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Biogeography of a changing landscape: Pipidinny Swamp, Yanchep National Park Western Australia

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Biogeography of a Changing Landscape:

Pipidinny Swamp, Yanchep National Park Western Australia.

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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

ABSTRACT

The resources of Pipidinny Swamp were utilised by the Nyoongar Aboriginal people for possibly 40,000 years. Since the late 1800s, the resources of Pipidinny Swamp were used by non-Indigenous settlers. More recently, the wetland was incorporated in the Yanchep National Park in 1991.

This study sought to reconstruct the changes to the natural and cultural environments within the wetland to provide background knowledge for the management board of the Park. Field investigations also demonstrated the dynamic state of the wetland over a six-month period between low water (Feb-Apr) and high water (Aug-Oct) by monitoring the groundwater system, the vegetation system, and the waterbird system. In addition, historical records relating to Pipidinny Swamp (mainly water level and waterbirds) were analysed to show the dynamic state of the wetland over several decades.

This study found that Pipidinny Swamp has been highly modified and severely degraded apparently due to past human activities. In the last decade, there has been a dramatic decrease in both the wetland's water level, as well as waterbird abundance and diversity. Furthermore, there has been an increase in the number of exotic vegetation species since market gardening commenced in the 1950's.

Such information will be useful to the Management Board of the Yanchep National Park to establish a database on both the cultural and natural environments of Pipidinny Swamp, and for development of future management plans for the wetland. The techniques adopted in this study also have broader applications for the management of other wetland habitats and areas of remnant bushland.

Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

(i) *incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education:*

(ii) *contain any material previously published or written by another person except where due reference is made in text: or*

(iii) *contain any defamatory material.*

Signature:

Date: 26/11/00

Acknowledgements

Firstly I would like to thank my supervisor Dr Hugo Bekle for his guidance, effort and patience throughout this project and from whom I have learnt a great deal. I would also like to thank The Department of Conservation and Land Management, in particular, Rod Hillman former Park Manager of the Yanchep National Park for providing much needed assistance and cooperation..

I would also like to thank the following two Western Australian government departments for providing data: Waters and Rivers Commission, Bureau of Metrology. Without this data it would have been difficult to complete most of this thesis's.

I would also like to thank my proof readers Stacy Gall and Alexander Watson for reading many chapters in the development of this thesis. I know it was painful on some occasions, but thankfully it is now all over.

To my parents, Bill and Rose, thankyou for all your support both emotionally and economically throughout my life. Thankyou for showing me what I can achieve if I work hard.

The most important person I would like to thank is my fiancée Stacy. Your love and support has guided me through the past two and half years. Thankyou for putting up with my sometimes unusual behavior and habitats.

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Chapter 1: Introduction

Wetlands on the Swan Coastal Plain are areas of high biological productivity which either directly or indirectly support most of the wildlife in this region (Davis & Humphries, 1988). Since European settlement, 80% of the original wetlands of the Swan Coastal Plain have been lost (see Bekle, 1980, 1998; Singleton, 1988). Consequently most of the remaining wetlands and associated biota are now protected. Monitoring and protection of these water resources is an important priority for government agencies including the Environmental Protection Authority (EPA), Conservation and Land Management (CALM), Waters and Rivers Commission (WRC), the Water Authority and the Department of Environmental Protection (DEP).

The plant communities associated with these wetlands represent the main source of primary production in wetland food webs. For example, sedges and rushes provide food and shelter for the fauna, such as waterbirds, within the wetland. The fringing vegetation help to stabilise, aerate the sediment and also filter materials passing into the wetland (nutrient stripping of surface run-off) (Davis, 1990).

Waterbirds are the most conspicuous inhabitants of wetland communities and occupy a position towards the top of the food pyramid. If a wetland supports a large number of birds and a broad diversity of species, then it can be assumed that the rest of the food pyramid is well represented and functional (Figure 1.1).

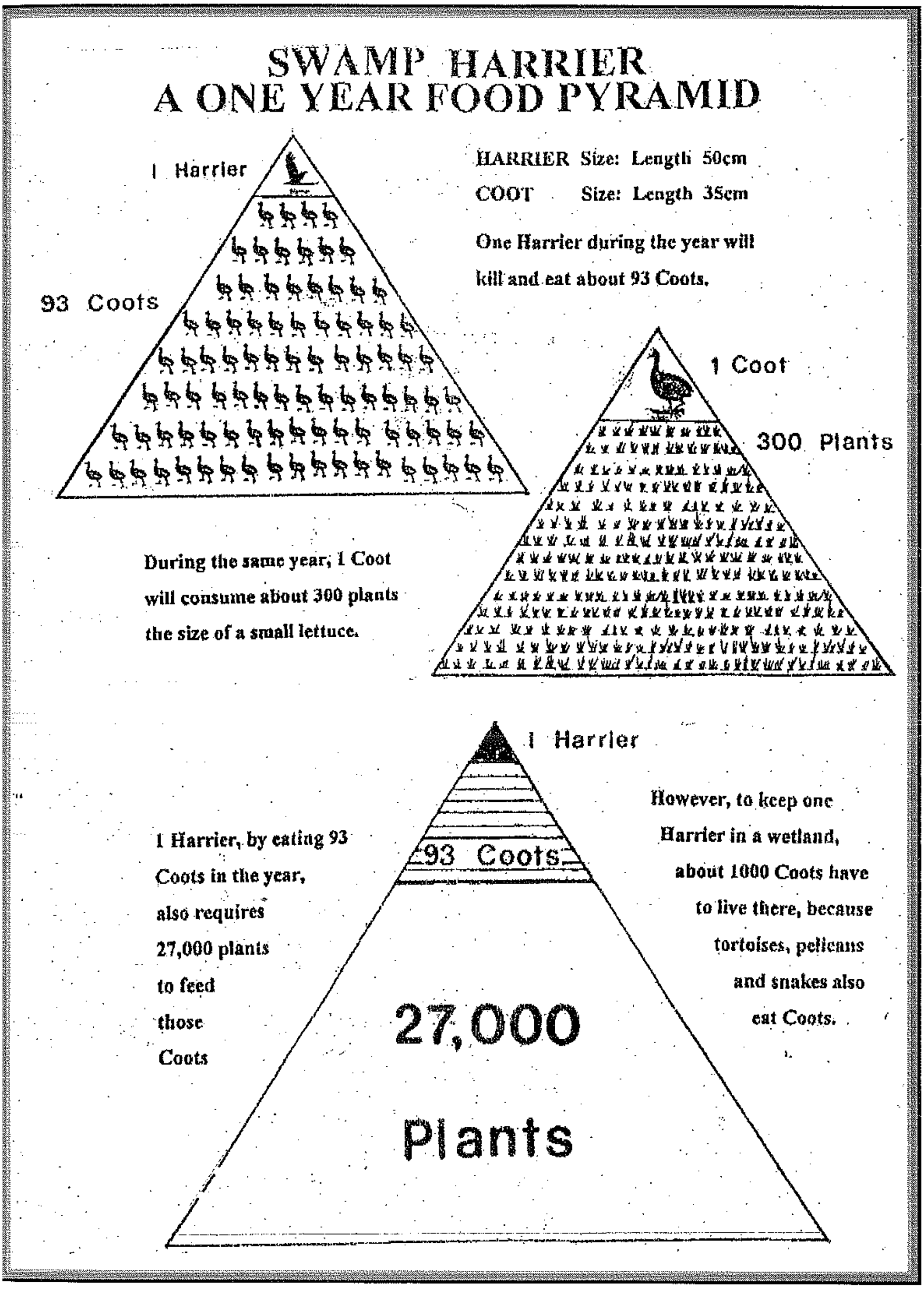


Figure 1.1. Food pyramid for wetlands. Modified from W.A Gould League (2000). *Worksheet on Representative Food Pyramid at Herdsman Lake.* Perth: Herdsman Wildlife Centre.

Not only are these wetlands important to the local avifauna, they are also visited by transequatorial migratory wading birds. Every year these waders travel from their Siberian breeding grounds in the Northern Hemisphere to feed in the warmer shallow waters of the Swan Coastal Plain. Since the Ramsar Convention on Wetlands of International Importance (UNESCO, 1971), Australia signed international agreements to protect the habitat of migratory waterbirds.. As examples the Japan Australia Migratory Bird Agreement (JAMBA) and the China Australia Migratory Bird Agreement (CAMBA) are designed to protect the habitat of these migratory birds.

The wetlands of the Swan Coastal Plain have supported human populations for more than 40,000 years. Aboriginal people utilised the food and water resources of these wetlands, particularly during the spring and summer months when water became scarce further inland (Hallam, 1975, 1998). Soon after arriving in Western Australia in 1829, European settlers discovered that Aboriginal people utilised the wetland environment on the Swan Coastal Plain. An example of this utilisation is in the form of the Yabaroo Budjarra Aboriginal Heritage Trail, north of the Swan River, that follows the chain of coastal wetlands northward. Further, Europeans discovered that the Aborigines and the wetlands were spiritually linked to the spiritual rainbow serpent, the Wagal.

Wetlands also provide important social values to human communities. They provide a focus for both aquatic and land based recreation, conservation and education activities. Wetlands also have important economical values with the rich peat soils used for intensive agriculture. Values of properties adjoining a wetland are considerably higher, especially if they have a view looking across water. Furthermore, the shallow waters of wetlands, especially estuaries, function as important nurseries for fish and other fauna of wetlands (Godfrey, 1988).

Many of these natural and cultural values were not immediately apparent to the early settlers. Consequently, many wetlands were lost due to drainage and reclamation. The following quotation provides an insight to early European impression of the wetlands from (*Swan River News*, August 11, 1847, p.161).

> At home, a lake is known only as a sheet of water which seldom or ever dried up, and it is naturally associated in one's mind with pleasant and picturesque scenery, but here it is quite different... there is an air of desolation about these lakes which strikes the spectator at once...It is complete still life without one point of interest in it, as far as striking scenery goes, and totally different from anything I ever saw outside of Australia.

Knowledge of the natural history and wetland functions is useful for management authorities for developing management plans. This knowledge helps to establish criteria for monitoring changes within the wetland, to determine rehabilitation strategies and the enhancement the natural features.

Many of the original wetlands of the Swan Coastal Plain have been lost to drainage or land reclamation (see Bekle, 1980, 1998; Singleton, 1988). Reasons for drainage and reclamation of wetlands included that wetlands made transportation difficult for the early settlers, they produced bad odours, they are mosquito breeding grounds, they were visually unattractive compared to British gardens and the peat soil represented valuable agricultural land (Singleton 1988). Furthermore, many of the wetlands that remain today have been severely modified and degraded.

The remaining wetlands located on the Swan Coastal Plain, except dumplands and sumplands, are now protected under the Environmental Protection Policy for Swan Coastal Plain Lakes (EPA, 1993) and as regional or national parks. Some of these wetlands also have community groups that help to protect the wetlands, for example Friends of Yellagonga Regional Park in Joondalup and Friends of Mary Carroll Park in Gosnells.

1.1 Study Area

Pipidinny Swamp (115° 41'E, 31°35'S) was selected for study because its natural history is relatively unknown. Recently incorporated into Yanchep National Park in 1991, the wetland now receives a high conservation status. Located in the south-west corner of the Park, Pipidinny Swamp is located approximately 45kms north of Perth on the Swan Coastal Plain in Western Australia (Figure 1.2). Pipidinny Swamp is situated on the Spearwood Dune System adjacent the Quindalup Dune System, in a low-level interbarrier depression with prominent karstic features (Arnold, 1990; Seddon, 1972) (Plates 1.1 &

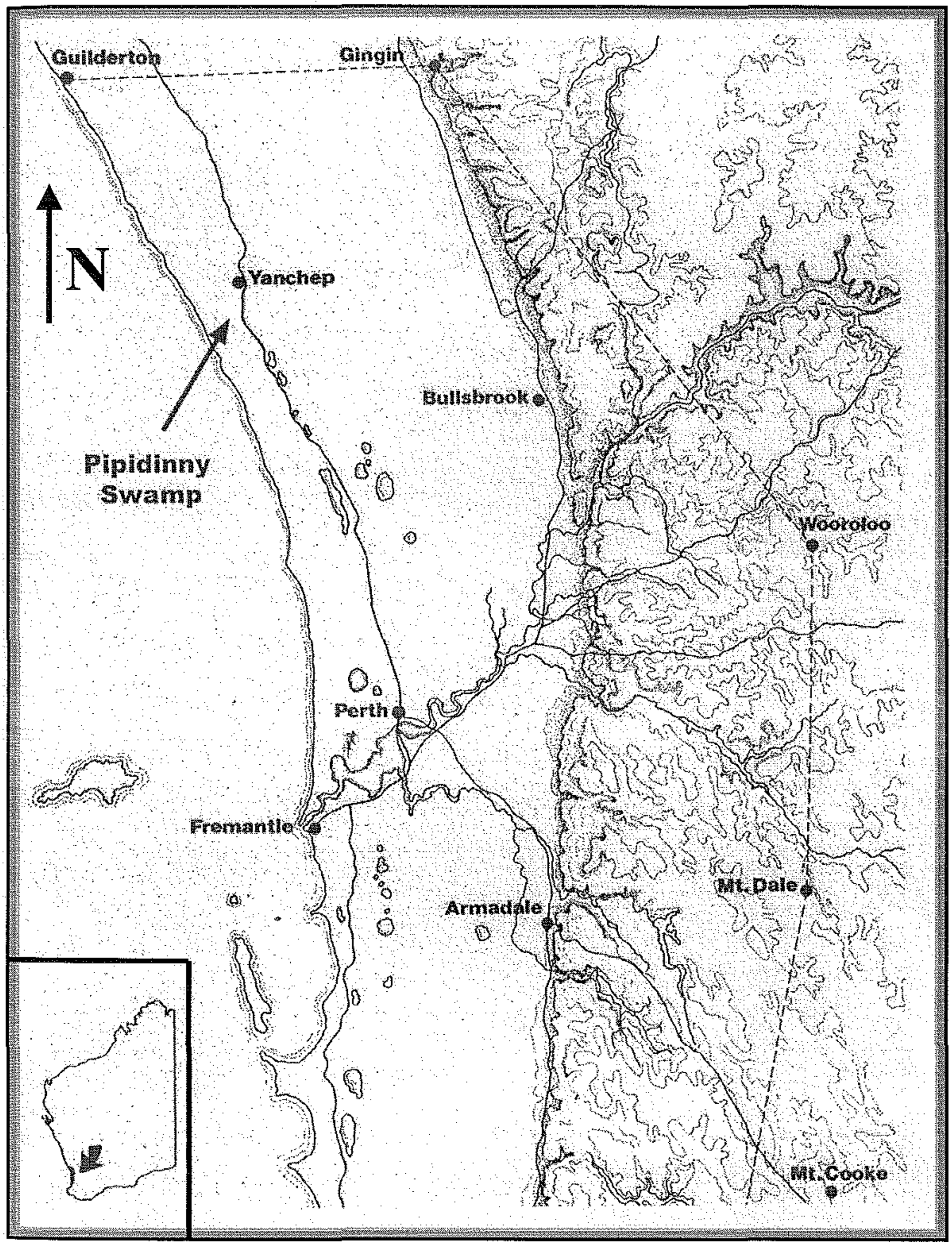


Figure 1.2 Map of Swan Coastal Plain, Western Australia, indicating the location of Pipidinny Swamp. Source: Adopted from *Flora of the Perth Region* (1987).

Plate 1.1 The view looking west over Pipidinny Swamp with the Quindalup Dune System clearly visible in the background (Photograph by B. Boucher, March, 2000).

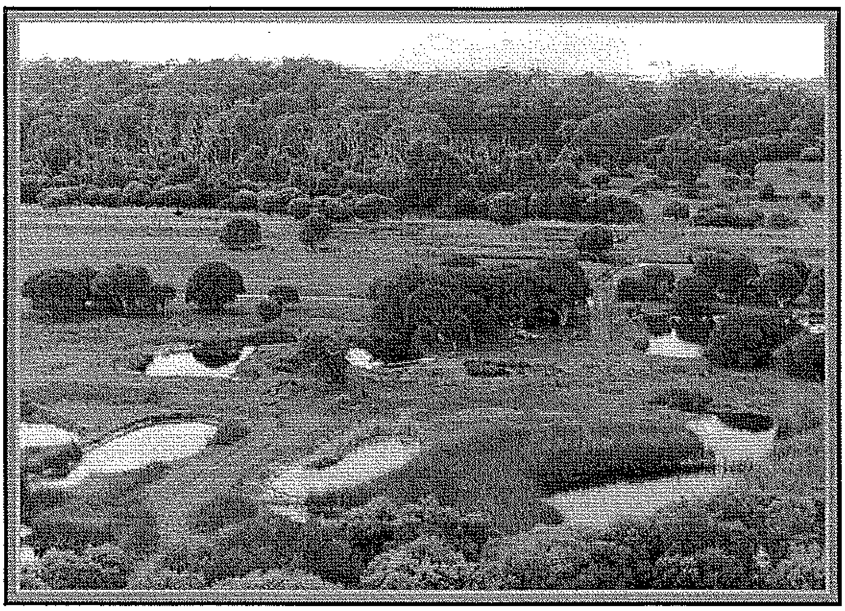


Plate 1.2 Standing on top of the Quindalup Dune System looking east over Pipidinny Swamp with the ponds nearly fill in a period of high water (Photograph by B. Boucher, September, 1996).

1.2). Pipidinny Swamp's geography is unique as the wetland is positioned along the boundary of two distinct geomorphic units on the Swan Coastal Plain. Pipidinny Swamp experiences a temperate, mediterranean climate with warm to hot, dry summers and mild, wet winters (Dames & Moore, 1986). It is an ephemeral wetland, which represents a surface expression of the Gnangara Groundwater Mound. The Gnangara Mound is an unconfined aquifer, rising up to 60 metres above sea level (ASL) (Davis, Rolls, & Wrigley, 1991) north of the Swan River on the Swan Coastal Plain, and is important as a supply of water to Perth's residents (Dames & Moore, 1986). Pipidinny Swamp is strongly influenced by seasonality and experiences large changes in water volume, depth and coverage. Perth's wetland water balance and monthly water level show that a moisture surplus exists for only four months of the year and for the remainder evaporation exceeds rainfall (Figure 1.3). Figure 1.4 shows the total rainfall received at rainfall for Perth Airport since 1945 (Bureau of Meteorology, [BOM], 2000). Consequently, wetlands, such as Pipidinny Swamp, are strongly influenced by seasonal variations in the climate and the associated availability of water.

1.2 Review of Research Conducted on Pipidinny Swamp

Due to past private ownership, little is known of Pipidinny Swamp and its regional significance as a habitat for wetland dependant flora and fauna. Monitoring of Pipidinny Swamp has only occurred in the last ten years and since joining the Yanchep National Park. This is in response to the Environmental Protection Authority's (EPA, 1990) guide to protection and monitoring of wetlands on the Gnangara Mound for the purpose of protecting Perth's water supply.

Currently there has been little research on Pipidinny Swamp, with the exception of a biological program by The Centre of Ecosystem Management at Edith Cowan

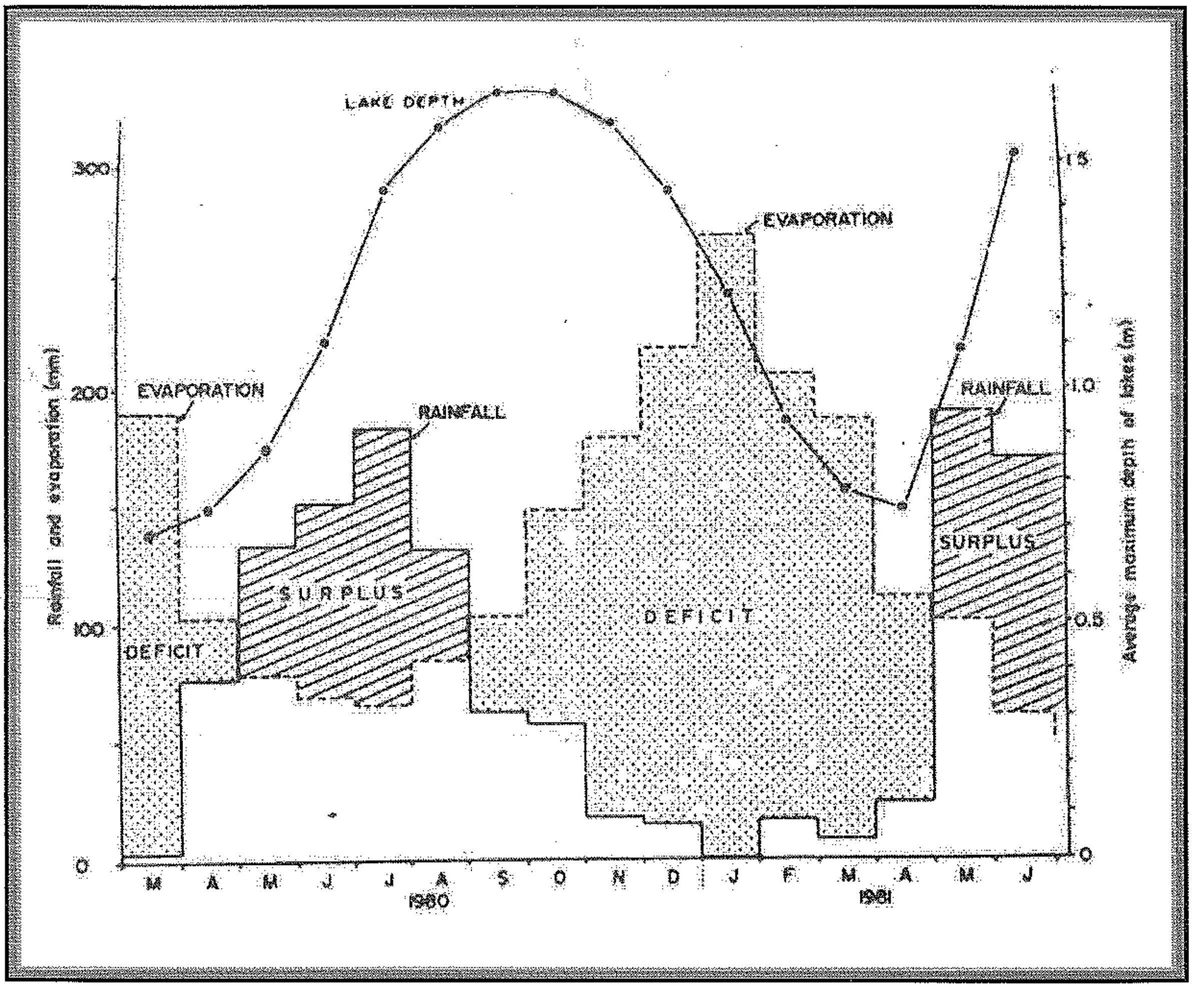


Figure 1.3. Perth's wetland water balance and monthly water level.

