ARAFURA SWAMP
WATER RESOURCES STUDY

Billabong off Mulpinji Creek

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DARWIN NT
# TABLE OF CONTENTS

**FIGURES**...........................................................................................................................................2

**TABLES**............................................................................................................................................3

**INTRODUCTION** .................................................................................................................................4

**BACKGROUND TO STUDY AND PROJECT AIMS**..............................................................5

**CLIMATE** .........................................................................................................................................7

**GEOLOGY**.........................................................................................................................................8

**VEGETATION AND WILDLIFE**...................................................................................................11

**THE CATCHMENT OF THE GOYDER, GULBUWANGAY AND GLYDE RIVERS**.............................................13

**THE RIVER SYSTEMS OF THE GOYDER AND GULBUWANGAY RIVERS** .........................................................13

**THE ARAFURA SWAMP**.........................................................................................................17

**THE GLYDE RIVER ESTUARY**..................................................................................................19

**RECOMMENDATIONS**.............................................................................................................26

**APPENDIX A** ..................................................................................................................................27

  **REGISTER OF THE NATIONAL ESTATE DATABASE** ............................................................................ 27

**GLOSSARY**....................................................................................................................................29

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**FIGURES**

**FIGURE 1:** LOCATION OF THE ARAFURA SWAMP AND THE CATCHMENTS OF THE GOYDER AND GULBUWANGAY RIVERS................................................................. 6

**FIGURE 2:** THE ARAFURA SWAMP (THE DARK GREEN AREA IN THE LOWER CENTRAL PORTION OF THE SATELLITE IMAGE). ..................................................................................... 6

**FIGURE 3:** AVERAGE MONTHLY RAINFALL FOR OENPELLI ............................................................... 7

**FIGURE 4:** ANNUAL RAINFALL FOR OENPELLI ...................................................................................... 7

**FIGURE 5:** NORTHERN AUSTRALIA SEA LEVELS RELATIVE TO TODAY’S LEVEL (IE 0 METRES RELATIVE SEA LEVEL) ........................................................................................................... 8

**FIGURE 6:** CROSS SECTION OF ARAFURA SWAMP (FOR LOCATION REFER TO FIGURE 8) ................. 8

**FIGURE 7:** REGIONAL GEOLOGY ...................................................................................................... 9
TABLE

Table 1: Flow rate required to maintain water levels for various percentages of the swamp.
Introduction

The Arafura Swamp is located approximately 550 kilometres east of Darwin. The swamp is situated in the catchment of the Goyder and Gulbuwangay rivers and is drained by the Glyde River. The Swamp and surrounding area are significant for a variety of cultural, environmental and economic reasons. The uniqueness of the area has been recognised and the Arafura Swamp and catchment has been included on the Register of the National Estate (refer to Appendix A).

The land on which the Arafura Swamp occurs is owned by the Yolgnu. The Yolgnu are the indigenous people of northeast Arnhem Land. The Arafura Swamp is vital to their livelihoods. The Swamp’s flora and fauna are basic food sources. The wetland flora is also used for medicinal purposes.

The Arafura Swamp forms an important ecological habitat. It contains the largest paperbark swamp in Australia and it is home to a diverse number of wetland species.

The catchment of the Goyder and Gulbuwangay rivers covers an area of about 9000 square kilometres. The Arafura Swamp covers an area of only 700 square kilometres (refer to Figure 1) in the dry season. In the wet the area of the swamp can extend to as much as 1300 square kilometres.

In the dry season water levels are maintained by large springflows that feed the Goyder River from a regional aquifer developed in dolomite of the Dook Creek Formation (refer to Figure 7).

The cultural significance of the Arafura Swamp relates to the virtually uninterrupted occupation and management of the area that has been occurring for thousands of years.
Background to Study and Project Aims

Between 1996 and 1998 the water resources of East Arnhem Land were mapped as part of the East Arnhem Land Water Study (Zaar et al, 1999). The East Arnhem Land Water Study mapped the regional aquifer systems and developed regional relationships that indicate the interaction between groundwater and dry season stream flows. On completion of the Study it became apparent that a more comprehensive study was needed to show the complex and variable relationship between rainfall, stream flow and groundwater processes at a catchment level. The dependence of the environmental health of the Arafura Swamp on large spring flow into the lower reaches of the Goyder River was determined in the Study. Also determined was the gap in knowledge of that dependence. In response to this gap in knowledge the Arafura Swamp Water Resources Study was initiated. The Arafura Swamp Water Resources Study builds upon the knowledge gained in the East Arnhem Land Water Study.

