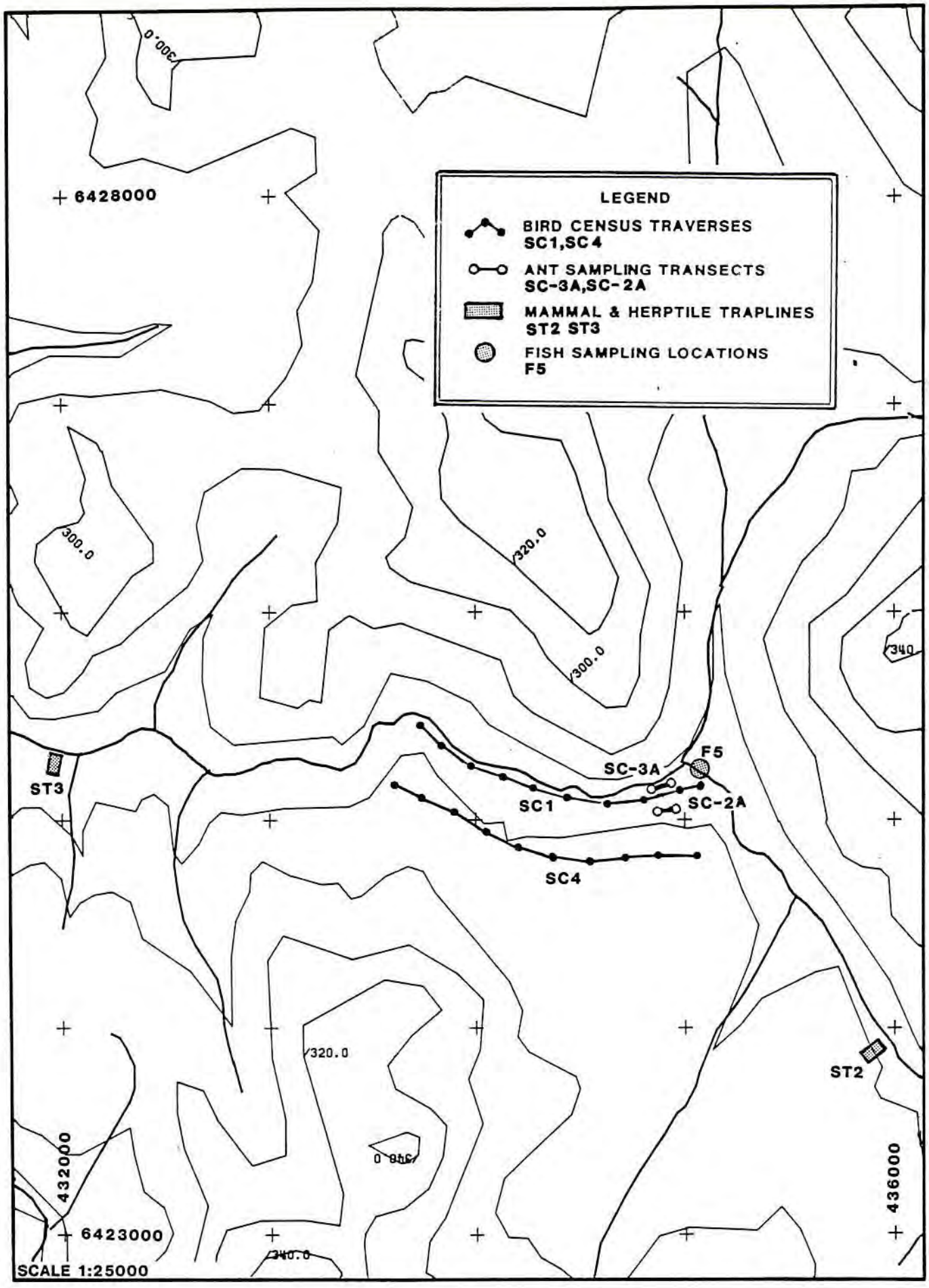
FIGURE 3A



RAISED CANNING DAM

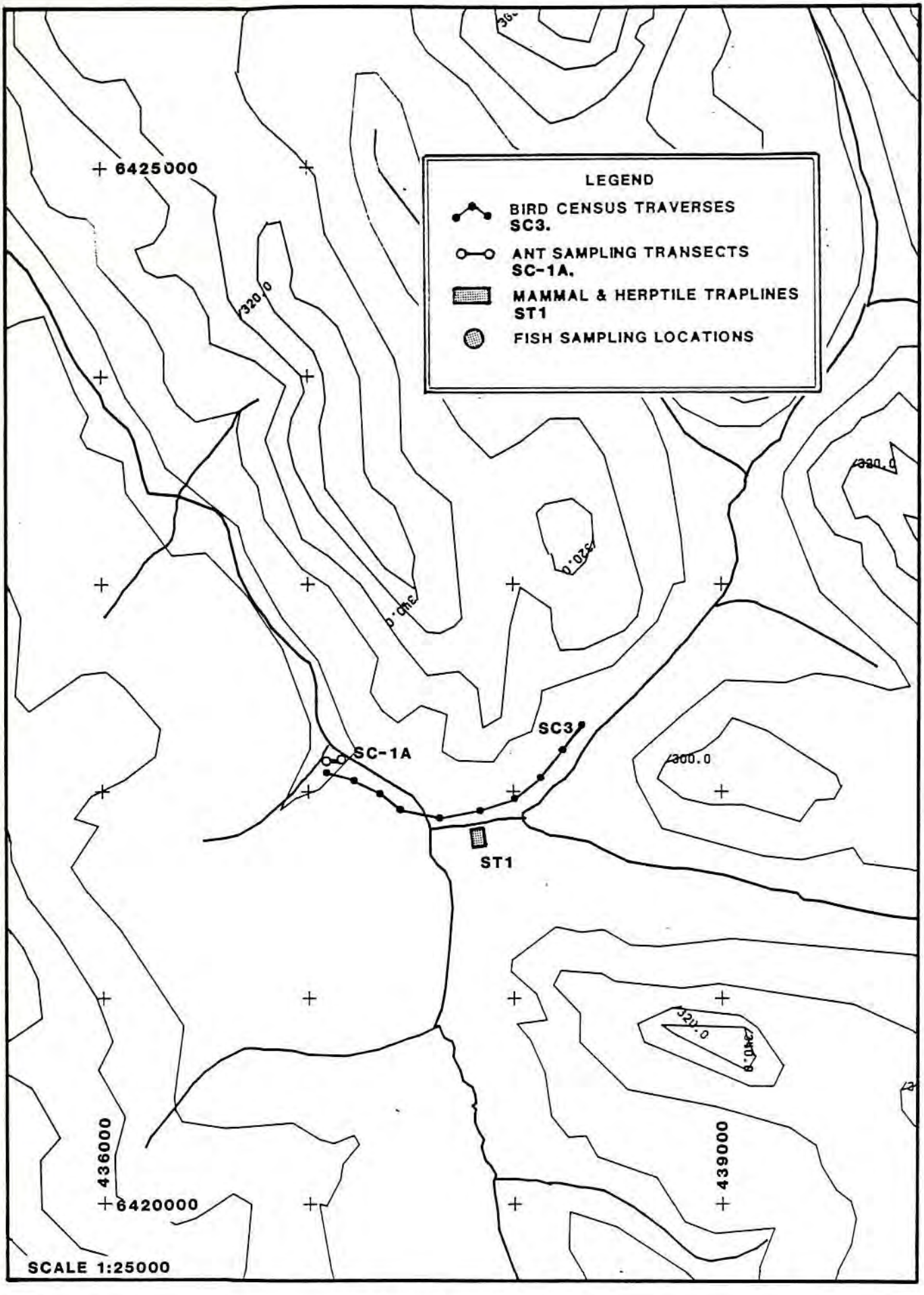
Fauna Sampling Sites

FIGURE 3B



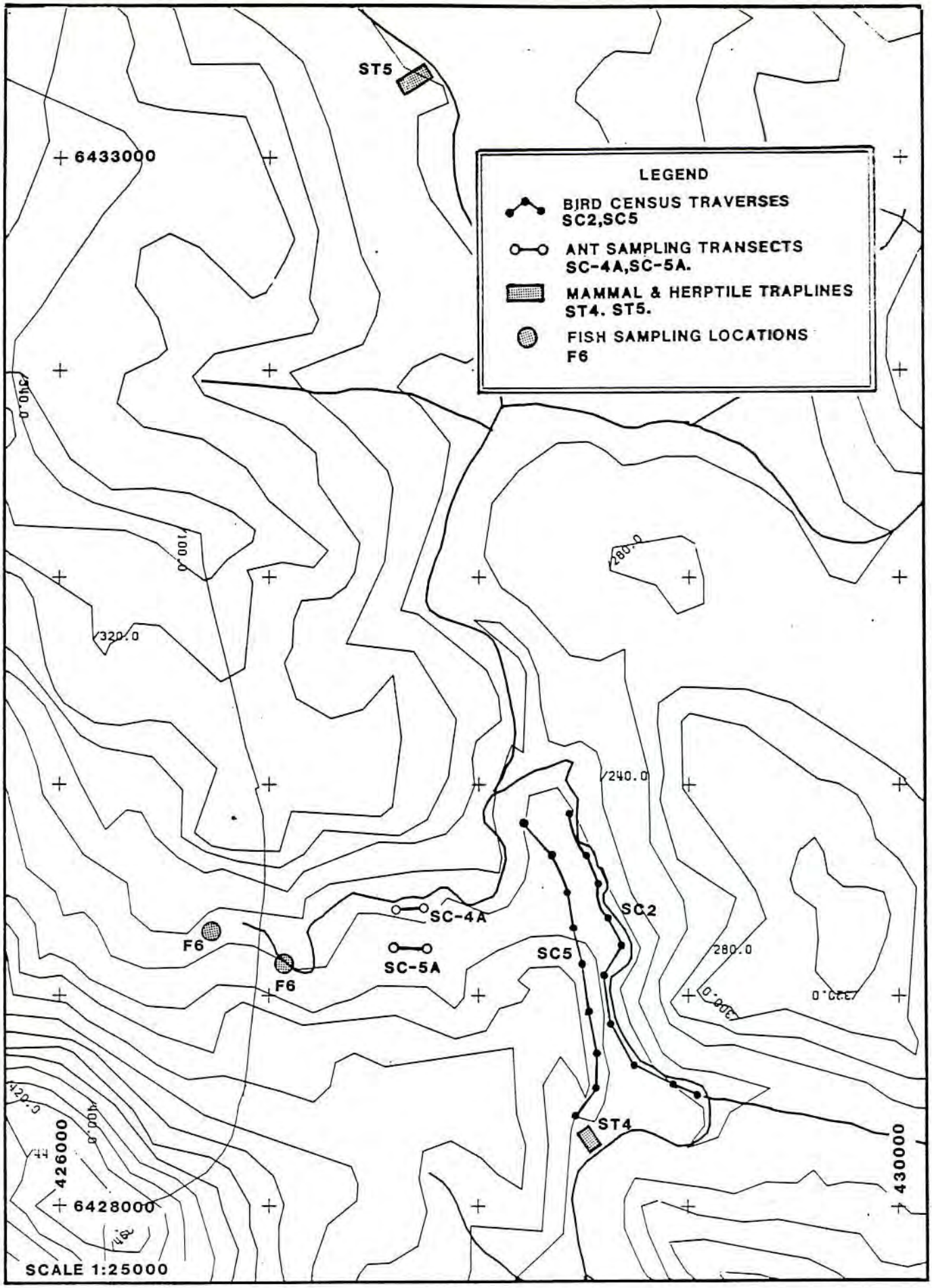
SOUTH CANNING DAM **Fauna Sampling Sites**