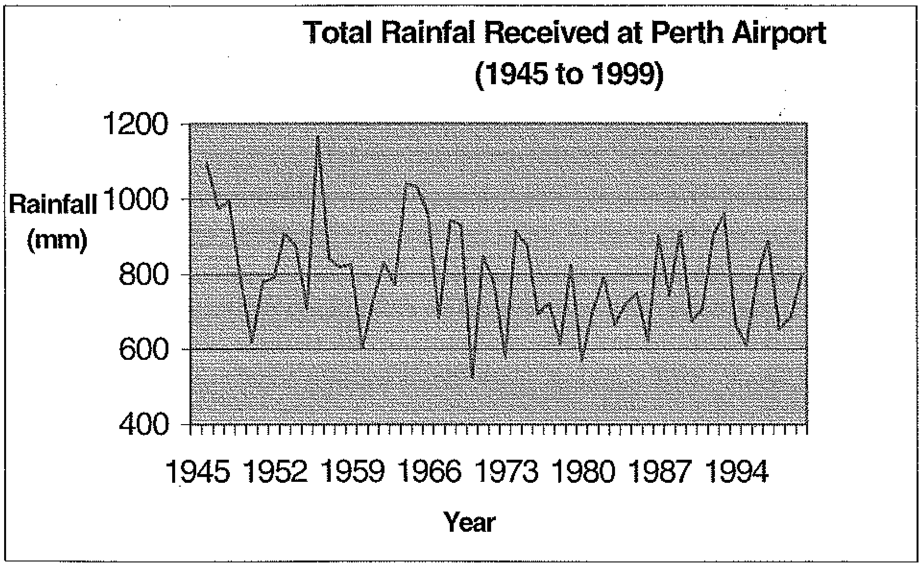


Figure 1.4 Rainfall received at Perth-Airport (1945 to 1999). Source: BOM , 2000.

University (Pinder & Horwitz, 1997; Somer & Horwitz 1999) on wetland macro invertebrates and water level and water quality from 1993. Little other research has been completed on vegetation, water quality and fauna within the wetland.

In 1983 the Western Australian State Government released its report, commonly known as the System Six Report, on the evaluation of both public and private bush land on the Swan Coastal Plain for conservation and recreational purposes (also known as 'The Red Book'). The System Six Report on the Swan Coastal Plain recommended that Pipidinny Swamp be designated as M3 which represents a National Park.

In 1989 the Yanchep National Park management plan recognised that the acquisition of Pipidinny Swamp was a priority and that the wetland should eventually be managed with the same objectives as the existing wetlands within the National Park. Previously, Landbank had privately owned the wetland, before reverting back to vacant Crown land that was administered by DOLA. The wetland has been subjected to numerous human activities which include market gardening, grazing from stock, filling in on the southern end, inputs from fertilisers and stumps from old SEC powerlines. These activities have degraded the wetland (CALM, 1989).

In 1987 a Wetland Advisory Committee (WAC) was established to assess all the wetlands on the Swan Coastal Plain surrounding Perth. The assessment of these wetlands were published in *Perth's Wetland Resource Book* (Arnold, 1990), This assessment grouped Pipidinny and Beonaddy Swamps together and classified Pipidinny Swamp as a modified, non-flowing (Lentic), seasonal wetland less than 25ha in size (19.3ha). The different vegetation zones areas were measured and mapped 6.5ha of sedge, 2.8ha of paperbark, 9.6ha of modified and cultivated land and 0.4ha of open water. There was no information given within this report on water level, water quality, or the fauna.

A study of sixteen wetlands surveying key indicators of environmental quality on the Gnangara Mound by Davies *et al* (1991) Pipidinny Swamp (Table 1.1). This report identified three groups of wetlands on the Gnangara Mound in relation to their nutrient status (Table 1.2). Pipidinny Swamp was grouped with Loch McNess (North and South), as wetlands that are less enriched and geographically separate from another group of wetlands that are also less enriched. This is compared to another group of wetlands (Coogee Springs, Carabooda, Nowergup and Neerabup) that lie within the most intensively cultivated region of the Gnangara mound that were classified as being enriched.

Table 1.1 Key indicators of environmental quality of wetlands on the Gnangara Mound.

Indicators of Environmental Quality
Depth, Conductivity, pH,
Nutrient Concentrations
Chlorophyll a
Algal Composition
TN : TP Ratios
Gilvin Levels
Vegetation Analysis
Sediment Nutrient Status
Pesticide Levels in Wetlands' Sediments
Macro invertebrates

Table 1.2 Results of the wetlands analysis indicating enrichment status.

Less Enriched (North)	Less Enriched (South & East)	Enriched
Pipidinny Swamp	Lake Adams	Coogee Springs
Loch McNess North	Lake Mariginup	Lake Carabooda
Loch McNess South	Lake Jandabup	Lake Nowergup
	Lake Joondalup	Lake Neerabup
	Lake Goolellal	

Halse, Vervest, Munro, Pearson and Yung's (1992) count of waterfowl in south-west Western Australia included Pipidinny Swamp for survey. The vegetation within the wetland was identified as sedges. This is a rather limited interpretation as considerable stands of bulrush and other wetland dependent plants, such as paperbarks, were omitted. In the March count, a total of 29 individual waterfowl were recorded and the November count recorded 142 waterfowl present on the wetland. No information was provided in relation to which species were recorded.

The Wetland Macro-invertebrate Monitoring Program of the Gnangara Mound (Pinder & Horwitz, 1997; Somer & Horwitz, 1999) is at present the only monitoring program being undertaken at Pipidinny Swamp. This program currently collects samples during spring, when water level is high and during Summer/Autumn, when water level is low. The first two sampling rounds showed that there was 22 macro-invertebrate species identified during spring compared to summer/autumn where 14 macro-invertebrate species were identified.

Water quality tests also completed by Somer and Horwitz (1999) show that the nitrogen levels, total phosphate levels and the Chlorophyll *a* range have increased since the summer/autumn 1997-98 sample. The nitrate/ite and ammonia levels varied greatly during the sampling rounds, while the ortho-phosphate levels were lower between summer/autumn 1995-96 and the spring 1997 sampling rounds.

1.3 The Purpose and Significance of the Study

The aim of this study is to describe the state of Pipidinny Swamp over a period of six months from low water to high water. This study also aimed to show how the wetland has been affected by past and present management. This study also aimed to reconstruct the land-use history of Pipidinny Swamp, and the transformations that have occurred to the wetland environment as a result of human activities in and around the wetland. This research also considers the future role of Pipidinny Swamp in Yanchep National Park.

With the recent inclusion of Pipidinny Swamp into the Park, the results of this study will be used for establishing a database that can be referred to in the development of future the plans for the wetland. This database can also be used as a reference point to monitor future changes within the wetland.

1.4 Aims and Research Question

The aim of this study is to show the dynamic state of the wetland environment. In doing so, the following questions are considered:

- What are the changes to the natural and cultural environments of Pipidinny Swamp?
- How is the wetland influenced by seasonality?
- Has waterbird diversity or abundance altered over time?
- How can Pipidinny Swamp be integrated into the future visitor experience of Yanchep National Park?

1.5 Theoretical Framework

This study has adopted a systems approach to studying the Pipidinny Swamp environment. This approach included both the human and environmental interactions that influence the wetland. A system is characterised by numerous reciprocal cause-effect pathways which influence other systems in a larger more intricate system (Watt, 1966, cited in Ellen, 1982). A wetland contains many systems which all have an influence on another system within the wetland. Since it is not possible to consider all of the complex interactions, only certain systems within the wetland have been studied.

Wetland systems given consideration include: vegetation communities, waterbird populations and the water balance. This study also used historical data to reconstruct past ecological changes within the wetland, identifying periods of landuse within the wetland. Such data analyses included using old maps, comparison of aerial photography over time (1941 to 1999), surveyors' field notes and oral histories.

Chapter 2: Methods

To analyse the dynamic state of the wetland over a six month period, results were obtained at periods of low water and high water and compared. Further, historical data, such as surveyor's notes (Figure 2.1) and "oral histories" from local residents were gathered to help show the dynamic state of the wetland previously. Previous studies of wetlands on the Swan Coastal Plain have used vegetation, waterbird and the hydrological systems to survey, monitor and describe the wetland. This study has used these three systems to show the dynamic state of Pipidinny Swamp.

2.1 Water level

The water level at Pipidinny Swamp was recorded fortnightly. The Water Authority has placed a water level gauge in Pond 1 (Figure 2.2) and the water level was recorded from this gauge (Plate 2.1). Records of the water levels go back to 1993 for Pipidinny Swamp. However, the WRC have been monitoring a bore situated between the wetlands and have occasional records going back to the 1970's. The water level data collected during the period of this study was compared to these previous records.

2.2 Vegetation Survey

Two detailed vegetation surveys were undertaken during the year. In the first survey, data was collected at the end of summer when the water level was the lowest (April). The second survey was completed during spring when the water level risen, after filling from winter rainfall (early September). Each survey included a detail description of the vegetation of the entire wetland basin.

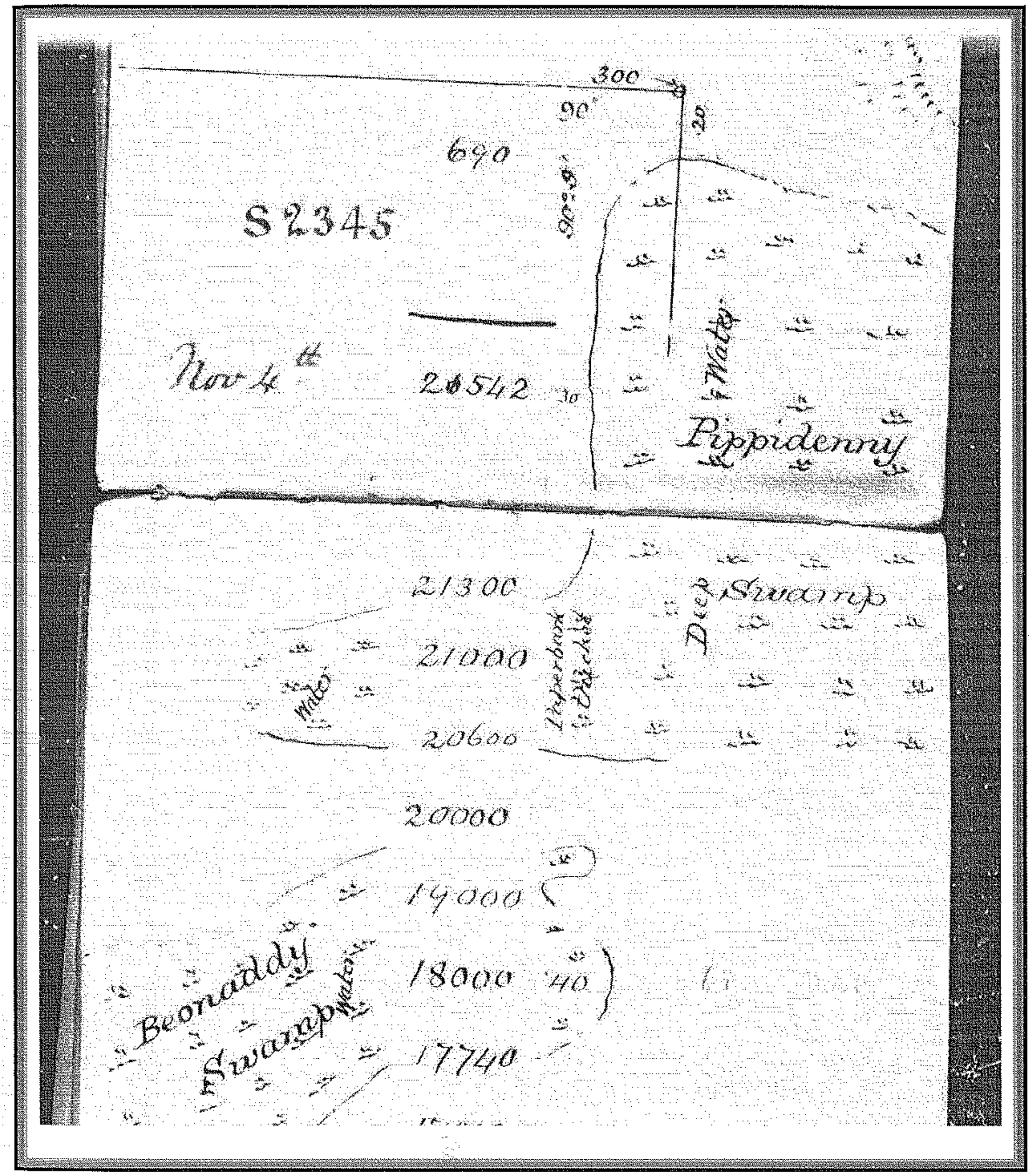


Figure 2.1 Surveyor Mr. W.A Saw's notes of Pipidinny Swamp on his expedition north of the Swan River in 1884.

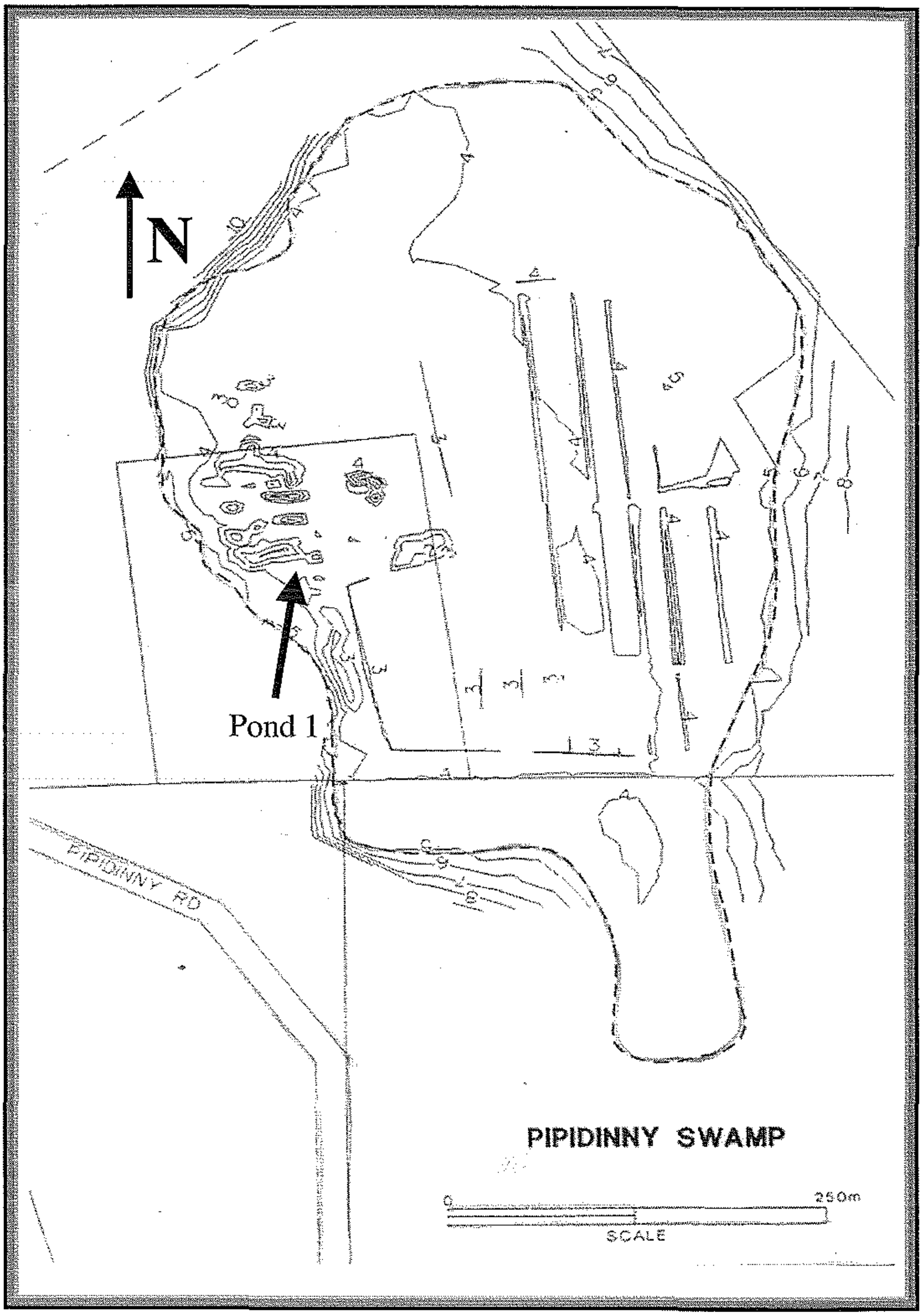


Figure 2.2 Bathymetry of Pipidinny Swamp indicating the position of Pond 1, the positions of the two vegetation transects and the positions of the waterbird surveys. Source: Water Authority.

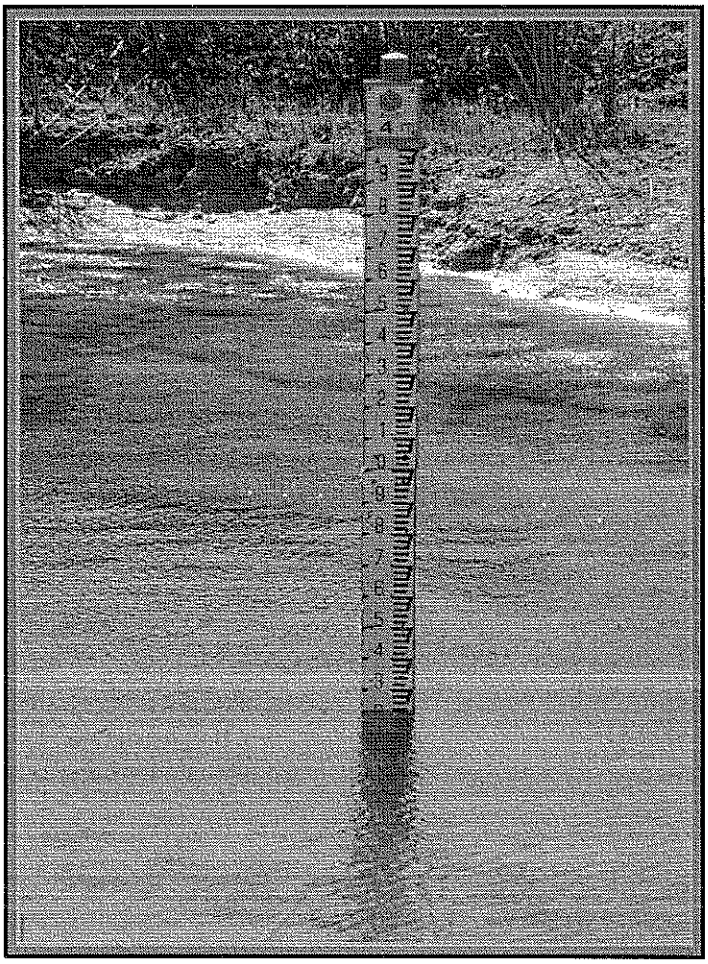


Plate 2.1 The water level gauge in Pond 1 indicating a depth 2.2 metres (Photograph by B. Boucher, March, 2000).

Two vegetation transects were also completed at low water and high water. Transects surveyed were located in the southern and northern portions of the wetland (Plate 2.2). Transect T-1 encompassed an area that has been extensively modified, while transect T-2 was located in an area that has been not as extensively modified as T-1. Transects were completed by taking photographs of vegetation found every two metres along the transects. Vegetation species that were located within one metre of the transect line were photographed and described.

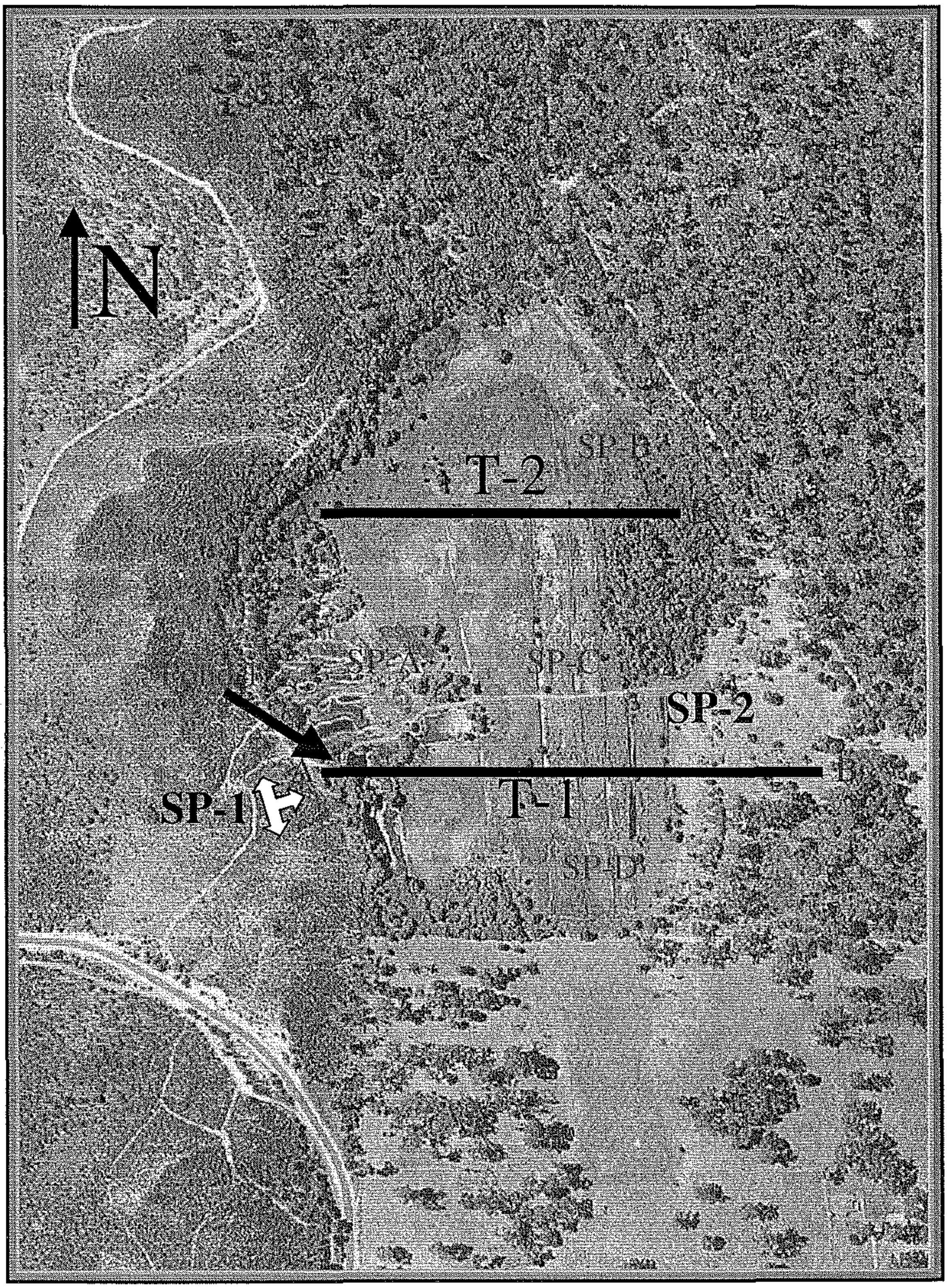


Plate 2.2 Aerial Photograph of Pipidinny Swamp 1999 (Height:9800ft) showing the positions of the vegetation transects T-1 and T-2 and the waterbird survey positions and the location of the water gauge (Pond 1) (Photograph obtained from DOLA).