The primary purpose of the Arafura Swamp Water Resources Study is to provide relevant information on the hydrology of the Arafura Swamp so that Aboriginal landowners and managers will be able to include water related aspects in their land management planning. The information can also be used to assist the local community in making informed land management decisions.

The specific objectives of the Arafura Swamp Water Resources Study were:
1. Develop rainfall/runoff relationships for the Arafura Swamp and contributing catchments, incorporating differences in runoff based on soils, vegetation, topography and geology.
2. Model surface water transport and flow patterns within the Arafura Swamp. This will aid land management planning for erosion and weed control, water quality management, and more effective management of land and water degradation issues.
3. Evaluate and describe the importance of groundwater systems. Identify the extent of aquifers and their discharges. Produce models to describe the relationships between rainfall, recharge, water table levels and groundwater discharges.
4. Integrate Indigenous knowledge.
5. Provide decision support materials in the form of maps, models, interpretive reports and databases that contain the natural and cultural knowledge.

This report briefly outlines how these objectives have been met during the three years of the project. The report is only one of a number of products produced as outputs from the Arafura Swamp Water Resources Study. The other products are:
- Arafura Swamp Water Resources Study Interactive CD
- Interactive GIS Project, Maps and Satellite Images
- Catchment Management Issues Document
All products are contained on the Arafura Swamp Water Resources Study CD that has been produced as the major output from this program of work.
Figure 1: Location of the Arafura Swamp and the Catchments of the Goyder and Gulbuwangay Rivers.

Figure 2: The Arafura Swamp (the dark green area in the lower central portion of the satellite image).
Climate

The region lies in the “wet/dry” monsoonal tropics, with a long dry season between May and October, and a wet season from November to April. An average of 1150mm of rain falls during the wet season. The driest months of the year are July and August. The catchment experiences a temperature range of 20-36 degrees Celsius.

The variation in rainfall during the year and from year to year can be seen from the average monthly rainfall and annual rainfall for Oenpelli, which is shown in Figures 3 and 4. Highest temperatures are recorded in October and November, when the mean daily maximum approaches 36°C. Evaporation is high, over 2200 mm per year, with monthly evaporation exceeding monthly rainfall throughout the dry season.

![Figure 3: Average Monthly Rainfall for Oenpelli](image)

![Figure 4: Annual Rainfall for Oenpelli](image)
Geology

The Arafura Swamp formed around 5,000-6,000 years ago after sea levels became stable after they had risen for about 12 thousand years. Since then sea levels have fallen slightly to their present level (refer to Figure 5).

Around 5,000 years ago the Arafura Swamp was a marine swamp. When sea levels fell and stabilised the freshwater swamp was formed. The swamp formed in a large shallow basin on the Raiwalla Shale. Up to 20 metres of marine clays has been deposited on the shale. Up to 2 metres of freshwater alluvial material has been deposited on the clay (refer to Figure 6).

Figure 5: Northern Australia Sea Levels Relative to Today’s Level (ie 0 metres Relative Sea Level)

Figure 6: Cross Section of Arafura Swamp (for location refer to Figure 8)
Figure 7: Regional Geology

- **Dolomite**
- **Raiwalla Shale**
- **65.5 -142 Million Year Old Sandstone**
- **540 - 2500 Million Year Old Igneous Rocks**
- **540 - 2500 Million Year Old Sedimentary Rocks**
- **Sea**
- **Catchment Boundary**
- **Swamp Boundary**
Figure 8: The Arafura Swamp Catchment. Map shows the Old Gove Road Crossing and Gauging Stations G8250002 and G8250003. (Map from East Arnhem Land Water Study, Zaar et al, 1999).
Vegetation and Wildlife

The following description has been taken from the register of the National Estate (refer to Appendix A). The main vegetation types are shown on Figure 9.