FIGURE 4A



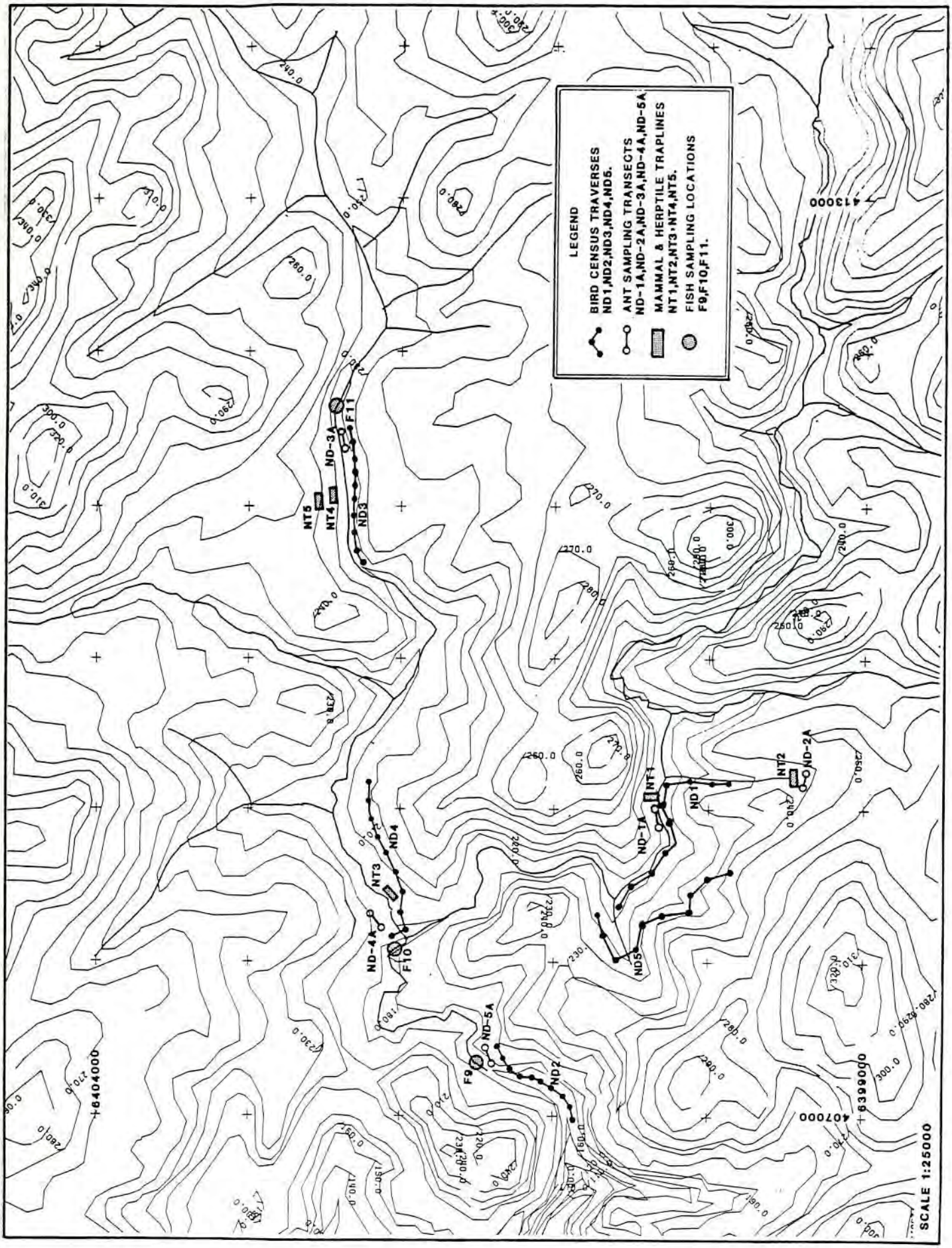
SOUTH CANNING DAM — Fauna Sampling Sites

FIGURE 4B



SOUTH CANNING DAM **Fauna Sampling Sites**

FIGURE 4C



NORTH DANDALUP DAM Fauna Sampling Sites

FIGURE 5

3. FAUNA OF THE NORTHERN JARRAH FOREST

The humid south-western corner of Western Australia is regarded by several authorities as a distinct zoogeographical region (Serventy & Whittell, 1976, Chapman & Dell, 1985). As defined by the avifauna this region includes the sub-humid area of the wheatbelt but for reptiles it is restricted to a much more confined mesic-temperate zone.

Climate and geological events have isolated south-western Australia from the south-eastern 'Bassian' region for long periods of time. Many endemic forms have evolved during these periods. The birds include the Western Rosella Platycercus icterotis, Red-capped Parrot Purpureicephalus spurius, Baudins Cockatoo Calyptorhynchus baudinii, White-breasted Robin Eopsaltria georgiana, Red-winged Fairy-wren Malurus elegans, Western Thornbill Acanthiza inornata and Western Spinebill Acanthorhynchus superciliosus. Amongst the mammals the south-western endemics include the Brush Western Wallaby Macropus irma, Honey Possum Tarsipes rostratus and the southern Bush Rat Rattus f. fuscipes. Examples of the endemic herptiles of the region are Sphenomorphus australis, Leiolopisma trilineatum, Diplodactylus polyophthalmus, Ctenotus labillardieri, snakes of the genera Notechis and Rhinoplocephalus and frogs in Crinia and Ranidella (J. Dell unpublished review). Other endemic forms have evolved which are not strictly of 'Bassian' origin for example the Red-eared Firetail Finch Emblema oculata and the Carpet Python Morelia spilotes imbricata. Some species are now restricted to south-western Australia although formerly having much wider distributions. Examples include the Numbat Myrmecobius fasciatus, Western Quoll Dasyurus geoffroii and Dibbler Parantechinus apicalis.

The forested Darling Plateau is a significant zoogeographic feature within the south-western faunal zone. It is an effective barrier between the drier wheatbelt and coastal plain which might otherwise have more similar faunas. Coupled with the isolating effects of the plateau topography, the heavier rainfall and distinct soil and vegetation complexes of Darling Ranges have led to the evolution of some locally distinct forms. The skink Ctenotus delli for example is restricted to a small area of the Northern Jarrah Forest. Generally however the vertebrate fauna of this system is drawn from that of the forested south-west and the adjacent sub-humid ecosystem.

The aquatic invertebrates of the scarp area however are particularly distinctive indicating considerable local isolation and evolution (Nicholls, 1933). Dell (1983) cites a review by Edward and Bunn (1983) which reported studies being undertaken on invertebrate fauna of streams in the Darling Ranges. These authorities considered that some elements were unnamed whilst others were rare, ancient and relictual and that this fauna had great biogeographical

significance.

In the Darling Range - Coastal Plain area (Darling System), the Scarp area is considered the most important environment for land snails (Dell 1983).

Christensen et al. (1985) analysed the mammal and reptile faunas from 25 surveys in the forests of south-western Australia. These analyses indicated the existence of four faunal zones. One of these, the 'Northern Jarrah/ Eastern Woodland Zone III', clustered the survey areas of Kelmscott, Dryandra, Sampson, Harris River and Jarrahdale and probably extends southwards to about Collie (33.5° S. Latitude). However many vertebrate species were widespread in the forested south-west.

The avifauna of the forested south-west is poorer in species than equivalent forests in south-eastern Australia. This is especially so for true forest 'Bassian' species and has been attributed to drier climatic periods in the regions history (Serventy & Whittell , 1976). Jarrah forest in particular is poor in species and has remarkably low bird population densities (eg. Wykes, 1983). A number of Jarrah Forest species have apparently declined in modern times perhaps over the last 40 years. These include the Western Yellow Robin Eopsaltria griseogularis, White-breasted Robin Eopsaltria georgiana (Serventy & Whittel, 1976), Grey Currawong Strepera versicola and in some localities the Rufous Treecreeper Climacteris rufa (D. Watkins R.A.O.U. pers. comm.)

South-western Australia represents a distinct biogeographic region for fishes, the Vlaminghian fluvial region (Allen, 1982). Chubb et al. (1979) lists four indigenous species from the Swan-Avon system Galaxias occidentalis, Tandanus bostocki, Bostockia porosa and Edelia vittata. These fishes are all endemic to south-western Australia but none are restricted to the northern Jarrah Forest (Allen 1982).

The best known invertebrate taxon of the Northern Jarrah Forest are the ants (Formicinae) which have been studied in relation to the monitoring of bauxite mining and rehabilitation and in the assessment of land systems and land use in the region (e.g. Majer, 1983; Rossbach & Majer, 1983; Majer et al., 1984). The ants have been found to be a functionally important component of the Jarrah fauna. Some species are predators of the economically important pest the Jarrah leaf miner Perthida glyphopa, whilst others disperse the seeds of the leguminous understory and assist post fire germination (Rossbach and Majer, 1983).

4. FAUNA OF THE PROJECT AREAS

4.1 Birds

Sixty (60) bird species were censused on the 18 traverses utilised during the fauna survey. The distributions and estimated densities for each species are presented in Appendix 1. Within each project area stream zone, Jarrah forest and Wandoo woodland traverses have been grouped. A small number of species were observed in the project areas but were not recorded on the census traverses and these are listed in Appendix 2.

The total bird densities and species richness values for the 18 traverses are presented in Table 2. These values are grouped by project area and broad habitat type. Bird species richness was highest in one Mundaring Stream zone traverse (ME2) and was generally higher in stream zones compared with forest and woodland sites. Excluding traverse (MEI), which had a woodland bird fauna (see below), the highest bird density also occurred at Mundaring although the stream zones at Raised Canning most consistently showed high densities. Within the project areas bird densities were always highest in the stream zones and lowest in the Jarrah Forest. Where Wandoo woodlands were present in the project areas their bird densities were typically intermediate. The general trend in bird densities between dam sites was somewhat reversed within the Jarrah forest where the highest values were in the higher rainfall Canning Dam and North Dandalup project areas.

The results of the similarity analysis of the bird census data are presented in a dendrogram (Figure 6). The traverses are clustered into three major groups. Group A collects all the stream zone sites from all project areas with the exception of Mundaring traverse MEI. The open stand of Eucalyptus rudis trees on this streamline forms a 'gallery' woodland and attracts a dry forest/woodland bird fauna and this traverse has therefore been classified with these habitats (Group C) in the analysis. Jarrah forest sites from South Canning, Raised Canning and North Dandalup are grouped in branch B. The drier Jarrah Forest at Mundaring is grouped in C with the Wandoo woodlands of Mundaring and South Canning. This reflects the pattern of rainfall in the region with the Jarrah at Mundaring receiving 800-900mm whilst all the other Jarrah sites were in rainfall zones in excess of 1000mm. The Wandoo sites in group C are closely linked especially the sites on flat areas with 'heavier' clay soils, i.e. Mundaring ME 4 and South Canning SC 3.