2.3 Waterbird Survey

Waterbirds were chosen since wetlands are their preferred feeding grounds, and provide specific niche requirements for waterbirds. For example, the long legs and webbed feet of most waterbirds are ideally suited to the shallow waters of the wetlands on the Swan Coastal Plain. Fortnightly waterbird surveys were conducted from April to September 2000. Since waterbirds are most active in the early morning and late afternoon when they are feeding, survey times coincided with these periods of daily activities.

A systematic pattern was used to survey the study site. The survey started with a scan of the wetland from Survey Position 1 (SP-1) looking east over the wetland. A more detailed investigation on foot surveyed the vegetation surrounding SP-A, -B, -C and -D between SP-1 and SP-2 (Plate 2.2). Some waterbirds were flushed out of the vegetation, so that they could be identified in flight.

2.4 Aerial Photography

Aerial photographs were analysed for changes to the vegetation coverage, extent of water coverage and surrounding land usage of the Pipidinny Swamp environment over time. The earliest photograph is from 1941 and the most recent photograph available was taken in 1999 (Table 2.1). Analyses of aerial photographs were conducted by interpretating features from the photos. Features examine on the aerial photographs included the time of year the photo was taken, the water coverage and the extent of the vegetation structure.

Table 2.1 Aerial Photographs of Pipidinny Swamp indicating Dates, Height and Scale (where available) used to compare changes in the vegetation coverage, extent of water and surrounding land usage of Pipidinny Swamp.

Year	Date	Height	Scale
1941	29/09/1941	10 000ft	1:30 000
1952	18/02/1952	15 000ft	1:30 000
1960	02/07/1960	7 920ft	1:3 960
1973	22/11/1973	25 000ft	1:82 300
1980	07/06/1980	☆	1:6 250
1989	☆	☆	☆
1992	04/12/1992		1:5 000
1996	☆	☆	☆
1999	☆	9 800ft	☆

☆ Not Available

2.5 Oral Histories

Oral histories from people who have lived around Pipidinny Swamp with information relating to Pipidinny Swamp were used to expand the historical records.

2.6 Materials

A pair of 7 x 35 binoculars were required for waterbird surveys.

Chapter 3: The Wetland Environment

3.1 Physical Setting

Pipidinny Swamp is situated upon an aeolian landscape (Seddon, 1972). The wetland is situated along the boundary of two geomorphic units between the older Spearwood Dune System to the east and the younger Quindalup Dune System to the west (Figure 3.1.1) (Arnold, 1990; Dames & Moore, 1986; McArthur & Bartle, 1980). The wetland receives aeolian material from the Quindalup Dune System composed of calcareous sand that contains lime. Lime deposited within the wetland has mixed with the typical black peaty soils associated with other wetlands on the Swan Coastal Plain. The addition of lime to this peaty soil results in the colour of the peat being white (referred to as 'Marl'; Jackson, 1997) as compared to the black peaty soils found on other wetlands. The only wetlands on the Swan Coastal Plain that contain 'marl' are Pipidinny Swamp and the wetlands on Rottnest Island. Beonaddy Swamp, located to the south of Pipidinny Swamp, also receives lime deposited by wind, but not as much as Pipidinny Swamp as it is located further inland.

3.2 Groundwater

Water is essential for all living organisms including those of the Swan Coastal Plain. The Gnangara Groundwater Mound north of the Swan River has supplied the North-West Corridor of Perth with all of its scheme water (Dames & Moore, 1986). Pipidinny Swamp is linked very closely to this Groundwater Mound. The wetland is situated on the western edge of this Mound and any disturbance to the groundwater.

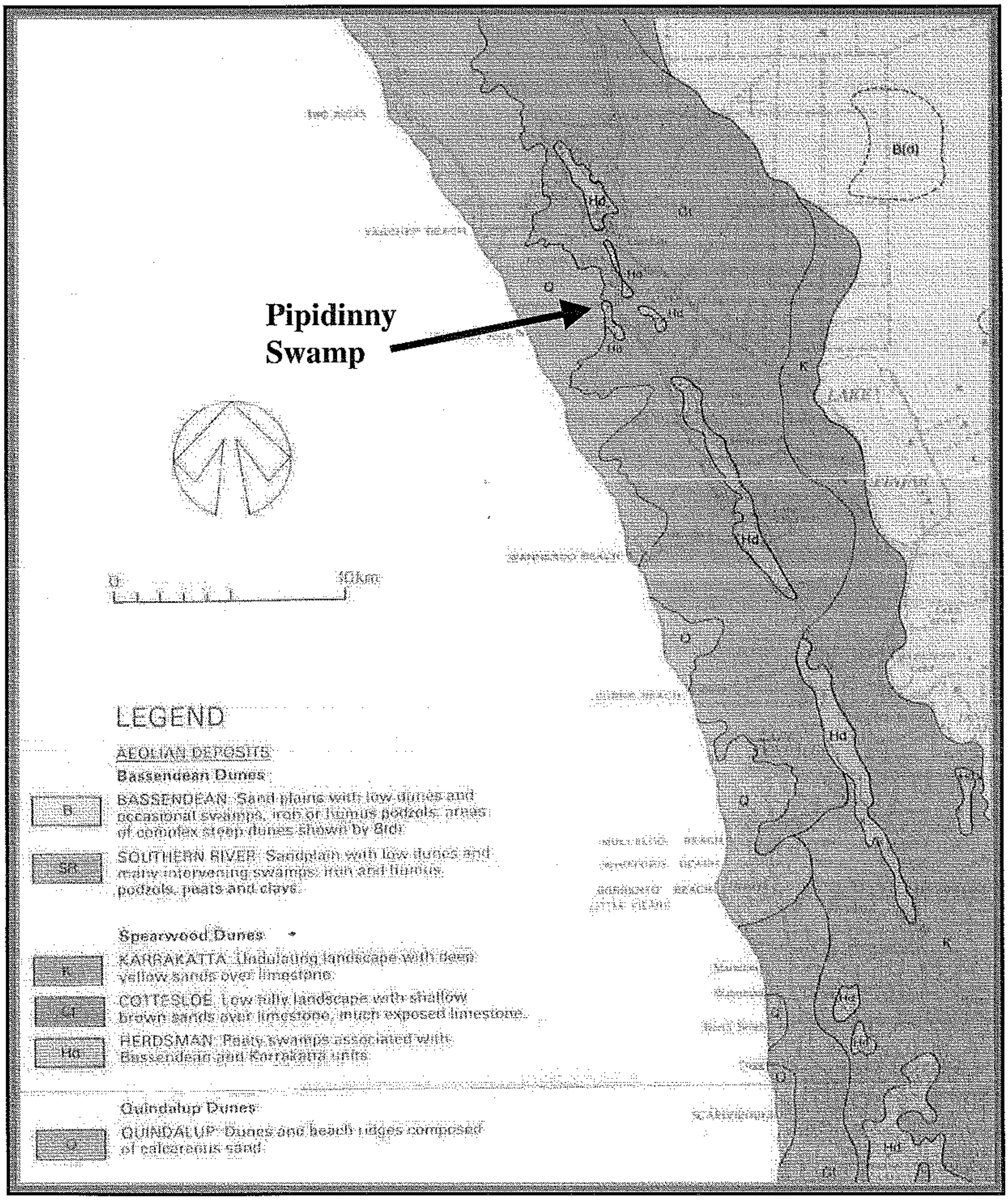


Figure 3.1.1 Map of the Swan Coastal Plain, Western Australia, indicating the boundaries of the Sand Dune System. Source: Figure 19 Dames & Moore, (1986).

system can be ecologically damaging to this wetland and many others located on the Gnangara Mound. For example, Pipidinny Swamp is part of a series of linear wetlands that run parallel to the coastline (Seddon, 1972). All of these wetlands are shallow and are either seasonal or semi permanent wetlands (Arnold, 1990; Dames & Moore, 1986; Bekle 1980, 1998; Davies et al., 1991). Any influence to the groundwater, even a change of half a metre to the water level, could affect the ecology of many of these wetlands, including Pipidinny Swamp.

This research of the groundwater system aimed to provide background knowledge of groundwater levels at Pipidinny Swamp and the surrounding area. Since groundwater data only exist since 1993, an analysis of a groundwater bore (JP21) (See Figure 3.2.1 for location of bore) situated between Pipidinny and Beonaddy Swamp was also studied to provide an indication of groundwater levels prior to 1993. WRC have been monitoring water level and conducting water analyses of bore JP21 since 1974. This data was also analysed to demonstrate the dynamic state of the wetland over a period of 26 years. The present survey monitored the groundwater level at Pipidinny Swamp from the water level gauge positioned within the wetland over a six-month period from April to September 2000. This data was analysed to demonstrate the difference in groundwater wetland between seasons of high and low water levels.

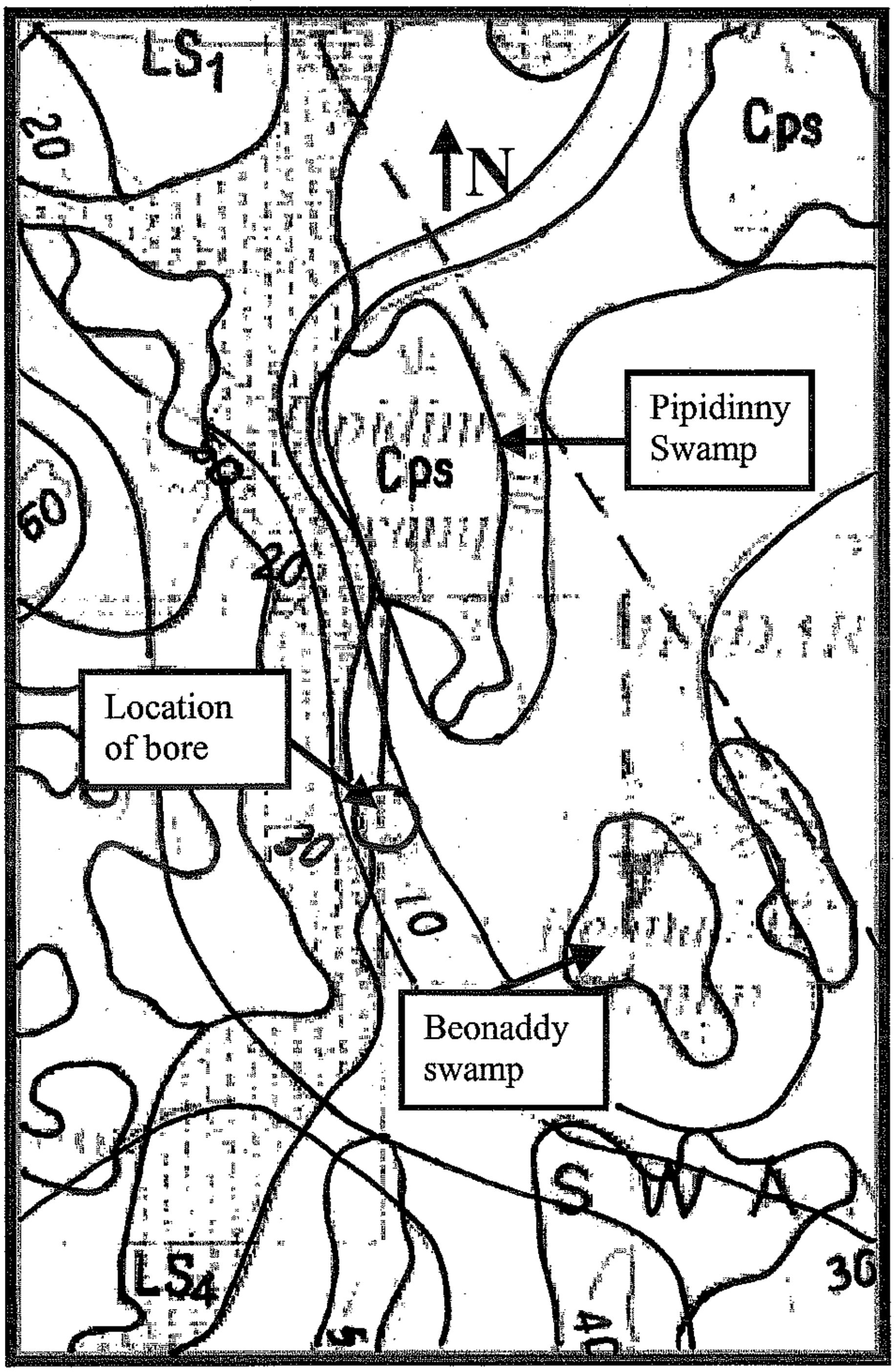


Figure 3.2.1 This map shows the location of bore JP21 situated between Pipidinny Swamp and Beonaddy Swamp. Adopted from, Yanchep Map in Geological Survey of W.A.

3.2.1 Results

3.2.2 Water levels at Pipidinny Swamp from 1993

The maximum recorded water level at Pipidinny Swamp occurred in October 1993 when a water level of 3.96m AHD was recorded. Since then, the maximum water level reading each year has varied between 2.98m and 3.25m AHD, with only one year recording a water level below three metres (1997 with 2.98m AHD) (Figure 3.2.1).

The minimum water level recorded at Pipidinny Swamp since 1993 was 1.61m AHD in April 1998. The minimum water levels each year since 1993 have fluctuated between 1.61m and 2.15m AHD. During this time period, the only year to record a minimum water level above two metres was in 1994 (2.15m AHD). Most of the minimum water level readings at Pipidinny Swamp have been just below two metres. The minimum water level reading at Pipidinny Swamp (1.61m AHD in 1998) was recorded in the winter following the lowest maximum water level which was recorded in 1997 (2.98m AHD).

It appears that the water level has remained relatively constant over the past four to five years since 1993. The water level was highest in 1993 and appears to be a result of the above-average rainfall that occurred during the years 1991/92 (Figure 3.2.2).

3.2.3 Hydrology from bore JP21

In 1974 monitoring commenced of the groundwater from bore JP21 that is situated between Pipidinny and Beonaddy Swamps. Over the past 26 years, monitoring of water level and a total of 35 different tests (i.e nitrate and turbidity levels) have been conducted upon water samples taken from bore JP21 (See Table 3.2.1 for these tests completed). Of the 35 tests completed only four tests showed an increase from the previous test, 15 tests showed a decrease, five tests results were the same and 14 tests were only completed once over the past 26 years. Other detailed analysis is required upon this data. Figure 3.2.3 illustrates the highest and lowest water level readings for each year from 1974 to 2000.

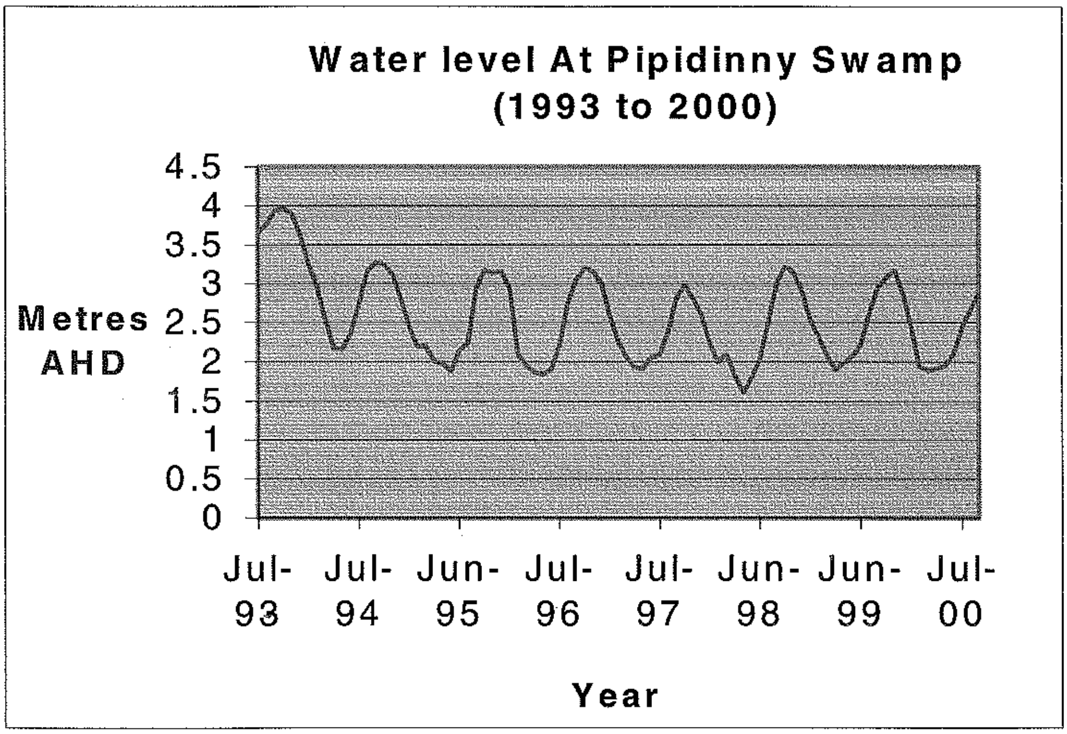


Figure 3.2.1 Water level at Pipidinny Swamp (1993 to 2000). Source: WRC, 2000.

The water level within Pipidinny Swamp has never exceeded 3.5AHD meters and never dropped below 2.30 AHD metres. The maximum water level reading from this bore was in 1978 recording 3.43m AHD. In 2000 the maximum water level recorded at this bore was only 2.58m AHD (11/07/2000), and represents the lowest maximum recorded.

Table 3.2.1. The test analyses completed and the number of times these tests were conducted on water samples taken from JP21 over the past 25 years. (Source: WRC).

Number of surveys	Type of Analysis
3	Alkai tot $CaC0_3$ mg/l
1	Ammonium as n mg/l
1	Arsenic mg/l
3	Bicarbonate $HC0_3$ mg/l
2	Boron mg/l
3	Calcium mg/l
3	Carbonate $C0_3$ mg/l
3	Chloride mg/l
3	Colour True Hazen
3	Cond Comp Lab u.sie/m
1	Copper mg/l
1	Depth Bed BTOC m
4	Depth Sample sl m
2	Fluoride mg/l
1	Free CO_2 mg/l
3	Hardness Total mg/l
2	Iron mg/l
1	Iron u/f mg/l
1	Lead mg/l
5	Level of bed sl m
3	Magnesium mg/l
1	Manganese mg/l
1	Nitrate as n mg/l
3	Nitrate as NO_3 mg/l
2	Odour-situ
1	P Total Soluble mg/l
3	ph (lab)
3	Potassium mg/l
1	Saturation Index
3	Silica mg/l
3	Sodium mg/l
3	Sulphate $S0_4$mg/l
2	TDS 180c mg/l
3	TSS Sum of Ions mg/l
3	Turbidity-Hach ntu
1	Water Temp-Situ Deg, c
1	Water Temp-Test Deg. C
1	Zinc mg/l

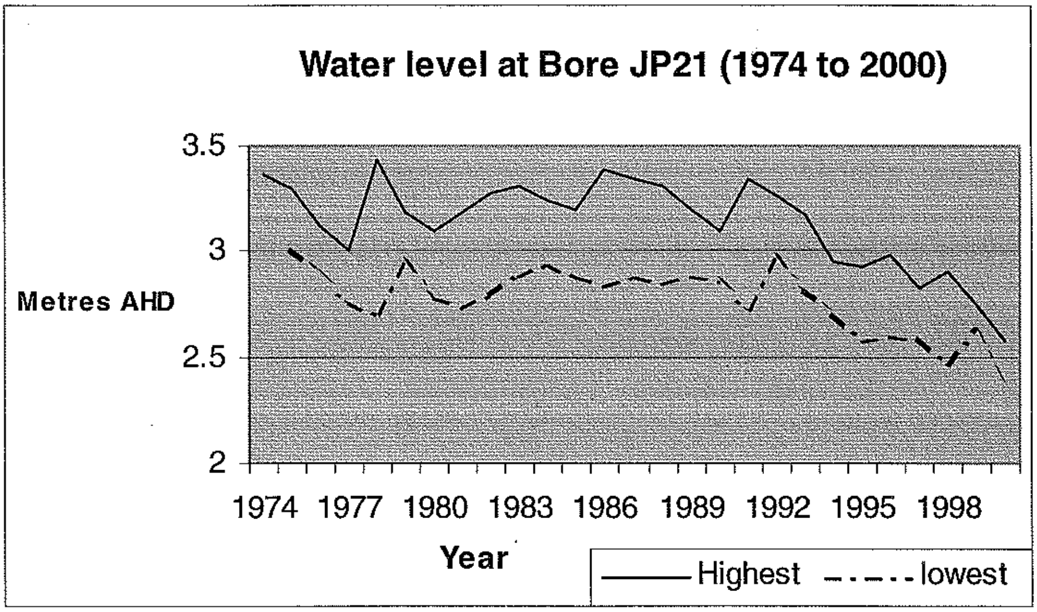


Figure 3.2.2 Indicates the highest and lowest water level readings per year at Bore JP21 (1974 to 2000). Source: WRC, 2000

The minimum recorded water level per year at bore JP21 occurred in 2000 with only 2.36m AHD recorded on 11[th] May 2000. This is only the second time that the water level has ever dropped below 2.50m AHD. The first time occurred in 1998 where a minimum water level of 2.46m AHD was recorded. From 1975 to 1992 the minimum water level per year recorded was consistent between 3.01m AHD to 2.70m AHD. After 1992 minimum water level readings per year have been slowly decreasing.

This research data indicates that the water level between 1973 and 1991 was seasonally dynamic, but fairly constant over this period. After 1991, however, the water level has been consistently decreasing. It is apparent from Figure 3.2.2 that the minimum water level reacts one to two years after a change in the maximum water level has occurred. For example, in 1976 the maximum water level recorded was only 3.01m AHD and the minimum water level was only 2.76m AHD. However, the following year in 1977 the water level dropped to its lowest minimum in twenty years with 2.7m AHD. The water level recorded for 2000 has not yet reach its maximum level as the water level generally does not reach the maximum until sometime in September, October or November. However, it appears that the water level for this study will be at the lowest maximum on record.

3.2.4 The Present Study

Water level monitoring commenced late in February 2000 and found the water level just below 2 metres (1.94 m AHD) (Figure 3.2.3). At this stage the water level is dropping and is near the lowest level for the year. The next two readings from the wetland during March shows a drop in the water level to 1.91m and 1.89m AHD. The second reading for March of 1.89m AHD was the lowest reading recorded on Pipidinny Swamp during this research period.

In early April 2000 the water level in Pipidinny Swamp started to increase. Over the next three months the water level increased by only 10 cm. The lack of water in Pipidinny Swamp at this time of the year is possibly due to the below average rainfall received for the months of May and June. The average rainfall received during May and June was 103.9 mm and 171.2 mm, respectively. However, this year the rainfall was well below average and received was only 20.8 mm for May and 95.4 mm for June.