“The swamp and its catchment comprise a complex mosaic of plant communities. Its striking features include large areas of paperbark open forest, numerous lagoons and their associated flora and fauna, and grassland plains over which are scattered numerous examples of the rare talipot palm. Other plant species of significance include Livistona Rigidia, Carpentaria Acuminata, Hanguana Malayana, occurring in some of the billabongs, and Colocasia Esculentia (taro). Fringing the wetland are extensive woodlands and patches of monsoon forest. Within the catchment of the swamp are found a diverse range of landforms including eucalypt woodlands and open forests, swamps with undisturbed floating mat communities, sandstone hills, sinkholes and springs. The swamp provides an important refuge and breeding area for a diverse fauna including both Crocodylus Porosus and Crocodylus Johnstonii, and abundant waterfowl including magpie goose, pygmy goose, black duck and whistling duck”.

The swamp discharges in the Glyde River, which is tidal for approximately 35 kilometres inland from its mouth. The coastal floodplain supports sedge and grasslands.

The Arafura Wetlands and catchment are in a relatively undisturbed condition, in part due to its remote locality and restricted access to European influences, and difficulties of access to feral animals. Feral buffalo and domestic and feral cattle are present, although in low numbers. The fringes of the swamp, coastal grasslands and adjacent higher country are burnt annually in a traditional burning regime.
Figure 9: Arafura Swamp Vegetation
The Catchment of the Goyder, Gulbuwangay and Glyde Rivers

The catchment consist of three distinct major components:
- The river systems of the Goyder and Gulbuwangay Rivers
- The Arafura Swamp
- The Glyde River estuary

A brief description of each component follows:

The River Systems of the Goyder and Gulbuwangay Rivers

There are two major rivers contributing flows to the Arafura Swamp. The Goyder River is the main source of water, draining an area of approximately 6050 square kilometres. The river flows all year downstream of the Old Gove Road Crossing (refer to Figure 10). The second major contributor is the Gulbuwangay River. The Gulbuwangay is a seasonal river with a catchment size of around 1500 square kilometres. It supplies significant inflow to the swamp during the wet season. Other water inputs to the swamp come from Gupulul Creek and some other small creeks around the edge of the swamp (refer to Figure 11).

Figure 10: The Arafura Swamp Catchment and Major Rivers
Stream development in the Goyder Catchment is geologically controlled. Where rock outcrops come to the surface the streams form wide shallow channels and are often occupied by dense aquatic forests. In other areas the channels are deeper.

Data from the Goyder River gauging station G8250002 located 1.5 kilometres downstream of the Old Gove Road Crossing (refer to Figure 8) indicates that the river has a mean yearly discharge of 935 million cubic metres. Figure 12 indicates runoff for the Goyder River at G8250002 and total rainfall at the rainfall recording station G8230237 which is located on the Liverpool River. Runoff is approximately 15 - 20% of the rainfall.

After the wet season has finished only the Goyder River downstream of where it joins with Annie Creek and Annie Creek maintain flows throughout the dry season. This flow is sustained by the aquifer formed in dolomite (refer to Figure 7). The dry season flow in the Goyder River is provides water to the swamp during the dry season after the seasonal streams have ceased flowing (refer to Figure 13).

A model was developed to predict spring flow into the Goyder River. Both Katherine and Liverpool River rainfall records were run through the model. From the results of the model it becomes clear that Katherine rainfall correlates better with Goyder River flow than Liverpool River rainfall. It is therefore assumed that Katherine rainfall is
Figure 12: Rainfall data for R8230237 (Liverpool River) and Runoff data for G8250002 (Goyder River) and G8250003 (Arafura Swamp)
similar to what falls on and recharges the dolomite aquifer, which in turn maintains spring inflow into the Goyder River. The model was used to extend the spring inflow record from the short period for which flow data is available for Goyder River G8250002 – 1966 to 1987, to the period for which rainfall exists for Katherine (since 1884). The predicted flows are given in Figure 14. The model predicted that flows ranged from as low as 0.6 cubic metres per second to as high as 8.7 cubic metres per second. The data also indicated that spring flows for the period for which the gauging station was open prior to this study – 1966 to 1987, were significantly higher than those that occurred over the previous fifty years or over the following 10 years.