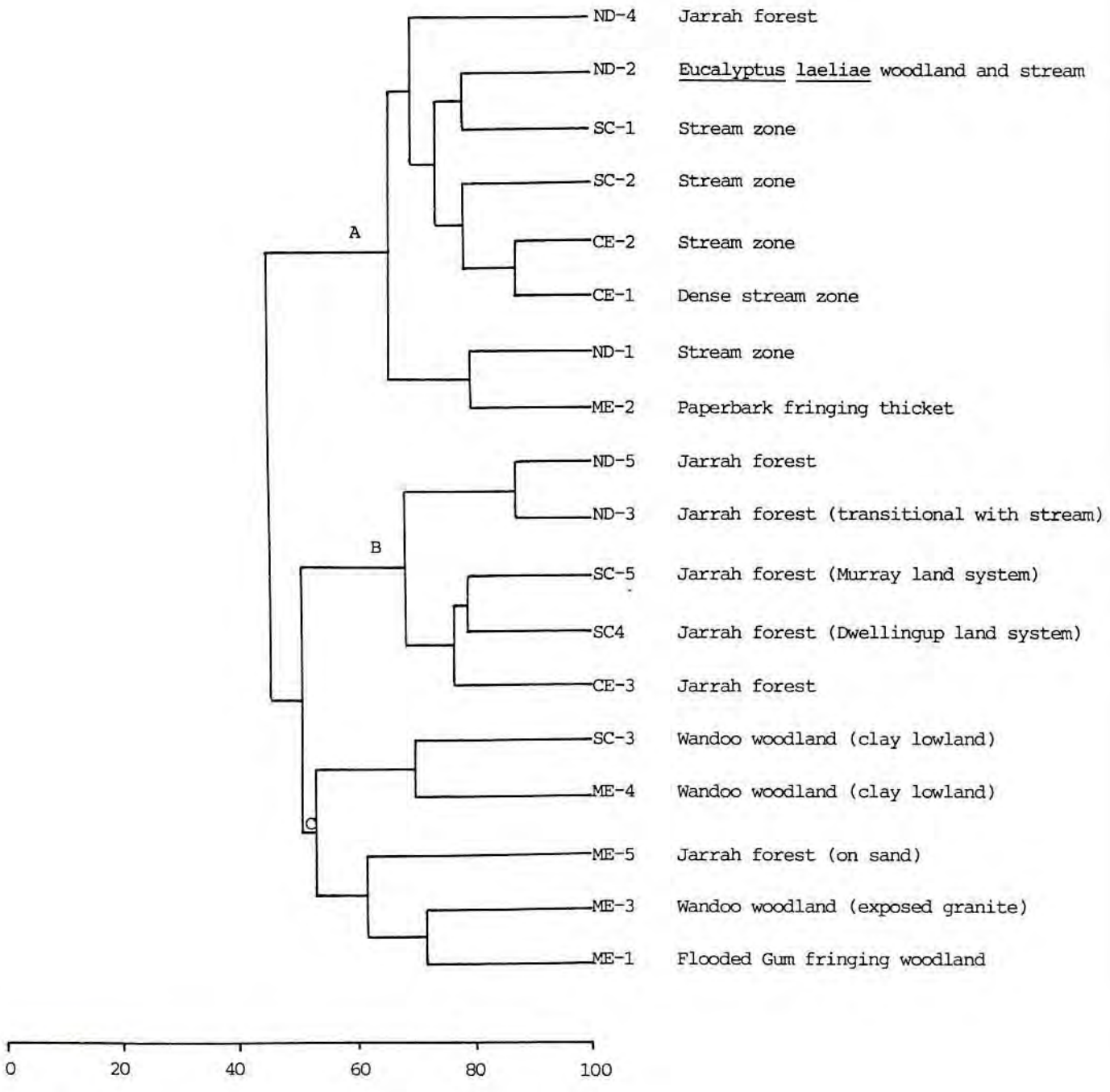
Considering the species/populations of highest conservation signifigance (Appendix 1): White-breasted Robins Eopsaltria georgiana were most abundant on one traverse at South Canning but were more widespread at Raising Canning and at North Dandalup. The species was absent from Mundaring. Yellow Robins Eopsaltria griseo-

Table 2

Species richness and total bird density values for the 18 bird census traverses. The results are grouped according to habitat and project area.

	Stream Zone									Jarrah Forest						Wandoo Woodland		
	ME1	ME2	SC1	SC2	CE1	CE2	ND1	ND2	ND3	ME5	SC4	SC5	CE3	ND4	ND5	ME3	ME4	SC3
RAISED MUNDARING																		
Species Richness	34	36								25						26	31	
Density (birds/ha)	16.0	74.1								15.9						12.2	43.9	
SOUTH CANNING																		
Species Richness			31	29							26	21						29
Density (birds/ha)			52.2	29.9							7.6	8.6						19.0
RAISED CANNING																		
Species Richness					30	28							26					
Density (birds/ha)					49.6	59.6							29.7					
NORTH DANDALUP																		
Species Richness							26	31	28					26	28			
Density (birds/ha)							30.9	19.8	21.3					8.8	18.4			

Figure 6. Classificatory dendrogram by the Cosine Theta Coefficient of 18 bird census traverses in the four water supply project areas.



gularis were generally rare and not recorded at Raising Canning. Red-eared Firetail Finches Emblema oculata were present in good numbers in the stream zones, at all project areas, with the highest density recorded at Mundaring.

4.2 Herptile Fauna

The herpetofauna of the four project areas is summarised in Appendix 3. The occurrence of species within the major habitat types in each area is indicated. The habitats are classified as stream zone, Jarrah forest, Wandoo woodland or Eucalyptus laeliae woodland (System 6 reserve proposal C 49). Within these classifications species found to have a strong association with granite formations are also indicated.

The herptile assemblages of the Jarrah forest and stream sites at South Canning, Raised Canning and North Dandalup areas were typical of the Northern Jarrah forest. The core species of this biogeographical region include Litoria adelaidensis, Crinia georgiana, Heleioporus eyrei, Ranidella glauerti, Ranidella pseudinsignifera, Diplodactylus polyophthalmus, Phyllodactylus maarmoratus, Phyllurus milii, Aprasia pulchella, Lialis burtonis, Pogona minor, Cryptoblepharus plagiocephalus, Ctenotus delli, Ctenotus labillardieri, Egernia luctuosa, E. napoleonis, Hemiergis inititialis, Leiolopisma trilineatum, Lerista distinguenda, Menetia greyii, Morethia obscura, Tiliqua rugosa, Varanus gouldii, V. rosenbergi, Rhamphotyphlops australia, R. pinguis, Morelia spilota, Notechis scutata, Pseudonaja affinis, Rhinoplocephalus gouldii and R. nigriceps. However at Mundaring in particular and in the drier habitats in the Canning drainage there is an intrusion of reptile species from the sub-humid eastern woodlands and wheatbelt and from the coastal plain and Darling Scarp (Chapman & Dell, 1985; Dell, 1983). At Mundaring these species include the geckoes Diplodactylus granariensis, Gehyra variegata and Oedura reticulata, the legless lizard Aprasia repens, the skink Ctenotus fallens (Museum records), the monitor Varanus tristis and the burrowing snake Vermicella semifasciata. At South Canning the skink Ctenotus impar occurred in the sandier habitats and the legless lizard Pygopus lepidopodus was common whilst at Canning Dam the sub-humid reptile fauna was represented by the Death Adder Acanthophis antarcticus and again by Gehyra variegata. North Dandalup shows no affinities with this sub-humid reptile fauna. In the direct area, Mundaring, some Northern Jarrah Forest reptiles disappear or become very rare e.g. Ctenotus delli, C. labillardieri and Egernia luctuosa. The herpetofauna of the four project areas thus shows the same biogeographical trends implicated in the similarity analysis of the bird sampling.

The granite formations in all project areas were important reptile habitats. This was especially so for the dragon Ctenophorus ornatus although this species was

generally scarce at North Dandalup near the limit of its distribution. Among the geckoes Diplodactylus polyophthalmus commonly occurred amongst granite slabs and Gehyra variegata was probably restricted to this habitat. The rare python Morelia spilota was captured at Mundaring and North Dandalup in the viscinity of granite formations. Radio-tracking has shown this species to use granite areas intensively for shelter (Worsley Alumina Pty. Ltd., 1985).

The large skink Egernia kingii was observed in all project areas. It is usually associated with talus, weathered boulders or artifical rock rubble (e.g. around culverts).

The Long-necked Tortoise Chelodina oblonga was common in the relatively still and intermittent headwaters at Mundaring and South Canning but was not recorded downstream at Canning Dam or on the fast flowing North Dandalup river.

4.3 Mammals

In Appendix 4, the mammal fauna of the four project areas is presented using the same habitat classifications. This fauna is typical of a wide area of the southern forests including the Northern Jarrah Forest. An exception is Gilbert's Dunnart Sminthopsis gilberti which is apparently inhabitant of heaths and woodlands with heavy soil in the eastern woodlands and wheatbelt (Kitchener et al., 1984). In this study it was only encountered in Wandoo Woodland on friable clay soil at South Canning. The Quenda Isoodon obesulus and Mardo Antechinus flavipes are far more common in stream zone vegetation and the Echidna Tachyglossus aculeatus is most frequently near granite outcrops and other open areas where their prey, meat ants Iridomyrmex purpureus, are abundant. From a conservation standpoint the most significant species recorded are the Western Brush Wallaby Macropus irma which is a common but declining species and the Western Quoll Dasyurus geoffroyi which is probably endangered. There are fairly regular recent records of the Quoll from the Northern Jarrah Forest, which may be its remaining stronghold, and from Perup Forest (Christensen et al., 1985).

The bat fauna for all project areas was certainly undersampled. All seven species recorded probably occur throughout. In addition Nyctophilus major is probably present in all areas and Falsistrellus mackenzei would be expected at least from the Canning and North Dandalup areas (Liene, 1984).

4.4 Ants

Seventy-four (74) ant species were collected at the 18 sampling sites in the project areas. These species are listed in Appendix 5 together with the number of individuals collected in the pitfall traps. Ant species collected only during the searches are shown as present or absent. At the foot of Appendix 5 the total species

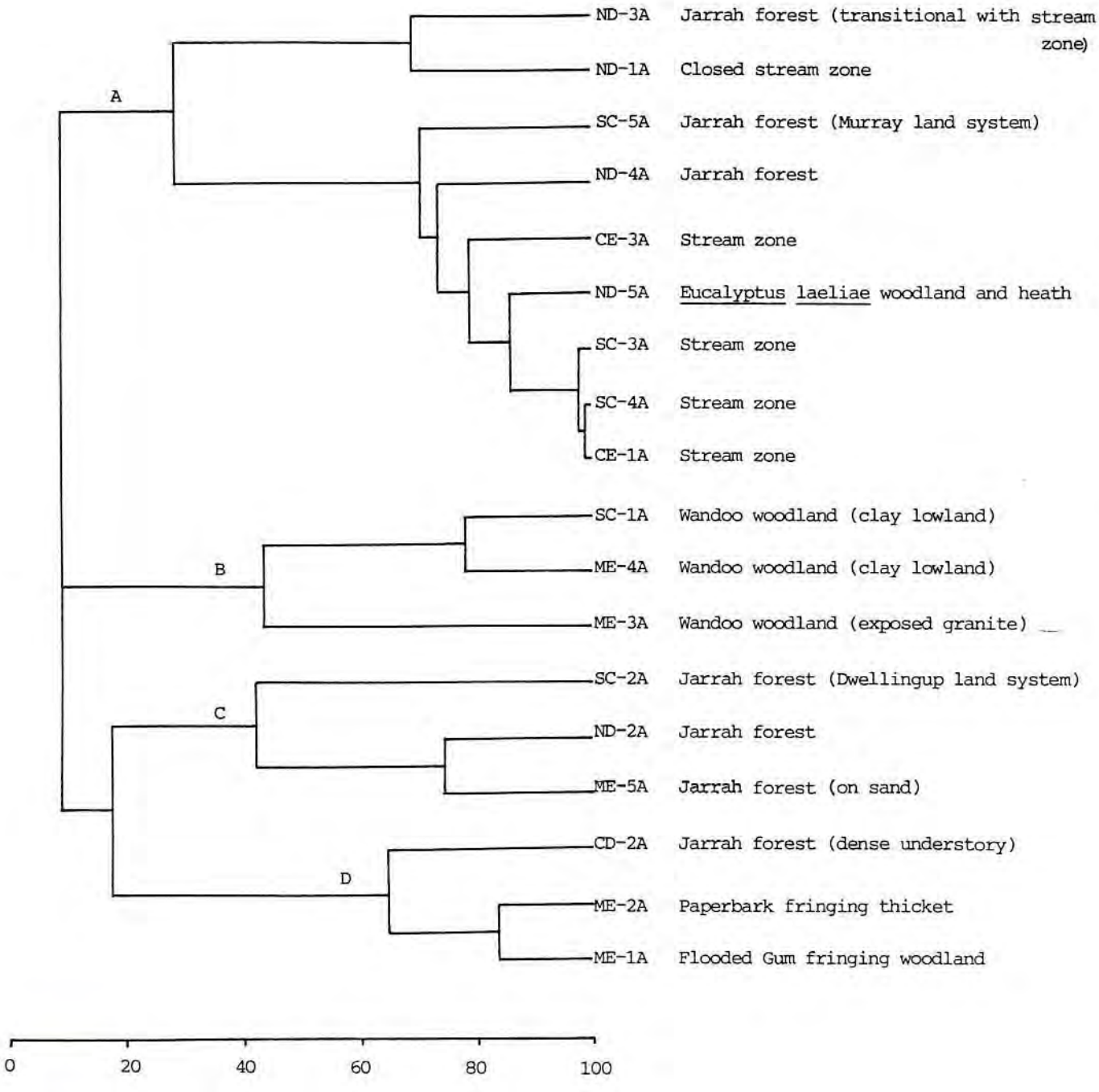
richness, pitfall species richness, species density/m , total individuals and dominance index are shown for each sampling site.