With the beginning of July the water level within the wetland started to increase and by the middle of July, the water had risen to 2.44m AHD. This upward trend of the water level continued until the end of the research period where the highest reading of

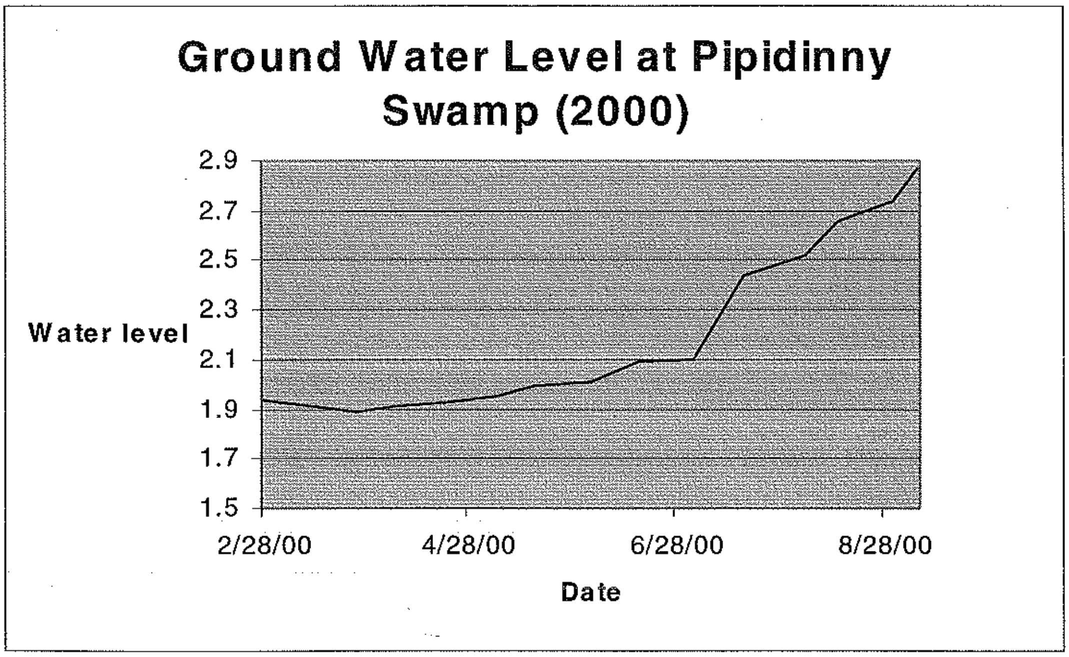


Figure 3.2.3 The water level recorded at Pipidinny Swamp during this present survey, 2000.

the water gauge was recorded on the last survey in September with a reading of 2.87m AHD. It is expected that the water level will continue to rise during September and October reaching the maximum level during the months of September through to November. During the summer months the water level is expected to slowly drop due to evaporation.

The dynamic state of the groundwater level within the wetland is shown above. During the winter months, the Gnangara Groundwater Mound is recharged from rainfall received on the Swan Coastal Plain. The level of the groundwater rises and in low level interbarrier dunes, the rising water level is seen as an expression of the groundwater mound. When the water level is low within the wetland, the surface area-volume ratio increases. This combined with high temperatures during the summer months result in high evaporation of water from the wetland. This results in the water level within the wetland decreasing until the winter rains recharge the mound the following year.

3.2.5 Conclusion

The data clearly indicates that an unknown, new influence is affecting the groundwater level at Pipidinny Swamp. The water level was the same between 1974 and 1990. Since 1990, the water level has dramatically decreased from 3.30m to 2.50m at high water.

There are three water abstraction factors that have an impact on the groundwater mound level. First, water is pumped from the Mound and used to supply one-third or more of Perth's scheme water. Water from the Gnangara Mound also supplies all of the scheme water for the residents of the Northern Corridor of Perth. Second, water is also pumped from the mound for the market gardeners located on the Gnangara Mound. Third, on top of the Mound there are huge areas where the native vegetation has been removed and replaced with introduced pine trees. This occurred about 1980, and now 20 years later these pine trees have now reached maturity. Pine trees when fully matured require more water to survive than most native vegetation found on the Swan Coastal Plain. As a result of the trees reaching maturity far more recharge and table water is being consumed by the pines than previously by the native vegetation. This has been seen to be a reason for the lower water level within the wetland by some local residents in the Wanneroo, Yanchep area.

It is unlikely that a single factor alone could be responsible for the change in the water level. However, it is more likely that the combination of all three factors together could have resulted in the decrease of the water level at Pipidinny Swamp. It should not be forgotten that the change in the water level could also be due to Perth and the Swan Coastal Plain receiving below average rainfall for the past five years. Further research is required of this data from the WRC to determine the factors influencing the water level changes.

3.3 Vegetation

Pipidinny Swamp is a seasonal wetland that experiences changes in its vegetation system between summer and winter. Most vegetation surveys of wetlands on the Swan Coastal Plain have surveyed the vegetation at times when water is low (end of summer) and/or high (winter) (e.g., Arnold, 1990; Davis *et al.*, 1991). A comparison of the vegetation over a six-month period will show the changing state of the vegetation. This research provides a description of the vegetation surrounding the wetland.

3.3.1 General Description

The Spearwood Dune System is situated to the east of the wetland and consists of younger and higher dunes that are less leached than the Bassendean Dune system to the east. The tall open forest that occurs on this dune system are dominated by *Eucalyptus gomphocephala* (Tuart), *Eucalyptus marginata* (Jarrah) and *Eucalyptus calophylla* (Marri). Smaller species, that includes species from the Proteaceae family, form the second tier in the vegetation structure. The leached surface soil has formed carbonate layers and columns of hard, compact limestone deposited from solution by percolating waters. These limestone deposits can be seen clearly at Pipidinny Swamp on the western side of the wetland. The exposed limestone has formed a cliff that has started to erode and crumble. Table 3.3.1 describes the species identified, and when whether it was surveyed in summer and/or winter.

Table 3.3.1. The vegetation species identified at Pipidinny Swamp and whether surveyed at summer and / or winter.

Native			Sum	Win
Family	Scientific	Common Name		
Cyperaceae	*Baumea articulata*	Jointed Twig Rush	*	*
Chenopodiaceae	*Atriplex cinera*	Coast Saltbush, Grey Saltbush	*	*
Haemodoraceae	*Conoslylis candicans*	Grey Cottonhead, White Conostylis	*	*
Apiaceae	*Hydrocotyle callicarpa*	Small Pennywort	*	*
Cyperaceae	*Isoplepis nodosa*	Knotted Club Rush	*	*
Lamiaceae	*Hemiandra pungens*	Snake bush		*
Mimosaceae	*Acacia lasiocarpa*	Dune Moses	*	*
Myrtaceae	*Melaleuca rhaphiophylla*	Swamp Paperbark	*	*
	Eucalyptus gomphocephala	Tuart	*	*
	Eucalyptus rudis	Flooded Gum	*	*
Papilionmaceae	*Hardenbergia comptoniana*	Native Wisteria, Wild Sarsaparilla	*	*
Rhamnaceae	*Spyridium globulosum*	Unknown	*	*
Typhaceae	*Typha orientalis*	Bulrush	*	*
Exotic				
Aizoaceae	*Carpobrotus edulis*	Pigface, Hottentot Fig	*	*
Asphodelaceae	*Trachyandra divaricata*	Strapweed	*	*
Asteraceae	*Ambrosia psilostahya*	Perennial ragweed	*	*
	Archotheca calendula	Capeweed		*
	Conyza albida	Tall Fleabane	*	
	Cursium stricta	Spear thistle	*	
	Hypochaeris radicatal	Unknown	*	
	Sonchus asper	Prickly sowthistle	*	*
Cactaceae	*Opuntia stricta*	Common Prickly Pear	*	*
Apiaceae	*Ciclospermum leptophyllum*	Slender Celary	*	*
Afiaceae	*Foeniculum vulgare*	Fennel	*	*
Euphorbia	*Euphorbia terracina*	Geraldton Carnation weed		*
Geraniaceae	*Pelargonium capitatum*	Rose Pelargonium	*	*
Poacene	*Avena barbata*	Beaded oat		*
	Corladeria selloana	Pampas grass	*	*
	Lagurus ovatus	Hare's Tail Grass		*
Solanaceae	*Anthocercis ilicifolia*	Fire weed		*
	Or			
	Anthocercis littroea	Yellow Tailflower		*
		Total Number =	24	28

The Quindalup Dune System, which was formed later than the Spearwood Dune System, consists of calcareous sands that are high in lime and low in soluble salts and generally unconsolidated (loose). These dunes usually are elongated and parallel with the coastline. The vegetation lacks the Proteaceae, Fabaceae and Myrtaceae families which are found elsewhere on the Coastal Plain (Seddon, 1972).

3.3.2 Description of Wetland: Low Water

The southern portion of the wetland is privately used as summer pasture for cattle and consists mainly of exotic grasses. Surrounding the southern portion of the wetland are mature paperbarks, which have been thinned and cleared for the grazing of cattle.

The vegetation on the last dune east on the Quindalup Dune System contains mainly low-lying native heath with small dune weeds species present. Native species include *Hardenbergia comptoniana* (Wild Wisteria), *Acacia lasiocarpa* (Dune Moses), *Conoslylis candicans* (Grey Cottonhead) and *Atriplex cinera* (Coastal Saltbush). Most of these species were not in flower during this study. Exotic species include *Asphodelus fustulosus* (Onion weed), *Trachyandra divaricata* (Strapweed). While grasses and daisies were found, specific identification could not achieved as it is difficult to identify species when not in flower.

The western fringe of the wetland consists of 2 to 4 metres high *Melaleuca rhaphiophylla* (Common Swamp Paperbark), *Eucalyptus rudis* (Flooded Gums), *Acacia cyclops* (Coastal Wattle) and *Spyridium globulosum*. Sedges and reeds including *Typha orientalis*

(Bulrush), *Baumea articulata* (Jointed Twig Rush) and the *Isoplepis nodosa* (Knotted Club Rush) surround the open water. Several exotic species have firmly established themselves in this area, including *Foeniculum vulgare* (fennel), the *Opuntia stricta* (Common Prickly Pear) and the Bulrush. Revegetation of the paperbarks is evident on the western portion of the wetland with young species establishing themselves towards the middle of the wetland.

In the middle of the wetland a small mature stand of paperbarks exist with young specimens also present. The cleared area in the western half contains mainly the herb *Hydrocotyle callicarpa* (Small Pennywort) and several other weed species that include *Lagurus ovatus* (Hare's Tail Grass) and *Archotheca calendula* (Capeweed).

In the north-eastern corner bulrush again dominates with one large *Corladeria selloana* (Pampas Grass) specimen also present. Across the northern portion of the wetland, bulrush and other introduced species are scattered among each other with not one specie dominating the entire area. The channels during the low water survey contain flowering bulrush that seem to be spreading from the channels into the surrounding north and south-east corners.

Several introduced species exist on the old market garden beds. These include several introduced grass, daisy and market gardening species such as *Ciclospermum leplophyllum* (Slender Celery). Several thistle species including the *Cursium stricta* (Spear Thistle) and the *Sonchus asper* (Prickly Sowthistle) are spreading throughout the wetland but mainly occur on the cleared areas. The Spear Thistle was flowering during this survey period. There was a particular species of Fleabane (Conyza) (probably *Conyza albida* – Tall Fleabane) prominent within the wetland during this survey. This species produces flowers around the middle and late summer and is once again prominent on the cleared areas within the wetland.

The cleared area on the eastern bank contains mainly *Carpobrotus edulis* (Pigface), while the rest of the fringing vegetation on the east is fringing paperbark with scattered dead Tuart trees.

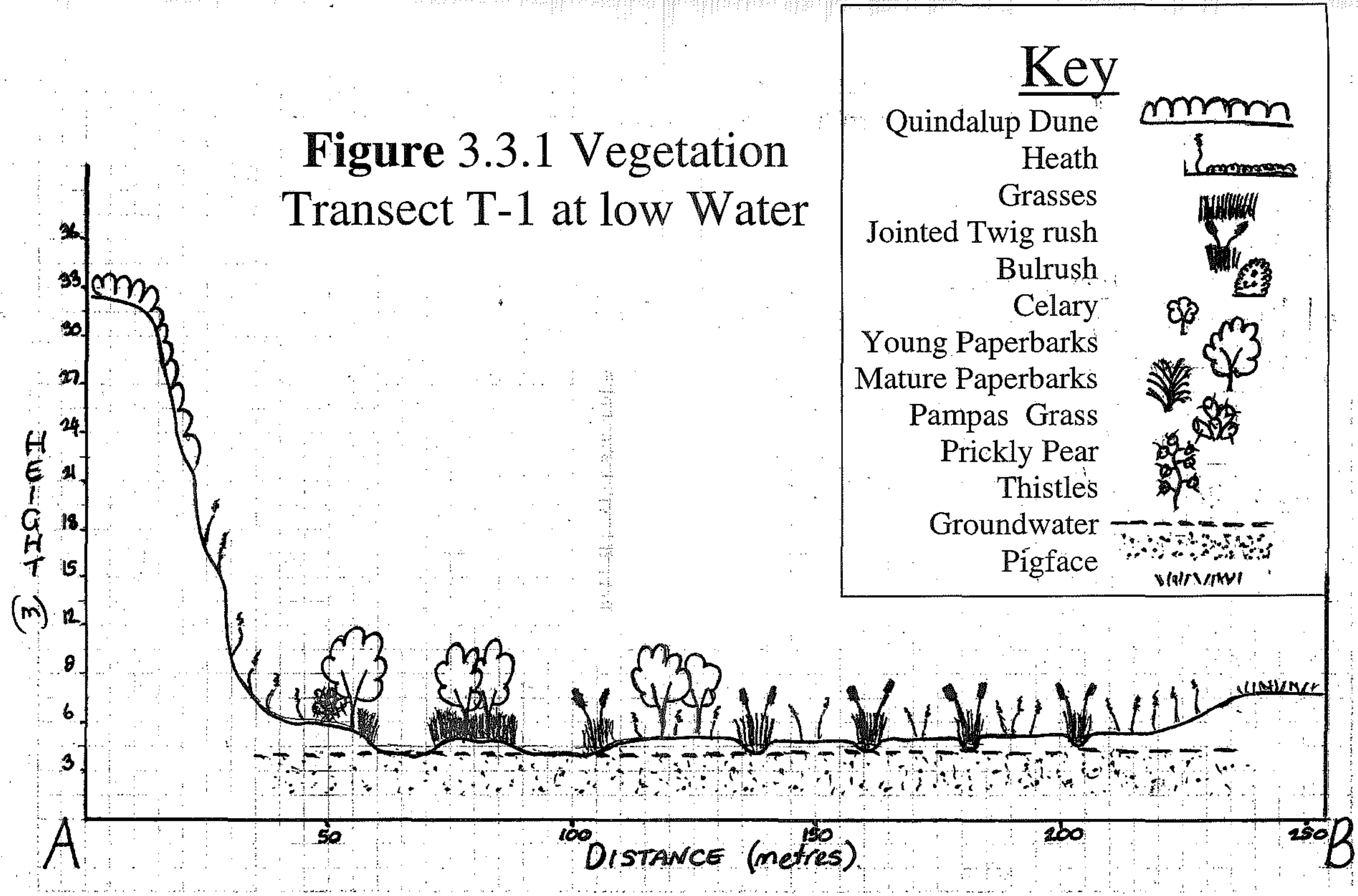
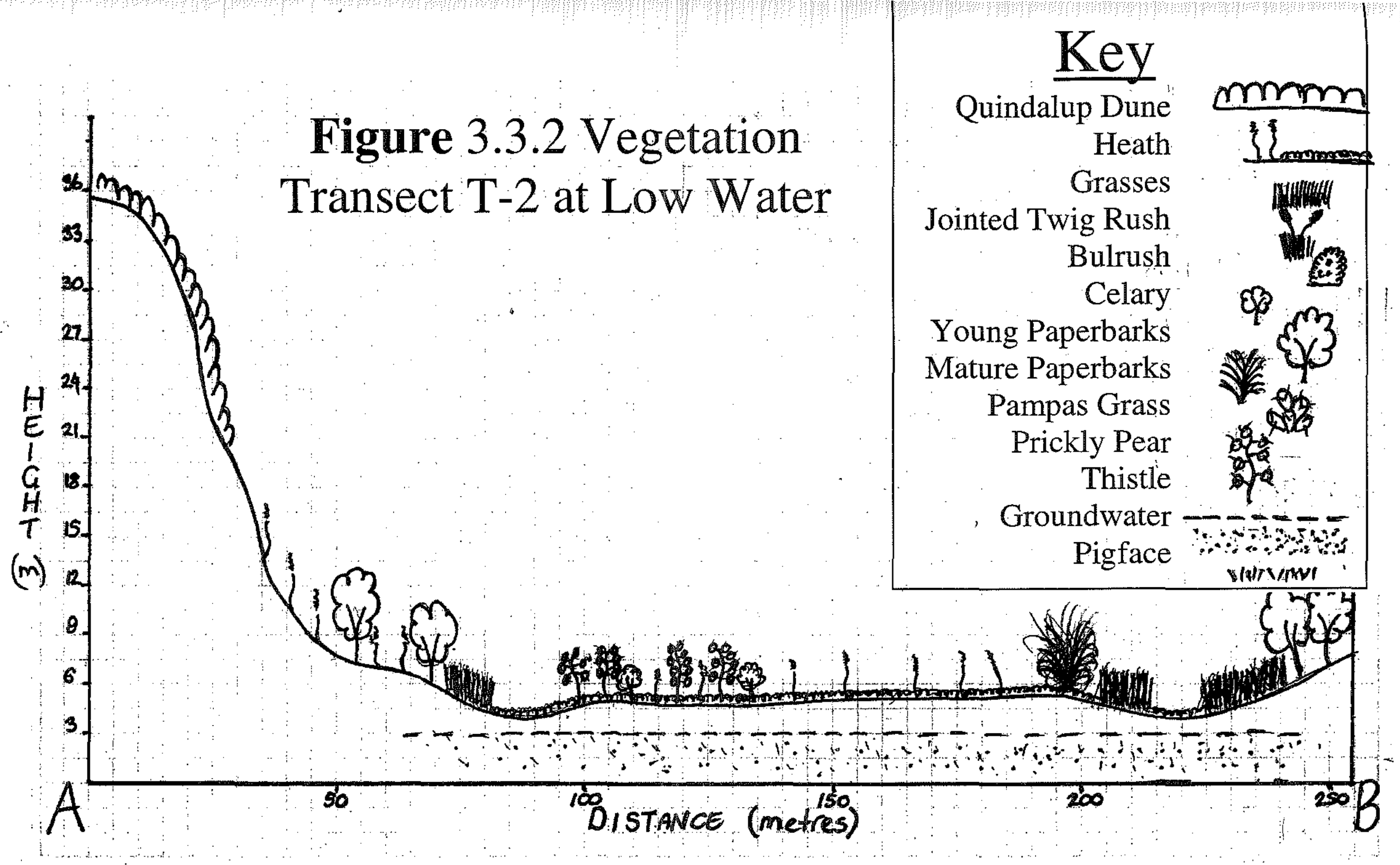


Figure 3.3.1 Vegetation Transect T-1 at low Water

Figure 3.3.2 Vegetation Transect T-2 at Low Water



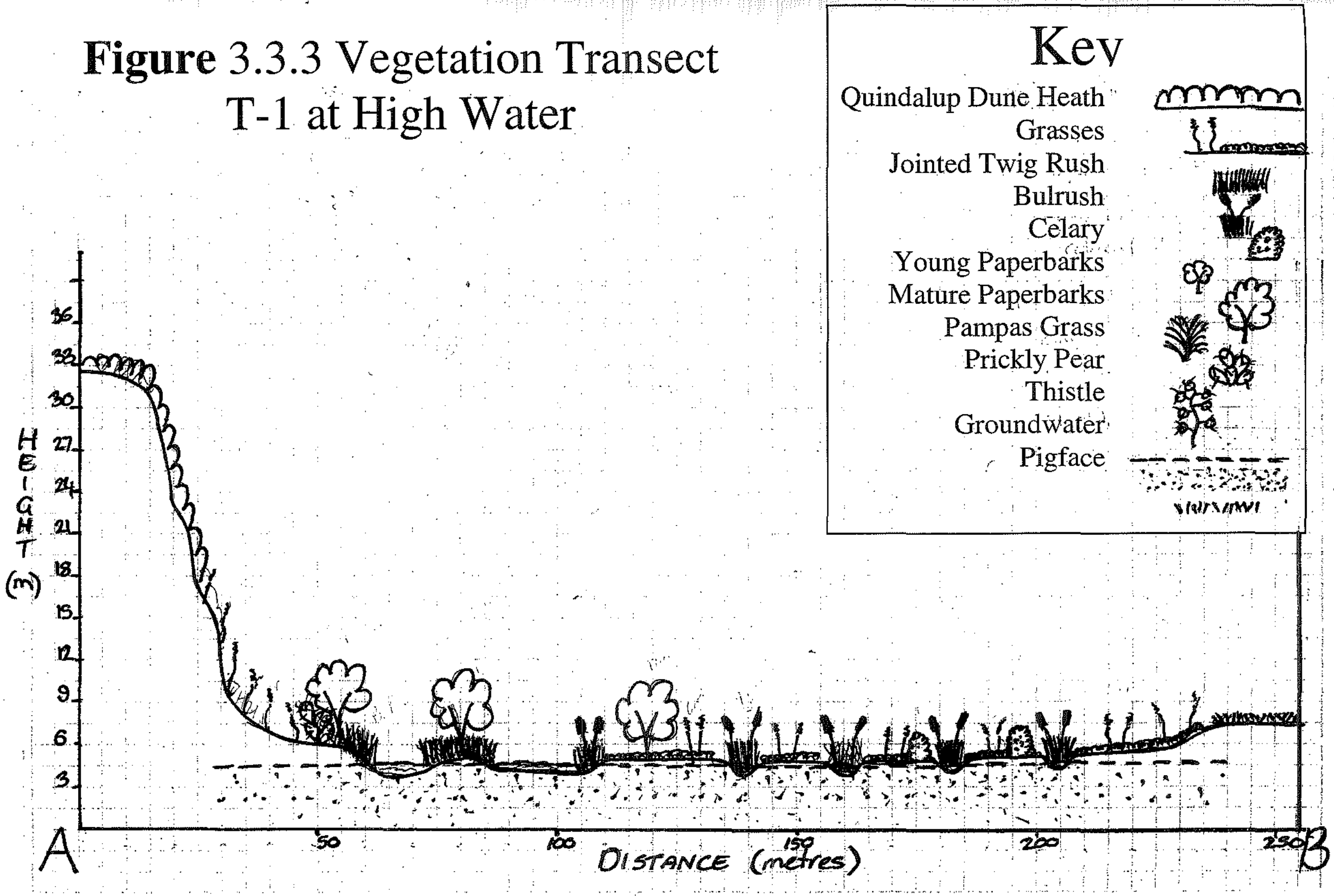
3.3.3 Description of Wetland: High Water

The vegetation during the winter survey still contained the same native species throughout the wetland. Most of the native species flower with increased water and growth of species is noticeable. The Wild Wisteria flourishes at that time of the year on the edge of the Quindalup Dunes. Also flowering at that time was Dune Moses with little bright yellow flowers with prickly stems very noticeable along with the *Hemiandra pungens* (snake bush). Along track edges, *Pelargonium capitatum* (Rose Pelargonium), *Euphorbia terracina* (Geraldton Carnation Weed) along with daisies and grasses are in flower. Some of these species include *Avena barbata* (Bearded Oat), Hare's Tail Grass and daisies such as Capeweed. *Anthocercis littroea* (Yellow Tailflower) were also found on the top of the dune.

Most of the Spear Thistles that were present during the summer survey expired by the winter survey. In addition, most of the bulrush that was present appeared dry and lifeless. The old garden market beds flourish with many weeds including the Slender Celery, Rose Pelargonium, Prickly Sowthistle and English Spinach.