**Figure 14: Predicted and actual spring flows at Gauging Station G8250002 located on the Goyder River**
The Arafura Swamp

When fully covered by floodwater the Arafura Swamp has an approximate area of 700 square kilometres, excluding the coastal plain. The area of the swamp, however, varies depending upon the intensity of the wet season.

The swamp forms numerous channels but lacks any continuous streams. There are only a few open water bodies with most being full of vegetation. This vegetation plays an important role in the dynamics of the swamp. Vegetation regulates water flow throughout the system resulting in flow being very slow. It also has an impact on water quality and acts as a seed trap.

Access to the Swamp during the time this study was undertaken was difficult due to the prevalence of unusually wet conditions. The data presented in Figure 12 indicates that the 1999/2000 and 2000/2001 wet seasons were 2 of the wettest years for the periods that the gauging stations G8250002 and G8250003 have been operated. Water resource data and anecdotal evidence for the region indicates that 1997/98 and 1998/99 were also very wet years. Hence data collection was largely limited to the edge of the Swamp and aerial reconnaissance.

A rainfall runoff model was created for the catchment to study the flood behaviour of the catchment. The model was used to generate floods of varying frequency and predict the response of the swamp to such floods.

The swamp acts as a large retention basin (storage basin) and therefore peak level to peak level correlations between river flows and the swamp height do not apply. The
swamp reaches peak levels after it receives a certain volume of water. For instance in 1972/73 at the Goyder River gauging station the river rose 6.4 metres, while swamp levels rose only 1.5 metres (refer to Figure 12).

To predict when levels will peak in the swamp requires a good knowledge of flows travelling down the Goyder as well as Gulbuwangay River. More rainfall gauges are needed in the catchment to better predict rainfall –flow relationships in the catchment.

The amount of spring inflow delivered by the Goyder River and other streams during the dry season controls the amount of water maintained in the swamp. The Goyder River baseflow model indicates that the Goyder River can deliver between 0.6 to 8.7 cubic metres per second of spring flow to the swamp. Data from G8250003 was used to determine the daily loss of water due to evapotranspiration (ET). ET for the swamp is approximately 5 mm / day. Using these figures, Table 1 identifies the flow rate required to maintain water levels for a certain percentage of the swamp.

Whilst spring inflows are responsible for maintaining a certain area of the swamp, some pools are maintained throughout the dry season from wet season runoff because the depth of water in the pool is greater than the amount evapotranspired during the dry season. Identifying these pools is important as they will be more easily affected by water quality changes and surrounding land use needs to be managed appropriately.

### Table 1: Flow rate required to maintain water levels for various percentages of the swamp

<table>
<thead>
<tr>
<th>Flow rate at G8250002 m³/s</th>
<th>Area of Swamp where water levels maintained km²</th>
<th>% of Swamp where water levels maintained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>52</td>
<td>9</td>
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<td>70</td>
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</tr>
<tr>
<td>5</td>
<td>86</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>104</td>
<td>18</td>
</tr>
</tbody>
</table>

One significant threat to the swamp is Mimosa. Seeds will spread slowly during a flood event and may be mostly trapped by vegetation and eventually settle. A flow model was developed to predict where seeds may be transported to during a flood event. The model assumed that at least one seed will find its way through the vegetation and the model tracks its path. The settling rate of the seeds was determined by soaking dry seeds in a bucket and counting until the majority of seeds had sunk. The seeds were then dried in the sun and the experiment redone. Seeds tend to settle slightly quicker the second time. This model could be used to assist in management of mimosa.
The Glyde River Estuary

The Glyde River estuary drains the Arafura Swamp into Castlereagh Bay, and then into the Arafura Sea. The estuary is 35km long and meanders over a width of 17km. The mouth of the estuary has a width of around 700 metres and this gradually becomes narrower until it is only a boat width in the upper parts of the estuary. The estuary is tidal except during floods. During the dry season 4 metre tides can be experienced at the mouth of the Glyde River estuary. At this time the flow within the Glyde is confined to the channels. During floods the estuary is fluvial dominated by strong flood inflows. Wet season flows often cover the coastal plain with freshwater. The coastal plain has a width of approximately 17km (refer to Figure 16 and 17).