A dendrogram was produced from the similarity analysis of these data (Figure 7). This dendrogram shows four main branches. Branch A (Figure 7) groups together an array of stream zone and higher rainfall Jarrah forest sites from South Canning, Raised Canning and North Dandalup. These sites have in common high moisture status and a dense to mid-dense shrub stratum. The stream zones at Mundaring have a different ant community and constitute different ant habitats (Group D). The ant community of the Mundaring stream zones does however have affinities with a Jarrah forest site with a dense understorey at Raised Canning (CE-2A). Group B gathers the ant assemblages of the Wandoo woodlands at Mundaring and South Canning. The woodland on clay soils (ME-4A, SC-1A) showing the strongest affinities in ant species composition. Jarrah forest sites in drier environments with relatively open understoreys are gouped in branch C. This includes forest sites in the drier project areas of the upper South Canning and Mundaring.

The results of the similarity analysis on ant communities contrast with that on birds in a number of respects. The biogeographic trend from the drier north and east to the wetter south and west is less evident. Further the ant fauna appears to be more responsive to the state of the understorey and the related local site moisture status than to the upper, tree stratum. Ant responses may be similar in this respect to those of small mammals and contrast with what was observed in birds and herptiles. The analysis of ant species composition distinguishes a second regional stream zone habitat group, re-classifies the remaining stream zone and Jarrah forest habitats, apparently according to understorey density, and elevates Wandoo woodland as a distinct unit differing from other drier habitat types.

The values for total and pitfall species richness generally fall within those described for undisturbed western australian ecosystems. However some sample sites differed from the expected range of 14 - 25 pitfall trapped species (Majer, 1983). All these were in stream zones. Sites ME-2A and ME-4A at Mundaring had excessively high species richness whilst in South Canning SC-3A and SC-4A richness was too low. Generally the sample sites had low dominance index values characteristic of undisturbed systems however Mundaring stream zone ME-1A and Canning stream CE-1A had high dominance indicies suggesting some perturbation. At Mundaring ME-1A this resulted from the abundance of the opportunistic meat ant Iridomyrmex purpureus. South Canning sites SC-3A and SC-4A had low richness and high dominance values indicating considerable disturbance. The presence of the tramp species Cardiocondyla nudum further supports this interpretation. This was apparently due to soil disturbance and vegetation changes induced by feral pigs. The slight disturbance at

Figure 7. Classificatory dendrogram by the Cosine Theta Coefficient of 18 ant sampling sites in the four water supply project areas



Canning CE-1A may also be attributable to these animals.

The species densities recorded in this study were higher than those recorded previously (Majer, 1983). This was not correlated with higher than normal species richness and so probably in some way relates to the efficiency of the traps. Ants were more abundant in the drier environment and more open vegetation at Mundaring. Such conditions are 'preferred' by ants in general.

4.5 Fishes and Freshwater Crayfishes

The results of the fish sampling are presented in Table 3 (Nomenclature follows Allen, 1982). The faunas of the Mundaring and southern Canning catchments contained five of the six expected indigenous fishes. Although in the Canning catchment their distributions are discontinuous (Aquatic Research Laboratory, 1987). The absentee was the Goby Pseudogobius olorum which occurs in the freshwaters of the Serpentine River (P. Chrystal pers. comm.). The Hardyhead Atherinosoma wallacei was absent from the Canning above the existing reservoir. Of the decapod crustaceans Marron Cherax tenuimanus was not recorded at Mundaring.

The indigenous fish fauna of the upper North Dandalup River appears to be depauperate with only Galaxias occidentalis present in any numbers. The Nightfish Bostockia porosa was recorded by the Aquatic Research Laboratory (Edward et al.) but was apparently scarce in this part of the river. The reasons for this are not known.

4:6 Aquatic Fauna Communities

The Aquatic Research Laboratory (ARL) of the University of Western Australia are undertaking a long term study of the macroinvertebrate and fish faunas of the North Dandalup and Canning River Systems. To assist in the current objective of assessing the representativeness of alternative project areas the laboratory has provided an appropriate analysis of its early data. Similarity analyses were carried out which were equivalent to those used to compare the terrestrial bird and ant faunas of the project areas. (For details on methods of analysis and results see Aquatic Research Laboratory 1987).

4.6.1 Macroinvertebrates

A total of 202 taxa were recorded by A.R.L. from the catchments of the two river systems. The North Dandalup Catchment held 144 taxa whilst the Canning Catchment had a higher species richness, with 164 taxa. Of these taxa a total of 106 were common to both catchments.

The broadest distinction between macroinvertebrate communities was not between the two river systems but between upland and coastal plain localities. However within that context the upland sites of the North Dandalup

Table 3.

The fish species collected by electro-fishing in streams of the Raised Mundaring, South Canning, Raised Canning and North Dandalup project areas. Species are recorded as being common (C) or present (P) at each site. The age classes are given in parenthesis (i.e. 0+ first year of life, 1+ second year, 2+ third year).

Sites	Mundaring				
	Helena & Darkin Rivers				
Species	**F1**	**F2**	**F3**	**F4**	**F5**
Atherinosoma wallacei	C(H)		C(1+)		
Bostockia porosa	C(0+)			C(0+)	
Edelia vittata	C(0+,1+)	C(0+)	C(0+)	C(0+)	N
Galaxias occidentalis	C(1+)		C(1+)		I
Gambusia affinis*		C(0+)		C(0+,1+)	L
Salmo sp*					
Tandanus bostocki				C(0+)	
Cherax quinquecarinatus	C(0+,1+)		P(1+)	C(1+)	
Cherax tenuimanus					

Sites	Canning			
	River			
Species	**F6**	**F7**	**F8**	
Atherinosoma wallacei				
Bostockia porosa	C(0+,1+)		P(0+,1+)	
Edelia vittata	C(0+,1+)		C(0+)	
Galaxias occidentalis	C(1+)			
Gambusia affinis*			C(0+,1+)	
Salmo sp*				
Tandanus bostocki	P(1+)			
Cherax quinquecarinatus	C(0+)		C(0+,1+)	
Cherax tenuimanus		P(2+)		

*introduced species

Table 3 cont. overpage.

Table 3. cont...

Sites	North Dandalup River		
Species	F9	F10	F11
Atherinosoma wallacei			
Bostockia porosa			
Edelia vittata			
Galaxias occidentalis	P(1+)	P(1+)	C(1+)
Gambusia affinis*			
Salmo sp*		P(1+)	
Tandanus bostocki			
Cherax quinquecarinatus	P(0+,1+)	P(0+,1+)	C(0+,1+)
Cherax tenuimanus	P(0+)		C(0+)

*introduced species

were distinct from those of the Canning with the exception of the one or two sites with permanent water close to the limits of the existing dam.

The distinctiveness of the upland streams of the North Dandalup and Canning River systems was attributed to stream permanence and duration of flow. North Dandalup's more southerly location and position near the scarp edge leads to higher rainfall and permanent stream types. With the exception of the lower reaches, the upland Canning catchment sites are on intermittent streams. Thus the Canning project area might be expected to have similar aquatic macroinvertebrate communities to low rainfall Mundaring, leaving North Dandalup with the most unique aquatic environment.

5. EVALUATION OF FAUNA RESOURCES

A number of ecological characteristics of the project areas could be used to evaluate their fauna resources and to rank the options in terms of their relative importance to wildlife conservation.

5.1 Community Representation

At the community level assemblages of animal species can be evaluated in terms of their representation within the state or its biogeographic regions. The importance of 'representation' should be weighted in favour of the most limited or impacted ecosystems, i.e. towards under-representation. Unfortunately the presence or absence of particular animal communities in conservation reserves cannot be adopted as a 'criteria' of representation. In contrast to the extensive knowledge of plant communities in the reserves or proposed reserves of the Darling System relatively little is known about animal communities. The occurrence of 'habitat' is not an adequate indicator of fauna here as a host of largely historical factors intervene in affecting the distribution and abundance of animals in south-western Australia. Further the presence of animal communities in reserves does not automatically establish confidence in their conservation, this being a function of long term management policies and techniques.

The results of the fauna surveys, and of the classicatory analyses of the bird and ant communities of the project areas, give rise to the following generalisations on 'representation'.

(a) The terrestrial fauna of all four project areas is generally representative of lower slopes and fluvial valleys of the Northern Jarrah Forest. However in the northern project areas there is a change in bird communities and incursion of reptile species reflecing some affinties with the eastern woodlands and/or coastal plain environments. This is especially the case at Mundaring which is strongly transitional between the Northern Jarrah Forest and adjacent sub-humid systems. Thus the Canning River and North Dandalup project areas are more representative of the restricted valley habitats of the Northern Jarrah Forest. Conversely the faunal assemblages at Mundaring would be expected to occur more widely and may be represented in for example the Julimar State Forest or Dryandra National Park.

(b) The habitat assessment shows that with the exception of some gallery woodland at Mundaring the bird communities of the stream zones are very similar in all project areas. This is also true for all the wetter Jarrah Forest sites at South Canning, Raised Canning and North Dandalup. Thus with respect to birds the impact is simply proportional to the area of habitat (or length of stream zone) to be inundated. The Wandoo environments have a

distinctive fauna which would be affected at South Canning and Mundaring.

The analysis of ant communities does not substantially alter this view apart from distinguishing the drier forest types and the Mundaring stream zones as sub-habitats. With the exception of the Wandoo woodlands the same fauna habitats are represented in the South Canning, Raised Canning and North Dandalup project areas and to a lesser extent at Mundaring.

5.2 Bird Species Richness and Relative Abundance.

The diversity, or species richness, and the relative abundance of wildlife could also be used to evaluate the different options. In Table 3 the parameters species richness and total density were presented for the bird communities censused on traverses within the project areas. Species richness in comparable habitats did not differ greatly between project areas although one Mundaring stream zone traverse had an exceptionally high number of species. The total densities of birds however showed large variations between habitats and project areas. In the stream zone habitats the highest bird densities were found at Mundaring, followed by Raised Canning , South Canning and North Dandalup. This trend was generally reversed in the poorer Jarrah habitats. The existence of the stream zone vegetation, with its higher productivity, probably influences the abundance and mobility of the adjacent Jarrah forest fauna. The loss of the stream zone area will almost certainly reduce fauna utilisation of the adjacent Jarrah forest.

5.3 Species of High Conservation Priority

The occurrence of species listed as "requiring special protection" under the regulations of the Wildlife Conservation Act (1950) may be of some signficance in evaluating the fauna of the project areas. The wildlife regulations however do not have any direct bearing on land-use or project development in constrast to the situation with rare flora. Permits are not required to clear or disturb habitat containing rare fauna as is the case for example with plants occurring on privately controlled land. During the fauna survey the following 'gazetted' species were recorded in the project areas (Government Gazette W.A., November 1995).