The fringing vegetation around this wetland still contained all the species recorded in summer. Weeds and grasses that are present are now competing for room to grow within the existing vegetation.

Figure 3.3.3 Vegetation Transect
T-1 at High Water



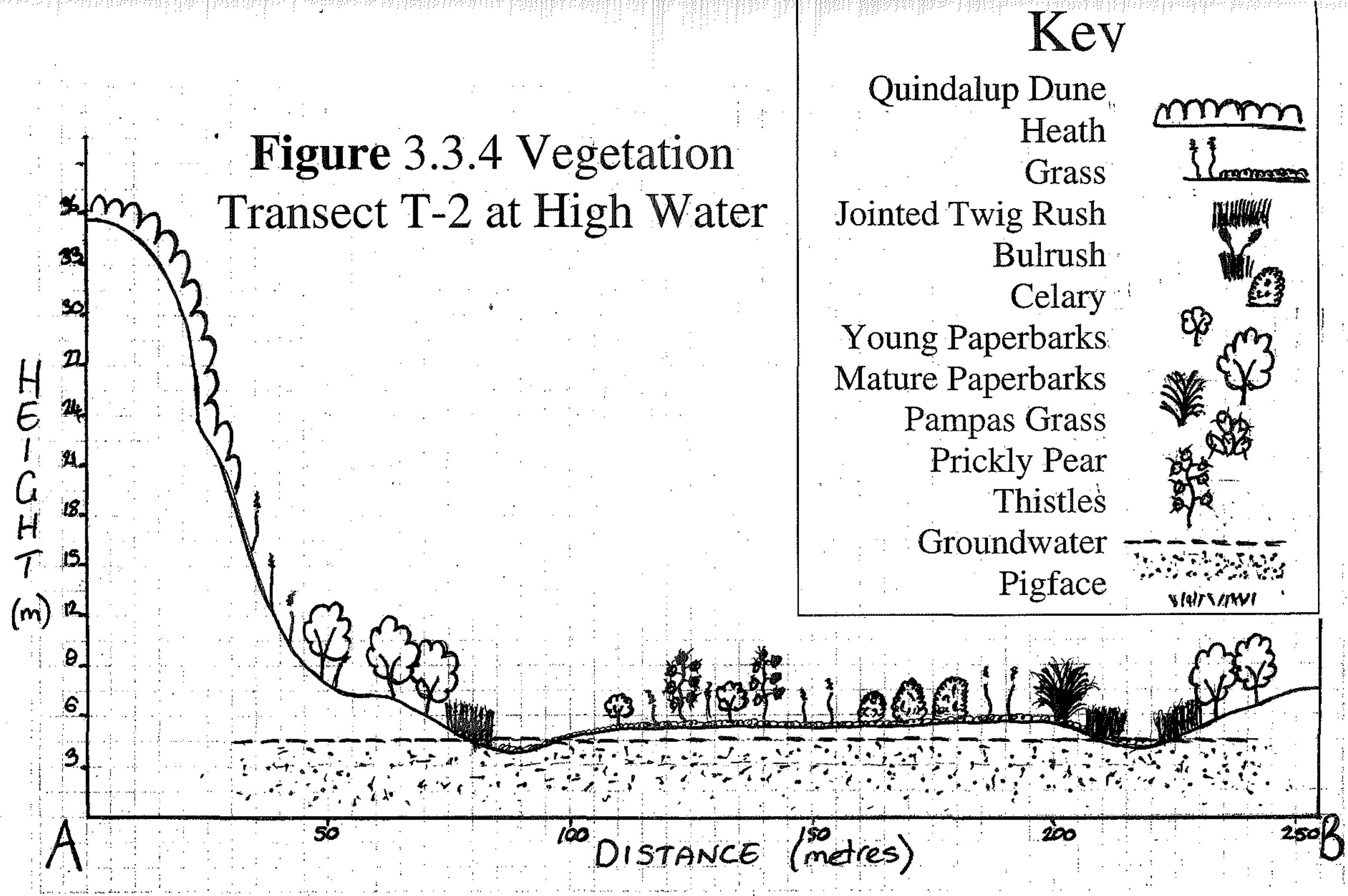


Figure 3.3.4 Vegetation Transect T-2 at High Water

3.4 Waterbirds

Ecological studies that assess the effect of an environmental disturbance can be categorised in one of two ways. 'Static' studies compare two sites simultaneously and assume sites are relatively similar, an assumption that does not hold true in most ecosystems. Conversely, 'dynamic' studies compare the same site over a number of years. As a result of the long period of time needed to complete such a study, these studies are rare. Consequently, there is a severe shortfall in the scientific literature of long-term ecological studies using the dynamic approach (however see Kattan, Alvarez-Lopez & Giraldo, 1992, Recher, 1997). This lack of dynamic studies is unfortunate, as they are important because changes in ecosystems often occur over long periods of time and may not be noticed without continuous or long-term monitoring.

This research used waterbirds as indicators of possible disturbances. Waterbirds are conspicuous inhabitants of wetland ecosystems and are positioned towards the top of food chain. A broad diversity of waterbird species and abundance indicates that the rest of the wetland ecosystems is in good health. For this purpose records of earlier surveys were obtained from private birdwatchers contacted through RAOU. RAOU was asked by CALM in early in the 1980's to conduct bird surveys at Pipidinny Swamp. CALM recognised that the wetland was an important waterbird habitat and was once described by representatives of Birds Australia W.A as the 'Kakadu of Western Australia'. RAOU have completed bird surveys at Pipidinny Swamp and the surrounding area for the past 16 years (since 1984, Table 3.4.1) with data on species composition, diversity and abundance from 1984 to 1999. This current research then conducted fortnightly waterbird surveys at Pipidinny Swamp and analysis of this data was compared to the waterbird Table 3.4.1 indicates what years surveys were completed, how many surveys were conducted that year and who conducted the surveys.

Table 3.4.1 Indicates the years surveys were conducted, how many surveys were completed, and record source.

Year	# of surveys	Surveys
1984	2	Barrett
1985	8	Barrett
1986	10	Barrett
1987	7	Barrett
1988	6	Barrett
1989	6	Barrett
1990	6	Barrett
1991	6	Barrett
1992	5	Barrett
1993	3	Barrett
1994	4	Barrett
1995	3	Barrett
1996	3	Barrett
1997	1	Barrett
1998	1	Barrett
1999	1	Barrett
2000	15	Boucher

Waterbirds were catogerised according to the way in which they use the lake environment. These range from those species which inhabit the water-surface (e.g., only ducks, swans and coot), to those species which depend on the lake habitat to live (which also include wader species and species that occur within the habitat on the water-edge). For this research, waterbirds were defined as those birds that depend on the lake habitat for at least some of their physiological needs, such as feeding, roosting, and breeding (Bekle, 1997).

Diversity is considered a primary indicator of eco-system health, stability and resilience (Clark, 1994). The oldest and simplest concepts of species diversity is the number of species found within a community- coined 'species richness' by McIntosh (1967). This research will assess how the waterbird community has changed over time, and it is believed that measuring species richness would be appropriate species 'diversity'.

3.4.1 Site Description

Bekle (1980) classified six different habitats at Lake Joondalup, which occurs in the same series of linear lakes about 20 kms south of Pipidinny Swamp on the Swan Coastal Plain. These are:

1) 'Peripheral zone', the area surrounding the wetland that remains dry all year round.

2) 'Flood zone', the area from the seasonal low water to the seasonal high water mark including the vegetation zones the Paperbark Woodland, the sedges and reeds.

3) 'Littoral zone', the area where the water depth is less than 0.5 meters, representing the low water mark.

4) 'Rushes zone', areas where rushes grow in water no deeper than 1.5 meters, but can tolerate seasonal dryness.

5) 'Open water', areas of open water where the depth is greater tan 0.5 meters.

6) 'Islands', isolated land surrounded by water on the lake.

Pipidinny Swamp contains all of these habitat zones, except for permanent islands. The wetland contains seasonally exposed spits which during periods of high water may form temporary islands.

The objective of this research was to determine

- What are the resident and visiting waterbird species that utilise Pipidinny Swamp?
- Has the diversity of waterbird species or abundance of waterbirds altered over time?
- Are any changes in waterbird (composition, diversity or total abundance?) attributed to a particular change/s in the ecosystem?

Comparing waterbird composition, diversity and abundance over time (years and seasons) provides evidence to the relevant authorities who manage the wetland as to whether or not the development of the area has been detrimental, beneficial or has had no impact. The main authorities who would use this information include; the owners, National Park Authority, and the managers, CALM. Others include City of Wanneroo, WRC, Water Authority, EPA, and the DEP.

3.4.2 Results from Previous Waterbird Surveys

A total of 35 waterbird species have been recorded at Pipidinny Swamp since 1984 (For final groups and Latin names see Table 3.4.2). These waterbird surveys reveal that no single species was recorded on every occasion. However, various waterbird species (8) were recorded on more than 75% of the surveys at Pipidinny Swamp before 1994 and are referred to as 'resident waterbird' species. These resident waterbird species included the White-faced Heron *Ardea novaehollandiae*, Pacific Black Duck *Anas superciliosa*, Dusky Moorhen *Gallinula tenebrosa*, Purple Swamphen *Porphyrio porphyrio*, Australian Reed Warbler *Acrocephalus stentoreus*, Maned Duck *Chenonetta jubata*, Grey Teal *Anas gracilis*, and the Little Pied Cormorant *Phalacrocorax melanoleucos*. Other waterbirds species that were recorded at Pipidinny Swamp by RAOU which are listed in Table 3.4.2

are considered 'visiting waterbirds' as they were not recorded on more than 75% of the surveys.

The earliest waterbird survey record at Pipidinny Swamp was on the 15th of December 1984. This count consisted of a total of 130 waterbirds from 17 species. Some species surveyed include Pacific Heron *Ardea pacifica*, White Ibis *Threskiornis molucca (T. aethiopica)*, Black Swans *Cygnus atratus*, Musk Duck *Biziura lobata*, Australian Shoveler *Anas rhynchotis*, Pacific Black Duck, Grey Teal and the Little Black Cormorants *Phalacrocorax sulcirostris* and Little Pied Cormorants.

One of the earliest winter waterbirds surveys in 1985 on the 7th of September found a total of 21 waterbirds present from six species. This count consisted of 1 Maned Duck and Little Pied Cormorant, 2 Australian Shovelers, 3 Black Swans, 4 our Pacific Herons and 10 White-Faced Herons.

Table 3.4.2 Waterbirds species surveyed at Pipidinny Swamp (1984 to 2000). # surveyed by Barrett, * surveyed by Boucher

Family	Comman Name Or Name	Scientific Name	Source of Record
Podicipedidae	Hoary-head Grebe	*Poliocephalus poliocephalus*	#
	Australasian Grebe	*Tachybaptus novaehollandiae*	#
	Australian Pelican	*Pelecanus conspicillatus*	#
Phalacrocoracidae	Little Black Cormanant	*Phalacrocorax sulcirostris*	#
	Little Pied Cormanant	*Phalacrocorax melanoleucos*	#
	Pied Cormanant	*Phalacrocorax varius*	#
Anhingidae	Darter	*Anhinga melanogaster*	#
Ardeidae	Pacitic Heron	*Ardea pacifica*	#
	White-Faced Heron	*Egretta (Ardea) novaehollandiae*	#,*
	Rufous-Night Heron	*Nycticorax caledonicus*	#
	Great Egret	*Ardea alba*	#
	Little Egret	*Egretta (Ardea) garzetta*	#
	Australasian Bittern	*Botaurus poiciloptilus*	#
Plataleidae	White Ibis	*Threskiornis molucca (T. aethiopica)*	#
	Straw-Necked Ibis	*Threskiornis spinicollis*	#
	Yellow-billed Spoonbill	*Platalea flavipes*	#
Anatidae	Black Swan	*Cygnus atratus*	#
	Australian Shelduck	*Tadora tadornoides*	#,*
	Pacific Black Duck	*Anas superciliosa*	#,*
	Grey Teal	*Anas gracilis*	#
	Australian Shoveler	*Anas rhynchotis*	#
	Hardhead	*Aythya australis*	#
	Maned Duck	*Chenonetta jubata*	#
	Musk Duck	*Biziura lobata*	#
	Blue Billed Duck	*Oxyura australis*	#
Rallidae	Buff-banded Rail	*Gallirallus phillippensis*	#
	Spotless Crake	*Porzana tabuensis*	#
	Baillous Crake	*Porzana pusilla*	#
	Black-tailed Native Hen	*Gallinula ventralis*	#
	Dusky Moorhen	*Gallinula tenebrosa*	#
	Purple-Swamp Hen	*Porphyrio porphyrio*	#,*
	Eurasian Coot	*Fulica atra*	#
Recurvirostridae	Black-winged Stilts	*Himantopus himantopus*	#
Hirundinidae	Welcome Swallow	*Hirundo neoxena*	#
Sylviidae	Australian Reed-warbler	*Acrocephalus stentoreus*	#,*
Accipitridae	Marsh Harrier	*Circus approximans*	#

On any one survey, a maximum of 18 waterbirds species were recorded at Pipidinny Swamp and occurred three times over the past 16 years, on the 20th December 1986, 16th January 1988 and the 10th January 1992. Previous waterbird surveys indicate that the total number of waterbird species counted at Pipidinny Swamp per year during the first eight years was between 18 and 28 species (Figure 3.4.1). However, the total number of waterbird species dropped considerably during the last eight surveys, from 19 species present in 1993 to only five species recorded during 2000. In 1999 no waterbirds species were recorded at Pipidinny Swamp on the only survey completed that year.

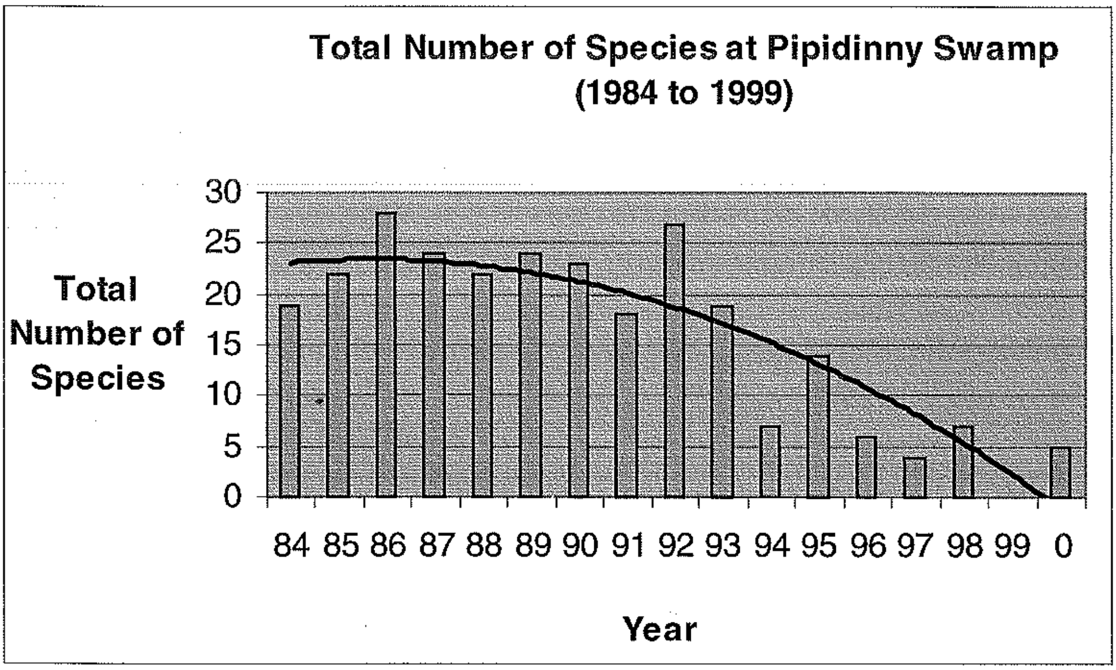


Figure 3.4.1 The total number of waterbird species found at Pipidinny Swamp per year (1984 to 2000). Trendline indicates a decrease over time.

The highest number of waterbirds surveyed at Pipidinny Swamp occurred on the 7th January 1989 with a total of 263 waterbirds. Between the years of 1984 and 1995 the highest number of waterbirds recorded at Pipidinny Swamp per year ranged from 91 to 263 waterbirds (Figure 3.4.2). The highest number of waterbirds surveyed per year since 1996, however has not exceeded 25 waterbirds. Numbers have dropped so low that during summer surveys in 1996 and 1999 no waterbirds were recorded at Pipidinny Swamp. The trendline on Fig. 3.4.2 indicates that waterbird abundance at Pipidinny Swamp increased between the years of 1984 and 1989 and that from 1990 to 2000 there has been a decrease.

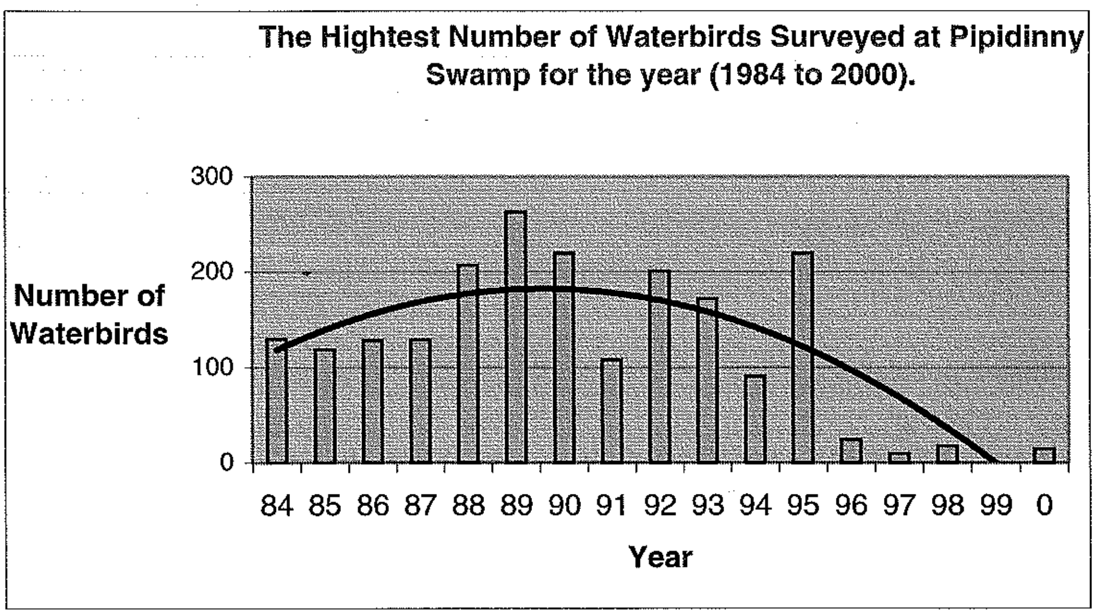


Figure 3.4.2 The highest number of waterbirds surveyed at Pipidinny Swamp (1984 to 2000), with trendline indicating an overall decrease in the number of waterbirds recorded.

3.4.3 Present Survey

The surveys conducted during this research recorded a total of five species at Pipidinny Swamp during the months of March to September (See Table 3.4.3). The only waterbird species recorded on every occasion was the Pacific Black Duck which are considered the only 'resident waterbird' that inhabits Pipidinny Swamp during this survey. The other four waterbird species were not recorded surveyed on more than 75% of the surveys at Pipidinny Swamp and are considered 'visiting waterbird' species. These waterbird species are the Australian Shelduck *Tadora tadornoides*, the Purple Swamphen, the White-Faced Heron and the Australian Reed Warbler.

Table 3.4.3. Results of waterbird surveys at Pipidinny Swamp (2000).

Survey Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Date	28/2	13/3	26/3	7/4	23/4	7/5	17/5	3/6	17/6	3/7	18/7	5/8	15/8	2/9	17/9
White-Faced Heron								1							
Australian Shelduck		2	2			2		2	2						
Black Duck	2	6	11	4	6	13	4	4	2	3	2	4	2	2	2
Purple-Swamp Hen	1	2		1			1		1	1			1		
Australian Reed-Warbler	6		2												

The highest waterbird species count was on surveys one to three (28th Jan, 13th & 26th March) and eight and nine (3rd & 17th June) with three species recorded. The lowest count of one waterbird species occurred on survey 5 (23rd April), 11 (18th July), 12 (5th Aug.), 14 and 15 (2nd & 17th Sept.).

The highest waterbird count was on survey three (26th March) and six (7th May) with 15 individual waterbirds. While the lowest waterbird counts were on surveys 11 (18th July), 14 and 15 (2nd & 17th Sept.) with only two waterbirds recorded.

Figure 3.4.3 indicates that waterbird diversity and abundance has changed over the length of the survey. Waterbird abundance is higher from surveys one to eight (28th Jan to 3rd June/ End of summer to early winter), and lower for surveys nine to 15 (17th June to 17th Sept/ Mid winter to early Autumn).

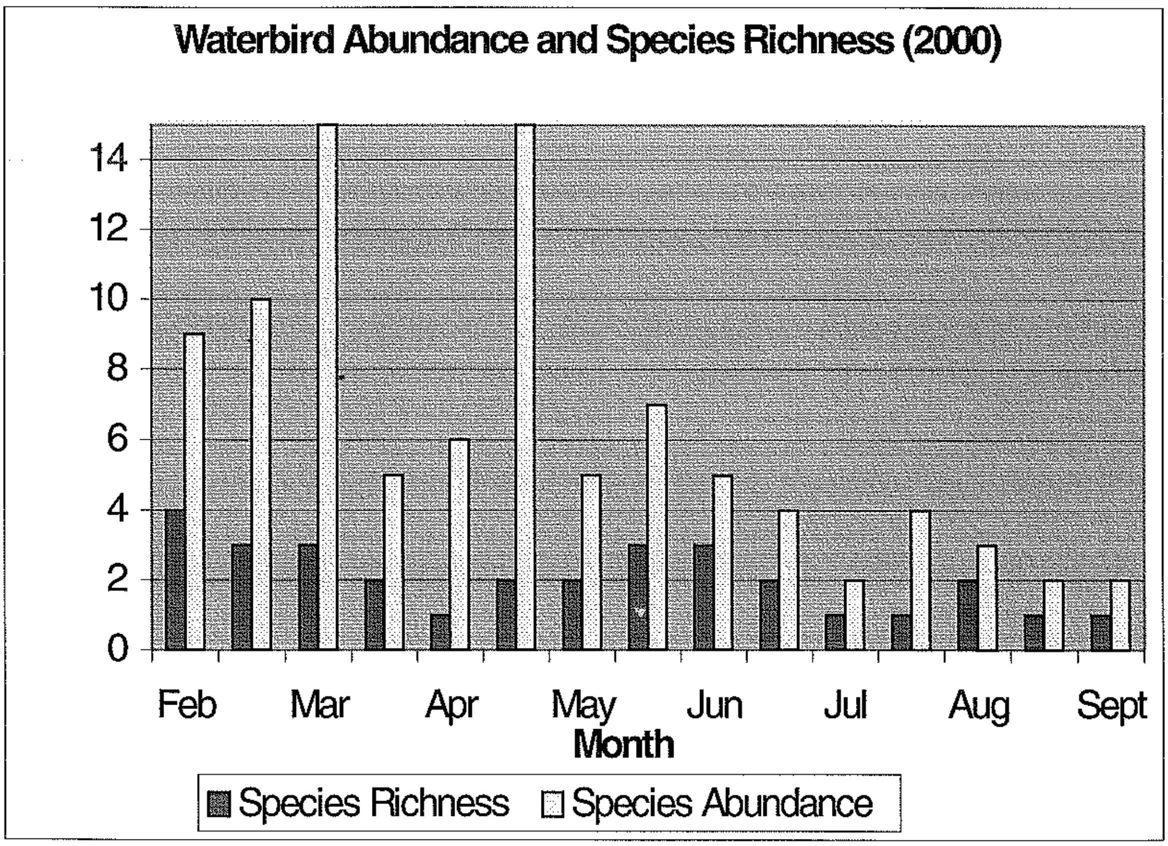


Figure 3.4.3. Waterbird Richness and Abundance at Pipidinny Swamp during the months of February and September 2000.