Figure 16: Satellite image of the Glyde River Estuary

The eastern side of the coastal plain has some spring-fed rainforest patches (refer to Figure 18) and the western side of the floodplain supports some water holes. Gupulul Creek and some other small streams flow from the coastal plain into the estuary.
Figure 17: Wet season flooding of the coastal plain

Figure 18: A spring fed forest
The estuary can be broken up into two stages, the funnel entrance, which is around 10km long, and the windy or sinuous part with a length of 25km. Other features of the estuary are detailed in the Figures 19 to 21.

Figure 19 shows the narrowing of the channel as the estuary moves upstream. There is an upward deviation of the curve at around 16km from the mouth. This deviation signals the end of the funnel section of the estuary and the beginning of the meandering section. It may also indicate a possible change in geology as it also correlates to one of the shallow cross sections.

**Figure 19: Distance from mouth of Glyde River (cumulative distance in metres) versus width (metres) when main channel is full of water**

**Figure 20: Distance from mouth of Glyde River versus cross sectional area of main channel**
Figure 21: Distance (metres) from mouth of Glyde River versus width-depth ratio.

The graphs (Figures 19 to 21) indicate a zone along the estuary where things change. This zone seems to be at the end of the exposed coastal floodplain section. There are also zones where the cross sections are very shallow and coincide with the change in channel properties. This indicates that there may have been some internal barriers in the system and these barriers may now be eroding.

A model was developed to reproduce the tidal processes in the estuary resulting from dry season and wet season flood conditions.

The dry season modelling results for tide gauge G8250007 located upstream of the mouth of the Glyde are given in Figures 22 and 23.

Figure 22: Modelled dry season tide height at G8250007
The wet season modelling results for tide gauge G8250007 are given below. (The wet season model is based on 500 cubic metres per second peak flow).

Figure 23: Dry Season tide velocities at G8250007

Figure 24: Modelled wet season tide height at G8250007
Figure 25: Wet season tide velocities at G8250007

The series of graphs show a distinct seasonality in the influence of flood and ebb tides.

In the dry season both the mouth (G8250006) and upstream (G8250007) records show a slight tendency to be flood tide dominant. That means, that the velocities are higher on the incoming tide (i.e. flood tide) than the outgoing tide (i.e. ebb tide). This behavior means that in the dry season sediments will tend to be pumped or moved upstream.

In the wet season during flood events the mouth becomes slightly ebb tide dominated while the upstream tides are severely dampened by the floodwaters. This behaviour means that the wet season will be responsible for exporting sediments from the estuary.

A series of satellite images spanning 20 years show that the estuary is expanding, with the upper zone cutting toward the swamp. Grazing and changes in vegetation occurring in this zone may have hastened this process.

Comparison of a 1980 satellite image to a 2000 image (Figures 27 and 28) indicates that the estuary has extended headward (i.e. towards the swamp) by approximately 4km over 20 years. This figure gives an average rate of extension of 200 metres per year. At this rate tidal waters may reach the pool at Murwangi (G8250003) by 2025.

Further work is required to identify management options to control this headward expansion of the tidal channels of the Glyde River.
Figure 27: 1980 Image of the Estuary

Figure 28: 2000 Image of Estuary
Recommendations

The Arafura Swamp faces a number of threats including:

- invasion by weeds
- damage from feral animals
- saltwater intrusion
- inappropriate or altered fire regimes
- decreased water quality

As the Arafura Swamp is an important wetland subject to natural and human influences, it needs to be effectively managed. This requires knowledge of the values and functions of the Swamp and its associated catchments.

The resource that maintains the health of the Swamp’s ecosystem is fresh water. Sound management requires a level of knowledge of the water resource that is appropriate for the assessment of the possible impacts of development and the likely threats to the health of the Swamp’s ecosystem.

This study has identified the need for better hydrological data on the short and long-term river and spring flows into the Swamp. This will require re-opening of the gauging stations G8250002 and G8250003. These stations were closed on completion of the study. There is also a need for better rainfall information in the catchment. This information could be gained if each community in the catchment maintained a daily read rain gauge.