Western Quoll - Dasyurus geoffroii (Raised Canning)
Crested Shrike-tit - Falcunculus frontalis (Mundaring)
Red-eared Firetail - Emblema oculatum (all project areas)
Dell's Skink - Ctenotus delli (South Canning, Raised Canning, North Dandalup)
Carpet Python - Morelia spilota imbricata (Mundaring, North Dandalup)

The Western Quoll has shown a dramatic decline in range since European settlement and is now restricted to a

few small pockets of forest in south-western Australia. The Northern Jarrah Forest is probably the most important area in its remaining distribution. The large area requirements of this species will render it vulnerable to further loss of habitat and is therefore considered the most important conservation priority.

Forested areas of south-western Australia are not the 'preferred' habitats of the Crested Shrike-tit. Its occurrence at Mundaring is marginal and therefore not of great conservation significance.

Red-eared Firetails were common in the stream zone vegetation in all project areas. The relative impact on this species will be encompassed by the area of stream zone inundated. Its dependence on the stream zone vegetation give it an intermediate priority. With each development its regional status should be monitored.

Dell's Skink was common in all project areas except Mundaring. Although of restricted distribution the species appears to have wide habitat preferences and is unlikely to be endangered by any dam projects. The Carpet Python was probably associated with outcropping granite formations. At North Dandalup it was recorded on the scarp below the proposed dam walls. Its occurrence in at least two of the project areas is not considered a major conservation issue.

Some species which are not 'gazetted' by the state wildlife authorities have shown a marked decline within a biogeographical region. One such species which was locally abundant in the stream zones of some project areas was the White-breasted Robin Eopsaltria georgiana. The high densities at South Canning (Table 2a) may confer additional fauna value on that project area.

5.4 Disturbance to Animal Communities

The ant sampling indicated disturbance in stream zone environments at Mundaring, South Canning and Canning (Raised Canning). The two South Canning sites were highly disturbed. Both here and at Raised Canning CE-1A the source appeared to be soil disturbance by feral pigs. This form of disturbance would be expected to affect other ground living invertebrate and vertebrate communities. One Wandoo woodland site at Mundaring (ME-4A) also showed signs of slight disturbance in the ant community. There was no evidence of disturbance in the ant assemblages at North Dandalup.

5.5 Aquatic System Impacts

The fish faunas of the Helena and Darkin Rivers (Mundaring), and the upper Canning River system are similar however the Canning apparently lacks the Hardyhead Atherinosoma wallacei. Marron Cherax tenuimanus were not recorded at Mundaring. All streams lacked the Goby Pseudogobius olorum found in the freshwaters of the Serpentine (P. Chrystal pers. comm.). The upper North

Dandalup River was depauperate in freshwater fishes particularly indigenous species.

Little is known about the biology of our indigenous freshwater fishes. However in an effort to evaluate the impact of the four dam projects Luke Pen of Murdoch University has provided an informal assessment. This is presented as Appendix 6 of this report.

Despite the paucity of fishes, North Dandalup by virtue of its permanent upland streams, probably has the unique aquatic environments of the four project areas. This has been demonstrated in part by a similarity analysis of the macroinvertebrate communities of the Canning and North Dandalup catchments (Aquatic Research Laboratory 1987).

At North Dandalup the type locality of the rare stonefly Riekoperla occidentalis may be threatened by the reservoir.

5.5.1 Impact of the reservoirs

As with the terrestrial fauna the major impact of the reservoirs is the loss of a fish habitat area. More specifically the loss streamline aquatic environments with their shelter and foodchains, the loss of shaded water, emergent and sub-emergent vegetation and of flooded ephemeral margins. Such environments are essential to meet all the ecological requirements of freshwater fishes. Of all the indigenous species Tandanus bostocki is the only one which may meet all its requirements in a dam environment.

The reservoirs are however frequently ideal environments for introduced predacious fishes such as the Red-fin Perch Perca fluviatilis. These fishes are voracious predators of the smaller indigenous fishes and crayfishes. The impact of heavy predation in the reservoir and upper reaches would be exacerbated by the absence of restocking from below the dam wall. This barrier would also genetically isolate fish populations above and below reducing their long term viability. In the South Canning catchment, with its high evaporation, the fishes could conceivably disappear altogether above the dam wall after a protracted dry period. Again the barrier would prevent restocking. Although most of the effects of dams are deleterious to freshwater fishes, in some instances these permanent water environments may offer refuges over the summer drought. This in turn would facilitate restocking of the headwaters in winter.

Generally however the impact of the reservoirs will be proportional to their area.

5.5.2 Downstream impacts

Most species appear to move upstream during the winter flow and Galaxias and Bostockia have been observed to spawn on the shallow ephemeral margins of headwaters. Dam walls limit the winter fish migration downstream and may exclude

fishes from suitable spawning areas (ie. typically dams are constructed where the rivers are incised and the discharge rate is highest). Barriers already exist at Mundaring, Raising Canning and North Dandalup and further impact at these sites will be small. However the South Canning dam would isolate a large area of headwaters from the main summer fish refugia.

The effects of altered flow downstream will depend on the magnitude and seasonality of the changes. The greatest changes will occur at North Dandalup and South Canning.

At South Canning there will be an aperiodic summer release of water to supplement the Canning Reservoir. Such flows would rarely occur in nature and may induce inappropriate responses in the fishes. Sudden releases of large volumes of cold "bottom water" from the dam could cause mortality due to temperature shock in fishes concentrated in warm stagnant pools. This could be avoided by initially releasing a trickle allowing temperatures to gradually equilibrate and then allowing the full flow. Galaxias in particular may migrate upstream in response to the flow only to be caught in short-lived pools. However the oxygenation of the stagnant pools which would take place and inhance survival, would possibly offset any mortality caused by inappropriate migration.

Some reduction in winter flows would result from all projects but again would be most severe at North Dandalup and South Canning. The main effects could include reduced mixing in the long-term pools and the loss of spawning areas due to a lack of overflow.

Reduced flow over summer is considered the most deleterious process and here North Dandalup will be most affected. Much higher summer mortality would be expected where pool size and life is shortened and deoxygenation and salinity increases (ie. due to evaporation). However the North Dandalup river close to the proposed dam wall is apparently already depauperated in fishes.

The downstream impact will almost certainly be greatest with the South Canning project. This would isolate a much reduced area of stream between two dams on the Canning River and releases from the South Canning Dam would be severely constrained by the nature of the dam and its role in the supply system. The raising of the existing Canning Dam would impact the aquatic systems of the Monadnocks reserve.

5.6 Independent and Interdependent Options

As an option the impact of the South Canning project increases because it is the second dam in the catchment. The construction of this dam will also impinge on the Raised Canning area through its downstream affects and in isolating the stream zone habitat in a relatively small area between the two dams. The isolation of small populations in reduced areas could in itself lead to local extinctions e.g. in Red-eared Firetails, White-breasted

Robins or indigenous fishes. The remnant stream zones in the upper reaches above South Canning would be equally isolated with the large full supply area acting as a barrier.

It is generally considered desirable in conservation terms to manage entire drainage or land systems for that purpose. The South Canning option would have an environment upstream of a conservation area managed for the purposes of water storage rather than just catchment as at present. This would reduce the viability of the stream zone within Monadnocks reserve.

5.7 Ranking of Options

The fauna resources of the four project areas are ranked in the summary table (Table 4). A scale of 1 to 4 has been used. The highest numerical values correspond to the highest fauna values and lowest preferred water supply option. The major rankings at the foot of the table indicate the consultants subjective evaluation of the balance of factors.

5.8 Further Investigations

Although conducted over a relatively short period the general survey of vertebrate fauna would appear to be adequate for ERMP purposes. The ground fauna at Raised Canning may be the only exception. Any further investigations should be oriented towards wildlife management. The following projects are recommended;

1) Regardless of which water supply alternative is selected a long term monitoring study of the stream zone birds, the Red-eared Firetail and White-breasted Robin, should be established. This should be a bird banding/recovery exercise aimed at determining population size, habitat area relationships, interchange etc. The most cost effective method may be to provide a postgraduate studentship or commission the Royal Australian Ornithologists Union.

2) The status of the Western Quoll at Raised Canning should be thoroughly investigated should this option be selected.

3) Should South Canning be selected then laboratory tests should be conducted on the temperature tolerances and acclimatisation rates of indigenous fishes.

4) Again should South Canning be selected an interdisciplinary group should look at the use of sluice gates on the stream to create spawning habitat for fishes when there are reduced winter flows below the dam.

5) Irrespective of which option is selected research on the biology of our indigenous freshwater fishes is urgently required.

Table 4

	Raised Mundaring	South Canning	Raised Canning	North Dandalup
Fauna representative of the Northern Jarrah Forest	1	3	4	4
Species richness and abundance (birds)	4	2	3	1
Area of habitat affected	3	4	1	2
Species of high conservation priority	3	2	4	1
Ecological disturbance	2	1	3	4
Aquatic Systems	2	4	3	1
Interdependence effects	1	4	1	1
Total Ranking	2	3	4	1

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Appendix 1

The bird species recorded within 60m of stations on the 18 bird census traverses in the four project areas. Estimated densities (in birds per hectare) are given for each species occurring on the traverse. Species nomenclature follows Blakers et al. (1984).