3.4.4 Discussion

Of the 18 waterbird species surveyed in 1984, the Pacific Black Duck, is now the only waterbird considered a 'resident' waterbird species. Only five waterbird species were recorded during surveys completed during 2000, representing a massive reduction in the waterbird diversity at Pipidinny Swamp. With the average rainfall received this year, waterbird numbers are not likely to increase this summer.

Changes in waterbird diversity and abundance at Pipidinny Swamp may be attributed to the change in the water level within the wetland. Water level records for Pipidinny Swamp exist from 1993 and indicate that the water level dropped around 1994. The water level within the wetland has remained low since this time. The water level from bore JP21 also indicates that the water level has also decreased around 1994. Around this time both the waterbird diversity and abundance at Pipidinny Swamp decreased significantly.

The lowering of the water level may directly and indirectly affect waterbird populations. Changes in water level can result in a change in the vegetation structure. For example, fringing vegetation species such as the Common Swamp Paperbark can reclaim ground within the wetland as seasonal flooding would no longer occur allowing the species to expand its area. This can result in the little open water that remains in the wetland to be surrounded by the taller paperbarks instead of low sedges, which can make the wetland undesirable for certain waterbird species. These waterbird species include the Musk Duck and the Blue-billed Ducks, which prefer deep open water to feed in. Both species are no longer recorded at the wetland.

The lowering of the water level and the change in the vegetation structure may also affect other wetland aquatic fauna that waterbirds feed upon. For example, bulrushes provide food and shelter for aquatic fauna. Changes in the vegetation composition as paperbarks replace reed beds can reduce associated dependent aquatic fauna. Lower populations of these aquatic fauna can in turn affect waterbird populations. A reduction of this food source (aquatic fauna) could result in this wetland not being able to sustain large waterbird populations.

The ground water level has dropped due to a combined result of a number of influences. The maturing of the pine plantations further east on the Coastal Plain may have resulted in an increase in the abstraction of the groundwater. The continuous low winter rainfall average for Perth between 1994 and 1999 (BOM, 2000) means that the Gnangara Groundwater Mound is not receiving the same amount of recharge as in the past. Finally abstraction of groundwater for human consumption by the Water Corporation for Perth residents also adds to the reduction of the groundwater level.

Fire has been reported at Pipidinny Swamp twice, and occurred during the summers of 1991 and 1992 and could have impacted on the waterbird population. Some fringing wetland vegetation is not fire tolerant and regeneration is slow (e.g., Common Swamp Paperbark). However, some wetland vegetation is fire tolerant and growth is aided by fire (e.g., Bulrush). Waterbirds, who are dependent upon the vegetation for food and shelter can be affected if vegetation is destroyed. For example, in 1991 and 1992 bush fires burnt through the wetland destroying most of the vegetation which provides this food and shelter for waterbirds. With little vegetation remaining in the wetland, waterbirds numbers correspondingly dropped. However, when the new growth of some vegetation species appeared, waterbird numbers then increased to over 200 individuals. Further, some fringing vegetation species were completely destroyed by the second fire, again reducing available habitats for waterbirds. Waterbird diversity indicates that fire may be the cause of the drop in waterbird diversity. The drop in the water level since 1994 has been detrimental to regeneration of vegetation.

3.4.5 Conclusion

This research of waterbirds was very effective in showing the changes in the waterbird population over time. Without continuous monitoring over years, knowledge of the decrease in waterbird population may not have been known.

Waterbirds within the wetland are very dynamic and changes occur not only between seasons, but from year to year as well. There has been a massive decrease in diversity and abundance of waterbirds. Waterbird populations may have been influenced by not only water availability but also by the vegetation and also fire. Continuous waterbird monitoring is essential for the wetland to help determine the optimal conditions for waterbirds.

Chapter 4: Reconstruction of the Changing Cultural Environment

4.1 The Aboriginal Cultural Environment

From the moment Aboriginal people first set foot upon the Swan Coastal Plain it has been a challenge to survive. These people explored, discovered and survived in Australia due to effective environmental management practices. With known Aboriginal sites dating back thousands of years, the term *Terra Nullis* was inappropriately applied to describe Australia. There are five known Aboriginal sites within the Yanchep National Park, all occurring near the wetlands.

Aboriginals have a very special spiritual relationship with the environment through the 'Dreaming', which they believed created everything on earth from the landscape to the knowledge gained by the Aboriginal people. They believe that the earth is their 'Mother' and consequently refer to earth as 'Our Mother' (Robinson, 1968). The following is a quotation from Galarrwuy Yunupingu from northeastern Arnhem Land (Northern Territory) and highlights the significance of land to Aboriginal people.

> The land is my backbone... I only stand straight, happy, proud and not ashamed about my colour because I still have land. I can paint, dance, create and sing as my ancestors did before me. I think of land as the history of my nation. It tell of how we came into being and what system we must live. My great ancestors who lived in time of history planned everything that we practice now. The law of history says that we must not take land, fight over land, and steal land, give land and so on. My land is mine only because I came in spirit from that land, and so did ancestors of the same land... My land is my foundation (cited in Nettheim, 1981).

Wetlands on the Swan Coastal Plain are spiritually significant to the Nyoongar (Nyoogar, Nungar, Noogar, Noougah) Aboriginal communities. These wetlands represent a place where the Wagal (spiritual rainbow serpent), rose to the surface during the 'Dreaming'.

This spiritual relationship with the land is reinforced in ceremonial songs and dances performed by Aboriginal groups. Local Aboriginal communities used the wetlands of the Yanchep National Park as a ceremonial place. Other Aboriginal also gathered here to join in celebration of the "Yanjidi" harvest. Yanchep and Yangebup's are names that have been derived from this word Yanjidi (Hallum, 1998).

On Grey's excursion north of the Swan River in 1841, he describes how the Aborigines frequently burn the leaves of the Bulrush to improve it (Grey, 1841). Moore, 1884 also describes the same burning of the bulrush leaves three years later and added that the fire improved the taste of the bulursh

Pipidinny Swamp is significant to the Nyoongar Aboriginal communities. Its significance is illustrated in the following 'Dreaming' story titled 'The Emu Cave Dreaming Story' narrated by Nyoongar Elder Mr. Ken Colbung (cited in Kauler, 1998, p. 69):

> There is a story about the shark, the whale and the crocodile and the fight they had and the formation of Rottnest and Garden Island. As the crocodile was walking back he laid down exhausted at what is now known as Yanchep Beach and here he shed that skeletal frame work and then moved on.
>
> The crocodile moved on to Two Rocks where in actual fact the yonga, the kangaroo and the bibilja, the scrub turkey and the head of the animals was waiting and he put a formal request to him to really come in and have a good rest. It was to there, that after consultation with the rest of the animals they made the decision that he could come forward providing he kept to the rules that they had laid down for him. The rules were that he shouldn't be jumping on trees and shouldn't be flying around and he shouldn't get into the water and that he should come forward. He had a special berry tree - the emu berry

> tree - that was there for him and also he should eat seeds but not meat.
>
> And so he made the decision and they allowed him to come in. First of all he went to Pipidinni Lake and at Pipidinni Lake he sat down and all the blood ran out of his body and you will see that Pipidinni Lake is coloured like blood - brown blood. Then he moved on from there and went to Nowgerup (Now means 'Sweet Water') and here all the marrow in his bones poured out of his body. The crocodile then moved onto Emu Cave where he laid down and had a good sleep and he remembered all the things that were told to him. Here the crocodile remembered that the bibilja had placed feathers on his body and he saw where the shark had stretched his legs and then he dreamed of this animal he wanted to be. The crocodile then came out a beautiful long legged bird with a long neck and a smaller head and beck that was more in line rather than a big head that could eat any animal. He was then one of the animals and due to the fact that he could not use his teeth and jaw any more he was given speed. Now you will find that the emu is one of the fastest birds alive and can run around to avoid its enemies.

Kauler (1998) noted that occasionally emus were found going under sprinklers or lying in water reminding them of the old days when they were a crocodile. She also remarked that the emu's legs are shaped like a crocodile, as is the skin.

Knowledge of the environment was very important to the survival of Aboriginal people. It determined all their activities including when and where they ate and drank. Their intimate knowledge of the seasons was reflected in the formation of the resource and weather-based Nyoongar calendar (See Fig. 4.1). The calendar contains six seasons and allows for the effective utilisation of the resources of the area at different times of the year. Movement and activities of Aboriginals occurred in response to the seasons, mainly the prevailing wind conditions, temperature and rainfall.

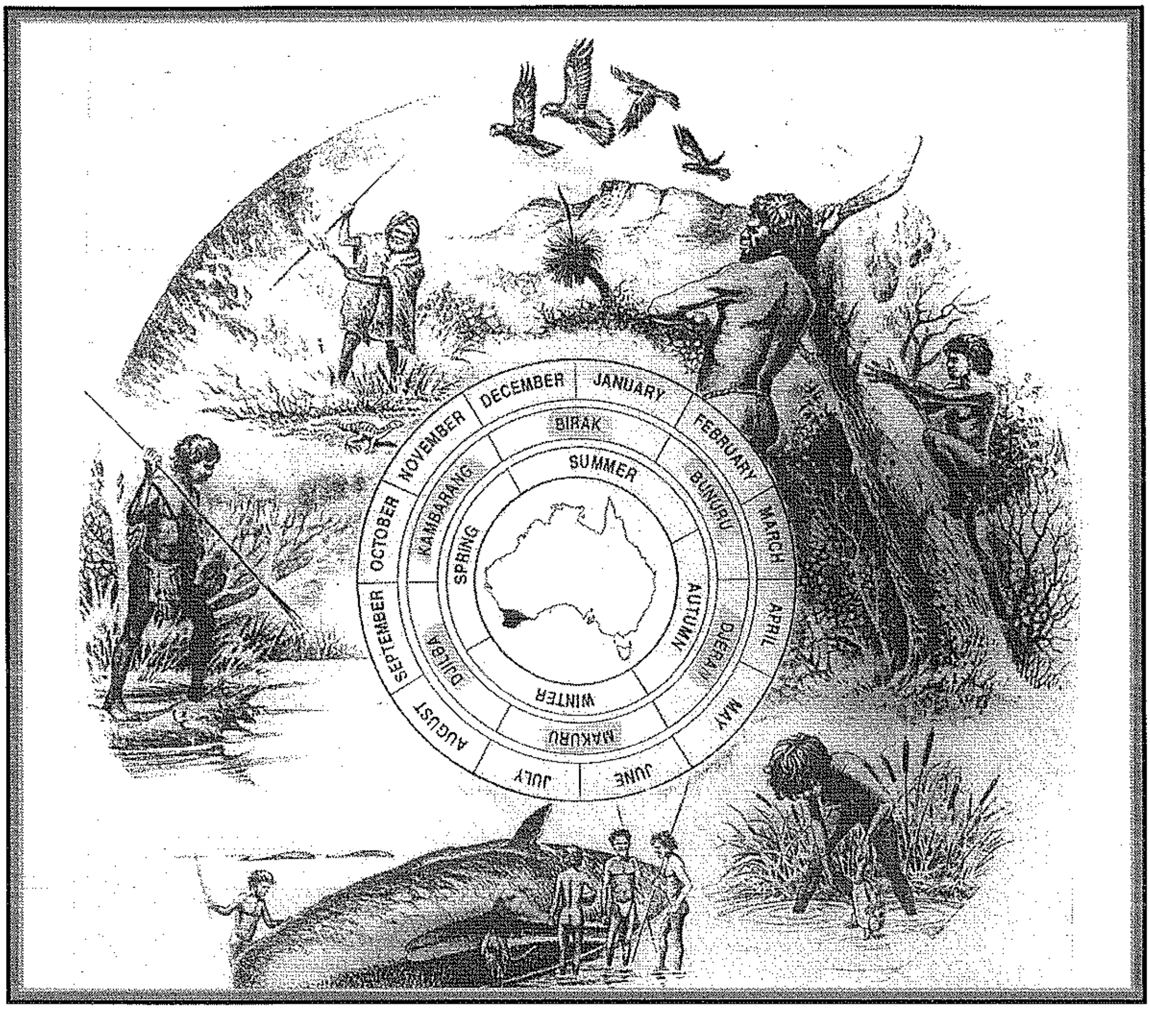


Figure 4.1. Shows the Aboriginal calendar for the south-west of Western Australia. Source: *Landscope*, 1994.

As an example of the effective utilisation of resources according to a particular season, Aboriginal communities moved inland during the winter months of 'Djeran' and 'Makuru'. This movement was in response to inland lakes filling with water from winter rainfall and the gathering of wildlife (mainly waterbirds) to these lakes. When inland fresh water lakes would dry up during the summer months of 'Birak' and 'Bunuru' the wildlife moved back to the Swan Coastal Plain where fresh water was available.

Aboriginal communities moved back to the Swan Coastal Plain during summer months to utilise the abundance of fresh water and wildlife. Wildlife ranged from insects and their larvae, aquatic animals such fish, frogs and crustaceans, birds, reptiles and marsupials.

4.2 Animal Foods at Wetlands

All waterbirds found in the South-West Region are edible. For example, Black Swans are eaten during summer when they are molting, while their young and the eggs are eaten at other times of the year (Hallum, 1998). Aboriginal communities valued Black Swans, Swamphens and Wattlebirds due to their pleasant taste.

Other aquatic animals were also collected during the summer months while communities occupied the coastal plain. Frogs were collected during spring and summer once water had dropped, making it easier to dig them out of the ground by hand. Turtles were collected from pools stranded in estuaries and also in coastal wetlands (Hallum, 1998). Fish formed most of the diet for Aboriginal communities during the summer months, and were caught a number of ways. For example, fish traps constructed out of brushwood or stones were used to trap fish at low water. Once trapped, the Aboriginal people would spear the fish. Fish were also herded towards shore using brushwood screens and then speared.

4.3 Plant Foods in Wetlands

Both aquatic and terrestrial root tubers were the major plant food source for Aboriginal communities, followed by seeds and fruits. An example of a vegetation species that contains an aquatic root tuber is the native bulrush. The bulrush was burnt to add to the taste to the tuber and to make harvesting the tuber easier (Moore, 1884). The tubers were roasted, pounded and then baked into small cakes that contained a high quantity of starch. The bulrush was harvested around March and April to take advantage of the higher levels of starch in the bulrush at that time of the year (Grey, 1841; Hallum, 1998). Grey, 1841 provides a list of foods eaten by Aborigines and includes 29 different roots, seven fungus, four sorts of gum, two sort of manna, two species of nuts from the Zamia palm, two species of pigface, two kinds of nuts, four fruits, the flower of several banksias and several seeds of leguminous plants.

Resources available to the Aboriginal people, especially wetlands, were never over exploited. Aboriginal people believed that by caring for the land by not using all the available resources, the land would in turn sustain the Aboriginal people. This environmental management practice by Aboriginal people was termed 'Caring for Country' (Young, Ross, Johnson, & Kesteven, 1991). For example, the use of fire to harvest the bulrush, as mentioned earlier, also helped to regenerate bulrush for the following year (also add in the example of the replanting of yams). Aboriginal respect for the environment was in stark contrast to the use of the environment by the Europeans who later settled in the region.

4.4 European Settlement

Mr George Grey was one of the first Europeans to explore the chain of wetlands north of the Swan River in 1841 (Chambers, 1991; Cockman, 1979). While Grey did not mention Pipidinny Swamp in his diary, he did however refer to the meetings with the Aboriginals around the campfire on the banks of Lake Joondalup and also at Yanchep (near what is now known as Loch McNess). The local Aborigines presented Grey and his party with "twenty-seven fresh-water tortoises, the average weight of each of which was half a pound" (Grey, 1841 [illegible] p.292).

Early European explorers surveyed Pipidinny Swamp three times in the second half of the 19th century. The first person to survey the area was Mr. Jay Cowle in 1867. Although he noted the existence of the wetland, he did not provide any description of the area.

The next person to survey the area was Mr. Alexander Forrest, in 1874. The existence of the Pipidinny Swamp was again noted, however Forrest included a small map of the wetland noting the presence of reeds within the water. Therefore, it appears that the survey was undertaken after the winter rains when the wetland contained water.

Mr. W.A Saw was the last person to survey the wetland in the 19th century, ten years after Forrest in 1884. Saw included a larger diagram of the wetland and the surrounding vegetation. Saw also noted the sharp rise of the land on the western side of the wetland and also Beonaddy Swamp further to the east (See Fig. 4.1).

The first usage of Pipidinny Swamp by Europeans was by the cattle drivers who stopped to water their cattle herds at a spring that was located within the wetland. However, the first land claim over Pipidinny Swamp was by Mr. Henry Gibbs in the middle 1800's by 1884 when he obtained land in the surrounding district. However, the wetland and the land immediately surrounding the wetland was not inhabited by the Gibbs family before the 20th century (Kennealy, 1994).

The first Gibbs family to inhabit the area around Pipidinny Swamp was early in the 20th century (around 1920) (Kennealy, 1994). Use of the actual wetland was minimal. However the surrounding land of the wetland was used for a homestead and market gardening. The aerial photograph on the 29th April 1941 provides evidence of little activity within Pipidinny Swamp. However, market gardening and the homestead around Beonaddy Swamp are evident (Plate 4.2).

The aerial photograph taken on the 16th of February 1952 indicates that clearing has occurred within the wetland for the purpose of market gardening. This aerial photograph also indicates that the market garden within Beonaddy Swamp has increased in size from the first photograph taken (Plate 4.3).

The Gibbs family first realised that for Pipidinny Swamp to be a productive market garden to grow vegetables, only trace elements were needed to be added to the peaty white soil. Mr. Max Gibbs recalled that during the 1950's and 1960's his family, along with the Singra and Mooney families, grew tomatoes within Pipidinny Swamp. Within

Pipidinny Swamp each family worked a separate portion of the wetland (Plate 4.3) (Max Gibbs, personal communication, April, 2000).

As the water level receded within the wetland during summer, the tomato plants were planted. When the water level dropped and exposed most of the wetland, springs were constructed near the cultivated area. Each morning before going to school Max Gibbs and the other kids in the Gibbs family took tomato soup cans and gave each tomato plant a tin full of water from the springs (Max Gibbs, personal communication, April, 2000).

Plate 4.2 Aerial Photograph of Pipidinny Swamp taken 1941. Photograph obtained from United Photos, Canberra.

Plate 4.3 Aerial Photograph of Pipidinny Swamp in 1952 and indicating where the Mooney, Singra and Gibbs' families grow tomatoes Photgraph obtained from United Photos, Canberra.

In 1960 the Department of Transport constructed an access road from Wanneroo Road to Pipidinny Swamp allowing access for the mining of marl (the white peat soil). The marl was used for the realignment of Wanneroo Road near the wetland in the early 1960's for the final topping of the road base before being sealed (Max Gibbs, personal communication, April, 2000). The aerial photograph shows that a track entering the wetland from the north (Plate 4.4).

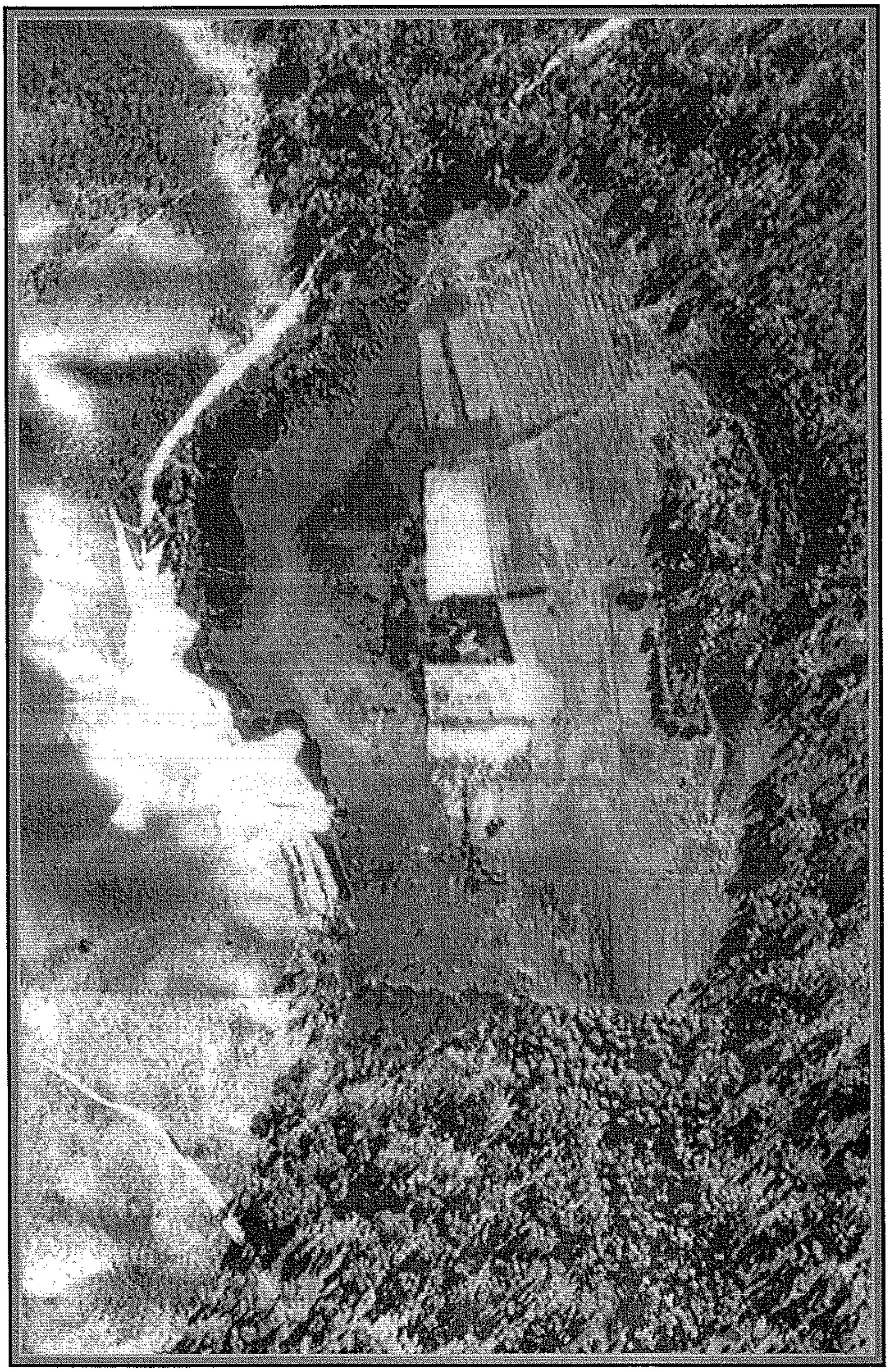


Plate 4.4 Aerial Photograph of Pipidinny Swamp in 1960. Photograph obtained from DOLA, W.A.