The dry season spring flow inputs into the Swamp need to be better understood. This information, which could not be adequately gathered during the period of the study due to the very wet conditions encountered in and around the Swamp, will enable areas to be identified that are sustained either by spring flow or by wet season runoff. The study has identified areas sustained only by wet season river flows as being more susceptible to adverse impacts from deterioration in water quality. Ecosystems will also be identified whose extent and health will vary with the natural variability in spring flows. This knowledge could be gained by a well coordinated program using the local community to measure the conductivity of the water across the plain during the mid to late dry season. Water input from spring flow should have a much higher conductivity than water remaining from flood flows.

The environmental health of the Swamp is being threatened by saltwater intrusion. The headward migration of the tidal channels of the Glyde River was identified during the study. The tidal channels have migrated upstream a distance of approximately 4 kilometres over the past 20 years. Options for controlling this headward migration need to be developed now.

Sustainable effective management of the Arafura Swamp and its catchment is dependent on Aboriginal landowners and community agencies delivering that management. Consideration should be given to extending the excellent Aboriginal land-management programs that already exist into a catchment based approach. What happens in one part of the catchment often impacts other parts of the catchment. The existing programs address issues at a local scale. Some issues can only be effectively managed at a catchment scale.
Appendix A

Register of the National Estate Database

Arafura Swamp, Ramingining NT

Class: Natural
Legal Status: Registered (27/03/2001)
Database Number: 000083
File Number: 7/04/002/0002

Statement of Significance: The Arafura Wetlands represent the largest fresh water ecosystem in East Arnhem Land and the largest contiguous paperbark swamp in the Northern Territory and Australia. At the end of the wet season the swamp covers an area in excess of 130,000ha. The swamp and its catchment comprise a complex mosaic of plant communities and represents the least disturbed example of this type in the Northern Territory. Its striking features include large areas of paperbark open forest, numerous lagoons and their associated flora and fauna, and grassland plains over which are scattered numerous fine examples of the spectacular and rare talipot palm (CORPHA ELATA). Other plant species of significance include LIVISTONA RIGIDA, a fan leaved palm, previously known only from the Roper River region; CARPENTARIA ACUMINATA, a feather palm, which is endemic to the Top End and known from only a small number of scattered localities; HANGUANA MALAYANA, occurring in some of the billabongs, which is not common in other wetland areas; and COLOCASIA ESCULENTA (taro), recorded in the Goyder catchment and on the Walker River. The presence of taro has considerable implications for the origins of tropical horticulture, with the first recorded traditional use of this species in Australia (Criterion A.4). Fringing the wetland are extensive woodlands and patches of monsoon forests undisturbed by buffalo and pigs. Within the catchment of the swamp are found a diverse range of landforms including eucalypt woodlands and open forests, swamps with undisturbed floating mat communities, sandstone hills, sinkholes and springs. The swamp provides an important refuge and breeding area for a diverse fauna including both CROCODYLUS POROSUS and CROCODYLUS JOHNSTONII, and abundant waterfowl including magpie geese, pygmy geese, black duck and whistling duck. Land adjacent to the swamp has the only significant breeding population of the endangered hooded parrot outside of the Katherine area.

Description: The Arafura Swamp is located on the northern coast of Arnhem Land and is the largest paperbark swamp in Australia, covering 900 square kilometres including the coastal plains. The swamp is fed by the Goyder and Gulbuwangay Rivers and numerous springs, and surrounded by low hills up to 100m high. The swamp discharges in the Glyde River, which is tidally influenced for approximately 20km back from the mouth. It is speculated that the swamp was formed as a result of the surrounding hills closing in at the northern end and forming a natural partial barrier and corresponding narrowing of the flood plain, which in turn restricts the entry of tidal influx. The coastal floodplain, swamp and surrounding hills support a rich diversity of plant communities. The plains on the coastal side support sedge and grasslands, while the swamp itself is covered by extensive paperbark forest. These
grade into eucalypt open forest and woodland, which continue onto the footslopes. Other specific communities include tall reedland at the southern end of the swamp where the Goyder River enters, and floating mat communities on the billabongs and waterways. There are large areas of high quality, undisturbed monsoon forest. In the Mirrngadja region there is a considerable number of monsoon forest species otherwise regarded as exclusively coastal in their distribution. The swamp is an important refuge and breeding area for birds, fish and the fresh water (CROCODYLUS JOHNSTONI) and salt water (CROCODYLUS POROSUS) crocodiles. The area supports abundant waterbirds including magpie geese, pygmy geese, black duck and whistling duck.