STUDY AREA	Raised Mundaring					Raised Canning			South Canning					North Dandalup				
VEGETATION	Stream		Wandoo		Jarrah	Stream		Jarrah	Stream		Wandoo		Jarrah	Streams			Jarrah	
SITE CODE	1	2	3	4	5	1	2	3	1	2	3	4	5	1	2*	3	4	5
SPECIES																		
PHALACROCORACIDAE																		
Phalacrocorax melanoleucos - Little Pied Cormorant	0.04																	
ANATIDAE									2.54									
Anas superciliosa - Pacific Black Duck										0.16								
A. gibberifrons - Grey Teal																		
Chenonetta jubata - Maned Duck	0.16					0.14	0.14											
ACCIPITRIDAE																		
Lophoictinia isura - Square-tailed Kite			0.04															
Accipiter fasciatus - Brown Goshawk									0.03						0.03			
A. cirrhocephalus - Collared Sparrowhawk	0.04	0.16																
Accipiter sp.								0.04										
Aquila audax - Wedge-tailed Eagle							0.03											
COLUMBIDAE																0.64	0.04	
Phaps chalcoptera - Common Bronzewing	0.64				0.32													
CACATUIDAE																		
Calyptorhynchus sp. - White-tailed Black Cockatoo	0.64			0.02						0.95			0.11		0.34			0.02
LORIIDAE																		
Glossopsitta porphyrocephala - Purple-crowned Lorikeet		0.21		0.16	0.50						0.14							
PLATYCERCIDAE																		
Purpureicephalus spurius - Red-capped Parrot	0.64	0.28	0.12	0.44		0.28	0.48	0.14	0.63	0.05	0.05	0.01	0.04	0.20	0.21	0.03	0.16	0.64
Platycercus icterotis - Western Rosella		0.71		0.12		0.64					0.15			0.16	0.21	0.08		0.21
Barnardius zonarius - Pot Lincoln Ringneck	0.64	2.07	0.32	1.27	0.04	0.08	0.32	0.48	0.11	0.64		0.47	0.16	0.64	0.32	0.16	0.64	1.20
Neophema elegans - Elegant Parrot		0.07		0.21										9.12	9.96			0.36
CUCULIDAE									0.33				0.16			0.07		0.04
Cuculus pyrrhophanus - Fan-tailed Cuckoo																		
Chrysococcyx basalis - Horsfield's Bronze-cuckoo		0.02		0.03														
C. lucidus - Shining Bronze-cuckoo		0.05		0.03		0.03	0.03	0.14	0.01	0.04	0.01	0.01	0.04			0.03	0.03	
ALCEDINIDAE																		
Dacelo novaeguineae - Laughing Kookaburra	0.07		0.04		0.07						0.39					0.02		0.02
Halcyon sancta - Sacred Kingfisher	0.32	0.03		0.03		0.64		0.02		0.04	0.07			0.04				
MEROPIDAE																		
Merops ornatus - Rainbow Bee-eater	0.31	0.04	0.08		0.16		0.03		0.03	0.03	0.05	0.07						
HIRUNDINIDAE																		
Cecropis nigricans - Tree Martin	0.23	1.59		3.82	1.59	0.60	0.96	0.28	0.31	0.05	2.50	0.07	0.04	0.25	0.80	1.27	0.05	2.05
CAMPEPHAGIDAE																		
Coracina novaehollandiae-Black faced Cuckoo-shrike	0.20	0.07	0.64	0.08	0.04				0.64								0.07	0.07
MUSCICAPIDAE																		
Petroica multicolor - Scarlet Robin	0.14	0.16	0.64		0.64			0.42			0.35	0.07					0.64	0.04
P. goodenovii - Red-capped Robin					0.16													
Eopsaltria georgiana - White-breasted Robin						1.91	0.64		4.45					1.27	0.14	0.64	0.16	
E. griseogularis - Western Yellow Robin		0.48										0.03						0.16
Falcunculus frontatus - Crested Shrike-tit		0.21																
Pachycephala pectoralis - Golden Whistler	0.20	1.91	0.21	0.64	0.08	1.91	1.27	0.80	2.50	2.55	0.15	0.03	0.08	2.55	2.55	0.48	0.16	0.16
P. rufiventris - Rufous Whistler	0.12	0.14		0.04										0.14				
Colluricincla harmonica - Grey Shrike-thrush	0.04		0.14	0.21		0.64		0.16		0.14		0.14	0.16	0.03	0.14		0.03	0.03
Rhipidura fuliginosa - Grey Fantail	1.91	5.09	0.64	2.55	0.64	3.18	0.80	1.27	5.09	1.27	0.47	0.03	0.14	4.46	1.27	0.95	1.11	0.95
MALURIDAE																		
Malurus splendens - Splendid Fairy-wren	0.28	5.73	1.27	0.52	1.91	0.80	4.46		0.47	0.64	0.07	0.14	0.10	0.32	0.24	0.16	0.21	0.64
M. elegans - Red-winged Fairy-wren	0.21					3.18	3.82	0.64	0.21	0.64			0.08	0.16	0.07	0.64	0.21	0.64
Malurus sp.	0.07	0.07	0.02	0.04	0.04	0.42	0.21	0.15	1.27	1.13	0.31	0.07		1.91	0.99	0.36	0.32	0.03
ACANTHIZIDAE														0.07	0.48	0.05		
Sericornis frontalis - White-browed Scrubwren	0.16	1.59		0.08		3.82	4.46	0.07	1.27	0.07					0.03	0.02		
Smicrornis brevirostris - Weebill	1.27	0.52	1.00	2.39	3.18	0.07	0.32		0.64		1.11	0.01	0.64		0.12	0.16	0.50	0.28
Gerygone fusca - Western Gerygone	1.06	1.27	1.27	0.16	1.91	0.64	0.24	1.27	0.28	0.36	0.63	0.63	1.27	0.32	1.91	3.82	0.57	2.55
Acanthiza apicalis - Inland Thornbill	0.80	4.46	0.28	2.55	1.27	5.73	5.09	4.46	8.91	6.37	0.22	0.63	0.64	1.27	1.91	1.13	0.28	1.91
A. inornata - Western Thornbill	0.64	3.82	0.32		1.11	1.27	1.91	5.09	0.15	0.07	0.31	0.63	1.59	0.24	0.32			
A. chrysorrhoa - Yellow-rumped Thornbill	0.80						1.27			0.14	0.31	0.15						
NEOSITTIDAE									1.27		0.33	0.77	0.64		0.35	0.14	0.12	
Daphoenositta chrysoptera - Varied Sittella																		
CLIMACTERIDAE												0.21						0.07
Climacteris rufa - Rufous Tree-creeper		0.04	0.12	0.14		0.16		0.16										
MELIPHAGIDAE																		
Anthochaera carunculata - Red Wattlebird	0.08	0.03	0.03		0.02									0.16	0.04			0.32
A. chrysoptera - Little Wattlebird		1.20		0.71		0.32	0.04		1.27	0.64								
Melithreptus brevirostris - Brown-headed Honeyeater			0.07								0.28							
M. lunatus - White-naped Honeyeater		2.55	1.00	6.37		0.48	1.27	0.64	0.35	0.64	1.91	0.63	0.07	1.27	1.27	0.42	0.03	0.16
Lichmera indistincta - Brown Honeyeater	1.91	5.09	1.59	8.28	0.16	0.21	0.08	0.64	0.05	0.80	0.63	0.12			1.27	0.05	0.04	
Phylidonyris novaehollandiae-New Holland Honeyeater	0.05	10.66		4.93		8.91	11.46	1.27	8.27	3.18	1.27			2.39	3.04	0.20	1.27	
P. melanops - Tawny-crowned Honeyeater											0.10							
Acanthorhynchus superciliosus - Western Spinebill	0.16	1.91	0.07	1.27	0.32	1.27	5.73	1.27	3.18	0.64	1.27	0.28	0.85	0.64	0.57	1.98	0.64	0.04
PARDALOTIDAE																		
Pardalotus punctatus - Spotted Pardalote	0.07	10.82	0.12	1.27		3.50	0.48	0.57	4.45	1.27	1.90	0.49	0.13	6.37	0.95	1.56	0.16	0.24
P. striatus - Striated Pardalote	1.03	3.11	1.83	3.82	0.71	1.70	1.96	3.11	1.39	0.80	3.80	0.95	1.06	1.91	0.85	5.09	0.88	3.82
ZOSTEROPIDAE																		
Zosterops lateralis - Silvereye	0.99	4.14	0.15	0.95	0.78	5.09	11.46	6.37	1.59	6.37	0.21	0.95	0.64	2.23	0.95	1.06	0.48	1.27
PLOCEIDAE																		
Emblema oculata - Red-eared Firetail		3.82				1.91	0.64		0.63	0.04				1.91	0.16	0.10	0.02	
ARTAMIDAE																		
Artamus cyanopterus - Dusky Woodswallow				0.80		0.07			0.19	0.20	0.05	0.07		0.03	0.05			0.57
CRACTICIDAE																		
Cracticus torquatus - Grey Butcherbird	0.07				0.16													
Strepera versicolor - Grey Currawong					0.16			0.03										
CORVIDAE																		
Corvus coronoides - Australian Raven			0.16		0.02			0.21										

* This stream zone consisted in part of Eucalyptus laeliae woodland.

Appendix 2

List of non-passerine bird species present in the project areas but not recorded on the bird census traverses.
(i.e. noted during periods of informal observation)

	Mundaring	Raising Canning	South Canning	North Dandalup
CASUARTIDAE				
Dromaius noaehollandiae - Emu	+		+	+
PHALACROCORDIDAE				
Phalacrocorax melanoleucos - Little Pied Cormorant				+
ARDEIFORMES				
Ardea pacifica - Pacific Heron	+			
ANATIDAE				
Tadorna tadornoides - Australian Shelduck				+
Anas superciliosa - Black Duck	+			+
A. gibberifrons - Grey Teal	+			+
Biziura lobata - Musck Duck	+			
ACCIPITRIDAE				
Aquila audax - Wedge-tailed Eagle	+		+	+
PSITTAGIDAE				
Calyptorhynchus magnificus - Red-tailed Black Cockatoo				+
STRIGIDAE				
Ninox novaeseelandiae - Boobook Owl	+	+	+	+
PODARGIDAE				
Podargus strigoides - Tawny Frogmouth	+		+	+
AEGOTHELIDAE				
Aegotheles cristatus - Owlet Nightjar	+		+	+

Appendix 3

The herpetofauna of the project areas and stream zones (S), Jarrah forest (J), Wandoo woodland (W) and Eucalyptus laeliae woodland (L). Species associated with the granite formations are indicated with an asterisk (*).

STUDY AREA	Mundaring			Raising Canning		South Canning			North Dandalup		
SPECIES	W	S	J	S	J	W	S	J	S	J	L
HYLIDAE - Tree Frogs											
Litoria adelaidensis	x	x		x			x		x		x
L. moorei	x	x		x					x		
LEPTODACTYLIDAE - Ground Frogs											
Crinia georgiana	x	x		x	x	x		x	x	x	x
Geocrinia leai									x		
Heleioporus eyrei	x	x						x			
H. inornatus						x		x			
H. psammophilus	x	x	x								
Pseudophryne guentheri								x			
Ranidella glauerti		x		x					x		x
R. pseudinsignifera	x	x		x					x		x
CHECIDAE - Tortoises							x				
Chelodina oblonga		x									
GEKKONIDAE - Gekkos											
Diplodactylus granariensis	x										
D. polyophthalmus	x			x			x	x	x*		
Gehyra variegata	x*		x*	x*							
Oedura reticulata	x										
Phyllodactylus marmoratus	x	x				x	x	x		x	
Phyllurus milii	x*		x*	x*							x*
PYGOPODIDAE - Legless Lizards											
Aprasia pulchella			x	x		x	x	x		x	
A. repens	x		x								
Delma fraseri		x	x								
Lialis burtonis	x		x	x				x	x		
Pygopus lepidopodus								x			
AGAMIDAE - Dragon Lizards											
Ctenophorus ornatus	x*			x*			x*		x*		
Pogona m. minor	x	x	x			x	x			x	
SCINCIDAE - skinks											
Cryptoblepharus plagiocephalus	x	x	x	x	x	x	x	x	x	x	
Ctenotus delli				x		x	x	x	x	x	x
C. impar								x			
C. labillardieri				x	x		x	x	x	x	
Egernia kingii	x			x				x	x		x*
E. luctuosa							x		x		x
E. napoleonis		x		x	x		x	x	x	x	
Hemiergis i. initialis	x	x	x	x	x	x	x	x	x	x	
Leiolopisma trilineatum		x		x	x	x	x	x	x		x
Lerista distinguenda	x	x	x	x	x	x	x	x		x	x*
Menetia greyii	x	x	x	x		x	x	x			
Morethia obscura	x		x	x	x		x	x	x	x	x*
Tiliqua r. rugosa	x	x	x		x	x	x	x		x	x
VARANIDAE - Monitor Lizards											
Varanus gouldii	x	x	x	x		x					
V. rosenbergi											x
V.t. tristis			x								
TYPHLOPIDAE - Blind Snakes											
Ramphotyphlops australis			x				x	x*			x*
R. pinguis		x									
BOIDAE - Pythons											
Morelia spilota imbricata			x*								x*
ELAPIDAE - Elapid Snakes											
Acanthophis antarcticus				x							
Notechis scutatus							x			x	
Pseudonaja a. affinis	x	x								x	
Rhinoplocephalus gouldii							x			x	
R. nigriceps									x*		
Vermicella semifasciata			x								

Appendix 4

The mammal fauna of the project areas and stream zones (S), Jarrah forest (J), Wandoo Woodland (W) and Eucalyptus laeliae woodland (L). Species associated with the granite formations are also indicated with an asterisk. Observations from secondary evidence are shown with + for scratchings or diggings and # for sound records. Introduced species are listed with (I).