The aerial photograph taken on the 29th January 1973 from the City of Wanneroo shows no increase of clearing within the wetland since the last photograph. Wanneroo Road has been realigned and sealed. This aerial photograph also shows the contour of the wetland and indicates that the pits are now present. These pits all occur on the western side of the wetland and are two metres deep as indicated by the contour lines overlaid on the photograph. These pits are a result of the mining activity that occurred for the removal of marl (Plate 4.5).

The aerial photograph taken on 20th December 1980 (Plate 4.6) shows many changes to the surrounding region as well as within the wetland. There are ten new tracks surrounding the wetland. There is evidence of clearing to the east of the wetland and also between Pipidinny Swamp and Beonaddy Swamp. Max Gibbs recalled that Mr. Tom Carafilis constructed irrigation channels to supply water to the crops within Pipidinny Swamp. The population in the surrounding area of Pipidinny Swamp has increased with new houses having been constructed. Main Roads have sealed Pipidinny Road from Wanneroo Road to the beginning of the Quindalup Dune System.

During the 1970's and 1980's Max Gibbs recalled that on the eastern bank of the wetland, where native vegetation has been cleared, strawberries were grown. An irrigation system with pipes and sprinklers was installed to water the strawberries. Remnants of this old irrigation system are still present today.

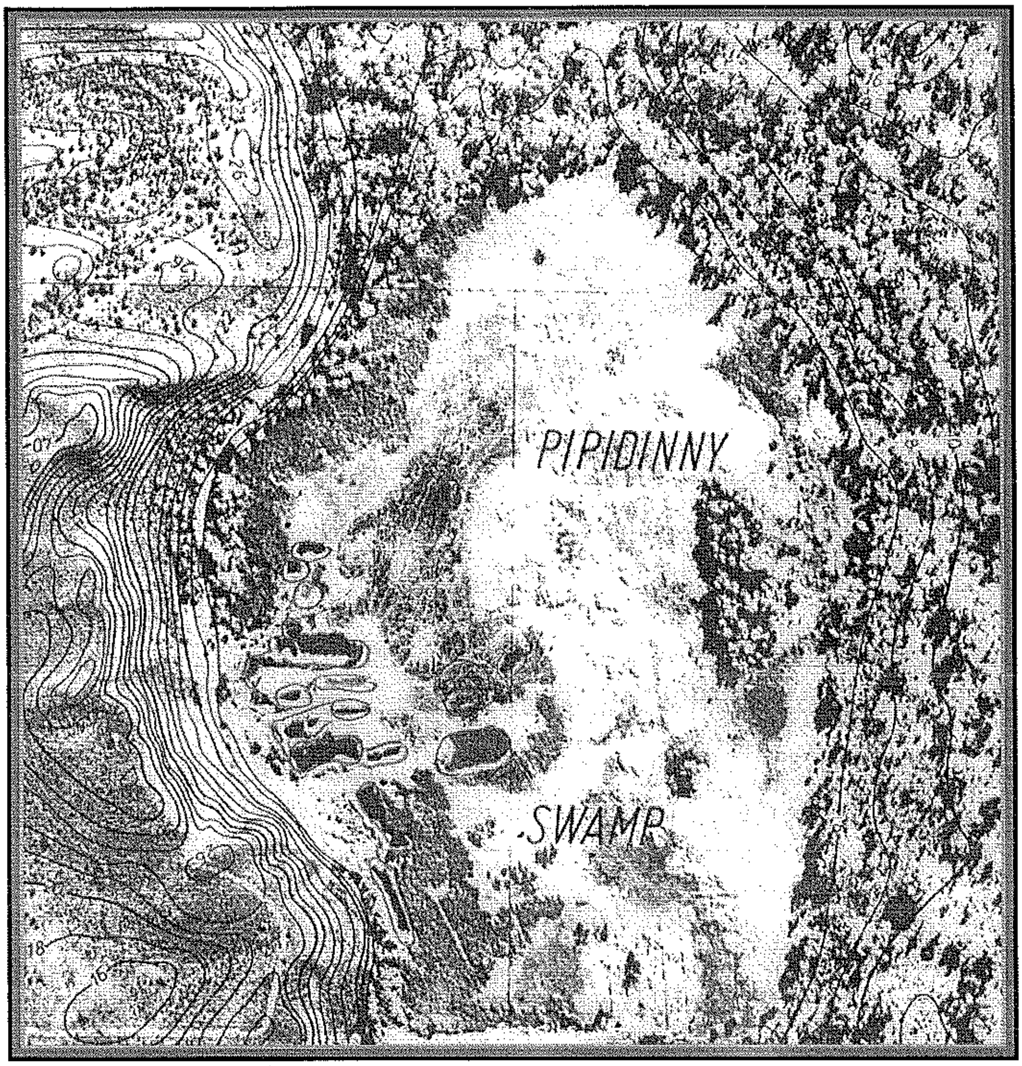


Plate 4.5 Aerial Photograph of Pipidinny Swamp in 1973 which also indicates contour lines. Photograph obtained from City of Wanneroo.

During the 1980's the wetland was owned by Landbank and was leased out for market gardening and grazing purposes (CALM, 1989). Late in the 1980's, the ownership of the wetland changed from private to public ownership. The National Park Authority finally obtained ownership in 1991. Since then the National Parks Authority has placed the management of Pipidinny Swamp into the care of CALM.

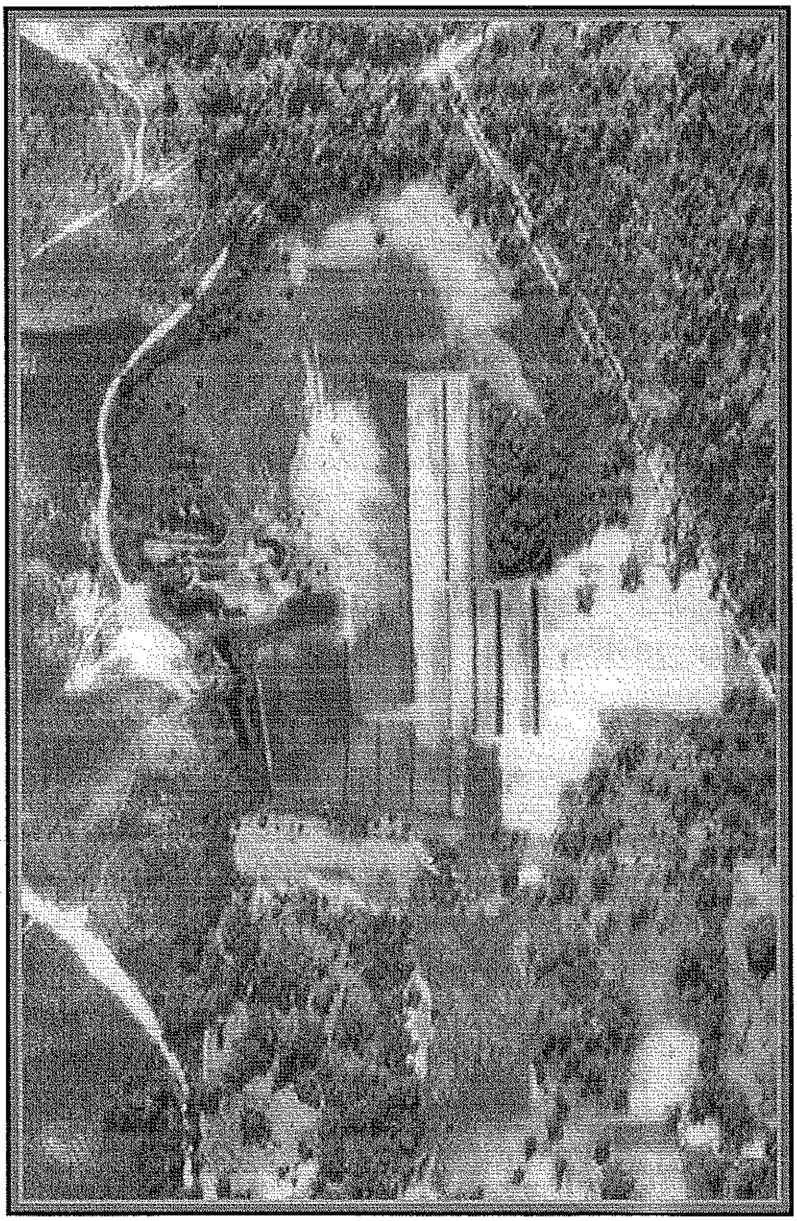


Plate 4.6 Aerial Photograph of Pipidinny Swamp in 1980. Photograph obtained from DOLA, W.A.

The aerial photograph taken in 1999 shows that Pipidinny Road has been sealed all the way to the beach. The road was sealed because land developers were planning to develop Eglington Beach, however, this has not yet occurred. Most of the tracks in the area have started to grow back over. There seems to be little activity within the wetland. However, the southern portion of Pipidinny Swamp is still been used for grazing (Plate 2.2).

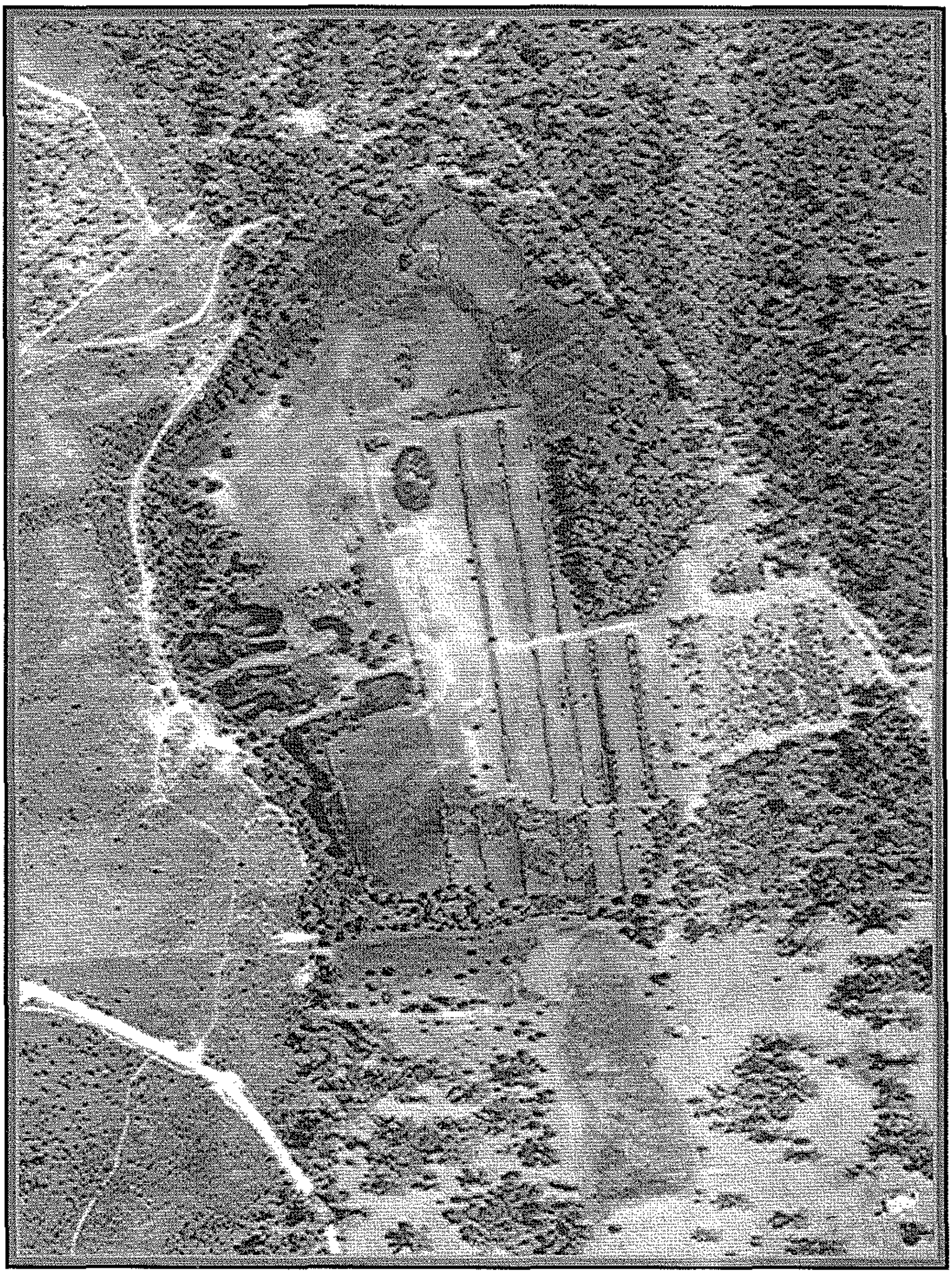


Plate 4.7 Aerial Photograph of Pipidinny Swamp in 1989. Photograph obtained from DOLA, W.A.

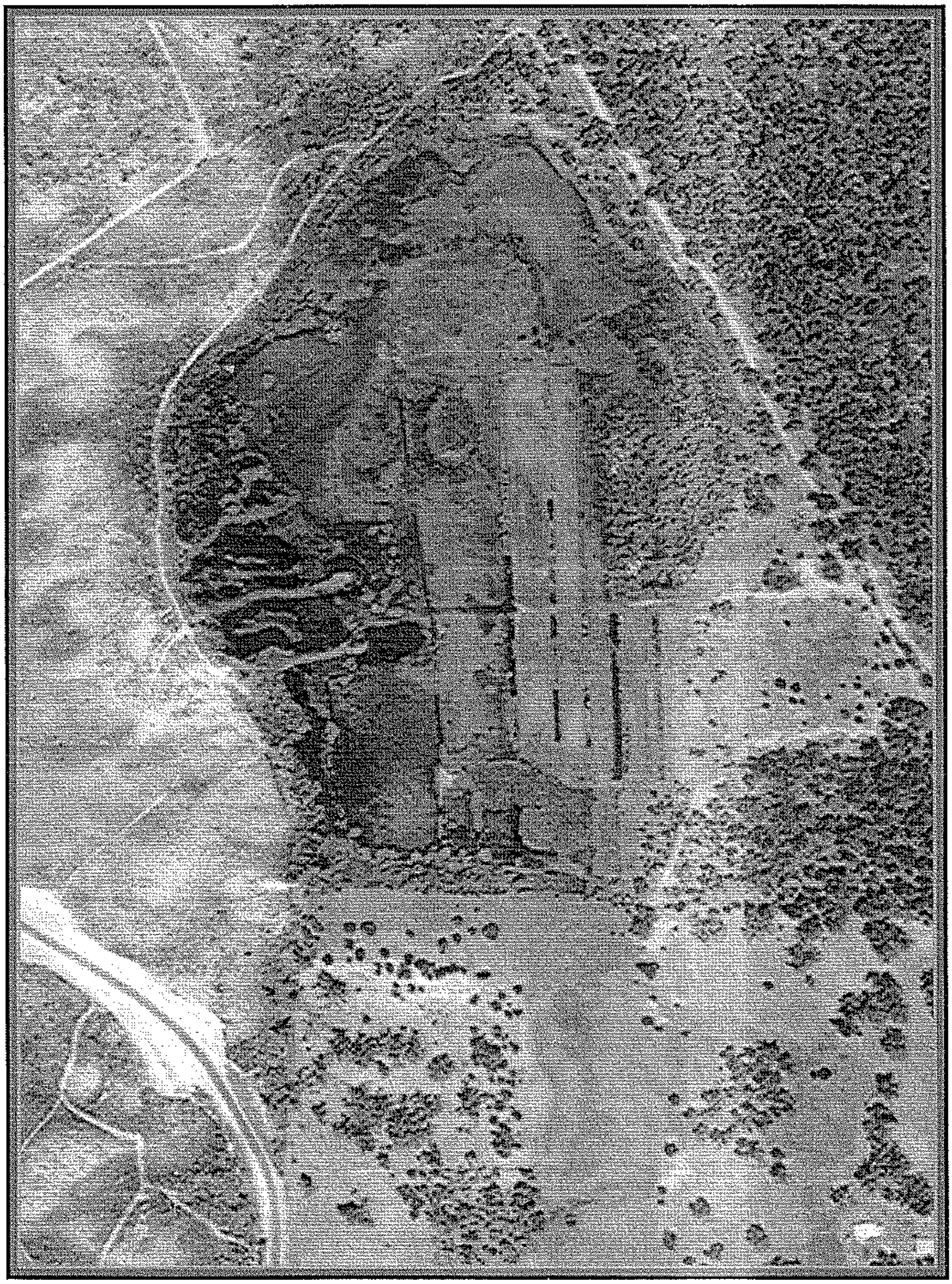


Plate 4.8 Aerial Photograph of Pipidinny Swamp in 1992. Photograph obtained from DOLA, W.A.

4.5 Conclusion

The cultural environment of Pipidinny Swamp is very dynamic with changes continually occurring on the wetland. Local aboriginal people first utilised the resources of the wetland to survive. Early Europeans then commenced utilisation of the water resources and then used the soil for horticultural purposes. Today, Pipidinny Swamp was included into the Yanchep National Park and managed with conservation and protection as the main objective. There has been numerous changes in the human cultural influence on Pipidinny Swamp.

Chapter 5: Reconstruction of Changes of the Natural Environment

This chapter reconstructs the changes to the natural environment within Pipidinny Swamp. It begins with the impact Aboriginal communities had upon the environment followed by that of the early Europeans. There is speculation that the early Europeans used this wetland during the 19th Century with only minimal changes to the natural environment except for the use of fire. It was not until the middle of the 20th Century that the European activity began to have a significant impact on the environment. From this point the natural environment has been ultilised, exploited and now conserved. It has been suggested that land use of the area surrounding Pipidinny Swamp has also influenced the natural environment of this wetland.

5.1 Aboriginal Influence Upon the Environment

From the moment Aboriginal people landed upon the shores of Australia 40, 000 years ago they learned to survive in a harsh environment. Surviving here required the Aboriginals to utilise the natural environment effectively. Questions still remain unanswered as to whether Aboriginal resource use actually changed the natural environment. It appears that any changes to the natural environment caused by Aboriginals may have been minor, however this is debatable.

Fire occurred naturally in this environment before Aboriginal people arrived on this continent. However, Aboriginals helped to control the frequency and severity of the fires' occurrence. Fire in the Australian environment has caused most native vegetation species to not only be tolerant of, but also dependent upon fire for survival. Examples of native vegetation species that are tolerant of and dependant on fire include Banksias, Zamies and Grass Trees. These species are in contrast to fringing wetland vegetation that are not fire tolerant.

Aboriginal people considered that unburnt country was unkept or not cared for. Aboriginals discovered that a burnt landscape was very productive in many ways. Fire helped to reduce the ground litter, which made transportation easier and promoted lush growth of the vegetation that attract fauna. For these reasons, 'fire-stick farming' practices were carried out by Aboriginal people which helped to shape the natural environment (Hallam, 1975; Kohen, 1995). For example, Dreaming trails such as the Yabaroo Budjerra Heritage trail would have been frequently burnt every three to four years by the Aboriginal people. This 'fire-stick farming' practice was to clear the undergrowth to make travelling along the trail easier and to also attract fauna that grazed upon the lush regrowth of the vegetation to be hunted by the travellers as a food source.

Aboriginals living around Yanchep were known to have used fire to make cultivation of bulrush easier. The bulrush was burnt to make harvesting the root tubers easier and to add to the taste of the tubers. With Pipidinny and Beonaddy Swamps being relatively close to Yanchep, it appears likely that fires were used in these wetlands to help cultivate the bulrush present there (Hallam, 1975; Payne, 1991).

5.2 European Influence Upon the Environment

The first Europeans to have an impact upon the natural environment as a result of landuse practices were the early cattle drivers during the early 1800's. Utilisation of the water resource by the cattle commenced the destruction of the wetland by Europeans. However, it was not the utilisation of the water that was the problem. It was the destruction of the vegetation and the land caused by trampling, grazing and introduction of exotic grass seeds by the feet, mouths and faeces of the cattle. Initially, the cattle may have damaged and consumed some of the fringing vegetation surrounding the permanent spring that existed on the eastern side of the wetland. With reduced vegetation cover to bind the soil together, the cattle may have eroded the bank of the spring. This erosion may have commenced the degradation of the spring, eventually causing the flow of water to the surface to stop Finally, the cattle may have also started the introduction of exotic flora into the wetland. Exotic seeds may have also been carried within the faeces of the cattle and eventually deposited in the wetland.

The April, 1941 aerial photograph (See figure 4.2) shows little European disturbance to the natural environment within the wetland. The wetland seems to contain open water with plenty of low vegetation, such as sedges and rushes. In the north-eastern section of the wetland, the peaty marl soil can be seen. Exposure of the marl could have been due to the removal of the vegetation by the cattle. In comparison, Wilgarup Lake to the north-east is also a seasonal wetland with a similar vegetation structure, it is shown that it is completely covered with vegetation and exposure of the soil is not evident. This may indicate that the cattle did not use this wetland. The southern portion of the wetland contains a thick stand of fringing wetland vegetation, such as paperbarks and possibly also Tuarts, Jarrah and Marri. Clearing of vegetation in and around Beonaddy Swamp is seen to have occurred and market gardening appears to have commenced.

Early in the 1950's the Gibbs family discovered that if trace elements were added to the soil, the wetland would be able to grow vegetables. As a consequence, approximately a quarter of the wetland was cleared to allow tomatoes to be grown. This is revealed in the February 1952 aerial photograph (See Figure 4.3) where part of the low vegetation (the sedges and rushes) within the wetland have been removed and exotic species (tomatoe plants) have been planted for marketing gardening purposes.

With the commencement of market gardening the wetland basin seems to have been altered. The open water that existed in the 1942 aerial photograph is no longer present and the eastern side of the wetland shows evidence of earthworks to create more land for market gardening. Further clearing of surrounding native vegetation from Beonaddy Swamp has allowed for more market gardening. There seem to be relatively few changes to the rest of the surrounding area.

The July, 1960 aerial photograph (See Figure 4.4) reveals that a track has been constructed from Wanneroo Road to the east, into Pipidinny Swamp. It appears that this track has allowed the mining of marl on the western side of the wetland, though it is possible that the mining activity had not commenced by that time. The track enters the wetland from north-east and circles around to the western side of the wetland. The vegetation on the western edge of the wetland appears to have already been removed, but the pits within the wetland are yet to be excavated.

The January, 1972 aerial photograph (Fig 4.5) indicate that clearing has taken place around the wetland. For example, the southern portion of the wetland, which contained fringing vegetation, has been removed. The vegetation surrounding the southern end of the wetland has also been thinned out. One interpretation is that the grazing cattle caused the thinning, by ring-barking the vegetation. The alternative interpretation is that the farmer(s) thinned out the vegetation to allow more land for the grazing of cattle. Exotic vegetation species, mainly grass species for the cattle, have invaded this area by this stage. Furthermore, a small area of native vegetation to the east of the wetland is also shown as cleared. This area of land was used to grow strawberries with old irrigation pipes still evident (See next plate) (Max Gibbs, personal communication, April, 2000) . Surrounding the wetland widespread clearing of native vegetation has been taking place. To the south-east, land has been subdivided and some of it is already cleared for market gardening. To the north-east above Loch McNess, a large area of native vegetation has been cleared and pine plantations have been planted.