**Condition and Integrity:** The Arafura Wetlands and catchment are in a relatively pristine condition, in part due to its remote locality and restricted access to European influences, and difficulties of access to feral animals. Feral buffalo and domestic and feral cattle are present, although in low numbers. This should remain so with the completion of the BTEC program in 1992 (Russell-Smith and Bowman 1991). Surveys in 1989 indicated feral pigs do not occur in the area (Bayliss and Yeomans 1989a, b). The swamp is free of the major noxious weeds common to many Top End habitats such as MIMOSA PIGRA, and the exotic para grass (BRACHIANA MUTICA), neither of which were in the swamp in a 1991 survey. Areas of dead MELALEUCA LEUCADENDRA were recorded in the southern and middle sections of the swamp in the 1991 survey. It is postulated this was caused by cyclonic winds, although further studies are indicated. The fringes of the swamp, coastal grasslands and hinterland are burnt annually in a traditional burning regime. The remaining community is re-establishing limited pastoral activities in the vicinity of the Old Arafura Homestead.

**Location:** About 172,000ha, 7km south-east of Ramingining, enclosed by straight lines joining the following AMG points consecutively: MG980430, NG100430, NG260030, NF260860, MF880860, MG880180 and commencement point.

**Bibliography:**
Bayliss P.G And Yeomans K.M (1989b). Aerial Survey Of Buffalo, Cattle and Bali Cattle in The Top End Of The Northern Territory and Adjacent Areas, 1989. Report To BTEC Administration, Department of Primary Industries And Fisheries, NT.
Conservation Commission Of The Northern Territory (Unpublished) Arafura Swamp: Vegetation Communities. Draft Internal Report, CCNT.
**Glossary**

**Alluvial** - Transported by water flow processes eg alluvial plain.
**Aquatic** - Living in, growing in, or frequenting water.
**Aquifer** - geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water.
**Australian Height Datum** - The datum used to determine elevations in Australia. This uses a national network of benchmarks and tide gauges and sets mean sea level as zero elevation.
**Catchment** - The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
**Conductivity** - The ability of water to transmit an electrical current. Conductivity is directly related to the abundance of minerals in the water.
**Discharge** - Means the volume rate of loss of water from a river or aquifer through bores and springs.
**Estuary** - An enclosed or semi-enclosed coastal body of water having an open or intermittently open connection to marine waters and fresh input from land runoff which measurably reduces salinity. Water levels vary in response to ocean tides and river flows.
**Environment** - The air, water and land, and the interrelationship that exists among and between water, air, and land and all living organisms.
**Evaporation** - Loss of water from the water surface or from the soil surface by vaporisation.
**Evapotranspiration (ET)** - The combined loss of water by evaporation and transpiration.
**Floodplain** - The portion of a river valley next to the river channel that is or has been periodically covered with water during flooding.
**Geomorphology** - The study of the origin, characteristics and development of land forms.
**Gigalitre** - A commonly used term to measure large quantities of water, equal to 1000 000 000 litres or 1 million cubic metres or 1 million kilolitres (kL).
**Groundwater** - Water that occurs beneath the land surface in the zone(s) of saturation.
**Hydrologic cycle (water cycle)** - The continual cycle of water between the land, the ocean and the atmosphere.
**Hydrology** - The study of water, its properties, distribution and utilisation above, on and below the earth's surface.
**Recharge** - Means the process by which water is added to a zone of saturation, usually by downward infiltration from the surface.
**Runoff** - Water that flows over the surface from a catchment area, including streams.
**Saturated Zone** - The subsurface zone in which all openings are full of water.
**Significant Adverse Impact** - Any impact resulting in degradation of an important resource, that is unacceptable because it cannot be mitigated or because of unacceptable conflicts in management of the use of the impacted resource.
**Transpiration** - The process by which plants take up water from the soil and release water vapour through the leaves.
**Unsaturated Zone** - The subsurface zone, usually starting at the land surface, that contains both water and air.
**Wetland** - Area of seasonal, intermittent or permanent waterlogged soils or inundated land, whether natural or otherwise, fresh or saline, eg. swamp.