STUDY AREA	Mundaring			Raising Canning		South Canning			North Dandalup		
SPECIES	W	S	J	S	J	W	S	J	S	J	L
MAMMALS											
TACHYGLOSSIDAE											
Tachyglossus aculeatus - Echidna +	x		x		x		x	x			x*
DASYURIDAE											
Dasyurus geoffroii - Western Quoll					x						
Sminthopsis gilberti - Gilbert's Dunnart						x					
Antechinus flavipes - Mardo		x				x		x	x		
PERAMELIDAE											
Isoodon obesulus - Quenda +					x		x		x		
BURRAMYIDAE											
Cercartetus concinnus - Western Pygmy-possum	x										
MACROPODIDAE											
Macropus irma - Western Brush Wallaby			x				x	x	x	x	
Macropus fuliginosus - Western Grey Kangaroo	x	x	x	x			x	x	x	x	x
MOLOSSIDAE											
Mormopterus planiceps - Little Flat Bat							x				
Tadarida australis - White-striped Mastiff Bat #							x	x	x		
VESPERTILIONIDAE											
Nyctophilus gouldi - Gould's Long-eared Bat		x									x
Nyctophilus geoffroyi - Lesser Long-eared Bat		x		x			x	x			
Chalinolobus gouldii - Gould's Wattled Bat							x				
Chalinolobus morio - Chocolate Bat											x
Eptesicus regulus - King River Eptesicus		x		x				x			x
MURIDAE											
Hydromys chrysogaster - Water-rat		x									
Mus musculus - House Mouse (I)								x	x		x
LEPORIDAE											
Oryctolagus cuniculus - European Rabbit (I)	x	x	x	x							
CANIDAE											
Canis familiaris dingo - Dingo (I)	x	x									
Canis familiaris familiaris - Dog (I)	x	x									
Vulpes vulpes - Fox (I)			x								
SUIDAE											
Sus scrofa - Pig (I) +	x	x	x	x			x	x			

Appendix 5

The number of ants of each species collected in sets of 20 pitfall traps established at 18 sampling sites in the four project areas. Ant species detected in hand searches of the sampling sites are indicated by (+). Total species richness, pitfall species richness, species density/m², total individuals and dominance index values for each sampling site are given at the foot of the table.

	SAMPLE SITES																		
	Mundaring					South Canning					Raised Canning			North Dandalup					
	ME-1A	ME-2A	ME-3A	ME-4A	ME-5A	SC-1A	SC-2A	SC-3A	SC-4A	SC-5A	CE-1A	CE-2A	CE-3A	ND-1A	ND-2A	ND-3A	ND-4A	ND-5A	
MYRMECIINAE																			
Myrmecia sp chasei										1	1		2			3		2	
Myrmecia sp nigriceps sp JDM5				+		+								1		+		+	
Myrmecia sp JDM 258											1								
Myrmecia sp JDM 610												5							
Myrmecia sp JDM 553				1															
PONERINAE																			
Brachyponera sp lutea	2	2	1	2	6	+	1		1	1	1		3	1	+	1		1	
Leptogenys sp JDM 88	+			1										3			2	2	
Cerapachys sp nov															9				
Cerapachys sp JDM 203				3	2						1							2	
Cerapachys sp nov																		3	
Rhytidoponera sp inornata	45	8	11	106	48	17	8	14	28	27	57	13	41		3	15	13	+	
Rhytidoponera sp violacea		6	7	18	1	3	6	5	+	14	9		2		9	21	3	9	
Rhytidoponera sp JDM 121										2		1			1	3		9	
Eubothropansra sp JDM 89									1								2		
MYRMICINAE																			
Anisopheidole antipodum			1	6		8		1						10					
Cardiocondyla nuda									1				1						
Chelaner sp nov.			1																
Chelaner sp JDM 61		7								1									
Monomorium sp 1 (ANIC)		15	13	7			7				4	15	6		12	14	7	2	
Monomorium sp 2 (ANIC)	1	92		27	28														
Pheidole latigena		40	3	147	57	36	29				15	31	30		18		27	13	
Pheidole sp JDM 399							1	2											
Pheidole sp JDM 379	43	37				17							6						
Podomyrma sp JDM 161						+													
Solenopsis sp JDM 34	1			2	1														
Tetramorium sp 6 (ANIC)			1	8	4					1						13			
Tetramorium sp JDM 206	5																		
Crematogaster sp JDM 33			7		1	1		2		2									
Crematogaster sp JDM 428													+		4		5	+	
Meranoplus sp JDM 220					1	2	1	2		1			4			2			
Meranoplus sp 12 (ANIC)		1					2									7			
Meranoplus sp 11 (ANIC)		1	1	2	2														
Meranoplus sp JDM 400				13															
DOLICHODERINAE																			
Dolichoderus sp JDM 211							+					+			+		1		
Hypoclinea sp nov	2	6	1	2	3						+		1		1			1	
Tapinoma sp JDM 314		26	18						2				1		7				
Tapinoma sp JDM 416						2						1							
Iridomyrmex sp conifer								234	158	73	427	97			9	129	204	279	
Iridomyrmex sp 14 (ANIC)	55	27	35	11			2		14	32		21	21	2		24			
Iridomyrmex sp darwinianus	9	185			7		8	22	5	7	+	18	5	5	155	11	176	5	
Iridomyrmex sp nitidus			650	250				7											
Iridomyrmex sp agilis	99	4	160	369	1	71	2	23				59		1	1		4	4	
Iridomyrmex sp glaber		152			1	+	10			2		2	55	20	29	7	4	156	
Iridomyrmex sp JDM 168						+													
Iridomyrmex sp agilis (pale)													6	5				6	
Iridomyrmex sp JDM 8			47										+	39	+	176		1	
Iridomyrmex purpureus	973	25			329								73					1	
Iridomyrmex sp 20 (ANIC)											19								
Iridomyrmex sp 18 (ANIC)	55			8	216														
Iridomyrmex sp nov		45																	

	SAMPLE SITES																			
	Mundaring					South Canning					Raised Canning			North Dandalup						
	ME-1A	ME-2A	ME-3A	ME-4A	ME-5A	SC-1A	SC-2A	SC-3A	SC-4A	SC-5A	CE-1A	CE-2A	CE-3A	ND-1A	ND-2A	ND-3A	ND-4A	ND-5A		
FORMICIDAE																				
Camponotus michaelseni						2			1	+	2	2	1		3		2			
Camponotus sp JDM 183						1				1										
Camponotus sp JDM 182	+	2	7	7	+	9			+				4					3		
Camponotus sp JDM 63	+	1	+	+	1						+				1			1		
Camponotus sp JDM 104			1	2	+	6	+			+	3	1	2	+	+		2	1		
Camponotus sp JDM 110												1			1		2	1		
Camponotus sp nov												1								
Camponotus sp JDM 287				1	1						+									
Camponotus sp JDM 27												+								
Camponotus sp JDM 199		1	3																	
Polyrachis sp nov		+		2	+						+									
Melophorus sp nov		+								55	25		26		12		30			
Melophorus sp JDM 221		18	5	39	8	4	5	1		2	29	17	21	1	5	25	3	4		
Melophorus sp nov							+			1										
Melophorus sp 1(ANIC)	48	62				1			+	+	+	3		4		9		18		
Melophorus sp 3(ANIC)	15	53	7	46	1						8					1	1			
Notoncus gilberti				1																
Prolasius sp JDM 446							5													
Stigmacros sp JDM 622	1	2	2	8	26		1			1	4	2	2							
Stigmacros sp JDM 114				2		1								1	2					
Stigmacros sp JDM 195																	1			
Stigmacros sp JDM 80				2											10					
Stigmacros aemula	1	2	2	8	26						4									
Total Species Richness	19	28	24	32	25	22	18	11	11	22	25	20	23	15	23	19	19	26		
Pitfall Species Richness	16	26	23	30	22	17	15	11	8	19	9	18	21	14	19	18	19	23		
Species Density/m²	7.4	10.4	9.6	11.2	8.4	8.0	6.2	4.8	4.2	7.0	8.4	7.0	8.4	4.6	7.2	7.6	7.2	9.0		
Total Individuals	1355	820	984	1101	742	209	87	313	209	226	635	290	312	94	285	468	489	524		
Dominance Index	.528	.119	.467	.195	.294	.181	.161	.572	.594	.233	.467	.182	.130	.233	.318	.229	.312	.374		

APPENDIX 6 - Notes on the possible effects of alternative dam developments on fish fauna.

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March, 1987

1. Introduction

It is my aim, in the short time available, to provide an understanding of the possible impacts of the reservoirs on fish fauna. Under this category included all fish species found in the Darling Range, freshwater crayfish (Marron, Gilgies and Koonacs), shrimps and the mussel. The author is not qualified to deal with planktonic or benthic invertebrate fauna.

Firstly a background to the Darling Range streamline aquatic environment (as the author sees it) shall be provided, so that a context may be created to which all discussion shall be referenced. An outline of the possible major effects of the reservoirs will follow.

It must be stressed that the discussion describes mainly possible and likely effects. Very little research has been done on our rivers and creeks to enable any detailed prediction of the consequences of proposed dam developments.

However the author is in the unique position to comment. Presently the author is studying the effect of minewater effluent on the biota of the Collie River South Branch. The effluent is essentially acidic freshwater, and is discharged into the river constantly. This enables a comparison of various different environments along the one river.

In summer the river upstream of the mine discharges no longer flows, and the river consists of isolated stagnant pools. Downstream the minewater maintains flow along the river, and thus supports well mixed freshwater pools which are connected by intermediate riffle zones. By comparing pools subject to minewater discharge, with upstream pools a considerable understanding of the Darling Range river environment has been gained.

2. Background - Darling Range Rivers

2.1 The environment

The rivers of the Darling Range mainly consist of drainage lines with small to large pools every so often. In winter the rivers are flowing and are therefore continuous. . However in summer and autumn many of the rivers cease to flow and pools become isolated. It is these pools which create the appearance of typical (permanently flowing) rivers. Without them the rivers would be little more than the flood lines characteristic of the Pilbara and Kimberley. Futhermore, without them the variety of aquatic fauna which could utilize the rivers would be severly limited. The pools provide an essential summer/autumn refuge for a large variety of aquatic fauna when flow ceases and the rivers begin to dry up.

When flow ceases so does pool mixing and as summer progresses the stagnant pools become increasingly less oxygenated. This forces many aquatic organisms into the

shallows where they can respire and this must inevitably lead to increased competition for resources. Towards the end of summer the pools provide a very harsh refuge but one to which there is no alternative. Where pools are particularly harsh, populations of marron and gilgies will probably be very low owing to a reduced carrying capacity.

Before large scale clearing it is likely that the rivers flowed for a longer period over summer, if not continuously. This would have caused prolonged mixing of the pools and resulted in far better dissolved oxygen levels than are found today. Therefore the pools would have provided better summer refuges in the past.

From my work on the Collie River South Branch, even a trickle of minewater maintains good dissolved oxygen levels. In comparison, the upstream pools, which are completely stagnant have dissolved oxygen levels which are quite lethal to fish and marron for much of their depth.

2.2 Fish and the river environment

With the onset of summer, fish, freshwater crayfish and shrimps take refuge in the pools. Conditions become increasingly harsh with increasing temperatures low dissolved oxygen and increasing salinity due to evaporation, as summer progresses. The fish keep to the shaded areas during the day to reduce their metabolic rate (fish caught in summer quickly die out of water while in winter they can stay alive for as long 10 minutes). This is not so for Gambusia affinis which thrives in shallow, unshaded warm water.

As soon as the river flows the fish move out of the pools. Over autumn and early winter they develop sexually and the native fish (Galaxias occidentalis, Edelia vittata and Bostockia porosa) begin to migrate up creeks and to flooded areas, where they spawn over late winter and early spring, among dense ephemeral aquatic vegetation. Over spring the fish fry quickly develop. With high dissolved oxygen and low temperatures the fish do not keep to the shade and can be readily seen. As summer approaches they slowly migrate back to the pools. Over summer Gambusia breeds, producing very large populations which plummet in size over winter.

The three large introduced fish found in the Darling Range utilize the rivers slightly differently. The Redfin perch (Perca fluviatilis) does not migrate up creeks, but will move throughout the river and spawns in spring. In summer large numbers of juveniles appear which seem to die off over the harsh summer but many survive to give rise to large stunted populations. Indeed Redfin perch seems to have acclimatised well and will probably be found in all rivers and reservoirs before long.