The 1989 the aerial photograph (See Figure 4.7) reveals that during the last 17 years, channels were constructed within the wetland on the eastern half to help irrigate the crops of the market garden. The fringing vegetation on the western bank of the wetland has expanded and is now thicker. This is possibly due to the lack of frequent fires occurring within the wetland. Without fires, the fringing vegetation such as paperbarks have been allowed to invade the western side of the wetland. Previously, fires would have destroyed any attempt by native fringing vegetation to grow here, possibly due to the cultivation of the bulrush by the Aboriginals.

Since European occupation of the surrounding land of Pipidinny Swamp in the early 1900's, fires within Pipidinny Swamp ceased to occur. As a result of Europeans clearing the bulrush, introduced market garden plants flourished within the wetland (as well as the native fire intolerant species). However, in the summer of 1991 a massive bush fire swept through the wetland destroying a large proportion of the vegetation that was present. Fringing wetland environments are not tolerant of fire, unlike the other surrounding natural vegetation which is dependant on fire. Introduced species or weeds regenerate quicker than the natural species present in the wetland. Removal of the natural fringing vegetation caused by the fire then allowed introduced weed species to establish themselves within the wetland.

The following year another bush fire burnt land from the coastline, near the Alkimos Shipwreck through Yanchep National Park, burning the wetland again. This fire destroyed just about all the remaining native fringing vegetation that was present. The introduced species then established itself firmly into the wetland dominating the vegetation. Most native vegetation is fire tolerant and benefits from frequent burning every three to four years. However, these fire tolerant vegetation species will not survive if fires occur in subsequent years as was the case at Pipidinny Swamp during 1991 and 1992.

After the 1992 fire, horses were allowed to graze upon the wetland from neighboring properties. Grazing of cattle did not impose much influence on the remaining native vegetation as the cattle fed on introduced species. However, with all the native species nearly all removed and introduced species slowly dominating, the horses had another impact apart from the removal of vegetation. With native species not present to hold the soil together, erosion of the soil surrounding and also within the wetland became a serious problem. Horses again assisted dispersal of introduced species of vegetation, whereby seeds were transported and deposited within the wetland by the feces.

Since 1991 CALM have managed the wetland and at different times during this time certain introduced species have been targeted to be removed from the wetland.

Chapter 6: Conservation and Management

Conservation and management of Pipidinny Swamp began when indigenous Australians began inhabiting the Swan Coastal Plain about 40,000 years ago. It continued under private ownership by early non-indigenous Australians until 1991, when Pipidinny Swamp was incorporated into Yanchep National Park. Since this time, the wetland has been managed by CALM under the Management Plan that existed for the National Park. This chapter will discuss conservation and management by government authorities who are responsible for managing Pipidinny Swamp and the wetland resources it provides.

6.1 Government Conservation and Management

Since 1971, Local, State and Federal governments have signed numerous treaties and formulated many policies protecting wetlands and preserving wildlife habitats dependent on wetlands. Recently, in 1997 the State government established five principle objectives in the conservation of wetlands. This policy adopted the 'Ramsar' definition of wetlands, which therefore classified Pipidinny Swamp as a wetland. Of the five principles outlined, three are directly related to Pipidinny Swamp. These are:

- To prevent further loss or degradation of valuable wetlands and wetland types, [such as Pipidinny Swamp] and to promote wetland conservation, creation and restoration.
- To maintain, in viable wild populations, the species and genetic diversity of wetland dependent flora and fauna [as is found in Pipidinny Swamp].

- To maintain the abundance of waterbird populations [found at Pipidinny Swamp], particularly migratory birds [that visit the wetland]. (The Government of Western Australia, 1997, p. 7)

CALM uses management plans to provide directions for conservation and management of wetlands. The formulation and development of management plans are essential in protecting and conserving wetlands such as Pipidinny Swamp. Management plans require background knowledge of the resources of an area, how these resources work, how they fit into the regional perspective and how the public view the management plan. Specifically, a management plan defines the objectives of future directions and provides a set of detailed guidelines for the management of the Park (Murray, 1989).

Moore (1989) describes four important segments in the formation of wetland management plans:

1). Information on resources;

2). Management objectives;

3). Management strategies or actions;

4). Implementation.

These four segments will be discussed in turn in relation to Pipidinny Swamp as part of Yanchep National Park.

6.1.1 Information on Resources

Information on the resources of an area, such as the background knowledge of the cultural and natural environments and the values of the area, are very important in the development of management plans. Examples of resource information needed to formulate a management plan can be found in Appendix A. Information regarding most of the topics in Appendix A can be found in earlier chapters of this research (for example, location of wetland). However, further research is needed to complement this research data. For example, a more detailed vegetation analysis is required to determine exactly what exotic flora species have invaded the wetland. Determination of what flora species are present will allow plans to be developed to eliminate these exotic flora species.

This research analysed certain systems concerning Pipidinny Swamp (e.g. water level, vegetation, and waterbirds). However, there are many other systems linked with this wetland which need further research (e.g. other fauna, influences upon groundwater, and water chemistry). This information is essential in developing an appropriate management plan for the wetland.

6.1.2 Management Objectives

The objectives of a management plan should be clearly defined and ultimately determine the future direction for the Park including Pipidinny Swamp. A management plan should also state the timeframe of the plan. For example, the previous management plan for the Yanchep National Park was designed to be utilised for approximately ten years and has now expired. The timeframe of the next management plan for the Yanchep National Park, which is currently under development, will be for approximately twenty years.

General objectives of a management plan can vary from conservation of the highest priority, to conservation and recreation of equal importance, to recreation of the highest priority (Moore, 1989). Another possibility is dividing the timeframe of the plan into different stages and designating different objectives to each stage. For example, the first half of a plan may designate the objective to be one of conversation of the highest priority, and the second half of the plan may designate the objective to be one of conservation and recreation of equal importance.

6.1.3 Management Strategies or Actions

In determining management strategies for a particular area such as a wetland, management concerns in relation to the wetland have to be identified and determined. Once these management concerns have been identified, they should be addressed by the management plan. Table 6.1 illustrates management concerns that have been identified in other wetlands managed by CALM. However, these management concerns may not apply to all wetlands. As such, each wetland should be assessed individually to identify the unique concerns associated with each wetland. Therefore, management plans should represent the uniqueness of each wetland.

Table 6.1. Management concerns identified in other wetland management plans developed by CALM.

Management Concerns
Water Quality
Water Levels
Bulrushes
Mosquitoes and Midges
Fire
Dieback
Regeneration
Garden Refuse and Litter
Tortoises
Recreation
Monitoring
Weeds
Community Involvement
Signs

CALM is currently developing the new management plan for the Yanchep National Park. The next management plan for Pipidinny Swamp should develop management strategies for all of the management concerns listed in Table 6.1. This research has identified other management concerns relating to the cultural and natural environments that will have an influence within the wetland. The management plan for Pipidinny Swamp should also address these management concerns (Table 6.2). Failure to address management concerns identified may lead to problems in the future.

Table 6.2. Other management concerns that should also be addressed by CALM

Other Management Concerns
Drainage and Filling
Excavation
Eutrophication and Pollution
Vegetation Structure in the Recharge Area
Erosion
Population
Land-use activities
Transportation
Education

Development of management strategies addressing cultural management concerns include transportation (construction of the Mitchell Freeway along the western boundary of the wetland) and population it is estimated the suburb of Eglinton to the west will have a population of around 13,000 people in 2020.

6.1.4 Implementation

Without commitment by management authorities, even the best plan can not succeed. Implementing a plan requires all the strategies to be outlined in detail, for example, documenting who's responsible for particular strategies, cost involved per strategy, priority of management concerns (high-medium-low), and frequency of strategies (one-off or continual).

6.2 Suggested Actions

There are a number of management concerns at Pipidinny Swamp. A management objective for Pipidinny Swamp could be that during the first ten years when urban development in the surrounding area will remain minimal, the wetland should be managed with conservation as the highest priority. During this time weed eradication should be a high priority for CALM, as well as regeneration of native flora species that perform ecological functions for the wetland. Regeneration of native species should be carried out by propagating seeds that have been collected from the wetland. By using seeds of native species found within the wetland the genetic make-up of the seeds are suited specifically for conditions at Pipidinny Swamp. This provides a greater chance of survival for these species compared to using seeds of other species from other wetlands whose genetic make-up may be slightly different to conditions at Pipidinny Swamp.

The protection of waterbird populations at Pipidinny Swamp should involve establishing an indepth investigation of the Gnangara Groundwater Mound and water level disturbances, the vegetation and other fauna found in and around the wetland. This is in accordance with the wetland conservation policy for Western Australia (The Government of Western Australia, 1997, p. 7).

The Park could promote and seek the help of volunteers in helping to control weed species. While there are volunteers that currently provide assistance, the Park should establish a 'Friends' group for the wetlands within the Park, such as the 'Friends of Yellagonga Regional Park'. Involvement of community groups such as Scouts, Girl

Guides, Environmental, Birdwatching, Bushwalking and Educational groups would help to reduce the economic concerns in managing this wetland for CALM (The Government of Western Australia, 1997,p. 7).

During the second ten years of the Plan, protection and enhancement of the natural features should remain a high priority. Cultural activities such as recreation and eco-tourism should also be a high priority. The development of trails and boardwalks generally helps to protect the vegetation by directing people through the wetland. This discourages people from wandering through the wetland destroying fragile vegetation areas. Construction of a boardwalk on top of the sand dunes to the west, with steps down into the wetland would help to control erosion of the sand dune. A boardwalk on top of this dune would provide an excellent waterbird viewing platform for the entire wetland.

On the eastern side of the wetland, upon the cleared area previously used for growing strawberries, a camping area could be constructed for walkers on the Yaberoo Budjara Heritage Trail who wish to camp overnight.

These are only suggested actions to be carried out in Pipidinny Swamp. Some actions are urgently required within the wetland (e.g., understand what is causing the decrease in the water level), while others suggestions are not as urgent (e.g., boardwalk)

7.0 Conclusion

This research found that Pipidinny Swamp is a wetland that has been severely modified and degraded due to past cultural activities within the wetland. However, Pipidinny Swamp is still a dynamic wetland with many changes occurring to the nature environment not only between seasons but also over a period of years. Not only have there been changes in the natural environment but also in the cultural environment. Pipidinny Swamp has been important to human populations for thousands of years. Indigenous Australians relied upon the natural resources provided by wetlands, and through conservation and management they were able to survive. The Indigenous people who relied upon Pipidinny Swamp also have spiritual links to this wetland through the 'Dreaming'. Later, under private ownership, non-indigenous Australians also relied upon the natural resources of the wetland. Non-indigenous Australians relied upon the water resources and the soil of the wetland, which were used for horticultural purposes. In 1991, Pipidinny Swamp was incorporated into the Yanchep National Park under the management of CALM. Since then conservation and management of the wetland's resources and habitats at Pipidinny Swamp has been a high priority for CALM.

Pipidinny Swamp is uniquely positioned on the boundary of two dune systems on the Swan Coastal Plain. To the west, the Quindalup Dune System consists of calcareous sand that contains lime, which is deposited within the wetland by aeolian processes. This deposition of lime has resulted in the wetland peaty soil being white. This is very unique as Pipidinny Swamp is the only wetland on the mainland of the Swan Coastal Plain that contains marl. Other wetlands to contain lime on the Swan Coastal Plain are located on Rottnest Island.

This research has shown that the natural environment of Pipidinny Swamp is very dynamic. The water level within the wetland is heavily influenced by seasonal changes. During the summer months the water level decreases due to the hot dry conditions that prevail on the Swan Coastal Plain. However, during the winter months the water level rises due to the milder conditions and an increase in rainfall. The water level in Pipidinny Swamp has also been changed over years, with this research showing a dramatic decrease in the water level over the past five years. What is causing this decrease is speculated in, with the blame been directed at the pine plantations and also the abstraction of groundwater for human consumption. More research is needed to exactly determine what is causing the decrease in the water level. The pits located in Pipidinny Swamp provide permanent water and the water chemistry in each of these pits appear to be different.

The vegetation within Pipidinny Swamp is also dynamic with changes not only occurring between seasons but also over years. Pipidinny Swamp originally contained low sedges throughout the wetland when early explorers visited the wetland. While under private ownership, the native vegetation was cleared to allow horticultural species to be cultivated. Now under the management of CALM the vegetation within the wetland still contains some exotic vegetation species. The decrease in water level over the past five years has also influenced the vegetation species present within the wetland. Weed species and fringing native species are now flourishing and invading the wetland where previously higher water levels would have prevented these species from growing. The vegetation within the wetland is also dynamic between seasons with this research showing that some species are dominant during the summer months while others are dominant during the winter months.

This research has shown that waterbird populations changes between seasons with the seasonal changes determining the waterbird populations. With the increase in rainfall inland lakes fill and waterbird populations move onto these inland lakes to breed. During the summer months when inland lakes dry out, waterbird populations congregate back on the wetlands of the Swan Coastal Plain where fresh water is still available. This research has also shown that over years the waterbird population has been dynamic. According to Birds Australia Pipidinny Swamp was considered the "Kakadu of Western Australia" in the 1980's because it supported a large abundance and diversity of waterbirds. Waterbird diversity and abundance at Pipidinny Swamp are now very low compared to the 1980's.

Wetlands on the Swan Coastal Plain support a large number of both flora and fauna species. Consequently a large biodiversity exists within wetlands including Pipidinny Swamp. Government policies have been formulated to protect the biodiversity of wetlands.

Since being incorporated into the Yanchep National Park, Pipidinny Swamp has been managed under the same guidelines as the remaining wetlands located in the Park. Under the new management plan Pipidinny Swamp should receive a greater profile than it currently receives. Pipidinny Swamp requires rehabilitation to enhance its natural attributes, such as the removal of exotic flora species. Continued conservation and protection of this wetland habitat is important to both humans and to flora and fauna species. The southern portion of Pipidinny Swamp, which is still privately owned, needs to be incorporated into the Park for conservation and protection. The grazing of cattle upon summer pastures on this portion of the wetland affects the remainder of the wetland. The nutrients from the cattle and the pasture find their way into the northern portion and degrade the entire wetland environment. Wetland conservation policies should prevent this from occurring, but unfortunately privately owned wetlands are not covered by this policy.

Finally, Pipidinny Swamp offers a different visitor experience to other wetlands located in the Park. Pipidinny Swamp provides important historical values and important natural values which are not found elsewhere. The wetland offers additional habitats for waterbirds and other aquatic animals.

8.0 REFERENCES

Arnold, J. (1990). Perth Wetlands Resource Book. Environmental Protection Authority *Bulletin* 266.

Bekle, H. (1980). The Wetlands Lost: Drainage of the Perth Lake Systems. *Geowest,* 16, 83-119.

Bekle, H. (1997). Birds. In *Yellagonga Wetlands. A Study of the Water Chemistry and Aquatic Fauna.* Perth, Western Australia: Centre for Ecosystem Management, Edith Cowan University.

Bekle, H. (1998). Inland Waters and Waterbirds. In *Wanneroo Joondalup Yanchep: Environment People and Planning.* Joondalup, Western Australia: City of Joondalup and City of Wanneroo.

Bekle, H., & Gentilli, J (1998). History of the Perth Lakes. *Early Days* 10(5), 443-460.

Buttimer, A. (1993). *Geography and the Human Spirit.* Baltimore: The John Hopkins University Press,.

Chambers, A. (1991). *The Pioneers. A Story of Wanneroo 1834-1985.* Wanneroo, Western Australia: City of Wanneroo.

Clark, J. (1994). *'The Plantation Effect'.* Auckland: Greenpeace New Zealand.

Cockman, M. (1979). *Wanneroo.* Wanneroo, Western Australia: City of Wanneroo.

Conservation and Land Management, Department. (1989). *Yanchep National Park Management Plan 1989-1999.* Como, W.A: Author.

Dames & Moore (1986). *Gnangara Mound Groundwater Resources: Environmental Review and Management Programme.* Perth: Water Authority of Western Australia.

Davis, J. A., & Humphries, B. (1988). Wetland Function. In *Wetlands in Crisis. What Can Local Government Do? Conference Papers 15th June.* E.P.A Bulletin 372. Perth, Western Australia: Environmental Protection Authority.

Davis, J. A. (1990). How Do Wetlands Work- and How Do We Manage Them To Maintain 'healthy ' Aquatic Ecosystems? In *Wetlands in Crisis. What Can Local Government Do? Conference Papers 15th June.* E.P.A Bulletin 372. Perth, Western Australia: Environmental Protection Authority.

Davis, J. A., Rolls, S. W., & Wrigley, T. J. (1991). *A Survey of the Environmental Quality of Wetlands on the Gnangara Mound, Western Australia.* Perth, Western Australia: Murdoch University. Water Authority of Western Australia and Environmental Protection Authority.

Department of Agriculture Western Australia (1987). *Flora of the Perth Region.* Perth. Author.

Department of Conservation and Environment, (1983). *Conservation Reserves for Western Australia: The Darling System 6* (Red Book). Perth, Author.

Ellen, R. (1982). *Environment, Subsistence and System. The ecology of Small Scale Social formations.* New York: University of Cambridge.

Environmental Protection Authority. (1989). Wetlands in Crisis. *What Can Local Government Do? Conference Papers 15th June.* E.P.A Bulletin 372. Perth, Western Australia: Author.

Environmental Protection Authority. (1990). *A Guide to Wetland Management in Perth.* EPA, Bulletin 374. Perth, Western Australia: Author.

Environmental Protection Authority. (1993). *Strategy for the Protection of Lakes and Wetlands of the Swan Coastal Plain.* Bulletin 685. Perth, Western Australia. Author.

Godfrey, N. (1988). The Value of Wetlands. in *Wetlands in Crisis. What Can Local Government Do? Conference Papers 15th June.* E.P.A Bulletin 372. Perth Western Australia: Environmental Protection Authority.

Government of Western Australia, (1997). *Wetlands Conservation Policy For Western Australia.* Perth Western Australia: Author.

Grey, G. (1841). *Expeditions in Western Australia 1837-1839.* T & W Boone, London

Hallam, S. J. (1975). *Fire and Hearth. A Study of Aboriginal Usage and European Usurpation in South-Western Australia.* Melbourne: Advocate Press Pty Ltd.

Hallam, S. J. (1998). Paradise Lost-The Aborigines. In *Wanneroo Joondalup Yanchep. Environment People and Planning.* Joondalup, Western Australia: City of Joondalup and City of Wanneroo.

Halse, S. A., Vervest, R. M., Munro, D. R., Pearson, G. B., & Yung, F. H. (1992). *Annual Waterfowl Counts in South West Western Australia-1989/90. Technical Report No. 29, 1992.* Como, Western Australia: Department of Conservation and Land Management,

Jackson, J. (1997). *Glossary of Geology. Fourth Edition.* Alexander, Virginia: American Geological Institute.

Kattan, G. H., Alvarez-Lopez, H., & Giraldo, M. (1992). Forest Fragmentation and

Extinction: San Antonio Eighty Years Later. *Conservation Biology,* 8, 138-146.

Kennealy, S. (1994). *Oral Histories of Wanneroo Wetlands. Recollections of Wanneroo Pioneers.* Joondalup, Western Australia: City of Joondalup.

Kohen, J. (1995). *Aboriginal Environmental Impacts.* Sydney, New South Wales: University of New South Wales Press.

McArthur, W. M., & Bartle, G. A. (1980). *Landforms and Soils as an Aid to Urban Planning in the Perth Metropolitan. North-west Corridor; Western Australia.* Perth, Western Australia: CSIRO.

McIntosh, R. P. (1967). An Index of Diversity and the Relation of Certain Concepts of Diversity. *Ecology* 48, 392-404.

Moore, G. F.(1884). *Diary of Ten Years Eventful Life of an Early Settler in Western Australia.* Perth, Western Australia: University of Western Australia Press, 1978.

Moore, S. (1989). How to Prepare a Management Plan. In *Wetlands in Crisis. What Can Local Government Do? Conference Papers 15th June.* E.P.A Bulletin 372. Perth Western Australia: Environmental Protection Authority

Murray, F. (1989). The Need For Management Plans. In *Wetlands in Crisis. What Can Local Government Do? Conference Papers 15th June.* E.P.A Bulletin 372. Perth Western Australia: Environmental Protection Authority.

Nettheim, G. (1989). *Aboriginies, Human Rights and the Law.* Blackburn Dove Communications.

Payne, S. (1991). *Burning Bush; A Fire History of Australia.* New York: Henry Holt Publishing Inc.

Pinder, A., & Horwitz, P. (1997). *Wetland Macro invertebrates Monitoring Program of* *the Gnangara Mound Environment Monitoring Project.* Perth, Western Australia: Edith Cowan University Centre for Ecosystem Management.

Robinson, R. (1968). *The Australian Aboriginal.* Sydney: A.H. & A.W Reed.

Recher, H. (1997). Impact of Wildlife on Avifauna of Kings Park, Perth, Western Australia. *Wildlife Research*, 24, 745-761.

Seddon, G. (1972). *Sense of Place.* Perth: University of Western Australia Press.

Singleton, J. (1988). The History and Tenure of Wetlands. In *Wetlands in Crisis. What Can Local Government Do? Conference Papers 15th June.* E.P.A Bulletin 372. Perth Western Australia: Environmental Protection Authority.

Somer, B., & Horwitz, P. (1999). *Annual report for the Wetland Macro invertebrate Monitoring Program of the Gnangara Mound Environmental Monitoring Project Summer/Autumn 1997/98, Spring 1998, and Summer/Autumn1998/99.* Draft. Perth, Western Australia: Centre for Ecosystem Management, Edith Cowan University.

(1847, August 11). *Swan River News,* p.161.

UNESCO (1971). *The Contracting Parties to the Convention on Wetlands of International Importance Especially As Waterfowl Habitat.* UNESCO.

W.A Gould League (2000). *Worksheet on Representative Food Pyramid at Herdsman Lake.* Perth: Herdsman Wildlife Centre.

Young, E., Ross, H., Johnson, J., & Kesteven, J. (1991). *Caring for Country: Aborigines and Land Management.* Australian National Parks and Wildlife Centre.

Appendix A

Resource information required to formulate a management plan include:

- Location
  - within the Park
  - area
  - surrounding land use and purpose
- Physical Features
  - Geomorphology
  - Soils
- Hydrology
  - Catchment
  - Drainage
  - Ground water
  - Water levels
  - Water quality
  - Factors affecting water quality
- Vegetation
  - Terrestrial
  - Littoral
  - Aquatic
- Fauna
  - Invertebrates
  - Fish
  - Birds – Waterbirds and terrestrial
  - Amphibians
  - Reptiles
  - Mammals
- Other planning considerations
  - System 6
  - North West Corridor
  - Metroplan

- Groundwater resources
- History
  - Aboriginal significance
  - European management
- Past land use activities
  - Private ownership
  - National Park
  - Surrounding use in the catchment area for the wetland.

- Fire
  - History
  - Environmental effects
- Past management
  - Firebreaks
  - Weeds
  - Midges
  - Bulrush
  - Signs
  - Rubbish
  - Recreational facilities