The trouts (Salmo species) do not spawn in the rivers, except in certain localities where gravel substrates are available but they are reported to migrate up creeks.

3. Effects of the reservoirs

3.1 Loss of streamline

The streamline provides shelter and shade for fish and crayfish. For example Bostockia porosa and marron will live amongst debris during the day and come out to feed at night. The debris provides shade, and shelter from predation by cormorants, water-rats, redfin, trout and so on. Aquatic plants will also provide shelter as will the steep riverbanks with their holes and crevices.

The effects of the loss of streamline are listed below:

3.1.1 Loss of shade

The narrow streamline, with much tree and shrub cover, provides much shade, thus keeping water temperature down. The proportion of pool shaded is much higher than for the reservoir. Shaded pools are cool pools and are much more favourable to native fish.

3.1.2 Loss of steep riverbank

A steep riverbank of up to three metres depth affords a number of advantages. Water will nearly always be present beneath the trees or shrubs and this will maintain:

a) shaded water;

b) flooded debris (fish habitat);

c) a flooded repositry of organic matter (leaves, flower blossoms etc.), which support benthic invertebrates which inturn supports fish;

d) a flooded repositry of terrestrial insects which fall from the trees (Galaxias occidentalis and the trouts will feed heavily on terrestrial insects, from the water's surface, which have been blown from the trees).

In comparison the reservoirs fluctuate greatly over relatively large distances. Debris and other organic matter will not always remain flooded for long enough to support aquatic fauna. Typical riverbanks provide a relatively stable habitat only being exposed or excessively flooded in exceptional years.

In a reservoir debris, organic matter and insects will fall short of the river for much of the year.

3.1.3 Loss of emergent and submergent vegetation

Over winter and spring flooded areas more or less stablise as the pools quickly fill up. Each pool is a "mini-reservoir" maintaining more or less stable water levels upstream for as long as six months. In these stable flooded zones abundant aquatic vegetation develops which provides shelter and protection for fish, enabling them to spawn in the floodwaters. The vegetation also provides protection for developing fish eggs and larval stages.

At the reservoir, however, the water level rises and continues to rise until water depths are many metres greater than initially. Water levels do not stabilize long enough to enable vegetation to develop. Hence no spawning habitat for fish.

3.1.4 Loss of shelter

Many tree and shrub species grow into the water providing water levels do no fluctuate too greatly from year to year. This peripheral vegetation provides much shelter for fish and crayfish below the water surface. Because of the great fluctuations in water level along the reservoirs such peripheral vegetation cannot develop.

3.2 Impact to fish fauna in reservoir

3.2.1 Native fish

A body of water the size of a typical Darling Range reservoir is totally alien to our native fish. This does not mean that they are unable to utilize a reservoir, but given the great difference between the typical streamline habitat and that afforded by a reservoirs, utilization by the small fish species (G. occidentalis, E. vittata and B. porosa) must be very limited.

Because of the large fluctuations in water level the stable environments required by E. vittata and B. porosa are simply not present. G. occidentalis, which is known to migrate large distances could probably negotiate the large distances involved to find suitable habitat.

During winter and spring large numbers of Galaxid larvae, which are planktonic, would be swept into the reservoirs. The larval stages of B. porosa and E. vittata appear to be benthic and therefore would not be swept long distances downstream. The Galaxid larvae would probably develop in the reservoir (feasting on zooplankton), and providing the streams are flowing, would move upstream when physically able.

Apparantly the freshwater cobbler (Tandanus bostocki) is quite abundant in the reservoirs. Virtually nothing is known about this species but if the reports are true then the reservoirs favour their existence.

If some native species can utilize the reservoir environment substantially then the reservoirs would serve one major advantage. Reserve populations of some native fish would always be present in the reservoirs to restock upstream sections following particularly bad drought years. At this point it would seem unlikely that the reservoirs could support large populations of the less mobile B. porosa and E. vittata, but the opposite could be the case for G. occidentalis and T. bostocki.

3.2.2 Introduced fish

Redfin perch and the trouts are known to be able to utilize the reservoir environment. Wellington Dam is known to support a large population of stunted redfin perch. This is good from the point of view of maintaining recreational fishing. However redfin and the trouts will predate on native fish and crayfish. Therefore the reservoirs will maintain a population of fish which may be overall detrimental to the "natural" environment. In winter when G. occidentalis is migrating upstream so are the trouts, and in the eastern states winter migration and predation by trout has been known to cause the virtual elimination of native fish from large sections of creeks.

3.2.3 Invertebrates

It is not generally known how well freshwater invertebrates utilize reservoirs. Apparently Wellington Dam supports a good population of marron.

3.3 Barrier to migration

Migration fo fish upstream is probably a very important aspect of the ecology of native Darling Range fishes. Galaxias occidentalis is known to migrate large distances and E. vittata and B. porosa are known to migrate to a lesser extent.

Because our climate is so variable, suitable fish habitat can appear in years of good rainfall and dissappear in drought years. Migration enables fish to make use of new fish habitat as it becomes available and thereby maximize their distribution in good years.

The dams (as do the stream gauging weirs), provide a barrier to migration. If the reservoirs do not provide good habitat for native fish, while at the same time supporting introduced fish (which further impacts upon the native fish population) then large healthy native populations will not be available to restock new upstream habitat. The populations of certain native species may "wither" over the years and finally dissappear. Healthy downstream (of the dam) populations are unable to get above the dams and so areas which in some years could support native fish populations remain unutilized.

The worst possible outcome is a slow replacement of one or more native fish populations, by introduced species. Interestingly, the Collie River South Branch supports virtually no freshwater cobbler above a gauging weir. While just below the weir they are commonly observed. Redfin perch are found both above and below the weir.

3.4 Downstream Effects: Effects of altered flow.

Ordinarily our native fish, crayfish etc. must deal with a fluctuating aquatic environment. This ranges from

periods of low or no flow over summer, to periods of flow with flood events over winter. Only occasionally would this pattern be interrupted, as for example in the case of a cyclone.

Fish habitat is provided by some degree of stability. For example the pools and the reservoirs provide permanent waters. If interruptions to stability have a pattern, as in the case of the seasons, fish will have adapted their life cycles to them over many thousands of years.

The basic life cycles of the fish have been described. These cycles can be disturbed by alterations to stream flow. Furthermore alterations of stream flow may lead to environmental degradation which effects aquatic fauna.

The following is an outline of the types of possible effects caused by alterations to stream flow brought about by dam operation. It must be noted that the effects of 'degree of alteration' can only be speculated as there is little understanding of river environments. Rather, possible effects of type of alteration will be described.

3.4.1 Increased flow over winter. (Example: None)

If the flow downstream of a dam is more or less similar in magnitude to that prior to the dam, effects should be minimal. As long as the flow keeps to the original streamlines the native fish should be able to cope.

If flow is much greater at times (improbable if not impossible) then migration of the small fish species upstream may be difficult. But fish most likely make use of periods of low flow to get about and given that such periods will still occur they should be able to continue their migrations in most years.

3.4.2 Increased flow over summer (Example: South Canning)

Any flow over summer is beneficial to fish. Even if the flow is minimal, it will be sufficient to maintain the water level of the pools, and hence stabilize habitat, and will also increase dissolved oxygen levels.

Low flow rates over a long period are of more benefit to the fish than short-term pulses of large volumes. The former serves to maintain a stable pleasant environment while the latter (short-term winter-like surges) will disturb fish habitat (eg. sediment mobilization, increased water turbulence) and provide only a short improvement in environmental conditions following the event.

Flow over summer will encourage G. occidentalis to swim upstream. The effect on the movements of other fish is unknown.

3.4.3 Reduced flow over winter (Examples: North Dandalup, South Canning and to lesser extent Raise Canning and Mundaring Proposals).

Providing flow is sufficient to maintain a connection between the pools of the river and to flood adjacent areas the native fish population should suffer only minor effects. Connection is required to enable migration, and flooding to provide spawning habitat. If flood levels are reduced then there will be a reduction in spawning habitat. This may effect the size of the populations. If no flooded areas are formed in winter and spring then the consequences for the native fish populations will be negative and severe.

A reduction in flow may prevent the deepest parts of the pools from being thoroughly mixed and flushed out over winter. This means that low oxygen water remaining from summer will sit in the bottom of pools over winter. This will lead to a reduction in the area of the pool bottom available to benthic organisms such as marron and gilgies, and hence to a reduction in pool carrying capacity.

3.4.4 Reduced flow over summer (Example: North Dandalup)

By far the worst consequences are as a result of this. Without flow the pools will not be mixed. They will stagnate, become deoxygenated and water levels will gradually drop due to evaporation and transpiration (made worse if farmers pump from them). As summer progresses conditions become worse as fish habitat becomes exposed, and aquatic plants die as water level drops, salinity increases and the aquatic fauna (including tortoises) becomes cramped in a warm, relatively deoxygenated and shrinking pool of water.

When no flow replaces some flow over summer as in the case of the proposed North Dandalup Dam the consequences for aquatic fauna (and flora) will be negative and very severe. The most apparent effect, with a reduction in dissolved oxygen, will be a much reduced marron population. The depth of the pools will be unavailable to those organisms which breathe in water. Hence a reduction in carrying capacity. Other bottom dwellers such as freshwater cobbler (*Tandanus bostocki*), *T. porosa* and gilgies will suffer also.

3.5 A question of stability

As far as possible downstream flows of the dams should mimic the type and seasonal pattern. This will minimize any impact on the life cycles of the native fish.

To reduce the disturbance caused by environmental changes long periods of low flow rate are preferrable to short periods of high flow rate. In the case of the latter, fish habitat will be too short-lived to support

native species.

Galaxias occidentalis, which will respond to sudden flow by migrating upstream, may be trapped in rapidly drying pools, when flow ceases.

In terms of the effects of downstream flows in the aquatic environment summer/autumn is the most important period of the year. But in terms of effects on the life cycle of fishes winter/spring is the crucial period. It is over this period that the native fish and large invertebrates breed. Only the introduced fish Gambusia affinis breeds in summer.

Intermittant flows over winter will disturb migration and may prevent fish from reaching their most productive spawning grounds. Widely fluctuating intermittant flows will not maintain flooded areas for sufficient periods to enable productive spawning.

In the cases of the proposed North Dandalup and South Canning Dams the winter flows fluctuate greatly. This will present a serious problem to fish requiring a period of some months of relative stability to complete breeding. Furthermore, following breeding typical spring conditions of relatively continuous flow are required by larval and juveniles for their development to adulthood.

If a "widley fluctuating - flow" winter is followed by a "no-flow" summer, as in the case of the proposed North Dandalup Dam, then the effects of poor breeding success will be exacerbated.

3.6 Problem of low temperature

A sudden change in temperature, caused by the flow of cold dam water, can be harmful to fish. This will be worst over summer when the temperature could drop from 25-30 C to 12 C in a few hours. To minimize the effects of temperature change the dam water should be introduced as a trickle to enable a slow temperature change which will permit the fish to acclimatise.

A reduction in water temperature over summer is favourable to fish, marron and gilgies. Metabolic rate is lowered and dissolved oxygen is increased.

Simple tank tests can be conducted to determine the minimum period over which fish can successfully acclimatise.

3.7 Persistance of species

Our understanding of the effects of dams on fish and large invertebrates is virtually zero. But native fish are found above and below existing dams. The major threat in the future probably lies in the illegal introduction of exotic fish species able to thrive in the environments created by the dams. Such species would displace native species.

As to which species are likely to persist above and below dams, under current conditions little can be said.

An adequate biological understanding exists only for G. occidentalis, Edelia vittata, Salmo gairdneri, Salmo trutta, and Gambusia affinis. Little is known about the requirements of Perca fluviatilis and Bostockia porosa in Darling Range waters and virtually nothing is known about the biology of Darling Range populations of Athernosoma wallacei, Pseudogobius olorum and Tandanus bostocki.